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ROYAL CANADIAN AIR FORCE

MAINTENANCE REPAIR HANDBOOK

TRANSPARENT PLASTIC

(This EO replaces Interim Pubs TO 01-1A-12, TM 208, AFRI R15/1, AFRI R15/4, AFRI R4/10, AFRI R1/36/3, AFRI M1/36/4)

ISSUED ON AUTHORITY OF THE CHIEF OF THE AIR STAFF

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PART 1

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INTRODUCTION

GENERAL

1 The success of many aircraft operations depends on the aircraft maintenance and skilful repair of transparent plastic panels. It is for this reason that a Maintenance and Repair Handbook has been published to assist personnel to achieve and maintain a high degree of serviceability in the field.

2 Many small firms are equipped to produce plastic parts (eg, extruded tubing) and these firms purchase bulk material from one of the larger chemical manufacturers. However, plasticizers or other reagents are often added and consequently the properties of the resultant plastic may differ from those of the original types. For application, such as flexible tubing, each specific formulation must be tested.

3 There are three types of transparent plastic commonly applied in windows, canopies, nose pieces, gun turrets and similar transparent enclosures of military aircraft. These materials are known as acrylic plastics (also known as acrylate or methacrylate base plastics), laminated acrylic plastic, and cellulose acetate base plastics. The acrylic plastics are manufactured under the trade name of:

Lucite - E.I. duPont de Memours Co. Inc.

Plexiglas - Rohm & Haas Co.

Perspex - Imperial Chemicals Ltd. (England).

4 Laminated acrylic plastics are made from acrylic plastic bounded by a vinyl resin interlayer but are not characterized by specific trade names. Cellulose acetate base plastics are manufactured under the commercial trade names of:

Fibestos - Monsanto Chemical Co.

Lumarith - Celanese Celluloid Corp.

Plastacele - E.I. duPont de Memours & Co. Inc.

Nixonite - St Nixon Nitration Works, Nixon, New Jersey.

5 This Engineering Order describes the handling and fabrication of such materials for use in aircraft enclosures, as well as methods of repair and maintenance.

GENERAL MAINTENANCE

6 Because of the use to which these materials are put in aircraft enclosures, optical quality is of paramount importance. This is particularly true of the acrylic plastics which are similar to plate glass in many of their optical characteristics. Ability to locate and identify other aircraft in flight, to land safely at high speeds, to maintain position in formation, and in some cases, to site them accurate-

ly through plastic enclosures, all depend on the surface cleanliness, clarity and freedom from distortion of the plastic. These factors, in turn, depend entirely upon the amount of care which is exercised in the handling, fabrication, maintenance, and repair of the material. Plastics have many advantages over glass for aircraft application, particularly light weight; ease of fabrication, and ability to lend themselves to repair procedures; but they lack the surface hardness of glass, and are very easily scratched, with resulting impairment of vision. Care must be exercised while servicing the aircraft to avoid scratching or otherwise damaging the plastic surface. Specific procedures will be discussed in later paragraphs of this order, but several general rules should be emphasized:

(a) Do not rub the surface with a dry cloth, as frequently the cloth does not clean perfectly and scratching and/or marring of plastic windscreens is a result. The use of a dry cloth forces the particles of grit and dust on the canopy and on the cloth to scratch and deface the surface.

(b) Transparent plastic material should be handled at all times with clean gloves.

(c) The use of harmful liquids (ie, gasoline, paint or dope solvents, thinners, and dopes) as cleaning agents should be avoided.

(d) Fabrication, repair, and maintenance instructions should be followed closely.

(e) Operations which might tend to scratch or distort the plastic surface should be avoided.

(f) Plastic surfaces should be cleaned only by washing with warm, soapy water, using a soft cloth that is free from grit.

IDENTIFICATION OF PLASTICS

7 Since the methods of working the two common plastic material (acrylic plastic and cellulose acetate base plastic) are different, it is important that the material to be worked is properly identified. In most cases, all aircraft panels are marked with the specification number so that an easy means of identification of the two types is available. In the event that materials bear no identification marks, there are several means of identification, some of which are listed below:

(a) Upon viewing the light transmitted through the edge of the panel, the cellulose acetate base type appear relatively dark and generally are tinted pink, green, or blue, whereas the acrylic plastics are quite transparent and colourless.

(b) The cellulose acetate material when rapped with the knuckles emits a dull sound as compared with the ringing note given off by the acrylic plastic. This method is only reliable when direct comparison of two materials is possible.

(c) Both acrylic and cellulose acetate base plastic have characteristic odours when burned. By burning a small sample of the questionable material and comparing the odours with a known sample identification can usually be made. The cellulose acetate base plastic burns with a smoky flame which will not propagate downward (ie, if a strip of the material is held with the flame uppermost, burning, both portions will fall away and the flame will soon die out). The burning of the cellulose acetate type is accompanied by a smell of vinegar which may be detected in the smoke immediately after the flame is extinguished. The acrylic plastic ignites more easily and burns with a clear smokeless flame which will propagate downward. The acrylic plastics are more rigid than cellulose acetate base material, and hence will bend less readily. In attempting to establish the identity of an unknown material in this way, it is well to use a known piece of equal size and thickness for comparison.

8 Acrylic plastics are used for transparent enclosures on cargo and combat type aircraft, whereas cellulose acetate base plastics are used usually on most training and observation aircraft and gliders. Due to its inferior qualities with respect to strength, resistance to weather, freedom from warpage, and transparency, cellulose acetate base plastic is not to be used as a substitute for acrylic plastic. Care is to be exercised therefore to properly identify the original and replacements or repair materials. Acrylic plastics contract at low temperatures five times as much as light alloy and ten times as much as steel. It is highly notch sensitive and its thermal conductivity is about 1/1000 that of metal.

PART 2

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STORAGE AND CARE OF PANELS

1 Transparent plastic sheets, especially the acrylic plastics, are thermoplastic and so will soften when heated sufficiently. Therefore, excessively hot storage areas are to be avoided. Plastic sheets are to be kept away from heating coils, radiators, hot water and steam pipes. Storage is to be in a cool, dry location away from solvent fumes, such as may exist near paint spray and paint storage areas. Although sunlight is not harmful to acrylic plastics, masked sheets are to be kept out of the direct rays of the sun as this may accelerate deterioration of the masking paper adhesive, causing it to cling to the plastic so that removal is difficult. Sheets are to be stored on solid shelves, not small sheets on larger ones to avoid unsupported overhead (see fig. 2-1). If the sheets are stored vertically, they should be amply supported.

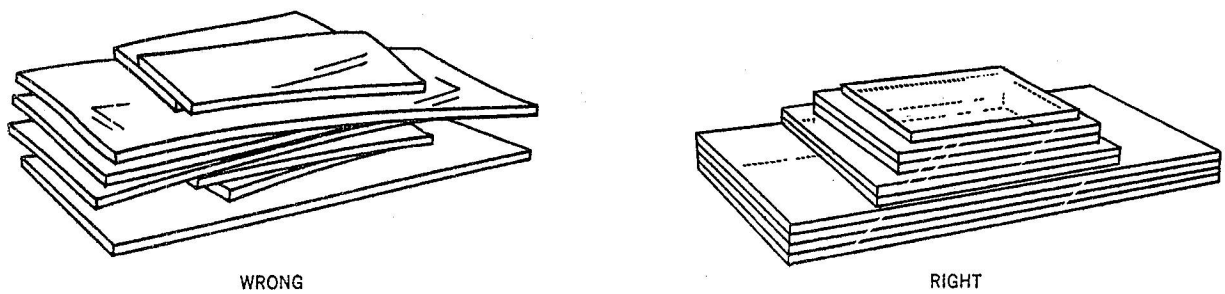

Figure 2-1 Right and Wrong Methods of Horizontal Stacking Acrylic Sheets

2 If, as a result of improper storage, plastic sheets become bowed, they may be straightened by removing masking paper, heating to forming temperature, placing on a flat surface protected by a layer of soft flannel and allowed to cool. Storage of acrylic sheets presents no special fire hazard since these materials are slow burning. Masking paper should be left in place as long as possible. While this paper is tough enough to protect the plastic surface from most minor scratches, care must be exercised to avoid scratches and gouges which may be caused by sliding sheets against one another or across rough or dirty tables. Any working of the sheets, such as cutting or drilling should be done with the protective paper in position. The paper may be removed by raising one corner and tearing off, after which the gelatine film should be washed off with warm, soapy water and a final rinse of clean water.

3 Washed sheets should not be placed in contact with one another, but may be stacked with wads of wet cotton wool separating the surfaces. Curved or formed sections should be stored so that they are amply supported and there is no tendency for them to lose their shape. Vertical masting, except in specially designed racks, should be avoided. Simple frames or supports are often desirable to relieve strain or unusual pressure on curved parts. Always cover parts with cloth or soft paper to protect from dust. Protect formed parts from temperatures higher than 49°C (120°F) which might tend to make them lose their shape.

MASKING

4 As mentioned above, most transparent plastic sheets are supplied with a coating of masking paper. This paper should be left in place as long as possible and any working done on the sheets should be done with the protective paper in position. If it becomes necessary to work on a panel which has had the original covering removed, the surface should be remarked as soon as possible. Either replace the original paper, or apply new paper (preferably fresh soft tissue paper) using approved adhesive such as: soft soap; smooth starch paster; gelatine adhesive; or a rubber type adhesive manufactured for this purpose. Care should be taken to keep the cover free from creases. If masking paper hardens to the surface of plastic sheets due to long improper storage, making removal difficult, moisten the paper with kerosene or hexane. The liquid will loosen the adhesive and free it from the plastic. Sheets so treated should be washed with soap and water and rinsed with distilled water before attempting forming operations.

CAUTION

Do not use gasoline, alcohol, benzene, acetone, carbon tetrachloride, fire extinguisher or de-icing fluid, lacquer thinners, or other solvent for acrylic plastics to remove masking paper as these will soften and craze the plastic surface (see fig. 2-2).

5 For formed parts, certain protective coatings are available which are applied by spraying. Since many compounds are inadequate or definitely harmful, only approved materials should be used. To remove stray masking from the plastic, peal it off or lift the corner of the film and blow a jet of compressed air under it. Sometimes a paper tap embedded in the film to assist in its removal is advisable, otherwise it is impossible to lift the corner and peal the masking off. A material has recently been approved for preventing damage during handling of plastic sheets and forms. It is a rubber latex whose main disadvantage is that it is fairly slow drying. It forms a rubbery skin which may be pulled off and the rubbery skin does not attain a good strength until left overnight or for twenty-four hours.

CEMENTING

6 The recommended cements for acrylic plastics are solvents or mixtures of solvents which soften the plastic, permitting the two surfaces to be joined to intermingle. When the solvent penetrates and evaporates, a hard clear joint is obtained.

TYPES OF CEMENTS

7 A general cement for use with DTD 339A plastics is made by forming a solution of acrylic plastic filings in glacial acetic acid, 100 gr. of filings to each pint of acid. The solution should be prepared at about 80°C (176°F).

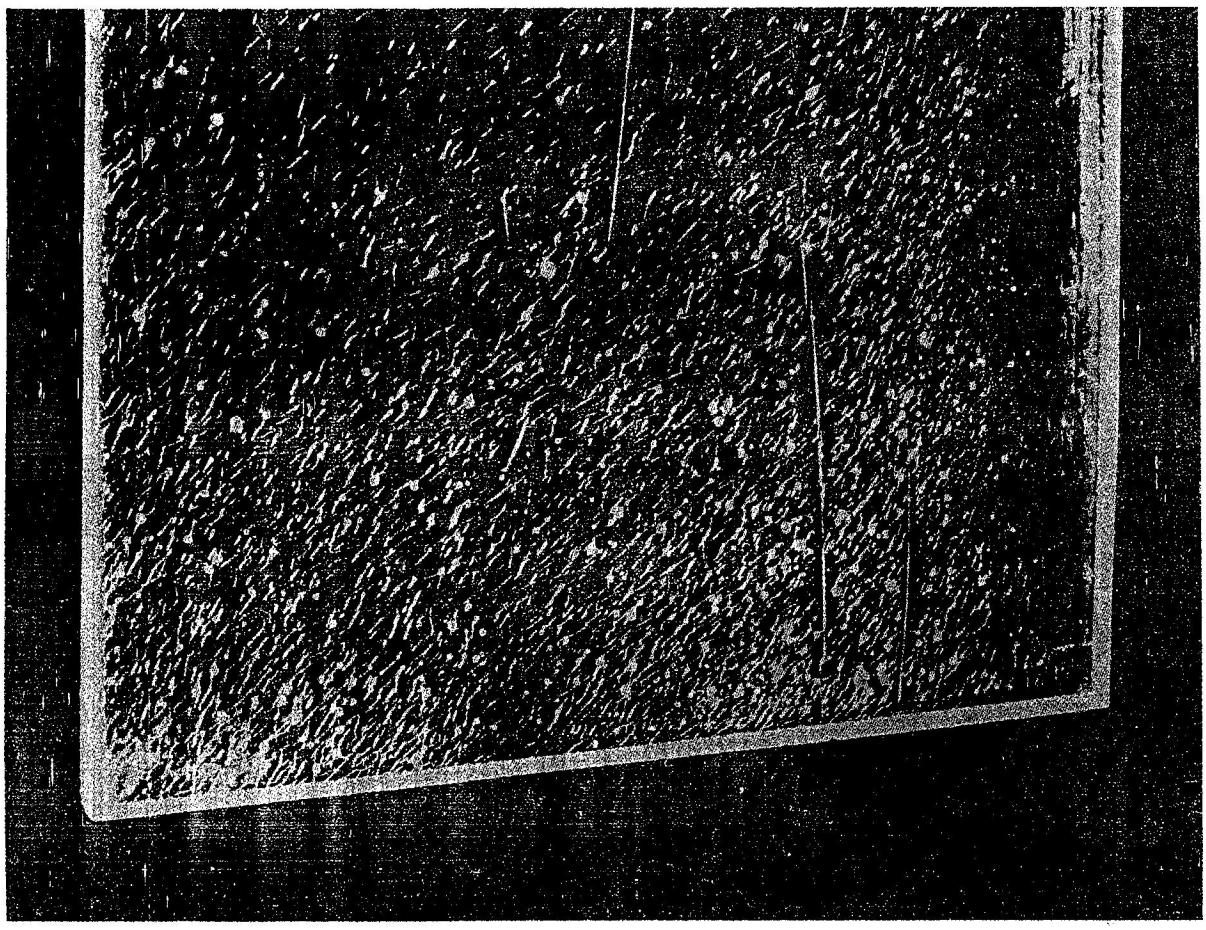

Figure 2-2 Crazed Acrylic Plastic

CAUTION

Glacial acetic acid is corrosive and irritating to the skin and eyes. It should be used carefully and handled only with rubber gloves.

8 A solution for DTD 339A may also be formed using acrylic plastic filings in chloroform or benzene 4% filings to 96% fluid. This adhesive should be prepared immediately before it is required for use.

9 Bostik cement No. 292 may be used with cellulose acetate base plastics. For cellulose acetate base plastic, a solution of base material filings and acetone, may be prepared, the preparation depending upon climatic conditions. Thick adhesive is most suitable for hot climate. (The use of acetone sometimes causes cloudy, unsightly joints of inferior strength. Acetone is highly inflammable).

10 A mixture of 10% benzol-alcohol to 2-3% ethyl acetate and 87-88% acetone.

11 A mixture of equal parts of monomeric methyl methacrylate (inhibited with 0.006% hydroquinone) and methylene chloride makes a very efficient cement (Spec. MIL-C-3116). This cement is apt to lose its methylene chloride components more rapidly than its monomer components. This loss is due to the higher rate of evaporation of methylene chloride and to the preferential absorption of methylene chloride by the plastic.

12 The specific gravity of the mixture provides a quick method of checking the relative proportions of the two components. This specific gravity is practically independent of the amount of plastic dissolved in the cement. Therefore, this mixture may be properly controlled by keeping the specific gravity within the following ranges at the following temperatures:

Temperature C.	Temperature F.	Permissible Range Specific Gravity
20°	68°	1.13 - 1.18
25°	77°	1.12 - 1.17
30°	86°	1.11 - 1.16
35°	95°	1.10 - 1.15
40°	104°	1.09 - 1.14

13 The specific gravity should be checked at least every four hours if the cement is used continuously and more often if the four hours check shows an excessive change in composition. If the cement is not used continuously, check specific gravity before each use.

