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ROYAL CANADIAN AIR FORCE

AIRCRAFT OPERATING INSTRUCTIONS

GENERAL

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NOTES TO USERS

1 Pilot's Operating Instructions General comprises information for pilots, supplementing that contained in the Pilot's Operating Instructions (POI) for individual aircraft types. The issue of Pilot's Operating Instructions General makes it possible to exclude from individual POI much information of a general nature, so keeping the latter as compact as possible. Therefore, Pilot's Operating Instructions General should be used in conjunction with the POI for the type being flown.

2 Comments and suggestions should be forwarded through the usual channels to Air Force Headquarters.

GLOSSARY OF TERMS

In the following Sections, use is made of certain terms, abbreviations and symbols with which the reader may already be familiar, but to ensure that he shall have a clear understanding of their precise meaning as used in POI General and POI, the following definitions and explanations are given.

Aerodynamic Balance	- That characteristic of a control surface which governs the force required to move the surface away from its trailing position. - The force can be reduced by having part of the control surface area ahead of the hinge line, or by fitting a balance tab to the trailing edge, either of which assists in moving the surface. In practice a combination of these methods is frequently used. A well designed control can be moved easily throughout the speed range of the aircraft, the degree of aerodynamic balance being a compromise between that required at high and that required at low speeds.
Aircraft Configuration	- The external conditions of the aircraft in the circumstances being considered. - An aircraft in take-off configuration for example, has its landing gear extended and the flaps, radiator shutters or gills at the setting usually used for take-off. The presence of fuel tanks or other external stores, RP rails, special aerials or similar equipment is also included where appropriate.
Corrected Airspeed (CAS)	- The IAS corrected for instrument and position errors.
Critical Mach Number	- The Mach number at which compressibility effects become marked. - It varies according to the design and condition of the aircraft, with the amount of "g" being applied and with turbulence.
Critical Speed	- The lowest speed on multi-engined aircraft at which the pilot is able to maintain a straight course after failure of one or more engines. - The essential factor for maintaining control after engine failure is the ability of the pilot to keep a straight course. The effectiveness of the rudder depends principally on the airspeed, so that below a certain speed the maximum amount of rudder which can be applied will not fully counteract the tendency to yaw induced by engine failure, and the maintenance of a straight course will not, therefore, be possible. The critical speed is influenced by the power delivered by the live engine(s), the amount of bank employed, and by many other variable factors, including weather conditions, height, loading, setting of trimming tabs, flaps and gills (or radiator shutters), position of landing gear, whether the propellers of the failed engine(s) is/are windmilling or feathered, and last, but not least, the general condition of the aircraft and the skill of the pilot.

GLOSSARY OF TERMS (Cont'd)

Equivalent Airspeed (EAS)	The IAS reading corrected for instrument, position and compressibility errors, i.e., the CAS corrected for compressibility error.
Full Throttle Height	The height up to which, at a given boost and RPM setting, the given boost can be maintained. - To maintain a desired boost pressure as height is increased, the throttle butterfly must be opened progressively. The height at which the butterfly reaches the fully open position is then the full throttle height for that particular boost and RPM setting and as height is further increased the boost falls. For every combination of boost and RPM there is a full throttle height.
Going Round Again	The act of completing at least one additional circuit before landing. - This results from a deliberate decision to do so taken at a safe height. The reasons leading up to this may be many and varied; instructions from air traffic control by radio, a red signal from the airfield controller, a baulked or badly positioned approach, or for practice purposes.
Gravity	The force producing acceleration of a body falling freely under the effect of its own weight. - In general technical usage "g" denotes both this force and the acceleration produced by it, which is 32.2 feet per sec. per sec., at the surface of the earth in a vacuum. Were it not for this force, a man would fly off the earth into space because of the earth's rotation. The force of gravity varies with the distance from the center of the earth, and thus slightly as between different points on the earth's surface, because the earth is not a perfect sphere. The weight of a body of a given density and volume, that is, given mass, is proportional to this force of gravity, and so also varies slightly. It is, however, assumed to be constant anywhere on the earth. If a body, aircraft, or man, for example, has a total force acting on it equal to 5 times its own weight, it will have an acceleration in the direction of the force of 5 times that due to gravity, namely 5g. Although g is a unit of acceleration, it is often used colloquially to indicate the force producing an acceleration as well as the acceleration itself. In aeronautics, g is often used in this way to represent the force during a manoeuvre as a multiple of the weight. In a banked turn or pull-out from a dive, the lift is greater than the weight and produces an acceleration towards the center of the curved flight path. The occupants of the aircraft feel as though their weight has been increased. "g" in inverted commas is used where the actual magnitude of the force is not given thus high "g", negative "g", etc.
Indicated Airspeed (IAS)	The speed of an aircraft as shown on the airspeed indicator. On Service aircraft it is measured in knots.

GLOSSARY OF TERMS (Cont'd)

Limitations	Airframe limitations are those operating conditions (e. g., speeds, mach numbers, weights or C of G positions) above or beyond which it would be dangerous to go.
	- Engine limitations are operating conditions, e.g., RPM boost, oil and coolant temperatures, etc., which, for reasons of safety or to ensure reliability of the engine, must be observed.
	- Human limitations are limits of acceleration, atmospheric pressure etc., which the human body is capable of withstanding.
Mach Number	- This is the true speed of an aircraft at any height divided by the true speed of sound at that height, expressed as a decimal, e.g., at about 25,000 feet the true speed of sound in air is 600 knots, if the true speed of an aircraft at this height is 450 knots the true Mach number will thus be $\frac{450}{600} = .75$
Mislanding	- An abortive landing. - This arises from troubles near the ground as, for example, a bad hold off, a bounce, or a touch-down with excessive drift, which usually necessitates going round again.
Normal Landing	- An uninterrupted landing carried out by standard methods, e.g., one which has been carried out at steadily decreasing power and airspeed, until the boundry is crossed at the recommended speed and the touch-down made with the throttle fully closed.
Overshooting	- The inability to make a normal landing due to the aircraft being either so high and/or travelling so fast on the final approach that an attempt to land would result in either overflying the airfield or over-running the landing area.
Position Error Correction (PEC)	- A correction to the speed indicated by the ASI, and height indicated by the altimeter, necessitated by reason of the failure of the airspeed system to transmit to these instruments the correct "free stream" total and static pressures. The error results from the positioning of the total pressure and static sources (pressure head and static vent).
Rated Altitude	- The full throttle height for rated - normally intermediate - boost and RPM under standard atmosphere conditions. - Engines with two speed superchargers have a rated altitude in low and a higher rated altitude in high gear. The actual full throttle heights at rated boost obtained in flight are influenced by ram effect and air intake efficiencies and thus may differ considerably from the rated altitudes for the engine quoted by the manufacturers.

GLOSSARY OF TERMS (Cont'd)

Safety Speed	-	The lowest speed on multi-engined aircraft above the stalling speed which, on take-off ensures a safe margin of control in the event of complete failure of the engine most affecting directional control. - It follows that having attained this speed on take-off will be safe to commence the climb knowing that should any engine then fail the aircraft will not stall or become uncontrollable and that, unless it is overloaded or basically underpowered, it will be possible at least to maintain height while appropriate corrective action is taken.
Standard Atmosphere	-	A set of atmospheric conditions laid down by the International Commission for Aerial Navigation (ICAN) for comparison of aircraft performance. - The standard atmosphere is assumed to have a pressure of 1013.2 millibars at a temperature of 15°C, at sea level, which temperature is assumed to decrease at 1.98°C per 1,000 feet up to 36,000 feet and to remain constant at -56.5°C above this height.
Standard Rate Turn	-	A turn involving a rate of change of heading of 180° per minute, irrespective of the reading of the turn indicator.
True Airspeed (TAS)	-	The true speed of the aircraft at any altitude, i. e., the distance made good per hour in still air.
Undershooting	-	The inability to make a normal landing due to the aircraft being either so low and/or so far from the airfield on the final approach, that power would have to be increased to reach the landing area.

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PART 1

HANDLING AND PERFORMANCE CONSIDERATIONS

SECTION 1

AIRFRAME LIMITATIONS

GENERAL

1 Aircraft should not be flown at indicated airspeeds, Mach numbers, or weights, in excess of those quoted as flying limitations in Pilot's Operating Instructions (POI) for the type; nor should they be flown at non-standard loadings or C of G positions outside the limits given in the POI. These limitations are fixed for considerations of safety and, in general, depend on factors which are not related to the skill of the pilot. Disregard of these limitations will lead to unserviceability and may strain the structure causing it to fail immediately or on a subsequent flight. Limitations take into account design strength calculations, safe handling and controllability.

2 In particular, exceeding the maximum IAS limitation of Mach number limitation (if any) involves risk of structural failure and should be avoided unless considerations of operational necessity or emergency make it essential for the pilot deliberately to take risks with his aircraft, balancing one risk against another. In all cases, if these limitations are unavoidably exceeded this must be reported at the end of the flight, so that an examination of the airframe can, if necessary, be made.

3 Mach number limitations are imposed only when they are essential, e.g., when there is a direct risk of immediate structural failure or when recovery from loss of control may result in structural failure.

4 The POI describe the behaviour to be expected at the highest Mach number at which the aircraft can be or has been flown.

5 This Section should be read in conjunction with Section 7.

CONSIDERATIONS FOR FIXING IAS LIMITATIONS

6 To allow for manoeuvring, the wings of an aircraft are designed to withstand a maximum safe positive lift of about two and a half times the maximum static weight in the case of heavy bomber and transport aircraft, and seven or more times the weight in the case of fighter types which are required to be more manoeuvrable. Similar but lower values are usually fixed for the maximum safe negative lift. In fixing the limitations based on strength calculations, there is a margin or factor of safety allowed. This factor is usually 1.5. Taking the case of the fighter this means that a positive lift of seven times the weight - a loading of 7g - can safely be applied and that the structure should not fail unless a loading of 1.5 times this - about 11g - is imposed. There is, however, increasing risk of permanent deformation - usually indicated by skin wrinkling - and failure as "g" increases above 7.

7 The air loads acting on an airframe depend principally upon dynamic pressure and vary roughly as the square of the IAS. Figure 1-1 shows how the dynamic pressure, which is 35 lb. per square foot at 100 knots, increases to no less than 875 lb. per square foot at 500 knots. Thus at a certain speed the total load on some part of the airframe, usually the wings or tail structure, increases up to the limit of safety. The strength of the tail structure is frequently the limiting factor because a considerable down load, produced by the elevators, is necessary in order to maintain the wings at the angle of attack required to produce the lift of 7g.

8 The maximum safe airspeed is calculated

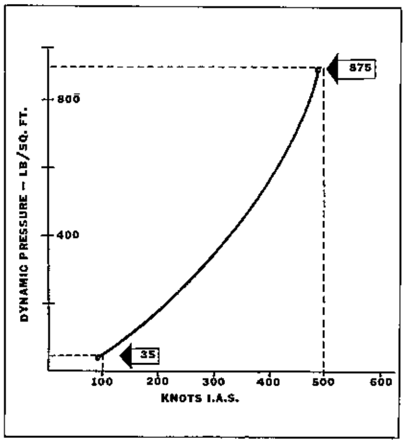


Figure 1-1 Variation of Dynamic Pressure with Airspeed

by the designers with regard to the above considerations. The IAS limitation imposed and quoted in POI for the type is based on this maximum safe airspeed, due allowance being made, if necessary, for the pressure error correction.

9 The speed limits for lowering the flaps and the undercarriage arise from calculations, either of the strength of the parts to withstand the air forces, or of the power of the operating mechanism. In addition, should the undercarriage be lowered at high speeds, there is the possibility that the aircraft may become suddenly uncontrollable or that the airframe may be subjected to dangerously severe stresses. For this reason, should the indicator show that the undercarriage, or one unit of the undercarriage, is not properly locked up, speed should immediately be reduced to that permitted with the undercarriage down and a landing made as soon as possible. These calculations normally assume that the flaps are used only during take-off and landing or for straight flight and gentle turns. Unless the POI for the type indicate that the flaps are designed to assist manoeuvres, they should not be used under conditions of loading appreciably greater than the "g" of steady level flight. It should be noted that the figures quoted are limits, and are not recommended as the best speeds at which to perform these operations. The limiting speeds quoted for the operation of other items, such as bomb doors and landing lights, are imposed for similar reasons.

THE V-g DIAGRAM

10 The information given in the preceding paragraphs is explained diagrammatically by the typical V-g (IAS and "g" load factor) diagram, Figure 1-2.

(a) In this, both positive and negative "g" loads are plotted against IAS in knots. The green "g" stall curves indicate the IAS at which the aircraft will stall at positive and negative "g", the speed increasing as the square root of the applied "g". Thus the aircraft to which this diagram would apply would stall at 100 knots IAS in normal flight (at 1g) and at 200 knots at 4g.

(b) The vertical red line represents the maximum safe speed - the IAS limitation.

(c) The green area of the diagram thus represents the safe manoeuvre zone or envel-

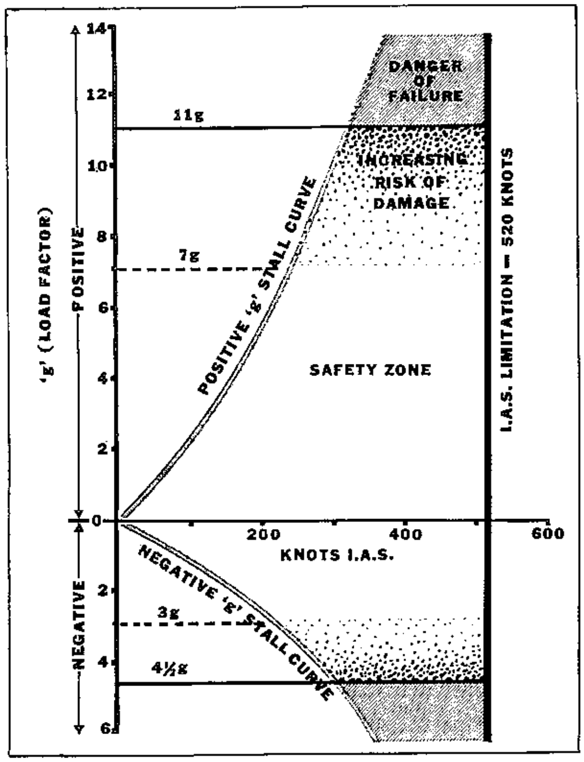


Figure 1-2 Typical Fighter Aircraft V-g Diagram

ope, neglecting compressibility effects. This is bounded by:-

(1) The "g" stall curves.

(2) The maximum safe "g" limits.

(3) The IAS limitation.

(d) The red areas represent the high "g" zones within which danger of damage or failure of the structure exists.

CONSIDERATIONS FOR IMPOSING MACH NUMBER LIMITATIONS

11 The Mach number corresponding to a given IAS increases as height is gained. In the case of high performance aircraft a speed may therefore be reached which, while less than the IAS limitation, is in excess of the Critical Mach number at the higher altitudes. At the Critical Mach number compressibility effects begin to become marked and as the Mach number increases, buffeting, changes of trim due to partial shock stalling, eventual loss of lift, progressive reduction in control effectiveness and even total loss of control may result. These effects, in particular loss of lift, occur at a lower Mach number and may be more severe if "g" is imposed during manoeuvres, if the air is turbulent, or if the aircraft is not "clean", e.g. if external fuel tanks or stores are carried. In addition at high IAS other trim changes may occur, due to aeroelastic distortion, which modify the high Mach number behaviour of the aircraft at the lower altitudes where a high Mach number corresponds to a high IAS.

12 Danger of structural failure does not always result directly from compressibility effects unless buffeting or vibration is severe and sustained - this may loosen rivets or weaken the structure due to fatigue. An indirect danger results, however, if the IAS limitation is exceeded as a consequence of control difficulties due to compressibility effects. A Mach number limitation is imposed when necessary for reasons of safety. The policy is however to avoid imposing a limitation if possible and to give information in the POI which will enable a pilot to investigate safely the compressibility characteristics of an aircraft at high speed. When the pilot has gained experience on the type, it is not harmful for him to exceed the Critical Mach number even up to the threshold of loss of control, provided that vibration or buffeting is not severe. At lower altitudes, however, should control be lost, even the most experienced pilot may be unable to prevent the IAS increasing to a dangerous extent before control is regained. In addition, after control has been regained, there will be a temptation to impose excessive "g" in order to regain level flight, if in fact recovery is possible at all, within the height available. At all altitudes there is the possibility, when flying in calm air at high Mach numbers, that no symptoms of compressibility will be apparent but that marked or severe symptoms may develop without warning or increase of speed if turbulent air is suddenly encountered or even moderate "g" applied. The possible results of the cumulative effects of turbulent air and high "g" should, therefore, be borne in mind.

13 The Critical Mach number decreases with increase in weight, "g" loading and turbulence. Owing to this variation as well as to the unpredictable errors of the machmeter, it is impossible to say for any type of aircraft at what indicated Mach number severe compressibility effects will occur in any given circumstances. For the lower altitudes, however, the danger of exceeding the IAS limitation makes the imposition of a Mach number limitation unavoidable in some cases. This is based on the results of flight trials to correspond as closely as can be estimated to the Critical Mach number for the type under the worst possible combination of circumstances likely to be encountered. Were this limitation to be rigidly imposed for all altitudes, it would be so low that the operational usefulness of the aircraft at the higher altitudes would be unnecessarily restricted. At such altitudes, should control be lost, the danger of exceeding the IAS limitation during recovery is much more remote. For this reason a higher limitation, or sometimes no limitation at all, is imposed above a certain height. If necessary additional Mach number limitations are imposed for the aircraft when carrying external stores; these limitations have the same significance and should be interpreted in the same way as those for a clean aircraft.

14 In the case of high speed aircraft not fitted with machmeters a series of IAS limitations, decreasing at the higher altitudes, is

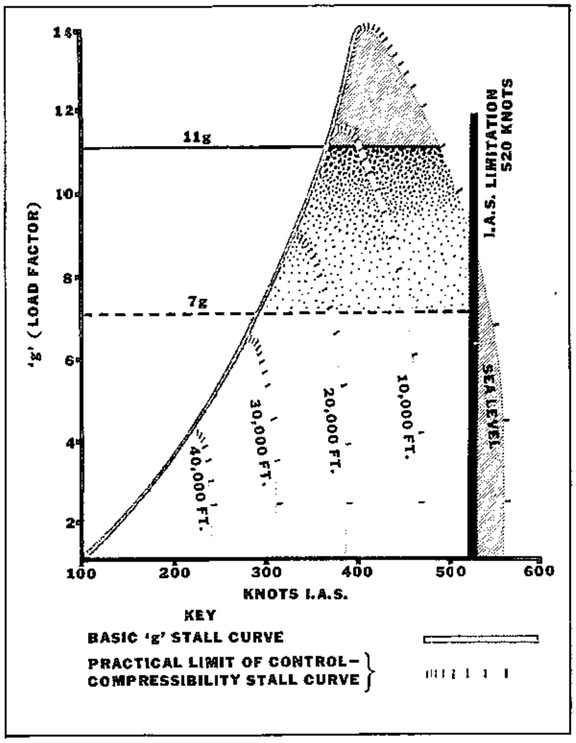


Figure 1-3 Manoeuvre Envelope Diagram

imposed. In such cases the highest of these is an overriding IAS limitation, as imposed for all aircraft. The lower values quoted in the POI as applying at higher altitudes correspond to Mach number limitations and should be considered as having the same significance.

WEIGHT LIMITATIONS

15 Pilot's Operating Instructions sometimes quote more than one weight limitation, for example:-

> "Maximum weight for take-off and gentle manoeuvres only.........."

and a lower limit -

> "Maximum weight for all forms of flying..........."

and a still lower limit -

> "Maximum weight for landing ...."

NOTE

The meaning to the pilot is that the aircraft must be handled gently, banked moderately, subjected only to small increase in "g", and should preferably be kept well within the IAS and Mach number limitations, until the weight falls to the limit at which all forms of flying are permitted. Similarly no attempt should be made at such high weights deliberately to stall the aircraft or to carry out any form of manoeuvre which, although not essentially involving high "g" loads, may in certain circumstances lead to the aircraft getting temporarily out of control and to the unavoidable imposition of high "g" loads during recovery. The limitation imposed for landing, when the strength of the undercarriage makes this necessary, should be exceeded only when an emergency landing is unavoidable and excess load cannot be jettisoned.

"g" LIMITATIONS

16 "g" limitations cannot be laid down for aircraft unless visual indicating accelerometers - "g" meters - are fitted. It is nevertheless important that excessive "g" loads are not imposed for the reason given in paras. 6 to 9 above. To ensure this, every endeavour is made to design the control circuits in such a manner as to require the application by the pilot of an abnormal force in order to deflect the control surfaces sufficiently to produce excessive "g" loads. Careful trimming is, however, necessary as explained in Section 7 of this Part.

17 The danger of breaking the aircraft is much greater at the lower altitudes because at the higher altitudes it is impossible to impose excessive "g"; Figure 1-3 showing "g" loads plotted against IAS for an imaginary aircraft, illustrates this. The diagram corresponds to the positive "g" part of the V-g diagram and in addition shows five manoeuvre zones or envelopes at different altitudes. Each zone is bounded by the green basic "g" stall curve and by the dotted yellow and green compressibility curve applying at the particular altitude. These curves show the limits imposed by compressibility effects on the ability of the aircraft to manoeuvre. They indicate at low "g", the prac-

tical limit of control which usually results from loss of control effectiveness or other causes; this may be expected to occur at about the same Mach number at any height and at a progressively lower airspeed as height is gained. At higher "g", however, there is an increasing tendency, due to compressibility, for the aircraft to stall before other compressibility effects become severe; this occurs at progressively lower Mach numbers as "g" is increased as shown by the sloping dotted parts of the curves. With an aircraft to which this diagram would apply, the safe limit of 7g could be reached only at altitudes below about 30,000 feet and the breaking load of 11g imposed only below about 11,000 feet. During pull-out from a dive higher "g" loads can be imposed as the speed and so Mach number, falls off during recovery. This will be clear from the diagram which also shows that as the Mach number falls with loss of height during a dive at constant (or even decreasing) IAS, there is increasing danger of reaching excessive "g" loads without stalling during recovery.

18 V-g recorders are fitted in some aircraft to provide a record of the airspeeds and "g" loads reached under operational flying conditions for the information of design authorities. They give no visual indication to the pilot of the loads and speeds but an on-off cock is fitted to enable the recorder to be brought into operation by the pilot when he is required to do so.

ALTITUDE LIMITATIONS

19 Although altitude limitations are not laid down or quoted in POI the following should be noted:-

(a) At heights of 10,000 feet and above, full efficiency of the body cannot be maintained without the use of oxygen. Above 35,000 feet augmented pressure in addition to oxygen becomes increasingly necessary and is essential at 40,000 feet and above; this may be achieved by means of pressure cabins, pressure suits or, if these are not available, pressure breathing apparatus can be used. This apparatus forces oxygen into the lungs, but under slight positive pressure only, as unfortunately a high internal pressure cannot be tolerated by the body in the absence of an increase in the external pressure; it is therefore, not suitable for use by itself at altitudes in excess of 44,000 feet and above 43,000 feet should be used in pressurized aircraft as a safeguard against the risk of loss of cabin pressure. Using pressure breathing apparatus only, the user's full efficiency should be maintained for about 15 minutes at a cabin altitude of 44,000 feet and for increasing periods at lower altitudes down to 40,000 feet.

(b) With pressure cabins, a sudden loss of pressure may occur, due to a defect or enemy action, and there is increasing danger, which is accentuated by any slight exertion, when flying at altitudes above about 45,000 feet. For these reasons, allowing a margin for safety and for unavoidable exertion in controlling the aircraft, a height of 43,000 feet should normally not be exceeded. A height of 48,000 feet is, however, permissible if pressure breathing apparatus is used as in the event of loss of cabin pressure protection is then afforded by the apparatus while the aircraft is descending to a safe height.

MANOEUVRES NOT PERMITTED

Intentional Spinning

20 Intentional spinning is permitted only in the case of certain approved aircraft types and within the limitations stated in the POI.

Aerobatics

21 Pilot's Operating Instructions for individual aircraft state whether aerobatics are permitted or not.

Prohibited Manoeuvres

22 The following manoeuvres are prohibited on all aircraft:-

(a) Flick roll

(b) Flick half roll

(c) Bunt

(d) Outside loop

Inverted Flying

23 Inverted flying, other than the brief inversions necessary in the execution of aerobatics is not permitted, except on aircraft designed or adapted for the purpose. Certain aircraft

have negative "g" oil tanks, negative "g" carburettors or their equivalent, e.g., injector pumps, and small negative "g" compartments in the fuel tanks. These ensure the maintenance of oil pressure and fuel feed for brief periods when, through badly executed manoeuvres, the aircraft remains inverted for longer than normally necessary. Negative "g" fuel and oil systems permitting sustained inverted flight under power, are not standard equipment.

General

24 The reasons underlying these prohibitions are partly considerations of strength and partly of control. Aircraft are designed to fulfil their operational role and not to perform manoeuvres of no operational value.

(a) Permissible aerobatics, on approved types, include:-

(1) Loop

(2) Stall turn

(3) Inverted glide (on approved training aircraft)

(4) Slow roll

(5) Barrel roll

(6) Half roll off top of loop

(7) Half roll

FLYING IN SEVERE TURBULENCE

25 "Bumpy" air imposes "g" on the airframe and the effect of either horizontal or vertical gusts on the aircraft is proportional to the speed at which it is flying.

26 The recommended speeds for flying in turbulent conditions should be maintained.

27 Control movements should be gentle, and no attempt should be made to fly the aircraft to close limits of accuracy. The aim should be to maintain a fairly constant attitude and/or IAS, accepting any variations in height which occur.

28 As the effects of bumps may increase the "g" imposed in manoeuvring, coarse use of the controls should be avoided and "g" restricted to the lower limits in rough weather.

C of G LIMITS

29 Flying limitations properly include the most forward and the most aft permissible positions of the center of gravity (C of G) of the aircraft. These positions are not usually quoted in POI as all the necessary information should be found in the respective -8 Engineering Order; the aircraft should be flown at standard loadings at which the C of G is within the safe limits. Due allowance should always be made for any shift of the C of G as fuel is used, stores dropped, and, in some cases, as the undercarriage is retracted.

30 It is, however, sometimes necessary to include in the POI some instructions on the use of fuel, the release of load, the disposition of crew, or the carriage of ballast in order to keep the C of G within the limits, and to give the aircraft the best handling characteristics.

31 Pilots may sometimes have occasion to carry non-standard loads and they must ensure that the disposition of such loads will keep the C of G within the limits. The balance of loading will be maintained by the omission of weight equal to the additional load to be carried at the same distance from the C of G or the addition of a greater or less weight at a correspondingly less or greater distance, on the other side of the C of G. If the position of the C of G is not known it may be assumed, for this purpose, to be at one-third of the root chord of the wing from the leading edge.

32 If these C of G limits are not observed, a condition may arise at some stage of the flight at which the aircraft may become uncontrollably nose or tail heavy and the trimmer range may be insufficient to enable the aircraft to be trimmed for the required condition of flight. If the C of G is too far aft, the aircraft may become longitudinally unstable to an uncomfortable or even dangerous degree.

WHEEL BRAKE PROBLEMS

33 The introduction of larger and faster aircraft into the RCAF has increased the failure rate on tires, wheels, brakes and anti-skid units. Failures sometimes occur following the equivalent of a rejected take-off or short runway landing where maximum braking has been used. The danger to both aircrew and groundcrew attempting a take-off shortly after more than normal braking has been necessary, is obvious and has resulted in damage to items of high value and others which were in short supply.

34 Unless an operational requirement involving a high calculated risk demands repeated high energy stops, a cooling period of at least one hour or until the brake can be touched by hand should elapse between such brake runs. In addition, whenever more than normal braking has been necessary, the pilot is to make an L14 entry that a close examination of wheels, brakes and tires is to be made before the next flight. This inspection will not be made until the wheels have cooled enough that the inspection can be done safely. Tires will be examined for cracks, flat spots and cord damage. Wheels and brakes will be examined for charred lining, abnormal discolouration or warpage.

SECTION 2

ENGINE LIMITATIONS

GENERAL

1 Pilot's Operating Instructions for each type of aircraft quote certain engine limitations which should be observed in the handling of an engine.

2 These limitations are based upon calculations and type tests on the bench. They may subsequently be modified in the light of service experience and operational requirements. While normally the same for any one type of engine, they may vary for the same engine when fitted in different types of aircraft.

3 The limitations are designed to secure an adequate margin of safety against immediate breakdown and to give the engine a reasonable life. Proper handling throughout the life of an engine will improve reliability towards the end of the periods between overhauls, and will also improve the chance of the engine standing up to operational overloads.

4 With piston engines, optimum reliability and long trouble-free life are assured by restricting the use of the higher powers as much as possible. During take-off the aim should be to use full take-off power for the shortest practicable time, the power being reduced as soon as this can be safely done. On lightly loaded aircraft and high performance types - e.g. fighters - it may not be necessary to use the full permitted boost at all if experience with the aircraft shows that in the particular conditions of weight, weather and available take-off run, take-off can safely be made at lower power and without having to use this reduced power for a disproportionately long period. Similarly, climb should be made at less than the full intermediate power permitted, even within the weak mixture range, provided overheating does not result and an acceptable rate of climb can be maintained.

5 With turbine jet engines, as with piston engines, the use of high powers involving high RPM and jet pipe and/or oil temperatures for an unduly high percentage in the aggregate of the total engine running hours, tends to reduce engine life and reliability. This applies even when high powers are used for periods not greater than permitted by the limitations. Consistent with safety, the aim should therefore be to use high powers as seldom as possible and for the minimum periods compatible with operational efficiency.

6 With all engines, the unavoidable use of engine conditions not permitted by the limitations or of the permitted conditions for longer than the periods laid down, should be reported after landing.

LIMITATIONS FOR PISTON ENGINES

7 The stresses and wear are increased at high RPM, due to inertia loading, and at high boost due to high gas pressures causing high piston and bearing loads. Consequently maximum RPM and boost limitations which apply at four main power conditions are usually imposed. See paragraph 10.

8 High cylinder temperatures lead to a break down in cylinder wall lubrication, to excessive gas temperatures, to detonation at high boosts, and to distortion. High oil temperatures cause failure of cylinder and bearing lubrication. Accordingly maximum cylinder, or coolant, and oil temperature limitations are also imposed for the four main power conditions.

9 Shortage of oil, or a defect in the lubrication system may result in inadequate lubrication and bearing failure. A minimum oil pressure limitation is therefore included.

10 The following table of engine limitations for a liquid cooled engine is typical of those quoted in POIs. It shows the principal limitations associated with each of the four main conditions.

TABLE 1

	Gear	RPM	Boost lb/sq.in.	Temperature, °C	
				Coolant	Oil
Max. Take-off 5 Mins. Limit	Low	2,750	+12		
Maximum Intermediate 1 Hr. Limit	Low High	2,600	+9	125	90
Maximum Continuous	Low High	2,400 2,600	+7	105	90
Operational Necessity 5 Mins. Limit	Low High	2,750	+18	135	105
Oil Pressure:- Minimum				45 lb/sq. in.	
Minimum Temp. for Take-off:- Oil Coolant				 +15°C +40°C	

11 It will be seen that Table 1 includes certain limitations not previously mentioned. These and some other limits quoted below are imposed when necessary for the following reasons:-

(a) Minimum oil and cylinder or coolant temperatures for take-off, to ensure proper circulation of the oil and to prevent damage due to rapid and uneven heating while using high powers.

(b) A maximum cylinder temperature prior to take-off, to ensure that the temperature will not exceed the higher maximum permitted with take-off power. For liquid cooled engines no such limit is necessary since the coolant temperature does not rise so rapidly.

(c) Minimum RPM at take-off or operational necessity boost, to prevent excessive bearing loads and detonation which may result at very high boost and lower RPM due to the higher volumetric efficiency. At low RPM there is a smaller loss of pressure at the valves due to interference because of the reduced velocity of the gas flow. Higher cylinder pressures and an increased weight of charge per stroke are, therefore, obtained at the same boost, i.e. the volumetric efficiency is increased. When no such limitation is quoted, a good practical rule with highly boosted engines is to avoid the use of take-off boost at RPM less than 150 below the maximum permitted for take-off. When boost in excess of the take-off limit is permitted for use in operational necessity, it should be used with not less than the minimum RPM allowed under these conditions. This does not apply to Bristol sleeve valve engines with which combinations of high boost and low RPM are not harmful.

(d) A maximum cylinder temperature for stopping the engine, imposed to prevent overheating of the ignition harness and cylinder distortion due to rapid and uneven cooling after the engine has been stopped. In all cases, engines should be run gently before stopping to achieve even cooling and to leave an adequate oil film on the cylinder walls.

(e) A diving RPM limitation, imposed for certain engines with propellers of limited pitch range on which the normal maximum RPM may be exceeded in a dive. This diving limit is usually allowed for a period of 20 seconds only, and with the throttle not less than one-third open. The POI for such aircraft quote this limitation.

(f) On other piston engined aircraft over-speeding may occur during diving, or sometimes in other conditions of flight, particularly if the propeller constant speed unit is sluggish in operation or defective. Such overspeeding should be momentary only, but if it persists for more than a few seconds, airspeed should be reduced, and appropriate action taken as laid down in Part 2, Section 4. If overspeeding exceeds 5 percent of the maximum permitted RPM or is allowed to persist for more than 20 seconds, the engine may be damaged. This is the significance of the overspeed limitations quoted in certain engine publications, although such limitations do not appear in the aircraft POI.

12 Some other points to be noted are:-

(a) Where mixture regulation is not automatic, boost in excess of the maximum quoted for use with weak mixture must only be used with the mixture control set to rich. With automatic regulation, a weak mixture is obtained with the throttle lever set to give not more than the maximum weak mixture boost or, in some cases, with the throttle lever set at or behind the economical cruising position marked on the quadrant.

(b) With interconnected throttle and RPM controls, at any selected boost, suitable RPM are automatically obtained while the propeller control is set to the interconnected, "auto", position.

(c) With some installations, the maximum boost permitted for take-off may not be obtainable on the ground owing to the absence of ram effect, use of hot air, use of intake filters, high altitude of the airfield, or high atmospheric temperatures.

(d) Serious damage may occur quickly from overheating or failure of the lubricating system and the limitations should be strictly observed. Pilots should frequently check the temperatures and oil pressure and adjust the gills or shutters, the airspeed or power, accordingly. Under normal conditions the oil pressure in the system tends to vary on many in-line engines through a considerable range, increasing with RPM but decreasing with rise in temperature which lowers the viscosity. In addition a progressive decrease in oil pressure under any given conditions tends to occur as the bearing clearances increase with wear. The minimum oil pressure quoted in the limitations in POI is a definite limitation; where, however, normal oil pressures are quoted in addition, these are for guidance only. Although it is permissible to run engines provided the oil pressure is not less than the minimum limitation, under steady running conditions as abnormal, particularly if rapid, drop in oil pressure or rise in temperature may be the first indication that trouble is developing. In such circumstances, even if the temperatures and pressures remain within the limits prescribed, the pilot should use his discretion and feather the propeller or, in the case of single-engine types, land as soon as practicable. Similarly when checking engines before take-off, should the pilot consider that the oil pressure is appreciably lower than experience indicates is normal on that engine under comparable conditions, a defect should be suspected.

(e) Although at any given power condition neither the RPM nor the boost limitation should be exceeded, combinations of RPM up to the maximum permitted for take-off with a lower boost may be used for short periods, as during take-off at light loads on certain types when a combination of maximum take-off RPM with less than the maximum permissible boost may be used if this gives sufficient power. Other examples are, when running engines on the ground, when reducing power after take-off, and during the approach. With Bristol sleeve valve engines the use of high RPM at low boost should, however, be avoided whenever possible.

(f) With maximum economical boost, RPM down to the minimum practicable may be used. At maximum continuous rich mixture boost, low RPM may also be used in most cases. If, however, the required speed can be maintained at maximum weak mixture power, this should be used unless rich mixture is necessary in order to prevent excessive engine temperatures.

(g) The term "operational necessity" is now quoted in POI instead of the term "combat" as, particularly for transport aircraft, it is more appropriate.

(h) The term "intermediate" is likewise now quoted in POI instead of "climbing", as this power condition may be used when necessary in level flight, as well as for climbing, for the permitted time, usually one hour. In the interest of reliability and engine life, however, it should not be used indiscriminately.

LIMITATIONS FOR TURBINE-JET ENGINES

13 For turbine-jet engines the following limitations are usually imposed. They apply at the same four principal power conditions as in the case of piston engines and are:

(a) Different RPM limits for continuous use, for climbing (intermediate), for take-off and for combat (operational necessity). These ensure that the combination of temperature and centrifugal stresses is kept within the desired limits. See (d). On the ground the maximum governed RPM of a turbine jet engine may vary. For this reason a variation, of ±100 (±50 for low revving engines such as the Avon) from the maximum RPM for take-off or in operational necessity, is permissible whether or not any tolerance is quoted in the engine limitations for the type.

(b) Maximum and minimum oil temperatures and, in some cases, normal and minimum oil and fuel pressures.

(c) Minimum RPM limitations for idling on the ground, and in some cases in flight above certain altitudes. In the latter case, these are imposed to ensure that combustion does not cease due to fuel pressure at the burners falling too low in relation to the blast of air from the compressor, or to maintain adequate pressure for the pressure cabin.

(d) Maximum jet pipe temperatures, for continuous and short period use, to prevent distortion of the turbine parts due to overheating. This is the most important limitation for turbine-jet engines. The power output of the engine is limited by the jet pipe temperature which it can withstand, and the maximum figure should not be exceeded as the turbine blades tend to distort under the influence of centrifugal force and thermal expansion. At temperatures above the maximum permitted, which is extremely critical, they may foul their shroud ring, resulting in major internal damage to the engine.

SECTION 3

SOME PRACTICAL ASPECTS OF HUMAN LIMITATIONS

INTRODUCTION

1 The performance of modern aircraft in speed and at altitude can exceed the capabilities to fit aircrew. The limitations of the body must be thoroughly understood by all aircrew and particularly by captains of aircraft who may be responsible for untrained passengers.

FORCES ACTING ON THE BODY

Centrifugal Forces

2 Some forces acting on the body are as follows:

(a) High speed manoeuvres cause centrifugal forces to act upon the body. The loading is measured in terms of gravity, namely "g". A loading of 3g is equivalent to a force three times that of gravity. In flight, "g" acts most frequently in a head-to-foot direction. Values in the region of 5g for about five seconds cause black-out because blood is drained from the head. Much higher values of "g" can be tolerated for a very short time. This explains why a pilot can break an aircraft without blacking out. If the force acts in the reverse direction from foot to head, red-out occurs. This is due to too much blood being forced into the eyes and occurs at "g" values about half of those required for black-out. Tolerance to "g" varies from individual to individual and in the same person on different days, and is decreased by illness, hunger, fatigue, hang-over, and oxygen lack. Methods of protection against black-out depend upon preventing the blood leaving, or assisting it to return to, the head. They include:

(1) Self protection. By straining and tightening the belly muscles as in grunting, and at the same time crouching and lowering the head, the extra tolerance given being in the region of 1g.

(2) Position. - By raising the legs in the sitting position, as when using elevated rudder pedals. Maximum protection is afforded by assuming the prone position.

(3) Anti-G suits - which exert pressure on the lower limbs and abdomen to the value of 1 lb. per sq. inch per "g". A properly fitted anti-g suit will increase the black-out threshold by 2g.

Linear Forces

3 These are encountered during accelerated take-offs, deck landings, ditchings and crashes. The same unit of measurement applies. Values which may be expected are, 3 1/2g for catapult launching and 3g for normal deck landing; these values are tending to increase. In crashes or ditchings the forces may considerably exceed 10g, but if aircrew wear correctly fitted harness and/or assume recognized crash positions, they can withstand such forces up to the breaking strength of the aircraft. The standard "Q" type harness provides protection up to 14g if correctly fitted with the lap belt as low and tight as possible and the shoulder straps locked. A high lap belt may allow the wearer to slip forward under the harness.

EFFECTS OF ALTITUDE

4 A proper understanding of the problem of oxygen, why it should be used, when it should be used, and how it should be used, is essential for aircrew safety. Regulations require the use of oxygen at altitudes above 10,000 feet. However, it is commonly believed that to go without oxygen above 10,000 feet is an indication of manliness or toughness, and that only sissies put on their mask at 10,000 feet. This is not true. The ability of a man to withstand anoxia bears no relation to his physical or glandular development. The difficulty seems to be accounted for by the fact that the early symptoms of anoxia (lack of oxygen) are quite similar to the early symptoms experienced from the use of alcohol, and are similarly as difficult for the person directly concerned to detect.

5 The changes in the characteristics of

the atmosphere begin having important effects on the operation of the body's combustion system at 10,000 feet. In fact, it may be said that high-altitude life begins at 10,000 feet. Below that altitude the physically fit body can make its own adjustment, but above that it will labor and eventually stall if not provided with protective equipment. A great many things can happen, but the foremost is running out of oxygen.

6 The earth is surrounded by a covering of mixed gases and water vapor. This is the atmosphere. It is more than 100 miles in depth, and is actually as much a part of our world as land and sea, being held to the earth's surface by gravity.

7 If one were to cut a piece of dry air from the atmosphere - say, 1 inch square and 100 inches high - and divide its gases into layers, you would have: 78 inches of nitrogen, 21 inches of oxygen, and about 1 inch of miscellaneous gases including carbon dioxide, argon, and hydrogen. Taken as it comes, however, the air contains a variable amount of water vapor, usually from 1 to 5 percent. This reduces the proportions of oxygen and nitrogen to that extent. The percentage of oxygen in the atmosphere remains the same whatever the altitude, whether sea level or 50,000 feet. There is, however, a smaller quantity of oxygen at high altitudes where the air is "thin" or "rare" than at sea level where it is dense.

8 The atmosphere is "piled" on the earth's surface like a haystack. The bottom layers are packed down and therefore are heavier than the layers near the top where the hay is loose.

9 If one could box a vertical column of air 1 inch square from sea level to the upper limit of the atmosphere and set it on a scale, it would be found to weigh 14.7 pounds. But because the gases in the air "pack down", the weight of the column would be greater in the lower 1/3 of the column than it would be in the upper 2/3.

10 Oxygen is literally the "breath of life". It is necessary in the combustion of all fuels - including gasoline and food. In fact, the body uses oxygen in much the same fashion as an internal combustion engine. It combines with carbon compound to produce driving energy. Carbon dioxide is given off as a waste gas.

11 The body obtains its oxygen by breathing air through the lungs. The lungs operate like a cylinder pump, the piston action coming from chest muscles which raise the ribs and from contraction of the diaphragm below the lungs.

INSPIRATION

12 Breathing-in pulls the chest wall and diaphragm away from the lungs and creates a negative pressure, or suction. The pressure of the atmosphere forces the air to rush in through the windpipe and inflate the lungs. This is the active phase of respiration and requires muscular effort.

EXPIRATION

13 Breathing out takes place when the chest muscles and diaphragm are relaxed. In this passive phase the chest cavity becomes smaller and pushes the air out of the lungs.

14 Oxygen is extracted from the air passing in and out of the lungs by millions of remarkable little sacs called the alveoli. These tiny pockets of delicate membrane are interlaced with a network of fine blood vessels. Their total surface area is between 700 and 800 square feet.

15 These air sacs are the point where the oxygen enters the blood stream, and where carbon dioxide leaves it. Their walls and the walls of the adjacent blood vessels are so thin that any difference in pressure on either side will cause gas to pass through. The blood is continually moving through the lungs, and the exchange of oxygen and carbon dioxide takes only a second or two. The lung's blood vessels are part of the circulatory system, which consists of:

(a) Arteries connecting with the network of blood vessels in the body.

(b) Veins completing the circuit back to the lungs. The oxygen entering the blood is loaded on a continuous fleet of efficient carriers, the red blood cells. The cells enable the blood to carry 100 times as much oxygen as can be dissolved in water.

16 Thus, the lungs serve as a supply depot and refinery for oxygen and a dump for carbon dioxide. The blood, acting as a hydraulic conveyor system, is pumped by the heart. The oxygen is carried into the body's tissues,

where it goes to work in a chemical laboratory burning food to produce energy so the body can work.

17 Oxygen moves from the lungs into the blood stream because it is under greater pressure in the air than in the blood, and a gas always diffuses from a region of higher to one of lower pressure. The atmospheric pressure of oxygen, however, is not the same as that of air, which is 760 millimeters of mercury at sea level.

18 Oxygen makes up only 21 percent of the air and likewise only 21 percent or 160 millimeters of the total air pressure at sea level. This is called its partial pressure. The partial pressure of nitrogen and other inert gases in the air are unimportant inasmuch as they are exhaled in the same quantity as inhaled.

19 While the partial pressure of oxygen is ample to supply the body with oxygen at ground level, its pressure decreases the same as atmospheric pressure when one rises to high altitudes.

20 How an increase in the oxygen content of the air breathed offsets reduction in partial pressure may be seen from this example: At 18,000 feet altitude, the partial pressure of oxygen is 80 millimeters, compared to 160 at sea level. If the proportion of oxygen is increased from 21 percent to 42 percent, its partial pressure is again 160 millimeters. To obtain 160 millimeters of oxygen pressure at 34,000, pure oxygen is needed. An allowance must be made for water vapor in matching breathing conditions found at ground level. Water vapor pressure in the lungs remains constant, and thus contributes an increasing percentage of the total as the air pressure is reduced.

21 Above 34,000 feet the oxygen in the blood decreases below normal, even with a supply of 100 percent oxygen to the lungs. The critical point is reached at 39,000 feet where 100 percent oxygen is barely enough to keep the oxygen content of blood within safe limits. The period at which one will remain conscious above that altitude is a matter of minutes, despite the mask. Without a mask and with no exercise, it is possible to keep the senses for thirty minutes at 18,000 feet; but at 25,000, consciousness will last only a few minutes; at 30,000, a minute or less, and at 35,000, thirty seconds or less. No harmful effects will result from breathing pure oxygen during air travel. It will not make the teeth brittle or result in pneumonia. When the pressure of the air is too low to force enough oxygen into the blood, the result is "anoxia", a Greek word meaning "without oxygen". The simplest words for it, however, are "oxygen want". The condition can produce a multitude of ill effects, depending on the degree of want. The effects may range, in comparision, from the exhilaration of a couple of highballs to passing out from one too many.

22 Lack of enough oxygen in the blood is a deficiency disease which begins when the oxygen saturation of the blood in the arteries drops below 95 percent. This is the normal amount at ground level. Ninety-five percent saturation means that the blood contains from 18 to 20 percent oxygen by volume. At 11,000 feet without an oxygen mask or at 37,000 feet with one, the blood's saturation will decrease to 85 percent. With this amount of decrease, if the ascent is fairly gradual, there will be no adverse effects felt, although the body is undergoing a depletion of oxygen supply. This, if continued, will affect the brain and lead to errors of judgment. The ability to navigate and to aim may be least when confidence is greatest. The greatest danger is at night. Vision is the first thing affected. For this reason, oxygen masks must be used from the ground up on night missions.

ALTITUDE SICKNESS OR ANOXIA

23 At 13,000 feet without and 37,000 feet with a mask the oxygen saturation declines to 80 percent. Tremor of the hands and a clouding of thought and memory, as well as greater errors of judgment, are likely penalties. At 18,000 feet without and 39,000 feet with a mask, the arterial load arrives at the limit of human tolerance. Anoxia or oxygen deficiency obviously can vary from slight to severe, when flying at altitude above 10,000 feet without oxygen or above 33,000 feet with 100% oxygen. Another way that this may occur is by taking alcohol; the alcohol is rapidly absorbed through the stomach and passes into the blood stream, and it is then carried all round the body in the blood stream, poisoning the tissue cells, and particularly the brain cells, preventing

these cells from carrying out the normal process of oxygen combustion. In effect, this produces an oxygen-lack in these cells. Few men would consider flying as aircrew behind a pilot who was intoxicated - but a pilot who is intoxicated has at least got some control and it is safer to fly with him than with a pilot flying at altitude who doesn't use oxygen. It need not be stressed how appalling the combination would be. If a man is made deliberately anoxic, and is watched, certain signs and symptoms characteristic of the condition will be seen. In tabulated form is shown these effects which are of importance as far as aircrew is concerned: -

(a) Brain

(1) Psychologically: - Sluggish inertia, hilarity.

(2) Decreased Mental Function: - Pugnacity, depression.

(3) Amnesia: - Amorousness, hysteria.

(4) Coma - Death: - Loquacity, euphoria, spurious self-confidence, etc.

(b) Loss of Visual Acuity

(c) Loss of Auditory Acuity

(d) Musculature

(1) Reeling gait

(2) Weakness

(3) Tremors and twitchings

Brain

24 The first effects of anoxia are noticed on the brain, which governs the higher centers. The brain cells are the most highly developed cells in the body, and as such are the most sensitive to the change of oxygen tension in the blood. These effects are not noticed by the person concerned but become increasingly obvious to an observer who is in full possession of his mental faculties.

(a) Psychologically - If a group of men were all to go out and get thoroughly drunk, no two individuals would behave the same. There would be someone singing, someone fighting, someone insisting on making speeches, someone making love, someone asleep, and so on. The same sort of thing happens to a man suffering from anoxia, either in an aircraft, or in a decompression chamber. As can be seen by the table, the psychological effects have been divided into a variety of subdivisions.

(1) Sluggish Inertia, Hilarity - The commonest scene in a pub late on a Saturday night, is people slumped over the table, hardly able to keep their eyes open and apparently just about to go fast asleep. The next is hilarity, and it is well known that that too is pretty common at a party, with a large crowd gathered round a piano and singing songs, etc. Anoxia affects people the same way.

(2) Pugnacity - This is not so common, but does occur from time to time.

(3) Depression - This is not common, although men have actually been seen weeping in the decompression chamber. Depression amongst drunks is said to be more common in women, especially gin drinkers.

(4) Amorousness - This type, when anoxic, will insist on throwing his arms around his neighbours. Hysterical outbursts do occur from time to time, and loquacity is fairly common.

(5) Euphoria - This is a mental state which is characterized by an unfounded feeling of well-being, optimism and bodily health or strength. This is one of the most characteristic mental effects of oxygen-lack, and as such, one of the most dangerous. Medical officers have seen men in the chamber on the verge of passing out, quite convinced that they are perfectly all right, and quite confident that they can do any job given them, although they are practically incapable of holding pencil or paper.

(6) Over-confidence - This condition is closely allied to euphoria and is instilled by oxygen-lack in the majority of men, in the same way that a sense of power and self-confidence is instilled by alcohol into a person under its influence. This spurious self-confidence is highly dangerous in flying, as the very best

pilot, navigator or radio operator under these circumstances has no idea of his limitations.

(b) Mental Function - That the mental function falls off the more anoxic a man becomes, is very easy to demonstrate. Men given a childishly simple problem when in the chamber and anoxic, see for themselves what a hopeless mess they make of it. There is also a very marked lag in the reaction time. When a man in the chamber, who is severely anoxic, is told to plug into his oxygen outlet he may finally accomplish it, but it will probably take him five or six minutes to do it.

(c) Amnesia or Forgetfulness - This always occurs in the anoxic state, and is extremely dangerous and not stressed enough. A man may behave in a grossly abnormal manner when anoxic, yet on being revived insist that he was perfectly all right the whole time. This is because of a complete blank in his memory. It is noted by personnel in the chamber, having been up at altitude and anoxic, and then brought down to ground level, that they have written down all sorts of things about which they have no recollection at all. Amnesia can be well demonstrated, and this is done in the chamber by borrowing money from a grossly anoxic man (and he usually lends without any demur whatsoever); on arrival at ground level he has no recollection of any transaction having taken place. There are many stories of pilots having collapsed in aircraft, getting into a spin and suddenly finding themselves, at five, four or three thousand feet with no recollection at all of how they got there.

(d) Coma - Death - Prolonged exposure to oxygen lack at high altitude probably about 20,000 feet, eventually leads to coma, and from coma to death.

Visual Acuity

25 It will have been noticed in the chamber that the lights become dim as anoxia takes effect, and then they brighten up again as oxygen is given. The seriousness of this needs no emphasis, especially at night. Night vision is reduced anything from 1 to 500 times with only relatively slight degrees of anoxia. Night fighters, realizing this effect, now take oxygen from ground level when going on night sorties. Although this effect is not so important in daytime, it can and does interfere with the accuracy of a navigator's work, with instrument flying or with a bomb aimer's work.

Auditory Acuity

26 Hearing is the last of the special senses to be lost. However, slight degrees of oxygen-lack do cause a lowering of hearing ability. This is of great importance to pilots in multi-engined aircraft, as they are liable when suffering from minor degrees of oxygen-lack to miss some slight alteration in the rhythm of their motors. With radio operators diminished hearing is obviously dangerous.

Musculature

27 Oxygen-lack causes a reeling gait, as in alcohol, and a leaden, heavy feeling in the limbs, usually accompanied by a cold sensation and sometimes pins and needles. Muscular weakness also occurs. This can be demonstrated in the chamber with a grip-testing machine. A normal grip would, say, be a 100 lbs. pressure and would fall, in the same individual when anoxic to about 20 lbs. pressure. Finally, as regards muscles, there are tremors and twitchings. A large number of personnel subjected to a fairly severe degree of anoxia, get these tremors and twitchings. The twitching nearly always commences in the hand with which you are writing, because those muscles are braced round the pencil and are thus burning up more oxygen than those elsewhere. These tremors and twitchings may spread to the arms, legs and face, and eventually the anoxic person may have what to all intents and purposes is an epileptiform fit.

28 From what has been stated, there should be a picture of what oxygen-lack means, with its accompanying dangers to the crew and the aircraft. It should always be remembered that a person will never notice that he is suffering from oxygen-lack unless he is on the watch for it, and in this lack of awareness lies its greatest danger. One should never allow himself to be misled by those wise gentlemen who state that lack of oxygen is a lot of bunk and that they never suffer any ill effects and never use oxygen up to 20,000 feet.

29 As seen in the foregoing discussion it is possible by increasing the supply of oxygen

while ascending to 38,000 feet to maintain the partial pressure of oxygen sufficiently to adequately fill the oxygen requirements of the human body.

30 However on ascending above 38,000 feet even if 100 percent oxygen is supplied to the pilot it is inadequate to maintain the partial pressure necessary to maintain proper body function.

31 It becomes obvious therefore that some other means than quantitively increasing the O_2 is required to fulfil the requirements of the human body at altitudes above 38,000 feet.

32 Two solutions have been adopted and these are:-

(a) Pressure breathing

(b) Cabin pressurization

PRESSURE BREATHING

33 To understand the meaning and advantages of pressure breathing, the part that oxygen pressure plays in the normal process of breathing should be reviewed. Oxygen pressure in the lungs must be maintained above 160 mm to minister to the oxygen needs of the body. Also, above 38,000 feet the symptoms of oxygen-lack may appear even though 100 percent oxygen is delivered to the mask. This level is, therefore, a critical level without either pressurization or pressure breathing. Pressure breathing is merely a means of raising this critical level by delivering oxygen under a positive pressure to make up that difference between the oxygen pressure in the stratosphere and 160 mm required to prevent anoxia. The delivery pressure of oxygen above 40,000 feet is controlled according to the altitude by the pressure demand regulator. Although the critical ceiling can be raised by pressure breathing to 45,000 feet, and for a few minutes to 47,000 feet without benefit of cabin pressurization, pressure breathing for more than a short time is uncomfortable, because the user must exhale against pressure. Contrary to normal breathing where inhalation requires effort and exhalation is a relaxation, pressure breathing necessitates no effort on inhalation, for the oxygen is forced into the lungs, but requires forceful contraction of the chest muscles to expel the lung air against pressure. This unnatural technique causes discomfort and fatigue.

PRESSURIZATION

34 Pressurization, as stated above, is another method of raising the critical ceiling. If the cabin pressure could be maintained at sea level atmospheric pressure (14.7 psi) at any altitude, no oxygen equipment of any type would be required. This method however, is impractical because of structural requirements and the danger of explosive decompression. Such an aircraft, if of the fighter type, would require a cockpit of sufficient strength to withstand a pressure of over one ton per square foot at 40,000 feet. Explosive decompression, that is, the very sudden loss of pressure such as would occur if the cabin were penetrated by a missile, would cause severe injury, if not death, to the occupant.

35 Research on the effects of explosive decompression have shown that the human body can withstand a certain amount of violent pressure change without serious effects. The extent of these effects vary with the size of the hole through which pressure is lost, the size of the cabin, the altitude and pressure differential, the difference in psi between the pressures within and without the pressurized cabin.

36 With a pressure differential of 2.75 psi, at 30,000 feet actual altitude the cabin altimeter will read 18,700 feet; at 35,000 feet actual altitude the cabin altimeter will read 22,000 feet and at 40,000 feet the cabin altimeter will indicate 24,900 feet. Provided that cabin pressure differential is maintained at 2.75 psi flights to almost any extreme of altitude can be made without exceeding the critical altitude of 38,000 feet where pressure breathing would be required.

EXPLOSIVE DECOMPRESSION EFFECTS

37 The effects of explosive decompression are a sudden impression of an explosion having taken place, a sensation of having been distended with air to the extent that air rushes out of the mouth and nose and occasionally pain in the ears and "bends" pain in one or more joints. Gas pains in the stomach are rare but do occur. The effects of explosive decompression last about 20 seconds. The cabin fills momentarily with a white mist of ice crystals resembling smoke but which quickly clears. On explosive decompression, make an immediate descent to a safe oxygen ceiling - 37,000 feet with the economizer and the demand systems,

42,000 feet with the pressure demand system.

38 Using the economizer or simple demand oxygen system unconsciousness will ensue in approximately 2 minutes at 46,000 feet, 1/2 minute at 48,000 feet and in 15 seconds at 50,000 feet.

USE OF OXYGEN IN PARACHUTE JUMPS

39 The possibility of having to bail out and join the caterpillar club is something every flyer must be prepared for. Swinging to earth on a piece of ballooning silk is dangerous enough without addition of other perils which may be encountered in descent. These include:

(a) Fouling the parachute on the plane by pulling the rip cord too soon.

(b) An initial falling speed too great for the chute to withstand.

(c) Unconsciousness from oxygen want at altitudes over 30,000 feet.

(d) Freezing while floating through subzero temperatures found at these altitudes.

(e) Strafing by enemy planes.

40 All of these perils may be minimized greatly by use of the free fall to a low altitude before opening the parachute. The longer the delay opening the chute, the less time exposed to high altitude perils. From 40,000 feet, a parachute descent takes 24 1/2 minutes, whereas a free fall requires a trifle over three minutes. The fall through the first 10,000 feet, where oxygen want and freezing are most dangerous, is accomplished in just over 1/2 minute.

41 It is at least theoretically possible to hold the breath that long. Whether it can be done during a bail-out depends on whether oxygen is breathed up to the point of jumping and on how much exertion is required to get out of the ship. In any event, delay removing the oxygen mask as long as possible and then take three or four deep breaths of pure oxygen. Hold this oxygen in the lungs as long as possible and then breathe as little as possible until well under 30,000 feet. Low-pressure chamber tests have indicated that if consciousness is lost from oxygen want, the fall into denser air will restore it in time to pull the rip cord.

42 To eliminate the risk, and to furnish an oxygen supply if the parachute is opened too soon, a bail-out bottle is often provided. This is a small oxygen cylinder.

43 The walk-around bottle carried in bombers also can be used in a parachute jump if there is time to connect it to the oxygen mask. It will probably be jerked off, however, when the chute is opened.

44 To avoid possible rupture of an eardrum during a free fall, constantly clear the ears. The danger is greater below 15,000 feet than above, because of the greater atmospheric pressure.

GETTING THE BENDS

45 When the cap is pulled off a bottle of pop, bubbles rush to the top. Much the same thing can happen to a person if the atmospheric pressure on his body is greatly reduced. In the pop, the bubbles are carbon dioxide forced into the fluid by pressure when the bottle is capped. They remain hidden in solution as long as the pressure is on. In the body the gas is nitrogen plus small quantities of oxygen, carbon dioxide, and water vapor, all of which have been absorbed by the flesh and blood and are held there by outside pressure.

46 At a high altitude, the pressure of nitrogen in the body becomes greater than that of atmospheric nitrogen. Circulation of the blood tends to remove the excess of body nitrogen, but the process is slow and at an altitude of 30,000 feet or more a condition known as bends is likely to result. Other names for it are aeroembolism and decompression sickness. It is believed that bubbles of gas seeking an exit appear in the joints and fat tissues as in the case of the bends suffered by deep-sea divers and caisson workers (sandhogs). The bubbles may appear in the blood and the muscles as well. In any event, the result is pain.

47 In a few instances the pain may occur under 30,000 feet but it is usually mild and passes away. Above this height, it can become so severe that an arm or leg is paralyzed. Occasionally a burning sensation in the lung called the chokes will appear. It may be followed by stabbing pains and a desire to cough but this gives no relief. Severe cases experience a feeling of suffocation and a bluish discolor-

ation of the nails and lips. Unconsciousness may follow.

PREVENTION OF BENDS

48 Unless an extended flight is made above 30,000 feet, there is no need to worry about the bends. For such flights the best way to prevent trouble is to breathe 100 percent oxygen for 45 minutes before taking off and then to continue inhaling 100 percent oxygen from the ground up. This method reduces the pressure of nitrogen in the lungs to zero and permits a large part of the gas in the flesh and blood to move out. It is called denitrogenation.

49 Long periods of flying at over 30,000 feet or an unusual amount of physical work above this altitude increase the chance of getting the bends.

50 Individual susceptibility to bends varies considerably. This can be determined to some extent by test "flights" in low pressure chambers. The individual's susceptibility may vary, however, from day to day.

51 To assure maximum resistance, get plenty of exercise on the ground and keep in good physical condition. Overweight makes men more susceptible because of the tendency of the bubbles to collect in fat.

52 Once the bends occur, descent to 25,000 feet will usually cause the pain to disappear, although any lung trouble (chokes) may continue longer. Fatigue may be a complaint for several hours afterwards.

53 Where the flyer is near collapse or unconsciousness, descent is imperative if he is to be saved. Meanwhile, he should receive 100 percent oxygen and, if breathing has ceased, artificial respiration. "Recompression" through an increase of barometric pressure (descent to lower altitude) will save the flyer in all cases if done in time.

COMMON FALLACIES ABOUT OXYGEN

54 It is incorrect to suppose that more oxygen can be secured at high altitudes by breathing faster. Breathing faster merely results in a sensation of dizziness and may lead to collapse.

(a) It is wrong to think that too much oxygen can do the body harm. The only effect of breathing oxygen in excess of the amount required is to waste oxygen needlessly.

(b) The symptoms of anoxia cannot be recognized by perceptible breathlessness unless exercise is being taken, despite popular opinion to the contrary.

(c) Oxygen cannot cure a "hangover".

NIGHT VISION

General

55 Night vision depends primarily on two factors, namely dark adaptation and training. The human eye cannot see in complete darkness, but, under conditions of very poor illumination, vision can be greatly improved with experience and training.

Dark Adaptation

56 If one eye is bandaged for a few minutes, and then uncovered in a dimly-lit room, it will be possible to see with the eye which has been protected; the unprotected eye will be blind until it has also become dark adapted. The sensitivity of the eyes is increased a hundred times after seven minutes in the dark. This increased sensitivity is destroyed temporarily by exposing the eyes for several seconds to bright illumination. Red light does not destroy dark adaptation, hence the use of red illumination which is now a standard requirement for instrument panel lighting. A flashlight can be used in well spaced two-second flashes without spoiling night vision or adaptation.

Training

57 The part of the eye most sensitive to conditions of poor illumination is not at the center. At night, objects should not be viewed directly, but with the eyes inclined 10° to either side. Night vision is adversely affected by tobacco, fatigue and anoxia. Vision deteriorates from ground level upwards at night unless oxygen is used.

INSTRUMENT FLYING

58 Under normal conditions, the body is orientated by both vision, and a sense of balance and turning given by the inner ear. When, without external visual aids, the body is sub-

jected to varying amounts of turning and vertical accelerations, the information which comes from the inner ear is entirely unreliable. Under these conditions, false sensations of attitude and turn ensue, so that flight without instruments is impossible. To the untrained pilot these false sensations are compelling, but must never be believed if they conflict with the information shown by the instruments. With continued practice in instrument flying these false sensations are easily suppressed but they quickly return without regular training.

SURVIVAL

General

59 Briefly the problems of survival are as follows:

(a) After an emergency descent they vary according to the terrain, but the broad principles of combating thirst, heat, cold and hunger remain. In hot climates water is the limiting factor. The body normally requires a minimum of one pint of water per day to maintain its full efficiency and to replace loss. Water loss can be minimized by any factor which reduces perspiration. In all cases, the chances of rescue are greatest in the first seven days, so any rations of food and drink available are best distributed with the maximum allowance to cover this period.

Desert Survival

60 To survive the desert follow these instructions:

(a) Maintain maximum efficiency for the first seven days and stay with the aircraft.

(b) Keep cool by resting in the shade and keeping still.

Jungle Survival

61 To survive the jungle follow these instructions:

(a) Make for the nearest human habitation and rely on the natives, for chances of being spotted from the air are small.

(b) Minimize the risk of disease by sterilizing all water and taking atebrin regularly.

Arctic Survival

62 To survive the Arctic follow these instructions:

(a) Build a wind break.

(b) Remain with the aircraft, but not in it.

(c) Protect the skin from the cold and keep a sharp look out for frost bite. If it occurs, warm the part slowly but do not rub.

Cold Ocean Survival

63 To survive cold water follow these instructions:

(a) To avoid heat loss, keep as dry as possible and set up a wind break.

(b) Keep a constant watch by means of a rota. If alone, use energy tablets to keep awake.

(c) Exercise as much as possible.

(d) Make preparations to collect rain water.

Warm Ocean Survival

64 To survive warm water follow these instructions:

(a) Take measures to keep cool and prevent perspiration loss by rigging up a shade and wetting the clothes with sea water.

(b) Do not drink salt water, but make preparations immediately to collect rain water.

HYGIENE

65 The captain of an aircraft is responsible for the general physical well-being of his crew and passengers. He should notify the medical authorities of any illness he may observe among the occupants of his aircraft, particularly if he suspects infectious disease. He should ensure that the regulations regarding insecticidal spraying of the aircraft are carried out. This spraying is required in certain areas to prevent transmission of disease by insects. The necessary briefing will be given by the appropriate medical authorities.

FLYING CLOTHING

66 Flying clothing is provided for the efficiency and comfort of flying personnel. The

range available provides for all eventualities and includes electrically heated garments. In large aircraft, extra clothing should be carried when either continuation of the flight at high altitudes is an operational necessity, the flight is over cold terrain, or to guard against failure of the cabin heating system. It also affords protection for the body in an emergency particularly in the event of fire and during a parachute descent in low temperatures. It assists in survival both on land and at sea under all climatic conditions. For these reasons it is also essential that a well fitting flying helmet, goggles and gloves should be worn during flight. Goggles should be attached to the helmet by the retaining straps provided and adjusted so that they are ready for immediate use if required. In hot climates when tropical clothing is worn a lightweight flying suit should be worn during flight to provide protection for exposed parts of the body such as the knees and arms.

SECTION 4

STABILITY, CONTROL AND TRIM

STABILITY

1 The stability of an aircraft is its tendency to return to its original trimmed condition after being displaced. The term stability is referred to the three axes of rotation, longitudinal, lateral and directional.

LONGITUDINAL STABILITY AND CENTER OF GRAVITY

General

2 An aircraft is designed to have its center of gravity (C of G) within certain permissible limits. With the C of G within these limits, the aircraft will have acceptable handling qualities. It should be pleasant to fly and can be trimmed without constant attention to the elevator control. If the C of G is allowed to travel beyond the forward limit, the aircraft will become too stable and will feel heavy on the elevator control. If the C of G is allowed to travel beyond the aft limit, the aircraft will become unstable, it will be difficult to trim and constant attention to the elevator control will be necessary.

3 In level flight, on releasing the control column after displacement, a stable aircraft will return to its original condition of flight either immediately or through a series of damped oscillations. An unstable aircraft will diverge further and further from its original condition, again either immediately or through a series of oscillations.

4 It is clear that longitudinal stability is influenced by the position of the C of G. This position will be affected by load distribution before flight, and will move in flight as fuel and ammunition are used up or bombs are released. The pilot must ensure that the positioning of the load before flight keeps the C of G within the permissible limits, and, on some aircraft, bombs and fuel tanks must be used in a particular order.

5 From the pilot's view point the longitudinal stability of an aircraft can be divided into two categories:

(a) Stability when the aircraft is in a steady condition of flight. This is a feature of the static stability characteristics of the aircraft.

(b) Stability when the aircraft is under "g" as in recovery from dives or in turns. This is a feature of the dynamic stability characteristics of the aircraft.

Stability in Steady Flight

6 If an aircraft is trimmed to a steady speed and condition of flight, and the speed is increased without retrimming, the aircraft is stable if a push force on the control column is

required to maintain the new speed. The size of the force depends on the amount the speed has been increased, the degree of stability and the aerodynamic balancing of the elevator. Conversely, if the speed is decreased, a pull force will be required to maintain this reduced speed. If the aircraft is unstable, however, there will be no tendency for the aircraft to return to its trimmed condition when the speed is increased, and pull force will be required to prevent the speed from increasing further; the converse will apply for a decrease in speed. From this, it will be apparent that if an aircraft is longitudinally stable in this manner it should be easy to trim and maintain a given speed and condition of steady flight, and if it is unstable it will be difficult to maintain a steady speed, and it usually will be tiring to fly. When diving stable aircraft, there is no reason why the stick forces should not be trimmed out as the speed increases, but it should be remembered that the trimming tabs are powerful controls and should be operated with care. If a stable aircraft is trimmed into the dive it may need a heavy pull force on the stick for recovery. On the other hand if it has not been trimmed into the dive, it may tend to come out too quickly. When diving an unstable aircraft, however, it is inadvisable to trim out the resultant pull force unless absolutely necessary, as it may tend to recover too quickly and require a restraining push force to prevent over-stressing the aircraft. It should be noted that in some cases the stability characteristics of an aircraft may change as the speed and angle of dive increase. The above recommendations apply only to trim changes not caused by compressibility effects at high Mach numbers. See Section 7 para. 16.

Stability Under "g"

7 If an aircraft is under "g", as in recovery from dives or in steep turns, it is desirable that a pull force on the control column should be necessary to impose that "g", and to maintain it. Also, to increase the "g", it should be necessary to increase the pull force. An aircraft that has these characteristics has this second type of longitudinal stability. As in para. 6 above, the size of the pull force will depend on the amount of "g", the degree of stability, and the aerodynamic balancing of the elevator. If an aircraft is unstable under "g" the pull force will disappear - often quickly and suddenly - as the "g" is imposed, and a restraining push force will be necessary to prevent rapid "self tightening" with a risk of over-stressing or "g" stalling the aircraft, or blacking out the pilot.

8 Although usually it is desirable for an aircraft to be longitudinally stable in all ways under all conditions, it will be sluggish and heavy to handle if it is too stable. Also the changes of trim with change of speed will be too large. Therefore, this feature is normally avoided particularly on fighter aircraft where a high degree of manoeuvrability is required.

9 As was shown in paras. 2, 3 and 4 the position of the C of G of an aircraft has a large controlling influence on its longitudinal stability, but the stability characteristics may also very with change of weight, speed, Mach number, altitude, power and configuration. From this it can be seen that it is a difficult problem to obtain the right degree of stability under all conditions of flight, but it is essential that a reasonable compromise should be achieved if the aircraft is to be pleasant and safe to handle.

LATERAL AND DIRECTIONAL STABILITY

10 The lateral and directional stability of an aircraft is obtained by correctly proportioning the fin area in relation to the dihedral effect; this effect is governed by the dihedral angle of the wings, the position of the wings relative to the fuselage, i. e., high or low wing, and the degree of sweep-back of the wings. It is not sensitive to the longitudinal position of the C of G.

11 If the fin area is too large, the aircraft may tend to turn to the right or left, banking and dropping into a spiral dive. This is technically known as "spiral" instability.

12 If the fin area is too small the aircraft will tend to wallow, the motion involving yawing and banking. This is known as "oscillatory" instability, and as the banking motion is most noticeable it is often confused with lateral instability.

13 It can be seen that as spiral and oscillatory instability are the result of directional and/or lateral instability, it is difficult to decide which of the latter is the cause. Directional instability may take the form of a quick

oscillation, "snaking", or a tendency for the rudder to be over sensitive. Lateral instability, shown by difficulty in maintaining lateral level, may be caused by bad aileron design.

DEGREE OF STABILITY DESIRED

14 While a high degree of stability tends in itself to reduce manoeuvrability, it can be offset by nicely balanced controls. Such an aircraft may be more pleasant to handle than one which attains its manoeuvrability with less well balanced controls and a lower degree of stability.

15 Although slight instability is often tolerated, it is most desirable to have positive stability, especially in conditions of flight that persist for a long time. A main design problem is to avoid such longitudinal instability as would make an aircraft tiring, or in extreme cases dangerous, to fly.

CONTROL

General

16 The handling qualities of an aircraft are a direct result of its inherent stability and control characteristics. Flying controls are designed, in general, to be both effective and well balanced and to have rapid response, but the following faults, although not common, may be encountered.

Ailerons

17 Drag - When an aileron is depressed, its angle of attack is increased, and although the lift of the aileron increases, the drag also increases. Where this drag is appreciable it causes the aircraft to yaw in the opposite direction to the bank. This is usually more apparent at low speeds than at high speed mainly due to the larger aileron deflections that have to be made for a given effect on the aircraft and hence the larger drag. At the stall on modern aircraft, however, although the aileron drag may be considerable, the ailerons usually are still effective in helping to raise a wing that may have dropped.

18 Overbalance - This may occur at any airspeed and is indicated by a progressive lightening of aileron stick force, or a tendency for the ailerons to move to their full travel unassisted.

19 Snatch - When encountered, this usually occurs at or near the stall or at high Mach numbers. It is due to the rapid movement of the center of pressure of the aileron and results in violent snatching or jerking of the control column.

20 Reversal - When the ailerons are applied at high speed there is a strong force tending to twist the wings and the higher the speed the stronger is the force. The more the wings twist the less effective the ailerons become, until eventually a speed would be reached where there would be an aileron reversal and the aircraft would bank in the opposite direction. In practice this reversal speed is always very much higher than the limiting speed of the aircraft, but near the limiting speed, a falling off of aileron effectiveness may be experienced.

Rudders

21 A fault which may occasionally be encountered is overbalance which is indicated by a progressive lightening of the foot loads with increasing rudder displacement. If, owing to bad design, the aerodynamic balance is too great it will become increasingly effective as the rudder is moved and may eventually cause the rudder to lock hard over. Also, at large angles of sideslip, the fin may stall, causing a rapid and large deterioration in rudder control, together with rudder overbalance. If this is experienced, the sideslip must be reduced by applying bank in the direction of the rudder and by attempting to centralize the rudder bar. The instinctive reaction to apply aileron against the rudder must be resisted until the rudder can be centralized, as this will only tend to increase the sideslip. If fin stall and/or rudder overbalance is encountered under asymmetric power, the live engine should be throttled at the same time as applying aileron in the direction of the rudder. Sometimes slight apparent rudder overbalance may be experienced under asymmetric power when large amounts of rudder trim are used. In this case the degree of rudder trim should be reduced.

Elevators

22 These controls in themselves are normally free from adverse characteristics but unpleasant stick forces may be experienced if the aerodynamic balance of the elevator or

the stability characteristics of the aircraft are at fault.

CONTROL SURFACE TABS

Introduction

23 In order to improve the balance of the controls and/or to enable the pilot to trim the aircraft, tabs are fitted which consist of small auxiliary control surfaces hinged to the trailing edge of the main control surfaces. If the pilot releases his controls, then by altering the angle relative to the main surface at which a tab is set, the main surface is caused to move to a new angle relative to the aerofoil to which it is attached, thus changing the aerodynamic flow conditions and so the lift produced by the aerofoil. The aerodynamic effect of all control surface tabs is similar.

Fixed Tabs

24 These are preset on the ground at a fixed angle to the main control surface. Thus, under a condition of no stick load the lift of the main aerofoil concerned is modified. For example, this type of tab is commonly used on ailerons to counteract a tendency to fly one wing low.

Trimming Tabs

25 These can be used to trim the aircraft in flight, for example to compensate for changes in power of in C of G position due to the consumption of fuel or the dropping of bombs. They are operated from controls in the cockpit and the following example will make their purpose and effect clear. Suppose an aircraft to be flying in a nose heavy condition, a pull on the control column will be required to make it fly level. By adjusting the elevator trimming tab control back, the tab will move down relative to the elevator which will then tend to move upwards thus reducing the pull force on the control column. There will be one position of the tab at which the moment at the elevator hinge, and so the required pull force on the control column, is reduced to zero. The aircraft is then said to be trimmed longitudinally for the condition of flight.

Servo Tabs

26 These are directly operated by the control column and/or rudder pedals, and movements of the main control surfaces are effected solely by the action of the servo tabs. On the ground, therefore, movement of the cockpit controls displaces the tabs only and no movement of the main control surfaces will take place.

Geared and Spring Tabs

27 These are commonly known as balance tabs. The effect of such a tab is partially to balance the aerodynamic loads on a main control surface, thus altering the control force necessary. The pilot has no separate control over a tab of this type, but the angle between it and its associated control surface is varied automatically when the latter is operated by the pilot.

28 Geared balance tabs move, under the action of gearing, in the opposite direction to the main control surface to which they are attached, thus reducing the force which the pilot requires to exert upon the control. Occasionally anti-balance tabs are used to reduce the aerodynamic balance; the tabs then move in the same direction as the main control surface, thus increasing the force which the pilot requires to exert.

29 Spring tabs are also connected to the main surface control circuit, but a spring is inserted between the circuit operating the tabs and the main control surface. This spring may be pre-loaded so that:

(a) The tab operates only after initial movement of the control surface, sufficient to produce a predetermined control force, has taken place or

(b) The tab moves as soon as any force is applied to the control, but to an extent varying with airspeed.

30 In effect, the spring tab acts as a geared tab, except that the effective gear ratio is changed with speed by the action of the spring. They are commonly fitted to ailerons to enable an increased rate of roll to be obtained without entailing excessive control forces. With these tabs, a certain "springiness" is commonly noticed when the main controls are operated on the ground.

31 In some aircraft, the feature of two or more of the foregoing types of tabs are combined. For example, both servo, geared and spring loaded tabs may also be connected to an overriding control whereby the pilot is enabled to vary the position of the tab relative to the main control surface. They then combine the functions of trimming tabs with those of the pure servo, geared, or spring-loaded types.

32 On certain other types of aircraft, the load on the controls may be varied by adjusting springs connected directly to the pilot's controls.

33 In cases where the cockpit controls are not directly connected to the main control surfaces, locking the cockpit controls on the ground does not prevent the control surfaces being moved by the wind; control surface clamps are then essential.

34 With certain arrangements of spring tabs partial or full movement of the pilot's control may be possible even with the main control surface jammed or locked. This is an additional reason necessitating a visual check before flight that the tabs and main control surfaces are free and respond correctly to movement of the cockpit controls. Before carrying out such checks, external clamps, internal locking gear and mechanical locks should be removed or released; otherwise an attempt to operate the cockpit controls may cause damage.

VARIABLE INCIDENCE TAILPLANES

35 On some aircraft the incidence of the tailplane can be varied in flight. This enables the lift to be adjusted in order to trim the aircraft as required. The result is the same as that achieved by means of the elevator and its trimming tab on aircraft with fixed tailplanes but is more efficient aerodynamically especially at high Mach numbers and if the required range of trim change is considerable. With variable incidence tailplanes, the elevator is used only as a means of temporarily changing the attitude of the aircraft; in steady trimmed flight the elevator is trailing at its neutral angle and trimming tabs are not required.

POWER OPERATED CONTROLS

36 On the larger, as well as very high speed aircraft, it is difficult or impossible to ensure that excessive force will not be required for operation of the flying controls. To overcome this, power operated controls are fitted. These may be operated by hydraulic or electrical power or by a combination of both. For example electrically actuated hydraulic rams may be used.

37 Essentially such systems are of two types:

(a) Those in which power is, in effect, used to augment the force exerted by the pilot on the flying controls. Such systems provide a degree of "feel" in that the resistance to movement of the controls is related to the actual force required to move the control surfaces. In these systems the pilot retains full manual control, but with increase of effort, in the event of power failure.

(b) Those in which the control surfaces are wholly power operated, "feel" being artificially introduced into the system. For example a spring bias device, or a device to increase the effort required to operate the flying controls at the higher speeds, may be embodied. In these systems power operation is duplicated as a safeguard against failure.

SECTION 5

RELATIONSHIP BETWEEN IAS, CAS, EAS AND TAS AND TRUE AND INDICATED MACH NUMBERS: ALTIMETER ERRORS

INSTRUMENT AND PRESSURE ERRORS AND THE RELATIONSHIP BETWEEN IAS, CAS, EAS AND TAS

Relationship Between IAS, CAS and EAS

1 An airspeed indicator is a pressure gauge measuring dynamic pressure, which is the total pressure within the head minus the still air pressure - static pressure - in the region of the aircraft. This pressure difference is indicated on the dial of the instrument in terms of IAS which at any given height is roughly proportional to:

$$\sqrt{\text{Total Pressure - static pressure}}$$

2 The speed indicated by the airspeed indicator is subject to three errors:

Instrument Error

(a) Each ASI has a small instrument error and while it may be necessary for navigators to take this into consideration, it may usually be neglected by the pilot, as an approximate determination of EAS is generally sufficient.

Position Error

(b) The pressure head will read the local IAS at its position on the aircraft. Due to movement of the air caused by the aircraft, it is difficult to find a position at which the motion of the pressure head through the air is exactly equal to the speed of the airflow at every angle of attack of the wings and at which the pressure at the static source is exactly equal to the static pressure in undisturbed air. Unless this is so, the IAS shown will be incorrect. These errors, which together constitute position error, are frequently considerable and must be allowed for by adding or subtracting the appropriate position error correction, as quoted in POI, in order to obtain the approximate CAS. On an aircraft with no position error and no instrument error, IAS and CAS would be the same.

Compressibility Error

(c) The pressure head, in addition to a small position error, is subject to compressibility error. This error arises from the fact that the mathematical basis on which the ASI is calibrated, assumes that air is an incompressible fluid. At low speeds, this assumption causes no appreciable error but above approximately 150 knots CAS, the compressibility effects must be considered. The compressibility error increases with speed and with altitude in accordance with Figure 1-4.

3 Both the total pressure and static pressure sources are subject to position errors but it is the static source which is normally most seriously affected. To reduce the position error therefore, static vents are often fitted. They are positioned so as to ensure that the static pressure supplied to the airspeed indicator and other instruments is, at all speeds and attitudes of the aircraft, as nearly as possible the true still-air pressure in the region of the aircraft. The best position is usually on the fuselage side about midway between the nose and tail; this is because the disturbance of the air by the aircraft tends to be greatest towards the front and rear. Thus, with the instruments connected to the total pressure source in the pressure head and to the static vent or vents instead of to a static source in the pressure head, small position errors are achieved.

4 Where the greatest attainable accuracy is necessary, instrument error must be taken into account as well as the PEC. In such cases the additional correction to be applied to the IAS can be found from the ASI calibration chart fitted near the ASI in the aircraft.

COMPRESSIBILITY CORRECTION TABLE

SUBTRACT CORRECTION FROM CALIBRATED AIRSPEED
TO OBTAIN EQUIVALENT AIRSPEED

PRESSURE ALTITUDE	CAS - KNOTS									
	150	200	250	300	350	400	450	500	550	600
5,000	0	0	1	2	2	3	5	6	8	10
10,000	0	1	2	3	5	7	10	13	17	21
15,000	1	2	3	5	8	12	16	21	27	
20,000	1	3	5	8	12	17	23	31		
25,000	2	4	7	11	17	24	32			
30,000	2	5	9	15	23	32				
35,000	3	7	12	20	29					
40,000	4	9	16	25						

Figure 1-4 Compressibility Correction Table

Relationship Between EAS and TAS

5 The EAS is the "real" speed of the aircraft, i.e., the true airspeed (TAS), only at standard sea level atmospheric conditions. The reason for this is that the dynamic pressure which operates the airspeed indicator depends not only upon the speed of the air impinging upon the pressure tube but also upon its density. Hence, as the aircraft ascends into less dense air, the dynamic pressure corresponding to a given TAS is less, and the airspeed indicator reads low. The EAS must, therefore, be corrected for altitude as set out in Figure 1-5 which shows how the true airspeed at any given EAS varies with altitude. The central curve refers to "standard atmosphere" and gives the factor by which the EAS is to be multiplied when the atmospheric temperature is that assumed in "standard atmosphere". The curves on either side refer to average temperatures in tropical summer and in sub-arctic winter conditions respectively. For example, an EAS of 200 knots at 25,000 feet, is a true airspeed of approximately 1.5 x 200 = 300 knots at a temperature of about -35°C "standard atmosphere", and about 290 knots at a sub-arctic winter temperature of about -50°C.

6 If neither a chart nor a computor is available for immediate reference a rough estimate can be made using the following formula which can be readily memorized:

> TAS = EAS + (EAS x 1.75 percent of height in thousands of feet)

The results, however, are increasingly inaccurate at heights above 20,000 feet and this formula should not be relied upon at the higher altitudes.

Relationship Between CAS and TAS

7 In Figure 1-6 is provided a convenient means of converting from CAS to TAS. This chart combines the compressibility correction with the air density correction.

Relationship Between RAS and CAS

8 In the nomenclature used by the RAF, the term RAS replaces EAS. That is, RAS is IAS corrected for instrument error, position error and compressibility error. In addition, in the RAF system, the position error correction and compressibility error are combined and termed the "Pressure Error Correction". Thus it is only at low speeds that the pressure error correction is the same as the position error correction.

Summary

9 The foregoing terms may be summarized as follows:

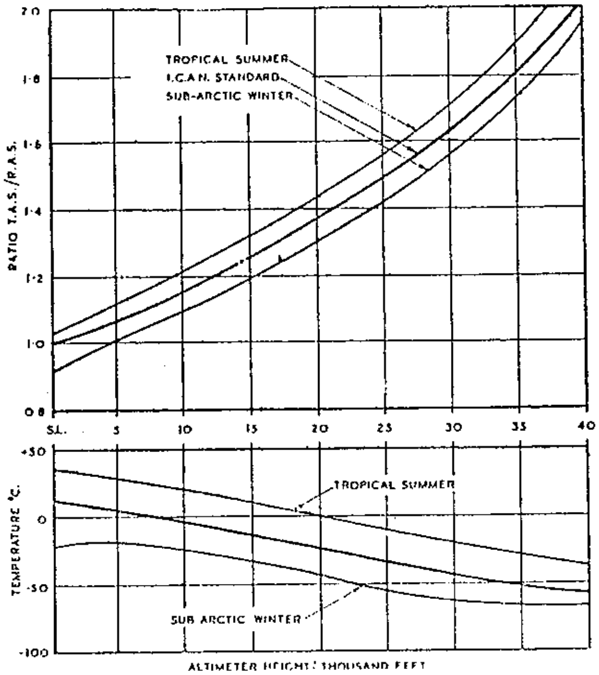


Figure 1-5 Variation of TAS with Altitude at Given EAS

(a) IAS (Indicated Airspeed) is ASI reading.

(b) CAS (Calibrated Airspeed) is IAS corrected for installation error, i. e., instrument error + position error.

(c) EAS (Equivalent Airspeed) is CAS corrected for compressibility error.

(d) TAS (True Airspeed) is EAS corrected for atmospheric density.

(e) RAS (Rectified Airspeed) is the RAF term for EAS and is IAS corrected for instrument error and pressure error.

10 At speeds up to 250 knots TAS the E6B dead reckoning computor (RCAF Ref. 6B/526) gives a reasonably accurate result for calculating TAS from CAS but at higher speeds, a computor incorporating corrections for compressibility as well as density is required. Such a computor is the RAF, Mark 4. The atmospheric temperature indicated by free-air thermometer in the aircraft corrected for adiabatic temperature rise (see para. 11 below) is set on the computor which then gives directly a sufficiently accurate result for normal DR navigational purposes.

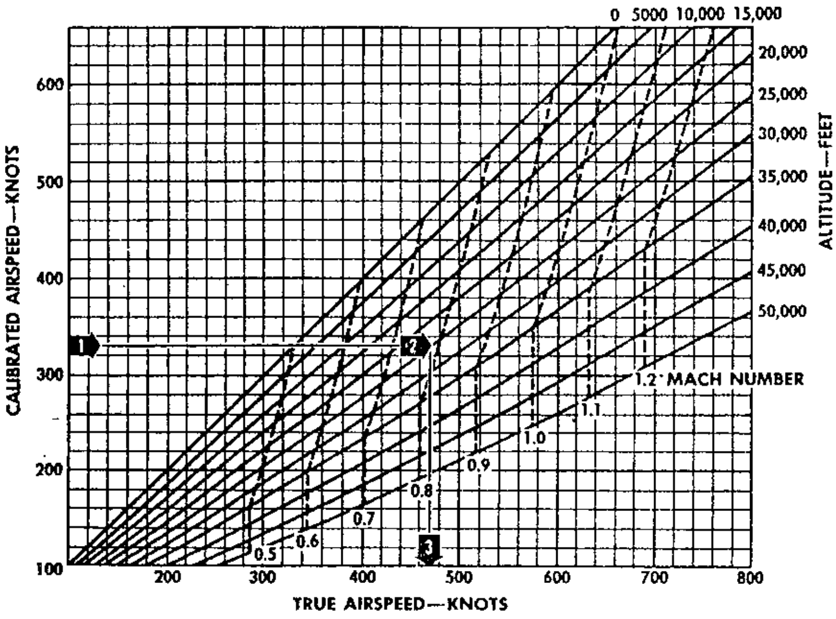
11 The adiabatic temperature rise referred to above results from the fact that at high speeds the air is heated by compression as the fuselage forces its way through. The free-air thermometer therefore indicates too high a temperature, if the speed is maintained for sufficient time. The indicated temperature, therefore, should be corrected in accordance with the thermometer calibration card, if fitted. If no such card is fitted a rough estimate of the number of degrees to be deducted can be made by dividing the TAS (to the nearest 50 knots) by 100 and squaring the results; e.g., at an estimated 480 knots TAS deduct $\frac{(500)^2}{(100)} = 25°C$.

RELATIONSHIP BETWEEN TRUE AND INDICATED MACH NUMBERS

12 Machmeters automatically correct for height, but not for position and compressibility errors. They are operated from the same pressure and static sources as the airspeed indicator and are therefore subject to the same position and compressibility errors, i. e., they show indicated Mach numbers. The relationship between true and indicated Mach numbers, however, is not the same as between true and indicated air speeds, since Machmeters allow for height, whereas airspeed indicators do not. Further, the position and compressibility error effect, and so the difference between true and indicated Mach numbers, is usually small. The Machmeter, however, is subject to instrument errors, which are unpredictable and may vary from time to time, of up to ±0.01 over the range 0.6 to 0.85M.

ALTIMETER ERROR

13 For normal DR navigation purposes a knowledge of the accurate true altitude is seldom necessary and there is at present no satisfactory method of correcting altimeter readings to give true altitude except in the lower layers of the atmosphere. This is because errors due to the difference between the true air temperature lapse rate of the atmosphere and the standard atmosphere lapse rate upon which the computors are based, generally increase with altitude and cannot easily be calculated and applied to the instruments. This error can be called the lapse rate error. At the lower



TO USE CHART:

Enter with CAS 1, move horizontally to altitude 2 to find Mach Number.

To find TAS, drop to vertical index scale of graph 3.

TAS values from the graph are correct only on an NACA standard day. Otherwise TAS values will tend to be conservative when true free air temperature is higher than standard, and optimistic when true free air temperature is lower than standard.

EXAMPLE:

On an NACA standard day, 330 knots CAS at 25,000 feet is .78 Mach Number and 470 knots TAS.

Figure 1-6 Airspeed Conversion Graph for NACA Standard Day

altitudes a fair approximation of the true altitude can be obtained if necessary by using the computor.

14 Like the airspeed indicator, the altimeter is subject to instrument, position and compressibility errors which should be taken into account, particularly when flying at low heights above terrain. The altimeter reads high when the ASI reads high (PEC negative), and vice versa, to an extent which varies with speed. At sea level the relation between the required correction to the altimeter in feet and the ASI PEC + compressibility error correction in knots is approximately:

IAS Knots	
220	(ASI PEC + Compressibility Error Correction in Knots) x 18
300	(ASI PEC + Compressibility Error Correction in Knots) x 30
400	(ASI PEC + Compressibility Error Correction in Knots) x 43

15 See Part 4, Section 6, Page 114A, paragraph 3 for a warning regarding the implications of altimeter errors.

SECTION 6

FLYING FOR RANGE AND ENDURANCE

INTRODUCTION

1 For maximum range, that is, to cover the greatest distance through the air on the fuel available, or to use the least quantity of fuel to cover a given distance, it is necessary to fly at a speed at which the greatest number of air miles per gallon of fuel (AMPG) will be obtained. For maximum endurance, that is, to remain in the air as long as possible using a given quantity of fuel, the speed should be that which ensures the least consumption of fuel per hour. In general, these speeds are not the same.

2 The optimum speeds for individual aircraft depend basically upon the aerodynamic characteristics of the airframe as well as upon the specific consumption (the gallons used per horse-power per hour) characteristics of the power plant driving it. The speeds are further influenced by conditions such as the all-up weights (AUW), altitude and air temperature. In the case of the best speed for range, the speed and direction of the wind must also be considered, since, this affects the distance covered over the ground in relation to the distance flown through the air.

3 The following paragraphs explain how these best speeds, which are quoted in POI are arrived at, and how the above variable factors affect the speeds as well as the actual range and endurance obtainable. They also give recommendations for handling the aircraft and power plant for maximum economy in varying conditions, as well as for obtaining reasonable economy when operational requirements make it impossible or undesirable to fly at the optimum economical speeds.

4 While the fundamental principles are the same for all aircraft, the power and specific consumption characteristics of turbine-jet engines introduce special considerations which are dealt with in paragraphs 46 - 57.

5 Pilot's Operating Instructions recommend the best speeds for optimum range and endurance; they frequently include fuel consumption data in the form of AMPG curves showing the distance through the air which can be flown per gallon of fuel at various speeds under average or specified weight and other conditions. In those cases where speeds throughout the POI are quoted in terms of MPH, or both MPH and knots, the consumption figures are calculated on the basis of air statute miles per gallon (AMPG). Where speeds are quoted in knots only, the curves are plotted in terms of air nautical miles per gallon (ANMPG) and any distance quoted should be understood to be in terms of nautical miles whether this is specifically stated or not.

BEST SPEEDS FOR GREATEST RANGE OR ENDURANCE

6 The figures in para. 8 give the fuel consumed by a certain aircraft when cruising at various indicated airspeeds, and these test results are exhibited graphically in the diagram alongside. The two sets of figures and the two curves give respectively, the gallons used per hour and the gallons used for 100 air nautical miles, both at 10,000 feet. Similar results are obtained for other aircraft. It will be seen that the lowest consumption per 100 miles is obtained at a considerably higher speed than that which gives the least consumption per hour, and that neither maximum range nor maximum endurance will be attained by flying as slowly as possible, see Figure 1-7.

7 The reason why the lowest consumption of fuel per hour does not occur when flying at the lowest possible speed, is to be found primarily in the way in which the drag of a wing varies with speed. To fly slowly, the angle of attack must be large, and the drag of the wings increases rapidly as the angle of attack is increased. From this it comes about that the least power is required from the engine at a considerably higher speed than the slowest possible, and so, the fuel used per hour will be least when flying well above stalling speed.

At 10,000 ft.		
I.A.S. knots	Gallons per	
	hour	100 miles
110	41	32
120	42	30
130	44	29
140	48	29½
150	52½	30½
160	59	32

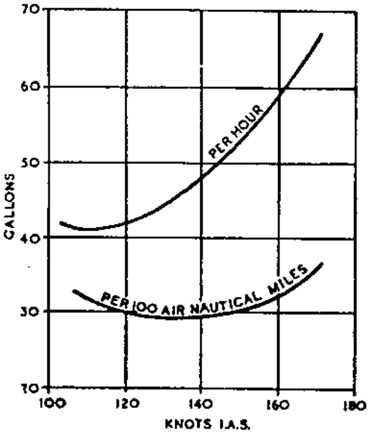


Figure 1-7 Fuel Consumption

8 To obtain the maximum air nautical miles per gallon, or the least gallons per air nautical mile, the aircraft must be flown even faster than the speed at which the least power is required; for so long as the increase in the miles covered in the hour, is greater than in the gallons used in the hour, the aircraft will do more miles per gallon. For example, at 10,000 feet in one hour: At IAS 120 knots we use 42 gallons, we travel 139 air nautical miles, which gives us 30 gals/100 air nautical miles. At IAS 140 knots we use 48 gallons, we travel 162 air nautical miles, which gives us 29 1/2 gals/100 air nautical miles.

9 It will be seen from these figures and curves that very little is lost in either range or endurance by flying 10 knots or so faster than the speed which gives the absolute minimum gallons in each case. In this case, 145 knots may be taken as a good practical range IAS, while 120 knots is as slow as it is ever worth flying for maximum endurance. The range speeds recommended in POI are fixed on this basis, that is about 10 knots above the absolute optima.

10 The speed for maximum endurance is generally about four-fifths of the speed for maximum range.

EFFECT OF ALTITUDE ON BEST SPEEDS

11 The best IAS for range is, in general, the same at all heights; for the drag is least when flying at the best angle of attack, which is the same, at the same IAS, at every height at the same load.

12 But, when at low altitudes, this IAS can be obtained at minimum RPM without using maximum weak mixture boost, a higher speed is usually better. In fact the best speed may be the speed that requires the maximum weak mixture boost if this speed is not very much greater than that recommended.

13 At the higher altitudes, when the recommended IAS cannot be obtained at power within the weak mixture range, the best speed is then the highest obtainable in weak mixture.

14 The best speed for endurance is the same at all heights.

EFFECT OF LOAD CARRIED ON BEST SPEEDS

15 The best speed for range or for endurance is proportional to square root of the AUW. A useful rule, for changes in AUW up to approximately 20 percent, is to reduce the speed by half the percentage reduction in AUW. For a 10 percent reduction in AUW, for example, by release of bombs or consumption of fuel, speed should be reduced by 5 percent. This adjustment can be ignored for short-range fighters; for bombers it is good enough to use one speed for the outward and another for the homeward journey. Pilot's Operating Instructions indicate how the speed should be varied with the weight at which the aircraft is flying at the time.

EFFECT OF WIND ON BEST SPEED FOR RANGE

16 A wind which increases or decreases the ground speed at a given IAS has a big effect on the range and it may seem that the aircraft should be flown faster into a head wind, and conversely; but, in fact, unless the wind is very strong it is not worth making any change. Figure 1-8 shows the effects of a 50 knot head wind and a 50 knot tail wind on gallons per mile of the aircraft taken as an example in para. 8. It will be seen that the recommended speed of 145 knots is nearly the best airspeed against the head wind, and that it is still quite a good airspeed with the tail wind. In stronger winds, it would be worth while to make a change of about 10 knots, especially to increase by 10 knots against a strong head wind, if this can be done while still using weak mixture.

EFFECT OF WIND ON RANGE

17 The big increase in the fuel used per 100 ground miles against the 50 knot head wind will have been noted. It should also be noted that this increase, from 30 to 43 gallons at 145 knots IAS, is not balanced by the reduction, from 30 to 23 gallons, when flying in the same wind in the opposite direction. There is a net increase from 60 to 66 gallons on the double 100 mile flight.

18 It may also be noted that these figures relate to one all-up weight. Actually, fuel used per air mile is greater on a heavily laden than on a lightly laden aircraft, and the effect of a head wind, therefore, will be most adverse when it is against a heavily laden aircraft.

EFFECT OF ALTITUDE ON RANGE AND ENDURANCE

19 The air miles per gallon would be the same at the same IAS at all heights if the engine used the same number of gallons per horse-power per hour. But, in fact, the specific consumption varies with engine conditions. Air miles per gallon tend to be less at the lower altitudes; they increase with height, but, fall away again at the higher altitudes. As far as range is concerned, it is a matter of balancing the increase in TAS at given IAS as height is gained, against any increase in gallons per hour resulting from an increase in specific consumption as the power necessary to maintain the recommended IAS varies with change of height. Variation of air miles per gallon with height is, however, not large in general.

20 Account must also be taken of fuel consumed in climbing to the height and, especially if the climb is not made in weak mixture, the fuel so used is only partially recovered in the subsequent descent. If the climb is made in weak mixture, range from take-off to touch-down will not vary much with the operational height. Climbing in weak mixture, however, does not necessarily give the greatest overall range. See paragraph 26.

21 On the other hand, in level flight maximum endurance falls with altitude, since the power required to maintain level flight at the best IAS increases because the aircraft must be flown at a higher TAS in the less dense air. On this account the endurance decreases roughly as under:

at 10,000 feet to 7/8 of that at sea level

at 20,000 feet to 3/4 of that at sea level

at 30,000 feet to 3/5 of that at sea level

This law may be modified slightly by change of specific consumption as the power varies with change of height.

EFFECT OF WEIGHT ON RANGE AND ENDURANCE

22 The fuel used per hour or per mile would be proportional to the AUW if it were not for variation in specific consumption with changes in power. In fact, it is commonly found that the percentage variation in range or endurance is less than the percentage difference in load carried, a change of 10 percent in AUW causing a change of only 7 percent to 8 percent in range or endurance.

EFFECT OF DRAG ON RANGE AND ENDURANCE

23 Range and endurance can be seriously affected by excrescenses or holes that add to the drag of the aircraft, and anything the pilot can do to withdraw excrescences or reduce leakage of air in and out of the aircraft will improve the range and endurance. If the drag is necessarily much increased, the best IAS may be appreciably lowered.

50 knot Wind
at 10,000 feet

I.A.S. knots	Gal, 100 mile		
	Tail	Calm	Head
110	23	32	53
120	22	30	47
130	22	29	44
140	22½	29½	43
150	23½	30½	43
160	25	32	44

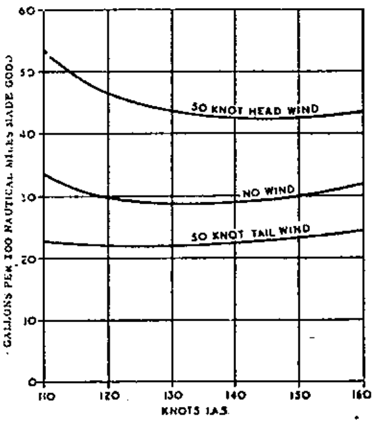


Figure 1-8 Effect of Wind on Range

EFFECT OF AIR TEMPERATURE ON POWER, RANGE, ENDURANCE AND OPERATIONAL CEILING

24 At high atmospheric temperature, at a given aneroid height, the density of the air is reduced; thus the weight of charge drawn into the engine per stroke at a given throttle setting and RPM is less, and so the power output is reduced. In order to maintain the same IAS therefore, an increase in boost and/or RPM will be necessary. The effect of this on range at the optimum height, is in general, not great, since, in the less dense air the TAS is greater for a given IAS. The reduction in endurance, however, is greater for similar reasons to those given in paragraphs 19 - 21.

25 The effect on operational ceiling is considerable, since power at given boost and RPM is reduced and the power required to maintain a given aneroid height is increased. To maintain the same ceiling, the AUW of an aircraft must be reduced by 1,000 lb. per 30,000 lb. per 10°C rise in air temperature and conversely.

ENGINE AND AIRCRAFT HANDLING FOR MAXIMUM ECONOMY

Climbing and Descending

26 When climbing, except at high altitudes on some aircraft, it is usually more economical to use the maximum boost and RPM permitted for climbing, although this involves the use of a rich mixture. The climb should be made at the IAS recommended for maximum performance in the POI. This is the speed which has been found to give the best rate of climb at climbing power. Height is thus gained quickly and the time for which rich mixture is used is shortened.

27 The use of high supercharger gear results in greater mechanical power losses and the same power output is, therefore, obtained in this gear at a higher boost than is required in low gear. Consequently when climbing, the change to high gear should be delayed until, when above the full throttle height for climbing power in low gear, the boost has fallen by the amount stated in the POI. On aircraft with automatic supercharger gear changes, the control is set to change the gear at a predetermined height, frequently that which gives maximum performance for a combat climb. For maximum economy in such cases, the switch should be left set to low gear and the change made by setting it to the "auto" position when the altitude, or fall in boost, recommended in the POI has been reached.

28 During a gentle climb in weak mixture, or in a descent with a fair amount of power, most air miles per gallon will be obtained at the same IAS as for maximum range in level flight.

Cruising

29 If rich mixture is used, not all the fuel is completely burnt and at the higher powers, the excess fuel acts as a coolant to prevent detonation. Rich mixture should, in fact, only be used for take-off, climb, and when power in excess of that obtainable at maximum weak mixture boost is required. For economical cruising, therefore, weak mixture should, if possible, be used, as in this case the fuel is fully burnt. If there is no manual mixture control, weak mixture will be obtained automatically by setting the boost at or below the weak limit or on certain engines by keeping the throttle(s) at or behind the economical cruising boost position.

30 It is more economical to obtain the required power by a combination of high boost and low RPM rather than by a combination of low boost and high RPM. The throttle should, therefore, be set to give the maximum weak mixture boost, or, if this is not obtainable at the altitude, that obtainable at full throttle, and the propeller should be adjusted to give any RPM, from the maximum permitted for use in weak mixture down to the lowest practicable, as necessary to give the required IAS. The practicable low limit is usually governed by the generator cut-out RPM, or in some cases by the onset of marked vibration. When selecting RPM, any other setting which gives undue vibration should also be avoided. With interconnected throttle and propeller controls, the RPM control lever should always be set to the interconnected, "auto", position. If, with maximum boost and the minimum practicable RPM, the IAS is still above that required, further reduction of power can only be obtained by reducing boost.

31 Maximum range and economy will in general be obtained by using low gear, but, at moderate and high altitudes, the use of this gear may necessitate selecting high RPM to give the power to maintain the desired speed. It will then be profitable to employ high gear. The correct choice of supercharger gear is usually stated in POI.

32 Where it is necessary to fly at a speed above that recommended for maximum range, or to fly at the range speed at very heavy loads and sometimes when towing gliders, the required power may not be obtainable at maximum weak mixture boost and RPM. In such cases, rich mixture must be used, and the boost should be increased up to the maximum permitted for continuous use in rich mixture, and again the RPM should be reduced until the required IAS is obtained. A periodic change to maximum weak mixture power should be made and once it is found, as a result of reduction of weight by consumption of fuel, etc., that the required speed can be maintained in weak mixture, the flight should be continued as in paragraph 30 above.

Summation

33 If there is a mixture control it must be set to the "weak" position. With engine limitations for weak mixture, use the highest boost and the lowest RPM, provided that the generator charges at the RPM used and that there is not undue rough running. Use low gear, unless flying at or near a height at which high gear is necessary to maintain the recommended IAS.

HANDLING THE AIRCRAFT FOR MAXIMUM ENDURANCE

34 The endurance at the recommended endurance speed will be about 15 percent greater than at the recommended range speed. When flying on the absolute minimum of power for level flight, which in theory will give the maximum endurance, all ability to manoeuvre disappears. Raising the nose will not cause the aircraft to climb, nor check descent, and may cause a considerable reduction of speed and a loss of height. Height will necessarily be lost in turns. Therefore, the recommended speed is higher than that which uses the absolute minimum of power although it will still give limited scope for manoeuvre.

35 No attempt should be made to maintain an exact height; the necessary continual adjustments of power will increase consumption. Height gained or lost should be corrected by such slight alterations of power as may be necessary from time to time.

36 Speed should be maintained within plus or minus 5 knots. Some aircraft, though stable at higher speeds, become longitudinally unstable at the best speeds for endurance and it may be tiring to fly such types at these speeds.

CRUISING AT CONSTANT POWER OR SPEED

General

37 In the foregoing paragraphs, it has been assumed that the aircraft is to be flown in such a manner as to achieve the greatest range or endurance. This may not always be practicable or operationally desirable.

38 There are three methods of cruise control which may be used in certain circumstances. Figure 1-9 shows the comparative effect on ANMPG of employing these three methods. Figure 1-9 shows IAS - ANMPG curves for a typical four-engined aircraft at four different

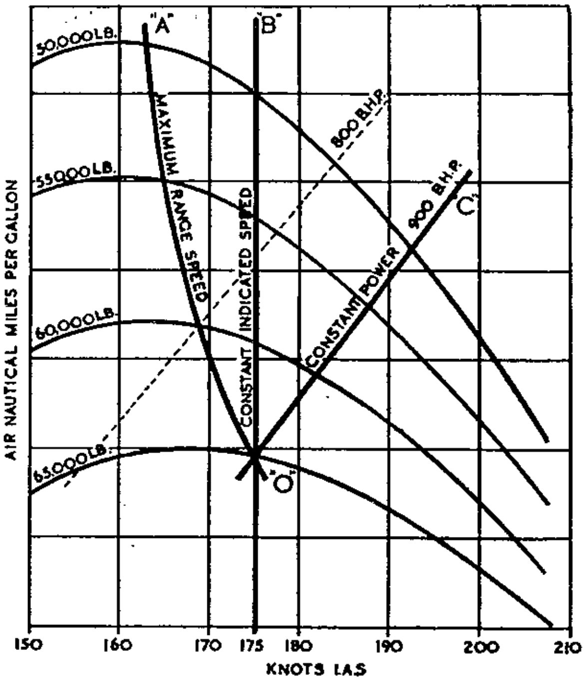


Figure 1-9 Variation of Air Nautical Miles Per Gallon with Airspeed

weights at 10,000 feet. It is readily observed from the curves that the optimum speed falls as the weight is reduced. The line OA represents the recommended range speed, i.e., slightly above the optimum speed, OB represents a constant IAS of 175 knots and OC shows the effect of cruising at a constant power of 900 BHP/engine. Paragraphs 39 to 45 give relative advantages and disadvantages of the three methods.

Recommended Range Speed

39 The line OA shows the most efficient method for fuel economy for long-range flight, regardless of all other factors. The greater the distance to be covered, the greater the advantage in using this method, that is, the more the other lines OB and OC diverge from line OA. This method can, therefore, be used to advantage when:

(a) Flight distance is so great that less efficient methods of operation cannot be used with safety.

(b) It is considered more important to carry the maximum service or payload rather than to save time.

(c) Maximum economy of fuel is of paramount importance.

40 This method has certain disadvantages however:

(a) It provides the slowest flight operation.

(b) It is often difficult to compensate for variable winds with any degree of efficiency and flight planning is complicated.

(c) Frequent adjustments of power may be necessary to maintain an exact IAS.

Constant IAS

41 This method is shown by the line OB and may be used in certain circumstances for the following reasons:

(a) Maximum range may be closely approached if a suitable airspeed is selected.

(b) One airspeed is sufficient for the normal weight and altitude range of most aircraft.

(c) Flight planning and navigation are simplified.

42 Its disadvantage is that under a given set of conditions more fuel has to be carried than under maximum range operation, in order to provide the same safety margin.

Constant Power

43 This is shown by the line OC. The advantages of this method are:

(a) It achieves acceptable fuel economy for short distances where the weight of fuel consumed is but a small proportion of the gross aircraft weight. The larger and more efficient the aircraft, the greater becomes the absolute distance over which this will apply.

(b) Maintaining constant power is usually the simplest procedure and thus there is less chance of the aircraft being operated incorrectly.

(c) At any given initial power, and therefore airspeed, this method will give a shorter flight time, than the other two methods, under the same conditions.

44 Its disadvantages are:

(a) As can be seen from the line OC its efficiency decreases rapidly as the flight distance, that is, fuel used increases. The high initial power necessitated by the initial weight must be maintained, or alternatively, a lower power may be selected which at the initial weight may affect controllability.

(b) The difference in power required between this and other methods increases progressively as the flight continues, particularly when the AUW is considerably reduced, for example, when bombs are dropped.

45 Where the necessity for reaching a destination by a certain time is of greater importance than fuel economy, or on short flights when variation in AUW is not great, methods at paragraphs 41 and 43 may be justified. In all other cases, method at paragraph 39 is recommended.

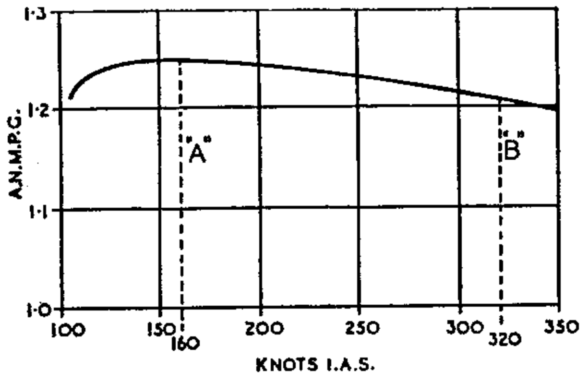


Figure 1-10 Typical Air Nautical Miles Per Gallon Curve for Turbine Jet Aircraft

CONSIDERATIONS AFFECTING TURBINE-JET PROPELLED AIRCRAFT

Best Speed for Range

46 Recommended speeds for range in turbine-jet propelled aircraft are much higher than those for piston-engined aircraft. The reasons for this are as follows:

(a) Turbine-jet engines operate most economically in the region of their maximum cruising RPM.

(b) The greater the rearward velocity of the jet wake relative to the atmosphere, the greater is the proportion of the energy lost in merely churning up the air behind. As the TAS of the aircraft increases, the velocity of the jet wake relative to the atmosphere decreases by approximately the amount of the increase in the forward speed of the aircraft. Less energy is thus lost and the overall propulsive efficiency increases.

(c) The jet propelled aircraft is invariably cleaner than a comparable piston engined type due to the low nacelle drag and the absence of a propeller. The minimum drag speed of the aircraft is thus higher.

47 The effect of the above characteristics is to produce a very flat ANMPG curve as illustrated in Figure 1-10. In the case illustrated it can be seen that the loss of range by flying at 320 knots instead of 160 knots is only 3 per-cent.

Best Speed for Endurance

48 For endurance the aircraft should be flown at the minimum drag speed, i.e., the speed that requires minimum RPM to maintain level flight, and so the minimum fuel consumption.

Effect of Altitude on Range and Endurance

49 Since the overall efficiency of the engine increases with increase of TAS, and the optimum range IAS for the airframe is comparatively low and substantially constant, it follows that it is advantageous to fly at the highest practicable altitude where the TAS corresponding to the recommended IAS is as high as possible. This also necessitates the use of high, and so economical, RPM to maintain the required IAS. In addition, the lower temperature at altitude somewhat improves the economy of the turbine jet engine. However, at very high altitudes the curve illustrated in Figure 1-8 is modified in that it tends to peak noticeably around the best IAS for the airframe and the ANMPG at the higher IAS fall considerably. This is due to the fact that the normal rise in drag that occurs at high IAS is accentuated at high altitudes by compressibility effects. It is therefore more important to maintain the recommended airspeed. The true ANMPG even at moderate altitudes such as 20,000 feet may be as much as double those obtained at sea level. As in all cases, but more particularly so with turbine-jet aircraft, the best height at which to fly must be worked out in relation to the total distance to be covered. The saving in fuel achieved in level flight at the higher altitudes must be balanced against the comparatively high consumption of fuel during the climb and during the descent, and on all but long flights it may not pay to fly as high as possible. A precise determination of the best altitude also requires a knowledge of atmospheric conditions, including wind speeds and directions at high altitudes, and the flight may have to be abandoned if the flight plan is found to be unsuitable. For instance, it is useless to climb to 30,000 feet, then finding this height to be impracticable, change the flight plan, descend to 10,000 feet and attempt to continue the flight, as the fuel so used may well have halved the range.

50 On some twin-engined aircraft greater

ANMPG and endurance are obtained in certain conditions by flying on one engine at maximum cruising RPM rather than on both engines running at lower, and so less efficient, RPM. When this applies the POI for the type include specific recommendations.

51 Endurance increases at the higher altitudes but to a much smaller extent than does range and in general varies very little. Taking into consideration, therefore, the quantity of fuel required to climb, greatest overall endurance will be obtained by flying at the lowest practicable airspeed at a low altitude.

Engine and Aircraft Handling for Economy when Climbing or Descending

52 Fuel consumption is greatly reduced at altitude and it is therefore important to reach the desired height as quickly as possible. The maximum permitted climbing RPM should always be maintained, but not exceeded, and the IAS should be high, as the thrust horse-power output of the engine increases with forward speed. Thus the POI recommended a climbing speed which is usually much in excess of that for a comparable piston engine aircraft.

53 On the descent, the extra fuel used on the climb cannot be recovered to the same extent as with piston engined aircraft for the following reasons:

(a) Fuel consumption at idling RPM is high compared with piston engined aircraft.

(b) It is usually necessary at altitude to maintain comparatively high idling RPM to ensure adequate cabin pressure and to prevent combustion ceasing. These high idling RPM are normally provided automatically and are thus beyond the control of the pilot.

54 For maximum economy in the descent, therefore height should be lost as quickly as possible. When flying for range, maximum air miles per gallon together with a comfortable rate of descent will be achieved by descending using the lowest practicable idling RPM at a speed as near as possible to the critical Mach number or limiting IAS without using the speed brakes. The distance thus covered during the descent can be added to the distance covered in level flight as shown in Figure 1-12.

55 In order to use the least amount of fuel during the descent, as required when flying for endurance, the descent should be carried out as recommended above, but air brakes should be used. In this case the rate of descent will be very high and the distance covered will be small. Care must be used when descending through cloud to avoid toppling gyro instruments during turns and also due account must be taken of the considerable altimeter lag at high rates of descent.

56 It will be seen that when using the first type of descent it is necessary to know the exact position from which the descent should be commenced. This will not always be possible under instrument conditions and working on a time basis is not always reliable. In such cases, therefore, the cruising flight should be continued at the cruising altitude until over the destination and the descent made using the air brakes as when flying for endurance. The overall ANMPG for the flight will not be materially reduced by so doing.

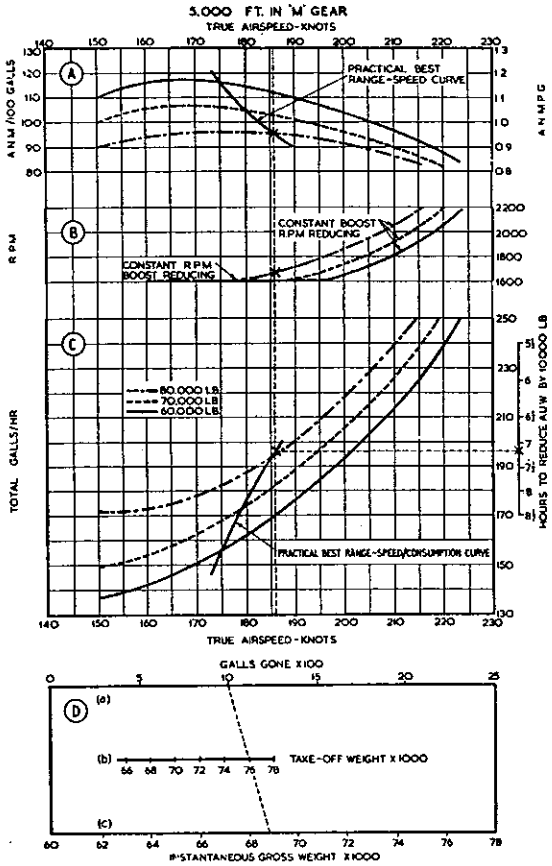
Constant Speed or Constant Power Cruising

57 Because the ANMPG curve is much flatter with this type of engine, there is not the same distinction between the three methods outlined in paragraphs 37 - 45. Provided the IAS is not more than, say, 25 knots above or below that recommended for range flying, cruising at a fixed speed or power setting will, in general, give comparable results.

FLIGHT PLANNING

General

58 For a long flight it is usually desirable to decide beforehand the best altitude and speed at which to fly. If a reliable meteorological forecast, including wind velocities at altitude, is available, a reasonably accurate estimate of the fuel required and ETA can thus be made. The ANMPG curves as hitherto published in POI are not ideal for this purpose, as they involve considerable calculation if a complete flight plan is to be prepared. Where appropriate, therefore, POI will include performance charts presented in a new form. These comprise curves plotted in relation to TAS and not IAS because in still air, TAS represents the actual ground speed at any height, and flight planning is thus facilitated.



NOTE: If this Chart had been plotted for some higher altitude the words "Constant boost" on graph B would then require to be interpreted as meaning "at constant maximum cruising boost, or above full throttle height for this boost, at the maximum obtainable boost which varies with the RPM Selected".

Figure 1-11 Typical Flight Planning Chart for Piston Engine Aircraft

59 In the case of piston engine aircraft POI will include related ANMPG curves, engine RPM curves, and gallons-per-hour curves, for various weights and at two or more heights. The heights chosen take into account the role of the aircraft, and, where appropriate, its performance under low and high supercharger gear conditions. Additional data such as the reduction in weight due to consumption of fuel may where necessary be included. In the case of turbine-jet propelled aircraft the curves take a different form as explained in para. 62.

Piston Engine Aircraft

60 Figure 1-11 shows a typical example of a chart for a piston engine aircraft which should be used as follows:

(a) First select the best altitude at which to fly by finding from the ANMPG curves on the charts (graph marked A in figure 1-9) the altitude at which the peak of the relevant ANMPG curve corresponds to the highest ANMPG, unless adverse winds forecast for this altitude or other factors indicate that some other altitude is likely to prove better. If the flight is to be a short one, the consumption of fuel to climb to a high altitude, which must always be allowed for when calculating the total fuel required, may more than offset the gain in ANMPG when flying level at such a height.

(b) If maximum range is required, or when ETA is not important and minimum consumption of fuel for the flight is, therefore, desirable, a TAS about 10 knots above that corresponding to the peak of the ANMPG curve for the starting AUW of the aircraft should be selected. The PRACTICAL BEST RANGE SPEED curve on Graph A in fact joins these points on the three weight/ANMPG curves and the best speed at any intermediate weight lies on this curve thus enabling the required TAS to be read off immediately. A ruler, as represented by the dotted line in the figure, placed vertically at this point will cut the appropriate RPM curve on Graph B at the RPM which, at maximum cruising boost, should give the required TAS. If flying above full throttle height for maximum cruising boost at the selected RPM the boost obtained should be accepted unless POI for the type indicate that under the particular conditions a change to high gear would be advantageous (see Note at foot of figure 1-11). The point of intersection of the ruler and the gallons per hour curves on Graph C will also show the consumption. A line projected horizontally, as shown, to cut "the hours to reduce AUW by 10,000 lb. scale" shows when a change in speed will be appropriate, by reason of the reduced AUW. At the end of this time the speed should thus be altered to that indicated by the ANMPG curve corresponding to the next lower AUW, the new RPM and consumption per hour being found as before. If the vertical ruler is found to cut the flat section of the RPM curve, this indicates that the required power will be less than that obtainable at maximum cruising boost and minimum practicable RPM and that boost should be reduced accordingly. The IAS which, at the height selected under the prevailing atmospheric conditions will correspond to the TAS chosen, may be found by means of a Dalton computor and, taking any necessary PEC into account, should be to within about 10 knots of that recommended for maximum range in the POI.

(c) If the object of the flight requires arrival at the destination by a certain ETA, first divide the distance by the time available. This, after correcting for anticipated wind speed and after allowing for time taken and distance covered on the climb to height, gives the required TAS. The chart may then be used as before to ascertain the RPM and fuel consumption, but if the TAS is high the fuel consumption will be greater than that obtainable when using the methods described in (a) and (b). No advantage will be gained by flying at a TAS less than that corresponding to the peak of the appropriate ANMPG curves.

(d) If desired these charts can be used for planning a "constant power" flight. First select the altitude as before and then the required TAS. For maximum range obtainable on a "constant power" flight, the TAS will be slightly above that corresponding to the peak of the curve for the mean AUW for the flight. The required RPM and fuel consumption which will not vary significantly throughout the flight except during the climb, can then be ascertained from the chart.

(e) In flight, if owing to a miscalculation in weight, presence of external stores, or for other reasons, the pre-determined RPM are found not to give the required IAS, and so TAS, the resulting IAS should be accepted unless, when flying for maximum range, it is more than about 10 knots above or below the IAS recommended, in which case power should be adjusted to keep the IAS within these limits. If flying for a required ETA, the RPM should also be adjusted to maintain the required IAS, and so TAS. In both these cases an adjustment to the fuel consumption estimate will be required and can be found from the chart by looking up the fuel consumption corresponding to the RPM found to be necessary after adjustment.

(f) Graph D can be used to ascertain the instantaneous gross weight of the aircraft at any time in flight provided that the take-off weight is known and that fuel flowmeters are fitted or that the amount of fuel already used can be estimated with reasonable accuracy from the fuel contents gauge readings. The graph should be entered at the number of GALLONS GONE on scale (a). A ruler, as represented by the dotted line on Graph D, lined up with this point and the TAKE-OFF WEIGHT on scale (b) then cuts scale (c) at the INSTANTANEOUS GROSS WEIGHT. This method may be used as an alternative to, or for the purpose of checking the weight arrived at by, the method explained in (b). It is particularly suitable for use with the heavier, and transport type, aircraft the POI for some of which include a graph of this type in the Flight Planning Charts. Pilot's Operating Instructions for some aircraft include a chart similar to Graph D but not embodied with the flight planning charts; these carry a fourth scale giving the best IAS and estimated ANMPG obtainable at any instantaneous weight. These indicated airspeeds correspond to true airspeeds about 10 knots above the peak of the ANMPG curves in accordance with recommended range flying practice.

61 For maximum endurance the aircraft should be flown at the speed corresponding to the "valley" of the appropriate fuel consumption curve, unless this is below the minimum practicable level flight IAS. Endurance can be calculated, after allowing for fuel used on the climb, by dividing the total fuel available by the consumption as shown by the curve corresponding to whichever of these speeds is the higher.

Turbine-Jet Propelled Aircraft

62 For turbine-jet propelled aircraft the charts take a different form. In this case the speed is not so critical and altitude is the determining factor. A chart of the type included in POI for turbine-jet propelled aircraft is shown at Figure 1-12. A family of such curves is included for two or more total fuel load conditions of the aircraft at each of two or more level flight speeds, one corresponding to the optimum range speed and one or more to high Mach number speeds. The curves show the total distance which can be covered on a

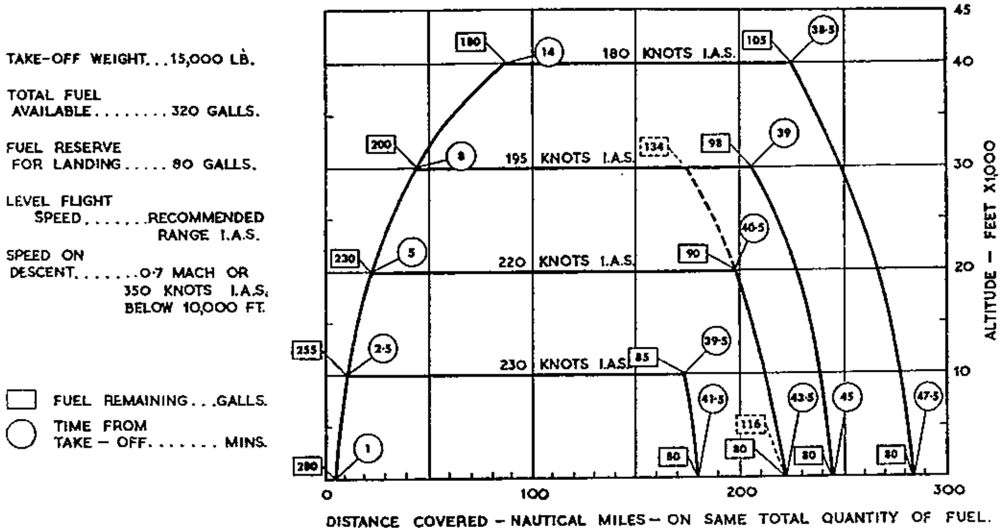


Figure 1-12 Typical Flight Planning Chart for Turbine-Jet Propelled Aircraft

given quantity of fuel; usually the total fuel capacity of the aircraft less an allowance for take-off and a reserve to allow for the possibility of having to go round again, and if necessary for demisting the windscreen before landing. Each curve of the family shows the maximum distance, in still air, which can be covered on the fuel available if the aircraft is flown at the altitude shown. The quantity of fuel in the tanks at the commencement and finish of the climb and commencement and finish of the descent is given by the figures in rectangles; the figures in circles show the time taken to cover each stage of the flight. It will be seen that the range of the aircraft is greatly increased by flying at the higher altitudes and that to cover a required distance it is essential that the aircraft should be climbed at least to the minimum altitude which will enable the distance to be covered. This altitude should be maintained until the point for descent is reached. The descent should then be made at the recommended Mach number or IAS to ensure that the time spent in descending, and hence the fuel used, is kept to a minimum. The point for commencing the descent is chosen so that the line of descent terminates at, or as near as possible to, the destination in order to avoid uneconomical cruising at low level. This point can be selected from the chart by noting the time after commencement of flight at which the descent should be commenced. It is, of course, possible to cover any required distance more economically by climbing above the minimum height which will give the required range. For example, 220 miles can be covered on about 200 gallons of fuel by climbing to 20,000 feet, but by climbing to 30,000 feet the total fuel required will be only about 164 gallons, as shown by the dotted line and figures in dotted rectangles; it is, therefore, desirable to fly at a higher altitude for the following reasons. Planning a flight with the aid of these charts necessitates having a really reliable meteorological forecast, as any subsequent departure from the plan may result in its proving impossible to reach the destination unless the desirable reserve for "going round again" is materially reduced. It follows, therefore, that if fuel can be saved in the early part of the flight by flying above the minimum altitude for the required range, there will be a margin in hand should subsequent descent to below the minimum altitude be necessitated by weather conditions. These charts do not show the effect on consumption of changes in speed as do the ANMPG curves for piston-engined aircraft, but as already explained this is not nearly so critical and provided that the IAS is within reasonable limits the overall consumption and range will not be noticeably affected. Climb should be made at the climbing IAS for optimum rate of climb and descent at the highest speed permitted by the limiting Mach number and at low altitude, the limiting IAS as explained elsewhere.

Summary

63 For range flying turbine-jet aircraft should be flown as high as possible as the best IAS for the airframe then gives the high TAS required for the most efficient operation of the engine. Endurance does not increase with altitude to the same extent as does range, but at any required height the aircraft should be flown at the lowest practicable RPM.

SECTION 7

HIGH-SPEED AND HIGH ALTITUDE FLYING

INTRODUCTION

1 This chapter explains certain flight characteristics which may be encountered when flying high-speed aircraft, particularly at high altitudes. The term compressibility is used when discussing the behaviour of aircraft at high speeds. Although air is, in fact, compressible at all speeds, that is, it can expand and contract under changes of pressure, this is neglected in simple theory of flight and only begins to be significant at speeds approaching the speed of sound. The compressibility of the air produces results most evident to the pilot when it occurs in the concentrated form of shock waves across which the air becomes instantaneously denser. Lack of appreciation of the reasons behind the behaviour of an aircraft at high speeds may lead a pilot to take action which, whilst natural and appropriate at normal speeds, may bring him into difficulties at high speeds and high altitudes. It is recommended that this Section be read in conjunction with Section 1 of this Part.

SIGNIFICANCE OF SPEED OF SOUND

2 When a wing is moving through air its approach is communicated by a pressure wave to the air, so that at some distance ahead of the wing the streamlines begin to diverge in order to pass round it. The speed of sound is the speed at which pressure waves travel through the air, so that as the speed of the wing approaches the speed of sound it becomes more difficult for its approach to be communicated ahead. Consequently, the flow of air over the wing changes in character as the speed of sound is approached. The Mach number is a simple way of measuring the nearness to the speed of sound; as it approaches 1.0 the flow over the wing and consequently the behaviour of the aircraft may be expected to change. For example, 230 knots EAS represents a Mach number of 0.36 at sea level, but 0.75 at 36,000 feet, and the behaviour of a typical fighter aircraft would probably be quite different at the latter height. There is a Mach number for any aircraft at which trim changes or control difficulties become severe due to compressibility and shock wave formation; this is its actual Critical Mach number which varies slightly with condition of airframe, flight conditions, atmospheric conditions such as bumpiness and "g" loading. A Mach number limitation is imposed for a particular aircraft type, only when it is essential, e.g., when there is a direct risk of immediate structural failure or when recovery from loss of control will result in structural failure. A Mach number limitation can be expressed in terms of true or indicated Mach number, but the figures quoted in POI for high speed types always refer to the indicated machmeter reading.

COMPRESSIBILITY

3 As air flows past the wing it is speeded up locally, especially over the top surface, and the airflow relative to the wing at some point may reach the speed of sound while the flight speed is still well below it. As the speed of sound is reached, and exceeded locally, it becomes increasingly difficult for pressure changes to travel ahead and they tend to pile up in a front or shock wave running out more or less at right angles to the surface of the wing. Forming locally, these shock waves develop as the Mach number increases resulting in a loss of lift, an increase of drag and a change of trim.

4 The Mach number at which shock waves begin to form and the actual Critical Mach number at which serious shock stalling develops are slightly reduced as "g" is increased.

5 Compressibility effects are minimized with a thin wing which has a higher Critical Mach number than a thicker wing. The behaviour of the aircraft at the onset of compressibility depends upon its individual design. The main effect is usually a breakdown of smooth flow over the wings and/or control surfaces.

6 On some types of aircraft there is a Mach number higher than the Critical Mach number, at which the changes of trim and loss of lift due to compressibility become so severe that control cannot be maintained even by a pilot with considerable experience of the type. Like the Critical Mach number this is a variable and is the highest Mach number which can be reached in the particular conditions. It is usually referred to as the "practical limit of control" and on an aircraft having a Mach number limitation, will be higher than the latter.

7 It may sometimes be necessary to refer to a Mach number at which the aircraft can be flown steadily enough for a particular operational purpose, e.g., for firing guns, for photography, or for formation flying. This should be referred to by some unambiguous term to ensure that it is not confused with the Critical Mach number, or the Mach number limitation.

COMPRESSIBILITY EFFECTS

General

8 The compressibility effects on an aircraft usually vary to some extent with altitude, with the application of "g" and with its forward acceleration. The following is a list of some of the effects that may be experienced:

Changes of Trim

9 Changes of trim are as follows:

(a) Longitudinal changes of trim are always experienced in some degree. On many aircraft there is a sequence of changes such as an initial nose-up change followed by a nose-down change. These changes may be slight and occur gradually but on some aircraft and, in certain circumstances, they may be large and take place rapidly.

(b) Lateral changes of trim are experienced on many aircraft, and wing dropping is often the limiting factor of control in compressibility. The ailerons are usually effective in checking this symptom initially and opposite rudder is sometimes helpful but the wing dropping cannot always be controlled as the Mach number is increased. However, on modern high speed aircraft this loss of control is overcome by the use of very large ailerons either fully power operated or power assisted.

(c) Directional changes of trim are unusual.

Buffeting

10 Buffeting in some degree is nearly always experienced, and often can be compared to pre-stall buffet. Buffeting of the tail control surfaces may be felt on the control column; occasionally aileron snatching may occur and also aileron "buzz" in which the ailerons oscillate at a high frequency. Buffeting may be much more pronounced and the Critical Mach number appreciably reduced if external fuel tanks or stores are carried.

Oscillation

11 Moderately rapid oscillations of the elevator and/or rudder may be experienced, resulting in "porpoising" and "snaking" respectively. Sometimes these symptoms can be checked by clamping hard on the controls. Normally it is inadvisable to try and check this behaviour by positive movement of the controls. Snaking may be prevented in some cases by accurate directional trimming, and by synchronization of the engines in the case of multi-engined aircraft.

Control Effectiveness

12 The effectiveness of the controls and trimming tabs deteriorates at high Mach numbers, sometimes resulting ultimately in loss of control.

Control Heaviness

13 Often the aerodynamic balancing of the controls is affected at high Mach numbers, and it is most common for the controls to become heavier.

VARIATION OF MACH NUMBER IN DIVE

14 Since the effects of compressibility depend mainly upon the Mach number, it follows that in level flight no marked symptoms should be experienced at speeds below the Critical Mach number. In a dive, however, the Mach number may increase rapidly and it is important for the pilot to have a general idea of how the Mach number is likely to vary in relation to the IAS.

15 The main features of variation of Mach number with height in a dive are:

(a) The highest Mach number is reached by diving from the greatest height; from a lower height, the peak Mach number will be less. For example, consider an aircraft making two dives at the same angle and power setting, and starting at the same TAS, but making one dive from 40,000 feet and the second from 32,000 feet. The following figures would be typical:

Dive from	40,000 feet	32,000 feet
Peak Mach number	0.89	0.85
which is reached at	29,000 feet	20,000 feet
EAS then being	330 knots	380 knots

With underwing pressure heads, which are subject to very large pressure errors at high Mach numbers, invariably over-registering, the distinction between IAS and EAS must be borne in mind.

(b) In any dive, the Mach number will reach its peak and begin to fall while the IAS is still rising. It is therefore possible for an aircraft to be in a steep dive with the pilot unable to do more than keep the attitude constant by pulling back on the control column, and for the IAS to be still increasing. Despite this, the Mach number will reach a maximum, then as the speed of sound increases in the warmer air at lower altitudes, it will begin to fall. When it falls to the critical value for the particular aircraft, recovery from the dive will be possible, but this may involve a very considerable loss of height.

(c) Table 2 shows the EAS corresponding to 450 knots TAS at various heights, the speed of sound in "standard atmosphere" conditions at each height, and the Mach number.

(d) It will be seen that if the true speed is constant in a dive, the Mach number can be falling although the EAS is rising rapidly. This further illustrates the point that the highest Mach numbers do not necessarily occur when the highest speeds are shown "on the clock".

USE OF ELEVATOR TRIMMER AT HIGH SPEEDS

16 Apart from the effects caused by the condition of longitudinal stability of the aircraft described in Section 4, paras. 2 - 9, both nose-up and nose-down changes of trim may occur at high Mach numbers, due to the varying effects of aeroelastic distortion and compressibility. If a nose-up change is trimmed out, any subsequent nose-down change may be rendered excessively violent. If a nose-down change is trimmed out, excessive "g" loads may result when speed is reduced. All such trim changes should, therefore, be held on the control column although the stick forces

TABLE 2

Height	EAS of Aircraft in Knots (i)	True Speed of Aircraft in Knots (ii)	True Speed of Sound in Knots (iii)	Mach Number at 450 Knots TAS (iv) = (ii) (iii)
40,000	225	450	570	.79
30,000	275	450	590	.76
20,000	330	450	610	.74
10,000	385	450	640	.71
Sea level	450	450	660	.68

may vary and become considerable. If prior to recovery from a dive a nose-up change is being held, it should be remembered that the aircraft will recover by merely relaxing the forward pressure on the control column. This pressure should be relaxed progressively as a sudden relaxation or application of a backward pressure may easily result in excessive "g" forces. At high altitudes this will result in a stall, but at low altitudes structural damage to the aircraft may occur.

17 The above recommendations apply to all aircraft, at least until the pilot has acquired considerable experience of the type at lower Mach numbers. In certain cases, however, the stick forces may become so heavy, as the effects of compressibility become more marked, that recourse to trimming is unavoidable if the speed is to be maintained or further increased. In such cases, when maximum performance is essential, judicious use of the trimmer in accordance with the recommendations in the POI is permissible.

18 If, after trim has been applied, the Mach number is then reduced, the aircraft may become heavily out of trim as the effects of compressibility diminish. The aircraft must, therefore, be retrimmed progressively and without delay, as otherwise these out-of-trim forces can increase rapidly, particularly if the Mach number is reduced quickly, for example, by using speed brakes.

EFFECTS OF AIRFRAME DISTORTION

19 At high indicated airspeeds, any of the effects described in paragraphs 16 - 18 may be accentuated or reduced by temporary distortions of the airframe and consequent changes of lift, particularly of the tail surfaces, resulting from the change in magnitude and distribution of the air loads to which the surfaces are subjected at high airspeeds independent of compressibility effects. Such distortion is sometimes called aeroelastic distortion because it alters the aerodynamic qualities of the airframe. In some degree this is inevitable and is allowed for in the design of the aircraft. The largest effect is noticed on the change of trim; this is most pronounced in denser air at lower altitudes where higher IAS are reached and may give rise to a change in the character or degree of the compressibility effects and a variation with altitude in the actual Critical Mach number.

EFFECTS AT VERY HIGH ALTITUDE

20 Apart from the difficulty of providing means for pressurizing the cockpit of the aircraft and for keeping the crew warm and ensuring them an adequate supply of oxygen, the ability of an aircraft itself to reach great altitudes is limited by the following considerations.

21 In paragraphs 14 and 15 above, it has been shown how the relations between EAS and Mach number varies up to about 40,000 feet. The temperature of the atmosphere, however, does not continue to decrease much above this height and the speed of sound, and so the TAS of the aircraft corresponding to the critical Mach number, does not continue to fall above this height. On the other hand, the EAS corresponding to a given TAS does continue to fall, because it depends upon the ever decreasing density of the air. At about 60,000 feet a Mach number of .75 corresponds to an EAS of about 150 knots and it follows that an aircraft with a critical Mach number of .75 could not fly faster than this at this height.

22 At very high altitudes, manoeuvrability is also greatly reduced for the reasons explained in Section 1. Assuming the aircraft taken as an example in paragraph 21, to stall, in level flight at 100 knots EAS and, therefore, at 150 knots at slightly more than 2g, it would be difficult to control since it could not exceed this speed. At some greater height the EAS corresponding to the critical Mach number would tend more and more to coincide with the stalling speed even at 1g. The aircraft would in fact be unable to reach the height at which the stalling and critical Mach number speeds coincided. Even at heights reached by present aircraft a marked reduction in manoeuvrability is experienced, especially if the wing loading is high, which increases the stalling speed, and the wing is thick, which reduces the critical Mach number.

23 The greatest altitude which an aircraft can reach, its ceiling, may be:

(a) The greatest height at which level flight and a minimum degree of manoeuvrability can be maintained for the reasons outlined in paragraphs 21 and 22.

(b) The greatest height at which the engine(s) can develop sufficient thrust to maintain the minimum flying speed and minimum rate of climb. This, rather than compressibility considerations, is the limiting factor with most aircraft. With piston engines the drop in density as height is gained reduces the weight of air, and so oxygen, which the engine can draw in, and the power it can develop to a point where the propeller thrust becomes insufficient. With turbine-jet engines a supply of air in excess of that required for combustion, is necessary to ensure adequate cooling of the turbine. As height is gained, therefore, the quantity of fuel supplied to the engine must be restricted, to balance the reduction in the total weight of air available. The thrust and so ceiling are accordingly restricted. A rocket-propelled aircraft can, however, reach its compressibility ceiling as the oxygen necessary for combustion of the fuel is carried or produced within the aircraft. The power plant can thus continue to develop high thrust in an atmosphere devoid of oxygen.

OTHER HIGH-SPEED EFFECTS

Effects on Instruments

24 Due to compressibility effects, a large increase in position and compressibility errors may occur at high Mach numbers with consequent effect on the altimeter and rate of climb indicator. On present aircraft, at low altitudes, as the Mach number increases, the altimeter may read progressively too low by as much as 500 feet or more in extreme cases. Pilots should also realise that at high indicated airspeeds a small pitch movement of the artificial horizon will indicate a high rate of climb or descent.

Effects on Cockpit Temperature, and Bumps

25 At high speeds, the pilot should be prepared for an increase in cockpit temperatures and for sudden and possibly considerable "g" due to bumpy conditions.

(a) The increase in cockpit temperature is due to heat produced by compression of the air as the fuselage forces its way through. The increase may be considerable as explained in Section 5, paragraph 11.

(b) The effect of bumps has already been discussed, but it should be noted that these effects are greatly increased at high speed. Speed, therefore, should be restricted and manoeuvres involving high "g" should be avoided in bumpy conditions. The safety harness should be tightly secured.

EFFECTS ON DESCENDING FROM HIGH ALTITUDE

26 On descending from high altitude, particularly in cold weather, considerable misting or icing up of the inside of the windscreen may be experienced unless adequate electrical or hot air windscreen heating is fitted. As a consequence sufficient fuel should be reserved for 5 or 10 minutes flying before landing to allow time for the windscreen to clear. Before the descent is started, wiping the inside of the windscreen with a rag that has been soaked in glycol helps to prevent ice and mist from forming.

27 Sometimes after a descent from high altitude mist forms on the outside of the windscreen when speed is reduced for the approach to land. The windscreen de-icing system may be effective in clearing this or it will disappear in a few minutes if the aircraft is flown at a high IAS. If the fuel state is too low to permit this, and the windscreen cannot be cleared with the de-icing fluid, a landing should be made with the canopy open if possible.

ADVICE TO PILOTS

28 The characteristics at high Mach numbers often vary slightly between individual aircraft of the same type. As a consequence pilots should familiarize themselves with the behaviour of the particular aircraft at progressively increasing Mach numbers.

29 When investigating the Mach number characteristics of an aircraft, it is always advisable to commence at as high an altitude as possible, where high Mach numbers can be reached at moderate indicated airspeeds, and hence the stresses on the airframe are smaller. The effects should then be investigated in successive stages at decreasing altitudes.

30 Care should be taken in trimming out the elevator forces at high Mach numbers, as on reducing speed, the changes of trim may be large and occur rapidly with a consequent

risk of "g" stalling or even overstressing the aircraft, or blacking out the pilot. Careful rudder trimming may assist in preventing snaking.

31 When no machmeter is fitted, the IAS limitations at different heights for the type must be known. If a machmeter is fitted, the Mach number limitations must be known. At high speeds it is usually better to watch the machmeter rather than the airspeed indicator, but care must be taken to see that the IAS limitation is not exceeded.

32 Should control be lost due to the Mach number limitation being exceeded inadvertently, the speed brakes should be opened and the throttle(s) closed. Control should be regained rapidly with the decrease in Mach number due to the resultant deceleration and to the decrease in altitude.

33 The effects of bumpy conditions are greatly increased at high IAS, with the possible risk of overstressing the aircraft and injury to the pilot. in these conditions "g" loads should not be intentionally imposed on the aircraft, and the speed should be reduced.

34 Aerobatics should not be commenced at speeds such that there is any possibility of the Mach number limitations being unavoidably exceeded in the course of their performance. Considerable space is required for manoeuvring and such heights may be gained or lost during manoeuvres in the looping plane. It is very important to allow for this when pulling out of a dive. Recommended speeds and heights for commencing manoeuvres are frequently given in POI for high speed aircraft. It should be noted that some manoeuvres may be impracticable above certain heights, since the minimum safe IAS for their commencement would then be in excess of the Mach number limitation.

35 With high speed aircraft, it is very easy to get further from base than is realized, particularly when high speed manoeuvres are being executed above cloud or in poor visibility. The comparatively limited range and endurance of such aircraft should be borne in mind and a frequent check made to ensure that ample fuel remains to reach an airfield, and for the descent if the flight has been made at altitude.

36 Abandoning aircraft at high altitudes without oxygen is likely to be fatal, and at high IAS at any height is extremely hazardous with or without oxygen. Modern high speed aircraft are fitted with ejection seats which to a large extent overcome these problems. Above 25,000 feet it is advisable to carry out a "delayed drop" at least down to this height, as if opened at high altitudes the parachute is more liable to tear and the wearer is subjected to cold and other high altitude effects for an excessive period.

37 If a life saving vest is worn when high altitude flying is being undertaken, the pilot should ensure that this is completely deflated. This is particularly important with pressure cabin aircraft as in the event of a rapid loss of cabin pressure the sudden expansion of the vest may restrict breathing and even cause severe bruising of the chest.

