EO 05-1-3/4

ROYAL CANADIAN AIR FORCE

HEAT TREATMENT

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LIST OF RCAF REVISIONS

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HEAT TREATMENT

GENERAL

1 Heat treatment is a series of operations, involving the heating and cooling of a metal or alloy in the solid state, for the purpose of obtaining certain desirable characteristics. The rate of heating and cooling determines the crystalline structure of the material. Almost all metals have a critical temperature at which the grain structure changes. Successful heat treatment depends largely on a knowledge of these temperatures as well as the time required to produce the desired change.

2 Heat treatment involves a cycle of events which may be described as follows:-

(a) Heating: Heating a metal to a temperature within or above its critical temperature under carefully controlled conditions.

(b) Soaking or Holding: Keeping a metal at an elevated temperature for a definite time, in order that it may become thoroughly saturated with heat and permit the necessary changes in grain structure to take place.

(c) Cooling: Returning a metal to room temperature by quenching in brine, water, oil or air, or by cooling slowly at controlled rates as in a furnace.

HEAT TREATMENT OF STEEL

GENERAL

3 The most common forms of heat treatment for ferrous metals are hardening, tempering, annealing, normalizing and case hardening. These are described in the following paragraphs.

HARDENING

4 Heat treatment considerably transforms the grain structure of steel and it is while passing through a critical temperature range that steel acquires hardening power. In order to obtain a condition of maximum hardness, it is necessary to raise the temperature of the steel sufficiently high to allow the change of state to complete itself. This temperature is known as the upper critical point. Steel that has been heated to its upper critical point will harden completely if rapidly quenched but in practice it is necessary to exceed this temperature by approximately 50° to 100°F to ensure thorough heating of the inside of the piece. If the upper critical temperature is exceeded too much, an unsatisfactory grain size will be developed in the hardened steel.

5 Successful hardening of steel will largely depend upon the following factors:-

(a) Control over the rate of heating, specifically to prevent cracking of thick and irregular sections.

(b) Thorough and uniform heating through of sections to the correct hardening temperature.

(c) Control of furnace atmosphere, in the case of certain steel parts, to prevent scaling and decarburization.

(d) Correct heat capacity, viscosity of quenching media to harden adequately and to avoid cracks.

TEMPERING

6 Steel that has been hardened by rapid cooling from a point slightly above its critical range is often harder than necessary and is generally too brittle for most purposes. In addition, it is under severe internal strain. In order to relieve the strains and reduce the brittleness, the metal is usually tempered. This is accomplished in the same types of furnaces as are used for hardening and annealing. However, less refined methods are sometimes used for tempering small tools.

7 As in hardening, tempering temperatures may be approximately determined by colour. These colours appear only on the surface and are due to a thin film of oxide which forms on the metal after the temperature reaches 450°F. In order to see the tempering colours, the surface must be brightened by buffing. When tempering by the colour method, an open flame or heated iron plate is ordinarily used as the heating medium. Although the colour method is convenient it should not be used unless adequate facilities for determining temperature are unobtainable. Tempering temperatures and corresponding oxide colours are shown in Figure 1.

ANNEALING AND NORMALIZING

GENERAL

8 When steel is heated to a point above its critical range, a condition referred to as austenite is produced. If slowly cooled from above its critical temperature, the austenite is broken down and a succession of other conditions are produced, each being normal for a particular range of temperatures. Starting with austenite, these successive conditions are martensite, troostite, sorbite and finally pearlite.

ANNEALING

9 The most important step in annealing is to raise the temperature of the metal to the critical point, as any hardness that may have existed will then be completely removed. Strains which may have been set up through heat treatment will be eliminated when the steel is heated to the critical point and then restored to its lowest hardness by slow cooling. In annealing, the steel must never be heated more than approximately 50° to 75°F above the critical point, and when large articles are annealed, sufficient time must be allowed for the heat to penetrate the metal.

10 Steel is usually subjected to the annealing process for the following purposes:

(a) To increase its ductility by reducing hardness and brittleness.

(b) To refine the crystalline structure and remove stresses. Steel which has been cold worked is usually annealed to increase its ductility. However, a large amount of cold-drawn wire is used in its cold-worked state when very high yield point and tensile strength are desired and relatively low ductility is permissible, as in spring wires, piano wires, wires for ropes and cables. Heating to low temperatures, as in soldering, will destroy these properties unless done quickly.

11 Assuming that the part to be annealed is heated to the proper temperature, the required slow cooling may be accomplished in several ways, depending on the metal and the degree of softness required. The common methods are packing and furnace cooling. Packing requires that the part be buried in some substance that does not conduct heat readily. For this purpose, a metal box containing slaked lime, ashes or powdered charcoal (Item 2) is satisfactory. Care must be taken to keep the material perfectly dry. In furnace cooling, the part is merely left to cool down with the furnace.

NORMALIZING

12 Normalizing, although involving a slightly different heat treatment, may be classed as a form of annealing. This process removes all strains due to machining, forging, bending and welding. Normalizing can only be accomplished with a furnace where the temperatures and the atmosphere may be closely regulated and held constant throughout the entire operation. A reducing atmosphere will normalize the metal with a minimum amount of oxide scale, while an oxidizing atmosphere will leave the metal heavily coated with scale, thus preventing proper development of hardness in any subsequent hardening operation. The articles are placed in the furnace and heated to a point above the critical temperature of the steel. After the parts have been held at this temperature for a sufficient time to allow the heat to penetrate to the centre of the section, they must be removed from the furnace and cooled in still air. Draughts will result in uneven cooling, which will again set up strains in the metal. Prolonged soaking of the metal at high temperatures must be avoided as this practice will cause the grain structure to enlarge. The length of time required for the soaking temperature will depend upon the mass of metal being treated.

13 The heat and temper colours of steel are shown in Figure 1. Figure 2 lists the critical temperatures for hardening, annealing and normalizing, and the quenching media or cooling procedure for obtaining the tensile strength shown.