14 A high grade storage battery hydrometer is ordinarily satisfactory to determine specific gravity, but since these are known to vary in their calibration, it is advisable to check them periodically against a fresh mixture or unused batch of this cement. At a temperature of 25°C (77°F), this mixture should read 1.13. If the hydrometer reading differs more than 0.01 from this value, the correction factor should be applied to all readings taken with this hydrometer.

15 If at the time of checking, the specific gravity of the cement is found to be too low, it should be adjusted by adding methylene bichloride to bring its specific gravity to the maximum end of the specified range. This adjustment required the addition of methylene chloride to the extent of approximately 2.5% by volume of the cement per 0.01 units of required correction of specific gravity. The cement should be thoroughly stirred and the specific gravity should be rechecked.

16 If the specific gravity of the cement falls too low, ie, the proportion of monomer is too high, the cement does not form a deep soft cushion on the plastic. Further, if the assembly is subject to any stress, severe crazing will result, reducing the strength at the joints.

17 If on the other hand, the specific gravity of the cement is too high, ie, if the proportion of methylene chloride is too high, too deep a cushion will be formed too quickly. Further the cushion will crust over rapidly, sometimes so fast that "blushing" (a frosty appearance in the joints) will result.

WARNING

Methylene chloride is toxic if its vapours are inhaled over a period of time. Adequate ventilation should be provided for personnel working with this cement. Because vapour concentrations are apt to occur inside a gun turret, for example, in a typical assembly operation, it is advisable to direct a current of fresh air up into the turret, if workmen are inside. Since methylene chloride vapour is heavier than air, the source of the fresh air referred to above should be as high above the floor as practical.

18 It has been found that this cement is not self combustible if it consists of more than 40% methylene bichloride, and will not burn readily if it contains more than 25% methylene bichloride.

19 Before using this cement, catalyist (benzoyl peroxide) should be added in the proportion of one capsule of catalyist to one pound (approximately one pint) of the cement.

20 Before the catalyist is added, this cement will remain liquid and usable for at least one year, provided the container is kept tightly closed. After the catalyist is added, however, the cement will tend to thicken unless kept under refrigeration.

21 Methylene bichloride, alone, may be used as a cement for acrylic plastics. It is more active solvent than the cement in paras. 11-20 above, and shorter soak periods should therefore be used. Methylene bichloride is also more apt to cause "blushing" or whitening of a joint.

22 Monomer "monomeric methyl methacrylate" may be used, alone, as a cement in an emergency, but does not create as deep a "cushion" as the cement in paras. 11-20 above, and is more apt to cause crazing.

BUFFING COMPOUNDS

23 The various producers of transparent plastics can supply polish suitable for their

product. There are several different materials from which such products may be made and the use of the wrong polish may damage the surface. Where the abrasion is slight and the loss of visibility due mainly to weather etching, only cleaner and polish conforming to Specification MIL-C-5547 or DTD 770 is to be used on. There are a number of standard commercial polishing compounds satisfactory for use in polishing acrylic plastic. These are usually composed of very fine alumina or similar "abrasives" in combination with wax, tallow, or grease finders and are available in the form of bars or tubes for convenience in applying to the buffing wheel. These compounds are sometimes referred to as "colouring" compounds. The finest grade is as coarse as is required for acrylic plastic. The commercial compounds that have been used satisfactorily are shown in Table 1.

24 Where a large amount of buffing is undertaken, so called "ashing compounds" are often used. These consist of water paste of abrasive compounds, such as pumice. Satisfactory compounds of this type are shown in Table 1.

25 Tallow is often applied to the buffing wheel when polishing acrylic plastic. Sometimes it is used in addition to buffing compound, sometimes alone. In the latter case, tallow functions similarly to wax in that it fills in air line scratches and gives a high gloss to the surface. The commercial tallows, shown in Table 1, have been used satisfactorily.

POLISHES

26 When buffing equipment is not available, it is possible to restore the surface of a scratched plastic panel by hand polishing. The polishes used for this purpose should have no chemical action on acrylic plastic, should not abrade the unscratched areas of the plastic, and should be able to reduce scratches. The commercial polishes, shown in Table 2, have been tested and found satisfactory. To remove grease and oil, wipe the plastic with a clean soft cloth soaked in kerosene or hexane. The commercial cleaners, shown in Table 2, have been tested and found satisfactory.

CAUTION

Do not use gasoline, alcohol, benzine, acetone, carbon tetrachloride, fire extinguisher or de-icing fluid, lacquer thinners, or other solvent for acrylic plastic to remove grease and oil. These materials soften and may craze the plastic. Since window cleaning compounds may contain these solvents, their use is also to be avoided.

(a) . The cloth used to apply polishes and waxes should be soft and clean. Cloths that meet Specification DTD 770, canton or domet flannel, flannelette, and diaper cloth are most satisfactory. Cloths should be set aside for use only on acrylic plastic surfaces and kept in closed containers or protected rolls to keep them clean and grit free.

CAUTION

Do not use hard, dirty or gritty cloths in cleaning and polishing acrylic plastics. Wiping with such cloths can put serious scratches on plastic surfaces reducing the vision of pilot and crew.

WAXES

27 As the final operation is cleaning or polishing acrylic plastic, a coat of wax may be applied. This wax not only fills in hair line scratches and gives a good gloss to the surface, but also provides some measure of protection to the plastic. Suitable waxes should have no chemical effect on the plastic and should contain no abrasive which might scratch unabrazed areas. Waxes may be of the paste or emulsion type. The wax compounds, detailed in Table 3, have been tested and found satisfactory.

MASKING TAPES

28 In cementing acrylic plastic, it is often necessary to protect certain areas of the plastic from the solvent action of this cement. For this purpose, heavy paper or cellophane tapes applied with pressure, sensitive adhesive are used. Any tapes to be used should be tested and used only if they prove satisfactory. The commercial tapes, shown in Table 3, have been tested and found satisfactory. To test, wet tape around a scraped piece acrylic plastic and emerse in cement for twenty to thirty minutes. If the tape strips off, clean and if the plastic beneath the tape has been protected from the

cement (not attacked or softened), it is satisfactory to use. Care must be taken in masking acrylic plastic as the adhesive used on some types of masking tape causes crazing on the plastic. Preferably, only tapes which have water soluble adhesive should be used. In some cases, it has been found that merely sticking paper on by means of adhesive, after handling tends to encourage crazing during storage conditions, and it is felt that this paper acts as a sponge to a certain extent. Any solvent vapour in the atmosphere where quite high concentration of vapour is formed, panels should be covered with soft soap and then preferably a grease proof paper and finally, the masking tape itself should be smothered with soft soap.

SANDPAPERS

29 Only fine grit sandpapers are to be used in finishing acrylic plastic. Grit size 320A is as coarse as is usually necessary and Grit 360A, 400A, 500A and 600A are usually preferable. Silicon carbide abrasives on a weight paper backing are recommended. Sandpaper should be used wet in sanding acrylic plastics, in order to reduce heat of friction. Papers of the waterproof or "wet-or-dry" type should be used.

GASKETS AND MASTIC MATERIALS

30 In aircraft installations, acrylic plastic panels should be mounted between gaskets or sealed with mastic compounds. Many different compounds are available and have been used for this purpose. However, acrylic plastics can be seriously crazed by the plasticizers or other chemical components which are used in some of these materials.

CAUTION

Use only gasket material and mastic compounds which have been approved. If these are not available, insert a protective layer of cellophane between the gaskets and the plastic panel.

CAUSE AND REMOVAL OF CRAZING

31 A large number of liquids have been examined experimentally, and it has been found that those which cause crazing can be generally classified as those liquids which either swell or dissolve the material, In some cases vapours from solids have been found to cause crazing. As regards the crazing patterns, the material as it is cast gives a random crazing pattern whilst heat treated material exhibits craze lines lying in the direction perpendicular to the direction of the applied tensile stress. As regards likely types and sources of solvent vapours which may cause crazing, there are many. Besides the more obvious one, such as fuels, dopes, polishers, etc, there are others which are not easily traced such as solvent vapours from rubbers and various types of other synthetic materials. In general, solvents which will cause crazing cannot be properly defined. The only criteria at the moment being whether or not a liquid swells or dissolves acrylic plastic.

32 When inspecting, the only type of crazing which is considered acceptable is the very fine variety which has no visible depth when viewed with the naked eye, but it is preferable to have no crazing whatsoever present. However, slight crazing occurs in such a large proportion of components at the present time that some may have to be accepted until means of preventing it are found. If crazing is of the directional variety and has visible depth, it should definitely be rejected. This type may spread when subjected again to the conditions which caused it and so lead to complete failure.

33 The possibility of removing crazing by heat treatment has been investigated. Although heat treatment at 100°C (212°F) for a number of hours improves vision through a crazed sample by expansion of the material, thereby closing the fractures, it has been found that there is no real healing of the material and the fractures reopon under a subsequent stressing operation.

GREASES

34 In certain stretch forming operations, it is advisable to apply a layer of grease over the cloth covering the die. These greases must not become too fluid at forming temperatures or excessive mark-off will result; they should not be too stiff or they will produce distortion in the formal part.

PART 3

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PART 3

TOCLS AND METHODS

GENERAL

1 The fabrication of acrylic plastic may be generally compared to that of other materials, such as wood or soft metal. Good craftsmanship, suitable equipment and proper design are no less essential to the successful fabrication of acrylic plastic than of other materials worked by similar methods. A craftsman experienced in the machining of brass will have little difficulty with acrylic plastic, for the machining qualities are quite similar. Light to medium woodworking equipment, with minor modifications, is satisfactory, but heavy duty machines, which are less apt to vibrate, are even better. General rules for machining apply, and once the "feel" of the plastic is obtained, clean accurate work can be expected. Tools should be kept sharp. Nicked or burred edges must be eliminated if a smooth, machined surface is desired.

2 Unlike metals, acrylic plastics are poor conductors of heat, and further, being thermo plastic (ie, softened by heat) tend to soften if excessive heat is generated during machining. Therefore, it is essential that ample means be provided to dissipate frictional heat, either by the use of a coolant, or in some cases, an air blast. The rate at which frictional heat can be dissipated is usually the controlling factor determining the speed at which machining operation can be performed. Excessive heat is generally unsatisfactory work. Water is the recommended coolant. Other coolants may contain chemicals harmful to the plastic. Care must be taken to use water only in cases where it will not come in contact with plastic surfaces protected with the masking material, since it results in the loss of strength of the masking compound, and makes removal difficult.

3 Since they are thermo plastics, acrylic plastics become soft and pliable when heated over 105°C (220°F). They can then be bent to almost any shape and will retain the shape when cooled, except for a small contraction caused by the lowering of temperature. The temper- a minimum of strain will be set up in the material during the forming operation. On the other hand, if acrylic plastics are heated too hot, the surface is too soft, and will pick up minor imperfections (called "mark-off") from the form. The proper temperature can be determined by experience. Complex shapes require somewhat higher temperatures than simple curves. The recommended procedure, therefore, is to heat the plastic sheet at least fifteen or twenty minutes at the proper temperature. As a general rule, the average temperature of the sheet should be at least 100° to 105°C (212° to 220°F) when it comes in contact with the form.

4 Care should be exercised while handling heated acrylic plastic sheets to avoid fingerprinting and otherwise damaging the soft surface. Operators should wear soft cotton gloves, not only to protect their hands, but also the surface of the plastic.

5 Forming should be carried out in a clean room, and the forms should be brushed free of dust and dirt before use. The acrylic plastic blanks should be slightly larger than the required finished size to provide an edge which can be handled freely without danger of scarring the surface of the material of the finished part. The pressures required to form acrylic plastics are extremely low; often the weight of the material itself is sufficient. The application of high, or even moderately high pressures, is neither necessary nor desirable, since it tends to increase the extent of mark-offs. After the material has been formed, it should be allowed to cool slowly. Cooling can be accelerated by means of a fan or other device. However, cooling preferably should be slow and uniform over the entire surface to reduce internal strain. If the formed part shows excessive mark-offs or other imperfections on the surface (except scratches), it can be placed back in the forming oven. It will resume its flat shape and original surface, except for

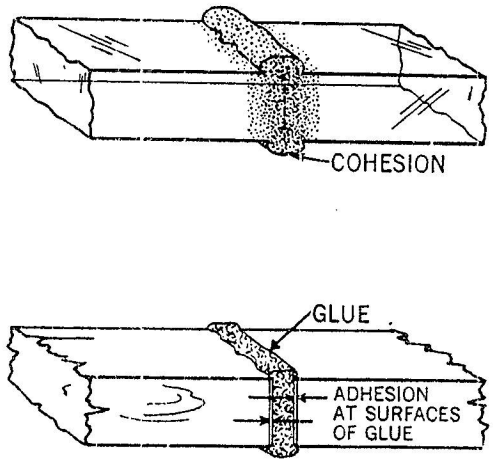

Figure 3-1 Distinction Between Cohesion and Adhesion

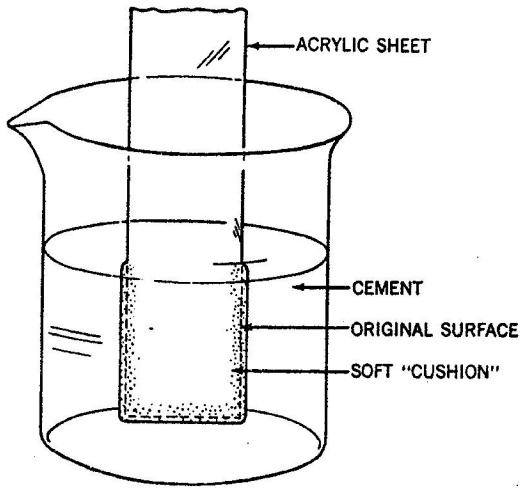

Figure 3-2 Formation of Cushion on Acrylic Plastic Surface by Immersion in Cement

scratches, and can then be formed again. It is usually easier and better to reform several times than to sand and polish mark-off and other mould imperfections.

6 With care and proper procedure, it is possible to obtain a cemented joint which approximates the original plastic in transparency and strength. Cementing of acrylic plastic depends on the intermingling of the two surfaces of the joints so that there is actual cohesion as in the material itself. This principle differs from gluing (wood to wood or paper to paper, for example) which depends on the adhesion of the glue to each of the two surfaces (see fig. 3-1).

7 To effect cohesion, an organic liquid solvent is used to attack the plastic, forming a well defined, soft surface layer called a "cushion" (see fig. 3-2). All known methods of cementing acrylic plastic are based on the solvent action which permits the two surfaces, when pressed together to intermingle and to unite in a true cohesive bond. Most cementing is done by the "soak method" which consists of dipping one of the two pieces to be cemented into the cement, until sufficient cushion is formed. Upon removal, the surface of this cushion is wet with cement. When this surface, is pressed against the opposite dry surface, the excess cement forms a second cushion, shallow, but enough to permit thorough intermingling of the two surfaces (see fig. 3-3).

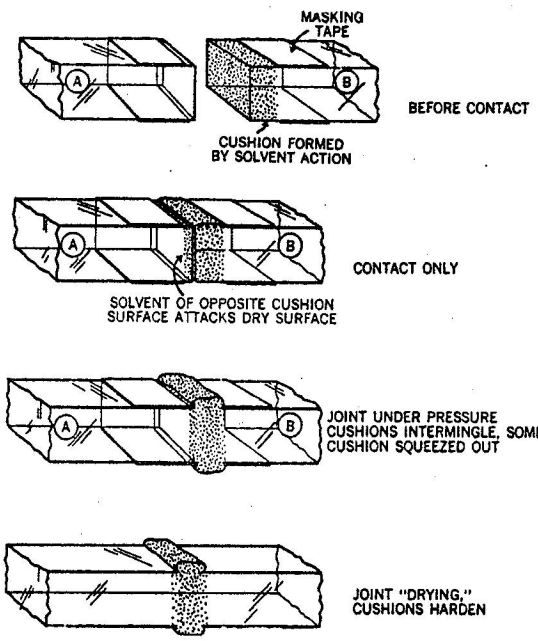

Figure 3-3 Diagrammatic Explanation of Cementing Operation Using Solvent Cement

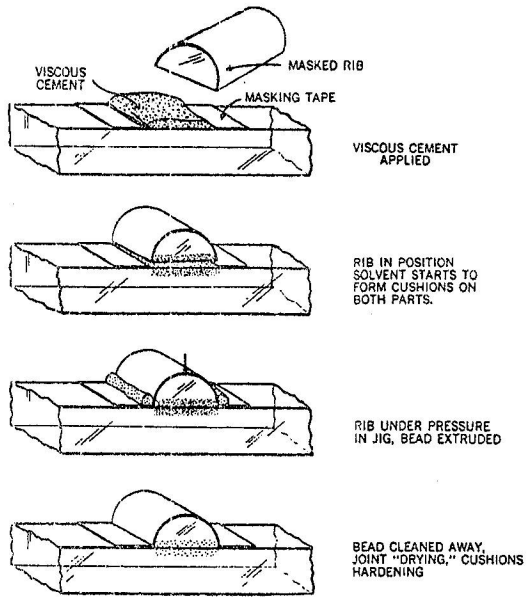

Figure 3-4 Diagrammatic Explanation of Cementing Operation Using Syrup Cement

8 Sometimes, for convenience in handling, clean acrylic shavings are dissolved in the cement to give it a thick, syrupy consistency, so that it can be applied like glue. This viscous cement, however, works on exactly the same principle as the soak cement (ie, the excess solvent softens and swells both surfaces permitting an intermingling of the cushions and the formation of a true cohesive bond) (see fig. 3-4). The viscous cement acts only as a carrier for the solvent. The solid content, usually only 3% is not sufficient to fill in any discrepancies in fit. Successful cementing of acrylic plastic requires careful craftmanship and is effected by a number of factors, the most important of which are detailed in paras. 3 to 21 of this Part.