38 Speed limitations applying at various altitudes, together with as much information as possible on the behaviour of the aircraft at high Mach numbers, and recommendations for handling at high speeds, are included in POI for the type where appropriate.

PART 2

POWER UNITS AND THEIR HANDLING

SECTION 1

GENERAL CONSIDERATIONS

INTRODUCTION

1 All power units drive the aircraft forward by displacing a mass of air rearwards relative to the aircraft. However, the method of doing this varies:

(a) With piston-engine/propeller power plants, rearward displacement of the air and forward thrust is produced by rotation of the propeller.

(b) With turbine-jet engines, thrust is produced in a forward direction with the engine as a reaction to the force expended in expelling the mass of heated air and combustion gases rearwards from the jet pipe. It should be noted that only a small proportion of the air entering the air intake combines with the fuel to produce combustion which then heats up the remainder of the air; this produces the pressure within the engine which serves to drive the turbine and to provide the force required to expel the gases from the nozzle.

(c) With propeller-turbine engines, the power developed within the engine is used in both ways, that is, to produce propeller thrust and reaction thrust.

PISTON-ENGINE/PROPELLER, POWER PLANTS

2 Piston engines are either air or liquid cooled. Radial and some small in-line engines are air cooled; larger in-line types are liquid cooled, the liquid being cooled in its turn, by the air stream passing through a radiator. In all types, a proportion of the heat developed is transmitted by the lubricating oil to the crankcase walls and, when fitted, the oil cooler, and finally dissipated to the air.

3 Piston engines may be divided into the following three classes according to the method whereby the pilot controls the power developed:

(a) Unsupercharged engines driving fixed-pitch propellers. - In this type, the controls consist of a throttle lever and mixture control. For any given throttle setting, power, proportional to the mass gas flow, varies as the RPM change with the attitude of the aircraft and as manifold pressure changes with altitude, since both affect the mass gas flow per minute. The mixture control regulates the fuel-air ratio to compensate for reduction in air density at altitude.

(b) Unsupercharged engines driving constant-speed propellers. - In this case, RPM control lever enables the required RPM to be selected; the constant-speed governor then automatically adjusts the propeller blade pitch angle, over the constant-speed range, to prevent variation in RPM. With this type, the mixture regulation is usually automatic. Variations in power for a given throttle setting thus only occur as changes in altitude affect the manifold pressure (boost). With all unsupercharged engines, being normally aspirated, the manifold pressure is always below atmospheric. The manifold pressure varies with altitude, and with throttle setting up to the rated full throttle height.

(c) Supercharged piston engines driving constant-speed propellers. - In these types, the manifold pressure is boosted by means of a supercharger; up to 20 lb/sq.in. or more above atmospheric in some installations. The supercharger is usually of the two-speed type which runs at a higher speed in high gear to maintain the manifold pressure at high altitudes. To reduce heating of the charge during boosting, some superchargers are of the two-stage type, the mixture being cooled by an intercooler between the two stages. A boost regulator interconnecting the throttle lever and butterflies, automatically maintains boost at the selected pressure up to the full throttle height for that boost. With two-speed superchargers, a change to high gear enables the required boost to be maintained up to a second "high gear" full throttle height. Thus, by means of the three-controls, throttle, RPM control lever and supercharger gear change, the pilot has control of the power throughout a considerable altitude and speed range. On all but a few older types, mixture regulation is fully automatic and on most types the supercharger gear changes can also be set to take place automatically under the control of an aneroid switch.

TURBINE-JET ENGINES

4 The thrust, which is a function of mass air flow and the acceleration imparted to this mass, is regulated primarily by the throttle lever. The mass air flow is determined by compressor RPM, forward speed, air temperature and density. The acceleration of the air is governed by the difference between the forward speed of the aircraft and the speed of the jet gases. The thrust, therefore, although primarily governed by the effect of the throttle on compressor RPM, is also affected by the forward speed of the aircraft and its altitude.

PROPELLER-TURBINE ENGINES

5 This type is not yet in service use. Details will be issued, as and when necessary, by amendment.

GENERAL

6 Power units of all types should be handled in flight in such a manner as to ensure that the required power is developed with the minimum practicable consumption of fuel, while keeping within the appropriate RPM, temperature, and boost limitations.

SECTION 2

CARBURETION

INTRODUCTION

1 With piston engines, it is necessary to supply a combustible mixture of fuel and oxygen to the cylinders. For complete combustion, the chemically correct proportion by weight is about three of oxygen to one of fuel. As oxygen represents about one-fifth of the weight of air, the correct proportion of air to fuel is approximately fifteen to one.

2 For reasons of economy, it is usual to run engines under cruising power conditions on a mixture weaker than the chemically correct; this ensures that the highest practicable proportion of the fuel is converted into useful work. At high powers, however, prevention of overheating of the valves, cylinder heads and pistons, necessitates the use of a mixture richer than the chemically correct to minimize the risk of detonation.

3 Although the ratio of weight of air to fuel required at any given power setting remains constant at all heights and temperatures, the necessary volume of air increases as height is gained because the density, that is the weight per cubic foot, decreases as the atmospheric pressure falls.

4 It is the function of the carburettor or fuel injection system to supply to the engine a mixture of the required strength, and, as far as possible, to do this automatically under all conditions of altitude and power.

5 Carburetion systems may be divided into three main types:

(a) Float type carburettors.

(b) Injection carburettors.

(c) Fuel injector pump systems.

6 Type (a) does not function when inverted unless fitted with special "anti-g" features. Types (b) and (c) function in any position as long as the fuel supply from the tank can be maintained. The essential features and general principles of operation are dealt with in the following paragraphs.

FLOAT TYPE CARBURETTORS

7 In this type, fuel is supplied through one or more jets opening into a restriction, known as the choke, in the main air duct through the carburettor. When the engine is not running and the air pressure in the carburettor choke is atmospheric, the level of fuel is maintained constant just below the opening of the jets by means of a float chamber. When the engine is running and air is being drawn in through the carburettor, the pressure in the choke falls to an extent depending upon the velocity of air flow. This fall in pressure due to venturi action sucks fuel from the jets, the amount depending upon the velocity of air flow and so upon the volume of air being aspired; it is thus proportional to the power developed by the engine.

8 To compensate for changes in air density with altitude, means are provided for varying the fuel flow from the jet either by the use of an aneroid controlled needle within the jet, or by an aneroid controlled valve admitting air to the jet, that is, by "air bleeding". Thus, the ratio of weight of fuel to weight of air is maintained substantially constant at all altitudes.

9 To provide the richer mixture required at high power, an additional jet or jets are brought into operation by interconnecting a valve either with the throttle or the boost regulator mechanism. On early types, and on those now fitted to some small engines, there is a manual mixture control which must be set to bring the enrichment jet into operation at all powers in excess of the maximum weak mixture power limit.

10 When the throttle is opened rapidly, a temporary weakening of the mixture occurs until the balance of pressures and fuel flow is re-established. To prevent a "weak cut" in these circumstances, an accelerator pump is usually fitted. The piston of this pump is connected to the throttle mechanism and forces a small additional quantity of fuel into the air duct as the throttle is opened.

11 For slow running with the throttle butterfly closed, a rich mixture is provided by what amounts to a small auxiliary choke tube and jet within the body of the carburettor. This feeds mixture into the main duct on the engine side of the butterfly when suction is high with the butterfly shut, but goes out of action as the butterfly is opened and suction in duct falls. A slow-running cut-out control enables fuel to be shut off from the slow-running jet to stop the engine. It does not control the other jets and is inoperative unless the throttle butterfly is fully closed.

12 With this type of carburettor fitted to unsupercharged engines, the throttle butterfly position and so manifold pressure is controlled by the throttle lever. On types fitted to supercharged engines, the butterfly position is regulated by a boost regulator. The pilot selects required boost (manifold pressure) by means of the throttle lever; the boost regulator then progressively opens the butterfly to maintain the selected boost as height is gained. When the full throttle height for the selected boost is reached, the butterfly is fully open and any further gain in height causes a fall in boost. On some types, the butterfly cannot open fully unless the throttle lever is set at or forward of a certain position.

INJECTION TYPE CARBURETTORS

13 In this type, the choke passage is retained purely as a means for "measuring" the air flow, fuel is not sucked through jets opening into the choke and there is no float chamber. Fuel is supplied, at a higher pressure than is required for float type carburettors, from a normal engine-driven fuel pump; it passes through a pressure equalizing device, a number of metering passages or jets and a manually controlled fuel cut-off valve, to an atomizing nozzle in the eye of the supercharger inlet. These carburettors are complicated, but the following is a brief outline of the essential features and principles of operation. Control of air flow is by means of a throttle butterfly, as in float type carburettors.

14 Regulation of quantity of fuel supplied, and of mixture strength is effected thus:

(a) In response to the throttle butterfly setting, and so to the boost, by interconnecting a valve, controlling the flow through a main jet, with the throttle linkage.

(b) In response to changes in altitude or temperature, by connecting the needle of the relevant metering jet to a pressure differential control unit. This consists of two chambers separated by a diaphragm, one side of which is connected to the pressure in the throat of the carburettor choke, the other to the pressure in the air inlet duct to the carburettor.

(c) At high power and for idling, by opening enrichment jets similarly controlled by a diaphragm unit, in response to the difference in fuel pressure on opposite sides of the main jet.

(d) To ensure that adequate fuel is supplied in response to rapid throttle opening, an accelerating pump is also provided on this type.

15 As with float type carburettors, the boost is set by means of the throttle lever, a boost regulator controlling the position of the throttle butterfly. On some versions of this carburettor, the lever controls only the butterfly, there is no boost regulator and it is necessary to advance the throttle lever progressively to maintain required boost as height is gained.

16 The fuel cut-off lever when set to "stop" or "cut-off", stops the flow of all fuel to the atomizing nozzle, irrespective of the setting of the throttle lever.

17 No manual mixture control is fitted to British versions of this carburettor, but, on American versions a manual enrichment control is combined with the fuel cut-off lever which then has three positions, "idle cut-off", "auto-lean", and "rich". In "auto-lean", mixture is regulated automatically as in paras. 14 (a) and (b); the rich position opening an additional enrichment jet for use at high powers.

FUEL INJECTOR SYSTEMS

18 These systems differ fundamentally from other types in that the air flow to the engine is not "measured" by means of a choke or venturi. Fuel is supplied to an atomizing nozzle fitted in the eye of supercharger inlet. In one type, fuel is fed by an engine-driven, direct-displacement, piston type, injector pump which runs at a fixed speed in relation to the engine RPM. Thus, the quantity of fuel supplied varies directly as the RPM, and so for a given throttle setting and boost, in direct proportion to the quantity of air fed to the engine. In other types, the pump is designed to supply an excess of fuel. The fuel then passes to a centrifugal, or governor operated valve, metering unit which regulates the quantity supplied to the nozzle proportionately with RPM. Fuel delivered by the pump in excess of engine requirements, is returned to suction side of the pump through the pressure relief valve. The supply of air, and so boost, is regulated by throttle butterflies controlled, in the usual way, by a combination of manual lever and boost regulator.

19 Variations of mixture strength in response to changes in boost or altitude, are affected in one case by means of a swashplate device which varies the stroke and so output per revolution of injector pump. The swashplate is controlled, in response to changes in boost and charge temperature, by means of a pressure capsule and a thermometer in the induction manifold which act upon a cam or fulcrum in the swashplate mechanism. This, in some cases in combination with an exhaust back-pressure responsive element, corrects for changes in altitude also. In the other versions, mixture strength is varied by passing the output from the metering unit through one or more variable orifice metering jets controlled in a similar manner.

20 A pilot operated fuel cut-off is fitted which cuts off all fuel irrespective of throttle setting. In the SU injector, however, the cut-off is not designed to cut off all fuel unless the engine is running at idling RPM.

ANTI-DETONANTS

21 Detonation is the sudden development of an excessive pressure in a cylinder of an engine at, or immediately before, the commencement of the firing stroke. With a given fuel and fuel/air ratio it occurs at a certain combination of compression pressure and charge temperature; it can be prevented by restricting either or both, or by varying the nature of the fuel itself. Restricting the compression pressure by lowering the compression ratio

of the engine, or the boost pressure, results in a loss of power and is not an acceptable solution for high duty engines. For various reasons it is impracticable to suppress the tendency for the fuel to detonate either by changing the composition of the fuel itself or by adding "anti-knock" substances, such as tetraethyl lead, beyond a certain point. Restriction of the charge temperature can be achieved to a certain extent by improving the design of the engine to ensure better cylinder cooling, by the use of intercoolers with two stage superchargers, or by using an over-rich mixture. To enable very high boost pressures to be used, some other means of restricting the charge temperature therefore becomes necessary. A convenient method is by injecting into the induction system, at high boosts, a fluid having a high latent heat of vapourization which, in the process of vapourizing, cools down the fuel and air with which it mixes. Water is the best known substance for this purpose, but its freezing point is too high for general service use unless mixed with certain other substances such as methanol. A mixture of 60 percent methanol to 40 percent water by volume has been found satisfactory under widely varying conditions. The injection of such a mixture, even at boosts somewhat below that at which its use is essential, gives a small increase in power at a given boost due to an improvement in volumetric efficiency resulting from the reduction in charge temperature. With water-methanol injection installed, a pump, supplying water-methanol to the induction system is switched on when maximum boost is required; an interconnection with the boost regulator then permits the throttle valve to open further to give an increased boost. When the water-methanol pump is switched off or the supply becomes exhausted, the boost regulator again automatically restricts the throttle opening, and so boost, to the maximum permissible without the use of the anti-detonant.

GENERAL

22 Some installations have provision for injecting alcohol to prevent throttle icing, others have the butterflies, or butterflies and body, oil heated. The use of de-icing fluid and of hot, cold and filter air intakes, as well as the function of superchargers, which form part of the carburetion system, are fully dealt with elsewhere in this publication.

23 On some in-line engines, poor distribution of the mixture to the cylinders may be experienced at low RPM, particularly in cold weather. This results in the lead in the fuel being deposited on the plug points of certain cylinders causing uneven running and misfiring. Where no automatic means is provided to overcome these defects, POI include recommendations for preventing them.

SECTION 3

TURBINE JET FUEL SUPPLY

INTRODUCTION

1 With turbine-jet engines the proportion of air to fuel by weight for complete combustion is similar to that required by a piston engine, that is approximately fifteen to one. However, to reduce the temperature of the burning gases to a figure at which the combustion chambers and turbine assembly can operate without sustaining damage by heat, a large quantity of additional air is supplied to the engine and the overall air to fuel ratio is approximately sixty to one.

2 With a piston engine, control of power is effected by varying the quantity of air supplied to the engine, the supply of fuel being regulated automatically in proportion to the amount of air. The thrust developed by a turbine-jet unit, however, is controlled by regulating the quantity of fuel injected into the combustion chambers. The RPM are increased by admitting more fuel as the throttle - in this case a fuel flow regulating valve - is opened. While the RPM are increasing this additional fuel uses up a higher proportion of the air delivered by the compressor leaving a smaller surplus for cooling. This causes a temporary increase in temperature of the gases and engine which results in an augmentation in the thrust and RPM. The increasing compressor RPM in turn causes a greater mass of air to be supplied to the combustion chambers until the correct ratio of total air to fuel, and so the correct normal working temperature is again established. The engine then settles down at a steady but higher RPM. The converse occurs when the throttle is partially closed to reduce RPM and thrust.

3 As on a piston engine, a correction for changing density of the air at the intake due to altitude and ram effect is necessary. This is provided by a barometrically controlled valve which governs the supply of fuel according to the air pressure at the intake.

FUEL TANKS

4 Turbine-jet fuel tanks, although similar to those fitted in piston engined aircraft are invariably fitted with anti-"g" valves and baffles to prevent, for short periods, fuel starvation under negative "g" conditions. Fuel starvation on turbine-jet engines is of greater significance than on piston engines because even momentary starvation may result in complete extinction of the flame with no chance of the engine picking up when the fuel supply is restored unless combustion can be restored by operating the relighting system.

BOOSTER PUMPS

5 Electrically driven booster pumps, usually referred to as low pressure pumps or tank pumps are fitted to provide tank selection and to ensure an adequate supply of fuel to the engine driven pump during starting, at high altitudes and at high power conditions.

LOW PRESSURE COCKS

6 Low pressure cocks are fitted so that fuel may be isolated from the engine driven pumps in cases of fire, or for servicing. They correspond to engine master cocks on piston-engined aircraft.

ENGINE DRIVEN FUEL PUMP

7 The engine driven fuel pump increases the fuel pressure to provide the necessary high pressure delivery at the burners in the combustion chambers. These pumps may be of the constant delivery type with which unwanted fuel during low power operation is bled back to the tank, or they may be of the variable delivery type designed to give an output varying in accordance with the pumps and so the maximum RPM of the engine, are determined by a governor.

THROTTLE ASSEMBLY

8 The throttle consists of a needle valve which controls the amount of fuel passed by the engine-driven pump in the case of the variable delivery type, or by altering the amount of fuel

bled back to the tank in the case of the constant delivery type. At high altitude and at low powers the pressure at the burners may fall too low to support combustion if the throttle is closed fully. Unless, therefore, some provision is made at the burners to overcome this shortcoming a minimum burner pressure control is fitted to the throttle; this bypasses the throttle valve when the fuel pressure falls below a certain value. An adequate fuel pressure is thereby insured irrespective of the setting of the throttle.

ALTITUDE OR BAROMETRIC PRESSURE CONTROL (BPC)

9 This device consists of a capsule type control valve responsive to intake pressure which is designed to regulate the output of the engine driven pump in accordance with changes in mass air flow brought about by changes in altitude and/or forward speed.

ACCELERATOR UNIT

10 As explained in paragraph 2 above a turbine-jet engine is accelerated by increasing the operating temperature of the turbine momentarily until the new engine RPM are obtained. With large engines the compressor turbine assembly has a large moment of inertia, and if the throttle is opened rapidly the turbine/compressor unit cannot respond quickly enough. As a consequence, the turbine temperature tends to rise to a dangerous point; in addition the compressor may commence to surge and in the case of axial flow compressors to stall completely. On large engines, therefore, accelerator units are often fitted which limit amount of fuel that can be passed by the throttle during acceleration thus limiting the temperature rise in the engines to an acceptable degree. In addition, air may be allowed to escape momentarily from the compressor, thus reducing the amount of power required to accelerate the rotating parts.

ACCUMULATOR

11 The accumulator consists of a reservoir containing a spring-loaded piston. During the starting cycle, fuel under pressure from the engine-driven pumps, is fed to the accumulator compressing the accumulator spring. When the spring is fully compressed a further increase in fuel pressure lifts a valve, called the trip or starting valve, and the contents of the accumulator are discharged into the burner ring. The accumulator is only necessary when the Simplex type of burner is used.

HIGH PRESSURE COCK

12 This cock is used to cut off the supply of fuel to the burners by opening a valve which allows fuel in the burner ring to discharge to atmosphere, and at the same time by-passing fuel from the delivery side of the throttle valve back to the tank or to the low pressure side of the engine driven pump. The high pressure cock should always be used for stopping the engine in preference to using the low pressure cock. This ensures that the engine driven pump is not starved of fuel while the engine is slowing down. If the low pressure cock is used for stopping an engine, damage may be caused to the pump and in any case the system will probably need priming before the next start.

BURNERS

13 The normal burner consists of a single fixed orifice through which fuel is forced in a fine, combustible spray. As the orifice is fixed the amount of fuel discharged can only be varied by varying the fuel pressure at the burner. Therefore at low fuel flows, atomization of the fuel is impaired by the low fuel pressure. This type of burner is known as the Simplex. In order to overcome this disadvantage the Duplex and Duplex types of burner have been developed. These consist of a double burner, which has a separate jet for low fuel flows and a large orifice for high fuel flows. There is a separate fuel pipe from the delivery side of the high pressure cock to each jet, that leading to the large or main jet being passed through a valve, called a pressurizing valve, which is usually embodied with the high pressure cock. The valve only opens to admit fuel to the large or main jet when a predetermined fuel delivery pressure is reached. During starting, and at low powers at altitude, fuel is supplied to the combustion chambers through the smaller or pilot jets only, the larger or main jets coming into operation as well at normal powers. The fitting of this valve renders an accumulator unnecessary with these burners.

TORCH IGNITERS

14 On some engines, torch or flame igniters are used to initiate combustion. A smaller burner, supplied with fuel from the main tank by a separate electrical pump is fitted in two or more combustion chambers. Early in the

starting cycle fuel issuing from these burners is ignited by an electrical igniter plug and a pilot flame is thus provided so positioned in the combustion chambers that when the fuel discharge from the main burners commences, it readily ignites. As the engine speeds up combustion becomes self-supporting and the torch igniters, plugs and fuel pumps are automatically switched off.

15 These igniters can be operated independently of the normal starting cycle thus enabling a windmilling engine to be relit in flight if combustion has ceased.

SECTION 4

SUPERCHARGERS

INTRODUCTION

1 The power developed by an engine is dependent on the weight of the mixture that is burnt in the cylinders. As the piston moves down the cylinder, it creates a depression and as the inlet valve opens, the charge that enters the cylinder is thus dependent on the pressure in the induction system which, in the case of an unsupercharged engine, is governed by the pressure of the atmosphere and the amount of throttle opening. When such an engine is running at full throttle, the pressure in the induction system is nearly that of the surrounding atmosphere. Consequently, the higher an aircraft climbs, the less is the weight of the charge entering the cylinders. As an aircraft climbs, the power output of the engine is reduced proportionately, since, the pressure and the density of the atmosphere both decrease with height. In order to increase the power output of an engine at sea-level and to maintain power as altitude is gained, it is necessary to devise a means of increasing the charge entering the cylinders. This has been achieved by the incorporation of the supercharger.

OPERATION

2 The supercharger is an engine-driven fan, which, on most engines, is interposed between the carburettor and the induction system. The fan, or impeller as it is called, is driven from the crankshaft through a train of gears which impart to it a high rotational speed. Superchargers may be divided into three main types; the single-speed, the two-speed, and the two-speed two-stage.

(a) The single-speed supercharger consists of an impeller geared to the crankshaft, giving an increase in boost pressure throughout the engine speed range.

(b) The two-speed supercharger is similar to the single-speed, but the gearing system allows a second speed to be selected to maintain a given boost pressure at altitude.

(c) The two-stage type of supercharger employs the same principles as (a) and (b) but has two stages coupled together. They are of the two-speed type, the whole unit being arranged to run at either of two speeds. Due to the high boosts obtainable with this arrangement, the charge becomes unduly overheated during compression. Charge coolers, known as intercoolers, are therefore embodied in the induction system to reduce the temperature of the charge. At low power, however, the mixture may become excessively cooled and to prevent this a charge heater, known as an afterheater, is sometimes incorporated. These together maintain the charge temperature within the acceptable limits, usually automatically in response to a thermostat in the induction system. Alternative forms of automatic charge temperature control are used in certain single-stage supercharged engines, although charge coolers are not embodied, as with single-stage supercharging excessive heating does not occur. The problem in this case is to prevent the charge temperature falling too low. In one system, control is achieved by arranging for the automatic selection at low RPM of hot air intakes; in others by the regulation of the hot-air shutters under the control of a thermostat in the induction system. Control of charge temperature in the above manner should not be confused with control of mixture strength in accordance with the temperature of the charge provided for in fuel injectors. When automatic control of the charge temperature is not embodied, charge temperature gauges are usually fitted, and blanking plates to the intercooler are frequently provided for use in cold weather.

CONTROLS

3 There are three controls that affect the pressure developed by the supercharger:

(a) The throttle lever.

(b) The RPM control lever.

(c) The supercharger gear selector.

4 The throttle lever position, within the limits imposed by the full throttle height, determines the boost pressure that is delivered by the supercharger. It is a boost selection lever and together with the RPM control lever, determines the power output of the engine. If a variable pitch propeller is fitted, the RPM control lever is in effect an engine speed control. The supercharger being geared to the engine crankshaft, changes in engine speed will be reproduced in the supercharger. Changes in the supercharger gear ratio will affect its output, but as will be seen in para. 6, an increase in supercharger speed does not always mean an increase in engine power output.

SINGLE-SPEED SUPERCHARGERS

5 With the single-speed supercharger, the ratio of engine speed to supercharger speed is fixed, and is not under the control of the pilot. The all-round performance of the engine is improved, but, the limiting altitude at which a given boost setting can be maintained, is reached during a climb, considerably below the height at which it is reached with a two-speed supercharger, in high gear, when fitted to a similar engine.

TWO-SPEED SUPERCHARGERS

6 The two-speed supercharger is under the control of the pilot, and the way in which he operates the controls named in 3 (a), (b), and (c) has a great effect on the power output. For take-off and low altitude flight, low or "M" gear should always be used; the use of high or "S" gear causes a loss of power during take-off, and would prove uneconomical. When the higher gear is selected, a certain amount of engine power is absorbed in driving the impeller at the higher speed, and in addition the higher rotational speed generates heat. The temperature of the mixture entering the cylinders is raised, thereby reducing the density and weight of the charge. It can be seen that nothing will be gained by changing to high gear, unless the resultant power output is at least equal to that given in low gear. This rule holds good whatever boost pressure is selected. For example, from Figure 2-1, it can be seen that this condition will not arise until the boost pressure in low gear at the maximum RPM recommended, has fallen by at least 2 lb/sq. in. At about 9,000 feet, the rising power line of high gear intersects that of low gear, and if the change is made at this height, the boost pressure is restored and the power output in high gear at +6 lb/sq. in. is the same as in low gear at the lower boost pressure. This pressure is maintained up to about 13,000 feet, when it once again begins to fall. It is important to observe that, although high gear is engaged, the power output is much lower than when low gear is giving the same boost pressures, and the engine has in fact a different set of ratings.

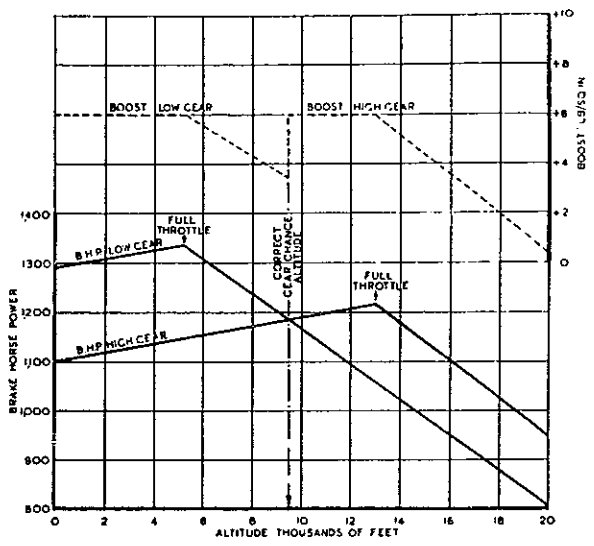


Figure 2-1 Variation of Boost and BHP with Height

7 To sum up:

(a) It is unnecessary and uneconomical to use high gear if the required boost pressure can be obtained in low gear.

(b) The use of high gear reduces the gross brake horse-power at a given power setting, owing to the high temperature of the charge.

(c) At any given power setting, high gear reduces the power transmitted to the propeller by absorbing more power to drive the supercharger.

(d) High gear should never be used until the boost in low gear has fallen by at least 2 lb/sq. in.

GENERAL

8 On some two-speed installations, the selection of high gear is automatic. On fighter-type aircraft, the automatic gear change is usually set for combat climb power conditions; if economical climbing power conditions are used, the automatic change over will occur too soon. The pilot can delay the change by selecting "mod." until the boost pressure selected has dropped by at least 2 lb/sq. in. then selecting "auto". Full instructions are contained in POI for the type.

SECTION 5

PROPELLERS

INTRODUCTION

1 Propellers may be divided into two classes, fixed pitch and variable pitch.

(a) Fixed-pitch propellers are now retained for use with low-powered aircraft. The pitch being fixed, the blade angle is necessarily a compromise between the requirements for take-off and for level flight.

(b) Variable-pitch propellers are used on all high-powered propeller-driven, aircraft and they will also increase the performance of low-powered aircraft. These propellers are used in conjunction with an engine-driven governor unit and are known as constant-speed propellers. The blade angles are automatically adjusted to variations of power and load, thus allowing the propeller to utilize engine power to the maximum at any selected engine RPM, boost and airspeed.

2 Constant-speed propellers may be electrically or hydraulically operated and are of two main types, non-feathering and feathering. They also include counter-rotating and braking types.

CONSTANT-SPEED PROPELLERS

3 All types of constant-speed propellers have the same principle of operation, although their construction may vary. In the earlier types, the pitch is moved to the fully coarse position by centrifugal force acting on weights mounted on the blades, and fine pitch is obtained by oil pressure working upon a single-acting piston. Other hydraulic propellers have double-acting cylinders and dispense with weights; while on electric propellers, the constant-speed unit makes and breaks contacts in order to operate an electric motor which turns the blades.

4 A constant-speed propeller will give the greatest possible efficiency throughout the range of engine and airspeeds for which it is designed. The constant-speed operating mechanism is mounted on the engine and adjusted by means of the RPM control lever. This lever enables the pilot to select any RPM within the governing range. The constant-speed unit functions by adjusting the propeller blade angles automatically to variations of power and flight conditions, thus enabling the selected RPM to be maintained. Each setting of the RPM control lever will maintain a definite engine speed.

Similarly, on engines fitted with automatic boost control each setting of the throttle will, within limits, maintain a definite boost pressure.

5 Operation of these two controls will provide the required combination of boost and engine RPM and the constant-speed unit will enable the power selected to be maintained up to the maximum full throttle height without further adjustment by the pilot.

6 With hydraulically operated propellers, the RPM are controlled within the constant-speed range solely by the RPM control lever, except when interconnected throttle and RPM controls are fitted.

7 With electric propellers, however, the constant-speed unit is only in operation with the selector switch set to "auto"; it then maintains RPM at those selected by the RPM control lever. With the selector switch central, the pitch is fixed. As an alternative to "auto" control, RPM can be selected manually by setting the selector switch to "increase" or "decrease" and then returning it to the central position; RPM will then remain constant, unless the boost or airspeed change. The propeller should normally be operated in "auto", but can be set for manual operation in the event of failure of the constant-speed unit, or to relieve the load on the battery after failure of a generator. Electric propellers change pitch considerably more slowly than hydraulic types, and greater care is necessary to prevent over-speeding due to too rapid throttle opening. When diving, the propeller should be set to give 200 to 300 below the maximum level flight RPM. There is a safety switch which trips and puts the pitch-changing motors out of action in the event of an electrical overload; it should not be reset to "on" for at least 30 seconds.

8 On some engine installations the RPM control lever and the boost control are interconnected. When the former is at "auto", the required RPM are selected automatically by the setting of the throttle lever.

9 The constant-speed unit governs over a certain range of RPM; the upper limit is the maximum engine RPM permitted for take-off or combat and the lower limit should provide control at the maximum diving speed; but on early 14° and 20° range propellers, their lower limit may not prevent over-speeding after a certain airspeed has been reached. Later propellers, with a blade angle range of 35° or more will control in the fastest dive.

FEATHERING PROPELLERS

10 Feathering is an emergency procedure by which the blades of a propeller are turned into a fore and aft plane to the air flow. This action stops the engine and reduces the drag of the "dead" propeller to a minimum. This type of propeller has a normal constant-speed range, but the angle through which the blades can be turned is still further increased to permit feathering.

11 Feathering is carried out on hydraulic propellers, by using an electrically driven high-pressure oil pump. This pump is independent of the engine and can therefore be used although the engine has failed; it is operated by pressing a pushbutton in the cockpit. Electric propellers are independent of oil pressure, the appropriate feathering switch being operated for feathering.

FEATHERING

12 Although feathering mechanisms may vary from one type of propeller to another, they all obtain their motive power for feathering from the electrical services of the aircraft. The blades of the propeller are moved through a large angle as quickly as possible and the rate of change is much greater than in normal constant-speed operation. The process of feathering and unfeathering imposes a severe drain on aircraft batteries, unless generators are charging satisfactorily.

13 The drill for feathering is:

(a) Close the throttle of the engine concerned.

(b) Operate the appropriate feathering mechanism as indicated in POI for the type.

(c) Turn off the fuel supply to that engine and, if fitted, switch off the booster pump(s) concerned.

(d) If engine failure is accompanied by fire, operate the correct fire extinguisher as soon as the propeller has stopped rotating.

(e) Switch off the ignition of that engine.

14 The drill for feathering is standardized for all types of propellers, but the feathering operation will vary according to the type of propeller fitted to the aircraft. The most important differences are as follows:

(a) With some types, propeller is feathered by operating the pushbutton only, while with others it is necessary to move RPM control lever through a gate to the feathering position before the pushbutton is pressed.

(b) Some pushbuttons must be held in manually during the feathering operation; others are solenoid operated, and, after pressure is released, they will remain in until feathering is completed. The pilot should always ensure that the pushbutton springs out when feathering is complete; if it does not do so, it should be pulled out by hand.

(c) Electric propellers feather at a slower rate than hydraulic propellers when the switch is moved to the feathering position. When the blades reach the feathered position, the current to the propeller motor is automatically switched off.

15 The above differences should be sufficient to emphasize the necessity of being conversant with the correct operation as given in POI. Feathering is an emergency action and, as such, should be instinctive and automatic.

UNFEATHERING

General

16 Apart from practice and test feathering, a propeller is normally feathered after engine failure or as a safeguard when low oil pressure or excessive temperatures have indicated the development of a possible defect. In these circumstances, an engine should not normally be restarted. When unfeathering for practice purposes or if, having regard to the reasons for which the propeller was feathered, the pilot considers that the circumstances nevertheless justify re-starting the "dead" engine, this should be done at a safe speed and/or height, to ensure that difficult will not be experienced due to the increase in critical speed resulting from the additional drag caused by the windmilling propeller.

Unfeathering Drill

17 The drill for unfeathering in flight is as follows:

(a) Set the throttle fully closed unless any other position is recommended in POI for the type. When the closed position is specified, it is important that the throttle should not be opened until the windmilling RPM have built up, as otherwise, should a blow-back occur, a fire may result.

(b) Set the RPM control lever just forward of the minimum RPM position, or just out of the feathering gate.

(c) Switch on the ignition.

(d) Operate the feathering pushbutton, or switch, in accordance with the instructions given in Pilot's Notes for the type. When the correct RPM have been reached, the pilot should check that the feathering pushbutton is fully out; if it is not, it should be pulled out by hand.

(e) Turn on the fuel supply and, if fitted, switch on the appropriate booster pump(s).

(f) Warm up the engine and then return to normal constant-speed conditions.

Unfeathering on Ground

18 On the ground, it has been customary in the past to unfeather the propeller, at least partially, before re-starting the engine. Although there is very little evidence to show that this practice has been in any way detrimental, the procedure outlined below is preferred by both the propeller and engine manufacturers:

(a) When a practice "feathered" landing has been made, the stopped engine should be restarted with its propeller still in the feathered position. This avoids discharging oil from the propeller into the sump while the scavenge pump is not working.

(b) The controls should be set and the engine started in the normal manner. When the engine is running steadily, and if the propeller has not started to unfeather, the pushbutton should be pressed in. When the propeller has moved from its feathered position, the pushbutton should be released, if applicable.

(c) In many cases, the propeller will start to unfeather without pushbutton being pressed, but when this occurs on some installations, pressing the pushbutton will first cause the propeller to re-feather before it finally unfeathers.

(d) If on certain engines difficulty if found in starting due to the high drag of the fully feathered propeller, it may be partially unfeathered first. This should not be done if there is any evidence, such as loss of oil through the breathers after starting, that flooding of the crankcase results. With radial engines there is a danger of hydraulic locking when starting in this manner and they should be started immediately the propeller has been partially unfeathered. If for any reason an immediate attempt to start cannot be made, or if an attempt is made and the engine fails to turn over through at least one complete revolution of the propeller when the starter is operated, no further attempt to start should be made until a check for hydraulic locking by hand turning has been carried out.

(e) Electrically operated propellers may be unfeathered either before or after restarting the engine.

(f) Engines must never be run at more than 1,000 RPM with their propellers feathered. During both restarting and unfeathering the throttle(s) of the "live" engine(s) driving the generator(s) should be set to give more than 1,500 RPM, thus ensuring that the batteries are being supported whilst bearing the starting and unfeathering loads.

WARMING UP AFTER FEATHERING

19 Engines may be warmed up in flight at as much as 2,000 RPM at small throttle openings, provided that the oil inlet temperature has not fallen below +5°C.

PRACTICE AND TEST FEATHERING

20 Practice and test feathering should not be carried out if the air temperature is below -15°C. Not more than twelve completed feathering and unfeathering operations should be carried out during the course of a single flight due to the drain on the aircraft batteries. The electrical load can be reduced by exercising the constant-speed unit to ensure an adequate circulation of warm oil before feathering.

21 On twin-engine aircraft equipped with a single generator, it is important to reduce the number of feathering and unfeathering operations on "generator engine" to the minimum required, and to ensure that the propeller of this engine remains feathered for as brief a period as possible. On all aircraft, it is advisable to switch off non-essential services to reduce the load on the batteries as far as possible.

22 If, on a four-engine aircraft, two propellers are in feathered position, the propeller of the engine which drives a generator should be unfeathered first so that the generator can supply current for the second unfeathering. A pause of some minutes between opening up the first engine and unfeathering the second propeller, will allow the battery to be partly recharged.

23 The oil inlet temperature on a "dead" engine should be watched to ensure that it does not drop excessively before unfeathering.

24 Feathering checks on the ground should be done with a ground battery plugged in and the master switch set to "ground".

COUNTER-ROTATING PROPELLERS

25 The counter-rotating propeller has been designed to enable the output of high powered engines to be more efficiently transformed into useful thrust; this is effected by having two separate propellers mounted in line on two shafts which run, one inside the other. The two propellers rotate in opposite directions, an arrangement which cancels out their individual torque reaction so improving some of the handling characteristics of the aircraft; these are also improved because slipstream is straighter than that behind a single propeller. The front propeller includes the pitch change mechanism and alterations of pitch are transmitted to the rear propeller by means of a translation unit.

26 The propeller has a normal constant-speed operation and is handled in a manner similar to the conventional single propeller.

Operating instructions applicable to a particular installation are given in POI for the type.

BRAKING PROPELLERS

27 These propellers, in addition to constant-speed and feathering functions, also incorporate reversible pitch. The pitch of the propeller can be reversed through "zero" pitch which enables the propeller to exert a braking effect. This effect can be used as a brake after touch down or as an aid to ground manoeuvring and water handling. Full throttle can be applied when the angle of the blade is in reverse pitch allowing maximum power to be available for braking purposes.

PROPELLERS FITTED WITH FINE PITCH LATCHES

28 To minimize the windmilling drag immediately following engine failure, certain propellers are fitted with a latch restricting normal pitch angle of the blades to an angle coarser than fully fine. To permit the propeller blades to over-ride this latch and so go to the fully fine pitch setting during the initial stages of the take-off run, thus ensuring that full power will be available, the mechanism can be temporarily unlatched by operating a switch. When switch is released, the latch is automatically re-set so that during take-off, once blade pitch has automatically coarsened beyond restricted fine pitch latch angle, the blades are prevented by latch from returning to fully fine setting while windmilling should the engine subsequently fail. When propellers are exercised during the pre-flight checks, they must be unlatched after finally returning the RPM control lever to the maximum RPM position; this must be done at a reduced boost to ensure that propellers will fine off past the stops before the switch is released. With propeller-turbine installations additional semi-automatic control of the latching mechanism is incorporated; details will be issued in due course.

PROPELLER FAILURES

Failure to Constant Speed

29 If the constant-speed unit should break down, propeller may become virtually "fixed pitch" at that blade angle which was being maintained immediately prior to failure in order to give RPM selected. If failure occurs during a climb, RPM may be high, but should not be too high for continuous flight. RPM should be kept as low as possible by restricting throttle opening and by avoiding high airspeeds. If the failure occurs during cruising flight, the RPM will normally be low and pitch coarse. These conditions will be suitable for level flight, but a baulked landing, or any manoeuvre requiring the use of high power, should be avoided.

30 If propeller is one of large pitch range, 35° or more, and failure occurs at high speed, the pitch may become fixed in too coarse a position to permit the use of enough power for level flight, and on single-engined aircraft a landing will be necessary.

31 Foreign matter in the constant-speed unit is a common cause of failure. At the first sign of trouble therefore, the immediate action should be to exercise the RPM control lever in an attempt to allow the circulating oil to move the foreign matter.

32 When flying in very cold conditions, frequent exercising of RPM control lever may be necessary to ensure that oil in the constant-speed unit does not become congealed and so cause sluggish operation.

33 Complete failure may be due to a fractured pipe and can lead to loss of oil pressure, and subsequently to complete loss of engine oil. In these circumstances, propeller should, when possible, be feathered immediately.

34 With electric propellers, as the pitch can be set in any position by deflecting the switch to "increase RPM" or "decrease RPM" and then to "fixed", there is an alternative control should the constant-speed unit fail.

Overspeeding

35 Overspeeding may be caused by complete loss of oil pressure or failure of the constant-speed unit. In either case the following actions should be carried out immediately to prevent serious damage to the engine.

(a) Reduce the airspeed.

(b) Close the throttle.

(c) If the propeller cannot be brought under constant speed control, attempt to feather.

(d) An attempt should be made to note the RPM reached and duration of over-speeding, the details being reported on landing.

Failure to Feather

36 If the propeller fails to feather in response to the normal feathering operation, then with electric and certain hydraulic types, an alternative method may be tried, which if successful will cause the propeller to feather although at a greatly reduced rate.

(a) With electric propellers, hold switch to the decrease RPM position until propeller stops rotating.

(b) With hydraulic propellers on which the RPM control lever has a feathering gate, the lever should be moved back to the end of its travel.

37 If the propeller will not stop rotating, the fuel should be turned off and then the ignition switched off. If the pitch is locked, it may be necessary to fly at a sufficiently low airspeed to keep the RPM within normal range. Less damage to engine will occur if a small throttle opening is used, even though the fuel and ignition are off, providing this does not cause an increase in RPM above the normal range.

38 It should be remembered that the drag from a windmilling propeller in fine pitch is considerably higher than that of one feathered. Flight on asymmetric power will be adversely affected and critical speeds will be higher.

SECTION 6

STARTING AND TESTING PISTON ENGINES

PRELIMINARY

1 This Section primarily covers supercharged engines driving constant-speed propellers, but the following principles apply, as appropriate, to all types.

(a) Prior to starting an engine, the aircraft should, if practicable, be faced into wind to ensure the best cooling possible.

(b) Where an aircraft is fitted with an electrical starter system, a starter trolley, of the correct voltage and in good condition, should always be used if available.

(c) Set all fuel cocks and engine controls as laid down in POI for the type.

(d) The engine should, if it has been standing for some time, be turned over, if possible by hand two revolutions of the propeller in order to break down the oil film which will have formed.

(e) With radial or inverted cylinder engines, it is essential that the propeller be turned at least two complete revolutions by hand as this will prevent damage by hydraulic shock if oil, or in certain cases fuel, should have drained into the cylinder heads which will be indicated by resistance to rotation. In this case, the plugs should be removed from the inverted cylinders which should then be allowed to drain.

(f) The ignition should never be switched on until the engine is ready to be started, but the booster pump between the tank and the engine to be started should be switched on for the period quoted in POI, for the type, with the fuel cut-off set to the off position, to expel air from the fuel lines. Slow running cut-outs, however, need not be held in the off position.

(g) No attempt to use mechanical means for starting must be made at the same time as hand cranking is in progress; otherwise there is risk of damage to the engine and injury to the person operating the handle.

(h) A check that the power developed by an engine is within acceptable limits can be made by noting that the RPM at a certain boost are within 50 of those at which the engine should run if in normal serviceable condition. If this test is always carried out at a boost bearing the same relation to the atmospheric pressure at the time of test, the effects on the power developed of variations in atmospheric pressure are automatically compensated for. This can conveniently be done by checking at a boost equal to the atmospheric pressure since this is the static reading shown by the gauge when the engine is not running. Before starting an engine, therefore, the static reading of the boost gauge should be noted, the engine being later opened up to this static reading for exercising and testing in accordance with recommendations in paragraphs 12 - 17 inclusive.

PRIMING

2 Fill the priming pump and fuel lines by working the plunger rapidly until resistance is felt, and then operate the pump by pushing the plunger home and at once withdrawing it steadily thus giving the pump time to fill before delivering the next stroke. In some aircraft, an electric priming pump, controlled by a pushbutton or tumbler switch, replaces the handpump. Priming may, if necessary, be continued while the engine is turning and until it is running smoothly. If the engine fails to start and over richness is suspected, the engine may be cleared by:

(a) Switching off the ignition.

(b) Turning off the fuel.

(c) Opening the throttle and having the propeller turned through several revolutions. The electrical starter may be used provided that the precautions, detailed in the following subparagraphs, dealing with failure to start, are first carried out.

(d) The throttle lever should never be "pumped" either before or after an engine has been started. With many types of carburettor this will cause an unpredictable excess of fuel to be delivered to the induction system if the engine is not running. If the engine is running, with all types of carburettor, an excessively rich, or uneven, mixture is promoted; this subjects the engine parts to undesirable fluctuations of loading and may lead to a "rich cut". It may also cause induction fires.

STARTING BY PROPELLER SWINGING OR HAND CRANKING

3 Small engines may be started as follows:

(a) Ensure that the wheels are correctly chocked.

(b) Prime the cylinders as instructed for the type.

(c) If an engine has not been run for some time, or is cold, it may be necessary to have it cranked, or the propeller pulled over by hand, for one or two revolutions with the ignition off and throttle closed or nearly closed. This ensures that the induction system and as many cylinders as possible are filled with a combustible mixture.

(d) Switch on the ignition and have the engine turned over smartly until it starts.

(e) If it fails to start after a few turns, over richness is the probable cause, so switch off the ignition, turn off the fuel, open the throttle and have the engine turned through several revolutions. Then turn on the fuel, close the throttle and proceed as in (d) above.

(f) There is a possibility that an engine, even if cold, may start when being pulled over by hand with the ignition off. Whenever hand turning a propeller the airman should accordingly take the greatest care, assuming a position and treating the propeller as if expecting the engine to fire.

STARTING BY MECHANICAL MEANS

General

4 When a booster coil is fitted and controlled by a separate pushbutton, this should be pressed when the starter is operated, and held in until the engine is running smoothly. Depending upon the type, the starter should be operated as outlined in the following paragraphs.

Direct Cranking Starter

5 Operate as follows:

(a) Switch on the ignition.

(b) Press the starter pushbutton.

(c) Release the pushbutton as soon as the engine fires. It should not be kept pressed for more than 30 seconds.

(d) If the engine fails to start, wait 30 seconds before making a further attempt.

Cartridge Starters

6 Operate as follows:

(a) Switch on the ignition.

(b) Index the breech; this is not necessary with later types of starter on which the action of pressing the starter pushbutton automatically indexes a cartridge and fires it, or on the mechanical type on which pulling the control also fires the cartridge.

(c) Without delay press the starter pushbutton and keep it pressed as this also operates the booster coil.

(d) Release the pushbutton when the engine is firing evenly.

(e) If the cartridge fires but the engine fails to start:

(1) Release the starter pushbutton.

(2) Switch off the ignition.

(3) When ready to make another attempt, switch on the ignition. On manually indexed electrically fired types, pull out the indexing control and return it slowly to index a fresh cartridge then press the pushbutton without delay. If, for any reason, the button cannot be pressed to start the engine immediately, no personnel should approach the propeller or engine for 30 seconds. With other types press the button, or operate the control, to index and fire the next cartridge.

(f) If a cartridge fails to fire, wait 30 seconds before indexing and firing a fresh cartridge; during this period no personnel should approach the propeller or engine.

Electric Inertia Starter

7 Operate as follows:

(a) Close the energizing switch and hold it until the hum becomes constant; for 10 to 15 seconds if the hum cannot be heard, or in very cold weather for 20 to 30 seconds, but never longer.

(b) Switch on the ignition.

(c) Centralize the switch and then set it to the engaging "mesh" position.

(d) When the engine is firing evenly, return the switch to the central position.

(e) If the engine fails to start, wait until the propeller stops rotating, then:

(1) Switch off the ignition, and the booster coil if separately controlled.

(2) Set the switch to the engage position to stop the flywheel, then return the switch to the central position.

(3) Have the propeller turned by hand half a revolution forward to ensure that the starter jaws are disengaged.

(4) Repeat operations in (a) to (d) above.

Combined Inertia and Direct-Cranking Starter

8 Operate as follows:

(a) With starters fitted with brush-lifting gear, flick the switch to the "engage" position momentarily to ensure that the brushes are returned to the commutator.

(b) Proceed as in para. 7 (a) to (d) above, but note that the energizing period should normally be 20 seconds. During cranking period, both the energizing and mesh switches, if two are fitted, should be on.

(c) If the engine fails to start, open both switches and wait 2 or 3 minutes before making a further attempt, then:

(1) Switch off the ignition and have the propeller turned forward by hand half a revolution to free starter from the engine before operating the engaging switch.

(2) The starter should never be operated on direct cranking for more than one minute.

After three attempts, the starter should be allowed to cool for 5 minutes.

Hand Cranking with Electric Inertia and Inertia-Direct-Cranking Starters

9 Operate as follows:

(a) Operate the brush-lifting gear, if fitted to lift the brushes from the commutator.

(b) Fit the crank handle and commence to turn it slowly, gradually increasing speed up to 70 to 80 RPM. One minute is usually sufficient to build up this speed, then:

(1) Remove the handle and operate the engaging mechanism.

(2) Switch on the ignition as soon as the propeller starts to rotate.

(3) If the engine fails to start, allow the flywheel to come to rest, and then repeat the procedure in (a) to (b) (2) above.

General Considerations

10 The use of fuel cut-offs, slow running cut-outs and booster pumps is dealt with in the section on fuel systems, while their application is given in the relevant POI.

(a) In very cold weather, engines which have been stopped long enough for the oil temperature to fall below 0°C may be difficult to start because:

(1) The oil thickens and prevents adequate cranking speed.

(2) The fuel does not vaporize so readily and provide a combustible mixture.

(b) In the case of (1), oil dilution can be used to make the engine easier to turn and to ensure an immediate flow of oil to all moving parts. In the case of (2), considerably more priming is required than under temperate conditions. Cold starts can be obtained using 100 octane fuel for priming down to -25°C and with high volatility fuel down to -35°C. This latter fuel is supplied to the priming pump from an outside source by means of a selector cock in the pump supply line.

(c) The oil pressure should be watched for the first few seconds, after which time if it has not built up to normal or higher, the engine should be shut down.

WARMING UP

11 The throttle should be opened gradually until the engine is running at about 1,000 to 1,200 RPM, or at those recommended in POI for the type. Warm up at this speed until the prescribed temperatures and pressures have been reached. Gills on radial engines should not be opened until the cylinder head temperatures reach +100°C; otherwise, congealed grease on chains or sprockets may overload and burn out the gill motors. In cold weather, hot air may be used. During warming up, test operation of the hydraulic pump(s) by operating the flaps and/or bomb doors.

EXERCISING AND TESTING

12 The engine can now be exercised and tested as laid down in POI for the type. The tests recommended are applicable, where appropriate, to all piston engines. Any alterations to this procedure will be quoted in POI for the type.

13 Before testing and exercising the engine, the following points of airmanship, applicable to all aircraft, should be remembered:

(a) Before opening the throttle, make sure that no other aircraft or anything else likely to be damaged, is in the path of the slipstream.

(b) Do not test the engines when the aircraft is standing on dusty or stony ground. Propellers pick up loose particles, and damage may be caused to your own, and inconvenience to other, aircraft.

(c) Make sure that the chocks are in position and/or that the brakes are on.

(d) If practicable, the aircraft should be facing into wind to ensure the best possible cooling.

14 The checks in paragraph 17 will disclose if the engine is running correctly, at the same time ensuring that ground running at high power settings, so damaging to any engine, is kept down to the minimum.

15 As a general rule, ground testing should not be carried out with the carburettor air intake control in the "hot" position, unless heavy throttle icing is being experienced. If the "hot" position is used, a slight drop in boost is to be expected. If an intake filter is fitted, this should be in the "filter" position.

16 During the run up period, the charging rate of the generator should be checked together with the RPM at which it "cuts in". The vacuum pump suction and change-over cock, if fitted, should be checked. Temperatures and pressures should be watched the whole time during the run up to ensure that the instruments are working and that the limitations laid down are not being exceeded.

17 After opening the cowling gills or radiator shutters, ensure that the RPM control lever is set to the take-off RPM position, the mixture control (if fitted) is in the auto rich or normal position, and the supercharger is in low gear; then carry out the following drill:

(a) At warming up RPM test each magneto as a precautionary check against a dead cut.

(b) Open up to the static boost reading.

(c) Exercise and check the operation of the constant-speed unit by moving the RPM control lever smoothly over its full governing range. This should be done at least twice to ensure the circulation of warm oil throughout the system.

(d) At the same boost, check the operation of the supercharger gear change, if fitted, by engaging high gear. Boost should rise slightly and RPM should drop if high gear has engaged correctly. On certain engines, a slight fluctuation of engine oil pressure will be noticed as the clutches engage. On these types of engine, the supercharger gear change is effected by oil pressure, and high gear should be left engaged for 30 seconds to ensure that clutch plates are cleared of oil sludge. On some installations a red warning light should come on as high gear is engaged. If the supercharger control is of the automatic type, the engagement of high gear can be checked by pressing a test pushbutton.

(e) At the same boost return the RPM control lever to the take-off RPM position and check the power output by noting the RPM. This reading should be within 50 of the RPM quoted in POI (known as the reference RPM) in the case of engines for which they are established at zero boost. With engines for which the reference RPM apply at higher boost settings which cannot conveniently be checked during a normal pre-flight test, or for which no reference RPM are quoted, the reading at the static boost should be within 50 of the RPM normally obtained.

(f) Test each magneto in turn. If there is marked vibration, engine should be stopped. If the drop in RPM exceeds the figure specified in POI but there is no undue rough running, a high power check may be carried out. A high power check may also be carried out after repair or inspection other than daily inspection, when the RPM drop exceeds the permitted figure, or at the discretion of the pilot. Before carrying out this check on high powered single engine types, the tail should be lashed down. If the checks at the static boost reading are satisfactory, no useful purpose will be served by a full power check.

(g) When a full-power check is required, it should immediately follow the checks at the static boost reading. First ensure that the RPM control lever is set to the take-off RPM position and then:

(1) Open throttle to the take-off setting and check the boost and RPM. If these figures are satisfactory:

(2) Throttle back until a drop in RPM is observed and test each magneto in turn. Throttling back ensures that the propeller is on the fine pitch stops and not constant speeding and, therefore, tending to mask any RPM drop during the ignition check. If the single ignition RPM drop is excessive and cannot be cleared, the engine should be shut down.

(3) The time spent on these tests should be kept to a minimum.

(h) After completing the checks either at static boost reading or at full power, steadily move the throttle to fully closed position and check the minimum idling RPM, then open up to between 1000 and 1200 RPM.

SECTION 7

STARTING TURBINE-JET ENGINES

PRELIMINARY

1 As with piston engines, the aircraft must, if practicable, be headed into wind for all ground running, and care should be taken that the wind is never coming from behind, as otherwise hot gases may re-enter the air intakes and cause overheating. Before starting an engine, the aircraft should be well clear of buildings, other aircraft, etc., as the stream of hot gases from the jet pipe may reach as far as 100 yards and objects behind may be damaged by heat and/or loose stones thrown up in its wake.

2 The ground in the immediate vicinity of the front of the aircraft must be kept free from loose objects, and all personnel should keep clear of the intakes, as the suction at high RPM can be very great.

3 It is essential, when starting electrically started turbine-jet engines, that ground starter and aircraft batteries are fully charged. Except in emergency, aircraft batteries should not be used.

STARTING

4 On most aircraft the starter sequences are fully automatic but on some, individual stages of the sequence may have to be operated by hand. It is important that hand controlled stages are operated at the correct time in the sequence otherwise the following faults may occur, of which the last two may cause overheating of the engine:

(a) Failure to light up.

(b) Torching - where flames come from the jet pipe.

(c) Resonance - recognized by a characteristic rumbling as the engine lights up.

5 On most installations the low and high pressure cocks and the tank pump should first be turned on, in order to allow fuel to be supplied to the engine driven fuel pumps; the throttle should be kept closed during the whole starting sequence. On most later installations the starter sequence is inoperative unless the throttle is fully closed.

6 The starter pushbutton should be pressed and then released after a short period. The starter sequence relay supplies, first a low voltage current for the operation of the starter motor, then current to the booster coils for the electrodes of the igniter plugs, and torch igniters if fitted, and finally, a high voltage current to the starter motor which then turns the engine at increasing RPM.

7 When the engine speeds up, fuel pressure rises until a valve opens and allows fuel to spray into the combustion chambers and be ignited by the incandescent igniter plugs or the flame from the torch igniters. On some installations the fuel pressure may rise too rapidly and fuel will be discharged into the combustion chambers before the engine RPM are high enough for a satisfactory light up. In these cases POI recommend using the high pressure cock in a manner which will limit the build up of fuel pressure to the correct figure. After light up occurs the engine speed increases under the combined influence of the turbine and the starter motor. After about 30 seconds, the current to the starter motor and igniter plugs is automatically cut-off and the engine then idles under its own power.

8 The starting sequence should never be interrupted, e.g., by disconnecting the battery; if this is done the sequence will continue when the circuit is re-established resulting in failure to start, flooding, and derangement of the system.

9 For some installations POI recommend that the high-pressure cock should be in the off position at the commencement of the starting procedure. This is to minimize the risk of resonance due to an excessive fuel air ratio at the low initial RPM. It is, however, im-

portant that the cock be set to the positions recommended and in accordance with the time delays quoted in POI. Otherwise, if the acceleration of the engine produced by the starter has begun to fall off when the cock is opened, the engine may fail to accelerate to the correct idling RPM and over-fuelling, leading to surging with excessive jet pipe temperatures, may result.

FAILURE TO START

10 If engine fails to start, the high-pressure cock should be closed; if the cause is not apparent one further attempt may be made before the fault is investigated. The most likely cause is a partially discharged starter battery which affects the igniter plugs, the fuel pressure and the cranking speed.

11 The engine must not in any case be restarted for three or four minutes in order to ensure the residual fuel draining through the dump valve, and also to allow the starter resistances to cool.

12 After a "wet" start, incomplete combustion known as "torching" may be experienced, when flames may come from the jet pipe. If this occurs, the pilot should turn off the high-pressure cock immediately and allow engine to cool. If necessary, the engine should then be turned by the starter with the high-pressure cock off, in order to blow excessive vapour from the combustion chambers. On some installations "resonance" may occur as the engine lights up. This can be recognized by the characteristic rumbling produced; if this occurs action should be taken as recommended in POI for the type.

WARMING UP

13 After starting, allow the engine to run at idling RPM for a brief period and at the same time check:

(a) Oil pressure, if a gauge is fitted.

(b) Burner pressure, if a gauge is fitted.

(c) Jet pipe temperature.

(d) All ancillary services.

RUNNING UP

14 Up to this stage the throttle lever must be kept in the fully closed position and must never be "pumped"; it may now be fully opened slowly and steadily and for such time only as is necessary to check:

(a) RPM

(b) Temperatures

(c) Pressures

15 If required, these checks should be performed against the brakes immediately prior to take-off. In the case of the more powerful jet engines, it may not be possible to run up to full take-off power against the brakes, in which case a check of the jet pipe temperature at cruising RPM will suffice. Apart from engine considerations, ground running should be kept to a minimum owing to high fuel consumption.

SECTION 8

MANAGEMENT OF PISTON ENGINES

TAXIING

1 Care must be taken to avoid overheating engines while taxiing; the aircraft should be kept moving steadily, thus avoiding bursts of power.

2 Gills or radiator shutters should be fully open and temperatures watched; they should not be allowed to exceed the maxima quoted in POI.

3 Aircraft should be taxied with the RPM control lever set for maximum RPM as the propeller will then give the greatest tractive effort and the best cooling for the power used.

4 Consistent with safety, the time spent on taxiing should be kept to a minimum, as many installations overheat on the ground.

TAKE-OFF

5 Engines should not be kept idling longer than necessary; whenever possible they should be set to not less than 1,000 to 1,200 RPM. Before take-off, engines should be cleared by opening up to the static boost reading or to the highest boost the brakes will hold, to clear the plugs and/or remove excess fuel from the supercharger casing.

6 Air intake filters and intake heat controls should be used as recommended in POI. Intake filters should invariably be used when operating in dust laden zones, and are in certain cases automatically in operation when the undercarriage is down.

CLIMBING

7 The RPM and boost are automatically maintained, except in certain engines, at the figures selected by the pilot until the aircraft reaches the full throttle height for the engine, after which the boost falls progressively as altitude is increased. On engines fitted with two-stage superchargers, changing to high gear permits a second full throttle height to be reached. In each case, the throttle valve opens as the aircraft ascends and thus the boost is maintained until the valve is fully opened. At the same boost and RPM the engine gives less power in high gear for two reasons; firstly, more power is absorbed in driving the supercharger in high gear, secondly supercharger heats the charge more in high gear and thus less weight of charge is drawn in at each stroke. High gear should normally be engaged at the height recommended in POI. When an aircraft is climbing, there will be a different full throttle height for each boost setting; the lower the boost selected the greater will be the full throttle height. See Figure 2-2. The height above which high gear must be used for maximum power varies with the boost, the RPM and the airspeed.

8 In certain engines, the throttle valve cannot open fully unless the throttle lever is advanced to a certain point on the quadrant. It is therefore necessary when climbing to advance the throttle lever when the boost begins to fall. The variation of boost with RPM results from the fact that raising the RPM speeds up supercharger and makes it capable of maintaining any required boost to a greater height, while the variation with airspeed arises from ram effect which helps the supercharger at high airspeeds and consequently raises full throttle height, thus, for example:

True Airspeed	170	260	345 knots
Add to Full Throttle Height	1,000	2,250	4,000 feet

GENERAL HANDLING

9 Throttle lever should always be moved slowly and evenly in order to avoid undesirable strain on the engine and overspeeding of the propeller, which otherwise may not have time to re-adjust its pitch.

10 The RPM control lever should also be moved slowly as otherwise the RPM are likely to overshoot the desired figure.

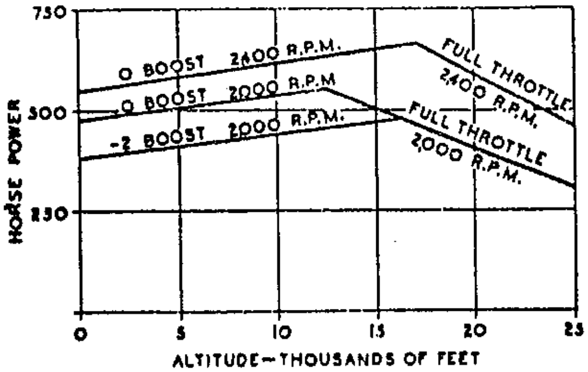


Figure 2-2 Variation of Full Throttle Height with Boost

11 The supercharger gear change must be effected smartly and firmly where the change is made by a lever. In most aircraft, manual change is made by means of a switch.

12 With most engines, at high boost, if an increase in power is required, the RPM should first be raised, and conversely if a reduction in power is required, the boost should be reduced. Combinations of excessively low boost and high RPM, however, should be avoided as the boost pressure acts as a "cushion" in the cylinder head thus preventing excessive inertia stresses. The power rating (boost and RPM) specified for take-off is designed to give the fewest RPM minutes and the least piston ring miles before reaching first power reduction point and should be used for every take-off.

13 With Bristol sleeve valve engines it is preferable to increase boost before RPM and conversely to reduce RPM first, as with these engines combinations of high boost and low RPM are considered to be less detrimental than are combinations of high RPM at low boost. During starting, run up, when opening up for take-off, and prior to landing, the use of low boost at high RPM is, however, unavoidable although for landing, RPM in excess of those permitted at intermediate power should not normally be exceeded.

14 If interconnected throttle and RPM controls are not embodied, aerobatics should be carried out with a high RPM setting in order that high power can be immediately obtained by advancing throttle lever. This precaution and those in paragraph 12 prevent a danger of detonation.

15 When cruising at low power, it is advisable to clear liquid-cooled engines at regular intervals by opening up to not less than intermediate power. Clearing in this manner should be carried out once an hour or more frequently depending upon the circumstances, as recommended in POI for the type or at the discretion of the pilot. This procedure is not normally necessary with the later air-cooled engines, or with liquid-cooled engines fitted with automatic charge temperature control. If a charge temperature gauge is fitted, clearing should only be necessary if the temperature has been allowed to fall below the minimum stated in POI for the type. See para. 16 below. Before entering circuit at the conclusion of a flight, engines should be cleared as recommended above. This is a wise precaution with all engines, especially if they have been running for a prolonged period at very low power in cold weather, to minimize plug fouling and to ensure that full power will be available if required.

16 With engines fitted with two-stage superchargers, on which the charge temperature is not controlled automatically, the charge temperature may fall excessively at low power settings. If a charge temperature gauge is fitted, RPM should be increased as necessary to prevent the charge temperature falling below the minimum. When neither automatic charge temperature control nor charge temperature gauges are fitted, the use of low RPM should be avoided under conditions of extreme cold unless maximum range is of paramount importance. If the use of low RPM is unavoidable the engine(s) should be cleared as in paragraph 15 above.

17 If the pilot has reason to suspect the functioning of the ignition system, a landing as soon as practicable is, in general, recommended. An ignition check in flight will not give a true indication of the full extent of the RPM drop which will be masked by constant-speed unit. Furthermore, if one magneto has failed completely, harm may result from "wetting" otherwise serviceable sparking plugs and there is a risk of blowback and damage to the engine when the ignition is switched on again.

EFFECTS OF LOW AND NEGATIVE "G" ON CARBURETTOR

18 When an aircraft is suddenly put into a dive, or is subjected to certain aerobatics or inverted flying, fuel moves to the top of the tanks. In float type carburettors, flooding first

takes place and a "rich cut" is experienced, followed by a "weak cut" if negative "g" is sustained. The engine will cut less readily and recover more quickly with the throttle well open, but the pilot must close the throttle before power begins to return to avoid serious overspeeding of the engine, as otherwise the propeller will be unable to re-adjust its pitch quickly enough to cope with a rapid return of high power.

19 The effect on the oil is similar to the effect on the fuel and the engine will stand only a momentary running at less than the minimum oil pressure quoted in POI.

20 Injectors and diaphragm carburettors are not affected by low and negative "g", while the "anti-g" float type carburettor is immune, except at low power when its behaviour is similar to the standard float type fitted with a restrictor, which reduces the recovery period from about 10 to 5 seconds. Sustained negative "g" will nevertheless lead to a "weak cut".

ENGINE TEMPERATURES

Cylinder Head Temperature

21 The importance of watching cylinder head or coolant and oil temperatures, and keeping them within limitations cannot be too strongly emphasized.

22 The cooling of air cooled cylinders is controlled by the setting of gills which in general should be:

(a) Fully open for all ground running, providing the cylinder head temperatures have reached +100°C.

(b) Closed or part open for take-off.

(c) Adjusted in flight as required.

23 If gills are closed, drag is minimized, and during take-off safety speed is reached earlier. On most types, the cowling gills are controlled by switches marked "open", "off" and "close". To operate the gill motor, the switch is depressed and set as required; when the desired setting is reached, as shown by the gill indicator the switch should be turned off.

24 The best setting in cruising flight varies with individual installations and with conditions. When the gills are opened in an attempt to combat over-heating, there comes a point beyond which the increase in drag may necessitate an increase in power to maintain an acceptable flying speed and temperatures may then rise still further. On the other hand, even if a reduced speed is acceptable and power is not increased, the reduction in airflow velocity over the cylinders may be such that the cooling still remains inadequate. In such cases it may nevertheless be possible to keep the temperatures within limitations by leaving the gills as initially set, and reducing power as low as is consistent with maintaining an acceptable airspeed.

25 The cooling of liquid cooled engines is in most cases regulated automatically, but the pilot also has control over flow of air through the radiator. Radiator shutters should be open only as much as is necessary for adequate cooling as this will reduce unnecessary drag.

26 The temperatures of all types of engines can be reduced by climbing aircraft at some 10 to 15 knots faster than the recommended climbing IAS; the loss in rate of climb by so doing will not be great. Climbing in weak mixture may lead to high temperatures.

Carburettor Air Temperature

26A It is necessary to distinguish between carburettor air temperature and mixture temperature. Mixture temperature is generally 15° to 30° C lower than carburettor air temperature. The following limiting values apply to carburettor air temperature.

(a) For all engine operations the carburettor air temperature is to be held between 30° and 36°C if possible, by use of carburettor heat when required. Operation in the range 0° to 30° C will cause carburettor icing unless air is abnormally dry. For operation at very low temperature (-25°C) the use of full carburettor heat before take-off or landing is desirable, to ensure maximum fuel evaporation. Under these conditions the possibility of severe icing is remote, regardless of carburettor air temperature, due to the low actual moisture content of the air.

Oil Temperature

27 On liquid cooled engines, the oil cooler is generally incorporated in the coolant radiator. In other installations, the cooler is separate and control is automatic, but, in some cases, the pilot can regulate the air flow through the oil cooler. Excessively high temperature and/or low pressure indicates that the engine has been overworked, that the oil cooler is not working properly, or that some defect has developed. Another reason, as described below, is "coring".

28 Coring is a phenomenon which occurs in some oil coolers at low atmospheric temperatures when the oil congeals and restricts the flow through the cooler. The action, should this occur, is either to close the shutters or to increase RPM immediately a sudden rise in oil temperature is noticed unaccompanied by a corresponding rise in coolant or cylinder head temperatures. If, however, coring is

well advanced and the oil temperature still remains high, the undercarriage and/or flaps should be lowered to reduce speed, and hence the air flow through the cooler, without reducing power. A descent to a warmer level is then advisable.

29 Generally, the engine should not be allowed to get cold or it may not readily respond when required. During descent, the engine may be kept warm by diving moderately with the throttle well open, rather than by gliding with the throttle closed. In a long glide with air cooled engines, the gills should be closed and the engine opened up at intervals.

STOPPING ENGINE

30 The correct stopping or running down of an engine is just as important as the correct starting and running up. Use of the correct procedure ensures that an engine is cooled down in the best way and that it is left in the most serviceable condition for future starting.

31 If a hot engine is shut down too rapidly, uneven cooling will result. This may cause damage to the cylinder block and distortion of the cylinders themselves. To ensure even and gentle cooling, the cowling gills or radiator shutters should be opened immediately after landing, and on reaching dispersal the aircraft should, if possible, be parked into wind.

32 On engines employing an oil operated clutch to operate supercharger gear change, it is necessary to exercise the clutches by changing gear once every two hours. This ensures that the gear change does not become jammed through oil sludge collecting on the clutch plates. If this exercising is not done in the air prior to landing, it may be done at this stage of the run down procedure.

33 If for any reason the serviceability of the engine is in doubt, such of the run up checks as may be required should be carried out. These checks should not normally be necessary, but if a fault is suspected, it is better discovered when stopping an engine, rather than subsequently when starting it before flight.

34 The engine should be idled at the RPM recommended in POI, usually between 800 and 1,200, to cool it before stopping. The idling period varies with the type of engine but is normally one or two minutes, or, in the case of radial engines, until the cylinder head temperatures fall to those recommended before shutting down, whichever is the longer. Idling at the recommended RPM allows the scavenge pump to remove surplus oil from the crankcase, thus reducing the danger of hydraulicing when starting up. Very low idling RPM should be avoided as they may cause fouling of the plugs. If there has been no reason to perform any other ignition checks, the magnetos should be tested for dead cut during this idling period.

35 To stop an engine, close the throttle and operate the slow running cut-out or the fuel cut-off. Switch off the ignition and turn off the fuel, after the engine has stopped. Cowling gills should be left open until the engine is thoroughly cooled.

36 Any additional instructions for stopping the engine will be given in POI for the type.

SECTION 9

MANAGEMENT OF TURBINE-JET ENGINES

INTRODUCTION

1 As the speed of the aircraft has a considerable effect on performance of the engine, it is necessary, here, to consider the handling of the aircraft and engine together.

TAXIING

2 During taxiing, the throttle(s) should be opened and closed smoothly and slowly in order to prevent "surging" and excessive jet pipe temperatures. In order to minimize the risk of grit or loose objects entering air intakes, pilots should avoid taxying close behind other aircraft or one which is being run up.

TAKE-OFF

3 Open the throttle(s) smoothly and slowly for the reasons given above until take-off RPM has been reached. The take-off run is longer than with a comparable piston-engine aircraft especially when high air temperatures prevail.

4 In order to improve the take-off run turbine-jet engines may be opened up against the brakes prior to take-off. On some types of aircraft it will be possible to open up full take-off RPM against the brakes. This should not normally be necessary and should be avoided except when the take-off run is restricted in relation to the weight of the aircraft and the temperature conditions prevailing.

5 On some aircraft an isolating valve is incorporated in the fuel system and is controlled by a switch. When the valve is closed the main fuel pump output is regulated by the setting of the throttle lever only, and control by the BPC and the ACU (if fitted) is cut out. Closing the valve safeguards the engine against a cut due to an incorrect fuel air ratio resulting from a defect in the pumps, or BPC and ACU servo control system. In flight the valve should be closed should RPM unaccountably drop possibly accompanied by a rapid change in jet pipe temperature, as this may be due to a defect in the fuel pumps or servo system. If combustion has ceased the engine should be relighted after the isolating valve has been closed and a careful watch should be kept on jet pipe temperatures while relighting is in progress. Valve should not be re-opened until after landing. With the isolating valve closed surging is more likely to occur, particularly on axial flow engines, if the throttle is opened quickly, careful handling of the throttle lever is therefore essential. With some installations it is recommended that take-off should normally be made with the isolating valve closed as a safeguard against sudden loss of power at a vital moment. Precise instructions for the use of these valves will be found in the POI for the aircraft.

CLIMBING

6 Always climb at the speeds recommended in POI for the type, as variations from these speeds, especially if lower speeds are used, reduce the rate of climb and increase the difficulty of reaching very high altitudes. The following points should be observed when climbing, particularly to high altitudes:

RPM Creep

(a) Although an aneroid controlled valve is fitted which is designed to maintain the correct fuel/air ratio irrespective of altitude, the RPM for a given throttle setting may tend to increase with increase of altitude. The throttle should therefore be closed progressively to maintain constant RPM. On later aircraft this tendency for RPM to creep with altitude is considerably reduced.

Increase of Jet Pipe Temperature

(b) On most engines there is a tendency for jet pipe temperatures to rise with increase of altitude, and, particularly at high altitude, temperatures may exceed the limit even though the RPM may be less than the maximum permissible. In these cases the jet pipe temperature must always be taken as the limiting factor and the throttle closed to keep the temperature below the limit. At high altitudes the jet pipe temperature is very susceptible to small changes in both throttle position and airspeed, a reduction of airspeed tending to increase the temperature.

Surging

(c) Surging may occur on some engines due to stalling of the compressor. The symptoms and corrective action differ according to the type of engine. With a centrifugal compressor, surge may produce audible detonation with a slight rise in JPT, and usually occurs when flying at low airspeeds, or when climbing at high power in low air temperature conditions. The remedy is to close throttle slightly or increase airspeed until the symptoms disappear. With an axial compressor, surge may produce no audible symptom, but if the throttle is opened a rapid and dangerous rise in JPT will occur, due to overfuelling. The remedy is to increase the airflow through the compressor without opening the throttle and to reduce the fuel flow by throttling thus promoting a stabilized air flow at a lower engine speed. The throttle should therefore immediately be closed, the airspeed increased if practicable, and the throttle then slowly re-opened. Should surging occur while taxiing or preparing to take-off out-of-wind, the throttle(s) should be closed, the aircraft should be headed as nearly as practicable into wind and the throttle(s) carefully re-opened. When the engine(s) are running steadily the aircraft should be turned back on the desired heading.

GENERAL FLYING

7 Fuel and oil tanks are so constructed that the supply of fuel and oil to the engines is maintained under conditions of negative "g" for a minimum of 15 seconds.

8 At high altitudes the engine becomes extremely sensitive to throttle movement and the range of the throttle movement may be very small due to:

(a) The lower limit dictated by the RPM required to provide adequate fuel pressure for combustion and/or for air pressure for cabin pressurization.

(b) The upper limit set by the throttle position above which the RPM and/or jet pipe temperature limitations are exceeded.

9 At very high altitudes combustion may cease if:

(a) The throttle is opened too rapidly. This usually results in a momentary increase in jet pipe temperature followed by flame extinction.

(b) The throttle is closed completely or the fuel pressure at the burners falls too low to support combustion. Later engines have either special burners or a minimum burner pressure valve fitted to reduce this effect. On engines not so fitted, POI usually quote, for selected altitudes, an RPM below which the engine should not be throttled.

10 Should combustion cease at any time or an engine be intentionally stopped in flight, the high pressure cock should be closed immediately. Although relighting is not practicable on all types of engine, on some types relighting in flight can be completely reliable, especially at the lower altitudes. Where this is so POI for the type indicates the correct procedure. In general the following points should be observed:

(a) The normal starting system using the starter motor should not be used as this may result in damage to the engine.

(b) The chance of successful relighting decreases with increase of altitude. 20,000 feet should be taken as the practical limit on present aircraft.

(c) The airspeed and engine windmilling RPM should be as low as possible.

STOPPING ENGINE

11 After the aircraft has been landed and taxied in, the engine will normally be cool enough to be stopped immediately by closing the throttle and turning off the high pressure cock. If, however, the temperature is much in excess of that recommended for idling, the engine should be run at about twice idling RPM for a short period to allow it to cool. The throttle should then be closed and after 30 seconds the high-pressure cock turned off. The engine will continue to turn for 1 to 2 minutes after combustion has ceased, but until it has stopped turning, the low-pressure cock should not be turned off as otherwise the fuel pump will be starved and the fuel system will need re-priming.

PART 3

AIRCRAFT SYSTEMS

SECTION 1

FUEL SYSTEMS

INTRODUCTION

1 Details of fuel systems and recommendations for their management are given in POI for each type of aircraft. The following paragraphs contain some notes on the principles involved, with information on the purpose and functioning of various components.

FUEL TANKS

2 Main fuel tanks may be non self-sealing or self-sealing. In one self-sealing type, the tank is contained in a special covering which minimizes the danger of a major leak developing as the result of a crash, and causes any small leak produced to be automatically sealed. In a second type, the fuel is contained in a flexible bag or series of flexible cells housed within rigid containers. With this type of tank, capacities vary as between individual aircraft. An air vent is fitted in the top of each tank to allow air to enter as fuel is used from the tank; when either the pressurizing or nitrogen systems are in operation, vents are then closed.

3 Additional tanks can be fitted to most aircraft. They include fixed tanks, and drop tanks which can be released after use when necessary, or in emergency, for example, before crash landing or ditching. When such tanks supply the engine(s) direct, they should not be used during take-off, landing or in combat conditions, but, should be used as early in a flight as possible.

FUEL CONTENTS GAUGES AND FLOWMETERS

4 The amount of fuel is indicated by fuel contents gauges. These are usually electrically operated and owing to the shape of the tank, etc., may not in all cases give accurate readings of very small quantities of fuel. Gauges are calibrated to indicate the contents of the tank with the aircraft in the flying attitude and a correction to the reading may be necessary, or a second scale provided, for use with the aircraft in a "tail-down" attitude on the ground. Some types of gauges give an accurate reading, but not until they have been switched on for a short time.

5 The flowmeters which register "gallons gone" are fitted in some aircraft. Each indicator shows, at any time, the total quantity of fuel used by the engine in the supply pipe of which the flowmeter is fitted. They may incorporate a by-pass to the main pipe controlled by a manually or electrically operated cock. The indicators should be set to zero before flight.

FUEL COCKS

6 These are of the following three main types:

(a) Tank cocks, which are either "on-off" cocks, or selector cocks enabling any one of two or more tanks to be selected.

(b) Engine master cocks, which are fitted in the supply pipe to each engine in aircraft where more than one tank can be used to feed each engine direct. They enable the supply to the engine to be cut off irrespective of which tank is in use.

(c) Cross-feed cocks, sometimes wrongly referred to as balance cocks, which are "on-off" cocks fitted in a pipe interconnecting the fuel systems in each wing. In some four engine aircraft, inter-engine, cross-feed cocks are fitted in the pipes interconnecting the tanks feeding the inner and outer engines on the same side, as well as a cross-feed cock interconnecting the tanks in both wings.

FUEL CUT-OFFS AND SLOW-RUNNING CUT-OUTS

7 In the case of injector type carburettors, fuel cut-offs are remotely controlled valves embodied in the injector which enable supply of fuel, at any throttle setting to be instantaneously cut-off. They furthermore prevent a hot engine from continuing to run when the ignition has been switched off; and when starting an engine, will prevent fuel from passing into the induction system during priming operations. These valves, which are controlled from the cockpit, may be operated either mechanically or electrically.

8 The control may take any one of four forms:

(a) A lever which has to be moved to a selected position on a quadrant.

(b) A spring-loaded toggle which must be pulled out, after which it will return to the "run" position.

(c) An electrical pushbutton switch which will spring out automatically when pressure has been released.

(d) On some older installations, tumbler switches which may or may not be spring-loaded to return automatically to the "run" position.

9 In the case of float type carburettors, the slow-running cut-out is a valve positioned on the delivery side of the float chamber which will, when operated, stop the supply of fuel to the slow running jets only. It will, therefore, not stop an engine when it is running at higher than idling RPM.

BOOSTER PUMPS, TRANSFER PUMPS AND TRANSFER SYSTEMS

10 Booster pumps are electrically operated. They may be fitted externally in the pipe leading from a tank or group of tanks, or may be of the immersed type fitted within a tank at its outlet. A by-pass permits fuel to flow from the tank, under suction from the engine-driven pump, when the booster pump is not running. The purpose of booster pumps is to prevent any portion of the fuel system from being below atmospheric pressure, thus preventing vapour or air locks from forming in the pipes, and to supply adequate fuel to the engine-driven pumps during take-off, landing, at high engine power settings, and at high altitudes. Booster pumps should always be switched on if the fuel pressure warning light comes on or flickers. Unless otherwise recommended in POI, they may be left on at all times in flight. Booster pumps cannot be relied upon to maintain sufficient fuel pressure for correct functioning of the carburettor or injector in the event of failure of the engine-driven pump. Booster pumps should never be left switched on when an engine is not running. If the fuel cut-off is not closed, this may lead to flooding of the supercharger casing and introduces a risk of fire. As booster pumps depend upon the flow of fuel through them to prevent overheating they should never be left switched on when the fuel tanks concerned are empty.

11 The same type of pump, when fitted in a tank which does not feed an engine direct, is known as a fuel transfer pump, and serves to pump fuel from this tank into another tank or collector box which feeds an engine direct.

12 In some systems, the tanks are selected merely by switching on the appropriate booster pump providing tank cocks, if fitted, are on.

13 A test ammeter socket is usually fitted in each booster or transfer pump circuit to enable its correct functioning to be checked.

14 As an alternative, or in addition to an immersed booster or fuel transfer pump, tanks, in particular drop tanks, are frequently pressurized to force fuel from them to the engines or into the main tanks. Pressure, from the exhaust side of the vacuum pump(s), or from the engine compressor(s) in the case of jet engines, is fed into the top of the tank through the venting system which is then sealed. In some systems, when auxiliary tanks are used to replenish main tanks, they are pressurized at all times, fuel being transferred automatically under the control of a float valve in each main tank whenever the contents of the latter fall below a predetermined level.

PRESSURIZING

15 In some systems, a tank or tanks can be

pressurized at altitude to maintain the pressure on the fuel so preventing vapour locks in system. Pressurizing can be selected either at will by operating a cock in the pressure line, or automatically above certain heights, by an aneroid valve.

USE OF NITROGEN

16 In some aircraft, there is provision for filling the space above the fuel in each tank with nitrogen, as a fire precaution. The gas is carried under pressure in cylinders and is turned on before starting the engines. The required pressure in the tanks is then automatically maintained.

WARNING LIGHTS

17 In many aircraft, a fuel pressure warning light is fitted for each engine; this lights up when the pressure at the carburettor or injector falls below a predetermined minimum.

18 In some installations, warning lights are fitted in the circuits of each booster or transfer pump; they come on when the pumps are not switched on, or are functioning incorrectly.

PRIMING SYSTEMS

Fuel System Priming

19 If an aircraft has been standing for any length of time, it is usually desirable before starting an engine, to prime the fuel pipes and engine-driven pump(s) to force out any air or fuel vapour trapped in the system. This should be done by selecting a tank and switching on the appropriate booster pump, or working the wobble pump for a few seconds after ensuring that the fuel cut-off is in the "off" position.

Induction Priming

20 On most aircraft, an induction priming handpump is fitted for each engine, or one pump with a selector cock serving two engines. This pump delivers fuel as a spray through nozzles fitted in the induction manifold, where it helps to enrich the mixture drawn in from the carburettor or injector during starting. In some aircraft, a selector cock is fitted between the fuel tank and the priming pump with a connection leading to a pipe outside the engine nacelle or fuselage. With this cock set to the appropriate position, high volatility fuel can be drawn through the external connection for priming in very cold weather. Before the engine is started, the priming pump should be worked until an increase in resistance is felt. The pump should then be worked firmly and steadily for number of strokes recommended in POI for the type, either just before the engine is started or while it is turning. If necessary, priming should then be continued until the engine picks up on the carburettor or injector, care being taken to avoid overpriming. After use, the pump should be screwed down and the selector cock turned off.

21 In some aircraft, an electric priming pump controlled by a pushbutton or tumbler switch replaces the handpump. It should be used as recommended in POI for the type.

GENERAL RECOMMENDATIONS FOR OPERATION OF FUEL SYSTEMS

22 In systems in which an engine is supplied through one main tank the whole time, there is little to do except to check that the main cock is correctly set, that the booster pump is on when required and to keep a watch on the contents gauges, and the flowmeter if fitted. Replenishment of the main tanks from auxiliary or drop tanks is either fully automatic or is effected by turning on pressure or switching on the transfer pump(s) as required. In the latter case, care is necessary to ensure that the main tanks are not overfilled.

23 In other systems, where a number of tanks may be used to feed an engine direct, avoid changing over to a fresh tank while at high power, in combat conditions, at low altitude or when about to land. The change over should preferably be made before the tank in use empties or, if maximum range or endurance are required, immediately the fuel pressure warning light flickers. The emptying tank should be turned off, then the fresh tank should be turned on and its booster pump switched on or wobble pump operated. This is important, particularly in the case of pressurized tanks, to prevent an engine cutting due to air or fuel vapour being drawn into the fuel system. In the event of an engine cutting due to fuel starvation when a tank empties, the throttle should first be closed. After the changeover has been made, engines should be idled until they are running smoothly and then opened up slowly.

If, with some injectors, difficulty is experienced in getting the engine to pick up, the cut-off should be placed in "off" position for a few seconds to permit pressure to build up.

24 The contents of additional and particularly of wing drop tanks, should be used as early in flight as possible. This avoids loss of fuel should conditions later necessitate drop tanks being released and also improved manoeuvrability and trim, where such tanks are fitted in positions remote from the C of G of the aircraft.

25 Cross-feed cocks should only be opened in the following circumstances:

(a) In the event of engine failure, to enable tanks normally supplying the failed engine(s) to be used for the live engine(s). The following example, which assumes that the port engine(s) has/have failed and that it is desired to feed the starboard engine(s) with fuel from the tank(s) in the port wing only, illustrates the correct use of a cross-feed cock in this case:

(1) Turn off the port engine master fuel cock(s).

(2) Ensure that the correct port tank(s) is/are selected by turning on the appropriate port cock(s) and/or switch on the appropriate pump(s).

(3) Open the cross-feed cock.

(4) Turn off the fuel cock(s) on all other tank(s) and/or switch off the booster pump(s) concerned. At the first signs of fuel starvation:

(5) Close the throttle(s) of the live engine(s). The actions then to be taken depend upon whether or not fuel is completely exhausted from the port wing, if there is still fuel available in the port wing, proceed as follows:

(6) Turn off the fuel cock(s) and/or switch off the booster pump(s) of the tank(s) in use.

(7) Turn on the fuel cock(s) and/or switch on the booster pump(s) of the tank(s) to be used next.

(8) Idle the engine(s) until smooth running is obtained, before increasing power further. If, however, fuel is exhausted from the port wing, proceed as follows:

(9) Close the cross-feed cock.

(10) Turn on the fuel cock(s) and/or switch on the booster pump(s) of the tank(s) to be used next.

(11) Idle the engine(s) until smooth running is obtained, before increasing power further.

(12) Turn off the fuel cock(s) and/or switch off the booster pump(s) of the port tank(s).

(b) To enable fuel from the tanks in one wing to be used to supply all engines in the event of the complete exhaustion or loss of fuel from the tanks in the other wing. The following example which assumes that it is desired to feed the engines with fuel from the tank(s) in the port wing, illustrates the correct use of a cross-feed cock in this case:

(1) Ensure that the correct port tank(s) is/are selected by turning on the appropriate cock(s) and/or switch on appropriate booster pump(s).

(2) Open the cross-feed cock.

(3) Turn off fuel cocks of all other tanks and/or switch off the booster pumps concerned. Then at the first signs of fuel starvation:

(4) Close the throttles.

(5) Turn off the fuel cock(s) and/or switch off the booster pump(s) of the tank(s) in use.

(6) Turn on the fuel cock(s) and/or switch on the booster pump(s) of the tank(s) to be used next.

(7) Idle the engine(s) until smooth running is obtained, before increasing power further.

26 If for any reason when all engines are running, one set of wing tanks is emptied before the other, turn off their fuel cock(s) and/or

switch off their booster pump(s) at the first signs of fuel starvation and before the cross-feed cock is opened. This will prevent the possibility of air being drawn through the empty tank(s) to the live engine(s) and thus causing power failure due to air-locks. If fitted, the booster pump(s) of the tank(s) in use should always be switched on when the cross-feed cock is open.

NEGATIVE "G" PROVISIONS WITH TURBINE-JET ENGINES

27 On some aircraft cleared for aerobatics the fuel system permits up to 15 seconds inverted flight without risk of fuel failure. This period should never be exceeded in any condition of inverted flight, as in addition to the risk of fuel feed failure, lubrication system may be adversely affected.

SECTION 2

NITROGEN SYSTEMS

INTRODUCTION

1 Fuel contained in an aircraft fuel tank gives off a vapour which mixes with the air in the space above the fuel. The ratio of air to fuel vapour varies with pressure and temperature; the warmer the fuel and lower the pressure, the greater the amount of vapour given off. When the ratio of air to fuel vapour falls within the critical range of 8:1 to 17:1, the mixture becomes explosive when exposed to a flame or spark. Conditions are frequently found during flight, when the temperature and pressure in the tanks are such that the mixture is within the critical range. Penetration of an aircraft fuel tank by incendiary ammunition or "flak" fragments can then produce an explosion which may disintegrate the tank and cause major structural damage to the aircraft. To eliminate the danger of explosion, the oxygen content in the mixture can be reduced by replacing the air above the fuel by an inert gas such as nitrogen.

DESCRIPTION

2 The nitrogen system is designed to feed nitrogen automatically to the tanks as the fuel is drained from them, the nitrogen inside the tanks being maintained at a pressure of 1/4 to 3/8 lb/sq. in. above the ambient pressure. When the aircraft descends, nitrogen is automatically fed at an increased rate into the tanks to compensate for the increasing atmospheric pressure outside the tanks. To prevent tanks collapsing during an abnormally steep dive, or when nitrogen supply is exhausted, a valve is incorporated in the air vent. This valve allows air, at ambient pressure, to enter the tank when the pressure falls slightly below the external pressure.

3 Pure dry nitrogen, under high pressure, is stored in small steel wirebound cylinders which are charged in situ from a charging trolley. The cylinders are grouped together in small numbers. Each cylinder is separated from the others by means of non-return valves, so that damage to any one cylinder will not affect the delivery from the others. Similarly, each group of cylinders is separated by non-return valves to prevent damage to a delivery pipe from one group affecting the delivery from one group affecting the delivery from the remaining groups.

4 The system is controlled by a master cock installed in the high-pressure piping between the cylinders and high-pressure reducing valve. The master cock is similar to the oxygen master cock, but it is clearly marked, normally around the spindle nut, with white-red-white bands 1/4 in. wide.

5 The nitrogen passes through the master cock to a pressure reducing valve which reduces the pressure from the cylinders to 10 to 30 lb/sq. in. Nitrogen is then fed to another reducing valve where the pressure is further reduced to 1/4 to 3/8 lb/sq. in. above ambient. The nitrogen is finally distributed to the fuel tanks by means of flexible hose.

6 Each tank is fitted with a vent valve which is arranged to blow off to atmosphere when the tank pressure rises to 1/2 lb/sq.in. above ambient. In aircraft fitted with a number of small tanks, one vent valve is sometimes used to serve several tanks.

OPERATION

7 As soon as conveniently possible after starting the engine(s) the nitrogen master cock should be turned fully on.

8 The pressure gauge should read 1,800 lb/sq.in. initially. Readings should be taken at hourly intervals until the end of the flight.

9 The nitrogen capacity is sufficient for the endurance of the aircraft and there should normally be a small residual cylinder pressure at the end of a long flight. If the readings show an abnormal loss of nitrogen, which would exhaust the supply before the flight is completed, a leak should be suspected.

10 At the end of the flight, a final reading should be taken and the master cock turned off.

SECTION 3

HYDRAULIC SYSTEMS

INTRODUCTION

1 The aircraft hydraulic system is the means by which the operation of such vital components as the landing gear and flaps is carried out. A thorough knowledge of the system will help the pilot to decide what actions should be taken in the case of hydraulic failure and will enable him to get the best service from his equipment. Although several different types of systems are manufactured and the services operated by them differ with aircraft types, the basic principles are standardized. These principles of operation are discussed in the following paragraphs, together with the different services and their emergency operation.

2 Liquid under pressure provides a convenient method of remote control for operation of components, such as retractable landing gear, flaps, bomb doors and speed brakes. Such systems are called "hydraulic" and the liquid used is a special kind of oil, free flowing and unlikely to freeze.

3 Liquids are practically incompressible; thus, when a force is applied at any point in a liquid, a corresponding pressure is transmitted immediately throughout the liquid.

DESCRIPTION

4 The simplest form of hydraulic system consists of four components; jack, control, pump and reservoir. These items are the basis of all systems.

5 Fluid is supplied from the reservoir to an engine-driven pump which generates pressure. A manually operated control valve directs the fluid under high pressure to desired end of the hydraulic jack, at the same time connecting the other end of the jack to the reservoir; the jack piston, or ram, is thus forced to move. When the ram reaches the end of its travel, the pump pressure immediately builds up and opens a pressure relief valve, allowing the oil to by-pass back to the reservoir. Other more complicated devices may be fitted to allow the pump to "idle" at low pressure, but, a pressure relief valve or its equivalent is always fitted in case such a device fails. A handpump is usually fitted to generate pressure if the engine-driven pump is not working; a non-return valve in the pipe line is then needed to prevent oil from handpump passing through the engine-driven pump back to the reservoir.

6 Each service has one or more jacks to convert the hydraulic pressure to mechanical operation. With the smaller services such as the hot/cold air intake shutters, the movement

of the jack or jacks is sometimes initiated by an hydraulic accumulator.

HYDRAULIC ACCUMULATORS

7 An hydraulic accumulator is incorporated in some systems; it has several possible functions, not all of which may be used in a particular installation. These are:

(a) To smooth out the fluctuations in the flow of oil when there is a restriction in the supply pipe such as may intentionally exist in the flap circuit to prevent too rapid operation.

(b) To act as an emergency supply of oil under high pressure for the operation of hydraulic brakes and small services such as hot/cold air intake shutters.

(c) To give initial impetus to other components operated hydraulically.

8 The accumulator consists of a large cylinder in which a "floating" piston separates the oil, under pressure from the pump, from air under pressure. The cylinder may be charged to the correct pressure with air from an external source. A gauge connected to the cylinder indicates the pressure available, and the correct figure with the system at rest, is usually quoted in POI. Pilots should check that the correct pressure is available before starting up, as low pressure may result in sluggish operation of the services.

LOCKING

9 An essential part of hydraulic systems is that the service can be locked when it has reached the desired position. Locking is obtained either hydraulically or mechanically. In the case of the hydraulic lock, the jack is prevented from moving, by closing the up and down lines, thus trapping the fluid above and below jack piston. This type of lock is particularly suitable for flaps since it is possible to lock the jack in any desired position. The mechanical lock prevents movement by a device such as a catch, which will engage with the component and hold it in position. This type of lock is suitable for landing gears where a positive lock is essential.

INDICATORS

10 The pilot must have an indication of the position of the components, as direct visual inspection is often impossible. Indicators, usually in the form of red and green lights for the landing gear, and a graduated scale for the flaps, are connected electrically to the locks and/or the components themselves. A separate red warning light and/or a warning horn is connected to the landing gear system and works in conjunction with the throttle lever, coming on if the landing gear is not locked down with the throttle lever less than one third open. In addition, mechanical indicators are fitted to some installations.

EMERGENCY OPERATION

11 The emergency operation of hydraulic systems may vary; it is, therefore, most important that the pilot understands the system fitted to his aircraft. The appropriate POI give detailed instructions for the operation of all emergency systems.

12 In general, the handpump is the first alternative means of operation. If an engine-driven pump fails or is inoperative, the handpump will take its place and will operate all the services, but at a slower speed. Complete pump failure is unlikely, as the majority of aircraft are fitted with more than one engine-driven pump.

13 In the case of pipe line fractures and consequent loss of fluid, emergency lowering of the landing gear can usually be effected by selecting "emergency" and operating the handpump. Sufficient fluid is reserved in the tank by means of a "stack pipe". After emergency selection, this fluid is supplied under pressure by the handpump direct to the down side of the undercarriage jacks, usually irrespective of the position of the landing gear selector lever. Selection of "gear down", before emergency operation, is sometimes recommended to assist the fluid on the up side of the jack to escape from the jack cylinder. On some systems, particularly those of large aircraft, air pressure from storage cylinders, or a slow burning cartridge system, is fitted in addition to the handpump. In these cases, on selecting "emergency" the pressure is fed to the down side of the landing gear jacks as before, but, as the pressure is greater, the operation is usually more rapid. The pressure will only be sufficient for one lowering. On some installations, the hydraulic accumulator is used to provide emergency pressure in the

event of the engine-driven pump(s) failing. In these cases, the accumulator, if fully charged, provides sufficient pressure for lowering the landing gear and then for limited use of the other services as indicated in POI for the type. The flaps are not normally lowered by the emergency system, but after lowering the landing gear, an attempt to extend them can be made using the handpump or the normal system.

14 Pilots should remember that where more than one indicator exists for a vital service such as the landing gear, all indications should be checked before assuming that the service is in the locked position. Again, if any one of the indicators shows that the landing gear is not locked down, although it is possible that the indicator has failed, all means of lowering should be tried. If, however, when all means of lowering have been tried, the pilot is still in doubt that the main wheel(s) of the landing gear is/are locked down, it is advisable to land with the landing gear retracted. Less damage will result to the aircraft and there will be less risk of injury to occupants, than if a normal landing is attempted and one of the landing gear legs subsequently collapses during the landing run.

SECTION 4

PNEUMATIC SYSTEMS

OPERATION

1 Although the pneumatic systems fitted to individual aircraft may differ slightly, the basic principles are the same. The services operated by these systems differ with aircraft types, but the principles of operation are as follows:

(a) Air from one or more engine-driven compressors passes into one or more air storage cylinders through an oil trap, a non-return valve and a pressure regulating valve. The regulating valve discharges compressor output to atmosphere when the pressure in the air storage cylinder(s) exceeds the maximum working pressure. After leaving the storage cylinder(s) the air then passes through a filter to a pressure reducing valve which delivers it to the required services at correct working pressure.

(b) A triple pressure gauge is fitted in the cockpit. The top needle of the gauge indicates the pressure available in the air storage cylinder(s), while the two lower needles indicate the working pressure at the brakes, when the brake lever is operated. The indications of the lower needles are a function of the amount of pressure applied to the brake lever and the position of the rudder pedals; they are not influenced by the available supply, provided that this is above a pre-determined minimum.

(c) Should failure of the engine-driven compressor occur, a limited supply of air pressure will still be available from the air storage cylinder(s). If it is known that the air supply has failed, the use of the pneumatic services should be kept to minimum to ensure that there is sufficient pressure for operating the brakes on landing. On most installations where pneumatic pressure is used for operating several services, a pressure maintaining valve is fitted. If the supply fails, this valve will cut out all the pneumatic services, except the brakes, when the pressure drops to a predetermined minimum. This minimum pressure will be sufficient for the correct functioning of the brakes after landing.

SERVICES SUPPLIED

2 The services normally operated by the pneumatic system are:

(a) Brakes

(b) Gun firing mechanisms.

(c) Supercharger rams.

(d) Carburettor "hot/cold" and/or "filter" rams.

(e) Some aircraft of later design may use the system to operate:

(f) Landing gear.

(g) Speed brakes.

(h) Windscreen wiper.

(j) Wing de-icer boots.

(k) Landing lights.

(l) Automatic pilot.

GENERAL

3 Air pressure, stored in separate bottles charged on the ground may also be used in emergencies for lowering the landing gear and flaps should the hydraulic system fail.

4 On aircraft not fitted with an engine-driven compressor the storage cylinder(s) may be charged from an extreme source. The operation of services will then be restricted by the capacity of the cylinder(s).

SECTION 5

SUCTION SYSTEMS

INTRODUCTION

1 Of the two means of motivating the gyros in gyroscopic flight instruments, electricity and air jets, the latter, known as the suction system, is the more common. The requirements of any motivating system are reliability and simplicity.

COMPONENT PARTS

Pump

2 A vane type pump which is capable of giving a maximum of 10 inches of Mercury (Hg) suction at normal engine operating speeds is driven by the accessory drive shaft of the engine. The selection of the size of pump for volumetric output depends on the number of instruments to be driven. An air-oil separator is incorporated in the system to prevent lubricating oil from getting into the lines.

Suction Relief Valve

3 At engine speeds over approximately 1,000 RPM, the pump draws the maximum of 10 inch Hg suction. This is more than is needed to operate the instruments, so a relief valve is provided in the form of an adjustable spring-loaded valve vented to the atmosphere. The valve is adjusted to give the desired suction in the line leading to the instruments, normally 4 1/2 to 5 inches Hg., and the tension on the spring is set so that any suction in excess of that required is relieved by allowing atmospheric pressure to enter the system through the valve opening.

Check Valve

4 This valve is used to prevent a reverse flow of air from the pump to the instruments in the event of an engine backfire. The danger of the reverse flow lies in the fact that oil might be forced into the cases of the instruments.

Pressure Relief Valve

5 A backward flow of air would close the check valve and the suction relief valve, thus causing a positive pressure in this portion of the suction system. It is possible that this pressure might become high enough to rupture the line connections, and consequently a pressure relief valve is incorporated between the check valve and the suction pump.

Turn Indicator Restrictor

6 This device is used to reduce the normal line suction to that required for operating the gyro of the turn indicator. There are three types of restrictors:

(a) A simple needle valve which merely reduces the suction to half the value of that in the main line.

(b) A spring-loaded regulating valve operating on the same principle as the suction relief valve. This type of valve maintains a constant suction on the turn indicator at all main line suction valves down to the minimum required to operate the turn indicator.

(c) A calibrated pipe of specific bore which serves the same purpose as the spring-loaded valve in paragraph 3.

Suction Gauge

7 This gauge measures the value of suction going to the instruments. It is calibrated to read up to 10 inches Hg., but it should register amount of suction used by the artificial horizon and the directional indicator. Certain aircraft are fitted with a switching mechanism in order that the suction at individual instruments may be determined.

Filter Systems

8 There are two types of filter systems which may be used in conjunction with a suction-operated system. It is possible to incorporate both systems in one installation, although this is not a normal practice.

Individual Filter System

9 In this system, each individual instrument has its own filter in form of a circular screen on the back of the instrument which holds a very fine porous paper. The suction gauge in this system shows the differential pressure between the case of the artificial horizon and the atmosphere. If the filter on any one, or all, of the instruments becomes clogged, the reading on the suction gauge will not be affected because the suction relief valve compensates for any restricted flow through the filters.

Master Filter System

10 This system makes use of one large common filter which is normally located in some part of the aircraft least exposed to air containing dirt. The suction gauge is connected between the case of the artificial horizon and the common line leading to the filter, thus giving a reading which is the difference in pressure between these two points. In a sense the suction gauge acts as a "flowmeter", because a clogged filter or a partially restricted flow will result in a drop in line suction.

ALTERNATIVE SOURCES OF SUCTION

11 On multi-engined aircraft, more than one suction pump is provided. A suction change-over cock is, in many cases, installed in the pilot's cockpit to enable him to change over the source of suction in the event of engine or suction pump failure. On later installations, no change-over cock is fitted, but a suction pump is then automatically isolated in the event of failure.

12 On certain obsolescent types of aircraft, a venturi system is available as an alternate source. This venturi is mounted in the region of the propeller slip-stream or exhaust to make the most use of the increased velocity of the air in these areas as the suction obtained when using a venturi varies directly as the velocity of the air through the venturi.

13 Most single-engine aircraft do not have an alternate source of suction. The reason for not providing an alternate source for single-engine aircraft is that a pump failure usually results only from an engine failure. However, at gliding speeds, it will be found that a windmilling engine will provide adequate suction for the instruments.

SECTION 6

ELECTRICAL SYSTEMS

GENERAL

1 In earlier aircraft, the electrical services are normally supplied from a battery in the fuselage; this is maintained fully charged by one or more engine driven DC generators. In later aircraft the output of the generator(s) is usually sufficient to supply the entire electrical load independent of the battery. Alternating current (AC) for radar equipment, etc., is supplied on some types of aircraft by an alternator(s) driven by the engine(s); on other types it is provided by means of inverters which convert DC current from the aircrafts' supply to AC at the required voltages and frequencies. These are sometimes incorrectly referred to as converters or motor-generators which, strictly speaking, are used to convert AC current to DC or DC current at one voltage to a different voltage.

POWER SUPPLY SYSTEMS

2 The generators supply electrical power, for operation of all electrical services and give a rated output of 1,500, 3,000 or 6,000 watts according to the type of aircraft. The voltage is controlled by an automatic voltage regulator at 28 or, in some types, 112 volts. The generators also maintain fully charged the small capacity batteries provided to damp out small fluctuations in voltage and to provide a small reserve of power for operation of the essential services in the event of generator failure, and in some cases for starting the engine(s) if a ground battery is not available. The battery alone will operate essential services at 24 volts (92 with 112 volts systems) for a limited time only. An automatic cut-out disconnects the generators from the system when engine RPM fall below a predetermined value to prevent battery discharging through generator windings when the output voltage, which drops as the RPM fall off, falls below that of the battery. In the case of piston engines the cut-out RPM are usually between 1,200 and 1,500; on jet engines the cut-out RPM differ according to the type of engine.

3 A red indicator light known as a generator, or power, failure warning light is usually fitted in the circuit from each generator, and comes on when the generator is not charging for any reason such as low engine RPM, generator or generator drive failure.

4 A fuse or circuit breaker is usually fitted in each generator field circuit, and some installations have a switch to put the generator out of action.

GROUND/FLIGHT OR MASTER SWITCHES

5 These are two-way switches in the main supply circuit from the battery to services. When these are set to "Flight" the battery is connected to the aircraft electrical system; when set to "Ground" all services, except the generator failure warning light, are disconnected from the aircraft battery and connected to an external ground battery socket. All services are then inoperative except with a ground starting battery plugged in and switched on. In a few cases, however, two external sockets are fitted and the Ground/Flight switch should then be used as recommended in POI for the type.

6 On some later aircraft, in particular types with pressure cabins, the Ground/Flight switch is not fitted in the cockpit because it is not desirable or convenient to bring heavy duty cables into a pressure cabin or cockpit. On such types the Ground/Flight switch is frequently fitted externally and is operable on the ground only. An additional switch, known as a battery isolating switch, is then fitted in the cockpit. This controls a relay in the main battery circuit and in "off" position isolates the aircraft battery from all electrical services except the engine fire extinguishers and any other services considered to be essential emergency services, e.g., the electrical dinghy release, intercommunication system or similar services. In the event of a crash landing battery isolating switch should be set to "off" to minimize fire risk. Before flight

the pilot should check that the Ground/Flight switch is set to Flight as well as that the isolating switch is at "on". Irrespective of the setting of the isolating switch, all services can be operated from a ground battery with the Ground/Flight switch set to Ground, and from the generators when these are running above cut-in speed.

7 On some still later installations no Ground/Flight switch is fitted; the ground battery socket and plug are then of a new 3-pin type. The third pin is not in electrical connection with the ground battery and serves merely as a means of automatically operating main aircraft battery circuit relay when the plug is inserted. This ensures that the aircraft battery is disconnected from electrical system if battery isolating switch has not previously been set to the "off" position. On removing the ground battery plug the aircraft battery is reconnected to the system unless the isolating switch is at "off". With this type of socket fitted, an adaptor is necessary to enable a ground battery fitted with a normal type of plug to be used.

SERVICES

8 The electrically-operated services usually comprise some or all of the following:

(a) Engine starters.

(b) Propeller feathering motors.

(c) Oil dilution solenoid valves.

(d) "Stop engine", low coolant level and oil pressure warning lights.

(e) Radiator and oil cooler shutters, gill and air-intake filter motors.

(f) Shutter position indicators.

(g) Fuel tank contents gauges.

(h) Fuel pressure warning lights.

(j) Fuel booster pumps.

(k) Flap and landing gear position indicators.

(l) Pressure-head, glove and clothing heating.

(m) Bomb gear and gun turret controls.

(n) Gun heating and firing circuits.

(p) DR and RI compasses.

(q) All internal and external lighting.

(r) Certain electrically-operated instruments.

(s) Radio and intercommunication equipment.

9 Electrical engine-speed indicators are operated from small independent AC generators on each engine.

FUSES AND CIRCUIT BREAKERS

10 The distribution system is usually divided into a number of main circuits, such as lighting, indicators and radio equipment, each controlled by a main fuse, or in some aircraft, by a thermal overload circuit breaker which achieves the same purpose, but which can be reset manually. A circuit breaker in its simplest form, resembles a pushbutton switch. An indication that the circuit breaker has come out is given by the button protruding. To reset the circuit breaker, the button is pushed in and should then remain in, unless the fault is serious, when it will again protrude. There is also a fuse in each generator field circuit. Subsidiary fuses are sometimes fitted in the circuits feeding certain individual items of equipment. Fuses are not usually fitted in the propeller feathering circuits; this precludes the possibility of a fuse blowing during feathering, which might prove disastrous.

FLIGHT OPERATION OF ELECTRICAL SYSTEMS

11 All the crew should be familiar with the location of all fuses, circuit breakers and spare fuses.

12 When starting engines on the aircraft battery ensure that it is well charged. On multi-engine aircraft, and engine driving a generator should be started first, warmed up and run up to generator cut-in speed, generator failure warning light out, so that this generator can support the battery while starting the other engine(s).

13 Care should be taken to ensure that the generator(s) are charging at all times. Engine RPM should not be reduced to a point where the generator failure warning light comes on, and when one generator only is fitted, practice feathering should be confined as far as possible to the engine not driving the generator.

14 Should a generator failure warning light come on at RPM above the cut-in speed, an attempt may be made, when practicable, to correct the fault by changing the fuses. If this fails to correct the fault, or if the fuse blows a second time, no further attempt should be made. All non-essential electrical services should then be switched off.

15 If one or more electrical services fail, appropriate main or subsidiary fuse should, when practicable, be checked and replaced; circuit breakers should be reset manually after a short pause to allow them to cool down. No attempt should be made to hold them in and most types cannot be held in against a serious fault. After resetting, if the fault is not serious, the circuit may remain live long enough to enable an essential service, such as a landing light, to be operated; circuit breakers may be reset several times if the service affected is essential. If, however, there is evidence of smoke or fire, or if a fuse blows or a circuit breaker comes out immediately on being replaced or reset, indicating that the fault is serious, the fuse should not be replaced or the circuit breaker reset unless the fault can first be located and rectified.

16 On the larger aircraft, voltmeters and ammeters are usually fitted in the charging circuit, which enable the generator output to be checked. On some aircraft, the voltmeter replaces the generator failure warning light. If on a long flight an ammeter shows a discharge, indicating that the electrical load is in excess of the generator output, any non-essential services should be switched off to ensure that the battery does not become discharged.

17 If a generator failure warning light comes on, then, with aircraft fitted with only one generator, not only should all non-essential electrical services be switched off at once and left switched off, but the operation of essential services such as radio and radar equipment should also be restricted in order to conserve the battery for the occasions when their use is imperative to the safety of the aircraft.

18 Owing to the considerable load imposed on batteries by the electrical equipment, it is important to ensure that, whenever practicable and unless otherwise recommended in POI for the type, the engine(s) is/are run above generator cut-in speed while the aircraft is stationary due to delays occurring either before take-off or after landing.

SECTION 7

STARTING SYSTEMS

DIRECT-CRANKING ELECTRIC STARTER

1 This starter may be either:

(a) A separate unit consisting of a motor, a reduction gear and an engaging mechanism or,

(b) A motor only, the reduction gear and engaging mechanism being incorporated in the engine.

2 In the event of failure of either of the above, an attempt may be made to start by hand cranking.

3 To start engine, the ignition is switched on, the booster coil, if fitted, operated and the starter pushbutton pressed until the engine fires.

4 To avoid damage to the starter, it should never be operated continuously for more than 30 seconds. If an engine fails to start, a pause of 30 seconds should be made to allow starter to cool before a further attempt to start is made.

5 If the engine is to be started by hand, a crank handle is needed, but this should not be used in conjunction with the electric motor as injury or damage may result.

ELECTRIC-INERTIA STARTER

6 This starter consists of a flywheel, a reduction gear and an engaging mechanism. The flywheel may be energized either by hand or by an electric motor, and the engaging mechanism operated either by hand or by a solenoid.

7 The starter is electrically operated by a single, three-position manual or pedal switch which is moved from a central position, one way to run the flywheel up to speed, and the other way to engage it with the engine.

8 To start the engine, the switch is set to the energizing position usually labelled "start" or "energize" for 10 to 15 seconds or, until the hum becomes constant; 30 seconds should, however, not be exceeded. With an auxiliary power unit supply 10 seconds should suffice. The ignition, and the booster coil if separately controlled, are then switched on, the starter switch is centralized and after a momentary pause, set to the position necessary to engage the flywheel with the engine, usually labelled "crank" or "mesh". When the engine is running smoothly, the switch is centralized and the booster coil switched off.

9 Should the engine fail to start, ignition, starter and booster coil should be switched off. After the propeller has stopped rotating, the switch should then be set to the engaging position to stop the flywheel turning and returned to the central position. The propeller should be turned forwards through half a revolution to ensure that starter jaws disengage and procedure outlined in paragraph 8 above should then be repeated.

10 To avoid damage to starter, the switch should never be set to the energizing position after the flywheel has been engaged with the engine and no attempt to re-energize a moving flywheel should be made. The accelerating periods should not be exceeded and after three attempts to start an engine, at least five minutes should elapse to allow the starter to cool before making a further attempt.

COMBINED INERTIA AND DIRECT-CRANKING STARTER

11 This starter consists of the same assemblies as those constituting the inertia starter described above, except that the installation of a more powerful starter motor allows the engine to be "direct cranked" electrically.

12 The running up of the flywheel and its engagement with the engine is controlled either by separate switches, or by a single, three-position switch usually labelled "start" or

"energize" and "crank" or "mesh". A combination of inertia and direct cranking operation is, therefore, possible.

13 The ignition and the booster coil if separately controlled, are first switched on. With starters fitted with brush-lifting gear for manual starting, the switch should be flicked to the engaging position momentarily to ensure that the brushes are returned to the commutator. The switch is then set to the energizing position until the hum becomes constant, normally for about 20 seconds, and then it, or the second switch is set to the engaging position. The switch(es) should be set to off when the engine is firing evenly, under normal conditions after not more than 30 seconds. With an auxiliary power unit running, the necessary energizing period should not exceed 10 seconds.

14 If the engine fails to start, the switch(es) should be set to off and two or three minutes allowed to elapse before a restart is attempted, during which time ignition should be switched off and the propeller turned forward half a revolution by hand in order to disengage the starter from the engine.

15 To avoid damage to the starter, it should never be operated in engagement with the flywheel for more than one minute continuously. If the engine has not started in this time, an investigation should be made to ascertain the cause.

HAND CRANKING WITH ELECTRIC-INERTIA AND INERTIA-DIRECT-CRANKING STARTERS

16 Operate the brush lifting gear to lift the brushes from the commutator.

17 After fitting the handle, the engine is started by turning slowly, gradually increasing the speed up to 70 to 80 RPM which should normally be attained in about one minute. The handle is then removed and the engaging mechanism operated. As soon as the propeller commences to turn, the ignition should be switched on.

18 If the engine fails to start, the flywheel should be allowed to come to rest and the ignition should be switched off before a further attempt to start is made by repeating the operations described in paragraph 17 above.

CARTRIDGE STARTERS

General

19 These consist of a magazine unit connected to a starter breech. The magazine is loaded with a number of cartridges each of which may be indexed into the firing position either by hand, by remote mechanical means or electrically. The cartridges are fired electrically or, in one type, by percussion mechanically. Gas pressure from each cartridge is converted by the starter unit into a rotary impulse sufficient to rotate the engine, under normal conditions, two or three times at high speed, after which the starter unit becomes automatically disengaged from the engine. The following paragraphs describe the four main types of cartridge starters.

Manually Indexed Electrically Fired Type Cartridge Starters

20 With these the magazine holds five cartridges and is rotated to index a fresh cartridge by pulling and then releasing a spring-loaded ring or toggle control. The cartridge in the firing position is then fired electrically by pressing a starter pushbutton which should be kept pressed until the engine is firing evenly as this also operates the booster coil.

21 If a cartridge fires but the engine fails to start, the starter pushbutton should be released and the ignition switched off. When ready to make another attempt, the ignition should be switched on again and the indexing control pulled and slowly released to index the next cartridge. The starter pushbutton should then be pressed without delay. If after indexing the fresh cartridge it is, for any reason, considered unwise or impracticable to start the engine, no personnel should approach the propeller or engine for a period of 30 seconds. This is to guard against the danger arising from the possibility of the engine turning due to spontaneous ignition of the cartridge caused by heat from the hot grid in the combustion chamber.

Electrically Indexed and Fired Type Cartridge Starter

22 With these types the magazine holding five cartridges is rotated to index a fresh

cartridge and then fired electrically by the single action of pressing starter pushbutton. On pressing the button a short delay occurs during which the magazine mechanism is operating. The pushbutton which also operates the booster coil should be held in until the engine is firing evenly.

23 If a cartridge fires but the engine fails to start proceed as in the case of mechanically indexed starters. There is, however, no danger of a fresh cartridge being indexed too soon with this type.

Manually Indexed and Fired Starters

24 On this type, fitted to small aircraft, the indexing control also fires the cartridge. As the handle is pulled a fresh cartridge is first indexed and the percussion fired by mechanical means as the control approaches the fully out position. On releasing control it springs back automatically resetting the mechanism ready to index and fire the next cartridge. On this type the magazine holds six cartridges. No starter pushbutton is fitted. There is no possibility of indexing a fresh cartridge prematurely.

Precautions with All Types of Piston Engine Cartridge Starters

25 If a cartridge fails to fire on pressing the pushbutton, or operating the firing control, a period of 30 seconds should elapse before a fresh cartridge is indexed or indexed and fired. During this time no personnel should approach the engine or propeller. If a fresh cartridge is indexed too soon, whether immediately fired or not there is a risk of the previous defective cartridge exploding spontaneously in the magazine due to heat transmitted to it while it was in the firing position. If more than one cartridge in succession fails to fire, a defect in the firing circuit or mechanism is the most probable cause. As a precaution a period of one minute should be allowed to elapse before the starter is approached by the ground crew for examination or adjustment.

26 Spent cartridges should be removed as soon as practicable; if left for a long period they may seize in the magazine.

Turbine Engine Cartridge Starters

27 With these starters, gas at high pressure generated by the burning of a cartridge, or cartridges, is fed to a starter unit. This is in effect a small high-speed auxiliary turbine engine driving the rotor of the main engine through a suitable clutch and gearing. The cartridges burn more slowly than those used in piston engine starters, the rate of burning and charge weight being such as to accelerate the main engine up to its starting RPM during the burning period which, according to the type of engine and starter, is between 2 1/2 and 10 seconds. The cartridges are fired electrically, by pressing a starter pushbutton. Means are provided to prevent the starter rotor overspeeding due to failure of the drive. Safety discs are also fitted to relieve the pressure should this rise unduly as a result of a partial or total blockage of the normal gas passages.

28 The breech unit of these starters comprises either:

(a) A fixed six chamber breech and firing mechanism so arranged that the cartridges are fired in pairs. After an unsuccessful attempt to start the engine, further operation of the pushbutton automatically fires the next pair of cartridges. Three starts, or attempted starts, are thus possible without reloading the breech by hand.

(b) One, two or three fixed cartridge chambers, depending upon the available space in the power plant. With these types one cartridge at a time is fired and one, two or three starts, according to the number of chambers fitted, are thus provided for without reloading.

29 Details of operation of the various types and precautions to be taken will be found in the POI for the aircraft in which they are fitted.

STARTING IGNITION

30 Booster coils provide starting ignition while the engine is turning over slowly and the voltage when generated by the magneto is insufficient to provide the necessary spark. They are controlled by separate pushbuttons or in some cases by the starter pushbutton. A booster-coil master switch is sometimes fitted.

31 The impulse starter is another means for obtaining starting ignition. It operates by "flicking" over the magneto rotor by means of a coiled spring: this ensures that sufficient speed is imparted to the rotor to give the necessary voltage.

SECTION 8

OIL DILUTION

INTRODUCTION

1 The oil dilution system provides a method for the introduction of a controlled quantity of gasoline into the oil system. This section deals with the subject in general; for detailed information respecting individual aircraft types consult the relevant Aircraft Operating Instructions.

2 Responsibility for oil dilution and for boil-off rests primarily with the technical staff, but may be delegated to aircrew. Responsibility should be defined in unit instructions. It is the responsibility of the individual carrying out the dilution and/or boil-off to record the action taken in the Aircraft Maintenance Form L14.

PURPOSE

3 The purpose of cold weather oil dilution is to lower the oil viscosity to facilitate the starting of piston engines. Lower viscosity reduces the torque necessary to rotate the engine and ensures an immediate and adequate supply of lubricant to all moving parts. It also minimizes the risk of bursting flexible hose lines , and oil coolers.

4 The purpose of anti-sludge oil dilution is to prevent the accumulation of internal engine sludge and carbon deposits. The washing action of the gasoline dislodges these deposits, which are subsequently picked up by the main oil filter.

SYSTEM

5 Gasoline is delivered from the engine and/or booster fuel pumps to the inlet oil line by way of a solenoid operated valve incorporating a metering orifice. The solenoid is energized by a spring loaded switch which opens the valve admitting fuel to the oil system. A hopper in the oil tank serves to reduce the amount of oil in circulation by partially separating the main reserve oil supply from the circulating oil. This reduces the amount of oil to be diluted and the quantity of diluent required. Diverter-segregator valves are used in some aircraft to control the flow of oil in the hopper. Dilution may be carried out at higher oil temperatures if authorized by the applicable AOI.

TYPES OF OIL

6 Engines operating on straight mineral oil, Specification 3-GP-100, are subject to the formation of sludge and carbon residues which form deposits on the interior of the engine and components. These deposits can result in malfunction of such items as supercharger clutches, propellers, valves, etc., and daily anti-sludge dilution is necessary to minimize these deposits. The ashless-dispersant oils , Specification 3-GP-315 and 3-GP-320, keep the carbon and sludge residues in suspension in the oil, and the contaminants are removed during oil changes; therefore anti-sludge dilution is not required. Refer to paragraph 10 following.

COLD WEATHER DILUTION

7 Adjust the oil level as necessary and dilute the engine oil in accordance with the specific Aircraft Operating Instructions to meet the prevailing conditions. Record dilution in the L14.

BOIL-OFF PROCEDURE

8 Boil-off means that after starting the engine operating temperature must be raised and maintained at a sufficiently high level to vapourize the gasoline. This vapour leaves the engine through the crankcase breather pipe.

9 Boil-off is to be done prior to take-off in accordance with the specific Aircraft Operating Instructions and consistent with the percentage of oil dilution present. Record boil-off in the L14. Adequate boil-off is essential to avoid the possibility of oil venting from the engine or oil tank breather.

ANTI-SLUDGE DILUTION

10 When cold weather dilution does not apply, oil dilution for this purpose is to be carried out each day that the engines are run regardless of the atmospheric temperature.

11 After the engine is started, run at the prescribed minimum and slow running rpm until the oil temperature has reached 40°C but not exceeding 50°C. Operate the oil dilution switch to bring about 10% dilution. For time of operation required consult the Aircraft Operating Instructions for the relevant aircraft. During this period the propeller variable pitch system and the oil activated supercharger clutch system are to be exercised, if installed. Carry out normal run-up procedure. Record dilution in the L14.

WARNING

If for any reason daily dilution has not been carried out and the procedure is subsequently restarted an accumulation of sludge may be deposited in sufficient quantities to plug or collapse the oil filters. To clear the system the filters must be examined and cleaned after each flight until it has been determined that it is again safe to leave them until the next scheduled inspection.

OVER-DILUTION

12 Over-dilution can be caused by excess dilution time, by insufficient boil-off or by an accumulation of gasoline due to a succession of dilutions without complete boil-off between each. Additional causes are a leaking solenoid valve or an oversize metering orifice. Evidences of over-dilution are:

(a) Excessive drop and excessive fluctuation of oil pressure.

(b) Oil venting through the engine or oil tank breathers.

OIL VENTING

13 Following oil dilution pilots should check for signs of oil venting from the oil tank or crankcase breather. On take-off the tower should provide a visual check.

14 At high power settings engine heat rapidly vapourizes the gasoline in the oil. If this is too rapid the vapour may not separate from the oil fast enough and a froth will occur. This results in an over-pressurization of the system forcing oil out the vents. This can rapidly reduce the oil reserve.

15 When venting occurs it can only be stopped by reducing power. Land the aircraft as soon as possible, check the oil level and carry out a complete boil-off.

CAUTION

On multi-engine aircraft when one or more engines have had power reduced to stop venting, a power increase of the remaining engines is to be avoided if possible.

THIS MAY INDUCE THEM TO VENT.

SECTION 9

OXYGEN SYSTEMS

INTRODUCTION

1 This section deals (in a broad sense) with aircraft oxygen systems. For more complete details on a particular aircraft system, refer to the operating instructions for that aircraft. For physiological effects of oxygen, see Part 1, Section 3.

DESCRIPTION

2 Oxygen is contained in cylinders which are usually a fixture in the aircraft. These cylinders may be either of the high pressure or the low pressure type. The British in general use the former while the Americans use the latter. In either system, over-all weight of the complete system for a given quantity of oxygen, is approximately the same. When the cylinders are a fixture in the aircraft, they are charged in the aircraft from a charging point, fitted in a convenient position near the outside of the aircraft. It is possible to carry removable cylinders which are replaced by full cylinders as required.

3 From the aircraft cylinders, the oxygen is fed to the crew via some form of regulator, tubing, and a mask.

4 The regulator, as well as preventing a direct delivery of oxygen under cylinder pressure, provides a means of controlling the supply according to the needs of the crew. Oxygen regulators can be divided into three main types, continuous flow regulators, diluter demand regulators and pressure diluter demand regulators. Continuous flow regulators are designed to supply a continuous flow of oxygen for any given altitude. The rate of flow can be increased as the altitude is increased. To prevent wastage of oxygen during exhalation, an economizer is used in conjunction with continuous flow regulators. Diluter demand regulators are designed to give a variable flow of oxygen depending on the demand. The oxygen is diluted with air, the percentage of oxygen to air varying with the altitude. Pressure diluter demand regulators work on the same principle as diluter demand regulators up to about 40,000 feet. Above this height oxygen is fed to mask under regulated pressure.

5 Some form of flow indicator will be found at each crew station to indicate whether oxygen is, or is not, flowing. These indicators give no indication of the magnitude of the flow.

6 With each regulator, there will be some form of pressure gauge, to indicate how much oxygen is available.

CONTINUOUS FLOW OXYGEN REGULATORS

7 Although continuous-flow equipment has practically disappeared from combat aircraft, it is still used extensively in air evacuation and troop transportation aircraft. The same type of cylinders and plumbing that is used in other systems is used in the continuous-flow system. However, the flight station equipment is quite different. These regulators can be divided into two main types; manually adjusted and automatic.

(a) The manually adjusted types are the British Mark 8 series, Mark 10 series, Mark 11 series and the American A-8 series. All of these regulators have valves which reduce the high cylinder pressure to a lower pressure for feeding to the mask. The rate of flow is manually adjusted either by varying the size of the orifice and keeping the reduced pressure constant, or by varying the reduced pressure and keeping the orifice constant.

(1) Single seat aircraft may be fitted with a Mark 8C, a Mark 11C or the American A-8 regulator.

(2) Two-seat aircraft may be fitted with one Mark 11B regulator or one Mark 8C regulator and one Mark 8D (no contents gauge). When the Mark 11B is on, both economizers will be fed with oxygen even though the aircraft is carrying only one person.

(3) In multi-seat aircraft, British Mark 10 series may be used. The Mark 10A supplies up to eight men; the Mark 10A* up to fifty men. These regulators are controlled from one position that is, from the pilot's position or from the engineer's position in a transport. All the crew or passengers need do is plug their bayonet connection into the oxygen outlet at their station.

(b) The American A-11 automatic continuous-flow regulator is designed for transport aircraft, to regulate the oxygen flow to several troop outlets. No manual adjustment is required. As a safety precaution, at least two regulators are used for any installation. No more than three are installed to supply oxygen to any one group of passengers. When the number of passenger outlets exceed thirty, instead of a single bank of four regulators, a new bank is used with a new passenger distribution line. The regulator contains no pressure gauge. One crew member is made responsible for noting the pressure at frequent intervals, on a pressure gauge installed at a convenient point in the distribution line.

DILUTER DEMAND OXYGEN REGULATORS

8 The diluter demand oxygen regulators operate on a completely different principle than the continuous-flow regulators. A separate regulator must be used for each station and a demand type mask must be used. All of these regulators are aneroid controlled to vary the percentage of oxygen to air from 0 percent at sea level to 100 percent at approximately 34,000 ft. No line shut-off valve is necessary with these regulators; the oxygen is automatically shut off when the regulator is not in use. One hundred percent oxygen can be obtained at any altitude by selecting "100 percent oxygen" on the regulator. A second control on the regulator, "Emergency" will deliver oxygen in a continuous stream. If this flow is restricted, as it would be if a pressure demand type mask were used, the pressure would build up and damage the regulator, or make exhalation extremely difficult. For these reasons the emergency is wired "off" when a pressure demand type mask is used. It may still be used, however, if the flow is not restricted. There are two types of demand regulators used in the RCAF, the Canadian Type C3 and the American Type A-12.

(a) The C3 regulator operates at a pressure of 25 psi since a reducer valve must be placed in the line prior to the regulator. In this regulator, suction created by inhaling acts on a diaphragm. The diaphragm moves a mechanical linkage and allows oxygen to enter the regulator. The oxygen pressure builds up in the regulator, and opens an air inlet valve. As the altitude is increased, the air inlet valve is restrained from opening and the percentage of oxygen to air is increased. The flow of oxygen-air mixture continues as long as there is suction on the diaphragm and the rate of delivery depends on the amount of suction exerted. Therefore, the exact amount required under various breathing conditions is automatically delivered. Since a positive line pressure must be available to open the air valve, an immediate warning of oxygen failure is given. The warning will be in the form of extreme inhalation difficulty. A bouncing-ball type flow indicator is used in conjunction with the regulator.

(b) The regulators of the A-12 series have an internal pressure reducing valve. Since oxygen pressure is not required to open the air inlet valve, there is no warning of oxygen failure as in the case of the C-3 regulator. Oxygen-air dilution is obtained by an aneroid which varies the size of the oxygen inlet and air inlet with altitude. This series of regulators requires the use of a Demand Type mask. However, a Pressure Demand Type mask may be used with the same restrictions as for the C-3 regulator. The emergency is to be wired "off" and only used when the flow is not restricted.

PRESSURE DILUTER DEMAND OXYGEN REGULATORS

9 The pressure diluter demand regulator is essentially a diluter demand regulator with certain modifications to provide pressure breathing for altitudes above the range of the diluter demand regulator. These regulators can be divided into two types; the manually adjusted and the automatic. The pressure differential provided by these regulators varies from zero at approximately 40,000 feet up to 18 inches of water at 48,000 feet. The foregoing pressures vary with different regulator types; the approximate range of pressure differential only, is suggested. Since some means must be provided to hold the oxygen in the

mask during pressure breathing, a special type of mask (pressure breathing) must be used. A normal demand mask would simply let the oxygen escape to atmosphere, see Figure 3-1.

10 The manually adjusted regulator used in the RCAF is the American A-14. This regulator is essentially an A-12 modified for pressure breathing. The regulator contains an internal reducing valve, oxygen-air diluter valves controlled by an aneroid, and an oxygen demand valve. The oxygen demand valve is controlled by a diaphragm which opens the valve on inhalation. On exhalation, the diaphragm closes the demand valve and oxygen ceases to flow. By spring-loading diaphragm, a positive pressure is built up in the demand side of the regulator. The pressure increase can best be explained by considering the demand valve as a second stage reducing valve. If diaphragm, operating this valve is spring-loaded, equilibrium will be reached as the pressure increases. A dial on the face of the regulator varies the amount of spring-loading; the dial is graduated in thousands of feet. At "normal" the pressure is atmospheric; at "safety" it is about 1 inch of water and at "45 thousand" it is about 8 inches of water. About 45 thousand the maximum pressure obtained is about 12 inches of water. There is no emergency control on this regulator. However, by selecting any of the pressure altitudes, a free flow of oxygen can be obtained. This pressure is controlled, hence there is no danger of damaging the regulator or of making exhalation abnormally difficult.

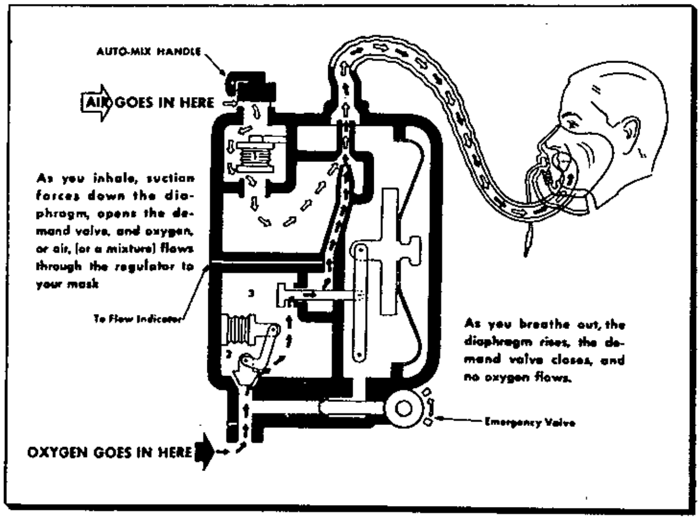


Figure 3-1 Diluter Demand Oxygen Regulator

11 The automatic pressure diluter demand regulator is a Pioneer Type. The A-1 series contains in one circular panel an oxygen cylinder pressure gauge, a flow indicator and a valve to select either "normal" or "100 percent oxygen". The 2867-A1 is the latest version and contains a line shut-off valve and no emergency valve. A safety press button is included which gives a small positive pressure at any altitude to overcome the effects of mask leakage. The regulator contains an internal pressure reducing valve which reduces pressure to between 40 and 60 psi. Suction created by inhalation moves a daiphragm which, through mechanical linkage to a demand valve, causes the demand valve to pass a quantity of oxygen proportional to the demand. Flow of oxygen through the demand valve is indicated by oscillation of a plate under oxygen flow indicator dial on regulator panel. Oxygen is channelled through an injector assembly and mixing tube, to the outlet of the regulator. Air enters the regulator through a second channel when the air valve on the regulator face is positioned to "Normal Oxygen". The quantity of air passed is controlled by the operation of an aneroid and check valve assembly. As altitude is increased, the aneroid progressively closes off the air channel until at between 28,000 and 32,000 feet, air channel is completely closed. The air channel is also controlled by a spring-loaded check valve that opens the channel only in the presence of suction within the regulator. Air is mixed with the oxygen in the mixing chamber and passed into the outlet of the regulator. The automatic pressure mechanism incorporates an aneroid in the back of the regulator. As atmospheric pressure decreases with altitude, the aneroid expands and through mechanical leakage to the diaphragm, progressively depresses the diaphragm, allowing the internal regulator pressure to rise.

12 The D-1 regulator is an automatic, pressure breathing regulator which is panel mounted. On the panel there is a line shut-off valve, a combination pressure gauge and flow indicator, a warning system switch and a valve to permit "100 percent oxygen" to be selected at any altitude. There is also an "Emergency" button which will provide free oxygen flow at

any altitude. The D-1 regulator differs internally from the A-1 regulator in three ways.

(a) The safety pressure is automatically controlled by an aneroid between the altitudes of 30,000 and 40,000 feet. Above 40,000 feet the automatic pressure aneroid takes over from the safety pressure aneroid.

(b) An oxygen warning system may be installed which makes use of two lights which glow if the frequency of inhalation falls below five per minute. One light is situated at the station where the regulator is placed; the second light is situated on a master panel where one man can observe the functioning of all regulators in the aircraft.

(c) The emergency switch gives a controlled pressure of 1.5 inches of water when thrown to the left or right and a variable pressure when pushed in, the pressure depending on how hard the button is pushed. This pressure is in addition to that produced by the automatic pressure mechanism.

OXYGEN MASKS FOR CONTINUOUS-FLOW SYSTEMS

13 A continuous-flow regulator provides a continuous flow of oxygen to the bayonet connection at the station. During exhalation, the oxygen is collected in an economizer in the form of a bag or bellows. Excess air at low rates of oxygen flow, is obtained from the atmosphere. Since the system is quite different from a Demand system, a special mask is required. The masks used in the RCAF, for the Continuous-Flow System with economizer, are the Type C, Type G, Type H and the Type A-8B. All of these masks contain an oxygen inlet port, air inlet valve(s), air outlet valve and a microphone.

14 The correct operation of the economizer depends on the mask making an air-tight fit on the face. When the user breathes in, he first sucks open the economizer valve and breathes pure oxygen until the bag in the economizer is empty, and then to complete the inhalation sucks open the air inlet valve in the mask to admit air. The mask and economizer work together as one unit. A badly fitting mask can cause discomfort and in extreme cases, a serious lack of oxygen can result, due to there being insufficient suction to open fully the economizer valve.

OXYGEN MASKS FOR DILUTER DEMAND REGULATORS

General

15 Since the Diluter Demand Oxygen Regulator carries out air-oxygen dilution in the regulator itself, the oxygen masks used for this system are somewhat different than for continuous-flow systems. The Type C mask, with outlet valve only, (no air inlet valves), can be used with all Diluter Demand Regulators. With this mask the "Emergency" control can be used on the above regulators as any excess oxygen escapes through the outlet valve. The Type A-13A Pressure Diluter Demand mask can be used with these regulators as long as the emergency control is not used when the mask is held tightly to the face. This mask is basically designed for pressure breathing . See Figures 3-2, 3-3 and 3-4.

A-13A Mask

16 The A-13A Pressure Diluter Demand mask is different from a conventional demand mask in that it will hold a pressure in excess of ambient. This requires three features which are not found in the demand mask.

(a) A flap or curtain of rubber, forming a ring around the inside of the mask, makes contact with the face, and helps to prevent the escape of oxygen.

(b) Two check valves keep the oxygen inlets closed while exhaling.

(c) A "compensated" type of exhalation valve in the floor of the mask, which opens at a pressure slightly in excess of that within the mask tubing. The housing of the exhalation valve forms a tube at the bottom which extends downward through a hold in the floor of the mask into the oxygen inlet tube. Through this tube, the incoming oxygen exerts its delivery pressure upon the lower side of the compensatory diaphragm. This pressure keeps the exhalation valve closed until a slightly greater pressure, produced by the act of exhalation, is brought to bear upon the upper surface of the main diaphragm. The valve then opens, and the exhaled air leaves the mask through the expiratory port. Exhalation will be difficult if the inlet valves do not seat during exhalation.

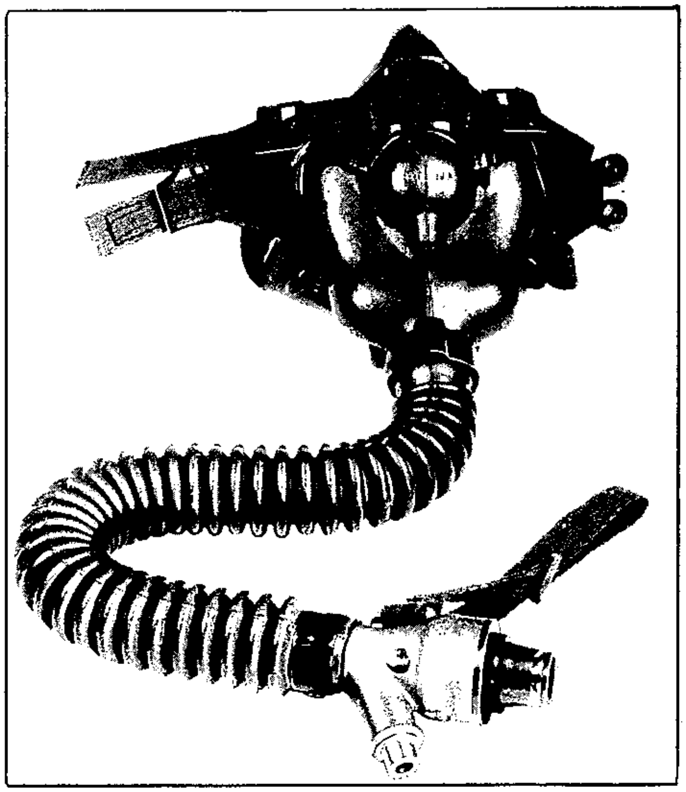


Figure 3-2 Type A-13A Mask

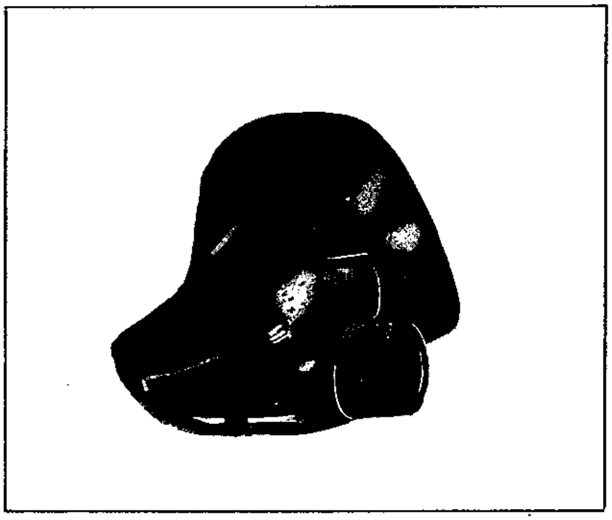
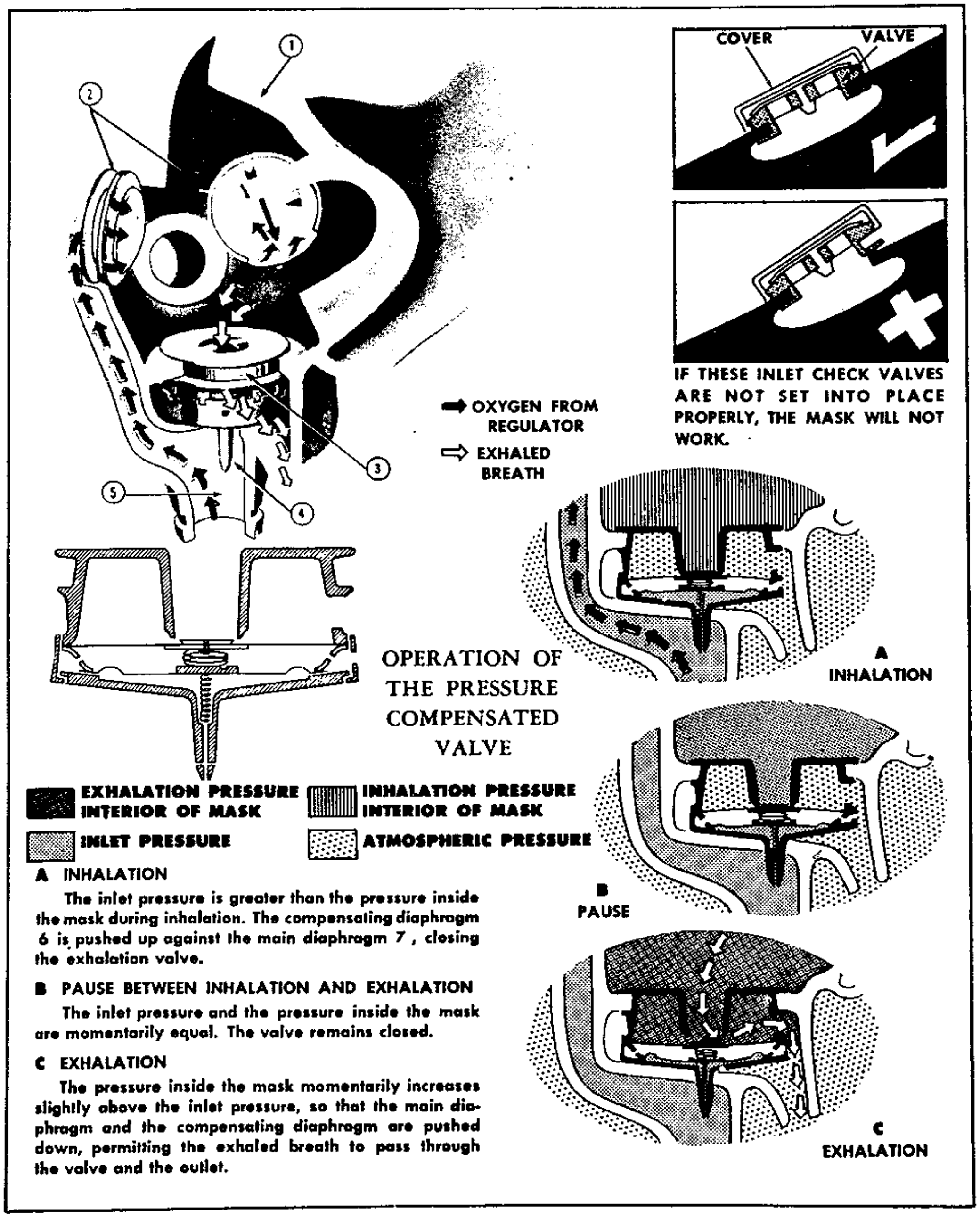


Figure 3-3 Type "C" Mask



IF THESE INLET CHECK VALVES ARE NOT SET INTO PLACE PROPERLY, THE MASK WILL NOT WORK.

A INHALATION

The inlet pressure is greater than the pressure inside the mask during inhalation. The compensating diaphragm 6 is pushed up against the main diaphragm 7, closing the exhalation valve.

B PAUSE BETWEEN INHALATION AND EXHALATION

The inlet pressure and the pressure inside the mask are momentarily equal. The valve remains closed.

C EXHALATION

The pressure inside the mask momentarily increases slightly above the inlet pressure, so that the main diaphragm and the compensating diaphragm are pushed down, permitting the exhaled breath to pass through the valve and the outlet.