CASE HARDENING

14 In many instances it is desirable to produce a hard, wear-resistant surface or case over a strong, tough core. This is known as case hardening and may be accomplished in several ways, the principal ways being carburizing, cyaniding and nitriding.

CARBURIZING

15 By heating steel while in contact with a carbonaceous substance, carbon released by this material will penetrate the steel to an amount proportional to the time and temperature. For example, if mild or soft steel is heated to 1350°F in an atmosphere of carbonic gases, it will absorb carbon until approximately 0.80% of carbon content has been attained at the surface, this being the saturation point of the steel for the particular temperature. By increasing the heat to 1650°F, the same steel will absorb carbon until a 1.50% carbon content has been attained. This is the normal saturation point for the increased temperature. The lower the carbon content in the steel or alloy, the more readily it will combine with carbon during the carburizing process. Solid liquid and gas carburizing methods are employed.

16 The simplest method of carburizing consists of soaking the parts at an elevated temperature while in contact with solid carbonaceous material such as wood charcoal (Item 3), bone charcoal and charred leather.

17 Liquid carburizing consists of immersing the parts in a liquid salt bath, heated to the proper temperature, to which amorphous carbon has been added. The carbon penetrates the pores of the steel as in the solid method, producing the desired case hardening.

18 Gas carburizing consists of heating the parts in a retort and subjecting them to a carbonaceous gas such as carbon monoxide (Item 4) or the common fuel gases. This process is particularly adaptable to certain engine parts.

(1) Normalizing describes a metallurgical process and not a set of mechanical properties.

(2) Draw at 1150° F for tensile strength of 70,000 psi.

(3) Tempering temperature:- The temperature to be used for the tempering of steel depends upon the chemical composition, the as-quenched hardness, the prior process and the method of tempering. The exact temperature should be determined by hardness or tensile tests of individual pieces. The tempering temperatures given are based on the tempering of 1 inch round specimens. For parts with greater or smaller cross-sectional areas, the tempering temperature should be adjusted accordingly.

(4) In general, for spring temper, draw at 700° to 800° F Rockwell hardness C40-45.

(5) Bars or forgings may be quenched in water from 1500° to 1600° F.

(6) The following optional annealing treatment for 52100 steel may be used:

Heat to 1430° F, hold for 20 minutes, and cool at controlled rates as follows:

1430° to 1370° F at a rate not to exceed 20° F per hour.
1370° to 1320° F at a rate not to exceed 10° F per hour.
1320° to 1250° F at a rate not to exceed 20° F per hour.

(7) Draw at 350° to 450°F to remove quenching strains. Rockwell hardness C60-65.

(8) In general, for spring temper draw at 725° to 900° F. Rockwell hardness C43-47.

(9) Thin gauge material or parts may be air-cooled if the corrosion resistance is not decreased thereby.

(10) Hardened by cold work only.

(11) When annealing or solution heat treatment is specified, heat type 321 at 1700° to 1950° F and heat type 347 at 1800° to 2050° F to produce maximum softness, corrosion-resistance, and stabilization. Thin sections may be air-cooled while other sections should be water-quenched.

(12) When stress relieving is specified, heat at 1600° to 1700° F for minimum of 1/2 hour to remove residual stresses due to welding or cold work and to stabilize material.

(13) Lower side of range for sheet 0.06 inch and under. Middle of range for sheet and wire up to 0.125 inch. Upper side of range for forgings.

(14) Not recommended for intermediate tensile strengths because of low impact.

(15) 16 Cr-2Ni corrosion-resisting steel shall not be tempered between 700° and 1100° F. To obtain a tensile strength in the range of 115,000 to 145,000 psi, the steel shall be oil-quenched from a temperature of 1800° to 1850° F after a soaking period of 1/2 hour at temperature and shall be tempered at not less than 1100° F. To obtain a tensile strength in the range of 175,000 to 200,000 psi, the steel shall be oil-quenched from a temperature of 1850° to 1900° F after a soaking period of 1/2 hour at the specified temperature and shall be tempered at not more than 700° F. This material does not respond to full annealing by slow cooling from above the critical temperature. To obtain maximum softening, the material should be process-annealed from 4 to 8 hours at 1150° to 1225° F and cooled in air or oil.

(16) Draw at approximately 800° F and cool in air for Rockwell hardness of C50.

Figure 2 (Sheet 1 of 3) Heat Treatment Procedure

SAE or AISI No. Carbon and Low Alloy Steels	Temperatures, °F, and Cooling Requirements					Recommended Sub-Critical Anneal °F	Approximate Tempering Temperature, °F, for Tensile Strength, psi,					Minimum Tempering Temperature °F
		Annealing		Hardening Cycle								
	Normalizing Air Cool (1)	Heating	Furnace Cool Below Approx. Temp. Shown	Heat to	Quench in		100000	125000	150000	180000	200000	
1025	1600-1700	1575-1650	900	1575-1650	Water	1250	(2)					700
1035	1600-1700	1575-1625	900	1525-1600	Water	1250	900					700
1045	1600-1700	1550-1600	900	1500-1575	(Oil	1250	1100					700
1095	1500-1600	1450-1525	900	1450-1525	(or	1250	(4)		1050	850	750	
2330	1600-1700	1425-1500	800	1450-1500	(water	1200	1150	950	800	750		700
3140	1600-1700	1450-1525	900	1475-1525	(Oil	1250	1250	1100	1000	025	700	700
4037	1600-1700	1525-1575	900	1525-1575	Oil or Water(5)	1200	1200	1100	925			700
4130	1600-1700	1550-1600	900	1550-1625	Oil or Water(5)	1250	1250	1100	925	800		700
4135	1600-1700	1525-1575	900	1550-1625	Oil	1250		1100	1050	850	750	700
4140	1600-1700	1525-1575	900	1525-1600	Oil	1250	1300	1200	1100	900	800	700
4150	1575-1650	1500-1550	900	1500-1575	Oil	1250		1200	1100	900	850	700
4340	1600-1700	1525-1575	600	1475-1550	Oil	1250		1150	1050	900	800	700
4640	1600-1700	1525-1575	750	1500-1550	Oil	1200	1200	1100	1000	900	750	700
52100	1600-1700	1400-1450	700(6)	1500-1550	Oil	1200	(7)					
6150	1600-1700	1525-1575	900	1550-1625	Oil	1250	(8)	1200	1000	900	800	700
6195	1600-1700	1500-1550	700	1525-1575	Oil	1200	(7)					
8630	1600-1700	1525-1575	900	1550-1625	Oil or Water(5)	1250	1200	1075	1000	750		700
8735	1600-1700	1525-1575	900	1525-1600	Oil	1250		1025	925	750	700	700
8740	1600-1700	1500-1575	900	1525-1600	Oil	1250		1100	1000	800	750	700