CUTTING

9 Because of its brittle nature, plastics should not be guillotined or cut by shears. Thin sheets of material (less than 1/2 inch thick) may be scribed and broken along the scratch marks. Thicker sheets should be cut with a fine saw. It may also be hand planed with very light cuts, and filed, if a coarse file is employed with fast light cuts. Rough edges should be finished by means of glass or emery paper. Cracking and chipping can be avoided by immersing the panel in water at 80°C (176°F) prior to the matching operation. The water must be wiped off rapidly when the sheet is lifted out of the bath to prevent surface markings. The use of hot water to heat acrylic plastics should be employed with extreme care and direct steam should never be used because the plastic may become milky or cloudy.

SAWING

10 Three general types of saws are generally used for cutting acrylic plastic; circular saws (usually employed for cutting squares and rectangles to a given size, trimming rough edges of flat sheets, and cutting long narrow strips for reinforcing or mounting with); band saws (used for cutting irregular flat shapes, and trimming formed parts to approximate dimensions as indicated by scribed lines); a veneer saw (particularly suited for trimming formed parts to shape while they are held in position on a jig).

11 Where extreme accuracy is not required, cutting lines may be pencilled directly on the masking paper. For close tolerances, however, it is advisable to scribe lay-out lines directly on the surface of the plastic. Use straight edges or lay-out templates according to the requirements of the job. If the masking paper is removed before scribing, it should be replaced again to within about one-quarter inch of the scribed markings before the piece is cut. A razor blade can be used to scribe and at the same time to trim back the masking paper. Lay-out templates may be from plastic sheeting, to which suitable handles can be cemented, or from light gauge metal. Sharp edges or rough spots in such templates should be carefully rounded or smoothed. In the case of metal templates it is good practice to cement thin flannel over the contact surface if such templates are to be used frequently.

12 Jig saws for cutting curves with small radii and band saws for larger curves and straight cuts in thick material should have accurate blade guides in good adjustments. Circular saws are preferred for straight cutting of pieces which are not too large to be fed to the saw. Circular saws should be equipped with stiffener washers at the shaft to minimize blaze vibration. Pull or table saws are practical for cutting large sheets since the plastic is held stationary on a table. Because of the length of band saw blades, they dissipate heat more rapidly than do circular saws. Accordingly, they operate at lower temperatures and are

better suited to cutting thick plastic sheets. However, no exact thickness can be established as the point work becomes beneficial to use a band saw instead of a circular saw.

13 Length of cut, speed of cutting, smoothness of cuts and other conditions usually differ in each case; and so the decision must be left to the experience and judgment of the individual craftsman. Experience has shown that circular saws for cutting acrylic plastic should be hollow ground to prevent binding. Blades with from five to eight teeth per inch and no set give good results when running at a peripheral speed of about 10,000 feet per minute (4800 rpm for an eight inch diameter blade). As a general rule, the thicker the material being cut, the larger the diameter and the fewer the number of teeth per inch needed.

14 The selection of band saw blades, specific types of work follows, in general, the rule for selecting circular saws. Wide blades, being more rigid, are suited for long straight cuts. Narrow blades are required for cutting curves. Tooth size should become more coarse with progress increase in thickness of the material being cut. A range of from eight to twenty-two teeth per inch is commonly employed. Fine teeth with no set, produce a smooth cut if the work is fed slowly. The use of coarser teeth with a slight set permits a more rapid feed but produces a rougher cut. In cutting curves, set is necessary even though narrower blades are used. For continuous heavy work, a 22 or 23 gauge blade is recommended. On lighter work, a 26 to 28 gauge blade will give good results. A range of speeds of from one thousand to one thousand five hundred feet per minute should be used. Saw guides in the case of both band saws and jig saws should be adjusted as closely to the work as possible and should control "weave" of the blade to the minimum thus contributing materially to the accuracy of the cut.

15 The feed for all types of sawing cannot be accurately stated. It must be learned from experience, but in general will be relatively slow. The feed should not be forced, but will vary with the thickness of the stock being cut, the type of blade used, the speed and sharpness of the blade, and the power available. Moderate smoking and smearing at the edge is an indication of too rapid speed. A good practice for obtaining smooth edges at the exit end of the cut is to slow down the rate of speeding as the saw blade leaves the cut. The chipping of edges with circular saws can also be minimized by adjusting the blade to the minimum height with relation to the table and the thickness of stock. Saw blades of all kinds should be kept sharp to obtain highest cutting efficiency. Dull blades cause chipping and require slower feeding to avoid excessive friction heat. It is advisable to clean all types of blades periodically by soaking them in acetone, toluene, methylene dichloride, ethylene dichloride, trichlorethylene (sold under trade names "chlorylene", "tirl-clene", etc), or some other suitable solvent to remove gummy deposit.

NOTE

Caution should be exercised in order to ensure that acrylic plastics do not come in contact with or are not exposed to the vapours of the above solvents.

TRIMMING THREE DIMENSIONAL FORMED PART

16 Formed sections of acrylic plastic are most readily trimmed to size using a band saw to follow the correct outline which has been previously scribed on the surface. Where exact dimensional requirements are to be met on a large number of pieces, the use of jig to hold the part in a rigid position is recommended, trimming being accomplished through the use of a veneer saw or a hand router equipped with an end mill cutter.

ROUTING TO SHAPE

17 For high speed portable routers, standard two bladed wood cutters give satisfactory results. On vertical spindle shapers, 2, 3 and even multiple blade cutters may be used (see fig. 3-5). For example, square routing or shaping to templates can best be accomplished with six to ten bladed cutters operating at about 7000 rpm. Cutters with only two or three cutting edges and two to three inches in diameter can be used for this work, but the speed must then be increased considerably. In general, the greater the speed, the less the number of cutting edges required. Cutters up to three inches in diameter may be used without difficulty. Cutters should be kept sharp. They should be ground with a back clearance of about 10°. The rake angle should be from 20 to 30° for the best results (see fig. 3-5).

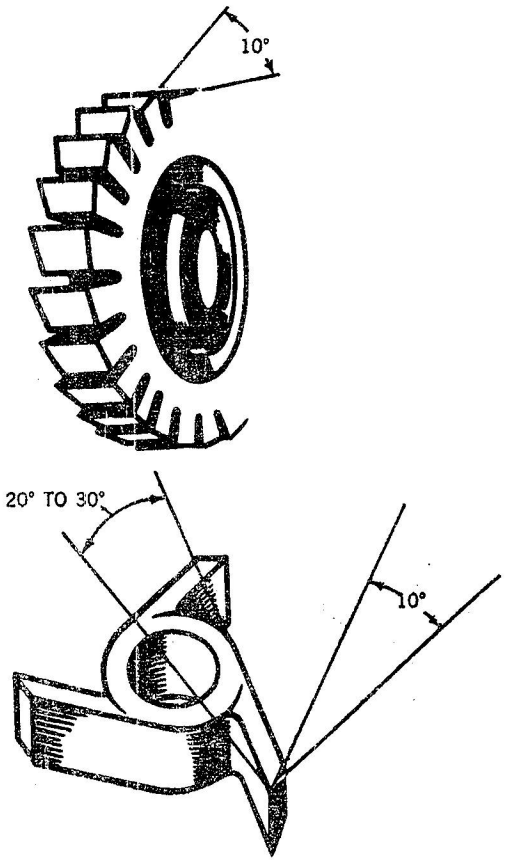

Figure 3-5 Typical Cutters for Routers

18 High routine speeds are preferable as they give smoother cuts, particularly on small diameter cutters (under 1 1/2 inches). High speeds also make it possible for each cutter blade to take a very light cut as it passes the material and so reduces the tendency to chip. Acrylic sheets must be fed slowly and continuously to avoid any tendency to crack or overheat. An air blast or a suction system will remove chips and cool the cutter simultaneously. The work may be held firmly by hand or by suitable fixtures which may be designed to serve at the same time as guides for the work.

SCRIBING AND EDGE SANDING

19 This method of cutting is most generally employed on flat sections or two dimensional curved pieces. The sheet is first cut to approximate shape on a band saw, using a scribed line as a guide, and cutting approximately 1/16 inch oversize. The choice of sander generally depends on the size and shape of the piece being sanded. Drum or belt sanders are most suitable for curved edges. Disc sanders work well when removing material from straight edges and outside curves. Air driven grinders and small electric hand grinders are best fitted for sanding irregular shapes or large pieces which are awkward to manipulate around a fixed machine.

20 The choice of abrasive and successive grades of abrasive depends on the amount of material to be removed and the finish desired and must of necessity be left to judgment. Grit sizes number 80 to 150 should be used. For best results, abrasive wheels, discs, drums and belts should operate at about 3000 surface feet per minute. Wet sanding is always preferred to dry sanding, as water, applied by spare or other means, dissipates frictional heat, eliminates "loading" of the abrasive, settles dust, increases the speed of cutting, and extends the life of the wheel. For surface sanding, used in finishing acrylic plastics, see paras. 62-64 below.

SCRIBE CUTTING

21 Where extreme accuracy is not required, thin acrylic plastic sheeting may be cut in a straight line in the same manner as glass, by scribing a line on the surface and breaking the sheet along the line. This method should not be used on thickness over about 0.080 inch. Acrylic plastics cannot be cut with shears or scissors.

ROUTING

22 Routers are used for a variety of operations, including machining flat sections to accurate contour (either regular or irregular), machining rabbeted edges to facilitate flush mounting and machining rib sections to predetermined cross sections. Equipment is used throughout the woodworking industry and is sometimes known as or used interchangeably with a "shaper". For certain rabbeting operations, a jointer may be used. For rabbet or stepped routs (see fig. 3-6), the teeth of the cutter should be backed off on the underside to prevent drag and thus avoid burning. Wherever possible, the corners of routing cutters should be ground to a 1/16 inch radius so as to produce a fillet at the bottom of the rout. This prevents stress concentration and consequently adds to the strength of the piece. Where an edge of the plastic bears on a router spindle collar as a guide during routing, the collar or edge should be oiled to reduce friction and excess heating. Cast sheets of acrylic plastic exhibit thickness

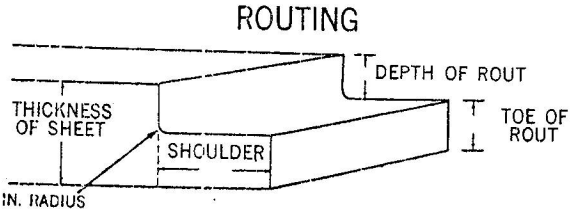

Figure 3-6 Diagram of a Step Rout or Rabbet

variations. Therefore, when a stepped rout is machined into the edge of the sheet, this possible variation in the thickness must be taken into consideration. By adjusting the cutter of the router to a definite height from the table, an accurately dimensioned toe may be produced (see fig. 3-7), but at the same time, the depth of the rout may vary according to the original thickness tolerance of the sheet. On the other

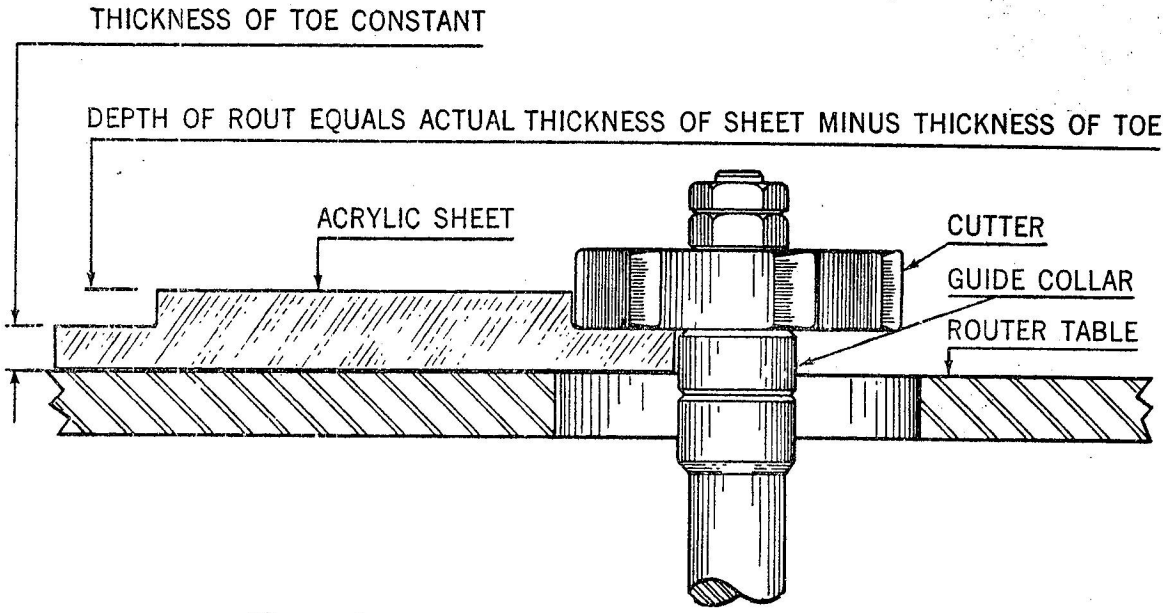

Figure 3-7 Routing to Obtain Accurate Toe of Rout

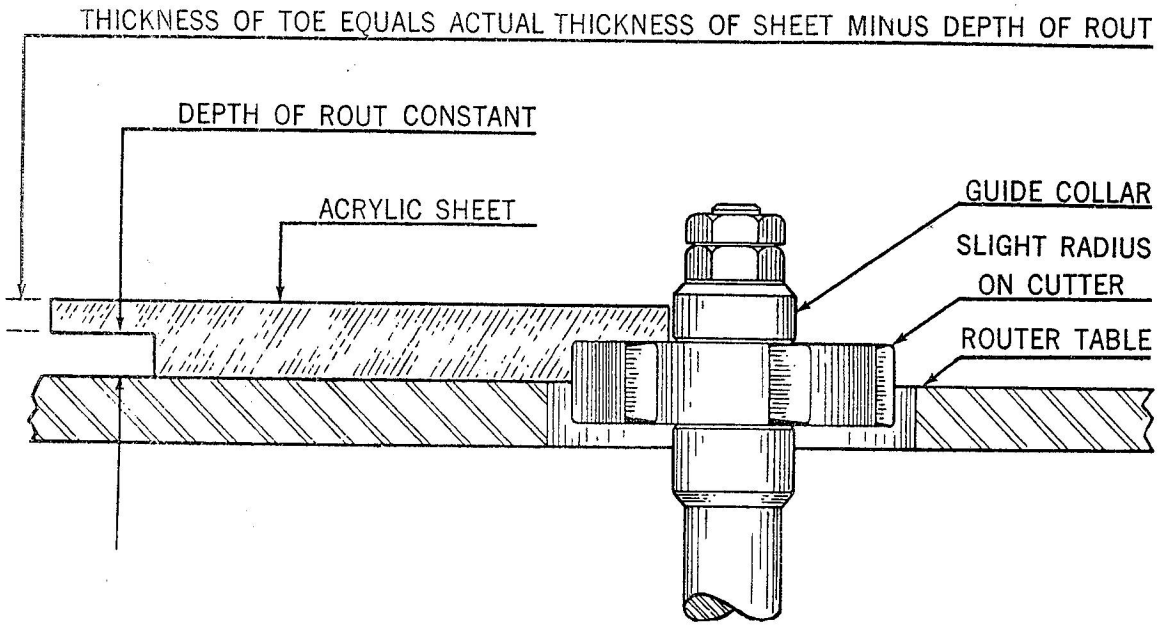

Figure 3-8 Routing to Obtain Accurate Depth of Rout

hand, if the stepped rout is machined as an undercut (see fig. 3-8), precision in the depth of the cut may be realized. In this case, however, the toe may vary in thickness due to the fact that there may be variance in the original calibre of the sheet. In short, it may be impossible to hold close tolerances in both the depth of the cut and the toe of the rout unless a subsequent, compensating machine operation is carried out after routing. Special cross sections can be routed by using cutters ground to the desired shape. Rib shape, for example, can be made by routing strips in much the same way that wood moulding is produced.