Figure 3-4 Operation of A-13A Mask

If seating is poor, exhalation pressure will be transmitted through the inlet ports to the oxygen inlet tube, act on the lower side of the compensatory diaphragm, and prevent the exhalation valve from opening. Similarly, if excess pressure "Emergency" is delivered by a "Demand" type regulator, the pressure on the lower side of the compensatory diaphragm will be difficult to overcome.

Pre-Flight Check for A-13A Mask

17 A pre-flight test shall be made by the user prior to every flight. Establish the security of all parts with special attention given to the inlet check valves. The plastic shields must be inserted over the inlet valves at all times. The arrows on the shields should point downward to prevent excess moisture getting into the valves. Put the helmet on and strap the mask securely in place. Close the end of the mask tube with the palm of the hand and inhale gently. This should cause the mask to be sucked in tightly to the face. If the mask appears to fit properly but still leaks air when the test is applied, the exhalation valve is at fault. It is not inserted properly or is defective and should be replaced, i.e., the exhalation valve is stuck and not seating properly or otherwise leaking. To check the inhalation check valves take a deep breath, close the end of the mask tubing with the palm of the hand and then exhale. The valves are working properly if no difficulty is encountered in exhaling. If it is difficult or impossible to exhale the inlet check valves are not properly inserted, are dirty or defective and should be replaced. Report all defective masks immediately to the safety equipment technician.

Care of A-13A Mask

18 Since the mask is worn next to the skin it should be kept as clean as possible. This will not only help to make the mask more comfortable but will reduce the danger of infection and prolong the life of the mask. For ordinary cleaning which should be accomplished after each flight, wash the mask with a pure soap solution and rinse it well with clean water. If a microphone is installed use a clean swab instead of running water in order to keep the microphone from getting wet. To disinfect an oxygen mask swab it carefully and thoroughly with a gauze pad which has been soaked in a water solution of merthiolate (1 gram of merthiolate to 1000 cc water). Spray the inner crevices to make certain that the disinfectant penetrates thoroughly. Wipe the mask clean with a clean cloth and let it dry before it is used. When not in use the mask should be kept in a clean dry place away from sunlight and heat as much as possible. Oxygen masks should be stored at a temperature in the range of 32° to 80°F.

Adjusting Buckles

19 The suspension harness buckles may need adjustment to obtain a proper fit of the mask. Loosen the free end of the webbing and slide it forward or backward, forward to shorten and backward to lengthen the suspension harness.

Fitting Mask

20 Align the upper webbing strap with the car lobe and adjust straps with this alignment.

Pressure Tests

21 Fit the mask securely to the face and attach the mask to the helmet. Connect the delivery tube to the regulator hose then turn the dial to the various settings and tighten the tension on the upper and lower mask str..ps to prevent leakage during the respiratory cycle.

Exhalation Valve Pressure Tests

22 Connect the mask to the regulator, set the regulator to a pressure setting, draw in and hold a deep breath. If the mask is properly fitted and the oxygen still continues to flow, the exhalation valve is faulty in that it is not holding pressure, and should be replaced.

Servicing Mask for Comfort

23 Since mask must be held firmly against the face to withstand higher pressures, painful pressure points, especially against the nose, may result. In this event adjust strap tension just enough to balance pressure requirements. Do not allow the cheek flaps to jam against the edges of the helmet. Make certain that the flaps are trimmed properly. Do not remove the strap across upper lip because removal impairs the essential efficiency of the breathing systems.

Lubrication

24 Lubrication or grease of any kind is not required and must not be used on this equipment.

EMERGENCY BAIL-OUT EQUIPMENT

25 The Type H-2 Emergency Oxygen Cylinder assembly is designed as an emergency source of oxygen for flying personnel operating at high altitudes. The unit contains a ten minute supply of oxygen in a shatter-proof cylinder, designed for a working pressure of 1800 psi. A valve in the head of the assembly restricts the flow of oxygen. Since the valve gives a constant size orifice, the rate of flow will decrease as the pressure in the cylinder falls. A pull on a ball and cable release starts the flow of oxygen through a delivery tube. The delivery tube is connected to a bayonet type disconnect assembly, which can be installed on any type of mask. The A-2 disconnect assembly is used with the A-13A type mask. It contains a one-way pop-off valve, which permits free flow of oxygen from aircraft oxygen regulator. When the bail-out bottle is in use, the accordion tubing from the aircraft oxygen regulator is disconnected and one-way valve prevents oxygen from escaping to atmosphere from the emergency cylinder. If the pressure, created in the mask by the oxygen flow from the bottle becomes excessive, the one-way valve acts as a relief valve and will allow excess oxygen to escape.

PORTABLE OXYGEN EQUIPMENT

26 The A-6 Cylinder is the portable oxygen cylinder used in the RCAF. It is shatter-proof and contains approximately a thirty minute supply of oxygen. When used with a "Demand" mask, the A-15 regulator is attached to the cylinder. A diluter mechanism in this regulator prolongs the duration of the supply. When used with continuous-flow masks a manually controlled constant flow regulator is fitted to the cylinder.

GENERAL NOTES

27 The following points are to be observed in the operation of oxygen equipment:

(a) When opening the line or cylinder valves, they should always be turned on fully.

(b) With the Mark 10 regulators, open the line valve before turning on regulator valve. Turn off the regulator valve before closing the line valve.

(c) When the supply dial indicates in the low sector, the pilot should descend below 10,000 feet. The supply should be turned off before the pointer reached "empty", to prevent the entry of moisture into the system.

(d) All traces of oil, grease or hydraulic fluid must be removed from the oxygen system pipelines and connections. Failure to do this may result in fire or explosion if an oxygen leak should occur.

(e) Ensure that the mask gives a good fit. This is especially important for Demand Type masks, since it is the suction created in the mask which operates the regulator.

(f) Under pressure breathing, the mask may tend to pull away from the face and cause leakage of oxygen. This may be compensated for by tightening the straps of the mask.

PART 4

AIRCRAFT EQUIPMENT AND HANDLING

SECTION 1

FLIGHT INSTRUMENTS

GENERAL

1 In addition to those instruments associated with the power plant, the flight instruments usually fitted in aircraft are of three general types, those operated by external air pressures, those operated by gyroscopes, and compasses. The following paragraphs give some brief notes on these instruments with details of the checks which should be made by the pilot.

PRESSURE-OPERATED INSTRUMENTS

Airspeed Indicator

2 This instrument indicates the speed of flight in knots by measuring the difference between the total and static pressures derived from the pressure-head or pressure-head and static vent(s), and is subject to certain errors which are discussed in Part 1, Section 5.

3 Before flight, check that the pressure-head cover and static vent plugs are removed, and that the pointer is not stuck over the stop. Check that pressure-head heater is switched on when there is a possibility of icing.

Altimeter

4 Altimeters are instruments for indicating the height of an aircraft above a datum, usually sea level. They are operated by air pressure on the same principle as an aneroid barometer; the scale, however, is graduated to show height instead of barometric pressure. The simple altimeter has one pointer and a scale divided into thousands of feet and subdivided at intervals of 200 feet. There is an adjustment for setting the pointer to coincide with zero on the scale. The sensitive altimeter has three pointers indicating in hundreds, thousands, and tens of thousands of feet respectively, and an adjustable barometric scale, reading in millibars or inches, which can be seen through a window in the dial.

5 Errors affecting accuracy of altimeter readings are of two classes; those inherent in the instrument or installation, and those due to non-standard atmospheric conditions. In the absence of obvious faults such as sticking or other abnormal behaviour, pilots may assume an altimeter serviceable if, when the sub scale is set to the altimeter setting, the pointers read ±50 feet of the known aerodrome height. This instrument is subject to considerable errors at high Mach numbers and very near the ground.

Vertical Speed Indicator

6 This instrument measures the difference in pressure on opposite sides of a choke, one side of which is connected to the static source and the other to a sealed chamber. This pressure difference corresponds to rate of climb or descent, which is indicated by the needle in terms of thousands of feet per minute.

7 Pilots should ensure that the pointer reads zero when the aircraft is on the ground or flying at a constant height. The pointer may be set to zero by rotating the small screw located in one corner of the frame of the instrument. Accuracy in a steady climb or descent may be checked by comparison with the altimeter and a watch. The indications given by this instrument should not be too closely relied upon in bumpy air, at very high rates of climb or descent, or during rapid changes in attitude at high Mach numbers.

Machmeter

8 This instrument is fitted in high-speed aircraft. It consists essentially of two elements. one responsive to air speed, the other to altitude, similar to the mechanisms of the airspeed indicator and altimeter respectively. These elements are mechanically interlinked in such a manner that the pointer indicates as a decimal fraction the relation between the speed of the aircraft at any height and speed of sound under the same conditions.

9 At low altitudes, the Machmeter may be checked by comparison with the airspeed indicator reading. An indicated reading of .5 is roughly equal to an EAS of 330 knots.

CONTACTING ALTIMETERS

10 These instruments embody a pressure aneroid unit similar to the standard altimeter but without an indicating dial or needle. When the equipment is switched on, the pressure unit completes an electrical circuit at a predetermined height. This gives warning to the pilot, either aurally in his headphones or visually by an indicator light, when the aircraft is approaching any required height between 500 and 15,000 feet; for example, during descent in an RP strike dive. The signal note and/or light comes on about 700 feet above selected height and continues until this is reached. The required height is pre-set by the pilot by means of a selector control which incorporates an adjustable barometric sub-scale, similar to the standard altimeter, for setting the QNH.

11 Serviceability checks of the equipment can be made by the pilot before flight as follows:

(a) Switch on the equipment.

(b) Set the pointer to an altitude of approximately 5,000 feet in excess of station altitude.

(c) Rotate the height scale until the yellow arrow indicates 1050 millibars on sub-scale.

(d) Rotate the pointer anti-clockwise until the signal is heard in the headphones or the light comes on.

(e) Continue rotating; the signal should cease when the pointer indicates an altitude between 600 and 800 feet below that at which the signal came on.

NOTE

If the ground barometric pressure at the station exceeds 1050 millibars the pointer may reach the stop before the signal ceases. Provided, however, it comes on as in (d) above there is no reason to assume that the equipment is unserviceable.

GYROSCOPIC INSTRUMENTS

Introduction

12 These instruments operate in accordance with gyroscopic principles. Broadly these are:

(a) The tendency of a rotating mass such as a wheel to resist any changes in the direction of the plane of rotation. This tendency is known as rigidity. It increases in proportion to the rotational speed and the mass.

(b) For a given direction of rotation, the rotating mass will always react in the same manner if any external force is applied in an effort to change the direction of the plane of rotation. This reaction is known as precession.

(c) Thus, if a pointer be connected by suitable linkage to the framework carrying the bearings of the wheel, and a scale be attached to the airframe, movement of the pointer in relation to the scale will indicate the degree and direction of any displacement of the aircraft from straight line flight.

13 In instruments of this type, the wheel or rotor has a series of vanes or buckets cut in its periphery and is rotated at about 9,000 to 12,000 RPM by a jet of air impinging upon them. The air jet is produced by applying suction to the case in which the gyroscope is mounted, this suction being derived from the throat of a venturi unit mounted outside the fuselage or from an engine-driven vacuum pump producing a negative pressure of 5 inches to 6 1/2 inches of mercury. On multi-engined aircraft two pumps are fitted, on separate engines, connected to a change-over cock, enabling either pump to be selected by the pilot

in the event of pump or engine failure. A suction gauge is provided, and on later installations the change-over cock is replaced by an automatic change-over device.

14 The gyroscope rotors used in these instruments have considerable mass, and after the engine driving the vacuum pump is started, a period of from 1 1/2 up to 5 minutes elapses before the gyros are brought up to full working speed.

15 In later aircraft the gyroscopes of these instruments are electircally driven instead of by suction. This results in the gyroscopes accelerating up to working speed more quickly.

Turn and Slip Indicator

16 The turn and slip indicator incorporates two instruments. The turn indicator applies the gyroscopic principles to indicate a rate of turn about the vertical axis of the aircraft. The slip indicator indicates lateral level while the aircraft is in straight flight, or the amount of "slip" or "skid" if the aircraft is turning.

17 A rough test for serviceability of the turn and slip indicator may be made by turning through a few degrees while taxiing. The turn needle will indicate the direction of the turn, while the slip indicator will register a skid. The turn indicator may also be checked by applying a pressure on one corner of the flight panel; as the panel is flexibly mounted, any movement of the panel will be indicated by the turn needle. With the aircraft standing on level ground, both the slip and turn indicators should be central. In the air, the aircraft should turn through 180° in one minute with the turn pointer indicating a rate one turn.

Direction Indicator

18 This instrument employs the gyroscopic principle of rigidity to provide a stable directional reference for accurate course steering and changing. Unlike the compass, it is not north seeking. It is free from acceleration and turning errors; a deadbeat indication of heading being given.

19 In the air, the synchronization of the direction indicator and compass should be effected at intervals, depending on the rate of precession. It should also be carried out after manoeuvres in which precession due to re-erection occurs, for example, after turns and prolonged climbs and descents. In synchronizing, care must be taken that the aircraft is laterally level and in steady flight. This will minimize re-erection precession and compass acceleration and turning errors will not be present. Compass deviation must, however, be taken into account. The direction indicator should be uncaged at all times except when its operating limits are to be exceeded. These limits are 55° either side of the vertical in the rolling or pitching planes.

20 The direction indicator should be ready for use after a suction of 4 inches to 5 inches of mercury has been applied for about two minutes although the rotor may not reach full speed for four or five minutes. The gyro should be tested for rigidity by caging and turning the knob in either direction; the movement should be firm. When taxiing the instrument should react immediately to turns.

Artificial Horizon

21 The artificial horizon employs an "earth gyro" to provide a direct indication of the aircraft's attitude in rolling and pitching planes, and in so doing can replace the natural horizon. An earth gyro is one which is controlled by gravity so that it maintains a given vertical position relative to the earth.

22 If the pitch or rolling plane limits of 55°, 60° in some types, either side of the vertical of the instrument are exceeded, the gyro will come up against the stops and topple. The horizon bar will then sweep backwards and forwards across the face of the instrument and true indications will not be given until the gyro settles down; this takes ten to fifteen minutes.

23 After starting, the instrument will require about five minutes at a suction of 4 inches of mercury for the rotor to attain full working speed, but satisfactory indications will usually be given about one-and-a-half to two minutes. If the instrument is serviceable, the horizon bar should take up a horizontal position near the miniature aircraft image, and while taxiing the horizon bar should remain horizontal during turns. In the air, the horizon bar should react immediately to any changes in pitch or roll.

ARTIFICIAL HORIZON, TYPE J-8

General

24 The type J-8 artificial horizon provides the pilot with a constant visual indication of the flight attitude of the aircraft in pitch and roll. The instrument has complete freedom through 360° of rotation about the roll axis and effective freedom of 360° about the pitch axis.

Presentation

25 The pitch attitude of the aircraft is indicated within a range of 27° in climb or dive by displacement of the horizon bar with respect to the adjustable miniature aeroplane. When the aircraft exceeds 27° in pitch, the horizon bar is held in the extreme position and the sphere becomes new reference. A continued increase of climb or dive angle approaching the vertical attitude is indicated by graduations on sphere. When the aircraft approaches 90° in pitch as it does during a loop, a controlled precession of 180° occurs. This controlled precession should not be confused with tumbling or upsetting of the gyro. After completion of this precession, the indicator is completely operable.

26 The attitude of the aircraft about the roll axis is shown by the angle between the miniature aeroplane and the horizon bar and also by the bank index relative to the degree markings on the bezel mask.

Characteristic Errors

27 After a loop, displacement of the horizon bar in excess of five degrees in pitch and/or bank may result. The J-8 indicator will immediately begin to correct these errors once true gravitational forces are sensed. This characteristic error is commonly called "sluggishness" or "lag" by pilots.

28 In successive loops, the above described error may become increasingly greater and may cause the horizon bar to reach the limit of its movement. This is normal in successive loops and is not indicative of a defective instrument.

29 Because of acceleration forces acting on the erection mechanism of the attitude indicator during a normal aircraft turn, errors in pitch and/or bank up to five degrees may be noted upon return to straight and level flight. This error is "turn error" and is also commonly referred to as "sluggishness" or "lag". The J-8 indicator will immediately begin to correct these errors once true gravitational forces are sensed. If errors in excess of the aforementioned tolerance are encountered, the instrument should be replaced.

Caging

30 The J-8 artificial horizon may be caged manually by means of a gyro centering device operated by pulling the cage knob. To cage the gyro, the PULL TO CAGE knob should be drawn smoothly away from the face of the instrument. (A violent or hard pull may damage the instrument.) A momentary stop will be felt when the bank caging mechanism is engaged; as the cage knob is pulled farther out the pitch caging mechanism is engaged. As soon as the knob reaches the limit of its travel, it should be released quickly.

31 A check to determine whether the caging mechanism has completely released can be made by pushing the caging knob against the instrument case after it has been released. If further travel is evidenced and/or precession of the gyro noted, the caging mechanism is not releasing properly or the erection mechanism is malfunctioning. Failure of the caging mechanism to release completely may result in tumbling of the gyro in manoeuvres.

32 The manual caging device on the J-8 artificial horizon serves a twofold purpose.

(a) It provides a means for quickly erecting gyro for scramble take-off. For scramble take-off, when quick erection is necessary, allow 30 seconds after power is applied to instrument for the gyro to attain speed, then cage the instrument immediately thereafter, to prevent unnecessary torque stresses on the instrument mechanism. The caging feature eliminates the necessity of applying ground power to aircraft on alert to keep the instrument erected.

(b) It provides a means for erecting the gyro when in-flight characteristic errors are induced by turns or aerobatics. In these instances, it is essential that the pilot realize that the indicator cages to the attitude of the aircraft and not to the true vertical. Therefore, the instrument should never be caged to correct in-flight errors unless the aircraft is in straight and level flight by visual reference to a true horizon.

CAUTION

Early production J-8 indicators incorporate ball bearings for engagement of the roll and pitch cams in the caging process. These bearings may break or fall off after excessively hard caging. Care is therefore required in caging the gyro. If there is any evidence of loose or broken bearings in the instrument, the indicator should be replaced immediately. Failure of these bearings will be evidenced by failure of the instrument to zero out when caged. Other deficiencies which render the instrument unserviceable will be reflected by excessive vibration of the horizon bar, by failure of the instrument to erect or level out, or by excessive errors resulting from turns or loops.

ARTIFICIAL HORIZON TYPE A/C (FERRANTI)

General

32A The type A/C artificial horizon provides the pilot with a constant visual indication of the flight attitude of the aircraft in pitch and roll. The instrument has complete freedom through 360° of rotation about the roll axis and effective freedom of 360° about the pitch axis.

Presentation

32B The pitch attitude of the aircraft is indicated within a range of 83° of climb or dive by displacement of the horizon bar with respect to the fixed miniature aircraft. If the pitch attitude exceeds 83° as it does during a loop, a controlled precession of 180° occurs. This controlled precession should not be confused with tumbling or upsetting of the gyro. It will be noted that during a loop two controlled precessions will be effected, one to attain inverted flight and one on attaining normal flight. After completion of these precessions, the indicator is completely operable.

32C The attitude of the aircraft about the roll axis is shown by the angle between the miniature aircraft and the horizon bar and also by the bank index relative to the degree markings on the bezel mask.

32D A power failure indicator is provided in the upper portion of the sky plate. The "OFF" flag will disappear when the power is switched on. If the "OFF" remains visible or disappears and reappears erratically, the instrument is not properly energized or is defective.

Gyro Erection Switch

32E A gyro erection switch is provided to enable the pilot to apply rapid erection to the gyro at a rate of 1 1/2° per second. Normally, any small errors are corrected automatically by the erection system within the instrument. However after the aircraft has engaged in aerobatics or other violent manoeuvres, the artificial horizon may be disturbed and indicate erroneous readings. After such manoeuvres, when the aircraft is straight and level again, or in a shallow climb or dive, the instrument can be quickly restored to a level position by depressing the gyro erection switch.

32F The gyro erection switch should not be operated under the following conditions.

(a) When the aircraft is making a turn.

(b) When the aircraft is engaged in aerobatics.

(c) When the speed of the aircraft is changing steadily for some period (more than about ten seconds).

(d) When the aircraft is in a dive or climb in excess of 83°.

(e) For 30 seconds after the application of power.

(f) For periods longer than one minute or oftener than every 30 seconds.

Operation

32G The artificial horizon is permanently connected into the power system of the aircraft and is energized when the main power switch is turned "ON". The instrument requires approximately 20 seconds for the gyroscope to reach operating speed and usually the instrument is erected at the end of this time. If the horizon bar is not level at the end of 30 seconds, level it by pressing the gyro erection switch.

CAUTION

> The gyro erection switch must not be depressed for periods exceeding ONE MINUTE. If the switch is held down for the full minute, AT LEAST 30 SECONDS must intervene before the next one minute period. If the switch is depressed for longer periods, the instrument may be damaged. DO NOT operate the switch for at least 30 SECONDS AFTER THE APPLICATION OF POWER.

32H Prior to take off the pilot has two simple duties. First to check that the "OFF" flag has disappeared behind the sky plate. Second, to check that the horizon bar is level as indicated.

Characteristic Errors

32J Loops - Instruments marked with a yellow dot are designed for loops at a rate of 20° per second and loops executed at this rate will have errors in pitch and bank of less than 2°.

32K Instruments without the yellow dot may have errors in excess of the above tolerance. Whenever rate of looping differs from the above and/or the axis about which the instrument has been looped is not truly horizontal errors of varying magnitude may be experienced.

32L Turn Errors - The instrument is designed for turn rates of 180° per minute at 250 knots. After accurately executed turns at the above rate and speed, errors in pitch or bank will not exceed 2°.

32M After turns at rates and/or speeds differing from the above or improperly executed, errors of varying magnitude may be experienced.

COMPASSES

General

33 All compasses work on the magnetic north seeking principle. The three main types are:

(a) Self-contained magnetic compasses such as the P4 and P6 in which the N-S indicator is directly attached to the magnets.

(b) Remote indicating magnetic (RI) compasses.

(c) Distant reading gyro - magnetic (DR) compasses.

NOTE

> The following paragraphs give a brief description of these types with recommendations for checking and setting.

Self-Contained Magnetic Compass

34 This type is fitted with a rotatable grid ring and glass. Attached to this are two luminous grid wires parallel to N-S axis of the scale of degrees marked on the periphery of the ring.

35 To set the compass, the grid ring is unclamped, rotated until the required course in degrees on the ring registers with a lubber mark on the fore and aft axis of the compass bowl, and then clamped. The aircraft is then steered so as to keep the N-S line of the magnetic system parallel with the two grid wires with its north seeking pointing to the N mark on the grid ring scale.

Remote Indicating Magnetic Compass

36 The magnetic unit of these compasses, which are fitted in smaller types of aircraft, is mounted in the rear fuselage to minimize magnetic interference from the engine(s). Movements of the magnets relative to the aircraft, are transmitted electrically to a repeater on the instrument panel when compass switch is on. The grid ring of the repeater is similar to that of the ordinary magnetic compass.

ROYAL CANADIAN AIR FORCE

ADVANCE REVISION

Serial #4 dated 1 Mar 61
(Sheet 1 of 1)

The sheet of this Advance Revision is to be inserted in the EO as follows:

Sheet 1 facing page 106

Part 4, Section 1, page 106, paras. 32N and 32O.

Add new para. 32N.

Acceleration Errors - An increase or decrease in speed will result in the horizon bar becoming slowly displaced in a vertical direction. A steady decrease in speed will indicate a "spurious" dive. This decrease would have to occur over a period of five to seven minutes for the dive indication to reach a magnitude of 30°. A steady increase in speed over a period of time will result in a "spurious" indication of climb. Here, again, the acceleration would have to extend over a period of five to seven minutes for the error to be equal to 30°. When the aircraft reaches a fixed speed, depressing the "Gyro Erection" switch returns the system to a correct indication in 15 or 20 seconds. As soon as the aircraft reaches a stable speed the instrument automatically, slowly, returns the horizon bar to a correct reading.

Add new para. 32O.

A typical situation during which the error just described might appear occurs when a jet aircraft goes into a steady climb just after take off. As the altitude increases, the efficiency of the engine increases and the aircraft picks up speed. Because of the characteristic error just described the artificial horizon indicates a steeper than actual climb. The longer the climb takes, the greater the error. For two minutes of steady increase in speed the error can amount to eight to ten degrees.

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37 Before flight, the repeater should be switched on and a check made that the needle responds to changes in aircraft heading while taxiing. Any required course may be set by rotating the grid ring of the repeater by means of the knurled knob.

Distant Reading Gyro-magnetic Compass

38 This is fitted in the larger aircraft. Repeater units at the pilot's, navigator's and other desired stations are operated electrically from a master unit in the rear fuselage. The master unit comprises an electrically driven gyroscope, the axis of rotation of which is stabilized relative to the earth under the influence of a magnetic element. The repeaters are similar to those used with the remote indicating compass.

39 A variation setting corrector between the master unit and the repeaters, can be set to the local magnetic variation so that the repeaters then indicate true and not magnetic bearings.

40 A control unit operated by the pilot, carries an "on-off" switch for the motor driving the gyroscope and a second switch marked "normal" and "setting".

41 To start the compass, switch to "on" and "setting". The repeaters will then be seen to surge until after a few minutes, when the gyro has stabilized, they settle down and oscillate over a range of 8° to 10°. The second switch should then be set to "normal". The instrument is then ready for flight. After setting the variation corrector, the required true course bearing should be set on the repeaters.

42 If, during flight, the indications appear erratic, or the gyroscope is "toppled" by exceeding limiting angles of 70° of bank, climb or dive, set the second switch to "setting" for a few minutes to restabilize the gyro; then return it to "normal". The DR compass should be checked against the ordinary magnetic compass to ensure that it is functioning properly.

43 After flight, compass should be switched off only when the aircraft is finally parked after taxiing.

J2 Compass

44 The J2 compass will topple at angles greater than 85° in the pitching plane. Looping the aircraft on a North-South heading, or rolling the aircraft on an East-West heading will render the compass most susceptable to toppling. Should the compass be toppled, it will reslave normally to the correct heading at the rate of 3° to 6° per minute.

45 If the fast slave button is pressed, the aircraft must be flown straight and level for two minutes after re-cycling. If this is not done, the fast slaving will cease before the compass is on the correct heading.

46 The fast slave button should not be pressed repeatedly without allowing sufficient time for the leveling switch to cool. Five minutes should be allowed after the initial actuation before pressing the button a second time. Ten minutes should be allowed between the second and third re-cycle.

SECTION 2

AUTOMATIC PILOT, MARK 8

INTRODUCTION

1 The Automatic Pilot, Mark 8, includes a gyro unit which operates the aircraft's ailerons and elevators by means of servomotors connected to the aircraft manual controls.

2 The system is operated by compressed air at a pressure of 60 lb/sq. in. supplied from an engine-driven compressor. The minimum pressure at which the system can safely be operated is 45 lb/sq. in. If this pressure cannot be maintained, no attempt should be made to use the automatic pilot.

3 A link to the DR compass is provided whereby accurate course keeping may be achieved. This is effected by a selector switch connected to a contacting device mounted on the setting pointer of the pilot's DR compass repeater. In addition, a mild form of evasive action is provided which will produce a yaw oscillation of approximately ± 15° for a period of 30 seconds.

4 Changes of course are made by banked turns, small corrections being made by resetting the pointer of the pilot's repeater. The aircraft will then turn on to the new course at approximately 3° to 5° per minute. For larger changes of heading, a turn of approximately a rate of 3/4 can be obtained by setting selector switch to the appropriate position, but in this instance the tendency of the aircraft's nose to drop during the turn must be countered by the use of the pitch control.

PILOT'S CONTROLS

Control Cock

5 This is the normal means of engaging and disengaging the automatic pilot. A locking catch is provided to prevent the lever from being moved inadvertently from "spin" to "in".

Clutch Lever

6 This is used for declutching the servomotors which operate main control surfaces and should only be used in an emergency.

Pitch Control

7 This is used to alter the fore and aft attitude of the aircraft.

Control Switch

8 This switch has three positions: "off",

"compass or course", and "jink or turn". When set to "compass or course", course is controlled by the pilot's DR compass repeater. With the switch in the "jink or turn" position the aircraft executes a weaving manoeuvre of about ±15° in a period of approximately 30 seconds. This position can also be used to introduce a rate 3/4 turn for large changes of course.

Combined Trim and Air Pressure Gauge

9 The dial of this instrument is divided into two sectors. The needle in the right-hand sector indicates the main pressure, that in the left-hand sector indicating fore and aft trim.

SEQUENCE OF OPERATIONS

Checks

10 Prior to take-off check that the clutch lever is in the "in" position (fully forward), and proceed as follows:

(a) Move the control column and the ailerons to their extremities of travel, to ensure that the clutches are engaged.

(b) With 60 lb/sq.in. on pressure gauge, check that the control surfaces are free in both the "spin" and "out" positions of the control cock. Where a Mark 14 bombsight is fitted, allowance is made for its simultaneous operation with the automatic pilot and a stop is provided to prevent the control cock lever being placed in the "out" position.

(c) Switch on the DR compass.

Engaging Controls

11 Engage the controls as follows:

(a) When convenient, set the control cock to "spin" unless, in the case of the Mark 14 bombsight installation, the cock is already at "spin". After not less than 5 minutes with the cock in this position, the automatic pilot will be ready for use.

(b) Set the pitch control to the desired pitch attitude of the aircraft.

(c) Trim the aircraft hands and feet off at the desired speed and on course; rudder trim is important.

(d) Set the pointer of the pilot's DR compass repeater parallel with the grid or lubber line.

(e) Set the control switch to "compass".

(f) Move control cock to "in", and check that the automatic pilot is engaged by feeling the control column, which should then resist any movement.

(g) If, after engagement, the aircraft does not fly level laterally, this may be corrected by applying rudder in the opposite direction to that normally used to raise a wing, viz:

(1) If the left wing is low, apply left rudder by trimming.

(2) If the right wing is low apply right rudder by trimming.

NOTE

> If the trim is incorrectly adjusted, the low wing will be depressed still further. No attempt should be made to correct lateral level by the aileron trimmer.

(h) If the aircraft departs slowly from the desired pitch attitude, allow it to settle before making any adjustment to the pitch control, then adjust slowly in the required direction.

12 There is only one position of the elevators which will give smooth engagement of the automatic pilot. Consequently, it may be found that whereas there is no "kick" when the aircraft is lightly loaded, there is a "kick" when at a heavier load or with different C of G positions. Maintenance personnel should adjust the elevator follow-up cable for an average loading condition.

13 If, however, it is found that on first engagement the aircraft has a nose up or nose down change of trim, subsequent engagements may be accomplished with less change of trim as follows:

(a) If on the initial engagement the change of trim was nose up, ease the control column forward prior to subsequent engagements and vice versa.

General Operations

14 The autopilot is operated as follows:

(a) Course changing - slow. - Small changes of course may be made while the control switch is at "compass or course", by resetting the adjustable pointer of the pilot's DR compass repeater. The rate at which the aircraft alters course will be 3° to 5° per minute and the turn will continue until pointer lies parallel to the grid lines.

(b) Course changing - fast. - The pointer should be set to the new course, and then the control switch turned to the "jink or turn" position a banked turn of approximately rate 3/4 will develop. When the aircraft is about 15° short of the desired course, return the control switch to "compass or course". During a fast turn, it will be necessary to keep the aircraft's nose up by small adjustments on the pitch control, returning control to its original setting as the turn is completed.

(c) Jinking. - If control switch is turned to "jink or turn" and left there, the aircraft will perform a mild jinking manoeuvre, swinging from side to side of mean course previously indicated on the pilot's DR compass repeater by about ±15°. The pitch control will need to be adjusted to prevent gradual loss of height during this manoeuvre.

(d) Should the DR compass fail, the pilot's repeater can still be used as a turning switch as follows:

(1) Switch off the DR compass.

(2) Align the pointer with the lubber line and put the control switch off.

(3) To effect a slow turn, displace pointer approximately 10° in the required direction.

(4) Place selector switch to "compass or course".

(5) Turn the selector switch off and re-align pointer when the new heading is reached.

(e) To effect a rate 3/4 turn proceed as above, but, put the control switch to "jink or turn" and anticipate the overswing by placing the switch off approximately 15° before the new heading is reached.

(f) Change of fore and aft attitude. The fore and aft attitude of the aircraft whilst under automatic control can only be altered by means of pitch control provided. The initial movement is slow and the attitude is reached with a minimum of overshooting. Changes of attitude are made only by the pitch control. The degree of adjustment will vary with the type of aircraft concerned and can best be ascertained by practice in conjunction with the scale provided. It is essential that after an adjustment has been made, sufficient time should be allowed for aircraft to settle, before making any further correction.

(g) Do not use manual elevator trimmer to change attitude when the automatic pilot is engaged. It may, however, be used to compensate for changes of trim, by adjusting it until the differentially operated pointer of the pressure gauge is flickering evenly between the red and green sectors.

(h) When it is desired temporarily to regain manual control, the control cock should be turned to the "spin" position. In this position, the aircraft controls are completely free and the gyroscope is maintained at working speed.

Flight on Asymmetric Power

15 The procedure to be adopted in the case of failure of one or more engines is as follows:

(a) Disengage the automatic pilot by moving the control cock to the "spin" position.

(b) Feather the propeller(s) of the unserviceable engine(s). If compressor is mounted on this engine, or on one of these engines, the automatic pilot must not be re-engaged.

(c) Trim the rudder to maintain straight flight.

(d) Re-engage the automatic pilot.

16 It will be found that the automatic pilot

will perform satisfactorily in the case of a four-engined aircraft with two engines failed on the same side, provided that all foot load can be trimmed out before engagement. It is possible to use automatic pilot, even though the available rudder trim is not sufficient, by applying sufficient foot load to the rudder to keep the aircraft on course with the wings level, but this is not recommended at night or in bad visibility.

17 Immediately prior to landing set:

(a) The control cock to "spin".

(b) The control switch to "off".

VITAL PRECAUTIONS

18 Observe the following precautions:

(a) Check that the clutches are engaged before take-off.

(b) Allow 5 minutes in the "spin" position before engagement. In the case of the Mark 14 bombsight installation, there is no "out" position and the gyro rotor is running continuously with the respective engine on which the air compressor is mounted.

(c) Do not disengage the clutches in the air except in an emergency, as it may not be possible to re-engage them if required.

(d) On no account should the pilot leave his seat when the automatic controls are engaged, except to hand over to another pilot.

SECTION 3

AUTOMATIC PILOT, MARK 9

INTRODUCTION

1 The Automatic Pilot, Mark 9 is an all-electric three axis control. At any airspeed, correctly co-ordinated turns up to an angle of bank of 45° can be obtained, but control in pitch is limited to 20° climb and 40° dive. In order to eliminate course wandering, the automatic pilot is monitored in azimuth from a remote indicating compass. Rudder, elevator and aileron control surfaces are operated by three servo motors which are controlled, each by a "rate-of-turn" type gyroscope, orientated to respond to movements about the appropriate aircraft axes, that is roll, pitch and yaw.

PILOT'S CONTROLS

Switch Box

2 This contains:

(a) The main switch for controlling the power supply to the automatic pilot.

(b) An "engage" push switch (green) and a "disengage" push switch (red).

(c) Two indicator lights:

(1) Amber, denoting automatic pilot ready for use.

(2) Green, denoting automatic pilot engaged.

(d) A fore and aft trim indicator.

(e) Three servomotor selector switches.

Pilot's Controller

3 This consists of a small control column capable of being moved fore and aft to control pitch, surmounted by a knob which is rotated for applying turns. Both lever and knob work in the natural sense. The rim of knob forms a safety switch and unless this is depressed the controller is inoperative. A duplicate con-

troller may be provided for the second-pilot.

Auxiliary Cut-out Switch

4 This switch is mounted on the aircraft control column and may be used as an alternative to the "dis-engage" switch on the switch box. A similar switch is also fitted on the second pilot's control column.

SEQUENCE OF OPERATIONS

Before Engagement

5 Proceed as follows:

(a) Ensure that the aircraft AC power supply is on.

(b) Put the automatic pilot main switch on. This switch will not stay on if the power supply is defective but will return automatically to "off".

(c) Put on servomotor selector switches. The amber light on the switch box will appear in approximately 45 seconds, denoting that the automatic pilot is ready for engagement.

Engaging Automatic Pilot

6 To engage the automatic pilot proceed as follows:

(a) Trim the aircraft manually.

(b) Press engage switch. The pitch attitude and aircraft heading immediately prior to engagement will then be maintained and any bank existing at that time will be slowly eliminated.

General Operations

7 The autopilot is operated as follows:

(a) To change pitch attitude. - Depress the rim of the pilot's controller and move the lever as required; when the desired attitude has been reached release the controller entirely.

(b) To change course. - Depress the rim of the pilot's controller and turn the knob as required. To recover from the turn release the knob. The time of recovery to straight flight is proportional to the angle of bank, approximately 10 seconds being required to recover from a 45° banked turn. To straighten out on a desired course, ease off the rate of turn progressively as the required heading is approached.

(c) Elevator trim. - On no account should the normal aircraft trimming controls be used to attempt to change the aircraft attitude when the automatic pilot is engaged. Fore and aft trim for any particular attitude should, however, be maintained by operating the elevator trimmer to keep the indicator in the switch box at zero.

(d) Servo selectors. - These switches permit any individual servomotor to be disconnected at will. When one or more selector switches are off, both the green and amber indicator lights will be on. Normally, the three selector switches should remain in on position, unless for any reason it is desired to operate a particular aircraft control manually. If, all three switches are put off, the automatic pilot will be inoperative; to re-engage, it will be necessary to put the selector switches on and press the engage switch.

(e) Power supply failure. - Failure of the AC supply causes automatic disengagement.

Disengaging Automatic Pilot

8 Depress the disengage switch (red) or the auxiliary cut-out switch.

Precautions

9 Observe the following precautions:

(a) For take-off or landing the main switch should be off.

(b) When testing on the ground, the engines should be run sufficiently fast to ensure that the generators are charging.

Flight on Asymmetric Power

10 Proceed as follows:

(a) Disengage the automatic pilot.

(b) Feather the propeller(s) of the unserviceable engine(s).

(c) Trim the aircraft to maintain straight flight.

(d) Re-engage the automatic pilot if circumstances permit.

SECTION 4

SPERRY GYRO PILOT, TYPE A.3

DESCRIPTION

1 The Sperry gyro pilot includes the following blind flying instruments:

(a) The direction indicator.

(b) The artificial horizon.

2 Two suction-driven gyros control the hydraulic servo-units through pneumatic relays, one controlling the rudder, the other the ailerons and elevators.

3 Above the directional card, there is a follow-up card which must be aligned with it before the gyro pilot is engaged. On the artificial horizon there is a bank follow-up pointer to be aligned with the zero point on the bank scale at the top of the gyro, and an elevator follow-up pointer to be aligned with elevator alignment pointer at the side of the gyro.

4 The pilot's controls are:

(a) The directional unit caging and course-setting knob, which is pulled out to uncage, pushed in to cage, and rotated for setting the course.

(b) The bank and climb unit caging knob, which is rotated for caging and uncaging.

(c) The rubber knob, which is turned to rotate the follow-up card into alignment with the directional card.

(d) The aileron knob, which is turned to align the bank follow-up pointer.

(e) The elevator knob, for similarly aligning the climb follow-up pointer.

5 The speed of response of each control is regulated as required by rotating the appropriate speed control knob in the direction indicated.

6 The gyro pilot is engaged and disengaged, according to the particular installation, by one of the following means:

(a) A single lever, controlling all three servo-units mechanically.

(b) A single cock, controlling all three servo-units hydraulically.

7 Automatic pilot emergency shut-off valve. May also be fitted, which must be "ON" before the automatic pilot can be brought into action. The automatic pilot emergency shut-off valve should be turned to "OFF" position only when system repair or maintenance is required.

8 Automatic relief valves in the servo-units permits the pilot to overpower them if necessary.

9 The pneumatic suction and the hydraulic pressure are shown by gauges. The suction should be between 3.8 and 5 ins. Hg and hydraulic pressure should be within 10 lb/sq. in. of the figure specified for the particular aircraft.

ACTION AND TESTS BEFORE FLIGHT

10 While warming up the engine proceed as follows:

(a) Uncage the gyros.

(b) Check the suction and oil pressures, with the engine running at 1,000 to 1,200 RPM.

(c) It is important that the system be bled of air, especially if aircraft has been parked contrary to instructions with controls locked by the gyro pilot, as movement of the controls by the wind may cause air to enter the system. The method of bleeding is as follows:

(1) Check that the RPM are sufficient to provide the correct suction and oil pressures.

(2) Engage the gyro pilot.

(3) Open the speed valves fully.

(4) Move each control hard over by means of the control knobs.

(5) Rotate these knobs a little further to misalign the pointers and then disengage the gyro pilot. On aircraft on which disengaging the gyro pilot turns off the oil pressure, leave the gyro pilot engaged, but open the servo-unit bypass valves.

(6) Hold the controls hard over manually for 30 seconds then re-engage the gyro pilot and repeat the procedure in the opposite direction.

(d) After a few minutes, check that readings of bank and climb unit are approximately correct for the ground attitude of the aircraft.

(e) Set the directional unit follow-up card and the bank and climb follow-up pointers. Take care to align the climb pointer correctly with the climb follow-up pointer and not with the horizon bar. Engage the gyro pilot and check that it operates each control in turn by making small movements of the control knob, then disengage the gyro pilot.

(f) Before disengaging, the pilot should also check that he can overpower the gyro pilot and that the system is free of air. Freedom from air is indicated by the feeling that the control is positively locked until sufficient force is exerted to overpower it; resiliency of feel indicates the presence of air in the oil.

11 During taxiing, change direction and check that directional gyro indicates approximately the changes made.

OPERATION OF GYRO PILOT IN FLIGHT

Engaging

12 To engage proceed as follows:

(a) Trim the aircraft with the trimming tabs.

(b) Ensure that both gyros are uncaged.

(c) Set the speed valves suitably.

(d) Set follow-up card and pointers.

(e) Engage the gyro pilot slowly.

Adjustment of Speed Valves

13 If a control "hunts", speed valve should be turned as required until the hunting ceases. It should not be turned further than necessary to stop hunting. The position at which hunting ceases should, therefore, be checked by opening the valve slightly until hunting occurs and then closing it again as necessary.

14 In rough weather, the valves should be turned a little further towards the slow position to avoid any risk of the aircraft being overstrained by too vigorous operation of the controls. They should not be closed so far that response becomes sluggish. Never close them completely, since that would lock the controls, which might then move right over when the valve was reopened.

Periodical Retrimming

15 The gyro pilot should be disengaged occasionally during a long flight or after release of load, and the aircraft retrimmed.

Changing Course

16 Small changes of course may be made in flat turns by slowly rotating the rudder knob.

17 For large changes of course, up to 30° bank may be applied with the aileron knob, and the rudder knob may then be turned at a suitable rate. Maintain height with the elevator knob and take-off bank as the desired heading is approached.

18 An alternative method of making banked turns, is to cage the directional unit and then to turn the aileron knob until the desired banked turn is obtained. Maintain height with the elevator knob. To resume straight flight, remove the bank by means of the aileron knob; then reset the follow-up card and uncage the directional unit.

OPERATING LIMITATIONS

19 The two gyros should normally be uncaged

ROYAL CANADIAN AIR FORCE

ADVANCE REVISION

Serial #5 dated 5 Jul 61
(Sheet 1 of 1)

The sheet of this Advance Revision is to be inserted in the EO as follows:

Sheet 1 facing page 113

Part 4, Section 4, page 113:

ADD the following at end of para. 22(d):

WARNING

Automatic pilots are to be disconnected prior to aircraft reaching minimum altitude preceeding final landing approach.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

on entering cockpit and left uncaged throughout the flight. They must, however, be caged before performing acrobatics and before steep dives and steeply banked turns.

20 The gyro pilot may start to hunt or over-control at cockpit temperatures below -15°C. If this occurs, gyro pilot must be disengaged and the aircraft flown manually; the bank and climb control unit should then not be used as a flying instrument.

FLIGHT ON ASYMMETRIC POWER

21 If the gyro pilot is in control at the time of engine failure, it should be disengaged and the tendency to yaw checked with the rudder.

22 To engage the gyro pilot after an engine failure proceed as follows:

(a) Open up live engine(s) as necessary, trim the aircraft.

(b) Turn the rudder and aileron speed control knobs towards the fast position, but avoid hunting.

(c) Set the follow-up card and pointers.

(d) Engage the gyro pilot slowly.

SECTION 5

PRESSURE CABINS

INTRODUCTION

1 The need for pressure cabins is discussed in Part 1, Section 3.

DESCRIPTION AND OPERATION

2 Pressure cabins are fitted to most aircraft which are capable of exceeding a height of 35,000 feet. The cockpit, or crew compartment, is made as airtight as possible, and air under pressure is supplied to it by an engine-driven pump or pumps. All controls which pass out of the pressure cabin are fitted with suitable glands, and doors and windows are made airtight by inflatable rubber seals.

3 Before flight, hoods should be inspected thoroughly for cracks and security. If the hood is of the "sandwich" type, it is important to check that the silica-gel containers are still effective for drying the air in the sandwich. The silica-gel crystals turn from blue to pink when they become ineffective. The hood must be tightly closed and pressurizing should be selected on the ground when it is intended to climb to altitude. The pressurizing and cabin seal control should be turned off before landing. Where a separate cabin seal control is fitted, it is important to check that this control is off before hood is opened, or extensive damage will occur to the rubber gasket.

4 Two controls are normally provided, one for inflating the cabin seals, and one for admitting the air under pressure. A cabin altimeter is usually fitted, showing the effective altitude when under pressure, and there is also a cabin pressure warning light, which comes on if the difference between cabin and external pressures falls below a certain figure. The oxygen flow should be regulated to correspond to the cabin altimeter reading.

PRESSURE FAILURE

5 Loss of cabin pressure may occur through failure of pump(s), stoppage of the engine(s), or by leaks developing in the cabin, for example, through enemy action, breakages, or by accidental release of the cabin seals. In turbine jet propelled aircraft, the cabin air supply is sometimes taken from main engine compressors, and the pressure may drop if the engines are run too slowly to compensate for normal cabin leakage. The pressure drop may be shown by an increase in cabin altitude when flying at a constant height, or by the cabin pressure warning light.

6 If the height is not greatly in excess of

35,000 feet when pressure failure occurs the pilot may make an attempt to find the cause and to remedy it. If, however, complete or partial failure occurs or cracks appear in the canopy at heights above 40,000 feet the pilot should:

(a) Open the speed brakes and descend immediately.

(b) Turn the oxygen supply to emergency until a cabin altitude below 40,000 feet is reached.

(c) If pressure breathing equipment is being used, turn the knob of the mask expiratory valve to HIGH until the cabin altitude is less than 40,000 feet.

(d) Not turn off the cabin pressurizing until below 38,000 feet.

(e) Not exceed the limiting speeds.

FURTHER INFORMATION

7 For details of the operation of individual pressurizing systems, POI for the aircraft concerned should be consulted.

SECTION 6

EJECTION SEATS

INTRODUCTION

1 When an aircraft is abandoned by parachute, the pilot has to compete with two forces which tend to impede his actions:

(a) Wind pressure due to the speed of the aircraft and slipstream from the propeller, where a propeller is situated in front of the pilot, and

(b) "g", when for example, an aircraft has to be abandoned in a spin.

2 Owing to the increasingly high speeds now attained, it has been found necessary to adopt a method by which a pilot, and other crew, where applicable, can be positively ejected, and this is now a requirement for all high-speed aircraft. When an ejection seat is fitted, it is generally desirable to abandon the aircraft by this method as it provides a surer means of escape and a greatly increased chance of clearing airframe obstructions.

2A Recent study and analysis of escape techniques from aircraft by means of ejection seats have revealed that:

(a) Ejection accomplished at airspeeds ranging from stall speed to 525 knots IAS result in relatively minor forces being exerted on the body, thus reducing the injury hazard.

(b) The crewmember will undergo appreciable forces on the body when ejection is performed at airspeeds of 525 to 600 knots IAS, and escape is more hazardous than at lower airspeeds.

(c) Above 600 knots IAS, ejection is extremely hazardous because of excessive forces on the body.

(d) Ejection at low altitudes is facilitated by pulling the nose of the aircraft up above the horizon ("zoom up" manoeuvre). The trajectory of the ejection seat from a level flight attitude is indicated in Figure 4-1. In comparison, Figure 4-2 indicates the ejection seat trajectory from an aircraft in a nose up attitude.

2B Figures 4-1 and 4-2 indicate that the trajectory of the ejection seat is not perpendicular to the flight path of the aircraft but rather, is the resultant of the aircraft velocity

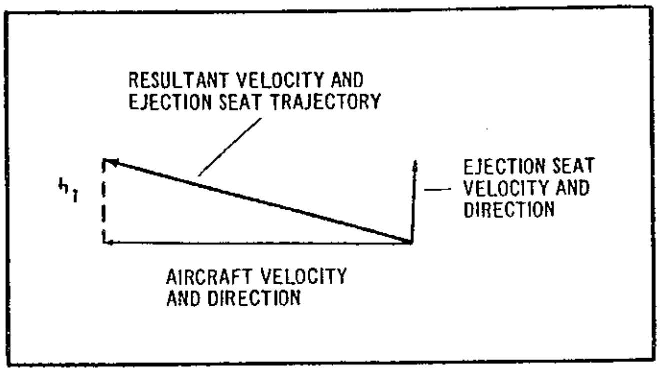


Figure 4-1

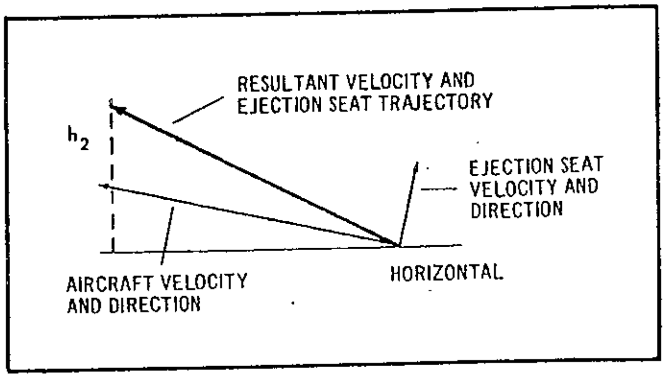


Figure 4-2

and upward velocity of the ejection seat. Since the ejection seat velocity is very small compared to the aircraft velocity, the ejection seat tends to follow a nearly horizontal path as shown in Figure 4-1. A "zoom up" manoeuvre, as indicated in Figure 4-2, will result in the ejection seat trajectory coming closer to the vertical, thus effecting an increase in altitude and an increase in the time available for separation from the seat and deployment of the parachute.

2C Flight tests have indicated the following approximate differences between ejection altitude and the altitude at which full deployment of the parachute occurs. This data is based upon use of an automatic safety belt and automatic parachute.

Flight Conditions	Full Deployment Above or Below Ejection Altitude
(a) Level Flight - 200 knots IAS	100 to 150 feet below
(b) 6° nose up - 200 knots IAS	20 to 70 feet below
(c) 12° nose up - 300 knots IAS	10 feet below to 60 feet above

2D With nose up attitude ejections, higher aircraft speeds will result in slight improvements in altitude of full parachute deployment relative to ejection altitude. For manual safety belt or manual parachute, full deployment will occur at a lower relative altitude.

2E The tests indicate that whenever circumstances permit, the aircraft should be slowed down as much as possible, prior to ejection. Also, when ejecting at altitudes below 2000 feet, pull the nose of the aircraft above the horizon if at all possible.

3 As the details will vary according to the installation in individual aircraft types, aircrew should be guided by the instructions in the AOI for those types rather than by the information given in paragraphs 1 to 2E above, which is of a general nature only.

WARNING

Some factors which affect all altimeters in use today are the following:

(a) Lag - Altimeters always show an altitude behind that of the aircraft whether climbing or diving. The pointers only unwind at a maximum rate of 600 to 625 fps (360 to 370 kts). If the vertical speed exceeds this, the instrument is unable to keep up and may be 5000 feet or more in error in a prolonged dive.

(b) Pressure Altitude - Over 24,000 feet, aircraft fly using the standard altimeter setting of 29.92" mercury. If the actual altimeter setting should be lower, then the indicated altitude will be higher than the actual altitude.

(c) Temperature - When the temperature at altitude is below standard the altimeter will read high.

(d) Hysteresis - The resultant lag or drift in the altimeter caused by the elastic qualities of the materials which comprise the instrument; the effects are most pronounced when a flight level temperature has been maintained for an extended period of time then suddenly a large altitude change is made.

Other factors which must be considered are the time intervals required for the ejection seat mechanism and the seat separator (if installed) to operate.

The safe ejection altitudes shown in specific AOIs are true altitudes; an additional 5000 feet or more should be added to the safe ejection altitude if the aircraft is diving, operating in a low pressure area or the temperature at altitude is below standard.

(Pages 115 and 116 Deleted by this Revision)

SECTION 7

MISCELLANEOUS EQUIPMENT

STEERABLE NOSEWHEELS

1 These are sometimes fitted to large tricycle-type aircraft with the object of improving their ground handling qualities. They enable the aircraft to be taxied with its rudder locked, thereby relieving the pilot of large foot loads when taxiing down or across wind.

2 The nosewheel is usually controlled by a separate steering wheel which may be concentric with the aileron wheel on the control column, or may be in any other convenient position in the cockpit. Sometimes the nosewheel is not steerable throughout its range, but casters freely after a certain angle has been reached.

3 No attempt should be made to turn the nosewheel while the aircraft is stationary, but once in motion, it may be used to control direction and the throttles left at any suitable opening. Throttles and brakes may be used to assist the nosewheel if required, but should never be used against it.

4 The nosewheel may be used to steer the aircraft down the runway in the early part of the take-off run, while rudder control is not fully effective.

COCKPIT HOODS

5 Most single-seat, and many training type, aircraft are fitted with sliding hoods, which in many cases are opened and closed manually by a winding handle, or occasionally by power-operated means. They are fitted with a jettisoning device for use in emergency.

6 In the past, it has been the practice to have the hood open for take-off and landing to provide an easier way of escape if the aircraft should turn on its back. With modern land based aircraft, however, this practice is being abandoned, for a number of reasons. On modern airfield surfaces, the risk of overturning on the ground is not nearly as great as it may once have been, and flying with the hood open on some aircraft provides a number of undesirable effects such as control buffeting and the entry of fumes into the cockpit; and it may also increase the stalling speed appreciably. Lastly, but by no means of least importance,

pilot's comfort is greatly enhanced by having hood shut, and this contributes considerably to the safety of the take-off or landing.

7 Hoods are not opened nowadays except for the sake of better visibility and in exceptional circumstances, to improve ventilation. Although it may be possible to open hoods at any speed in some cases a speed limitation is imposed. In all cases, unless POI state otherwise, it is recommended that they should only be open at speeds in the neighbourhood of, or below, those given in POI for flying at reduced airspeed. If the presence of fumes in the cockpit is suspected, the oxygen should be turned fully on. On aircraft in which an engine and propeller are in front of the pilot, hoods should be open for taxiing, as this usually enables a better lookout to be kept.

8 If an emergency requires the hood to be jettisoned, the pilot should first lower his seat fully, if time permits, and should keep his head well down. If it is not possible to lower the seat, the head should be kept well forward.

WINDSCREEN AND HOOD DE-ICING AND DEMISTING

9 Removal of ice from the outside of the pilot's or crew's windscreen is effected by an alcohol spray. The necessary equipment comprises a storage tank for alcohol, a handpump and a spray pipe forward of the windscreen.

10 Usually a Rotax type handpump is fitted, but some aircraft may have a Ki-gass pump. The Rotax type pump comprises a plunger and locking device and a flow regulator. When plunger is depressed, a spring returns it slowly; this action feeds a continuous flow of alcohol to the spray pipe. The plunger should not be depressed again until it has reached the fully out position. The rate of return of the plunger and consequently the rate of flow of the alcohol can be controlled by the flow regulator; by setting regulator from 1 to 4 the flow is regulated from slow to fast. Delivery from the Ki-gass type pump is only obtained when the plunger is depressed and the pump operated. There is no flow regulator.

11 Some later aircraft have electrically driven windscreen de-icer pumps. Normally the delivery of alcohol is at a constant rate, but an emergency flow can be obtained from an additional Ki-gass type handpump.

12 One of two types of spray pipe may be fitted. A single spray pipe forward of windscreen is used where a windscreen wiper is installed: the slipstream and action of wiper spread the alcohol over the windscreen. Where there is no wiper, the alcohol is fed from a perforated pipe which runs along the base of the windscreen.

13 Many hoods are of the moulded bubble type and are referred to in the POI for some aircraft as canopies. Some hoods of this type especially those fitted to pressurized aircraft, as well as many windscreens, are of the sandwich type which help to prevent misting. The air between the two sheets of glass or plastic is kept in circulation and dried by passing it through cartridges containing a drying agent, usually silica gel crystals. The crystals change colour, usually from blue or green to pink, when they become saturated with moisture thus giving an indication that the cartridges require replacing. In some cases the air is circulated by means of electrically driven fans or pumps.

CABIN HEATING AND VENTILATION

14 Most modern aircraft are warmed by air passed through some form of heating muff which draws its heat from the engine exhaust system, or from the jet pipe in gas turbine engines. Occasionally heat may be provided by the coolant system of a liquid-cooled engine. In either case, heat may be regulated by a master control and by individual crew members at their stations. It should be noted that on the ground, it is rarely possible to check whether a cabin heating system is operating satisfactorily, as there is insufficient airflow. In flight with the radiator type of cabin heating system, if the coolant temperature is below the minimum for cruising, air may not be warmed, regardless of position of the heat-control valve.

15 Ventilation is often provided by louvres which can be adjusted to admit any desired amount of cold air or to blank off the supply completely. On transport aircraft, there is usually a louvre at each crew and passenger position, and there may be master control valves in addition. On some aircraft, cold air is supplied through the cabin heating system when the heat is turned off; in this case the

amount of cold air is usually controllable.

16 For information about heating and ventilation systems in various aircraft, the appropriate POI should be consulted.

COCKPIT LIGHTING

17 New aircraft coming into service are now fitted with a dual system of cockpit lighting. Two kinds of illumination are used; ultra-violet lighting for the instrument panel and red lighting for the whole cockpit. To avoid reflection from the windscreen and windows, a black coaming is usually fitted below the windscreen. In order to increase the visibility of the instruments without the need for a large amount of lighting, the instruments required for night flying are marked with a fluorescent paint which glows orange when activated by ultra-violet radiation.

18 The best way of using the dual system is to turn up the red floodlighting until controls and markings can just be seen, and then to turn up the ultra-violet lighting until the markings are clear enough to be easily read.

19 As both the red and the ultra-violet lighting are provided by the main aircraft electrical supply, there is an emergency lamp, supplied from a separate alkaline accumulator, for use in the event of failure of the main batteries.

AIR-INTAKE FILTERS

20 Engine air filters are fitted to all service aircraft except flying boats, their function being to prevent undue engine wear due to the inspiration of dust or sand into the engine. In the majority of installations, the filter can be by-passed in order that maximum engine performance may be obtained in normal flight. Air filters are intended to be used at all times for engine running on the ground, starting up, taxiing, take-off, initial climb, and in flight through dust laden atmosphere.

21 The majority of installations are fitted with a removable filter panel which may be either of the wet or dry type. The filter panel consists of a rigid frame containing the filtering material. A dry type filter element is constructed from cotton wadding compressed between layers of gauze and supported by light-gauge wire mesh. This acts as a sieve which retains the dust load. A wet type filter element consists of a layer of absorbent cotton gauze sewn between two layers of woven wire mesh, the whole being saturated with oil thereby forming sticky surfaces on which the dust particles are collected.

22 The control system for the engine air filter installation varies in different aircraft, and reference should be made to POI for the type. Some aircraft have separate controls for filter and for the hot air intake, whereas others have a three-position lever or switch marked "filter" - "hot" - "cold, ram or normal", at appropriate positions. The mechanism for the selection may be operated manually or by electric or electro-pneumatic means. In addition to the pilot's control, some aircraft embody an automatic inter-lock with landing gear which ensures that the filtered air intake is always in circuit when the aircraft is on the ground. Thus, with the landing gear down, filtered air is obtained regardless of the position of the pilot's control. On this type of installation, the pilot's control should be set in the "filter" position for take-off as if this control is in the "normal" position, raising the landing gear will cause a change from "filter" to "normal" and at high power this may result in a weak mixture cut.

23 Filter installations are of two main types, ramming and non-ramming. Non-ramming installations are preferable as very high filtration efficiencies can be obtained, but only at the expense of an increased pressure drop which affects engine performance. In future, non-ramming installations will generally be confined to those engines having a large reserve of boost above normal take-off boost.

24 The pressure drop reduces full throttle height of the engines to a degree varying with the particular installation but this reduction seldom exceeds 2,000 to 3,000 feet. Thus unless the normal full throttle height at the required take-off boost is less than 2,000 to 3,000 feet above the altitude of the airfield, the required boost should be obtainable for take-off.

25 With engines having little or no reserve of boost, take-off from airfields at a high altitude or under tropical conditions, may necessitate by-passing the filter in order that full take-off boost may be obtained. Similarly, if

a take-off is required to be made from a restricted runway, from an aircraft carrier, with a heavily loaded aircraft, or when glider towing, it may be necessary to use a boost rating in excess of that normally used for take-off, and by-passing of the filter may then be essential. In such cases, the POI for the type may recommend that filter should be by-passed for take-off. On certain aircraft, particularly naval types, means are provided which enable landing gear interconnection to be cut out of circuit, thereby permitting the pilot to select "normal" air intake for take-off. On later types landing gear interconnection is being deleted in favour of a simple straightforward pilot's control.

HOT/COLD AIR INTAKES

26 When flying in certain conditions of humidity and temperature, ice will quickly build up on throttle butterflies and in the induction system. To obviate this, most aircraft are fitted with a shutter system to blank off the entry of the cold air and obtain warm or hot air from inside the engine cowling.

27 The intake shutters may be operated from the cockpit either manually by means of control rods and cables or, electro-pneumatically by a selector switch which may have a third position for selecting filtered air. On some installations, fitted with gapless ice-guards, air is automatically drawn through the hot air intake when the ice guard becomes blocked.

28 The effects of warm air can be summarized as follows:

(a) The use of warm air causes a loss of power at given RPM and boost by reducing the weight of charge drawn in. Therefore, cold air should be used for maximum power, although, when a take-off or landing is made in severe icing conditions or in cold humid weather, it may be advisable to use warm air to prevent carburettor icing. When taking off, however, the all-up weight and available run should then be considered in conjunction with the slight loss of power, due to the reduced weight of cylinder charge. Warm air should not be used at boosts in excess of +18 lb/sq. in., or at any take-off power, if the outside air temperature exceeds +10°C (+50°F), as the resulting temperature rise may cause detonation.

(b) If warm air is used, a change back to cold air must not be made during take-off, when going round again, or during a mislanding, until power has been reduced.

(c) When warm air is used the ram effect is lost, the full throttle height is lowered, and the power obtainable above full throttle height is reduced.

(d) If the carburettor is fully compensated for varying charge temperatures, the use of warm air may have no adverse effect on range; it may even increase range by improving the charge distribution at low power, especially in cold weather. If the carburettor is not temperature-compensated, warm air will decrease range. The adverse effect may not be serious, but should be borne in mind.

(e) Cold air must always be used for starting, as if warm air is used:

(1) With an up-draught carburettor, a backfire may ignite any priming fuel which may have reached the engine bay.

(2) The intake shutters may be damaged by backfiring.

SAFETY HARNESS

29 The safety harness should be worn at all times in flight; in an emergency there may not be sufficient time for fitting it. The harness should always be tight and locked before taking off, landing, crash landing or ditching. It should be kept reasonably tight in flight, but may be unlocked to provide greater freedom of movement.

30 It is important that the "Q" or "Z" harness is fastened correctly as it is designed to hold the wearer down as well as back. The correct method of fastening is as follows:

(a) Before putting on the harness, test the quick release box to make sure that it unlocks properly. Then fasten the two thigh straps and pull them down tightly. Next fasten shoulder straps, which may be comfortably loose for taxiing and normal flight, but should be pulled tight and the harness then locked before taking off and landing.

(b) Should the shoulder straps be tightened before the lap straps, the quick release box will be displaced upwards, thus considerably reducing the vertical restraint on the wearer.

(c) The harness is usually fitted with a release which, in the unlocked position, frees the shoulder straps, thus permitting wearer to lean forward although still hold down securely by the thigh straps.

(d) If quick release box fails to release, one of the thigh straps can be pulled right through its buckle, thus if the shoulder straps are slackened, wearer can slip out of the harness. For specific thigh strap, refer to applicable aircraft AOI.

(e) Z type harnesses are fitted in the later aircraft. The general design and method of adjustment is similar to that of the Q types, which they supersede, but they, together with their attachments, are more strongly constructed, being stressed to stand a loading of 25g. The release mechanism with Types ZA, B and C is so arranged as to permit, within limits, free forward and backward movement, after operation of the release lever. Details of the operation of this release vary with different aircraft and particulars are given in POI for the type. With ZD type harnesses fitted to Mark 1A type ejection seats, shoulder straps are attached to the parachute stowage. and the release is then arranged to permit this stowage to move forward with the wearer.

CAUTION

Aircrew are to ensure that, in the fully back position, with the manual lock of the inertia reel in use, there is sufficient slack in the shoulder harness to permit the forward release to operate, otherwise the harness cannot be disengaged other than by the safety belt or by releasing harness buckles.

INSTRUMENT FLYING PRACTICE EQUIPMENT

Introduction

31 This equipment enables instrument flying conditions to be simulated in clear weather. The simulation is obtained by making use of two colours which are complementary to each other, i.e., cutting off different parts of the spectrum. Each alone is a clear transparency, but combined they can cut out all daylight. The colours used are blue and amber.

Equipment

32 The equipment consists of screens of one of these colours, which are attached to the aircraft, and goggles of the other colour worn by the pilot. The screens are attached to the windscreen, side panels and forward parts of the canopy, leaving a clear space behind the pilot through which there is an unrestricted entry of light, and are normally detachable in flight. The goggles are provided with filters of different intensities suitable for varying daylight conditions. When amber screens and blue goggles are used the scheme is known as the amber screen system. When blue screens and amber goggles are used the scheme is known as the blue screen system.

Characteristics

33 Both systems give the pilot under training the impression of darkness outside the cockpit according to the density of the goggle filter being used, while inside the cockpit he has an unrestricted view of instruments and controls. Using the amber screen system the pilot's vision of red indicator lights and of colours on maps is considerably impaired and with the darker density filters they may be visible to him. The blue screen system is most satisfactory in climates where bright sunshine and clear visibility is normal but less useful in conditions where mist or haze frequently occur. The amber screen system is suitable in conditions where limited visibility due to haze or mist is prevalent. When goggles are not worn the blue screens give an impression of pale blue daylight and distance visibility is reduced in misty or hazy weather. Amber screens, however, provide greater contrasts in misty or hazy weather than are obtained with either blue screens or even through clear panels and therefore afford slightly improved visibility under these conditions. In either case the instructor or safety pilot has an unrestricted view both inside and outside the aircraft.

Instructions for Use

34 The screens should be correctly fitted to the aircraft and if for the type of aircraft it is necessary to use an additional light to illuminate the cockpit this should be turned to maximum brightness. When ready to commence practice the pilot should put the goggles on and ensure that they fit correctly.

SECTION 8

OPERATING NOTES

INTRODUCTION

1 This chapter deals with points of airmanship which are common for the correct operation of most types of aircraft, and with which most pilots are familiar; therefore, they are not usually mentioned in individual POI.

CHECK LISTS

2 The object when using the pilot's check list is to ensure that there are no obvious defects in the aircraft and that all ground and picketing equipment has been removed and, if applicable, properly stowed. Such checks are not necessarily intended to replace the daily inspection and, with experience, it should be possible to carry out a thorough check in a few minutes, even in the case of a four engine aircraft. The check lists are arranged in a systematic order. The external checks are listed in clockwise order around the aircraft starting and finishing at main crew entrance; the internal checks start at the rear and work forward, while cockpit checks are arranged in order from left to right and, where applicable down the center. These check lists deal with the "standard" aircraft and deliberately exclude any items of operational equipment which must, of necessity, vary according to the role of the aircraft. They also include a full list of the checks to be carried out, both before take-off and before landing, and also details of the actions to be taken both before and after stopping the engines. It is not suggested, however, that it would be possible, or even practicable, to complete all the checks before every take-off and before and after every landing. The check lists aim to provide enough information to enable a pilot, even on a type of aircraft with which he may be unfamiliar, to ensure that the aircraft is correctly prepared for flight. To fly an aircraft safely, though not necessarily in accordance with operational requirements, reference should be made, if need be, to the POI which should be stowed in the pilot's cockpit of every aircraft. After flight, compliance with the check lists should enable the pilot to leave the aircraft in as high a state of serviceability as possible. The method of using the check lists must depend upon the circumstances. Pilots may wish to work through all or part of a check list thoroughly and they may find the assistance of another member of the crew a help in doing this. When thoroughly familiar with an aircraft some pilots may not wish to use the check lists except to refresh their memories from time to time. The check lists contain only those items which it is the responsibility of the pilot, as pilot, to check; they do not include such items as may be the particular responsibility of other members of the crew. Pilot's Operating Instructions embodying these check lists should be stowed in the cockpit of every aircraft to ensure that the pilot has to hand all essential information.

WHEEL BRAKES

3 Most aircraft are fitted with pneumatically operated brakes; in some types they are operated hydraulically. Efficiency and life of aircraft wheel braking systems can be greatly increased by careful operation. The risk of damage due to brake failure can be minimized as follows:

(a) Before entering the aircraft, pressure pipe lines attached to the oleo legs should be inspected for fracture or signs of wear.

(b) Before starting up, note the supply pressure. If it is below the minimum permissible figure, the system should be "topped up" by an external charging unit.

(c) On starting up, ensure that the pressure is being built up by the pump(s) and if gauges showing the pressure applied at each brake are fitted, check the pressures indicated with the brakes on.

(d) When running up against chocks, the brakes should be applied as an additional precaution before power is increased. Chocks of the correct size should always be used to pro-

vide the maximum resistance and to facilitate their subsequent removal.

(e) As soon as the aircraft starts to move forward for taxiing, brakes should be checked for operation, individually and together.

(f) In aircraft having manually operated brake systems, it is advisable to apply and release the brakes a few times prior to landing to determine by feel whether the brake system is functioning properly. If the pedals feel "soft" or "spongy", it may be possible to "pump up" the brakes prior to landing to ensure the best possible operation. A pumping action on the pedals will transmit hydraulic fluid from the reservoir to the braking system. After landing a single smooth application with constantly increased pedal pressure is most desirable for short landing rolls in emergencies. This procedure is equally important when operating on emergency braking systems, since emergency systems usually supply only three full brake applications before the system is depleted.

(g) Immediately after landing or any period when there is considerable lift on the wings, extreme care is to be used during any brake application to prevent skidding the tires and causing flat spots. Proper traction cannot be expected until the tires are carrying heavy loads. In the event that maximum braking is required after touchdown, lift should first be decreased as much as possible by raising the flaps and dropping the nose (on tricycle gear aircraft) before applying brakes. This procedure will improve braking action by increasing the frictional force between the tires and the runway. Where applicable aircraft equipped with reverse pitch propellers, reverse pitch should be utilized wherever possible in lieu of normal wheel braking.

(h) Allow the brake drums to cool down before applying the parking brake. It is desirable that the brakes should be released as soon as the chocks are in position.

(j) On aircraft with adequate forward vision, the tail wheel lock, if fitted, may be used to keep straight, thus saving the brakes. When used, it must be disengaged before attempting to turn.

Use of Brakes in Air

4 To stop the wheels spinning after take-off, the brakes should be applied momentarily. This should be done before retracting landing gear; otherwise, if brakes are applied during retraction, an undesirable stress may be imposed on the landing gear structure.

5 Vibration of the aircraft in flight may be caused by wheels spinning in the nacelles. In these cases, an application of the brakes to stop the wheels will also stop this vibration.

SPEED BRAKES

Introduction

6 The low drag characteristics of jet aircraft combined with lack of propeller braking has given rise to the necessity for the use of speed brakes; their main purpose is to provide rapid deceleration, and to restrain build-up of speed when high rates of descent are used. In addition, it is now possible at high altitudes to achieve Mach numbers at which control difficulties may arise, and speed brakes are an invaluable aid in regaining control in these circumstances. In some cases, however, the use of speed brakes at high Mach numbers may induce buffeting to a degree which counteracts any advantage obtained by their use in these circumstances. Speed brakes are designed so that they are capable of decelerating the aircraft rapidly at high indicated airspeeds and high Mach numbers, and should be effective at all altitudes up to the limiting speed of the aircraft. Any trim change due to their use and any effect on the aircraft's stalling speed is kept to a minimum.

Types of Speed Brakes in Use

7 The terms dive brakes, dive flaps, lift

spoilers, and brake flaps, have all been used to describe the various forms of speed brakes. On British aircraft they normally take the form of prongs (finger type) extending and retracting vertically, or perforated or plain flaps retracting into the upper and lower surfaces of the center section or wings. The type used in American aircraft are normally situated on or under fuselage. Speed brakes may be electrically, hydraulically or pneumatically operated by a control in the pilot's cockpit which normally is situated adjacent to throttle control.

Uses

8 Speed brakes are normally used in the following circumstances:

(a) To reduce high indicated airspeeds or high Mach numbers in order to maintain control.

(b) To reduce excessive speed as required when entering the circuit or when forming up for formation flying.

(c) To permit a high rate of descent without excessive airspeed or Mach number.

(d) To adjust overtaking speed during AI interceptions.

(e) To increase manoeuvrability by reducing excessive speed in various tactical manoeuvres, such as dive-bombing and RP attacks.

9 In certain circumstances, they may be used during approach and landing, to reduce speed and prevent excessive "float" during the hold-off. Their use in these circumstances is not normally recommended, as little advantage is gained if the correct flying technique has been applied in the first instance. If, however, speed brakes are used as an additional aid for the approach and landing, it should be remembered that the stalling speed may be higher and forward acceleration slower than normal any loss of speed, particularly in a turn, will be difficult to regain and may involve a large loss of height; in addition, going round again will be more difficult. Their use should, therefore, be confined to special cases when it becomes necessary to lose height and speed rapidly during an approach, but then only if the POI for the type indicate that they are effective at such low airspeeds. In the case of aircraft without flaps, the use of speed brakes for landing will be covered in the POI.

Effects

10 Individual characteristics of speed brakes vary with different aircraft, but the following main characteristics will be encountered on the majority of service types:

(a) Deceleration: Speed brakes are equally effective at the same IAS at any altitude, but become increasingly less effective with reduction in IAS.

(b) A degree of buffeting which varies with the airspeed and Mach number.

(c) Change of trim.

(d) An increase in stalling speed.

11 Present designs are effective in their primary function within certain limitations, but pilots should investigate the effects of their use in different circumstances at a safe height, in order to familiarize themselves with any characteristics which become apparent particularly when their use is extended beyond that for which they were originally intended.

DESCENT FROM HIGH ALTITUDE

Introduction

12 Descent from high altitude is not purely

a question of reducing engine power and diving the aircraft at high speed. The problems of high-speed flight in changing temperatures and of efficient engine operation must be considered.

Piston Engine Aircraft

13 When flying at altitudes in the region of 35,000 feet true airspeeds are likely to be very high and maximum permissible speeds can easily be reached when descending. The maximum indicated speeds or Mach numbers, for various heights, quoted in POI should not be exceeded.

14 There are two extreme methods of descending, one by diving the aircraft at the maximum permissible speed, and the other, by increasing drag through lowering the flaps, landing gear or speed brakes, at the same time reducing engine power, to prevent excessive airspeeds. The method to be employed depends upon the type of aircraft and equipment with which it is fitted. A compromise between the two extremes is normally used.

15 With fighter-type aircraft, a rapid descent can be carried out by diving at high speed with reduced engine power. However, use of too small a throttle opening should be avoided as undesirable inertia loads will be placed on the engine if low boost is used. Cruising RPM and at least a third throttle opening should be used, and will prove suitable for most aircraft. Engine temperatures must be watched carefully, and if they become low, rate of descent and airspeed should be reduced and the power increased for a short warming period. Oil cooler shutters, and/or cowling or radiator shutters should be fully closed.

16 On aircraft fitted with an automatic supercharger gear changing control and with "auto" selected, the pilot need not worry about the change over from high to low gear during descent, but on aircraft with manually operated

supercharger controls, presuming high gear has been used at high altitude, the change over from high to low gear during descent must be made by the pilot. The most suitable time for the change is before the descent is started, as power is normally reduced and greater fuel ecomony will be achieved by an early change to low gear.

17 On larger types of aircraft, where high speeds are undesirable, a reasonably high rate of descent can sometimes be obtained by lowering the flaps and/or landing gear. The limiting speeds for the lowering of these services must not be exceeded and on certain types of aircraft, this may seriously reduce the rate of descent obtainable. If speed brakes are fitted, these should always be used; high rates of descent at reasonable airspeeds can be obtained and at the same time, sufficient power for efficient engine operation can be used. Engine considerations are the same as for fighter type aircraft; temperatures must be watched, and warming periods should be frequent, particularly in icing conditions.

18 Weather conditions have a bearing on the method of descent to be used. High speeds and rates of descent are undesirable in cloud, particularly in turbulence; on the other hand, rapid passage through icing layers may be required. Descent from very low temperatures to warm and humid conditions frequently produces airframe icing and windscreen misting or icing. Sufficient time must be allowed for the windscreen to clear before landing.

Turbine-jet Propelled Aircraft

19 At heights above 35,000 feet, cruising flight on some types of turbine-jet aircraft may be at a speed approaching the Critical Mach number. Due to the low drag of this type of aircraft, a small downward displacement of the nose will result in a rapid increase in speed. A rapid descent, at a speed below the Critical Mach number, cannot therefore be made without the use of speed brakes.

20 Providing the engine is fitted with a minimum burner pressure valve, the throttle may be closed, the speed brakes extended, and the descent made at a speed just below the Critical Mach number. If a minimum burner pressure valve is not fitted, it is inadvisable to throttle back to any great extent and the descent should be made at the minimum RPM setting quoted in POI. It must be remembered that, even with the speed brakes open, it is easy to exceed the speed limitations at high altitudes. Use of the speed brakes may cause considerable buffeting which must not be confused with compressibility effects.

21 As height is lost and the speed brakes become more effective, the angle of dive will steepen at a constant indicated Mach number. Before the speed brakes are closed, speed must be reduced and angle of dive decreased, as the ensuing acceleration may cause the aircraft to exceed the limiting speed.

22 Should the speed brakes become inoperative, the flaps and/or the landing gear may be used to increase drag, but the limiting indicated speeds for these services must not be exceeded during the descent.

23 It must be remembered that fuel consumption is high and sufficient fuel must be left for the descent and landing. In addition, especially in humid conditions, the windscreen and side panels may become iced-up on the descent and it may be necessary to fly at low altitude for five to ten minutes for the purpose of de-icing or demisting. Pilot's Operating Instructions quote the minimum fuel required for the descent, and landing, but not necessarily for de-icing or demisting under adverse conditions.

TRICYCLE TYPE AIRCRAFT

Main Differences from Other Aircraft

23 The wing incidence of the tricycle type aircraft when resting on its three wheels, is much less than that of the conventional aircraft and consequently:

(a) The forward view is better for taxiing, for the initial take-off run, and for the landing run.

(b) The ground attitude is one of low lift and low drag, which gives a good take-off acceleration, but a poor retardation in the landing run; effective braking is, therefore, particularly important.

24 The main wheels are aft of the center of gravity, whereas on the conventional aircraft they are forward of the center of gravity. Consequently:

(a) Impact of main wheels with the ground tends to pitch the aircraft forward, reducing the wing incidence. It is, therefore, unlikely to "balloon off" and the decreased incidence after touch-down reduces tendency to bounce over an uneven surface.

(b) The main wheels being aft of the center of gravity, give directional stability to the aircraft when all wheels are on the ground, so that any tendency to swing, especially at high speed, is almost eliminated.

25 When landing the brakes may be applied as hard as necessary once the nosewheel is firmly on the ground, as there is no risk of "nosing over". Over rough surfaces, however, only sparing applications of the brakes should be made in the early stages of the landing run.

Ground Handling

26 The following points should be observed in ground handling:

(a) The aircraft should be parked, especially when in a restricted space, with the nosewheel straight. If this is not done, a sudden unexpected turn may result from the next attempt to taxi forward and may lead to an accident.

(b) When starting from rest, engines must not be opened up on one side only to produce a turn, unless nosewheel is set for that direction of turn. To do so would impose a severe side load on the nosewheel.

(c) No aircraft should ever be turned on one wheel, since this practice causes severe tire wear, but with the tricycle, the attempt to do this also severely strains the nosewheel. Always move forward a little before turning.

(d) Care should be taken when taxiing slowly not to over-strain the nosewheel by turning too sharply. The castoring range of the nosewheel is limited.

(e) With toe-operated brakes, it is usually easier to taxi with the rudder pedals held central.

Take-off

27 During take-off proceed as follows:

(a) The aircraft should be taxied forward a few yards before the throttles are opened to ensure that the nosewheel is straight.

(b) The nosewheel should be eased off the ground as sufficient speed is gained. As the take-off speed is approached, move the control column steadily and firmly back until the aircraft leaves the ground; on some types, considerable backward pressure may be necessary. Care should be taken to avoid striking the tail on the ground.

Normal Landing

28 For normal landing proceed as follows:

(a) It is most important to check the brake pressure before coming in to land, since most tricycle type aircraft cannot be stopped without brakes within the normal airfield unless the wind is very strong.

(b) Approach and flatten out in the normal manner, touching down with the main wheels first.

(c) Continue to move the control column back to prevent the aircraft from pitching forward suddenly, and to keep some of the weight off the nosewheel after it has made contact. Always lower the nosewheel to the ground before the elevator control is lost.

(d) The brakes should not be applied until the nosewheel is firmly on the ground, as this causes a violent pitch forward on to the nosewheel.

Slow Landing

29 For slow landing proceed as follows:

(a) The landing run can be varied greatly and depends upon the amount of tail down attitude before the main wheels touch.

(b) After a slow landing has been made,

it is particularly important to use the elevator control to lower the nosewheel gently and not to apply the brakes until the nosewheel is down.

(c) Care should be taken to avoid striking the tail on the ground.

STARTING ON INTERNAL BATTERIES

30 Engines, fitted with electric starters, should not, in general, be started on the internal batteries if a suitable external battery is available. Most aircraft batteries have a 40 ampere-hour capacity and for weight considerations their plates are very thin; prolonged use of the starter will cause the battery to be rapidly discharged and may eventually lead to buckling of the plates.

31 If it is desired to start on the internal batteries, the following points should be borne in mind:

(a) On multi-engine aircraft, an engine driving a generator should be started first and run at RPM sufficient for the generator to cut in. The batteries will then have the support of the generator when starting other engine(s).

(b) Engines should then, whenever possible, be run above the minimum RPM at which the generators cut in.

(c) The use of the electrical services before take-off should be kept to a minimum, or battery may become completely discharged.

LANDING GEAR OPERATION

General

32 To eliminate misunderstanding between aircrew members and to prevent premature retraction of the landing gear, the following procedures are the only signal methods to be used by the pilot when landing gear retraction and extension are to be carried out in multi-engine aircraft (except aircraft with tandem-seating).

Landing Gear Retraction

33 When the aircraft is safely airborne, the pilot is to signal the co-pilot or crewchief to raise the landing gear, with a sharp movement of his right hand from seat level up to eye level, with the thumb extended upward. The co-pilot or crewchief is then to select landing gear up. If there is any doubt in the mind of the co-pilot or crewchief as to whether the signal has been given, he is to check verbally with the pilot.

Landing Gear Extension

34 When the pilot wishes the landing gear extended, he is to signal with a movement of his right hand from eye level to seat level with the thumb extended downward. The co-pilot or crewchief is then to select landing gear down and when the landing gear is locked in down position, and all indicators show the landing gear to be down and locked, he is to indicate to the pilot verbally that the "landing gear is down and locked".

SECTION 9

TELECOMMUNICATIONS

INTRODUCTION

1 This chapter deals with the airborne telecommunication equipment that is common to most aircraft. For more complete details on all telecommunication equipment in a particular aircraft system refer to the operating instructions for that aircraft.

RADIO COMPASS AN/ARN6

Introduction

2 The AN/ARN6 is a remotely controlled automatic radio compass installation capable of providing automatic or manual D/F information over a frequency range of from 100 to 1750 Kcs in four bands. The equipment may be used to provide:

(a) Automatic visual bearing indication of the direction of arrival of a signal and simultaneous aural reception of modulated signals (automatic D/F bearings and homing).

(b) Aural reception of modulated signals using a non-directional antenna (radio range flying).

(c) Aural reception of modulated signals using a loop antenna (for radio range flying and communications reception under conditions of severe interference).

(d) Aural - Null indication of the direction of arrival of signals using a loop antenna (manual D/F bearings and homing).

3 The range of the equipment is, to a large degree, dependent on the power of the ground transmitter and freedom from adjacent channel interference. Assuming average conditions, it may be stated that automatic D/F bearings should be obtainable up to a 150 nautical mile range and aural bearings up to 300 nautical miles.

Pilot's Controls

4 The following controls are provided on control box C-149/ARN6 located near the pilot's position:

(a) Function Switch - A four position switch labelled OFF-COMP-ANT-LOOP. This control turns the equipment on and selects the mode of operation desired. COMP position enables the unit to operate as an automatic D/F with visual presentation of bearing. ANT position connects the set to a non-directional antenna for radio range reception. LOOP position connects the set to the loop antenna only for manual aural D/F operation.

(b) Tuning Meter - The meter is used to assist in tuning the receiver properly. The tuning knob is adjusted for maximum deflection of the meter to the right.

(c) Loop L-R Switch - Used to rotate loop to obtain aural null when set is used for manual D/F and to obtain maximum signal when loop antenna is being used for radio range or communications reception.

(d) Light Control - Controls degree of illumination present on tuning dial.

(e) Tuning Control and Dial - Used to control frequency to which receiver is tuned. Dial is calibrated in kilocycles.

(f) Control Button - The control button is used to transfer control of the set from one control box to another in installations equipped with dual controls. Pressing the control button transfers control to this position.

(g) Audio Control - Used to control radio compass gain when aural monitoring is being maintained.

(h) CW Voice - This control provides a tone for reception of CW signals when placed on the CW position. This is eliminated on VOICE position.

(j) Bank Switch - Selects frequency band required; i.e., 100-200 Kcs, 200-410 Kcs, 410-850 Kcs, 850-1750 Kcs.

(k) Indicator - The indicator is a separate unit consisting of a reference index, azimuth scale, pointer and variation setting knob. The pointer shows the bearing of the station to which the receiver is tuned relative to the fore-and-aft axis of the aircraft. The VAR knob controls and position of the azimuth ring against the index. For D/F homing the zero point on the azimuth ring is set against the index; for taking true bearings, the true heading of the aircraft is set against the index; for magnetic bearings, the magnetic heading of the aircraft is set against the index.

Sequence of Operation

5 Inasmuch as this equipment was designed as an automatic D/F equipment with visual presentation, it will normally be employed as such. Two methods of employment are available: (1) automatic homings and (2) automatic D/F bearings. The procedures for carrying these operations are as follows:

(a) Automatic Homing

(1) Turn function switch to COMP position.

(2) If a dual control installation (i.e., if aircraft is fitted with both pilot's and navigator's control boxes) push control button to transfer control to operating position.

(3) Rotate band switch to desired frequency band.

(4) Turn tuning control to desired frequency and tune for maximum swing of the tuning meter. Adjust audio control for desired headset level. Listen for station identification to be sure that the correction station is being received. Turn VAR knob on the indicator until the azimuth zero is at the index.

(5) The indicator pointer will now show bearing of the station relative to the fore and aft axis of the aircraft. To carry out a homing, turn aircraft in direction of the indicator pointer until the pointer is at zero. If aircraft heading is held at zero degrees on the radio compass indicator, the aircraft will ultimately fly over the radio station antenna. Station passage will be indicated in a rather sudden 180° reversal in the indicator pointer. Cross winds, however, cause the flight path to be curved line, if the aircraft is flown to keep the radio compass needle on zero. To assess drift the aircraft must be flown on a constant heading and as the compass needle moves off zero to port or starboard the drift is assessed as starboard or port respectively. To correct for drift the aircraft must be turned in the direction of the radio compass needle until the radio compass needle indicates a bearing an equal number of degrees on the opposite side of the index.

(b) Automatic D/F Bearings and Fixes - Automatic D/F bearings for track and/or ground speed check or position fixing can readily be obtained with the ARN/ARN6 equipment. Prior to use for either purpose, the following steps should be taken in order to ensure accurate bearings/fixes:

(1) When taking bearings to be used for ground speed checks, select station whose estimated bearing is approximately at right angles to the track of the aircraft.

(2) When taking bearings to be used for track checks select stations whose estimated position is either ahead or astern of the aircraft.

(3) When selecting stations to be used for a three bearing fix, when possible choose those whose geographical locations are spaced at approximately equal intervals about the aircraft.

(4) Tune in the stations very carefully and ensure that station is positively identified.

(c) The procedure for obtaining automatic bearings or fixes is as follows:

(1) Adjust VAR knob on the indicator until it's bearing scale at the index reads the true heading of the aircraft.

(2) Set function switch to COMP position.

(3) Tune in the selected station and record the reciprocal bearing.

(4) The recorded bearing will be station to aircraft bearings measured from true north.

(5) If a fix is desired, repeat the above on two additional stations. Project lines from the stations at the recorded bearings. The aircraft position will be within the vicinity of the small triangle made by the intersection of the projected lines. Bearings should be taken on a fore and aft axis first.

Manual Aural D/F

6 While this equipment is normally used as an automatic device with visual presentation, breakage of the sense antenna or precipitation static may make automatic operation impossible. Under these conditions, homing bearings and fixes may be taken using the manual-aural method of operation. It will be noted that all bearings taken with the function switch on the LOOP position will be subject to 180° ambiguity as the "sense" antenna circuit is completely disconnected in this position. Procedures for manual-aural operation are as follows:

(a) Manual Aural Homing

(1) Adjust VAR knob on indicator until zero point on azimuth ring is at index.

(2) Turn function switch on ANT or LOOP position, tune in and identify station.

(3) Place CW-VOICE switch on CW position.

(4) Place function switch on LOOP position if not already done.

(5) Rotate loop by means of LOOP L-R switch until an aural null has been established. Reduce volume level to a degree sufficient to make null well defined and not too broad. Note bearing.

(6) Fly aircraft on a constant heading and after an interval of three to four minutes (dependent on speed of aircraft and distance from station), take another bearing. If bearing has increased in comparison with original bearing, station is on starboard side of the aircraft and if bearing has decreased, station is to port. This rule will always apply, and serves as a means of resolving the 180° ambiguity.

(7) Having resolved 180° ambiguity, turn aircraft in direction of station, rotate loop until indicator pointer reads zero and adjust heading of aircraft until steering on the aural null. Continue to fly aural null, carrying out frequent checks on off-null signal strength build up as the station is approached and adjusting volume level to maintain clear null definition.

(8) As the station is approached, the strength of the signal will increase and the null will become much sharper and increasingly more difficult to maintain in spite of reductions in audio control settings. At this time, the loop should be rotated by means of the LOOP L-R switch to read 090 or 270 and the established heading maintained until a wing tip null is obtained. This will indicate station passage.

(b) Manual - Aural Bearings and Fixes

(1) Adjust VAR knob on indicator until true heading of aircraft on azimuth ring is opposite index.

(2) Place function switch on ANT position, tune in and identify desired station.

(3) Place function switch in loop position.

(4) Using LOOP L-R switch rotate loop until aural null is established. Placing CW-

VOICE on CW position may assist in establishing a well defined null. If any doubt exists as to the "sense" of the bearing, the 180° ambiguity should be resolved as in (a) (6) above. Having resolved the ambiguity, record the reciprocal bearing and project a line through the station on the recorded bearing. The bearing provided will be a station to aircraft bearing measured from true north.

(5) If a fix is desired the above procedure should be repeated on two additional stations. Project lines from the stations at the recorded bearings. The aircraft position will be within the vicinity of the small triangle made by the intersection of the projected lines.

Additional Functions of AN/ARN6

7 In addition to its primary functions of automatic and manual D/F operation, the radio compass may also be employed as a communications receiver for radio range flying and reception of control tower transmissions. Ordinarily this will be carried out using the sense antenna with the function switch placed on the ANT position, however, if reception on this mode is noisy due to precipitation static better results may be obtained by operating in LOOP position. To use receiver in this manner, proceed as follows:

(a) Tune in desired station.

(b) Turn function switch to LOOP position.

(c) Rotate loop with the LOOP L-R switch until maximum signal is obtained.

(d) Adjust AUDIO control for desired headset level.

NOTE

It should be noted that cone of silence indications are not always reliable while receiving on LOOP. In some cases, an increase instead of a decrease in signal may be noted. This is the result of certain types of radio range transmitting antennae and loop location on the aircraft. Under such conditions, it is considered that the preferable procedure would be to switch from LOOP to ANT position of the function switch for the final phase of the radio range approach.

Summary of Precautions During Operation

8 The following precautions will be observed:

(a) Select radio stations that provide stable bearings. Do not use a station for bearing unless it can be identified by headset signal on COMP operation. High powered clear channel stations should be used when possible. Any interference from other stations will cause an error in bearing. Tune equipment accurately. Station identification must be checked.

(b) Night effect or reflection of radio waves from the sky may be recognized by fluctuations in bearings. Night effect is worse at sunrise and sunset. The higher the frequency of operation, the greater the night effect. Night effect can best be overcome by using stations operating on the lower frequencies and taking a average of the fluctuations.

(c) Mountain effect is considered to be the reflection of radio waves from mountain surfaces. Do not rely fully on bearings taken in mountainous areas.

AIR-TO-AIR GROUND IFF (AN/APX6)

Introduction

9 The basic purpose of the transponder AN/APX6 is to enable the aircraft in which it is installed to identify itself automatically as a friendly aircraft whenever it is challenged by proper signals from other appropriately equipped bases. The equipment also permits the identification of specific aircraft from numerous other friendly aircraft. Provision is also made for the transmission of a special coded signal known as the emergency reply. Replies from the AN/APX6 may be seen by the ground station at least as far as normal radar range and quite possibly beyond.

Pilot's Controls

10 The transponder AN/APX6, requires no tuning adjustment in flight and is controlled remotely by the pilot by means of either the radar set control type C544/APX6 or type C629/APX6. Both of these controls perform identical functions - the only difference being a slight one in their mountings. The following operating controls are mounted on the front of the radar set control:

(a) Master Control - A five position rotary switch. In the OFF position no primary power is supplied to the equipment. In STBY position, all primary power is turned on. The tubes are heated, and, after a delay of approximately one minute, are ready for operation; but the receiver is desensitized to prevent operation. In LOW position, the receiver is partially sensitive, and the equipment operates only in the presence of strong interrogations. In NORM position, the receiver is at full sensitivity, and provides maximum performance. In EMERGENCY position, the receiver is operated at full sensitivity, and four pulse replies are transmitted, regardless of the mode of interrogation received or the setting of mode 2 and mode 3 switches. To prevent accidental emergency operation, a push-button dial stop is located to the left of the MASTER control.

(b) MODE 2-OUT-I/P Switch - A three position toggle switch. In OUT position, the equipment transmits normal mode 1 replies to mode 1 interrogations, but does not respond to mode 2 interrogations. In MODE 2 position, normal mode 1 operation is obtained; in addition, normal mode 2 replies are transmitted to mode 2 interrogations. In I/P position (Identification of Position), the equipment responds to mode 2 interrogations whenever the pilot operates his communications transmitter.

(c) MODE 3-OUT Switch - A two position toggle switch. In OUT position, the equipment operates in mode 1. In MODE 3 position, the equipment provides normal mode 1 operation, normal mode 2 operation (if MODE 2-OUT-I/P is set at MODE 2), and normal mode 3 operation.

(d) DESTRUCT Switch - A two position toggle switch, protected against accidental operation by a guard cover. Regardless of the setting of the MASTER control, the destructors will be fired if the DESTRUCT switch is turned to ON, or if the impact switch is tripped. It should be noted that destructors are not currently fitted in RCAF aircraft based in Canada.

Sequence of Operation

11 If IFF facilities are required during flight, it is only necessary for the pilot to switch the MASTER control to the NORM position for mode 1 operation. Should other modes of operation be required they may be switched on as outlined above.

Emergency Operation

12 Emergency operation may be effected by setting the MASTER control to EMERGENCY. The special four pulse emergency reply will then be transmitted regardless of the mode of interrogation received and the setting of the mode 2 and mode 3 switches.

VHF COMMUNICATIONS

General

13 Very high frequency (VHF) is the term applied to the frequency band lying between 100 and 156 megacycles per second. Its main characteristic is that it provides communications over ranges approximating line of sight. This range will vary from 30 miles for an aircraft at 1000 ft. to 200 miles for an aircraft at 40,000 ft. Air-to-air ranges will be, in theory, double the possible ground-to-air range.

Pilot's Controls

14 The great number of different types of VHF control units make it extremely difficult to cover the operation in this manual. For more complete details on the operation of the VHF control refer to the operating instructions for that aircraft.

SECTION 10

JET ASSISTED TAKE-OFF
JATO

INTRODUCTION

1 Accelerated take-off by means of rocket assistance is used as an alternative to catapult launching when engine power of the aircraft is insufficient to ensure that take-off speed will be reached within the available length of deck or runway.

DESCRIPTION

2 The installation comprises rocket carriers, one or more beneath each wing constructed to carry a maximum of one, two, three or four rockets, the number required depending upon the weight and available power of the aircraft.

3 The number of rockets required for each take-off on a particular aircraft depends upon loading, length of deck or runway available, the wind velocity and other prevailing conditions. The correct number is ascertained from the JATO performance charts included in the POI for the aircraft.

4 The rockets are fired electrically by the pilot at a predetermined distance from the start of the take-off run. This distance is also found from the performance charts. In most installations the rockets fire simultaneously; in some later installations, however, they may be arranged to fire in sequence at predetermined intervals.

5 The expended rockets and their carriers can be jettisoned by the pilot after take-off.

CONTROLS

6 JATO controls for the pilot comprise:

(a) A master JATO switch.

(b) A firing pushbutton.

(c) A jettison lever or switch.

PRE-FLIGHT PROCEDURE

7 The carriers and appropriate number of rockets, as found from the chart for the aircraft, are placed in position and the electrical firing circuits are connected and tested by the ground crew.

8 The pilot ascertains from the chart the correct firing point and notes some distinguishing feature on the deck or runway, at a corresponding distance from the starting point, for use as a "firing point".

9 After the usual pre-take-off checks have been completed and the aircraft has been lined up in the direction of the take-off, the JATO master switch should be switched on.

TAKE-OFF

10 Even experienced pilots may be erratic on their first jet assisted take-off, and it is, therefore, recommended that at least the first two take-offs should be made from an airfield. On the first, the rockets should be fired at normal take-off speed, so that they continue to fire in the air; on the second, a jet assisted take-off in accordance with the recommendations below should be attempted, the rockets being fired at the correct "firing point" as found from the chart.

11 A pilot's first jet assisted take-off from a flight deck should be under conditions ensuring that he has ample distance in which to take-off. A steady wind speed over the deck of not less than 25 knots, or even more with some types is desirable.

12 The take-off should be commenced in accordance with the normal carrier take-off technique.

13 The take-off should be continued as recommended in POI for the type for JATO take-off from runways or carriers, as appropriate. A good forward view is most desirable for carrier take-offs and on tailwheel types it will generally be found advantageous to raise the

tail as soon as possible. Some increase in take-off run may however result, and on types with lockable tail wheels it may pay to delay raising the tail. On some types the tail should be lowered again before take-off. In any case the precise instructions in POI for the type should always be followed.

14 When the pre-determined "firing point" is reached the firing button should be pressed for half a second. The rockets should then fire either simultaneously or, when applicable, in sequence. It is important that rockets should be fired as near to the correct firing point as possible. Rocket assistance continues until the charge is fully burnt, by which time the aircraft should be airborne. If the rockets do not fire within half a second of pressing the push-button the take-off should be abandoned. In this event, or if for any reason take-off is cancelled, the JATO master switch should be turned off and locked before leaving the cockpit.

15 For structural reasons and to ensure that the blast clears the tailplane, the rockets are usually mounted so that their axes are inclined downwards. The additional lift from the vertical component of rocket thrust, and in some cases the nose-up pitching moment produced by the rockets, causes the aircraft to unstick at a speed below its normal unassisted take-off speed. This reduction in speed varies between 3 and 10 knots - depending on angle at which the rockets are set and the degree of thrust they provide. If the nose of the aircraft is permitted to rise unduly, the aircraft thus attaining a steep angle of climb, a large proportion of the available thrust is used in lifting the aircraft into the air at the expense of forward acceleration, the result being that aircraft is left in a dangerously nose-up attitude with insufficient flying speed by the time the rockets are expended. This danger can be avoided if, in tailwheel types, the aircraft is not allowed to assume a nose-up attitude greater than the normal ground angle. In fact, little or nothing will be lost if the tail is allowed to rise during the take-off run, normal take-off attitude being gained as the ship's bow is approached. With nosewheel aircraft the nose should not be allowed to rise until the ship's bow is approached when the normal unassisted take-off attitude should be assumed. It is emphasized that rocket assistance for take-off should be regarded as providing extra thrust for accelerating the forward speed and not for providing lift for climbing. On no account must the aircraft be "pulled off" and care must be taken to avoid a steep nose-up attitude.

16 After take-off the JATO master switch should be turned off.

17 When well clear of the ship, or when over a safe dropping area if taking off from land, the aircraft should be flown straight and level at the recommended IAS quoted in POI and the rockets and carriers jettisoned. Carriers and rockets should not be jettisoned when practice take-offs are being carried out and the airspeed limitation in this configuration must then be observed throughout the flight.

PRECAUTIONS

18 Jet assisted take-offs must not be made from an airfield with an inflammable surface, owing to the danger, especially in hot weather, of fire spreading from that type of surface to the after part of the aircraft. Surfaces such as rubber or wood chips set in tar or bitumen on a concrete runway, or asphalt runways, which offer no immediate resistance to fire, would be dangerous. Take-offs from grass or plain concrete runways are safe. Very loose surfaces should be avoided, as the rocket jets may project sand, small stones or hard earth through tail surfaces. After each JATO the tailplane and elevator should be inspected for damage.

19 Jet assisted take-offs on wood or metal decks are safe; if, however, the wooden deck of a ship is very dry, especially under summer weather conditions, a hose should be played on its surface before take-off is attempted.

20 Unless a greater distance is specifically recommended in POI for a particular type, it may be assumed to be quite safe to range other aircraft on the deck behind an aircraft making a jet assisted take-off, provided that there is a space of not less than 50 feet between the nose of the second aircraft and the rockets of the first, at the instant they will fire. The jets of hot gases from the rockets hit the deck and spread along the surface; personnel, therefore, should not remain on the deck while a jet as-

sisted take-off is in progress, e.g., holding chocks for other aircraft.

21 After landing with rockets in place, a careful inspection should be made and if a rocket has not fired, the electrical circuit should immediately be disconnected. No personnel should approach the rear of the rocket until a period of at least ten minutes from the time of the previous take-off has expired.

PART 5

ALL WEATHER OPERATION

SECTION 1

AIRFRAME ICING

ICING CONDITIONS

1 Apart from hoar-frost, ice forms on the airframe when supercooled water droplets strike the aircraft. Icing has been experienced at temperatures as low as -40°C (-40°F), but it is most common and usually most severe between 0°C and -7°C (32°F and 19°F), in which temperature range, the concentration of free super-cooled water is normally at a maximum. However, in very turbulent cumulus or cumulonimbus cloud, this concentration of water may occur at heights where the temperature is appreciably lower. In such clouds, serious icing may be encountered at temperatures down to -18°C (0°F).

2 Occasionally, under a warm front, rain falls into freezing air from milder overlying air and an aircraft flying in these conditions will accumulate ice rapidly. This phenomenon is known as freezing rain and it is not likely to occur above 5,000 feet. The pilot should either turn back and avoid the rain, or climb to a height where the air is either above freezing or below -7°C (19°F).

3 Hail does not itself give rise to airframe icing, but is a serious hazard as it can cause damage to the airframe or engine, especially at high speeds. It is frequently associated with turbulent conditions and should be avoided wherever possible. Failing this the aircraft should be flown at the speed recommended for flying in conditions of severe turbulence; where a range of speed is permitted the speed should be the lowest in this range.

4 Aircraft thermometers may not be accurate, and unless a reliable thermometer correction is available, severe icing is a possibility at apparent temperatures from a few degrees above 0°C (32°F) down to a few degrees below -7°C (19°F), or in clouds of great vertical development down to a few degrees below -18°C (0°F).

5 Except at high speeds, the normal rate of ice accretion in severe conditions is about 1 inch in 10 minutes. A fall in IAS at given engine conditions in level flight, or a loss of height at given IAS, may be noticed when the thickness reaches 1 1/2 inches; the effect on performance only becomes serious when, at a thickness of about 2 inches, the ice begins to form jagged edges. Therefore, it is normally possible to fly in severe icing conditions for about 20 minutes before the accumulation of ice becomes dangerous.

6 An icing layer is usually about 3,000 to 4,000 feet thick, and at comparatively low altitudes it may be climbed through without taking on too much ice. The best practice is to climb as quickly as possible into air at -7°C (19°F) or lower. Alternatively, if the icing layer is high enough, pilot may, if conditions permit, descend and fly below it.

7 Icing conditions are frequently accompanied by severe static electricity, especially in cumulus type clouds and when hail is falling. Trailing aerials should be earthed and reeled in, and unnecessary radio switched off.

EFFECTS OF ICE ON STALLING SPEED

8 Roughness, or a change of contour of the wing surface may result in an appreciable increase in the stalling speed, so that a thin coat of ice or even rime or hoar-frost may cause difficulties at low speeds. When a landing is made with any form of ice on the wings,

the approach speed should be increased as necessary.

9 Prior to take-off, all aircraft surfaces must be cleared of any traces of snow, ice, rime or hoar-frost. When icing conditions prevail, it is advisable to raise the tail as soon as possible and to fly the aircraft off at a higher speed than usual.

ICING AT HIGH IAS

10 At speeds above about 390 knots IAS, airframe icing may become abnormally severe, with a rate of accretion of 1 inch in less than 2 minutes under the worst conditions. Full use should be made of the climbing performance of modern high-speed aircraft to get above any serious icing layer, but, descents through likely icing conditions should be made at much lower speeds of the order of 200 knots or less. If the flight must be continued in the icing layers, speed should be reduced in order to delay the rate of ice accretion.

11 Where stone guards are fitted to turbine-jet engines, they are also subject to this high rate of ice accretion which may be rapid enough to cause serious loss of power in 3 to 4 minutes.

12 Exposed aerials, at high IAS, are also subject to rapid icing and, subsequently, to excessive vibration which may cause them to fracture.

DETECTION OF ICE

13 Airframe icing may be detected in several ways:

(a) By careful attention to IAS and height when flying in likely conditions.

(b) By visual observation of windscreen, leading edges, aerials or similar projections which can be seen from the cockpit. At night a flashlight should be used for this purpose.

(c) By vibration or uneven running of the engine(s). This often results from propeller icing which may also be disclosed by the noise of ice fragments striking the fuselage.

(d) By an ice detector. Under icing conditions, the forward facing ports of detector become blocked with ice and the pressure in the head becomes negative, thus operating a warning light in the cockpit.

REMEDIAL MEASURES

14 The following should be observed in combatting icing:

(a) Severe icing, for the most part, can be avoided by careful flight planning and close observation of the rate of accretion.

(b) The pressure-head heater should be switched on.

(c) Wing and propeller de-icing pastes reduce adhesion of ice so that it is more readily dislodged by centrifugal forces, control movements, or vibration. The efficiency of pastes depends upon smooth application. Their use does not relieve the pilot of the need to avoid severe icing conditions as far as possible.

(d) Propeller de-icing equipment of the slinger-ring type should be turned on slightly in icing conditions and only turned on fully if it appears that ice on the propeller is causing vibration. Then, after a few seconds, increase the RPM to maximum momentarily to throw off the ice, before returning both the RPM and the de-icer to normal.

(e) Alcohol windscreen de-icing equipment is normally fitted. It is important not to operate the pump before regulator valve is turned on; otherwise, alcohol may be discharged into the cockpit and the effect upon the pilot can be serious. If fitted, the regulator(s) should be set as required and the pump(s) should then be operated to spray alcohol on to the windscreen.

(f) The airframe de-icing system should be in operation.

AIRFRAME DE-ICING EQUIPMENT

15 De-icing systems are fitted to some aircraft to remove ice from the aerofoils. The pulsating rubber boot system employs mechanical means for breaking up the ice film, which is then blown away by the air stream; it is still used on some aircraft. In a system now in use on some aircraft, however, de-icing fluid is fed to the leading edges to prevent adherence of ice. Such systems are arranged to be controlled either manually or, if an ice

detector is fitted and operative, automatically. Thermal systems in which heat is conducted to the leading edges will be fitted to some future aircraft. Details of individual installations and instructions for their operation are given in POI for the aircraft in which they are fitted.

SECTION 2

ENGINE ICING

INTRODUCTION

1 Icing encountered by aircraft engines can be divided into two distinct types, impact icing and carburettor icing. Each is formed in an entirely different manner, and may be experienced either individually or in combination with the other, between temperatures of -15°C and +25°C (5°F and 77°F). Present engine design endeavours to make the preventive measures entirely automatic, but, there is still much that the pilot can do to prevent the formation of ice, or to get rid of it once it has formed. To this end, he must know something of its cause and effect, and be fully conversant with the type of engine installation in his aircraft and the preventative devices fitted to it.

IMPACT ICING

2 Impact icing occurs at the same time and in the same manner as airframe icing, namely by the freezing of supercooled water-droplets on striking a part of the aircraft; in the case of engines, in the vicinity of the air intakes.

3 Gradual blocking of the air intakes of a piston engine first causes a disturbed airflow, which in turn upsets the mixture reaching the cylinders. The result is rough running, a drop in boost and finally, as the blockage becomes complete, the engine will stop. There will be a considerable risk of fire due to fuel entering the induction system.

4 The outside air temperature required for the formation of this type of icing is sufficiently low for the air, on reaching the carburettor and being subjected to further cooling by expansion and refrigeration (see paragraphs 8 and 9), to reach a temperature below that at which ice will stick. Therefore, it is only necessary to guard the intake mouth, in order to prevent blockage of the intake to carburettor.

PREVENTION OF IMPACT ICING

5 Some engines are fitted with "gapped" ice guards, in the form of a meshed screen fitted about 2 inches ahead of the intake mouth. As the screen becomes blocked with ice, air is drawn through the gap, and the only effect on the engine is the loss of "ram" and in consequence, full throttle heights and power at greater altitudes, is reduced.

6 When gapless ice guards are fitted, as the intake becomes blocked, an automatic secondary intake is opened inside the engine bay, admitting warm air. With this system, not only is the ram effect lost, but there is also a slight loss of engine efficiency due to the hot air.

7 Many aircraft are also fitted with a manually operated "hot/cold" air intake control. The method of operation is to by-pass the main intake when hot air is selected, and to open a second trunk admitting hot air from the engine bay in a similar manner to that employed with gapless ice guards. Some engines may have a heat exchanger in the exhaust system from which the hot air is drawn. By virtue of its similarity, this system inherits the same disadvantages as those employing gapless ice guards. On engines not fitted with ice guards, hot air should be used whenever flying through sleet or snow, or in airframe icing conditions.

CARBURETTOR ICING

Throttle or Adiabatic Icing

8 In the induction system, the constrictions

at the throttle valve and choke venturi, cause a local increase in the velocity of the airflow, with a consequent drop in pressure and temperature and may cause ice to form. Since each grain of ice constricts the flow still further, and the more the air flow is constricted, the greater the local velocity and the lower the temperature, ice tends to build up more and more rapidly. Temperature reduction caused by this means may be as great as 25°C (45°F), but, differs with various types of carburettors.

Refrigeration Ice

9 When fuel is injected into the airstream a certain amount evaporates. Heat required for evaporation is taken from the surrounding air and metal which are already being cooled adiabatically, thus still further reducing the temperature of the mixture. The drop caused by refrigeration may be as much as 4°C (7°F) and therefore ice may be formed in the carburettor when the outside air temperature is well above freezing point.

10 When flying through air containing visible moisture either as cloud or rain, some of this moisture will also evaporate in the carburettor, further reducing the temperature of the airstream. Although the actual drop caused by water evaporation is quite small and is not a great hazard in itself, its effect may be sufficient when added to the other causes, to bring the temperature below freezing point.

11 The amount of icing encountered depends on the relative humidity of the outside air. Air having a relative humidity of 50 percent at +10°C (50°F) will have a relative humidity of 100 percent when its temperature is reduced to 0°C (32°F). A further drop of 1°C (2°F) will cause condensation to take place below freezing point and ice will form. As a general rule, the lower the temperature of the outside air, the smaller will be the amount of moisture it contains. Therefore, the amount of icing liable to be experienced when flying in clear air (cloudless), may be expected to be greater when the air is warm. If the relative humidity is high, large amounts of ice may form in the carburettor when no visible moisture is present, and in temperatures as high as 32°C (90°F), assuming that the overall temperature drop in the carburettor due to the phenomena discussed above, is over 30°C (54°F). In modern carburettors this is unlikely, but, there are still some types in use having a possible drop of 33°C (60°F).

RECOGNITION

12 The formation of ice in the carburettor is indicated by a slow decrease in boost pressure. If an automatic boost control is fitted, the throttle valve will be progressively opened, maintaining the boost, and until the valve has reached its fully open position for the power setting, no indication will be available. The fall is gradual and fairly steady, and is sometimes accompanied by intermittent and slight flickering of the needle of the boost gauge as small pieces of ice break away. If the aircraft is above full throttle height, the boost reading will begin to fall immediately ice accretion starts.

REMOVAL AND PREVENTION OF CARBURETTOR ICE

13 Vulnerable parts of most carburettors are heated by the circulation of engine oil or coolant through the throttle valve and the ducts around the carburettor barrel. As long as the engine controls are handled to maintain the temperature of the heating medium at above 60°C (140°F) this system is very efficient and the resultant slight heating of the charge has a negligible effect on the power output of the engine.

14 There is a very considerable rise in the temperature of the charge as it passes through the supercharger, and the risk of refrigeration ice has been largely eliminated by the practice of injecting fuel directly into eye of the impeller.

15 In the earlier float-type carburettors, fuel is injected into the airstream before it passes the throttle venturi and valve. Unfortunately, few of these carburettors have barrel heating and the only means of combating the ice is to use the hot air intake control, or in extreme cases to attempt to break away the ice by moving the throttle valve by force. This latter method must only be used as a last resort, as there is a considerable risk of breaking or straining the throttle linkage.

HOT/COLD AIR-INTAKE CONTROL

16 Most engines are fitted with hot/cold air-intake control and hot air should be used

whenever throttle icing is suspected, or when flying through sleet, snow or heavy rain, even though the outside air temperature may be as high as +20°C (68°F). If the relative humidity of the air is high the use of hot air is also advisable in non-heated carburettors both on the ground and in the air when using small throttle settings, for example, approaching to land, descending through cloud, taxiing, etc.

17 When a take-off is made in severe icing conditions, or in cold, humid weather, it may be advisable to use hot air to prevent carburettor icing. The all-up weight, and take-off run available, must be considered in conjunction with the slight loss of power due to the reduced weight of the cylinder charge. On certain engines, hot air should not be used at boosts in excess of +18 lb/sq. in., or at any take-off power if the outside air temperature is higher than +10°C (+50°F) as the resultant temperature rise may cause detonation. If hot air is used, a change back to cold air must not be made during take-off, when going round again or during a mislanding, until power can first safely be reduced. Reference should be made to individual POI which will give details of the correct operation of the air intake controls for a particular aircraft type.

18 Conditions may be found, when the use of hot air will start rather than prevent icing. If refrigeration and adiabatic cooling effects of the carburettor are high and are assisted by the weather, the final temperature may drop below that at which ice will stick, and in such conditions the use of hot air may raise the temperature to within the icing range. In this case, cold air should be selected, and any ice which has formed will then break away and dissipate slowly.

19 Some engines are fitted with a three position air-intake control marked "hot", "warm" and "cold". The "warm" position may be used to prevent icing, but will necessarily reduce range. If range is of paramount importance, cold air should be used until icing becomes evident then hot air used to disperse it, and the control then returned to "cold".

20 With Bendix-Stromberg carburettors, it will be found that under certain conditions, particularly when descending through cloud, snow or heavy rain at low throttle settings, ice will form at the throttle valve. This may cause jamming, or make it impossible to close the throttle completely for landing. Being of the direct injection type, these carburettors are prone only to adiabatic cooling. The pilot should, therefore, aim to keep throttle valve as wide open as possible when descending, keep the engine as warm as possible by maintaining high RPM, and descend through the icing layer as rapidly as is compatible with the safety of the aircraft. Jamming of throttle may be avoided by exercising it frequently, thus breaking away any ice which may have formed, before the amount becomes dangerous.

AXIAL FLOW JET ENGINES

21 Axial flow jet engines are seriously affected by icing. Ice forms on fixed inlet screens and compressor inlet guide vanes (stator) and restricts the flow of inlet air. This causes a loss of thrust and rapid rise in exhaust gas temperature. As the air flow decreases, the fuel-air ratio increases, which in turn raises the temperature of the gases going into the turbine. The fuel control attempts to correct any loss in engine RPM by adding more fuel, which aggravates the condition. Complete turbine failure from extreme over-temperature may occur in a matter of seconds after ice builds up in engine inlet. Critical ice build-up on inlet screens can occur in less than one minute under severe conditions. With the inlet screens out, serious blocking of the air passages between the inlet guide vanes can still occur in four minutes or less.

22 The idea that heating due to ram pressure at high speed will prevent icing is dangerous. Not enough heat is generated at subsonic velocities to prevent the formation of ice.

23 The rate of engine icing for a given atmospheric icing intensity with outside air temperature below freezing is relatively constant up to an airspeed of approximately 250 knots TAS. The rate of icing increases with increasing airspeed above 250 knots. Therefore, a reduction of airspeed to a safe minimum will reduce the rate of inlet icing.

24 Serious inlet duct icing can occur without the formation of ice on the external aircraft surfaces. When jet aircraft fly at velocities below approximately 250 TAS, and at high

power setting, as in a climb, the intake air is sucked, instead of rammed into the engine compressor inlet. This suction causes a decrease of air temperature. Under these conditions, air at an ambient temperature above freezing may be reduced to sub-freezing temperature as it enters engine. Free moisture in the air may become supercooled and could cause engine icing while no external surface icing would be evident. The maximum temperature drop which can occur on most current engines is a drop of approximately 5°C (41°F). The greatest temperature drop occurs at high RPM on the ground and decreases with:

(a) Decreasing engine RPM.

(b) Increasing airspeed.

CENTRIFUGAL FLOW JET ENGINES

25 The centrifugal compressor type of engine is relatively free of icing difficulties. Engines in this category are the J33 and Nene types, installed in the T-33 aircraft. While it has been possible to ice the J33, the icing conditions must be extremely severe. J33 engines have also iced during ground running in F-94 aircraft when the suck-in doors at the top of the fuselage were open. In flight, the turning of the air as it enters the engine effectively separates the water droplets from the air and deposits them on the engine surfaces where icing is not considered serious.

INDICATION OF JET ENGINE ICING

26 The initial symptoms of engine icing will be obtained from a signal by the ice detector, if fitted, and/or by an increase in tailpipe temperature. These are usually the only indications prior to complete engine failure. Corrective action, as outlined in paragraphs 27 to 30 should be taken immediately.

OPERATION OF NON-ANTI-ICED AXIAL FLOW ENGINES

27 Avoid atmospheric icing conditions whenever feasible. It is recognized that the most proficient weather service cannot always predict accurately just when or where icing may be encountered. However, many areas of probable icing conditions can be avoided by careful flight planning that utilizes available weather conditions.

28 If possible, avoid take-off when the temperature is between -10°C and 5°C (14°F and 41°F) if fog is present or dew point is within 4°C (39°F) of the ambient temperature. These are conditions under which jet icing can occur without wing icing.

29 If ambient temperature is in the range of 0°C to 5°C (32°F to 41°F) the speed of the aircraft should be maintained at 250 knots or above to prevent inlet duct icing.

30 If icing conditions are encountered at freezing atmospheric temperatures, immediate action should be taken as follows:

(a) Change altitude rapidly by climb or descent in layer clouds or vary course as appropriate to avoid cloud formations.

(b) Reduce airspeed to minimize rate of ice build-up.

(c) Maintain close watch of exhaust gas temperature, and reduce engine RPM as necessary to prevent excessive tailpipe temperature.

OPERATION OF ANTI-ICED AXIAL FLOW ENGINES

31 Normally jet engines protected by anti-iced systems and retractable inlet screens are not susceptible to the icing hazard. However, retractable inlet screens should be retracted prior to take-off when the conditions given in paragraph 28 exist.

SECTION 3

COLD WEATHER OPERATION

INTRODUCTION

1 In cold weather, aircraft can be operated safely and efficiently if personnel, both groundcrew and aircrew, are aware of the difficulties involved and of the precautions that must be taken, Some difficulties and precautions are outlined in the following paragraphs. Aircrews must realize that extremely low temperatures, long periods of darkness and isolation all tend to decrease the efficiency and morale of personnel. They must pay attention to details which are often overlooked in summer operations.

METEOROLOGICAL

2 The following phenomena are peculiar to cold winters:

(a) Inversions often exist which cause the temperatures at approximately 5,000 to 10,000 feet to be from ten to thirty degrees centigrade higher than at ground level. At these heights, the conditions may well be comparable to those experienced in temperate climates in winter or even in summer. Above these heights, temperatures again begin to fall.

(b) Ice fog and ice crystals will frequently occur at low temperatures. Ice fog is a heavy concentration of ice particles which have formed on nuclei in the air and is most prevalent in industrial areas. Ice fog can occur, however, at aerodromes located in isolated areas at very low temperatures and can be caused by the mere running of an engine. The propeller wash and products of combustion from an aircraft engine can provide the disturbance and nuclei, under certain atmospheric conditions, to fog an aerodrome to a depth of as much as 50 feet. While the horizontal visibility in this type of fog may be reduced to a few hundred feet, little difficulty will be experienced in landing an aircraft as the downward visibility is generally adequate. When landing in ice fog at night on a lighted runway, there is no problem provided aircraft landing lights and navigation lights are left "Off" to reduce glare. Ice crystals result from the sublimation of water vapour and is a form of precipitation. The concentration of ice crystals is light in comparison to ice fog and horizontal visibility is seldom below five miles. When ice crystals prevail, the operation of aircraft can rapidly produce ice fog. This latter should be borne in mind when planning to land at an aerodrome reporting ice crystals and under these conditions, a straight in approach or minimum of low flying in the area is recommended.

(c) During midwinter in the sub-arctic, the sun does not dissipate fog and low clouds. Layers of thin mist at approximately 200 feet may persist throughout the day. These are generally quite thin and while horizontal visibility is poor, vertical visibility is good. The formation of ice and frost should always be anticipated under these conditions.

(d) Blowing snow is very often experienced. Like ice fog, it obscures the landing strip and the same rule applies regarding the use of landing lights and identification lights. Severe conditions of blowing snow may make a safe landing impossible.

PERSONNEL

3 Personal care is of the utmost importance. Some of the dangers are as follows:

(a) The danger of snow blindness is present both in the air and on the ground. Eyes must be protected with snow glasses or suitable goggles. During the latter part of winter, even in the Arctic, adequate precautions are necessary to prevent sunburn.

(b) Local freezing will take place if the exposed skin is allowed to come into contact with cold metal. If the skin is moist, it will stick to the metal instantly and forcible separation may be necessary.

(c) Uncovered parts of the body should not be exposed to slipstream. Remaining in the slipstream at low temperatures is sufficient to cause freezing of skin with painful cracking, and at -50°C (-58°F), severe freezing of exposed parts may occur.

(d) The wearing of winter clothing during flight is recommended for cold weather operations. Survival, without the proper kit, would be impossible in the case of a crash landing or a "bail-out", particularly if injuries were sustained.

(e) Hot drinks such as coffee or soup are helpful in combating fatigue during long exposure to cold.

(f) Maintenance personnel, very often attempt to work on aircraft, outside, without shelters or heat. Work done under these conditions tends to be of low quality and the practice should be discouraged. The time taken in erecting shelters and providing heat is not wasted when the efficiency with which a job is done is taken into consideration.

(g) When removing batteries from aircraft, avoid spilling electrolyte on parka or mitts Acid in the electrolyte burns holes which reduces the protective quality of winter clothing.

AIRCRAFT

4 Some of the difficulties associated with the operation and maintenance of aircraft in low temperatures are discussed as follows:

(a) Short periods of ground running should be avoided. If the engine is not brought up to operating temperature, the water vapour in the products of combustion that escape past the piston will condense inside the crankcase and will be distributed throughout the oil system. This may produce split coolers, choked oil lines and possible engine failure.

(b) If for any reason an engine is given a series of short ground runs during cold weather, the operator should keep in mind that short runs do not boil off the diluent but they do mix the diluted oil in the short system with the undiluted oil in the tank body. If the engine is diluted, as described in paragraph 13, after each short run, all oil in the system becomes heavily diluted. The first sign of this trouble is overflowing of the oil tank caused by the addition of several gallons of gasoline to the oil. The second difficulty is the excessive time required to boil off all the diluent. Therefore, avoid short ground runs.

(c) Aircraft dispersed in the open will accumulate snow, ice, and frost. Ice may form inside hollow structures such as air intakes and in the vicinity of fuel tank vents because of condensation. It is usually advisable to fit blanking plates to air intakes after shutting down to prevent snow from entering. Snow and frost can be brushed off the exterior of aircraft without difficulty but heat may be required to remove ice. Most de-icing fluids will not remove ice at ground temperatures below -20°C (4°F) but above that temperature they are very effective. Snow should be removed from aircraft if a thaw is forecast to prevent later freezing. Covers should be fitted on aircraft removed from a warm hangar during precipitation to prevent icing of the airframe. Ice or snow which has accumulated inside propeller spinners must be removed as the resulting unbalance may cause severe vibration.

(d) Plastics will very often crack when moving an aircraft from hangar to outside air temperature. Indications of weakening may be given by small cracks originating at the edges of mounting frames or at small radii on curved panels. Before flight, cockpit hoods should be checked for cracks, as they may lead to disintegration in the air.

(e) Control cables that have been tensioned inside a hangar or in a temperate climate will lose tension or become slack in low temperatures because of the different coefficient of thermal expansion of steel cable and an aluminum airframe. The airframe contracts more than the cable with a given temperature drop. If cables are tensioned in a warm hangar, they should be tensioned as closely as possible to upper limits but not so highly tensioned that forces required to move the controls are excessive.

(f) Electric batteries lose a large percentage of their capacity at low temperatures; as much as 50% at -18°C (0°F), and they cannot be charged at their normal rate. Pilots should satisfy themselves that the batteries in their aircraft are fully charged before leaving the aircraft dispersed in the open at low temperatures. If the batteries are not fully charged there is a danger of freezing the electrolyte and splitting the battery cases. If the batteries are fully charged there is no danger from freezing but their usefulness is very limited. It is recommended that when the forecast temperature is below -30°C (-22°F), batteries should be removed from aircraft and kept in a warm place to ensure that they can be used when required.

(g) Certain types of synthetic rubber, used in flexible oil and fuel lines and for coating electrical cables, lose their flexibility at low temperatures. This material will crack if subjected to bending. Care should be exercised to ensure that cables and flexible lines are not bent accidentally or unnecessarily.

(h) Plastic filling material used in the skin of fighter type aircraft may become loose under continuous cold temperature conditions. This material should be replaced because the flying characteristics of aircraft may be imparied.

(j) Tires on aircraft dispersed at low temperatures may stiffen with a flat spot frozen on them. Flat spots will disappear when the aircraft is taxied.

(k) Hydraulic and pneumatic systems and propeller seals have a tendency to leak during very cold weather. Corrective action should be taken when leaks are discovered. However, small leaks or seepage will usually disappear when the temperature increases.

(l) Special precautions should be observed when ground running aircraft engines on ice or snow surfaces or chocks may not prevent the aircraft from slipping.

(m) Aircraft that are parked on snow or ice can develop a high static charge during snow removal. This presents a very real danger of fire if refuelling is to be carried out. The fuel air mixture produced when gasoline evaporates at temperatures from -10°C to -40°C (14°F to -40°F) is explosive. The recommended procedure is to ground the aircraft electrically, as well as possible and wait at least 30 minutes for the charge on rubber and plastic parts to leak off before refuelling is carried out. Care must be taken to bring the aircraft to the same electrostatic potential as the refuelling equipment as called for in normal refuelling procedures. In addition, personnel who are refuelling must discharge any static charge built up in their bodies by touching any metal surface of the aircraft with their bare hands before refuelling.

(n) When refuelling an aircraft at remote northern stations, the fuel brought to the aircraft may be in drums taken from a fuel cache. Precautions to be taken when using cached fuel are as follows:

(1) Refuelling is normally done with a hand pump. Personnel operating the refuelling equipment should be warned against allowing fuel to soak their mitts as the insulation quality will be reduced and frozen hands may result.

(2) Fuel from drums should always be filtered.

(3) The octane value of cached fuel may be lower than normal. Fuel deteriorates slowly in drums.

(4) Do not use fuel from a drum that has been partly used as the remaining fuel may be contaminated.

PRE-FLIGHT CHECKS

5 The following checks, in addition to those required in temperate climates must be carried out before starting the engines:

(a) Inspect the landing gear locks for icing and all landing gear, hydraulic and air lines for cracks, breaks or leaks.

(b) Inspect the fuel tank vents for icing.

(c) Ensure that pitot covers have been installed to prevent entry of precipitation or blowing snow.

(d) Inspect hinges of all control surfaces to ensure that no particles of ice or hard snow are liable to cause jamming.

(e) Ensure that all snow, ice and frost has been removed from the aircraft.

(f) During the initial check, and again after taxying to the take-off position, test all main and auxiliary controls to ensure that they move freely and have not become stiff or blocked with ice and snow.

(g) All necessary windows and the astrodome should be defrosted before crew enters the aircraft. A light film of frost may form again during the warming-up of the engines or when the crew enters the aircraft; this light film can be removed with alcohol. Keeping a window open during run-up helps to prevent misting of the windscreen.

(h) Ensure that emergency equipment is complete and correctly stowed.

(j) The radio compass loop may require warming before it will operate in the auto position.

(k) Check the oxygen system for fullness. If a system is filled in a warm hangar, and the aircraft is moved outside, the system will require topping up when the aircraft has cooled to the outside temperature because of the contraction of oxygen at the lower temperature.

(l) Check to see that the air intake screens are removed. Under certain atmospheric conditions these screens will ice over preventing air from entering the induction system. Should this occur in flight, select an alternative source of air, i.e., hot air.

(m) Check the satisfactory operation of gills and oil cooler shutters.

STARTING

6 Engine starting during very cold weather is always easier and smoother if engines and accessories are first preheated. This should be done if time and equipment are available. If however, cold starting is required, the following information will aid the operator in obtaining successful starts:

(a) Batteries, either internal or in a battery cart should be fully charged and kept as warm as possible. This can be done by keeping the batteries indoors until just before they are required.

(b) Engines become increasingly difficult to turn as the temperature decreases. If one man can pull the engine through with the propeller a cold start may be safely attempted. If this is not possible, heat should be applied. If the installation is such that the propellers are too high or the engines are too large to pull through by hand, the test can be made using the starter. If the engine is too stiff to cold start, the clutch in the starter will slip.

(c) To obtain successful starts without pre-heating the engine, it is particularly important that cranking speed and priming are adequate. The cranking speed will depend on the outside air temperature and the percentage of oil dilution. Considerably more priming is required than under temperate conditions, in some cases as much as ten times more. With practice, cold starts at outside air temperatures down to -30°C (-22°F) can normally be made using 100 octane fuel for priming. Below this temperature, high volatile fuel or engine heating is usually required. The large amount of priming used in cold starting, results in excess fuel flowing from engine drains and is an additional fire hazard.

(d) Inoperative oil pressure transmitters are very often the cause of zero oil pressure indications when cold starting engines. Since no dilution reaches the oil in the line to the transmitter, this oil congeals. Upon subsequent restarting, the engine oil pressure is not high enough to push the congealed oil through the line to the transmitter, hence, zero oil pressure is registered on the gauge. When cold starting an engine, if the oil pressure does not begin to show within 30 seconds, the engine should be stopped immediately. If it is suspected that the oil pressure transmitter is causing the trouble, apply heat to the pressure line and transmitter. Upon restarting the oil pressure should register immediately if congealed oil in the line to the transmitter was the cause of the trouble.

(e) A difficulty that sometimes occurs when attempting to cold start engines is oil starvation. Normally, only the short system, which consists of the hot-well in the oil tank, the engine and sump, the oil cooler and lines is diluted. After stopping the eninge, there is a possibility that undiluted oil from the tank body will flow into the feedline to the oil pump. If this happens when the aircraft is dispersed during cold weather, the undiluted oil will congeal in the feedline. When a cold start is attempted, the feedline will remain clogged with congealed oil and zero oil pressure will be indicated. The engine must be stopped immediately and the oil feedline heated until the oil will again flow from the tank.

(f) The difficulty in starting an engine at low temperatures presents the additional problem of maintaining starters in a serviceable condition. Pilots should exercise great care that the precautions to be observed in the use of electric starters are not violated.

(g) In the case of radial engines, if the first attempt to cold start fails, the spark plugs may become wet and it is usually useless to make further immediate attempts. Allow five or ten minutes before making another attempt since the heat generated during the false start, may vaporize the priming fuel.

(h) The oil in auxiliary components, particularly vacuum pumps, may congeal or under conditions of extreme cold, become solidified. When a cold start is attempted, drive shafts of these auxiliary components may shear. Pilots should carefully check to ensure that correct vacuum and pneumatic pressures are obtained before taking off.

(j) When external heat is used, the amount required and where it is directed will vary with different aircraft. Generally, heat should be directed on the cylinders, accessories, oil feedline, and oil coolers. The amount of heat required will depend upon the air temperature, wind velocity, whether engine covers are being used and the percent of oil dilution in the engine oil system.

WARMING-UP

7 Engine warming-up and boil-off of oil diluent are important. Some aspects of this phase of cold weather operations are as follows:

(a) Carburettor hot air should be used to aid combustion during warming-up. Intermittent injections of prime or of carburettor deicer (alcohol) on aircraft so fitted will aid smooth running during warm-up. A suitable minimum engine speed should be used until minimum oil temperature is reached and it should then be increased progressively until the engine is warm. If an increase in RPM results when the mixture is moved from "Auto Lean" to "Auto Rich" it indicates that mixture is too lean owing to the cold air and all ground running and taxiing should be in "Auto Rich".

(b) If the diluent is not boiled off before take-off there is a danger of oil spewing. This is caused by the diluted oil foaming in engine crankcase to such an extent that the scavenge pump cannot handle the large volume of oil bubbles. The foam is then spewed through the crankcase breather. Spewing can generally be stopped by reducing power and RPM on the engine or engines affected.

TAXIING

8 Precautions to be observed during taxiing are:

(a) When taxiing on slush, the aircraft should be kept moving until dry snow is again reached; unnecessary turning should not be attempted as this will tend to stop the aircraft.

(b) Great care must be taken in looking out for obstacles. This applies particularly after a recent snow fall, when airfield markers may become covered and difficult to see.

(c) "Glare ice", that is ice formed by water freezing on the top of packed snow or runway surfaces occurs during early winter and spring, and during mid-winter thaws. The wheels will lock very easily under these conditions; brakes should, therefore, be used judiciously and in good time. In addition, pilots must watch for spots that are clear of ice because if brakes are being applied when the aircraft moves onto a clear patch, the aircraft will be in danger of nosing over, swinging or damaging its tires.

(d) Taxiing will allow the engine and carburettor to cool, and a sudden increase of power may result in faltering of the engines. On reaching the take-off position, ensure that engines are warm, and power is increased gradually.

(e) Pitot heat should be switched "ON" when taxiing to ensure that the pitot is warm before taking off.

(f) In icy conditions "taxi slowly". If idling RPM is high, try a low RPM setting and carburettor heat to reduce power, unless in extreme cold the use of carburettor heat results in a power increase.

TAKING OFF

9 Some of the precautions to be observed when taking off are:

(a) When taking off at low outside air temperature, particular attention must be paid to the relationship between carburettor air temperature manifold pressure, and brake horsepower otherwise detonation, with a consequent loss of power, or undue wear to the engine caused by excessive power will result. Reduce the manifold pressure from that normally used for take-off by 2 percent for each 11°C (51°F) the ambient air temperature is below 15°C (59°F). The same power from the engine will be obtained at the lower indicated manifold pressure under the cold conditions as would be obtained under temperate conditions using the normal take-off manifold pressure. The same rule should be observed when using military rated (30 minutes) or maximum continuous power settings where carburettor air temperature is below standard altitude temperature. Where a torquemeter is fitted, the desired power should be obtained by advancing throttle until either the appropriate limit of manifold pressure or torque pressure is reached. At low ambient temperatures the torque pressure limit, and at high ambient temperatures manifold pressure limit will be reached first.

(b) The rate of acceleration when taking off from unpacked snow or slush is poor, therefore, a precautionary type take-off should be carried out.

(c) Pack or remove excessive loose snow on the runway before attempting to take-off. Taxiing the aircraft up and down the runway to pack the snow may suffice in some conditions.

(d) When there are more than two inches of slush on the runway, a take-off should be avoided if possible since there is a danger of the landing gear becoming frozen either in the up or the down position.

(e) It is again emphasized that under normal conditions, no attempt should be made to take-off with ice, snow or frost on the wings. If it is necessary, in extreme urgency, to take-off under these conditions, the aircraft should be allowed to fly off with trims set at normal take-off settings and on no account should it be pulled off or climbed steeply. A stall under these conditions may be abrupt and dangerous. Such a take-off should only be made with the aircraft lightly loaded, and when no other alternative exists.

(f) An inversion may cause complete and sudden frosting of the windscreen during a climb from the field. In this event instrument flying will be necessary until the frost disappears.

(g) Flight instruments may be unreliable during extremely cold weather because of bearing friction caused by congealed lubricants. Electrically operated instruments are normally more reliable than vacuum operated instruments for cold weather operations.

DURING FLIGHT

10 Precautions to be observed during flight are:

(a) After take-off from slush, the landing gear, bomb doors, where permissible, and flaps should be operated several times to prevent freezing in the "Up" position.

(b) On aircraft that are not fitted with a warm oil bleed from the constant speed unit to feathering line, propeller controls should be exercised frequently.

(c) The ability of an engine to reach and maintain the desired operating temperatures depends upon the design of the engine cooling and lubrication systems. These systems are modified when necessary to enable required operating temperatures to be obtained, and to assist in the initial warming up on the ground. When an aircraft, operating from a cold region subsequently lands in a temperate climate, close attention should be given to the engine temperatures as the cooling capacity of the radiators and oil coolers may have been intentionally reduced.

(d) While in flight, coring of the oil cooler may take place. This will be indicated by a large rise in oil temperature. To uncore,

ROYAL CANADIAN AIR FORCE

ADVANCE REVISION

Serial #3 dated 19 Aug 60
(Sheet 1 of 1)

The sheet of this Advance Revision is to be inserted in the EO as follows:-

Sheet 1 facing page 142

Part 5, Section 3, page 142, para. 9(a), line 7 - Change sentence to read:-

> Reduce the manifold pressure from that normally used for take-off by 2% for each 11°C (20°F) the ambient air temperature is below 15°C (59°F).

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

manually select the oil cooler shutters to the closed position. This will stop the flow of air through the cooler so that the hot oil which flows around the cooler jacket can free the congealed oil in the core. Normal circulation of oil will then be restored and the shutters should then be set to an intermediate position which will prevent a recurrence.

(e) Above 60° or 65°N latitude, a magnetic compass is generally unreliable and may become quite useless because of large vertical component of the earth's magnetic field. Gyro steering will then be required. Since air operated gyros may be unreliable if the cockpit is not warm, the course should be frequently checked by astro compass if possible. In ad-

dition, pilots should note that low temperatures frequently cause bubbles to form in magnetic compasses which renders them unserviceable.

(f) Radio transmissions may become completely unintelligible because of interference from precipitation static. To greatly reduce precipitation static, use the loop antenna in the maximum position. This procedure can be used for range flying but must not be used for radio range let-down.

LANDING

11 Precautions when landing are:

(a) When landing on clean snow, difficulty in judging height will be experienced. Therefore, height should be judged by reference to objects such as trees, fences, hangars or other aircraft, and the pilot should permit the aircraft to sink gently with power until contact is made.

(b) If a landing is to be made with ice on the aircraft it should be remembered that the stalling speed is increased. The approach should be made accordingly.

(c) Brakes should be used judiciously and in good time. If there is any probability of overshooting, the pilot should increase power and make a second approach.

(d) Provided runway length will permit, landings in slush should be made with a minimum of flap because there is a danger of damaging the flaps with slush that is thrown up by the wheels.

(e) Engine temperatures should be maintained during a descent to land to avert possible choking or failure of the engine to pick up to normal power in the event of a balked landing.

AFTER LANDING

12 Aircraft engines and oil systems should be diluted if the aircraft is to be left dispersed at low temperatures.

13 The correct use of oil dilution is of the utmost importance when operating in cold weather. To understand the correct use, pilots should know the reason for diluting and how much dilution is required. Engine oil, when extremely cold, resembles very heavy grease and will not flow. When an engine with undiluted oil in it cools, the oil in cylinders, bearings and accessories solidifies and the engine becomes so stiff that it is impossible to turn it. By adding gasoline to oil, and mixing within the engine the resulting mixture remains fluid at low temperatures thus permitting the engine to be turned by the starter or pulled through by hand. This mixing of gasoline with oil is called oil dilution. The quantity of gasoline to introduce into the oil will depend upon the estimated low temperature and is usually measured in percentage of gasoline in the mixture or in the time in minutes taken to dilute the system. Dilution is required below 5°C (41°F). At any temperature below this, the dilution required is that which will produce a viscosity equal to the viscosity of undiluted oil at 5°C (41°F). A chart can be made for each type of aircraft which gives the percentage or minutes of dilution required for low temperatures. If the pilot follows this chart no lubrication difficulty should be encountered in cold starting.

14 The following procedure is recommended for aircraft that are to be left dispersed during cold weather:

(a) Stop engine(s), check oil level in tanks, replenish if necessary but allow adequate airspace for anticipated quantity of dilution.

(b) Restart engine(s) for dilution.

(c) Operate engine(s) at suitable speed, normally 1000 to 1400 RPM depending upon the type of aircraft.

(d) Cylinder head and oil temperatures should be less than 150°C and 60°C (300°F and 140°F) respectively while dilution is carried out to minimize vaporization of diluent.

(e) Engine oil pressure will decrease as dilution progresses. It can be prevented from falling below minimum permissible by increasing RPM as required. However, momentary pressures below the minimum while exercising pitch and feathering are permissible.

(f) Operate the propeller control through three complete cycles obtaining an RPM drop each time. This action provides diluted oil to the outboard side of the dome assembly thus preventing freezing in the last selected position.

(g) Operate the feathering button three times near end of the dilution period. A drop of 400 RPM each time will circulate enough diluted oil in the feathering system to ensure proper functioning when the engine is again started. When the feathering pump is being operated, care must be taken to protect the feathering pump motor and not to exceed its limitations.

(h) Carry out dilution of accessories, (vacuum pumps, starters, etc) if applicable.

(j) Shut down in normal manner, holding the dilution switch "ON" until the engine stops.

(k) Fuel tanks should be filled as soon as possible after landing to prevent condensation.

(l) If the aircraft is dispersed, all covers and blanking plates should be fitted. Special covers may also be needed to protect the landing gear locks and micro-switches. Blowing snow will enter openings, therefore it is necessary to ensure that bomb doors, windows, hatches and doors are closed. For short stops, it is advisable to install blanking plates in the coolers to slow the cooling rate. This will be particularly effective when the wind chill factor is high. Close cowl gills if fitted.

(m) Parking brakes should not be left "ON" as they may freeze in this position if any moisture is present. The rubber inflation bags in pneumatic brakes stiffen at low temperatures and will hold the brakes on after the pressure has been released.

(n) Batteries should be checked as outlined in paragraph 4 (f).

(p) Throttles should be left in the partially open position after shutting down. This will permit starting if the engine controls become too stiff to move and may prevent freezing of the butterfly.

(q) Have the condensate drained from the oil tank, "Y" drain, engine sump, etc., as required on the type of aircraft.

SECTION 4

OPERATING UNDER TROPICAL CONDITIONS

INTRODUCTION

1 Tropical conditions vary. The maximum temperature may be high and be followed by a relatively low minimum temperature after sunset. Some areas have a high temperature and a low humidity, except during the rainy season, while others have a high humidity throughout the year. Aircraft being operated under these conditions require protection from heat and humidity.

GENERAL

2 Observe the following considerations:

(a) When operating from desert regions, every effort should be made to exclude dust and sand from engines and moving parts.

(b) Other considerations being equal, the air is less dense than in temperate climates. True stalling speed will be greater, although the indicated stalling speed will remain the same.

(c) Head protection from sun and suitable sun goggles may be necessary for tropical flying.

(d) On the ground, certain plastic materials soften when exposed to the sun. Therefore, when aircraft are dispersed in the open, covers should be fitted over cockpits, turrets, and astrodomes.

(e) Control cables may tighten due to the cables having a different coefficient of expansion from that of the material used in the construction of the aircraft.

(f) Heat will cause the fuel in the tanks to expand and vapourize. On the ground, fuel tanks situated in the wings should be shaded with covers. Fuel pressurizing should be used, when climbing to altitude, to prevent vapour locks and the possibility of fuel boiling.

(g) Aircraft being operated under these conditions have modified cooling and lubricating systems; a high viscosity lubricating oil may also be used.

(h) To assist survival following a crash landing or ditching, ensure that:

(1) The emergency equipment is complete and securely stowed.

(2) The drinking water tanks are full.

STARTING UP AND TAXIING

3 The following points should be noted:

(a) When starting up, care should be taken not to overprime the engine, as the priming fuel will atomize readily. An unsuccessful start is almost invariably due to the richness of the initial prime; it is preferable first to underprime and then to increase the amount of priming as required.

(b) The warming up time should be kept to a minimum and engine and instrument tests should be as short as possible. Care must be taken to keep cylinder head, oil, and coolant temperatures below their maximum when running up on the ground and when taxiing.

(c) When conditions permit, ascertain from air traffic control before starting up, that the take-off will not be delayed. If forced to wait, with engines running, for other aircraft to take-off, maximum temperatures may be exceeded and it will be necessary to stop the engine(s).

(d) Brake drums overheat quickly while taxiing, and unnecessary braking should be avoided.

(e) Oil inlet temperatures, cylinder head or coolant temperatures should not exceed the cruising limitations for the engine, and they should never exceed the maxima, prior to take-off, quoted in POI for the type. As a general guide it may be assumed, that if temperatures are high at the start of the take-off, the rise in coolant temperatures is unlikely to exceed 15°C to 20°C (59°F to 68°F); with air cooled engines, the corresponding rise in cylinder head temperatures is much greater, and may be as much as 60°C to 80°C (140°F to 174°F).

(f) When possible, tractors should be used for moving aircraft to and from dispersal points.