See Notes in Sheet 1 of 3

Figure 2 (Sheet 2 of 3) Heat Treatment Procedure

SAE or AISI No. Corrosion Resistant Steels	Temperatures, °F, and Cooling Requirements					Recommended Sub-Critical Anneal °F	Approximate Tempering Temperature, °F, for Tensile Strength, psi, (3)					Minimum Tempering Temperature °F
	Normalizing Air Cool (1)	Annealing		Hardening Cycle								
		Heating	Cooling Media	Heat to	Quench in		100000	125000	150000	180000	200000	
302		1900-2100	Water(9)	(10)								
303		1900-2100	Water(9)	(10)								
304		1900-2100	Water(9)	(10)								
308		1900-2100	Water(9)	(10)								
309		1900-2100	Water(9)	(10)								
310		2000-2150	Water(9)	(10)								
316		1900-2100	Water(9)	(10)								
321		1700-1950	(11) and (12)	(10)								
347		1800-2050	(11) and (12)	(10)								
410	1525-1575	1500-1600	Furnace cool	1750-1850 (13)	Oil	1450	1400	1050	(14)	800	750	
416	1525-1575	1400-1500	Air cool	1750-1850 (13)	Oil	1450	1250	1050	(14)	750		
420		1550-1650	Furnace cool	1800-1900	Air or Oil	1450	1425	1125	1050	1000	075	
15/431 Si-Cr				1850-1950	Oil	1225			(14)			(15)
For Springs				1700-1725	Oil		(see note (16))					

Figure 2 (Sheet 3 of 3) Heat Treatment Procedure

19 When pack carburizing, the parts are packed with the carburizing material in a sealed steel container to prevent the solid carburizing compound from burning and to retain the carbon monoxide and dioxide gases. Nichrome boxes, capped pipes of mild steel or welded mild steel boxes may be used. The container should be so placed as to allow the heat to circulate entirely around it. The furnace must be brought to the carburizing temperature as quickly as possible and held at this heat from 1 to 16 hours, depending upon the depth of case desired and the size of the work. After carburizing, the container should be removed and allowed to cool in air or the parts removed from the carburizing compound and quenched in oil, or water. Air cooling, although slow, reduces warpage and is advisable in many cases.

20 Carburized steel parts are rarely used without subsequent heat treatment. This consists of several steps to obtain optimum hardness in the case, and optimum strength and ductility in the core. Grain size of the core and case is refined.

(a) Refining the core is accomplished by reheating the parts to a point just above the critical temperature of the steel. After soaking for a sufficient time to ensure uniform heating, the parts are quenched in oil (Item 1). The temperatures required are given in Figure 2.

(b) The hardening temperature for the high carbon case is well below that of the core. It is, therefore, necessary to again heat the parts to the critical temperature of the case and quench them in oil to produce the required hardness. A soaking period of 10 minutes is generally sufficient. The temperatures required for this treatment are listed in Figure 4.

(c) A final tempering operation is necessary to relieve the hardening strains produced by the previous treatments. This is accomplished by heating to the temperatures specified in Figure 4, soaking until uniformly heated, and cooling in still air. When extreme hardness is desired, the temperature should be carefully held to the lower limit of the range.

CYANIDING

21 Steel parts may be surface hardened by heating while in contact with a cyanide salt, followed by quenching. Only a thin case is obtained by this method and it is seldom used in connection with aircraft construction or repair. Cyaniding is, however, a rapid and economical method of case hardening and may be used in some instances for relatively unimportant parts. The work to be hardened is immersed in a bath of molten sodium or potassium cyanide from 30 to 60 minutes. The cyanide bath should be maintained at a temperature of 1400° to 1650°F. Immediately after removal from the bath, the parts are quenched in water. The case obtained in this manner is due principally to the formation of carbides on the surface of the steel. The use of a closed pot is required for cyaniding, as cyanide vapours are extremely poisonous.

NITRIDING

22 This method of case hardening is advantageous due to the fact that a harder case is obtained than by carburizing. Many engine parts, such as cylinder barrels and gears, may be treated in this way. Nitriding can only be applied to certain special steel alloys , one of the essential consituents of which is aluminum. The process involves the soaking of the parts in the presence of anhydrous ammonia at a temperature below the critical point of the steel. During the soaking period, the aluminum and iron combine with the nitrogen of the ammonia to produce iron nitrides in the surface of the metal. Warpage of work during nitriding can be reduced by stress relief annealing previously, and by exposure to nitrogen at temperatures no higher than 1000°F. Growth of the work is similarly prevented but cannot be entirely eliminated and some parts may require special allowance in some dimensions to take care of growth. Nitralloy is a typical nitriding steel.

23 The temperature required for nitriding is 950°F, and the soaking period is from 48 to 72 hours. An airtight container must be used and should be provided with a fan to produce good circulation and even temperature throughout. No quenching is required and the parts may be allowed to cool in air.

HEAT TREATING PROCEDURE

GENERAL

24 Equipment necessary for heat treating consists of a suitable means of bringing the metal to the required temperature, a temperature measuring device and a quenching medium. Heat may, in some instances, be supplied by means of a forge or welding torch. For the treatment required in aircraft work, a furnace is necessary.