DRILLING

23 Standard vertical spindle drill presses are satisfactory. They can be in the single head, multiple head or radial types. Portable hand drills may also be used where convenient. For all drilling operations, clamps or fixtures should be provided for holding the work securely. Portable hand drills may be used for acrylite, but even with special jigs they will not produce the most accurate results. Regular machine twist drills can be used successfully if ordinary care is observed. Standard drills, ground for hard metals, have a tendency to pull into the material, however, and cause "grabbing" in much the same manner as with copper and aluminum. This may be overcome by using a drill modified to the following specifications (see fig. 3-9).

Flute Angle	17°
Lip Angle	70°
Lip Clearance Angle	4 -8°

Polished Lands one-quarter the width of the heel

(a) A thin web gives deep flutes and thus facilitates removal of chips. However, if the web is too thin, the drill wobbles and hence some compromise must be made between wobbling and convenient chip removal. Polished flutes at heels furtherrate chip removal. Drills must be handled with special care to avoid nicking or scratching them as such imperfections will mar the surface of a hole. Both cutting lips must be ground to the same length and same angle if an accurate hole is to be secured. For drilling thin sheets, two other types of drills are also satisfactory.

24 One is a flat base drill such as has been used for many years to drill cellulose plastic. The other is a modified long lead twist drill with a sharp lip angle. Hollow and mills, mounted in a vertical drill press can be used for drilling large diameter holes in thin stock. They produce clean, accurate holes and exhibit no tendency to chip on the break-through. Flycutters (or trepanning tools) are useful for cutting holes of more than one inch in diameter.

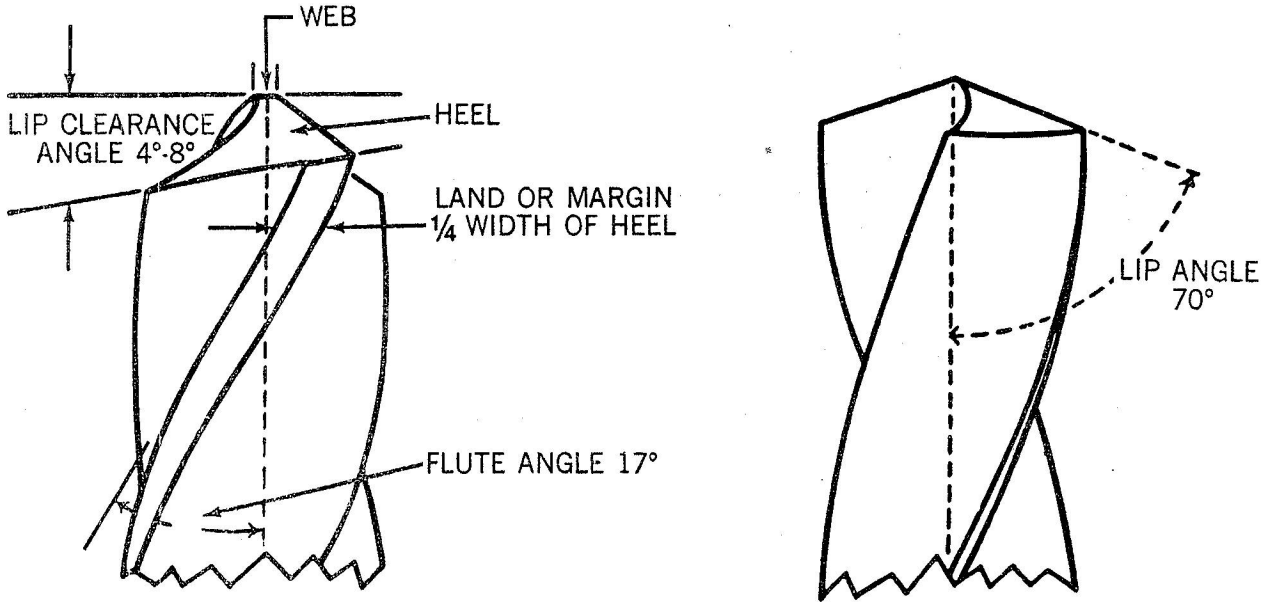

Figure 3-9 Diagram of Recommended Drill for Acrylic Plastics

Hole saws may be used for the same purpose. Neither of the tools should be run at high speed.

25 Experiments with the 3/16 inch drill at a constant speed have shown that one hundred and twenty feet per minute is an excellent drill speed for amply lubricated equipment. With heavier machines and automatic speeds, however, higher speeds may be feasible. As in the case of sawing, the feeding rate is a matter of experience and judgment. Too fast a feed causes chipping and strain cracks. Proper feed is achieved when smooth, continuous, spiral chips or ribbons result. As the drill penetrates the plastic, frictional heat accumulates. To avoid overheating, the rate of speed should be decreased and the depth of cut increases. A heavy spring mounted on the depth gauge of a hand fed drill press in such a way that it is necessary to compress the spring slightly just prior to break-through is often helpful since it automatically slows up the speed at this critical point. Drill lubricants serve several purposes. They aid in chip removal, carry away heat and improve the surface finish of the hole. The best lubricant for drilling acrylic is a thin, mild, soap solution. Shallow holes can be drilled satisfactorily without lubricant, if care is exercised in feeding to avoil overheating. However, holes in thin sheets will be improved if a lubricant is used or an air jet is directed at the hole. In drilling deep holes, the plastic should be immersed in the lubricant or provisions made to direct a steady stream of lubricant at the drill. In the latter case, the drill must be withdrawn every half inch to allow the chips to be cleared and the hole to be filled with lubricant.

THREADING AND TAPPING

26 Taps and dies similar to those used in metal working industry are used for the purpose of producing threads in holes and iron rods respectively. It is possible to thread or tap acrylic plastics satisfactorily with standard thread forms. However, threads for mounting or attaching where stressed for vibration as likely to be encountered are not recommended. If threading or tapping is necessary, the precautions following should be observed closely. Such threads as the USS (American coarse thread series), Whitworth Standard (British Standard series) and Acme are generally satisfactory. Sharp "V" threads are to be avoided due to the ease with which the apex fractures. Coarse pitch threads are preferred because of their added strength. When threading or tapping to fit a metal bolt or nut, allowance should be made for the difference in the thermal expansion coefficient of the two materials. Special types of thread inserts are available for use when thread wear may be encountered. Fittings or inserts are advised if the thread is expected to withstand high stresses of shocks. Either hand or machine methods may be employed for threading or tapping acrylics. Standard taps and dies may be used without modification. In cutting threads, the tap or dies may be operated at a 25% slower speed than is used for brass or cellulose plastic. Higher speeds cause excessive frictional heat and gumming of the chips. Taps should be backed out frequently to avoid jamming. In hand tapping small holes, 3/16 inch or less, it is not necessary to use a lubricant if care is exercised. On larger holes, a lubricant such as the mild soap solution recommended for drilling is satisfactory. For machine tapping or threading, the work should be flooded with lubricants.

TURNING

27 Standard metal working lathes may be used in turning acrylic plastics. Heavy wood latches may be used but are usually less satisfactory. In general, relatively few turning operations involving lathes are required in the fabrication and repair of acrylic plastics. Where necessary, the same techniques as used for brass or copper should be employed. The cutting edges of the tools should have no rake and should have a scraping rather than a cutting action. Tools and work should be firmly held to prevent "chattering".

FORMING

Ovens

28 Ovens are used for softening acrylic plastic sheets prior to forming. A circulating air oven is preferable, either by steam, electricity or gas. An indirect or transfer method is desirable when using gas heat to avoid the possibility of accumulating soot or other foreign matter in the oven in the event of incomplete combustion. A fan or other means of forced circulation should be employed to maintain as uniform a temperature gradient as possible throughout the oven. The oven should be capable of operating over a range of 105° to 177°C (220-350°F). It is advisable to provide automatic control, so that any desired temperature can be maintained within a few degrees

throughout the oven. For uniform heating, it is best to hand the sheets of plastic vertically. Any protective masking compound should be removed prior to heating.

29 Vertical supports can be accomplished by an overhead mono-rail mounted in the roof of the oven, and equipped with a spring channel, or a series of spring clips for grasping the plastic sheet. Thick heavy pieces are best supported by drilling a series of holes (spaced about six to twelve inches apart), close to along edge of the sheet, and threading a heavy cord through the holes and around a supporting pole. For small pieces, which are inconvenient to hang and for pieces cut to finished dimensions which have no scrap edge to which the clips or channels can be clamped, shelves or drawers must be provided. Shelves, covered with soft felt or flannel, should be of open work construction to allow maximum circulation of air around the sheet to assure uniform heating. The oven should be so designed that sheets which are hung vertically are heated by opposing streams of air which impinge directly upon opposite sides of the sheets. The air distribution should be uniform over the entire surface. Such an arrangement necessitates careful filtration of any fresh air which is admitted to the oven, and also frequent cleaning of the oven to prevent the accumulation of dirt which might be deposited on the sheet. Doors should be kept to minimum size to prevent undue cooling of the oven during loading and removal of sheets. It is highly desirable, however, to have one section of the oven sufficiently large to permit the introduction of large formed sections for softening and reforming. White cotton gloves should be worn for handling the unmasked sheeting.

30 In an emergency, any available ovens, such as a kitchen baking oven may be used, In the event that the volume of work does not justify the expense of an oven, other less desirable means may be employed for heating acrylic plastics prior to forming. For example, infrared lamps (type R-40) may be used. They are usually arranged on seven to eight inch centres in a bank sufficiently large to cover the maximum size sheet involved. The sheeting should be placed approximately eighteen inches from the face of the lamp to secure even distribution of the radiant heat. An alternative method employs a bath of mineral oil, heated by immersion heaters or steam coils. This method is somewhat hazardous, however, due to the danger of handling sheets covered with hot oil, and it is also difficult to clean the plastic afterwards. As a last resort, a so-called "heatgun" or blow torch may be used. Such equipment should be avoided wherever possible, however, since it is almost certain to cause severe distortion. In general, any method other than oven-heated is undesirable, and should be used only when the latter is not available.

FORMS

31 Since most forms for acrylic plastics are subjected to no great pressure, they may be made of material as brittle as plaster. The choice between plaster, wood, plywood, impregnated wood, metal, masonite or combinations of materials, depends on considerations of cost, ease of fabrication, dimensional stability and length of expected service. For simple two dimensional shapes, metal, masonite or plywood forms are easily made. For more complicated shapes, reinforced plaster forms are easier to make and are perfectly satisfactory. Forms should be free of wavings and other variations in contour which might cause optical distortions on the formed part. The surface should be sand-smooth and covered with soft cloth, such as billiard felt, outing flannel, flannelette, or imitation chamois, or flocked or suede rubber sheeting. Where cloth is used, holes on the dye surface should be avoided and an application of medium grease may be advisable. The form should be provided with a base or some other means to hold it at a comfortable working level. It also should be somewhat larger than the finished piece. This precaution permits the use of slightly oversized sheets, which not only simplifies handling, but also compensates for the slight tendency of the plastic to curl away from the form, and to flare the edges. It is also helpful to mark a trimmed line on the form, indicating the limits of the finished piece.

32 The form should be provided with some means of holding the edges of the acrylic plastic sheet against the form. In some cases, flat rubber bands fastened to the form block, so that they can be snapped over the edges of the formed piece, will exert the necessary pressure. In other cases, it is well to provide a wooden yoke, or frame, the lower edge of which is contoured to fit the forming block at a point

just outside the trimmed line of the piece. This yoke should be hinged or otherwise fastened to the form so that it will fit exactly when pressed down on the hot plaster. This ring may be the exact size and contour of the piece, so that when the plastic has cooled, the piece may be scribed on the form around the inside of the ring. The sheet should not be scribed, however, until it has cooled, since it will contract the ring cooled. In an emergency, it is often possible to make forms from plaster using the broken panel itself as a mould in which to test plaster. The broken panel is taped securely together and its inside surface well greased with vaseline or soap. Sand is packed around the outside surface to provide adequate support, while the plaster is poured and allowed to set. Forms should be stored carefully when not in use to avoid denting or chipping, as such defects may show up in the formed plastic when forming is resumed. Wooden forms should be stored in a dry place to avoid warpage.

Two Dimensional (Drape) Forming

33 Remove all masking paper from the plastic before heating performance. If after unmasking, the sheets become dusty or dirty, rinse well with distilled water; or if ordinary tap water is used, dry the sheet thoroughly by blotting with soft tissue paper. Any solvent in ordinary tap water will dig into the plastic surface if this precaution is not taken. Wearing soft cotton gloves, remove the hot plastic sheet from the oven, and lay it carefully over the form. Edges of the sheet should be held against the form, either by hand or by means of hold-down rings, or yokes, until the sheet has thoroughly cooled. Cooling may require ten minutes to half an hour, depending on room temperature and the thickness of the sheet.

Three Dimensional Forming

34 Parts with compound curves may be formed from acrylic sheets by several different methods, or occasionally by combinations of these methods.

Stretch Forming (Manual and Mechanical)

35 Many compound shapes can be made by stretching the heated plastic sheet across the form. Heat the sheet slightly hotter than for drape forms. Fasten a number of wooden carpenter's clamps or anchor clamps to the edges, six to ten inches apart. Holding the sheet by these clamps, draw the sheet down around the form. For some shapes, one edge of the sheet may be clamped to the form with carpenter's clamps, anchor clamps, vice clamps or C clamps, and the sheet stretched over the form from the other edges. Since five to ten men may be required for the stretching, depending on the size and thickness of the piece and the extent of the stretch, the form must be well built and firmly mounted. Care must be exercised to keep the stretching of the sheet as uniform as possible. A metal ring can then be clamped in position around the edges, leaving the crew free to work on another form. This method has the advantage of requiring a minimum of equipment and is, therefore, desirable where only a few replacement parts are to be made.

Male and Female Forming

36 For compound shapes of irregular contour, such as those with reading, fluting, steps, etc, male and female forms may be used. Stretch the hot sheet across the top of one form, usually the female, and hold in position with clamps while lowering the other form into place. As above, do not use high speeds and high pressures, since both tend to increase the extent of bolt marks or mark-off on the plastic sheet. The basic objection to this type of forming lies in the fact that both surfaces of the plastic sheet come in contact with the mould surfaces and the chances for mark-off are therefore doubled.

Pressure and Mechanical Methods of Moulding

37 Various mechanical methods of moulding plastics are in general use throughout industry. These employ the use of various pressure systems, vacuum systems, hydraulic presses, pneumatic presses, etc, but these processes will not be detailed in this order as they are not generally common within the Service.