TAKE-OFF

4 Take-off distances will be longer when the air is less dense.

DURING FLIGHT

5 To avoid overheating it may be necessary to climb the aircraft at higher airspeeds than those quoted in POI.

6 Low flying may result in higher engine temperatures than those obtained in temperate climates.

LANDING

7 Landing distances will be greater when the air is less dense, as the true airspeed will be higher than the indicated airspeed.

8 When heat is rising from the ground, judgment of height may be difficult and a false horizon is obtained due to mirage effect. Ground objects should be used to give an indication of the height of the aircraft above the ground.

AFTER LANDING

9 After landing, parking brakes should not be applied until the brake drums have cooled.

10 If it is necessary to fill fuel tanks to their maximum capacity, refuelling should be carried out at the coolest time in the twenty-four hour period.

SECTION 5

FLYING THROUGH CUMULO-NIMBUS OR EXTREMELY TURBULENT CLOUD CONDITIONS

INTRODUCTION

1 When it is impracticable to avoid extremely rough air conditions in cumulo-nimbus type clouds, the following recommendations should be observed:

(a) If possible the aircraft should always be prepared before the turbulence is encountered.

(b) Unless the automatic pilot is known to be reliable in these conditions it should be disengaged; the aircraft should be trimmed for level flight at the speed recommended in paragraphs 2 and 3 below, and a constant course maintained throughout.

(c) The landing gear should be kept retracted and the flaps should not be lowered unless this is specifically recommended for the type.

(d) The pressure-head heater should be switched on and the carburettor heat control set to give warm air.

(e) All loose equipment should be securely stowed and crew and passengers tightly strapped in.

RECOMMENDED SPEEDS

2 At high speeds the stresses imposed on the airframe by turbulence may be considerable, and the stalling speed may be increased appreciably in rough air, particularly if any "g" is imposed. Consequently, all coarse use of the controls should be avoided and, unless flying near the ground is unavoidable, no attempt should be made to maintain a constant height, variation in altitude caused by up or down draughts being accepted without corrective action. The aim should be to maintain a constant attitude with the aid of the artificial horizon and a reasonably constant airspeed, irrespective of fluctuations of the instruments.

3 When POI for the type recommend speeds for flying in turbulent conditions the aim should be to maintain these speeds as closely as is practicable without resorting to coarse use of the controls or sudden changes in power settings. If no speeds are quoted in the POI the following speeds should be maintained:

(a) On heavy aircraft such as bomber and transport types, 1.6 to 1.65 times the power-off stalling speed at the approximate weight.

(b) On fighter and advanced trainer type aircraft, 1.6 to 1.65 times the stalling speed gives about the same degree of safety as on the heavier types but if it is operationally desirable to fly at a higher speed, up to 2.5 times the stalling speed is permissible. It should, however, be realized that this will entail greater discomfort.

(c) On lighter types such as basic trainers and light communications aircraft, about twice the stalling speed should be maintained.

4 Power should be set to give the required speed before the turbulent area is entered, and should not be altered until clear of the area. With piston engined aircraft at least 2,000 RPM should be maintained.

HEIGHT TO FLY

5 To avoid the most severe turbulence in cumulo-nimbus type clouds, it is generally advisable to fly below 8,000 feet but well clear of the ground, or at 25,000 feet or above.

UNRELIABILITY OF INSTRUMENTS

6 Instruments depending upon atmospheric pressure, in particular the altimeter and rate of climb indicator, should not be relied upon as they may give false readings due to local turbulence. Heavy rain or icing may give errors in ASI readings of up to 70 knots, even with the pressure-head heater on, but if power and speed have been selected beforehand fluctuations may be disregarded. Check that the vac-

uum changeover cock, if fitted, is set to the correct source.

LIGHTNING

7 Certain precautions are advisable if there is a possibility of the aircraft being struck by lightning. A phenomenon which occurs near thunder-clouds, but is not dangerous in itself, is "St. Elmo's Fire", which appears like a bluish flame of halo playing on projecting parts such as propellers or guns or windscreens. It is not a flame and is not hot; it often serves as an indication of nearby thunder clouds. To counteract the distraction caused by lightning or St. Elmo's Fire, cockpit lighting should be turned up to full intensity.

EFFECTS OF LIGHTNING STRIKES ON AIRCRAFT

8 The following effects may occur:

(a) The pilot may be temporarily blinded.

(b) Compasses may be rendered unreliable until they have been reswung.

(c) Trailing radio aerials may be severed.

(d) If radio or radar is being used in the aircraft there will be an increase in amount of interference as the area of greatest electrical disturbance is approached. The crew should inform the pilot of such conditions.

PRECAUTIONS

9 Observe the following precautions:

(a) The bonding of the metal parts of an aircraft is sufficiently good to prevent serious internal sparking if the aircraft is struck by a lightning flash.

(b) Lightning should be expected in all large cloud masses from which showers of rain, hail or snow are falling, especially if the meteorological forecast indicates the possibility of thunderstorms. Heavy radio static on medium frequencies is usually a reliable warning.

(c) Trailing aerials should be earthed, to reduce possibility of electric shock on touching the winch or cable, and then wound in.

(d) The adoption of any or all of these precautions must depend on conditions of service on which the aircraft is engaged, and therefore must be at the discretion of the pilot.

(e) It is not advisable to jettison fuel if the presence of electrical disturbances is suspected.

SECTION 6

OPERATING IN RAIN

GENERAL

1 The operation of aircraft in rain does not normally require any particular handling technique, but the following safety precautions may avoid possible damage or failure.

IN FLIGHT

2 When flying in rain, pressure-head heaters should be switched on, and if the outside air temperature is within the zone likely to give carburettor icing, the air intake control should be set to the "warm" or "hot" position.

3 If windscreen wipers are fitted, the rate of operation should be regulated to give the best results; the most rapid operation does not necessarily give the best vision. Airspeed affects the efficiency of the wiper, and, as a general rule, the best results will be obtained at the lower speeds.

4 Many aircraft are not equipped with wipers consequently vision from them when flying in rain is usually poor, however, "clear vision" panels are often fitted for use in these conditions. These panels are set at an angle to the main windscreen, and are not obscured by rain to the same extent. In very heavy rain, they may be opened, and are so designed that the entry of air and moisture is reduced to the minimum. A member of the crew, posted as a lookout at one of these panels, can be most useful.

5 When conditions become poor, a reduction in airspeed will improve visibility, and will leave more time for avoiding action should this be necessary. With very high-speed aircraft, it is particularly important to reduce speed, as high speeds in rain may result in damage to the airframe.

TAKING-OFF, LANDING AND GROUND HANDLING

6 The time when most care is needed, is during landing and when taxiing. An efficient lookout is essential, and pilots should be aided by their crew in this respect. If landing on wet grass, the brakes must be used with care. It is most difficult to tell when a wheel is "locked" and is skidding, consequently aircraft can easily get out of control through misuse of brakes.

7 Large puddles may form during heavy rain, and considerable drag on the landing gear can be felt when passing through them at speed. If possible, such water should be avoided, particularly when operating in light aircraft, as the drag caused may result in a swing during the take-off or landing run. Damage may also be caused to the flaps and control surfaces by water being thrown up in this way.

8 Particular care should be exercised when starting up, and leaving or entering the dispersal area. Chocks may easily slip on a wet surface and brakes may prove ineffective when required most, particularly on a wet and oily surface.

PART 6

EMERGENCIES

SECTION 1

FIRE ON THE GROUND

REFUELLING AND STARTING PRECAUTIONS

1 During refuelling, none of the electrical services, including the radio and radar equipment, should be operated. Electrical fuel contents gauges may, if necessary, be switched on prior to refuelling, but they should not be switched off until refuelling has been completed and the presence of fumes within the aircraft can no longer be detected. It is essential that all mechanical refuelling appliances are earthed before refuelling operations are commenced

2 Should a fire occur, ground crew must immediately warn the pilot by giving the "cut motors" signal, as per CAP 100, Appendix III, Figure 9, and at the same time alternately point to the fire extinguisher and the engine in question.

ACTION TO EXTINGUISH FIRE

3 It is not advisable to open the throttle as the fire may not be an induction system fire which can be sucked through the engine. With any other type of fire, the effect of opening the throttle may be a disastrous increase in the severity of the fire. It is, therefore, advisable to stop the engine as quickly as possible and the following action should be taken as soon as warning is received from the ground crew or fire is observed by the pilot:-

(a) Close the throttle.

(b) Stop the engine using the fuel cut-off or slow running cut-out, or, if neither is fitted, by switching off the ignition.

(c) Turn off the fuel and switch off booster pump(s), if fitted.

(d) Switch off the ignition, if this has not been done in (b) above to stop the engine.

4 An intake fire may be dealt with by the ground crew blanketing the intake as soon as the propeller has stopped. In the case of any other type of fire, or of a serious intake fire, the ground crew should use fire extinguishing equipment and or call for the pilot to operate the fire extinguisher system as soon as the engine has stopped. The pilot should operate the fire extinguisher system on his own initiative if he considers it necessary, but not before the engine has stopped as the fire is liable to recur if the engine is still running, as soon as the brief action of the extinguisher is finished.

5 On certain small aircraft with unsupercharged engines, it is possible to extinguish small fires in the air intake by turning off the fuel and opening the throttle, but, if the pilot is in any doubt as to the effectiveness of these methods, he should carry out the action detailed in paragraph 1 above.

6 No attempt must be made to restart an engine that has been on fire until it has been examined. An exception can be made, however, in the case of an intake fire that has been successfully dealt with by blanketing intake and without use of any type of fire extinguisher.

SECTION 2

FIRE IN THE AIR

FIRE RISK

1 Precautions against fire are a design requirement for all aircraft. This fact, together with the development of safety devices and extinguisher systems, has greatly reduced the risk of fire in modern aircraft. Fires, other than those caused by enemy action, usually originate in the engine nacelle after mechanical failure of the engine or of the ancillary components; defects in the induction, exhaust, fuel, oil and hydraulic systems also constitute a fire hazard. A fire elsewhere in the aircraft seldom occurs; if it does it can be caused by short circuiting of the wiring, mishandling of pyrotechnics, leakage of the fuel system or unauthorized smoking by passengers or crew. Pilots should be conversant with:

(a) The fire warning and extinguisher systems.

(b) The action to be taken in the event of fire.

(c) The layout of the fuel system.

(d) The main structural details of the aircraft.

FIRE WARNING

Fuselage Fires

2 As even a small amount of smoke will quickly fill the fuselage, there is normally adequate fire warning; dependent on the type of fire, this smoke may or may not be accompanied by a pungent odour. Normally, prompt action by the crew will successfully combat this type of fire. The pilot should remember that opening the cockpit windows may fill the cockpit with smoke and fumes as a forward draft is induced. Once the pilot is certain that the fire has been extinguished the windows should be opened to remove toxic fumes. With pressure cabins the extinguisher fluid used, a water glycol mixture, does not produce toxic fumes and no ventilation is necessary.

Engine Nacelle Fires

3 Visual indication of engine nacelle fires may not be immediate due to the position of the engine and engine cowling. The pilot is assisted by red fire warning lights in the cockpit which are operated by flame switches in the engine nacelles. These warning lights show a steady red in event of fire, and are usually fitted close to, or recessed in, the feathering pushbutton of the relevant engine in multi-engined aircraft. On later installation, these lights may also be arranged to give an intermittent flashing signal in the event of loss of coolant and/or low oil pressure. This flashing signal is a "stop engine" warning and although fire is not present, immediate action should be taken to stop the engine; otherwise, engine seizure will occur with the attendant risk of fire. On single-engined aircraft, the warning light is mounted in a convenient position and if an intermittent light appears the pilot should immediately reduce power and land as soon as practicable. If a steady light appears the pilot should proceed as recommended in paragraphs 5, 6 and 7 below.

Fuel Tank Bay Fires

4 On some later aircraft a separate fire warning and extinguishing system is fitted for each of the fuel tank bays. Such systems, which are independent of the engine fire extinguishing systems, may be manually operated, but will usually be fully automatic. When automatic, should fire occur in a tank bay, an extinguisher operates together with its associated warning light, if fitted, under the control of flame switches. In manually operated systems the warning lights come on automatically, but the extinguisher will not operate until the appropriate tank fire extinguisher pushbutton is pressed. These systems are also operated automatically by the inertia switch in the event of a crash. In all cases the pushbutton, if fitted, should be pressed as a precaution, as in the case of engine fire extinguishing systems.

Tank bay fire extinguishing systems are intended to cope with fires occurring in the tank bays outside the tanks, due, for example, to a leaking tank or fuel connection; they afford no protection against explosions within the tanks themselves. To prevent such explosions, nitrogen systems are installed; they do not afford protection against fires occurring outside tanks and may be installed independently or as well as fuel tank bay fire extinguishing systems.

IMMEDIATE PREPARATION TO ABANDON AIRCRAFT

5 On suspecting fire, the captain should at once warn the crew to prepare to abandon the aircraft or, if the height precludes a parachute descent, to prepare for an immediate crash landing. Should the fire show no signs of abating after action has been taken to extinguish it and there is risk of explosion or structural failure, the captain should give orders to abandon aircraft if height permits. If there is sufficient height, pilots should not hesitate to abandon the aircraft rather than to attempt a crash landing. Landing with the aircraft on fire is seldom justified; there is little chance of saving the aircraft after landing and there is a great risk that the fire may spread rapidly when it is too late to jump.

6 If the aircraft is too low to be abandoned by parachute, and immediate crash landing may be necessary. Fuel should not be jettisoned as the proximity of the petrol vapour to the fire may cause an explosion. Drop tanks, whether containing fuel or not, may, however, be dropped at the pilot's discretion. Fuselage bombbay drop tanks should always be dropped in the event of a fuselage fire.

ACTION TO EXTINGUISH FIRE

7 If a fire occurs at the engine it is most probably a fuel or oil fire. The pilot should, therefore, stop the supply of fuel immediately, the throttle should be closed, and the engine stopped if possible. Although the fire may be checked by operating the fire extinguisher, it is liable to recur if the engine is still running, as soon as the brief action of the extinguisher is finished.

8 To obviate the presence of unburnt exhaust gases, delay switching off the ignition until the engine has stopped or nearly stopped. The fire extinguisher should then be operated as the last action.

9 If propeller will feather, the following actions should be taken at once:

(a) Close throttle of the engine concerned.

(b) Feather the propeller.

(c) Turn off the fuel to this engine.

(d) Switch off the ignition, and when the engine has stopped

(e) Operate the fire extinguisher.

10 If the propeller will not feather, the following actions should be taken at once:

(a) Close throttle of the engine concerned.

(b) Move the RPM control lever to the minimum RPM position.

(c) Turn off the fuel to this engine.

(d) Switch off ignition, and after waiting until the engine has slowed to minimum RPM -

(e) Operate the fire extinguisher.

ACTION WITH TURBINE-JET ENGINES

11 The principles applied to piston engines are also applicable to turbine-jet engines the sequence being as follows:

(a) Turn off the fuel (HP and LP cocks).

(b) Close the throttle.

(c) Reduce the airspeed.

(d) Operate the extinguisher.

12 For further information, pilots should read the POI for the particular aircraft type.

ACTION WITH FIRE EXTINGUISHER SYSTEMS

13 On most installations, the fire extin-

guishers fitted in the engine nacelle discharge simultaneously when fire extinguisher pushbutton in the cockpit is operated. On a later type of semi-automatic fire extinguishing system provided that a fire has started, action of the extinguishers, which operate in stages with a time interval between each stage, is started automatically by flame switches immediately feathering pushbutton is pressed. To ensure operation of the system in the event of failure of the flame switches, the fire extinguisher pushbutton should always be pressed as the last action of the drill which should be carried out as with the earlier types of fire extinguisher, (see paragraphs 7 and 8 above).

ENGINE NOT TO BE RESTARTED

14 The pilot must not attempt to restart an engine following the successful extinction of a fire in its nacelle. The fire is liable to recur if the engine is restarted, and the fire extinguisher system will not act a second time until replenished on the ground.

ACCIDENTAL OPERATION OF FIRE EXTINGUISHER SYSTEMS

15 If the fire extinguishers have been accidently discharged:

(a) Piston engines - Continue flight with throttle not less than two-thirds open; after two or three minutes return to normal flight conditions. This minimizes corrosion of the engine and fouling of the sparking plugs, as it ensures the rapid dispersal of the methyl bromide which vaporizes rapidly at temperatures of 4°C (39°F) and above.

(b) Turbine-jet engines - Flight should be continued for two or three minutes at not less than two-thirds maximum permitted RPM then return to normal flight conditions.

16 The operation of the fire extinguisher system, accidental or deliberate, must be reported after landing in order that the necessary action may be taken to minimize fouling and to replenish the extinguisher system.

SECTION 3

FLIGHT ON ASYMMETRIC POWER: GENERAL CONSIDERATIONS

INTRODUCTION

1 On any multi-engine aircraft, flight on asymmetric power could be taken to mean a difference in the amount of power being delivered by the engines. In this publication, however, the term asymmetric power refers to the condition of having one or more engines failed on a particular wing.

2 This and the following sections are essentially of a general nature only. Pilot's Operating Instructions for individual aircraft types should be consulted for characteristics of various types and marks.

CRITICAL AND SAFETY SPEEDS

3 The terms critical speed and safety speed have already been defined, and as they are used extensively hereinafter, it is essential that their full implications are clearly understood. Aircraft of same type are frequently handled on take-off under different conditions, such as differing all-up weights, carrying a variety of external stores, and at maximum or lower boost according to conditions. As this is so, POI may quote two safety speeds, the higher to cover a take-off at maximum permissible all-up weight using maximum boost, and the second to cover a take-off at an average training load using a lower boost setting. Whatever the take-off conditions however, the safety speed quoted caters for the failure of that engine - outer engine in the case of four engine aircraft - which, due to the direction of rotation of the propellers, promotes the greater yaw.

4 The critical speed, being the lowest speed at which any individual pilot can maintain directional control of his aircraft under

given conditions, is a variable and does not take account of the element of surprise attending sudden failure of an engine, which the pilot is unable to anticipate. The safety speed must provide a margin over the critical speed under take-off conditions, to allow for surprise, to ensure that the aircraft will not stall and, so far as is practicable, that it will be able to maintain height following sudden failure of any engine.

5 Safety speed should be attained as soon as possible after take-off. Once this speed is reached, the climb may safely be commenced as, should any engine then fail, it should not be difficult, even with the aircraft in take-off configuration and with the live engine(s) delivering take-off power, to maintain a straight course by instant and coarse use of the rudder assisted by aileron as required, and without applying trim. There should be no risk of stalling the aircraft if this speed is maintained while further appropriate action is taken. If aircraft is overloaded or of an underpowered type and height cannot be maintained, a safe controlled landing should present no undue difficulty the landing gear being raised, or at least unlocked if necessary.

ACTION WHICH CAN BE TAKEN

6 When engine failure occurs, the application of bank towards the live engine(s) may assist in maintaining direction. Moreover a small amount of bank towards live engine(s) will give the optimum performance on asymmetric power. However, this amount of bank is very small, it varies with the airspeed, and it cannot be assessed accurately on existing flying instruments, but as an aircraft's performance is virtually as good when the slip indicator is central, it is a golden rule that it should be kept in this position under all conditions of flight on asymmetric power, provided that the speed is above the critical speed. Furthermore, this is a much simpler point of reference and all the time the pilot can keep the slip indicator central, the airspeed will, of necessity, be above the critical speed for the conditions prevailing.

7 The action to be taken in the event of engine failure depends upon four main factors, the airspeed, the performance of the aircraft when one or more engines have failed, the load being carried and the height which has been reached. During take-off the pilot should, as far as practicable, keep his hand on the throttles until the landing gear is up and safety speed has been attained.

8 The failure of all engines calls for the same action as engine failure on a single-engine aircraft.

SECTION 4

TWIN-ENGINE AIRCRAFT: FAILURE OF ONE ENGINE DURING TAKE-OFF

ENGINE FAILURE BEFORE BECOMING AIRBORNE

1 If engine failure occurs before becoming airborne, it will be advisable, almost invariably, to abandon the take-off and attempt to pull up as quickly as possible:

(a) Close both throttles and switch off the ignition.

(b) Apply the brakes.

(c) If the space ahead is insufficient, retract the landing gear. If, however, speed is very low, an attempt may be made to turn the aircraft.

(d) Turn off the fuel.

ENGINE FAILURE WHEN AIRBORNE, BUT BELOW SAFETY SPEED

2 On the majority of heavily loaded high performance aircraft, this will generally mean a forced landing straight ahead. In these circumstances, the live engine should be used within the limits imposed by the critical speed to select the best landing area.

3 If, however, the pilot has attained an airspeed equal to or greater than his critical speed it is clear that the maximum possible corrective use of the rudder assisted if necessary, by the ailerons, will enable the aircraft to be kept straight, particularly if the circumstances allow power to be reduced on the live engine.

4 Once the propeller of the failed engine has been feathered, trim has been applied and any load which can be jettisoned with safety has been jettisoned, it may be possible to climb away slowly with the live engine running at the maximum power which can be held with the rudder. If bank has been applied to assist the rudder, it should be taken off when the aircraft has been brought under control directionally, as its continued use may detract from the aircraft's performance.

ENGINE FAILURE WHEN AIRBORNE AND ABOVE SAFETY SPEED

Immediate Actions

5 Whether the aircraft will climb or not, the following is the action to be taken immediately an engine fails. If the aircraft is at a very low height and will not climb, it may not be possible to complete this procedure before landing. Nevertheless, the following drill should be carried out, so far as is practicable, in all circumstances:

(a) Keep straight by instant and coarse use of the rudder, and if necessary, depress the nose to maintain speed.

(b) See that landing gear is up or rising.

(c) Feather, or if this is not possible, set to minimum RPM, the propeller of the failed engine.

(d) Trim the rudder as necessary to relieve the foot load.

(e) Jettison all external stores that may safely be jettisoned. This may not be necessary if the aircraft has a good single-engine performance.

(f) Close the cowling gills, or radiator shutters, of the failed engine.

(g) If the flaps have been used for take-off, they will generally impair the aircraft's ability to climb on one engine. They should, therefore, be raised as soon as a safe height is reached.

Subsequent Actions

6 These will depend on the aircraft's ability to climb on asymmetric power:

(a) If, after carrying out immediate actions detailed in paragraph 3 above, the pilot is in doubt as to the ability of the aircraft to climb, he should continue to use full take-off power and raise the nose of the aircraft gently in an attempt to gain height, but he must not allow the airspeed to fall below his critical speed.

(b) If the aircraft will not climb, the choice of landing area will be restricted, but full use should be made of the live engine to reach the best available landing space. The pilot must always keep the airspeed above his critical speed for the amount of power being used.

(c) If aircraft will climb, a turn in either direction may be started at a safe height, and the aircraft flown to a suitable position for landing.

(d) The use of take-off power may be continued so long as it is found to be necessary, but RPM and boost should be reduced to the climbing limitations as soon as this may be done with safety. The cowling gills, or radiator shutters, of live engine should be opened as necessary to avoid overheating.

SECTION 5

TWIN-ENGINE AIRCRAFT: FAILURE OF ONE ENGINE IN FLIGHT

INTRODUCTION

1 In this chapter the aircraft is assumed to be flying at a safe height and speed, and to be capable of maintaining height on asymmetric power after jettisoning all or such part of the load as may be possible, if this is required. If engine failure occurs early in the flight it may be necessary also to jettison part of the fuel load.

2 Paragraphs 6 to 8 discuss the immediate actions required to get the aircraft under full control and to prepare for flight on asymmetric power. In paragraphs 9 to 13 the subsequent actions necessary to maintain a suitable height for flight to an airfield are discussed.

3 On a number of aircraft the power normally used for take-off and the maximum power permitted for climbing are almost identical, but the speed for maximum rate of climb is below the safety speed. In such a case, the pilot may, if faced with an engine failure on a high power climb, need to throttle back the live engine in order to maintain directional control.

4 If the automatic pilot is in use when engine failure occurs it should be disengaged at once. Unless POI for the type recommend otherwise, it may, however, be re-engaged subsequently.

5 For practice purposes engine failure may be simulated by feathering a propeller, but this should not be done at temperatures below -15°C (6°F) as otherwise it may not be possible subsequently to unfeather it owing to congealing of the oil in the dome.

IMMEDIATE ACTIONS

6 If the engine failure is clearly due to a mechanical breakdown or is accompanied by fire, propeller must, if possible, be feathered without delay. In other circumstances cause of failure should be investigated before feathering:

(a) Keep straight and level by instant and coarse use of rudder, putting the nose down if necessary to maintain at least critical speed.

(b) Trim the rudder as necessary to relieve the foot load and to centralize the slip needle.

(c) Close the throttle of the failed engine, then re-open it slowly to see if any power is available. If there is not close it again and set the RPM control lever to the minimum RPM position.

(d) Increase power as necessary on the live engine and then retrim the aircraft as required.

(e) If a manually operated vacuum selector cock is fitted, set this so that the live engine supplies suction to the gyro instruments.

(f) When dependent on instruments, or if any difficulty is experienced in checking the swing, it may be advisable to throttle back both engines at once and put the nose down in order to maintain directional control more easily. Power on the live engine may then be increased to that required for level flight, provided that directional control can be maintained.

7 Now make a systematic check of the possible causes of failure:

(a) Check the ignition switches, fuel contents gauges and fuel warning lights. Check fuel cocks, fuel pressure and booster pumps. If a shortage of fuel is suspected, opening a cross-feed cock without first turning off the tanks which were supplying the failed engine may, by admitting air to the fuel lines, cause the other engine to cut.

(b) Check for carburettor icing. If this is suspected carry out the recommendations in Part 5, Section 2.

(c) If flying in weak mixture, try rich mixture. If there is no manual mixture control, the engine may run at a boost above the weak mixture limit.

(d) Check operation of the supercharger clutches by changing gear.

8 If the failure cannot be rectified proceed as follows:

(a) If possible feather the propeller of the failed engine, turn off the fuel and switch off the ignition.

(b) Close the cowling gills, or radiator shutters, of the failed engine.

(c) Set the fuel cocks for continuous supply to the live engine.

(d) If the engine driving the generator, on the aircraft fitted with only one generator, has failed, switch off all non-essential electrical equipment and restrict the use of the essential services to the minimum required for safety.

SUBSEQUENT ACTIONS

9 Check all the possibilities of reducing drag. Centralize the turrets and if possible retract them. See that the flaps and landing gear are up fully and that the bomb doors are properly closed. As far as possible, close all apertures.

10 If difficulty is experienced in maintaining height, disposable load and then fuel should be jettisoned as required. If it is necessary to jettison fuel, the failed engine should first be stopped by feathering if possible, its fuel supply and ignition turned off, and if there is any suspicion of fire, its fire extinguisher operated. The amount of power used on the live engine should be increased beyond the climbing limitations only to prevent a dangerous loss of height.

11 The ability to climb on asymmetric power depends upon both height and speed. The ceiling in both high and low gear is very much reduced. In the example illustrated in Figure 6-1 the full throttle height power in high gear is less than the power required to maintain height at that altitude. The ceiling on asymmetric power is, therefore, the low gear ceiling of about 11,000 feet. Figure 6-2 shows the effect of speed on the same aircraft, it being just possible to maintain the full throttle height of 10,000 feet at 145 knots. At a lower speed, the ceiling will be higher, but at the maximum rate of climb speed of 120 knots, at heights in excess of about 11,000 feet, it will be necessary to descend until height can be maintained, unless load can be jettisoned. If, for economy, power is reduced to the maximum permitted in weak mixture, the ceiling will be still further reduced.

12 It follows from paragraph 11 that:

(a) A fairly rapid loss of height is to be expected initially if the failure occurs very

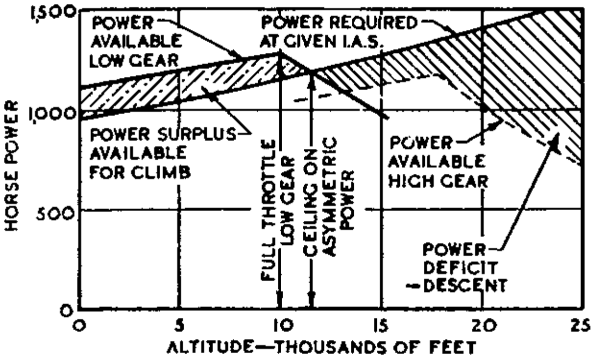


Figure 6-1 Power Requirements During Flight on Asymmetric Power

much above rate altitude. This height is quoted in the engine manuals, if not in POI.

(b) The rate of descent will decrease as the aircraft approaches the ceiling on asymmetric power, which will usually be near the rated altitude. Thus, if conditions permit, descent should be made, at least, to the rated altitude.

(c) If height is still being lost slowly at the rated altitude, level flight may yet become possible as the aircraft is lightened by the consumption of fuel. Although less power is developed by the engine below full throttle height, the aircraft requires less power to fly at given IAS.

13 In general, on asymmetric power, the aim should be to maintain the recommended range speed, but if height cannot be maintained in weak mixture at this speed, conditions will govern which of the following actions should be taken:

(a) Accept a small rate of descent if practicable, in order to maintain the range speed in weak mixture, when maximum range is of paramount importance.

(b) Use rich mixture, if required, when it is of primary importance to maintain height.

(c) An infinite number of variables exist between (a) and (b); each being governed by the conditions prevailing at the time. Pilots should always judge each case on its merits, but should also remember that the range speed is the most efficient speed.

RANGE ON ASYMMETRIC POWER

14 On many types of aircraft there is a considerable loss in range when flying on asymmetric power since a 25% to 35% richer mixture is used at the boost setting required to maintain flight. On other types, however, where a speed approaching the optimum range speed can be achieved without exceeding the weak mixture limitations, the loss in range will be only slight.

15 Maximum range will be obtained by flying in weak mixture at the normal recommended range speed.

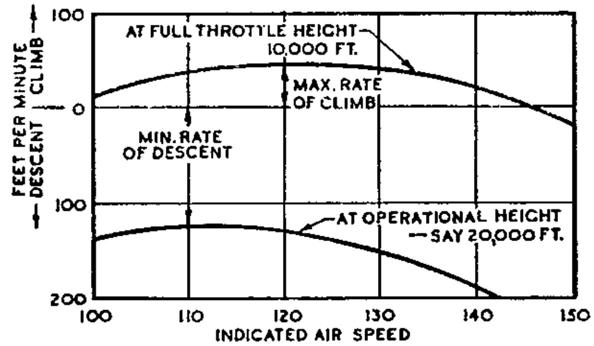


Figure 6-2 Variation of Full Throttle Height with Speed During Flight on Asymmetric Power

SECTION 6

TWIN-ENGINE AIRCRAFT: APPROACH AND LANDING ON ASYMMETRIC POWER

INTRODUCTION

1 If an aircraft will not maintain height on asymmetric power with landing gear and flaps up, the pilot has only a limited choice of action, which will normally be confined to using the available power to:

(a) Keep the rate of descent to a minimum.

(b) Select the best possible landing area.

2 If an airfield cannot be reached, a "wheels up" landing, using flaps as required must be made. The pilot should, if possible, select his landing area while he still has at least 1,000 feet of height in hand. This will allow him time to choose the best available landing area. If it is possible to reach an airfield, the pilot's course of action will be governed to a great extent by the amount of height in hand. If this is less than 1,000 feet it will normally be advisable to carry out a "wheels up" landing unless aircraft is fitted with a rapid acting and low drag landing gear. If there is more than 1,000 feet available, the pilot will, in most cases, be justified in attempting a "wheels down" landing. In this case, the landing gear should be selected down in the usual position on the down wind leg, and the flaps selected as required when it is certain that the landing area can be reached.

3 It is emphasized that in the case of an aircraft which will not maintain height on asymmetric power with the landing gear and flaps up, the pilot alone can best decide his course of action depending upon the circumstances prevailing, height, rate of descent, and the drag of the landing gear when lowered.

4 The remainder of this section deals with aircraft on which it is possible to maintain height on asymmetric power with the landing gear and flaps up.

5 When returning to an airfield, the pilot should obtain by radio as soon as possible the weather conditions prevailing for landing. If these are such as to prevent an approach for normal circuit height, or if visibility is so reduced as to impair judgment, an early diversion, while ample height remains, should be made to another airfield at which weather conditions are more suitable.

APPROACH AND LANDING

6 After joining the circuit, the landing gear should be lowered in the normal position on the down wind leg, and at the same time power should be increased to compensate for the drag of the landing gear. It must, however, be borne in mind that if only partial hydraulic power is available or if the handpump has to be used, it will take longer than is normal to lower the landing gear. If, however, an hydraulic pump is being driven by the live engine, its effectiveness will increase as RPM increase. The aim should be to have the landing gear locked down before commencing the crosswind leg, so that it does not later distract the pilot's attention from judgment of the approach. The airspeed must not be allowed to fall below the critical speed for full power.

7 Lower the flaps partially, usually to the maximum lift position. If setting the flaps to the maximum lift position results in improved handling characteristics and lower critical speeds, they may be lowered earlier in the circuit, before lowering the landing gear. The advisability of doing this varies with aircraft types, and the pilot must judge this from his experience of the type he is flying. If there is uncertainty, the flaps should not be lowered until after the landing gear.

8 During the crosswind leg, all checks prior to landing, with the exception of final flaps, should be completed before the turn is made towards the landing area. After turning in, the aircraft should normally be at a height of 600 to 800 feet in clear weather, and at this stage, the decision to land or to go round again should be taken. Regardless of height however,

the speed must be maintained at or above the critical speed for full power until this decision has been taken.

9 . Once the decision to land has been taken and speed has, therefore, been reduced, this decision must not be altered. If, for any reason, it then becomes apparent that a successful landing cannot be made, a "wheels up" landing must be carried out straight ahead, using all controllable power to try and reach the most suitable landing area.

10 When it is certain that the airfield can be reached safely, the flap setting should be increased as required. The airspeed may then be reduced below the critical speed for full power and the power of the live engine gradually reduced as speed is lost, as in a normal engine assisted approach. The aim should be to cross the airfield boundary at the correct height and at the correct final speed for a normal engine assisted approach.

11 Rudder trim should not be wound off, since it will assist materially when using the live engine on the approach. It will not cause the aircraft to swing on landing as its effect at low speeds is negligible.

UNDERSHOOTING

12 If, after the decision to land has been made, it is realized that the airfield cannot be reached, do not on any account, raise the nose and attempt to stretch the approach to the airfield, and thus allow the speed to fall below the critical speed. On no account, increase power beyond the limits of rudder control.

(a) Raise, or at least unlock, the landing gear.

(b) Use the live engine, within the limits of rudder control, to regulate the rate of descent, to avoid obstacles, and to choose the best available landing area.

(c) Lower the flaps, fully if possible, and complete the landing.

GOING ROUND AGAIN

13 In clear weather, the latest stage at which the decision to go round again must be taken is after the final turn in towards the landing area has been completed, and before any more than maximum lift flap is lowered, by which time the height of the aircraft should be approximately 600 to 800 feet.

14 Regardless of height, however, ensure that the airspeed is at or above the critical speed for full power, and if necessary depress the nose to maintain this speed until the decision to land has been made.

15 If it is decided to go round again, open the throttle fully to reduce the rate of descent and then, in quick succession, select the flaps and landing gear up in the order which will reduce the drag most rapidly. The order in which the flaps and landing gear should be selected up is quoted in POI. As soon as possible, check the rate of descent and commence to climb away.

MISLANDING

16 Mislanding should never be attempted on asymmetric power. A little engine may be used to correct a high hold off or a bounce, but this must only be within the limits of rudder power, which will naturally be slight at these low airspeeds. On no account, therefore, attempt to take off again.

SECTION 7

FOUR-ENGINE AIRCRAFT: FAILURE OF ONE OR MORE ENGINES

INTRODUCTION

1 The same principles for flying on asymmetric power apply to a four, or more, engine aircraft as apply to a twin. The degree to which an engine failure affects a four engine aircraft depends upon which engine fails, inner or outer, port or starboard. When both engines on the same side have failed, a four-engine aircraft may be considered as similar to a twin-engine aircraft with one engine failed.

2 As the failure of one engine on a four-engine aircraft deprives the pilot of only 25% of the total power, ability to maintain height and to climb will be less impaired than by the failure of one engine on a twin-engine aircraft.

3 The failure of an inner engine on a four-engine aircraft should not lead to serious control difficulties. As far as maintenance of control is concerned, the failure of an outer engine will be comparable to, though in general less severe than, the failure of one engine on a twin-engine aircraft.

FAILURE OF ONE ENGINE DURING TAKE-OFF

4 The principles outlined in Sections 3 and 4 of this Part are in the main applicable in event of failure of an outer engine, except that the power available for climbing away will be reduced by only 25% as opposed to 50% in the case of a twin-engine aircraft.

5 The safety speeds quoted in POI are applicable to failure of an outer engine . If an inner engine fails, the safety speed will clearly be much lower.

6 If an outer engine should fail at an airspeed below the pilot's critical speed, it will always be necessary to close, at least partially, the throttle of the opposite outer engine in order to maintain directional control. It may then be possible to complete actions outlined in this Part, in Section 4, paragraph 5 and then, consistent with rudder control, to increase power, if necessary, on the live outer engine and climb away. If a landing becomes inevitable, power should be used within the limits of rudder control to govern the rate of descent, and to select the best possible landing area.

7 With an inner engine failure it should normally be possible to complete the emergency actions and climb away.

FAILURE OF MORE THAN ONE ENGINE DURING TAKE-OFF

8 If aircraft is still on the ground, carry out actions detailed in this Part, in Section 4, paragraph 1. It should be noted, however, that unless the speed is extremely low, it will always be advisable to retract the landing gear rather than to attempt to turn the aircraft.

9 If the aircraft is airborne, but at a low altitude, a crash landing ahead will be almost inevitable. Such power as can be controlled with the rudder, should be used to check the rate of descent, and to assist in choosing a suitable landing area.

10 In the later stages of the take-off when there is height in hand, it may be possible to continue climbing after carrying out the immediate actions detailed in this Part, Section 4, paragraph 5.

FAILURE OF ONE OR MORE ENGINES IN FLIGHT

11 The principles outlined in this Part, in Section 5, apply in these cases with certain amplifications as detailed below.

12 With any three engines still available it should be possible on all four-engine aircraft to maintain height with ease in rich mixture, and in weak mixture at the lower altitudes. It may not be necessary to jettison any load.

13 An engine failure may not be apparent at once and it may pass unnoticed for some

time, unless a close watch is kept upon engine temperatures and the performance of the aircraft. RPM and boost will, in general, be maintained and the automatic pilot, if engaged, may mask any tendency to swing. At moderate airspeeds, the failed engine can be detected by setting all the RPM control levers to give maximum RPM and noting on which engine RPM do not respond fully. In other circumstances a continuous fall in engine temperatures will betray the defaulting engine. Alternatively, the tendency to yaw should be trimmed out and the throttles of the engines on the side of the suspected failure independently closed and then opened again. When the throttle of the failed engine is closed, there will be no further tendency to yaw, thus indicating which engine has failed. If the automatic pilot is in use when engine failure is discovered, it should be disengaged.

LANDING

14 A three engine circuit and landing should be carried out exactly as for a normal circuit and landing, but the airspeed must be kept above the critical speed for full power until the decision to land has been made.

15 Going round again on three engines should present no difficulties, see Section 6, paragraphs 13 to 15 of this Part.

16 When both engines on the same side have failed, a two engine circuit and landing may be made using the technique described in this Part, in Section 6, paragraphs 6 to 11.

17 Going round again on two engines will only be possible if the aircraft is very lightly loaded and, therefore, has an adequate rate of climb.

SECTION 8

TURBINE-JET PROPELLED AIRCRAFT: FAILURE OF ONE ENGINE

GENERAL

1 The principles of flying on asymmetric power described in this Part, in Sections 3, 4, 5, 6 and 7 apply in full to the existing turbine-jet propelled aircraft.

2 At moderate speeds, the yaw resulting from engine failure is slight due to the absence of drag from a windmilling propeller, and at high speeds this yaw may not be noticeable. At high speeds therefore, the engine instruments may give the only indications of engine failure.

SECTION 9

PROPELLER-TURBINE AIRCRAFT: FAILURE OF ONE ENGINE

(To be issued later by amendment)

SECTION 10

CRASH LANDING, DITCHING AND ABANDONING AIRCRAFT: GENERAL CONSIDERATIONS

INTRODUCTION

1 Circumstances can arise which necessitate a forced alighting on land or water or the abandoning of an aircraft by parachute. In such emergencies, immediate and almost automatic reactions and the execution of the correct drills are essential.

2 Emergency drills are evolved in order to avoid panic and to ensure the quick safe exit of personnel with all necessary rescue aids and survival equipment from a distressed aircraft; they should set out clearly the duties of every individual in the aircraft, whether crew member or passenger.

3 Drills must be practised regularly in order that they become an automatic reaction. It has been proved beyond doubt that automatic and instant response founded on efficient drill has been responsible for the saving of life in many incidents. In practice drills, the sudden simulation of incapacity by one or more members of the crew has proved a valuable aid to training. It is the aim, in Sections 10, 11, 12 and 13 of this Part, to set out as simply as possible the basic essentials of abandoning aircraft, crash landing, and ditching drills.

ACTION BY AIRCRAFT IN DISTRESS

General

4 The action to be taken will always depend upon the degree of urgency of the situation. There is, however, one guiding principle; if there is any danger, however slight, or any likelihood of danger, immediate signals action should be taken to inform a ground station. Any unnecessary signal may be cancelled, but if signal action is deferred the aircraft may disappear without trace. The procedures for the varying degrees of emergency are detailed in the following paragraphs.

Difficulty

5 When an aircraft is in difficulty a message should be transmitted by W/T using the precedence "OP", or by R/T giving its position, informing base of the difficulty and requesting any desired information. This procedure may be employed at any time at the descretion of the pilot. Such action may be taken when flying through very bad weather, when uncertain of position or when engine trouble is suspected, etc. The receipt of a "difficulty" signal does not necessitate any immediate action by ground stations.

Urgency

6 If the captain considers that the aircraft is in danger and in urgent need of assistance, a message should be transmitted on the appropriate frequency using precedence "XXX" on W/T or "PAN" on R/T giving the following information:

(a) Position and time.

(b) Course and speed.

(c) Altitude.

(d) Type of aircraft.

(e) Nature of danger and assistance required.

(f) Intention.

7 This message should be repeated on the HF, MF, or VHF distress frequencies and if necessary on the international distress frequency, 500 k/cs.

Distress

8 The captain of an aircraft in distress should, when time permits, have a distress call and message transmitted on the frequency in use and then repeat the distress message on the appropriate distress frequency. On W/T the priority "SOS" and on R/T "MAYDAY" should be used.

(a) Distress call is done as follows:

(1) SOS or MAYDAY, three times.

(2) Aircraft callsign, three times.

(3) 20 seconds dash.

(4) Aircraft callsign.

(b) Distress message is done as follows:

(1) SOS or MAYDAY, three times.

(2) Aircraft callsign, three times.

(3) Position.

(4) Course and speed.

(5) Altitude.

(6) Type of aircraft.

(7) Nature of distress.

(8) Intention.

9 As much of the information outlined in paragraph 8, sub-paragraphs (3) to (8), as time permits, should be sent in order given. It may at times be necessary to combine the distress call and message in one signal. If it appears that circumstances will not permit the transmission of a full distress message, then the aircraft's position should be included in the call. Even an inaccurate DR position gives some indication of the correct area to be searched.

Cancellation

10 It is essential that any "difficulty" "urgency" or "distress" message should be cancelled if the danger no longer exists. The cancellation must be made on all frequencies on which the original message was despatched and should be given an appropriate priority It should be amplified by an explanatory message.

CRASH LANDING AND DITCHING STATIONS

11 Approved crash landing and ditching stations are decided upon for all types of aircraft, bearing in mind the following main points:

(a) The parts of the airframe that are safest and strongest.

(b) The parts of the airframe that are weakest and likely to break off on impact.

(c) The position of escape exists.

(d) The likely places for severe inrush of water, in ditching cases only.

(e) The presence of projections likely to cause injury.

(f) The position of equipment which may become dislodged easily.

(g) An aft facing position is always preferable to a forward facing one.

(h) Who should open or jettison escape hatches.

(j) Even distribution of essential duties, such as, warning passengers, closing bulkhead doors, etc.

(k) The method to be adopted in removing and taking out of the aircraft the internally stowed emergency equipment and allocation of this responsibility among the crew members; similar considerations apply to any externally stowed emergency equipment.

(l) The order of leaving the aircraft, allocating the use of escape hatches as equally as possible.

(m) In ditching cases only:

(1) Who should operate the dinghy manual release or who should launch the valise dinghy.

(2) The order of boarding the dinghy.

12 Crash landing and ditching stations seldom differ, but occasionally slight changes have to be made for the reasons given in 11 (d).

EXAMPLES OF CRASH LANDING AND DITCHING STATIONS

13 In aft-facing crew or passenger seats with safety harness secured, the feet should be braced against suitable supports, with the hands holding or braced against parts of the aircraft structure; the head should be braced against the back of the seat. If the back of the seat does not provide this support, the head should be clasped and braced in the hands, with the fingers firmly interlocked behind.

14 Seated on the floor facing aft, the back should be against a convenient surface which provides support, for example, a main spar or bulkhead; the feet should be against suitable supports and the head clasped and braced in the hands, the fingers being firmly interlocked behind. A development on this scheme is to have a second person adopt a similar position supported by the knees of the first person. This attitude should also be adopted on certain types of transport and troop-carrying aircraft, where "belts" - that is, webbing straps about 2 feet wide - are provided which are fastened across the fuselage immediately prior to crash landing or ditching, to afford the necessary support for the back.

15 Lying on the back along the fuselage floor feet forward against a fixed portion of the aircraft structure, the knees should be flexed, the hands gripping suitable handholds. A development on this scheme is to have two people lying on their backs side by side, each with one arm round the neck of the other, and the free hand holding a suitable handhold in the aircraft structure.

16 Forward facing in the crew or passenger seats with safety harness secured, the feet should be braced against suitable supports, the hands holding or braced against parts of the aircraft structure. It is advisable in this position, whenever possible to have the head braced with one arm across the forehead, the hand holding a suitable handhold or other part of the aircraft structure.

PROCEDURE TO BE ADOPTED IN CRASH LANDING AND DITCHING

Warning of Crew and Passengers

17 The crew and passengers should be warned as follows:-

(a) The captain should pass the warning immediately an emergency arises.

(b) The captain should give the cautionary signal for forced landing or ditching on the intercom, i.e., "prepare for forced landing" or "dinghy, dinghy prepare for ditching". The intercom message should be duplicated by sounding six short rings on the warning bell.

(c) The captain should give the executive order for imminent ditchings or forced landing by sounding one long ring on the warning bell.

(d) The member of crew nearest the wireless operator should give him verbal warning.

(e) In passenger carrying aircraft, at least one crew member should inform passengers and also assist them to take up their crash landing or ditching stations.

Captain - Immediate Actions

18 The captain must:-

(a) Warn crew. State intention.

(b) Prepare the aircraft for crash landing or ditching.

(c) Secure his safety harness and check

that his personal safety equipment is at hand.

(d) Ensure that the appropriate distress action has been taken and that the correct emergency drill is being carried out.

(e) Keep the crew informed of the proceedings.

(f) Order the wireless operator to his crash landing or ditching station. The wireless operator should remain at his set for as long as possible and be the last to take up his emergency station.

(g) Jettison the hood on single seat aircraft.

(h) Just before the touch-down, warn the crew to brace.

(j) When the aircraft has come to rest, release his safety and parachute harnesses and leave the aircraft through the allotted hatch, taking with him, after ditching, the correct items of survival kit. After crash landing, he should leave the aircraft as quickly as possible owing to the fire risk. If there is no fire, he should return and collect all useful kit and equipment.

19 Captains of aircraft must appreciate that distress and emergency signals must be made as early as possible to enable the greatest possible measure of assistance to be given.

Navigator - Immediate Actions

20 On the captain's order he should:

(a) Calculate the aircraft's position.

(b) Pass this position to the wireless operator together with the true course of the aircraft, altitude, and a short weather report, including if possible, visibility and, if ditching, the state of the water.

(c) Pass the estimated position of crash landing or ditching to the wireless operator.

(d) Destroy secret papers. Place charts, with latest positions marked, in a satchel ready to take out of the aircraft.

(e) Carry out his duties as set out in the drill.

(f) Jettison the appropriate escape hatches.

(g) Ensure that the bomb doors are closed.

(h) Take up his crash landing or ditching station.

(j) Brace when ordered.

(k) Leave the aircraft when it has come to rest through the allotted escape hatch, taking with him, after ditching, the correct items of survival kit. After crash landing, leave the aircraft as quickly as possible owing to the fire risk. If there is no fire, return and collect all useful kit and equipment.

Wireless Operator - Immediate Actions

21 On receipt of the warning he should:

(a) Take the appropriate distress action.

(b) Turn the IFF to emergency.

(c) Pass any fixes and bearings received to the navigator.

(d) Receive the estimated position of crash landing or ditching from the navigator and transmit same.

(e) Destroy secret papers.

(f) On the captain's order, take up his crash landing or ditching station, after clamping the key.

(g) Brace when ordered.

(h) Leave the aircraft when it has come to rest, through the allotted escape hatch, taking with him, after ditching, the correct items of survival kit. After crash landing, he should leave the aircraft as quickly as possible owing to the fire risk. If there is no fire, he should return and collect all useful kit and equipment.

Remainder of Crew - Immediate Actions

22 Actions of the remainder of a crew do not involve similar technical responsibilities

to those of the pilot, navigator, or wireless operator, nevertheless they may have to assist in other respects, for example:

(a) One member, usually the second pilot or engineer, should help the captain to secure his safety harness, attach his single-seat type dinghy if applicable, and be of general assistance to him.

(b) One or more members should jettison the appropriate upper or side hatches and, in the case of a ditching, should check the security of the lower hatches.

(c) One member should check that the survival equipment is available for immediate removal and that all loose items of equipment are properly stowed.

(d) In passenger carrying aircraft, at least one member should ensure that the passengers are carrying out their correct drill.

(e) , Assist in jettisoning equipment.

(f) Take up crash landing or ditching stations as soon as possible after essential duties have been carried out.

(g) Brace when ordered.

(h) After ditching leave the aircraft, when it has come to rest, through the allotted escape hatch with the correct items of survival kit. After crash landing, leave aircraft as quickly as possible through the correct exits, owing to the fire risk. If there is no fire, return and collect all useful kit and equipment. In either case, every possible assistance should be rendered to passengers to enable them to leave the aircraft safely.

PREPARATION OF AIRCRAFT

23 The aircraft should be prepared for ditching as follows:

(a) All external stores should be jettisoned, bombs should be dropped "safe" and the bomb doors closed.

(b) Unless the aircraft is, or has been on fire, surplus fuel should be jettisoned and the jettison cocks closed. After jettisoning fuel before a crash landing, as much time as possible should be allowed before touch-down to permit fuel that has settled on the fuselage and mainplanes to dry; otherwise, on touch-down the sparks caused by friction may ignite the fuel. In any case, drop tanks may be released whether containing fuel or not.

(c) The security of all lower hatches should be checked; before ditching all bulkhead doors, camera and flare chutes should be closed, the aircraft flotation gear, if fitted, inflated.

(d) The appropriate upper or side escape hatches should be opened or jettisoned. On single-seat aircraft the hood should be jettisoned.

(e) Loose items of equipment in the fuselage should be either jettisoned or securely stowed.

(f) All crew members should have on their helmets.

WARNING TO PILOTS

24 The safety harness should always be tight and locked. At the moment of touch-down, an arm held across the forehead with the hand gripping a convenient hold will minimize the risk of injury from gunsights and other similar obstructions.

SECTION 11

CRASH LANDING

GENERAL

1 Experience has shown that the probability of successfully landing high performance jet aircraft on unprepared surfaces is marginal. It is therefore recommended that pilots of high performance jet aircraft bail out rather than force land away from an aerodrome. However, if circumstances should force a pilot into the position of having to crash land rather than bail out, the following points on crash landings will apply.

CHOICE OF CRASH LANDING AREA

2 This has to be left to the pilot's discretion, but wherever possible a strip of land with a reasonably smooth surface, free from large obstructions, should be selected. Grass, mud, plough, sandy surfaces, or root fields are the best choice. If possible, the crash landing area chosen should be within easy reach of help. Pilots should always bear in mind the features of the territory over which they are flying, in order that a crash landing strip may be chosen without undue delay.

AIRCRAFT HANDLING

3 The following points should be noted:

(a) Full control of the aircraft to the point of touch-down is essential. The approach speed should, therefore, be adequate to ensure this, even though it may mean a slightly higher speed on impact.

(b) If it is not possible to crash land on ground free from obstructions, the impact of the fuselage with obstacles should be postponed for as long as possible, in order that the fuselage hits the obstruction at a slow speed. The longer the period of deceleration of the fuselage, the less severe will be the eventual impact, and this in turn will reduce the risk of serious injury to the occupants.

(c) Because of the varying conditions that may be encountered, the choice of undercarriage position must be left to the discretion of the pilot. He must bear in mind at all times the field condition and size, the type of aircraft including its landing speed and type of undercarriage, the approaches and overshoots to the field and any other factors pertinent to the success of his forced landing. However the recommendation of Para 1 should be noted.

(d) Whenever possible, the landing should be made into wind.

(e) The battery isolating switch should be set to "off" immediately prior to touch-down.

PERSONAL EQUIPMENT

4 Parachute harnesses should be removed when practicable as they will impede escape from the aircraft if worn. Helmets, with leads tucked firmly away, should be worn for protection.

USE OF FLAPS

5 The amount of flap to be used depends upon whether power is available and upon the characteristics of the particular aircraft. If power is not available, the flaps should not be lowered fully until just before flattening out; an undesirably steep approach is thus avoided.

USE OF ENGINE(S)

6 A powered approach should be carried out whenever power is available. Therefore, when a crash landing is inevitable it should be executed before fuel is exhausted. It is important that just before touch-down, the engine(s) should be throttled right back and, if practicable, the ignition should be switched off, as, apart from other reasons, evidence has shown that when windmilling in fine pitch a propeller is less likely to break off and strike the fuselage than when the engine is under power.

7 It is considered that the risk of a propellor breaking off and striking the fuselage is probably greater if it is feathered than when it is windmilling as the blades, being edge on, are more liable to break off than to bend.

8 In any case of crash landing necessitated by engine failure, it is, however, not recommended that propeller of the failed engine(s) should be unfeathered before touch-down. In these circumstances the Captain should, where possible, send the rest of the crew to suitable crash positions aft and, if the aircraft has dual controls, he should, if practicable, complete the landing in the seat on the opposite side to the feathered propeller(s).

ACTIONS AFTER CRASH LANDING

9 It is important not to relax or move until the aircraft has finally come to rest.

10 Fire extinguisher pushbuttons should be

operated at the first opportunity after touchdown.

11 Immediately the aircraft comes to rest, the occupants should, owing to the risk of fire, leave through the recommended exits with the greatest possible speed, and immediately run up wind. When the risk of fire has passed, the crew should return and collect all useful kit and the emergency equipment.

SECTION 12

DITCHING

DIRECTION OF APPROACH AND ALIGHTING

1 An alighting into wind should always be made if the surface of the water is smooth, or if the water is smooth with a very long swell. It should, however, be borne in mind that in many conditions it is advisable to alight along the swell and across wind, accepting higher "ground" speed and drift which result. A direction of approach which is a compromise between waves, swell and wind direction may be the best choice The danger of "nosing" into large waves or swell is generally greater than the danger involved in ditching across wind. A landing into swell or long waves should be avoided whenever possible; the limiting condition being that where the drift in a cross-wind alighting cannot be counteracted while maintaining control near the stall.

DIRECTION OF WIND

2 Swell is the undulating movement of the water's surface caused by past or distant disturbances by the wind. The direction of the swell does not necessarily bear any relation to that of the surface wind.

3 Waves move down wind and the foam pattern is at right angles to the direction of the surface wind, though doubt may remain as to which of two ways wind is blowing. Waves cannot, however, be taken to move with the wind inshore, or in fast moving estuaries.

4 In open water, waves break down-wind and this may be observed from a low height. If the waves are running across a swell, the direction of breaking is not a reliable indication of wind direction.

5 Wind direction may be obtained by dropping a smoke float. Smoke from a ship may be misleading, since the trail lies along the resultant line of the wind velocity and the ship's motion. At low altitudes, spray blown off waves gives a reliable indication.

6 When the surface is unbroken, gusts may sometime be observed rippling the surface in great sweeps which indicate the direction of the wind.

STRENGTH OF WIND

7 The strength of the wind may be gauged from the appearance of the water, but only if the wind has been blowing with the same force and direction for some time. The wind will be stronger than the appearance of the water suggests, if it is freshening, blowing off a nearby shore, running with swell and tide, or during heavy rain. Moreover, the breaking of waves may be due to shallow water. Bearing these points in mind, indications are:

A few "white horses"	10 to 20 knots
Many "white horses"	20 to 30 knots
Streaks of foam along wind direction	30 to 40 knots
Spray from crests	40 to 50 knots

STATE OF WATER

8 Water always appears from the air to be calmer than it really is. Swell can only be properly appreciated close to the surface, and it may be of far greater consequence in ditching than the more obvious, but much smaller, waves.

9 If the wind is not moving with the swell,

but across it, a "cross-sea" is created with waves running in a different direction from that of the swell.

10 If possible, fly low over the water and study its surface before ditching. Pilots should endeavour to have constantly in mind the state of the water and wind, rather than leave both observation and estimation till an emergency arises.

GAUGING HEIGHT

11 Judgment of height is not easy over the water, especially when it is calm, or at night.

(a) The aneroid altimeter cannot be relied upon for this purpose. On some aircraft, the trailing aerial can be used, the wireless operator signalling the captain when the current drops as the aerial weight hits the water.

(b) The radio altimeter, when fitted, should be used in preference to other methods, especially at night.

(c) During night ditchings, the landing light may be helpful in gauging height. It must be borne in mind, however, that the bright light may upset the pilot's night vision and when mist exists, the reflection causes a glare which may obscure the surface of the water.

(d) It may be possible for a pilot to lay his own flarepath with flame floats. He will then be able to gauge height by their light.

PERSONAL EQUIPMENT

12 Life-saving waistcoats should be worn at all times whilst flying over water or inland within five miles of the coast. They should not be inflated until the need for them is near, as they expand at altitude. If the aircraft ditching exits are large, jackets may be fully inflated before ditching; but if they are small, jackets should be only partially inflated until after leaving the exit.

(a) Parachute harnesses should be removed when practicable, unless they are attached to a dinghy.

(b) Helmets, with leads tucked firmly away, should be retained for protection in the dinghy.

(c) Collars and neckties should be loosened.

(d) Emergency equipment should not be removed from its stowage before ditching.

DITCHING NEAR SHIPPING

13 If possible, the aircraft should be ditched well ahead, and slightly to one side, of the ship's track.

AIRCRAFT HANDLING IN DITCHING

14 The aim should be to achieve:

(a) An approach speed adequate to allow some margin after flattening out, to provide good control at the best altitude of impact for the particular aircraft, and to attempt to prevent the tail striking a wave crest or swell top which might cause the aircraft to "nose" in.

(b) A touch-down in a tail down attitude.

(c) The best compromise, in relation to waves, swell and wind, when choosing the direction of approach.

15 In no circumstances should the landing gear be lowered. If it is down, or partially down, every effort should be made to retract it.

USE OF FLAPS

16 On most aircraft, flaps should be lowered to reduce speed of approach and touch-down. It is better, if possible, to use a medium setting and not to lower the flaps fully. Little, if any, further reduction of speed is obtained by using more than half flap, and the use of full flap may well impair ditching characteristics of the aircraft, and also give an undesirably high rate of descent. Flaps should be lowered to setting recommended in POI for the type.

USE OF ENGINES

17 The value of power in ditching is so considerable that, when it is certain that the coast cannot be reached, the pilot should always ditch before fuel is exhausted. If a ditching must be made due to reasons other than fuel shortage, the bulk of the fuel should be jettisoned if possible, leaving sufficient for power to be used as necessary throughout the approach. Providing control can be maintained, power should be used to ensure the flattest approach and the slowest touch-down. Propellers of engines that have failed, or are not to be used during the approach, should be feathered.

LIGHTS

18 Before ditching at night, all bright internal lights should be dimmed in order to accustom the eyes to the external darkness, but the upper identification lamp may be put on if it does not cause reflections which upset vision.

19 After ditching, all lights should be left on to facilitate search should the aircraft remain afloat, and to assist when collecting equipment and boarding the dinghy.

BEHAVIOUR OF AIRCRAFT ON IMPACT

20 An aircraft alighting in the prescribed tail down attitude will often encounter a small primary impact as the rear of aircraft strikes the water. A more severe secondary impact and violent deceleration will usually follow; the nose will tend to bury as the aircraft comes to rest. The control column should be held hard back after the first impact. If the alighting has been made too fast, the aircraft may bounce; it may also slew to one side after impact.

IMPORTANT WARNING

21 The crew must not relax or move until the aircraft has come to rest. They must be prepared for a double impact, the first when the tail of the aircraft strikes, then a second and greater shock as the nose hits the water. They must also be prepared for the aircraft to slew to one side.

RELEASE OF DINGHY

22 Reliance should not be placed upon the automatic inflation of the dinghy. The manual release should be operated, but only when aircraft has come to rest; otherwise, premature release may cause the loss of the dinghy.

23 One of the crew should be detailed to assist the dinghy from its stowage and into the water and then to prevent cordage becoming entangled, the dinghy being carried under the wing or fuselage, or punctured by some jagged edge or point. On some aircraft with jet engines in wings, special care may be necessary to avoid damage by hot jet pipes.

24 If the dinghy is upside down and cannot be righted from the wing, one man should jump into the sea and:

(a) Grasping the handling patches on the bottom of the dinghy with both hands, lean back and haul on them with his knees on the buoyancy chamber, being prepared to become submerged for a moment, or,

(b) If there are no handling patches, place his feet on the bottom of the ladder and haul on the two nearest stabilizing pockets, leaning back as above.

25 Do not jump on to an inverted dinghy, as this will expel air trapped underneath and make righting more difficult.

BOARDING DINGHY

26 Board the dinghy as follows:

(a) As soon as the aircraft comes to rest, the crew should collect survival equipment and leave by the hatches as detailed in the dinghy drill.

(b) Do not jump into the dinghy; this may damage it.

(c) To board from the water, grasp the ratlines with one hand and the bottom rung of the ladder with the other, pushing it down to help insert the foot; then pull up with both hands on the ratlines.

(d) On some aircraft, ditching ropes are provided at the escape hatches to assist personnel in leaving the aircraft and boarding the dinghy.

(e) A fully inflated life jacket helps in boarding from the sea. There is a rescue line coiled on the dinghy which, when uncoiled, may help a man to reach the dinghy.

AFTER BOARDING DINGHY

27 Proceed as follows:

(a) On instructions from the captain, cut the painter with the floating knife carried near the point of attachment of the former.

(b) Paddle away from the aircraft, but keep nearby while it floats to increase the chance of being located.

(c) Check for leaks, and if necessary use leak stoppers provided. Connect the topping-up bellows and inflate till rigid; topping-up may assist crew in the water to board. Bale out water.

(d) Rig the dinghy cover.

(e) It is important to keep dry if possible but clothing should not be taken off, whether wet or dry.

SPECIAL NOTES FOR SINGLE-ENGINE AIRCRAFT

28 In general the pilot should, if possible, abandon the aircraft by parachute, as most single-engine types may be expected to dive under when ditched. On the other hand, some have been proved to possess excellent ditching qualities The decision whether or not to bale out should be based upon the aircraft's ditching characteristics (see POI for the type). As ditching does not necessarily involve serious injury to the pilot, he is not precluded by this advice from using what height remains to fly towards a ship or coast at the risk of finally having to ditch. The pilot must balance the risk of not being picked up if he bales out unseen, against the risk of ditching.

29 Reduction of speed by the use of flaps, and engine if possible, is important. If the flaps cannot be partially lowered they should be lowered fully unless advised to the contrary in POI.

30 With single-engine aircraft it is more important than with larger aircraft to ditch into wind unless there is a steep swell.

SINGLE-SEAT DINGHY, "K" TYPE

31 When using the single seat dinghy:

(a) Pull in the lead and, if the dinghy has not left the pack, rip off the cover and grasp the bottle. Pull out the locking pin and slowly unscrew valve (one turn opens fully). Inflate slowly, assisting the dinghy to unfold.

(b) Board by the narrow end aided by the loop handles. If the other end rises, let go and give the dinghy a little push to fill the water pocket.

(c) When aboard, throw out the drogue to make the dinghy ride the waves better and ship less water.

(d) Should the dinghy capsize, remove the hood and the apron elastic and slide out head first.

(e) This dinghy paddles well if the water pocket is collapsed and the drogue hauled in; lie well back and use the forearms only.

(f) Remain attached to the dinghy in rough weather and do not run for shore; it is safer to lie off till sighted.

SECTION 13

ABANDONING AIRCRAFT BY PARACHUTE

INTRODUCTION

1 Up to airspeeds of about 175 knots it is usually possible to bale out of most aircraft. It is, however, generally desirable, particularly above this speed, for the body to be assisted out by rolling the aircraft and falling out, or by bunting by kicking control column forward, with the harness undone. This does not apply to larger aircraft with downward escape hatches. At high speeds, abandoning an aircraft becomes increasingly impracticable unless seat ejection is fitted. At low altitudes excess speed should be used to gain height before abandoning.

2 There are three types of parachute in use: the back type, the chest type and the seat type. Flying personnel may be required to wear any one of these at short notice; they should, therefore, familiarize themselves with their fitment, with the positions of the rip-cord handles, and with the operation of the quick-release boxes.

3 The state of serviceability and the packing of the parachute is the responsibility of the safety equipment section, but this does not relieve flying personnel of their duty of making a daily inspection as follows:-

(a) Check that the scarlet safety thread is intact on the locking pins.

(b) Check that locking pins are not bent.

(c) Examine the pack cover for damage and ensure that the canopy is not showing.

(d) Examine the harness straps and the stitching for deterioration and breakages.

(e) Ensure that the quick-release box functions easily and correctly.

(f) Ensure that the harness is fitting correctly.

WARNING CREW BEFORE ABANDONING AIRCRAFT

4 When the captain considers it is probable that the aircraft will have to be abandoned, he should issue the cautionary warning on the intercom, "prepare to abandon aircraft, prepare to abandon aircraft". The intercom message should be duplicated by sounding three short rings on the warning bell.

(a) Crew members should put on parachutes at this time and should assist passengers to don theirs.

(b) The member of the crew nearest the wireless operator should warn him in case he has not received the captain's order.

(c) When it is certain that the aircraft must be abandoned, the captain should issue the executive order "eject, eject", and at the same time sound one long ring on the warning bell.

(d) When it is essential to leave aircraft immediately, the captain should issue only the executive order "eject, eject", at the same time sounding one long ring on the warning bell. A member of the crew should warn the wireless operator.

DUTIES OF CREW MEMBERS

5 The duties of the crew are as follows:-

(a) The captain and navigator should pass to the wireless operator the necessary information for distress action.

(b) The wireless operator should carry out the appropriate distress action if time is available.

(c) Before the executive order "eject, eject" is given, the captain should instruct the wireless operator to either wind in or jettison the trailing aerial.

(d) Each man should check that his parachute is correctly fitted and that articles of equipment which connect him to the aircraft, such as microphone leads, oxygen pipe-lines, etc., are disconnected as close to the body as possible to prevent them catching in the aircraft or in parachute rigging when the jump is made, and loose ends tucked away. Collars and neckties, if worn, should be loosened.

(e) Helmets and goggles, properly secured and with various leads tucked firmly away, should be left on as they afford extra protection.

(f) Emergency rations and other useful items of survival equipment should be pocketed.

(g) Always ensure that the single-seat type dinghy is attached correctly as even if a landing is not made in water, emergency equipment may be useful.

(h) Prior to the executive order "jump jump", each parachute exit should be opened or jettisoned by a crew member, usually the first man detailed to go out of that particular exit.

ABANDONING AIRCRAFT

6 The recommended exits are marked "parachute exits" and the drill lays down both the appropriate exit for each member of the crew to use and the strict sequence in which the crew should abandon the aircraft.

7 It may be necessary to abandon an aircraft:

(a) While it is under control and ample time is available.

(b) In an emergency, in which speed of exit is vital.

8 In 7 (a), the crew should act deliberately using the available time to ensure exact execution of the "abandon aircraft drill".

9 In 7 (b) each man must generally leave by the nearest exit as quickly as possible, but the recommended exits should be used if practicable since other exits may be dangerous.

10 Should chest type parachutes be opened accidentally prior to abandoning the aircraft, they should be fitted to the harness. The canopy and rigging lines should then be gathered together and held tightly in the arms across the chest. After leaving the aircraft, the arms should be opened when the canopy will immediately spread.

11 If descents are made from high altitude, the use of oxygen should be continued to the last possible moment, as a man without oxygen may lose consciousness in less than one minute during the activity of leaving an aircraft at such heights. Consequently when leaving an aircraft at these heights without an emergency oxygen set:

(a) Make all arrangements to abandon the aircraft whilst still using the main oxygen supply.

(b) Take a few deep breaths of oxygen before disconnecting the supply.

(c) Hold the breath, abandon the aircraft, then, when the breath can no longer be held, pull the rip-cord.

(d) If an emergency oxygen set is carried, the pulling of the rip cord should be delayed, if possible, until 15,000 feet is reached to reduce the opening shock to the canopy. If no wrist altimeter is carried a rough estimate of 15,000 feet may be made by allowing five seconds for each 1,000 feet of drop above this height.

12 Information on aircraft fitted with ejection seats is given in Part 4, Section 6.

ABANDONING AIRCRAFT, SINGLE SEAT

13 The pilot should:

(a) Take the appropriate distress action.

(b) Disconnect and tuck away all leads, checking that the "K" type dinghy "dog lead" is attached.

(c) Loosen the collar and tie.

(d) Check that the emergency rations are on his person.

(e) Jettison the cockpit hood, taking care to lower the seat and keep the head well down to minimize the possibility of injury.

(f) Bale out, either by sliding over the side or inverting the aircraft and falling out.

(g) Never stand up in the cockpit and pull the rip cord in that position, as the parachute is likely to foul.

(h) If the aircraft is in a spin, abandon it by diving over that side of the aircraft which is towards the axis of the spin. For example, if the aircraft is in a spin to the left, the occupants should dive over the left-hand side of the aircraft.

DESCENT BEFORE OPENING PARACHUTE

14 If a man leaves an aircraft by falling out backwards or forwards with raised knees he invariably somersaults, and continues to do so whilst he remains doubled up. If the rip cord is pulled the parachute will open correctly but the lift webs, as they are pulled out, may be drawn between the legs and the body will be left hanging head downwards when the parachute is fully open, which may be dangerous. Somersaulting should be checked, therefore, before the rip cord is pulled by keeping the legs together and slowly straightening them.

15 The rip cord handle should be grasped immediately after leaving the aircraft. If unaware of its position, the best and quickest method of finding it is to look for it and not make frantic grabs in the hope of finding it. Once clear of the aircraft, the body soon loses speed, the rush of air past the face becomes relatively slight and the eyes can be opened easily without goggles. Movement of the limbs is normal. On the other hand, injury to the eyes or darkness, may prevent the handle being seen, and all personnel should be familiar with the position of the rip cord handle and quick release box so that they can feel for and find them, both easily and quickly; they should also practice grasping the rip cord handle with the left-hand to avoid embarrassment should the right-hand and/or arm be injured.

16 The parachutist should be well clear of the aircraft and allow time for his motion to slow down before he pulls the rip cord. The handle should be freed by giving it a twist to pull one corner out of the pocket; a quick jerk will then free the pins and allow the canopy to develop. The arms should then be folded across the chest to keep the harness in place during opening. When baling out at very low altitudes the rip cord should be pulled out immediately after leaving the aircraft.

CONTROL DURING DESCENT

Damping Oscillation

17 Parachutists tend to swing especially at high altitudes, and this may cause air sickness. Oscillation can be effectively damped by distorting the even periphery of the canopy as follows:

(a) Seat or back type parachutes. - Grasp high up on the two front or the two back lift webs and pull down hard until the hands are level with the shoulders. Hold this position until the swinging ceases and then gradually release the pull so that the lift webbs are once more in their normal position.

(b) Chest type parachutes. - Take hold of one lift web with both hands and pull down strongly; air will be spilled out of the canopy on one side and the oscillation will cease. Relax the pull gradually. An alternative method is to reach up high and grasp both lift webs; pulling them down strongly and quickly in a series of alternate jerks to break up the rhythmic oscillation.

Turning

18 During the earlier stages of descent the parachutist should turn to face in the direction in which he is drifting. To turn, grasp a main suspension strap or a handful of rigging lines on the side towards which it is desired to turn and pull down the canopy about three feet. Then grasp a strap or handful of rigging lines on the other side with the other hand, and, without pulling down, give a vigorous twist to canopy in the direction of the turn required. Release the canopy and the body will follow. Do not attempt to turn near the ground, as this increases the rate of descent.

Sideslipping

19 The parachute may be sideslipped during descent by pulling down on the rigging lines on the side towards which it is desired to move. If the canopy collapses, it will reopen when the lines are released. By sideslipping, the parachutist has some control over the direction of descent and may be able to avoid a bad alighting area. Since sideslipping increases the rate of descent, the parachutist should aim to fall short of an obstacle rather than attempt to glide over it. Sideslipping should not be attempted near the ground, except in emergency.

Preparation for Landing

20 A good landing is possible on any line of drift provided that the correct attitude of the body is assumed just before the ground is reached. Turn the body from the shoulders slightly across the line of drift, if not already drifting sideways, ready for a fall on the side of the knee, thigh and the round of the back. If the feet and hands are held pointing in the line of movement, there is a risk of pitching on to the knees, then the hands or elbows, and finally the face.

ALIGHTING ON LAND

21 A parachute landing should, if possible, be made facing the direction of drift. When within 100 feet of the ground rotate the plate of the quick release box from the locked to the release position. The best method of touch down is to keep the legs together and slightly bent. As soon as the ground is touched, roll on to the knees, hip, shoulder and back, then give the plate of the quick release box a sharp blow inwards whereupon the harness will be instantly released.

ALIGHTING ON WATER

22 As surface of the water is approached, the plate of the quick release box should be rotated from the locked to release position. When within a few feet of the water the body should be straightened and the feet placed together. Then as the feet touch the water the harness should be released by giving the plate on the quick release box a sharp blow inwards. The elbows should be kept pressed close to the sides, but at the same time hold the nose to prevent water entering. These precautions will minimize the possibility of body injury. If the parachutist actually enters the water wearing the harness, his movements will be hampered.

STATIC LINE

23 To aid an injured man in abandoning an aircraft, there is a length of webbing which has a clip at one end and is attached at the other end to the aircraft structure near the main parachute exit. This is the static line. The injured man is assisted to the exit, his parachute fitted and the static line clip is attached to the parachute rip cord handle. The injured man is then assisted through the exit and as he falls away, his rip cord is automatically pulled.

SECTION 14

LANDING AFTER BRAKE FAILURE

INTRODUCTION

1 If a pre-landing check is carried out, failure of the brakes should normally be detected in the air. The technique to adopt can then be decided upon and a suitable airfield selected before the landing is made.

LANDING AREA

2 The best landing run should be selected, into wind and uphill if possible. If the wind is light, it may be advantageous to use the longest run irrespective of wind direction. The length of run can be reduced by landing on a rough surface; it is preferable, therefore, to land on grass rather than on a runway.

3 If a landing run of adequate length for the conditions prevailing cannot be found, it will generally be advisable to land with landing gear retracted. Less damage will result and there is less risk of injury to occupants, than if a normal landing is made and the landing gear subsequently retracted while speed is high. The chief risk, when retracting while speed is comparatively high, is that one landing gear leg may retract before the other.

APPROACH

4 Full advantage should be taken of the approach area to ensure that the touch-down is made at the beginning of the landing run. The short landing technique should be employed using full flap, and power as necessary, to keep the touch-down speed as low as possible.

USE OF ENGINE

5 The engine(s) of all types of aircraft should be throttled fully back, but should be left switched on during the initial stages of the touch-down and landing run. When the possibility of having to use power in an emergency no longer exists, the fuel cock(s) should be turned off and the booster pump(s) and ignition switched off. If it is obvious that the aircraft is about to over-run the landing area, the landing gear may then be retracted with little risk if speed is low.

DRAG

6 All means of producing drag such as opening speed brakes or bomb doors should be used immediately after touch-down. Occasionally, parachutes have been successfully streamed from the rear hatches of large aircraft.

FURTHER INFORMATION

7 If a special technique is required for landing a particular type of aircraft, advice is given in the appropriate POI.

PART 7

TESTING OF AIRCRAFT

SECTION 1

FLIGHT TEST PROCEDURE FOR JET ENGINED AIRCRAFT

GENERAL

1 A flight test card, Figure 7-1, has been designed for use on all jet engined aircraft. It can be adapted for aircraft having one or two engines and as a result, parts of the card may not apply to the particular aircraft being tested.

2 The test card has been designed as a means of recording data and to standardize flight test procedures through the service.

3 Pilots testing aircraft should be thoroughly familiar with CAP 100, EO 05-1-1 (Pilot's Operating Instructions General) and the Pilot's Operating Instructions for the aircraft being tested. Particular reference should be made to CAP 100, Chapter 104, Section 4, Flight Testing Aircraft. To determine allowable tolerances and the correct method of function of equipment and instruments, reference should be made to the Maintenance Manuals and Pilot's Operating Instructions for the aircraft being tested. If a pilot has any doubt as to the serviceability or airworthiness of an aircraft he should declare the aircraft unserviceable.

4 Regulations and instructions cannot be issued to cover all contingencies and therefore all pilots testing aircraft should exercise due caution and good judgment at all times. The test card cannot cover all items of a particular squadron or unit aircraft, but can be used as a standard guide.

EXPLANATION OF TEST CARD AND TESTING PROCEDURE

External and Tarmac Check

5 In addition to the normal pre-flight checking of an aircraft, a thorough and comprehensive external check is to be made, checking such items as loose rivets, excessive skin gaps, poor fitting de-icer boots, bent corners on panels, etc.

Internal Check

6 A thorough and complete cockpit check is a pre-requisite for a test flight. Every item in the cockpit is to be checked thoroughly. Care is to be taken that items not immediately within view of the pilot, such as circuit breakers, are included. All controls except undercarriage controls are to be tested and all instruments are to be checked for serviceability and correct readings.

Engine Start

7 The engine(s) are to be started in the normal manner as per operating instructions, any variance from normal being noted.

Ground Check

8 All readings are to be noted on the test card in the spaces provided. This section of the test card is self explanatory.

Taxi

9 Parking brakes are to be checked for slipping at high power settings. Foot and hand brakes are to be checked for grabbing and positive action. On pneumatic type brakes, check for correct pressure on master supply and each wheel. Nose wheel steering is to be checked specifically for shimmy, ease of steering, self centering and castoring.

Take-Off

10 Check emergency fuel system for operation and desired engine reading. Check RPM and JPT obtained on take-off. Check also for excessive JPT.

Climb

11 Climb is to be carried out at the recommended power setting and ASI for the aircraft. Check items listed in order on the test card during climb through every 10,000 ft. Climb to highest operating altitude of the aircraft.

High Cruise

12 Level off at cruising power. Maintain altitude for a minimum of 5 minutes. Check pressurization specifically for leak rate.

Dive

13 At full throttle dive aircraft to the specified limiting Mach. number. Check that compressibility effects are normal for aircraft type and that Barber Pole and airspeed correspond in relation to one another.

Cruise

14 An altitude of 25,000 ft. is an average at which instruments, etc., should be tested on all jets. Flight instruments must be checked at both a low and a high altitude to ensure that they function within the tolerance, throughout the height range of the aircraft.

Dive

15 Make a rapid descent, speed brakes open from 25,000 ft. to at least 5,000 ft. The main purpose of this manoeuvre is to check for proper canopy defrosting or demisting.

Low Cruise

16 Pull up and level out at 10,000 ft. Check all items in the order on the test card. Check for maximum positive G in a high speed turn. Check for negative G by rolling aircraft upside down and pushing forward on central column.

Stall

17 The aircraft is to be stalled clean and dirty. Stalling speeds are not to be in excess of 5 knots of the specified stalling speed. Check that stalling characteristics are normal for the aircraft type.

Aerobatics

18 Particular reference is to be made to ease of control for the aircraft type throughout the manoeuvres. In the rolling plane it may be found that one wing is excessively heavy. Spins are to be checked for ease of entry and recovery. Special attention is to be made to the height lost during recovery and this must not be excessive for type.

Undercarriage and Flaps

19 Check all items listed on the test card plus timing of the services both up and down.

Fuel

20 Check all fuel tanks, pumps and indicators for proper feeding of tanks and instrument functions.

Radar and Gunsight

21 Check as required for aircraft type.

Radio

22 Check all radios on all frequencies. Check radio compass on all bands for homing and station passage.

Miscellaneous

23 This space is provided for reporting on any particular equipment with which the aircraft may be fitted.

Remarks

24 This space is provided for any unserviceabilities noted.

TYPE	NO.	DATE	PILOT		
TIME	UP	DOWN	TOTAL	ALT. SET.	AIR TEMP.

1 EXTERNAL AND TARMAC CHECK AS PER EO's FOR THE AIRCRAFT.

2 INTERNAL CHECK AS PER PILOTS OPERATING INSTRUCTIONS.

3 ENGINE START AS PER PILOTS OPERATING INSTRUCTIONS.

4	GROUND CHECK		
	RPM		
I	JPT		
D	Oil Pressure		
L	Fuel Pressure		
E	Oil Temperature		
	Fuel Flow		
	Generator		
		Left	Right
	Harness		
	Seat Adjustment		
	Rudder Adjust		
5	TAXI		
S	Parking Brakes		
E	Brakes		
R	Nose Steering		
V	Hydraulics		
I	Canopy		
C	Oxygen		
E	Flaps		
S	Speed Brakes		
6	TAKE-OFF		
	Emergency Fuel		
	RPM		
	JPT		
7	CLIMB		
	RPM		
	JPT		
	Oil Pressure		
	Fuel Pressure		
	Oil Temperature		
	Fuel		
	Pressurization		
	Cockpit Heaters		
	Oxygen		

	Hydraulic System		
	Trims		
	Flight Instruments		
8	CRUISE		
H	At highest Altitude for 5 Minutes		
I	Pressurization		
G	Defrosters		
H	Fuel Transfer		
C			
R	RPM		
U	JPT		
I	ASI		
S			
E			
9	DIVE		
C	At Full Throttle Dive To		
H	Limiting Mach.		
E	High Mach. Effects		
C	Barber Pole and ASI		
K	Extend Speed Brakes		
S	Hydraulic Check		
10	CRUISE - LEVEL AT 25,000 FEET		
M	Trims		
E	DI		
D	T and B		
I	AH		
U	Compass		
M	Cockpit Heaters		
C	RPM		
R	JPT		
U	Fuel Pressure		
I	Oil Pressure		
S	Oil Temperatures		
E	Fuel Flow		

Figure 7-1 - Test Flight Form for Jet Engine Aircraft - RCAF Form F140A (Sheet 1 of 2)

11	DIVE	
C	Rapid Descent to 5,000 Ft.	
H	Speed Brakes Open	
E	Max. Speed	
C	Demisting	
K	Instruments	
S	Trims and Hydraulics	

12	CRUISE - LEVEL AT 10,000 FEET		
	Full Throttle ASI		
	RPM		
	JPT		
	Oil Pressure		
L	Fuel Pressure		
O	Fuel Flow		
W	Fire Lights		
	All Fuel Tanks		
C	Speed Brakes		
R	Max. "G"		
U	Max. "-G"		
I	G Suit Valve		
S	Crossfeed		
E	DI and AH		
	T and B		
	Altimeter		
	Flying Controls		
	Trims		
	Engine Relight	Left	Right

13		GENERAL	
S		Clean ASI	
T		Dirty ASI	
A		Characteristics	
L L			
A	B	Rolls	
E	A	Loops	
R	T	Roll Off Top	
O	I	Spins	
	C		
	S		
U	C	Undercarriage	
N	A	Control	
D	R	Lights and Indicator	
E	R	Horn and Cut-Out	
R	I		
	A		
	G		
	E		

F		Flaps	
L		Control	
A		Indicator	
P			
S			
		Tank Indicators	
F		Fuel Pumps	
U		Tip Tanks	
E		Crossfeed	
L		Pressure Cocks	
R	G	Ranging	
A	U	Target Lock-On	
D	N	Scale	
A	S	Reticule	
R	I		
A	G		
N	H		
D	T		
R		VHF	
A		Radio Compass	
D		IFF	
I			
O			

14	MISCELLANEOUS

15	REMARKS

Figure 7-1 - Test Flight Form for Jet Engine Aircraft - RCAF Form F140A (Sheet 2 of 2)

SECTION 2

FLIGHT TEST PROCEDURE FOR RECIPROCATING ENGINED AIRCRAFT

GENERAL

1 A flight test card, Figure 7-2, has been designed for use on all reciprocating engined aircraft. It can be adapted for aircraft having from one to four engines and as a result, parts of the card may not apply to the particular aircraft being tested.

2 The test card has been designed as a means of recording data and to standardize flight test procedures throughout the service.

3 Pilots testing aircraft should be thoroughly familiar with CAP 100, EO 05-1-1 (Pilot's Operating Instructions General) and the Pilot's Operating Instructions for the aircraft being tested. Particular reference should be made to CAP 100, Chapter 104, Section 4, Flight Testing Aircraft. To determine allowable tolerances and the correct method of function of equipment and instruments, reference should be made to the Maintenance Manuals and Pilot's Operating Instructions for the aircraft being tested. If a pilot has any doubt as to the serviceability or airworthiness of an aircraft he should declare the aircraft unserviceable.

4 Regulations and instructions cannot be issued to cover all contingencies and therefore all pilots testing aircraft should exercise due caution and good judgment at all times. The test card cannot cover all items of a particular squadron or unit aircraft, but can be used as a standard guide.

EXPLANATION OF TEST CARD AND TESTING PROCEDURE

External and Tarmac Check

5 In addition to the normal pre-flight checking of an aircraft, a thorough and comprehensive external check is to be made, checking such items as loose rivets, excessive skin gaps, poor fitting de-icer boots, bent corners on panels, etc.

Internal Check

6 A thorough and complete cockpit check is a pre-requisite for a test flight. Every item in the cockpit is to be checked thoroughly. Care is to be taken that items not immediately within view of the pilot, such as circuit breakers, are included. All controls except undercarriage controls are to be tested and all instruments are to be checked for serviceability and correct readings.

Engine Start

7 The engine(s) are to be started in the normal manner as per operating instructions, any variance from normal being noted.

Ground Check

8 All readings are to be noted on the test card in the spaces provided:-

(a) Magnetos are to be checked at the prescribed RPM for the aircraft.

(b) Pitch change should conform to that laid down in EOs. The generator is to be checked at the same time for cut out.

(c) Other items under ground check are self explanatory.

Taxi

9 Parking brakes are to be checked for slipping at high power settings. Foot and hand brakes are to be checked for grabbing and positive action. On pneumatic type brakes, check for correct pressure on master supply and each wheel. Nose wheel steering is to

be checked specifically for shimmy, ease of steering, self centering and castoring. The tail wheel lock is to be checked for locked position and ease of unlocking.

Take-Off

10 Boost and RPM to be noted and checked for surging and fluctuations.

Climb

11 Carry out climb at the recommended power settings and ASI for the aircraft. During the climb, engine and flight instruments are to be checked. Climb to the highest operating altitude for the particular aircraft and level off at cruise power settings. Check oxygen system for proper functioning.

Dive

12 At climb power settings dive aircraft to maximum allowable speed. Check trim and high speed effects, excessive vibration and wing heaviness.

Cruise

13 At normal operating altitude and cruising power, check all items listed on the test card in order. Flight instruments are to be checked against tolerances laid down in the Maintenance Manual and EOs. Compasses are to be accurate to within 3°. It is suggested that compasses be checked against runway headings or known land directions, on all cardinal points.

Stall

14 The aircraft is to be stalled clean and dirty. Stalling speeds must not be in excess of 5 knots of the specified speed. Check that stalling characteristics are normal for aircraft type.

Aerobatics

15 If the aircraft is aerobatic, manoeuvres specified on the test card are to be carried out. Particular reference is to be made to ease of control for the type throughout the manoeuvres. During rolls it may be found that one wing is excessively heavy. Spins are to be checked for ease of entry and recovery. Special attention should be made to height lost during recovery ensuring that it is not excessive for type.

Undercarriage and Flaps

16 Check all items listed on the test card plus timing of the services both up and down.

Cockpit

17 Items listed on the test card are self explanatory.

Radio

18 Check all radios on all frequencies. Check radio compass on all bands and for homing and station passage. Check radio altimeter over an airfield, this instrument cannot be checked accurately to ± 10 feet but a good approximation of 50 feet can be made over an airfield. Check ILS for serviceability and accuracy.

Miscellaneous

19 This space is provided for any particular equipment an aircraft may have.

20 This space is reserved for unserviceabilities which may be noted.

TYPE		NO.		DATE	PILOT
TIME	UP	DOWN	TOTAL	ALT. SET	AIR TEMP.

1 EXTERNAL AND TARMAC CHECK AS PER EO FOR THE AIRCRAFT.

2 INTERNAL CHECK - CARGO, PASSENGER, CREW COMPARTMENT, ETC., AS PER PILOTS OPERATING INSTRUCTIONS AND EOs.

3 ENGINE START AS PER PILOTS OPERATING INSTRUCTIONS.

4 GROUND CHECK

GROUND RUN	Mag. Check At RPM				
		1	2	3	4
		L R	L R	L R	L R
	Change Pitch At RPM				
	Decrease To				
	Generators				
	Voltage				
		1	2	3	4
	Max. RPM				
	Max. Boost				
	Oil Pressure				
	Fuel Pressure				
	Idle RPM				
	Superchargers				
	Low				
	High				
	Warning L.				
OIL	Temp.				
	Control				
COOLANT	Open				
	Closed				
	Temp.				
	Cylinder Head Temps.				
MIXTURE					
	Normal				
	Rich				
	Idle Cut-Off				
CARB HEAT	Control				
	Temp.				

FUEL	Total Supply				
	Tank Indicators				
	Tank Selectors				
	Transfer Pumps				
	Booster Pumps				
	Cross Feed				
	High Pressure Prime				
MISC	Vacuum				
	De-Icer Boots				
	De-Frosters				
	De-Icer Windscreen				
	De-Icer Props.				
	Carb. Alcohol				
	Heaters and Blowers				
5	TAXI				
SERVICE	Parking Brakes				
	Brakes				
	Nose Wheel Steering				
	Tail Wheel Lock				
6	TAKE OFF				
CHECK	Airborne ASI				
	Controls				
	RPM				
	Boost				
7	CLIMB				
READINGS	RPM				
	Boost				
	Coolant				
	Oil Pressure				
	Oil Temperature				
	Fuel Pressure				
	Cylinder Temperature				

Figure 7-2 - Test Flight Form for Reciprocating Engine Aircraft - RCAF Form F140B (Sheet 1 of 2)

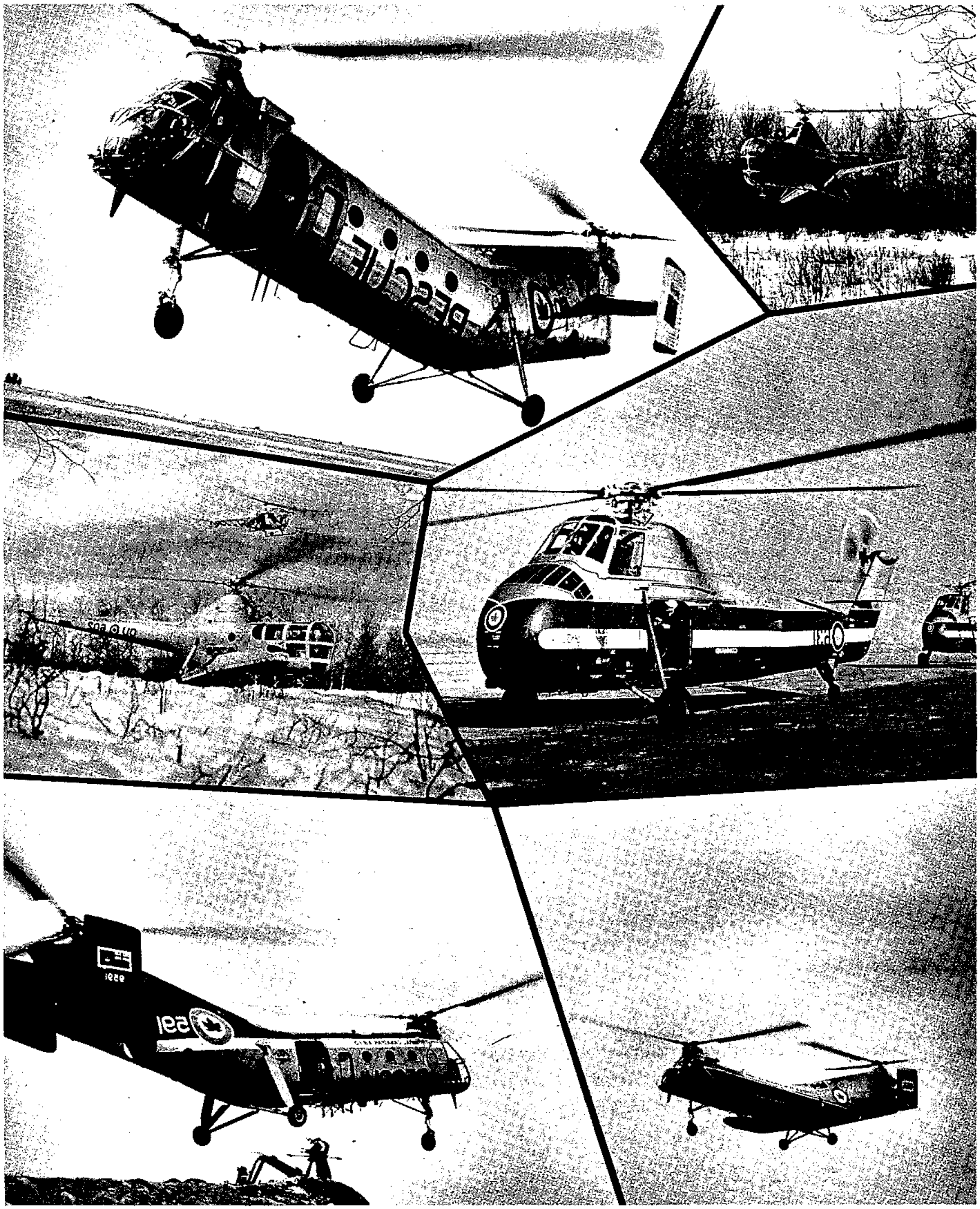
8	CRUISE				
	RPM				
H	Boost				
I	ASI				
G	Oxygen Pressure				
H	Blinker				
	Connector				
9	DIVE				
C	Power Setting				
H	Max. IAS				
E	Instruments				
C	Trims				
K					
10	CRUISE				
	RPM				
	Boost				
	Oil Pressure				
	Fuel Pressure				
	Coolant				
	Carb. Air				
	Oil Temperature				
	Feathering				
		1	2	3	4
L	AH				
O	Mag. Compass				
W	Flux. Compass				
	DI				
C	ASI				
R	Altimeter				
U	T and B				
I	VSI				
S	B16 Compass				
E	Aileron and Trim				
	Rudder and Trim				
	Elevator and Trim				
	Heaters and Blowers				
11	GENERAL				
S	Clean ASI				
T	Dirty ASI				
A	Characteristics				
L					
L					

	B	Rolls	
A	A	Loops	
E	T	Roll Off Top	
R	I	Spins	
O	C		
	S		
	C	Undercarriage	
U	A	Control	
N	R	Lights	
D	R	Indicator	
E	I	Horn and Cut-Out	
R	A	Hydraulic Pressure	
	G		
	E		
F		Flaps	
L		Control	
A		Indicator	
P			
S			
C		Canopy	
O		Seat Adjust.	
C		Harness	
K		Rudder Adjust.	
P		Ventilation	
I			
T			
R		VHF	
A		HF	
D		Radio Compass	
I		Radio Compass	
O		ILS	
12		MISCELLANEOUS	
13		REMARKS	

Figure 7-2 - Test Flight Form for Reciprocating Engine Aircraft - RCAF Form F140B (Sheet 2 of 2)

PART 8

HELICOPTER FLYING, THEORY AND PRACTICE



Frontispiece

PART 8

HELICOPTER FLYING, THEORY AND PRACTICE

SECTION 1

BASIC HELICOPTER AERODYNAMICS

INTRODUCTION

1 Helicopters and related rotary-wing aircraft are so varied in their configuration and concept that it is impossible to give adequate coverage of all principles involved in one simple outline of basic aerodynamics. Therefore, this material will be primarily restricted to the single rotor helicopter of the type which employs a compensating tail rotor.

The Autogyro and the Helicopter

2 Before proceeding, the difference between the autogyro and the helicopter should be explained since the two are frequently confused. Both machines are similar in that they are both supported by rotary wings. However, the autogyro is propelled by a separate propeller, or by other normal means of propulsion, and the main rotor merely rotates by windmilling as the machine gathers speed; hence, a short landing or take-off run is necessary. The helicopter, on the other hand, while it is of more complex construction, derives its propulsion both vertically and horizontally through a mechanical drive coupled directly to the main supporting rotor. This enables the machine to take off and land without any run; in addition it can hover, and fly backwards or sideways. All these capabilities are beyond the autogyro's scope, and because of this vastly increased versatility the helicopter has generally superseded the autogyro.

DEFINITIONS

3 Though the aerodynamics of the helicopter are based on the same laws that govern the flight of fixed-wing aircraft, the significance of some considerations is somewhat changed. In explaining helicopter principles, it is necessary first to re-emphasize some well known definitions, and then proceed to explain those terms purely related to rotary-wing flight.

(a) Lift - That portion of the resultant of the aerodynamic forces acting through the centre of pressure at right angles to the relative airflow. It should be noted that, in this sense, lift is not necessarily vertical from the horizontal, nor is it always directly opposite to the weight of the aircraft, see Figure 8-1.

(1) The first diagram depicts lift produced by a cross-section of an aerofoil or a rotor blade. The total lift reaction of a rotor system is portrayed in the next diagram, and is shown acting perpendicular to the rotor disc, see Figure 8-2.

(b) Drag - That portion of the resultant of the aerodynamic forces acting through the centre of pressure parallel to the relative airflow, see Figure 8-3.

(c) Angle of Attack - The angle between the chord and the relative airflow, see Figure 8-4.

(d) Pitch Angle - The angle between the chord of a rotor blade and a reference datum on the hub of the rotor. This angle is rigged mechanically by the rigger and is similar to the angle of incidence of a conventional aerofoil. In flight this angle is changed mechanically by the pilot as he alters his flight controls, see Figure 8-5.

(e) Rotor - A system of rotary aerofoils - including the blades, the hub assembly, and shaft.

(f) Rotor Disc - The area contained by the tips of the rotor blades in flight. This area will vary slightly as the blades flex under differing flight conditions, see Figure 8-6.

(g) The Tip Path Plane - The plane containing the disc, see Figure 8-7.

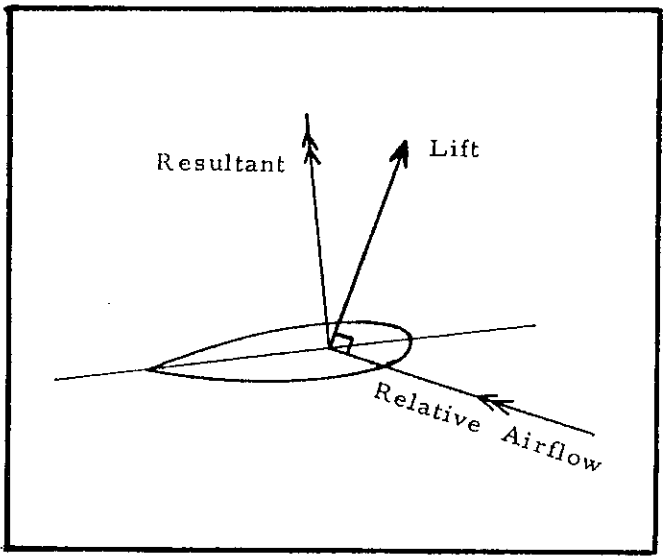


Figure 8-1

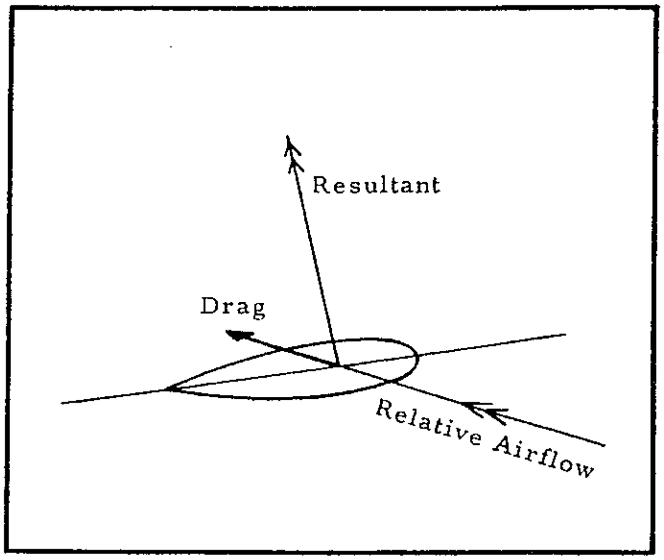


Figure 8-3

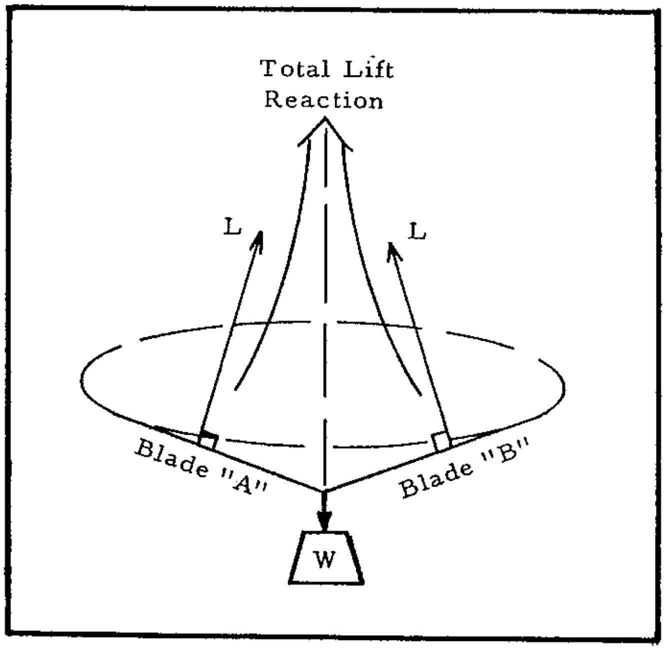


Figure 8-2

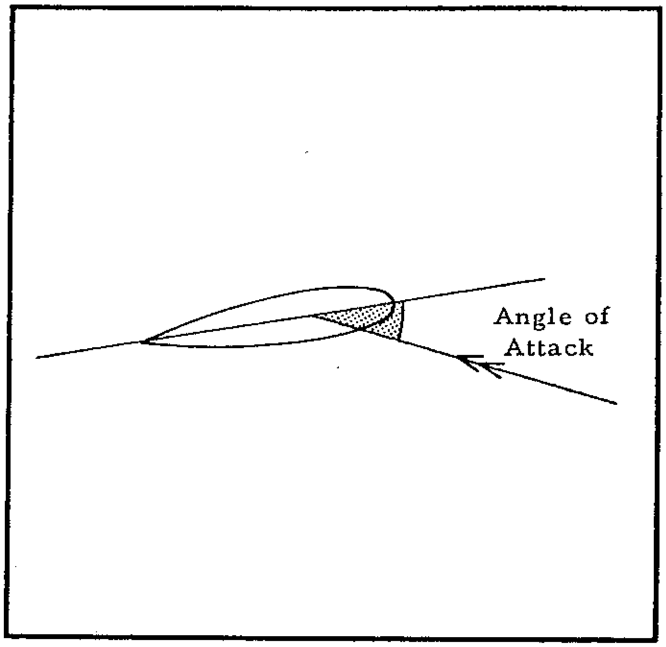


Figure 8-4

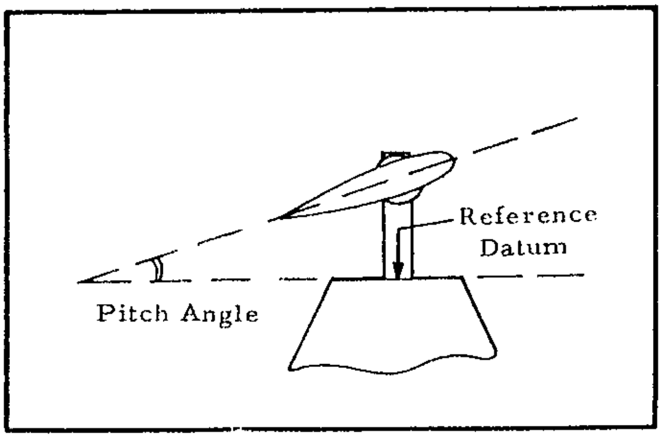


Figure 8-5

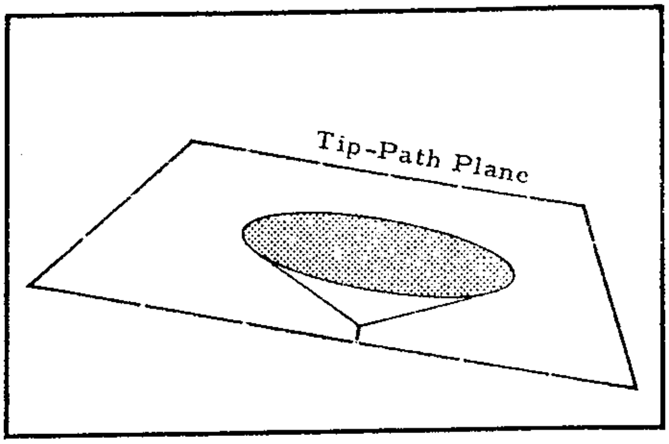


Figure 8-7

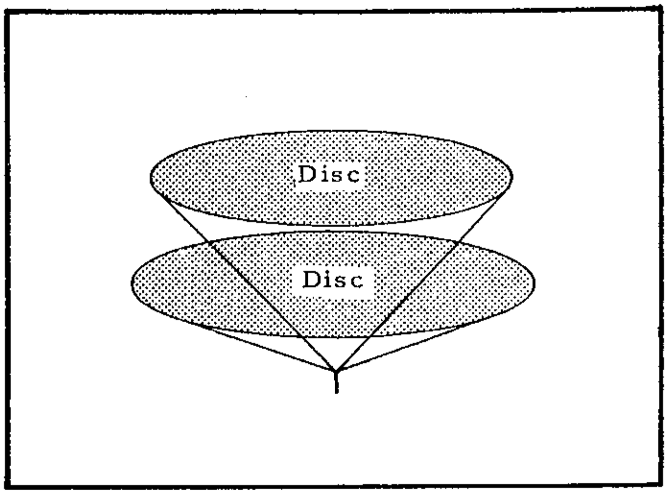


Figure 8-6

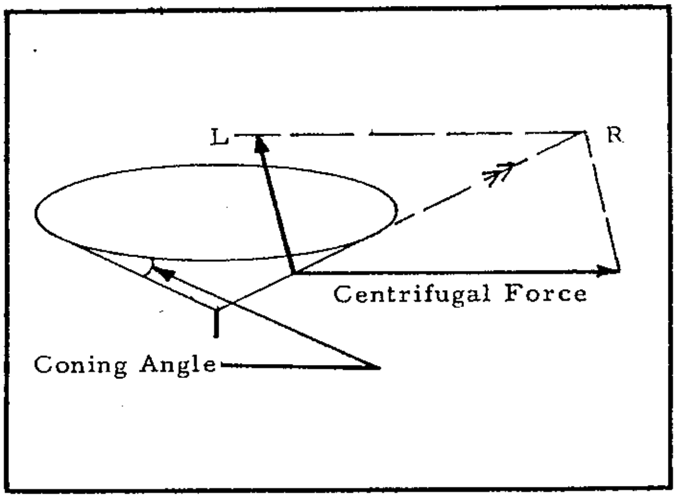


Figure 8-8

(h) Coning - Movement of the rotor blades aligning them along the resultant of centrifugal force and lift. Hence, an increase in lift would increase the coning angle, or conversely an increase in rotor rpm would decrease the coning angle, see Figure 8-8.

(j) Rotor Plane of Rotation - The plane containing the centres of mass of the rotor blades in rotation. While this differs from the tip path plane and often is not exactly parallel to it, it frequently is more convenient to use the tip path plane, or disc, in diagrams dealing with the plane of rotation, see Figure 8-9.

(k) Axis of Rotation - "An actual or imaginary line about which a body rotates". The plane of rotation is at right angles to the axis of rotation.

(m) Flapping - The angular movement of a rotor about a horizontal (or near horizontal) axis. In fully articulated rotors the individual blades are free to cone as well as flap about the flapping hinge, eg, Sikorsky or Vertol. Semi-rigid rotors merely permit the rotor to flap through this hinge and the blades are permitted to flex of their own accord when coning, eg, Bell H-13 and Hiller H-23, see Figure 8-10.

(n) Flapping Angle - The angle between the drive axis and the axis of rotation. When the drive axis and the axis of rotation are co-axial, the rotor is not flapped, see Figure 8-11.

(p) Feathering - The angular movement of a rotor blade about its longitudinal axis. Thus any change of the pitch angle of a rotor blade is a feathering movement, see Figure 8-12.

(q) Dragging - The angular movement of an individual rotor blade about an axis vertical to the blade. The dragging hinge is incorporated only in fully articulated heads, and permits restricted pivoting movements of each blade separate from the common drive axis, see Figure 8-13.

(r) Leading and Lagging - When a blade lies ahead of its normal radial position it is said to be "leading". Conversely, when it lies behind it is "lagging".

(s) Dissymmetry of Lift - When the helicopter moves in horizontal flight, the difference in blade airspeed between the advancing and retreating blades increases the lift of the advancing blade and decreases the lift of the retreating blade. This dissymmetry of lift would interfere with progressive flight, and in practice the pilot moves the cyclic control to decrease the lift of the advancing blade and increase that of the retreating blade.

4 The above list of helicopter terms is by no means complete. Further terms will be introduced and explained later as required.

HELICOPTER CONTROLS

5 Fundamentally there are three flight controls in a helicopter: the cyclic stick, the collective pitch lever, and the rudder pedals. The collective lever, which is usually operated by the left hand, increases or decreases the total lift of the main rotor hence it controls climbs and descents. This lever also embodies a throttle control which enables the pilot to increase or decrease engine torque to maintain the desired amount of power supplied to the rotor systems. The cyclic lever is normally held in the right hand and is used to tilt the main rotor in the desired direction of flight. The rudder pedals control the pitch of the tail rotor, enabling the pilot to counter any changes in torque applied to the main rotor, and, in addition, to initiate turns and prevent slip or skid as he would in a fixed-wing aircraft. On tandem-rotor helicopters, where torque is eliminated by contra-rotation of the rotors, rudder control is used as a steering device by differentially tilting the main rotors to opposite sides of the aircraft.

The Collective Lever

6 This lever derives its name from the fact that, when it is raised, it simultaneously increases the pitch angle of all rotor blades equally, or, when lowered, the pitch of all blades is decreased equally. Such changes are termed collective pitch movements. Thus,

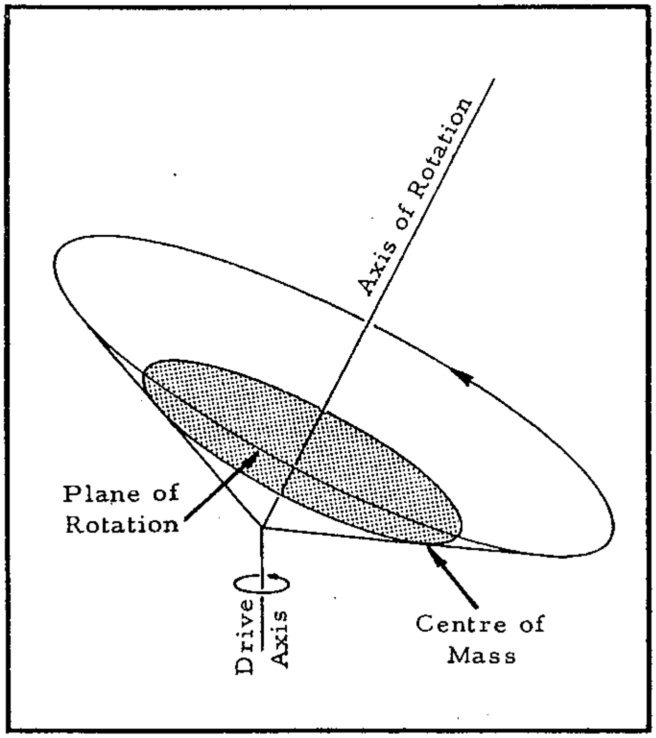


Figure 8-9

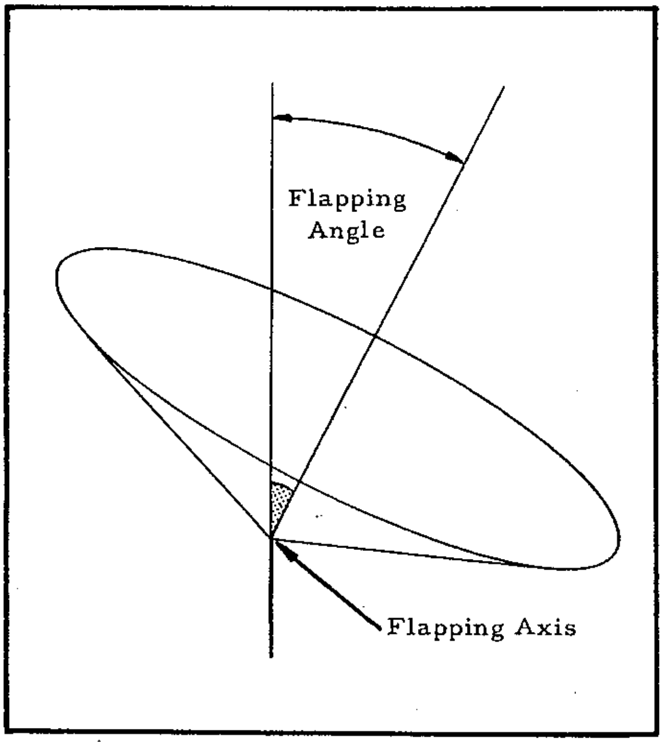


Figure 8-10

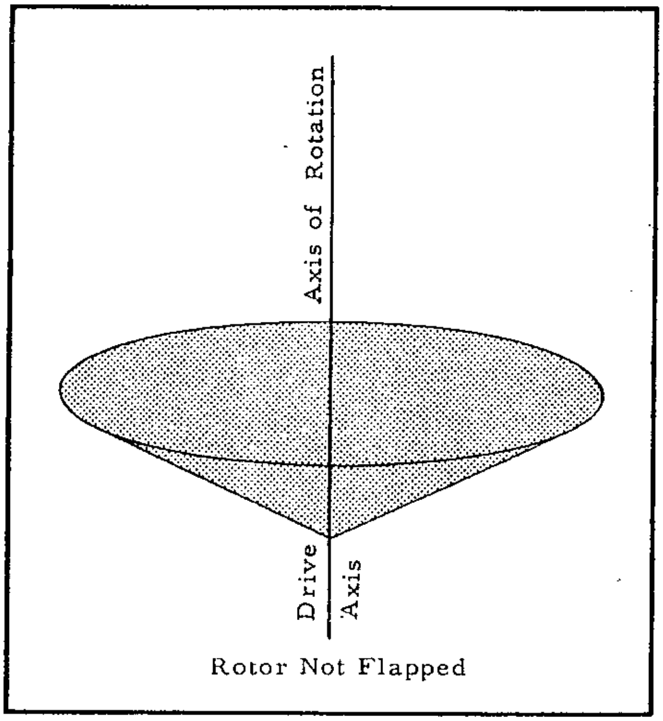


Figure 8-11

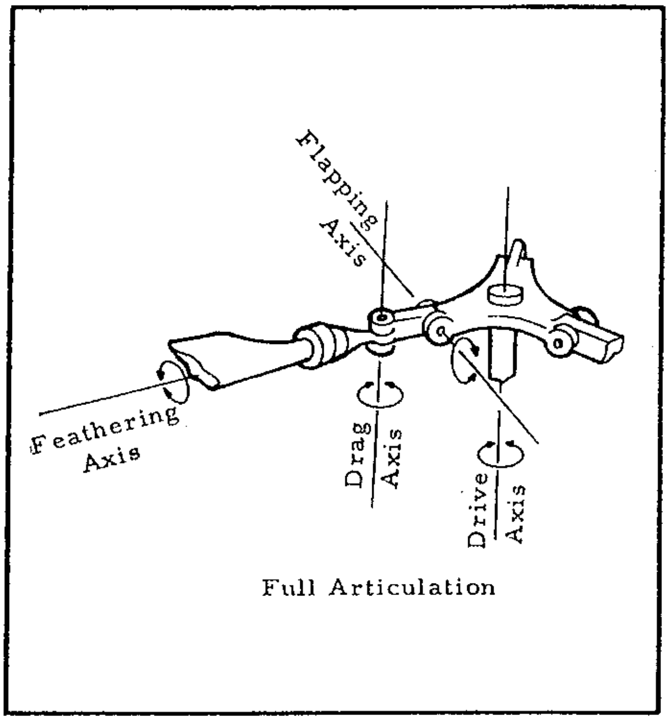


Figure 8-12

throughout rotation, for a given setting of the collective lever, the blades will maintain a constant degree of collective pitch.

7 When the collective pitch lever is raised in flight, the angle of attack of all blades is increased, thereby increasing the lift and causing the aircraft to climb. However an increase of lift will cause an increase in drag, and, unless the engine power is increased, the rotor RPM will fall off rapidly. Constant rotor RPM is not only necessary to maintain the climb, but is critical at all times in flight to maintain adequate control of the helicopter. For this reason most collective levers are designed to open the throttle as the lever is raised and to close the throttle as the lever is lowered. This additional function is of great assistance to the pilot, but is by no means adequate to compensate completely for all flight and load conditions. Positive throttle control is also provided on most helicopters by the provision of a twist grip control on the collective lever, thus permitting the pilot to maintain constant throttle co-ordination.

The Cyclic Stick

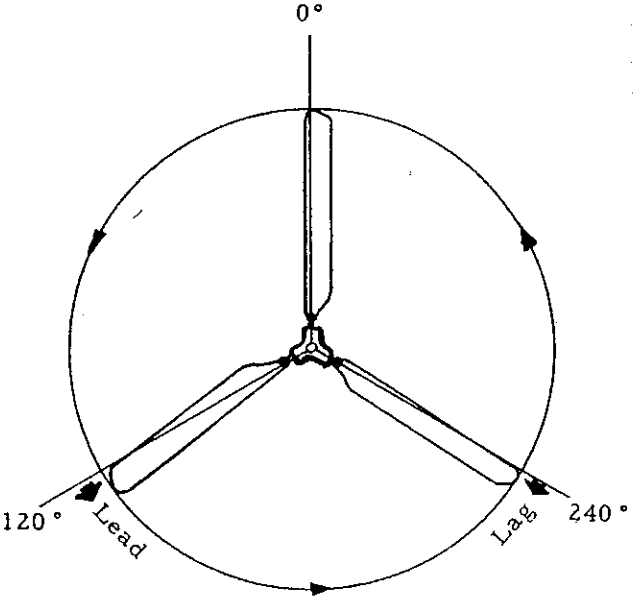
8 This lever is so named because it changes the pitch of the rotor blades cyclically. That is, while it may diminish the pitch angle of a blade through one half of the blade's cycle, it will add the same amount of pitch to the blade as it traverses the other half of its cycle. In effect, the cyclic control will reduce the lift in one half of the rotor disc and proportionately increase the lift in the other half, thereby causing the rotor system to tilt, or flap, in the desired direction. The direction in which the rotor is flapped will determine the direction in which the helicopter will move, and the amount by which the rotor is flapped will determine the speed at which the helicopter will travel.

NOTE

It may be seen that the cyclic is used to tilt the total lift reaction from the vertical, giving both a horizontal and vertical component to lift. This horizontal component provides the thrust which moves the helicopter in a given direction, see Figure 8-14.

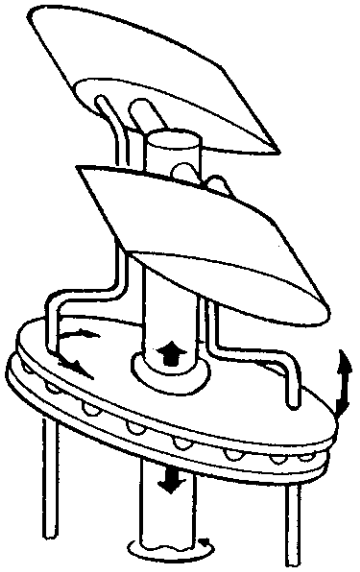
The Control Orbit

9 Collective and cyclic stick movements are converted into pitch changes in the rotor



Blade-Dragging Movements

Figure 8-13



Swash-Plate Control System

Figure 8-15

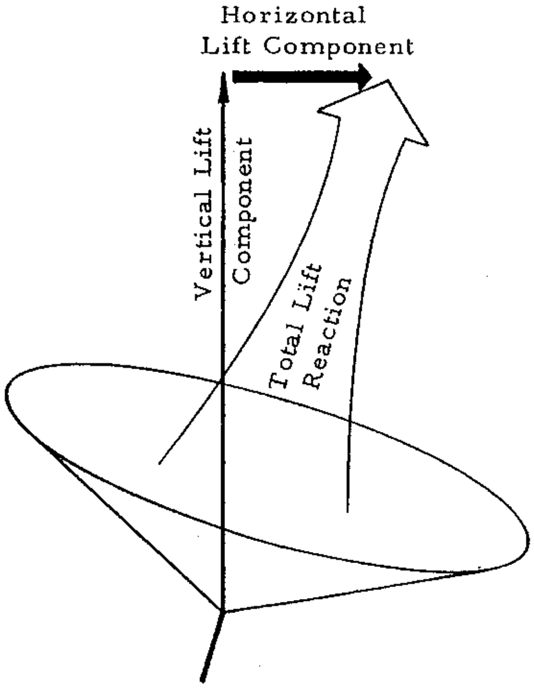
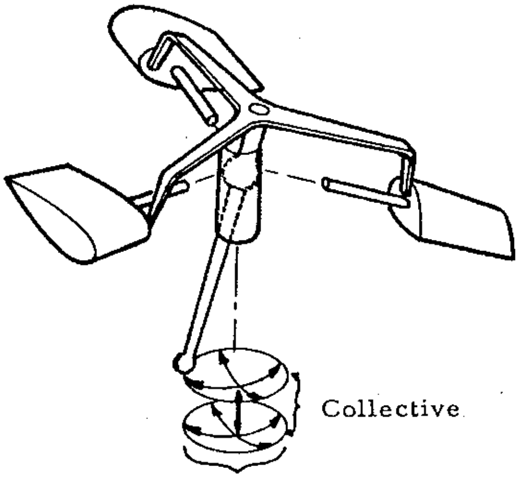


Figure 8-14



Spider Control System

Figure 8-16

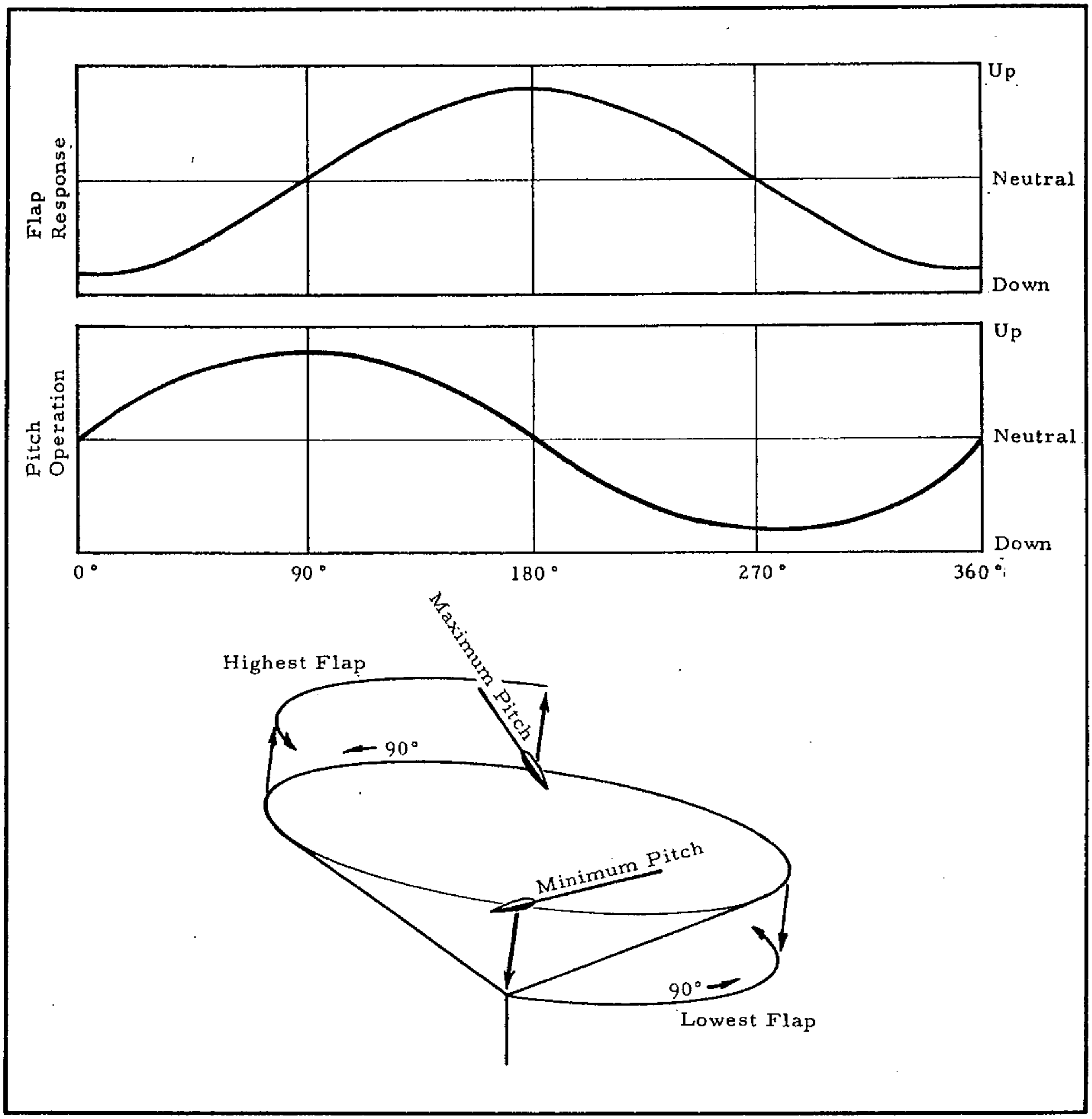


Figure 8-17

system by means of a control orbit located on the main driveshaft and operated from below the rotor head. The two types of orbit most commonly used are the "swash plate" and "the spider". In each case, the collective lever will raise or lower the whole control orbit effecting equal pitch changes simultaneously to all blades, and in each case, the cyclic control will tilt the control orbit in the direction in which it is desired to tilt the rotor disc.

(a) The Swash Plate System - This system employs two plates. The lower plate will not rotate, but is free to slide up and down the driveshaft in response to collective stick movements. This plate also tilts according to the direction in which the cyclic lever is moved. The upper plate, which rotates with the main rotor, bears against the lower plate and actuates the blade pitch control rods. Up and down movements of the lower plate will force the upper plate to change rotor pitch collectively. A tilting movement of the lower plate will force the upper plate to tilt; as the upper plate rotates, it actuates the cyclic pitch movements of the blades, see Figure 8-15.

(b) The Spider System - The central operating arm is free to pivot or slide about a ball socket which is contained in a sleeve within the main rotor driveshaft. Collective movements raise or lower the whole spider, producing equal pitch changes in all blades. Cyclic control movements tilt the spider, producing proportionate cyclic pitch changes in all blades, see Figure 8-16.

Phase Lag

10 When the cyclic pitch of a rotor blade is changed, its aerodynamic response is delayed, and the actual change of rotor tilt takes place when the blade has travelled approximately 90 degrees. Thus, to tilt the rotor forward from the horizontal, it is necessary to apply the pitch (and lift) changes to the blades in advance, that is, to reach maximum pitch while they are still athwartships. A study of sine curves helps to show the relationship of the pitch operating arm position and the blade flapping response.

11 This effect is akin to the principle of gyroscopic precession, in that a deflecting force applied to the gyro will take effect 90 degrees beyond in the direction of rotation. To offset this phase lag, the pitch change levers in the head are constructed to actuate 90 degrees ahead of their respective blades, and as a result of this a movement of the cyclic in a given direction initiates rotor flapping movement in the same direction, see Figure 8-17.

Tail Rotor Control

12 The tail rotor is primarily an anti-torque device preventing the fuselage from turning in the opposite direction to the main rotor. It is operated from the same drive as the main rotor, but at a much higher RPM. The tail rotor usually rotates about six times to one rotation of the main rotor, and the gearing is designed to prevent sympathetic vibrations between the main and the tail rotor systems.

13 The pilot cannot vary the tail rotor RPM independently from the main rotor but effects yaw control through tail rotor pitch changes actuated by his foot pedals. Since an increase or decrease of collective pitch changes the torque output of the engine, the pilot must co-ordinate these power changes with compensating pedal movements to maintain heading. On a single rotor helicopter with a counter-clockwise rotating main rotor, an increase in engine power necessitates an increase of left pedal. This increases the pitch and the counter-torque effect of the tail rotor. The pilot may also regulate this counter-torque force to offset slip and skid in normal flight, or to initiate and control hovering - or "pedal" - turns. The pedals control yaw in the same sense as the rudder bar of a fixed wing machine, ie, application of left-pedal initiates a yaw to the left, or corrects for yaw to the right.

14 The tail rotor is rigged so that in cruising flight the rudder pedals are central. Under these conditions of moderate power, some counter-torque force is necessary, and hence,

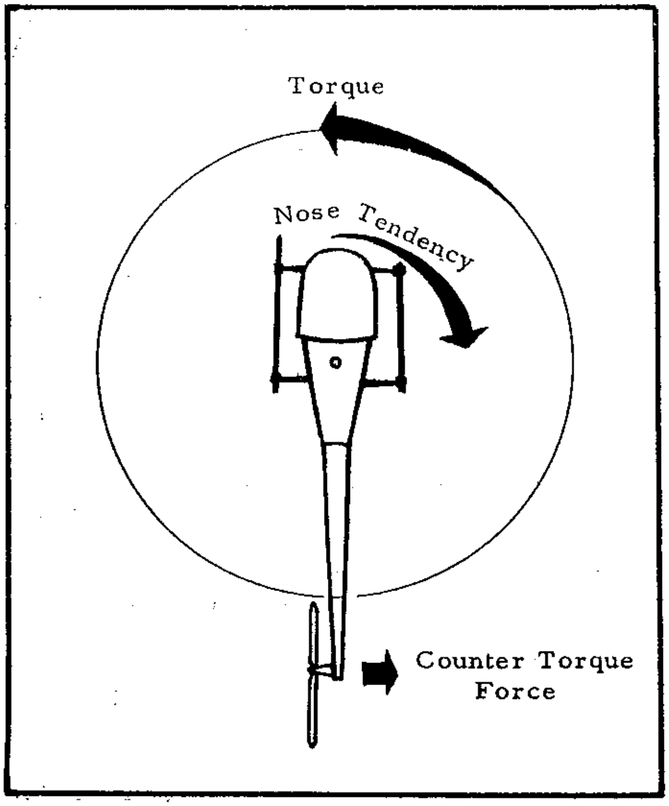


Figure 8-18

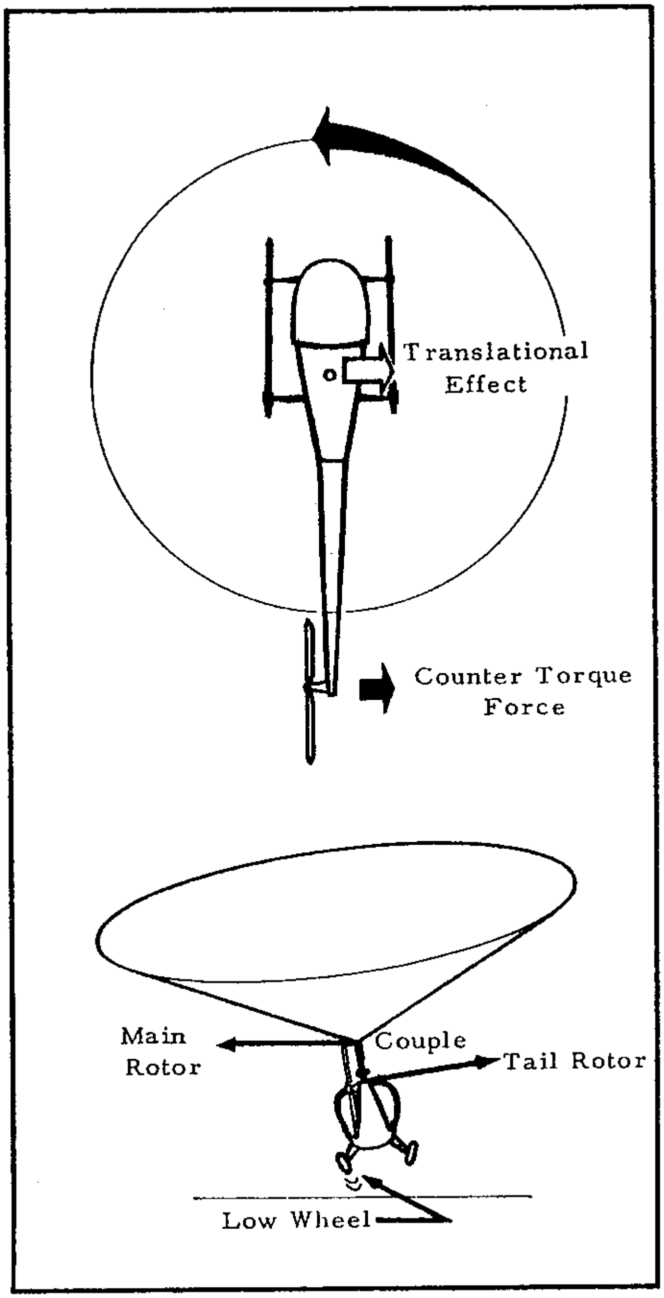


Figure 8-19

with neutral rudder selection, there is still a small amount of positive pitch exerting this force through the tail rotor. At all times during forward flight, weathercock forces in the fuselage reduce the effect of torque forces, and less rudder is required to compensate than when hovering at comparative power settings. Zero tail rotor pitch settings are achieved with the foot pedal partly right; fullright pedal will produce a negative tail rotor pitch. These zero and negative pitch settings are necessary to enable the pilot to maintain yaw control while descending in an autorotative glide without any torque output from the motor, see Figure 8-18.

Further Effects of Tail Rotor

15 The tail rotor is designed to offset the turning effect of torque. While this effect is successfully overcome, the force produced by the tail rotor acts of one side of the helicopter along a line at right angles to the direction that the fuselage is facing, and produces a sideways drift in proportion to the output of the tail rotor. This drift is particularly noticeable during the hover when minimum weathercock action and the demand for high power calls for heavy application of tailrotor control. At such times, the helicopter tends to move bodily sidewards, and this tendency must be countered by the pilot pressing the cyclic in the opposite direction to eliminate the drift force. Even in cruising flight, this effect is still present to a lesser degree, and in the heavier helicopters the cyclic control is off-rigged to provide sufficient compensation when held central at cruise.

16 It may be seen in the above diagrams, that, when the pilot holds the cyclic control to the left in the hover to eliminate drift to the right, the left wheel of the helicopter will hang low and be the first to strike the ground when landing. Any attempt by the pilot to level the wheels prior to touch-down by the use of right cyclic will initiate a dangerous sidewards movement to the right. Some helicopters are so designed that the couple, as shown in the above diagram, is eliminated. Nevertheless, most helicopters will still tilt laterally due to a force explained in paragraph 40, see Figure 8-19.

HELICOPTER ROTOR SYSTEMS

17 The Chinese are known to have developed the flying top thousands of years ago. In spite of the fact that the concept of rotary-wing flight is probably as old as kite-flying, and in spite of the apparent simplicity of the idea, rotary-wing flight lagged far behind fixed-wing flight when the latter became possible. The difficulties of rotary-wing flight only became evident after the advent of the gasoline engine when each stage of development brought new and complex problems. This created an ever-widening gap in progress between rotary-wing and fixed-wing development. The problems encountered were solved in different ways by

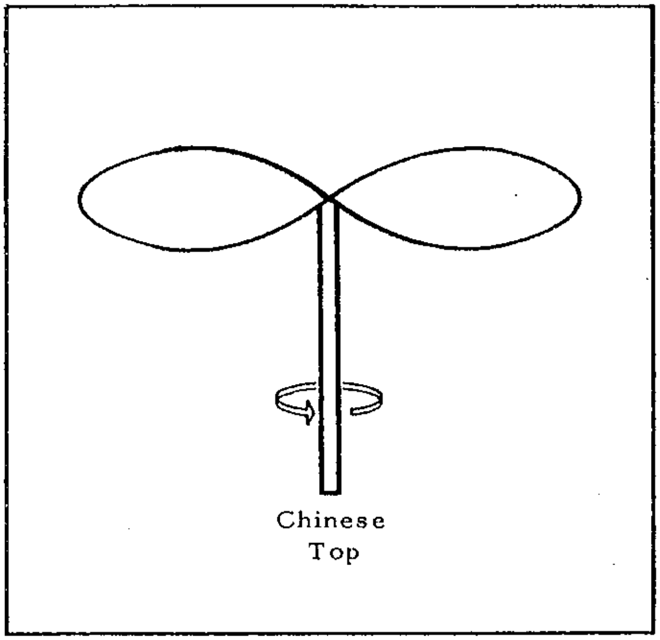


Figure 8-20

different inventors but, in general, success was achieved by increasing the articulation of rotors. Finally, within quite recent years, the helicopter has become a practical flying machine, see Figure 8-20.

Articulation of Rotors

18 Broadly speaking, rotors may be divided into three main categories, according to the number of pivots built into them. These are: rigid, semi-rigid, and fully articulated. The rigid rotor fell into disuse long ago when found to be impractical for helicopters and gyroplanes. Today, variations of both the semi-rigid and fully articulated rotor systems are commonly in use. The principles of the three main categories of articulation are as follows:

(a) Rigid Rotors - The earliest man-carrying helicopters employed rigid rotor systems. Such rotors merely rotated about their drive axes, like horizontal propellers, though some were capable of variations of pitch enabling the pilot to vary the lift and gain limited control. By the use of combinations of several rotors, some degree of success in free flight was achieved, and by increasing the lift of one rotor and decreasing that of another, pilots were enabled to tilt the machine in the desired direction and thereby to move the machine laterally. Unfortunately, this principle proved to cumbersome, see Figure 8-21.

(b) Semi-rigid Rotors - Rather than tilt the whole machine to gain propulsion, it was found more convenient to construct a system that would tilt the rotor independently from the machine. The semi-rigid rotor was developed from the rigid rotor by adding a flapping hinge. This now enabled the rotor to tilt (or flap) independently. However, all the problems were by no means solved. As the rotors gained horizontal speed, tremendous vibrations and stresses developed both in the mast and at the roots of the blades. To offset these bad effects, drag hinges were incorporated at the roots of the blades and the fully articulated rotor was developed. However, for light helicopters, using only two blades and requiring only a lightweight rotor suspension, it was found practicable to retain the semi-rigid rotor. A gymbal type mounting was used, allowing the whole mounting yoke to tip universally around the mast. Further development of this device permitted the elimination of the problems of geometric imbalance, see paragraph 19.

(c) Fully Articulated Rotors - Semi-rigid construction was not sturdy enough for heavier helicopters. Greater strength was achieved by rigidly securing the whole central mounting to the mast. The blades were then attached to this mounting by a system of pivots. This arrangement necessitated the use of drag hinges. Thus, the fully articulated rotor was evolved.

(1) The blades of a fully articulated rotor are free to feather, flap, and drag. Dragging, sometimes called hunting, is a natural tendency of the blades to pivot independently ahead or behind their normal radial

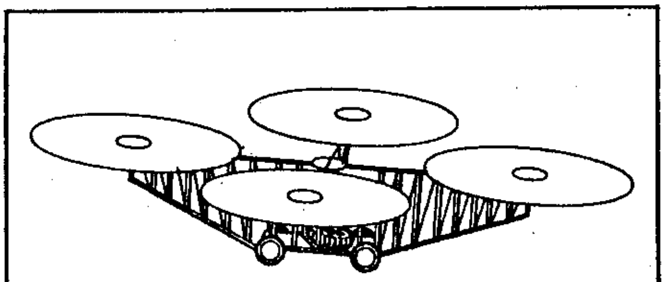

An Early Concept
Using Rigid Rotors

Figure 8-21

position whenever the rotor is flapped. The addition of drag hinges minimizes both fatigue at the roots of the blades and severe vibration. The causes of such dragging are manifold, but the need for drag hinges becomes most evident when the rotor is flapped to accelerate or decelerate the helicopter and when the axis of rotation angles away from the drive axis. Under this condition, the centres of mass of of the individual blades will endeavour to rotate at constant velocity around the new axis, see Figure 8-22. A blade WITHOUT A DRAG HINGE (Diagram B) would be forced, geometrically, to remain aligned at right angles to its mounting, and the blade centre of mass (C of M) would be forced to revolve around the drive axis and not to follow its natural path around the new axis. This would result in the rear blade C of M being required to travel through a shorter arc than that of the forward blade while each rotates 180 degrees; this means that the rear blade must slow down and the forward blade must speed up to cover the distances in the same time. The inertia of the blades would oppose these speed changes and try to bend the blades. If the blades were too rigid to bend, tremendous vibrations and stresses would be built up. The incorporation of a drag hinge permits the blades to pivot at the roots and the blades are no longer forced to accelerate and decelerate. This means that the centres of mass travel at constant velocity, though the blades now lead and lag strictly in a geometric sense (Diagram C). It will be noted that, as the blade advances from rear to front, it leads geometrically, and as the blade retreats, it lags geometrically. No acceleration or deceleration remains as a product of geometric imbalance.

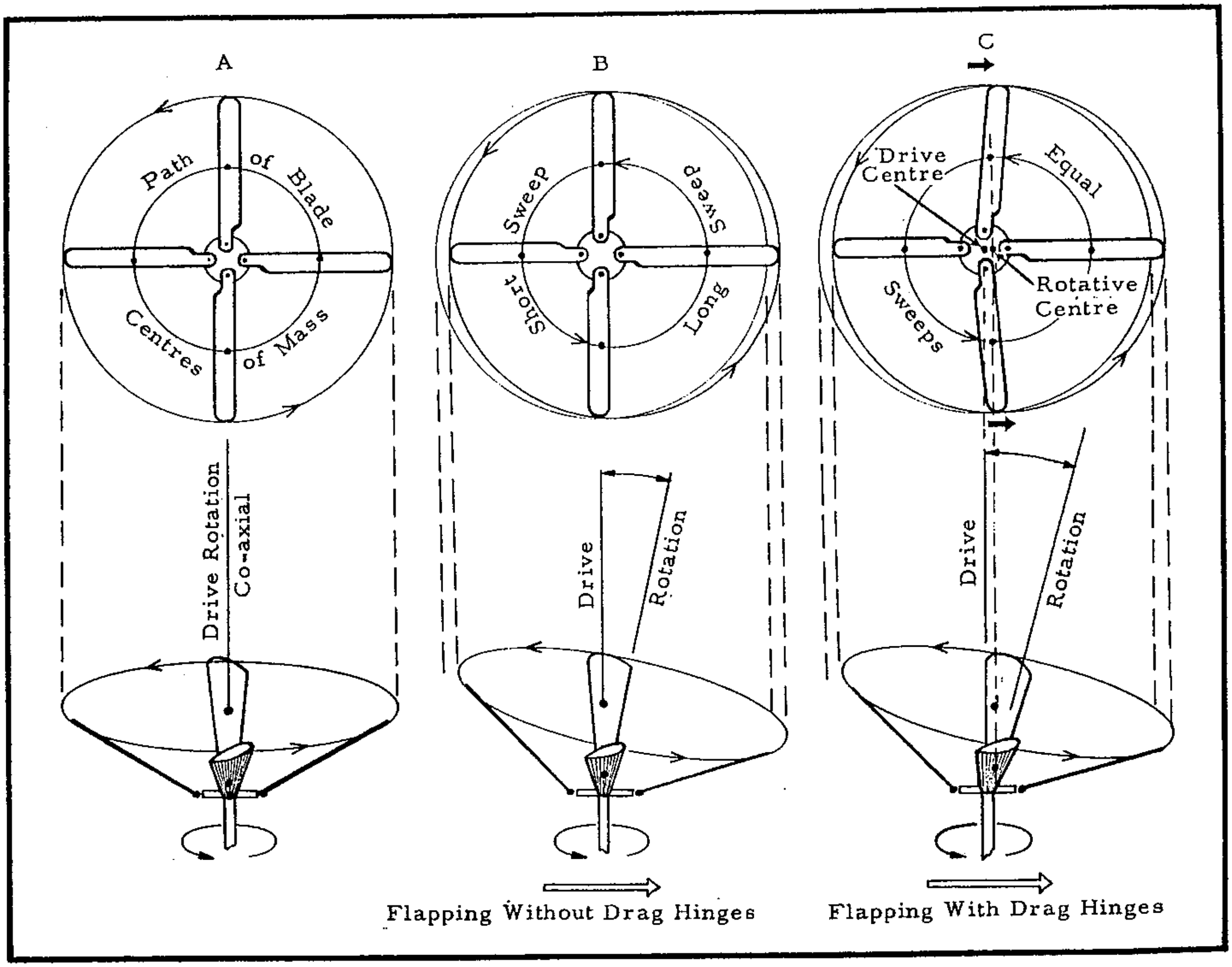
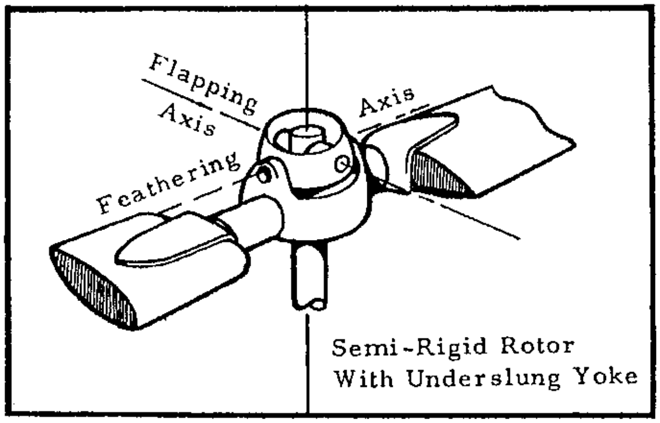
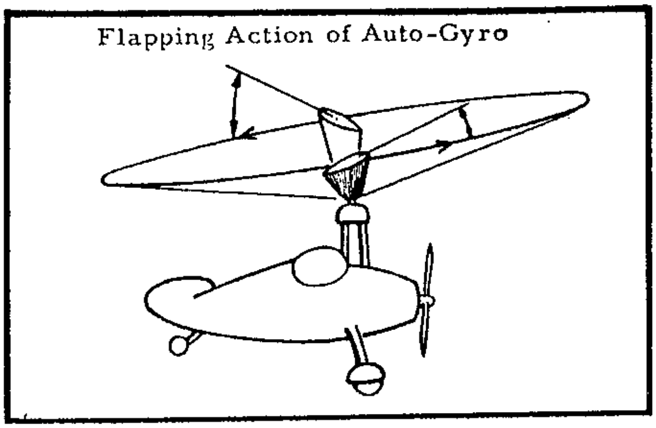


Figure 8-22



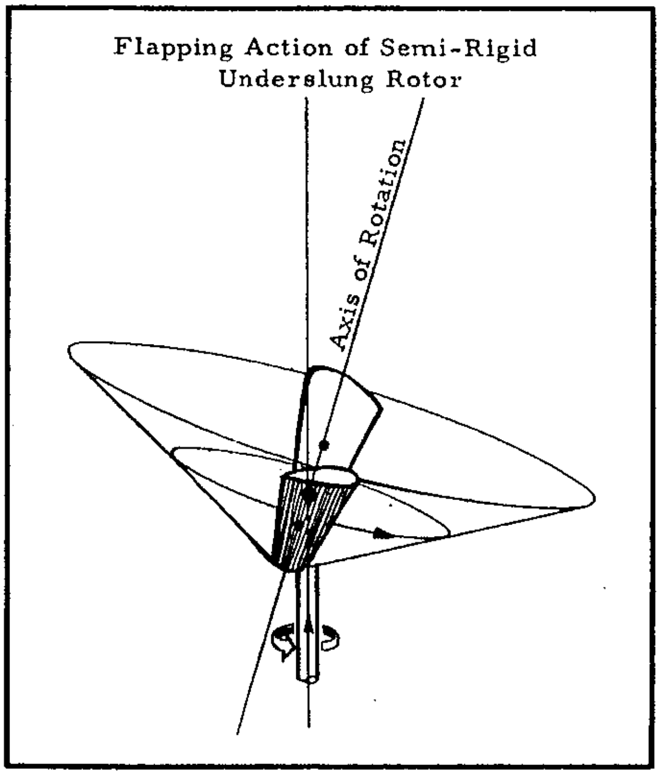
Semi-Rigid Rotor
With Underslung Yoke

Figure 8-23



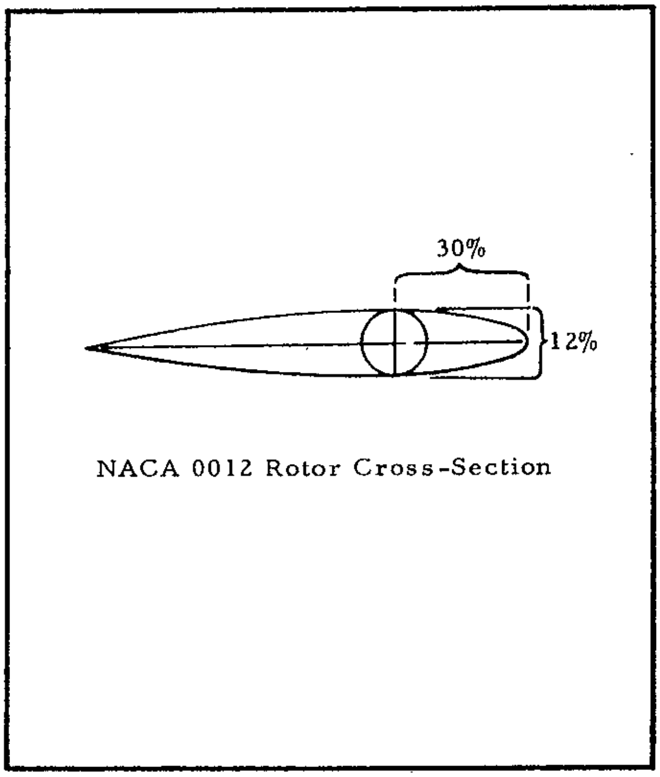
Flapping Action of Auto-Gyro

Figure 8-25



Flapping Action of Semi-Rigid
Underslung Rotor

Figure 8-24



NACA 0012 Rotor Cross-Section

Figure 8-26

(2) In practice when drag hinges are used, drag dampers must be incorporated to eliminate oscillations through the drag hinges. These oscillations are produced as the blades first advance through the resistance of oncoming airflow, and then, after they pass through the front of the disc, they are released from this pressure as they sweep downwind. Drag hinges and dampers also help to absorb the shock of quick engagements during start-up, or during recovery from autorotative flight.