FURNACES

25 Heat-treating furnaces are of many designs and no one size or type perfectly fills every heat treating requirement. The size and quantity of metal to be treated, and the various treatments required, determine the size and type of furnace most suitable for each individual case. The general construction of the furnaces is very similar. Furnaces may be heated by means of oil, gas or electricity.

26 A salt bath is often used for small parts that have been finish-machined and for rivets requiring heat treatment. In the salt bath, the parts are heated by submersion in molten salt, which is kept at the required temperatures by means of electrical resistors. Figure 3 is a schematic drawing of a furnace used for this purpose which is simply a large crucible surrounded by fire brick. Parts heated in the salt bath are free from scaling, although extreme care must be used to remove all traces of the salt after treatment.

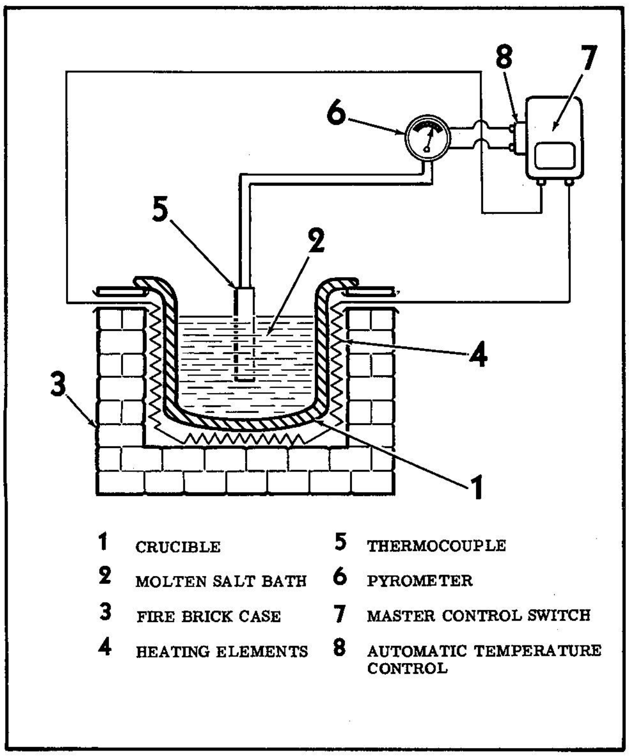


Figure 3 Salt Bath Type Furnace

27 In any heat-treating furnace, the temperature at any point in the working zone, with a normal charge, must not vary more than ±25°F from the desired temperature. However, where a tolerance is given as in Figure 2, keep the temperature within that tolerance. The furnace should be equipped with automatic controlling and recording instruments, preferably of the pyrometer type. These should be accurate within 1% of reading taken on a master calibrator.

QUENCHING

28 The tendency of steel to warp and crack during the quenching process is due to the fact that certain parts of the article cool more rapidly than others and is difficult to overcome. Whenever the change in temperature is not uniform, internal strains are set up in the metal which result in warpage or cracking, depending on the severity of the strains.

QUENCHING TANKS

29 Quenching tanks must meet the following requirements:

(a) Locate oil and water quenching tanks so that the time involved in transferring material from the furnace or salt bath to the tanks is kept to a minimum.

(b) Tanks must be deep enough to permit vertical quenching of long parts which distort excessively if quenched in any other position.

(c) Tanks must be equipped with agitators to ensure thorough circulation of oil or water. Compressed air agitation is prohibited.

(d) The temperature of the quenching oil (Item 1) must be maintained within the range of 65° to 140°F at the beginning of the quenching operation. The volume of oil in the tank must be such that, after quenching is completed, the temperature of the oil does not exceed 190°F.

(e) The temperature of the quenching water must not be higher than 100°F at the beginning of the quenching operation and must not exceed 190°F at the end of the quenching operation.

WARPAGE

30 To reduce warpage after heat treatment, observe the following precautions:

(a) Never throw the part into the bath. By permitting it to lie on the bottom of the bath it is apt to cool faster on the top side than on the bottom side, thus causing it to warp or crack.

(b) Agitate the part slightly in the bath to destroy the coating of vapour which prevents it from cooling rapidly.

(c) Quench the part in such a manner that all parts will be cooled uniformly and with the least possible distortion. For example, a gear wheel or shaft should be quenched in a vertical position.

(d) Immerse irregularly shaped sections so that the largest parts of the section enter the bath first.

STRAIGHTENING OF PARTS WARPED IN QUENCHING

31 Warped parts must be straightened by heating first, and then by applying pressure. This pressure should be gradual and must continue until the piece is cooled. If the article is not too large in cross section, it may be placed between the centres of a lathe, then heated by some means until lard oil, applied to the surface, begins to smoke. At this point, pressure should be applied to the convex side by means of a tool shank held in the tool post. The pressure should be sufficient to spring the part slightly in the opposite direction from that in which it is bent. Local heating must be avoided. The best method is furnace heating, at 675° (±25°) F. Straightening should be confined to parts for which heat-treatment does not exceed the 180,000 to 200,000 psi range.

CARBURIZING PROCEDURE

32 Use externally heated baths or pots of an approved type. For liquid carburizing by the perlitonizing method, Perliton 60 (Item 5) is an approved salt and must be used as follows:

(a) Make up the bath or pot initially using Perliton 60 and add this salt as required, to maintain the working level.

(b) When the freshly made up bath becomes molten, add sufficient Perliton carbon (Item 6) to form a complete crust on the top of the salt.

Steel Type	Carburizing		Hardening		Tempering
	Soaking Temp. °F	Quench	Soaking Temp. °F	Quench	Soaking Temp. °F
SAE. 1015	1650	Oil (See Note 1)	1450	Oil or Water (See Note 3)	375
SAE. 1020	1650	Oil (See Note 1)	1450	Oil or Water (See Note 3)	375
SAE. 1025	1650	Oil (See Note 1)	1450	Oil or Water (See Note 3)	375
SAE. 4615	1650	Oil (See Note 1)	1500	Oil	350
SAE. 4620	1650	Oil (See Note 1)	1500	Oil	350
SAE. 4815	1650	Cool In Medium (See Note 2)	1475	Oil	350
SAE. 4820	1650	Cool In Medium (See Note 2)	1475	Oil	350
NE. 8620	1650	Oil (See Note 1)	1525	Oil	350

(1) Oil quench from carburizing. Cooling in the box or pack may be used when pack (solid) carburizing.