CEMENTING

Fitting

38 For a satisfactory joint, the two pieces to be cemented together should fit accurately. In butt joints, for example, both edges must be made true and square before starting a cementing operation. It is also preferable to cement flat surfaces rather than curves. It is, therefore, advisable to route or sand curved sections to present flat surfaces before cementing. Where two curved surfaces must be

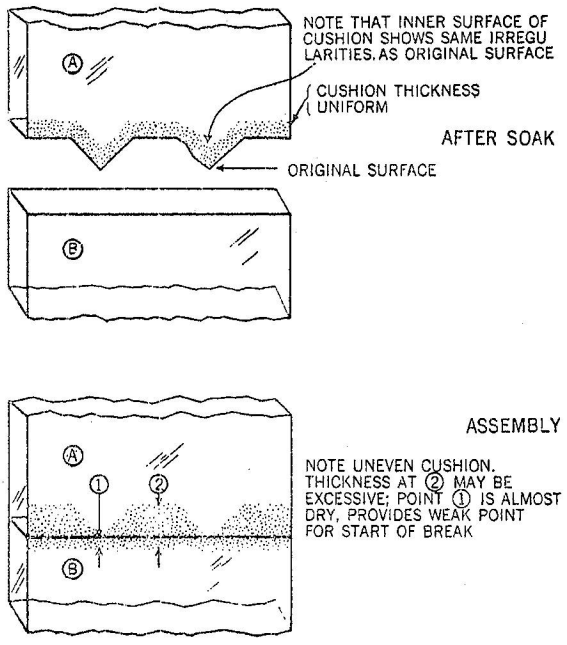

Figure 3-10 Irregularities in Joint Caused by Cementing Rough Surfaces

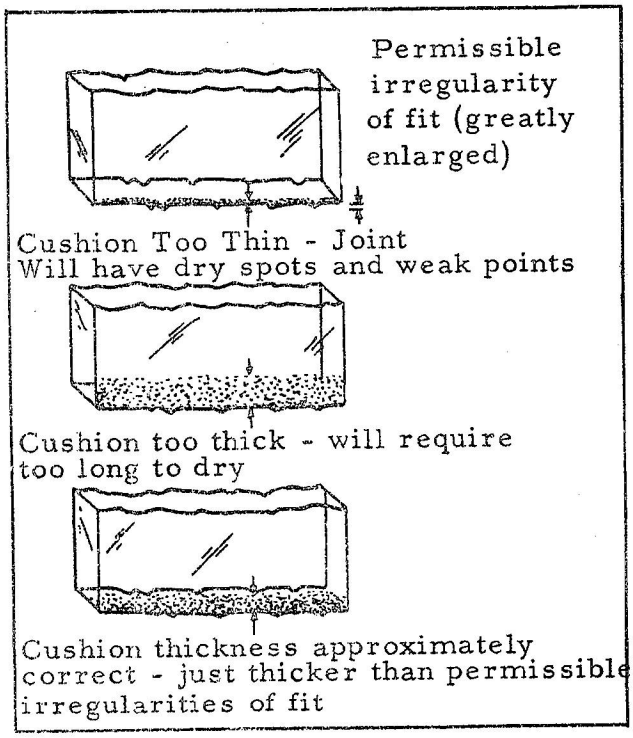

Figure 3-11 Proper Cushion Thickness Depends on Soaking Time

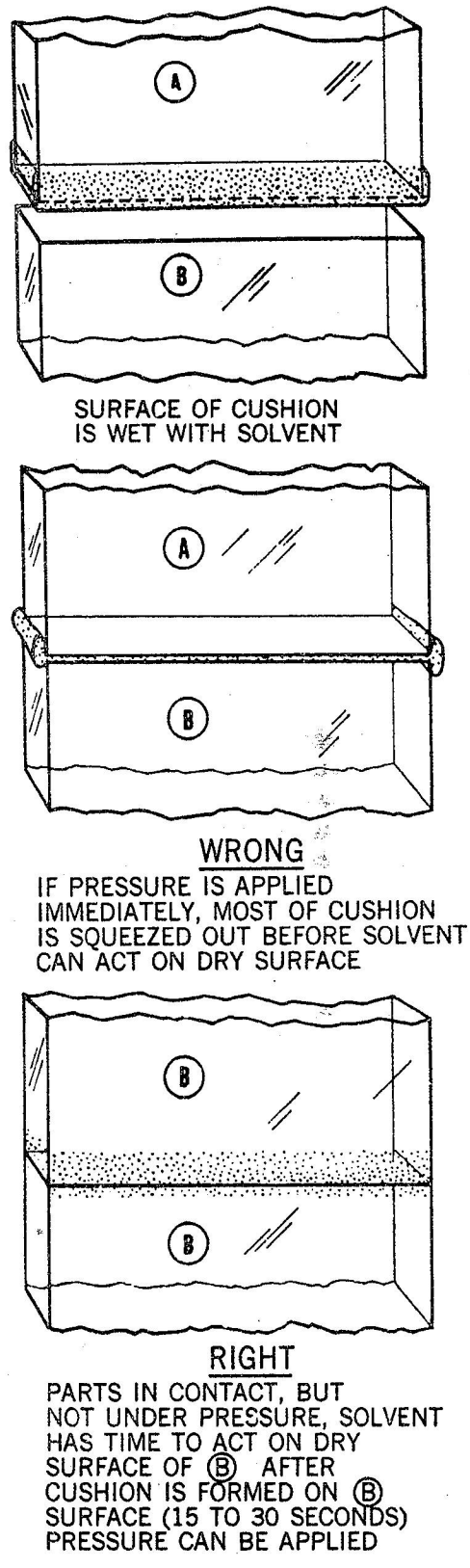

Figure 3-12 Cement on Cushion of Piece "A" Must Form a Cushion on Piece "B" Before Applying Pressure

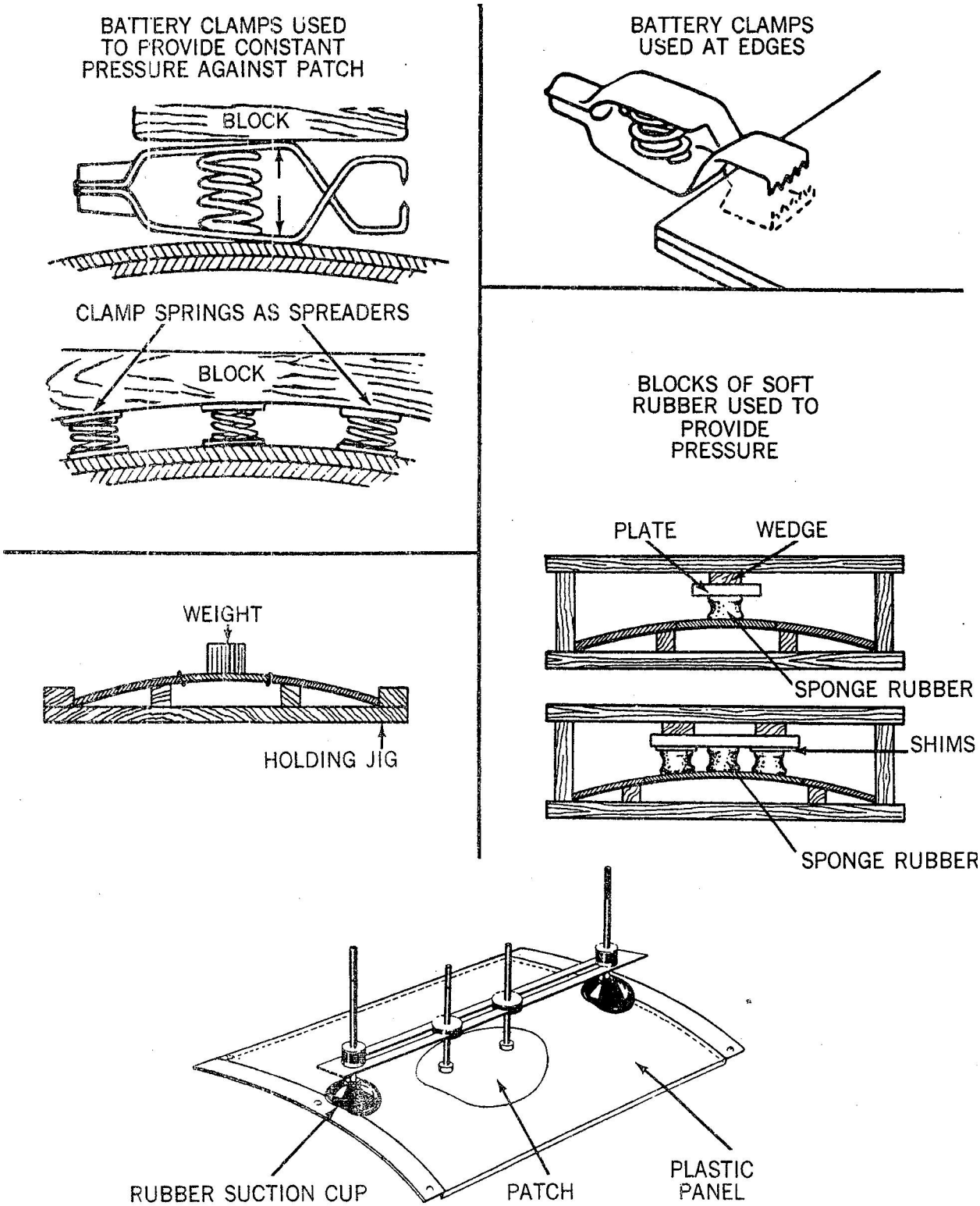

Figure 3-13 Typical Jigs Used to Hold Cemented Assemblies Together During Setting

cemented, as in overlapped joint and two curved sections, the curves of both should be same radius. It should not be necessary to force either piece more than a small fraction of an inch out of shape in order to make the surfaces come in complete contact.

Finishing

39 The two surfaces should have a fairly smooth finish. It is not necessary that they be polished. Surfaces should at least be sanded smooth. The reason is apparent when one realizes that the solvent penetrates at an even rate on every point on the exterior surface. It, therefore, translates the texture of the original surface to the inner limit of cushion. If the exterior surface is irregular, the cushion is uneven in thickness when it is pressed against a smooth surface (see fig. 3-10). For example, the cushion may be completely extruded where there is a projection on the first surface. This forms weak points along the joint at which a break can occur. just as paper tears along a line of perforations.

Masking

40 To confine the softening of the cement to the area of the joint, it is necessary to mask surrounding plastic. For this purpose, use a tough paper or cellophane tape impervious to the action of the cement and back with a pressure sensitive adhesive. It is important that the tape be well applied, particularly at the edges and that enough overlap (approximately 1/4") be allowed so that the cement does not seep under the edges and attack the plastic to be protected. Be sure that the edges are firmly attached and there are no air bubbles beneath the tape. The tape should not be applied until ready to cement, for it may pull away from the joint or come loose if allowed to stand too long.

Soaking

41 The function of the cushion formed by the cement is only to permit intermingling of the two surfaces to be bonded . The liquid on the cushion, surface, not the cushion itself, is the bonding agent. The size of the cushion need be no greater than necessary to obtain intimate contact. Although no arbitrary soaking time can be set, an average of about fifteen minutes in normal cement will form a cushion deep enough to take care of normal permissable irregularities of fit (see fig. 3-11). It should be remembered that the deeper the cushion, the longer the drying time and the more of the solvent that will be trapped in the joint. On the other hand, too thin a cushion may not give good contact of the surfaces, and the joint may have dry spots and vapour bubbles in it. The cushion, therefore, should be somewhat deeper than the maximum allowable irregularities of fit.

Assembly

42 The interval between the soak tank and the assembly of the joint is perhaps the most critical of the whole cementing operation. As stated before, it is not the cushion but the liquid on the cushion surface that affects the bounding. Since these liquid cements evaporate quickly, it is necessary that the joint be assembled as quickly as possible. If the cushion surface is allowed to dry or if it is wiped free of this liquid before the joint is closed, apparently sound joints may result under pressure, but when the pressure is removed, the joint may break open, or will at best have poor strength, since there was no liquid left on the cushion to form a cohesive bound. Therefore, the soak tank should be near the cementing operation and the job or jigs should be so arranged that the operator can assemble the two parts accurately with a minimum of delay. If the interval between soaking and assembly is too long and the cushion surface dries or crusts over, it should be wet again with solvent, using a small pan of solvent and a brush placed near the cementing jig. It is, however, important to allow a slight interval between the time the two pieces are placed in contact and the time pressure is applied. During this interval, the liquid surface of the cushion will be absorbed by the opposite dry surface. If, however, pressure is applied immediately, this liquid is at least partially squeezed out of the joint (see fig. 3-12). Ordinarily fifteen to thirty seconds is a sufficient interval.

Jigs

43 In many cases, the success of a cementing job depends on the design of the jigs holding the two sections in place until the joint is hard. The jig should keep the two pieces firmly together but should not force either of them out of shape. Under the latter conditions, the action of the cement on the stressed part is almost certain to cause objectionable crazing.

44 The pressure should first be large enough to squeeze all air bubbles from the joint and

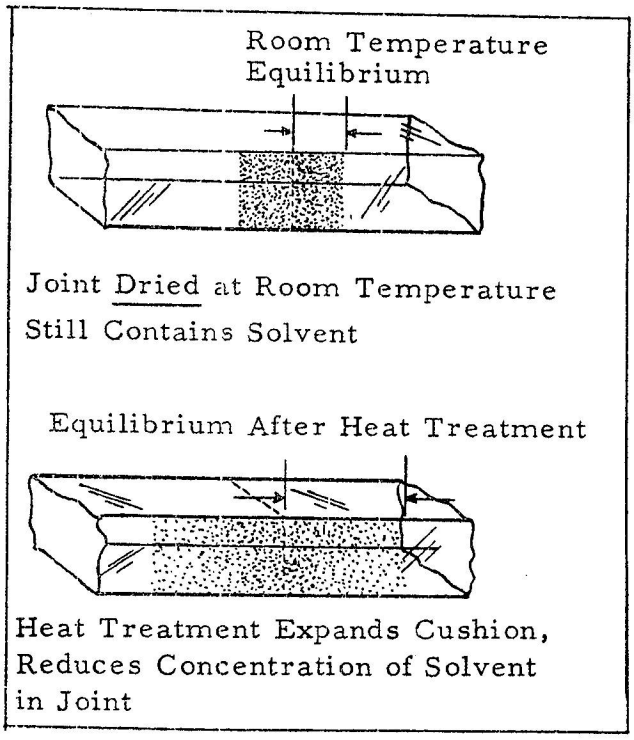

Figure 3-14 Effect of Heat Treating a Cemented Joint

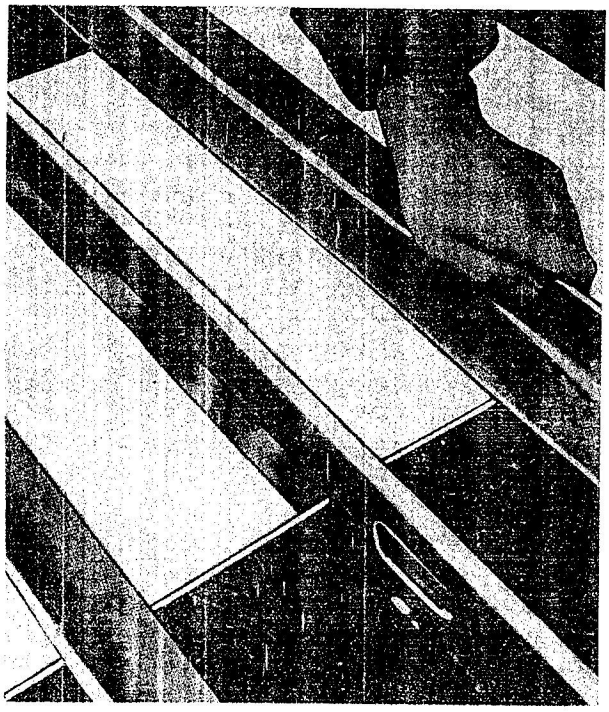

Figure 3-15 Heating Edges of Acrylic Sheets Prior to Heat Welding

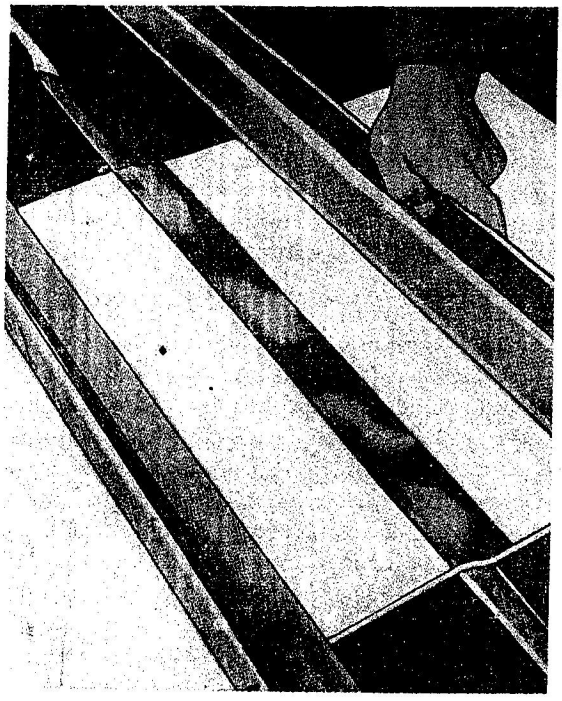

Figure 3-16 Heat Welded Joint With Lateral Pressure Applied

assure thorough intermingling of the cushions; second, be applied evenly all along the joint to avoid stress concentration at any point; and third, should be maintained to compensate for the shrinkage that takes place in the joint during setting or hardening. Since the swelling action of the cement in forming a cushion causes an increase in volume, the cushion will shrink as the solvent evaporates. If the two pieces are attached so rigidly that they cannot move together while drying, the cushion, as it shrinks, draws the extruded material or feeds back into the joint. The joint will then be marked with a curve or dimple, or even by air bubbles. The three vital conditions are best met by using spring clips (spring clothes pins or battery clamps) either alone or in conjunction with wood or metal jigs (see fig. 3-13). For cementing a rib in position, for example, the jig would be applied with a bar directly above the rib; then, between the bar and the rib, battery clips would be inserted at about two-inch intervals. For most joints an arbitrary figure of approximately ten pounds per square inch has been found satisfactory, provided, however, that this pressure does not force either of the parts appreciably out of shape. Excessive pressure should be avoided in order to avoid localized stress concentration which would cause crazing.