Compensation for Geometric Imbalance in Semi-rigid Rotor Heads

19 The gymbal mounting of the yoke in the semi-rigid rotor head will not, in itself, eliminate the problems of geometric imbalance, see Figure 8-23. However, by underslinging the yoke, it is possible to compensate for coning and to keep the blade centres of mass rotating about the point where the drive axis and the axis of rotation intersect. Since this point is common to both axes, geometric imbalance will not occur. This common point may be seen

in Figure 8-24 at the intersection of both axes.

Flapping

20 In the case of the helicopter, the obvious purpose of tilting - or flapping - the rotor is to incline the rotor's lift and thereby produce a horizontal component of lift, usually termed thrust. However, it is significant to note that La Cierva, who was the first man to employ a flapping hinge, incorporated it into his gyroplane to serve a purpose rather different from that to which it was later applied in the helicopter. During his early experiments with a rigid rotor he found that, as the machine gathered speed, the advancing blade produced greater lift than the retreating blade. This dissymmetry of lift forced the machine to roll. Incorporating a flapping hinge permitted the advancing blade to climb throughout its sweep, thereby meeting the air at a shallower angle of attack. Conversely the retreating blade flapped downwards and, in so doing, increased its angle of attack. By this means the blade with the greater flight velocity had the smaller angle of attack, and the blade with the smaller flight velocity had the greater angle of attack. As a result, lift was equalized laterally, see Figure 8-25. This resulted in the rotor flapping up in front, a reaction which was of no detriment to a gyroplane but which, in the case of a helicopter, would only reverse the machine's forward movement. To avoid this reaction, once cyclic pitch changes have been used to initiate rotor tilt, and once the helicopter has gathered speed, further application of cyclic pitch is used to diminish the angle of attack on the advancing blade, and at the same time to increase the angle of attack on the retreating blade. This movement maintains symmetry of lift and also prevents the rotor from flapping to the rear and slowing down the helicopter. Refer to Chapter on TRANSITION, paragraph 38(d) and (e).

Tail Rotors

21 Helicopter tail rotors are constructed with flapping hinges. Since a tail rotor is dragged sideways through the air in a similar way to the main rotor of a gyroplane, dissymmetry of lift would occur if flapping were not permitted. Such dissymmetry would have a rolling effect on the main body of the helicopter. Due to flapping, a small amount of geometric imbalance is present, but as long as the blades are kept short, and slightly flexible, no undue vibrations occur and no drag hinges are required.

Desirable Properties of a Rotary Aerofoil

22 The design of a particular aerofoil is influenced greatly by the aircraft type. For instance, the aerofoil needed for the wing of a bomber differs considerably from that of a fighter. Each is designed for a specific purpose. Often an aerofoil has to be a compromise of opposing requirements to achieve a suitable degree of success. This holds true for a helicopter blade; it has very special requirements, and to achieve the desired performance some degree of compromise has to be made. In practice, an aerofoil of symmetrical cross-section has proven highly suitable.

23 A symmetrical aerofoil is one whose camber on the lower surface matches that on the upper surface. The particular aerofoil cross-section used for the H-5 helicopter is typical. The specification for this blade cross-section is NACA 0012. It is a symmetrical aerofoil with a thickness/chord ratio of 12%. In addition, the point of maximum thickness is located 30% of the distance back from the leading edge. The blade feathers about a point which is approximately coincident with the intersection of the chord and the line of maximum thickness. Such a cross-section produces

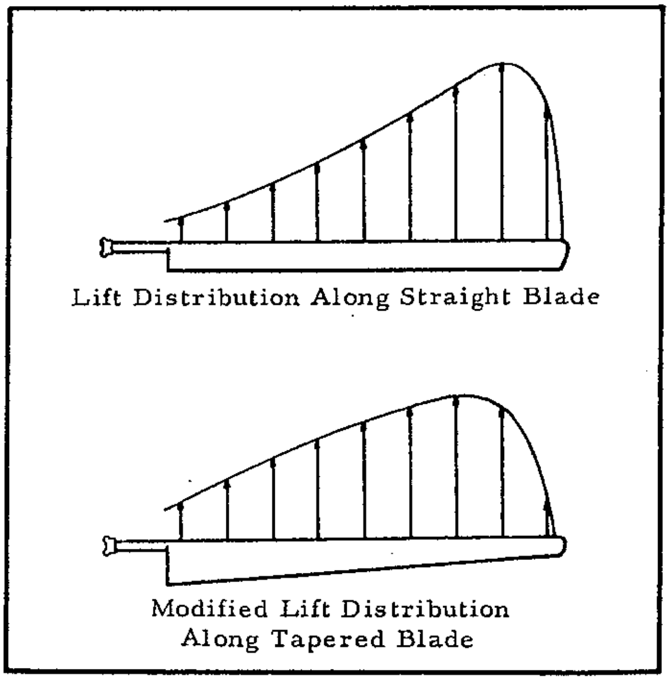
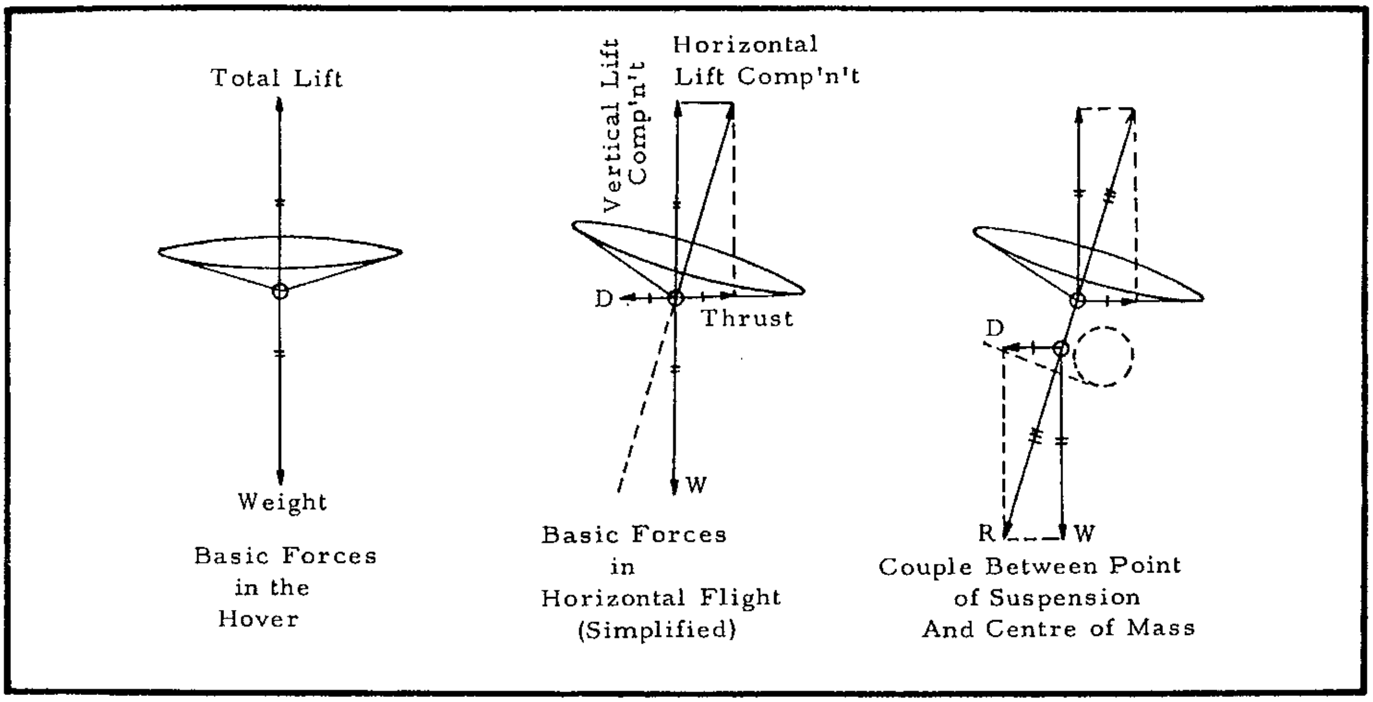


Figure 8-27



Basic Forces in the Hover

Basic Forces in Horizontal Flight (Simplified)

Couple Between Point of Suspension And Centre of Mass

Figure 8-28

the two following desirable aerodynamic characteristics, see Figure 8-26.

(a) The centre of pressure remains as constant as possible throughout a wide range of angles of attack. On most aerofoils the C of P moves forward with an increase of the angle of attack; in the case of a helicopter rotor, this angle is constantly changing and excessive movements of the C of P ahead or behind the feathering axis would cause considerable control interference.

(b) The lift/drag ratio provides efficient performance throughout a wide range of velocities. This is necessary because the resultant velocity of the tip of a rotor blade is far greater than that of a blade segment close to the blade root.

Movement of the Centre of Pressure

24 Due to the difficulties in designing an aerofoil with an absolutely stable C of P, certain back-pressures build up in control systems. These pressures vary as the pitch angles, attitudes, and velocities are changed. Because such back-pressures would make control difficult for the pilot, helicopter control systems are designed to compensate for this. This is done by several means, including: irreversible hydraulics, irreversible cams and cranks, screwjacks, and bungee trim bias.

Lift Distribution Along a Rotor Blade

25 The great difference in velocity between the blade tip and the blade root creates proportionate differences in the amount of lift produced by various parts of the blade. Horizontal movement of the helicopter will cause further differences in lift distribution, giving more lift to the advancing blade than the retreating blade. However, for clarity, the diagrams illustrate the distribution of lift produced by a blade during a hover. From the first diagram, it can be seen that most of the lift is concentrated towards the tip. This pattern would cause considerable flexing strain near the roots of a rigid or semi-rigid rotor, and for all types of rotors it would be inefficient to produce lift from the outer portion of the disc only. For this reason, the blades are usually modified to produce a more even lift distribution, see Figure 8-27. This is normally achieved by either tapering the blades towards the tips, or by decreasing the pitch angle progressively from root to tip by blade twist. Tapering metal blades has proven prohibitively expensive and it has been found more practicable to twist them. This twist should not be overdone: in the event of a blade tip stall too much of the blade would reach the

stalling angle simultaneously, and the stall would spread back along the blade too rapidly to permit safe recovery.

THE FOUR BASIC FORCES

26 The overall effects of the four basic forces: lift, weight, thrust, and drag, may be related to the helicopter in much the same way as they relate to the fixed-wing aircraft. Lift opposes weight, and thrust opposes drag. However, marked differences exist between the fixed and rotary wing basic forces. For instance, in the helicopter, thrust is produced by inclining lift, aerofoil drag is overcome by torque parasite drag alone directly opposes thrust. Another difference is that thrust can be non-existent in the hover, or may be applied in any direction regardless of fuselage heading. Finally, in the case of most helicopters, the application of these forces produces greater fuselage pitching moments. These points are explained in more detail below, see Figure 8-28.

(a) Lift - Paragraph 3(a) has already shown how the lift created by the separate blades may be considered together as one total lift reaction acting at right angles to the disc. Lift may be increased by an increase of RPM, or by an increase of collective pitch; in both instances, torque must be increased to sustain the greater lift. In the hover, the disc is horizontal and the total lift reaction is perpendicular, directly opposing weight. While hovering, an increase of lift in excess of weight would cause the helicopter to climb vertically.

(b) Thrust - When the rotor is tilted from the horizontal, lift is displaced from the vertical. Under these conditions, total lift may be resolved as two component forces: the first is vertical and opposes weight; the second is horizontal and provides thrust. The more lift is inclined the shorter will become its vertical component and the longer its thrust component. Thus, as thrust is increased, the helicopter will tend to sink. Therefore, in the initial stages of acceleration, while the rotor is being tilted, it is usually necessary to increase power sufficiently to prevent sink. In diagrams depicting these basic forces, the horizontal thrust component is drawn from the point of suspension.

(c) Drag - The drag produced by the rotor system is primarily a product of blade rotation. The purpose of the engine is to provide torque to offset this drag which is created as the rotor produces lift. This form of drag is present both in the hover and in cruising flight, and being offset by torque, does not oppose the thrust component of lift. Hence, the drag force shown in the second and third diagrams is the remaining drag produced by the fuselage and other parasite forms as they are pulled through the air by thrust. Such drag is non-existent in the hover. When the rotor is tilted and thrust is produced, drag increases in proportion to the square of the velocity, until finally drag equals thrust and these forces are in balance. At this stage, acceleration ceases.

(d) Helicopter Configuration - In the hover, the helicopter's centre of gravity will rest directly below the point of suspension. A horizontal movement of the helicopter in any direction relative to the fuselage will create parasite drag. Such drag will vary according to the aspect presented by the fuselage as it moves through the air. The centre of drag will normally be somewhere near the centre of gravity and, for convenience, has been shown in the same position in the third diagram. It may be seen that thrust acting through the point of suspension, and drag acting through a point beneath, will create a couple tending to tilt the fuselage downwards in the direction it is travelling. The greater the flight velocity, the more marked will be this attitude change. The streamlining of the fuselage favours forward flight, but because of drag and weathercock forces translation backwards or sidewards is usually limited to comparatively low speeds.

VELOCITIES AFFECTING ROTOR SYSTEMS

27 A study of rotary-wing theory requires some understanding of the various velocities which affect the blades. These velocities combine to provide the resultant path of the blades through the air. By studying these velocities, the speed and direction of the relative airflow over the aerofoil can be determined at any stage of the blade's rotation. During the hover, a rotor blade is affected by two velocities: the rotational velocity of the blade, and the downwash or induced velocity of the air being displaced through the rotor. In horizontal flight, the flight velocity of the whole machine affects the rotor in addition to the other two velocities.

These three velocities are explained in detail, see Figures 8-29, 8-30 and 8-31.

Tangential Velocity (VTa)

28 This could also be termed the rotational velocity of the blade. At a given instant in rotation, this velocity may be shown as a vector drawn at a tangent to the path of the blade. For a given RPM, this velocity will increase proportionately with the distance measured outwards from the hub of the blade. The only time when this velocity alone would affect the rotor would be during a ground run in still air and with zero pitch on the blades.

Downwash Velocity (Vd)

29 As soon as the collective lever is raised, the positive angle of attack of the blade will cause the air to be displaced downwards. In actual fact, the blade is now climbing relative to the air, and a vector depicting this component of the blade's movement relative to the air would have to be shown as an arrow pointing upwards. During the hover in still air, the blade will be subject to both VTa and Vd (upper Diagram 30). Hence, as the blade travels around its arc it also climbs through the air. The resultant of the two vectors shows the actual path and speed of the blade. When the helicopter is descending in full autorotation, the downwash velocity is replaced by an upflow of air through the rotor system (lower Diagram 30). In this instance the downwash vector would be replaced by an arrow pointing downwards, and the resultant would give a greatly increased angle of attack to

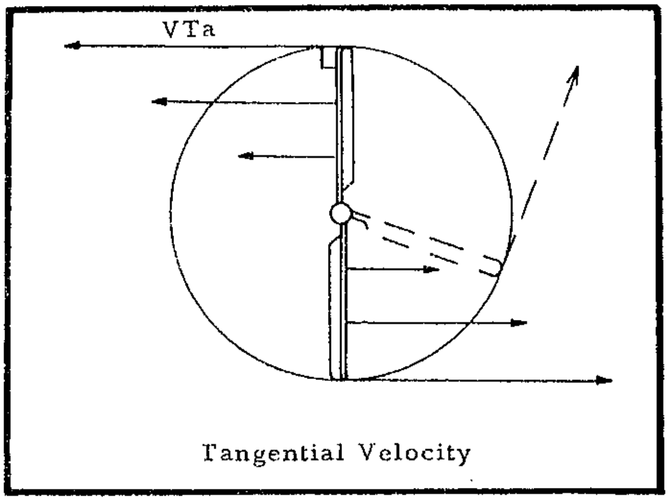


Figure 8-29

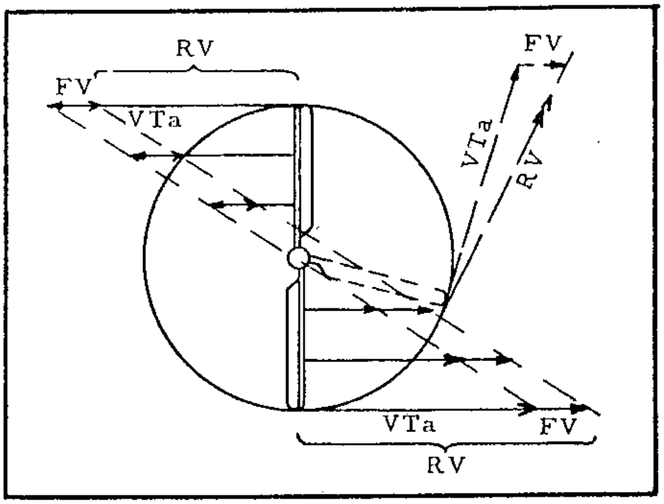


Figure 8-31

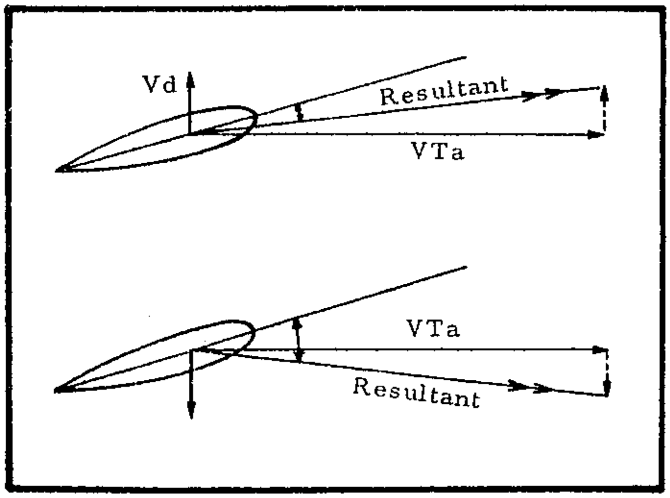


Figure 8-30

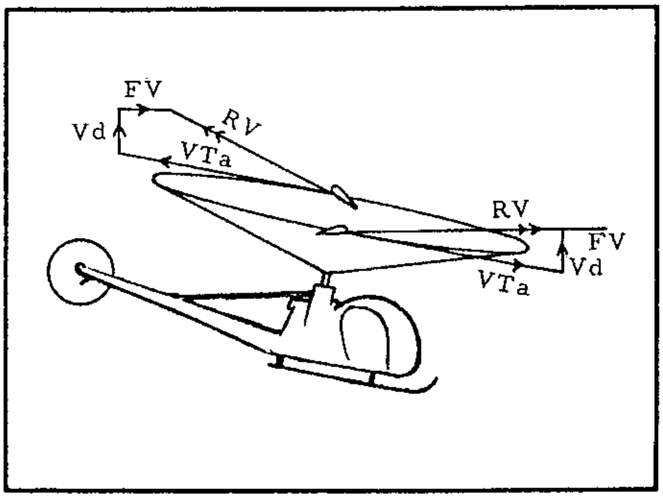


Figure 8-32

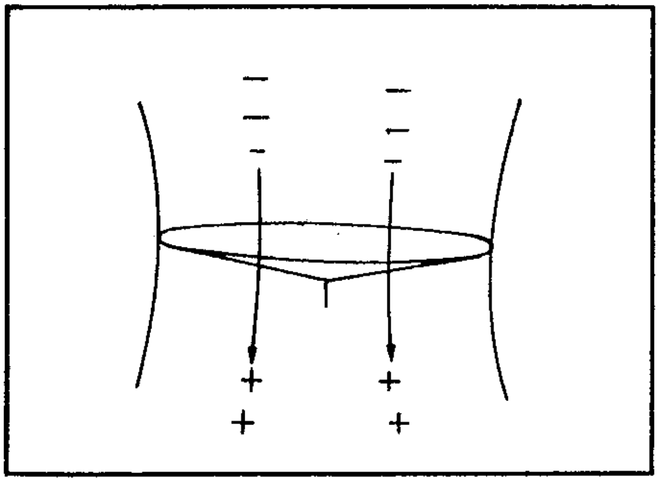


Figure 8-33

the aerofoil. During a descent under power, air is still drawn downwards through the rotor disc, and the downwash vector would still be depicted as an arrow pointing upwards.

Flight Velocity (FV)

30 When the rotor is tilted from the horizontal, the helicopter will start to move in the direction of tilt, thereby introducing a flight velocity. This velocity affects the whole helicopter; thus, regardless of the position of the blades at any given instant, flight velocity will affect them all with regard to both speed and direction. In plan view, this velocity may be plotted along with the tangential velocity as shown. The resultants shown in Figure 8-32 however, are not accurate, since in this view the downwash velocity cannot be shown. Nevertheless, it is often necessary to use this diagram as a preliminary step before plotting the final resultant by using a side view diagram of the rotor. In Figure 32 the correct Resultant Velocities (RV) are shown for the blade in both the athwartships positions. The relative airflow - sometimes called the Relative Wind - is the reciprocal of the (RV).

TRANSLATIONAL FLIGHT

31 Whenever the helicopter moves horizontally through the air, such movement may be described as "Translation". The helicopter may even be stationary relative to the ground, but if there is a wind blowing, the helicopter would still be translating through the air to maintain its position over the ground. It is a surprising truth that the helicopter in the hover requires considerably more power than it does in cruising flight. As the helicopter reaches a flying speed of 10 to 15 knots the pilot notices a marked increase in lift and, as he accelerates to around 50 knots, he must decrease power progressively to avoid climbing. This phenomenon is a product of translational lift, and affects the helicopter whether it moves forwards, backwards, or sideways, see Figures 8-33 and 8-34.

Translational Lift

32 At first, it may appear that the increased lift produced by translation is a product of blades moving faster through the air but a moment's reflection will show that while the advancing blade picks up speed, the retreating blade loses speed by the same amount. What actually happens is that, as the helicopter increases speed, the whole rotor disc acts on an ever-increasing mass of air per unit of time, ie, the mass flow through the rotor is increased. Thus the disc becomes relatively more efficient. This is similar to the effect upon a fixed-wing aircraft, in that the lift increases as the wing accelerates and acts on a greater mass of air per unit of time. Another source of translational lift, closely allied to the former, is provided by the change of motion of the air through the disc as the aircraft moves from the hover. While in the hover, much of the rotor's energy is dispelled in the effort required to climb through an already moving column of air. In forward flight the air ahead of the rotor is not "warned" into previous motion, and, as a result, the rotor reacts on more stable air, and the rotor's energy is used more efficiently providing more lift.

33 Ignoring drag for the moment, the power required to draw the air through the disc and to support the aircraft is called

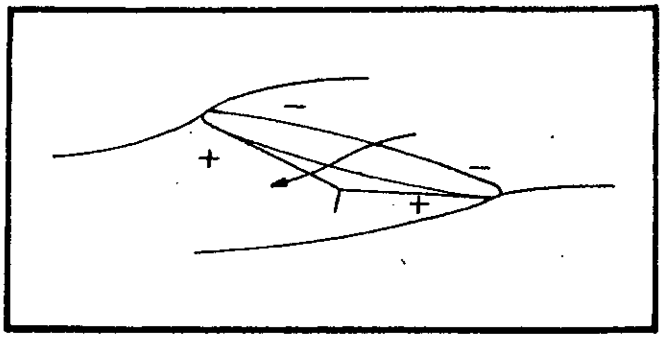


Figure 8-34

"Induced Power". This is plotted as curve "A" Figure 8-35. As the helicopter increases speed, the power required to support the helicopter becomes less and less.

Drag

34 Fuselage Profile Drag - This drag is virtually non-existant in the hover and as the helicopter accelerates, increases as the square of the speed. The power required to overcome this form of drag is plotted as curve "B".

(a) Rotor Profile Drag - Drag is produced by the blades as a component of blade total reaction. This was described earlier in the definitions. When considered purely in relation to forward speed, rotor profile drag increases only slightly with an increase of flight velocity. This increase is due to the extremes of attitude at which the blade meets the air at the front and rear of each sweep as the rotor tilts further forward to increase the velocity. In each extreme, the rotor is operating at an angle of attack where the lift-drag ratio produces proportionately high drag for the amount of lift created, see Figure 8-36.

Total Power Required

35 A study of the graph shows that high power is required at zero airspeed. As the rotor is tilted, the vertical component of lift is shortened, due to the tilting of the total lift reaction of the disc, and a small increase of power is required to prevent sink. At 10 to 15 knots, the power required falls off rapidly until around 35 knots. Minimum drag and optimum efficiency is obtained at approximately 45 knots, after which any further increase in speed calls for an increase in power owing to the build-up in fuselage drag (this varies as the square of the velocity). Flight at minimum power is achieved around 45 knots. Therefore, this speed is best suited for maximum endurance. As the speed is increased further, the power required increases gradually at first, and at 65 knots, in this case, maximum range efficiency is achieved. Any further increase in speed would call for too great an increase in power to gain any greater efficiency in range.

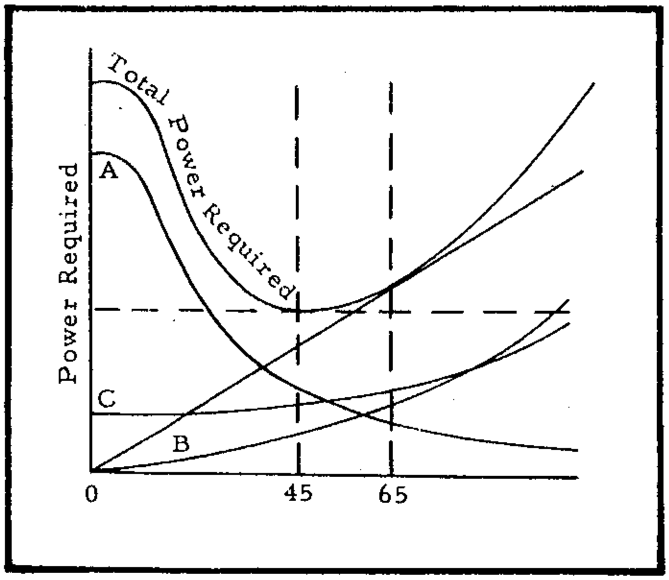


Figure 8-35

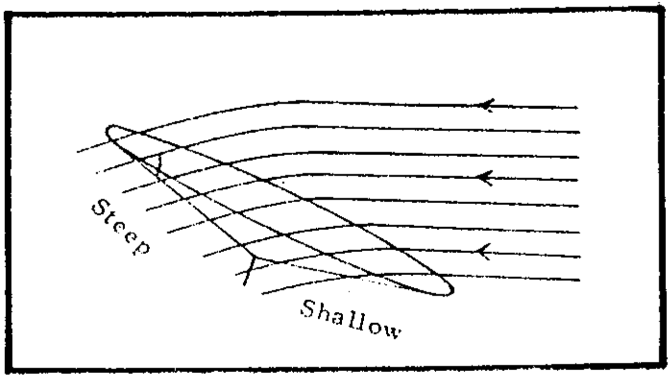


Figure 8-36

TRANSITION

36 Earlier, when describing the purpose of the cyclic stick, it was pointed out that the rotor may be tilted in the required direction by movement of the cyclic control in that direction. Flapping the rotor in this manner tilts the total lift reaction and starts the helicopter moving in a given direction. All accelerations, or decelerations of the helicopter, as a result of cyclic change are known as transitions. That is, so long as the flight velocity of the helicopter is changing in any manner, the helicopter is undergoing transition. It should be remembered that any change of speed or direction is a change of velocity and is, therefore a transition. When the helicopter is hovering, there is no transition; or when the helicopter is cruising at a a constant velocity, there again is no transition. In the latter case, of course, the helicopter is translating, and continues to do so through any state of transition.

Step-by-Step Analysis of Transition

37 A typical example of helicopter transition is that of a helicopter moving from the hover into cruising flight. Consider the pure case of a hover followed by a departure along a flight path, with no wind, and with the hover conducted away from ground effect. Five clear-out stages of this transition make this study simpler though, in actual flight, each stage would tend to blend into the next. In truth, on many machines there is such a marked lag between control action and aerodynamic result, that this step-by-step breakdown is completely realistic.

38 In each stage, the lift distribution in the disc is analysed and, thereby the flapping tendencies may be determined. To do this, the advancing blade is compared with the retreating blade, each in its opposite position athwartships; blade velocities are analysed with respective angles of attack, and therefrom, the actual lift which each blade produces may be determined and compared as the blades pass through opposite sweeps.

(a) The Hover - Hovering in still air, in a perfectly balanced helicopter, the cyclic control is held central and the rotor disc is level with the horizon. At this stage each blade is travelling through the air at equal tangential velocity, and equal downwash velocity. Hence, their resultant velocities are the same. With only collective pitch applied, and the cyclic held central, the pitch angles of each blade are the same. As a product of equal velocities, of equal pitch, and of a constant attitude, the angle of attack of each blade is the same and so is the lift produced. Since lift throughout the disc is equal, there is no tendency for the rotor to flap or for the helicopter to move into transition, see Figure 8-37.

(b) Cyclic Forward - To initiate forward movement of the helicopter the rotor must first be flapped forward by movement of the cyclic control. This next stage of analysis explains how the cyclic upsets the equilibrium and initiates the flapping action which follows the cyclic movement. Only the cyclic control system is moved and nothing has happened as yet to change the resultant velocities which are still equal. The pitch angle on the advancing blade has been decreased and that on the retreating blade has been increased; this change has affected the angle of attack of each blade in the same manner. It follows that the retreating blade has gained lift at the expense of the advancing blade, and that the total lift has not changed but that it has been redistributed. The retreating blade now climbs and the advancing blade descends, and due to the 90 degree phase-lag, mentioned previously in paragraph 10 maximum flap is reached at the rear of the disc, minimum flap at the front, see Figure 8-38.

(c) Rotor Flaps - At this stage it will be assumed that, though the helicopter is about

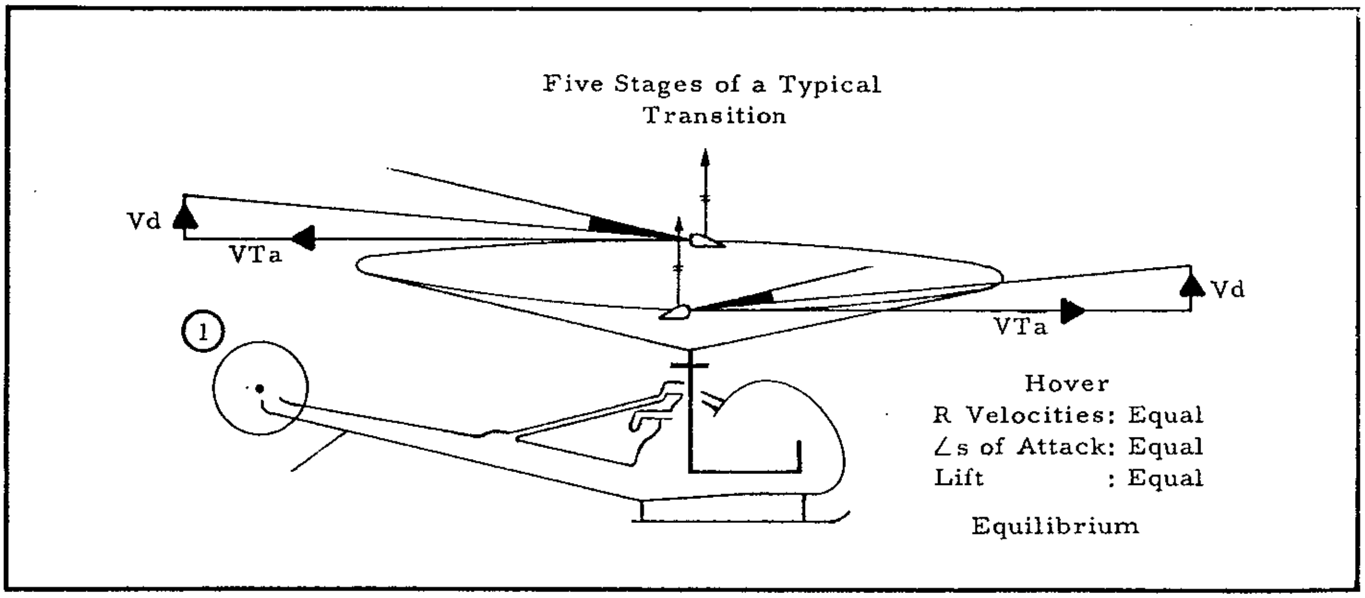

Five Stages of a Typical Transition

Figure 8-37

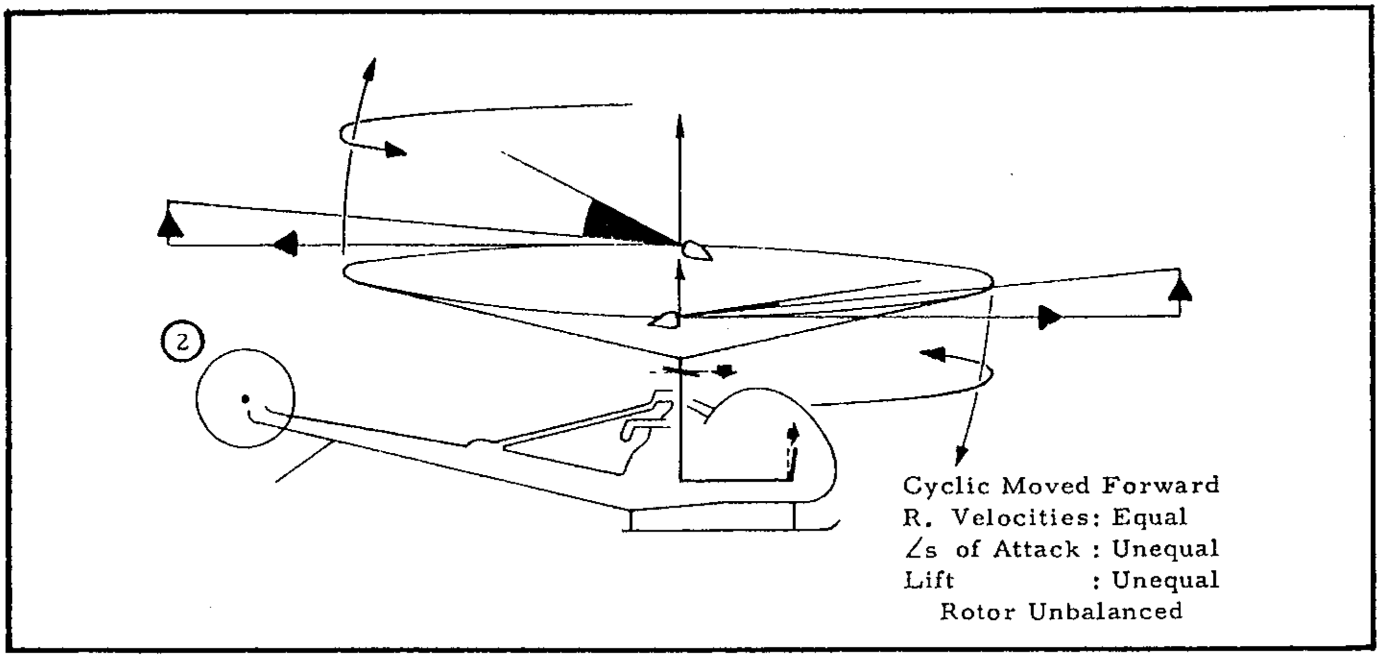


Figure 8-38

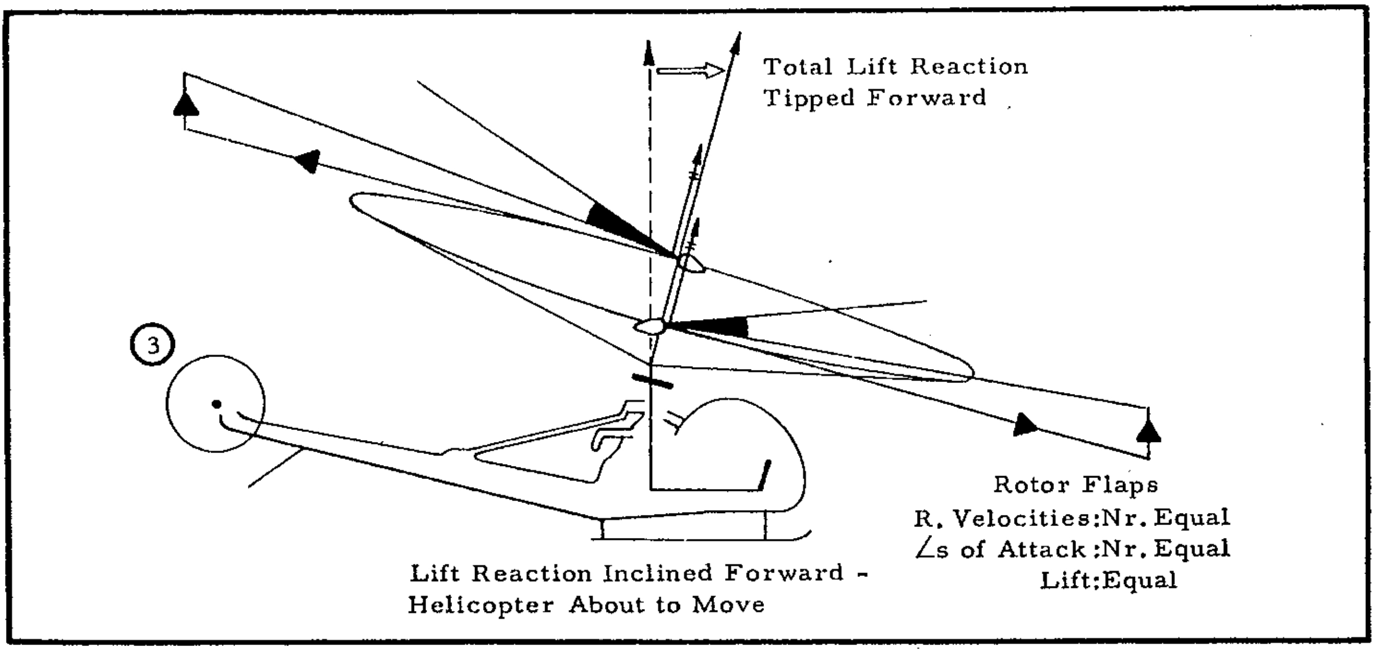


Figure 8-39

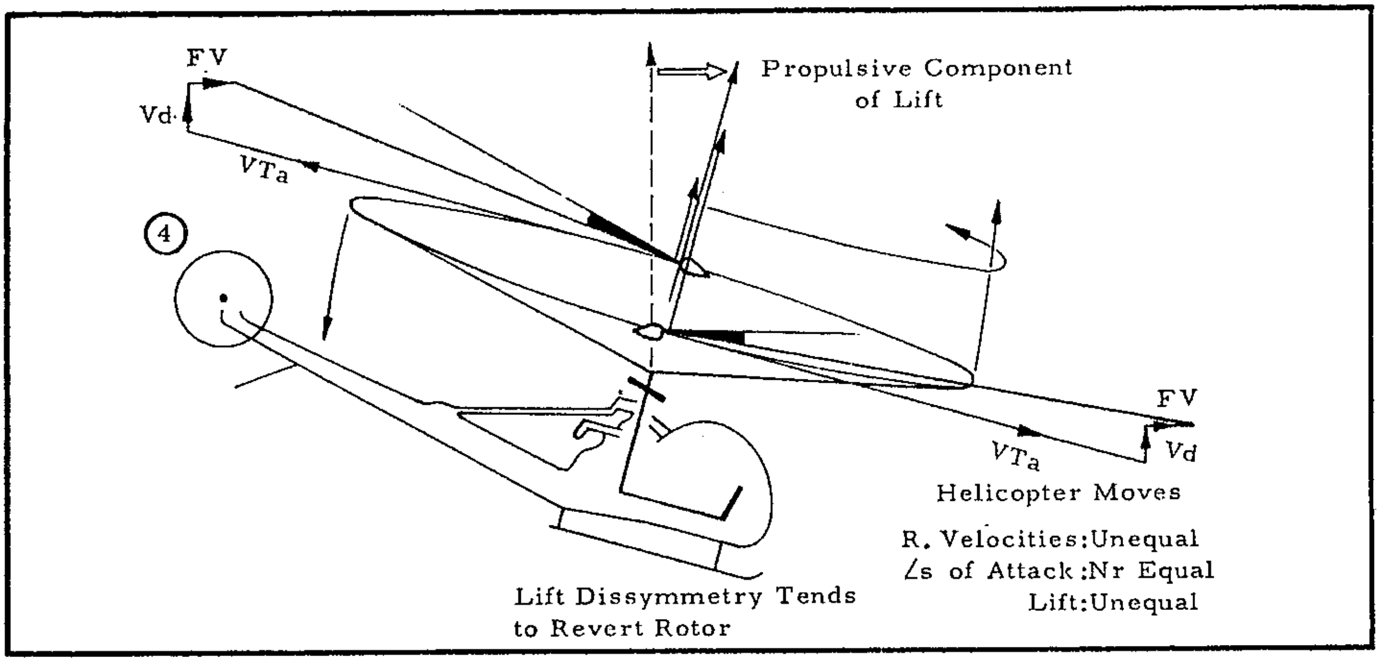


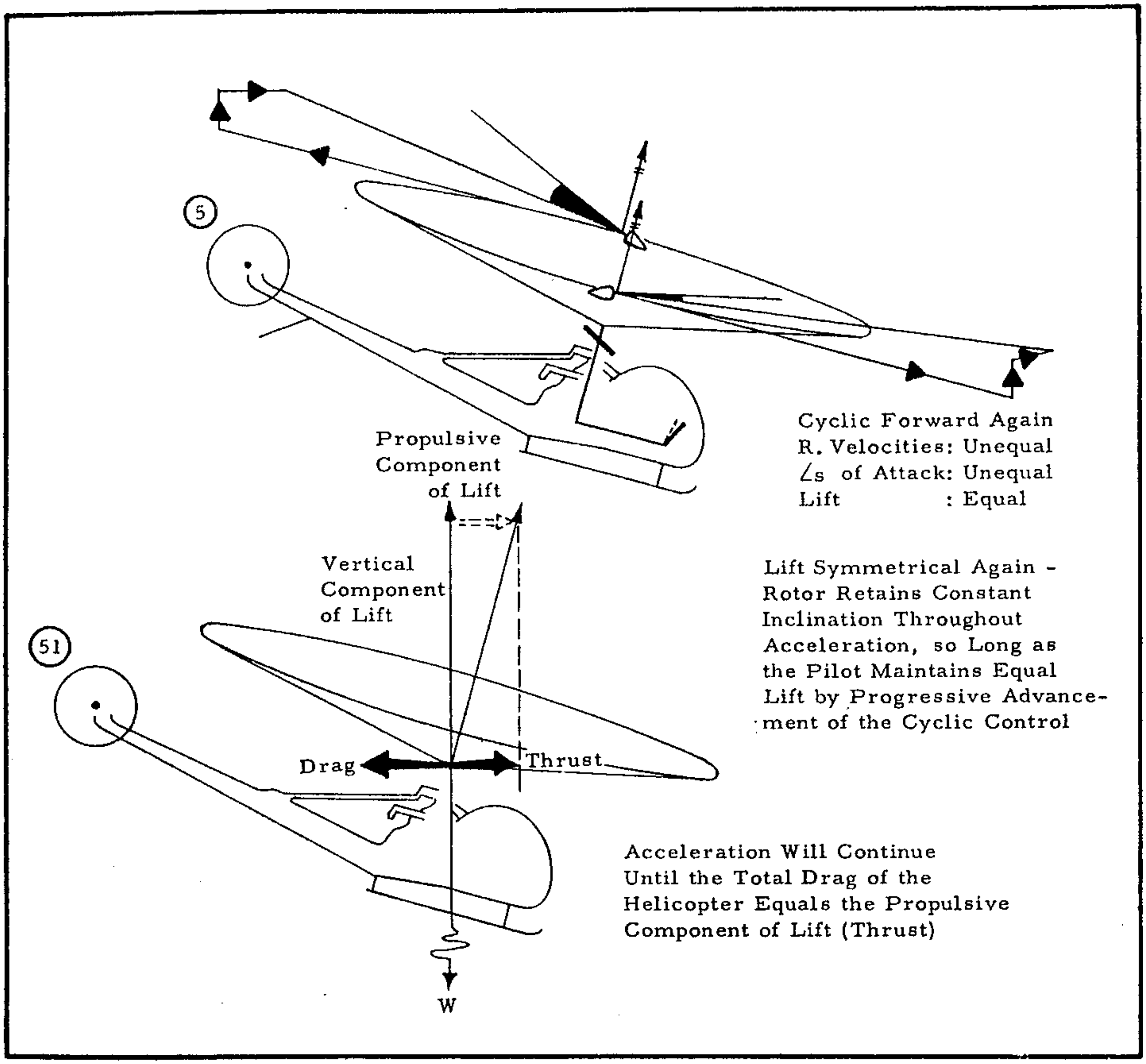
Figure 8-40

to move, it has not yet noticeably done so. For this reason, the velocities may be considered virtually equal relative to the blades. When describing flapping earlier, it was explained that, by changing the paths of the blades, the upgoing blade decreases its angle of attack and that the downgoing blade increases its angle of attack. By this means, the lift differential between the blades is progressively equalized. It follows that the amount that the rotor flaps is dependent upon the extent of the original cyclic movement. The degree to which the rotor is tipped relative to the horizon determines the amount of horizontal thrust the rotor provides as long as this tilt is maintained. This thrust accelerates the helicopter forward until such time as total drag balances this thrust force, see Figure 8-39.

(d) The Helicopter Moves Forward - As the helicopter accelerates forward the blade resultant velocities will be changed by the introduction of the flight velocity. The advancing blade will meet the air at a greater speed than the retreating blade. If the pilot makes no further cyclic change, the angles of attack will remain approximately equal. As a result of differing velocities and equal angles of attack, lift dissymmetry will occur. Due to the 90 degree phase lag, lift dissymmetry will not tip the rotor sideways, but will cause the rotor to flap to the rear slowing the helicopter down. As explained under the description of "flapping", the helicopter pilot will not allow the rotor to flap back, but will progressively move the cyclic further forward to eliminate this rearward tilting tendency. "Rotor Stability" is the term frequently used when referring to the rotor's opposition to remaining flapped in a pre-selected direction during transitional changes, see Figure 8-40.

(e) Cyclic Forward Again - As the pilot notices the rearward flapping tendency, he counteracts this by applying more forward cyclic. This maintains the same tilted relationship between the rotor disc and the horizon, see Figure 8-41. Aerodynamically he is equalizing lift; he is balancing the changes in velocities with proportionate changes of pitch angles. As long as the forward thrust of the rotor exceeds the total helicopter drag, the machine continues to accelerate or to undergoe transition. Throughout transition the pilot must progressively move the cyclic forward to maintain the same amount of tilt. When acceleration ceases, the cyclic requires no further movement.

39 In essence, cyclic control and transition work together. In any acceleration or deceleration, the cyclic must first be moved to unequalize lift and to flap the rotor; then secondly, the cyclic must be moved progressively in the original direction throughout the whole period of transition. Thus, it may be seen that the cyclic is used to re-equalize lift and to maintain equilibrium.

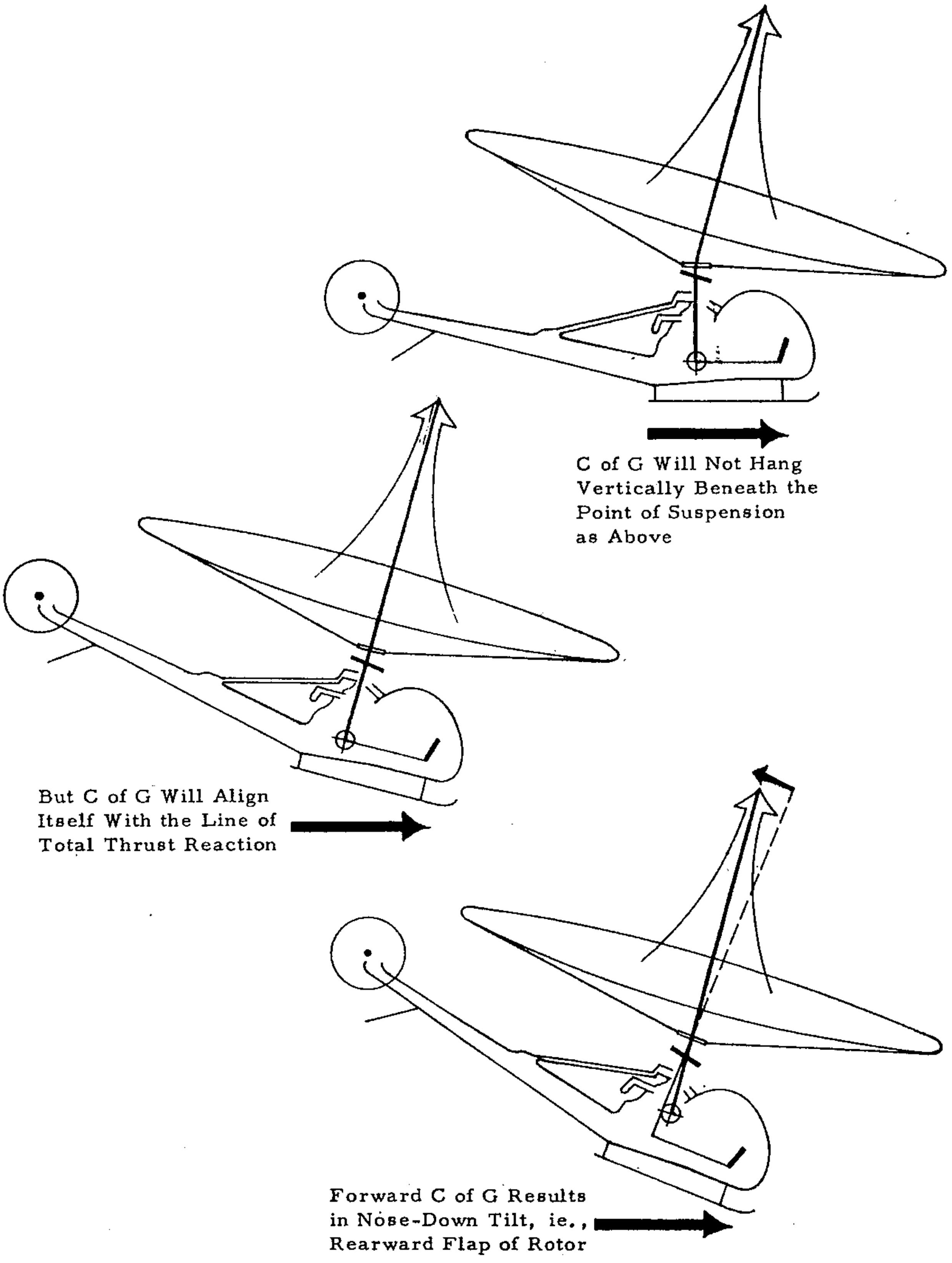


Cyclic Forward Again
R. Velocities: Unequal
∠s of Attack: Unequal
Lift : Equal

Lift Symmetrical Again - Rotor Retains Constant Inclination Throughout Acceleration, so Long as the Pilot Maintains Equal Lift by Progressive Advancement of the Cyclic Control

Acceleration Will Continue Until the Total Drag of the Helicopter Equals the Propulsive Component of Lift (Thrust)

Figure 8-41



C of G Will Not Hang Vertically Beneath the Point of Suspension as Above

But C of G Will Align Itself With the Line of Total Thrust Reaction

Forward C of G Results in Nose-Down Tilt, ie., Rearward Flap of Rotor

Figure 8-42

Relationship of Fuselage Attitude to Disc

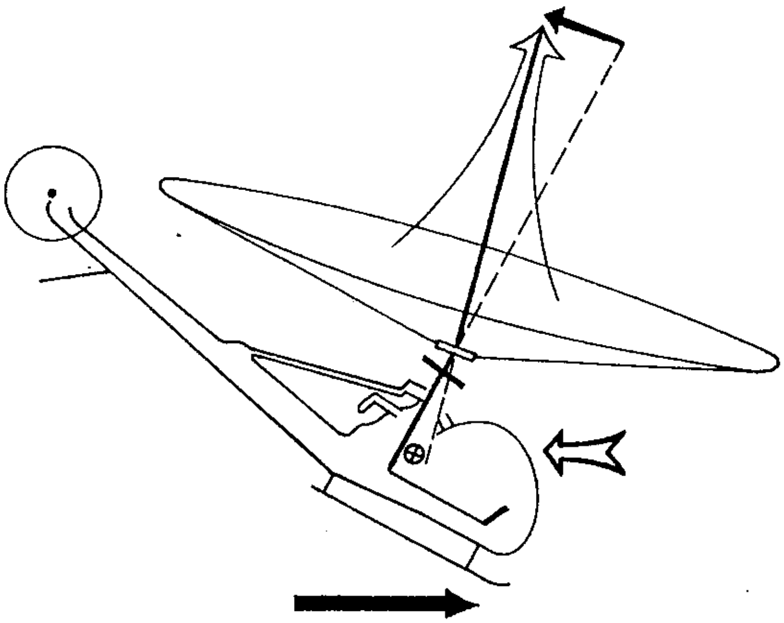
40 It will be noticed in the diagram showing the fourth stage of transition, that the nose of the helicopter has dropped and the fuselage is shown tipped parallel to the disc. This tendency for the fuselage to change attitude is produced as the helicopter C of G aligns itself with the line of total lift reaction. This action may be compared with straightening out of a kinked piece of rope when it is pulled from both ends. Once the fuselage has paralleled the disc, the drive axis and the axis of rotation are back in line and the rotor is no longer flapped in the strict terms of the definition. This may at first appear confusing because, in looser terms, the tilt relative to the horizon is often referred to as flap when quite possibly there is no flap present. This change of attitude of the fuselage does not change the effect of the pilot's controls relative to the rotor, and no adjustment on the part of the pilot is necessary. This tendency for the C of G to align itself with the axis of rotation also explains why a helicopter may still hang low on one side during the hover even though its design has eliminated the tail rotor couple already described in paragraph 16, see Figure 8-42.

Flapping Effect of Fuselage Drag

41 As the helicopter gathers speed, the parasite drag of the fuselage will cause the fuselage to swing further back than shown in the previous illustration. In some helicopters at high speeds, the rotor is, in fact, flapped to the rear.

Relation of Control Orbit

42 The tilt of the control orbit is directly related to the tilt of the cyclic control. While the pitch of the rotor blade is directly governed by the control orbit, the plane of the rotor disc does not necessarily follow the plane of the control orbit. The relationship under varied flight conditions of: the disc, the controls, the blade angles, and lift is clarified in Figures 8-43 and 8-44.



Fuselage Drag May Cause Excessive Tilt
In Conjunction With Forward C of G

Figure 8-43

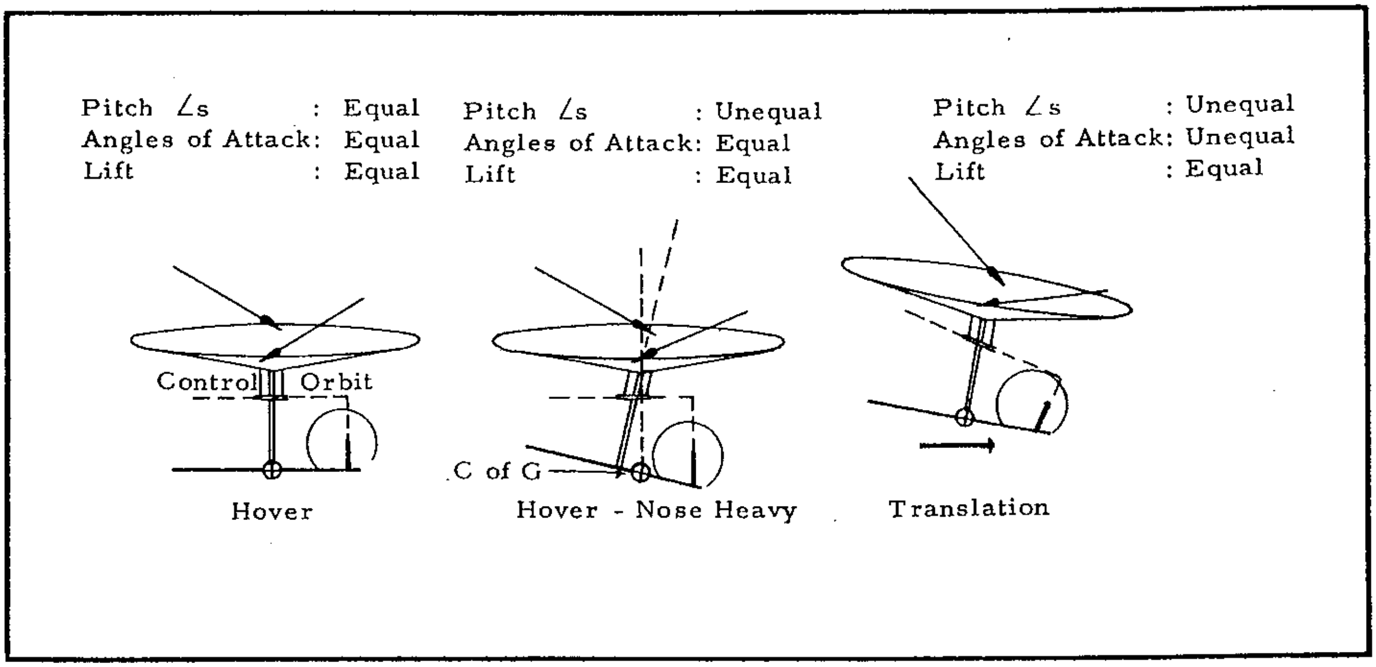


Figure 8-44

Lateral Control of Cyclic During Acceleration

43 It will be remembered that, during the hover, the cyclic must be displaced sideways to oppose the translational effect of the tail rotor. In the case of the anti-clockwise rotor, the cyclic would be held to the left. As the helicopter moves forward into translation, the tail rotor effect is reduced and the cyclic must be moved laterally towards the centre. However, as speed further increases, the lateral pressures on the cyclic control increase progressively, tending to return the stick to the left. The pilot must overcome this with right pressure, and in many cases may use control trim to assist, In other helicopters, the control jacks or the servo system may absorb this pressure for him. This opposing pressure of the cyclic is created by forces in the rotor attempting to tilt the control orbit to the left. Referring to the last diagram, showing the control orbit tilted forward relative to the disc during translation, it may be seen that considerable cyclic pitch changes are taking place with each rotation, forcing the blades to make rapid feathering movements. The inertia of the blades and control links resists these feathering movements, and pressures are fed back to the control orbit as it forces these changes. The pressures on the orbit act upwards on the advancing side and downwards on the retreating side. Hence, opposing cyclic pressure must be exerted to counter these pressures, see Figure 8-44.

44 In translational flight, the direction of the air inflow relative to the disc differs between the front of the disc and the rear of the disc; this is due to the air's prolonged exposure to deflection as it flows back above the disc. In addition, due to coning, the blades present a different aspect relative to the transverse flow of air when compared in their fully forward and fully aft positions. These combined effects produce a quite different relative airflow to the blades in these two positions, and the rear blade produces a little less lift than the leading blade. Due to the 90 degree phase lag, this will cause a downward flapping effect as the blade travels across the rear sweep reaching maximum effect in the lateral advancing position. This lateral flapping is minor compared with the fore and aft tilt, and the resulting line of tilt is displaced a few degrees from the fore-and-aft line, see Figure 8-45. To compensate for this effect, some helicopters offset the control linkage a few degrees less than the full 90 degrees that is required to accommodate phase lag, so that when the cyclic moves forward it will incorporate a slight lateral correction, see Figure 8-46.

LIMITATIONS TO FORWARD SPEED OF HELICOPTERS

45 The maximum speed of helicopters appears to be limited to somewhere between 150 to 200 knots regardless of how efficient

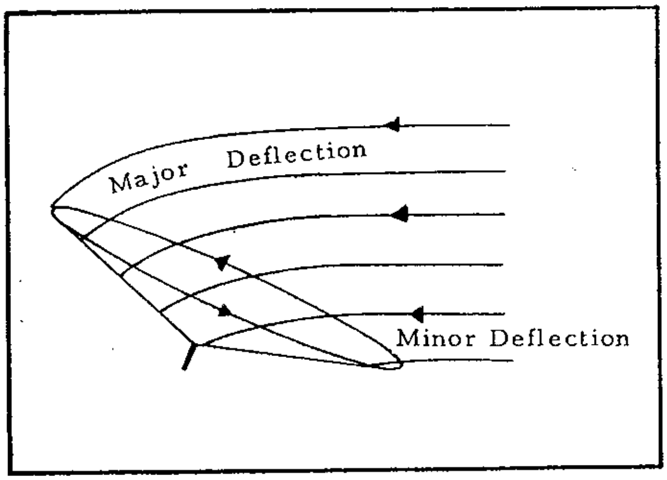


Figure 8-45

or powerful the machine may be. Addition of wings or provision of propulsion by separate means may move the aircraft at greater speeds, but, with the introduction of such modifications, the aircraft is no longer purely a helicopter in concept.

46 It may seem logical that the forward speed limit is reached when the cyclic is displaced fully ahead against the stop, but several aerodynamic effects may have already imposed their limitations before the cyclic has reached its limit. These limiting effects are:

(a) Reverse Flow.

(b) Retreating Blade Tip Stall.

(c) Advancing Blade Compressibility Stall.

Reverse Flow

47 As the rotor translates in a given direction, it is not hard to see that near the root of the retreating blade there is a region where the blade is "backing up" relative to the airflow. This will occur where the tangential velocity of the blade is outweighed by the flight velocity of the helicopter in the reverse direction. At section "C", the resultant airflow is neither forward nor backwards over the blade; in actual fact, the flow will be vertically downward onto the top of the blade due to the downwash velocity. At this point, the air moves downwards only as a product of the general displacement of the air throughout the whole disc. The blade directly beneath is ineffectual in drawing the air down and, to some degree, locally opposes the downward flow. The region where air is striking the blade on the top side producing a reverse effect to lift extends outwards from section "D" to section "B". At "B", the resultant airflow is flowing approximately along the chord of the blade, and outwards from here, the blade is producing beneficial lift, see Figure 8-47.

48 The reverse flow region not only deprives the retreating blade of a proportion of its lift but it also opposes lift. This negative effect varies relative to the negative angle of attack. Starting from zero degrees, the negative angle will impose a definite negative lift reaction. Negative lift increases further inboard until the negative angle exceeds a point where the negative stall occurs; negative stall is less effective than negative lift, is not so serious a probelm, and is further moderated by its position close inboard minimizing its moment. The extent of the retreating blade affected in this manner is comparatively small; however, the loss of positive lift and the creation of downward forces creates a rearward flapping tendency. This, in turn, necessitates additional forward movement of the cyclic. The reverse flow effect, in itself, does not impose a limit on the maximum speed of the helicopter. What it does do,

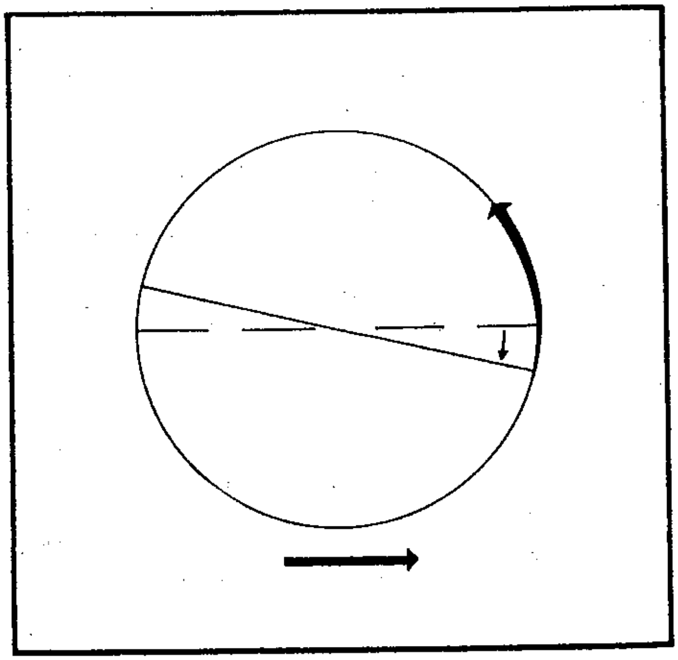


Figure 8-46

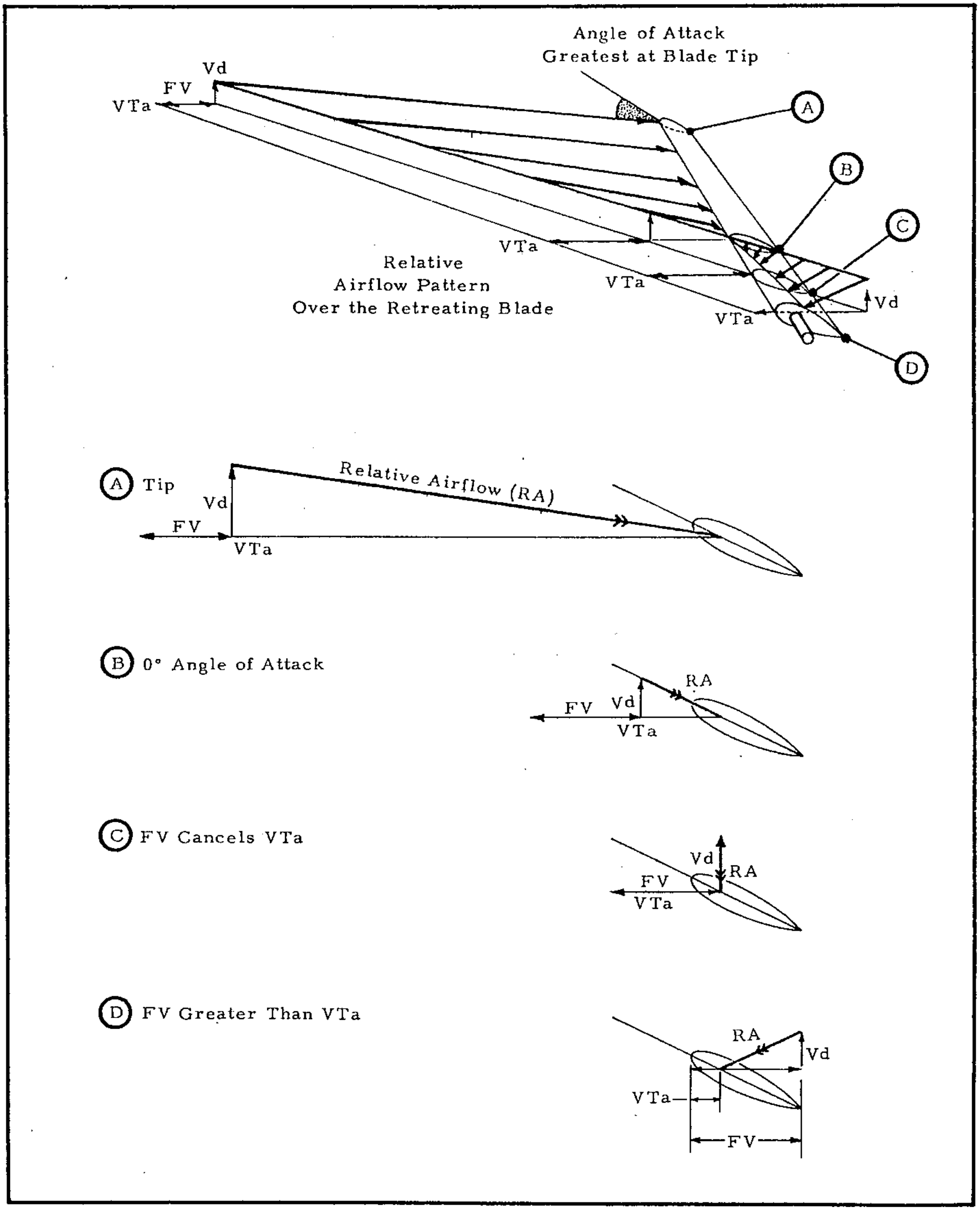

Angle of Attack
Greatest at Blade Tip
Vd
FV
VTa
A
B
C
D
VTa
VTa
VTa
Vd
Relative
Airflow Pattern
Over the Retreating Blade
A Tip
Relative Airflow (RA)
Vd
FV
VTa
B 0° Angle of Attack
RA
FV
Vd
VTa
C FV Cancels VTa
Vd
RA
FV
VTa
D FV Greater Than VTa
RA
Vd
VTa
FV

Figure 8-47

however, is to necessitate increasing pitch on the retreating blade. This lowers the ultimate speed at which the retreating blade will be pitched sufficiently to cause a stall at its tip, see Figure 8-48.

Retreating Blade Tip Stall

49 The speed at which the retreating blade tip will stall is dependent upon the total pitch of the blade. This pitch is the product of the collective setting as well as that of the cyclic. The collective setting will vary according to the load of the aircraft, the atmospheric density, and the rotor RPM. The cyclic setting will be dictated by the requirements of transition (paragraph 37) whereby the cyclic must overcome lift dissymmetry, and also, the cyclic must offset the reverse flow effect just mentioned. As speed is increased, these cyclic requirements are increased and the retreating blade pitch is built up until finally the stalling angle is exceeded. Since the relative airflow meets the retreating blade at the steepest angle at the tip, it follows that the outer segment of the blade will be the first part to stall due to excessive pitch. In practice, it has been found that the retreating blade tip stall takes place in the disc segment shown, and reaches maximum effect slightly aft of the lateral position. The 90 degree phase-lag will delay maximum flap to a point just beyond the full rear position. The pilot will feel this stall as a rearward tilt of the helicopter with a rolling tendency towards the advancing blade, see Figure 8-49.

Recovery from the Retreating Blade Tip Stall

50 While the practical aspects are dealt with later in the section covering the handling of the aircraft in the stall, some mention of recovery techniques is required at this stage. Primarily the pilot must avoid opposing this tilt with a counter movement of the cyclic. This can only increase the pitch angle of the retreating blade and accentuate the stall, whereas recovery can be achieved only by reducing the angle of attack. There are several possible ways of doing this.

(a) Reduction of collective lever settings will reduce the pitch angle throughout the whole disc. Lift can be maintained at this lower pitch angle by a subsequent increase in RPM. Since RPM can be increased only slightly in most helicopters, it may be necessary to reduce speed to maintain height.

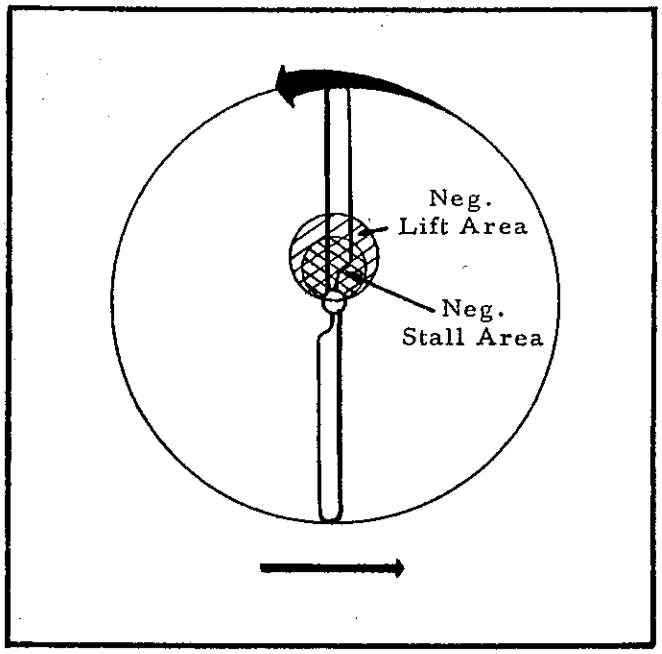


Figure 8-48

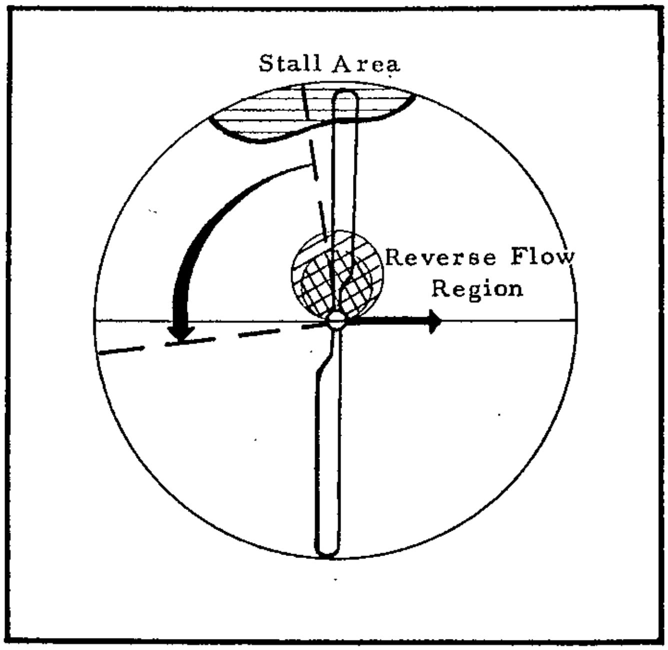


Figure 8-49

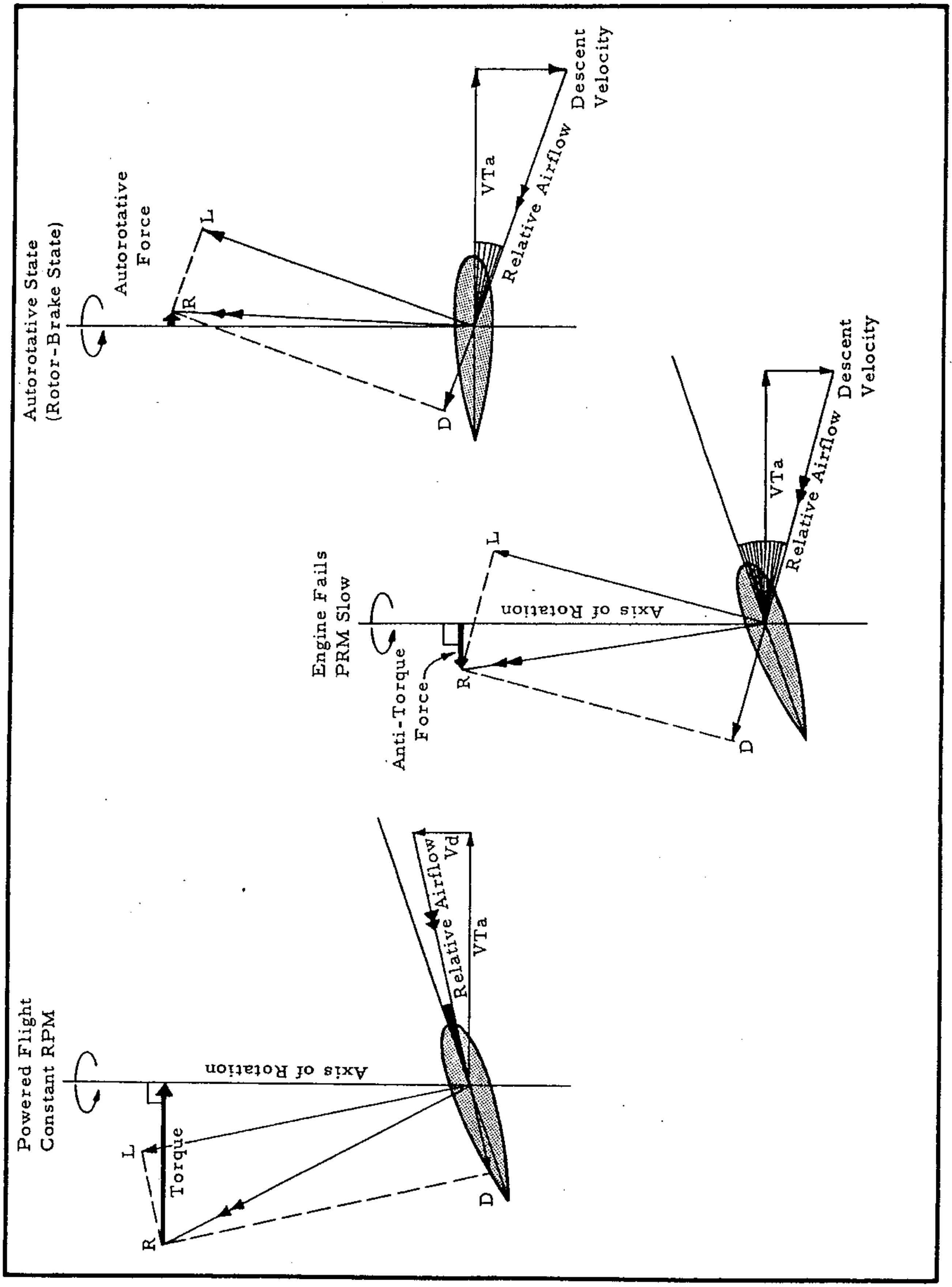

Powered Flight
Constant RPM
Axis of Rotation
L
Torque
R
D
Relative Airflow
Vd
VTa
Engine Fails
PRM Slow
Anti-Torque
Force
Axis of Rotation
L
R
D
VTa
Relative Airflow
Descent
Velocity
Autorotative State
(Rotor-Brake State)
Autorotative
Force
L
R
D
VTa
Relative Airflow
Descent
Velocity

Figure 8-50

(b) The helicopter's rearward tilt during the stall will effectively tip the retreating blade and reduce its angle of attack. Provided the cyclic is not pushed forward during the stall, the helicopter will frequently recover. The pilot may now move the cyclic as required to assume a suitable attitude or to cruise at a slightly lower speed.

(c) There is a fallacy that a simple increase of rpm alone will unstall the blade; the argument being that the forward speed has stolen the lift capability from the retreating blade and that, by increasing the blade's velocity, lift can be regained. The truth is that an increase of RPM alone at this stage will merely bring the relative airflow closer to the tangential path of the retreating blade, and actually increase the angle of attack. However, if collective pitch is decreased first to unstall it, as in (a) above, the blade will remain unstalled throughout a subsequent RPM increase. It is also true that a rotor designed to operate at higher RPM will not encounter the onset of the stall until a higher speed is reached. This is because, in the first place, the collective pitch angle required to maintain lift is less, and in the second place, lift dissymmetry is less and so requires less forward cyclic to offset it. This reduction of lift dissymmetry is a product of the reduced effect of flight velocity brought about when the tangential velocity is increased.

Advancing Blade Compressibility Stall

51 A rotor, designed to operate at increased rpm, could quite successfully delay the onset of the retreating blade stall until an appreciably higher airspeed is reached. Unfortunately, such a design would develop another limitation. The normal speed of a rotor tip while hovering is in the region of 350 to 400 knots. When a flight velocity of 150 knots is added to the tangential velocity of the advancing blade tip, it can be seen that the resultant velocity will approximate 550 knots. The critical mach number for a rotor blade is around 0.8; hence, at an airspeed of 150 knots, such a blade would encounter a compressibility stall at its tip. A further solution is to design a blade with a nearsonic cross section. This may provide slight speed advantages. However, this would be to the detriment of helicopter manoeuvres at the lower speed ranges where a helicopter is more useful.

52 It can be seen that a helicopter has very definite speed limitations, but, as mentioned earlier, the addition of stub wings, or a separate means of propulsion, will permit higher speed. The use of stub wings will permit a decrease of collective pitch as airspeed increases, allowing greater latitude for cyclic pitch before the retreating blade tip stalls out. Disconnecting the drive from the main rotor, and using a separate means of propulsion, ie, conversion to the autogyro principle in flight, will permit the rotor to flap rearwards rather than using cyclic to overcome lift dissymmetry. In this case only collective pitch is applied to the retreating blade, thereby reducing the problem of retreating blade tip stall.

THEORY OF AUTOROTATION

53 The most frequent question asked by laymen about helicopters is: "What happens when the engine stops?" The reply, in essence, is that the machine is put into autorotation and a glide landing may be carried out with a safe margin of control. To understand autorotation, let us study the relative airflow and the rotor's turning forces during three steps: first, in powered flight; secondly, just after engine failure; and thirdly, in full autorotation. For the purpose of this first study, it will be assumed that the helicopter is not translating, and that the segment of blade studied is selected as representative of a near average for those aerodynamic forces acting on all segments of the blade throughout its rotation. The effects upon the blade of flight velocity, will be discussed later.

(a) The Rotor in Powered Flight - In the hover, the relative airflow is determined by the resultant of the tangential and downwash velocities. Lift is at right angles to the relative airflow, and drag is in line. The resultant aerodynamic force (R) is depicted by completing the rectangle. The actual torque force required to rotate this segment of the rotor is the force required to overcome the counter rotative effect of the resultant aerodynamic force. This torque force can be represented by the line drawn from R and at right angles to the axis of rotation, see Figure 8-50.

(b) The Rotor After Engine Failure - After engine failure, the flow of air down through the rotor will cease. This will be replaced by an upflow through the disc as the machine starts to descend. The relative airflow produced

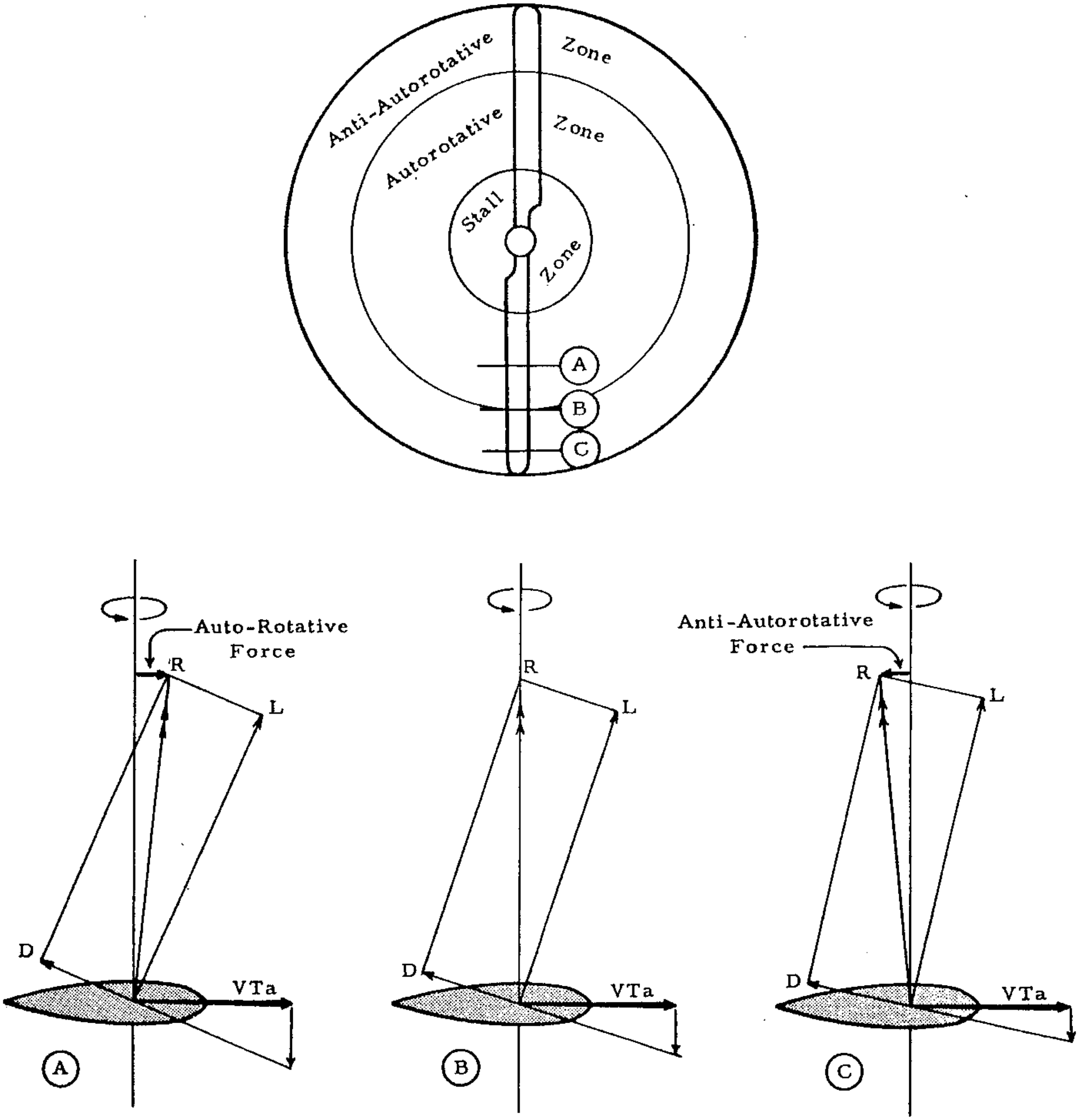

Anti-Autorotative
Zone
Autorotative
Zone
Stall
Zone
A
B
C
Auto-Rotative
Force
R
L
D
VTa
A
R
L
D
VTa
B
Anti-Autorotative
Force
R
L
D
VTa
C

Figure 8-51

by a combination of tangential velocity and the descent velocity will now meet the rotor blade at a greatly increased angle of attack. As a product of this, the resultant aerodynamic force will be inclined much further forward than previously, and, as shown in the diagram, will be just behind the axis of rotation. The line at right angles to the drive axis joining point R represents an anti-autorotative force which will rapidly slow the rotor down. If this condition is permitted to exist more than a second or two, the rapid loss of RPM will diminish the centrifugal force and will permit the rotor to cone excessively. Recovery may then become impossible. To overcome this slowing effect, the pilot may reduce drag by promptly lowering his collective lever to the limit of its travel.

(c) The Autorotative Force - By lowering collective, the pilot can reduce drag considerably. In achieving this drag reduction a proportion of lift is lost, the vertical speed of the helicopter will increase, and the angle of attack will also increase. The combined effect will be to tip the resultant further forward, and in this instance, the resultant is shown to lie ahead of the rotative axis producing the autorotative force. The amount by which the resultant lies ahead of the axis determines the autorotative capability of the blade segment. This autorotative is not distributed evenly throughout the rotor. In fact certain parts of the disc are incapable of producing an autorotative force. However, all helicopters are designed to produce sufficient autorotative forces to maintain adequate flying RPM in the rotor system.

Distribution of the Autorotative Force

54 Due to the effects of tangential velocity, only certain areas of the disc will produce the autorotative force; the remaining areas of the disc will tend to counter autorotation, see Figure 8-51.

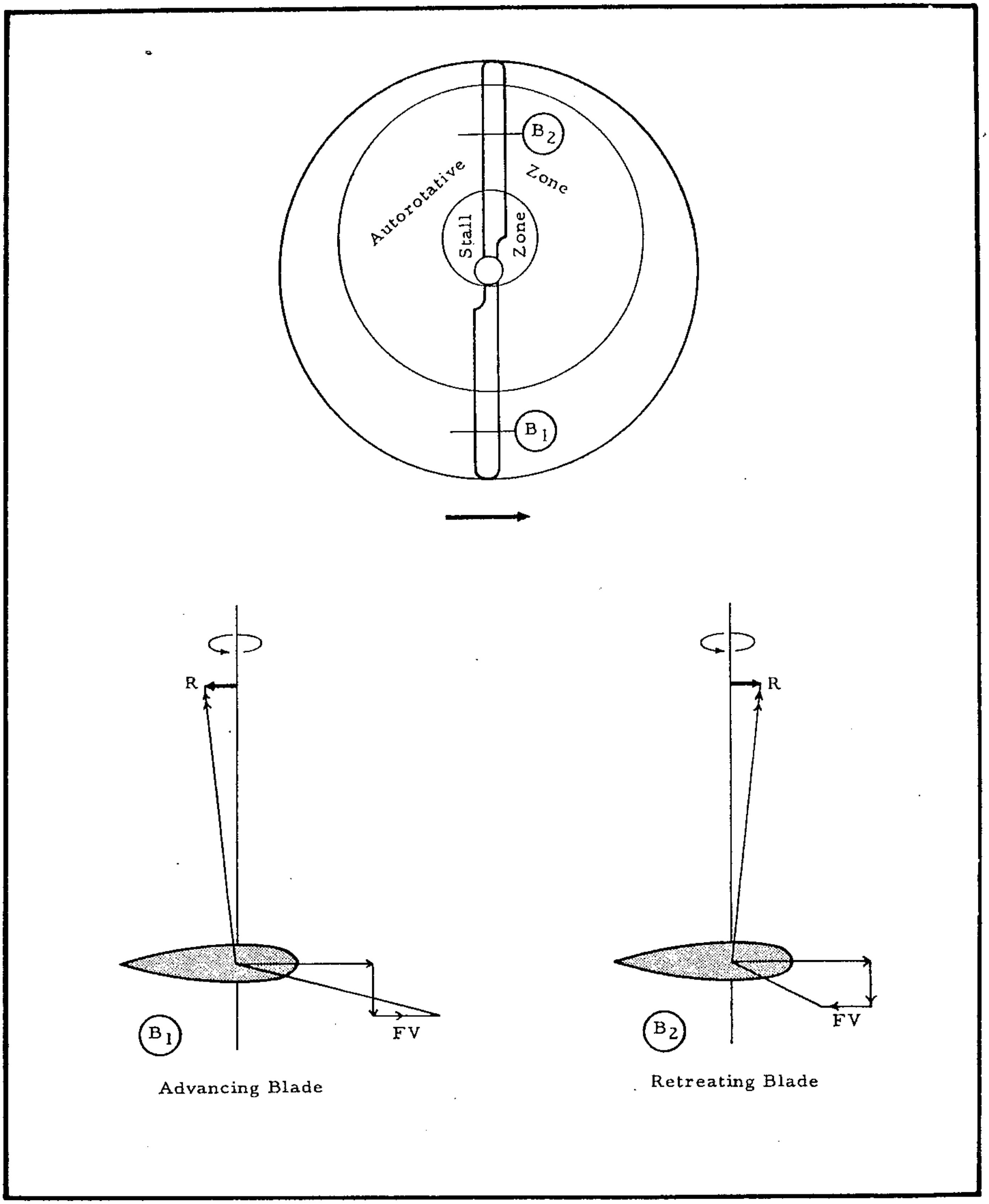
(a) A comparison of cross sections taken at (a), (b), and (c) above, shows that as the tangential velocity component lengthens the resultant aerodynamic force tips backwards behind the axis of rotation. Hence, the inner segment of the blade favours autorotation, and the outer segment counters autorotation. Close to centre, the angle of attack is steep enough to create a small stall region which, due to its location, has little effect.

(b) Introduction of a flight velocity in autorotation will have the result of tipping back the resultant at point B1 on the advancing blade, and of tipping the resultant forward at B2 on the retreating blade. Thus, with an increase of flight velocity, the autorotative zone moves across the disc towards the retreating blade. It should be remembered that these zones represent the distribution of turning forces and do not indicate lift distribution. Hence, a shift in the position of the autorotative zone will not create any flapping tendencies. In practice, it is found that best total lift in autorotation, and therefore, the minimum rate of sink, is produced when the helicopter is translating at its best endurance speed. The benefits of translational lift are still present in autorotation. The effects of varying airspeed during autorotation are discussed later in those sections dealing with the practical aspects of autorotation, see Figure 8-52.

Autorotative Performance

55 The "windmill brake" effect of a rotor in descent is comparable in its effectiveness to a parachute of similar dimensions to the rotor disc. The airflow pattern set up in descents is extremely complex and aerodynamicists find it exceedingly difficult to relate their equations to actual performance results throughout all ranges of rates of descent. However, the following explanation of the relationship of pitch settings and RPM control in governing the rate of descent is a sound explanation and does not involve complex theory.

56 The designer's problem is to produce a rotor which will windmill in autorotation and yet provide sufficient lift to reduce the rate of sink to practical proportions. It has been found that a rotor which can be set to give a small angle of negative pitch with the collective fully down will produce considerable torque, but only a small brake effect. To increase the latter and yet retain sufficient windmilling capability, the pitch angle may be increased from negative to zero, or even to a small positive setting, so long as the blade is efficient and its profile drag is minimized. The cross-section design of a rotor blade incorporates minimum drag qualities at autorotive settings. In many helicopters, with the collective fully lowered, there is a slight excess of autorotative torque tending to



Advancing Blade

Retreating Blade

Figure 8-52

overspeed the rotor. Once the pilot has initially recovered his RPM after engine failure, he will raise the collective lever sufficiently to prevent overspeed. The majority of helicopters autorotate safely throughout a limited range of RPM. This range permits some control over the rate of descent. Raising the collective to reduce the RPM to the safe maximum also minimizes the rate of descent. While such a change may be small, it may be significant when conditions demand an increased glide.

The Autorotative Flare

57 The rate of vertical descent in an established autorotation may be anywhere in the range from 1200 to 2400 ft per minute dependent upon many factors. These include the type of helicopter, the load carried, the atmospheric density, airspeed in autorotation, and the collective setting. Obviously, the high rate of sink must be eliminated before a successful landing can be achieved. In addition, in many helicopters, most of the forward speed must be arrested: rough terrain can make a running landing most precarious, and the high centre of gravity makes many helicopters extremely prone to tipping once rotor control is lost. On many light helicopters, descent can be arrested by a last-moment increase of collective pitch: sink will be eliminated, and the inertia of the rotor will maintain RPM to develop sufficient lift and control to enable the pilot to complete a safe landing. Forward speed may be reduced by tipping the helicopter backwards as the collective is raised. In other helicopters, a flare is frequently necessary to arrest, first of all the descent, and secondly, the forward movement. To achieve the flare, the pilot tilts the rotor progressively rearward by aft movement of the cyclic control. The flare permits the pilot to bring the helicopter to a near hover just above the ground and, from here on, there is sufficient rotor inertia to control the final landing with collective pitch. The technique employed will vary with the type of helicopter and with the circumstances. Frequently, a combination of these techniques provides the best results.

Flare Theory

58 The effect of flaring the helicopter is to increase momentarily the angle of attack throughout the whole rotor disc. This increases the total lift reaction, and, at the same time, shifts the inclination of the lift reaction from a position forward, to the vertical, and then to the rear. The increase of total lift arrests the sink; the rearward tilt of lift arrests forward movement. The increase of the angle of attack also increases the overall autorotative area in the disc this build-up of the autorotative forces gives a momentary and valuable surge to the rotor RPM. The increased rotor energy, thus created, serves to prolong the brief period during which the pilot must land the aircraft by use of collective pitch. The higher the airspeed, when entering the flare, the more effective a small movement of the cyclic will be in eliminating sink. It is, therefore, possible to prolong the flare, or even to zoom the helicopter up again if the entry speed is high. Hence, a flare can be made fairly flexible and adjusted to suit the circumstances, see Figure 8-53.

VORTEX RING

59 Wind tunnel tests show that under certain flight conditions, back eddies, or vortices, form around the periphery of the rotor. The vortex ring state is said to exist when these eddies are of sufficient magnitude to cause a considerable loss of lift, see Figure 8-54. Under this condition, the helicopter sinks rapidly, buffeting from side to side with poor control response. An increase of collective pitch, in an attempt to recover, only aggravates the situation. The sensation is quite similar to the stall in a fixed-wing aircraft. However, the cause and the recovery are quite different.

60 The exact conditions in which the vortex ring develops vary with the type of helicopter. But, generally speaking, the helicopter must be flown under at least partial power, at a flight speed usually less than 15 knots, and at a rate of descent usually in excess of 300 to 500 feet per minute. A possible alternative way to set up a similar condition is to carry out an excessively rapid turn under power. In this instance, the abrupt turn quickly reduces the helicopter's speed down to the critical range while the heavy load forces of the turn cause the helicopter to "mush" sufficiently to form a vortex ring.

61 To explain the formation of the vortex ring, it is easier first to study the airflow during a hover out of ground effect, or during flight at a very low airspeed. Under these conditions, the helicopter is maintaining height

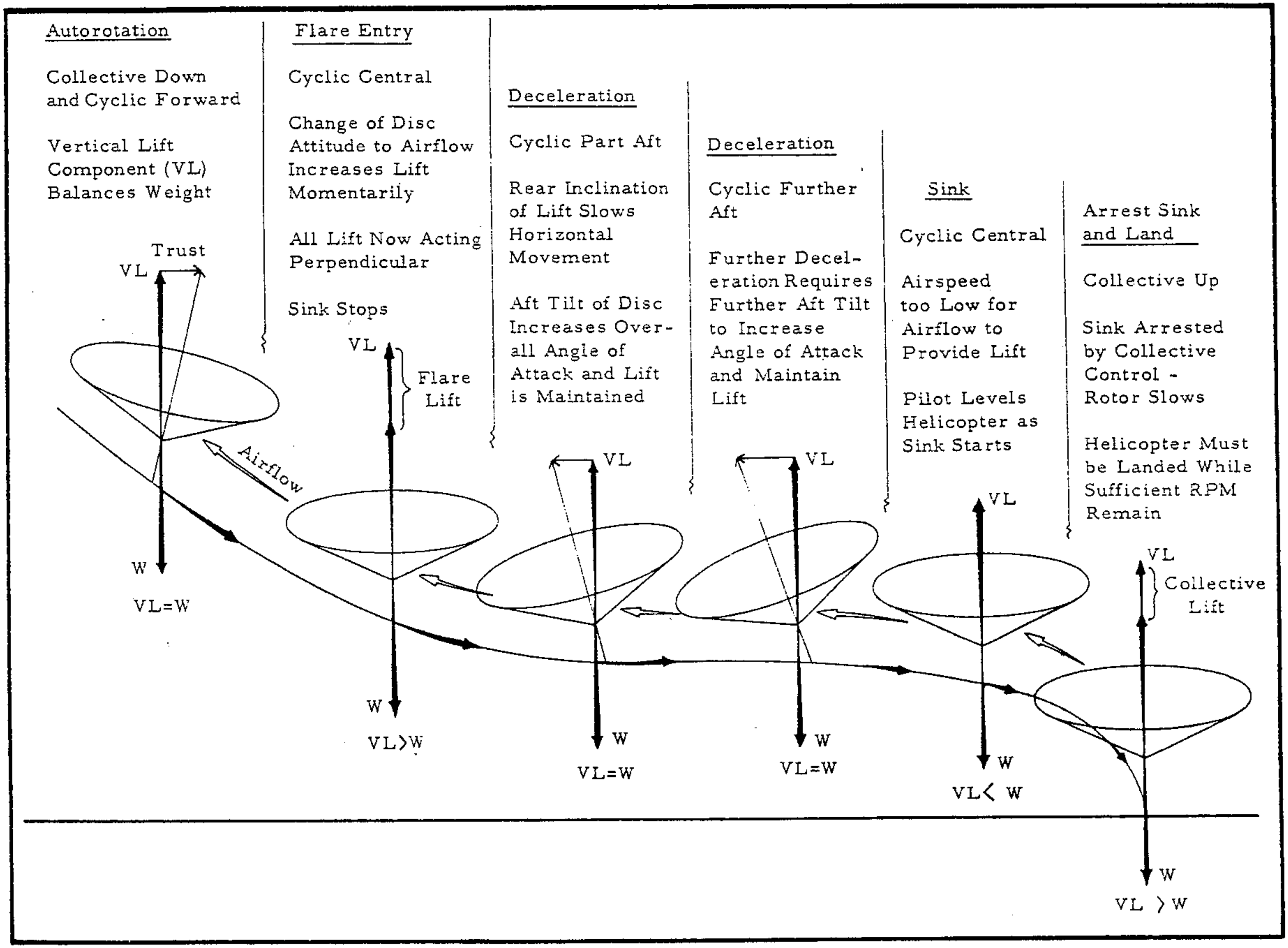

Autorotation
Collective Down and Cyclic Forward
Vertical Lift Component (VL) Balances Weight
Trust
VL
W
VL=W
Airflow
Flare Entry
Cyclic Central
Change of Disc Attitude to Airflow Increases Lift Momentarily
All Lift Now Acting Perpendicular
Sink Stops
VL
Flare Lift
W
VL>W
Deceleration
Cyclic Part Aft
Rear Inclination of Lift Slows Horizontal Movement
Aft Tilt of Disc Increases Over-all Angle of Attack and Lift is Maintained
VL
W
VL=W
Deceleration
Cyclic Further Aft
Further Deceleration Requires Further Aft Tilt to Increase Angle of Attack and Maintain Lift
VL
W
VL=W
Sink
Cyclic Central
Airspeed too Low for Airflow to Provide Lift
Pilot Levels Helicopter as Sink Starts
VL
W
VL< W
Arrest Sink and Land
Collective Up
Sink Arrested by Collective Control - Rotor Slows
Helicopter Must be Landed While Sufficient RPM Remain
VL
Collective Lift
W
VL > W

Figure 8-53

by climbing upwards through a column of air which is being displaced rapidly downwards through the disc. Due to this displacement, the pressure of the air below the disc is greater than that of the surrounding air whereas the pressure above the disc is less. While the general flow of air through the disc is fairly smooth, small eddies occur around the edge of the disc similar to the wing tip vortices which form around a fixed-wing aerofoil. These eddies are small enough to be of little account. However, if insufficient power is applied to hold the machine in the hover, the machine will sink downwards in its own descending air column. So long as this sink is gradual, the machine remains quite controllable and can be returned to the hover if sufficient power is applied. In such a sink, the air drawn down past the rotor builds up a greater pressure as it is forced down against the more stagnant air beneath. Beyond a certain rate of sink, this air under increased pressure spills out in gushes around varying segments of the disc. In addition, as the sink starts, the airflow pattern changes, and the relative upward flow of air outside the disc adds momentum to the air eddying around the edge of the disc. The greater the rate of sink, the greater these vortices become, and progressively more and more of the disc is affected. Since the outer portion of the disc provides most lift, excessive interference of the normal airflow in this critical region destroys much of the helicopter's lift capability. Hence, if the helicopter is permitted to sink beyond a certain rate, the vortices become large enough to cause a rapid increase in the rate of sink. An addition of power only serves to widen the pressure differential above and below the disc. This increases the vortices and aggravates the condition. Buffeting caused by air spilling from under the disc and the variations of blade drag caused by the vortices together create considerable yawing fluctuations which are difficult to counter with pedals. Cyclic control is also affected: cyclic pitch response is reduced by the vortices, and the effect of tilting the disc to gain thrust is diminished by the reduced lift components. Despite these difficulties, recovery is quite simple but involves a further loss of height. For all these reasons, it is essential that the combination of conditions inviting the vortex ring state must be avoided when close to the ground or close to obstacles. In the majority of helicopters, safe approaches can be carried out if the final descent, when the airspeed drops below 20 knots, is conducted at a rate of sink less than 500 feet per minute.

62 Recovery can usually be carried out promptly by a complete reduction of power or by easing into forward speed. Whichever method is used, some height is bound to be lost. By putting the machine into full autorotation, the normal autorotative airflow is set up; in these conditions, the vortices leave the disc and form above where they are harmless. The pilot may now ease the cyclic forward and pick up flying speed while he increases power to return to normal flight. Alternatively, autorotation may be avoided, and recovery may be completed with less height loss. In this case, the cyclic is eased forward and, after a further sink, the machine translates out of its own downwash. It is also possible to combine both techniques effectively by reducing power and easing forward on cyclic simultaneously.

Atmospheric Density

63 Since the vertical take-off and landing capability of a helicopter enables a helicopter to perform where no other aircraft can, many helicopter operations are conducted in mountains, or in humid forests. In such locations atmospheric density imposes severe limits on performance. These limitations may be overcome by skilled flying techniques which are discussed later. Because changes of atmospheric density critically influence the performance of helicopters, the pilot should be keenly aware of the three main factors influencing atmospheric density, namely: altitude, temperature, and humidity. Probably the most frequent cause of operational accidents among experienced helicopter pilots has been over-estimation of the machine's climbing capability through failure to recognize an atmospheric change, and through subsequent failure to allow for this in selection of a departure path over obstacles. In such cases, the pilot may well have attained the required performance in the same place on a previous occasion, but has failed to realize that an intervening increase in temperature or humidity has greatly reduced performance. Though the pilot may be highly skilled in handling his aircraft, the fact that significant atmospheric changes may occur without their becoming obvious to him necessitates a short discussion of the basic factors influencing atmospheric density.

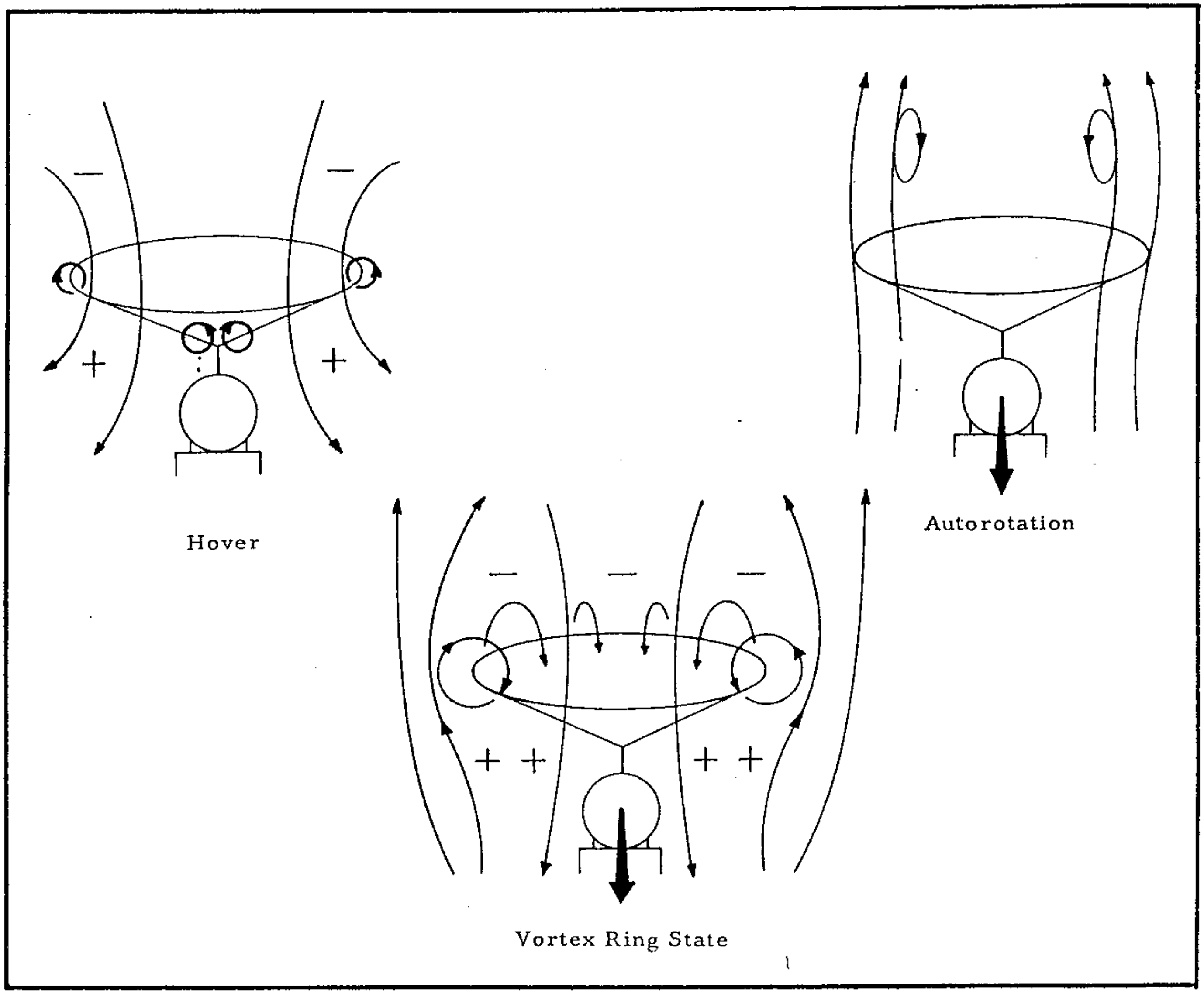


Figure 8-54

(a) Altitude - A few hundred feet increase in altitude can make all the difference in a helicopter's ability to hover out of ground effect. Under standard atmospheric conditions, an H-5 helicopter for instance with a full load can hover effectively at 2000 feet ASL; but at 3000 ft due to the decrease in atmospheric density, an H-5 cannot produce sufficient lift to hold height without first moving into translation. In ground effect, say within ten or fifteen feet of high ground, the same helicopter can hover at 5000 feet ASL or better, with a full load. Thus, at heights greater than 3000 feet ASL, such a helicopter must fly a path which would enable it to pick up sufficient translational lift to support it before losing buoyancy of the ground effect "air bubble". In any helicopter at critical heights, a hurried, steep departure over trees could be disastrous if the pilot lifted the machine above ground effect before transitional lift has been acquired.

(b) Temperature - While most pilots may not overlook those reductions in density related to altitude changes, practically all run into difficulty, sooner or later, through failure to realize the full significance of the decrease in density due to an increase in temperature. At a given altitude, any increase in temperature will have a marked effect upon take-off performance, and it follows that the higher temperature ranges are the most critical. A departure from a confined location which may have appeared comparatively easy at, say, 15.6° or 21.1°C (60 or 70°F), could be disastrous if not handled most delicately should the temperature rise to 26.7° or 32.2°C (80 or 90°F).

(c) Humidity - Probably, humidity is the most insidious element affecting density and performance. In conditions of high humidity, an aircraft gains less lift from the air because of the high proportions of water vapour present. Water vapour is quite invisible, and in a direct sense it cannot be felt, but it is considerably less dense than the air it displaces. Therefore, the ability of air to support an aircraft is governed by its humidity content. Prior knowledge of the RELATIVE humidity is important to the pilot but this measure alone does not denote the amount of water vapour the air contains compared with the amount it could contain before moisture becomes visible AT THAT GIVEN TEMPERATURE. In assessing humidity, then, temperature is a vital factor: at low temperatures air can contain only a little water vapour, at high temperatures it can contain considerable amounts. Thus, a high relative humidity at a low temperature may have no effect on performance, but, at a higher temperature, a medium reading for relative humidity may be most significant. In summary, if the temperature is low, though it may be snowing or raining, humidity is relatively unimportant; on a hot day, though there may not be a cloud in the sky, humidity may be critical.

64 This concludes the discussion of basic helicopter theory. The material covered so far has been predominantly theoretical. Ensuing topics will be primarily of a practical nature, and will outline general handling techniques with their explanations founded upon the theory that has already been covered.

SECTION 2

BASIC HELICOPTER FLYING PRACTICE

THE PRACTICAL ASPECTS OF HELICOPTER FLYING

Introduction

1 Helicopter flight may be compared in many ways with fixed-wing flight, yet the differences are such that even the most experienced and versatile of fixed-wing pilots will find that conversion to contemporary types of helicopters is both challenging and fascinating. In normal forward flight a helicopter handles in much the same manner as a fixed-wing aircraft; the controls perform a very similar function. It is in slow flight, hovering, and other manoeuvres close to the ground that the helicopter assumes its own individuality both in performance and in the handling techniques required. In this environment, the pilot's thinking and reactions must be as different in concept as is the machine he is flying. Since the helicopter performs most of its tasks close to ground environment, and since it is in this environment that the fixed-wing pilot has most to learn, the main focus of this manual will bear on manoeuvres close to, or in contact with the ground.

2 To avoid confusion, all discussions unless otherwise specified, will deal with light and medium helicopters employing a single main rotor rotating anti-clockwise, and with an anti-torque tail rotor. This discussion also assumes that the reader is acquainted with the relevant theory in Section 1, because, in many instances, direct references are made to particular paragraphs and diagrams in the earlier section.

CONTROL MANIPULATION

3 The actual purpose and the manipulation of the main helicopter controls is explained in some detail in Section 1 commencing paragraph 5. The basic uses of the cyclic and rudder controls is covered adequately but further explanation of collective control manipulation is required.

The Collective Lever

4 Fundamentally the purpose of the collective lever, with its twist grip, is to control power and RPM, and these, in turn control height. Manipulation of collective, alone, has the following effects:

(a) Raising - increased pitch, increased boost, and decreased RPM.

(b) Lowering - decreased pitch, decreased boost, and increased RPM.

5 Operation of the twist grip, alone, results in the following:

(a) Opening - increased boost, increased RPM, no change in pitch.

(b) Closing - decreased boost, decreased RPM, no change in pitch.

6 In practice these controls are co-ordinated to produce changes in collective pitch along with proportionate increases or decreases in boost sufficient to ensure near constant RPM. The safe range of operating RPM in flight is quite small on most helicopters. The upper limit is governed by the maximum engine speed and the centrifugal stress limits of the rotor head. The lower limit is governed by the coning angle of the blades. This angle increases as the RPM decreases and as the centrifugal force is reduced. The effect of such an increase in the coning angle is to reduce the total lift reaction of the disc. This may be explained either as the product of a reduction of the disc area (Section 1, Figure 8-6), or as the product of the increased tilt inwards of the lift component (Section 1, Figure 8-2). The loss of lift requires increased pitch to compensate, which, in turn, produces increased blade drag. A point may easily be reached where engine power, at this low RPM, cannot provide the force to recover, nor even to maintain RPM. This state, which is known as OVERPITCHING, is characterized by the helicopter sinking despite raising the collective. Also, the increased torque forces may make it impossible to counter yaw with the tail rotor and the machine may turn against the "rudder". In addition, the cyclic control becomes less effective. Obviously, such a condition must be avoided. By keeping RPM

on the high side, during close to ground manoeuvres, the pilot may maintain a good margin of insurance. It is easier to reduce RPM than to regain them.

7 To avoid the risk of excessive RPM losses, collective manipulation should always be co-ordinated to favour a slight excess of engine power in proportion to the pitch setting during any period of adjustment. Hence, when increasing pitch, lead by twisting the throttle further open before raising the lever; when decreasing pitch, lower the lever before reducing the throttle twist grip setting.

8 When it is desired to change the RPM, and to maintain constant boost, the throttle should be moved first. However this will cause a change of manifold pressure and will then require an adjustment of the collective lever. To increase rpm, increase the twist grip setting, then lower the lever; to decrease RPM decrease the twist grip setting, then raise the lever cautiously.

9 Remember that any collective or throttle adjustment will change the torque effect of the main rotor and will call for simultaneous adjustment of the anti-torque rotor to prevent fuselage yaw.

Effect of Other Lift Forces Upon Collective Control

10 While the collective lever and twist grip provides the means of controlling height, its effect is considerably modified by several extraneous forces. These influencing factors include primarily: translational lift, ground cushion effect, rotor tilt, atmospheric density, and loss of lift through power drainage by the tail rotor.

(a) Translational Lift - When a helicopter moves in any direction away from a true hover (in still wind), translational lift begins to relieve the load on the rotor. An increase in air speed provides a proportional increase in translational lift. This is explained fully in Section 1 paragraphs 32 and 33. Hence, as the helicopter moves from the hover, the collective lever must be lowered progressively if level flight is desired. Simultaneously the throttle twist-grip setting would normally be reduced to prevent a build-up in RPM. This reduction of collective pitch and power settings continues as the helicopter accelerates, until drag forces overcome translational benefits in the vicinity of 50 knots. Any further increase in speed will, therefore, require an increase of collective settings to overcome the build-up of drag. Conversely, a deceleration requires a reduction of collective settings until the speed drops appreciably below 50 knots, whereafter, collective settings must be progressively increased as the helicopter returns to the hover.

(b) Ground Cushion Effect - In the hover, and at slow speeds very close to the ground, considerable lift benefit is gained from the ground cushion effect. This is produced as the air, being displaced downwards through the disc, is slowed in its deflection by a build-up in air pressure immediately beneath the helicopter where the normal flow is impeded by the ground. Ground effect is most noticeable from zero to 10 feet and decreases rapidly thereafter to a distance approximately 2/3 of the rotor diameter above the ground while in the hover. In practice, and dependent upon the type of helicopter, the best height to hover may vary from 2 to 10 feet above the ground, since, at lower levels the high compression of "air cushion" makes hovering difficult. At such lower positions the supporting cushion becomes too compact and shifty. The effect of the "air cushion" upon the collective control is such, that, as the helicopter moves slowly upwards from the ground, more and more power is required to maintain the same rate of climb until out of ground effect. Conversely, as the helicopter sinks closer to the ground less power is required. Usually a helicopter arrives or departs from a ground hover along a sloping path so that, during an arrival, the helicopter will have the benefits of some translational lift while the ground cushion effect is building up. During departure the helicopter will move forward in ground effect until translational lift is gained. Such techniques avoid excessive demands from the engine and will permit safer handling of heavy loads. When hovering in a medium or strong wind, the ground cushion is barely effective. The downflow is deflected to the rear and dissipates without much noticeable build-up. However, the translational effects provided by the wind will more than offset any resulting loss of lift. Hence, a hover in a stiff wind requires less collective and throttle setting than in a still air condition.

(c) Rotor Tilt - This effect is noticeable only during a rapid departure from a hover. In such a departure, the rotor is tilted rapidly forward by means of the cyclic control to provide rapid acceleration. The tilt of the disc deflects the downwash to the rear and tends to blow the supporting air cushion backwards behind the machine. Simultaneously a further loss of lift is encountered as the total lift reaction of the rotor is now tilted forwards to provide thrust. This tilting of the lift forces lessens the vertical lift component. The loss of the cushion effect and the inclination of lift together require a rapid increase in collective and throttle settings, otherwise the helicopter will sink nose forward into the ground. However, once power is increased, the helicopter will pick up translational lift very rapidly and power will then have to be reduced.

(d) Atmospheric Density - The full effects of atmospheric density are explained in Section 1, paragraph 63 dealing with altitude, temperature and humidity. The prime effect upon collective control is that, as air becomes less dense, the collective must be raised higher to give sufficient pitch to compensate for the reduced lift. The increased pitch in turn creates increased drag, demanding a greater output from the engine. Hence, the throttle setting must be increased with the collective setting.

(e) Tail Rotor Effect - Whenever the power output of the engine is great, and when the air speed is too low to provide adequate weathercock forces, considerable anti-torque forces must be provided by the tail rotor to prevent yaw. The tail rotor is driven by engine power, and is therefore a drain upon the engine output to the main rotor. In hover conditions, then, the tail rotor itself is actually depriving the main rotor of a quite noticeable proportion of lift capability. Hence a greater throttle setting is required to provide sufficient power from the engine to supply both the main rotor and tail rotor.

Conclusion

11 Probably the simplest way in which to regard collective control co-ordination, is to think of the lever as the means of governing pitch and power, and of the twist grip as the means of controlling RPM. Before raising the lever, lead with an increase of RPM unless the latter are already on the high side. Because of the many side-effects which may produce or detract from lift, the collective controls become the means whereby the total lift is regulated. The control provides the difference between the extraneous lift forces affecting the machine and the desired total amount of lift required by the pilot for any given condition of flight.

INTRODUCTION TO NORMAL FLIGHT

Effects of Controls in Normal Flight

12 Probably the best way to introduce a student to the helicopter controls is in normal cruising flight. Under these conditions there are many similarities with the control of fixed-wing aircraft.

(a) Cyclic Control - The cyclic control governs attitude. Fore-and-aft movements regulate the nose position, lateral movements control the lateral level. In actual fact the cyclic directly governs the disc attitude, but this is normally followed by a corresponding change in attitude for the fuselage. In some machines there is a pronounced lag between cyclic movement and fuselage response, and many pilots, at first, have considerable difficulty through over-controlling, or chasing the attitude with the cyclic stick.

(b) Collective Control - The collective lever, combined with the twist grip, regulates height, or climb and descent. This may be compared with the fixed-wing throttle in the sense that an increase initiates a climb and a decrease initiates a descent.

(c) Pedal or "Rudder" - Pedal control prevents slip or skid in the same sense as does the rudder in a fixed-wing aircraft. In addition pedal is also used to counter the torque produced whenever the power settings are changed. Many light helicopters lack "foot feel" in the pedals, and are similar to a link trainer in that there is no natural control position to which the pedals will return of their own accord if foot pressure is released. Changes in airspeed alone, without changing power, also require a change of pedal setting; at high speeds, for a given power setting, weathercock forces in the fuselage will counter much of the torque effect of the rotor system and less tail rotor effect is required than when flying at a lower speed. Conversely, if speed is reduced the left pedal must be advanced, if power is increased at the same time, eg, when approaching a hover, even more left pedal must be applied.

Turns

13 Turns are very simple; by applying bank with lateral cyclic, by preventing slip and skid with rudder, and by applying gentle back pressure on the cyclic to ease the nose round the horizon, a turn may be easily accomplished. Steep turns are also simple, however speed will rapidly decrease and recovery must be made early to avoid coming to a premature stop. This loss of speed is due to the flaring effect produced by pulling back on the cyclic control.

(a) Most helicopters require no rudder movement when a turn is initiated. A pilot previously trained on fixed-wing aircraft may encounter difficulty in avoiding improper application of pedal when entering a turn. However a power change initiated in a turn always calls for simultaneous adjustment of pedals. A particular instance where a fixed wing pilot may encounter trouble is in the initiation of a descent in a left turn. In this case RIGHT pedal must be applied as the collective lever is depressed or a flat skidding turn will ensue. Fundamentally, the tail rotor is an anti-torque device, and must be used as such. Secondarily, it is used to overcome the incidental slips and skids caused by turbulence or the inaccuracies of turns.

Climbs and Descents

14 Here again, there is great similarity to the fixed-wing aircraft, though the principle of controlling airspeed with nose attitude is far more conspicuous. In fact, cruise, or climb, or descent at, say, 50 knots requires virtually constant attitude throughout. A fixed-wing pilot may feel most uncomfortable, at first, climbing with the aircraft nose down. If he does attempt to climb nose upwards, he will zoom a little at first and then start to sink. This follows as the airspeed falls to zero, and as the helicopter loses translational lift.

15 To clarify the co-ordination of controls in a typical entry to a climb or a descent, consider an entry to a climb from level flight while maintaining the same airspeed. To initiate the climb, the pilot must raise the collective lever to register the required climbing boost, leading this movement with an advance of throttle through the twist grip to ensure maintenance of RPM. Simultaneously left pedal must be increased to counter the increased torque produced by the power change. On some machines it is also necessary to prevent a rolling tendency to the right by increasing left pressure on the cyclic stick. The nose must be kept in the same attitude throughout if it is desired to hold the speed constant.

APPROACH INTO WIND

Constant Speed Approach and Overshoot

16 Before attempting to make a full descent involving a deceleration to the hover, the basic principles of a constant speed approach into wind should be understood. The method of regulating the initial stages of a normal approach is identical.

17 Once again, fixed-wing principles may be applied, selecting the desired airspeed by governing nose attitude with fore-and-aft cyclic, and regulating the rate of sink with collective and throttle. The airspeed is very sensitive to slight attitude changes, therefore, very close observation must be maintained to judge the nose attitude, and cyclic movements should be very gentle. Light helicopters have less inertia than heavier ones, and, therefore, will accelerate or decelerate quite rapidly in response to attitude changes, Any changes in power setting when entering the approach, or when adjusting rate of sink, must be accompanied by pedal adjustments to correct for torque changes. An overshoot may be carried out quite easily by simply increasing power to initiate the climb. At this stage, the nose should be held constant to maintain the same airspeed in the climb. Rudder and cyclic adjustments must again be made to prevent yaw and roll.

Approach Into Wind to the Hover

18 The helicopter is extremely versatile. Successful approaches can be made from an immense number of angles of descent and direction, provided the pilot fully understands the elements involved. The most efficient and simplest approach, however, is carried out straight into wind from four or five hundred feet above ground. The descent angle should be similar to that of a fixed-wing approach,

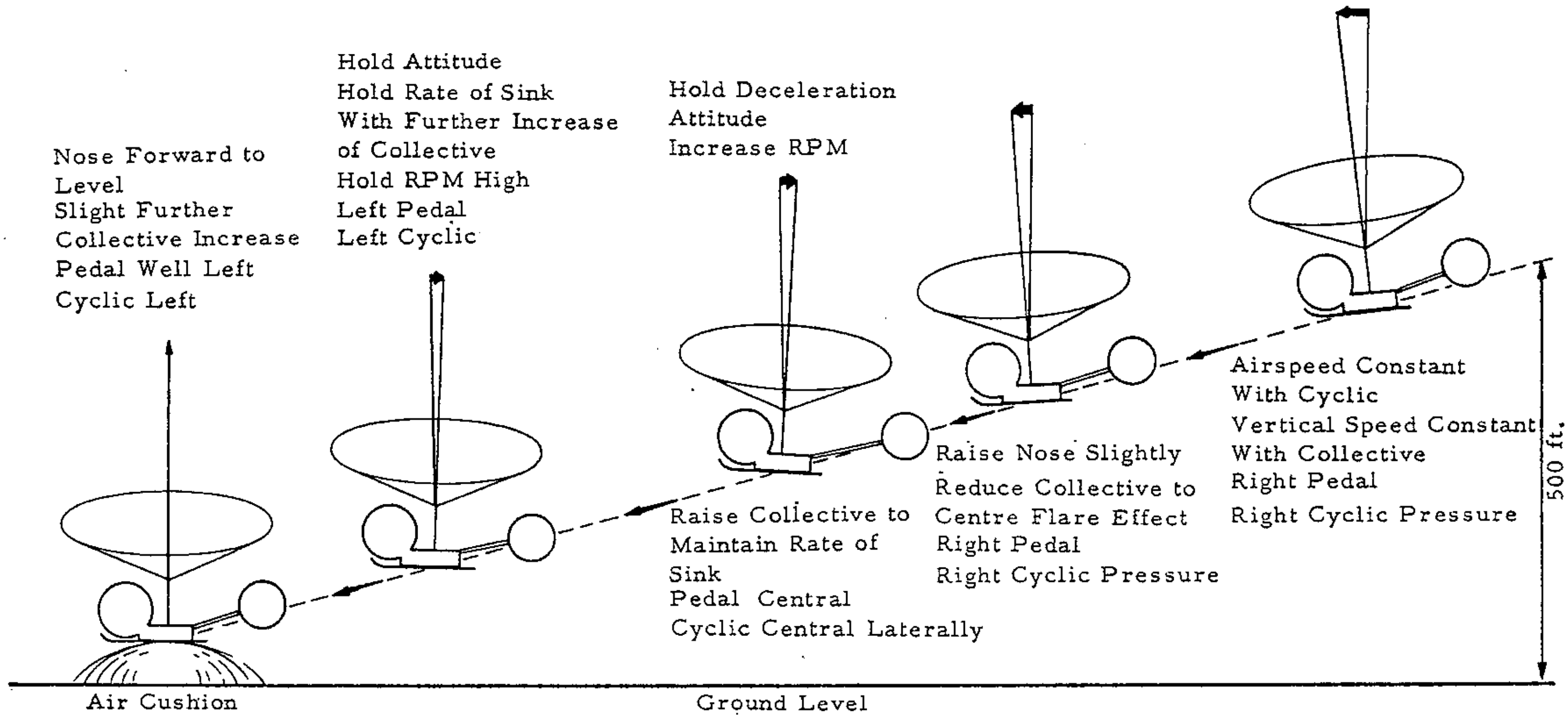

Nose Forward to
Level
Slight Further
Collective Increase
Pedal Well Left
Cyclic Left
Hold Attitude
Hold Rate of Sink
With Further Increase
of Collective
Hold RPM High
Left Pedal
Left Cyclic
Hold Deceleration
Attitude
Increase RPM
Raise Collective to
Maintain Rate of
Sink
Pedal Central
Cyclic Central Laterally
Raise Nose Slightly
Reduce Collective to
Centre Flare Effect
Right Pedal
Right Cyclic Pressure
Airspeed Constant
With Cyclic
Vertical Speed Constant
With Collective
Right Pedal
Right Cyclic Pressure
500 ft.
Air Cushion
Ground Level

Figure 8-55

though this may vary somewhat. Because a light helicopter possesses less inertia than a heavier machine, it does not require such great power changes at the end of the descent. It may, therefore, safely approach from a steeper angle.

19 Starting the descent a suitable distance downwind, the pilot will commence the approach, selecting a low cruising speed if the wind is light, and a somewhat higher speed if the wind is strong. For the first part of the descent airspeed should remain fairly constant, and should be regulated by very gentle adjustments of attitude. The collective and throttle should be regulated to maintain constant RPM whenever height adjustments are made to remain on a constant descent path. Again adjustments should normally be very gentle. Pedal adjustments should be made to prevent both slip-and-skid, and yaw, during power changes.

Airspeed Adjustments

20 Unless special requirements dictate otherwise, the final part of a descent should never be rushed, see Figure 8-55. The ensuing excessive attitude and power changes, with their many accompanying difficulties, should be avoided. For these reasons, an early and gentle adjustment of attitude is required to commence deceleration. It should also be understood that, at speeds higher than the maximum endurance speed of the helicopter, a given attitude will provide a given airspeed. However, once the nose attitude rises slightly above the maximum endurance position, any further adjustment governs the rate of deceleration. This means that, if the nose is raised noticeably above the attitude held early in the approach, the machine will decelerate rapidly. Due to the premature loss of translational lift, the machine will increase its rate of sink, arriving close to the ground prematurely. But, if the nose attitude is adjusted very finely, a given rate of deceleration can be established; the pilot then merely uses his fore-and-aft adjustments to either increase or decrease his rate of DECELERATION. Such adjustments must be extremely fine. While there are several other aspects to be watched carefully on an approach, it is essential first to understand this principle: fine cyclic adjustments must be used throughout the descent, and, once the airspeed drops below that of best endurance, further adjustments regulate the rate of deceleration.

21 The beginner has great difficulty in judging the rate of deceleration required to bring him to a standstill exactly over the position chosen. Probably the best way to overcome this problem is to develop a sensitivity towards "apparent movement". This concept is based on the principle that, for a given groundspeed, the closer to the ground, the greater is the sense of apparent movement. If the helicopter pilot takes note of the gradual apparent movement at about three or four hundred feet above ground, he will note that objects are drifting quite slowly by. If he then, merely adjusts his attitude to retain this apparent rearward drift, he will slow down at the ideal rate and arrive close to the ground with only a slight residual movement. Hence, if, as he gets nearer to the ground, things appear to be speeding up, he must then increase his rate of deceleration by raising the nose very slightly with increased back pressure. Conversely, if things appear to be slowing down, he must gently relax the backwards pressure. This is akin to tightening or slackening the reins when riding a horse.

Height Adjustments

22 While airspeed must be carefully adjusted by the cyclic control to arrive over the right position in the hover, collective and throttle adjustments are required to follow the right approach path down a constant line of descent, so that, when the aircraft arrives above the spot, the desired hovering height is reached. Early in the approach, while the airspeed is constant, the only interference to the maintenance of an accurate approach angle originates from either over-controlling or from air turbulence. However, once deceleration is commenced, the progressive loss of translational lift requires increased collective lift and proportionate power to ensure maintenance of RPM. A study of the "total power required" curve in Figure 8-35 shows that the loss of translational lift with deceleration is not constant. Below maximum endurance speed, the requirement for additional collective lift increases slowly at first, and builds up rapidly as the speed drops below approximately 25 knots. On a gradual approach the required adjustments are quite gentle and are easily governed, but on a rapid final descent, the build-up of power is much more rapid and much harder to co-ordinate. In addition, a rapid descent requires extra lift and power to overcome the downward inertia. These factors

involve unnecessary strain on the part of both the pilot and the machine. A gentle, shallow approach also permits the gradual build-up of a supporting air cushion which provides partial lift compensation as the last remnants of translational lift disappear. In the final part of the approach, a beginner will frequently raise the nose a little too high. This may be because of an instinctive desire to round-out, as in a fixed-wing aircraft or an instinctive desire to restrain any premature sink by raising the nose. He must remember that pulling back excessively on the nose will cause rapid loss of translational lift, and will be followed by a rapid sink, often with the tail dangerously close to the ground. The recovery opposes instinct, and requires that the nose be eased forward to avoid too rapid a loss of translation. At the same time, collective settings must be rapidly increased. Such a circumstance is difficult to handle, and is confusing. Therefore, the pilot should resolve early not to allow his feelings to force him to raise the nose in this final part of the approach.

23 As the helicopter arrives at a standstill, the rotor disc is actually tipped slightly to the rear. During the approach, this aft tilt has provided the deceleration force, and must be eliminated at the exact instant the helicopter arrives in the hover. This requires that the nose be eased slightly forward into the normal hovering attitude, placing the disc level with the horizon, or slightly forward if there is a noticeable wind. Failure to make this adjustment will cause the helicopter to move to the rear.

24 To maintain a constant descent path during deceleration the pilot will at first depress collective slightly to overcome a slight flaring tendency as the nose is raised. In addition, the deceleration down to maximum endurance speed requires a slight depression of collective. Then, as the speed continues to fall, a gradual increase of collective is needed. The lower the speed, the more rapidly must the collective settings be increased, but, before any increase of collective is made, ensure that the RPM are increased in advance. This increase of RPM is good insurance to provide extra engine power potential and to minimize the risks of over-pitching when close to the ground.

25 Throughout the deceleration, the rotor faces the airflow in a slightly flared attitude. Since flares produce extra lift, and the collective has remained slightly lower than it would otherwise have been. At the end of the approach, the rotor is returned forward to the hovering attitude and the flare is lost. Subsequent loss of lift will cause the helicopter to sink, but, if it is necessary to hover, the collective and power settings must be increased slightly to hold height.

Directional Control

26 Directional control on the approach is provided by a combination of pedal and lateral cyclic adjustments.

(a) Pedals - At the commencement of the approach descent the pilot will depress the collective lever. This reduction in power calls for some application of right pedal to prevent yaw as torque is reduced. Any subsequent height corrections or airspeed changes will call for pedal adjustment. The increase in collective settings, as the helicopter loses translation, requires the removal of right pedal pressure, and the progressive increase of left pedal pressure. The decrease in airspeed also entails a progressive loss of fuselage weathercock forces, allowing the torque forces present to yaw the fuselage more readily to the right. This calls for additional left pedal movement. Hence, the approach starts with a right pedal setting, and finishes in the hover with a marked left pedal setting.

(b) Lateral Cyclic - Lateral cyclic is primarily used to keep the machine level laterally, or to make adjusting turns should it be necessary to correct for drift. Application of lateral cyclic is complicated by the tail rotor translational effect which tends to move the machine bodily to the right in the hover (Section 1, paragraph 15). Many of the larger machines are rigged so that in cruising flight, with the cyclic central, the main rotor tilts a degree or two to the left. This compensates for the sidewards pull exerted to the right by the tail rotor under these power and airspeed conditions. When power is reduced the sideways pull exerted by the tail rotor is also reduced, and it is necessary to remove the rigged-in left tilt of the rotor by a suitable application of right cyclic. As power is increased, approaching the hover, the tail rotor pitch is increased considerably by application of left pedal. On both light and heavy helicopters, this will produce a strong lateral drift force to the right, and must be corrected by a pronounced application of left cyclic control. On some helicopters, eg, the H-5, this application requires considerable strength, and should be countered by early application of trim. The pilot may relieve this load somewhat by completing his approach with the helicopter nose facing slightly to the left of wind, thus providing a wind-drift element to the left, and offsetting to some degree the right drift tendency of the tail rotor.

(c) Confusion of Drift with Slip-and-Skid - During the approach, when the pilot may be preoccupied by other control requirements, he may confuse slip-and-skid with drift and take the wrong corrective action. This problem may be readily determined. If the ball of the turn and bank indicator is off-centre, or, if the machine is tilted laterally while holding a straight course, the pilot will know he is skidding. By levelling the machine with cyclic and by centering the ball with pedal, he will correct the error. If there is no slip and skid indicator he will adjust the pedal to prevent yaw after levelling the machine laterally.

THE HOVER

27 It is not always necessary to hover before landing, nor is it always practicable to do so. However, for the beginner, a good hover is the necessary prelude to a good landing. While a good hover may look relatively easy to the uninitiated, it is, in fact, one of the more exacting manoeuvres which a pilot is required to execute. A considerable degree of concentration is required to remain stationary. Unfortunately hovering cannot be taught, it can only be learned through practice. However, some explanation of control manipulation is essential, and a clear understanding of the following detailed points should be of considerable help.

28 The helicopter should be hovered at a height where full advantage may be gained from ground effect, and where there is no risk of snagging the tail or catching the wheels prematurely on the ground. Sufficient left pedal is applied to produce an anti-torque force from the tail rotor equal to the torque produced by the engine, thereby maintaining a constant heading. In zero wind the helicopter is kept stationary over the ground by keeping the plane of rotation of the rotor horizontal fore-and-aft. If there is a wind blowing, the rotor will be tilted forward, into the wind, sufficiently to prevent the helicopter from being blown back. This does not necessarily mean that the attitude of the fuselage itself will be the same as that of the disc, since the fuselage attitude will be dependent upon the relationship of the Centre of Gravity to the Centre of Lift. Hence, the fuselage may be nose down or tail down. In addition, the introduction of the anti-torque force from the tail rotor necessitates a slight opposing lateral tilt of the rotor disc to counteract the sideways drift introduced by the application of pedal. Hence, the fuselage as well as being nose or tail down, will invariably hang slightly down to one side. From this, it is apparent that the hover should be controlled by governing the plane of rotation, as opposed to controlling the attitude of the fuselage. In actual practice, it is difficult to see the disc itself and therefore, to use this alone as a medium of reference. However, if it is remembered that a change in attitude of the fuselage signifies a similar change in the disc attitude, it can be seen that an overall awareness of total attitude is necessary to maintain positive hovering control.

29 If, in still air, the helicopter starts drifting off in any direction, it is because the rotor disc has been permitted to tilt in that direction. This allows air to spill out of the ground cushion and the helicopter will commence to sink. This, in turn, requires an increase of collective pitch to prevent the sink, and the accompanying increase of torque necessitates a movement of the anti-torque pedals to maintain heading: While all this has been going on, pendulous forces have been trying to align the fuselage C of G under the centre of lift and, at the same time, the pilot has taken corrective cyclic action to tilt the rotor disc back in the direction opposite to the original disturbance. These latter two effects take place almost simultaneously, usually resulting in an over-correction, renewing the cycle of movements in the reverse direction. An inexperienced pilot will at first aggravate these pendulous oscillations but, with time and practice, he will be able to control them. The key to success lies in the ability to recognize any slight change in attitude during a hover and thereby to anticipate any requirement for control manipulation. By anticipation, the pilot may make the necessary selection and return the control to neutral before the helicopter has a chance to move.

30 Hovering "out of ground effect" is a term applied when the helicopter is hovered in still air at a height, or in conditions where the cushion cannot build up sufficiently to assist in supporting the helicopter. This condition is applicable when hovering at altitude or over a small pad such as a pinnacle. It is, therefore, necessary to apply increased power and pedal in order to produce the lift required to support the helicopter. The pilot must be aware of the necessity for increased power to compensate for the lack of ground cushion.

31 During the hover, and indeed during nearly all manoeuvres in a helicopter, gross or extremely abrupt manipulation of the cyclic control introduces unusual vibrations and forces which are fed back into the cyclic from the gyrations of the rotor disc. This undue and unnecessary tilting of the rotor disc prevents the formation of an effective ground cushion, and calls for changes of power to control the varying rates of sink following the misuse of cyclic control. This, in turn, requires continuous re-adjustments to the pedal settings to compensate for the varying torque. These continuous adjustments to the tail rotor also vary the percentage of engine power being absorbed by the tail rotor and, therefore, the percentage of power available to drive the main rotor. This affects the RPM and lift of the main rotor, necessitating adjustments to the throttle setting. It all adds up to a vicious cycle of events, each part of which confounds the next. In essence, the pilot is making work for himself. If he can hold the cyclic control reasonably still, and maintain a steady hover, he will soon rest on an effective ground cushion. This will obviate the necessity for continuous power changes, and therefore, the necessity for exaggerated pedal co-ordination.

LANDING FROM THE HOVER

32 Once a steady hover has been established it is safe to lower the helicopter and to complete a landing. But, since certain features of the hover will influence the landing, these factors should be discussed, starting from the hover.

Attitude

33 It was explained, while discussing the hover, that the attitude of the fuselage may well differ from that of the disc, and that the disc itself may not be level with the horizon. Wind, tail rotor effect, and centre of gravity, all interfere with the level of the fuselage just prior to landing, and most probably the wheels or skids will not hang parallel to the surface of the ground. Under such circumstances, it may seem logical to move the cyclic control to bring the wheels level before impact. Unfortunately, while this may successfully level the wheels, the helicopter will move in the direction the cyclic control is moved. At the moment of ground contact a forward movement may be acceptable, provided the terrain permits, but a sidewards or rearwards movement could produce a disastrous tipping effect. A successful hover, or a safe landing can only be achieved by holding the disc in the correct attitude; any attempt to change the level of the fuselage to match the ground can only intefere with the level of the disc.

34 While the helicopter is being lowered from the hover, correct cyclic control is achieved by ensuring that the machine is held as near stationary as is possible until the part of the undercarriage that was hanging nearest the ground actually makes contact. Thereafter the remainder of the undercarriage may be lowered gently to the ground, provided cyclic adjustment is made to maintain the disc in the same hovering attitude throughout. This requirement for cyclic movement during the latter stage of the landing is created by the change of attitude of the fuselage as the undercarriage adjusts to the ground. Such a change of fuselage attitude would cause the rotor to tilt in unison with the fuselage if the cyclic was not moved in opposition. Failure to make the required cyclic adjustment would incline the lift of the rotor towards the last point to make ground contact, and would probably initiate a movement of the machine in that direction. This could easily cause the helicopter to tip over. In all landings, regardless of the contour of the ground, ensure that the disc attitude is held constant both before and during ground contact.

Collective and Rudder Control

35 During the hover prior to landing, the helicopter should be held a few feet above the ground. The height selected should be such that the "air cushion" gives best support without becoming so compressed that it adds to the difficulties of holding the helicopter still. Once it is decided to descend from the hover, the

collective should be lowered gently to initiate the descent and, thereafter, further lowered to force the helicopter down through the compressed "air cushion". This movement must be regulated so that initial ground contact is gentle, and so that the subsequent adjustment of the undercarriage to the ground contour may be governed by collective while the necessary cyclic adjustments are made.

CAUTION

It must be emphasized that these downward movements of the collective lever must be infinitesimal until the machine has completed full contact. Positive downward collective movements will cause the helicopter to lunge downwards with possible dire results.

36 While the collective is being lowered, other co-ordinated control movements must be made. The reduction of pitch may necessitate a reduction of the twist grip setting to prevent an excessive build-up of RPM. In addition, the change in torque will necessitate a decrease of tail rotor pitch, which the pilot achieves by decreasing left pedal. Such a decrease of tail rotor forces will diminish the requirement for rotor tilt to the left and, therefore, the cyclic control should be eased slightly from the left to prevent the initiation of a movement to that side. Once the helicopter has been settled squarely on the ground, the collective lever may be lowered fully and the RPM reduced to a suitable idle. Exceptions to this could arise. If the pilot was unsure of the stability of the supporting surface, or if the ground was considerably off-level, the pilot would avoid any risk of tipping by supporting the aircraft with the main rotor. This would be accomplished by maintaining a sufficiently high collective position, and full flying RPM.

37 Like the hover, landings may look easy but, nevertheless, they require considerable concentration and practice. A landing should never be rushed unnecessarily; there is no shame in raising the helicopter clear of the ground and trying again if the initial contact feels unsure.

TAKE-OFF TO THE HOVER

38 The normal take-off, in a helicopter, is much easier than the landing. If any errors develop in the early stages the machine can be lifted well clear of the ground, where space can absorb the wobbles involved in correction. Nevertheless there are definite pitfalls to be avoided.