(2) Cool in the carburizing medium (in the furnace with carburizing atmosphere, in the salt bath or in the pack) from carburizing.

(3) Where oil or water quenching is specified, use water quenching only when oil quenching will not produce the desired properties, and then only on parts not readily subject to distortion and cracking.

Figure 4 Carburizing and Subsequent Heat Treating Operations

(c) When the bath is at operating temperature, the surface of the salt must not become exposed. If bare patches appear, add more carbon (Item 6) to maintain the coverage.

(d) For solid carburization in furnaces, Perlite S (Item 9) is an approved medium. Metal boxes are required to contain the pack.

PREPARATION OF MATERIAL FOR CARBURIZING

33 All material must be reasonably clean and free from grease, oil, paint and scale prior to carburizing. Where necessary, clean in accordance with instructions in EO 05-1-3/20 and include pickling or light grit-blasting as a final operation. Material which is to be carburized or otherwise heat treated in a salt bath must be dried thoroughly as moisture will cause dangerous spattering of the salt.

LOADING OF MATERIAL

34 Material must be so located that all surfaces to be carburized are in direct contact with the carburizing medium. Surfaces must not come into contact with each other, with the sides of the furnace of bath, or with any other interferences.

CARBURIZING SEQUENCE

35 Use the sequence of operations for the complete heat treatment cycle as shown in Figure 4. For soaking time, see Figure 5. In cases where the required minimum case depth, as determined on a test piece, is not obtained on the first carburizing cycle, repeat the cycle. Areas which are not to be carburized must be copper plated to a thickness of 0.003 inch minimum prior to carburizing. After carburizing strip the copper plating by immersing a solution of 4.8 pounds of chromic acid (Item 7) and 8.4 ounces of sulphuric acid (Item 8) per Imperial gallon of water at room temperature, for a time sufficient to remove the plating.

HARDENING AND TEMPERING AFTER CARBURIZING

36 Harden after carburizing by one of the following methods:

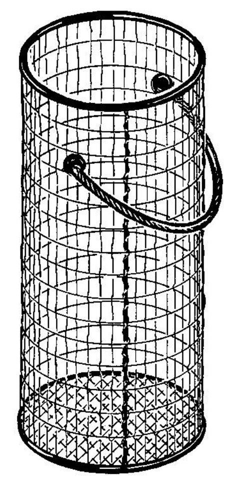
(a) In a furnace with neutral atmosphere.

(b) In a salt bath with neutral hardening salt.

Required Depth Of Case (+25% - 10%)	Approximate Soaking Time	
	Liquid Carburizing Medium (Hrs)	Solid Carburizing Medium (Hrs)
0.005	1-1/4	5/6
0.010	2	1-1/3
0.015	3	2
0.020	4-1/2	3
0.025	6-1/4	4
0.030	8	5-1/4
0.035	10-1/2	6-3/4
0.040	14	8-3/4

Soaking time is defined as starting when the furnace or salt bath, after insertion of a load, reaches the required soaking temperature. Soaking time finishes when the load is removed from the furnace or salt bath, or in the case of cooling in the heating medium, when this cooling is started.

Figure 5 Carburizing Soaking Times



NOTES:

1. FABRICATE CONTAINER FROM STAINLESS STEEL WIRE MESH, OR MILD STEEL WIRE MESH METALLIZED WITH STAINLESS STEEL.
2. MAKE MESH AS LARGE AS POSSIBLE WITHOUT ALLOWING RIVETS TO PASS THROUGH.
3. WELD ALL SEAMS.
4. SIZE: 3-1/2 IN. DIAMETER
5. LENGTH: OPTIONAL.

Figure 6 Air Furnace Rivet Container

(c) In a furnace used for gas carburizing with the same atmosphere conditions as employed for carburizing.

(d) In all cases, material must be quenched or cooled from carburizing as shown in Figure 4 before subsequent hardening.

REMOVAL OF SALT AFTER CARBURIZING OR HEAT TREATMENT

37 Where any adhering salt remains on material which has been carburized, hardened or tempered in salt baths, remove the salt by rinsing and scrubbing in water immediately after quenching or cooling from the heat treating operation.

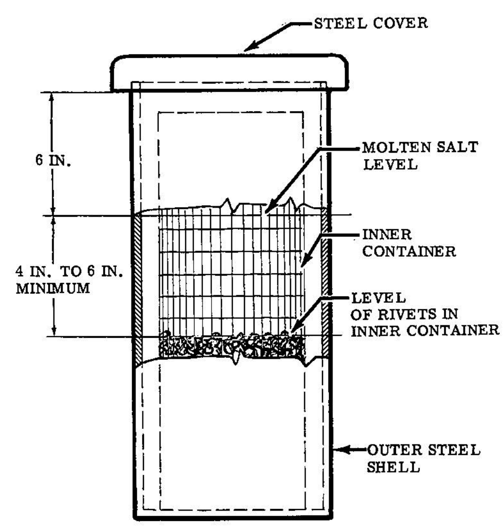
HEAT TREATMENT OF ALUMINUM ALLOY

GENERAL

38 For information on the heat treatment, forming and machining of aluminum and its alloys refer to EO 105-10-1.

HEAT TREATMENT OF RIVETS

39 Rivets requiring heat treatment are usually heated in small screen wire baskets, (see Figure 6), which allow free and rapid circulation of water during the quenching process. The time required for the rivets to reach the proper temperature will depend upon the relationship between the volume of the charge and the heating medium.