45 When placing the assembly in the jig, and at intervals thereafter, it is advisable to examine the joint carefully. If slipping is noted before the joint has set, the pressure can still be readjusted or the job taken apart for reassembly. After the assembly has been locked in its jig, any excess cement and cushion which has extruded from the joint should be removed by scraping the excess on the masking tape and then removing the tape. This simple procedure is especially recommended in right angle, over-lap or rib joints wherever there are corners in which the cement can collect. By working carefully and by cleaning the joints promptly, it is possible to save a great deal of sanding and polishing time putting the joint in order.

46 The assembly should be allowed to stand in its jig at least four hours and an additional four hours should elapse before the assembly is subjected to handling or given heat treatment.

Curing and Heat Treatment

47 A solvent joint does not dry; that is, it will never become entirely free of solvent. If left at room temperature, the solvent in the cushion will penetrate to a certain depth and no further. In other words, an equilibrium of solvent and plastic is established that remains practically stable at any fixed temperature. If the temperature is raised, the cushion will slowly enlarge until a new equilibrium is reached. On cooling, the cushion will be larger and correspondingly harder if it contains less solvent per unit of volume. Heating a solvent joint long enough to expand its cushion to a new equilibrium will, therefore, produce a much stronger joint (see fig. 3-14).

48 Heat treating of cemented joints must, however, be undertaken with caution. Heat first activates the solvent which softens the cushion. The cushion then slowly expands as the solvent penetrates the material. If the plastic at that point is thin, or if the original cushion is already too large, this expansion may cause serious weakening of the section. In heat treating, it is also important that the temperature used should not approach the softening point of acrylic plastic nor too far exceed the boiling point of the cement. Suitable treatment would consist of forty-eight hours at 50°C (122°F). If, however, this temperature causes undue dimensional changes in intricate assemblies, it may be desirable to heat treat at 45°C (113°F) for ninety-six to one hundred and sixty-eight hours. Within these limitations, it can be said that the strength of a solvent joint depends on the highest temperature to which it has been subjected. For example, if an untreated joint is heated by direct sunlight, the cushion is softened and the joint may be dangerously weakened. If, however, the joint has already been heat treated, its strength will not fall below a safe limit when slightly reheated.

49 Heat treatment offers an additional advantage if the cement contains monomer. The same process (polymerization) by which this liquid becomes solid in the casting of acrylic plastic sheets takes place when the joint is heated. In other words, the monomer hardens into acrylic plastic, increasing the strength of the joint.

50 Whether or not the joint is heat treated, it is important that it be thoroughly hardened before machining, sanding or polishing to remove the bead. The softened material in the joint continues to shrink until it has fully set. If the joint is trimmed or sanded too soon, a visible recessive scar will be left along the joint.

Summary of Cementing Procedure

51 Strict adherance to the following summarized points should result in strong and durable joints:

(a) Both pieces to be joined should fit accurately without forcing.

(b) The surfaces to be cemented should be polished or at least be sanded or machine smooth.

(c) The area around the joint should be masked against the etching action of the cement, using a tape impervious to the cement.

(d) Use only an approved cement. For convenience, clean acrylic plastic shavings can be added to make a syrup cement which can be handled like glue.

(e) Dip one of the two pieces of plastic in cement for approximately fifteen minutes until the surface has softened into a "cushion".

(f) Assemble the two pieces QUICKLY, so that the cement on the surface of the cushion will soften the opposite, dry surface of the other piece.

(g) Allow the two pieces to come in contact for a short interval (fifteen to thirty seconds) before applying pressure to allow the second cushion to form.

(h) Clamp the two pieces together (by means of spring clips, clothes pins or a jig incorporating springs) under just enough pressure to assure intermingling of the two cushions. This pressure need not be great and should be distributed evenly along the joints.

(j) Clean the joint promptly by scraping excess cement and extruded cushion onto the masking tape and removing the tape.

(k) Allow the assembly to stand in the jig at least four hours.

(l) After an additional four hours, the assembly should be heat treated forty-eight hours at 50°C (122°F).

(m) Remove excess cement, clean and polish the joint.

HEAT WELDING

52 It is possible to bound acrylic plastic sheets together by the use of heat and pressure. The process is quick and simple and use joints that are transparent and approximately as strong as the original material. The probable mechanism of the process is that the plastic decomposes into minomer when brought in contact with a very hot metal surface. The surface quickly becomes semi-liquid, soft and wet with monomer. If two such semi-liquid surfaces are immediately brought together with sufficient pressure for them to intermingle, an excellent bond is formed.

Equipment

53 The equipment necessary for heat welding acrylic plastic consists essentially of a means of quickly heating the two areas to be joined simultaneously to a temperature of 350°C (660°F) and the means of holding the two sections together at a pressure of approximately two hundred and fifty pounds per square inch until cool. A convenient heating medium consists of an electrical resistant strip of stainless steel, with a rheostat to control its temperature. It should be held in a frame designed to keep it hot when in use. The voltage and amperage necessary to obtain the required temperature will vary depending on the size and shape of the strip. With a 30 x 2 x .069" blade, for example, a heavy duty transfer with a secondary output of 456 amps and 3 volts is used.

54 Suitable jigs should be arranged to hold the two sections to be joined in rigid alignment. Otherwise, since the plastic around joint becomes heated and soft, the two sections will be forced out of line when pressure is applied. Lateral pressure can be applied to the two sections to be joined by screws, bracket pinion, air cylinder or hydraulic presses. Whichever means is used, should be quick acting and preferably reversible. In addition, it is desirable to confine the joint under pressure by bringing polished metal or transite to bear on the top and bottom of the joint. This vertical clamping action should not be taken until the full lateral pressure has been applied. Simpler equipment, such as soldering irons or electric plates may be used in special cases, provided they develop the required temperature throughout the area to be bounded.

Butt Welding

55 Joints properly made at the proper blade temperature 350°C (176.6°F) have a strength very nearly that of the material itself. If the blade is cooler than 300°C (570°F) the acrylic plastic does not decompose enough to form a liquid surface; and if hotter than 400°C (750°F) the monomer vaporizes so rapidly that there is insufficient liquid left on the surface to form a bound. The temperature of the blade should be checked frequently with a pyrometer.

56 The two acrylic plastic sheets to be joined should be held rigidly in line by a jig set as close to the edges as possible. The heated material next to the joint becomes soft and will not remain accurately aligned under pressure unless properly supported by the jig. When the sheets are thus aligned, the hot blade is brought between the two plastic edges and the joint is closed on the blade until through this pressure and the softening of the material against the blade, a perfect contact between the two edges and the blade is established all along the blade (see fig. 3-15). The pressure is then released

so that the liquified surface is not extruded as it liquifies. At this point, edges of the material should be boiling and soaking slightly. In general, a joint should be heated only long enough to establish perfect contact and to this bubbling condition (approximately thirty seconds). If it is heated any longer, the adjacent material is too deeply softened and will be formed too easily under subsequent pressure.

57 The heating blade is then withdrawn and the edges brought immediately together under a spring or dead-weight pressure of about two hundred and fifty pounds per square inch of joined area and maintained until the entire joint is cool below forming temperature (see fig. 3-16). The material immediately adjacent to the joint is soft and forms under this pressure pushing outward as a rounded ridge or beads. If pressure is not maintained until the joint is cool, the distorted material will tend to return to its original shape, tearing or tending to tear apart. Experiments have shown that if pressure is released before the joint is cool, this shrinking fact of the material decreases the tensile strength of the joint from 10 to 15%. Further, if a distorted joint is plane smooth and then repeated, a groove is formed by the shrinking fact of the remaining material.

58 These disadvantages can be overcome by confining the joint above and below the weld. Two rigid non-heat conducting surfaces, placed on either side of the joint and pressed against it after lateral pressure is applied, reduce distortion. This confining of the joint not only makes it possible to polish the joint immediately, but reduces loss of strength if the joint is heated for forming.

59 An important point is to allow the joint to cool as slowly as practicable. The plastic expands when heated. If cooled too rapidly, the surface becomes rigid forming a shell over the still hot interior. This uneven cooling sets up severe internal strains in the material. Thus, chilling not only tends to make the joint brittle but creates a tendency to crease. If cooled slowly as in a confined joint, it is impossible to obtain a joint with a minimum of stress.

60 Heat welded joints will contain dirt unless blade and plastic are kept clean. When proper precautions are taken, however, the resultant joint is very nearly invisible and has the advantage of immediate full strength without the delays, complicated jigs and hazards of the conventional solvent joints. It is apparent that many variations of the welding technique are possible, depending on the type of joint and its strength requirements. Many different heating elements may be used and various jigs may be devised to apply the low pressures required.

FINISHING

61 The process by which acrylic plastic sheeting is manufactured results in a product which has a highly polished perfectly transparent surface. Because the material is relatively soft as compared to glass and because it is thermo plastic and softens under the influence of heat, any sanding or buffing operation which is carried out to remove a surface blemish may result in an ultimate finish of poorer than that of untouched sheeting. For this reason, it is important that acrylic plastic be handled carefully during fabrication and servicing so that unnecessary finishing operations can be avoided.

CAUTION

Under no circumstances should astrodomes, sighting panels or other critical optical parts be sanded or polished. Such sections should always be replaced when scratched.

SANDING

62 Under no circumstances should sanding be employed when ordinary buffing can be used to remove the blemish. Furthermore, sanding should not be employed unless some type of mechanical buffing equipment is available, since hand polishing is not sufficiently effective to restore polish to a sanded surface.

Hand Sanding

63 Where sanding is indicated, the finest sandpaper that will remove the scratch or other defect (no coarser than #320) is used first. This is wrapped around a felt or felt covered wooden block and the defective area rubbed lightly, using water or a 2% soap solution as a lubricant. Use of soap will speed and improve the sanding operation. The abrasive paper should be of waterproof type. Light pressure should be used and the strokes should be circular, not straight back and forth. An area having a diameter of about two to three times

the length of the defect should be sanded in order to minimize optical distortion and excessive thinning (see fig. 3-17). The initial sanding should be followed by similar treatments using successively finer grades of sandpaper grits in the following sequence: 360A, 400A and 500A or 600A. During each step, the deeper scratches left by the preceding grade of abrasive should be removed. As regards the evidence of the effect of such small surface fractures on mechanical strength, impact test bars and bend test bars of acrylic plastic were scratched in certain directions, the depth of the scratch measured and then the specimens tested for impact and flexural strength. It was found that in general, scratches on the compression side made no difference to impact and flexural strength. Scratches made on the tension faces in the direction of the tension stress gave no measurable effect on the strength but scratches perpendicular to the direction of the tension stress on the tension face were very critical and curves were obtained relating depth of the scratch to change and strength. In the case of impact strength with scratches across the width of the tension face, it was shown that a rapid drop in strength first occurred followed by a less rapid drop; the two parts forming an "elbow" in the curve. This elbow appeared at 50% of the unscratched value for impact strength and for scratch depth, the elbow corresponded to roughly 0.02 inches, when 1/2 cross section test pieces were used. As regards bend strength at about the same scratch depth, a similar elbow appeared in the curve, but at about 70% of the unscratched sample strength.

Machine Sanding

64 The same general procedures used in sanding apply to sanding with power driven sanding machines. The same succession of sandpaper grits is used. The generous use of water as a lubricant is especially necessary to dissipate frictional heat. Extremely light pressure is to be used. Sanders are used in a variety of types, including stationary and portable belt sanders, reciprocators or vibrators, disc and flexible shaft operated drum sanders. The belt sander consists of an endless belt (in widths up to twelve inches and a wide variety of alignments), rotating over two drums and is usually used for edge sanding. A disc sander is simply a rotating disc usually mounted in a vertical plane to which is cemented a disc of sandpaper. A flat table is provided in front of the disc to serve as a rest for the work being sanded. Flexible shaft sanders are usually fitted with a number of different shapes and sizes of sanding covers and drums. These are generally used for edge sanding rather than surface sanding. For surface sanding, portable sanders having an orbital motion are preferred. Such sanders consist of one or more moving pads, covered with the desired grade of grits, which in some cases may be inflated to give slightly rounded sanding surfaces.

CAUTION

Power sanders should only be used where the severity of the defect is such as to require excessive hand sanding. Only flat surfaces or surfaces with a radius of curvature greater than thirty-six inches should be so treated. Machine sanding tends to flatten curved surfaces of small radii, thereby producing excessive optical distortions and thinning out.

ASHING

65 An alternative to sanding is ashing, which involves the use of a thick abrasive paste on a cloth-wheel. In this operation, speed and pressure are critical factors. It is essential that both be held within limits to prevent over-heating of the plastic. Over-heating will result in poor finish and in extreme cases formation of drag-marks on the surface. As a further precaution against over-heating, the plastic or the wheel should be kept in constant motion with relation to the other. For ashing, a wheel speed of approximately 900 surface feet per minute is recommended.

MACHINE BUFFING

66 Single or double spindle buffing blades are suitable for ashing and buffing plastic sections that can be easily manipulated. For larger parts, portable flexible shaft (either electric or pneumatic driven) machines are useful. Wheels for ashing and polishing may vary in diameter from six to twenty-four inches, depending on the nature and size of the work. For the preliminary removal of sanding, filing or scraping marks, a relatively hard ashing wheel is recommended and it should consist of stitched cotton cloth discs. For polishing and buffing, a softer unstitched wheel is needed. The wheels themselves are approx-

imately half the diameter of the discs used for buffing. Canton or Domet flannel or muslin make excellent material for polishing wheels.

67 In order to remove the scratches caused by sanding or ashing if either of these operations is used, the plastic is buffed. It is often possible to remove scratches by buffing alone. However, deep buffing resulting in localized heating of the sheets, known as "buff burn" should be avoided. It is important that the surface of the plastic be carefully washed between successive finishing operations to prevent the transfer of coarse abrasive to buffing wheel. For buffing, surface speeds of 2000 surface feet per minute are recommended.

68 If the buffing wheels have been used before, remove any hardened tallow by running them against a metal edge. Start wheel spinning and apply the stick of tallow to the wheel for a few seconds. Then bring the bar of buffing compound in contact with the edge of the wheel for a few seconds. Apply the edge of the spinning wheel to the plastic surface lightly. Keep it moving over the surface and put only light pressure on the buff. Excessive pressure may heat and soften the plastic. Buff along and across any scratch. Continue buffing until all scratches have been removed. Wipe the buffing compound from the plastic surface and apply a coat of wax as described in para.70 below.

HAND POLISHING

69 In emergencies, when buffing equipment is not available, a good cleaner or polish can be applied by hand to remove light scratches, and other minor imperfections. Use a soft damp cloth such as soft fibre cloth, imitation chamois, glove lining or outing flannel or flannelette. The area to be polished should be washed free of dirt and grit and rubbed vigorously with the polish. Precaution should be taken not to rub too long in one place. Rub with a free circular motion over a fairly wide area. Several applications of cleaner may be necessary.

WAXING

70 To finish to a high polish and to protect the surface, use a good paste or water emulsion wax. This final application is usually done by hand. Most polishing waxes will effectively fill tiny hair scratches and make them less apparent. The wax also imparts a protective coating to the plastic. Wax should be applied with a soft cloth in the same manner as polish.