Before Lift-Off

39 With the collective fully down, and with the engine operating at a suitable idling RPM, complete pre-take-off checks should be made. Since the type of helicopter under discussion usually has a very small C of G traverse limit, the pilot should ensure, just prior to take-off, that the weight and balance is within limitations. An off-balance condition can cause the fuselage to hang so low on one side that the cyclic will bear against the opposite stop before it has sufficient purchase to hold the disc level with the horizon. A serious accident could easily ensue. Helicopters using trim devices should be adjusted to an estimation of hovering trim.

40 When the pilot is fully satisfied, he should then position the cyclic for take-off. By this means he locates the disc in the attitude he estimates should be required when the machine rises to the hover. In relation to the true horizon the disc should tilt slightly forward if there is a wind, and also tilt slightly left to offset the tail rotor drift force to the right which develops as the anti-torque force is applied. The cyclic position to achieve this while sitting level on the ground, will usually differ considerably from that required once the machine breaks clear of the ground. This is the product of the fuselage attitude change and is the reverse of the movement encountered during landing. Hence, on the ground, the cyclic should be initially located slightly forward and left of centre. Next, with the collective lever still fully down, the pilot should open the throttle twist grip until the RPM are close to the take-off setting. Subsequently the collective is raised progressively, and minor adjustments are made with the twist grip to bring the RPM to the exact take-off setting. Collective manipulation should be co-ordinated with advancing left pedal to counter the torque force being created. Such co-ordination will prevent the helicopter from swinging as it becomes light on the undercarriage. Many variants influence the collective setting at which the helicopter will become airborne; these include atmospheric density, all-up weight, and the amount of translational lift provided by the wind. At the best, the pilot

can only estimate this setting. For this reason the collective should be raised quite slowly until the pilot senses the aircraft is becoming light on the undercarriage. Throughout this stage the cyclic should be held stationary in the estimated position, subject only to minor adjustments.

Lift-Off

41 Once it is evident the helicopter is about to become airborne, raise the collective with a more positive movement. The movement required should be such that the helicopter will break clean from the ground with no delay, but should not be so great that it is necessary to depress the collective again to prevent sailing high above the point where the helicopter can rest on the newly created air cushion. Usually all points of the undercarriage will not break ground simultaneously; as a result, when the fuselage tilts into the hovering attitude, the cyclic must be moved opposite to the drooping side sufficiently to prevent the rotor disc from changing its attitude along with that of the fuselage. As the helicopter arrives in the hover, minor adjustments of all controls may be necessary to make corrections for turbulence or mis-control.

Errors and Corrections

42 Beginners are frequently prone to making two main mistakes during take-off. These two errors, and their correction, are as follows:

(a) Placing cyclic in the hover position either prior to take-off, or too soon during take-off - In such an instance, there is considerable risk of rolling the helicopter in the direction the cyclic is mis-located, once the collective is raised, the tail rotor effect will usually favour a roll over to the right, therefore, ensure the cyclic is held left of centre.

(b) Attempting to break clear of the ground too slowly - This usually is the outcome when a student attempts to make a very careful and smooth departure by raising the collective too slowly after the machine becomes light. It is extremely difficult to locate the cyclic in the exact position to maintain the correct disc attitude throughout take-off, and therefore it is quite normal for a beginner, or even an experienced pilot to wobble during a take-off. Such a wobble, with the wheels still dragging the ground, can readily develop into a toppling couple. With the machine well clear of the ground a wobble presents no dangers. This concept of ensuring a clean break from the ground is the safest procedure during basic training. However, at later stages, conditions are frequently encountered where it is safer for the pilot to "feel" his way gently through a take-off. This latter technique is necessary when there is any risk of snagging a part of the undercarriage under a root, snow crust, or some other tipping media.

(c) Recovery - While both the above errors should be avoided, safe recovery can be made if executed promptly. If the machine shows signs of leaning or dragging, pull quickly up on the collective lever and lift the whole machine into space. If the cyclic control is adjusted simultaneously to the normal hover position, any violent oscillations will disappear as the C of G swings back underneath the centre of lift. High RPM during take-off are, once again, good insurance. In this recovery, quick response to collective movement can be assured if the RPM are high. At lower RPM settings, the collective response may become extremely sluggish.

DEPARTURE AND CLIMB-AWAY

43 Generally speaking good helicopter operation is achieved by smooth, gentle manipulation of controls, By giving the machine adequate time to perform the required manoeuvre, maximum performance can be obtained with minimum strain. This is as true of the departure and climb-away, as it was of the approach and arrival to the hover. By such a technique, the helicopter may be accelerated into the climb smoothly and safely using minimum power and attitude changes. The helicopter will also pick up the benefits of translational lift before losing all the support provided by the "air cushion".

Fore-and-Aft Cyclic Control

44 To move forward from the hover, the pilot selects forward on the cyclic stick sufficiently to tilt the rotor disc, and thereby provide a forward component of the rotor's lift force. This forward force provides the acceleration thrust. The amount by which the cyclic control is moved ahead will determine the rate at which the helicopter will accelerate. However, rapid acceleration is

rarely necessary and by tipping the disc well forward, the pilot introduces added complications. First of all, by tipping the rotor's total lift reaction forward excessively, he noticeably reduces the vertical component of lift, and the helicopter will sink nose forward unless collective settings are increased. Secondly, tipping the disc well forward blasts backwards the supporting air cushion and, here again, the helicopter will require more power to support itself. Such unnecessary power additions leave less reserve for weight lifting or high altitude operation, and calls for the application of extra throttle, extra collective, and extra rudder at a time when the pilot is already fully occupied. A hurried departure also entails unnecessary risk. In the event of engine failure, a probability which is increased by the higher power settings, the machine is already sitting in a dangerously nose-down attitude. Also a sudden faltering or failure of engine power will set up vicious yawing tendencies hard to correct at these high power settings. By contrast, a gentle departure presents the pilot with fewer difficulties, and provides more time to concentrate on the requirements of departure.

45 As the helicopter moves forward gently off the air cushion, translational lift is increased with very noticeable benefits at around 20 knots. (See Translational Flight Section 1, paragraph 31). As translational lift increases, the helicopter will start to climb. The nose should be held sufficiently depressed to maintain acceleration up to whatever speed is required for best climbing performance. At this stage the attitude should be adjusted to hold the new speed. However, at about the same time that translational effects become evident, the effects of lift dissymmetry will tend to force the main rotor to flap to the rear. To maintain acceleration the pilot must oppose this force by progressively moving the cyclic forward to maintain a constant disc attitude until he has completed the acceleration. At this stage there will be no further build-up of the force and, in those helicopters so fitted, the cyclic control should now be trimmed to hold this new position. (See Transition, Section 1, paragraph 38(d)).

Collective and Pedal Control

46 A gentle departure requires very little collective, or power adjustment during the acceleration. Frequently, the hovering settings are quite adequate to provide support during acceleration and, once climbing speed has been attained, great power changes are rarely required for the climb. It may be found that, as translational lift reduces the loads on the rotor, the RPM may tend to build-up excessively; in this case the throttle should be twisted back. Any gusts or turbulence affecting climb should be countered by opposite movements of the collective.

47 During the hover, considerable left pedal is needed to counter the high power torque output of the engine. As the machine moves forward, the fuselage gains weathercock stability. This increasing stability serves more and more to hold the helicopter straight against the torque output, and, as a consequence, the left pedal setting should be decreased throughout the acceleration. Any collective or throttle changes will tend to swing the helicopter and should be opposed by opposite pedal adjustments. Good co-ordination will provide a smooth departure.

Lateral Cyclic Control

48 As the helicopter gathers speed, and as the tail rotor pitch is decreased by diminishing left pedal, the sidewards translational effect of the tail rotor also decreases. For this reason the cyclic should be moved towards centre from its displaced position to the left as the speed builds up. On some machines it is also necessary to oppose a pressure which tends to force the stick to the left when the cyclic is pushed well forward. This force is created by the inertia of the blades which opposes large cyclic pitch changes; in some control systems this force is fed right back to the control lever. (See Section 1, paragraph 43). Servos, or the use of lateral trim at this stage, will eliminate the effects of this force.

Departure Path

49 The ideal departure path is into wind, and away from obstructions. The angle of departure varies with the helicopter; the lighter ones starting directly into the climb, and the heavier machines generally remaining low on the "air cushion" until adequate translational lift is acquired. The path of climb and departure should also take into consideration a balance of speed with height; too quick a climb with too little speed means excessive power settings and leaves the machine in a most difficult

recovery situation should the engine fail. Alternatively, a very low departure at a high speed can be equally dangerous should the engine fail. The ideal departure path, then, is a balance of many considerations; including terrain, wind, altitude, type of helicopter, load carried, and engine failure precautions.

EFFECTS OF WIND, GUSTS AND TURBULENCE

50 A helicopter performs surprisingly well in strong wind conditions, in fact, landing and take-offs in the open are made easier by the presence of the translational effects of wind. On the other hand gusts and eddies can make helicopter flying quite hazardous. The helicopter provides a smoother ride than the fixed-wing aircraft when flying through mountains or close to irregular obstructions.

Blade Sailing

51 A problem peculiar to rotary wing aircraft is that of blade sailing. During the engagement, or the slowing down of the rotors, in either strong winds or in gust conditions, the blades revolve at a critical speed where they are passing in and out of a stalled condition. With each rotation into and out of wind, or with each sweep into and out of a gust, a blade may pick up flying speed as it advances, and stall abruptly as it swings back downwind. This can develop into violent up and down sweeps which may cause considerable damage. A steady, stiff wind presents little problem if the collective pitch is kept to a minimum and the cyclic control is held into wind. By this means the pitch of the advancing blade is kept to a minimum and will prevent the blade from lifting before it stalls on the other side. However, in a violent gust condition, little can be done to prevent eddying air from lifting up an advancing blade and dropping it abruptly as it rotates out of wind.

52 On helicopters with highly flexible blades, such as the H-13, or on helicopters employing centrifugal droop stops, it is possible for a stalling blade to sweep down on the retreating side and strike the tail boom of the helicopter.

53 Certain precautions can be taken to minimize the risks of blade sail when starting and stopping in adverse conditions.

(a) In a strong wind, stay clear of turbulence created on the lee side of obstructions.

(b) Keep the collective fully down, and incline the cyclic forward into wind.

(c) Minimize the period of engagement or deceleration of the blades.

(d) Avoid engagement, or shut down, when exposed to the slipstream or downwash of another aircraft.

(e) Face the helicopter well out of wind so that, in the event of blade sail, the tail is swung away from the position of lowest blade deflection.

Cruising Flight

54 At cruising height, proceed as follows:

(a) Strong Winds - At cruising height, strong winds will have marked effects on the range of the helicopter and may cause considerable drift. Under these conditions wind effects are the same as they are for any slow speed aircraft.

(b) Gusts and Turbulence - The flexibility of the blades and the flapping effects of the rotor absorb much of the usual bumpiness; a helicopter passenger will be surprised at the comparatively smooth ride. For the pilot, however, some of the flapping forces are fed back through the controls, and handling the machine is continuous, and quite arduous work. In addition, updrafts will cause the RPM to surge upwards, and downdrafts will have the reverse effect. At high density altitude, or at a high all-up-weight, the pilot may have to reduce the speed of the helicopter and increase the rotor RPM slightly. This is to avoid retreating blade stalls resulting from sudden increases in angles of attack of the retreating blade.

Take-Off and Landing

55 Take-off and landing are accomplished as follows:

(a) Strong Winds - If the wind is steady, a strong wind can provide great lift benefits. Translational lift will permit the helicopter to take-off or land with either far less power or with an increased load. In a strong wind, power changes will be much less during acceleration and deceleration, necessitating far less movement of the rudder pedals. In addition, the weathercock effects of the fuselage and the requirement for less power during the hover, place less demand on the anti-torque rotor. This has two beneficial effects: first, the drain of power by the tail rotor is reduced; secondly, the need for left cyclic correction for tail rotor drift is also reduced. In all, such a wind is a great asset during take-offs and departures in the open.

(b) Gusts and Turbulence - Thermal turbulence does not exist at ground level; however, mechanical turbulence can cause considerable difficulty. Gust conditions, or rapidly shifting winds can also prove hazardous. The onset of a gust can provide a sudden surge of translational lift, which can be lost just as abruptly once the gust has passed. Such changes demand quick and accurate adjustments of collective and throttle along with accompanying pedal corrections. In addition, high RPM are essential to provide spontaneous reaction to collective adjustments. Wind shifts require quick pedal changes to prevent the helicopter from swinging, and rapid cyclic adjustments may be required to prevent the aircraft from being moved bodily sideways.

(c) Light and Variable Conditions - On a hot day these conditions can be quite hazardous. The wind direction may be quite difficult to detect and may change completely during an approach or departure. Should a helicopter arrive or depart inadvertently downwind, it will pass through a stage, while still moving over the ground, when the airspeed is zero and all translational lift is lost. Under heat conditions this unexpected loss of lift may be impossible to replace since the engine may have insufficient reserve of power. The helicopter will then sink prematurely to the ground, probably with disastrous results. When operating in these doubtful conditions, all departures and arrivals should be made at the maximum permissible RPM, thereby eliminating both the risk of premature settling, and of overpitching in an attempted recovery.

CAUTION

You should never permit yourself to get into this position. Ensure you are into wind and have sufficient power to maintain control before losing all transitional lift. If uncertain make another approach.

Close to Ground

56 At low level, proceed as follows:

(a) Stiff Winds - At low level the helicopter pilot may be easily misled by his close proximity to the ground environment. Apparent movement relative to the ground frequently confuses even quite experienced pilots. Frequently, when turning downwind, the pilot will advertently let the airspeed fall off. This is particularly likely when turning downwind during a ground search; after moving slowly into wind the pilot's preoccupation with both the search, and with the avoidance of obstacles, may readily detract from his focus upon airspeed. He may end up sinking, through the loss of translational lift, and a recovery attempt may lead to settling with power and disaster.

(b) Gusts and Turbulence - Again the pilot should keep a close watch to maintain adequate airspeed throughout all manoeuvres. An interesting effect of gustiness, during strong wind conditions, is that, when flying across wind at low level, the helicopter is buffeted more than when it is flying up, or downwind at the same height. This is the product of flying across narrow bands of air travelling at different speeds. The helicopter nose will first be affected as it noses through the side of a gust, and, as the helicopter emerges into slower moving air, the tail is the last to be affected. Such variations cause considerable yawing.

Confined Areas

57 Strong winds, gusts, and turbulence all amount to much the same thing when flying at low level down among obstacles. There are many dangers to the helicopter under such circumstances, and generally the pilot would be well advised to stay out of closely confined openings.

(a) Wind Sheer - A sudden drop of wind strength may be encountered as the helicopter sinks below obstacle level. The sudden loss of translation may be sufficient to prevent adequate control.

(b) Eddies and Swirls - These may have the effect of suddenly swinging the helicopter and possibly striking the tail on some obstacle

(c) Downdrafts - Behind obstacles, these may add to a sudden loss of wind strength, creating additional hazards, either while flying just above obstructions, or while flying within the confined area.

CAUTION

This condition is to be avoided.

PEDAL TURNS

58 Pedal turns are a very useful manoeuvre. Operationally they offer many practical uses. During training, they are an excellent co-ordination exercise. A full pedal turn consists of hovering over a fixed point and pivoting the machine, either way, through 360°. Operationally a partial turn is more frequently used. Some of the uses for pedal turns, or "turn-arounds" as they are frequently called, are as follows;

(a) Clearing turns to ensure adequate clearance prior to departure in helicopter traffic,

(b) Close-to-ground manoeuvering, as in sling loading, or in avoidance of obstacles within confined areas, and

(c) Inspection turns prior to back-up, or sidewards drift downwind.

Wind and Gust Limitations

59 Strong winds, bearing against the weathercock surfaces of the fuselage, may prevent the tail rotor from providing sufficient turning effect to rotate the helicopter fully out of wind. In addition, the cyclic limits of the machine may be reached across or downwind, prior to gaining sufficient cyclic purchase to hold the aircraft over a fixed point. Such sideways or backwards movements may carry the helicopter into obstructions or, by depriving the helicopter of translational lift as it moves with the wind, the machine may sink prematurely to the ground. The general safety rule for determining whether a turn would be safe or not, is to attempt a turn to the left. In this case the pilot is opposing the torque forces and the machine will resist more readily than to the right. If it will not turn left, do not try the right turn; while the machine may turn completely round to the right, the cyclic limits may be exceeded under such conditions.

60 Gust conditions can be dangerous during turn-arounds. It may be quite easy to turn downwind before a gust strikes. But a sudden gust while facing downwind, and with the cyclic already fully back, can be highly dangerous. The sudden increase of lift dissymmetry in the main rotor will cause the rotor to flap upwards abruptly against the gust. The effect is to raise the tail and depress the nose. This shortens the vertical lift component by tilting and, at the same time, the machine will be carried downwind rapidly losing translational lift. These two sudden lift losses may well be beyond the collective lift capabilities of the machine, and a crash will ensue as the aircraft noses into the ground drifting rapidly downwind. These dangers are very real, but, if the pilot observes the precaution of trying out a left turn first, or avoids attempts to turn in strong gust conditions, pedal turns may be considered a normal and safe manoeuvre.

Manipulation of Controls

61 As in all other manoeuvres, careful control co-ordination is the secret of success. However, for clarity, the control movements are described separately.

(a) Pedal - The pedal is used to initiate the turn in the desired direction and, therefore, to control the rate of turn. In still wind conditions, pedal control is extremely simple, but becomes more difficult as the wind gets stronger. The turn-around should be started by hovering nose into wind. Application of pedal in the desired direction will initiate the turn but, dependent upon wind strength, this initial movement will be resisted by the weathercock effect of the fuselage and tail surfaces, and, as the nose moves further across wind, more and more pedal must be applied to overcome this resistance. Once the nose has swung past the 140° position, the resistance will quickly disappear and opposite pedal may be necessary to retain a constant rate of turn. This effect is produced as the tail swings into wind and the machine is once more aligned by the weathercock forces. However, facing downwind, weathercock effects produce less stability than when facing into wind. As the nose passes the 180° position once again pedal must be applied in the original direction to turn the aircraft out of alignment with wind. An increase of pedal pressure should be applied to maintain a constant rate of turn until past the 270° mark. After this the nose will tend to swing around into wind of its own accord, requiring some opposite pedal to slow it down if the wind is strong.

(b) Cyclic - The cyclic is used to hold the helicopter in position over a fixed spot on the ground. The stronger the wind, the greater will be the cyclic manipulation. Starting into wind the cyclic will be inclined forward to eliminate drift. Thereafter, the cyclic will always be held into wind despite the heading of the helicopter. This will keep the rotor tilted in approximately the same direction relative to the wind. If a left-hand turn is accomplished, the cyclic is rotated to the right of the aircraft as the nose swings left across-wind. Downwind the cyclic is swung progressively from the right to the rear. Across-wind, with the nose to the right of wind, the cyclic is located to the left, and then swung forward as the aircraft swings into wind. In both crosswind positions the fuselage presents more drag, than when aligned with the wind requiring an increase in lateral cyclic movement to prevent sideways drift.

(c) Collective and Twist Grip - Basically the collective is used to hold the helicopter at the ideal height to provide adequate ground clearance and, at the same time, to obtain optimum support from ground effect. In still wind, application of left rudder will absorb RPM, and the machine will tend to sink; application of right rudder will release extra RPM and the machine will tend to climb. In strong winds left turns will absorb still more RPM, and full applications of right rudder will also absorb a proportion of power because, at this setting, the small negative pitch angle, now applied to the tail rotor, begins to re-create tail rotor drag. Collective and throttle co-ordination must be applied to counter these effects, and may call for frequent adjustments as the pedal forces vary. A left turn should be preceded by a slight increase in RPM in anticipation. Completion of the turn will require reduction of throttle to prevent an over-rev. The initiation of a right turn usually produces a slight increase of RPM, which disappears when the turn is completed.

The Right-Pedal Recovery

62 On most light helicopters, or on heavier helicopters when carrying heavy loads, it is wiser to turn left in manoeuvres requiring a part pedal turn. That is, provided that the choice can be made between a right or left turn. Though initiation of the left turn may be more difficult, the recovery back into wind to the right, in event of difficulty, can be made very readily. This quick and easy recovery is a product of the torque force. By merely relaxing left pedal, the helicopter will veer back into the wind of its own accord, and the reduction of tail rotor load will release more power to the engine and free more lift for the main rotor. This will lift the helicopter well clear of the ground, and also relax control tensions as the nose swings back into the wind.

Variations of the Turn-Around

63 Considerable training benefits may be gained by practicing the following variations of the turn-around. For safety, these variations should be practiced in light wind conditions. It is not considered necessary to detail the required control movements, as it is felt that the pilot, at this stage can gain greater benefit by applying his own knowledge and by working out his own control co-ordination.

(a) Select a point into wind, about twenty feet ahead of the nose, and fly a circle around it, keeping the nose pointed towards this spot. The circle may be completed either to the left or right.

(b) Select an imaginary point about twenty feet downwind behind the tail. Fly a circle, either way, keeping the tail pointed towards the mark.

(c) Select a point about forty feet to one side of the machine. Fly a forward circle around it, and then try the reverse, backing around the circle.

SIDEWAYS FLIGHT

64 Due to the marked weathercock forces which affect the fuselage at the higher air-speeds, sidewards flight should only be

attempted from the hover, or when flying at very slow speeds. Attempts, at too high an airspeed, impose considerable strains upon the controls and upon the structure of the machine. Sideways flight, frequently used in conjunction with partial turn-arounds, is a valuable manoeuvre when manipulating sling loads or when landing among obstacles. Like the turn-around, sideways flight provides excellent training co-ordination practice.

Manipulation

65 Starting from the hover facing into wind, the pilot should first select a suitable destination a short distance to one side of the helicopter; aimless movements do not provide the same opportunity for practicing skill and precision. He should ensure that the path is clear, and, if the route passes over a gulley or deep depression, he should be prepared to compensate for the temporary loss of ground effect. Throughout the manoeuvre, visual reference should be maintained both to the front and to the side of the machine. The secret of success is to guide the machine, rather than to force it. Movement is initiated by light application of cyclic in the desired direction. Alternatively, the pilot may take advantage of the minor variations of the hover and, by picking the right instant as the helicopter sways towards the right direction, he may merely encourage the trend to continue. By either of these means, the pilot will avoid overcontrol and minimize the problems of oscillation. Whenever a helicopter starts to move in any direction, or alternatively whenever a helicopter decelerates, the forces of lift dissymmetry come into play. Hence, as the helicopter starts to move sideways, the rotor will attempt to re-assert itself, and flap back in the opposite direction. Frequently, a beginner will allow this effect to catch him by surprise and, as he applies opposite cyclic too late, will start up a wild lateral swinging movement of the fuselage. The best way to describe the correct movement of the cyclic to prevent such difficulty, is by terming the movement a "squeeze through" of the cyclic. After the initial sideways movement of the cyclic, the control should be "squeezed through" against the opposing force fed back from the rotor. This opposing force is only a temporary feed-back since only a very small acceleration is involved. Also, the pilot should beware of applying too gross a lateral movement in opposition to this force. This would cause the helicopter to move sideways too fast for good control, and would involve the creation of a greater lift dissymmetry force. Lateral speed should be kept constant at little more than a walking speed, and is controlled by lateral cyclic.

66 The pedals should be used to maintain the original heading of the nose. Pendulous movements of the fuselage, wind shifts, and power changes all interfere with the maintenance of a constant heading. Their yawing effects should be countered with pedal as required. A student must carefully observe the difference between sideways and rotative movements of the nose to avoid wrong interpretation and mis-correction. Collective and throttle movements should be co-ordinated to maintain a suitable ground clearance while remaining supported on the "air cushion". Use of rudder to prevent swings may drain away RPM, and should be countered by throttle adjustment. Fore-and-aft cyclic is used to correct for deviation ahead or behind the desired track. Finally, as the helicopter approaches the destination, lateral cyclic should be gently eliminated, and the helicopter allowed to drift into position. Sudden attempts to arrest the helicopter usually end up in needless swings. During the slow-down, height should be maintained with collective, and heading maintained with the pedals.

Alternate Methods

67 In a very light wind there is no requirement to fly sideways at all, unless obstructions dictate otherwise. It is easier to do a quarter pedal turn to face the desired direction, and then to proceed towards the destination, see Figure 8-56. Alternatively, in a stiffer wind, and particularly if the distance to be covered is much in excess of a hundred yards, a quick and easy manoeuvre is as follows. As the cyclic is applied sideways sufficient rudder should be applied to keep the nose facing into the relative wind. This means that, as the machine moves faster, the nose should be pointed further around in the direction of traverse, and the cyclic should be eased, from the side, to a forward position in unison. In this manner the helicopter is actually flying ahead into wind, but is also flying at such a speed and heading that the track made good along the ground is the product of drift rather than of sideways movement. Weathercock forces do not therefore limit the

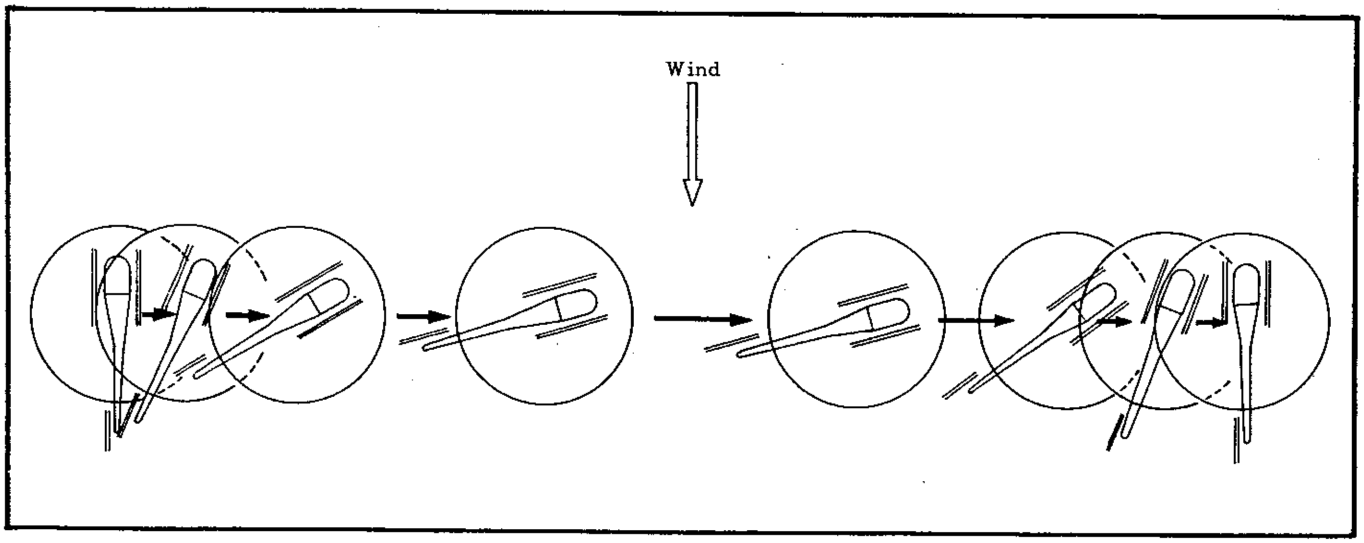


Figure 8-56

speed nor make control difficult. The exact reverse of these movements is effected as the machine approaches close to the destination. Cyclic is moved slowly back and to the side opposite the direction of aircraft movement, and the nose is swung back to remain faced into the relative windflow. Upon arrival, the cyclic and pedals should be re-centred as for the normal hover. If carried out correctly, the helicopter will arrive in the hover over the desired spot without deviation from the intended track. This is a smooth and effective manoeuvre if carried out correctly. This manoeuvre, and modifications of it, are most useful, and provide considerable satisfaction to the pilot who masters them.

Practice Exercise

68 This is a very good exercise which provides excellent preparation for sling work. It involves both pedal turns and sideways flight, facing in all directions relative to the wind. To carry out this exercise pick a fairly calm day, then select a right-angled intersection where two fences cross each other, see Figure 8-57. This should be on fairly level terrain, and clear of other obstructions. The exercise involves flying an X-shaped pattern around the intersection. Start facing the nearest arm of the fence squarely. The helicopter should be hovered clear of the ground and about fifteen feet back from the fence. It is best to begin with the helicopter facing as near into wind as the above requirements permit, then move the helicopter sideways away from the intersection for a short distance, constantly holding the height and distance back. Select a fence post and swivel the machine up, around, and over the fence with the nose pointing always towards the post. With the tail now into wind, and with the whole helicopter on the other side of the fence, move on sideways until close to the intersection. At this point pivot the nose sideways, holding the tail fixed over a point on the ground, until aligned along the second arm of the fence. Continue the manoeuvre until the original point is reached.

BACKWARDS FLIGHT

69 This manoeuvre is closely related to sidewards flight both in its purpose and in the method of control. However, due to the difficulties of backward reference, it should only be used when it is not possible, first, to turn the machine halfway out of wind, and then to allow it to drift sideways downwind into the required position.

Manipulation

70 Before practicing this manoeuvre, the pilot should satisfy himself that the terrain to the rear is clear, and that there is some means of recognizing the destination prior to arrival. This can be achieved by previous inspection, or by temporarily swinging the tail to one side to permit inspection. Once he is satisfied, the pilot should not attempt to keep referring to the rear, but should concentrate his reference forward and to the side. By this means, he can more readily detect unwanted swings and speed variations. To commence the manoeuvre, the cyclic should be handled in a similar manner to that required in sideways

flight. In this case, it is eased gently to the rear sufficiently to initiate movement, and then "squeezed through" to overcome the lift dissymmetry forces which tend to raise the rear of the machine. Backward movement of the helicopter should be kept constant and slow by the regulation of aft cyclic. Quick accelerations downwind entail the sudden loss of translational lift provided by the wind. Moving at too high a speed towards the tail, a helicopter may suddenly whip around to face the opposite direction.

71 As the helicopter starts to move backwards, two other effects appear simultaneously. First, the loss of weathercock stability, due to the reduction of wind effect, will tend to swing the nose to the right. Secondly, loss of translational lift will cause the helicopter to sink. The sink should be opposed by an increase of collective settings which, again, will cause the nose to swing to the right. Both of these swinging tendencies should be corrected by left pedal. When approaching the destination, the helicopter may easily be stopped by returning the cyclic to its original position and allowing the machine to drift to a standstill. At the same time, collective settings should be decreased and left pedal relaxed to the original hover position.

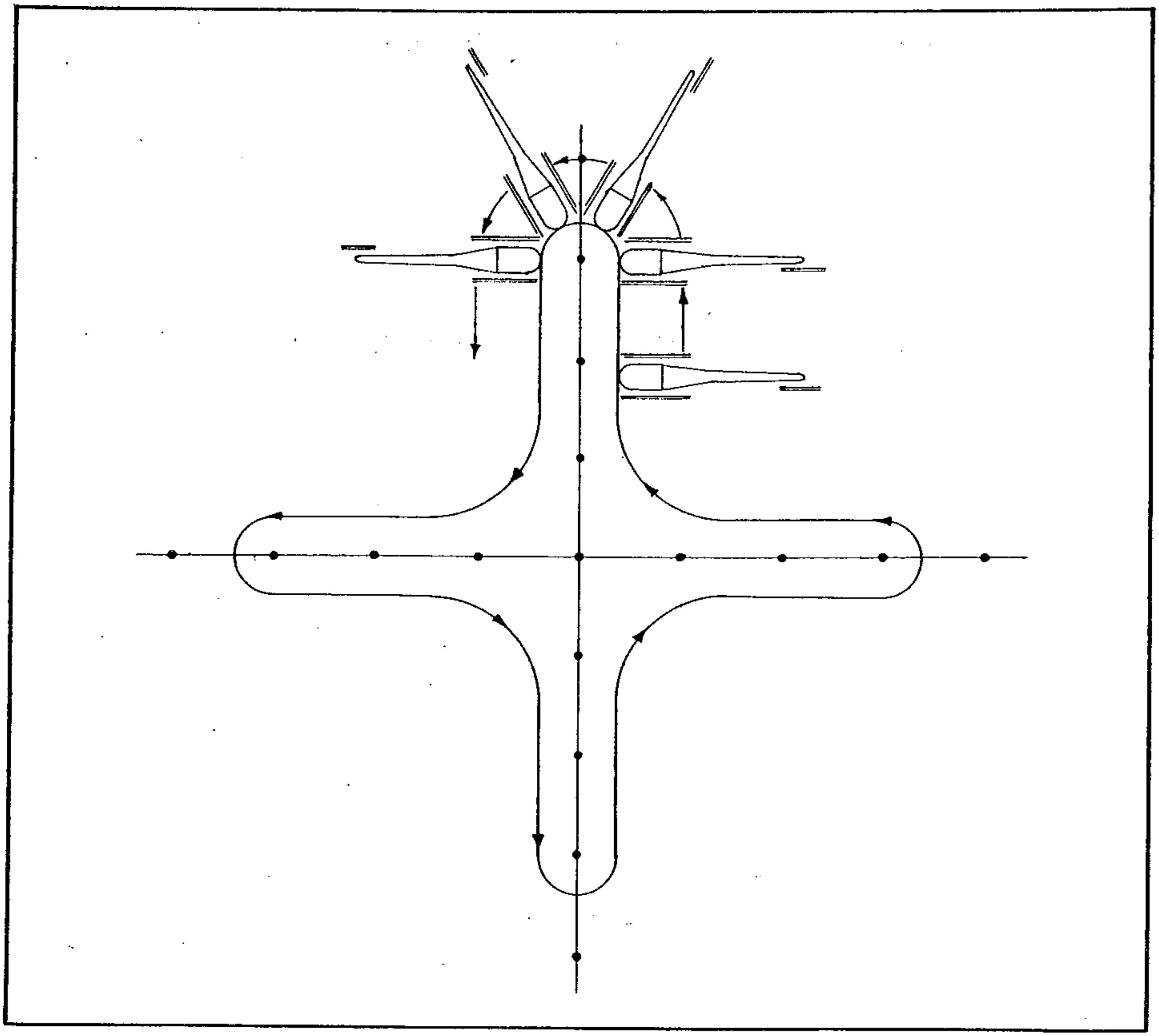


Figure 8-57

72 In light winds the alternative method, described briefly in paragraph 69, should be used. The nose should be turned to the left for preference. In this position prompt use of the right pedal recovery is permitted. Then, as the machine is allowed to drift sideways downwind, the collective settings should be increased slightly to counter the loss of translational lift.

OVERPITCHING

73 Overpitching has already been described briefly in paragraph 6. However, before getting involved in some of the more advanced manoeuvres, the pilot should know more about the circumstances that may lead him into this condition. Also he should know how to recover before the condition becomes too aggravated.

Vulnerable Conditions

74 Overpitching occurs when, in an attempt to produce lift, the collective pitch lever is raised so high that the engine has insufficient power to overcome the excessive drag now being produced by the blades. A loss of RPM ensues, and the rotor cones excessively. Lift is lost as a result, usually at a time when the pilot is seeking to increase lift under critical conditions. Overpitching can, and should be avoided. It is caused by misjudgement of conditions or by mishandling the controls. The pilot is most likely to run into difficulty when flying in conditions of low atmospheric density, such as: mountain operation, operation in high temperature, operation in high humidity, or any combination of these three. The potential is increased by: heavy loads, rushed manoeuvres, attempts to recover rapidly from steep descents, disregard or lack of knowledge of wind direction during arrivals and departures, or by heavy fistedness in handling the collective controls. All these conditions add up to a higher than usual collective setting. In normal cruising flight, overpitching will not occur, the presence of adequate translational lift will preclude any requirement for excessively high collective. Therefore, it is when the machine is moving at low speed, or when it is hovering, that overpitching is likely to occur. Since most low speed manoeuvres are carried out close to ground, usually in the process of take-off or landing, there is usually little room to recover. If the pilot should allow overpitching to take place so close to the ground, he must recover instantaneously or run into disaster.

Avoidance

75 Using proper precautions, the pilot can avoid overpitching when flying under difficult conditions. First of all, he should reduce the load to within safe limits for the expected conditions. He should then take advantage of any favourable wind by landing at exposed positions rather than in shelter. Extreme caution should be used when arriving or departing in light and variable conditions. Manoeuvres should be extremely gentle. Departures and arrivals should not be rushed, and the flight path should be as shallow as possible while close to the ground; this will take advantage of ground effect and minimize the "G" forces by avoiding quick roundouts or pull-ups. RPM should be set as high as handling limitations permit throughout any potentially critical condition. By this latter means, the same lift can be maintained at a slightly lower collective pitch setting and, in addition, the higher RPM offer an increase of engine power potential. One further precaution, which applies mainly to very light helicopters, is to avoid heavy-fisted handling of the collective lever. Frequently, light machines employ collective levers which move freely despite any imposition of excessive rotor loads and, in addition, these levers may have only a very small traverse to provide the whole operating range. Overpitching can be the product of only a very small movement and is very hard to sense. In such aircraft, the pilot should be familiar with the critical manifold pressure at which overpitching will occur. By carefully watching the boost gauge when operating in critical conditions, the pilot can predict and prevent trouble.

Recovery Action

76 If, despite all the above warnings, the pilot finds he has inadvertently overpitched, he may still recover by prompt corrective action. The recovery may appear to be the opposite of any natural reaction, but it works. As soon as the pilot becomes aware that the RPM are falling off, he must immediately depress collective sufficiently to reduce the drag factor back within the engine's capability. Since lowering collective also closes the throttle slightly, this effect must be countered by the pilot simultaneously twisting outwards to increase the twist grip setting and to keep the throttle fully open. If things have not already gone too far, the engine RPM will pick

up and the pilot should continue to manipulate to get them as high as possible. Such manipulations are known as "milking". Despite the lower collective setting, lift will actually be increased. The engine is no longer wasting its power against excessive drag. It must be admitted that the helicopter will sink a few feet before lift is recovered, but, if the machine is over flat terrain or water, the increased ground effect will assist the recover. The dangers of overpitching close above trees are obvious.

77 Frequently the excessive torque produced by overpitching causes the nose to yaw to the right despite the full application of left pedal. In fact, the full application of pedal is merely serving to steal more power from the engine. If there is sufficient lateral space, the pilot may assist recovery by easing gently forward on the cyclic and carefully relaxing pedal. In this manner translational lift may be gained, and the drain of power through the tail rotor will be minimized. The pilot must beware, however, of swivelling around too far to the right, too soon, as this may carry the helicopter downwind at low speed, depriving the rotor of any translational lift.

LANDINGS AND TAKE-OFFS OUT-OF-WIND

78 If the wind is not too strong the helicopter may be lowered onto the ground, or lifted off, with the nose pointed out-of-wind or downwind, Such a manoeuvre may be necessitated by the shape of a clearing, or the wind may have shifted after landing. However, the final part of an approach, or the early part of a departure, should not be carried out facing far out-of-wind, unless the helicopter has a large reserve of power. This is necessitated by the need to retain as much translational lift as is possible. Of course, during the high speed stages of an approach or departure, translational lift is adequate, and it is safe at these stages to be faced out-of-wind if necessary. An out-of-wind landing normally involves arriving over, or to one side of, the spot with the aircraft facing into wind. Then, as the machine slows into the hover, a pedal turn should be used to align it with the opening. Facing this way, the helicopter is lowered, or flown sideways into the opening.

79 An out-of-wind take off may entail a vertical climb to clear obstacles, or it may entail a departure without obstacles. In either case the helicopter should be swung back into wind by the shortest turn as soon as circumstances permit. This will minimize any tendency to be carried downwind as the helicopter rises into the faster moving air, and will permit acceleration into wind at the earliest possible moment. These two departures are described in detail.

(a) Vertical Take-Off, Out-Of-Wind - Here it is assumed that the helicopter is sitting behind an obstruction and that there is room to turn while climbing. The nose is facing approximately downwind. First of all, the pilot should hover the machine to determine both the cyclic position to hold the hover, thereby to ensure a straight climb, and, also, to check there is sufficient power remaining to re-assure sufficient lift to clear the trees. Once satisfied, the pilot will apply maximum RPM and then lift the collective to initiate the climb. On many machines, added impetus may be added to the climb by landing after the test hover, and then building up the power surge on the ground. By this means, a maximum density "air cushion" can be formed, and serves to spring the helicopter off the ground. This technique is known as the "jump take-off". As the helicopter rises clear of the ground, the nose should be allowed to swing around to the right. This action frees the engine from excessive tail rotor power drainage. However, this swing must be restrained sufficiently to maintain full control. As the helicopter climbs up through the spiral, the wind will affect the helicopter first from the tail, then from the side, and finally from the nose. As in the turn-around, the cyclic should always be held into wind to prevent movement downwind. It should also be remembered that, as the machine climbs above the obstruction level, the wind usually strengthens. Therefore, at this stage, the cyclic must be inclined further to compensate. As the nose swings close into wind the cyclic may be pushed forward to initiate departure, provided the path is clear ahead.

(b) Low Level Take-Off, Out-Of-Wind - In this case it is assumed that the helicopter is sitting tail into wind, and that obstructions are low enough to permit a shallow departure towards the wind. A test hover again is a good idea, though this time there should be no power problem. As the helicopter is lifted well clear of the ground, the cyclic is moved back further into wind. This movement should be such that the helicopter starts moving backwards into wind to pick up translation, but at the same time there should be no risk of the tail catching obstructions. The pilot may then turn the aircraft with pedal. It is easier to start to turn to the right but, as the machine gathers speed, turning at the same time, very considerable left rudder will be required to prevent the nose from whipping violently into wind. Conversely, a left-hand turn is hard to initiate, but easier to control later. There is little to favour one direction against the other. Cyclic control is manipulated to depress the rotor disc into wind, and to maintain a suitable rate of acceleration. To achieve this, the stick is swung from the rear around to the side into wind, and finally forward as the helicopter revolves to face its direction of travel. Care should be taken not to exceed the manufacturer's airspeed limitations for sidewards flight.

80 If the aircraft is facing only partially out-of-wind, the cyclic should be inclined into wind as the helicopter leaves the ground. The machine should then be turned the shortest way into wind, while the collective is manipulated to clear any obstacles.

LANDINGS ON DOUBTFUL SURFACES

81 This technique should be employed whenever the pilot is in any doubt whatever about the surface he is landing upon. Such doubts would arise when landing on a snow crust, soft deep snow, ice, mud, marsh, erosion or any other surface that may give way under the full weight of the helicopter.

82 Here again, the pilot is advised to increase RPM before attempting the landing. He should hover over the selected spot and lower the machine very gently with the maximum depression of collective. The cyclic is then adjusted to keep the rotor in the exact hovering position as the fuselage aligns itself with the surface. As the weight comes onto the undercarriage, the collective should be lowered only as far as is necessary to ensure stability. The RPM must be kept high to provide immediate collective response in the event of surface failure. If it is desired to shut-down the engine, the ground may first be tested for supporting strength by either or both of two methods.

(a) Ample RPM are maintained while the collective lever is slowly lowered. At the same time the cyclic is kept moving towards each wheel in turn as the downwards pressure is increased. Such movements will help the pilot predict the direction the helicopter will lean should the surface give way under the temporary increase of pressure under each wheel.

(b) While maintaining adequate RPM, the helicopter is repeatedly dropped from the hover onto the surface with increasing pressure each time. This method is particularly suitable for compacting soft snow This procedure may be very well for compacting snow on a land surface but breaking through the ice by this method is not a safe practice. It is suggested that on an unknown ice surface, snow covered or otherwise, that the full weight of the helicopter should not be applied to the surface until it is known that the surface is safe. If necessary, a crewman can be lowered from the helicopter to test the surface by taking ice borings.

83 Should the helicopter break through, recovery is quick and simple provided the pilot has retained high RPM. Adequate RPM will ensure instantaneous response to a quick upward movement of collective, enabling the helicopter to clear the ground. Simultaneously the cyclic should be moved as required to return to the hover position.

84 Particular care should be exercised if it is intended to park the helicopter for prolonged periods on ice covered with deep snow. Snow has the effect of insulating the ice beneath and, despite intense cold, the ice may remain quite thin. In addition, the snow may hide breathing holes in the ice. The added weight of the helicopter may, over a period of time, permit the water to well-up through the ice and to remain unseen beneath the snow. Under such conditions the ice will bow downwards very slowly until it finally breaks under pressure. In a recent instance, a helicopter had been parked for an hour before the ice suddenly gave way.

NO-HOVER LANDINGS AND TAKE-OFF

85 No-hover landing and take-off techniques add grace and facility to normal arrivals and departures. They should not be attempted until the normal hover arrival and departure techniques have been mastered since a somewhat finer sense of feel is required. However, the

no-hover techniques are very useful, particularly when operating under high density altitude conditions, or when arriving in a steeply confined area with a heavy load. In fact, under either of these conditions, a no-hover landing or take-off may prove the only possible means. Such techniques permit operation when the power available is just below that required to support the machine in the hover. For training purposes, the pilot can simulate overload conditions by checking the power required to hover and then deducting an inch or two of manifold pressure. He may then use this setting for his maximum available power.

Landing Techniques

86 At high altitudes, landing approaches should be kept shallow. The intention should be to arrive with the minimum increase in power as translation is lost. In confined areas, the approach should again be kept as shallow as possible, and the rate of sink must be gradual. Again, the intention is to arrive with the minimum requirement for a power increase.

87 Before committing himself, the pilot must have previous knowledge of the surface he will arrive upon. His decision to use a no-hover landing is probably based on a limitation of power and, once he has reached the final stages of the approach, he can rarely turn away. The surface, therefore should be proven sound and sufficiently level. The last part of the arrival should be aimed to bring the helicopter down along a constant path until it is stationary six or twelve inches above the ground. At such a low level in the final stage, the pilot is taking all possible advantage of the air cushion. As soon as the machine stops, or even slightly before this, it is permitted to sink on the ground. In the hover arrival, it will be recalled, the cyclic was pressed forward upon arrival to prevent the machine from moving back. This movement also eliminated a small amount of lift that had been retained by the flared attitude; hence it was necessary to raise collective to prevent sink. In the no-hover arrival, no such increase of power is required. In fact, if conditions permit rolling the machine on at a slow walking speed, a very considerable saving can be made in the power required. Such techniques have proved invaluable to operators when carrying optimum loads to high altitudes. The pilot should remember also that maximum RPM are a prerequisite for optimum performance.

Take-Off Techniques

88 Again it is assumed that insufficient power is available for hover techniques, though, of course, the pilot may at any time use a no-hover departure for convenience. To start with, RPM should be increased to the maximum as sufficient collective is raised to lift the wheels off the ground. Cyclic should be inclined forward sufficiently to start translation as early as possible, though some restraint should be used to avoid unnecessary sink. Under very limited power restrictions there may be only sufficient power to just break the machine momentarily clear of the ground. In such a case, it may be quite possible to ease the machine ahead into translation with the undercarriage catching the top of the bumps on the ground. This latter technique, like the landing with residual movement, becomes comparable with the running take-off and landing technique. In all limited power departures, the intent should be to move ahead picking up maximum translational lift while losing minimum ground effect.

(a) Confined Area Departure - In confined areas, normally the collective and cyclic movements are co-ordinated to follow a straight climb path along the minimum slope required to clear all obstacles. However, there are occasions when sufficient ground space may permit a "ZOOM" TAKE-OFF. In this case the helicopter is accelerated ahead very close to the ground. When translational lift is felt, the rotor is allowed to tilt back sufficiently for the helicopter to adopt the minimum climb to clear all obstacles. Such a departure should never be attempted in a manner that would prevent the pilot from completing a gentle flare stop should he fail to gain sufficient translational lift in time.

(b) High Altitude Take-Off - Normally a high level helicopter pad is located in a position where the pilot may literally lunge the machine off the edge of the mountain into the prevailing wind. In such a case, there is probably insufficient power for the helicopter to break ground by normal methods. The pilot may then employ the jump take-off technique and purposely overpitch momentarily. By the time the RPM begins to drop, cyclic has been co-ordinated so that the machine has jumped clear of the edge of the pad. Once into space, the pilot may depress collective to recover RPM; the build-up in speed, as the aircraft translates, will carry the machine away from the mountain. Level flight can be gained with quite a small altitude loss.

RUNNING LANDINGS AND TAKE-OFFS

89 Running landings and take-offs are most frequently used in high altitude fields where insufficient power is available for no-hover techniques, and where some suitable surface is available to provide an adequate run into wind. Such a surface should be fairly smooth to avoid the risk of ground resonance during the prolonged period the aircraft is running light upon its undercarriage. Ground resonance is fully explained in a later chapter. As was the case with the no-hover technique, maximum RPM is used to gain maximum power. For training purposes, the pilot should restrict himself to a power setting several inches below that required to hover. Calm, or light wind conditions, will offer the most opportunity for learning the use of restricted power. In stronger winds, crosswind arrivals and departures may be completed, using similar cross-control or skid techniques to those employed on fixed-wing aircraft. With training in mind, it is best to start the description of these techniques with the take-off.

Running Take-Off

90 To take-off, the helicopter is positioned into wind with a clear run ahead. The RPM are increased to maximum as the collective is raised to the available power limit. The pedal should be adjusted well left to oppose torque, and the cyclic displaced slightly left to counter the tail rotor force introduced by the pedal. The brakes are now released and the cyclic inclined sufficiently forward to start the roll. If the wheels are caught in depressions in rough ground, twitching the tail with pedal adjustments will usually free one side at a time and allow the machine to start rolling. As speed increases, the left rudder setting is reduced to offset the increase of weathercock forces. The reduction of tail rotor power drainage, and the increase of translation lift, will increase both the power and lift available for the rotor. The helicopter will then become lighter on the undercarriage, and in some types, the machine will lift its tail and run ahead while balanced on the nose wheels or the front of the skids. In such instances, it is necessary to ease back on the cyclic when the fuselage attitude changes in order to retain the same rotor disc attitude. Careful balance must be maintained; with the cyclic control too far forward, the machine will tend to dig its front end and trip; with the control too far back the machine will no longer accelerate. Throughout the ground run, the cyclic should be held sufficiently left to overcome the tail rotor sidewards effect. If handled correctly, the helicopter will gather sufficient speed to provide sufficient translational lift, and will rise slowly into the air.

Running Landing

91 After selecting a suitable landing run into wind, the pilot commences a shallow approach, which is completed at high RPM both to provide maximum power reserve, and to minimize the risk of overpitching in the final stages. The approach itself is very similar to that of a fixed wing aircraft. The round-out should be initiated gently at 40 to 50 feet above the ground, and should be completed with the helicopter in the landing attitude about 10 feet up. The round-out is accomplished by a progressive backward movement of the cyclic. A small amount of upward collective should be applied if there is any tendency to sink. The ideal speed for entry into the round-out should be approximately the maximum endurance speed for the type. After round-out the cyclic should be adjusted to maintain the exact landing attitude, fore and aft as well as laterally. The running landing attitude, on most machines, is with the nose positioned just above the horizon. This attitude should prevent landing prematurely on the nose wheels, or skid fronts, as this may start "porpoising". On the other hand, if the nose is too high, damage may be done to the tail rotor or boom, and, in addition, the machine may decelerate too rapidly for good handling. The collective is used to control the sink and the landing, as the speed diminishes after round-out. On lightly laden machines, particularly if the round-out is at such a rate that a mild flare is produced, the collective may have to be depressed to get the machine down. On others, the collective may have to be raised quite quickly to cushion a rapid sink.

92 Throughout the landing roll, adequate RPM should be maintained to provide effective tail rotor control for steering. Sudden torque

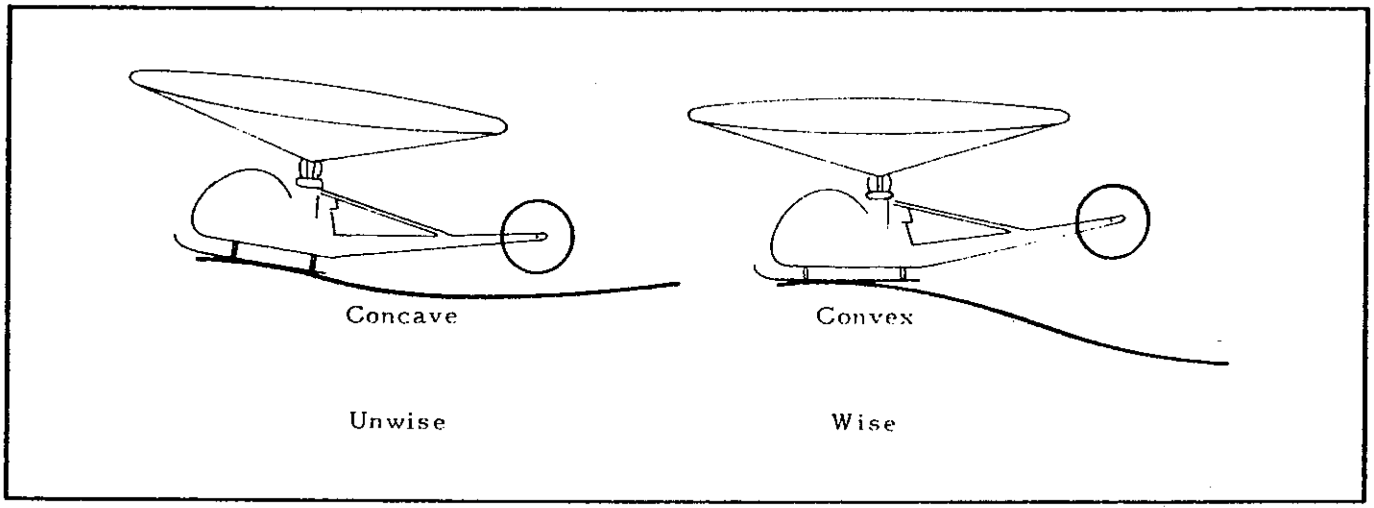


Figure 8-58

changes should be avoided or the machine may veer rapidly in response. If landing on skids on a dry surface, or on wet sand or soil, the collective should be retained high to prevent tripping due to excessive ground drag. If landing on wheels, the collective should be lowered more rapidly to assist in slowing the machine, and to minimize the period of ground resonance vulnerability. Brakes may be used as necessary. The pilot should take care not to pull back too rapidly on the cyclic to slow the machine; the nose may rise suddenly and the tail strike the ground. In addition, quick aft cyclic movements while rolling over rough terrain, may lower the rotor disc sufficiently to permit the tail to buck into it with dire results.

OFF-LEVEL LANDINGS AND TAKE-OFFS

93 While a helicopter pilot will normally land on the most level spot he can find, frequently, in rough terrain, he will be called upon to land upon sloping or uneven surfaces.

Considerations

94 In selecting the landing surface, a newcomer is frequently surprised by how misleading an irregular surface can appear from only a few feet above. Invariably the slopes and irregularities appear to be of much smaller dimensions than they actually are. The best selection can be made only by hovering to one side at the lowest safe level. In making his choice of a landing spot, the pilot should generally avoid landing in a depression. He should stay away from locations where the rear of the undercarriage may sink low, with the ground behind saucering up towards the tail rotor. Convex surfaces are usually much better; they will normally provide extra clearance from the tail, see Figure 8-58.

95 Taking into account the wind direction, the helicopter may be landed facing any way relative to the slope; though, when landing facing down a slope, particular care should be exercised to avoid catching the tail while hovering just prior to initial ground contact. The amount of slope a helicopter can land upon is generally restricted to the limitations of cyclic traverse. However, a machine with high C of G, and an unstable undercarriage may not permit such latitude. Some machines may be stable enough to load or unload while the pilot balances the machine against the side of the slope. In this instance two extra precautions should be taken. First, it is quite possible that the main rotor may catch the slope; the pilot should remember to watch for this while concentrating upon the undercarriage. Secondly, instances are recorded where, on steep slopes, passengers have actually walked up the slope into the main rotor disc.

96 Despite the eddying and swirling effects over uneven terrain, there are occasions when the wind can be used to advantage. By selecting a landing spot where the machine faces across the slope, and where the wind is blowing up the slope, the pilot can take advantage of the extra support the wind provides. The wind will bear against the keel surface of the machine on the down-hill side, and assist in holding the machine in a difficult position. Conversely,

wind blowing down a hill against the side of a helicopter, can add to the difficulties.

Re-Circulation

97 At this stage, an explanation of re-circulation should be given. This phenomenon may vitally affect the machine if the pilot is required to make a landing in a deep depression or near the base of a cliff. It occurs when the ground contour serves to funnel the downwash back up again to where the rotor will re-circulate the air downwards. This can also happen in deep clearings in dense bush, or when landing close to large buildings, see Figure 8-59. The effect is to dissipate much of the supporting air cushion and to accelerate the downward flow through the disc. As a result, the helicopter will sink rapidly onto the ground. Re-circulation can also occur on just one side of the disc. This will happen when only one side of the rotor is close to a dense obstruction. In such an instance, the loss of lift on the one side can force the helicopter to translate into the obstruction.

Off-Level Landing

98 After the pilot has selected his landing spot, the helicopter is moved over the position and held in an exact hover. Extra RPM should be selected to maintain ready response to collective movements. The pilot should be prepared to take plenty of time, he should also expect surprises when he finds out the true slope of the terrain, and he should be prepared to recover instantaneously from any abortive attempts. The collective should now be lowered very slowly, holding the machine in the steady hover with cyclic. No attempt should be made to try to adjust the fuselage attitude with cyclic. While it is possible that the pilot may find a spot that fits the angle of fuselage suspension, most frequently there will be a considerable fuselage attitude change as the undercarriage adjusts to the ground. As the first point of contact is made, the cyclic control must be adjusted in exact unison to prevent excessive wobbles, and to keep the rotor disc in its original hovering attitude. The collective should be further depressed very slowly to permit steady cyclic control of disc attitude. Since the true horizon may now be hidden behind surrounding contours, the pilot must judge his cyclic movement by adjusting it to oppose the slant of the fuselage. This also may be thought of as pressing the cyclic control towards the centre of the rise. If the cyclic approaches the opposite stop before the remainder of the undercarriage is squared on the ground, the pilot may easily return to the hover by raising the collective lever and by centralizing the cyclic to the hover position. Frequently, by moving only a few feet to one side, he may find a better landing position. All the time that the collective is being depressed, the pedal control should be adjusted to match the change in torque. While balancing on one point, the differential effect of wobbles may cause the machine to pivot on one wheel. This effect will also call for pedal corrections. In some instances, the ground contour can be felt out, and the machine can be better aligned, by pivoting slowly on one point until a second

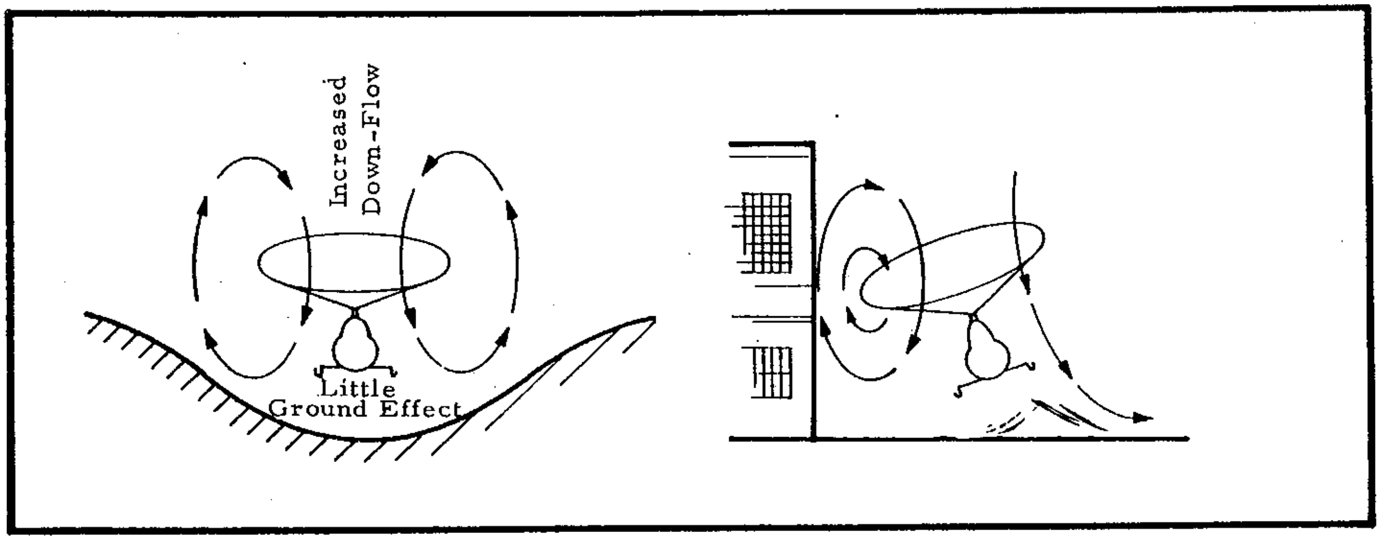


Figure 8-59

wheel, or part of a skid, comes in contact with a high spot. From this position, balance is less ambiguous since the machine can only tilt in one direction when supported by more than one contact point. If difficulty arises during the landing process, or, if the cyclic limits are exceeded as the result of unexpected tipping, recovery is extremely easy so long as high RPM have been maintained. By simply lifting the collective, the lowest point of the machine will rise first. This will immediately bring the attitude back within the orbit of cyclic control. Usually it is best to lift the machine completely clear, since it is quite possible that the sudden return of cyclic purchase may cause the machine to trip inwards against the hill. This would happen if the pilot was at all slow to adjust the cyclic away from the full up-slope position. With the undercarriage completely clear of the ground, such misadjustment can only cause a wobble at the worst.

99 Assuming that the landing has been so far successful, and that the undercarriage now appears to be firmly on the ground, the pilot should not be too ready to relax. For instance, there are occasions when a helicopter may remain misleadingly balanced with one wheel still in the air and catch the pilot by surprise as it suddenly settles. Also the pilot should not relax until the wheels are firmly chocked, if the slope is much in excess of ten to fifteen degrees. Without chocks, the pilot should maintain flying RPM, keeping collective at the ready. The pedals should be adjusted to prevent the nose or tail suddenly swinging down-hill. In fact the pilot should treat the machine as if it was still being flown. A further warning is to avoid shutting down a fully articulated rotor while sitting on a steep slope. At low RPM, gravitational forces will cause the blades to pivot on the drag hinges, first leading and then lagging, as they pass through the down-hill position. Violent sway forces can act on the mast, and may topple the helicopter.

Off-Level Take-Off

100 The take-off seems surprisingly easy after the effort involved in landing. This is particularly true if the machine is lifted abruptly clear of the ground. The cyclic control should be positioned as it was at the end of the landing. High RPM should be maintained while the collective is raised quickly enough to assure a clean lift off. Pedal is co-ordinated to prevent swing. As the machine clears the ground, the cyclic is returned to the hover position. This take-off method may involve a small wobble, but it is both safe and easy. However, when flying a comparatively simple machine such as the H-13, it is not difficult to make a smooth, safe departure by raising the skids in stages, in the reverse manner to the landing.

CAUTION

Where there is any risk of the undercarriage snagging in roots, mud, or any other restraining medium, the helicopter should be eased off very gently. This will allow the pilot time to sense any snagging and permit recovery from any tipping tendencies.

PINNACLE LANDINGS

101 When operating over rough terrain, frequently the most suitable place to land is the top of a pinnacle. A pinnacle landing may vary from easy to difficult dependent upon the wind, the shape of the apex, and the proximity of brush or trees.

Considerations

102 The wind may play quite an important part. If it is strong, it will determine the direction and angle of approach, and also the way the machine may face during the landing. A strong wind will cause eddies over the pinnacle with an updraught in front, and a downdraught at the rear. This downdraught should be remembered during the approach, and should be allowed for by using a higher approach. A second consideration is the decrease of ground cushion effect. This is particularly noticeable over a sharp peak, and calls for the avoidance of a steep, rushed approach. A third consideration is the possibility that the contours may be such that the machine may only be landed facing one direction. Here again, the influence of wind must be considered. If brush or other obstructions are growing up the side, these may also interfere with, or prevent the landing.

Technique

103 After selecting what appears to be a suitable pinnacle, the pilot should descend to make a closer scrutiny. Usually the best way to size up the pinnacle is to carry out a low

level circuit around it. This will enable the pilot to take all the above considerations into account. He may also determine the exact position and shape of the apex by viewing it carefully from at least two sides at low level. In this way, he can decide upon the best direction of approach, and pick the exact landing spot. A high level reconnaissance serves little use other than to provide original selection, since at such heights it is impossible to distinguish the slopes, or the apex accurately. Make the approach as near into wind as terrain and downdraughts permit, increasing the RPM to provide maximum reserve in the hover. The flight path should be kept shallow, taking into account, however, the possibility of downdraughts. A low approach provides a better concept of the apex, and involves less strain when arresting the descent over the pinnacle. The arrival should be aimed to centre the undercarriage over the peak. This may well mean that the helicopter must settle with the undercarriage astraddle the pinnacle, and the wheels resting on opposite slopes. Since it is impossible for the pilot to see how the machine is fitting onto these slopes, he must feel his way. This may be done by lowering the machine until one part of the undercarriage touches a slope. Then, holding the height exactly, the machine is edged gently away from the first point of contact. Again the machine is lowered and similar adjustments are made, until the machine finally rests squarely on its undercarriage. If the helicopter is not quite level, slight adjustments of the tail rotor may assist by rolling a low wheel up a slope and a high one down. Also, in feeling the way down onto the pinnacle, the pedal control may help in swinging the wheels into position to give better adjustment in ground contact.

104 An alternative method of feeling the way onto a sharp peak, is to approach the last few feet with the front wheels level with the top. The front wheels are then rolled forward lightly onto the peak with the apex passing between them. The helicopter is then inched ahead over the peak with the wheels still in contact, until finally the rear wheels come to rest against the peak. If conditions are not too turbulent, the machine may be shut down, provided it is near level, and well secured with blocks. However, it should be remembered that, on a windy day on a pinnacle top, there may be considerable risk of blade-sail.

105 The take-off is very simple. With adequate RPM, the machine should be lifted well clear. As the helicopter moves away, the space beneath may be used to dive and pick up translation rapidly, thereby minimizing the requirement for power.

CONFINED AREA OPERATIONS

106 One of the greatest attributes of a helicopter is its ability to arrive and depart in closely confined terrain. In this environment the helicopter comes into its own, being the only machine which can be moved quickly, and safely, from one location to the next. Yet, such operations are by no means as simple as they may appear to the layman. Steep arrivals and departures over high obstacles are not part of the most natural flight performance of the machine. However, a good understanding of the concept of confined area work will enable a pilot to obtain impressive results with the optimum of safety.

The Philosophy of Confined Area Operation

107 A study of the techniques used by experienced pilots indicates that there are several underlying basic principles. These combine to provide a general philosophy. There is nothing very rigid about the techniques employed, nor should there be. They are as flexible as the helicopter, and vary with every condition and every pilot. However, for training purposes, certain basic patterns are usually provided, and the pilot may add to, or subtract from, these as his experience and understanding broadens. To provide a suitable basic concept, this manual first outlines the fundamental principles and, thereafter, discusses the basic techniques. The principles that are to be kept in mind are as follows:

(a) All departures and arrivals should be made as shallow as space and obstacles will permit. It is better to crowd close to the top of a tree, with plenty of control capability, and with a good view of the path ahead, than it is to sink too steeply into a blind spot while operating with the bare margin of control. This principle ensures that full use is made of all possible advantages:

(1) Maximum translational lift is gained during departure; lift capability, or payload, is not wasted in an unnecessarily steep climb.

(2) Maximum use of translational lift in the approach is retained to the last. There is no sudden surge of power required at the end to kill off excessive sink.

(3) Maximum ground effect is retained to the last in departure, and regained at the earliest during the approach.

(4) There is minimum risk of mishandling the controls and overpitching.

(5) There is minimum risk of settling with power (vortex ring state) in the final arrival.

(6) There is maximum ability afforded to determine exact dimensions of the opening, and to observe clearance ahead and to the side. There is minimum worry about obstacles in the blind spot behind and beneath.

(b) Avoid rushing any stage of confined area arrival or departure. The helicopter gives its best when given time. This way it handles easiest; minimum attitude changes combine with minimum power changes. Only by allowing sufficient time may the pilot exercise maximum judgement.

(c) Every manoeuvre should be pre-planned. The pilot should know the whole plan before committing himself. Before landing or take-off, the pilot will determine his route and technique in the light of all known factors. While airborne a reconnaissance of any unknown landing site is essential. At all times the pilot should have in mind a safe path to abort his attempt if necessary.

(d) At each and every stage the pilot must also be sizing up the next step ahead. Conditions are constantly changing, the operation may be borderline. Blindly following a pre-determined plan may be disastrous. By observing the helicopter's performance at any given stage, the pilot can determine whether he has sufficient reserves of power and control to continue into the next stage. If the pilot is still unsure, he may attempt the next move only if he has sufficient room to abort safely.

(e) Always keep an "ace up your sleeve". At no time should the helicopter be committed intentionally to the use of every available ounce of power. A reserve should always be kept available in case of misjudgement or sudden changes of conditions. For example: always maintain high RPM when near obstructions, this will allow provision for sudden increases in lift without the risk of overpitching. Where possible, depart along a route which will allow a right pedal turn if trouble is encountered; the subsequent decrease of the tail rotor pitch will add power to the main rotor. These reserves may be life savers if used rightly. But, above all, the pilot should never enter a situation knowingly where he will have to rely on the use of such reserves.

(f) Know the conditions and their effects on performance. The pilot should aim to develop a full understanding of the effects of any changes. Experience has frequently shown that a minor change in wind strength, or air density, can make the difference between success and disaster. Such minor changes may be hard to determine, therefore, the pilot must cultivate a sensitivity in this direction. (See Section 1, paragraph 63 - Effects of Atmospheric Density).

Handling Techniques

108 In actual operations it may be assumed that, whatever the size of the helicopter, the pilot will be frequently called upon to carry out confined area arrivals and departures under critical conditions. These conditions may be imposed by only one, or a combination of the following: heavy load, high temperatures, high humidity, or high altitude. The techniques discussed are designed to permit optimum performance under adverse conditions.

Reconnaissance

109 The selection and inspection of a landing area from the air may be compared very closely with the "dummy run" taught early in fixed wing training when learning precautionary loading techniques. After making a rough selection, at cruising altitude, of what appears to be a suitable spot, the pilot then descends to make a close inspection. This amounts to a "drag" run, or a series of runs, along the intended approach and departure paths. By this method, the pilot may safely determine the suitability of the selected spot. He may make a choice of the most suitable techniques and judge fairly accurately the machine's power reserves available at each stage of the final run. To do this the pilot selects a run as near into wind as obstructions and the shape of the opening will permit. Selection of a

landing or departure path should always be based on the principle of least resistance. For instance, where the choice is between a steeper approach into wind, or a shallower approach out-of-wind, the pilot must decide from his own experience which is the better. In the light of his machine's capability, and his own ability, he must choose the approach that calls for least strain and effort. The inspection run can be used to good effect in estimating the slopes involved, and the wind condition. During training where a choice of routes, or methods, is available, the pilot should try out all of them. He will learn much from comparison. The inspection run should take the pilot at slow speed along the intended approach and departure paths, passing right over the mouth of the opening at minimum height. Such a technique permits a true measure of obstacles, and of the routes of least resistance. It provides time to note landmarks which may assist in the final run. The low airspeed and altitude gives a chance to size up the turbulence, and to judge the minimum safety clearance of obstacles. An accurate measure can be made of the power reserve required to make the landing. In addition, only by passing close over the mouth of the opening, can the pilot obtain any accurate concept of its size, and of landing surface. Finally, a departure route and suitable take-off technique can be formulated by the pilot as he completes the inspection. All these factors can be determined during an alert and watchful reconnaissance run, or during a series of such runs.

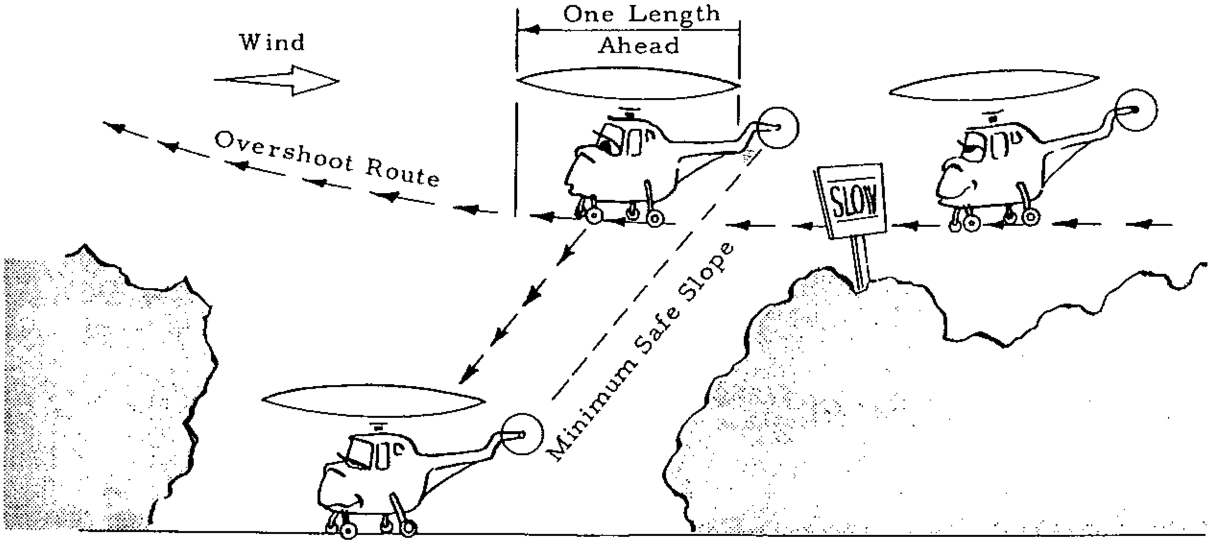
Confined Area Approach and Landing

110 Assuming that conditions are fairly critical, a quite shallow initial approach should be made. Any turns should be gentle. Admittedly there is a disadvantage to this shallow approach. The selected opening may not be visible at a little distance back. However, the earlier run should have made the pilot familiar with the opening's whereabouts in relation to the more conspicuous landmarks. It is also good practice, particularly for a beginner, or for any pilot when there is any doubt, to aim to undershoot the opening by as much as a hundred yards. This technique involves flying the machine through a gentle round-out to a minimum safe height above the trees or other obstructions. Under smooth conditions this may only be four or five feet clear of obstructions. The airspeed should still provide adequate translational lift and should be fast enough to prevent any risk of sinking; there is no ground effect up here. On the other hand, the airspeed should be slow enough to give sufficient time to feel out the situation while decelerating slowly in preparation for the final descent. Hence, the airspeed must be diminished during the early approach to prevent rushing this tree-top stage. During this "drag-in", the pilot has ample time to restrict his groundspeed to the ideal for entry into the particular size of opening. He may increase the RPM to the normal emergency operation setting. He may also trim his controls, if required, and open any doors or hatches that may increase his vision. The course selected during this stage should take advantage of any gaps. Generally, it is better to fly through gaps between obstructions, rather than go over the obstructions. This is true, even if the passage is quite small. Of course, if the air is turbulent, it would then be wiser to go over, rather than through. Finally the pilot can decide whether to commit himself to the landing, or whether to abort the approach. In this position he is already flying a level path, and a glance at the manifold pressure will indicate whether his power reserve is adequate to complete a landing. His judgement of the power reserve required will be dependent upon his present knowledge of the landing surface, and upon the steepness of the approach. If he is satisfied that the surface is good, a no-hover landing can be used safely, and will require very little extra power. If in doubt about the surface, he must calculate on more power reserve to permit a hover landing. In both cases, of course, he can count on some benefits from ground cushion effect. However, in making the decision, the pilot must remember that, under critical conditions, once he has started down into the opening there is no turning back; he must go on down. If he should decide to abort while still flying level, there is little effort required. The machine will readily translate ahead across the opening and depart. A steeper approach would have given less opportunity to measure and decide, and would have made abortion at any stage difficult, or even impossible.

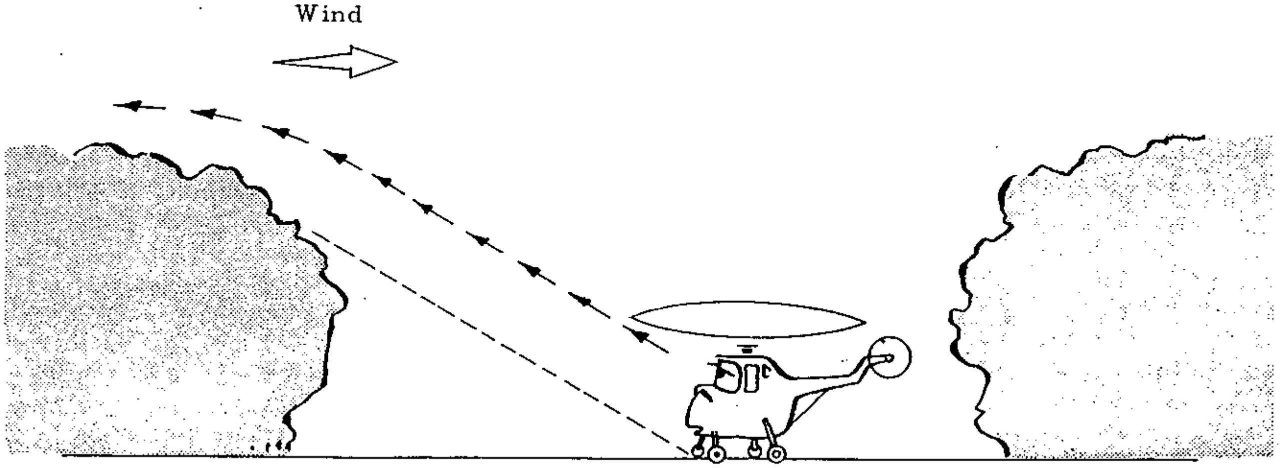
111 Once the machine moves over the edge of the opening, the pilot is in an excellent position to judge the earliest moment to continue his descent forward. He is close enough to obstructions that he has an accurate concept of the distance to be flown to clear his tail.

The flight path should then be constant in slope, though it may involve pedal turns or sidewards flight to avoid obstacles. This constant slope ensures that the machine will diminish the sink at an even rate with the airspeed. No sudden sinks or decelerations are involved requiring corrective control and undesirable increases of power. In addition, translational lift is diminished constantly and smoothly; maximum benefit is retained until ground effect is felt.

112 The slope should be kept as shallow as the confinement will reasonably permit. The pilot, who can see ahead easier than below or behind, does not have to worry about the obstacles that have already passed to the rear. In addition, the landing is much easier to judge when the approach is not excessively steep. The landing itself should be as normal as conditions permit. A no-hover landing may be done onto a level surface if required. If there are any doubts about the surface, normal hover techniques should be applied for off-level or soft surfaces. In some cases it may be impossible to put down, and, on heavier machines, it is fairly safe to unload and reload in the hover. When such a method is used on light machines such as the H-13, the passenger must be warned to ease himself carefully between the skid and the fuselage, and to transpose his weight slowly from the aircraft to the ground. He must be cautioned that any sudden change of weight distribution can cause



All Confined Landings: Approach Slowly



Normal Take-Off: Gentle Acceleration up Minimum Slope

Figure 8-60

the helicopter to lurch into the trees despite the pilot's best efforts. It would be particularly dangerous to step out on the skid and to jump clear. The leverage at this point is very great and weight on the skid would tip the whole machine sideways, necessitating full application of opposite cyclic to hold the machine. The sudden release of the weight would throw the machine completely out of balance in the reverse direction. Several fatal accidents have occurred in this manner.

113 To clarify all the advantages of approaching a confined area with a shallow descent, it is an excellent idea for the student to try out the steep approach. This would start high up, and end in a near vertical descent. He may then compare this with the performance and power settings required for the shallow approach in the same conditions. Of course, the steep approach should not be attempted without adequate power reserves and in smooth flying conditions. Nor should this be attempted into an opening that the pilot has not already proven safe. Also the pilot should avoid any combination of sink and airspeed that may cause the particular type of helicopter to settle with power.

114 The steep approach is the instinctive one, see Figure 8-60. The pilot can see the objective quite easily - AT FIRST: Also, as he gets lower, he will find the helicopter wants to sink in steps, moving forward and then down, each manipulation calling for greater amounts of power and involving more difficult control. Frequently the pilot will find himself trying to hold the helicopter in a near hover fifty or sixty feet directly above the opening. If the opening is small, the chances are that, here, he cannot even see the landing point beneath the blind spot of the machine. He has to lower the machine under difficult conditions until he is close enough to determine the size of the opening; that is, if he is still over it. Should the hole prove too small, he can abort, provided he had sufficient power available in the first place. Assuming that he did not get into these difficulties above the hole, and was able to follow a visible path all the way down, the final arrival would still be excessively difficult, and any attempt to abort and pull back out of the opening may well be impossible.

Confined Area Take-Off and Departure

115 The decision of how much load may be carried out of an opening can only be made after the pilot has sized up several factors. These include: the wind strength and direction, both below and above the obstructions; the atmospheric density conditions; the particular response of his machine, combined with his own ability; and the path of least resistance for departure which will provide the most lift. Then the machine should be backed as far downwind as space permits. This will provide the shallowest departure path. Here the machine should be loaded and then test hovered. This hover will determine the balance of the machine and provide the pilot with the "feel" before departing. Also, the reserve of power available for the climb can be measured, and the best method of departure resolved. If the pilot is fully satisfied that the helicopter will climb readily up the minimum slope path, he may go ahead and do so. In this departure he should handle the machine gently, without any rush, and climb at the setting which will just clear the trees. A high reserve of RPM throughout will minimize the risk of over-pitching. The pilot can develop a safe habit, setting high RPM and refusing to raise the collective any further once the climb is established. This will counter a natural tendency to creep up with the collective and risk over-pitching with subsequent sink into the obstruction. The pilot will normally find, at a set collective position, that the rate of climb will tend to increase due to improved translation. In fact, he will probably find that, to hold the path constant, he may have to depress the nose and ease down on the collective. Once clear of the obstruction, a normal acceleration and departure may be completed.

116 If, during the initial hover, the pilot has any doubts about the capability of completing such a departure, he has several alternate choices.

(a) If there is sufficient room within the opening, he may attempt the first part of the departure. If he finds the machine is climbing satisfactorily, and if he is confident it will continue to do so despite possible lift changes, he should carry on upwards. If the performance proves doubtful, he should make an early decision and abort the attempt. This may be achieved by flaring gently, and sinking back into ground effect within the available space.

(b) If there is space for a fairly long horizontal run in ground effect, the pilot may

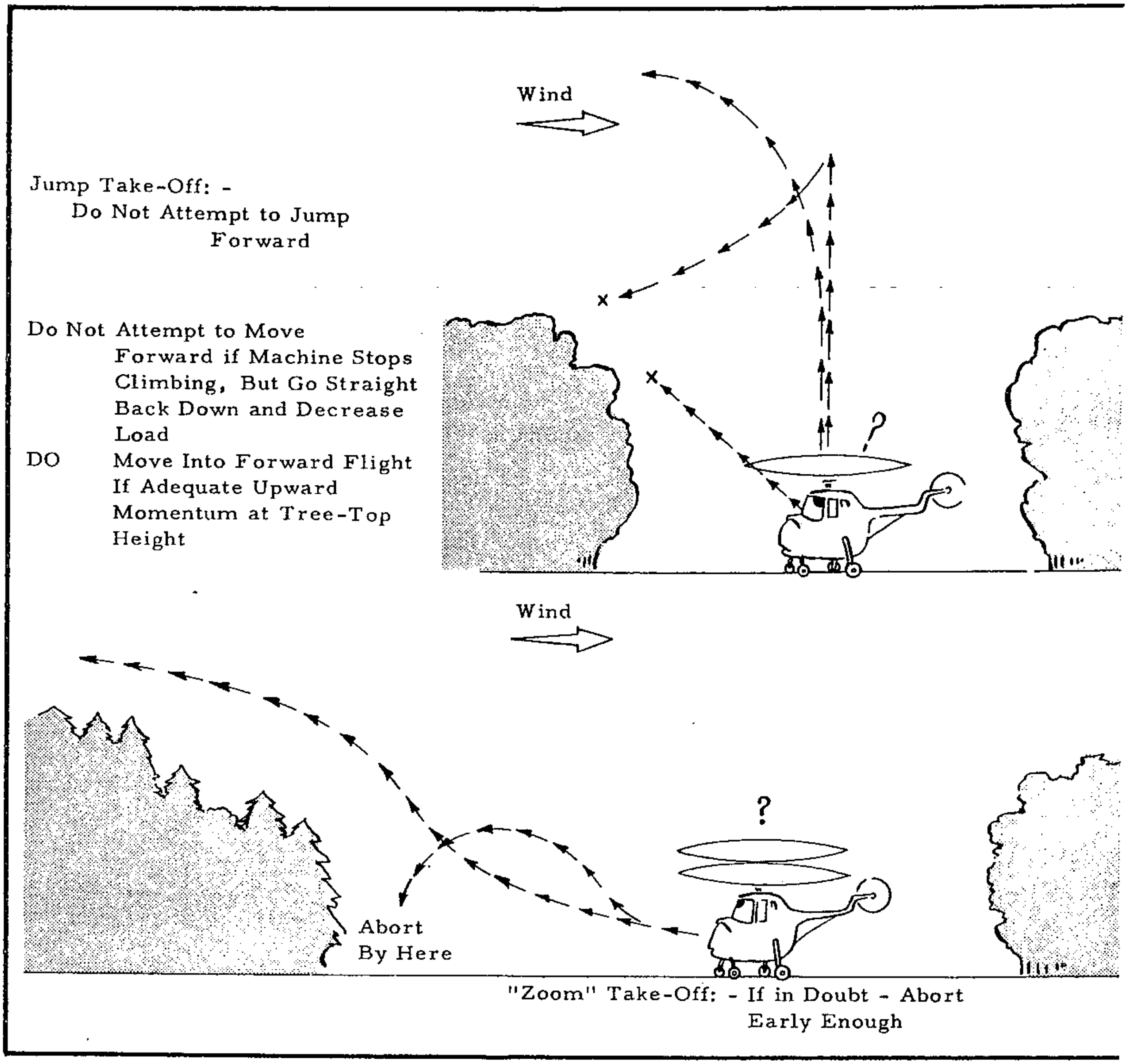


Figure 8-61

attempt to ZOOM TAKE-OFF. This technique was described earlier under "No-Hover Take-Off Techniques" (See paragraph 88 (a) of this Section).

(c) If there is no space to attempt (a) or (b), a VERTICAL JUMP TAKE-OFF may be tried. In this technique the pilot must take most particular care not to overpitch or he may find himself above the level of the trees, sadly lacking RPM see Figure 8-61. The technique entails a departure from the ground, commenced by surging the RPM up to the maximum permissible. The surge is accompanied by a positive upward movement of collective. This way a denser than normal "air cushion" is built up under the machine. This provides the machine with extra support and great upward momentum. Care must be maintained to ensure that the climb is absolutely vertical, so that, if the machine cannot climb into the open, it can be allowed to sink slowly back down the way it came. To make a safe departure, the machine must have adequate momentum to carry it on upwards above the level of the trees. If the momentum is adequate, the pilot may ease the cyclic forward once he is level with the tree tops. Then, while still climbing, the helicopter will gain forward translational speed. The pilot should not attempt to ease the cyclic forward if the initial momentum is only enough to lift the machine only a few feet above the trees. The danger here is that, as the rotor tilts forward in an attempt to pick up speed, the total lift reaction is inclined. This causes a reduction of vertical lift, and the machine will sink as it moves forwards. If the trees are close, the aircraft may strike them before sufficient lift can be recovered.

TRANSITIONS AND QUICK-STOP FLARES

117 Helicopter manoeuvres are rarely rushed, and, as a general policy, abrupt changes in attitude are avoided if they are not necessary. However, a flare is a quite abrupt manoeuvre, and there are many instances where it is used most effectively. There are circumstances where a quick deceleration is imperative, and it is here that the flare is used. For example; a helicopter operating at low level in restricted visibility, or in field operations, may have to stop suddenly to avoid obstruction. The manoeuvre required is termed a quick-stop. Another example is the use of a flare after an engine failure. In this case the machine is dived down in autorotation and the flare is used to arrest both the descent and forward speed prior to landing.

Transitions

118 Practicing quick stops at a fairly low level provides an excellent means of learning both the flare and the recovery. Before such practice is attempted, transitions provide an intermediate training step, they require very little flare and deceleration is slower. The purpose of a transition is simply to move from one position to another above the ground, and is normally practiced into wind. Above all, the pilot should avoid such manoeuvres facing downwind, particularly if the wind is strong. The complete loss of translational lift, while drifting downwind out of ground effect, could be quite dangerous.

119 The helicopter should be hovered into wind about 50 feet above ground. The objective is to accelerate ahead to cruising speed and then decelerate to the hover. This is an excellent co-ordination exercise if the height and heading are held absolutely constant. The helicopter is tilted forward into translation with the cyclic. At first the machine will want to sink; this will call for an increase of collective, and pedal adjustment may be necessary. As translation increases, the cyclic must be eased further forward to maintain acceleration and overcome lift dissymmetry. The increase in translation will require reduction of collective to prevent climbing, and, in addition, the reduction of torque plus the increase of weathercock forces will require less left pedal. After reaching cruising speed, the helicopter is then decelerated. The nose is raised gently to slow the machine down, placing the rotor in a mildly flared attitude. This partial flare may create a slight excess of lift and, for a short while, it may be necessary to depress the collective. Then, as translational lift fades away, the collective should be raised again. The last part of the slow-down, and of the adjustment to the hovering attitude, are quite difficult to co-ordinate without some loss of height. The rotor has to be returned forward to the hover position at just the right speed to kill off the last bit of forward drift, without inducing the machine to back-up. This movement interferes with lift somewhat by removing any flare benefits just as translation is reaching a low ebb. At this height, ground effect is no help. All of these effects put a heavy demand on collective and throttle, and these must be applied rapidly to prevent sink. Up to now, the pedals have been subjected to quite gentle adjustments to keep straight, but this last movement of collective will call for considerable application of left pressure. During the partial flare it may be necessary to decrease throttle to prevent an overspeed, this is due to the autorotative forces in the flare. This reduction of power must be corrected for the moment the collective is raised.

The Quick Stop

120 The quick stop is merely an intensification of the transition. Its purpose is to stop the machine abruptly with the nose faced into wind. There are two main variations: the into-wind stop, and the downwind stop. The latter entails turning the machine back into wind during the stop, avoiding the dangers involved in slowing down while facing downwind. Logically, if the machine is travelling across-wind, a partial turn should be used to swing into wind by the shortest direction.

The Into-Wind Stop

121 As in the transition, the machine is hovered at about 50 feet above level terrain. Such a height provides adequate tail clearance during flares, and also provides ready reference to indicate any slight variations of height. The machine should be accelerated as before, to a fast cruising speed and then placed in a horizontal flare. This requires the cyclic to be pulled back steadily to lift the nose to a higher position than previously. This larger cyclic change produces a considerable amount of lift through the flare. To oppose this, the collective must be lowered considerably, probably to the bottom of its traverse. If the nose is pulled up too suddenly, so much lift is produced temporarily that the machine will zoom regardless of bottom collective settings. It is possible, however, to flare so abruptly that the machine will "mush" horizontally without zooming. This takes considerable practice if the machine is to be kept on a dead level course. Lowering collective in the flare also requires considerable application of right pedal to keep straight. In addition, the throttle should be wound well back to prevent an over-rev.

122 During the latter stages of the flare, the machine will tend to sink, but the pilot should not be in a great hurry to raise the collective until most of the speed is lost. The machine will decelerate more rapidly if he increases the flare attitude to prevent this sink. However, extreme attitudes at low speeds should be avoided, since recovery becomes quite difficult. As soon as the groundspeed is reduced to about 10 knots, the recovery should be commenced. This calls for large and well co-ordinated movements. Cyclic, collective, throttle, and rudder must all be adjusted together; requiring application of the right amount, at the right time, and at the right speed of adjustment. The cyclic must be moved forward to reach hovering position as the machine stops moving. Throttle must be re-opened and collective raised to meet, exactly, the greatly increased demands for lift. Left pedal must be strongly applied to counter the great increase in torque.

123 An alternative way to complete the flare is to handle the machine in the same manner as in an autorotative landing. Instead of raising the collective early, it is held down while the nose is pushed forward to the landing attitude. The machine is then allowed to drop until about 15 or 20 feet above ground, where the collective is raised sufficiently to slow the sink and then to land the aircraft. At this last stage, on many machines, it is advisable not to attempt to complete a landing without re-engaging engine power. Such landings can be difficult and afford no means of recovery if misjudged.

The Downwind Stop

124 The simple, and safe way to stop the machine, while travelling downwind, is to turn it to face the other way while doing the flare. The downwind stop can be carried out turning either way, though most machines will handle easier in the left turn. This is because the nose naturally swings to the left as the collective is dropped in the flare.

125 The same technique is employed as for the into-wind stop except that the machine is rolled simultaneously into the turn. The backwards pressure on the cyclic to flare the machine will serve also to keep the nose in the right position on the horizon during the turn. As the machine faces into wind, the bank is rolled off, and the quick stop completed. Best results are attained by quite casual movements, and the helicopter will slew around in surprisingly little space. One common pitfall is the tendency to start killing off speed while anticipating the turn. A low airspeed entry may mean premature loss of airspeed, and the machine may end up at zero airspeed, across wind, being blown sideways. It should also be remembered, that the stronger the wind, the higher must be the completion airspeed, if the machine is to avoid being blown backwards. Usually, best results are obtained if the pilot makes a point of entering with a high airspeed. Finally, there is little or no risk of stalling in a flared turn. However, if the pilot should keep the collective high through such a turn, he may encounter a brief stall.

Landing from the Turning Flare

126 A frequent use for this kind of a flare is the downwind arrival. This is most useful when operations demand concealed flying, or when it is more convenient to approach the landing from downwind. In this manoeuvre, the machine is allowed to lose height during the turn, and a landing is completed after the helicopter is rolled out of the turn and faced

into wind. To start this arrival, the helicopter should begin to turn as it comes opposite the landing pad, while travelling downwind. The fact that both height and airspeed have to be lost, requires more room and time in the turn. Therefore, a somewhat wider sweep should be made.

127 To the layman this may appear a somewhat hair-raising technique. But, in addition to the convenience of such an arrival, it is safe, and has several advantages. Throughout the turn the helicopter is autorotating, this means that there is no problem of engine failure at such a moment. Also, in autorotation, the helicopter creates no downwash; so, if the approach has to be made close to a line of parked aircraft, minimum disturbance is created, and for the minimum time. Frequently, a landing bay at a downtown heliport may demand a downwind approach. While it may be possible for a powerful helicopter to decelerate downwind and slowly turn into wind, this very technique which looks so much safer to a passenger, may prove disastrous for a less powerful machine. On the other hand, a flaring turn produces its own lift, and the machine can be faced into wind before it is stopped. This, then, is a safe and highly practical technique.

AUTOROTATION

128 It is only rarely that an engine failure occurs, but, when it does happen, the event is sudden and the pilot must be well practiced at the art of making autorotative arrivals. Generally speaking, the autorotation is a much safer predicament than is the forced landing in a fixed-wing aircraft, despite the much reduced duration of the descent. This is primarily because the helicopter can be landed at, or near, zero ground speed in rough terrain. This may wreck the helicopter but rarely are there any injuries. A second great advantage of the autorotation is its immense flexibility which permits rapid adaptation to almost any circumstances. Turns can, and should be, made at low level in an attempt to swing the helicopter into wind. A downwind arrival is bound to be made at a comparatively high groundspeed. Even a sideways impact, while still turning, may well prove safer. Such an arrival, while shallowing out of a flaring turn, has the benefits of both the reduced ground speed, and the gentler rate of sink normally produced by a turning flare.

129 Throughout the autorotation, the helicopter responds quite well to all cyclic and pedal movements regardless of speed; though the machine may feel less stable than usual. At the higher speed ranges, control adjustment may be a little stiff. Most helicopters will sink slowest at the maximum range speed, and this speed, or slightly higher, is normally found best for most purposes. The rate or sink will vary with the type, the conditions of atmospheric density, the load carried, and the airspeed. The vertical speed may, therefore, range anywhere from 1000 to 2500 feet per minute. Obviously such a rate of sink would be hazardous for landing and both airspeed and sink are arrested by using some suitable form of a flare. The collective should not be used prematurely to kill-off the descent, since the available RPM must be retained to carry out the landing. The inertia of the blades will usually provide sufficient energy to allow only three or four seconds for the landing once the collective has been raised.

The Basic Autorotation

130 In truth, there is no such thing as a standard autorotation. An engine failure may occur at any height or heading under any flight or atmospheric condition. However, for the purpose of understanding and practicing the fundamentals, the following basic pattern is suitable for most machines.

131 Starting at about 500 feet above ground, facing into wind with a clear landing run ahead, the machine should be set in a level cruise. After ensuring that there is adequate clearance from other traffic and obstructions, the pilot simulates engine failure. This can be done two ways. The more realistic way is to close throttle and then dump the collective lever QUICKLY to the bottom. The slightest delay may invite excessive coning and great difficulty in recovering. The easier and smoother way is to lower the collective and wind back RPM sufficiently to allow the rotor to autorotate, free wheeling independently. Either way the helicopter will sink rapidly for the first 150 to 200 feet and then stabilize at a more gradual sink. When the engine fails, the sudden loss of torque will yaw the aircraft and must be corrected with right rudder. In addition, it may be necessary to transpose the cyclic to the right. Normally the cruising attitude is ideal for the autorotation, and, if held, will provide a good autorotative speed. In some

machines, after collective has been depressed fully to set up autorotation, the rotor speed may become excessively high. Such high RPM may be absorbed to good effect by a slight upward adjustment of collective; this will provide an increase of lift, and, therefore, a longer and shallower glide. While practicing engine failures, it should be remembered that, while the engine is idling, there is little engine inertia and that the rotor is disengaged. Therefore it is wise to idle at high RPM. As long as the needles of the rotor tachometer register any separation, the engine is providing no propulsion whatever to the rotor.

132 Throughout the descent, the airspeed is held constant with cyclic. If the speed builds up too high, the rate of sink increases and the controls become stiff and jerky. If the speed drops too low, the rate of sink increases and there will also be insufficient speed to obtain an effective flare. The best descent airspeed for the basic autorotation is in the speed range between the best endurance speed and the best range speed. The flare should be entered at a height that will provide adequate clearance for the tail throughout the flare. The rate of pull back should be gradual enough to prevent the machine from zooming up again, but fast enough to prevent sink. However, if the pilot finds himself a little too high at this stage, he can momentarily decrease the rate of pull-back to widen the curve of round-out, and then increase the movement again to arrest the sink. Any attempt to actually push the cyclic forward again, as a result of a high round-out, will only initiate too rapid a sink for subsequent flare recovery. Throughout the flare maintain lateral level and heading with normal control manipulation. The nose should be pulled progressively back, increasing the flare attitude sufficiently to prevent premature sink. The aim should be to level at the last moment, and to arrive at near zero groundspeed. In strong winds, the final flare attitude is shallow and easily attained. In light winds, the attitude may be quite extreme. It follows that any attempt to arrest a machine while headed downwind would call for a most extreme and hazardous attitude and should be avoided.

133 The flare will create an increase of rotor RPM, providing a valuable reserve for the landing. At the end of the flare the nose is eased forward to the landing attitude and the helicopter should be allowed to sink freely until about 20 feet above the ground. The student must fight the urge to pull the collective prematurely, and a drop of even 50 feet or more is quite safe. In fact if he tries a gradual recovery, or attempts to limit the rate of sink, by using collective and throttle, he is inviting trouble by setting up vortex-ring conditions. At 20 feet the student should recover to the hover, co-ordinating collective, throttle, and rudder to hold the position. After recovery, he may practice landing rapidly. Soon he will be able to land direct from the flare using a touch of throttle for safety. Solo power-off landings are not permitted, they will be demonstrated to student by qualified instructors. The touch-down from the autorotative landing should be at a near standstill, though some machines may allow arrivals up to 15 or 20 knots on cultivated terrain.

134 The period of descent is usually too short to attempt restart of the engine. Only in such cases as when the pilot realizes spontaneously that he has just knocked off the switches, or leaned out the engine too far, has he any chance of a re-start. Generally the pilot has all he can handle, flying the machine to the safest arrival, to permit any drills from eclipsing his attention from this most vital aspect. Brakes may be set or re-adjusted to advantage; however, their use is debatable, and varies with the type. On the H-5, any arrival expected to be less than 5 to 8 knots on rough terrain is usually better with the brakes partially on. Their use will snub much of the recoil that tends, otherwise, to build up into a wild dance or resonance.

Turning Autorotations

135 The turning autorotation entails the same procedure as in the basic autorotation, with the addition of a suitable turn to swing the aircraft into wind. The helicopter will turn either way though the reduction of torque will normally favour a left hand turn. About 500 feet, facing downwind is a good height and position to practice from. With practice, 180° turns can be made on most light and medium helicopters from considerably less altitude.

136 When the engine fails, the pilot should rapidly adjust the controls for autorotation and commence a turn via the best route to bring him facing into wind for a landing in the

most readily available open space. The turn should be regulated to adjust for the rate of sink established and the distance required to be covered. The effect of turning is to create a gentle flare. This provides both higher RPM and increased lift. The collective may be raised slightly to take advantage of the extra RPM and to further reduce the rate of sink. While turning the aircraft, the nose should be kept well below the horizon or the airspeed will drop off excessively. When straight into wind, carry on as for the straight autorotation and flare at the normal height. In most machines, the turn, and rate of descent, will become much more casual and easier to control if the airspeed is reduced 5 to 10 knots below that normally used for a straight autorotation. However, any pause, before the final flare and after coming out of the turn must be avoided; in such a circumstance, the helicopter will start to sink more rapidly and the airspeed will be too low for a good flare. In an arrival where the turn is completed at a low airspeed, and where it is still too high to flare, the helicopter should be kept turning and then doubled back, so that the turning flare never stops until the final flare is commenced. Alternatively there may be times when height does not permit the full turn before flaring. In such a case the turn may be successfully completed while banked in the flare, and, should this fail to bring the machine around completely, the pilot can still carry out a safe arrival. By levelling the machine across wind, the pilot may apply quick pedal to face the machine along the line of drift, and roll the machine safely on. It should be borne in mind that, during autorotation, the available right pedal traverse is considerably reduced. Therefore, such a drift correction made to the right would be far more limited than one made to the left.

Varied Speed Autorotations

137 Both straight and turning autorotations may be made more flexible by varying the airspeed during descent. The helicopter autorotates perfectly well throughout its normal full range of flying speeds. However, there are limiting factors which determine the range of speeds which may be used at any given stage. The lowest rate of sink occurs at maximum endurance speed. This rate increases considerably as the speed is reduced to zero and, again, increases at high airspeeds. The maximum range speed is frequently used, though the rate of sink is not the minimum. In this case, a greater ground coverage may be obtained in the reduced period of time. Hence there is a wide range of angles of descent which the pilot may select to reach a suitable spot. However, in most machines, a vertical autorotation all the way down, is impracticable since some airspeed must be regained to permit flaring the aircraft.

138 A good height to start practicing varied speed autorotations is about 700 feet. At later stages, all heights may be tried. First of all, a normal straight autorotation should be started over a given position; distances covered during the descent, and during the flare, should be carefully noted. This procedure should then be repeated, but this time the helicopter should be dived to pick up and maintain maximum range speed. A little higher speed should be used if the wind is strong. While height may appear to be wasted in the early dive, 700 feet will usually provide sufficient height to enable the machine to round-out ahead of the previous position. A gentle entry into the flare at this higher speed will also prolong the flare, and again the distance covered will be greater. Autorotations commenced at 500 feet may provide no extra coverage in the descent if dived, but the prolonged flare that can be made, will still carry the machine appreciably further ahead. Where the problem is reversed, and the intention is to arrive at a much shorter distance ahead, or beneath the starting point, reduced speed or zero speed autorotations may be used.

Zero-Speed Autorotations

139 This type of autorotation is used when the machine is high over the intended landing spot, and when there is not sufficient height to autorotate through 360°. It is particularly effective in strong winds. Immediately the engine is failed, the helicopter is flared abruptly. This prompt reaction will retain height while the airspeed is reduced to zero. Any wind present will then blow the helicopter backwards to a more advantageous position. Care should be taken to level the machine as soon as the airspeed registers zero. Should the nose be held up too long, there is no way of detecting how fast the aircraft is backing-up relative to the air, until the machine suddenly whips around to face the opposite way. Sinking at zero airspeed, and drifting backwards, is an odd sensation but it is quite safe, and the

descent may be continued until recovery of airspeed is necessary. Usually 400 feet or more is required to dive the machine sufficiently to pick up airspeed, and to make a safe flare. During the recovery dive, the pilot should not hesitate to depress the nose well down, the rate of sink will be rapid, but so will be the build-up of airspeed. If, while practicing, the pilot finds his recovery is too low, he may apply upward collective to assist the pull-out. However, he must beware of situations where he attempts to pull-out with the airspeed down around 15 knots as this may involve the risk of inducing the vortex-ring state.

140 There are other variations of autorotation which entail only a partial reduction of speed, where the desired descent path is not so steep. In other cases, the entry height may be such that it is impossible to reduce speed and then recover sufficient airspeed for the normal flare recovery. In such cases the "falling flare" may be used. In fact, on some machines, this technique may be advantageous for most autorotations. The falling flare entails a minimum change of attitude, it is done quite slowly, and, while it requires close judgement, it also provides plenty of time and "feel" to facilitate achieving best results.

141 The falling flare is entered at a height between 150 and 200 feet, and the airspeed may be as low as 20 knots less than the maximum endurance speed. It should not be attempted in strong winds because the airspeed must be reduced down to approximately 10 knots before the sink is arrested sufficiently to allow a safe arrival. During an autorotation where the speed has been reduced to between 40 and 25 knots, the rate of sink is usually quite gentle. At such an entry speed to the flare, the pilot merely raises the nose very slowly to ensure a gradual decrease in the rate of sink. The rate of pull-back should be such that the minimum rate of sink is reached as the helicopter arrives about 20 feet above the ground. If the entry airspeed is adequate, the sink can be stopped completely; if the entry speed is low, the rate of sink can still be appreciably diminished. So long as the arrival sink at 15 to 20 feet above the ground is no greater than the drop-off from a normal flare arrival, there is no problem. For the arrival, the attitude is adjusted with cyclic, and collective is used to arrest the sink and to lower the helicopter to the ground. Such arrivals may be used effectively any time the airspeed is low on the approach. However, its use must be predicted sufficiently to allow at least 100 feet of sink during the flare.

Autorotative Arrivals into Confined Areas

142 In the event of an engine failure over restricted terrain, the helicopter should be turned immediately to provide an approach towards the best opening among the obstructions. During the turn, the pilot should assess the wind strength and the rate of sink against the distance required. He can now determine exactly where he should touch-down, and can manoeuvre to arrive precisely at this point. Accordingly, the rate of turn can be increased or decreased, and the airspeed can be adjusted. Even the flare is extremely flexible. The helicopter can be banked, flown sideways, pivoted, and literally wormed into position by a determined pilot. A flare can be stretched by gentle handling, or shrunk by mushing. In some helicopters a momentary surge of collective, during the flare entry, can leap the helicopter forwards and upwards with surprisingly little loss of RPM. If necessary, as when arriving in an opening among high trees, the flare may be quite high and the helicopter dropped vertically into the gap. Even a long vertical drop may be considerably cushioned by last-minute use of collective.

Low Level Autorotations

143 Engine failure could occur during the hover or at any time during an arrival or departure. Successful autorotations can be carried out, terrain permitting, following engine failure at low level. This is, provided the pilot allows sufficient height during departures and approaches to turn into wind, and provided he avoids hovering at the wrong height or flying too fast, too low. The manufacturer's handling notes will usually warn the pilot against hovering above a height of approximately 10 feet and below an upper limitation of around 400 feet. The danger lies in being unable to gain sufficient forward speed to flare successfully and stop the sink. The handling notes will also warn against high speed low down, since this entails risk of collision during the swerving and tucking that follows engine failures at such speeds. All these critical conditions should be avoided at low level.

144 An engine failure in the low level hover can be handled quite successfully, and many machines will permit actual practice of the procedure. When the engine fails, collective is not moved until the helicopter sinks. Spontaneous application of right rudder and right cyclic are necessary to hold the machine in position. The collective lever is merely raised the last part of its traverse to stop the final sink and cushion impact.

145 When the helicopter is moved ahead into the climb, the normal gentle departure with minimum power and minimum nose depression, allows the pilot best chance to recover from an engine failure. At low speeds and low levels, the collective again should not be depressed but merely used to cushion arrival. The cyclic is used to level the machine; pedal is used to keep straight. The machine will arrive with some forward speed since the pilot can have no chance to initiate a flare. Up around the 50 to 100 foot mark, the collective may be depressed, but the machine must be flared spontaneously to counter the resulting sink and to reduce forward speed. This technique will preclude the helicopter's tendency to drop rapidly at the beginning of the autorotation, and will permit lowering collective and thereby conserve rotor RPM for the landing. At greater heights, up to about 250 feet, the collective should be dropped promptly and the falling flare should be used to prevent the machine from sinking excessively. Engine failures during an approach are usually easier. This is because little attitude change is required, and quite low power is being used until the aircraft is at a quite low level.

Engine Handling

146 The possibility of engine failure can be reduced by proper engine handling. All the rules for the careful handling of normal aircraft engines apply. However, there are some additional considerations, and these are based on the fact that the engine drives the rotor through a free-wheeling unit and a clutch. This means that the normal inertia provided by the propeller blades is missing, and should the engine falter momentarily in flight, there will be no inertia to keep it going, nor will there be any windmill force to help re-start. For these reasons, if the engine is at all susceptible to carburettor icing, the pilot must be constantly adjusting carburettor heat with each change of collective or throttle setting In addition, he must be doubly cautious when leaning out the mixture. Fuel handling will not permit him to drain one tank dry before switching to the next.

Conclusions

147 Genuine engine failures are rare, particularly if the pilot takes the normal precautions required for helicopter engine handling. By flying at a suitable height, and by remaining in good practice, the pilot can greatly minimize the risks involved. Though it may be impossible to save the helicopter from substantial damage due to failures over difficult terrain, the pilot should remember that, so long as he arrives at minimum ground speed, and uses his collective to best effect, he is very unlikely to hurt himself.

HIGH SPEED STALLS

148 Adequate coverage has been given in Section 1 to fully explain the vortex-ring condition and how recovery is made. However, while the theory of high speed stalls has also been explained, the practical aspects require further discussion. For this reason, the only stall to be discussed in this section is the high speed stall. This refers to the retreating blade tip stall and not to the advancing blade compressibility stall, since it is assumed that the latter will not be encountered in contemporary light helicopters.

149 The retreating blade stall occurs when the combination of both cyclic and collective pitch together cause the blade to meet the relative airflow at an angle in excess of the stall. Thus the onset of a blade stall is not related to a fixed collective setting nor to a fixed cyclic setting, but is related to the combination of both. A high collective setting permits a smaller cyclic movement before the stall, conversely, a large cyclic displacement permits only a small collective setting. Interpreted into practical elements, this means that high speeds should be avoided when carrying heavy loads or when flying in low atmospheric density conditions. Added to the effects of cyclic and collective adjustment, turbulence is another factor which changes the speed at which such stalls may occur. The effect of turbulence is to momentarily change the direction of the relative airflow. The stall can happen when the air itself flows upwards to meet the blade at a steeper angle, or when

the machine itself descends relative to the air. One further effect of turbulence is to create greater than normal flexing of the blades, and thereby cause temporary changes to the pitch angle.

150 In conditions where the pilot is cruising close to the stall condition, he may offset the risk of the stall if he increases the RPM. This enables him to retain the same airspeed with a slightly lower collective setting and with the cyclic slightly less advanced. (See Section 1, paragraph 50). Unfortunately the maximum continuous RPM setting for a helicopter is rarely much higher than cruising RPM, so only a slight advantage is gained in this manner. Should conditions be turbulent, the advance in RPM alone is not enough. In such conditions, the pilot will be correcting with cyclic for the buckings and surging caused in the main rotor. Each time the nose comes up he will tuck it down. The danger lies in the fact that the beginning of a blade tip stall is registered by a similar rise of the nose attitude. In this case, the worst thing the pilot can do is to push forward on the stick. It will be recalled that, by so doing, he will further increase the stall on the retreating side of the disc, and as the blade sweeps into a vicious stall, it may well flex down sufficiently to collide with the tail. Here is undoubtedly one of the worst things that could happen to a helicopter. Therefore, when flying with a heavy load on a hot day, or at high altitude, the pilot should decrease RPM AND decrease airspeed. One further point to remember is that, due to atmospheric density changes, the indicated airspeed at which the helicopter stalls, decreases by about 2 mph per thousand feet of climb.

151 Should the stall be encountered, it will require proper corrective action. In many machines the fringe stall is quite mild and merely causes a little interference on the cyclic. It may not even be recognized as a stall. If it is suspected, decreasing the airspeed and increasing RPM will soon correct. Should the machine get into a more positive stall, the pilot should do all he can to decrease the retreating blade angle of attack. If the stall is not extreme, recovery is quite simple. Above all, the pilot must avoid pushing forward on the cyclic control until after the stall is corrected. He must decrease the pitch angle of the stalled blade, and to do this he may depress collective, or ease back on cyclic, or both. Increasing RPM, after depressing collective, will help to defer further stalls once normal flight is resumed at a lower speed.

WEIGHT AND BALANCE

152 The helicopter, like the fixed-wing aircraft, has definite limitations of both all-up weight and balance. The total weight limitations are set by the structural capabilities of the helicopter and allow for the extra forces encountered in turbulence and normal manoeuvres. The pilot may frequently find he has to set his own limitations below this maximum when he is anticipating high level operations, or if, on hot days, he is expecting to work in confined areas. Balance is perhaps more critical. Certainly the usual centre of gravity traverse for the single rotor helicopter is much less than the range of limitations for fixed-wing aircraft; the H-5 permits only 3.8 inches of traverse. These limits are set by the range of movement of the cyclic control system.

Balance

153 The method used for determining the balance point is identical to that used for all aircraft, see Figure 8-62. To obtain the basic weight, the machine is depleted of all loose articles of the type which may be interchanged prior to any normal flight. In addition such other variables as fuel and oil are drained. The machine is jacked up, supported at specified points, and the weight on each jack is measured. For easy calculation a reference datum is used, located at a point selected by the manufacturer, just ahead of the nose. Every weight, or weight change, can be calculated as having a specific turning or lever effect behind this point. The basic C of G is calculated by finding the moments of the weight on each jack; ie, by multiplying the weight by its distance aft of the reference datum. Total moments are then divided by total weight to give the total arm, or the distance back of the basic C of G behind the reference datum. This basic C of G may well be out of the balance limits set for actual flight. It is the pilot's responsibility to ensure that, when everything and everybody is loaded aboard, the C of G is then within the limits. To help in this regard, the basic weight and moment are recorded in 05- -8 of Engineering Orders and kept along with the Form L14 for ready reference. The "dash 8" will also provide the moments

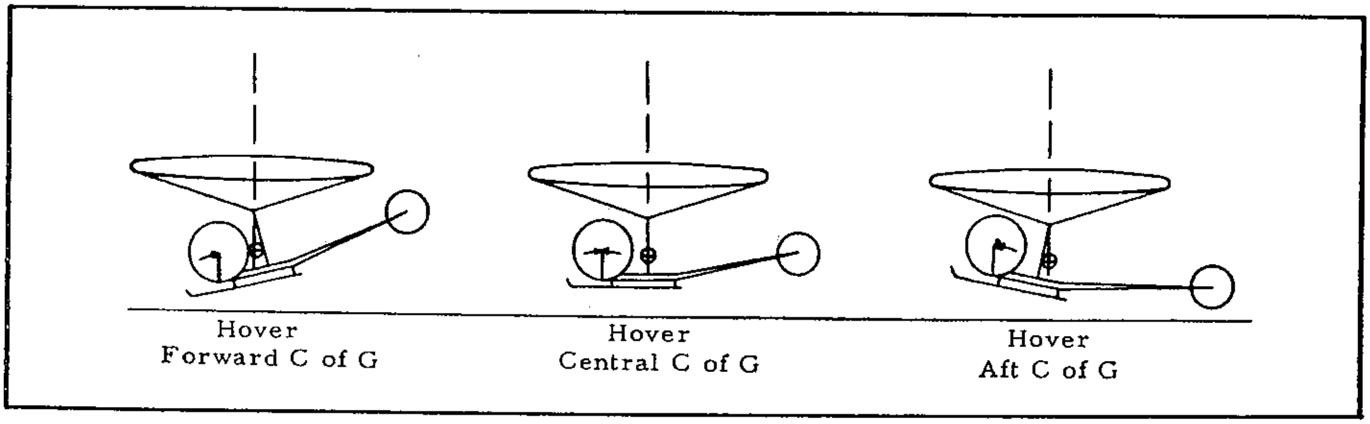


Figure 8-62

for given weights located in passenger seats, baggage compartments, fuel tanks, hoists, etc. The pilot can then readily make a quick calculation to ensure safe flight when any unfamiliar balance condition is anticipated.

154 The practical balance limits are such that, in most helicopters, the C of G traverse will range from a little in front, to a little behind the point of suspension centered through the mast. This range will be predetermined by consideration of landing attitude, proximity of the tail boom to the disc, and the actual limits of cyclic control at full speed ahead or to the rear. Lateral limits must also be considered when using a hoist or external rescue litters. To permit the maximum of ease and safety, when handling heavy loads the pilot will usually ensure that the load is placed as close to the helicopter's point of suspension as possible. For the same reason, the engine mounts, the fuel tank, the sling hook, and all other weight bearing points are located as close to this point as possible. Or, if they are far from the centre, they are usually counter balanced carefully by some opposing object. Frequently, in light helicopters, the pilot may find himself adjusting small counterweights located well ahead or behind the C of G. On some machines the battery is adjustable, and on all helicopters, the fuel load is adjusted, before take-off and in flight, to maintain safe balance limitations.

155 Because the load is so frequently varied, the pilot has ample opportunity to become familiar with the weight and balance effects of any changes. A mental check of weight and balance should be included among the factors considered by the pilot in any pre-take-off check. When in doubt, the pilot should go to the trouble of calculating the C of G location as follows. The weight of each item added to the machine is multiplied by its distance back from the reference datum; this gives its moment. All weights are added together including that of the basic machine. In addition, all moments are added together, to give the total moment of the total weight. The total weight is divided into the total moment, giving the total arm. This measurement locates the distance that the C of G is now located behind the reference datum. The final figure can be compared with the limits set by the manufacturer, and the pilot can readily ascertain whether he will be operating within limits. If the balance is within limits, he will also know whether the machine will hover nose down, tail down, or level.

156 One further weight and balance consideration is the effect of downwash on external loads. When carrying a large deck on the sling, the downwash bearing against the surface may reduce the lifting power considerably. In such cases this effect may be reduced effectively by lengthening the support cable below the area of concentrated blast. External litters, apart from their own weight, add considerably to their turning effect when affected by downwash. To offset this, the litters are usually provided with streamlined covers which are designed to minimize both the effects of airspeed and downwash. The pilot should not think he will gain any advantage by leaving off litter covers to reduce weight. Most helicopters designed to carry external litters, should be re-rigged if it is anticipated that litters may be used. The cyclic is repositioned to provide increased purchase opposite to the forces exerted by the litter.

Flight with Off-Balance Loads

157 Requirements may occur quite frequently for carrying off-balance loads at the extreme ranges of the C of G traverse. Typical instances are: casualty evacuations with external litters, hoisting, and internal transport of awkwardly shaped loads. Under varying off-balance conditions there are specific precautions which should be taken by the pilot.

(a) Before Take-Off - The pilot should be aware in advance which way the helicopter will hang when raised to the hover. However, as in normal take-offs, or off-level take-offs, he should not anticipate the change of attitude by premature cyclic movement or the helicopter will try to tip over in the direction cyclic is applied. Conversely, too late an application of cyclic will permit the C of G to swing rapidly beneath the point of suspension, continuing far beyond its proper alignment. Such an oscillation may carry momentarily beyond the limits of cyclic correction and the machine will traverse rapidly in the direction of its low side. Previous awareness and correct manipulation will enable the pilot to take-off safely under such conditions.

(b) Tail-Heavy Configuration - In this state, the helicopter will sit in the hover with cyclic well ahead of the centre position. As the machine is accelerated to cruising speeds the cyclic will progress towards the forward stop. Naturally the pilot will avoid attempting to fly at high speeds in this condition. If, however, he should enter turbulence and the nose should rise irresistibly, the resulting slackening of speed will usually allow him to regain full control.

(c) Nose-Heavy Configuration - In this state of balance the cyclic will be held well back in the hover. As the machine gathers forward speed the control availability will increase. The pilot should be careful of conditions requiring rapid decelerations or any form of backwards flight, such as turn-arounds or inadvertent downwind arrivals.

(d) Lateral Off-Balance - The pilot should be cautious of turns towards the down side. The cyclic will already be crowding the opposite side in straight flight. The machine will turn readily towards the low side, but will not allow much corrective purchase to recover from the turn. This is particularly noticeable in bumpy conditions.

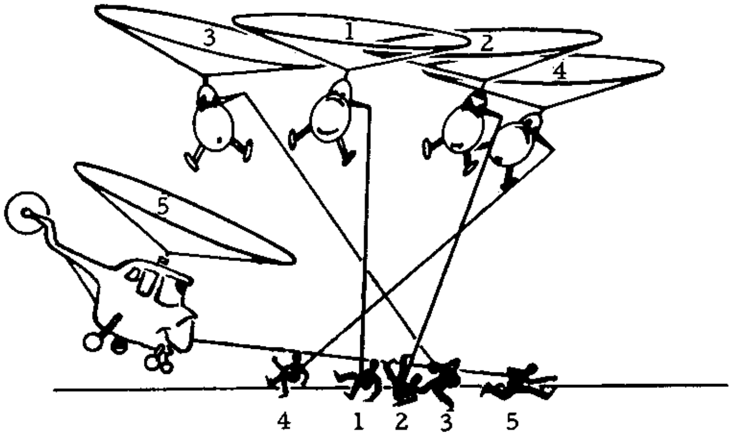
158 In any off-level conditions, the pilot should normally avoid practice autorotations. This is because, when the collective is lowered, many machines require considerable cyclic adjustment merely to maintain the previous attitude. If the cyclic adjustment is in the same direction as the control has already been moved to counter the off-balance weight, it is quite possible that there will be insufficient purchase left to give adequate control. Pilots should also be warned that autorotations with external litter pods have led to fatal accidents, and should be avoided. The risk here is that a litter cover may fly up into the rotor; the quick-snap fasteners may not be adequate to oppose this complete reversal of airflow. In addition, the litters themselves are not adequately streamlined from beneath, and serve to blank off part of the autorotative region of the rotor disc. Reduced rotor RPM may ensue.

HOISTING

159 Hoisting is probably one of the most difficult procedures a pilot is required to perform on a light helicopter, see Figure 8-63. With a larger machine, the addition of the average hoist load has far less critical effect upon the helicopter's ability to remain hovering out of ground effect, and the leverage effect of the load interferes far less with the pilot's ability to balance the machine. In the smaller machine, the pilot frequently has no crewman aboard to help direct him over what is usually a blind spot, nor can he be informed of the exact moment the load will arrive on, or depart from the ground. The effect of such surprise changes is a sudden change in the power required to hold height, and a sudden need to adjust cyclic to prevent excessive tilt from forcing the machine to charge off in the direction of tilt.

160 If weight and space limitations permit carrying a crewman, the problem is eased considerably. That is, provided the crewman is well trained. The pilot should encourage the crewman to direct the operation in much the same way as a GCA operator directs a landing. A progressive commentary, using selected terms, is essential to provide the pilot with a clear picture of the requirement. For instance, if the crewman says "up five", there must be some means of determining whether he is referring to the machine or the object on the hoist. Distances should be given

Figure 8-63



Hoisting in Light Helicopters is Probably One of the More Difficult Sequences Performed by a Helicopter Pilot. Students are Advised First to Practice With A dummy

Figure 8-64

in feet to provide accuracy, and progressive counts should be given as distances diminish or increase.

Control Technique

161 It is assumed that the helicopter is approaching a clearing to pick up a stranded person. The approach is made into wind, and the last 40 to 50 feet should be traversed dead level very slowly. The door should be open and the RPM set high. The hover most probably will be done out of ground effect, and the pilot should gauge the capability of lifting the load without sinking into the tree tops. During the last part of the level approach, the pilot may find his vision cut off completely by the floor of the helicopter. In some machines, cutaways or blisters may permit a continuous view. Whatever the circumstances, the pilot will have less difficulty locating himself directly over the spot if the last stage is completed extremely slowly, see Figure 8-64. The hoist is then lowered as the pilot holds accurate height and position. A few extra feet of cable should be played out to permit leeway while the passenger is attaching himself. In passing, it should be noted that in cold dry winter conditions, helicopters will pick up very high static charges. If the passenger touches the cable before it touches the ground he may get a violent, though fairly harmless shock.

162 Once the passenger is secure, the pilot should take up the slack and ensure that the hoist is directly over the hook. Failure to correct any misalignment will cause the passenger and the helicopter to swing in opposite directions as the weight lifts clear of the ground. As the hoist takes on the weight, the pilot must increase the collective setting, and the power, to prevent sinking. In addition, the tilting effect of the load must be exactly countered by a cyclic adjustment in the opposite direction. If the machine has a trimming system, quick bias should be made. In some machines, such a trim adjustment may be impossible at the time, and compensation should have been previously made. It is just as the load breaks the ground that all the fun begins when training. For this reason, early practice should always be made using a dummy, well away from obstructions. The effect, as the load leaves the ground, is to cause the aircraft to sway and sink at the same time, if the pilot's corrections are not synchronized. The dummy will hit the ground going sideways, and again the load effect on the hoist will be changed momentarily. Wild swings and sways may easily develop, with the machine and the dummy travelling in opposing oscillations. Provided no obstructions exist, the pilot can snub these oscillations by moving ahead and upwards into normal flight, hoisting at the same time. Assuming that all has gone well so far, the passenger is hoisted up level with the cabin door. Here the passenger should secure a firm hand and foothold since he will be unable to climb in until the pilot has played-out a little extra cable. Once safely inside, the passenger may disconnect himself. Lowering a passenger entails returning over the opening, and the reverse of the previous sequence is performed.

DISORIENTATION

163 Probably the most frequent cause of fatal helicopter accidents is disorientation. The helicopter pilot is far more dependent upon constant, adequate, visual reference than is his counterpart in fixed-wing aircraft. This is because the helicopter is less stable in all directions of movement simultaneously, and will change its attitude far more suddenly than the fixed-wing. Also, the reduced acceleration forces and the wobble sensations involved make such changes far harder to detect should visual reference be lost momentarily. Furthermore, the sluggish reaction to control corrections on many helicopters prevents recovery at low levels if the correction is not initiated at a sufficiently early stage. Disorientation may be caused by: white-out, grey-out, height in excess of 1000 feet, mountain effect, wave movements and rapids when close above large bodies of water, and flicker vertigo; or, disorientation may occur if the horizon is lost at any time because of darkness or bad visibility. The fixed-wing pilot may be reluctant to heed these dangers having encountered them to some degree before. But the only way to fully appreciate the inherent danger in the helicopter is to have encountered them and survived. It is hoped the newcomer will pay sufficient heed to this warning, but will still be prepared to fly close enough to these conditions to recognize and understand them.

White-Out

164 The ability to cope in white-out conditions varies with the type of helicopter. The

inherent qualities of stability and recovery response certainly influence the degree of intensity of white-out in which the pilot can operate. Most pilots with winter flying experience will be aware of the difficulties of landing in large open areas with little reference, after a fresh snow fall has whitened the terrain to an even tone. The problem is not significant when clear skies prevail, sufficient light and shadow contrast permits adequate reference. In heavy overcast conditions the problem is increased particularly if precipitation or low cloud limits horizon reference. Probably the most difficult condition is when the sky is obscured with an even, light overcast, and when light precipitation is falling. This condition produces glare which is reflected in all directions, it obscures all shadow contrasts, and relief is almost impossible to detect even within a foot or two of the ground. This is the condition which can most readily produce snow blindness, and is not uncommon in the Canadian North.

165 Under such conditions, the helicopter pilot may be quite successful in making a normal approach and descent, particularly if he uses a nearby bush line as a positive horizon reference. However, the greatest problem arises as the helicopter settles close to the ground. Down at this level, and at any speed less than about 10 to 15 knots, any loose or powdery snow will blow up in front of, and around the helicopter. This great cloud of swirling snow would not be too great a problem if the horizon was clearly distinct beforehand, but on a hazy day, or with no close reference to trees or contrast, control can be readily lost. At night only a little flying snow can be enough to thoroughly confuse the pilot. Very small helicopters may produce insufficient blow to destroy all vision. Some of the larger helicopters seem to displace the snow so rapidly that is possible to see straight down and detect the stationary snow surface beneath. Some other helicopters appear to have no such saving graces. When anticipating such difficulties the pilot can assist himself by passing low over the intended landing path several times to sweep the area clear. To be effective this must be done quite slowly, but the airspeed must be such that the nose of the helicopter remains just ahead of the cloud.

Grey-Out

166 Grey-out in a helicopter is no different from that experienced by sea plane pilots when flying low over water in conditions of poor and moist visibility. This occurs in rainstorms or in low ragged ceiling conditions. In such cases, the grey of the water and the grey of the sky merge in the haze of the horizon. Under bad conditions the pilot will tend to fly lower and lower since this brings the horizon closer and reduces the amount of haze between him and the horizon. Moisture and condensation on the windshield add to the difficulties. At such low levels, a further reduction of visibility may force the pilot inadvertently into the water. This has happened to many bush pilots on float planes, who, because of their slow speed, have usually been fortunate enough to bounce out again. In a helicopter there will be no such bounce. The pilot is advised to stay out of such conditions.

Height Disorientation

167 This is probably the hardest of all to believe, but can readily be tried at any time without incurring much risk. This feeling is usually most pronounced in the smaller and slower moving helicopters. It is aggravated greatly if the machine is less stable than average. Up to 1000 feet altitude, there is no sense of insecurity. On the bigger helicopters, particularly if the cockpit is well framed-in and the pilot has adequate reference to the machine around him, a height of several thousand feet can be achieved before the sense overwhelms him. A passenger will not sense the same problems, the correlation between the remote horizon and the near machine is not his problem. However, the pilot has a very different problem; he is flying an unstable machine whose controls are slow to respond, and whose attitude and movement are uncannily hard to judge. If the machine has adequate instruments he can rely on these to maintain orientation, but, without them at height, ground movement is so remote he cannot tell whether he is going up or down, or whether he is flying forwards, backwards, or sideways. All he can tell is that he is holding the machine near level. The sensation is not harmful if the pilot does not over tense and lose the ability to maintain approximate attitude. With practice, a pilot will become used to high flying, particularly when it is frequently required, as when flying over mountain valleys. However, normal helicopter operation rarely calls for high climbs, and the pilot will normally shun flying over one or two thousand feet unless conditions absolutely demand otherwise.

Mountain Effect

168 The helicopter pilot's dire need for a good horizon can be the source of considerable discomfort and possible disorientation when flying along mountain valleys. The steep walls of the mountains towering above provide no accurate reference to the horizon, particularly when they are capped by sloping ridges. In rough air conditions, so frequently encountered in the mountains, this can have a quite disturbing effect on any pilot not used to the condition. Fortunately, like the height problem, a pilot will get used to the situation, and it will cause him little difficulty. A beginner should be aware of the problem and encroach mountains with caution.

Water Effects

169 There are several conditions where water can present a problem. Glassy water affects the helicopter pilot the same as it affects a seaplane pilot; the only way to tell height is by close reference to a shoreline. Other helicopter problems are encountered when hovering, or when flying low and slowly, over a large area of water with an agitated surface. Once again, reference to a shoreline or fixed object is all that is needed; but, for a pontoon helicopter landing in a large river or lake, or a helicopter hoisting over open or flowing water, it is sometimes impossible to tell whether the helicopter is stationary or not. Under such conditions, the pontoon pilot should land the helicopter with what he knows is a positive forward component to avoid risk of tripping while inadvertently landing backwards. The pilot, hoisting over water, can use the individual in the water for reference, provided there is no blind spot. A further complication of hoisting over water is that the downblast fans out over the water in all directions with a great scurrying movement. This movement of the water surface itself can be distracting, and has caused giddiness to some; but the main problem is that the same pattern appears on the water when the helicopter is still, or when it is moving up to 15 knots in any direction. The instruments are of no use to the pilot in any hover, and, in this case, he has no means of reference at all to maintain an accurate position. A log in the water, or even a boat will help, but it should be remembered that a small boat or a rubber dinghy will blow along with the downwash. Caution should be exercised in approaching survivors in the water. Dinghies have been known to be sucked into the rotor system when the survivor's weight has been removed, with drastic results. Additionally, near accidents have resulted when attempting to hoist survivors from the water with their parachutes still attached. Parachutes can also be sucked into a rotor system and survivors should be picked up at a safe distance from these objects. For safety of operations, survivors should not be hoisted from dinghies. This will make it necessary for survivors to swim away from the dinghies to a safe distance or be assisted in leaving the dinghy by the helicopter crewman.

Flicker Vertigo

170 Disorientation can take many forms, one of the strangest and, so far, least known, is that of flicker vertigo. Medical research is investigating this phenomenon and it appears that it affects only certain pilots under certain conditions. The basic cause is a form of hypnotism that occurs when strong sunlight is passing through the rotor disc and casting flickering light upon the pilot's immediate field of vision. Not very much is known about the dangers of this condition nor the corrective action. However, it does not appear to have been the cause of much trouble so far. It is suggested that, if the pilot is aware of insecure feelings while under such flicker conditions, he may turn the aircraft to avoid the effect, and land.

Night Flying

171 As long as there is moderate reference, night flying represents very little problem. Even autorotations can be practiced safely on a bright night, provided that the surface offers some light and dark contrasts. Landing lights will assist many arrivals and departures, though arriving on light surfaces such as concrete or snow, the landing light can create extremely bright reflections within the canopy and can completely cut off all external vision except straight down. On very dark nights, adequate control can be safely maintained for cruising flight, so long as there is a liberal sprinkling of lights on the ground. With less reference, it is possible to fly many helicopters quite reliably on instruments. However, if turbulent conditions exist, control by instruments is not quite so satisfactory as in the fixed-wing machine. To date the helicopter should be regarded as suitable only for VFR

flight, though it is being flown occasionally IFR, and will undoubtedly evolve into a machine that can be flown under all conditions, and on the blackest of nights.

172 Landings, on black nights, present little problem if there are reference lights on the ground. Without such reference, a letdown would be virtually impossible without the use of aircraft landing lights. A blacked out approach into a large open area can be a most harrowing experience, once below about 35 knots the airspeed indicator is completely unreliable, and the pilot has no way of determining whether the machine is travelling forwards, backwards or sideways. Complete disorientation can occur. Obviously such attempts should be avoided. One last instance of disorientation at night arises when a helicopter is being assisted into a landing by a would-be helper with a bright lamp. Such a person, if he runs around, or swings the lamp, can readily so confuse the pilot that the latter cannot tell whether it is the helicopter moving or the light, and, if the light is bright, the pilot will not be able to tell which way is upwards.

ICING CONDITIONS

173 Icing presents a very real problem for the helicopter pilot. Despite the ease and rapidity with which a helicopter may usually be landed, there are definite dangers whose avoidance calls for alertness and good judgement. Icing will build up on helicopters in a similar manner, and in similar conditions, to ice build-up on fixed-wing aircraft, however, the outcome may present rather different problems. Icing may form on the rotors, on the windshields, on the fuselage, and on the control linkages. During flight in suspected icing conditions, ice may form on all parts of the aircraft simultaneously, or, at other times, it may accumulate only on some parts and not on others. For instance, it is quite possible for icing to build-up on the rotor to quite a dangerous degree before any adherence is noted on the windshield or fuselage. Such variations may be explained by the difference in impact velocities, and by the differing temperatures created as the air is expanded or compressed by various aerofoil effects.

Rotor Icing

174 Both the main and tail rotors may be affected. Usually, when one rotor is affected, the other will be affected to a similar degree. The main rotor is the more vital of the two, because icing, in this case, will interfere with lift as well as control capability. The rate of build-up of ice on the rotor is dependent upon the type of ice encountered, and also upon the tangential velocity of any particular segment of the blade. Usually, ice accretion occurs at a slower rate towards the blade tip; however, a mere covering of 1/8 of an inch around the leading contours of the blades can be sufficient to cause disaster. This high sensitivity to a comparatively thin ice coating is explained by the fact that the load supported, per unit area of the blade face, is extremely high in the outer segment of the disc. This high blade loading may be up to ten times the wing loading of conventional aircraft.

175 In conditions of suspected icing the pilot should land frequently to inspect the rotor. Critical stages of icing can develop rapidly and it is unwise to wait for more obvious signs. On rescue missions, where continued flight is paramount, ice can usually be satisfactorily removed by landing and rapping the leading edges with a pine bough. This practice, of course, is not recommended for non-metallic blades. In flight, the pilot can get some idea of the degree of ice formation by noting any requirement to raise collective that is otherwise unexplained. Also a wise precaution is to bank the machine either way periodically and to check the cyclic response. Any discovery of sluggishness should be followed by a landing at the earliest possible moment. The pilot must be particularly wary of the pitfall of failing to realize the full significance of his predicament soon enough. Under rotor ice conditions, cruise flight may present very little difficulty, but as speed is decreased, there may well be insufficient power, or control, to bring the machine to a hover. Of course, it is possible that the pilot may find a suitable spot for a running landing, but the truth is that good airmanship dictates a precautionary landing long before this. The most significant point of this discussion is that all this CAN happen, and happen quickly, before any visual signs appear elsewhere on the machine.

Windshield and Fuselage Icing

176 Ice will normally appear on the

windshields and fuselage together. In these instances, the pilot can readily observe the type of ice and rate of accretion. Fortunately, this type of build-up will usually form with, or before, the build-up of ice on the critical parts of the main rotor. Under most conditions, this ice will serve as an adequate warning to the pilot to suspect icing elsewhere. A frequent possibility is that ice will form on the fuselage but not on the blades, except near the roots where they are moving comparatively slowly. In this location, ice has comparatively little aerodynamic effect, but the pilot must remember that ice on the fuselage usually infers that ice is forming at much the same rate on the control links of the rotor head. For this reason, the pilot should frequently exercise the controls through their full limits to ensure response.

177 The other effects of windshield and fuselage icing are more obvious. The pilot's forward view will become restricted, but this rarely presents an acute problem. The sideways reference is usually sufficient to permit opening a side window or hatch so that the pilot can get an adequate, though uncomfortable, view ahead. Fuselage icing, of course, has its accumulative weight penalty, and, added to rotor icing, can be dangerous.

Frozen Control Linkages

178 After a near-fatal incident encountered by the writer, a specific word of caution appears well warranted. The exposed parts of the control linkages have already been mentioned, along with the means of recognizing the icing condition and the means of ensuring safe manipulation. On some helicopter types, insidious icing of controls can occur in seemingly unexposed locations. The instance referred to took place in calm air, and in a wet snowfall. No ice was forming either on the rotor or the fuselage, and all appeared to be going well. After a period of time, the second pilot handed over control to the captain. The ensuing slight wobble called for a larger control correction than had been used for some time. The captain then found that the cyclic could only be moved an inch in any direction and that the collective was solid; only throttle and rudder responded. By this time the machine had rolled to a dangerous attitude, but, by considerable force, both pilots together were able to carry out a recovery and complete a crude landing. The rotor was stopped and no ice showed anywhere on the head or on any visible links. Inspection behind the cowlings showed that snow, passing into the main air-ducts leading to the engine, had first melted and then re-frozen onto the chains and sprockets operating the control jacks. The lesson to be learned from this occurrence is that, even when no signs indicate ice accumulation, the controls should be exercised freely and frequently to ensure response.

VIBRATIONS

179 Most helicopters are subject to a variety of quite pronounced vibrations. Some of these vibrations remain constant under all flying conditions, others come and go, or modify, as the airflow and the rotor disc loading changes in flight. The pilot will become accustomed to these vibrations and will readily detect any unwarranted changes. This chapter deals only with the abnormal vibrations. It describes the different types of vibration, and explains how they may frequently be recognized and associated with particular system of moving parts. The pilot should train himself to observe, and to describe accurately, the type of vibration he encounters; by this means, he can do a great deal to facilitate more rapid rectification.

Classification of Vibrations

180 The frequency at which the vibration occurs will give a good indication of its source. A vibration caused by the engine, clutch, engine driveshaft, or any ancillary component driven directly by the engine, will cause a very rapid vibration. A vibration in the tail rotor, or its gear box, will be at a lower frequency, because, at the tail rotor gear box, the drive speed is reduced from that of the engine. The main rotor, the head and its assembly, all operate at a much lower rotational speed, and any vibrations in this group are usually slow enough to permit counting. According to these groups of origin, abnormal vibrations are classified as HIGH, MEDIUM, or LOW frequency. Low frequency vibrations may be subdivided again as 1 for 1, 2 for 1, 3 for 1, etc. This is dependent upon the number of off-balance beats felt per rotation of the main rotor, and is related to the number of blades affected.

Identification and Cause

181 A high frequency vibration may be caused by the engine, or any item which operates at engine speed. Because many parts of the machine may vibrate in sympathy, the exact origin is frequently hard to detect. On the other hand, this vibration is easy to identify, it can be both heard and felt. It will be heard as a buzz, and can be felt in the seat and the floor, though it may not affect the controls at all. A medium frequency vibration can be readily distinguished by the lower rate of vibration. Again, certain parts of the machine may vibrate in sympathy. If the interference originates from the tail rotor itself, it can usually be felt in the foot pedals. Such vibrations may be modified by a superimposed pulse; in this case the basic vibrations again originate from the tail rotor, and the superimposed beat is a product of downwash effects as the main rotor blades sweep past the tail rotor. Some tail rotor vibrations may only be detected during turns, or as side draughts bear against the tail in turbulence. The causes of medium frequency vibrations may be any of the following:

(a) Faulty function of the tail rotor grear box and bearings,

(b) Burnelling, or seizure of control linkage bearings,

(c) Damaged tail rotor surfaces,

(d) Tail rotor blades out-of-track, and

(e) Mass balance of blades displaced.

182 Low frequency vibrations are readily recognizable as such, and careful sensing and observation in flight can frequently help to analyze the cause. Most frequently the problem is the outcome of some form of unbalance in the rotor blade or blades; though it is possible that the rotor driveshaft is bent, and will cause similar symptoms to (b) and (c) below. These forms of unbalance are created by the following causes:

(a) Blade(s) out-of-track - This vibration may be caused by a damaged or warped blade, or by misadjustment of the control links. One blade is providing a little more, or a little less, lift than the others, and is following the other blades along a slightly different track.

(b) Blades leading or lagging out of balance - This may be termed chordwise unbalance, and, on fully articulated rotors, is caused by faulty damper action. On semi-rigid rotors, the cause is usually a misadjustment of the drag link or its equivalent.

(c) Mass unbalance - This may be caused by moisture seepage in the blades, by the loss of a counter-balance weight, or by damage to the blades.

183 When a blade(s) is out of track, the machine will develop a vertical limping motion, frequently the pilot will feel a feedback into the cyclic control system. Careful observation of the edge of the rotor disc will often show that the blades are not all correctly aligned. A vibration from this cause will be evident at all stages of flight, though it may be more aggravated at high speeds or under heavy loads. Chordwise unbalance can usually be sensed as a combined vertical and horizontal displacement affecting primarily one side of the machine. With fully articulated rotors, it is most noticeable when the rotor is flapped to a marked degree. In the hover it diminishes. In such cases, suspicions may be confirmed by a damper check, In the hover, the cyclic is very quickly swung in a circle in the direction of rotation of the rotor. The cyclic is neutralized and the machine will settle down. Throughout this check, the machine will remain fairly stable, but there will momentarily be a bumping in the head as the dampers are exercised to their limits. This vibration should diminish after two or three further rotations. If the bumping is irregular, or unduly slow in elimination, a faulty damper or set of dampers is the cause. Mass unbalance usually takes the form of a lateral vibration, and is fairly constant throughout all flight conditions.

184 The helicopter should not continue to be flown if any marked vibration is present. The pilot should return the machine for adjustment, and while doing so, he should make careful observations. He should, at the same time, avoid arriving at any hasty conclusions. Full diagnosis should rest in the hands of the maintenance technicians.

TRACKING

185 Whenever the rigging of the helicopter is changed, or, whenever a rotor blade comes out-of-track, a process known as tracking is

carried out. The purpose of this procedure is to determine which blade, or blades, is out of setting so that suitable adjustments can be made. The details of the procedure may vary a little with the types of machines and equipment, however, the principle is fundamentally the same.

186 To carry out this operation, a near calm day is selected to ensure that gusts do not interfere with the measurements to be made. Prior to engagement, each blade tip is smeared with a different coloured grease. A position is carefully marked on the ground beneath the tip of a blade, in a location which can be readily seen by the pilot from the cockpit. This point is later used to locate the tracking flap. The rotor is then engaged and run at a pre-determined throttle and collective setting. This setting is usually indicated in the relevant operating instructions; and, in most cases, is designed to simulate the operating stresses placed on the rotor under load. Once this setting has been selected, cyclic is held perfectly still and the pilot signals the crewman with the flag, to make the measurement. The flag is a strip of white canvas held securely in a vertical position, in an open frame beside the top of the pole. This is raised beside the rotor disc and then carefully edged until the blades bear against the flag. The flag is then withdrawn and the rotor stopped. Each blade leaves its own coloured mark, and any blade which is more than an inch or so away from the alignment of the others should be adjusted to bring it towards them. Such adjustments are made by locknut adjustments on the pitch control links, or by means of small trim tabs on the trailing edges of the blades. An accurate result is normally gained through a series of several runs and adjustments.

GROUND RESONANCE

187 Ground resonance can be a fearsome thing. Should it occur, and if the pilot fails to correct, the helicopter can be disintegrated within a very few seconds. Fortunately, ground resonance can usually be avoided, and, if it arises, it can usually be eliminated quite readily. Generally speaking such resonance will only occur in a fully articulated rotor, though it is possible that similar sympathetic vibrations can be created with semi-rigid rotor heads when badly out of balance. Ground resonance can only occur when the helicopter is resting very lightly on its undercarriage, and when some force sets up a rhythmic motion of both the undercarriage and the blades. It will only happen, therefore, during landing, take-off, or run-up. Under such circumstances, a displacement of the centre of gravity of the rotor takes place and the blades lead and lag in unison with the rhythm of the undercarriage as it dances on the ground. The actual resonance takes place as the wheels tap against the ground. Resonance may develop into the rhythmic build-up of a dance between a pair of wheels, or it may involve each of the wheels in rotation. As a wheel touches the ground it recoils in harmony with the swing of the rotor, adding impetus to the sway of the head, which in turn accentuates the pounding of the wheels. This wild dance can build up, from nothing, into a wild flailing within a few revolutions of the main rotor.

Causes

188 Some helicopters seem to be more vulnerable than others, even though they may be of identical types. The causes range over a pretty wide scale, and include: misadjustment of the rotor blades; misadjustment of the undercarriage; mishandling of the controls; irregularities of the landing surface; and, it seems in some cases, a mere susceptibility to ground resonance.

(a) Faulty Rotor - Any form of rotor imbalance during the landing can quite readily start resonance. The centre of mass of the rotor is already eccentric, and a light contact with the ground may be all that is needed to cause further displacement.

(b) Faulty Undercarriage - Misadjustment of oleos, or faulty tire pressure, can accent any sensitivity to a rhythm during landing. Such a sway, if it coincides exactly with the normal beat of the rotor, can lead to resonance.