NOTES:

1 COMPLETE CONTAINER CONSISTS OF INNER CONTAINER FITTING IN OUTER SHELL.

2 INNER CONTAINER SAME AS AIR FURNACE CONTAINER.

3 FABRICATE OUTER SHELL FROM STEEL TUBE WITH WELDED STEEL BASE AND HINGED STEEL COVER.

4 SIZE OF OUTER SHELL: 4-1/2 IN. DIAMETER.

5 LENGTH OF OUTER SHELL: TO SUIT INNER CONTAINER.

Figure 7 Salt Bath Rivet Container

40 When heat treating in salt baths, the quality of rivets in the inner containers must be such that, when lowered into the outer shell in the salt bath, the top layer of rivets is at least four to six inches below the level of the salt, see Figure 7. The covers of the outer shells must be in place during heat treatment.

41 Anodized rivets may be heat treated in air furnaces or salt baths. In the latter case, the rivets must not be allowed in direct contact with the molten salt.

SOLUTION HEAT TREATMENT

42 The heat treatment consists of holding the rivets at the proper temperature for from 5 to 60 minutes, depending on the size and number of rivets, and the heating method used. Immediately following this treatment, the rivets are to be quenched in cold water. The start of the soaking time is defined as the time at which, after insertion of a load, the furnace or salt bath reaches the specified soaking temperature required by the alloy. Solution heat treating temperatures for the following units are:

17S - 925° - 950°F
24S - 910° - 930°F

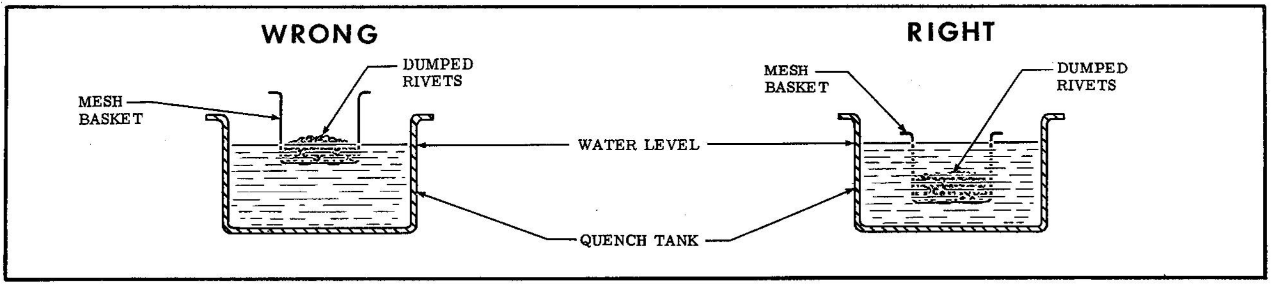


Figure 8 Location of Basket in Quench Tank

QUENCHING

43 When quenching rivets after solution heat treatment, place a large wire mesh basket in an almost totally immersed position in the cold water of the quench tank, as shown in Figure 8, and dump the rivets from their containers into the basket. After quenching, dry rivets in warm air (not exceeding 150°F) or in alcohol, followed as soon as possible by anodizing.

44 Rivets removed from the cold water and held at room temperature should be driven within one hour after quenching, but may be held for much longer periods without hardening if stored under refrigeration. Rivets will harden completely at room temperature in about 24 hours due to the effects of aging. Rivets driven in the fully hardened or partially hardened condition show a much greater tendency to crack than those driven within one hour after quenching. Rivets made from 17S alloy may be driven without heat treatment, however if cracking occurs during rivetting they must be heat treated. Rivets made from 24S alloy must be heat treated before use, whereas, 2S, A17S-T, 53S, 53S-W and 53S-T rivets may be driven in the condition in which they are received.

HARDNESS TESTING

GENERAL

45 Hardness testing is important in the determination of the results of heat treatment as well as the condition of the metal before heat treatment. The Tables in EO 05-1-3/25, represent a close approximation of the relation between the tensile strength and hardness of wrought carbon and low alloy steels only. These figures are for inspection of these materials but should not be used for other metals except in a very general manner. The methods of hardness testing in general use are: Brinell, Rockwell, Vickers (British), and Shore Scleroscope. The hardness values obtained from Alclad sheet cannot be converted into tensile strength due to the coating on the alloy, but this coating may be removed from areas to be tested in order that the hardness and corresponding strength of the base material can be determined.

BRINELL HARDNESS TEST

46 This test consists of pressing a hardened steel ball into a flat surface of the metal being tested by the application of a known pressure. The impression made by the ball is measured by means of a microscope with a micrometer eyepiece, and the Brinell number is obtained by dividing the load in kilograms by the area of the spherical impression made by the ball, measured in square millimeters. The thickness of all samples used for testing must be sufficient to prevent bulging on the underside. The Brinell tester, see Figure 9, consists of the following major parts:

(a) An elevating screw and anvil for bringing the sample into contact with the ball.

(b) A manually-operated hydraulic pump for applying pressure to the hardened steel ball which is mounted on its actuating member.

(c) A pressure gauge for determining the applied pressure.

(d) A release mechanism to relieve the hydraulic pressure after the test has been made.

(e) A microscope with micrometer eyepiece for calculating the area of the impression.