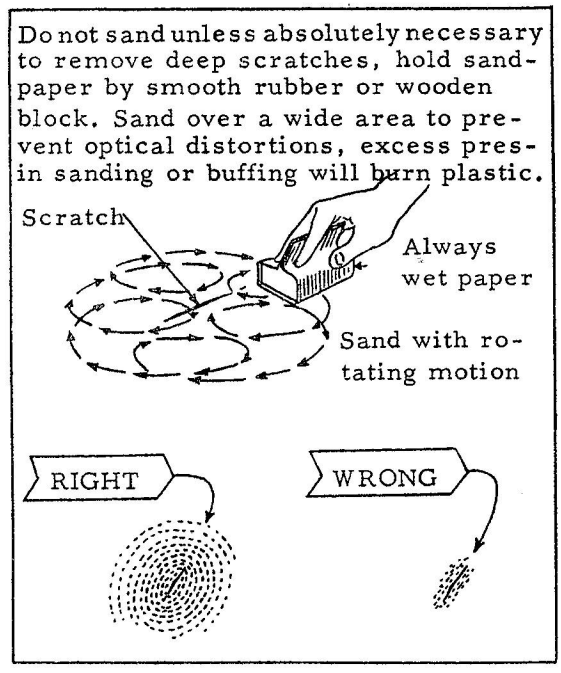

Figure 3-17 Proper Method of Sanding Acrylic Plastics

PART 4

TABLE OF CONTENTS

REPAIR PROCEDURES

SECTION 1

ACRYLIC PLASTICS

1 The materials used in the maintenance and repair of acrylic and acetate base plastics are detailed in Table 1 of this Engineering Order. In general, repairs to acrylic plastic panels are at best only make-shift methods and usually result in serious impairment of clear vision characteristics. They should be considered for temporary use only and damaged sections should be replaced as soon as possible. No attempt should be made to restore warped or shrunken panels to shape. If panels become distorted due to weathering, they must be replaced. Small repair patches may be remoulded by application of heat and light pressure, but the temperature should be closely controlled. 100°C (212°F) is the correct temperature for remoulding patches up to 1/8 inch thick and 110°C (230°F) for remoulding panels over 1/8 inch thick. The former will require three to four minutes heat, while 1/4 inch material will require about thirty minutes heating. No attempt should be made to completely remould distorted panels, since the application of heat, necessary for the process, causes shrinkage and it is liable to result in the panel becoming partially opaque after the repair has been effected. Panels of acrylic plastic are subject to slight changes in area due to temperature variations. A permanent shrinkage of 0.1% in linear dimensions is usual after continued exposure to sunshine, and a further temperature shrinkage may occur during conditions of extreme cold. For this reason, holes drilled in acrylic plastic panels, for the purpose of receiving fixing screws, bolts or rivets are given a clearance which may be from 1/16 inch to 1/8 inch or more in diameter according to the size and estimated linear contraction of the panel. Care should be taken when replacing transparent panels to ensure that these clearances are retained.

REMOVAL OF SCRATCHES

2 To remove deep scratches from the acrylic plastic panels, the procedure as outlined in Part 3, para. 10, of this order should be followed. For removing light surface scratches, use only the last two grades of paper (500 and 600) and otherwise proceed as in Part 3, para. 10 of this order. Care should be taken when using abrasives to prevent the formation of flats which will cause optical distortions. After the scratches have been removed, the material should be polished. As previously mentioned, all cloths or pads used for polishing must be quite clean and free from grit and must not be used for any other purpose; any that have been dropped on the ground or the bench should be discarded. It is important that no solvent should be used in a cleaning preparation and to guard against mistakes it is advisable not to use any cleaning preparation or polish unless it is definitely known NOT to contain any such solvent. Paraffin may safely be used in emergency for cleaning acrylic plastics but gasoline should not on any account be used as it may contain an aromatic hydro-

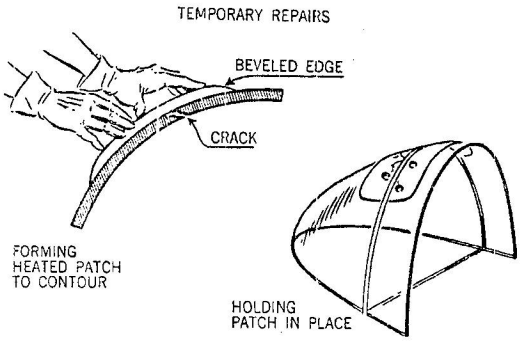

Figure 4-1 Overlay Patch to Reinforce a Crack

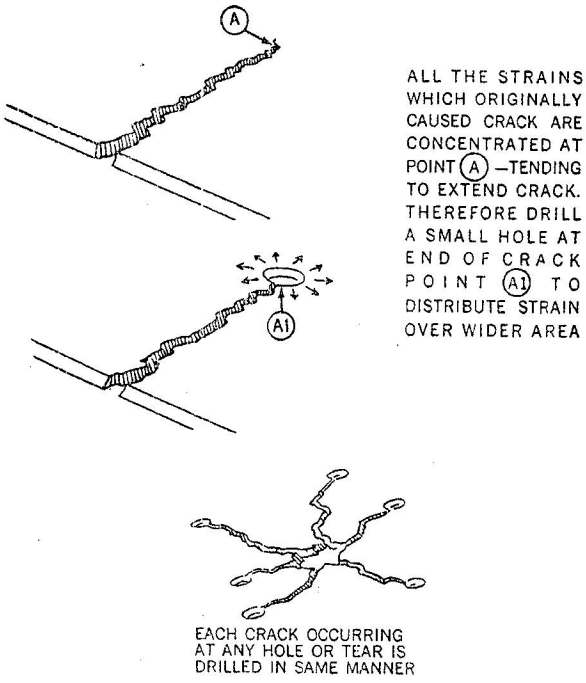

Figure 4-2 Drill Holes at End of Cracks to Reduce Stress Concentration

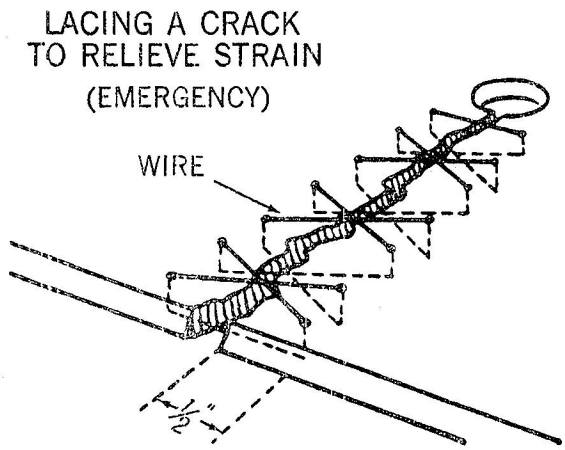

Figure 4-3 Lacing a Long Crack With Flexible Wire

carbon such as benzol which is a solvent of the acrylics.

PATCHING

3 The repair by patches of damaged panels of acrylic plastic may be grouped into three categories: Patches secured by screws or rivets; inlay patches secured at the edges by an adhesive; and overlay or lap joints secured by an adhesive (see fig. 4-1). Cemented lap joints should not be used in any position where clarity of vision is essential, since the use of an adhesive on the surface of acrylic plastic tends to produce a minute greasing effect which cannot be removed. For emergency repair of cracks and holes, small holes should be drilled at the end of each crack (see fig. 4-2) to relieve stress concentration and prevent further lengthening of the cracks. In the case of long cracks, a series of small holes may be drilled along both sides through which soft wire is laced (see fig. 4-3). Acrylic plastic may be satisfactorily remoulded for the purpose of making patches only, by the application of heat and light pressure. The temperature should be closely controlled. 100°C (212°F) is the correct temperature for remoulding material up to 1/8 inch thick and boiling water is a suitable medium for applying the heat. 110°C (230°F) is the correct temperature for remoulding material over 1/8 inch thick, emersion in oil or glycerine being a suitable method of applying the heat. The time required for the material to become heated through is dependent on its thickness, 1/8 inch material requiring three to four minutes while 1/4 inch material will require about thirty minutes. When in the softened condition, a patch may be moulded by pressing it against the curved panel to which it is to be fitted or by pressing it into a mould made of wood or white metal. The pressure on the patch should be maintained until the material has cooled to room temperature and the material should be quite cool before attempting to polish it after heating. Moulded repair patches should not be used in positions where clear vision is necessary as instances have been recorded of transparent material becoming partially opaque after remoulding.

Patches Secured by Screws or Rivets

4 Transparent patches secured to acrylic plastic panels by mechanical means may be of the same material or of a cellulose acetate base plastic. For panels up 5/32 inch in thick-

ness, a patch of 3/64 inch material may be used; for panels of greater thickness, the patch should be of 5/64 inch material. In all instances, patches should be applied to the inside surface of the panel to minimize air resistance and erosion of the joint.

5 The holes for screws or rivets should be drilled at intervals of one inch to two inches and should not be less than 1/4 inch from the edge of the patch. Rivets should be of the tubular or semi-tubular pattern, and should be 3/32 inch for 1/8 inch diameter. The rivet holes for 3/32 inch diameter rivets should be drilled 7/64 inch diameter (#35 drill) and those for 1/8 inch diameter rivets should be drilled 9/64 inch diameter (#28 drill). Patches may be secured by bolts or by set-screws. When bolts are used, fine clearance holes should be drilled in both patch and panel. Set-screws require clearance holes in the patch and a tapping hole in the panel. The set-screw is passed through the hole in the patch and screwed tightly in the panel, after which the projection end should be cut off and filed flush. Repairs may be weather-proof by filling cracks and spaces with one of the approved cements.

6 Transparent patches secured by mechanical means to panels which are slightly curved in one direction only will not require moulding to shape. Where patches must be sharply curved, or curved in two directions, the instructions given for moulding patches (see para. 1 of this section) should be followed.

Inlay Patches Secured by Cement

7 For the repair of sight panels, the use of inlay patches is ideal, but it calls for a high degree of fitting skill. Good results can only be obtained if the edges to be joined mate perfectly, otherwise air bubbles will appear in the finished joint which will be weakened and its transparency impaired. The method of repair by inlay patches may be conveniently divided into information for filling circular holes up to one inch or two inch diameter and information for filling larger holes.

8 Small holes, up to one inch or two inch diameter should be made circular. Such holes may be cut with a drill, a trepanning tool, a centre-bit, or a washer cutting tool. Since the centre of the drill or bit will normally coincide with the centre of the original hole, a solid centre must be provided for the tool. For this purpose, a short strip of the material of which the panel is made should be cemented across the hole with cement. If such material is not available, a bridge piece may be made from a strip of any similar material or of hard wood, and temporarily bolted to the panel. If the bridge piece is fixed on the reverse side of the panel to that from which the drill is to be introduced, it will act as a location until the boring operation is completed, but if this is not convenient, the bit may with care be made self-locating once the cutting is well started and the severance of the bridge piece will not matter. The edge of the hole should be bevelled to the full thickness of the panel at an angle of three degrees to enable the inlay patch to be fitted in the form of a wedge and thus prevent it from falling through the hole in the panel during the fitting and cementing process. The bevel should be formed so that the inlay patch is inserted from the side of the panel which receives air pressure during flight; the tendency will then be for the patch to be forced more securely against the panel.

9 An even firmer method of securing an inlay patch is to bevel the sides of the hole in the panel for half the thickness of the panel from each side. Two inlay patches are then fitted, each half the thickness of the panel, one from each side. The two patches are cemented together during fitting so that they become in effect a single plug able to resist pressure from both sides. The material from which an inlay patch is to be made must always be the same as that of the panel, and of the same thickness, except in a special instance where a plug is made from two laminations, each half the thickness of the panel.

10 Circular blanks of the material for inlay patches may be cut by means of a tubular cutting held in the chuck of a drilling machine and used at a cutting speed of about four hundred feet per minute. An oil emulsion coolant should be used. The blank must be beveiled around the edge to its full thickness at an angle of three degrees and carefully mated up to the hole it is required to fit. Smooth files and the blade of a penknife or other sharp light cutting tool should be used to obtain smooth flat fitting surfaces. As the practicable size of circular inlay patches will not exceed two inches diameter, the normal curvature of a transparent panel

should not be subject to preclude their use, but where the curvature is complex, use of discs will be impractical and repair will be only possible by means of overlay patches. Before cementing a patch in a panel, all trace of oil or grease should be removed from the surface and the patch by cleaning in methylated spirits. The edges or surfaces to be joined should be rubbed with durex emery cloth, using plenty of water; there is no need to polish these surfaces. The cementing of the patch in place should be carried out as detailed in Part 3, para. 8, of this order. The joint after repair should be clean of all surplus adhesive by using durex emery cloth with plenty of water. Finally polish as previously detailed. Initial creasing of the plastic surface may occur at the joint, but this effect tends to disappear leaving a comparatively clean and clear union.

11 Repairs by inlay patches requiring insertions larger than two inch diameter discs should be effected by cutting a hole in the panel to a rectangular or square shape with rounded corners and shaping a piece of the same material as the panel to suit the hole. As with circular patches, all edges should be bevelled three degrees and the mating surfaces finished with the utmost care. In cutting away the edges of the damaged material preparatory to fitting a patch, it should be remembered that horizontal lines must be cut outside the line of sight. The procedure for fitting, cementing and cleaning rectangular and square patches is the same as in para. 10 above.

Overlay Patches Secured by Cement

12 Overlay patches on flat transparent panels require little fitting skill. If possible, the damaged area should be trimmed away before patching. A piece of plastic of sufficient size to cover the damaged area is cut to size and the edges bevelled. If the section to be repaired is curved, the patch should be formed to the same contour.

13 The patch may be softened by heating and suitably shaped by pressing it directly over the area to which it is to be applied. When held in place until cool, a good fit is assured. The inner surface of the patch may then be treated with cement and pressed into position. Slight pressure should be maintained on the patch by weights or clamps until the cement hardens. An alternative method of holding the patch in place is to place a "bridge" over the patch, the ends of the bridge being fixed to the solid plastic outside the patch by means of suction cups. A screw in the centre of the bridge serves to apply light pressure to the patch. The third method necessitates drilling a hole in the centre of the patch. Through this hole, a long screw is inserted carrying a larger washer which serves to distribute pressure uniformly over the patch. To the other end of the screw (inside the enclosure) is attached a wooden or metal "spider" which rests against the undamaged plastic and serves to anchor the screw so that it may be tightened thus applying pressure to the patch. The joint when dry should be cleaned of all surplus cement by using Durex emery cloth with plenty of water. Finally polish as previously detailed.

Butt Joints with Overlay

14 The edges of the panels to be joined should be milled to ensure that the meeting surfaces are parallel. The panels should be brought together until a gap of only 1/16 inch remain between their edges. This gap can be maintained by laying the panels on a sheet of black paper coated with paste. An overlay strip of similar composition and thickness to the panels and 3/4 inch 1 1/2 inch in width should be cut and laid in position on the panels to be joined. The surfaces of the panel immediately on either side of the strip should be covered with masking tape to protect them from the cement. The strips should then be removed and an excessive amount of cement, should be poured on the margins of the panels on which the strip is to be placed and in the 1/16 inch groove, care being taken to prevent the formation of bubbles. The joints should then be made by placing one end of the strip in position and gently lowering the remainder until contact is made along the entire length of the strip. A light pressure should be applied with the fingers to remove air bubbles and excess cement, the latter being scraped away from the edges of the strip. After approximately one hour, the backing paper and masking tape may be removed and the joint baked for twenty-four hours at from 40°C to 60°C (104°F to 140°F).

Butt Joints Without Overlay

15 The panels to be joined should first be milled on their edges so as to leave a groove 1/16 inch wide on each side of the assembly when the two panels are brought together.