(c) Faulty Handling of Controls - If the cyclic is rocked laterally, or rotated at a critical stage in landing, again the C of Mass of the blades may be disturbed sufficiently to induce resonance. Landings upon the apex of a particularly sharp pinnacle are particularly sensitive to small wobbles initiated through the cyclic. If the apex has a hard surface, vulnerability to resonance is increased.

(d) Effect of the Landing Surface - A light touch-down, from a hover landing into a hard surface, will more readily induce resonance than a similar touch down on grass or a soft surface. A soft surface absorbs any tendency to recoil, whereas a hard surface aggravates it. During a rolling landing or take-off, surface undulations can readily induce resonance. Contact of first one wheel then another can become a wild dance if the undulations are severe. Even on a good cement runway, the undulating effect of running lightly over the joins of cement slabs can cause resonance. One of the worst features of ground resonance is that it can most readily occur during a prolonged ground roll. This means that a heavily laden helicopter, using a high altitude field, is very vulnerable.

Corrective Action

189 Prevention is usually better than cure. Prior to take-off, ascertain, that the undercarriage is properly serviced, and do not accept a machine with leaking dampers or with other obvious faults. If, after becoming airborne, the rotor is found to be out of balance, land either on soft ground, or land positively enough to squash out any sympathetic beat tendencies that may develop between the wheels and the ground. If, at any time, the machine goes into resonance there will be absolutely no doubt in the pilot's mind that it is occurring. By quickly raising the machine off the ground, all resonance will immediately disappear. Unfortunately there are times when load conditions prevent such action, the typical instance being a rolling take-off at height. The only possible cure is to squash out the resonance at the earliest moment. This is done by dumping the collective as abruptly as possible and closing the throttle. Hard application of the rotor brakes can help to destroy the sympathy of the beat in the head, and judicious use of the wheel brakes can help to snub the rhythm of the wheels.

CONCLUSION

190 No manual dealing with a contemporary subject can ever be complete regardless of how thoroughly each topic is covered. Change and development are continuous, and can never be completely recorded. The helicopter is constantly changing and so are the techniques required to operate it. This work is a mere

Figure 8-65

record of this School's experience, its views and opinions. The knowledge contained is limited primarily to the types of equipment used at the school, and to the purposes the school most frequently serves. Contact and discussion with civilian operators, and with the Armed Services of other countries, has helped considerably in broadening or reaffirming these views. Certain topics, such as night flying, instrument flying, high altitude operations, and sling loading have been treated very briefly. This School's present level of knowledge of these fields is too limited to warrant authoritative record. As new techniques are tried, and proved, additions and amendments will be submitted.

EO 05-1-2L

ROYAL CANADIAN AIR FORCE

SELF-SEALING FUEL & OIL CELLS PACKING, STORAGE, MAINTENANCE & SALVAGE

(This EO replaces EO 05-1-2L dated 19 Jun 59)

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

25 AUG 60

LIST OF RCAF REVISIONS

DATE	PAGE NO	DATE	PAGE NO

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SELF-SEALING FUEL AND OIL CELLS PACKING, STORAGE, MAINTENANCE AND SALVAGE.

GENERAL

1 The following instructions apply specifically to self-sealing fuel and oil cells of American design, in which the flexible layer is immediately adjacent to the contents. However, certain of the precautions listed apply equally to the British type of self-sealing tanks, in which the sealant layer is applied to the outside of a metal tank.

PACKING

2 All cell openings are to be adequately covered with moisture-resistant adhesive tape or other suitable material to prevent entrance of foreign matter into the tank. The cell is to be supported in its crate with lint-free padded wooden supports which are to be arranged in a manner to ensure that no damage will result to the fittings or cell liner during shipment. Care is to be exercised when nailing the shipping crate together, to ensure that no nails protrude into the crate or the cell and that the fittings do not jam against or protrude through the crate. Instructions for correct handling and storage are to clearly marked on the crate; e.g., USE NO HOOKS, THIS SIDE UP, and any other applicable instructions.

STORAGE AND HANDLING

3 Since cells deteriorate with exposure to light and heat and through improper handling, the following instructions are to be rigidly conformed to by all concerned:-

(a) Store cells in a clean, dry, dark and cool place, away from operating electric motors, with sump drains open.

(b) Always store cells in shipping crates. To ensure that these containers are available when required, they should be dismantled with care and stored after new or reconditioned cells have been removed from them for use. All personnel handling these crates are to exercise the degree of care consistent with contingent re-use.

(c) Crated cells are not to be stored over three high. If cells are not crated, they must be stored on suitable padded racks, resting on the largest surface, i.e., in position in which it is installed in the aircraft. Care must be exercised to ensure that cells are not stored in any manner which may cause damage to protruding fittings.

(d) Suitable supports, padded with lint-free material, are to be installed inside semi-flexible cells, while stored to prevent their distortion. Where cells are equipped for external support, these are also to be fitted during storage.

(e) Cell fittings or openings are not to be used as hand grips during handling or installation.

(f) When installing spare cells, always install first the cell which has been longest in storage.

MAINTENANCE AND INSPECTION

4 The following inspections are to be carried out on all aircraft equipped with self-sealing fuel cells:-

PRIMARY INSPECTION

(a) Through inspection doors or drain openings, where practical, visually inspect the adjacent tank structure and all cell fittings and connections for signs of leakage, indicated by swelling, softening, or by a soggy, swollen or delaminated appearance. Leakage only occurs in a very advanced stage of deterioration, in which sealing layers of the cell are completely deteriorated.

PERIODIC INSPECTION

(b) Check the fuel strainers for the presence of rubber particles. Any accumulation of rubber particles will indicate advanced deterioration of the cells.

(c) The interior of each cell is to be inspected with the aid of a mirror and safety light through the filler neck, inspection door, fuel contents gauge opening, or sump for the following:

(1) Diffusion of liquid through the synthetic liner, indicated in its initial stages by a swelling of the cell wall, with later stages recognized by a soggy, swollen or delaminated appearance.

(2) Loosening of the seams of the liner.

(3) Loosening of the fittings from the liner.

NOTE

> If there is any indication of the above, cells are to be removed from the aircraft, properly crated and returned for repair or disposal action.
>
> On completion of the above inspection, a capacity check is to be carried out by comparing the amount of fuel required to fill the tank with the amount specified adjacent to the filler cap.

TYPES OF CELL FAILURES AND CAUSES

5 The most common types of fuel cell failure associated with normal service are:-

(a) Diffusion of liquid through the synthetic layer, causing sealing swelling and subsequent deterioration.

(b) Collapse of the cell.

(c) Loosening of the fittings from the liner.

(d) Leakage between cell and surrounding structure.

NOTE

These failures may generally be detected as follows: The diffusion of liquid through the synthetic liner, loosening of seams in the liner, and loosening of the fittings from the liner, found by visual and hand inspection of cell interior. Soft swollen area of cell surface, wrinkles in liner, or separation of the sealing layers from the liner, indicate leakage or diffusion of the fuel. The result of the capacity test noted in para. 4 (c) will indicate whether the cell has partially collapsed. Leakage of fuel between the cell and surrounding structure may be the result of improper attachment of fittings or partial failure of tank outlet connections. The first sign of failure of this nature in cells installed in a sealed structure will be collapse of these cells.

NOTE

In order to determine the serviceability of a cell, defects and acceptable limitations are included as Appendix "A" to this Engineering Order.

GENERAL PRECAUTIONS FOR REMOVAL AND INSTALLATION OF CELLS

6 The general precautions outlined below are to be adhered to in all cases:-

(a) All inner supports and outside stiffeners are to be removed prior to collapsing the cells for installation or removal. These may be replaced by coating with soapy water. DO NOT DRIVE THEM INTO PLACE OR USE OIL OR GREASE.

(b) Ensure that all fittings are disconnected from the cell before removing from aircraft.

(c) When possible, cells are to be warmed to a temperature of 26.7°C (80°F) before collapsing and are to be left in a collapsed condition only as long as necessary for installation.

(d) Do not bend cells in the vicinity of fittings or inspection doors, or pry on rubber fittings with any tools.

(e) Before entering cells, remove all sharp instruments from pockets, remove shoes and cover bottom of cell with a heavy lint-free cloth. Light bulbs must not be allowed to come in contact with the interior of the cell. Compliance with the provisions of EO 00-80-4/7 is required.

(f) All openings must be covered when the cell is removed from the aircraft to prevent entrance of foreign matter.

(g) The torque to be applied to all fitting connecting screws is not to exceed 25 inch-pounds, regardless of the manufacturer's instructions. This torque limit does not apply to spider type fitting attachments, in which case the manufacturer's instructions apply. The above torque loading should be applied with a torque wrench, if available. However, a four inch spanner may be used in lieu of the torque wrench. The following procedure for connecting rubber moulded fittings is recommended:-

(1) Inspect fittings and threaded parts prior to installation to ensure freedom from foreign matter, damaged threads, or other defects.

(2) Align mating surfaces so that screws or bolts can be started with minimum torque.

(3) Distribute a sufficient number of bolts uniformly about the fitting to ensure an even seating of the mated surfaces.

(4) Install the remaining bolts, then torque all bolts to the specified value, using a diametrically opposite sequence.

(5) If torque drops after bolts have been torqued to a specified value, do not tighten bolts to regain torque value; this is normal and is due to "cold flow" of the rubber fitting surface. Instead, loosen all bolts and completely retorque fitting.

NOTE

Excessive torques result in deformation of synthetic rubber, contributing to compound failure and fuel leakage. If after securing the fittings as directed, a leak is detected, the torque should be checked. If it has not fallen greatly below the initial torque, or below 20 inch-pounds, the mating surfaces should be examined for the cause of the leakage. Overtightening must not be resorted to, as it will definitely result in failure of the fitting and surrounding cell area. This may not be evident on surfaces which are dry and have not been exposed to fuel, but when synthetic rubber is subjected to extensive compressive forces and exposed to the action of fuel, it will crack or chunk off over the mating surfaces and delaminate on the edges.

(h) Seam sealing materials, such as Prestite or Sealube, are not to be used as rubber to rubber and metal to metal applications for self-sealing cells. These materials contain solvent detrimental to synthetic rubber, and also have a lubricating effect on synthetic rubber, causing increased "cold flow". Should some of the paste accidentally get into the screw threads, and into the bottom of the blind tapping, the increased friction results in rapid torque build-up without corresponding cramping pressure on the fitting stalk.

WARNING

Personnel working with their heads in these cells, must use smoke respirators, or gas masks having a breather connected by a tube to the outside air instead of to the usual gas mask cannister.

SALVAGE

7 For salvage action proceed as follows:-

(a) The cells are to be removed from the aircraft as soon as possible.

(b) Before commencing salvage or entering the cell, it is to be completely drained, flushed and aired in accordance with the procedure outlined in EO 00-80-4/7.

(c) See procedure outlined in paras. 6(b), (d) and (e).

(d) All serviceable parts, such as detachable fittings are to be salvaged and stored with the cell for re-issue.

(e) After removal, the cells are to be immediately inspected by qualified personnel for evidence of damage or deterioration, then brushed or sprayed internally with engine oil, Ref. 34A/35. Serviceable cells are to have all apertures sealed in accordance with EO 05-1-2AV and tagged for re-issue. Damaged cells are to be returned to supply section for repair.

(f) Cells which require repair will not be treated with oil. They are to be properly crated and returned for repair.

LISTS OF KNOWN FUEL CELL AND FITTING DEFECTS AND ACCEPTABLE LIMITATIONS

1. SERVICEABLE SELF-SEALING CELLS.

a. Cell Interior:

CONDITION	LIMIT
(1) Loose liner at throat of fitting.	1/2-inch looseness in width around entire circumference at throat of fitting (see figure 2).
(2) Edge looseness at liner lap.	Acceptable up to 1/4-inch width maximum length of liner lap,provided 1-inch bond is maintained.
(3) Edge looseness on liner reinforcements, corner patches, and chafing patches.	1/2-inch maximum looseness,provided loose area does not exceed 15 percent of total area. Blisters or separations other than in the edge area allowable up to 15 percent of total area.
(4) Looseness under cemented components such as attaching straps, baffle shoes, etc.	15 percent of individual area, provided 1/4-inch bond is maintained around the edge (see figure 3).
(5) Blisters between liner and fitting flange.	1/4-inch maximum dimension; maximum one per lineal foot and two per fitting provided 1-inch bond is maintained (see figure 2).
(6) Damaged grommets in accessories.	Acceptable provided serviceability is not affected.
(7) Damaged coating on accessories (metal, wood or rubber).	Acceptable provided rust, corrosion or other deterioration is not present.
(8) Checking due to weather, ozone, dry cracking or surface imperfections	Acceptable provided there is no indication of activation.
(9) Blisters in liner laps.	1/4-inch maximum dimension; average one per lineal foot of splice with a maximum of five in any one 5-foot length of splice (see figure 4).
(10) Blisters, delaminations, or ply separations.	1-inch maximum dimension provided there is a 6-inch bond between blisters and no more than one per square foot of total cell area.
(11) Channels in inner-liner laps.	1/8-inch by 3-inch maximum dimension with a maximum of one in any 5 lineal feet of splice (see figure 4).
(12) Channels around entire outer edge of fitting flange.	1/4-inch maximum width (see figure 2).
(13) Channels at tapered construction step-off area or edge of lap splices of any ply.	1/4-inch maximum width entire length of lap (see figure 5).
(14) Open end channels in three-ply liner overlaps or tailored corners.	1/8-inch by 3-inch maximum dimension provided 1-inch minimum bond is maintained between end of channel and sealant (see figure 4).

Cell Interior (continued)

	CONDITION	LIMIT
(15)	Cuts or holes in inner-liner.	Not acceptable.
(16)	Buffing through inner-liner.	Not acceptable.

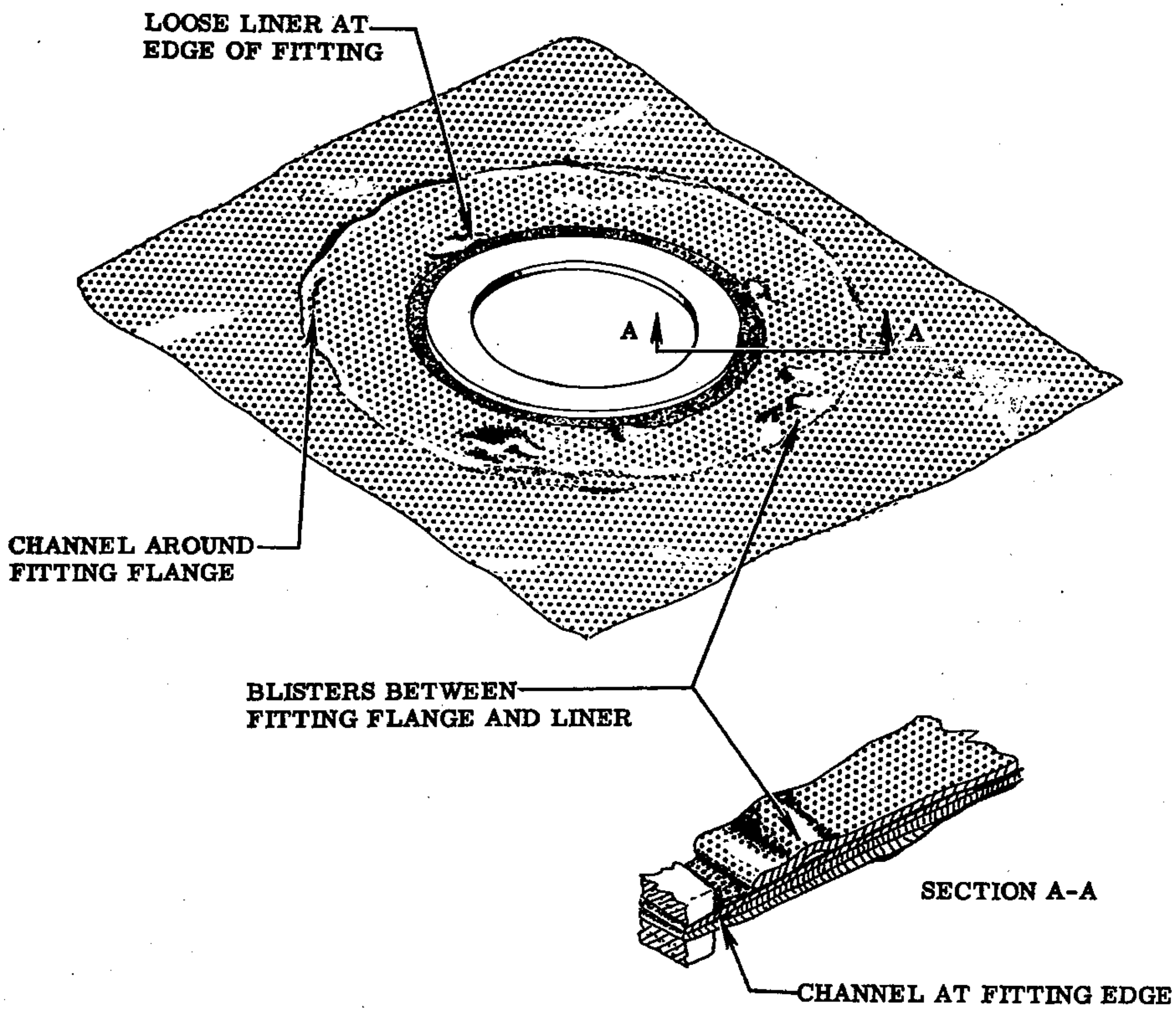


Figure 2

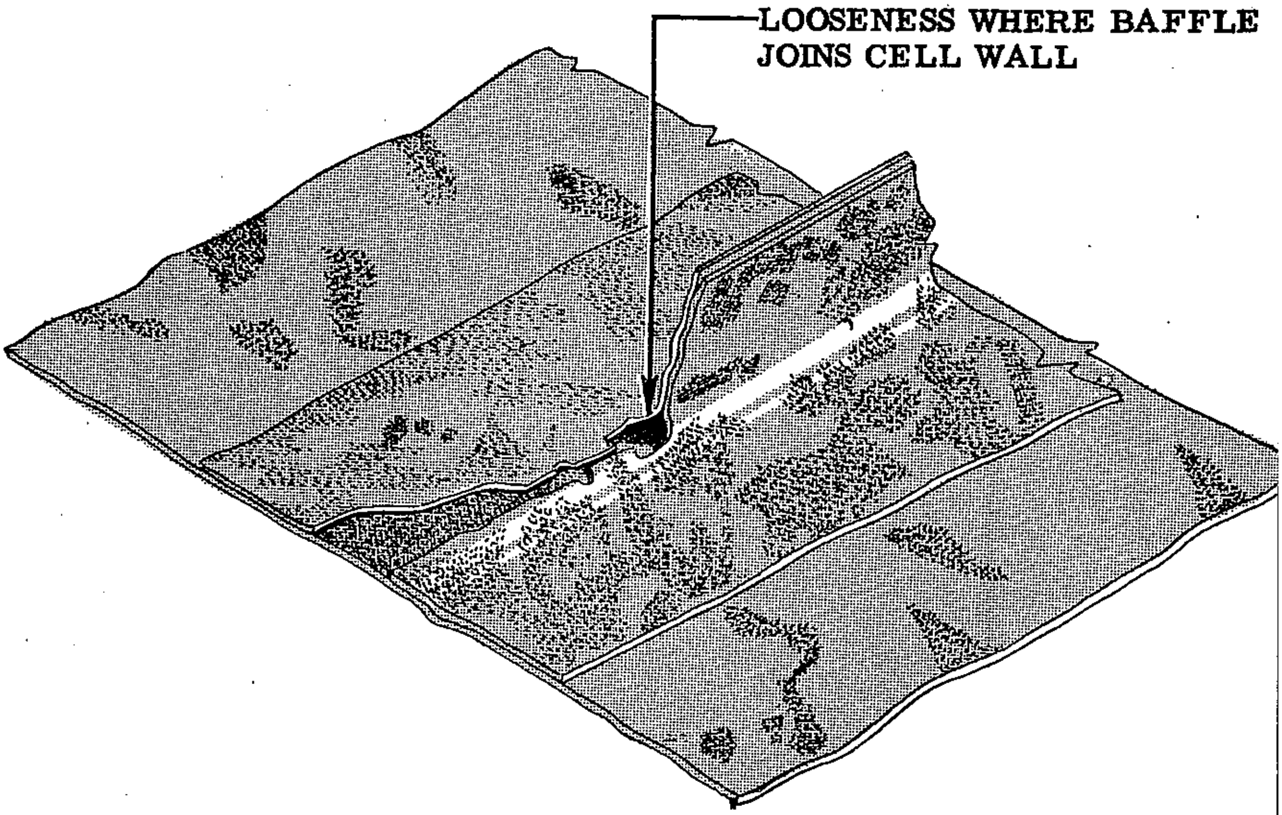


Figure 3

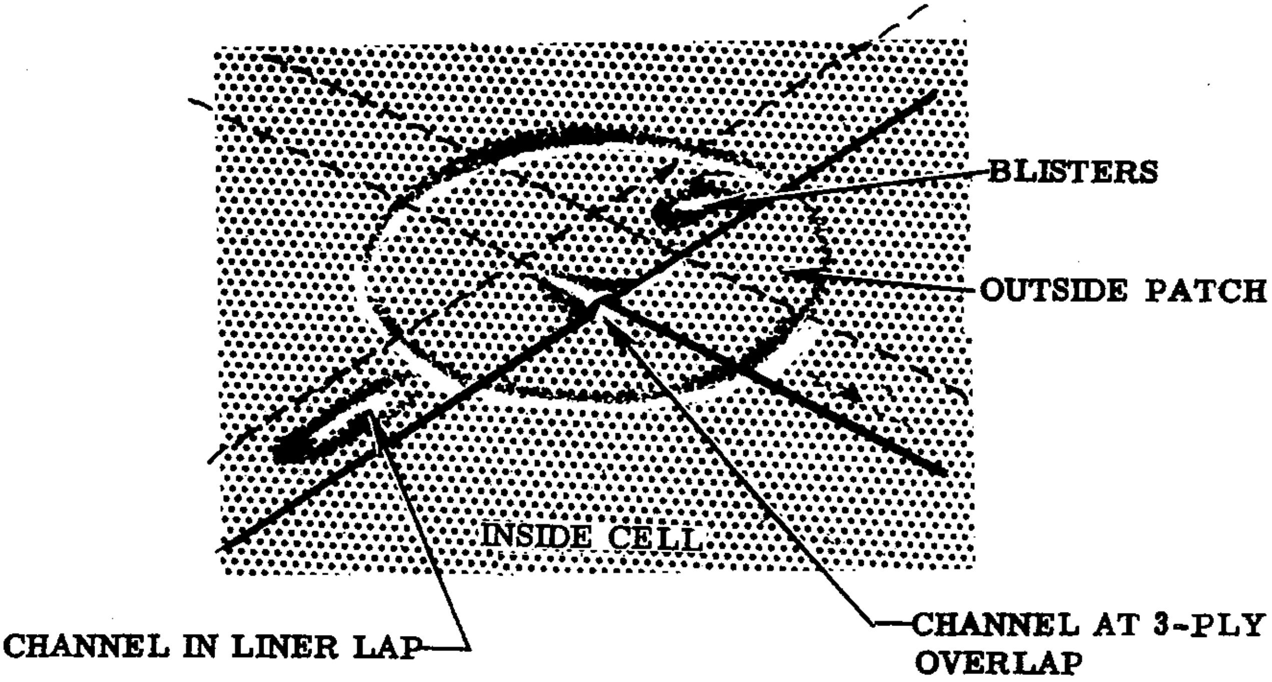


Figure 4

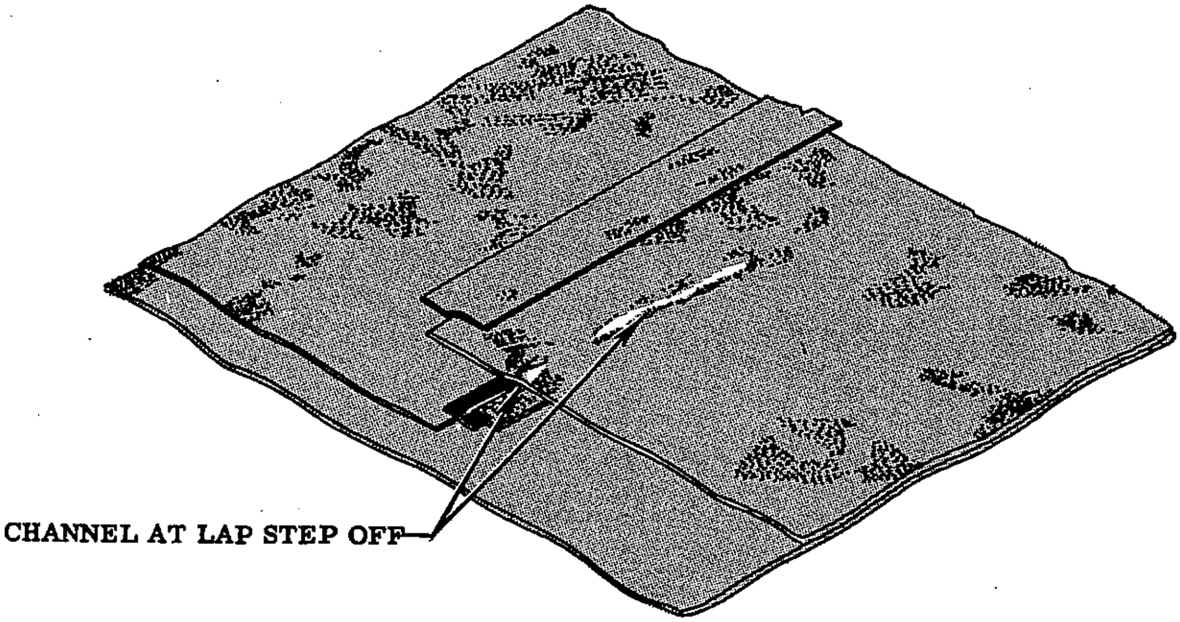


Figure 5

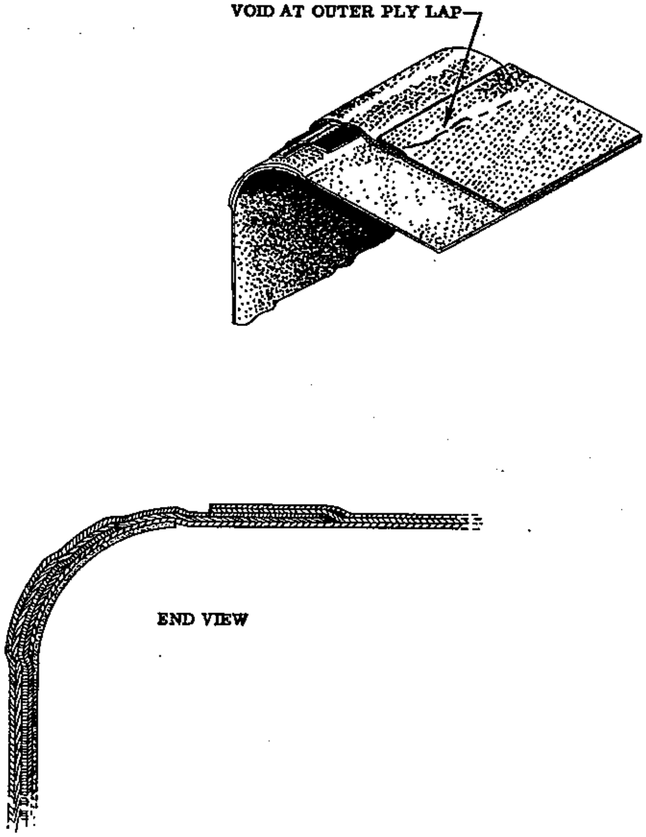


Figure 6

b. Cell Exterior:

CONDITION	LIMIT
(1) Blisters or ply separation between any plies except liner and sealant.	1-inch maximum dimension.
(2) Skim coat blisters.	Acceptable.
(3) Loose hanger straps or hanger attaching points.	Acceptable up to 15 percent of total area provided 1/4-inch bond is maintained around the edge.
(4) Loose or damaged tapes, corner patches, and other outside accessories.	1/2-inch maximum allowable looseness provided this looseness does not exceed 15 percent of the total area.
(5) Checking due to weather, ozone, dry cracking or surface imperfections	Acceptable.
(6) Damaged grommets in accessories.	Acceptable, provided serviceability is not affected.
(7) Damage through outer cord or fabric ply.	Not acceptable.
(8) Channels or bridging of outer plies at cord or fabric splice.	1/2-inch maximum width full length of splice (see figure 6).
(9) Outer ply cuts or splits parallel to cords where cords are not damaged.	Not acceptable; may result in outside activation.

c. Fittings:

(1) Rubber Face Fittings.	
(a) Gouges, splits, or deep indentations on the sealing surfaces.	1/16-inch maximum depth by 1/16-inch maximum length.
(b) Weather checking of surfaces other than sealing surfaces.	Acceptable.
(2) "O" Ring Fittings.	
(a) Sealing face without groove:	
1. Scratches within the sealing area.	Not acceptable (see figure 7).
2. Burrs on mating surface.	Not acceptable (see figure 7).
3. Damage to protective coating.	Acceptable.
4. Corrosion or rust.	Not acceptable.

Fittings (continued)

CONDITION	LIMIT
(b) Sealing face with groove:	
1. Minor surface damage outside of "O" ring groove other than rust, corrosion or burrs.	Acceptable (see figure 7).
2. Physical damage to "O" ring groove.	Not acceptable.
3. Corrosion or rust.	Not acceptable.
4. Cement or other foreign material in "O" ring groove.	Not acceptable.
(3) Bent or broken fittings.	Not acceptable.
(4) Thread damaged fittings.	Acceptable provided serviceability is not affected.

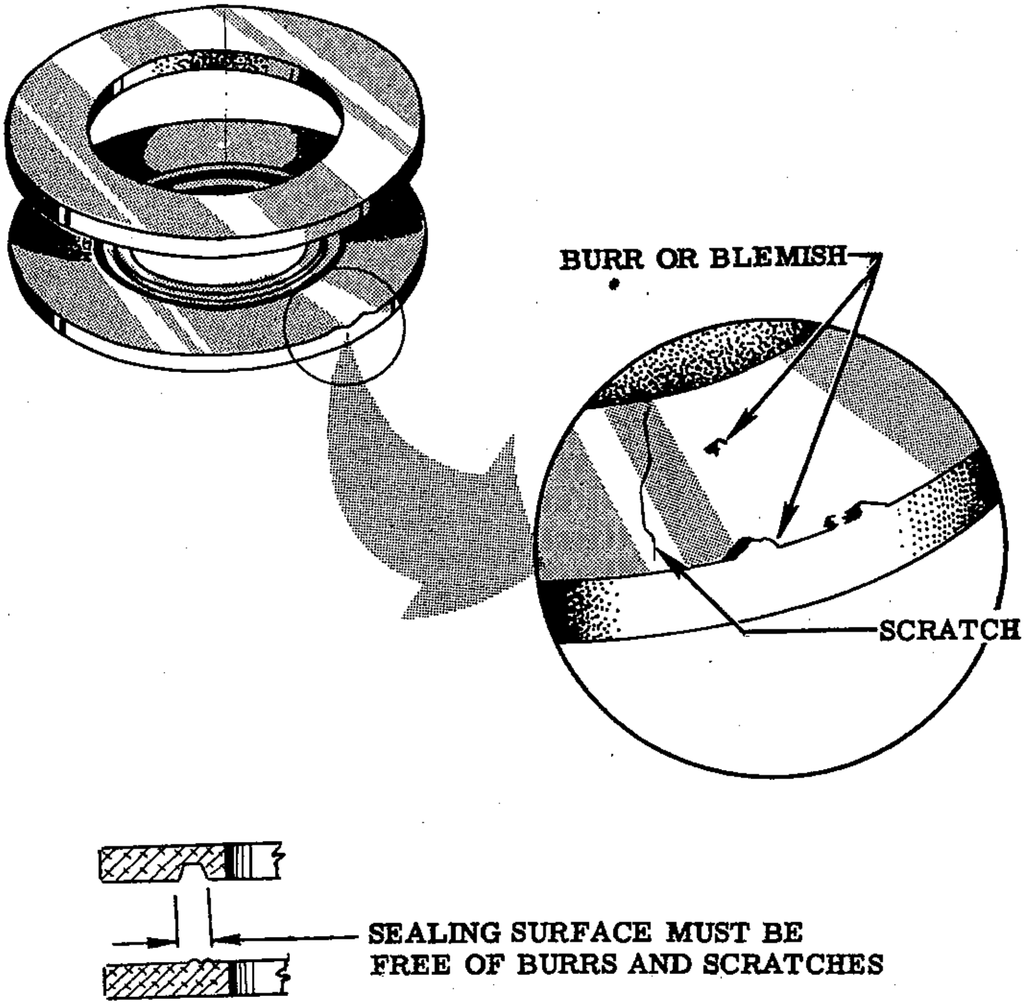


Figure 7

2. SERVICEABLE BLADDER TYPE CELLS.

a. Cell Interior:

CONDITION	LIMIT
(1) Loose liner at throat of fitting.	1/2-inch looseness in width around entire circumference at throat of fitting, except*Firestone 1052-6 construction on which 1/16-inch edge looseness will be allowable (see figure 2).
(2) Loose liner lap.	1/4-inch looseness maximum width in edge of liner lap and full length of lap provided 1-inch bond is maintained, except*Firestone 1052-6 construction o which 1/16-inch edge looseness will be acceptable.
(3) Edge looseness on liner reinforcements and chafing patches.	1/2-inch maximum allowable looseness provided this looseness does not exceed 15 percent of total area. Blisters or separations other than in the edg area allowable up to 15 percent of the total area.
(4) Looseness of cemented internal support components such as attaching straps, baffle supports, etc.	Acceptable up to 15 percent of component area provide 1/4-inch solid bond is maintained around the edge (see figure 3).
(5) Blisters between fitting flange and adjacent ply.	1/4-inch maximum dimension; maximum one per lineal foot and two per fitting provided 1-inch bond is maintained (see figure 2).
(6) Damaged grommets in accessories.	Acceptable provided serviceability is not affected.
(7) Damaged coating on accessories (rubber, metal or wood).	Acceptable provided no rust, corrosion or deterioration is apparent.
(8) Weather checking or minor surface imperfections in liner ply and reinforce-	Acceptable provided serviceability is not affected.
(9) Blisters between liner laps.	1/4-inch maximum dimension; average one per 5 lineal feet of splice with a maximum of five in any one 5-foot length of splice (see figure 4).
(10) Blisters between plies (in cell panels).	1/4-inch maximum dimension; minimum of 6-inch bond between blisters and no more than one per square foot of cell area.
(11) Channels in liner laps.	1/8-inch by 3-inch maximum dimension with a maximum of one in any 5 lineal feet of lap (see figure 4).
(12) Channels around entire outer edge of fitting flange.	1/8-inch maximum width around entire fitting flange (see figure 2).
(13) Buffing through inner-liner.	Not acceptable.
(14) Exposed fabric.	Acceptable provided fabric is not damaged.
(15) Delamination between plies.	1-inch maximum dimension; average of one per 5 square feet of area with a maximum of five in any one 5 square feet of area. Minimum 6-inch solid bond between delaminations.
(16) Cuts or holes in inner-liners.	Not acceptable.

* TV 1/2 - T-33 aircraft only.

b. Cell Exterior:

CONDITION	LIMIT
(1) Skim coat blisters.	Acceptable.
(2) Lap Splice edge looseness.	1/4-by 3-inch maximum dimension provided there are no more than one per lineal foot.
(3) Loose or damaged hanger straps or hanger attaching points.	Acceptable up to 15 percent of component area provided 1/4-inch solid bond is maintained around the edge (see figure 8).
(4) Loose tapes, corner patches or other outside non-load carrying accessories.	1/2-inch maximum allowable looseness provided this looseness does not exceed 15 percent of the total area.
(5) Skim coat off outer ply.	Acceptable provided cords or fabrics are not cut or broken.
(6) Mislocated, blistered, split or weather checked tape.	Acceptable; missing tape to be replaced.
(7) Blisters or looseness between labels or decals and body of cell.	Acceptable.
(8) Weather checked or surface imperfections in outer ply or reinforcements.	Acceptable provided fabric is not damaged or broken.
(9) Blistered, loose or missing lacquer coating.	Acceptable.
(10) Blisters between fitting flange and adjacent ply.	1/4-inch maximum dimension; maximum of one per lineal foot and two per fitting provided 1-inch bond is maintained (see figure 2).
(11) Delamination between plies.	1-inch maximum dimension; average of one per 5 square feet of area with a maximum of five in any one 5 square foot area. Minimum 6-inch solid bond between delaminations.
(12) Damaged grommets in accessories.	Acceptable provided serviceability is not affected.
(13) Blisters between outer ply laps.	1/4-inch maximum dimension; average one per 5 lineal feet of splice with a maximum of five in any one 5-foot length of splice.
(14) Blisters between plies (in cell panels).	1/4-inch maximum dimension; minimum of 6-inch bond between blisters and no more than one per square feet of cell area.
(15) Channels in outer ply laps.	1/4-inch width entire length of lap.
(16) Channels around entire outer edge of fitting flange.	1/8-inch maximum around entire fitting flange (see figure 2).
(17) Damage through any cord or fabric ply.	Not acceptable.

c. Fittings:

CONDITION	LIMIT
(1) Rubber Face Fittings.	
(a) Gouges, splits or indentations on the sealing surface.	1/16-inch maximum depth by 1/16-inch maximum length.
(b) Weather checking of surfaces other than sealing surface	Acceptable.
(2) "O" Ring Fittings.	
(a) Sealing surface without groove:	
1. Scratches within the sealing area.	Not acceptable (see figure 7).
2. Burrs on mating surface.	Not acceptable (see figure 7).
3. Corrosion or rust.	Not acceptable.
(b) Sealing surface with groove:	
1. Minor surface damage outside "O" ring groove other than rust, corrosion or burrs.	Acceptable (see figure 7).
2. Physical damage to "O" ring groove.	Not acceptable.
3. Corrosion or rust.	Not acceptable.
4. Cement or other foreign matter in "O" ring groove.	Not acceptable.
(3) Bent or broken fittings and/or damaged dome nuts.	Not acceptable.
(4) Elongated or torn holes in fitting areas of cells using U. S. Rubber removeable two-piece metal compression fittings.	Acceptable provided the elongation or tear does not extend beyond the outer or inner sealing groove of the inner ring, or over one-half the distance to the next hole.
(5) Thread damaged fittings.	Acceptable provided serviceability is not affected.

(After Installation)

3. SELF-SEALING CELLS.

a. Cell Interior:

CONDITION	LIMIT
(1) Loose liner at throat of fitting.	1/2-inch looseness in width around entire circumference at throat of fitting (see figure 2).

Cell Interior (continued)

CONDITION	LIMIT
(2) Edge looseness at liner lap.	1/2-inch maximum depth provided remainder of bond is good (see figure 4).
(3) Edge looseness on liner reinforcements, corner patches, and chafing patches.	1/2-inch maximum looseness provided loose area does not exceed 20 percent of total area. Blisters or separations other than in the edge area allowable up to 20 percent of total area.
(4) Looseness under cemented components such as attaching straps, baffle shoes, etc.	20 percent of individual area provided 1/4-inch bond is maintained around edge (see figure 3).
(5) Blisters between liner and fitting flange.	1/2-inch maximum dimension; maximum two per lineal feet and three per fitting, provided 1-inch bond is maintained (see figure 2).
(6) Damaged grommets in accessories.	Acceptable provided serviceability is not affected.
(7) Damaged coating on accessories (rubber, metal or wood).	Acceptable provided rust, corrosion, or other deterioration is not present.

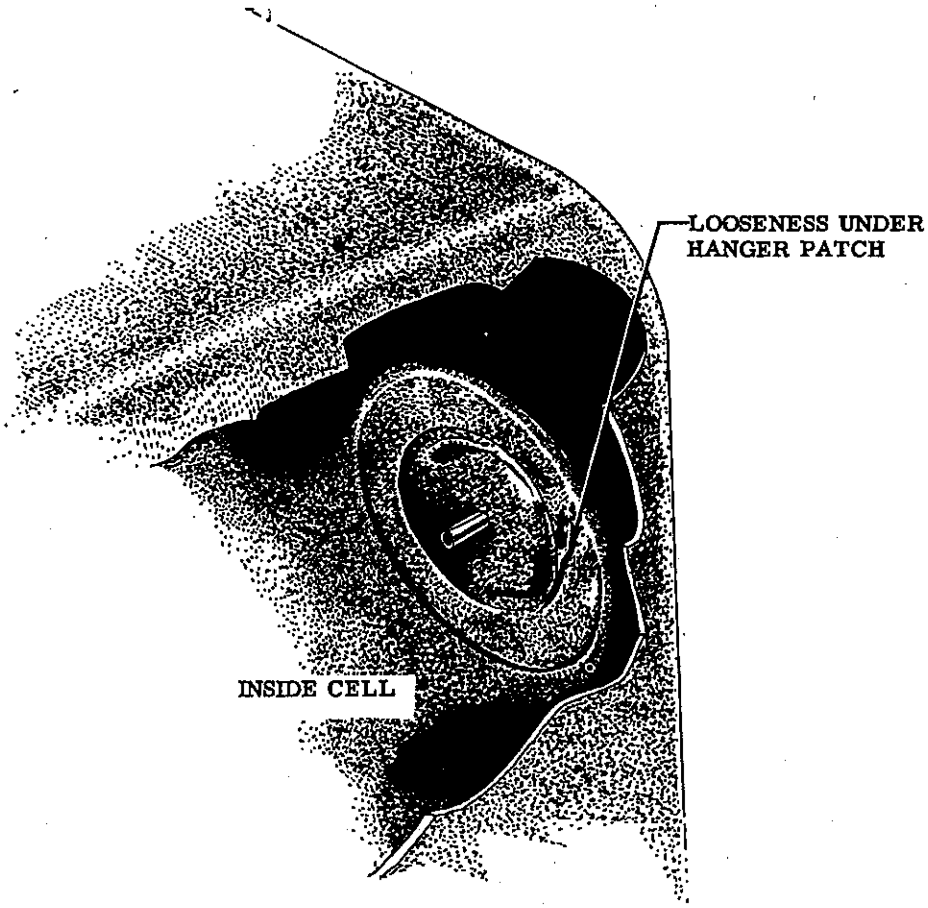


Figure 8

Cell Interior (continued)

CONDITION	LIMIT
(8) Checking due to weather, ozone, or dry cracking, or surface imperfections	Acceptable provided there is no indication of activation.
(9) Blisters in liner laps.	1/2-inch maximum dimension; maximum of five in any 5 lineal feet of splice with a minimum of 6-inch bond between blisters (see figure 4).
(10) Blisters, delaminations or ply separation.	1 1/2-inches maximum provided there is a 6-inch bond between blisters and no more than one per square foot of cell area.
(11) Channels in inner-liner laps.	1/4-inch by 3-inch maximum dimension with a maximum of one in any 5 lineal feet of splice (see figure 4).
(12) Channels around entire outer edge of fitting flange.	1/2-inch maximum width (see figure 2).
(13) Channels at tapered construction step-off area or edge of lap splices of any ply.	1/2-inch maximum width (see figure 5).
(14) Open end channels in three ply liner overlaps or tailored corners.	1/4-inch by 3-inch maximum dimension provided 1-inch minimum bond is maintained between end of channel and sealant (see figure 4).
(15) Cuts or holes in inner-liner.	Not acceptable.
(16) Buffing through inner-liner.	Not acceptable.
(17) Damaged anchor fittings.	Maximum cut or worn area 25 percent of total dimension.
(18) Activated areas.	Not acceptable.
(19) Broken stiffeners or supports.	Not acceptable.

b. Cell Exterior:

NOTE

Only accessible portions of the cells will be inspected.
Cells not to be removed from aircraft for inspection.

(1) Blisters or ply separations between any plies except liner and sealant.	1 1/2-inches maximum dimension.
(2) Skim coat blisters.	Acceptable.
(3) Loose hanger straps or hanger attaching points.	Acceptable up to 20 percent of total area provided 1/4-inch bond is maintained around the edge.
(4) Loose or damaged tapes, corner patches or other outside accessories.	Acceptable provided sealant is not activated.
(5) Checking due to ozone, weather, or dry cracking	Acceptable.

Cell Exterior (continued)

CONDITION	LIMIT
(6) Damaged grommets in accessories.	Acceptable provided serviceability is not affected.
(7) Damage through outer cord or one fabric ply.	1-inch maximum dimension.
(8) Channels or bridging of outer plies at cord or fabric splice.	1/2-inch width maximum full length of splice (see figure 6).
(9) Outer ply cuts or splits parallel to cords where cords are not damaged.	Acceptable provided activation of sealant is not evident.

c. Fittings:

NOTE

Fittings not to be disturbed for inspection unless leakage is suspected.

(1) Rubber Face Fittings.	
(a) Gouges, splits, or deep indentations on the sealing surface.	1/16-inch maximum depth by 1/16-inch maximum length.
(b) Weather checking of surfaces other than sealing surface.	Acceptable.
(2) "O" Ring Fittings.	
(a) Sealing face without groove:	
1. Scratches within the sealing area.	Not acceptable (see figure 7).
2. Burrs on mating surface.	Not acceptable (see figure 7).
3. Damage to protective coating.	Acceptable.
4. Corrosion or rust.	Not acceptable.
(b) Sealing face with groove:	
1. Minor surface damage outside of "O" ring groove other than rust, corrosion, or burrs.	Acceptable (see figure 7).
2. Physical damage to "O" ring groove.	Not acceptable.
3. Corrosion or rust.	Not acceptable.
4. Cement or other foreign material in "O" ring groove.	Not acceptable.
(3) Bent or broken fittings.	Not acceptable.
(4) Thread damaged fittings.	Acceptable provided serviceability is not affected.

4. BLADDER TYPE CELLS.

a. Cell Interior:

CONDITION	LIMIT
(1) Loose liner at throat of fitting, except sump type and three plane fittings.	1/2-inch looseness in width around entire circumference at throat of fitting except*Firestone 1052-6 construction on which 1/16-inch edge looseness wil be allowable (see figure 2).
(2) Loose liner at throat of sump type and 3-plane fittings.	1/4-inch maximum looseness (see figures 9 and 10)
(3) Loose liner lap.	1/4-inch looseness maximum width in edge of liner lap and full length of lap provided 1-inch bond is maintained, except*Firestone 1052-6 construction on which 1/16-inch edge looseness will be acceptable.
(4) Edge looseness on liner reinforcements and chafing patches.	1/2-inch maximum looseness provided looseness does not exceed 25 percent of total area; blisters or separations other than in the edge area allowabl up to 25 percent of the total area.
(5) Looseness of cemented internal support components such as attaching straps, baffle supports, etc.	Acceptable up to 25 percent of component area provided 1/4-inch solid bond is maintained around the edge (see figure 3).
(6) Blisters between fitting flange and adjacent ply.	1/2-inch maximum dimension, maximum two per lineal foot and three per fitting provided 1-inch bon is maintained (see figure 2).
(7) Damaged grommets in accessories.	Acceptable provided serviceability is not affected.

* TV 1/2 - T-33 aircraft only.

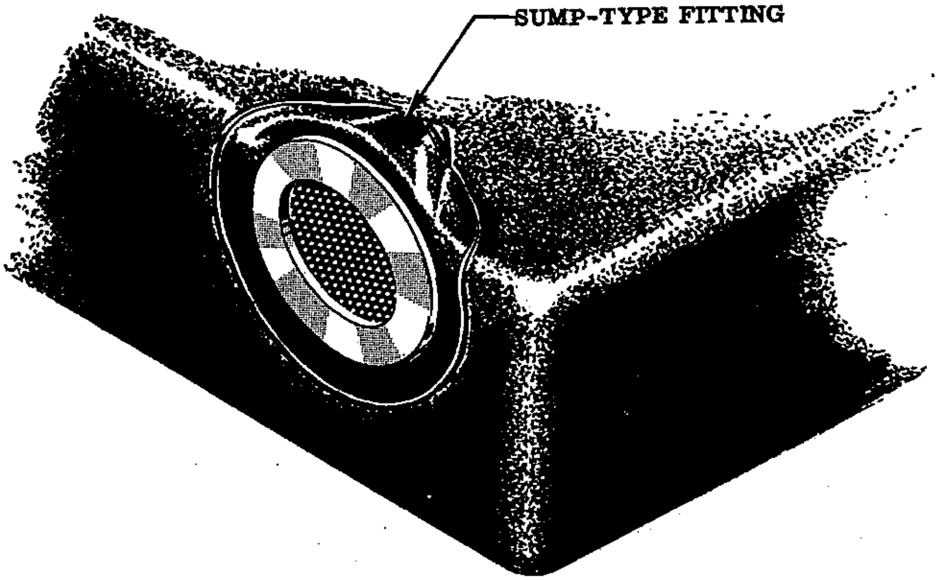


Figure 9

Cell Interior (continued)

CONDITION	LIMIT
(8) Weather checking or minor surface imperfections in liner ply and reinforcements	Acceptable provided serviceability is not affected.
(9) Blisters between liner laps.	1/2-inch maximum dimension; maximum of five in any 5 lineal feet of splice with a minimum of 6-inch bond between blisters (see figure 4).
(10) Blisters between plies (in cellpanels).	1-inch maximum dimension; minimum of 6-inch bond between blisters and no more than one per square foot of cell area.
(11) Channels in inner-liner laps.	1/4-inch by 3-inch maximum dimension with a maximum of one in any 5 lineal feet of splice (see figure 4).
(12) Channels around entire outer edge of fitting flange.	1/4-inch maximum width around entire fitting flange (see figure 2).
(13) Damaged coating on accessories (rubber, metal or wood).	Acceptable provided rust, corrosion, or other deterioration is not apparent.
(14) Exposed fabric.	Acceptable provided cords are not cut or broken.
(15) Split or damaged corner reinforcements.	Acceptable.
(16) Cuts or holes in inner-liners.	Not acceptable.
(17) Delamination between plies.	1 1/2-inches maximum dimension; average one per 5 square feet of area with a maximum of five in any 5 square feet of area, minimum of 6-inches between delaminations.
(18) Broken stiffeners or supports.	Not acceptable.

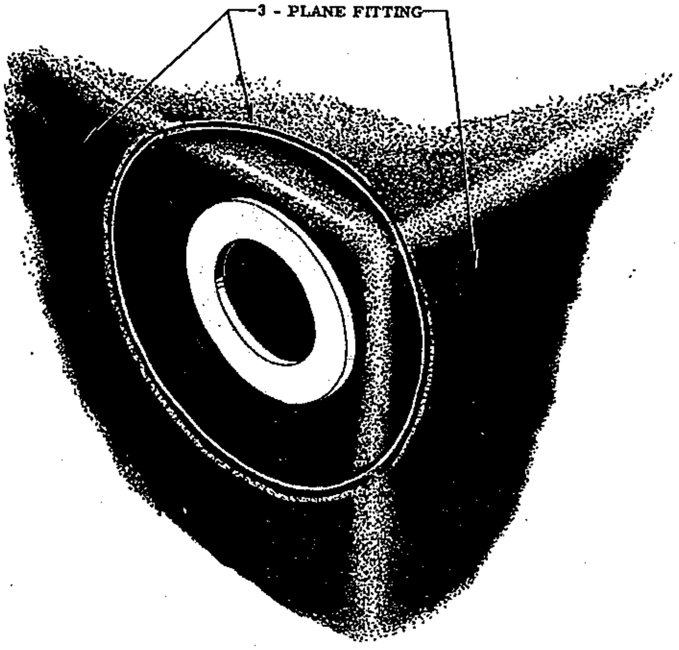


Figure 10

b. Cell Exterior:

NOTE

Only accessible portions of the cells will be inspected. Cells not to be removed from aircraft for inspection.

CONDITION	LIMIT
(1) Skim coat blisters.	Acceptable.
(2) Loose or damaged hanger straps or hanger attaching points.	Acceptable up to 20 percent of component area provided 1/4-inch solid bond is maintained around the edge (see figure 8).
(3) Loose tapes, corner patches, or other outside non-load carrying accessories.	1/2-inch allowable looseness provided this looseness does not exceed 20 percent of the total area.
(4) Lap splice edge looseness.	3/8-inch by 3-inch maximum dimension provided there are no more than one per lineal foot.
(5) Skim coat off outer ply.	Acceptable provided cords or fabric are not broken.
(6) Mislocated, blistered, split or weather checked tape.	Acceptable.
(7) Blisters or looseness between labels or decals and body of cell.	Acceptable.
(8) Weather checked or surface imperfections in outer ply or reinforcements.	Acceptable.
(9) Blistered, loose or missing lacquer coating.	Acceptable.
(10) Damaged grommets in accessories.	Acceptable provided serviceability is not affected.
(11) Damage through any cord or fabric ply.	Not acceptable.
(12) Delamination between plies.	1 1/2-inches maximum dimension; average one per 5 square feet of area with a maximum of five in any 5 square feet. Minimum of 6-inches between delaminations.
(13) Blisters between fitting flange and adjacent ply.	1/2-inch maximum dimension with a maximum of two per lineal foot and three per fitting, provided 1-inch bond is maintained (see figure 2).
(14) Blisters between outer ply laps.	1/2-inch maximum dimension; average two per 5 lineal feet of splice with a maximum of five in any one 5-foot length of splice.
(15) Blisters between plies (in cell panels).	1-inch maximum dimension with a minimum of 6 inches between blisters and no more than one per square foot of cell area.
(16) Channels in outer ply laps.	1/4-inch by 3-inch maximum dimension with a maximum of one in any 5 lineal feet of splice.
(17) Channels around entire edge of fitting flange.	1/4-inch maximum width around entire fitting flange (see figure 2).

c. Fittings:

NOTE

Fittings not to be disturbed for inspection unless leakage is suspected.

CONDITION	LIMIT
(1) Rubber Face Fittings.	
(a) Gouges, splits or indentations on the sealing surface.	1/16-inch maximum depth by 1/16-inch maximum length.
(b) Weather checking of surfaces other than sealing surface	Acceptable.
(2) "O" Ring Fittings.	
(a) Sealing surface without groove:	
1. Scratches within the sealing area.	Not acceptable (see figure 7).
2. Burrs on mating surface.	Not acceptable (see figure 7).
3. Corrosion or rust.	Not acceptable.
(b) Sealing surface with groove:	
1. Minor surface damage outside "O" ring groove other than rust, corrosion or burrs.	Acceptable (see figure 7).
2. Physical damage to "O" ring groove.	Not acceptable.
3. Corrosion or rust.	Not acceptable.
4. Cement or other foreign matter in "O" ring groove.	Not acceptable.
(3) Bent or broken fittings and/or damaged dome nuts.	Not acceptable.
(4) Elongated or torn holes in fitting areas of cells using U.S. Rubber removeable two-piece metal compression fittings.	Acceptable provided the elongation or tear does not extend beyond the outer or inner sealing groove of the inner ring, or over one-half the distance to the next hole.
(5) Thread damaged fittings.	Acceptable provided serviceability is not affected.

ROYAL CANADIAN AIR FORCE

EO 05-1-2P
10 Jun 63

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

REMOVAL OF SNOW, ICE AND FROST FROM AIRCRAFT SURFACES

(This EO replaces EO 05-1-2P dated 13 Nov 62)

INTRODUCTION

1 Aircraft parked outside, during cold weather conditions are subject to being coated with snow, ice and hoar-frost on control surfaces and other areas. Aerodynamic efficiency of the aircraft is seriously affected if this accumulation of snow, ice and hoar-frost is not completely removed.

2 It is mandatory that all accumulations of snow, ice or hoar-frost, no matter how slight, on aircraft surfaces be completely removed before the aircraft is signed out as serviceable.

PURPOSE

3 The purpose of this EO is to provide a source of preventive measures to be observed while aircraft are subjected to cold weather operations and the action, cautions and approved solutions necessary in the removal of ice snow and hoar-frost from aircraft surfaces.

PREVENTION AIRCRAFT SURFACES

4 Covers in good condition are the best method of protection against snow, frost or ice accumulations. Approved aircraft covers for RCAF use are listed in CAP 10, Section 27D and are available on demand.

5 Caution should be exercised when using covers at temperatures exceeding 25°F (approximately -5°C) as rain or wet snow may freeze covers to surfaces. To prevent covers from freezing to surfaces, a film of anti-icing fluid should be applied first. A satisfactory procedure is to apply the anti-icing fluid to the surfaces after the last flight of the day and then apply covers. Frost and light snow which then form can easily be removed with minimum sticking of covers.

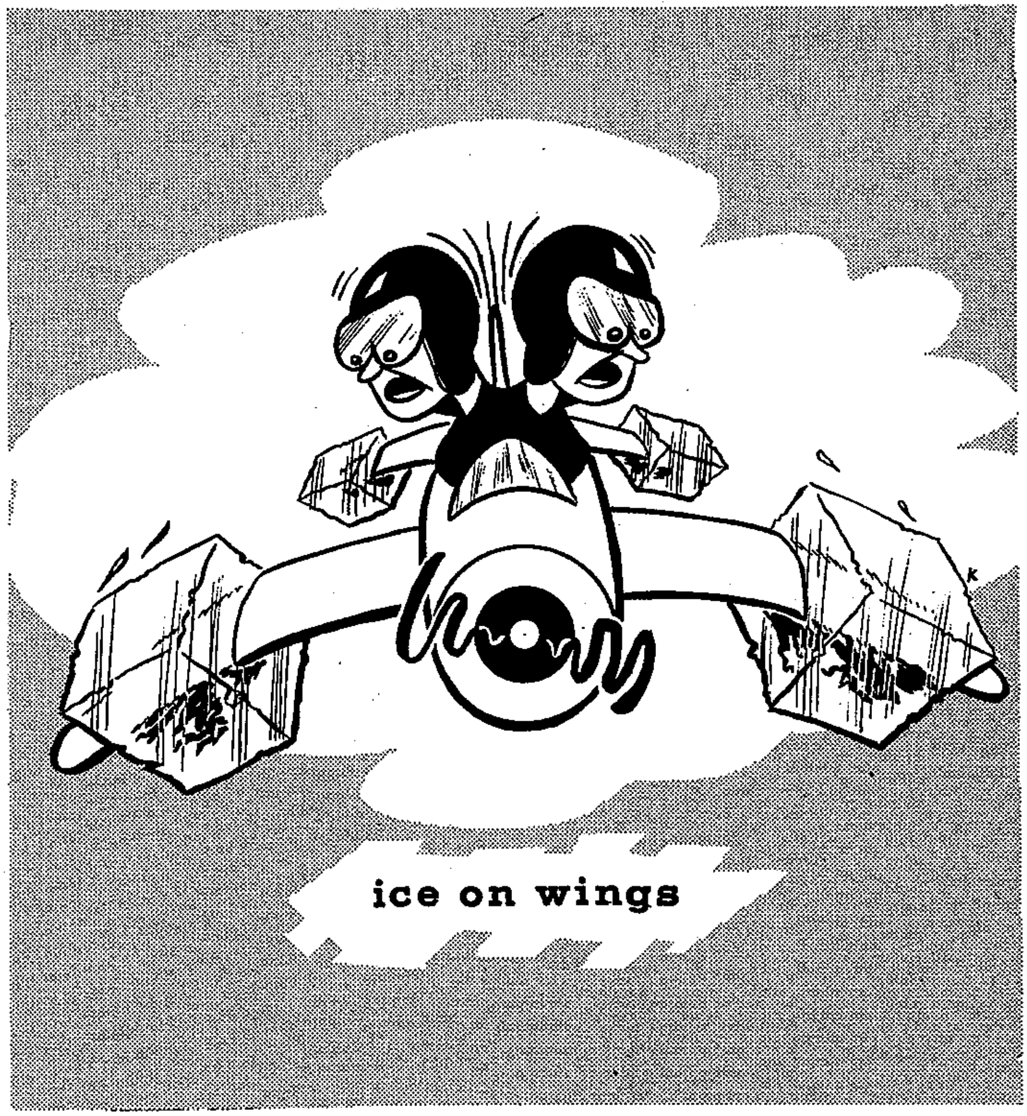
6 Covers are never installed over aircraft surfaces with frozen or freezeable moisture present. Wet covers are not to be used for covering aircraft surfaces but should be completely dry before applying. Care must also be exercised to ensure that covers are free from accumulations of oil, grease, hydraulic fluid etc., as these conditions create a fire hazard.

7 Covers when not in use should be completely dried and hung or stored in a dry place,

8 When approved covers are not available, an alternate method of protection is the use of a net made of 1-1/2" cotton webbing constructed with 3" square openings. The net should be draped over the wing and secured exercising the same precautions as specified for approved covers. When the net is removed, 90% of the snow is removed.

CANOPIES

9 Canopies and perspex surfaces should be covered to prevent snow and ice accumulation. Covers should be of the fitted type normally supplied with each type of aircraft.



PITOT HEATERS

10 Pitot tube covers should be used at all times to ensure no drifting snow or freezing rain enters the pitot tube.

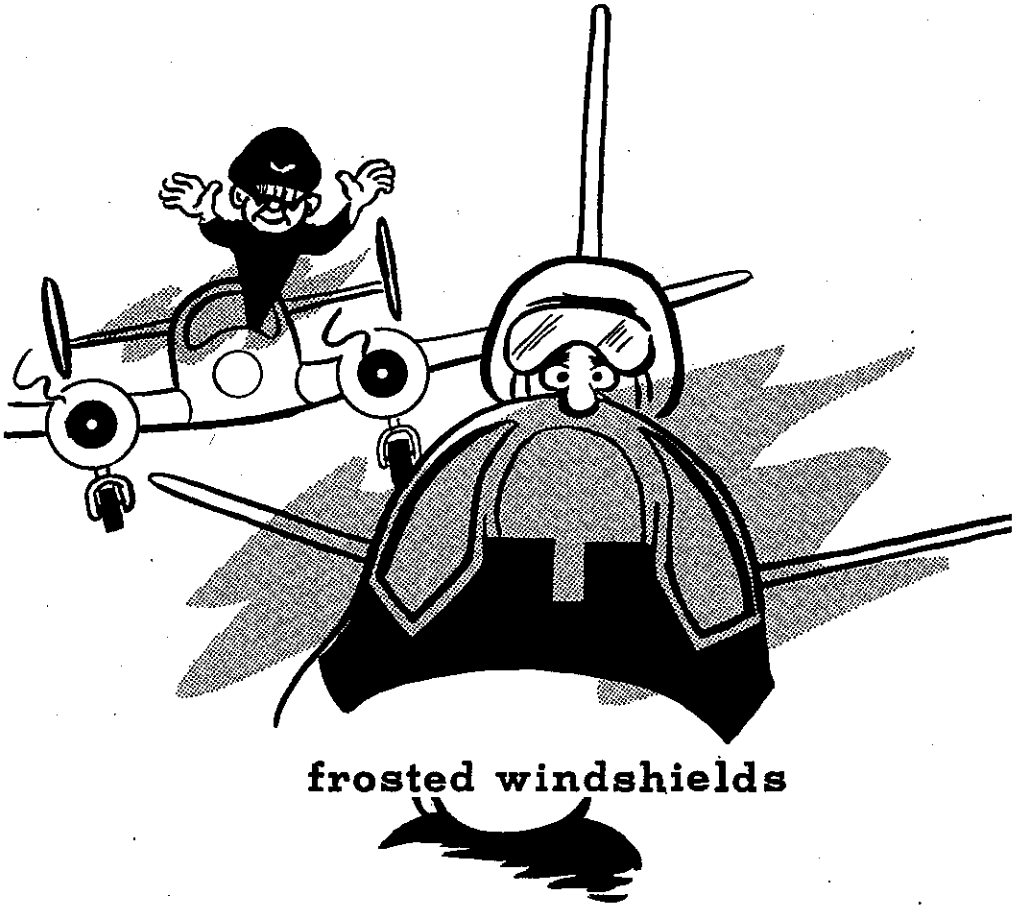
REMOVAL

11 Removal of snow, ice and hoar-frost from aircraft metallic surfaces may be carried out by one of the following methods:

(a) Defrost the aircraft in a heated hangar ensuring that all surfaces are completely dry before removing from hangar.

(b) Sweep the aircraft surfaces with a hand broom.

(c) Spray the metallic aircraft surfaces with anti-icing and de-icing defrosting fluid specification MIL-A-8243A, Ref. 34A/6850-00-582-4685 (EO 45-1-4).



frosted windshields

(1) Use defrosting fluids sparingly and ensure the mixture does not enter the engine(s) compartment.

(2) Excessive use of defrosting fluid could result in flushing action of lubricants. Ensure that all exposed control surface bearings, actuator and/or screw jack moving parts are adequately lubricated after each application of defrosting fluid.

CANOPIES

12 . When it is necessary to defrost canopies or perspex surfaces the only recommended method is to apply heat using approved ground heating units. Ducts should not blow directly on perspex surfaces if the temperature of the surface will exceed 49°C (120°F) at any spot.

PROPELLERS

13. Alcohol anti-icing systems will not remove ice already formed on propellers. Therefor all ice deposits on propellers should be removed before starting engines. If icing temperature exist, anti-icing systems should be operated immediately after engine starting.

JET BLAST

14 The use of jet blast from another aircraft as a means of defrosting will only be used in extreme emergency. If the jet blast method is used the distance between the tail pipe and the nose of the aircraft being defrosted will be at least 38'. Personnel will ensure before using the jet blast as a defrosting method, that all debris in the proximity of the aircraft is removed because of the possibility of damage to the aircraft.

CRITICAL AREAS

15 Air inlets and vents should be thoroughly inspected for ice or snow accumulations. Static pressure source for flight instrument that are located flush with the skin of the fuselage are very susceptible to icing conditions. These are to be thoroughly inspected.

CAUTION

The use of sharp pointed objects, such as screwdrivers, scrapers, ice picks or items of a similar nature for the removal of snow or hoar-frost from aircraft surfaces is strictly forbidden.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAMO/C Eng 1

DE-ICING CHEMICALS

1 Anti-Icing Fluid Ref. 34A/6850-00-582-4685 to Specification MIL-A-8243.

2 Ethylene glycol Ref. 34A/6850-21-572-4610 to Specification 3-GP-850.

CHECK POINTS

1 Top and bottom of all flight surfaces.
2 Air intake and vents.
3 Control hinge gaps.
4 Hinge points.
5 All movable parts.
6 Antennas and radar enclosures.
7 Windshields and adjoining areas.
8 Ensure bearings etc., adequately lubricated after use of de-icing fluid.

DEPOSIT	DRY SNOW	WET SNOW	FROZEN SNOW	ICE	FROST
WEATHER	1 Overcast skies. 2 Temperature below 30°F	1 Overcast skies. 2 Temperature 30 - 35°F	1 Temperature drop after wet snow fall.	1 Uniformly overcast skies. 2 Temperature 25 - 32°F	1 Temperature near freezing. 2 Clear skies-night. 3 High relative humidity 4 Little or no wind.
PREVENTION	1 Protective covers. 2 Frequent removal of snow prevents packing.	1 Waterproof protective covers. 2 Frequent removal more important.	1 Do not allow wet or dry snow to remain on surface, thaw and refreeze. 2 Do not remove the aircraft from hangar during snowfall.	1 Frequent application of anti-icing fluid may prevent freezing. 2 Remove water or slush that may freeze.	1 Protective covers. 2 Application of anti-icing fluid (temporary protection only).
REMOVAL	1 Sweeping 2 Cloth strip 3 Ground run.	1 Sweeping 2 Mopping 3 Cloth strip.	1 Sweep to remove loose deposits. 2 Apply chemicals by mop or spray. 3 Use heat under cover as alternative method.	1 Allow ice to melt off in hangar. 2 Apply chemicals generously. 3 Use heat under cover.	1 Chemicals mop or spray. 2 Cloth strip. 3 Place aircraft in bright sun.
CAUTIONS	1 Chemicals are wasteful in removing dry snow	1 Check all openings, moving parts, etc., where snow may collect and freeze.	1 Check surfaces for frozen snow after wet or dry snow has been removed.	1 Check all openings and movable parts.	1 Do not underestimate effect of frost. Remove from top and bottom of all flight surfaces and antennas.

DEPOSIT	DRY SNOW	WET SNOW	FROZEN SNOW	ICE	FROST
CAUTIONS (Cont'd)	2 Check all air intakes and openings for blown snow.	2 Dry surface after removal of snow. 3 Check for frozen slush on underside of surfaces.	2 Do not heat surfaces over 160°F. 3 Check lubrication of bearings, etc., on control surfaces as per para. 11(2).	2 Check for run-off water that has frozen between or on underside of surfaces. 3 Check lubrication of bearings, etc., on control surfaces as per para. 11(2).	2 Check lubrication of bearings, etc., on control surfaces as per para. 11(2).

ROYAL CANADIAN AIR FORCE

EO 05-1-2S
12 Jul 63

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

AIRCRAFT GENERAL

AIRCRAFT FUEL TANKS - FUEL LOADS

(This EO replaces EO 05-1-2S dated 26 Feb 54)

1 The operation of aircraft with reduced fuel load to increase the pay load on scheduled flight is authorized. Passenger and freight sections are to adhere strictly to aircraft loading tables where pay load is increased in proportion to the reduced gasoline load.

2 Care must be exercised in the case of bladder cells, self-sealing fuel cells, and integral tanks which embody a sealing compound in the seams and joints, which are likely to remain empty for an appreciable length of time due to reduced fuel loads, as subsequent cracking and checking will result. Preferably these tanks should be sprayed internally with lubricating oil, Ref. 34A/9150-21-802-4293 (3-GP-45), or alternately retain a minimum of one-quarter of the normal fuel capacity.

3 The above does not apply to aircraft used for training purposes. The fuel state of these aircraft is to be in compliance with existing instructions. At completion of day or night flying prior to storage in hangars or outside, fuel tanks are to be filled to safe capacity. Allowance is to be made for volumetric increase of the fuel due to temperature changes.

NOTE

Where aircraft are being ferried to contractors for repair or servicing, where practical, captains are to ensure that the amount of fuel carried is not greater than the minimum safe fuel load requirement for the intended flight.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAMO/CEng3

ROYAL CANADIAN AIR FORCE

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

ENGINE AIR FILTERS AND SCREENS REMOVAL

(This EO replaces EO 05-1-2T dated 4 Oct 62)

GENERAL

1 Serious power loss or complete engine failure can occur if air intakes become blocked with ice or snow. In order to eliminate this hazard screens and filters shall be serviced in accordance with this order.

DEFINITIONS

2 For the purpose of this order, the following definitions shall apply:

(a) SCREEN - A coarse wire mesh screen at or near the air intake.

(b) FILTER - A fine filter designed to remove all dust and grit from the air entering the engine.

(c) DECK SCREEN - A coarse wire mesh screen immediately adjacent to the carburettor.

(d) COLD SECTION - That portion of the induction system upstream of the point where heated air enters the system.

(e) HOT SECTION - That portion of the induction system downstream of the point where heated air enters the system.

PROCEDURE

3 All screens and filters in the COLD SECTION shall be removed whenever icing conditions may be anticipated. Screens and filters in the HOT SECTION shall remain in place. Deck screens are not to be removed.

NOTE

On some engines, removal of screens and/or filters will necessitate installation of spacers or distance pieces. Reference to the applicable -2 or -4 EOs will determine if these can be procured or if they are to be manufactured locally.

Care must be taken to ensure that no pieces of rubber sealing strips or similar material can be drawn into the induction system when screens and/or filters are removed. Any sealing strips, gaskets etc. remaining in the induction system must be securely cemented in place.

SPECIAL WEATHER CONDITIONS

4 Icing conditions may be encountered at any time of the year in some areas such as the North Atlantic route, and Northern Canada. The CTSO of the unit concerned will ensure that the requirements of paragraph 3 are observed regardless of the season of the year.

STORAGE

5 Screens and filters removed from induction systems should not normally be carried in the aircraft, but should be stored under unit arrangements.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAMO/C Eng

EO 05-1-2U

ROYAL CANADIAN AIR FORCE

AIRCRAFT FINISH SCHEMES AND MARKINGS

(This EO replaces EO 05-1-2U dated 8 Mar 57, Revised 10 Jun 59)

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

10 FEB 64

LIST OF RCAF REVISIONS

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AIRCRAFT FINISH SCHEMES AND MARKINGS

PURPOSE

1 The purpose of this Engineering Order is to provide general information on the markings of RCAF aircraft.

GENERAL

2 Aircraft markings include:

(a) Identification markings;

(b) Maintenance, servicing and emergency markings;

(c) Finish schemes (anti-corrosion, fuel/oil resistant, etc.);

(d) Special marking. (anti-collision, tow targets, search and rescue aircraft etc.).

3 RCAF aircraft markings have been standardized in order to economize and provide a distinct identification scheme. The identification marking drawings have been prepared with the view to improve and standardize the appearance of RCAF aircraft. The basic paint scheme is for appearance and to reduce corrosion due to salt sprays, fuel, oil and exhaust gases. Special markings have been prepared to increase aircraft visibility tow targets and search/rescue purpose.

POLICY

4 Aircraft marking drawings are prepared in accordance with general policies set forth by AFHQ. Maintenance, servicing and emergency markings are prepared in accordance with ABC and NATO symbols and standards (EO 00-60-11/1) and applicable aircraft -2 Engineering Order.

5 AMCHQ/SOED is responsible for the preparation of drawings for all aircraft markings and is responsible for the co-ordination of information with the applicable AMCHQ/aircraft specialist officers and AFHQ.

6 • Requests for deviations or waivers from this Engineering Order or the applicable aircraft drawings shall be submitted to AMCHQ/SOED who will co-ordinate any changes and secure final decisions on questions affecting the marking policy.

7 It is important to apply up-to-date markings at the earliest opportunity and to ensure that all markings and finishes are maintained in a presentable and legible state.

8 The marking and finishing of aircraft is detailed in RCAF drawings prepared by AMCHQ. These drawings are presently distributed as the RCAF aircraft identification drawing Zerox book but will be published as EO 05-1-2W in the near future. Full size drawings may be procured from AMCHQ as outlined in CAP 16, Vol. 1, Art 21.6.02.

9 In the event of conflict between this Engineering Order and specific aircraft engineering orders the problem(s) shall be forwarded to AMCHQ for evaluation and clarification.

10 Inspection - All aircraft shall be inspected at each periodic inspection for finish and marking deterioration.

APPLICATION

11 Units will apply aircraft markings and finishes:

(a) As changes in the relevant aircraft drawings dictate.

(b) When deterioration is detected.

12 Repair Depot and Contractors will apply markings when specified by AMCHQ.

13 The method of application of paints and decals is to be in accordance with current engineering order and specifications.

SPECIAL MARKINGS

SEARCH AND RESCUE AIRCRAFT

14 Aircraft used for search and rescue operations are marked with a band of fluor-

escent paint with a blue border on the rear portion of the fuselage. Helicopters, not conducive to this type of marking, are marked on the top with a fluorescent paint. Large capital letters RESCUE in fluorescent paint are marked on the sides of the fuselage.

COMBAT AIRCRAFT

15 Aircraft used in operational roles are marked with a minimum of identification and special markings. Aircraft marked with camouflage schemes, in accordance with AFHQ direction, shall be finished in accordance with latest RCAF aircraft identification and marking drawing.

UN MARKINGS

16 Identification markings for RCAF aircraft serving in "direct" support of the UN are white with a contrasting UN emblem, letters and numerals. Aircraft serving in "indirect" support of the UN are finished the same as the standard RCAF scheme with the addition of the UN emblem above the Canadian Ensign (located on the vertical stabilizer).

SQUADRON MARKINGS

17 Squadron badges approved by AFHQ shall be centrally located on the port side of the nose of the aircraft. Squadron markings are applied by the squadrons at the discretion of the Commanding Officer.

DECALCOMANIAS

18 Decalcomanias shall be applied in accordance with EO 05-1-2X.

LINE IDENTIFICATION MARKINGS

19 The last three numerals of the aircraft registration number may be applied to the front of the aircraft to facilitate identification on the ground, as shown in the latest identification and marking drawing for the particular anti-collision aircraft.

ANTI-COLLISION

20 Anti-collision markings are used to increase aircraft visibility. These are now accomplished by the use of fluorescent paint in lieu of red paint.

WING WALKS AND FLAME RESISTANT AREAS

21 The coating of the wing walks and flame resistant areas shall be applied in accordance with applicable drawing.

AMBULANCE MARKINGS

22 Ambulance aircraft are to be marked conspicuously with the Geneva Red Cross on a white background when so directed by AFHQ.

SPECIAL IDENTIFICATION MARKINGS

23 Special identification markings such as on the Golden Hawk aircraft and tow-target aircraft; insignia, roundels, letters and numerals are included in the related identification and marking drawing.

EMERGENCY, MAINTENANCE AND SERVICING MARKINGS - EXTERIOR AND INTERIOR

GENERAL

24 Maintenance, servicing and emergency markings are markings specified by engineering requirements in accordance with NATO and ABC Standards - Ref. EO 00-60-11/1. These markings may be exterior or interior, painted or affixed to the surface as a decal.

SPECIAL MARKINGS

BASIC WEIGHT

25 The basic weight figures of an aircraft shall be marked next to the entrance in black letters. Passenger aircraft need not be marked as this information is available in the RCAF Form L36 or L38.

PRESSURE FASTENERS

26 Safety marks are to be applied in the form of lines painted across the head of pressure fasteners continuing on the skin of the aircraft fuselage or components when pressure fasteners are in the locked position. The paint shall be of a colour that will give a distinct contrast to the basic metal or painted surface. EO 05-1-2Q outlines the applicable contrasting colour.

EXTERIOR EMERGENCY MARKINGS

27 Examples of exterior emergency markings are: Fire Axe, First Aid Kit, Fire Extinguisher, Dinghy Survival Kit etc. These markings are located on the fuselage. A dotted line should be applied with the letters "CUT HERE" in two inch letters to indicate the areas which should be cut. The applicable letters "Axe stowed inside here" or "Fire extinguisher inside here" shall be located inside the dotted lines.

AREAS NOT TO BE MARKED

28 Due to the hazard of chipping paint, areas around fuel filler caps shall be left unpainted at least one inch surrounding the caps. The entire cap shall be left unpainted.

29 Para. 28 is also to apply to lubricating oil filler caps.

30 Areas subject to severe chipping such as wing tip seams and aileron hinges are to be left unpainted. The size of the area not to be painted should be approximately one inch in width, the exact dimension to be determined by the width of the hinges or seams.

31 Areas not affecting the appearance of the scheme, which for reasons of paint stripping or labour time are difficult to handle should be left unpainted. Approval not to paint such areas shall be granted by CTSO or his delegated representative.

32 Transparent panels or windows are not to be painted.

SAFETY PRECAUTIONS

33 Not only the fire hazard but also the human respiratory hazard must be considered when painting aircraft. All personnel engaged in refinishing shall be familiar with EO 00-80-4/19.

ROYAL CANADIAN AIR FORCE

EO 05-1-2
14 Feb 64

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

GROUND TO EARTH CONDUCTIVITY FOR RCAF AIRCRAF

(This EO replaces EO 05-1-2V dated 24 Sep 63)

PURPOSE

1 Aircraft stored in hangars and aircraft undergoing maintenance operations have a tendency to accumulate an electrostatic charge which presents a potential fire hazard. This charge, therefore, is to be brought to the ground.

GENERAL

2 Grounding is to be accomplished by means of a connection from the approved metallic part of the aircraft to an approved grounding point when:

(a) Aircraft are hangared, refer to EO 05-1-5A/11.

(b) Electrical facilities or equipment is used, i.e., electrical extensions, electric drills, testing of electrical components, etc.

(c) Maintenance work is contemplated and jacking up of the aircraft is necessary.

(d) Polishing, buffing or rubbing down.

3 For grounding instructions during refuelling or defuelling aircraft, refer to EO 00-80-4/6.

4 Units are to ensure that the following is accomplished:-

(a) Grounding chains or springs on aircraft which ensure ground to earth when the aircraft is in normal taxiing position are kept in a serviceable state.

(b) Aircraft high tension grounding cables are complete with approved clamps and are checked monthly for continuity.

(c) To have the CE section check grounding rods for resistance yearly or when the validity of adequate grounding is in doubt. A grounding connection of 10,000 ohms resistance or less at the connection is preferred. However, grounding connections up to 100,000 ohms are acceptable. Grounding connections in excess of 100,000 ohms will not be used for the dissipation of static electricity.

METHOD OF MEASUREMENT

5 The approved technique to be used in determining the resistance value of grounding rods is called the three point method and requires the following procedure. Let R_1 = resistance of first grounding rod in ohms; R_2 = resistance of second grounding rod in ohms; and R_3 = resistance of third grounding rod in ohms. The resistance for each of the three grounding rods may be determined by using a 24 volt aircraft battery and a multirange ammeter connected in series between any two grounding rods. As a safety measure, to prevent possible battery

damage during rod resistance measurement where the rods may have extreme low resistance, connect a known resistance of say 100 ohms in series with the battery and grounding rods. The measured battery voltage and the resistance of the grounding rods in pairs is to be calculated using Ohms Law ($e = IR$), and the following equations:

$A = R_1 + R_2 + 100,$ $B = R_1 + R_3 + 100,$ $B = R_2 + R_3 + 100,$

$A' = A - 100,$ $B' = B - 100,$ $C' = C - 100$

The individual resistances are then to be calculated using the following equations:

$$R_1 = \frac{A' + B' - C'}{2} \qquad R_2 = \frac{A' + C' - B'}{2} \qquad R_3 = \frac{B' + C' - A'}{2}$$

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/SAMO/CEngl

APPLICATION OF DECALCOMANIAS

PURPOSE

1 The purpose of this Engineering Order is to outline the procedure for the application of decalcomanias to aircraft exterior and interior surfaces.

TYPES OF DECALCOMANIAS

2 There are three types of decalcomanias for use on aircraft surfaces. These types are as follows:

(a) Water applied decalcomania to Specification 63-GP-2a Type I.

(b) Varnish applied decalcomania to Specification 63-GP-2a Type II.

(c) Pressure sensitive decalcomania MAT9-1 Type III and IV.

POLICY

3 MAT9-1 Type III and IV decalcomanias only may be applied to aircraft external surfaces. The use of types I and II decalcomanias to aircraft external surfaces creates a hazard to flight safety.

4 Units purchasing squadron crests for use on exterior of aircraft in accordance with EO 05-1-2U shall ensure they are to Specification MAT9-1 Type III and IV.

APPLICATION OF WATER DECALCOMANIAS

5 The following items are required for the application of water applied decalcomanias to Spec. 63-GP-2a.

(a) One gallon container.

(b) Dry cloths or sponge.

(c) Detergent (Item 6).

(d) Plastic squeegee (Item 8).

6 Apply decalcomanias as follows:

(a) Mark out the surface area on which the decalcomania is to be applied.

(b) If this surface area contains breaks and protrusions such as hinges, door opening, flanges etc., cut the decalcomania prior to application and apply in smaller sections.

(c) Thoroughly mix two or three level teaspoons of detergent (Item 6) in one gallon of cold water. Stronger solutions should be avoided as they will cause deterioration of the decalcomania.

(d) Start the removal of a small section of the paper backing. Then hold the emblem face down on a clean surface and remove the backing, a small area at a time.

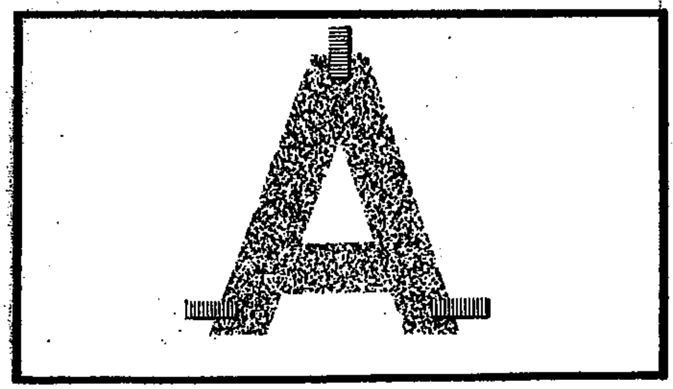


Figure 1

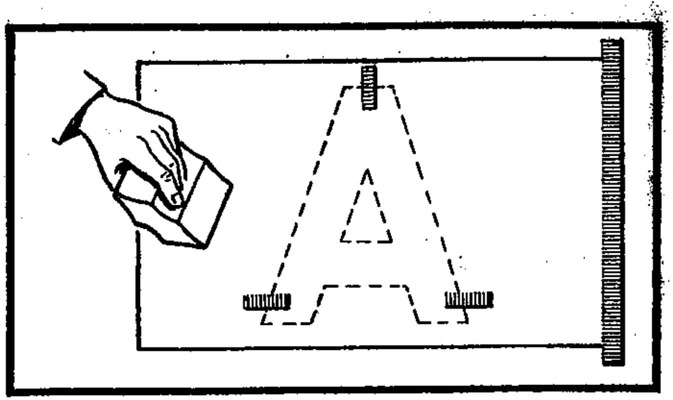


Figure 2

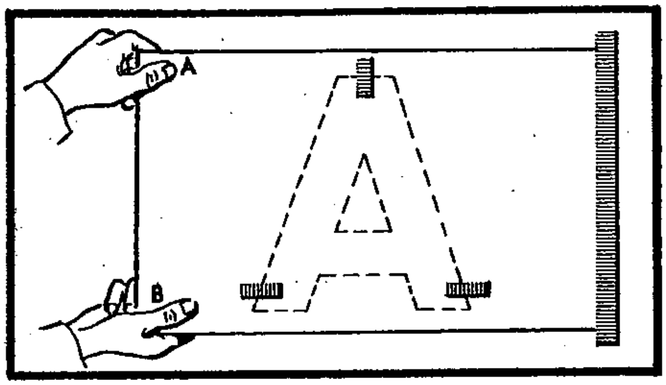


Figure 3

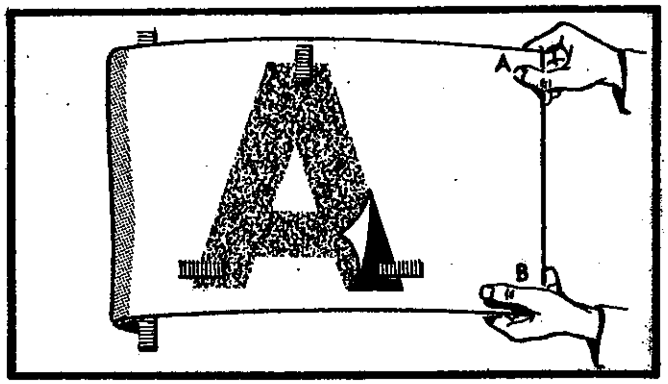


Figure 4

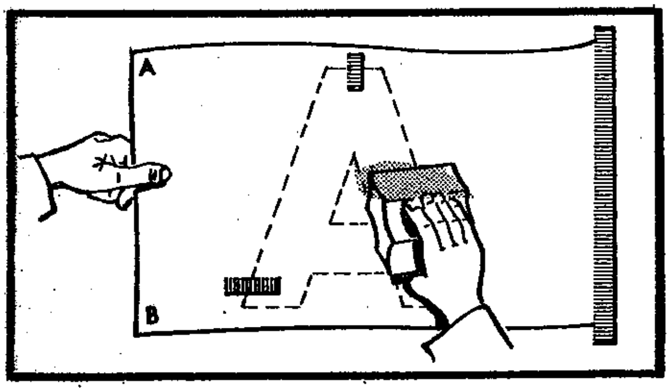


Figure 5

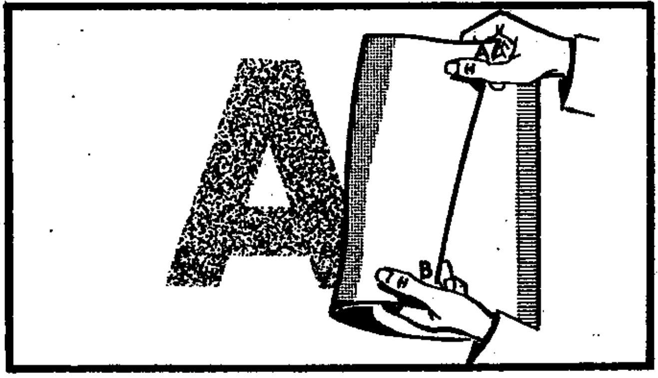


Figure 6

(e) Flood adhesive side with the wetting solution prepared in paragraph 6(c). This will prevent the adhesive side from sticking to itself should a wrinkle occur.

(f) Then, flood the aircraft surface on which the decalcomania will be applied with the wetting solution of paragraph 6(c) above.

(g) Position the emblem. Squeegee from top of emblem to bottom using light overlapping strokes to smooth out the emblem.

NOTE

> When applying emblems using the water method it is desirable to wrap several thicknesses of soft cloth over squeegee to avoid hairline scratches.

(h) Dry entire area with cloth and resqueegee with firm overlapping strokes. Dry with cloth.

(j) Work out any blisters with squeegee. If blisters are persistent puncture with pin and then squeegee.

(k) Allow emblem to dry then resqueegee to assure complete adhesion.

(m) Allow emblem to dry thoroughly for 24 hours. Then coat entire emblem with clear lacquer (Item 5) overlapping the adjacent surface to a quarter of an inch.

APPLICATION OF VARNISH DECALCOMANIA

7 The procedure for the application of Type II varnish applied decalcomanias to Spec. 63-GP-2a is the same as Type I above subject to the following exceptions.

(a) Transfer varnish (Item 9) is required.

(b) Following the removal of the backing as described in paragraph 6(d) apply one very even thin coat of transfer varnish (Item 9) on the adhesive side of the decalcomania.

(c) Allow the transfer varnish to become tacky prior to proceeding as outlined in paragraph 6(e) and following.

(d) After application of decalcomania remove surplus cement around edges, with a naphtha saturated rag. Wipe dry with soft cloth.

APPLICATION OF PRESSURE SENSITIVE DECALCOMANIAS

8 The following items are required for the application of Type III and IV pressure sensitive decalcomanias to Spec. MAT9-1 (Item 1).

(a) Plastic squeegee (Item 8).

(b) Masking tape (Item 10).

(c) Application tape (Item 4).

(d) Clean cloth.

9 Apply pressure sensitive decalcomanias as follows:

(a) Mark out the surface area on which the decalcomania is to be applied.

(b) Clean painted surfaces by wiping with clean cloths and toluene (Item 2). Then wipe the surface dry with clean dry cloths. For unpainted aluminum surface, degrease by wiping with clean cloths and thinner (Item 3). Then wipe dry with a clean dry cloth. Etch the area to which the decalcomania is to be applied with phosphoric acid treatment as specified in EO 05 1-2AH. Rinse thoroughly by wiping with clean cloths moistened with water and wipe dry. Blow water out of all seams and joints with compressed air.

(c) Separate the paper liner of the decalcomania at one corner only. To start, part the film from the liner using the thumb, or a piece of masking tape then bend the corner. This will make it easier to remove later.

(d) Tape the decalcomania into position with small strips of masking tape, see Figure 1.

(e) Cut a piece of application tape (Item 4) 4 inches larger in both dimensions than the decalcomania. Place it over the decalcomania and wipe down with the plastic squeegee. Put a strip of masking tape on one edge to serve as a hinge, see Figure 2.

(f) Lift corners marked A and B in Figure 3. Keeping the application tape (Item 4) taut, pull firmly to the right. The decalcomania and tape will come up together. Continue pulling until the entire decalcomania is separated from the surface.

NOTE

Do not remove the tape hinge.

(g) Fold the application tape (Item 4) over the hinge so that the paper liner on the decalcomania is exposed. Take care not to pull off the hinge. Now remove the paper liner, see Figure 4.

(h) Swing decalcomania back into position, see Figure 5, but do not let it touch the surface until the plastic squeegee presses it down. Wipe over the entire application tape surface. Heavy pressure on the film is required for good contact with the application surface. Using heavy pressure and a wiping motion, draw plastic squeegee across film at an angle of 60° to the surface. Start wiping at the centre of one edge. Wipe toward the top edge and back down over the same area beyond the bottom edge. Always wipe at least half an inch beyond the edges to obtain good edge adhesion. Proceed across film with parallel, overlapping vertical strokes, exerting maximum pressure at all times.

NOTE

Be sure all edges are adhered.

(j) Lift corners marked A and B in Figure 6, and carefully pull the application tape (Item 4) from the decalcomania.

(k) Immediately re-wipe the decalcomania with plastic squeegee to assure good edge adhesion.

(m) Any blisters caused by trapped air should be punctured with a pin or blade, and the air worked out with the finger or plastic squeegee. This should be done immediately after completing the application.

(n) At this point, all openings covered by the decalcomania shall be cut out. All edges and areas surrounding rivets should then be pressed down using the plastic squeegee or a small roller.

NOTE

> MAT9-1 Type III and IV decalcomanias are so strong and flexible that they may be pulled up immediately if an error in application is made. Should the film be stretched or distorted, allow it to regain its original shape and size before re-applying it.

(p) Finally, after applying the decalcomania, all edges shall be sealed with clear lacquer (Item 5). The width of the seal shall be one quarter inch and shall be divided equally between the surface of the decalcomania and the adjacent surface.

REMOVAL OF DECALCOMANIAS

10 Remove the Type I and II decalcomania to Spec. 63-GP-2a by scraping it with a putty knife, sharp pocket knife or razor blade.

11 Remove the Type III and IV decalcomania by rubbing with a cloth saturated with methyl-ethyl-keytone (Item 7). Where decalcomanias have to be removed from painted surfaces, ensure that the methyl-ethyl-keytone does not spread beyond the area of the decalcomania. After the decalcomania has been removed, examine the painted surface carefully to determine whether the solvent has removed any of the paint. If the paint film has deteriorated in any way, it must be stripped and the affected area repainted.

INSPECTION

12 Reject and replace decalcomania which, after application, exhibit any of the following defects:

(a) Tears or wrinkles.

(b) Air blisters which cannot be smoothed out.

(c) Poor adhesion or inadequate edge contact.

(d) Discolouration.

Item Number	Material	RCAF Ref.	Specification	Manufacturer
1	Decalcomania	Class 7690	MAT9-1 Type III	Sampson Matthews Ltd 1165 Leslie Street Don Mills Toronto
2	Thinner Toluene	33A/467	TT-T-548A	
3	Thinner Etch Primer Ethanol	34A/6810-21-802-3438	MIL-C-15328A	
4	Tape, Application Scotch Brand No. 343	33G/8135-21-800-9530		Sampson Matthews Ltd 1165 Leslie Street Don Mills Toronto
5	Lacquer Clear	33A/8010-21-805-6744	1-GP-159 (Type I)	
6	Detergent General Purpose	33CM/7930-21-803-6785	2-GP-103	

Item Number	Material	RCAF Ref.	Specification	Manufacturer
7	Methyl-Ethyl-Ketone	33C/520	15-GP-52	
8	Plastic Squeegee	29/7920-21-800-5144		
9	Varnish Transfer	33A/498		Canada Decalcomania Co. Ltd.
10	Masking Tape 1"	33G/103	53-GP-79	

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAMO/CEng3

ROYAL CANADIAN AIR FORCE

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

PIPE LINE IDENTIFICATION

(This EO replaces EO 05-1-2Y dated 10 Mar 55)

GENERAL

1 To avoid confusion by maintenance personnel in the identification of Pipe Line in aircraft and ease the tracing of Pipe Line systems, the following symbols and colour codes are to be used on all RCAF aircraft.

2 The colour codes represent designations for systems only. For coding lines which do not fall into one of these systems, the contents shall be designated by black lettering on a white tape.

3 The geometrical symbols shall be in outline only in bands approximately 3/16" wide and confined to the right-hand side of the tape within 1/4" from the edge. The symbols shall be spaced approximately as shown above. Lettering and symbols shall be printed in black.

4 The main function of the line shall be printed on the tape as shown in illustration. The lettering shall be 3/32" high minimum and each line repeated at intervals not exceeding the diameter of the tube on which it is to be used.

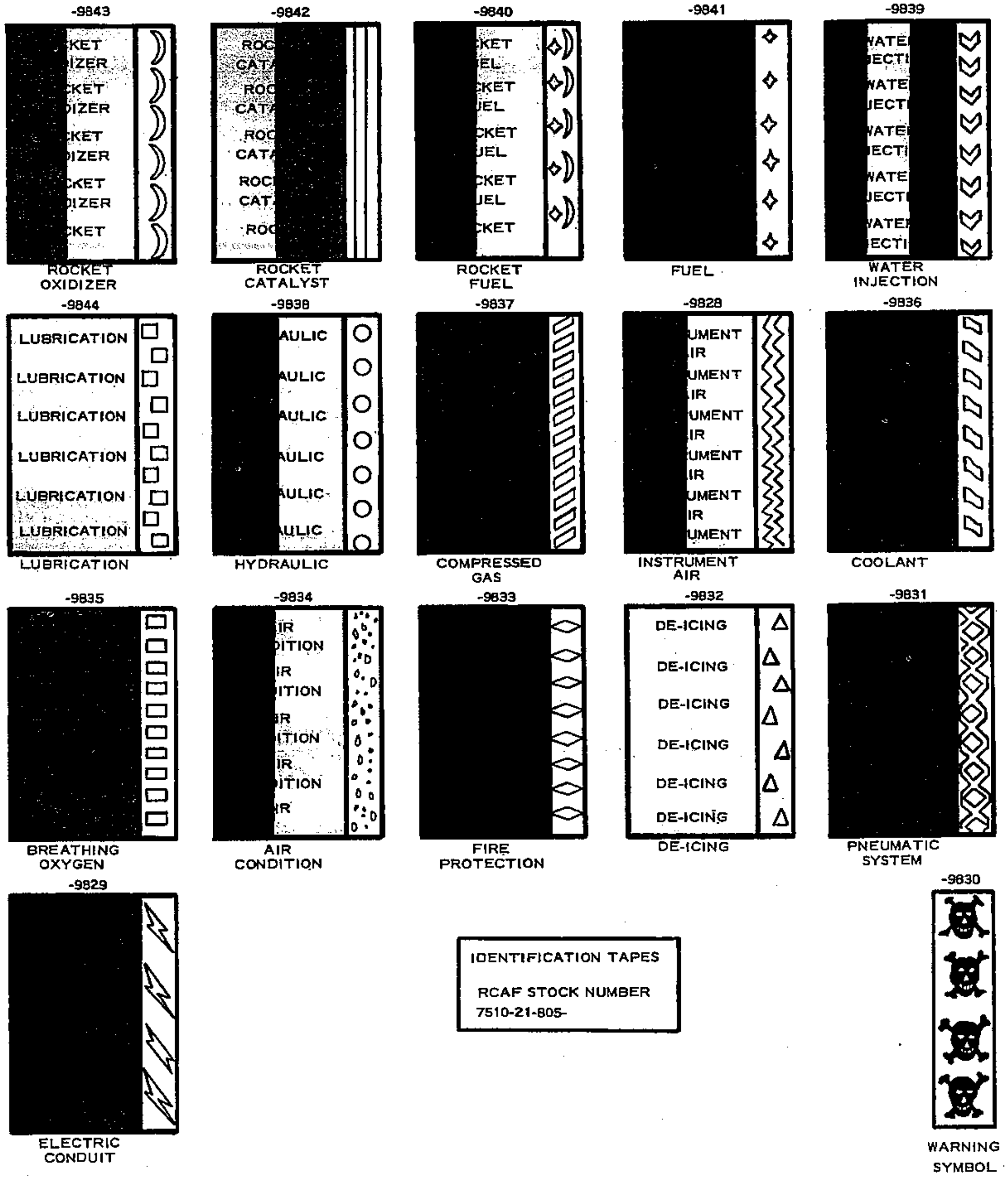
5 Subsidiary functions or identification of line content may be indicated by the use of additional words or abbreviations which shall be carried on a second tape adjacent to the first or alternatively, interposed between the words descriptive of the main function.

6 Colours used on these tapes shall conform to ANA Bulletin #166 or CGSB-1GP-12A.

RCAF Colour Code CGSB 1-GP-12A		Colour	ANA 166 Code No.
Light Blue	-2-6	Light Blue	501
Light Green	-3-7	Light Green	503
Light Yellow	-5-1	Light Yellow	505
International Orange	-8-2	International Orange	508
Insignia Red	-9-3	Insignia Red	509
Brown	-4-4	Maroon	510
Aircraft Grey	-1-6	Aircraft Grey	512
Black	-10-1	Black	514

7 Part numbers required by Aircraft Contractors shall not appear on these tapes but may be applied on a separate white tape.

8 Tapes except the warning tape to be one inch minimum width. The warning tape to be 3/8" wide.



IDENTIFICATION TAPES

RCAF STOCK NUMBER
7510-21-805-

9 Warning symbol tapes shall be applied to those lines whose contents are considered to be dangerous to maintenance personnel. Warning tapes to be placed adjacent to system identification tapes.

10 One band shall be located on each tube segment, 24" or shorter, provided that both ends of the segment are within the same compartment. One band shall be located at each end of each tube segment longer than 24" where the tube segment passes through more than one compartment or bulkhead, additional bands shall be applied so that at least one band is visible in each compartment, or on each side of the bulkhead.

11 Pressure transmitter lines shall be identified by the same colours as the lines from which the pressure is being transmitted.

12 Filler lines, vent lines and drain lines from functions or related functional equipment specified hereon shall be identified by the same colours as the function lines.

13 Telecommunication and armament system wave-guides are to be classified as pipe lines and are to be identified in accordance with para. (2) sentence 2 using the single word "Wave-Guide".

14 Tapes shall not be used on Pipe Lines in the engine compartment where there is a possibility of the tape being drawn into the engine intake. For such locations, suitable paints conforming to this colour code, and which have no deleterious effect on the material used for the lines, shall be used for identification purposes. In these cases, the geometrical symbols may be omitted.

15 No changes are to be made in colour code or symbols in this Engineering Order without prior consideration by Tripartite Authorities through the RCAF ASCC Member.

16 This EO conforms to AND 10375, latest issue.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/SAMO/CEngl

INSTALLATION OF SEALS, RINGS, GLANDS AND PACKING

(This EO replaces EO 05-1-2Z dated 23 Oct 56)

FOREWORD

The term seals as applicable to aircraft, aircraft engines and their accessories will cover "O" rings, glands and packings used on alcohol, fuel, hydraulic, oil and pneumatic systems and acessories.

GENERAL

1 When installing seals the general procedures contained herein are to be followed to ensure satisfactory service. Where detailed direction is required to carry out a specific installation in any component involving seals, reference is to be made to the applicable AFEO -2 or -3 of the component concerned and if necessary to approved applicable manufacturers' overhaul instructions.

PROCEDURE

2 For all installations of seals the following general procedures are to be observed.

(a) Ensure that correct type of seal is used for the fluid and system.

(b) Visually inspect seal for imperfections, unusual hardness or softness, nicks or cracks.

(c) Refer to AFEO 00-35-1 for age control and cure date information.

NOTE

If any doubt exists as to identification of material, immerse the seal for at least 10 hours in the fluid in which it is to operate. If the swelling exceeds 3% of the original size or if the seal becomes soft and flabby the seal is to be rejected.

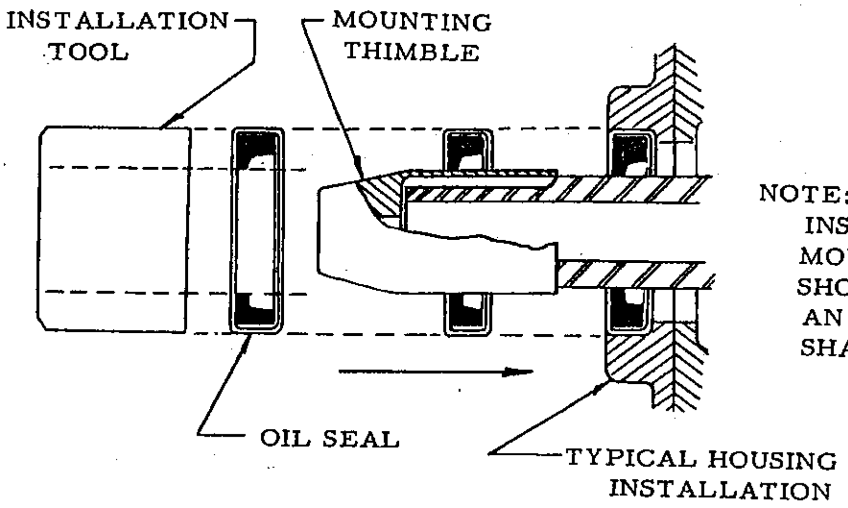
(d) Ensure that the surface of the shaft on which the seal operates is smooth and free of burrs, nicks or scratches, which may damage the sealing lip, a small scratch may result in costly leakage.

(e) If the seal is to be installed over a square end, threaded, splined or keyed portion of a shaft, the seal is to be protected by a suitable well lubricated mounting thimble, see Figures 1, 2 and 3. In an emergency and if no other means is available an alternate method is to wrap the shaft with heavy well lubricated kraft paper.

(f) Where possible the installation is to be checked by hand for freedom of movement prior to testing of the complete system.

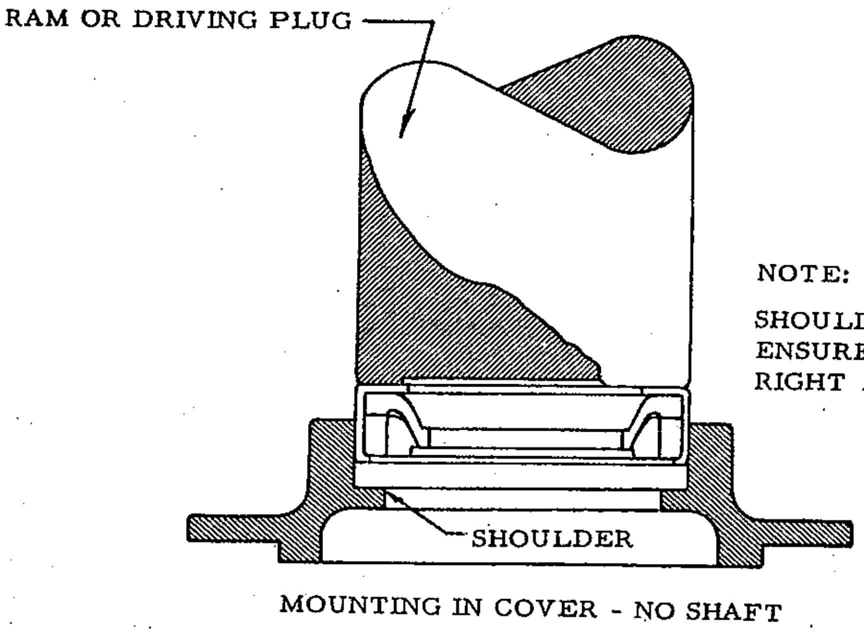
(g) For static and reciprocating pneumatic seal installations grease 3-GP-605 is to be used as a lubricant.

(h) The seal, shaft etc., is to be lubricated with the fluid in which the system operates.



NOTE:
INSIDE DIAMETER OF MOUNTING THIMBLE SHOULD ACCOMMODATE AN EASY SLIDE FIT OVER SHAFT.

Figure 1



NOTE:

SHOULDER PROVIDES STOP AND ENSURES MOUNTING SEAL AT RIGHT ANGLE TO THE SHAFT

Figure 2 (Issue 1)

METAL ENCLOSED SEAL INSTALLATION

3 When installing a metal enclosed seal it is imperative that a proper size installation tool be used to localize the pressure on the face of the metal case as closely as possible to the outside diameter. The installation tool to be not more than .010" smaller than the diameter of the bore and is to have a flat contact surface. The tool is to be placed squarely in position and tapped on the end with a mallet.

NOTE

Avoid direct hammer blows on the face of the seal.

4 See Figures 1, and 2 for various installations. If the tool is to be used as in Figure 1 the inside diameter is to be not less than .020" larger than the outside of the mounting thimble.

V-RING PACKING INSTALLATION

5 V-ring packing installations are to be adequately lubricated with the system fluid and installed with the sealing lips adjacent to the fluid, making certain that the packing ring is properly seated by tapping lightly with a suitable blunt rod or similar tool. DO NOT USE A SCREWDRIVER OR OTHER SHARP TOOL. When sets of packing rings are installed each ring must be installed individually.

6 When installing V-ring glands in a hydraulic component with an adjustable gland nut, tighten the gland nut until the V-ring stack is compressed firmly together then loosen the gland nut to the first locking point (not to exceed one sixth of a turn). Occasionally when a set of strut glands have been installed in a heated hangar and aircraft later moved outside into low temperature, slight shrinkage of packing takes place with the result that leakage often develops. As a preventative measure, the aircraft after removal from a warm hangar, should be left outside for approximately thirty minutes then taxied a short distance to settle the new glands. The aircraft should then be jacked up outside, air pressure released from the struts and the gland nut readjusted in accordance with instructoins herein.

7 V-ring glands installed in hydraulic components and held in compression by the gland nut will take on a permanent set over an extended storage period. To minimize this condition after renewal of glands and prior to delivery or storage, back off the gland nut sufficiently to relieve any compression, yet leave sufficiently tight to retain the glands in their proper location. A tag indicating that readjustment is required prior to test or installation is to be attached to the component.

8 If no adjustable gland nut is used, metal shims of graduated thicknesses will be inserted behind the adaptors of the packing glands in such a manner that the glands will be held firmly in place. To facilitate the installation of shims they may be split and the open end brought together after insertion in the gland. Staggering of open ends is preferable.

"O" RING INSTALLATION

9 "O" rings generally require no adjustment after installation. However, care must be taken when installing new "O" rings that they do not twist or nick, or early failure will result. After installation check to make sure that the "O" ring is of the proper size to give a "squeeze" in the installed position, see Figure 4. "O" rings may be removed easily by use of a small tool made of duralumin or brass rod, see Figure 5. Care is to be taken not to scratch or mar the groove or corners.

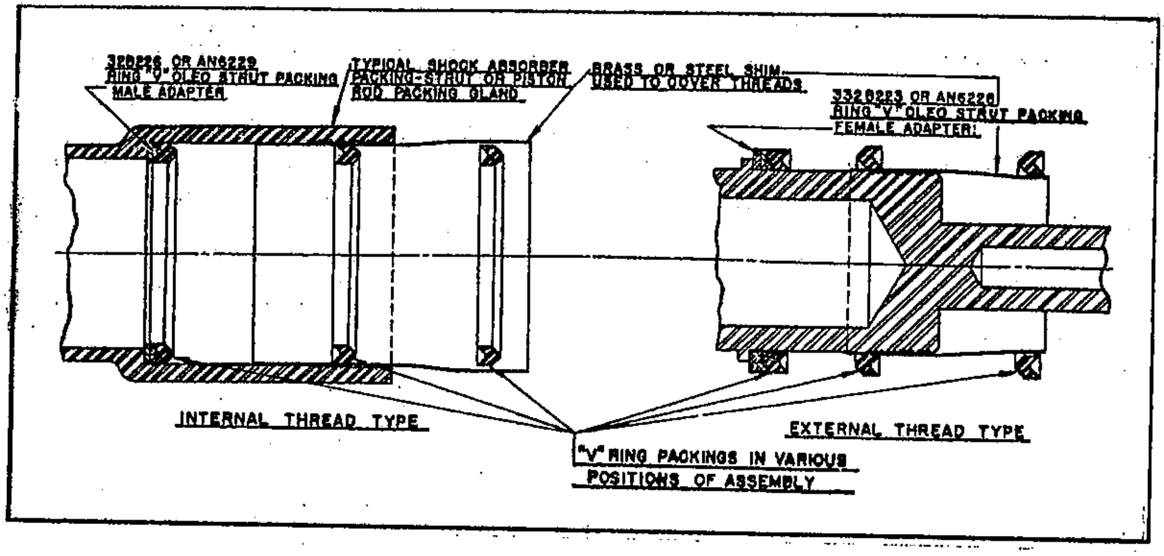


Figure 3

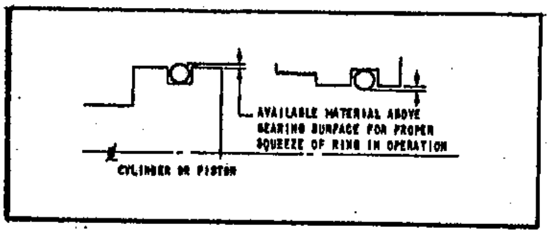


Figure 4

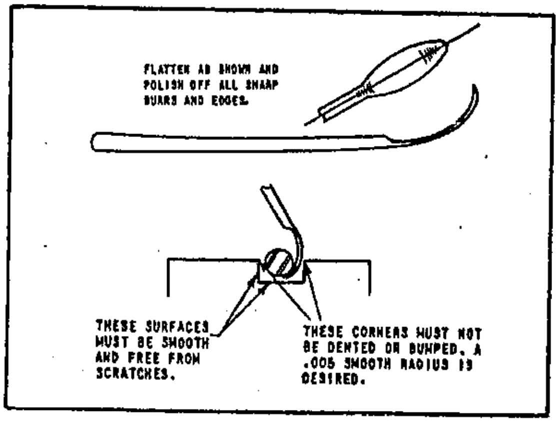


Figure 5

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/SAMO/C Eng 1

ROYAL CANADIAN AIR FORCE

EO 05-1-2AC
18 Oct 54

DESCRIPTION & MAINTENANCE INSTRUCTIONS

AIRCRAFT GENERAL

INSPECTION OF AIRCRAFT EXTERNAL OPENINGS DURING THE NESTING SEASON OF BIRDS

(This EO replaces EO 05-1-2AC dated 14 Nov 51)

GENERAL

1 To prevent the serious hazards which may develop through the birds building nests in aircraft, wings, carburettor air intakes and various orifices, the following inspection is to be carried out during the nesting period from April to July.

INSPECTION

2 A thorough inspection of all external orifices (carburettor air intakes, air intake ducts, exhaust tailpipes, control surface operating arm orifices, heater air intake ducts, and others) is to be carried out before flight during this period.

CAUTION

Particular care is to be exercised if aircraft are inactive for any period of time.

STORAGE PERIODS

3 When aircraft are stored all the orifices are to be suitably blanked off.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By
AMC/SACO/ACA

ROYAL CANADIAN AIR FORCE

EO 05-1-2AD
8 Nov 63

DESCRIPTION AND MAINTENANCE INSTRUCTIONS
FORCED LANDING INSTRUCTIONS HOLDER

(This EO replaces EO 05-1-2AD dated 14 Aug 52)

GENERAL

1 To avoid Forced Landing Instructions being misplaced or damaged after being stowed in RCAF aircraft, a standard type holder has been approved by AFHQ which will accommodate an RCAF envelope, DND 320 NSN 7530-21-562-7259. This envelope is large enough to hold all requirements for Forced Landing Instructions for service aircraft.


NOW I WONDER WHERE THOSE FORCED LANDING INSTRUCTIONS ARE?

Figure 1

Figure 2

2 The following materials are required to manufacture one holder locally:

32B/5 NSN 8305-21-804-9928 Cotton duck, 8 oz, 11-1/2" x 12" ea 1 piece
28/227 Fasteners snap ea 2
28/ Screw (AN530-8-8) ea 5
28/5310-00-515-8058 Washer ea 5

Prepared by:
AMC/SAMO/AM/CEng ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

30

EO 05-1-2AE
20 Apr 53

ROYAL CANADIAN AIR FORCE

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

CONDITION OF AIRCRAFT & ENGINES RETURNED TO CONTRACTORS FOR OVERHAUL

GENERAL

1 Repairable aircraft and engines have been stripped of components and accessories prior to shipment to repair and overhaul contractors. In some cases aircraft have been robbed of all accessory equipment except the bare minimum required for the flight to the contractor's plant. In other cases the units were unable to repair the aircraft for fly away and rail shipment to the plant was required. These practices result in overloading of the repair and overhaul programs, disruption of the planned phasing of the supply of spare parts and needless expenditures of funds.

PROCEDURE

2 No removal or exchange of components or accessories will be made except as follows:-

(a) Accessories or components may be exchanged on engines which are to be shipped to contractor on time expiry or when the cause of failure of the engine is not required to be determined. All exchanges are to be noted in the engine log book and unserviceable items tagged as such.

(b) Accessories or components may be exchanges on aircraft which are allotted to contractor for complete overhaul. All exchanges are to be noted in the aircraft log book and unserviceable items tagged as such. This action is not to prejudice the aircraft serviceability for fly-in.

3 Each aircraft or engine will, in all cases, be complete and checked to the current checking list upon transfer to the contractor's plant.

ISSUED ON THE AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By
AMC/SACO/ACT2

ROYAL CANADIAN AIR FORCE

EO 05-1-2AG
16 Sep 63

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

CARRYING OF VOLATILE & INFLAMMABLE FLUIDS IN RCAF AIRCRAFT

(This EO replaces EO 05-1-2AG dated 29 Mar 60)

1 The carrying of supplies of any volatile and inflammable fluids in aircraft, to supplemen that aircraft's requirements, is to be restricted to flights where:-

(a) The normal capacity of the aircraft tank (s) is not sufficient to complete that flight.

(b) An RCAF Source of supply is not available prior to the return to the aircraft's base.

2 Where supplementary supplies of these fluids are required to be aboard an aircraft in accordance with the above paragraph, the following instructions are mandatory:-

(a) The Captain of the aircraft is to be notified prior to the intended flight.

(b) When fluids are obtained from bulk storage the containers shall be to RCAF Reference 40D/7240-00-222-3088 (MIL-C-1283) five US gallon containers with flexible spout (or equivalent) or sealed cans. There is to be a minimum of 10% air space allowed for expansion of the fluid.

(c) Containers are to be securely stowed and grounded in accordance with Figure 1 and located in a ventilated compartment away from electrical equipment which is liable to cause combustion.

3 Containers are to be marked (stencilled) as to contents.

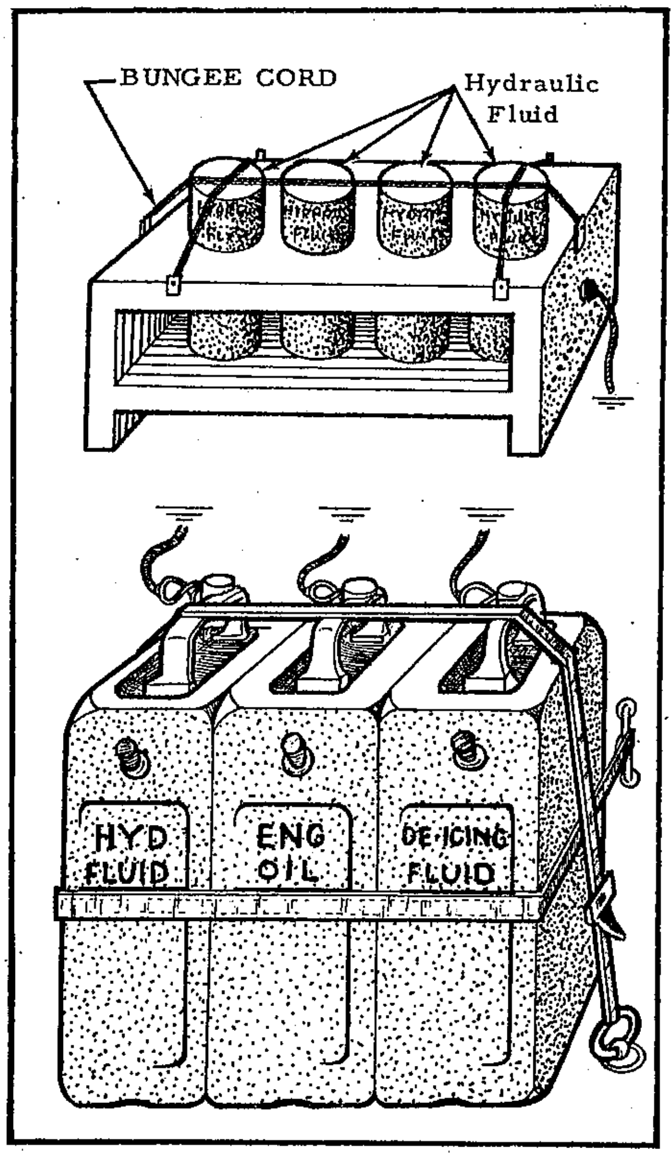


Figure 1

Prepared By:-
AMC/SAMO/CEng3 ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

EO 05-1-2AH

ROYAL CANADIAN AIR FORCE

CORROSION CONTROL
AIRCRAFT

"REVISION"
NOTICE

LATEST REVISED PAGES SUPERSEDE THE SAME PAGES OF PREVIOUS DATE

Insert revised pages into basic publication. Destroy superseded pages.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

28 OCT 53
Revised 24 Nov 61

LIST OF RCAF REVISIONS

DATE	PAGE NO	DATE	PAGE NO
29 Oct 57	9		
9 Mar 60	ii		
9 Mar 60	7		
9 Mar 60	8		
9 Mar 60	9		
5 Sep 61	9		
24 Nov 61	ii		
24 Nov 61	7		
24 Nov 61	8		
24 Nov 61	9		

FOREWORD

Corrosion in its various forms is the result of poor housekeeping. It should be remembered that the best preventive maintenance scheme known is a high standard of cleanliness, combined with immediate action if corrosion is found.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

PART 1

FORMS OF CORROSION

GENERAL

1 There are four main forms in which corrosion will be encountered and it is the purpose of this Engineering Order to aid personnel in identification, to take the necessary action to remove the corrosion and to inhibit the surface to prevent further corrosion. Corrosion when encountered will be in one of the following forms:

(a) Intragranular (Surface) Corrosion.

(b) Intergranular (Intercrystaline) Corrosion.

(c) Dissimilar Metal (Electrolitic) Corrosion.

(d) Stress Corrosion.

INTRAGRANULAR (SURFACE) CORROSION

2 This is by far the most common form of corrosion which will be encountered in the RCAF, and early recognition of the symptoms is essential in combating this corrosion. Figure 1-1 shows a section of a panel which has been attacked by intragranular corrosion. The tell tale dirty white blotches which form on the skin are very evident in the picture, and indicate that preventive action should be instigated immediately.

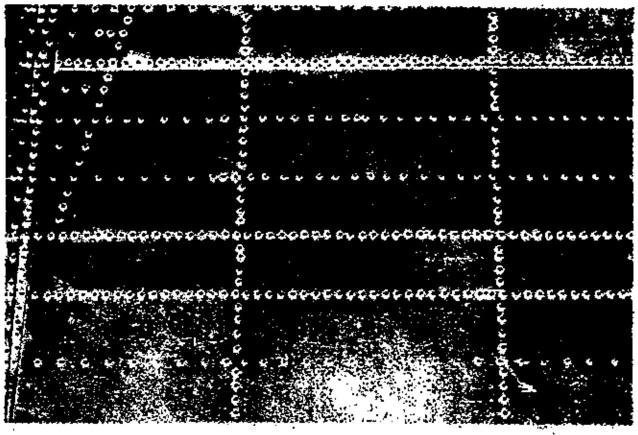


Figure 1-1 Surface Corrosion

3 Areas which are the most susceptible to this form of corrosion are the undersurfaces of wings and tailplanes, lower portions of air intakes, the areas around the battery compartment and areas subjected to relief tube spray, hot exhaust gases and the gases from gun fire. These areas should be inspected at regular intervals for any indication of corrosion.

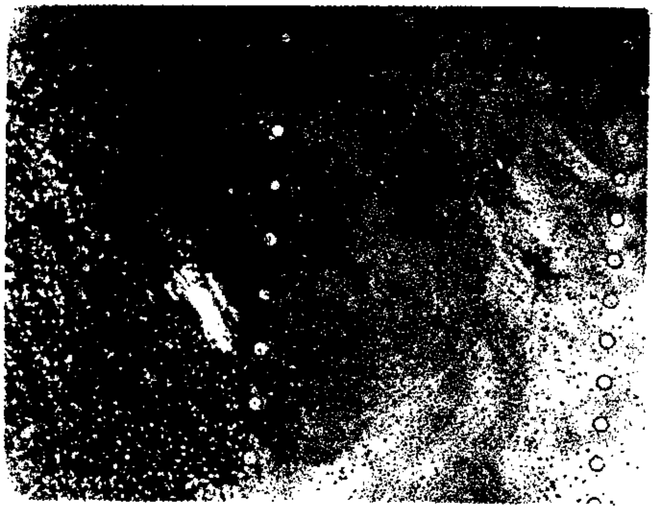


Figure 1-2 Severe Surface Corrosion

4 In Figure 1-2 we see a panel which has been allowed to proceed to a serious degree. The left hand side of the picture shows the surface appearance before the corrosion product has been removed, while the right hand portion of the panel has been cleaned and tested for penetration. The test for penetration is carried out using a 5 normal solution of sodium hydroxide, caustic soda, 1 part to 4 parts water by weight, which is applied to the surface and left for 2 minutes. Using a flashlight and a magnifying glass, 4 power or greater, inspect the base of the pits to see whether they have turned black. If the base of the pit is black, it indicates that the clad has been penetrated and that either the panel should be replaced or a form of surface treatment carried out. For recommended surface treatments, see Part 2. It will be left to the discretion of the Chief Technical Officer as to whether the panel will be replaced or surface treatment carried out.

5 In the case of extruded members or castings, the extent of corrosion allowed will depend upon the location and function of the member involved. In all cases the Chief Technical Officer will decide what program will be carried out. A suggested maximum reduction in cross sectional area due to the action of surface corrosion is 10%.

INTERGRANULAR (INTERCRYSTALINE) CORROSION

6 A second and perhaps the most serious form of corrosion which will be encountered is intergranular or intercrystaline corrosion. The corrosion is more prevalent in the heat treatable aluminum alloys such as 17S, 24S, 57S, (52S Alcoa) and 75S, which have been subjected to improper heat treatment. In Figure 1-3 we have a photograph (x500) of a longitudinal section of a sample which has been improperly heat treated. In this photograph, it is possible to see the precipitation in the grain boundaries. It is this precipitation of alloying ingredients in the grain boundaries of the material which seriously decreases the materials' resistance to corrosion.

Figure 1-3 Grain Boundary Precipitation

7 The first indication that corrosion is beginning to attack a member will be the formation of slight blister-like raises on the surface of the metal. Upon probing with a sharp tool the metal will flake away much like rotten wood.

Figure 1-4 Intergranular Corrosion

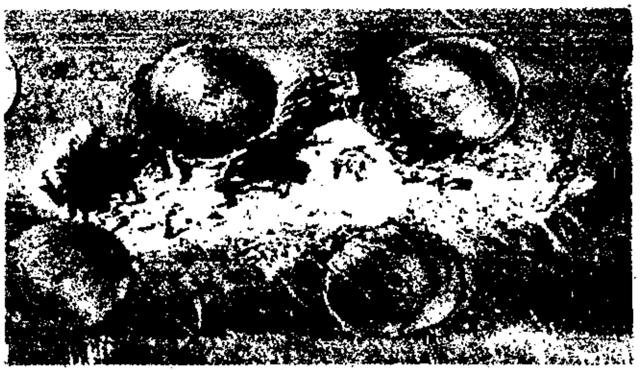


Figure 1-5 Intergranular Corrosion

Figures 1-4 and 1-5 show the appearance of a member after probing in which corrosion has reached an advanced stage. In Figure 1-6 we have a cross sectional view of a member which showed only a slight blister effect on the upper surface. The member when sectioned and subjected to microscopic examination showed the effects of severe intergranular corrosion. As shown, Figures 1-6 and 1-7, the effect of intergranular corrosion, dark lines, is to destroy the grain boundaries which in turn reduces the strength of the material. The fact that intergranular corrosion can reach a serious extent before being evident, makes it essential that when this form of corrosion is suspected, steps are taken to determine the extent of the damage. In Figure 1-8 we have a longitudinal cross section of a section of corroded metal showing the complete breakdown of grain structure which has occurred.

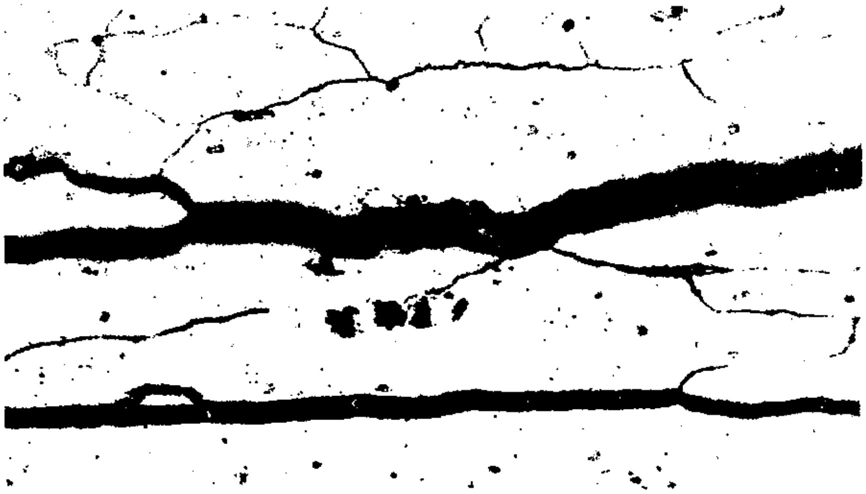


Figure 1-6 Micro Photograph - Destroyed Grain Boundaries

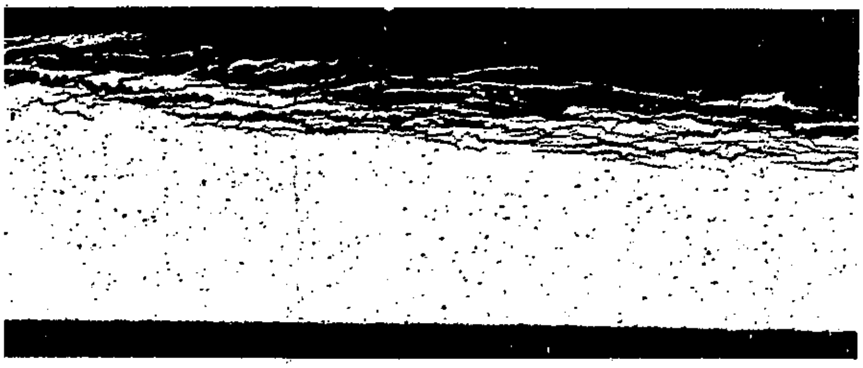


Figure 1-7 Micro Photograph of the Probed Area - Transverse

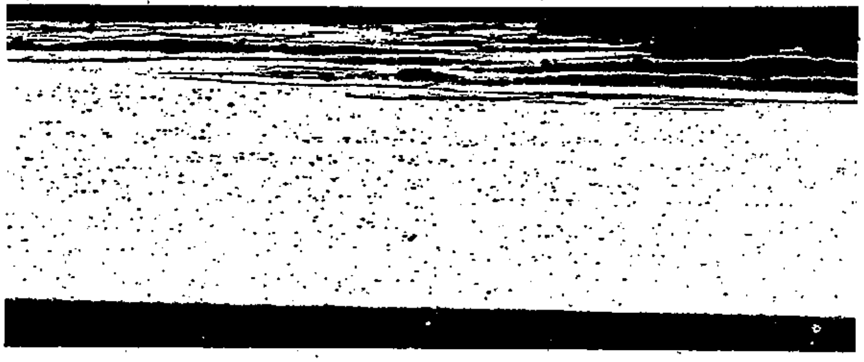


Figure 1-8 Micro Photograph of the Probed Area - Longitudinal

8 The use of clad sheet has, to some extent limited the danger due to improper heat treatment. However, if surface corrosion is allowed to penetrate the clad on a section which has been improperly heat treated, intergranular corrosion will attack the base metal. This action may be seen on Figure 1-9 where corrosion lines may be seen extending from the base of the pits. With clad material, corrosion may proceed until the only sound metal is the clad. In Figure 1-10 we have a example of this, but in this photograph the outer clad has been removed to show the extent of damage to the base metal.

NOTE

There is no known method of inactivating this form of corrosion. The only corrective action that may be taken is the replacement of the affected components.

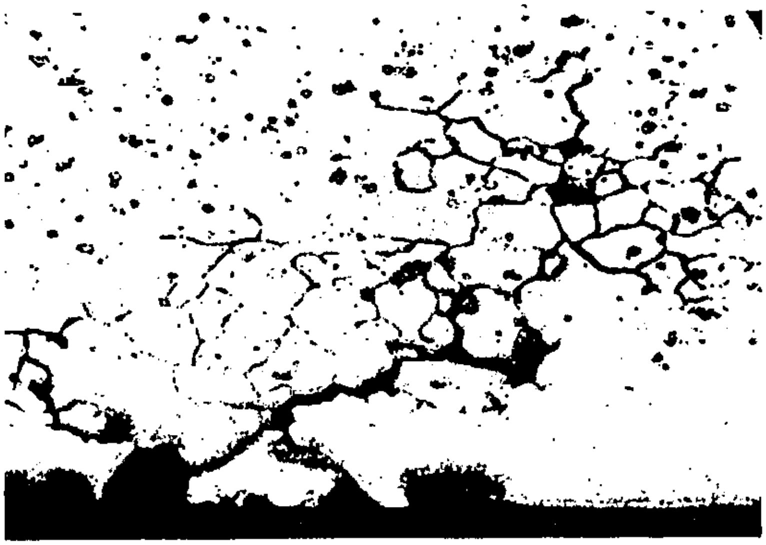


Figure 1-9 Intergranular Corrosion

Figure 1-10 Severe Corrosion of Core Material

DISSIMILAR METAL (ELECTROLITIC) CORROSION

9 A third form of corrosion encountered will be that caused by the contact of two dissimilar metals in the presence of an electrolyte, a solution capable of conducting an electric current. It has been established that every metal and alloy has an inherent electrical potential, and when one metal is in contact with a metal of different potential, in the presence of an electrolyte a galvanic cell is produced, and a current will flow from one metal to the other, resulting in the dissolution of one of the metals. The metal from which the current flows is the anode and that to which the current flows is the cathode. The degree of corrosion may be estimated from the difference in potential between the two metals forming the cell with the anodic, negative, metal being corroded. Table 1 lists the galvanic series in sea water, but is not true in every respect since corrosion is proportional to the current flowing in the cell and this is influenced by cell resistance, ratio of contact areas, concentration, aeration, and type of corrosive medium.

TABLE 1.

GALVANIC SERIES IN SEA WATER	
1	Magnesium
2	Magnesium Alloys
3	Zinc
4	Aluminum (52SH, 61S, 3S, 2S, 53ST in this Order)
5	Clad 24ST and Clad 17ST
6	Cadmium
7	Aluminum (75ST, A17ST, 17ST, 24ST in this Order)
9	Mild Steel
10	13% Chromium Stainless Steel Type 410 (Active)
11	50-50 Lead-Tin Solder
12	18-8 Stainless Steel Type 304 (Active)
13	Lead
14	Tin
15	Manganese Bronze
16	Naval Brass
17	Nickel (Active)
18	Inconel (Active)
19	Admiralty Brass
20	Aluminum Bronze
21	Copper
22	70-30 Copper-Nickel
23	Nickel (Passive)
24	Inconel (Passive)
25	Monel

NOTE

A passive metal denotes a metal upon which a protective oxide film readily forms, that prevents further attack on the metal.

Table 1 is for information only. The positions of the metals in this Table does not enable the rate of corrosion to be determined.

STRESS CORROSION

10 This type of corrosion occurs when a particular member is subjected to both high stresses and corrosive conditions. This form of corrosion happens infrequently and is evident by the metal cracking in the areas of maximum stress. Aluminum, brass and magnesium alloys are particularly susceptible to this kind of failure. Stress corrosion will occur along lines of cold working if the metal has been stressed too highly and not properly relieved through heat treatment.

PART 2

CORROSION CONTROL

GENERAL

1 It is of the utmost importance that aircraft be kept thoroughly clean at all times. Whenever flying commitments permit a definite time should be set aside for cleaning aircraft. This cleaning of aircraft is considered essential in order to maintain airworthiness and to inhibit corrosion. In order to avoid damage to the aircraft through use of harmful materials, only those materials which have received AMCHQ approval are to be used. In washing aircraft and in paint removal from metal surfaces, care must be exercised to maintain the proper concentration of solution used, as a strong solution may be found to cause corrosion.

CLEANING

2 Instructions and approved methods for cleaning aircraft as detailed in EO 50-10A-2 Aircraft Cleaning External are to be followed.

SALT WATER OPERATIONS

3 Aircraft involved in operations from salt water shall be washed down with fresh water at the end of the days flying. Components not otherwise protected against corrosion shall be dried and either sprayed or wiped down with lubricating oil or hydraulic fluid depending on components being treated. Care shall be taken to ensure that as little fluid as possible is deposited on exhaust pipes or collector rings. The fluid will also be kept off all rubber components.

4 Magnesium or aluminum alloys are used in the landing gear wheels and unless protected, corrosion will set in rapidly. Inspection of the wheels should include a careful visual inspection of the paint surface. Portions of the wheel where the paint has deteriorated, peeled or chipped must be retouched with lacquer.

5 Hull and float interiors will be drained and flushed at regular intervals and in manner described in the applicable -2 Engineering Order.

METAL IN CONTACT

6 When fabricating metallic parts, care must be exercised to prevent corrosion at the fraying surfaces. Similar metals present no difficulty and require only the use of zinc chromate primer before fabrication. The use of dissimilar metals present a much more difficult situation and precautions must be taken. In most instances the materials should be separated by an insulating material. Steel when in contact with aluminum should be cadmium plated or metalized with aluminum and then receive two coats of primer which must be dry before assembly. The installation of press fittings is accomplished using a heavy zinc chromate paste.

BATTERY ACID

7 To neutralize spilled battery acid, use sodium bicarbonate, baking soda, or sodium borate, borax, dissolved in water. The alkali salt must be completely removed after neutralization with copious quantities of water to prevent corrosion.

GUN BLAST PANELS

8 Gun blast panels and areas which the hot gases pass over shall be cleaned with an approved cleaner at the end of the days' flying, if the guns have been fired.

REMOVAL OF DRY CHEMICAL EXTINGUISHING AGENTS

9 When aircraft have been subjected to 21F/283 and 691 Dry Chemical extinguishing agents, the following preventative measures, if taken IMMEDIATELY will prevent corrosion:

(a) Remove as much of the powder as possible by sweeping, brushing, vacuuming, or blowing with compressed air.

(b) Wash affected parts thoroughly with soap and water.

(c) Rinse thoroughly with clear water.

CORROSIVE LIQUID CHEMICAL - FIRE EXTINGUISHING AGENT

10 Aircraft, engines, components and areas affected by discharge of Methyl Bromide (MB) Chlorobromomethane (CB) or Freon (CF_3BR) fire extinguishers are to be thoroughly sprayed with a suitable solvent and blown out with dry compressed air with special attention given to the valves and piping of the extinguishing system.

REMOVAL OF CORROSION PRODUCT

11 There are several means of removing the corrosion product, but care must be used to ensure that no further damage is done to the skin. Mechanical methods of removal may be one of the following; sandpaper, scrapers, wire brushing, aluminum wool.

NOTE

In no case shall steel wool be used in removing corrosion product from aluminum panels. The use of steel wool may cause electrolitic corrosion due to particles of steel wool embedding in the aluminum clad.

NOTE

Whenever possible chemical means of removing the corrosion products are preferred to mechanical means.

CORROSION REMOVAL - ALUMINUM

CHROMIC ACID WASH

12 A 10 percent solution shall be made by mixing 18.5 ounces, Avoirdupois, chromic acid Federal Spec. O-C-303 in 1 Imperial gallon of water. Stir the solution until the chromic acid is thoroughly mixed.

Procedure

13 The procedure for application of the corrosion inhibiting coat shall be as follows:-

(a) Clean the affected areas thoroughly using an approved solvent.

(b) Clean the corroded areas of corrosion product using the acid wash and a stiff fibre brush.

(c) Wash the area thoroughly with warm or cold water to remove all traces of corrosion.

(d) Coat area with the 10 percent solution of chromic acid applied uniformly with cloths, felt pads or brushes and allow to dry. This will act an an inhibitor.

(e) The chromic acid shall be thoroughly removed with a damp cloth and the metal dried. This is necessary to prevent staining of the finish.

CAUTION

The operator must wear protective clothing while carrying out this operation.

The chromic acid solution must be limited to a chromic acid content of between 9 and 11 percent. This corresponds to a hydrometer reading of 1.068 to 0.184.

Rags wetted with chromic acid solution shall be placed in a metal container to avoid the possibility of a fire caused by spontaneous combustion.

Acid solutions are to be contained in glass or earthenware containers.

Reference is to be made to EO 00-80-4/22 for further precautions when handling acid solutions.

PHOSPHORIC ACID TREATMENT

14 A 10 percent phosphoric acid alcohol solution shall be prepared by mixing the following:

Isopropyl Alcohol 3-GP-525	7 parts by volume
Phosphoric acid 85% . . . Federal Spec. 0-P-313	1 part by volume
Water	2 parts by volume

Procedure

15 The procedure for application of this corrosion, inhibiting coat shall be as follows:

(a) Clean the affected area thoroughly using an approved solvent.

(b) Apply the acid solution with a stiff fibre brush, scour to remove all traces of the corrosion product. Allow the solution to remain for 2 or 3 minutes.

(c) Wash thoroughly with hot or cold water and dry.

WARNING

Phosphoric acid treatment in general has the same application as the chromic acid treatment but should not be used where it could become entrapped and remain in contact with the structure as it will cause severe corrosion.

Do not allow material to remain on the surface more than 3 minutes.

CORROSION TREATMENT OF MAGNESIUM ALLOY

16 The treatment consists of a simple dip operation requiring one-half to two minutes, according to the freshness of the solution, in the following bath maintained at room temperature 21.1° to 32.2°C (70° to 90°F).

Sodium Dichromate	1.5 lbs.
Concentrated Nitric Acid	1.5 pints
Water	to make 1.0 gallon

Technical grades of these chemicals may be used. Pure aluminum, glass or ceramic tanks may be used for containing the solution. Welded pure aluminum tanks are most practical for large installations. After the dip the parts should be held above the tank for approximately five seconds. This allows the adhering solution to drain off, and produces a better colored coating. The parts are then washed in cold running water followed by a dip in hot water to facilitate drying.

17 Magnesium die castings should be given a ten second dip in the chrome-pickle solution heated to 49°C (120°F). Longer time of treatment results in an excess of powdery deposit.

18 Articles too large to be immersed should be well brushed with a generous amount of fresh solution which is allowed to remain on the surface for about one-half minute and is then washed off. The coating thus formed is less uniform in color than that produced by the dip process but is equally good as a paint base.

NOTE

In treating riveted assemblies, care must be taken to avoid trapping solution in the joints.

When applying this chrome-pickle solution, precaution must be taken to ensure that this solution does not come in contact with areas where injurious effects may occur, such as plated surfaces, bearing surfaces, brass or copper.

SURFACE PROTECTION

19 Where additional surface protection is necessary zinc chromate primer Spec. MIL-P-6889A type 1 shall be used followed by a cellulose nitrate lacquer Spec. MIL-L-7178.

ROYAL CANADIAN AIR FORCE

EO 05-1-2AJ
22 Nov 63

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

LIGHT ALLOY THREADED PARTS
LUBRICATION OF THREADS

(This EO replaces EO 05-1-2AJ dated 28 Feb 54)

GENERAL

1 With a threaded light alloy part is screwed into another light alloy section, the threads unless properly lubricated are liable to bind. This is particularly noticeable if the parts are overtightened.

2 It is essential that the proper lubricant is used. Threads are to be lubricated with lubricant, anti-seize, RCAF Ref. 34A/9150-21-802-4306. This compound is resistant to oil, gasoline, hydraulic fluid and alcohol.

3 Care is to be taken when assembling hydraulic lines that an excess quantity of lubricant is not applied as contamination of the hydraulic fluid will result, with possible malfunction of the system.

OXYGEN SYSTEMS

4 Threaded light alloy components used in systems carrying oxygen under pressure, when assembled, must be lubricated with compound, anti-seize and sealing (for Oxygen systems) RCAF Ref. 34A/8030-00-243-3284.

CAUTION

When assembling systems carrying oxygen under pressure no other form of lubricant shall be used.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAMO/CEng 1

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

AIRCRAFT CONTROL CABLE TENSIONING-GENERAL

1 Where aircraft cable tensions are suspected of inaccuracy and affecting their intended role, the aircraft is to be brought into the hangar and allowed to remain in the constant-temperature area for as long as possible, before commencing cable tensioning, to ensure that the temperatures of the aircraft structure are stabilized.

2 To achieve best results, the aircraft should be placed in the hangar or in the shade, never in the direct sunlight. The aircraft should be shielded from draughts or hot-air blasts from heaters.

3 Temperature readings should be taken from the interior of the wheel wells as the temperature changes more rapidly at this point than that of the internal airframe structure.

4 The following are suggested points to check to obtain the best results:-

(a) Errors inherent in the measuring instrument; calibration is generally accurate within five percent. Avoid shocks or jarring of the instrument.

(b) Errors in the method of taking readings; take several readings at the same location and avoid snapping of instrument from the cable.

(c) Errors in temperature readings; two categories cover this phase, namely, human errors which can be corrected by rechecking readings, and errors due to unequal heating or cooling of the aircraft.

(d) Errors in positioning of the tensiometer; ensure that the cable is held firmly against the back of the tensiometer, when placed on the cable. Do not position the tensiometer within six inches of any type of cable connections as these increase the stiffness of cable resulting in high readings.

(e) Errors in the control positioning; neuttralize the controls.

(f) Errors in the use of risers; ensure risers are retained for the particular instrument at all times.

5 This Engineering Order shall be used in conjunction with the applicable aircraft -2 EO. Engineering Order 65D-20AA-2 may be referenced for further information on cable tensiometers.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/SACO/ACC

ROYAL CANADIAN AIR FORCE

EO 05-1-2AN
22 May 62

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

AIRCRAFT ALIGNMENT SYMMETRY CHECKS

(This EO replaces EO 05-1-2AN dated 8 Oct 54)

GENERAL

1 This instruction details the general procedure to be followed and the equipment required when performing aircraft alignment and symmetry checks. In addition, an alternative symmetry check method is detailed using a water-level method.

2 This order is to be read in conjunction with, but is not to supersede, the applicable -2 or -3 EOs. Aircraft diagrams, required dimensions, special instructions and special equipment required will be detailed in the applicable aircraft EO.

DEFINITIONS

3 An alignment check involves the measurement of distances between reference points on the aircraft and distances between reference points projected from the level aircraft to the floor plane.

4 A symmetry check involves the measurement of elevations to reference points on a level aircraft relative to a horizontal reference plane.

5 These measurements are then checked against the established dimensions as laid down for the applicable aircraft.

6 Alignment and symmetry checks shall be performed when any of the following conditions have occurred:

(a) Heavy landing (when warranted by the results of inspection in accordance with para. 7 of this EO).

(b) Abnormal loads have been placed on flying surfaces and/or fuselage due to the "G" limits being exceeded, or other causes.

(c) When a major structural component is changed.

(d) When the flying characteristics of the aircraft are such as to cause doubt in the correctness of the aircraft alignment.