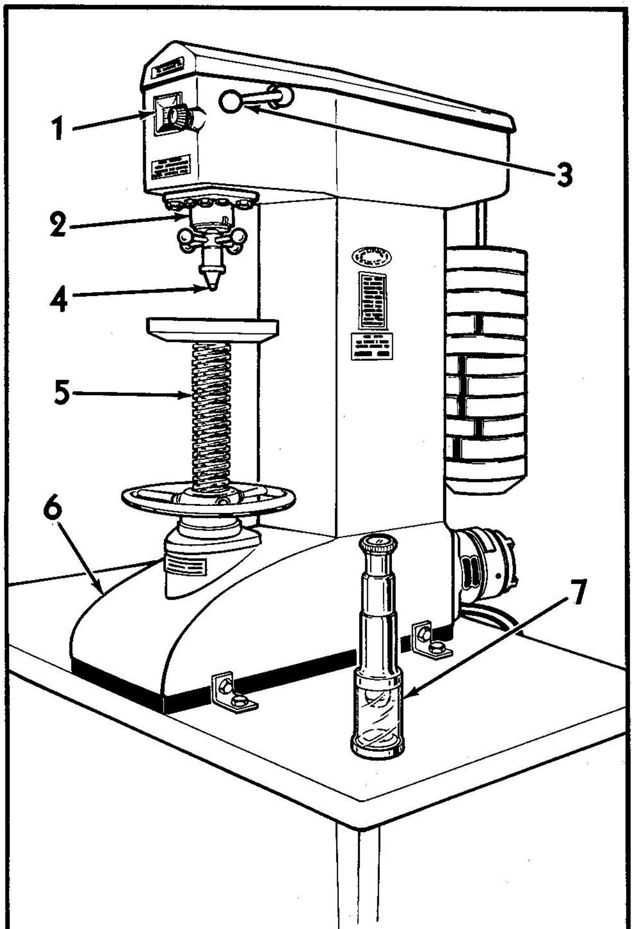


Figure 9 Brinnel Hardness Tester

47 The test is performed as follows:-

(a) Prepare the sample by filing, grinding and polishing to remove all scratches and variations that may affect the reading.

(b) Place the sample on the anvil of the machine and elevate until the hardened ball contacts the surface to be tested.

(c) Apply the load by pumping the handle.

(1) A load of 3000 kilograms is required for steel, while 500 kilograms is used when testing softer metals, such as aluminum alloy, brass and bronze.

(2) Normally, the load should be applied for 30 seconds, although this period may be increased to 1 minute for extremely hard steels, in order to produce equilibrium.

(d) Release the pressure and measure area of impression with calibrated microscope.

(e) Calculate the Brinnel number, completing the test.

$$\text{Brinnel No.} = \frac{\text{Load on indenting tool (kg.)}}{\text{Area of impression (mm}^2\text{)}}$$

(f) After obtaining a Brinnel number for a metal, its corresponding tensile strength may be determined by referring to EO 05-1-3/25.

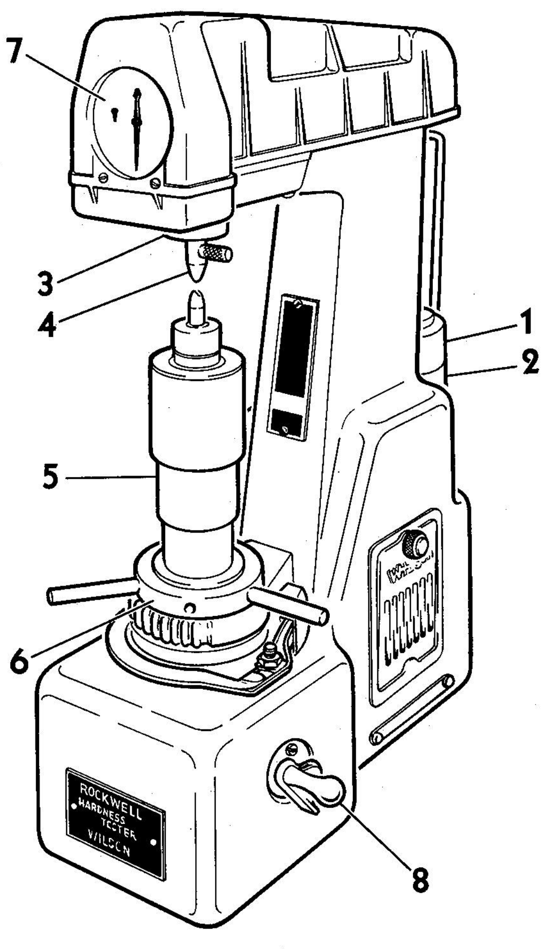
(g) Reference may also be made to EO 05-1-3/25 to identify the metal and determine its heat treatment.

ROCKWELL HARDNESS TEST

48 The Rockwell hardness tester, see Figure 10, consists of a base or stand, elevating screw, anvil, penetrator, a device for applying the load and a dial indicator. The test consists of the measurement of the difference between a minor and major load applied to a

diamond penetrator or hardened steel ball. In all tests, a minor load of 10 kilograms is first applied, in order to seat the penetrator in the surface of the specimen. The actual penetration is then produced by applying a major load. When using the diamond cone penetrator, this major load is 150 kilograms but when a 1/16 inch steel ball is used, the load is reduced to 100 kilograms. An indication of the application of the major load may be observed by watching the dial indicator. After the pointer comes to rest, this major load is released, leaving the minor load still applied.

49 As Rockwell hardness numbers are based on the difference between the depths of penetration at major and minor load, it will be evident that the greater this difference, the less the hardness number and the softer the material. This difference is automatically registered when the major load is released by a reversed scale on the indicator dial, which thus reads directly the Rockwell hardness number.



1 MAJOR LOAD
2 WEIGHT PAN
3 PLUNGER ROD
4 PENETRATOR
5 ELEVATING SCREW
6 HAND WHEEL
7 INDICATING GAUGE DIAL
8 CRANK HANDLE

Figure 10 Rockwell Hardness Tester

50 There are two types of Rockwell hardness testers, the standard and the superficial The standard tester has a load range from 60 to 150 kilograms and is used for general testing of aircraft materials and parts, finished or unfinished. The superficial tester has a load range of 15 to 45 kilograms and is used mostly for surface hardened and thin materials.

ROCKWELL HARDNESS SCALES

51 The various Rockwell scales and their applications are shown in Figure 11. The type of penetrator and load used with each will depend on the type of material being tested.

52 The dial indicator on the tester is provided with two scales; the black or C scale and the red or B scale. The C scale is used when testing with the diamond cone and 150 kilogram load, while the B scale is used in connection with the steel ball penetrator and 100 kilogram load. Readings, when recorded, must be prefixed by the letter B or C to show which scale has been used. When the readings fall below the table value, C-20 (B-98), (refer to EO 05-1-3/25, the material is considered too soft for the diamond cone and a 1/16 inch hardened ball should be used. The diamond cone must be used for all hard materials (those above 100 on the B scale), as the steel ball may be deformed by the test.