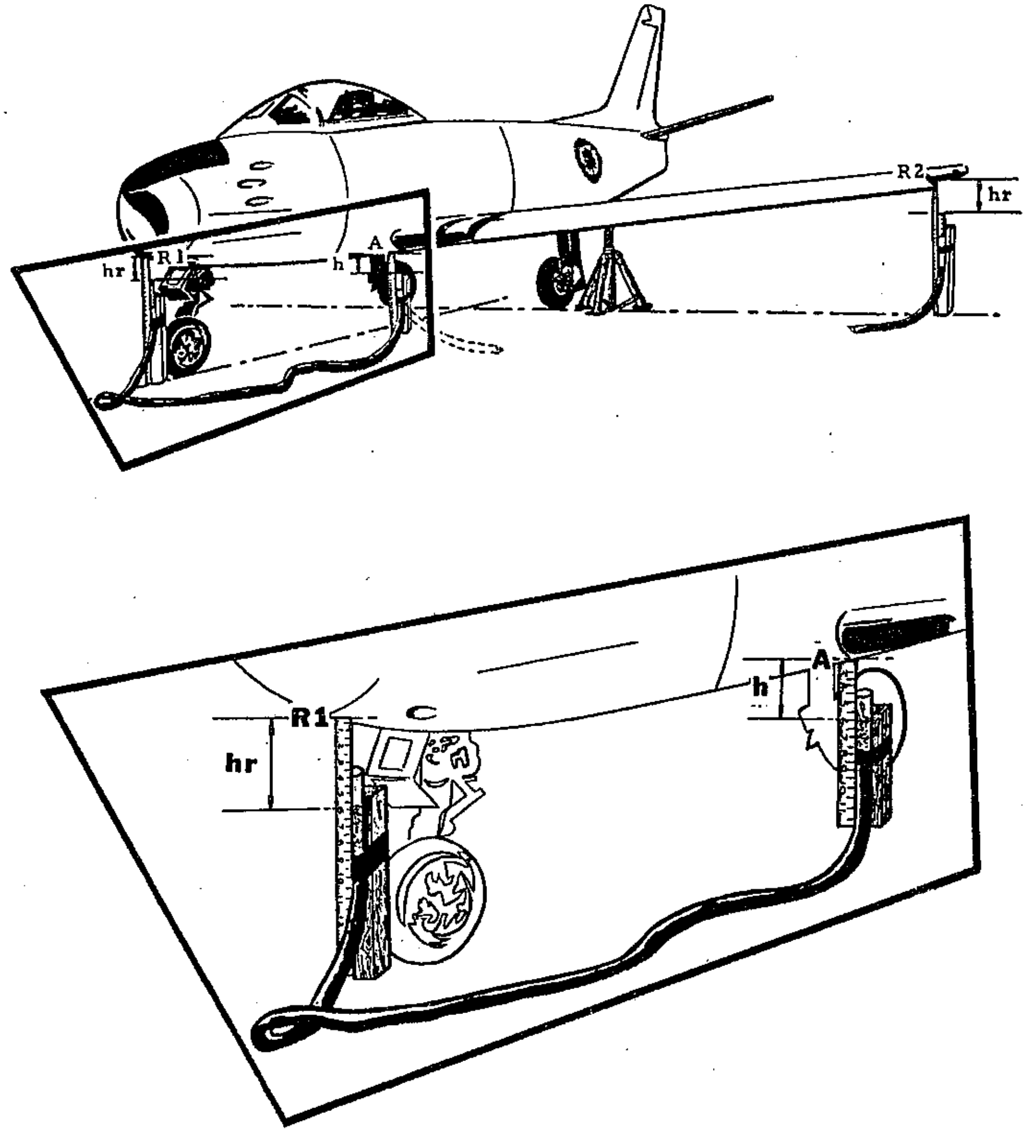
7 A visual inspection of the aircraft shall be carried out after a heavy landing or when there is possibility that "G" limitations of the aircraft have been exceeded. Special attention is to be given the following (where applicable) for signs of cracks, ripples or failure:

(a) Power plant mounting.

(b) Tail pipe supports.

(c) Centre section fairings.

Symmetry Check -- Water Level Method



A...DATUM POINT

R...REFERENCE POINTS

h...DATUM MEASUREMENT

hr..REFERENCE MEASUREMENTS

Figure 1 Symmetry Check - Water Level Method

(d) Slats.

(e) Drop tank attachment points.

(f) Flying control surfaces and the hinge points.

(g) Fuselage and wing skin.

(h) Popped or pulled rivets or sheared bolts.

EQUIPMENT REQUIRED

8 The following list of equipment is only of a general nature. Special equipment required will be detailed in the applicable aircraft EO.

(a) Wing jacks and pads.

(b) Nose or tail jack and pads.

(c) Spirit level and levelling bar.

(d) Two-foot scale.

(e) Six-foot scale or rod.

(f) Six-foot steel tape.

(g) Fifty-foot steel tape.

(h) Two plumb bobs and lines.

(j) Chalk line and chalk.

(k) Transit or surveyors' level.

ALIGNMENT CHECK

9 Both alignment and symmetry checks are to be performed in still air and preferable on a hard, smooth, level surfaced floor.

10 With the aircraft located on a hard level surface, proceed to jack the aircraft and level it in the longitudinal plane using the spirit level and levelling brackets. Similarly adjust the lateral level of the aircraft by means of the wing jacks. Check the longitudinal and lateral level to ensure the aircraft is accurately levelled before any measurements are taken.

11 Using the applicable aircraft diagrams, locate the required reference points on the aircraft and project these points to the floor plane using the plumb bob and line. Mark and connect these projected points using a chalk line to mark the floor. Measure and record the distance between the connected reference points using the steel tape, which has been pulled taut before measurements are taken. Check the dimensions obtained and compare these with the dimensions quoted in the applicable EO.

NOTE

If discrepancies are found between actual dimensions and those quoted in the applicable EO, a structural check and investigation must be made to determine the cause.

SYMMETRY CHECK

12 Level the aircraft in the same manner as that detailed in para. 10. Locate the transit or surveyors' level on the right-hand side of the aircraft midway between the wing tip and tailplane. Ensure that the site chosen is such that the line of sight to the datum point and right-hand reference points is not blocked by parts of the aircraft or jacking equipment.

13 Locate the aircraft datum point and place a steel rule against it, ensuring that the rule is at right angles to the plane of the floor by means of a plumb bob held against the aircraft near the datum point. Take a sight through the level on the rule and record the reading. Repeat this process for all right-hand reference points and record the readings.

14 Move the transit or level to the left-hand side of the aircraft and repeat the procedure as outlined in paras. 12 and 13 for all left-hand reference points.

15 The actual dimensions between the datum point and the reference points are obtained by subtracting the datum point reading from each of the recorded reference point readings. The plane of the datum point is considered as the zero dimension. In the calculation of vertical measurements, a positive value indicates the reference point is above the datum point, and a negative measurement indicates the reference point is below the datum point.

NOTE

If discrepancies are found between actual dimensions measured and those quoted in the applicable EO, an investigation must be made to determine the cause.

SYMMETRY CHECK - WATER LEVEL METHOD

16 The following instructions detail an alternative means of performing an aircraft symmetry check where a transit or level is not available or is not practical. This symmetry check method is based on the principle that "liquid always seeks its own level". Refer to Figure 1.

EQUIPMENT REQUIRED

17 In addition to the equipment as detailed in para. 8, less item (k), the following equipment is required to carry out a symmetry check by the water-level method:

(a) Approximately fifty feet of plastic garden hose. Where possible transparent hose is preferable to facilitate the removal of all air bubbles from the hose.

(b) Two lengths of heavy walled glass tubing, such as water gauge tubes as used in steam or hot water boilers. If available, straight lengths of heavy plastic tube may be substituted.

(c) Two standard twelve-inch steel rules.

(d) Two locally manufactured tripods, or lengths of two by two lumber approximately three feet in length. The height of the tripods or supports will be dependent on the aircraft being checked.

(e) A vegetable or mineral dye may be added to the water for water level contrast, if desired, e.g. ink.

PROCEDURE

18 Fill the plastic hose with water ensuring that no air bubbles remain in the hose, as this condition would cause erroneous readings. Install the glass or plastic tubes in each end of the hose and top up the complete assembly until the water level in both ends is within three or four inches of the open tube end.

19 Locate the aircraft datum point and support one end of the hose assembly under the point by attachment of the hose to the tripod or wooden support. Keeping the other end of the tube at approximately the same height, move it to the reference point for which a measurement is required. The second tripod or wooden support is then used for the support of this end.

20 With the hose assembly, set up as above, for each reference point that a measurement is required, measure the following:

(a) Distance from datum point to water level.

(b) Distance from reference point to water level.

NOTE

Care is to be taken that the heights of the gauge tubes are not varied during the taking of measurements (a) and (b) above.

21 The actual dimensions of the reference points required are obtained as indicated in para. 15.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAMO/CEng

ROYAL CANADIAN AIR FORCE EO 05-1-2AS
12 Jul 63

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

AIRCRAFT WARNING STREAMERS MANUFACTURING AND MAINTENANCE

(This EO replaces EO 05-1-2AS dated 15 Feb 60)

GENERAL

1 Warning streamers are required to provide a visual indication that:-

(a) Safety devices and/or locks are engaged on the aircraft.

(b) Protective covers are in place.

(c) The aircraft, engines, and/or accessories are unsafe for electrical power.

PROCEDURE

2 The following factors are to be used as a guide in manufacturing and placing of streamers.

(a) Streamers per para. 1(a) and (b). - A warning streamer shall be permanently attached to any safety device and/or lock where the failure to remove it before flight or replace it after flight could result in damage to aircraft systems or controls, affect the flying characteristics of the aircraft, create a hazard for personnel or prejudice the role of the aircraft.

NOTE

Permanently attached means attaching by sewing or rivetting. Under no circumstances are streamers to be attached by means of snaps, pins or ties.

(b) Streamers as per para. 1(c). - A warning streamer shall be attached to the master battery switch and the external electrical receptacle when it is unsafe for electrical power to be supplied to the aircraft (Ref EO 00-80-4 para 7).

NOTE

The streamer in this case may be held in place by using wire or pins.

(c) The streamers are to be coloured red with a minimum width of 2" and having a minimum length of 18" readily visible from any angle and at a reasonable distance. Warning streamers must not interfere with the opening and closing of canopies and doors with the ground operation of the aircraft. Relaxation of the minimum measurement will be permitted only where interference will occur.

(d) The streamers are to be made up by the unit, and commensurate with economy and availability. The type of material used can be left to the discretion of the unit CTechSO.

REPLACING

3 Streamers to be replaced when their effectiveness has become deteriorated through being:-

(a) Detached, torn or frayed.

(b) Discoloured or covered by grime or grease to such an extent that normal cleaning methods are not effective.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/SAMO/CEng3

A/

ROYAL CANADIAN AIR FORCE

EO 05-1-2AT
6 Apr 61

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

PITOT STATIC SYSTEM MAINTENANCE

(This EO replaces EO 05-1-2AT dated 3 Dec 58)

1 Cases have occurred where pitot static lines have been crossed or left disconnected after maintenance. To prevent recurrence an entry is to be made in the L14-1B whenever any work is carried out which could cause leaks or malfunction of the system.

2 The L14 entry is to be made against the instrument trade and is to call for a pitot static functional and leak test. The readings of the aircraft cockpit instruments are to be compared with those of the pitot static tester when carrying out these tests.

3 Tape shall not be used to seal pitot or static openings. The calibrated pitot hole on shark fin type pitot tubes shall be sealed by using an adaptor in accordance with EO 20-150J-6A/1. Aircraft having static vents on the fuselage shall have these sealed by using an adaptor as outlined in EO 20-150JA-2A with the centre suction cup of this adaptor sealed off.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/SACO/ACA

ROYAL CANADIAN AIR FORCE

EO 05-1-2AU
20 Nov 63

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

USE OF SCRIBERS FOR "MARKING OUT"

(This EO replaces EO 05-1-2AU dated 14 Nov 57)

PURPOSE

1 The effectiveness of the protective coating on light alloy metal is dependent on its continuity. A break in this coating due to scratches, etc., bares the metal to the agents of corrosion.

GENERAL

2 A scratch on the surface reduces the load which the material can carry. In addition scratches increase the probability of failure when the material is subjected to fatiguing stresses.

3 Use a lead or grease pencil. Pencil marks are easily visible on the bright surface of the metal.

CAUTION

Scribes, or any tools which produce a scratch on this type of material, are not to be used for "marking out".

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAMO/CEng1

A

ROYAL CANADIAN AIR FORCE

EO 05-1-2AV
11 Jun 59

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

PIPE LINE AND APERTURE BLANKING PROCEDURES

(This EO replaces EO 05-1-2AV dated 14 Jan 58)

PURPOSE

1 The purpose of this EO is to eliminate those conditions which would result in the malfunction of the aircraft as a result of foreign objects entering systems through pipe lines or apertures.

GENERAL

2 When it becomes necessary to disconnect pipe lines or remove fittings from aircraft components, precautions must be taken to ensure that foreign objects will not enter the resulting apertures.

PREVENTION

3 To prevent foreign objects from entering apertures during maintenance or repair the pipe lines are to be capped with approved plastic plugs or caps. Other openings are to be plugged with the "push in" or "push on" type of plastic plug. Approved types of plugs are catalogued in CAP 10, Section 40D.

4 Where plastic plugs are not available, suitable plugs should be manufactured as an emergency measure. These plugs may be manufactured from wood, fibre, plastic, metal, etc., or any composition that will not crumble or leave residue in the apertures. Do not use cloth, cork, tape, paper, etc., as these may enter the apertures and be overlooked or leave a residue that could cause a malfunction.

5 When components have been removed from an aircraft for any reason regardless if they are serviceable or unserviceable, they are to have suitable plugs inserted in the apertures until the component is replaced on the aircraft or as required for testing or rework.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/SACO/ACC

A

ROYAL CANADIAN AIR FORCE

EO 05-1-2AW
14 Mar 58

PARKED AIRCRAFT - REDUCTION OF FIRE HAZARD DURING PERIODS OF SUNSHINE

PURPOSE

1 The purpose of this EO is to eliminate the fire hazard which may exist when aircraft are parked outside during sunny periods.

GENERAL

2 Instances are on record where aircraft fires have occured while the aircraft are parked outside during periods of sunshine. The resulting investigations revealed that these fires were possibly caused by the following methods.

(a) The reflection of the sun off a concave highly polished surface of the fuselage.

(b) The concentrated rays of the sun passing through certain curvatures of canopies blisters, astradomes, windows etc.

PREVENTION

EXTERIOR

3 Inspect painted or fabric surfaces for any indication of charring or scorching.

4 If scorching or charring is evident, check fuselage skin panels for a dished or concave condition that might reflect and focus the sun's rays on another portion of the aircraft.

5 Remedy the concave condition by use of a diagonal stiffener riveted to skin interior of affected panel. If stiffener repair not feasible, paint affected area with aluminum paint.

INTERIOR

6 The concentrated rays of the sun passing through certain curvatures of glass or perspex could be a fire hazard if they were directed upon combustible materials. To remedy this situation, all combustible materials should be removed from the aircraft on completion of flights and inspections. Where it is not practical to remove these items they should be moved to a location in the aircraft where they are not directly under canopies, blisters, astradomes etc. Specifically maps and other paper items should be stored in appropriate containers. Computers and instruments of doubtful fire resistance should not be left on windscreen shelfs or glare shields. Rags and containers with combustible petroleum products must be removed from the aircraft immediately upon completion of the task for which they are required.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/SACO/ACC

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

CLEANING & DECONTAMINATION ENGINE OIL SYSTEMS, ACCESSORIES AND METAL OIL TANKS

(This EO replaces EO 05-1-2AX dated 14 Mar 62)

PURPOSE

1 The purpose of this Engineering Order is to establish a procedure to be followed to remove contamination from an aircraft engine oil system. These instructions shall apply to all components and oil lines of the engine oil system.

INTERNAL ENGINE FAILURES

2 Where internal engine failure has occurred cleaning and decontamination of the complete oil system is to be accomplished as follows:

(a) Drain the oil from the complete oil system.

(b) Temperature regulators, diverter-segregator valves, propellor-feathering pump assemblies, propellor governors, distributor valves, oil cooler assemblies, oil temperature regulators, supercharger actuators, fuel injection pumps, fuel master control units (when oil heated boost venturi hanger is installed), and oil pressure transmitter are to be removed, cleaned, suitably tagged, marked "Repairable" and prepared for shipment for overhaul.

NOTE

Should any component within the oil system be suspected of being the cause of the engine failure, it is to be tagged with an L54 in accordance with EO 00-10-1. If the components are being returned for decontamination purposes only they will be tagged with a W5 "Repairable" tag.

(c) Remove external oil scavenge strainer stack assembly, dismantle, clean and inspect mesh elements and re-assemble. Clean and inspect filter housing cover plate and by-pass spring. Re-install stack assembly and check scavenge filter for leaks during engine run up.

NOTE

Component to be returned with engine in accordance with EO 10-1-2A.

(d) All accessory hoses and oil lines are to be dismantled, inspected for trapped foreign material (paying special attention to all quick disconnect fitting) and thoroughly cleaned and flushed with cleaner fluid to Spec. 3-GP-8A RCAF Ref. 33C/182 before re-installation on the aircraft.

(e) All accessory oil lines showing indications of fracture or deterioration are to be replaced.

(f) Removed oil coolers are to be tagged with the following minimum information.

(1) Aircraft registration. Engine serial. Reason for removal and number of hours installed.

NOTE

When preparing oil coolers for shipment, drain off oil and flush with cleaner fluid RCAF Ref. 33C/182, drain, dry and seal all parts. The cores are to be blanked off with suitable plywood coverings to prevent physical damage and prevent foreign matter from entering the cores during handling. It is recommended that the oil cooler and temperature regulating valve are cleaned as soon as possible after removal from the aircraft or the petroleum varnish, tar and carbon compounds in the oil will form a hard coating which is very difficult to remove. Use only recommended cleaning agents as many agents satisfactory for cleaning copper are highly corrosive to aluminum.

CAUTION

Oil coolers of the Clifford type are not to be flushed on removal, but drained of residual oil, blanked off and prepared for shipment.

(g) Hydromatic and counterweight propellers are to be removed, cleaned, sprayed with cleaner fluid RCAF Ref. 33C/182 and given a close visual inspection paying particular attention to the more highly stressed parts. The instructions of EO 15-30AB-2E are to be observed when servicing hydromatic propellers. Extreme care must be exercised while cleaning dome and barrel assemblies to ensure that no particles of foreign material remain, or are inadvertently introduced during re-assembly.

(h) Line surge valves, if installed are to be removed from the aircraft cleaned and re-installed.

(j) Non integral (removable) metal oil tanks are to be removed from the aircraft after an internal engine failure and cleaned as follows:

CAUTION

Diverter-segregator valve are not to be flushed or cleaned with cleaner RCAF Ref. 33C/182 or other solvents. A new or overhauled diverter-segregator valve will be installed at each engine change or when oil contamination is suspected.

(1) Using cleaner fluid RCAF Ref. 33G/182, slush, rock, roll, rotate or spray interior of tank until thoroughly clean, clean the exterior.

(2) Flush inside of tank with water, preferably with water under pressure.

(3) Clean all sections and areas of the tank with steam using a nozzle or hose, steam temperature should not exceed 102.7°C (215°F) and should not be used for periods longer than 30 minutes.

(4) Blow out tank with dry air to remove any steam condensate.

(5) Thoroughly inspect each tank for presence or any residual particles of foreign material and if any are found, repeat the cleaning steps (1) to (4).

(6) Tanks that cannot be thoroughly cleaned by the preceding process are to be placed unserviceable and returned to a Repair Depot for cleaning.

CAUTION

Do not use rags to wipe up residual fluid because of the danger that particles of the material may become detached and remain in the tank.

(k) Integral (non-removable) metal oil tanks are to be cleaned as follows:

(1) Drain contents of tank and remove all connections, inspection doors, flanges, fittings and pumps.

(2) Using cleaner fluid RCAF Ref. 33C/182 under air pressure spray interior of tank thoroughly. Special attention should be paid to all corners and recesses of the tank.

(3) If the engine is installed, disconnect all vent lines from tank to engine and flush with cleaner fluid. Blow out tank thoroughly with dry air.

(4) Inspect tank for foreign material and if such are found repeat cleaning process.

NOTE

The cleaning procedure for contaminated rubber oil tanks shall be accomplished in accordance with EO 05-1-2AY.

CAUTION

When carrying out cleaning operations, every precaution is to be taken against fires. The flash point of Spec. 3-GP-8 RCAF Ref. 33C/182 is 38°C (100°F).

NORMAL ENGINE CHANGE

3 Cleaning procedure at normal engine change shall be carried out as follows:

(a) If contamination is found in engine oil system prior to normal engine change (i.e. contamination which would have been sufficient to warrant an unscheduled removal). Cleaning procedures will be required as outlined in para. 2.

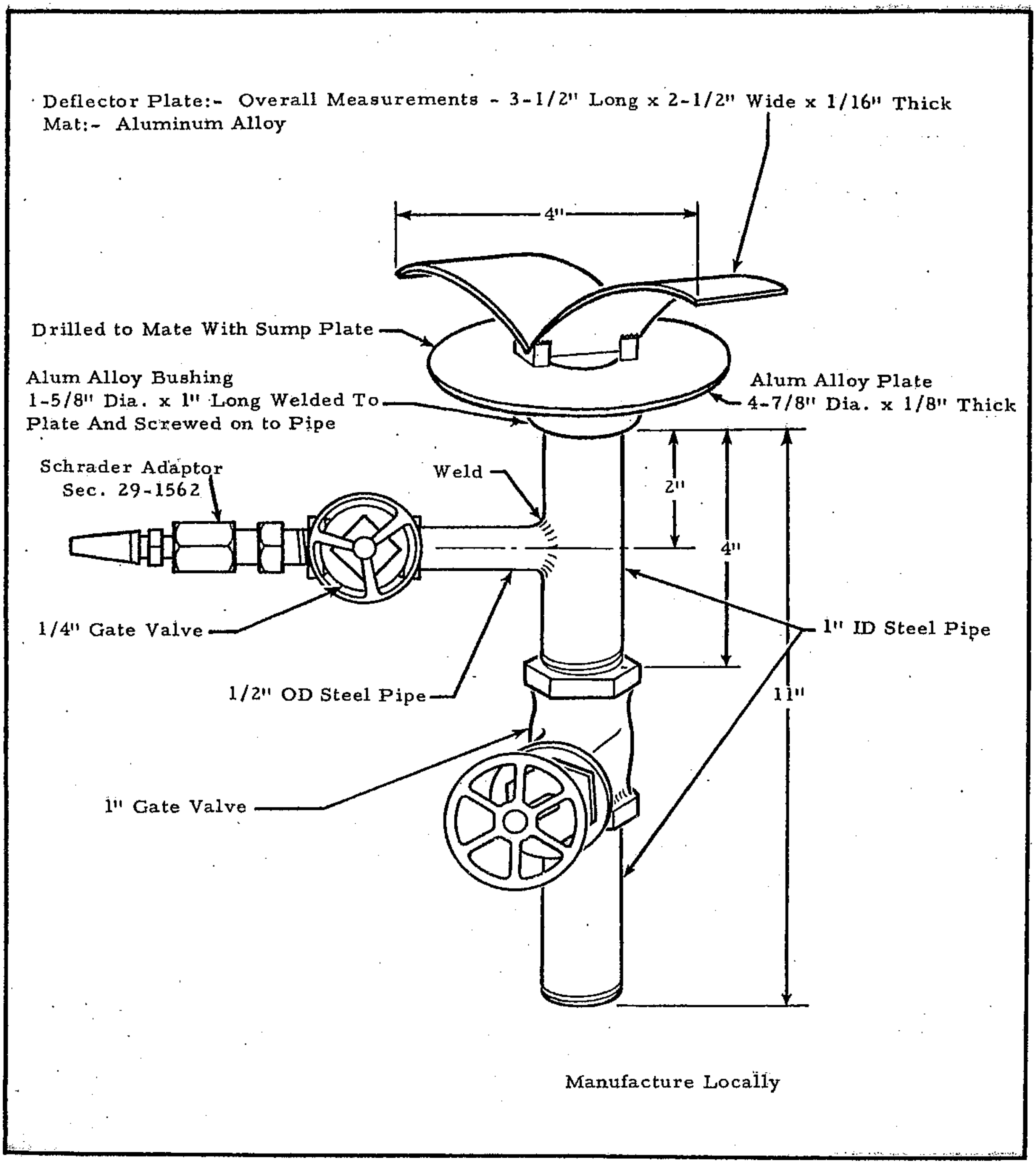
(b) Engine oil system free of contamination at normal engine change will require cleaning as outlined in paras. 2(a), (c), (d), (e), (g), (h), para 3(d) (e) and (f).

(c) Where engine oil systems are found free of contamination at normal engine change, integral and removable tanks shall be cleaned in accordance with para. 2(k), (1), (2), (3), (4).

CAUTION

Diverter-segregator valves shall not be flushed or cleaned with cleaner RCAF Ref. 33C/182 or other solvents. A new or overhauled diverter segregator valve will be installed at each engine change or when oil contamination is suspected.

(d) Oil coolers are to be drained of oil and flushed with cleaner RCAF Ref. 33C/182.



Manufacture Locally

Figure 1.

CAUTION

Oil coolers of the Clifford type are not to be flushed on removal, but drained of residual oil, blanked off and prepared for shipment.

(e) Propeller governors if not time expired are to be removed, cleaned, flushed with cleaner RCAF Ref. 33C/182.

(f) Propeller feathering pumps are to be drained and flushed with cleaner 33C/182.

INSPECTION FOLLOWING ENGINE CHANGE

4 The oil filters and magnetic drain plugs are to be examined for signs of foreign material after the first test flight following an engine(s) change(s).

CLEANING DURING OIL CHANGE

5 In order to facilitate the cleaning of oil tanks without removing the tank from the aircraft for reasons other than those outlined in paras. 1 to 4 an attachment was designed. See Figure 1 employing the principle of agitation of cleaning fluid RCAF Ref. 33C/182 in the tank.

6 The flushing attachment, see Figure 1, consists of a light alloy flange which is drilled to allow it to be detached to the oil tank by the sump cover plate studs. On the upper side of the flange two deflector plates of similar material are welded across the drain pipe orifice to which is welded a circular internally threaded boss. Into this screwed a 1" internal diameter steel pipe having a 1" gate valve at its lower end and a 1/2" inside diameter steel pipe welded into position at right angles over a 1/2" diameter hole drilled mid-way between the adaptor flange boss and the gate valve to which is fitted a standard schrader adapter for connecting the air pressure supply to the attachment. The method of operation is as follows:-

(a) Open tank filter cap and drain tank, disconnect tank from engine and oil cooler, blank off pipes.

(b) Remove sump cover plate and gasket.

(c) Bolt flushing attachment and gasket into position and close both gate valves.

(d) Partially fill tank with cleaner fluid RCAF Ref. 33C/182 (1/2 to 2/3).

(e) Connect air hose to adaptor, ensure tank is vented to atmosphere and open 1/4" gate valve (allow to flush 30 minutes to one hour).

(f) Close 1/4" gate valve and remove air hose.

(g) Drain tank by opening 1" gate valve, allow to drain, inspect tank.

(h) Replace gasket and sump cover plate and lock. Fill tank.

NOTE

This method of cleaning oil tanks is not recommended for large tanks having heavy baffling.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/SAMO/CEng2

DESCRIPTION AND MAINTENANCE INSTRUCTIONS

CLEANING INSTRUCTIONS FOR REPAIRING, PACKING, SHIPPING AND STORAGE OF AIRCRAFT REMOVABLE FUEL AND OIL CELLS

(This EO replaces EO 05-1-2AY dated 18 Aug 60)

PURPOSE

1 Fuel cells and containers improperly cleaned are a potential fire hazard and a menace to life, if the proper ratio of oxygen and fuel fumes are present within the cell or containers. However, cleaning in itself is not sufficient action to preserve the materials during handling shipping and storage, therefore certain inhibiting action is required. The purpose of this EO is to acquaint RCAF personnel with the safest, efficient and most economical practices in the handling of fuel cells.

GENERAL

2 To ensure the safety of all concerned with the handling of fuel cells and also to ensure that the maximum expected performance is received from these items the instructions in the ensueing paragraphs are mandatory.

CAUTION

The contents of EO 00-80-4/7 are to be read before proceeding with the instructions contained in this EO, and the safety precautions observed at all times.

METAL FUEL TANKS REMOVABLE

3 CLEANING - The following method is to be observed for cleaning non-integral metal fuel tanks prior to repair or returning to supply section.

(a) A ground wire is to be attached securing the tank to a suitable grounding post.

(b) The tank is to be completely drained by opening the drain fitting in the sump. All inspection covers are to be removed and the remaining fuel or oil drained through the openings. Residue which remains in the tank is to be removed by a suitable suction pump.

(c) The tank is to be inverted, grounded and placed on suitable trestles in an area that will allow free circulation of air around the tank. The area selected should not be in the vicinity of other equipment which could ignite vapour escaping from the tank.

(d) The tank is to be flushed with hot water admitted at the lowest possible point and allowed to overflow at the top, thus removing deposits of combustible material adhering to the inside of the tank. The tank will be flushed for the minimum period of three hours for fuel tanks and one hour for oil or alcohol tanks. These flushing instructions are not applicable to CF104 external and internal tanks.

(e) CF104 metal tanks are to be cleaned/purged with varsol 3-GP-8 followed by forced air drying.

METAL FUEL TANKS REMOVABLE (Cont'd)

REPAIR

4 If repairs are to be accomplished at the unit the tank is to be steamed for a minimum period of 3 hours prior to welding or being subjected to an open flame.

CAUTION

Before steaming is carried out on CF104 metal tanks, remove all accessories subject to damage such as booster pumps, contents transmitters, level float valves and switches.

PACKING

5 Tanks are to be packed in the re-usable containers provided. If re-usable containers are not available suitable containers are to be manufactured and packing shall be in accordance with existing instructions CAP 16, Vol. 3.

SHIPPING

6 Prior to returning fuel tanks to the supply section it is the responsibility of the section returning to ensure the tanks have been properly cleaned in accordance with the paragraph 3(d) of this EO. CF104 metal tanks are to be cleaned as per paragraph 3(e). Marking and shipping of containers will be in accordance with CAP 16, Vol. 3.

STORAGE

7 When tanks are removed from the aircraft for storage they are to be placed in tank containers or provided with proper trestles. They are to be drained and cleaned as per paragraph 3. On completion of cleaning process the interior of the tank is to be sprayed with SAE 10W oil and all openings blanked off. Tanks should be stored in a well ventilated area away from any type of fire hazard such as electric motors, electrical control panels etc.

REMOVABLE RUBBER FUEL AND OIL CELLS - SELF SEALING AND NON-SELF SEALING CLEANING

8 Clean fuel and oil cells inside and outside to remove any oil or foreign substances. Cleaning may be accomplished by using a solution of soap paste (33C/684) and hot water not exceeding 200°F. After cleaning, remove all soap residue with clean hot water not to exceed 200°F. If the above is not available clean by hand using detergent 33C/667 mixed with warm water. Rinse with warm water.

REPAIRING

9 Clean as per paragraph 8 above. Repair instructions are contained in EO 05-1-3/14.

PACKING

10 Shall be in accordance with CAP 16, Vol. 3.

STORAGE

11 Provide adequate protected storage for non-metallic fuel cells, observing the following precautions.

(a) Cells are of rubber and must not be exposed to direct sunlight.

(b) Cells should be packed in special containers. Do not remove cells from containers except as required for inspection and installation.

STORAGE (Cont'd)

(c) Stacking of containers is permissible but do not allow partial or complete collapse of the lower containers or cells.

(d) Do not place cells, whether in or out of containers near heaters or hot pipes.

(e) Whenever a rubber cell has been in service and filled with fuel, spray, paint or slush the interior surfaces of the cell with engine oil SAE 10W (34A/35) prior to storage and within ten days of the removal of fuel from the cell. Do not permit excessive amounts of oil to remain in the cell. Where repairs are required on a cell, accomplish prior to oiling. After initial oiling, re-oil interior surfaces of cells at intervals of two months. When the cells are to be put back into service, flush the oil out with cleaner (33C/182). After the first and each subsequent oiling, mark cells with a tag containing the following information: "Interior sprayed (or painted or slushed) with oil date".

(f) When removing cells from storage for installation, use the oldest cells first.

SHIPPING

12 Prior to returning rubber fuel tanks to the supply section, it is the responsibility of the section returning to ensure:

(a) The tank is cleaned as per para. 8.

(b) The tank interior surfaces are sprayed with SAE 10W (34A/35) engine oil as detailed in para. 11(e). Marking and shipping of containers will be in accordance with CAP 16, Vol. 3.

REMOVABLE NYLON PLIOCEL FUEL CELLS

CLEANING

13 Clean nylon fuel cells by moistening a lint free cloth with methyl ethyl Ketone (33C/520) or acetone (33C/417). Either of these solvents will remove any residual matter left by the fuel.

REPAIRING

14 Clean as per para. 13 above. Repair instructions are contained in EO 05-1-3/14.

PACKING

15 Prior to packing fog the interior of the cell with a solution of equal parts of water and glycerine (14B/43). If spray equipment is not convenient, apply with a lint free cloth moistened in the solution.

STORAGE

16 If a nylon fuel cell is to remain without fuel for a period exceeding seven days, spray the interior as outlined in para. 15 above.

SHIPPING

17 Prior to returning nylon fuel cells to the supply section, it is the responsibility of the section returning to ensure:-

(a) The tank is cleaned as per para. 13.

(b) The tank interior surfaces are coated with the water and glycerin solution outlined in para. 15.

(c) Marking and shipping of containers is in accordance with CAP 16, Vol. 3.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAMO/CEngl

EO 05-1-4

ROYAL CANADIAN AIR FORCE

AIRCRAFT GENERAL

AIRCRAFT TYPE DESIGNATION

(This EO replaces EO 05-1-4 dated 29 Mar 63)

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

12 FEB 64

LIST OF RCAF REVISIONS

DATE	PAGE NO	DATE	PAGE NO

AIRCRAFT GENERAL

AIRCRAFT TYPE DESIGNATION

1 The following table designates the new mark number, where applicable, allotted to RCAF aircraft. Correlating the information contained in the following tables and airframe log books will determine the correct mark number.

2 Effective immediately, these new mark numbers shall be recorded on all airframe log books and used in correspondence, returns, flystats, demands, and other specific records.

Aircraft	Mark	Original Mark	Role	Specification Requirement	Engines Fitted
Albatross	CSR110	CSR110	Search and Rescue	Grumman Design No. 231	Wright R1820-82
Argus	1	1	Long Range Maritime Patrol	AIR 15-11	Wright R3350-EA1
Argus	2	1	Long Range Maritime Patrol	AIR 15-11	Wright R3350-EA1
Bristol (170)	31	31	Freighter		Bristol Hercules 734
Canuck	5C	5	Electronic Counter Measure	AIR 17-14	Orenda 11
Canuck	5D	5	ECM Phase 3	AIR 17-14, issue 5	Orenda 11
Canuck	5	5	All Weather Fighter		Orenda 11
Canuck	3D	3CT	Dual Trainer	RM1-38	Orenda 8
Canuck	4B	4	All Weather Fighter		Orenda 11
Caribou	CC108 DHC-4A	CC108 DHC-4	STOL Transport	AER OC 4A161 Issue 2	P&W 2000-7M2
Cessna	L19A	L19A	Army Observation or Pilot Trainer	Cessna Spec. 955A (Variation A) 1 Oct 53	Continental 0-470-11
Cessna	L19E	L19E	Army Observation	960 Dated 1 Dec 55 Revised 1 Feb 57	Continental 0-470-11
Cessna	L182D	L182D	Liaison	Cessna Spec. 7050 Model 182 Revised 28 Jun 60	Continental 0-470-L
Cessna	L182F	L182F	Liaison	Cessna Spec. M-182-2 Revised 18 Sep 62	Continental 0-470-L
CF101B		F101B	All Weather Fighter	USAF 4005 Serial 209 Control C12682	J57 - P55
CF101F		F101F	Dual Trainer	USAF 4005 Serial 209 Control C12682	J57 - F55
CF104		CF104 (Model 683A)	Strike Reconnaissance	Model 683-04-12 Fighter Bomber	Orenda J79-OEL-7
CF104		CF104D (Model 583A)	Pilot Trainer	Model 583-04-15 Dual Trainer	Orenda J79-OEL-7
Chipmunk	2	2	Light Conversion Trainer		Gypsy Major CIG 7G, 10 Mk 1-3 or 10 Mk 1-3A
Comet	1A	1XB	Transport		Chost 50 Mk 1
Cosmopolitan	109	CC109	Medium Range Transport		Napier Eland 504A
Cosmopolitan (Serial 11161, 11162, 11163)	540	CL540	Medium Range Transport	Unmodified	Napier Eland 504A

Aircraft	Mark	Original Mark	Role	Specification Requirement	Engines Fitted
Dakota	3	3	Freighter	RM1-4	P& W R1830-92
Dakota	3N	3	Navigation Trainer	RM1-2	P& W R1830-92
Dakota	3R	3	Radio Trainer		P& W R1830-92
Dakota	3CSC	3	Special Communication	RM1-42	P& W R1830-90C
Dakota	3C	3	Freighter	RM1-4	P& W R1830-90C
Dakota	3SR	3	Search and Rescue	RM1-4	P& W R1830-92
Dakota	3CSR	3	Search and Rescue	RM1-4	P& W R1830-90C
Dakota	4	4	Freighter	RM1-4	P& W R1830-90C
Dakota	4SC	4	Special Communication	RM1-42	P& W R1830-90C
Dakota	4ST	4	Special Transport	RM1-14	P& W R1830-90C
Dakota	4MN	4	Navigation Trainer	RM1-2	P& W R1830-92
Dakota	4M	4	Freighter	RM1-4	P& W R1830-92
Dakota	4MSR	4	Search and Rescue	RM1-4	P& W R1830-92
Dakota	4MR	4	Radio Trainer		P& W R1830-92
Dakota	4SR	4	Search and Rescue	RM1-4	P& W R1830-90C
Expeditor	3T	1 and 2	Pilot Trainer		P& W R985 AN-14B
Expeditor	3NMT	3N	Light Transport	EO 05-45B-6A/130	P& W R985 AN-14B
Expeditor	3N	3N	Navigation Trainer		P& W R985 AN-14B
Expeditor	3NMT	3NM	Light Transport	EO 05-45B-6A/130	P& W R985 AN-14B
Expeditor	3NM	3NM	Navigation Trainer		P& W R985 AN-14B
Expeditor	3NMT(s) *	3NM	Navigation Trainer Personnel Transport		P& W R985 AN-14B
Expeditor	3TM	3TM	Light Transport		P& W R985 AN-14B
Harvard	4	4	Pilot Trainer		P& W R1340 AN1 S3H1
Harvard	4	4	Pilot Trainer		P& W R1340 AN1 S3H1
Helicopter Hilier	CH112	UH-12E	Training Reconnaissance	AIR 101-7	Lycoming VO-540-B1D
Helicopter Sikorsky	H5	S-51	Search and Rescue Reconnaissance	RM1-27	P& W R985 AN-5B4
Helicopter Sikorsky	H19	S-55	MCL Support	AIR 101-1	P& W R1340-S1H2
Helicopter Sikorsky	H34A	S58	Transport Search and Rescue	AIR 101-3	Wright R1820-84
Helicopter Vertol	H21A	H21A	Transport Search and Rescue		Wright R1820-103
Helicopter Vertol	H21B	H21B	Transport Search and Rescue MCL Support	AIR 101-4 AIR 101-5	Wright R1820-103
Helicopter Vertol H44A	H44A	V44	Search and Rescue Transport	AIR 101-4 AIR 101-5	Wright R1820-103

* Special

Aircraft	Mark	Original Mark	Role	Specification Requirement	Engines Fitted
Helicopter Vertol 107	CH113	11-9	Search and Rescue Transport	AIR 101-8	General Electric T58-8B
Hercules	C130B	C130B	Heavy Transport	ER 2400M	Allison T56-A7
Lancaster	10P	10	Long Range Photographic		Packard Merlin 224
Lancaster	10MP	10	Maritime Patrol	RM1-25	Packard Merlin 224
Lancaster	10AR	10	Area Reconnaissance	AIR 15-10	Packard Merlin 224/14A
Mitchell	3PT	3	Pilot Trainer		Wright Cyclone R2600
Neptune	P2V7	P2V7	Anti-Submarine Warfare	Detail Spec. NAVAER SD 344-7A-1	Wright R3350-32W each 2 Westinghouse J34-WE-36 each 2 (Jet)
North Star	1	1	Long Range Cargo Transport	RM1-31	Rolls Royce Merlin 622
North Star	1M	M1	Long Range Cargo Transport	RM1-31	Rolls Royce Merlin 622
North Star	1MST	M1	Special Transport Aircraft	RM1-31	Rolls Royce Merlin 622
North Star	C5	C5	Special Transport Aircraft		P&W R2800 CA15
Otter	DHC-3	DHC-3	Light Utility Search and Rescue	AERDC 3-1-G1 Issue 8 (RCAF)	P&W R1340 S1H1G
C119	G	F	Heavy Transport Freighter		Wright R3350-89A
Sabre	5	F86E (Model 172)	Transitional Trainer		Orenda 10
Sabre	6	F86E (Model 172)	Day Interceptor Fighter		Orenda 14
Tutor	CT114	CL41A	Pilot Trainer	RAD-41-106 (Issue 3, 23 Jan 62)	General Electric J85-CAN-40
T33	3PT	AN	Jet Trainer		RR Nene 10
T33	3AT	AN	Jet Trainer		RR Nene 10
Yukon		CC106	Long Range Transport	AIR 19-11	Rolls Royce Tyne 515/10

ROYAL CANADIAN AIR FORCE

LIST OF SPECIAL INSPECTIONS

AIRCRAFT GENERAL

(This EO replaces EO 05-1-5 dated 10 Jul 61)

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* Asterisks appearing opposite entries denote changes since last issue

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

ROYAL CANADIAN AIR FORCE

EO 05-1-5/9
17 Sep 59

SPECIAL INSPECTION

EARPHONE FAILURE

EQUIPMENT AFFECTED:	10EC/27819 Earphone, Campbell #4031 used in Aircrew Helmets
BY WHOM WORK WILL BE PERFORMED:	Units Telecom Personnel
WHEN WORK WILL BE PERFORMED:	Immediately
RCAF FORM ENTRIES:	NA
INSPECTION OF SPARES IN STOCK:	Yes
RETURNS:	NA

PURPOSE

1 Reports have been received of in-flight failures and erratic operation of headsets. Failures are caused by lack of pressure equalization. The manufacturer has provided an equalization vent located in the back of the earpiece consisting of a small rubber insert with a small hole through it. The failure is attributed to the DND Inspection Services stamp lacquer which has been applied to the back of the earpiece in such a manner as to seal the equalizing vent.

INSPECTION DATA

2 The following is the sequence of inspection:-

(a) Inspect all earpieces, Ref. 10EC/27819, in use and in stock to establish the manufacturer.

(b) Examine earpiece manufactured by Campbell Manufacturing Part #4031 for sealed equalizing vent.

(c) Pierce the vent with a common pin if necessary.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:-
AMC/S Tel O/Tel AM

ROYAL CANADIAN AIR FORCE

EO 05-1-5/10
12 Jul 60

SPECIAL INSPECTION

MICROPHONE CORD

EQUIPMENT AFFECTED:	6DA/54, 6DA/55 and 6DA/56 Oxygen Mask MS 22001
BY WHOM WORK WILL BE PERFORMED:	Operating Units
WHEN WORK WILL BE PERFORMED:	Next Inspection
RCAF FORM ENTRIES:	Log Book
INSPECTION OF SPARES IN STOCK:	As Applicable

PURPOSE

1 To prevent oxygen leak. Reports indicate that some microphone cords Ref. 10/29524 are received with the stay cord protruding too far beyond the outside rubber insulation, thus allowing the microphone cord to pull out of the cord channel in the mask.

INSPECTION DATA

2 The following is the sequence of inspection:-

(a) Pull the microphone out of the mask.

(b) Ensure that the distance between the anchor terminal at the end of the stay cord and outer rubber insulation of the microphone cord does not exceed 1/8". Also ensure that the anchor terminal is positively secured to the stay cord.

(c) In the negative, proceed as follows:-

(1) Cut the stay cord 3/8" from the outer rubber insulation and saturate the end of the stay cord with varnish MIL-V-173A Ref. 33A/486.

(2) Crimp a new anchor terminal Ref. 5K/117 allow to dry.

(3) If the microphone leads exceed 1-1/2" cut and install new terminal.

(d) Replace microphone into the mask.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:-
AMC/S Tel O/Tel AE

ROYAL CANADIAN AIR FORCE

EO 05-1-5/11
31 May 61

SPECIAL INSPECTION

CONDITION OF WHEEL RETAINING NUTS

EQUIPMENT AFFECTED:	Aircraft Generally
BY WHOM WORK WILL BE PERFORMED:	Operating Units, RDs and Contractors
WHEN WORK WILL BE PERFORMED:	On or before the next Periodic Check
RCAF FORM ENTRIES:	L14-1B, L14-5
INSPECTION OF SPARES IN STOCK:	Not applicable
RETURNS:	Not required

PURPOSE

1 Cases have been reported where the wheel retaining nuts have cracked. To prevent this, units are to inspect existing installations and reject all nuts that have peening or other marks brought about by tightening methods other than approved wheel retaining nut wrenches.

INSPECTION DATA

2 The wheel retaining nuts are to be inspected as follows:

(a) Gain access to the wheel retaining nuts as outlined in the relevant -2 aircraft EO.

(b) Inspect the Spec. AN7502 retaining nuts for signs of damage or burred corners particularly in the vicinity of the cotter pin slots.

(c) Reject and replace any nuts in this category.

ADDITIONAL DATA

3 The following additional data will apply:

(a) Units are to ensure that wheel retaining nuts are tightened with an approved type wrench.

(b) Future procurement of these nuts will be to Spec. MS21025 which calls up a stronger steel and cotter pin hole location at hex corners only.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/SACO/ACA

EO 05-1-5/12
27 Aug 63

ROYAL CANADIAN AIR FORCE

SPECIAL INSPECTION

MICROPHONE JACK

EQUIPMENT AFFECTED:	Headset Cord 10EA/56726 and Helmet (Modified to EO 05-1-6A/13)
BY WHOM WORK WILL BE PERFORMED:	Operating Units
WHEN WORK WILL BE PERFORMED:	Immediately
RCAF FORM ENTRIES:	NA
INSPECTION OF SPARES IN STOCK:	As required
RETURNS:	NA

PURPOSE

1 To ensure that the female connector sockets of microphone jack JJ-055 have been assembled correctly.

INSPECTION DATA

2 The connector sockets of jack JJ-055 are of tubular construction with a flat pressure spring, and a contact leaf which engages the pin of the male connector through a cut-out section of the tubular socket. Proceed with inspection as follows:

(a) Disassemble microphone jack and examine the two connector sockets.

(b) If correctly assembled the pressure spring will be above the contact leaf. If found to be otherwise, remove the retaining screw, spring, and leaf. Re-assemble correctly.

(c) Re-assemble microphone jack JJ-055.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAVO/T2

ROYAL CANADIAN AIR FORCE

EO 05-1-5A
18 Aug 64

LIST OF SPECIAL INFORMATION

AIRCRAFT GENERAL

(This EO replaces EO 05-1-5A dated 31 Oct 63)

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LATEST DATE	EO NO	TITLE
8 Jul 53	05-1-5A/1	Anti-Precipitation Static Antenna
	/2	(Rescinded)
	/3	(Rescinded)
	/4	(Replaced by EO 05-25A-5A/8)
	/5	(Rescinded)
	/6	(Rescinded)
	/7	(Rescinded)
18 Dec 57	/8	Fuel Tank Cover Assemblies
27 Aug 62	/9	Preferred Anstat Type Antenna Fittings
14 Feb 63	/10	Preferred Design Type of Pitot Static Tube Cover Assembly
16 Sep 63	/11	Grounding Aircraft to Hangar Floors
*31 Jul 64	/12	Conversion of Instruments to White Lustreless Dial Markings

* Asterisks appearing opposite entries denote changes since last issue.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

EO 05-1-5A/1
8 Jul 53

ROYAL CANADIAN AIR FORCE

SPECIAL INFORMATION

ANTI - PRECIPITATION STATIC ANTENNA

(This EO replaces EO 05-1-5A/1 dated 29 Apr 53)

EQUIPMENT AFFECTED:	Lancaster Dakota, Canso, North Star, Mitchell and Expeditor Aircraft
BY WHOM WORK WILL BE PERFORMED:	Operating Units, RDs and Contractors
WHEN WORK WILL BE PERFORMED:	As required when 126-TS-101 fail only; replacement of serviceable unit NOT required.
RCAF FORM ENTRIES:	L14, Log Book
MODIFICATION OF SPARES IN STOCK:	NA

PURPOSE

1 To provide details on replacing damaged "ANSTAT" mast adaptor chuck assemblies with a new type.

INFORMATION DATA

2 The following information data applies:

(a) Anti-precipitation static antenna masts which are found to have damaged mast adaptor chuck assemblies Type 126-TS-101, will be replaced with a new Type 126-TS-101A, designed to take a strain of five hundred pounds. (Failure will be evident when the chuck assembly can no longer hold the antenna wire).

(b) The damaged part shall be forwarded to the manufacturer by each unit having failures, for replacement on a no charge basis.

(c) Parts will be shipped to:

Technical Enterprises Ltd.,
Toronto Municipal Airport,
Malton, Ontario.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/STelO/Tel PS

EO 05-1-5A/8
18 Dec 57

ROYAL CANADIAN AIR FORCE

SPECIAL INFORMATION

FUEL TANK COVER ASSEMBLIES

GENERAL

1 Reports have been received from some units on fuel tank filler cap (AC39B5435) hinge pi failures through shearing action.

2 Corrective action to be taken as follows:-

(a) With cover assembly suitably supported, remove the centre post using a pin punch an dismantle the cover assembly.

(b) Enlarge the pin hole in the centre post to 0.136" using a #29 drill.

(c) Replace the original hinge pin with a piece of piano wire (0.128" dia. Ref. 30B/1832) o equal length and re-assemble the cover assembly.

(d) Cut a pin 1/8" x 5/8" from a rivet (28/8816) and set in base of centre post to complet the assembly.

NOTE

Do not clamp the cover assembly in a vise.

ADDITIONAL DATA

3 This filler cap is presently fitted to Mitchell and C119 aircraft. This repair scheme ca be adapted to varying sizes of this type of cap by changing the dimensions.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/SACO/ACA

ROYAL CANADIAN AIR FORCE

EO 05-1-5A/9
27 Aug 62

SPECIAL INFORMATION

PREFERRED ANSTAT TYPE ANTENNA FITTINGS

INTRODUCTION

1 This special information leaflet is published to acquaint all users with the preferred anstat type antenna fittings and the items they replace.

INFORMATION DATA

2 The following is a list of the preferred type fittings and the items that they replace.

PREFERRED TYPE			REPLACES
SEC REF.	PART	DESCRIPTION	
10EP/5970-21-802-5504	IL5/U-6	Insulator, strain tensioner	10EP/21052 10EP/21053 10EP/21054 10EP/24571 10EP/31729 10EP/50638
10EC/54079	MS25052-1A or SI-1-600	Insulator, strain	10EC/24569 10EC/21051
10EC/48963	MS25053-1	Tee	10EP/24568

3 These preferred types were selected as the result of a meeting held at AMCHQ with representation from the major users on 31 May 60. Procurement is being taken only on the items listed in the left hand column of para 2 but the replaced items may be issued pending depletion of stocks.

4 There may be cases however where a replaced type will be issued in lieu of a preferred type e.g. 10EP/21052 and 10EP/21053 which do not have a chuck assembly fitting nor are they insulated. These items are perfectly serviceable tensioner units provided that the chuck assembly Dayton Part 14021, which consists of chuck assembly and anti-flutter sleeve, is fitted. This is the same chuck and anti-flutter sleeve assembly used on the preferred type and may be demanded by Part Number or salvaged from a broken preferred type. Provision will be made for local procurement on the receipt of a demand. This action is required since limited stocks of 10EP/21052 and 10EP/21053 still remain and can be used to fabricate a serviceable grounded type antenna installation.

5 Where a grounded antenna is required the preferred type may be modified by drilling the chuck holder assembly to accept a #4 self-tapping screw. A suitable length of bonding strip can then be connected from the chuck holder to an appropriate location on the aircraft.

6 Any further problems encountered in the installation of these fittings are to be brought to the attention of AMCHQ by completing a UCR with a draft modification leaflet drawn up in accordance with EO 00-5-6 for the applicable aircraft.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAVO/T1

ROYAL CANADIAN AIR FORCE

EO 05-1-5A/10
14 Feb 63

SPECIAL INFORMATION

PREFERRED DESIGN TYPE OF PITOT STATIC TUBE COVER ASSEMBLY

INTRODUCTION

1 This Special Information Leaflet is published to acquaint all users with the preferred type of pitot tube cover which is adaptable to many types of aircraft installations, and which can be manufactured locally.

INFORMATION DATA

2 Specific manufacturing details of this particular design are applicable to the CF101 aircraft and are contained in EO 05-185A-5A/11. Adaptation of this cover assembly to other aircraft pitot tube installations can be readily accomplished by changes in the specific drawing dimensions.

3 The design of the cover assembly is acceptable in that, once properly installed, it is not easily disturbed from its installation on the tube either by wind or normal ground handling of the aircraft.

LOCAL MANUFACTURE

4 To locally manufacture this assembly user units may demand RCAF Drawings 28039, 28037, 28038 and 48234 now available. Briefly, the cover consists of the standard type slip-on fabric tube and warning streamer to which is fixed a length of elastic cord and an aluminum alloy retainer piece. The design is such that with moderate tension between the installed retainer and the tube cover via the elastic cord, retention of the cover over the tube is maintained.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAVO/IES1

ROYAL CANADIAN AIR FORCE

EO 05-1-5A/11
16 Sep 63

SPECIAL INFORMATION

GROUNDING AIRCRAFT TO HANGAR FLOORS

GENERAL

1 The present system of grounding aircraft to hangar floors is effected through cables employing clips alligator (RCAF Stock No. 5940-00-502-4890). The clips being snapped onto grounding rods embedded in the hangar floors.

2 It has been noted that this system is not satisfactory when several aircraft require grounding to the same grounding point. This creates congestion, faulty grounds, broken alligator clamps and ground cables.

3 To reduce these conditions to a minimum and effect a permanent and positive grounding system, several more satisfactory methods have been investigated and with proper installation can meet the electrical requirements of EO 05-1-2V.

4 Because no individual method of ground connection is perfect and a variety of proven satisfactory systems are already in use, it is not mandatory to standardize. Therefore the details of fabrication and installation of the grounding methods outlined in this EO are presented as suggestions which have been used with good results. Engineering Officers may choose according to existing installations and unit fabrication resources.

5 It is to be noted that these connectors are suitable for dissipating static electricity from aircraft and refuelling tenders but are not specifically authorized for use in special weapons applications.

METHOD 1

6 Proceed as follows:

(a) As shown in Figure 1, drill and tap existing hangar floor grounding rod to accommodate a 1/4" bolt.

(b) Manufacture 2 or more grounding cables as shown in Figure 1 by soldering a fitting of 7/8" brass stock as per detail "A" of Figure 2 to approximately 18" of grounding cable (length may be varied as required).

(c) Drill required holes in brass cover plate, (countersunk to avoid sharp edges) pass cables through and solder 1/4" lug to other end of cable.

(d) Attach lug ends to hangar grounding rod using 1/4" bolt and star washers to prevent loosening.

(e) Solder a male connector of 1/2" hexagonal brass stock (detail "B" of Figure 2) to required length of cable to reach aircraft.

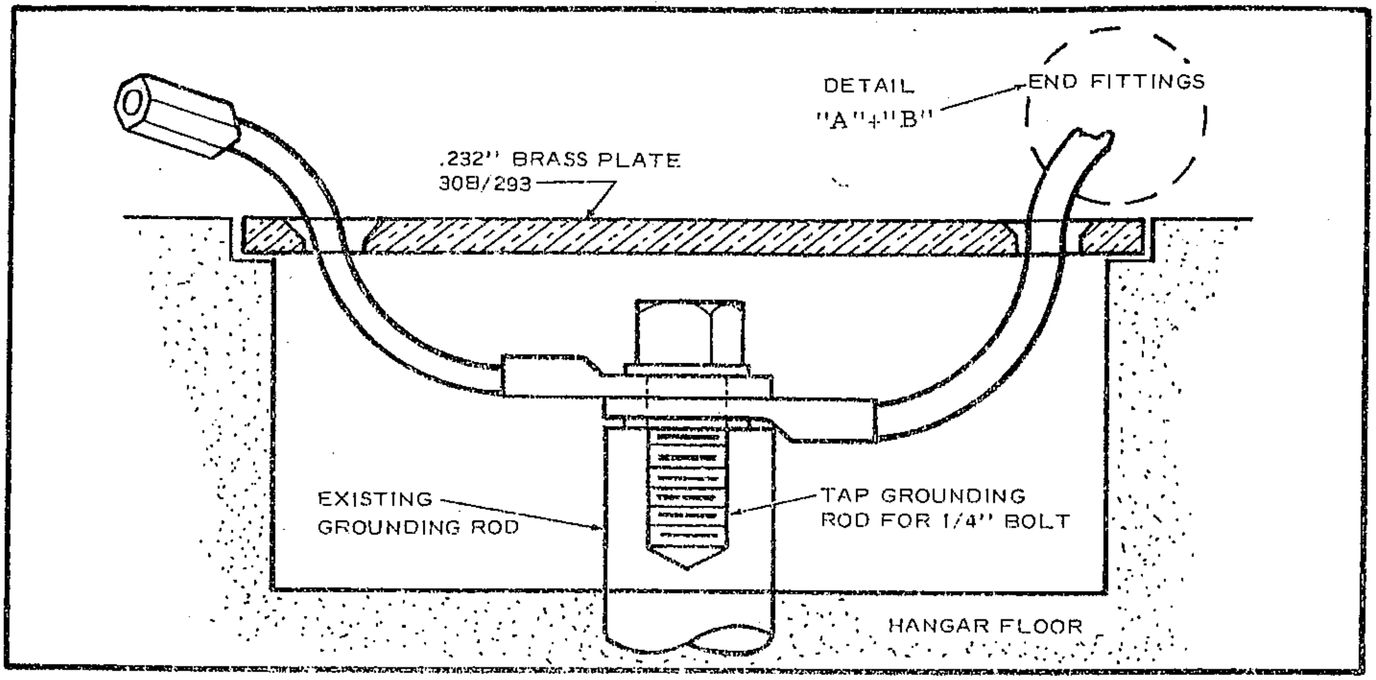
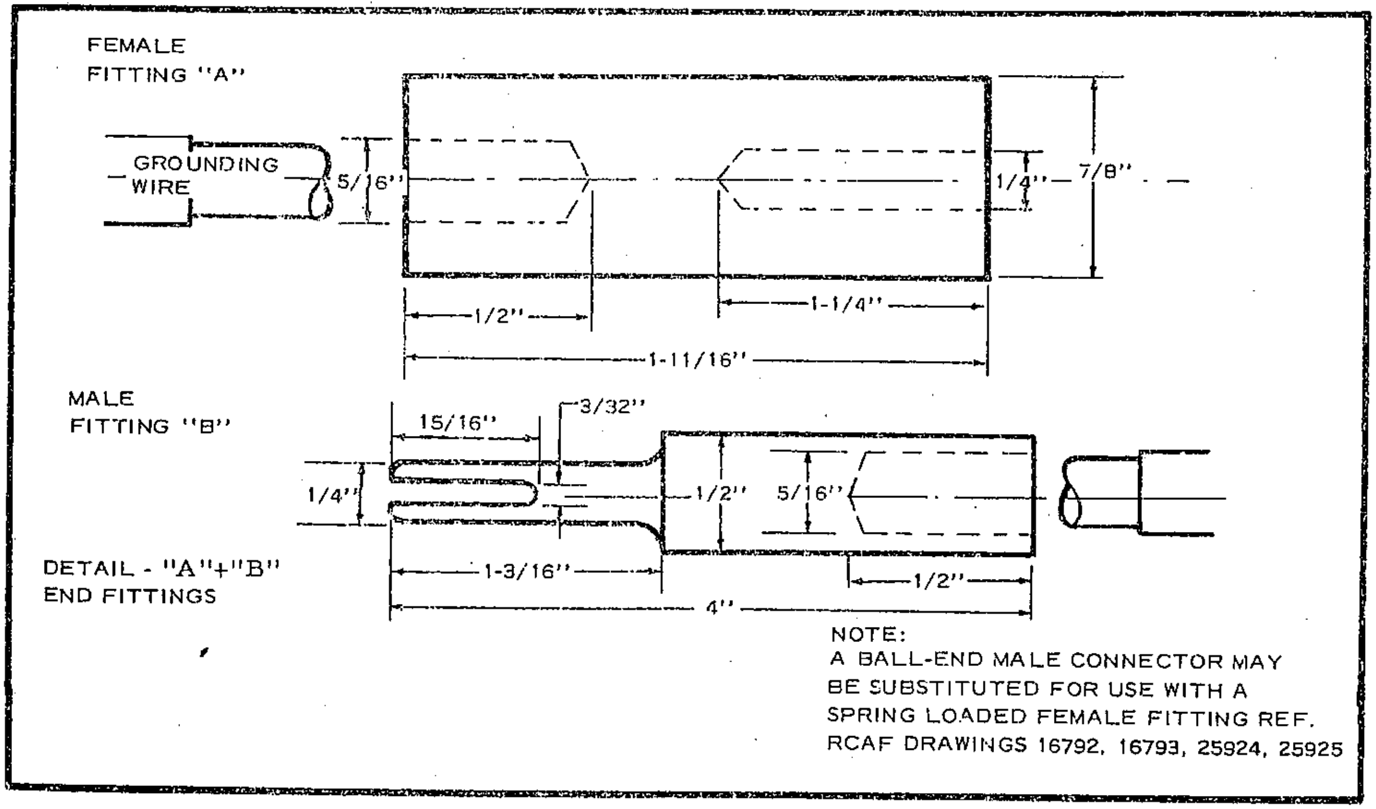


Figure 1



NOTE:
A BALL-END MALE CONNECTOR MAY BE SUBSTITUTED FOR USE WITH A SPRING LOADED FEMALE FITTING REF. RCAF DRAWINGS 16792, 16793, 25924, 25925

Figure 2

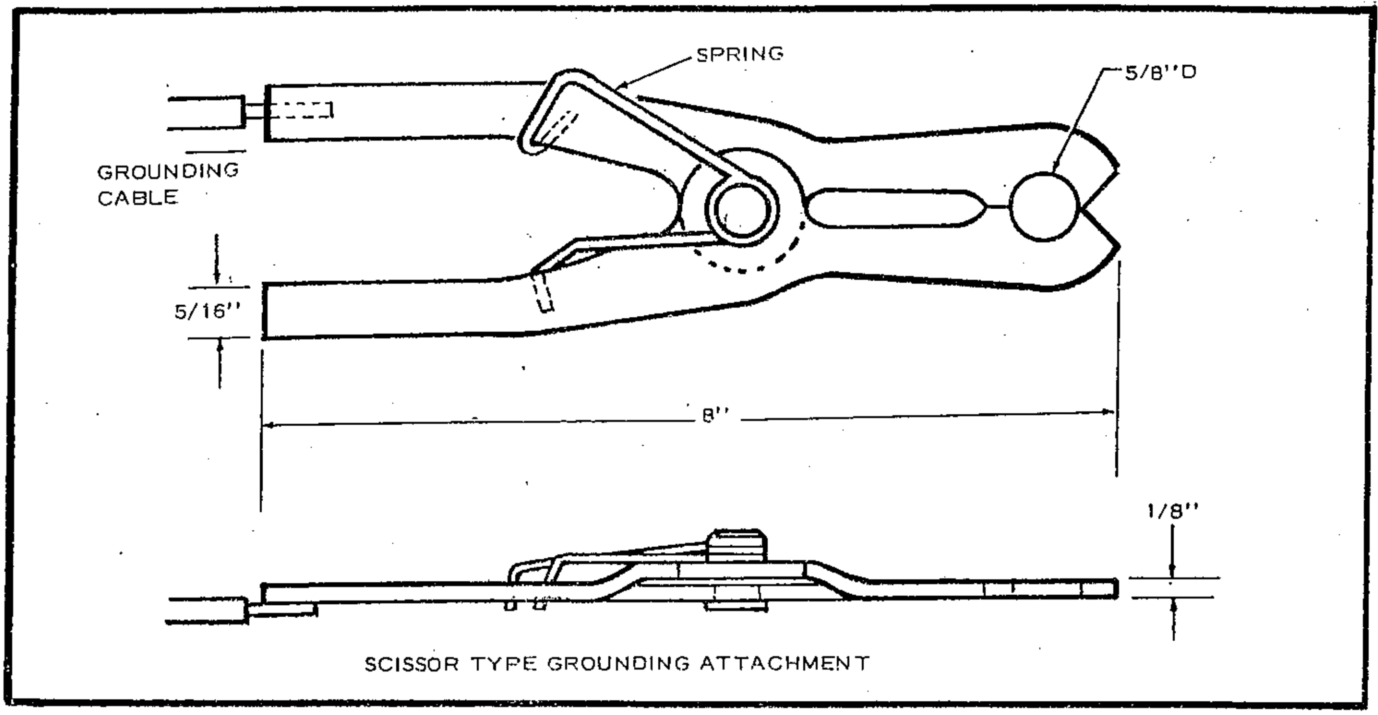


Figure 3

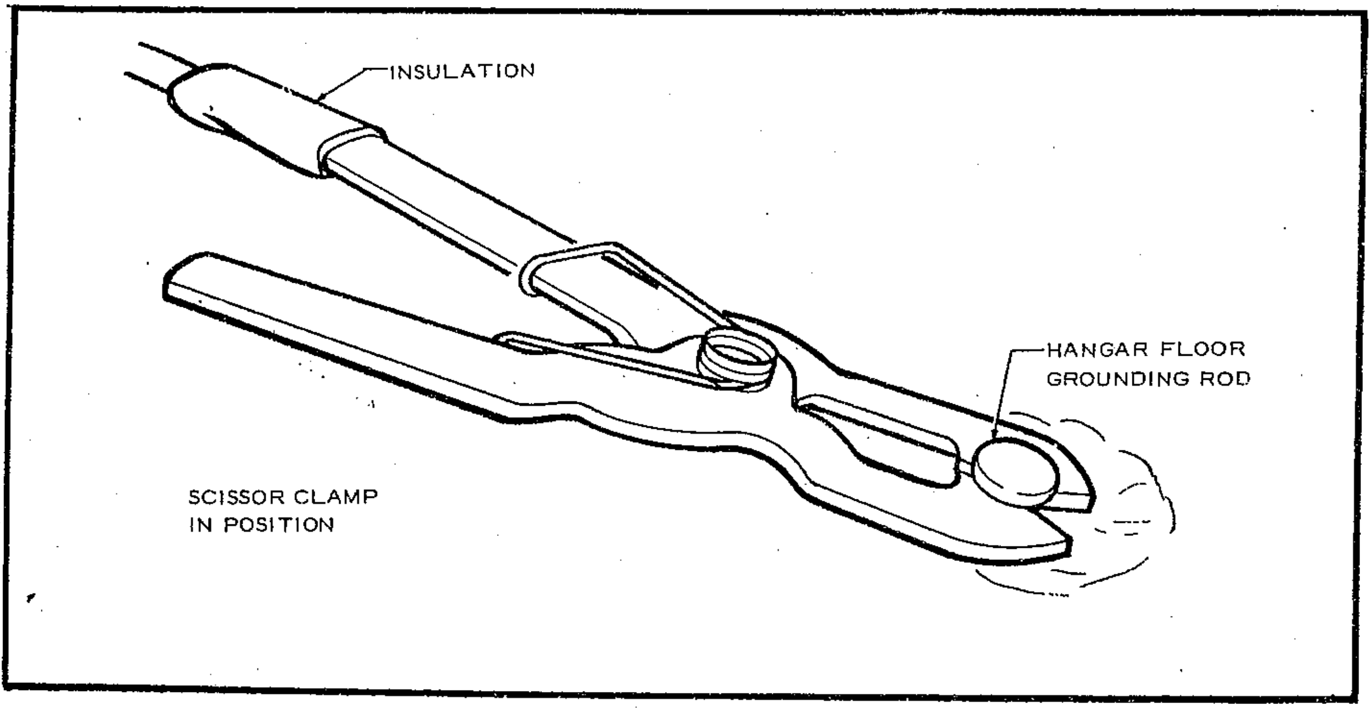


Figure 4

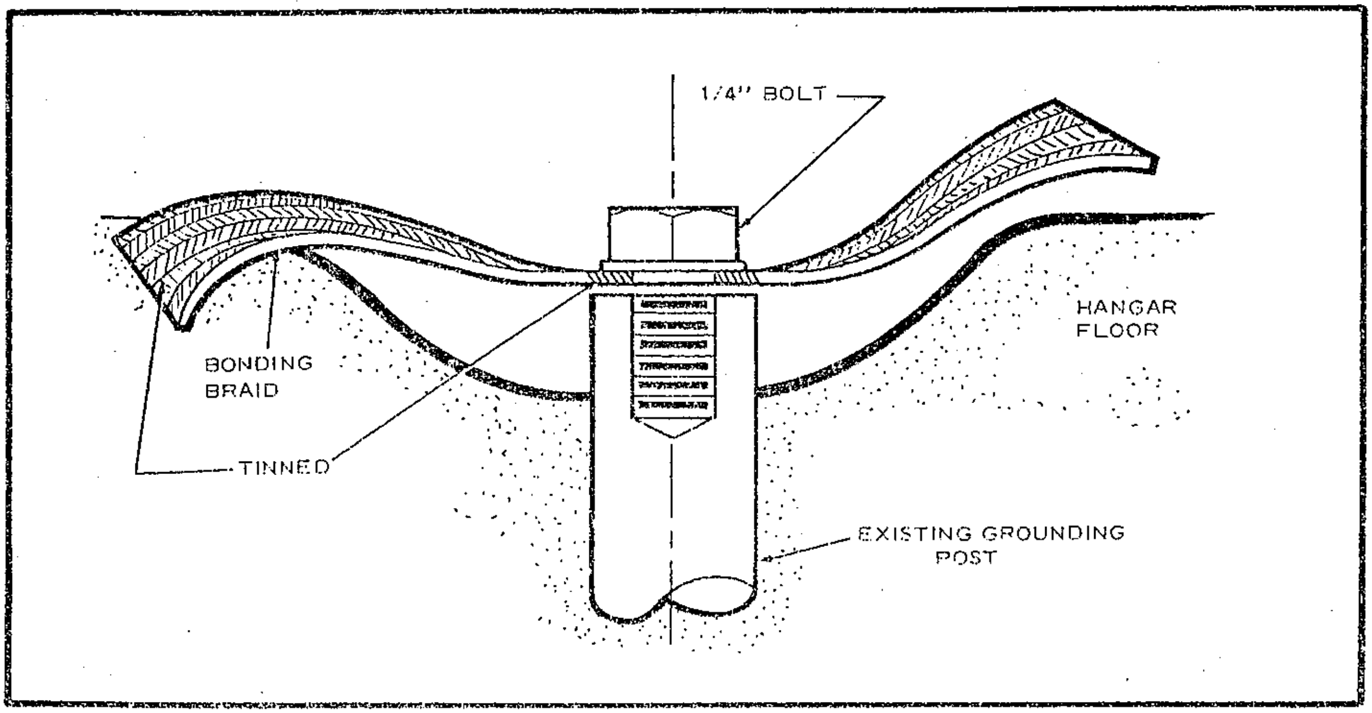


Figure 5

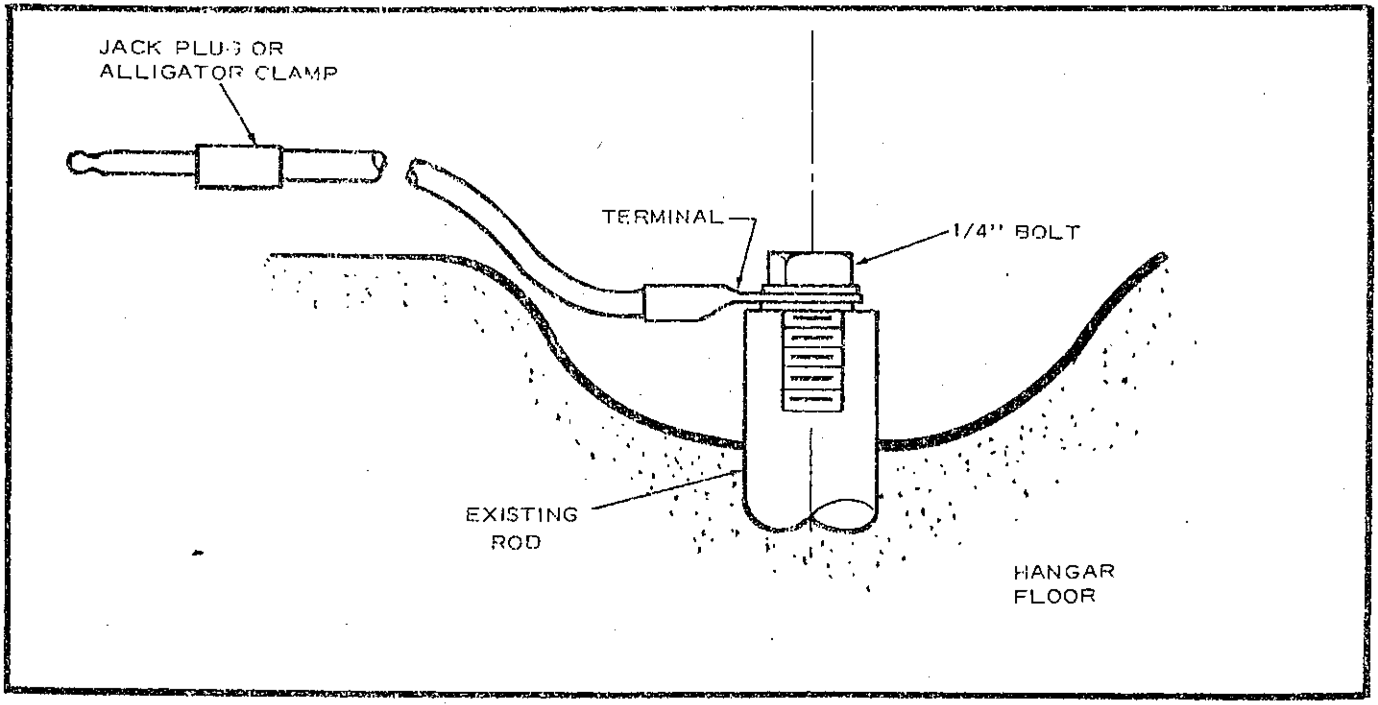


Figure 6

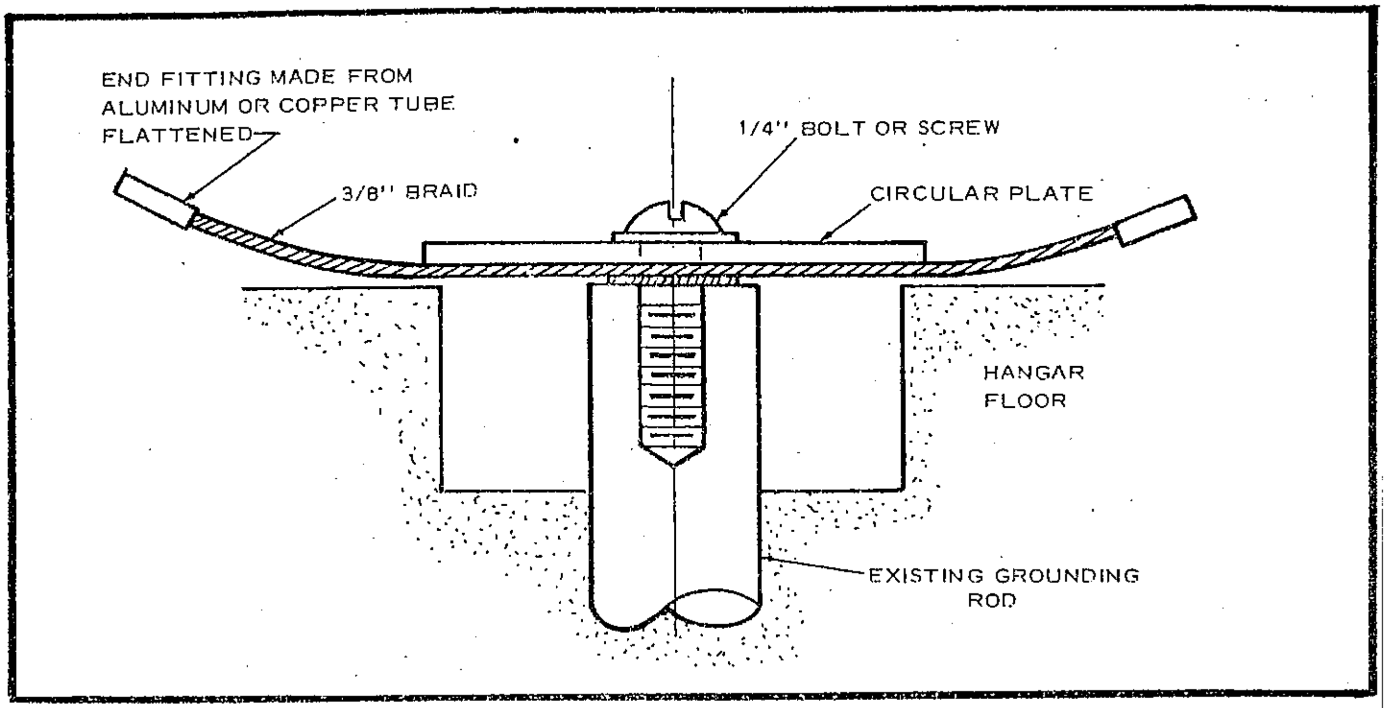


Figure 7

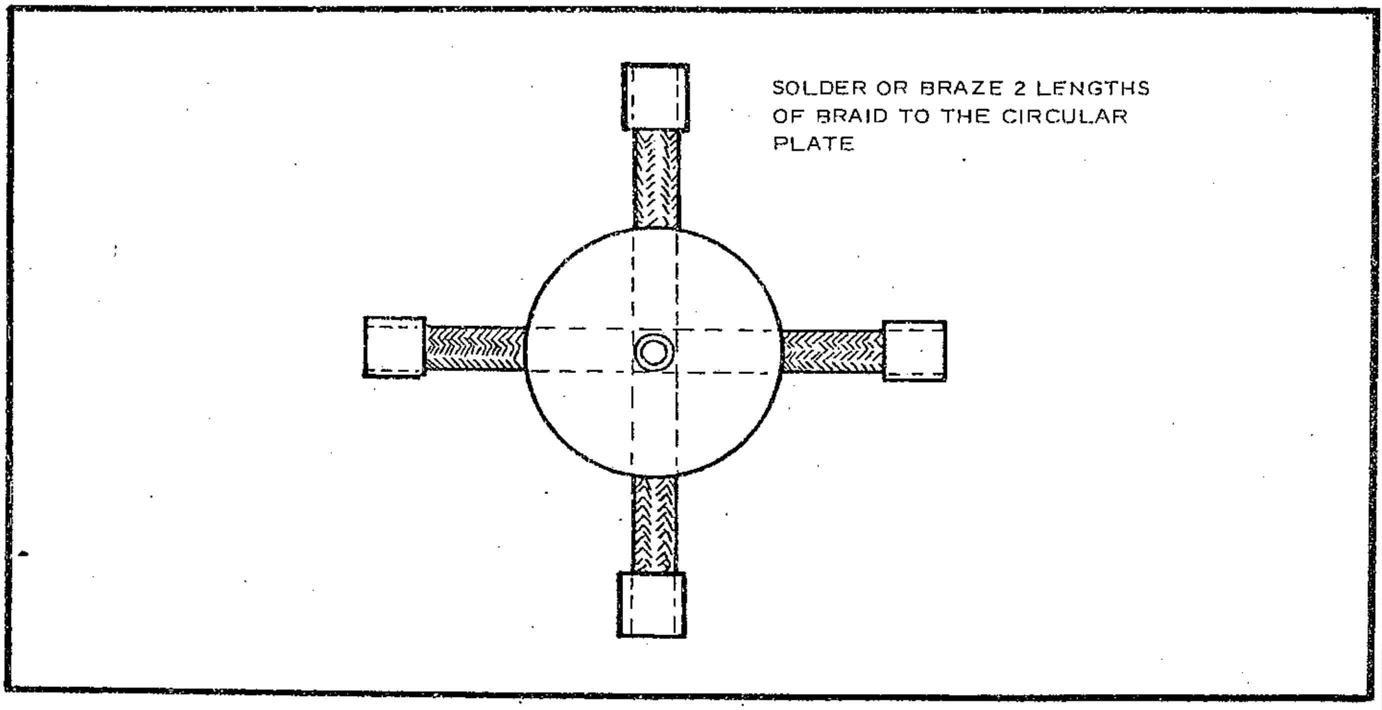


Figure 8

METHOD 2

7 This is an improved type of clamp, manufactured from CR steel as per Figures 3 and 4 and attached to cable, length as required. The advantages of this clamp are its flat contour which precludes damage from vehicles running over it and its economy and simplicity of manufacture.

METHOD 3

8 Proceed as follows:

(a) Tap hole for 1/4" bolt into existing ground rod.

(b) Silver solder two strips of braid bonding wire at right angles to a circular brass plate. Attach clips to each end of braid by flattening 3/8" copper or aluminum tubing.

(c) Secure plate to grounding rod through centre, using 1/4" bolt.

(d) For details of this method see Figures 7 and 8.

METHOD 4

9 A variation of Method 3, used where only two connections are required.

(a) Tap hole for 1/4" bolt into existing ground rod.

(b) Using braided bonding wire of suitable length, tin ends approximately 1-1/2" to prevent fraying and 1" in the centre.

(c) Drill hole through braid and attach to rod using 1/4" bolt, see Figure 5.

METHOD 5

10 Proceed as follows:

(a) Tap existing ground rod for 1/4" bolt.

(b) Solder lug to ground wire and attach to rod using 1/4" bolt.

(c) Using suitable length of wire to reach aircraft, attach a locally manufactured jack for use with aircraft having integral grounding points. Alligator clamps should be used only on aircraft which do not have such points, see Figure 6.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAMO/CEngl

EO 05-1-5A/12
31 Jul 64

ROYAL CANADIAN AIR FORCE

SPECIAL INFORMATION

CONVERSION OF INSTRUMENTS TO WHITE LUSTRELESS DIAL MARKINGS

INTRODUCTION

1 To increase the clarity of aircraft instrument dials AFHQ has now directed that lustreless white paint be substituted in lieu of fluorescent radio-active and non radio-active paints. This EO is published to advise user units of the policy of the conversion programme.

INFORMATION DATA

2 Conversion to lustreless white dial finish will be carried out during normal repair and/or overhaul on all instruments except:

(a) Those installed in aircraft which utilize ultra-violet and/or fluorescent instrument lighting.

(b) Instrumentation on loan from other services or civilian organizations.

3 After conversion, instruments will be allotted new part numbers and NATO stock numbers (NSN).

4 Units are not to demand under the new NSN until stocks of the old NSN are depleted. Demands for the old stock number will automatically be filled by the newer item as stock levels change.

ADDITIONAL DATA

5 The following additional data applies:

(a) It is estimated that the complete conversion of any one item [illegible] approximately 2 years.

(b) AFHQ letter 1006A (DAITel) dated 7 Jan 64 refers.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAVO/IES1

ROYAL CANADIAN AIR FORCE

LIST OF FIELD MODIFICATIONS

AIRCRAFT GENERAL

(This EO replaces EO 05-1-6A dated 15 Mar 62)

TABLE OF CONTENTS

LATEST DATE	EO NO	TITLE
	05-1-6A/1	(Rescinded)
	/2	(Rescinded)
	/3	(Replaced by EO 35AA-10APN2-6A/1)
	/4	(Rescinded)
	/5	(Rescinded)
12 Nov 53	/6	Standardization of Electrical Connectors for B-16 Type Compasses
8 Mar 57	/7	Extension Cord Switch
	/8	(Replaced by EO 05-1-6A/15)
	/9	(Rescinded)
	/10	Replaced by EO 05-1-6A/13
	/11	(Rescinded)
8 Apr 60	/12	Antenna Connector UG-102/U

TABLE OF CONTENTS (Cont'd)

* Asterisks appearing opposite entries denote changes since last issue

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Replaced 05-6A/15

ROYAL CANADIAN AIR FORCE

EO 05-1-6A/6
12 Nov 53

MODIFICATION

STANDARDIZATION OF ELECTRICAL CONNECTORS FOR B-16 TYPE COMPASSES

EQUIPMENT AFFECTED:	All Aircraft fitted with B-16 Type Compasses
BY WHOM WORK WILL BE PERFORMED:	Operating Units, RDs and Contractors
WHEN WORK WILL BE PERFORMED:	As required on replacement of compasses.
RCAF FORM ENTRIES:	L14, Log Book
MODIFICATION OF SPARES IN STOCK:	NA

PURPOSE

1 This Modification provides for standardization of the electrical connectors for the B-16 type standby compasses.

MODIFICATION DATA

2 Where electrical connectors other than type AN3116-1 are fitted to the aircraft wiring for the B-16 type compasses such connectors are to be replaced with this standard type.

PARTS REQUIRED

3 The following part is required for embodiment of this Modification and is to be demanded from the appropriate Supply Depot:-

RCAF REF	PART	DESCRIPTION	QUANTITY
5CC/493	AN3116-1	Connector	1

PARTS RENDERED SURPLUS OR OBSOLETE

4 Connectors removed as a result of this Modification are to be disposed of in accordance with CAP 16, Vol. 1, Chap. 13.

WEIGHT, LOADING AND BALANCE DATA

5 The effect on the weight, loading and balance of aircraft is negligible.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/SACO/ACA

ROYAL CANADIAN AIR FORCE EO 05-1-6A/7
8 Mar 57

MODIFICATION

EXTENSION CORD SWITCH

(This EO replaces EO 05-1-6A/7 dated 22 Jan 54)

EQUIPMENT AFFECTED:	AF/AACX-203 Extension Cord RCAF Ref. 10EA/27829
BY WHOM WORK WILL BE PERFORMED:	Units and RDs
WHEN WORK WILL BE PERFORMED:	At Units Discretion
RCAF FORM ENTRIES:	L14, E133
MODIFICATION OF SPARES IN STOCK:	As Required

PURPOSE

1 To replace push-to-talk switch on extension cord 10EA/27829 to provide a locking circuit for the microphone.

MODIFICATION DATA

2 The following is the sequence of operations:

(a) Remove switch aviometer type 9002.

(b) Connect Roanwell switch Type 9992, 10EA/33905, as per Figure 1.

PARTS REQUIRED

3 The following part is required to effect this modification:-

RCAF REF.	PART	DESCRIPTION	QUANTITY
10EC/33905	9992	Roanwell switch	1
10EA/46149		Cord protector kit	1

PARTS RENDERED SURPLUS OR OBSOLETE

4 The following part is rendered surplus by the embodiment of this modification:-

RCAF REF.	PART	DESCRIPTION	QUANTITY
	9002	Aviometer switch	1

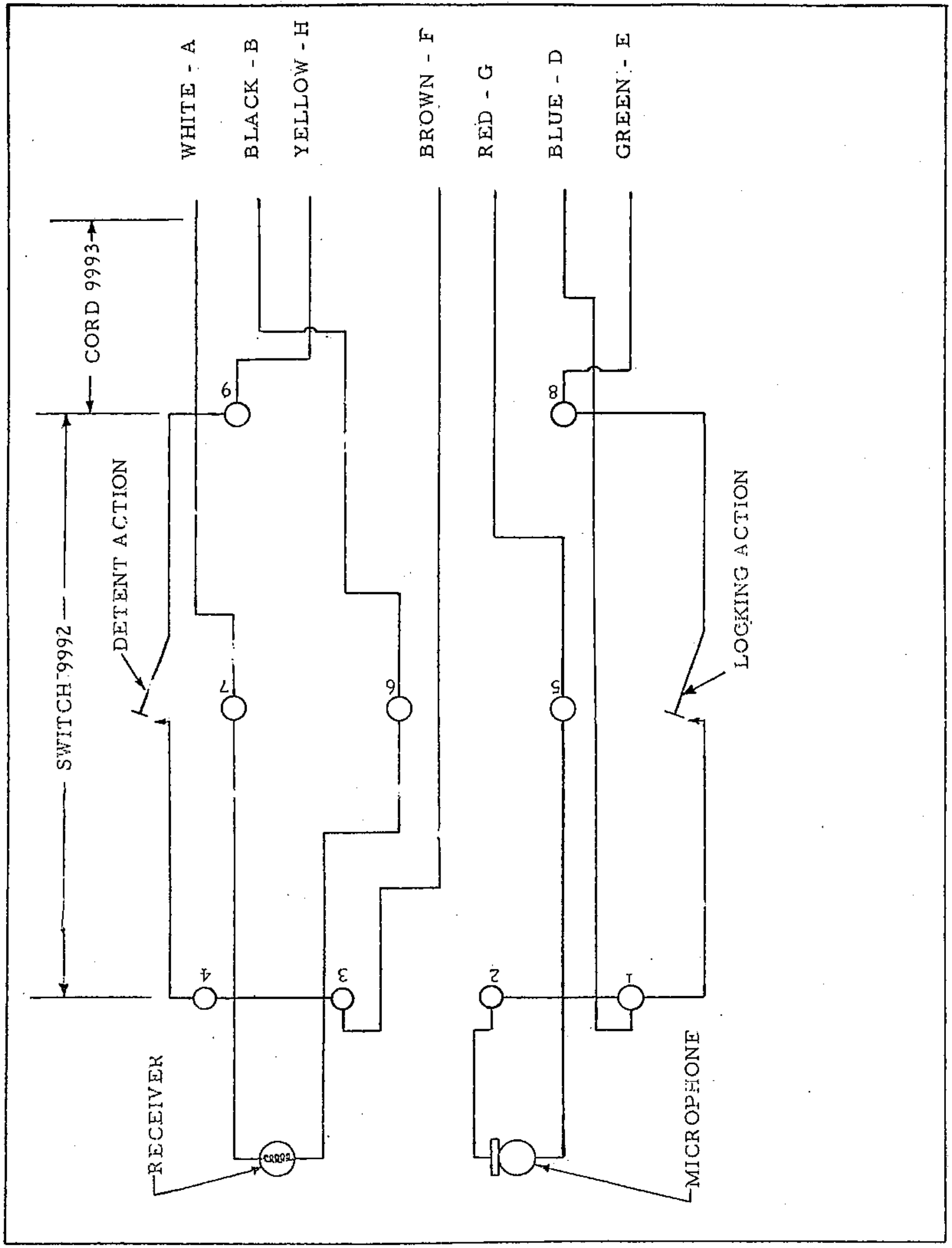


Figure 1

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By
AMC/S Tel O/Tel AF

ROYAL CANADIAN AIR FORCE

EO 05-1-6A/12
8 Apr 60

MODIFICATION

ANTENNA CONNECTOR
UG-102/U

EQUIPMENT AFFECTED:	All aircraft fitted with AN/ARN-5 and RC-103
BY WHOM WORK WILL BE PERFORMED:	Operating Units
WHEN WORK WILL BE PERFORMED:	Next Inspection
RCAF FORM ENTRIES:	L-14
MODIFICATION OF SPARES IN STOCK:	NA

PURPOSE

1 To prevent damage to antenna receptacle UG-103A/U on R-89B/ARN-5, R-530B/ARN-5 and BC-733D receivers. Damage occurs when connection is being made between the receiver and the antenna connector. The bevel tips of UG-102/U sometimes enter a gap between the pin and the phenolic insert and damage to the pin results.

MODIFICATION DATA

2 The following is the sequence of operations:-

(a) Disconnect antenna connector UG-102/U from BC-733D localizer receiver.

(b) Using a small file round off the end of the two pins of UG-102/U.

(c) Connect the antenna to the receiver.

(d) Disconnect antenna connector UG-102/U from R-89B/ARN-5 or R-430B/ARN-5 receiver.

(e) Repeat paras. 2 (b) and 2 (c).

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:-
AMC/S Tel O/Tel AE

ROYAL CANADIAN AIR FORCE

EO 05-1-6A/13
27 Jan 61

MODIFICATION

HELMET CORD REPLACEMENT

(This EO replaces EO 05-1-6A/13 dated 22 Jul 60)

EQUIPMENT AFFECTED:	Helmet used with Sabre and T-33 Aircraft (See Note below)
BY WHOM WORK WILL BE PERFORMED:	Operating Units
WHEN WORK WILL BE PERFORMED:	As soon as possible
RCAF FORM ENTRIES:	NA
MODIFICATION OF SPARES IN STOCK:	As required

NOTE

This modification must be carried out in conjunction with EO 05-5E-6A/304 (Sabre) and EO 05-50C-6A/366 (T-33).

PURPOSE

1 To improve helmet wiring and to provide a better helmet cord assembly.

MODIFICATION DATA

IMPORTANT

Two different methods of attaching the cord to the helmet are outlined in this leaflet. The user is to be given the opportunity to decide which method is to be used. Figure 2 shows Method "A" and Figure 5 Method "B".

2 The following is the sequence of operations:

METHOD "A"

(a) Remove the two receivers Ref. 10EC/27819 from the helmet.

(b) Remove headset cords Ref. 10EA/29525 and 10EA/29526 from the helmet.

(c) Stitch the microphone connector harness to the helmet as shown in Figure 1, using thread nylon Ref. 32P/415.

(d) From the new cord assembly Ref. 10EA/56726 remove the cross bar strain reliefs at the end of receiver cables. Retain the cross bars.

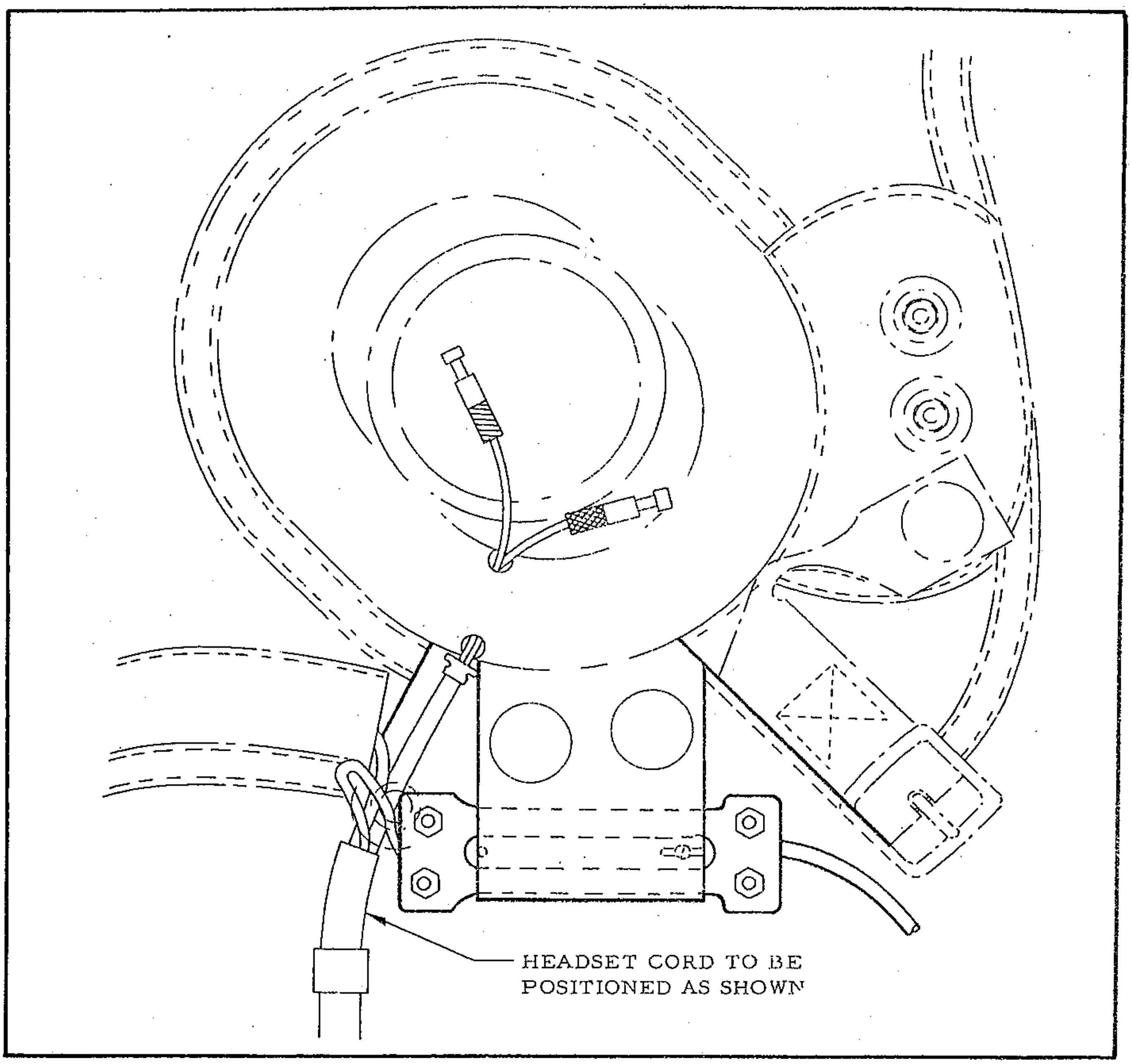


Figure 2

MODIFICATION DATA (Cont'd)

(e) Insert the longer receiver cable through the channel across the back of the helmet, from right to left, refer to Figure 2.

(f) Feed the receiver cables through the holes in the rubber earpieces and replace the cross bar strain reliefs removed in para. 2(d).

(g) Insert the receiver leads in the receiver sockets and tighten the securing screws on the side of the receivers.

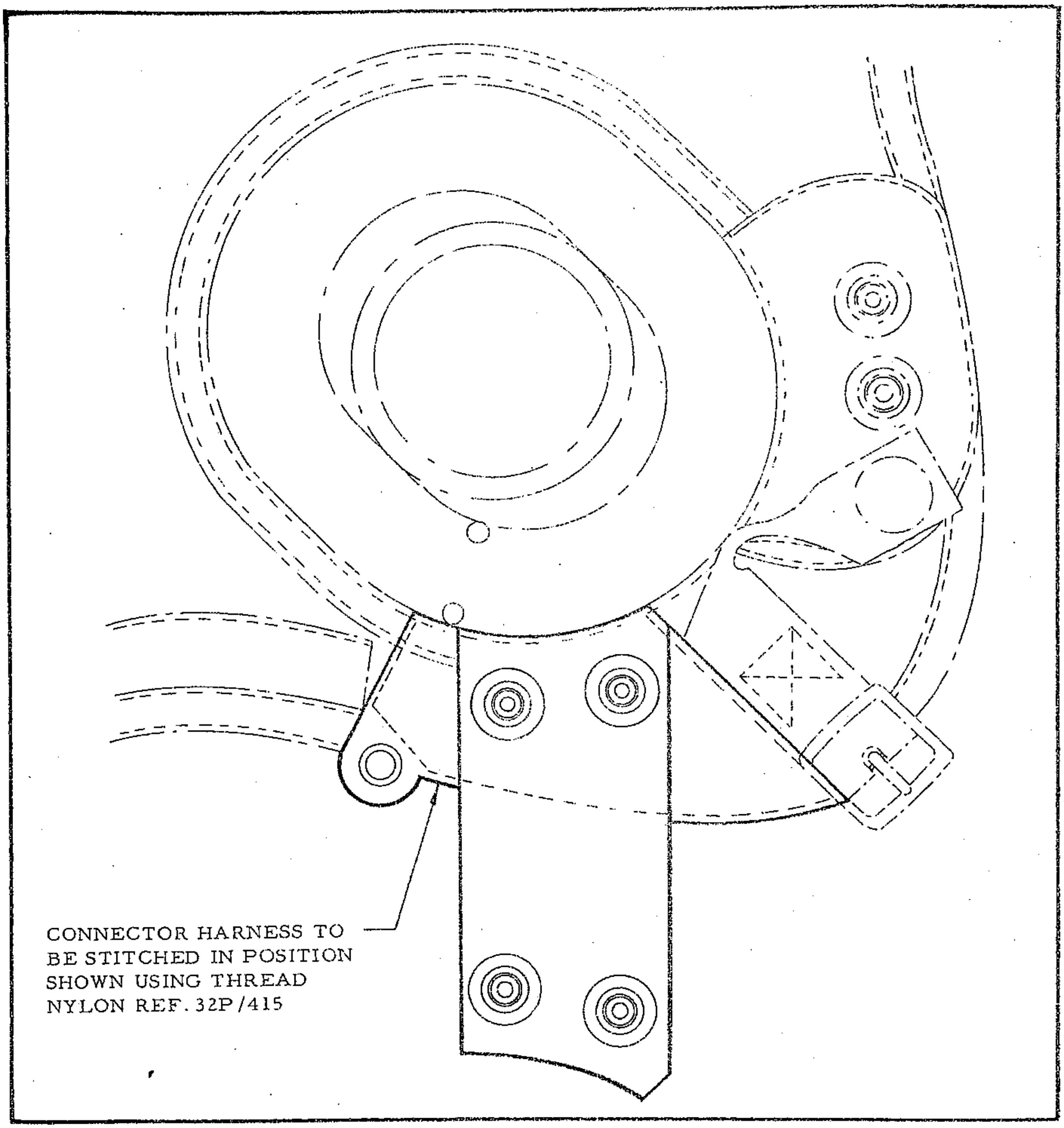

CONNECTOR HARNESS TO
BE STITCHED IN POSITION
SHOWN USING THREAD
NYLON REF. 32P/415

Figure 1

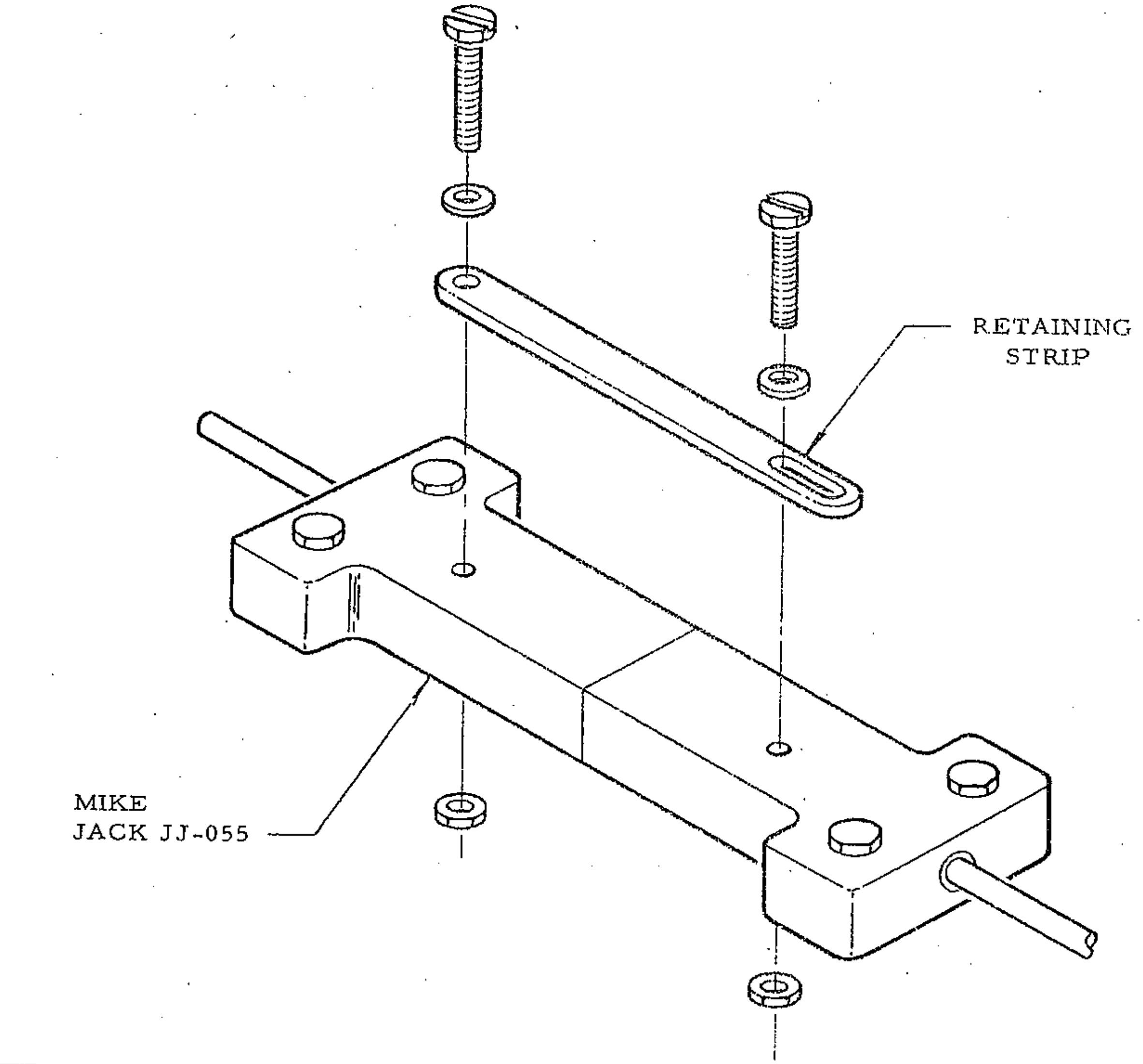


Figure 4

MODIFICATION DATA (Cont'd)

(v) Insert the receiver leads in the receiver sockets and tighten the securing screws on the side of the receivers.

(w) Replace receivers in the helmet rubber earpieces.

(x) Stitch headset cord to the helmet as shown in Figure 5.

(y) Remove and discard strain relief assembly shown in Figure 3 from headset cord.

(z) Connect microphone PJ-292 to jack JJ-055 and install retaining strip as shown in Figure 4. Microphone cord fitted with plug PJ-291 tape connectors together with tape Ref. 33G/135.

(aa) Excess microphone cable should be taped with Ref. 33G/135 tape, polyvinyl chloride.

(ab) Check helmet.

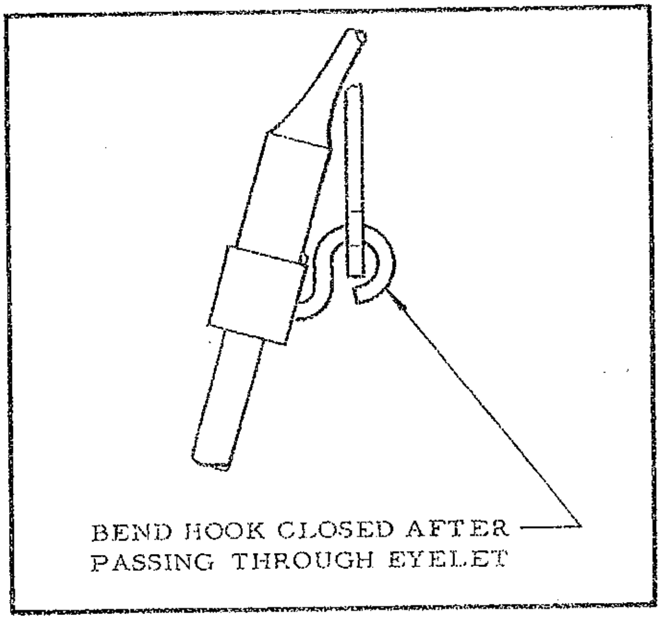


Figure 3

MODIFICATION DATA (Cont'd)

(h) Replace the receivers in the helmet rubber earpieces.

(j) Pass the cord strain relief hook through eyelet on the microphone connector harness and bend the hook closed; refer to Figure 3.

(k) Connect microphone plug PJ-292 to jack JJ-055 and install the retaining strip as shown in Figure 4. Microphone cord fitted with plug PJ-291 tape connectors together with tape Ref. 33G/135.

(m) Position microphone connector into the leather harness and fasten.

(n) Excess microphone cable should be taped with Ref. 33G/135 Tape, polyvinyl chloride.

(p) Check the helmet.

METHOD "B"

(q) Remove the two receivers Ref. 10EC/27819 from helmet.

(r) Remove headset cords Ref. 10EA/29525 and 10EA/29526 from helmet.

(s) From new cord assembly Ref. 10EA/56726 remove the cross bar strain reliefs at the end of receiver cables. Retain the cross bars.

(t) Insert the longer receiver cable through the channel across the back of the helmet, from right to left or for aircrew personnel who prefer having oxygen mask fastening to the right, insert cable from left to right.

(u) Feed the receiver cables through the holes in the rubber earpieces and replace the cross bars removed in para. 2(s).

PARTS REQUIRED

3 The following part is required to effect this modification and is to be demanded from 1 SD Downsview and 30AMB Langar:-

RCAF REF.	PART	DESCRIPTION	QUANTITY
10EA/56726	351362-1	Cord and harness assembly	1

PARTS RENDERED SURPLUS OR OBSOLETE

4 The following parts are rendered surplus as a result of this modification and are to be returned to stock if serviceable:-

RCAF REF.	PART	DESCRIPTION	QUANTITY
10EA/29525		Cord headset (AF/AACX-206)	1
10EA/29526		Cord headset (AF/AACX-219)	1

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared By:
AMC/S Tel O/Tel AE

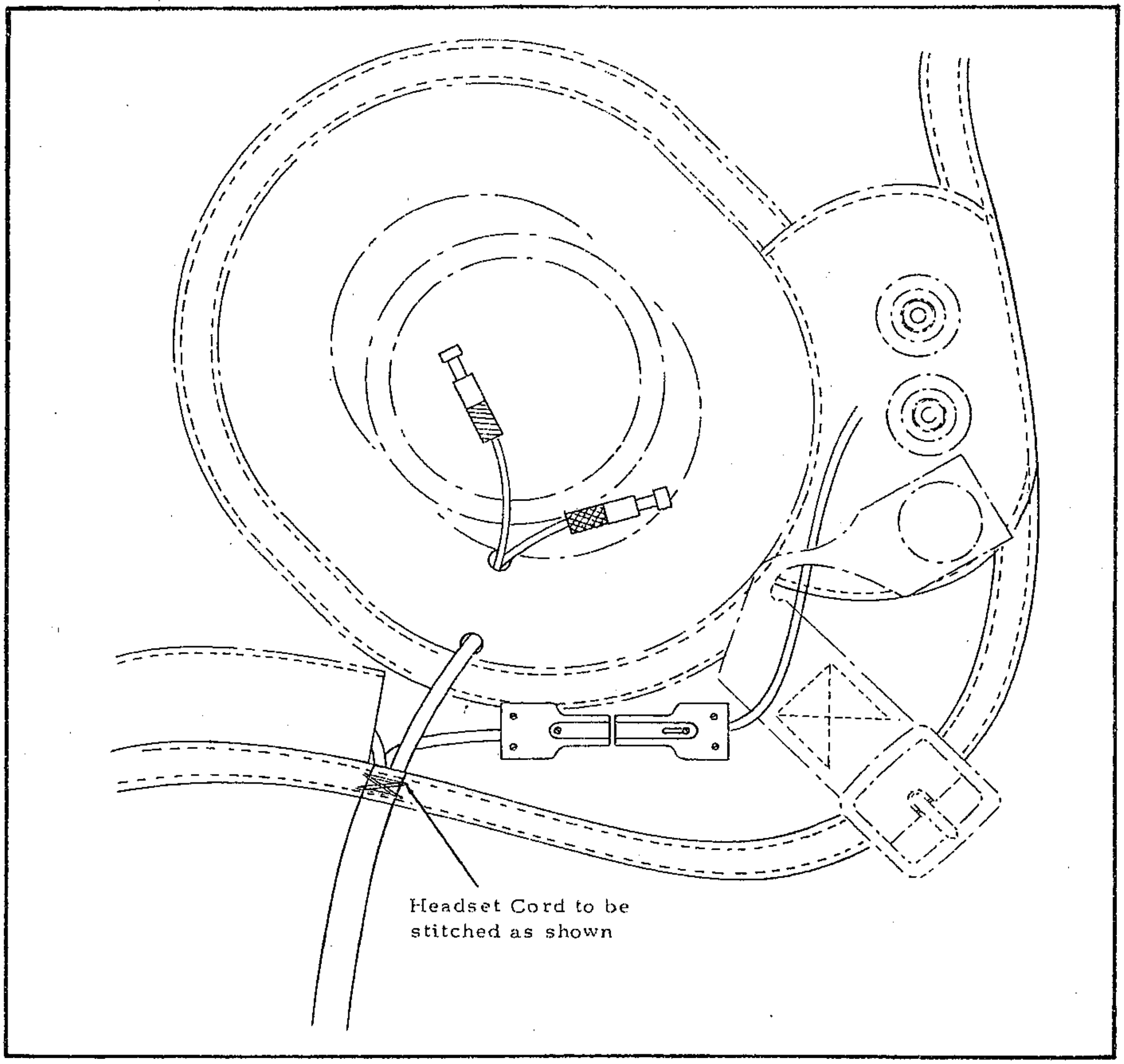


Figure 5

ROYAL CANADIAN AIR FORCE

EO 05-1-6A/14
1 Feb 61

MODIFICATION

I.L.S. SIX-CHANNEL FACILITY

EQUIPMENT AFFECTED:	Aircraft fitted with R-89B/ARN-5A (10EU/23271) and BC-733D (10EU/14475)
BY WHOM WORK WILL BE PERFORMED:	Unit Telecommunications personnel
WHEN WORK WILL BE PERFORMED:	As soon as possible
RCAF FORM ENTRIES:	L14, L61
MODIFICATION OF SPARES IN STOCK:	NA

PURPOSE

1 To fit all aircraft with six channel ILS facilities.

MODIFICATION DATA

2 The following is the sequence of operations:-

(a)	Remove	10EU/23271	R-89B/ARN5A	Receiver
(b)	Remove	10EU/14475	BC-733D	Receiver
(c)	Install	10EU/43677	R-430B/ARN5C	Receiver
(d)	Install	10EU/57031	BC-733D (Mod)	Receiver

PARTS REQUIRED

3 The following parts are required for embodiment of this modification and are to be obtained on a one for one exchange basis.

RCAF REF.	PART	DESCRIPTION	QUANTITY
10EU/43677	R430B/ARN5C	Receiver	1
10EU/57031	BC-733D (Mod)	Receiver	1

PARTS RENDERED SURPLUS OR OBSOLETE

4 The following parts are to be returned in exchange for required items:-

RCAF REF.	PART	DESCRIPTION	QUANTITY
10EU/23271	R-89B/ARN-5A	Receiver	1
10EU/14475	BC-733D	Receiver	1

WEIGHT, LOADING AND BALANCE DATA

5 The effect on the weight, loading and balance of aircraft is not affected.

Prepared By:
AMC/STelO/TelAE

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

ROYAL CANADIAN AIR FORCE

EO 05-1-6A/16
25 Jan 62

MODIFICATION

STANDARDIZATION OF ANTENNA LEAD-IN WIRE

EQUIPMENT AFFECTED:	All Aircraft Using Non-Co-axial Antenna Lead-In Wire
BY WHOM WORK WILL BE PERFORMED:	Units, RDs and Contractors
WHEN WORK WILL BE PERFORMED:	When replacement of Lead-In wire is required
RCAF FORM ENTRIES:	L14-1B, L14-6B
MODIFICATION OF SPARES IN STOCK:	NA

PURPOSE

1 To standardize aircraft internal non-co-axial antenna lead-in wire by replacing existing lead-in wire with teflon insulated cable Amphenol Part 414-260.

MODIFICATION DATA

2 The following is the sequence of operations:

(a) Remove existing non-co-axial antenna lead-in wire.

(b) Replace lead-in wire with same length of teflon insulated cable.

PARTS REQUIRED

3 The following part is required to affect this modification and is to be demanded from depot stocks:

RCAF REF.	PART	DESCRIPTION	QTY.
5E/6145-00-722-9700	Amphenol 414-260	Cable, RF Teflon, insulated	AR

PARTS RENDERED SURPLUS OR OBSOLETE

4 The following part is rendered surplus as a result of this modification and is to be disposed of in accordance with CAP 16, Volume 1, Chapter 13:

RCAF REF.	PART	DESCRIPTION	QTY.
		Existing lead-in wire	AR

WEIGHT, LOADING AND BALANCE DATA

5 The weight and balance change resulting from the instructions contained herein is negligible.

ADDITIONAL DATA

6 The following additional data applies:

(a) It is estimated that this modification will require 1 to 5 man-hours dependent on aircraft type.

(b) This modification is issued as a result of a recommendation submitted by ATCHQ Message S4152 dated 30 Jun 61.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/STelO/TelAF

ROYAL CANADIAN AIR FORCE

EO 05-1-6A/17
29 Aug 63

MODIFICATION

SHOCKMOUNT REPLACEMENT

EQUIPMENT AFFECTED:	All Aircraft equipped with AN/APS-42B
BY WHOM WORK WILL BE PERFORMED:	Units, RDs and Contractors
WHEN WORK WILL BE PERFORMED:	On or before next Periodic Inspection due
RCAF FORM ENTRIES:	L14-1B, L14-6
MODIFICATION OF SPARES IN STOCK:	NA

PURPOSE

1 To replace the existing shockmounts, supporting the indicator IP-215(A)/APS-42B, with shockmounts of greater carrying capacity.

MODIFICATION DATA

2 The following is the sequence of operations:

(a) Remove the indicator IP-215 from its shockmounts.

(b) Remove shockmounts Part 7001-K.

(c) Install new shockmounts Ref. 27LM/312 in place of those removed.

(d) Re-install the indicator IP-215.

PARTS REQUIRED

3 The following parts are required to incorporate this modification and shall be provided from unit resources or demanded from depot stocks.

RCAF REF.	PART	DESCRIPTION	QTY.
27LM/312	770-4G	Shockmount	8

PARTS RENDERED SURPLUS OR OBSOLETE

4 The following parts are rendered obsolete and shall be disposed of in accordance with CAP 16, Vol 1, Chapter 13.

RCAF REF.	PART	DESCRIPTION	QTY.
10EP/48322	7001-K	Shockmount	8

WEIGHT, LOADING AND BALANCE DATA

5 The effect on weight and C of G is negligible.

ADDITIONAL DATA

6 The following additional data applies:

(a) It is estimated that this modification will require approximately 2 man-hours.

(b) This modification was originally published under EO 35AA-15APS-42B-6A/19. Aircraft modified under this EO will not require additional work, but L14-6 is to be annotated to reflect the change.

(c) This modification is raised as a result of 412 (T) Sqn UCR 3322/A80 dated 26 Apr 63.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAVO/T1

ROYAL CANADIAN AIR FORCE

EO 05-1-6A/18
8 Oct 63

MODIFICATION

DISABLING DOUBLE CHANNEL FACILITY

EQUIPMENT AFFECTED:	All Aircraft fitted with Bendix VHF Control CNA-21CNX
BY WHOM WORK WILL BE PERFORMED:	Units, RDs and Contractors
WHEN WORK WILL BE PERFORMED:	On or before next Periodic Inspection due
RCAF FORM ENTRIES:	L14-1B, L14-6
MODIFICATION OF SPARES IN STOCK:	NA

PURPOSE

1 To eliminate the possibility of accidentally switching the SC/DC toggle switch on the VHF control to the double channel position, consequently losing the VHF facility.

MODIFICATION DATA

2 The following is the sequence of operations:

(a) Remove the cover from the aircraft radio junction box.

(b) Trace the wire that runs to pin 50 on the VHF control CNA-21CNX, and remove from its present terminal in radio junction box.

(c) This wire shall be suitably taped and stowed away.

(d) Carry out a functional test with the SC/DC toggle switch in both positions.

PARTS REQUIRED

3 Nil

PARTS RENDERED SURPLUS OR OBSOLETE

4 Nil

WEIGHT, LOADING AND BALANCE DATA

5 The weight and balance change resulting from instructions contained herein is negligible.

ADDITIONAL DATA

6 The following additional data applies:

(a) It is estimated that this modification will require approximately one-half man-hour.

(b) RCAF Drawings detailing the Bendix VHF interconnection wiring for the specific aircraft may be obtained on request from AMCHQ/SOED/ES.

(c) This modification is raised as a result of 412 Sqn Uplands UCR 3322/A92, dated 15 May 63.

Prepared by:
AMC/SAVO/T1 ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

MODIFICATION

ANTENNA LEADING EDGE PROTECTION

(This EO replaces EO 05-1-6A/19 dated 4 Oct 63)

EQUIPMENT AFFECTED:	All Aircraft fitted with Anti-precipitation Static Antenna Masts and in special instances to Metal Blade Antennae
BY WHOM WORK WILL BE PERFORMED:	Units, RDs and Contractors
WHEN WORK WILL BE PERFORMED:	On or before next Periodic Inspection due
RCAF FORM ENTRIES:	L14-1B, L14-6
MODIFICATION OF SPARES IN STOCK:	NA

PURPOSE

1 The purpose is twofold:

(a) To prevent erosion of the leading edge of anti-precipitation static antenna masts.

(b) To prevent chipping of the leading edge of metal blade antennae, if found necessary.

MODIFICATION DATA

2 The following is the sequence of operations:

(a) Clean off the mast or the metal blade antenna making use of methyl ethyl ketone solvent.

(b) Mask off an area 11/16" on each side of the mast or antenna leading edge centreline and sand lightly to remove gloss.

(c) Cut a strip of 1/64" thick synthetic rubber 1- 3/8" wide, length as required, and sand one side lightly.

(d) Apply one coat of adhesive cement to the masked off area of the mast or antenna and to the sanded side of the synthetic rubber. Allow to dry for one hour.

(e) After the adhesive cement has dried for one hour apply the synthetic rubber to one side of the mast or antenna, then carefully wrap around the leading edge without stretching the rubber.

(f) Take particular care to ensure good adhesion at the edges.

PARTS REQUIRED

3 The following parts are required to incorporate this modification:

RCAF REF.	PART	DESCRIPTION	QTY.
33C/520	CGSB15-GP-52	Solvent, methyl ethyl ketone	AR
32C/449	63707	Rubber, synthetic	AR
33G/8040-21-805-9846		Cement, adhesive	AR

PARTS RENDERED SURPLUS OR OBSOLETE

4 Nil

WEIGHT, LOADING AND BALANCE DATA

5 The weight and balance change resulting from the instructions contained herein is negligible.

ADDITIONAL DATA

6 The following additional data applies:

(a) It is estimated that this modification will require approximately 2 man-hours.

(b) Local purchase is authorized from BF Goodrich Canada Ltd., Kitchener Ont. of rubber, synthetic Part 63707 available in rolls 30" wide.

(c) This modification is raised as a result of Station Vancouver UCR 2356/A136 dated 11 Dec 62 and AMC technical survey.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

Prepared by:
AMC/SAVO/T1

EO Divider
RCAF L52B
7530-21-801-0426

(Position 2)

EO____________________

(Position 3)

EO

ROYAL CANADIAN AIR FORCE

AIRCRAFT WEIGHT & BALANCE DATA

"REVISION"
NOTICE

LATEST REVISED PAGES SUPERSEDE THE SAME PAGES OF PREVIOUS DATE

Insert revised pages into basic publication. Destroy superseded pages.

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

14 AUG 59
Revised 5 Dec 62

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PART 1

DESCRIPTION AND INSTRUCTIONS FOR THE USE OF EO 05-1-8

DESCRIPTION

1 This EO contains information necessary to personnel involved in the weighing of RCAF aircraft.

2 Due to the variety of aircraft employed by the RCAF, it has become necessary to issue a general instruction EO 05-1-8, Weight and Balance Data, and to issue supplementary Weight and Balance Data in the "-8" EO series for the particular type of aircraft being weighed.

3 This EO includes standard definitions and instructions to be carried out prior to weighing the aircraft and instructions for the use of the two weighing Forms L36 and L38. The EO for the particular aircraft shall provide all the necessary information to determine the weight and centre of gravity location under various load conditions which may be encountered by the field.

INSTRUCTIONS FOR USE

4 EO 05--8 shall be considered part of the aircraft equipment for transport, communications aircraft, helicopters and other types not covered below and as such shall be carried at all times. It is not necessary to carry the -8 EO in fighter aircraft, fighter type aircraft employed on training roles and single engine training aircraft.

5 The current duplicate copy of the aircraft Forms L36 and L38 shall be held with the aircraft log books by the unit operating the aircraft. A copy of the current Form L36 shall be forwarded to CHQ and a copy to AMCHQ after each aircraft weighing.

NOTE

The requirement for a CHQ copy may be cancelled by the command concerned.

6 Personnel responsible for the weighing of aircraft shall fill in the name of the unit or detachment carrying out the weighing in the Aircraft Basic Weight Change Record L38 contained in the Aircraft EO 05--8.

7 An aircraft shall be weighed:

(a) At time of manufacture.

(b) After a modification, when the leaflet so directs.

(c) At the discretion of the Chief Technical Services Officer.

(d) Whenever the validity of the weighing record is in doubt.

8 Each aircraft shall be weighed every two years with a tolerance of ± 60 days.

RESPONSIBILITY FOR WEIGHING AIRCRAFT

9 The repair, overhaul, modification and calibration of aircraft weighing scales shall be in accordance with CAP 16, Vol. 1, Chap. 12.11. The distribution shall be in accordance with CAP 603, D116 dated 19 Jul 56.

10 Commands and #1 Air Division shall be responsible to arrange for short courses of instruction for selected personnel on the weighing of aircraft and operation of aircraft weighing scales.

11 Commands and #1 Air Division shall be responsible for ensuring that the provisions of EO 05-1-8 are being carried out by units under their Command.

12 The Unit Chief Technical Services Officer shall be responsible for the compliance of instructions contained in EO 05-1-8.

PART 2

STANDARD DEFINITIONS

WEIGHT

1 All weights shall be stated in pounds and weight totals shall be given to the nearest whole pound.

BASIC WEIGHT

2 The Basic Weight is defined as the weight of an aircraft and its normal operational equipment necessary to enable the aircraft successfully to complete its rôle, and includes all fluid systems filled to capacity (hydraulic system, coolant system, de-icer system, etc.) but not including fuel, oil, drinking and washing water. Trapped fuel and oil is included in the aircraft Basic Weight.

OPERATIONAL LOAD

3 For weight and balance calculations operational load shall be defined as crew, fuel, oil and cargo. The word crew shall be taken to mean all personnel carried in the aircraft and responsible for the operation and maintenance of the aircraft for any particular flight. Cargo shall be taken to mean any or all of the following:-

(a) Freight.

(b) Passengers.

(c) Baggage, crew and passenger.

(d) Catering requirements, crew and passenger.

(e) Additional safety equipment over and above the scale laid down for the Basic Weight.

(f) Ammunition.

(g) Bombs.

(h) Rockets.

(j) Pyrotechnics over and above the scale laid down for the Basic Weight.

GROSS WEIGHT

4 The Gross Weight or All Up Weight as it is sometimes referred to is obtained by adding the basic weight and the operational load. The Gross Weight may be referred to as:-

DESIGN GROSS WEIGHT

(a) The Design Gross Weight is defined as the weight of an aircraft when loaded for its primary role. This is the weight upon which stress analysis is generally based.

MAXIMUM GROSS WEIGHT FOR TAKE-OFF

(b) This is the maximum overload gross weight at which the aircraft may take off. If this is greater than the Design Gross Weight, the aircraft shall be restricted to level flight and gentle manoeuvres until such time as the weight has been reduced by fuel consumption, dropping of bombs, etc., to the Design Gross Weight.

MAXIMUM GROSS WEIGHT FOR LANDING

(c) This is the Maximum Gross Weight at which the aircraft may be landed. Usually this conforms to the design gross weight, but in certain cases landing at a weight above normal is permitted. When this Maximum Landing Weight is not quoted, it is understood that the Design Gross Weight is to be the Maximum Weight for landing.

REFERENCE DATUM

5 The Reference Datum is an imaginary plane at or forward of the nose of the aircraft chosen so that all moments will be positive. All horizontal distances for balance purposes are measured from this line which is a pre-determined distance from some fixed jig point on the airframe. Diagrams for each aircraft show this reference datum as balance station zero.

ARM

6 For balance purposes the "Arm" shall be taken to mean the horizontal distance from the reference datum line to the C of G of the item given in inches.

7 Moment is defined as the weight of an item multiplied by its arm and is to be given the "inch-pounds" for these calculations.

AVERAGE ARM

8 The average arm of a system can be defined as follows:

$$\text{Average Arm} = \frac{\text{Sum of the Moments of that System}}{\text{Total Weight of the System}}$$

When an aircraft is weighed in its basic condition, the resultant will be known as Basic Arm.

BASIC MOMENT

9 The Basic moment is the sum of the moments of all items included in the basic weight. When using data from an actual weighing of an aircraft, the Basic Moment is the total moment of the Basic aircraft in respect to the reference datum.

CENTRE OF GRAVITY

10 The Centre of Gravity of an aircraft is defined as the point at which the total weight of the aircraft is assumed to act and about which the aircraft would balance if suspended. The distance of the C of G from the reference datum is found by dividing the total moment by the weight of the aircraft.

C OF G LIMITS

11 The C of G Limits encompass the range of movement which the C of G can have without making the aircraft unstable. The C of G of an operationally loaded aircraft must be within these limits at all times. In some cases the take-off and landing limits may be specified.

TRAPPED FUEL AND OIL

12 The weight of fuel and oil remaining in the aircraft fuel and oil system when they are drained using the draining points provided and with the aircraft in the normal ground position.

RESIDUAL FUEL

13 The weight of fuel which cannot be used by the engines under normal conditions of flight but which may be drained using the draining points provided with the aircraft in the normal ground position.

BALLAST

14 Permanent fixed ballast, that is bolted or otherwise permanently attached to the aircraft and is required to maintain the proper C of G conditions, is to be shown on the applicable basic weight checking list in the -8 EO of the aircraft and will therefore be weighed and reflected in the basic weight. (Permanent Ballast is usually necessary to compensate for permanently removed items of basic equipment or to maintain C of G positions within C of G limits).

15 Semi-permanent fixed ballast that is not shown on the applicable basic weight check list in the -8 EO of the aircraft but is weighed with the aircraft will be shown in column 1 of the L36.

16 Loose or temporary ballast such as shot or sand bags etc. are to be removed from the aircraft prior to weighing. (Semi-permanent or temporary ballast is used to compensate for items that make up operational load that have been removed on a temporary basis e.g. ammunition, bombs, crew member etc.).

NOTE

If the removal of loose ballast is not feasible and is thereby weighed with the aircraft, it must be recorded in column 1 of the L36 and calculated accordingly.

PART 3

INSTRUCTIONS FOR USE OF CHARTS AND FORMS

GENERAL

1 There are two parts to the weight and balance problem. First, we must have the correct information as to basic weight and moment; second, the gross weight and balance must be retained within safe limits with the addition of the operation load. The first part is controlled after the basic weight and balance have been determined by weighing the aircraft. The second part is controlled in the loading of the aircraft and is indicated on the weight and balance clearance form.

PRIMARY WEIGHING INSTRUCTIONS

2 The following instructions are to be followed:-

(a) Assemble the necessary equipment, including scales, hoisting equipment, jacks, cribbing, levelling bars, level, measuring tape, plumb bob and string.

(b) Clean the aircraft removing grease, dirt and moisture.

(c) Pump the fuel from the aircraft tanks into the refuelling tender. A sufficient quantity of fuel shall be left in the aircraft tanks to enable draining to be completed using tank drains with the aircraft in the normal ground attitude. All draining of fuel tanks shall be carried out in compliance with the safety precautions laid down in EO 00-80-4/6.

(d) Drain the oil tanks, but if this is impractical, fill the tanks to normal capacity.

(e) Fill the reservoirs of the hydraulic anti-icer and coolant system to normal level.

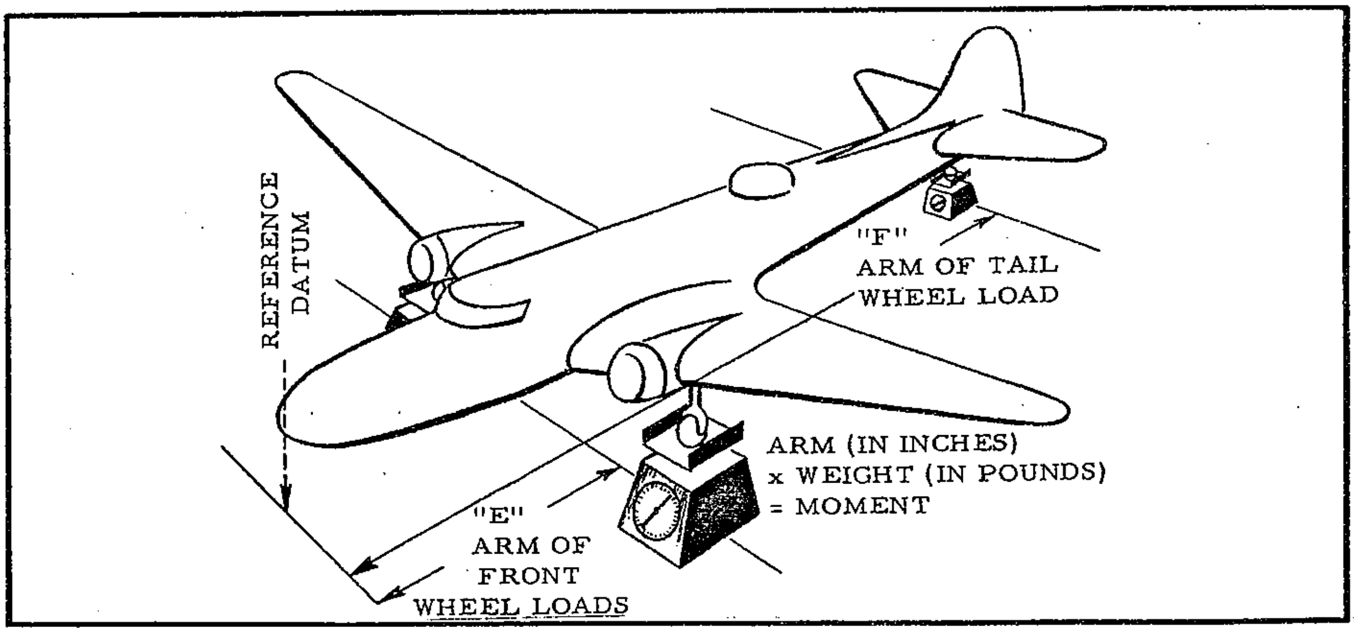


Figure 3-1 Weighing Aircraft

RCAF L36 (REV.)
40M-7-54

AIRCRAFT WEIGHING RECORD

Date Weighed____________________ Type and Mark________ RCAF NO.__________

Place Weighed____________________ Weighing Officer________________

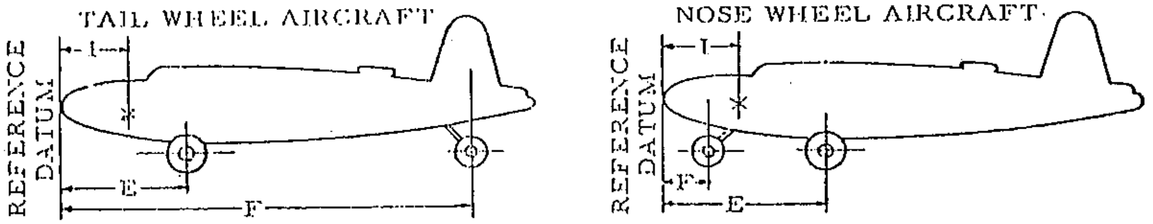
Wheel	Scale Reading	Tare	Net Weight	Arm (Inches)	Moment
Left Main					
Right Main					
Sub-Total (Both Main)				E	
Nose or Tail				F	
Total (As Weighed)				H(C of G)	

MEASUREMENTS

I - inches, the distance from the reference datum to some accessible exterior jig point or frame of the aircraft from which a plumb bob can be dropped to the ground. Obtain from the diagram on the balance computer or relevant EO.

E - inches; the distance from the reference datum to the center line of the main support points.

F = inches, the distance from the reference datum to the center line of the nose or tail support point.



DIAGRAMS FOR MEASURING VARIOUS TYPES OF AIRCRAFT TO DETERMINE ARM OF SUPPORT POINTS

<u>NOTE</u>: Existing stock of 40M-7-54 are to be used until depot stocks are depleted.

Figure 3-2 (Issue 2) Form L36

AIRCRAFT WEIGHING RECORD (Cont'd)

Description	Net Weight	Arm	Moment	Moment/1000
Total (As Weighed)				
Oil in Aircraft	−		−	
Total of Items Weighed but not Part of Basic Weight (From Col. 1 below)	−		−	
Total of Basic Items not in Aircraft When Weighed (From Col. 2 below)	+		+	
Basic Aircraft		H (C of G) Index		

Column 1

Items Weighed But Not Part of Basic Weight	Weight	Arm	Moment
TOTAL:			

Column 2

Basic Items Not in Aircraft When Weighed	Weight	Arm	Moment
TOTAL:			

REMARKS:

Type of Scales used ____________________
Method of Support ____________________
Attitude (Level-Normal) ____________________

Whenever possible aircraft are to be weighed with all and only basic equipment installed. If any item of basic equipment is missing, it must be recorded in Column 2. Items weighed, but not part of the basic equipment, must be noted in Column 1. Items listed in Column 1 and/or Column 2 must be considered when finding the CG of the Basic Aircraft.

Figure 3-3 (Issue 1) Form L36 (Cont'd)

RCAF-L38
15-M-51
AMC-1885-L38

AIRCRAFT BASIC WEIGHT CHANGE RECORD

Basic Weight (as weighed) ____________
Basic Moment (as weighed) ____________
Basic C of G (inches from Datum) ______
Basic Index ______________________

Item (+ or -)	Weight	Arm	Moment	Revised A/C WT	Revised A/C Moment	Revised C of G Index	Date	Unit	Job Order No.	Signature - Wt & Bal. Section

NB 1 This form is to be completed by the Weight and Balance Section immediately following each aircraft weighing or weight change made during maintenance.

2 New weighing records are to be compared by Unit Engineering Officers to existing Record of Daily Wt and C of G changes to ensure that unaccountable variations are investigated.

Figure 3-4 Form L38

(f) Inflate or deflate the main landing gear oleo struts to normal extension or to any desired height. It may be helpful for levelling and in jacking aircraft to lash a rope around the torque arm of the oleo or to apply a stiffener so that the strut will not extend when the aircraft is lifted. The nose wheel may be blocked to prevent turning.

(g) Check the aircraft against the applicable Basic Weight Check List in EO 05--8 and any differences shall be listed in column 1 or 2 of the L36.

(h) If aircraft tail is to be jacked or hoisted to place the aircraft in the level position, the following sequence will be observed:-

(1) Release brakes.

(2) Jack or hoist tail to level position, if using a sling check the chain with a level to ensure it is a perpendicular lift.

(3) Place jacks in wing jacking positions and operate all jacks and hoist simultaneously to maintain a level lift.

NOTE

The above precautions are necessary to reduce the possibility of side loadings or thrust on the scales which may result in a false weight being recorded. Jacking precautions as laid down in the "-2" EO of the Aircraft EO series shall be complied with at all times.

NOTE

The aircraft must be weighed in a closed hangar. Heating fans directed on the aircraft shall be turned "OFF".

USE OF AIRCRAFT WEIGHING RECORD L36

3 Instructions for the use of the form are as follows:-

(a) Fill in the identifying data and enter the actual scale readings in the first column.

(b) Subtract the tare weight, if any, from the scale readings to obtain the net weight. (The tare weight is the weight of equipment required for weighing the aircraft, such as chocks and lifting bars which are included in the scale readings).

(c) Determine the arms E and F by measurement from the datum line to the center line of the aircraft support points when the aircraft is in the horizontal position. Be sure to read the measuring tape graduations correctly.

(d) Multiply the sub-total net weight of the main support points and the net weight of the nose or tail support point by their respective arms (dimensions E and F) to obtain their moment.

(e) Add the net weights and the moments of the main support points and the nose or tail support points.

(f) Divide the total moment by the total net weight to obtain the C of G position in inches from the reference datum.

(g) Transfer "Total (as weighed)" weight, arm and moment to the reference side of the L36.

(h) Subtract the total weight and moment of items entered in column 1.

(j) Add the total weight and moment of items entered in column 2.

NOTE

Aircraft should normally be equipped completely as laid down in the Basic Weight Check List in EO 05--8. If this is done columns 1 and 2 should not normally be required.

When columns 1 and 2 of the Weighing Record are used, they are to be considered as an inventory of any deviation in equipment from the Basic Weight Scale.

(k) Complete final line of the Weighing Record showing the C of G and Moment/1000. For a light aircraft the moment may be given directly, while for heavy aircraft Moment/10,000 may be used. It shall be left to the discretion of the weighing officer to decide the method of recording the aircraft moment.

(m) Information regarding the type of scales used, the attitude of the aircraft, during weighing, the method of support, and the weight and location of ballast, if installed, is to be entered in the "REMARKS" paragraph.

NOTE

Sample copies of Forms L36 and L38 form part of EO 05-1-8. Each relevant aircraft weight and balance EO 05--8 shall contain complete current weight and balance data on these forms and they shall form part of the aircraft "-8" EO. Transport, communication and helicopter aircraft shall carry the completed EO 05--8 at all times. The duplicate copies of Forms L36 and L38 shall be kept with the aircraft log book, plus the L36 from the previous weighing. Stocks of forms are to be demanded as required.

AIRCRAFT BASIC WEIGHT CHANGE RECORD L38

4 This form shall be used to record the result of each aircraft weighing and all changes which may occur as a result of addition or removal of installed equipment. Personnel responsible for the serviceability and loading of the aircraft will observe the following action:-

(a) It is the responsibility of the Chief Technical Services Officer to ensure that the addition or deletion of basic equipment (see definition of Basic Weight, Part 2, para. 2) after weighing, must be correctly recorded in the L38, Basic Weight Change Record, and the new Basic Weight calculated. If such changes in the aircraft equipment warrant it, the aircraft shall be re-weighed and a new L36 completed.

MAINTENANCE PERSONNEL

(b) When the C of G limits are shifted to the critical ranges by a weight change, an entry shall be made in the L14 Aircraft Maintenance Record set. The aircraft will remain unserviceable until such times as the critical condition is rectified or the aircraft weighed and found to be within the C of G limits.

LOADING PERSONNEL

(c) Personnel responsible for the loading of the aircraft shall refer to this form to obtain the C of G index prior to loading of the aircraft.

BASIC WEIGHT CHECK LIST

5 The Basic Weight Check List consists of a check-off list for all fixed operating equipment items (e.g. machine guns, cameras etc.) which:

(a) Have a definite location in the aircraft.

(b) Are, or at some time will be, installed.

(c) Are an alternate installation for standard equipment, In addition, the weight of each item is given in pounds, its location, from the reference point (arm) in inches and the moment calculated.

6 Items will be listed according to their compartment location. For example A - nose B - pilot's compartment etc. Equipment within each compartment should be listed consecutively e.g. equipment in compartment "A" to be listed as A-1, A-2 A-3 etc.

7 The column "Delivery Equipment" may be used by the manufacturer/contractor to check off the items in the aircraft at the time of delivery. User units should consider the check list an inventory and X all items

presently installed in the "In Aircraft" column. Any items not installed, designated with an O in the same column.

NOTE

When an aircraft is weighed, items which have been previously tallied with an X but are temporarily removed must be listed in column 2 of the L36. (When such basic weight items are replaced after the aircraft weighing, they must not be recorded in the L38 since they have already been calculated).

Some Basic Check Lists itemize optional equipment such as wheels, skis, flotation gear, float ladders etc. When an aircraft is weighed, only that equipment which is necessary for its present configuration should be considered. It is obvious that the balance of optional check list items which are not required must not be listed in column 2 of the L36. Subsequent changes to the configuration as weighed, by substitution of the optional items, must be recorded in the L38 unless it is considered necessary to re-weigh the aircraft.

PART 4

BALANCE COMPUTER(COX & STEVENS)

GENERAL

1 The purpose of these descriptions and instructions is to provide a means for determining the basic index on an applicable load adjuster when provided with the aircraft basic weight and total moment.

DESCRIPTION

GENERAL

2 The balance computer has an appearance similar to the widely used mathematical slide rule. The balance computer, however, adds and subtracts moments. Each loading scale represents a combination of weight and moments or the effect of load (weight) placed in a given location. In agreement with all standard aeronautical drafting practices, the left end of the balance computer represents the nose of the aircraft and the right end represents the tail. Consequently, loading any items that cause the indicator hairline to move to the left tends toward a forward center of gravity position, and loading any item that causes the indicator hairline to the right tends toward an aft center of gravity position.

BASE

3 The base of the balance computer contains grooves in which the slide and the indicator move back and forth. The far (top) side of the face shows the balance ranges; the rear (bottom) side shows the index scale. On the back of the base is a plan view of the fuselage showing the compartmentation and centroids with a corresponding reference scale in inches. On the portion under the slide is a grid consisting of horizontal and sloping vertical lines with the horizontal lines representing gross weight and the sloping lines representing percent of MAC or inches from reference datum. The forward and aft sloping limits are marked in red. The loading range may be thought of as representing that short section of the aircraft in which the C of G may be located for all conditions of safe flight. Dangerous flight conditions exist if the C of G falls beyond the loading range.

CAUTION

When the C of G falls within the critical flight conditions, the applicable -8 EO for the specific aircraft must be checked, the -8 EO of the specific aircraft being the final authority for C of G limits.

SLIDE

4 The top face of the flat sliding portion of the balance computer has loading scales for use in adjusting the C of G position. They are designed to fit the requirements of specific aircraft models. The various loading scales are used to compute the effect on the C of G when such items as fuel, bombs, crew and cargo are loaded in various parts of the aircraft. The reverse side of the slide usually shows scales with the weight plotted against moment/constant. These scales are used to rapidly determine the index for a particular basic condition of weight and moment.

INDICATOR

5 The indicator is a rectangular piece of transparent plastic, with a hairline perpendicular to the scales, and is used to make the balance computer setting. The

hairline indicates a C of G position in relation to the balance limits. In all operations on the balance computer, the indicator hairline is used to line up the settings.

DEFINITIONS

6 In order to obtain a reading on the balance computer, the following definitions should be understood:-

INDEX

(a) "Index" as a term used in connection with the balance computer is a value expressing the combined effect of weight and moment.

SIMPLIFIED MOMENT

(b) "Simplified moment" is the moment (inch-pounds) divided by a constant. Its purpose is to make the numerical size of a moment smaller. The constant may be 100, 1000, 10000, etc., depending on the size of the particular aircraft. The constant to be used with the specific aircraft computer normally appears on the left hand end on the back face of the slide.

EXAMPLE

$$\text{Simplified moment} = \frac{\text{moment}}{\text{constant}} = \frac{4,500,000}{1,000} = 4,500$$

BASIC INDEX

(c) "Basic index" is that location on the balance computer index scale, expressed numerically, which represents the C of G location of the aircraft in its basic condition. Whenever any change is made to the aircraft basic condition which adds, subtracts or moves weight and thereby changes the basic C of G location, the basic index must be determined as per paragraph 7.

DETERMINATION OF BASIC INDEX BY BALANCE COMPUTER

7 The basic weight and moment/constant scales are on the back of the slide. Since the range of weight and moment/constant is so great as to require scales two, and frequently three, times the length of the slide, they have been divided into sections. No complications are involved, however, in finding basic index when basic weight is located on one section of the compound scale and moment/constant on another.

BASIC INDEX DETERMINATION SETTINGS

8 The operations involved in determining the basic index by use of balance computer settings are as follows:-

METHOD 1

(a) Move indicator until hairline is over the arrow at zero index.

(b) Move slide until the basic weight is under hairline.

(c) Move indicator until hairline is over basic weight moment/constant. If this is not possible, proceed to determine basic index as per Method 2.

(d) Read basic index at intersection of hairline with index scale.

METHOD 2

(e) Move indicator until hairline is over the arrow at zero index.

(f) Move the slide until the basic weight is under the hairline.

(g) Move indicator to the right until hairline is over the final moment/constant figure at right hand end of the same scale on which the basic weight occurs.

(h) Move slide to the right until the mark for the same moment/constant that resulted from procedure (g) is under hairline on next scale below.

(j) Move indicator until hairline is over actual basic moment/constant.

(k) Read basic index at intersection of hairline with index scale.