53 Several anvils are included as regular equipment with each machine, and their selection depends upon the shape of the sections to be tested.

54 The procedure for making the Rockwell

test is as follows:-

(a) Prepare the sample as described for the Brinnel test. The surface finish must be proportional to the load used. For the higher load, the surface should be polished with No. 1 abrasive paper. The lower load requires a very smooth finish. Use No. 00 abrasive paper.

(b) Select the proper penetrator and place the corresponding weight on the weight pan.

(c) Place sample on the anvil and, by turning hand wheel, raise slowly until contact is made with the penetrator. Continue turning until the pointer of the indicator has made three revolutions and is within five divisions (plus or minus) of the upright position. This applies to the 10 kilograms or minor load on the sample.

(d) Apply the major load by means of the handle shown in Figure 10.

(e) Release the major load by returning the handle to its original position, and read the hardness number directly on the indicator scale.

Scale	Testing Application
A	For tungsten carbide and other extremely hard materials. Also for thin, hard sheets.
B	For materials of medium hardness, such as low and medium carbon steels in the annealed condition or aluminum.
C	For materials harder than Rockwell B-100.
D	Where somewhat lighter load is desired than on C scale, as on case hardened pieces.
E	For very soft materials such as bearing materials.
F	Same as E scale but using 1/16-inch ball.
G	For metals harder than tested on B scale.
H & K	For softer metals.
15-N, 30-N, 45-N	Where shallow impression or small area is desired. For hardened steel and hard alloys.
15-T, 30-T, 45-T	Where shallow impression or small area is desired for materials softer than hardened steel.

Figure 11 Rockwell Scales

(f) The tensile strength corresponding to the hardness number, identification of material and condition of temper may be determined by reference to tables in EO 05-1-3/25.

VICKERS DIAMOND PYRAMID TESTER

55 The Vickers hardness tester is similar to the Brinnel machine, using a diamond shaped point. The diagonal of the impression is measured and calculation made to obtain the hardness number.

SHORE SCLEROSCOPE HARDNESS TEST

56 Testing hardness with the scleroscope consists of dropping a diamond-tipped hammer upon the test specimen from a definite height and measuring the rebound produced. In one type of tester, the height of the rebound must be measured directly on the scale of the machine, while on another the amount is indicated on a dial.

57 The tester, see Figure 12 consists of the following major parts:

(a) A base, provided with levelling screws and a clamping arrangement to hold the sample to be tested.

(b) A vertical glass tube mounted on the base and containing the cylindrical diamond-point hammer.

(c) A suction head and bulb for lifting and releasing the hammer.

(d) A scale, visible through the glass tube, for determining the height of the rebound.

(e) A magnifier hammer with a larger contact area is supplied for use with extremely soft metals.

58 The test is made as follows:-

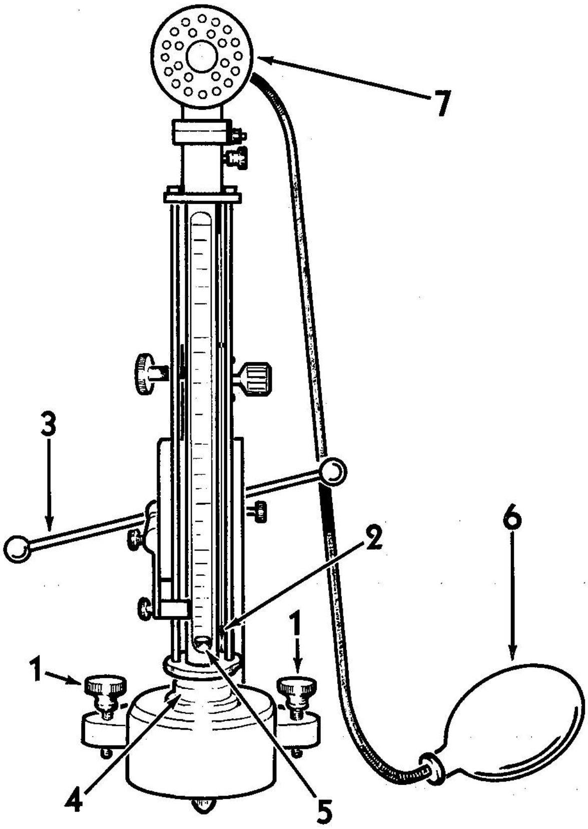


Figure 12 Shore Scleroscope

(a) Level the instrument by means of the adjusting screws. The level position is determined by means of the plumb rod shown at (2), see Figure 12.

(b) Prepare test specimen as described for the Brinnel and Rockwell tests and clamp it on the base. This is done by raising lever (3), inserting the sample, and exerting pressure on the clamping shoe (4).

(c) Raise the hammer (5) by squeezing and releasing the bulb (6).

(d) Release the hammer by again squeezing the bulb and observe its rebound.

(e) Several tests should be made at different points of a specimen, and an average reading taken to reduce visual error.

(f) The results obtained from the test may then be checked against the values given in EO 05-1-3/25.

SHORE DUROMETER TEST

59 For the shore durometer test, refer to EO 05-1-3/25.

MATERIAL SPECIFICATIONS

60 For table showing item numbers, materials, specifications and manufacturers, see Figure 13.

Item No	Material	RCAF Ref	Specification	Manufacturer
1	Oil, General Purpose, Low temperature, Anti-corrosive	34A/124	3-GP-335	
2	Charcoal, Powdered			Commercial Grade
3	Charcoal, Wood			Commercial Grade
4	Carbon Monoxide, for Gas Carbonizing			Commercial Grade
5	Salt, Perliton 60			E F Houghton & Co of Canada 100 Symes Rd. Toronto 9
6	Carbon, Perliton			E F Houghton & Co of Canada 100 Symes Rd. Toronto 9
7	Acid, Chromic	33C/494	O-C-303	
8	Acid, Sulphuric	33C/4	15-GP-8	
9	Perlite S			E F Houghton & Co of Canada 100 Symes Rd. Toronto 9

Figure 13 Table of Material Specifications