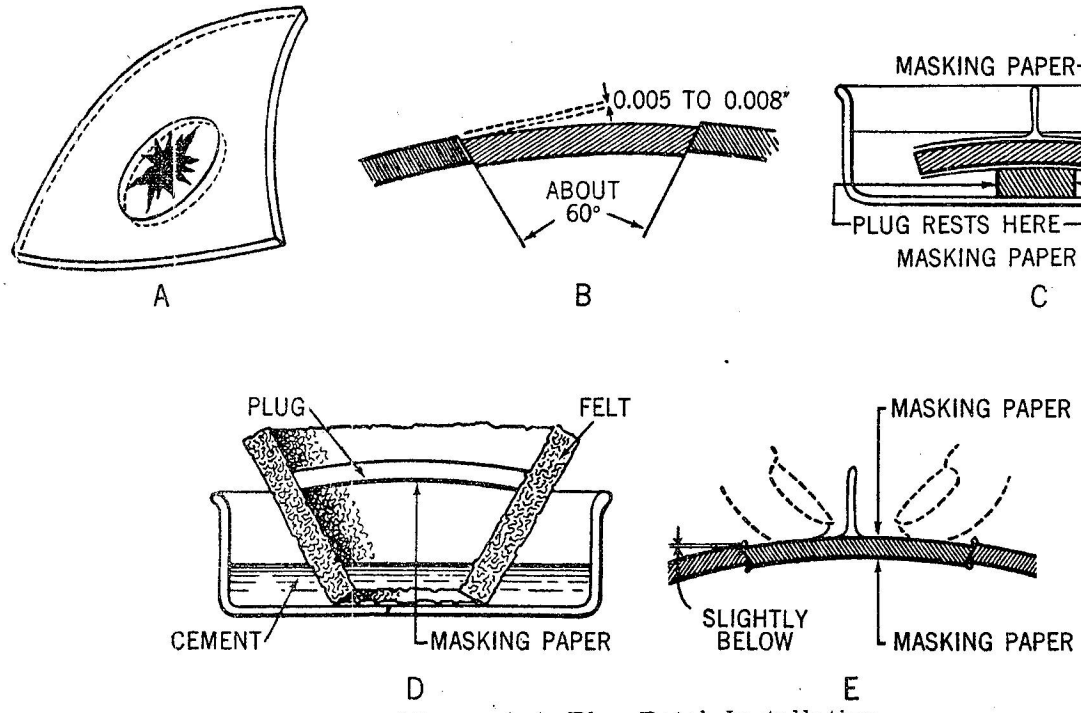

Figure 4-4 Plug Patch Installation

Masking tape should be used as described in para. 14 above. Backing paper, if used, will have to be removed and replaced by masking strips after the initial drying of the joints in order to run the cement into the 1/16 inch groove on the underside of the panels. In other respects, the procedure is similar to that outlines in para. 14 above. Butt joints without overlay should only be used where no increase in thickness can be permitted.

Repair of Holes and Cracks

16 Acrylic plastic up to a certain temperature (roughly 50°C to 60°C (122°F to 140°F) behaves as a glass like hard solid and once a fracture has started in it, little extra energy is needed to propagate the fracture through the bulk; ie, its resistance to crack propagation is low. Therefore, in the failure of a structure, the critical stage in the process of the failure is the initial development of a surface crack in the structure. Cracks in a transparent panel should be prevented from spreading by burning a hole at each end of the crack with a 1/16 inch diameter hot wire or needle. The crack should be covered by cementing a strip of acrylic plastic over it. This may be accomplished by either of two methods. The first method is to cut a strip of the transparent material 1/2 inch wide and long enough to cover the crack plus 1/4 inch overlap at each end of the crack. With the covering strip in position, and using a No. 27 drill, drill a hole through one end of the crack and through the strip. Repeat at the other end of the crack and if the length of the crack is more than three inches, drill one or more intermediate holes of the same diameter through both the crack and the strip. Apply cement to the hole of one surface of the strip and to the area it covers surrounding the crack and clamp the strip to the panel by means of two or three small bolts and washers through the holes. When the cement has set, remove the bolts and washers, tap the holes and plug with shredded pieces of acrylic plastic which have been dipped in cement. Clean and polish the surface. The other method is to cut a strip of the transparent material two inches wide and long enough to cover the crack plus about one inch overlap at each end. The strip should be bolted or rivetted to the panel in the manner described in paras. 4-11 above, the holes for the screws or rivets being drilled well clear of the crack in the panel.

17 Where holes having radiating cracks, repair the holes with a circular inlay patch. At the extremity of each crack, drill and tap a hole and plug with a shredded piece of acrylic plastic which has been dipped in the cement. Paint the crack with a solution of the cement and when it has set, clean and polish the surface.

18 Owing to its brittle nature, acrylic plastic should only be drilled when the hole is to be plugged or filled with a cemented patch. Otherwise holes should be forced with a hot wire or needle.

Cemented Fabric Patch

19 Badly fractured areas may be reinforced in an emergency by cementing a layer of strong fabric over the damaged section. Rubber cement, clear lacquer or acetate soap (at risk of crazing) may be used as an adhesive.

Plug Patch

20 Another effective patch for temporary repairs is the plug patch shown in Fig. 4-4. The damaged area should be removed by cutting a circular hole in the panel and bevelling the edges, as shown. A plug is cut and bevelled to fit. If the panel is curved, the material from which the plug is to be cut should be formed to the existing curvature and cemented as discussed previously.

SECTION 2

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CELLULOSE ACETATE PLASTIC

1 No attempt should be made to remould distorted panels, since the application of heat necessary for the purpose causes severe shrinkage and is liable to result in the panel becoming partially opaque after the repair has been effected. Distorted panels should be replaced by new ones at the earliest opportunity. In general, the repair procedures used on cellulose acetate base plastic are similar to those in Section 1 for acrylic plastic.

Removal of Scratches

2 Scratches may be removed from the surface of cellulose acetate base plastic by means of various grades of abrasive paper and by initial and final polishing in exactly the same manner as that detailed in Section 1, para. 2, of this Part. In addition, the final polishing of cellulose acetate base plastic may be effected by means of a cellulose polish. The cleaning fluid may be made up by adding a small quantity of a plasticizer, such as triacetin, to a liquid which is not a solvent to the acetate. The use of such a fluid has the effect of checking the deterioration of the acetate in hot climates. In emergency, paraffin may safely be used for removing grease from a cellulose acetate base plastic.

MATERIALS

3 Table 4 lists the various sizes of sheeting available as well as other materials which are recommended for use in the fabrication and repair of acrylic and cellulose acetate base plastics.

Comments

4 One of the chief differences between acrylics and acetate base plastics lies in the nature of the cements used. Because of the different chemical composition of the two materials, different solvents are required. In general, these cements are two types, the solvent type and the dope type (see Table 4).

5 The solvent-type cement is generally used where transparency must be maintained in the joint. It is relatively quick drying and hence is well adapted for use in making emergency repairs. The drying time will vary with the size of the joint and atmospheric conditions. Normally, from six to ten hours are allowed for thorough drying. Acetone may be used as a solvent-type cement.

6 The dope-type cement is preferred for use where the surfaces to be joined do not conform exactly. This cement softens the surfaces of a joint and at the same time creates a layer between the pieces being cemented. It does not yield a transparent joint, however, and is slower drying than the solvent type. From twelve to twenty-four hours must be allowed for the joint to reach full strength.

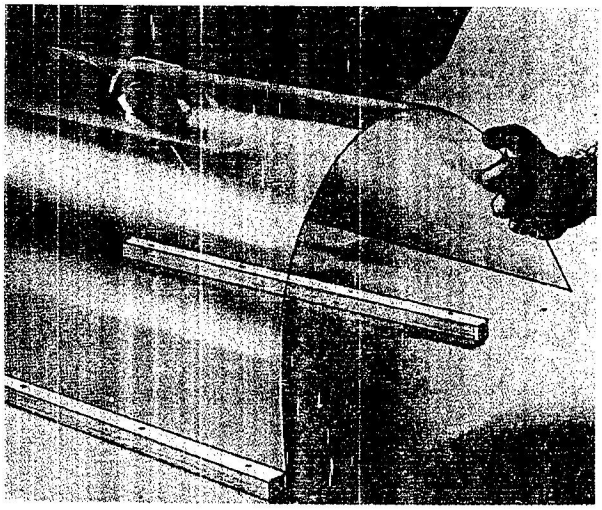

Figure 4-5 Cold Forming Cellulose Acetate Base Plastic

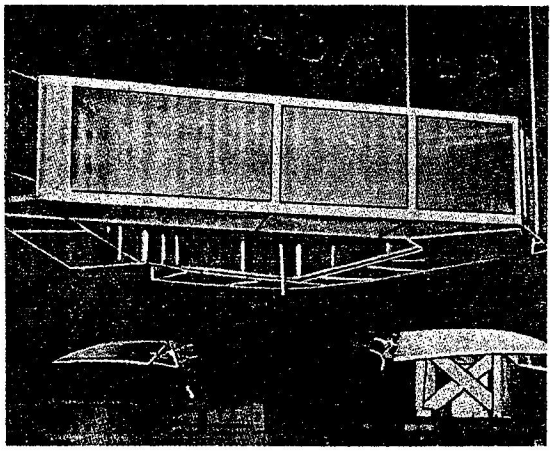

Figure 4-6 Heating and Cooling Ducts Used in Forming Cellulose Acetate Sheet

FABRICATING PROCESSES

Machining Operations

7 Cold dry cellulose acetate sheets have a tendency to chip during machining. For best results, sheeting should be conditioned for about twenty-four hours at a temperature between 27°C and 32°C (80°F and 90°F) and a relative humidity of about 55%. If water is used as a lubricant, it should be used sparingly, since acetate base plastics absorb moisture more readily than acrylic.

Cutting

8 Where extremely close tolerances are required, an automatic metal shearing device may be employed. For thin sheets, ordinary hand type tin shears are satisfactory.

Forming Techniques

9 Cellulose acetate plastic may be formed cold if the curvature is of a simple nature and does not have a radius less than seventy times the sheet thickness (see fig. 4-5). Sheets should not be cold formed below a temperature of 27°C (80°F). Care should be taken in every case to avoid cracking or crazing. The correct temperature for hot forming cellulose acetate plastic will be between 121°C and 138°C (250°F and 280°F). The heating time should range between four and twelve minutes for sheets from 3/32 to 1/4 inch. Sheets must not be heated over 138°C (280°F) to avoid the reappearance of tiny sheeter lines which are inherent in the plastic, and which will impair the optical quality of the sheet. Particular care should be observed in this operation, since forming temperatures are much more critical for acetate plastics than for acrylics. High pressures must be avoided in forming hot cellulose acetate sheets to prevent transferring marks from the surface of the form block to the surface of the plastic. A square chamber containing a heating unit and a fan is suspended above the form to blow hot air on the sheeting while it is being formed. Cold air ducts may also be provided to accelerate cooling of the sheet (see fig. 4-6). Men working under these conditions should be careful about breathing highly heated air.

PATCHING

10 The general directions for the repair of panels, as detailed in Section 1, are applicable to cellulose acetate base plastic. These panels must be repaired with cellulose acetate base plastic patches in every instance where a cement is used. The cement used must be one approved for this type of material. Where the repair patch is secured by screws or rivets, the patch may be of either cellulose acetate base plastic or acrylic plastic. The cellulose acetate base plastic may be drilled with less risk of cracking than the acrylic plastic.

Preparation of Patch

11 A hole is cut in the damaged panel extending beyond any radiating cracks in the material. The patch should be circular or oval and in no case have sharp corners. If the panel

to be patched has a curved surface, the patch should have the same curvature. A curved patch is made by heating a piece of cellulose acetate in an oven about 135 to 138°C (275 to 280°F) for three to ten minutes, depending on thickness, until sufficiently soft and then forming by hand over the part of the panel to be repaired or over the same part of a similarly curved panel. The edges are then machined or filed and scraped to a taper of about 30°. The plug of similar shape is cut from a sheet of material or from a piece previously formed to match the contour of the panel. The edges of the plug are machined or filed and scraped to a taper matching that of the edges of hole until the plug fits perfectly in the hole with the upper surface from 0.005 inches to 0.008 inches below the surface of the panel. The plug and panel should be marked with a china pencil so that the plug may be properly relocated. The patch is now ready for cementing.

12 The plug after being fitted is covered on both sides with a double thickness of acetate to within 1/32 inch to 1/16 inch of the edge and then completely emersed in acetone for five to six minutes. The tape should be pressed smoothly and tightly to the plastic;particularly around the edge so that the acetone cannot leak underneath and mar the surface of the plug. On some curved surfaces, it is preferable to use overlapping strips of tape, rather than a single width, to avoid folds and buckles. If masking tape or paper is not resistant to acetone, they must be made so. In this case, the masking paper is fitted on both sides of the plug to 1/4 inch of the edge and is then painted with molten paraffin to within 1/32 to 1/16 inch of the edges of the plug. When the masked plug is put into the acetone bath, it should not be supported by its edges which will become soft during soaking. While the plug is emersed in the acetone, the edges of the hole should be painted several times with acetone and finally given one coat of cement. The plug is then put back in the hole in the same position as originally fitted, using a pencil mark as a guide, and press down by hand with sufficient pressure to force out air bubbles without squeezing out an excessive amount of the softened material. The plug should come to rest with its top surface slightly below the top surface of the panel.

13 After three to five minutes, the panel is placed in a holding jig in which the plug is held under uniform pressure for sixteen to twenty-four hours. Pressure may be applied through sponge rubber blocks. springs or weights. It is important that the pressure during the setting period be sufficient to prevent the formation of bubbles and be uniformly distributed over entire area of the joint. This can usually be accomplished on curved surfaces by use of cardboard shim between the rubber blocks or springs and the pressure placed on the holding jig to made the compression of each the same. For emergency patches, after fitting the plug, the edge of both plug and hole are simply painted with acetone for a few minutes and then with one coat of cement. The plug is then set in place and pressure as previously described. The bound is not as strong as obtained by the above method in which the joining surfaces are more effectively solvent by the acetone.

Finishing

14 After the panel is taken from the holding jig and the cement has thoroughly hardened, the patch area is scraped, wet-sanded and buffed to the level of the patch. These operations should preferably be done first in one direction and then at right angle. Buffing is done first on hard wheel using a cutting compound and then on a soft wheel with a wiping compound to bring out the polish.

PART 5

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MAINTENANCE OF TRANSPARENT PANELS

GENERAL

1 Vision is so vital in aircraft that proper day to day maintenance of transparent enclosures is of prime importance. Not only should proper maintenance methods be carried out thoroughly whenever vision is impaired by dirt or scratches, but every effort should be made to eliminate scratching or fingerprinting in the course of servicing the aircraft.

CLEANING EXTERIOR SURFACES

2 Flush with plenty of water, using the bare hand gently to feel and dislodge any dirt, salt or mud. Wash with soap and water. Be sure the water is free of dirt or other possible abrasives. A soft cloth, sponge or chamois may be used in washing, but only as a means of carrying soapy water to the plastic. Go over the surface only with the bare hand so that any dirt can be quickly detected and removed before it scratches the plastic surface.

3 Dry with a clean camp chamois preferably. However, a soft clean cloth or soft tissue may be used if care is taken not to continue rubbing the acrylic plastic after it is dry. Remove oil and grease by rubbing lightly with a cloth wet with kerosene or hexane.

CAUTION

Do not use the following materials on acrylic plastic: gasoline, jet fuel, alcohol, benzine, acetone, carbon tetrachloride, fire extinguisher or de-icing fluids, lacquer thinners or window cleaning sprays, because they will soften the plastic and cause creasing.

4 Do not rub the acrylic plastic with a dry cloth since this is not only likely to cause scratches but it also builds up an electro static charge which attracts dust particles to the surface. If the surface does become charged, patting or gently blotting with a clean damp chamois will remove this charge as well as the dust.

5 If after removing dirt and grease, no great amount of scratching is visible, the plastic should be waxed with a good grade of commercial wax. These waxes will fill in minor scratches and help prevent further scratching. The wax should be applied in a thin even coat and brought to a high polish by rubbing lightly with a soft dry cloth, as described in Part 3, para. 10, of this Order.

6 If after removing dirt and grease, the plastic surface is found marred by scratches, apply an approved polish by hand; or if buffing equipment is available, buff out the scratches as described above. A buffing wheel mounted in a portable electric drill may be used for this purpose.

CAUTION

Do not attempt either hand polishing or buffing until the surface is clean. If dirt, grit and sand are present during these operations, they may cause more serious damage than the original scratches. Since even skilful sanding, buffing and polishing introduce slight optical distortions, these operations should not be performed on navigator astrodromes, gun turret sighting panels, and similar critical optical parts. These parts should be washed and waxed only. If they are damaged by a number of deep scratches, they should be replaced.

CLEANING INTERIOR SURFACES

7 Dust the plastic surface lightly with a soft clean cloth. Do not WIPE the surface with a dry cloth.

8 Wipe carefully with a soft damp cloth or sponge. Keep the cloth or sponge free of grit by rinsing frequently in clean water. Apply wax as described above.

HOT CLIMATE PRECAUTIONS

9 To prevent distortion of plastic enclosures in hot climates, it is recommended that doors and windows of aircraft be opened slightly to permit free circulation of air through the cabin when the aircraft are parked out under the direct rays of the sun. This will assist in preventing a high temperature condition on the inside of the plane that might soften the plastic sheets.

10 In general, sunlight has very little effect on acrylic plastic. Therefore, covers need not be used as a protective measure unless there is danger of sand storms which will cause abrasion of the plastic sheets, or unless covers are required for camouflage purposes. In any case, covers should not be drawn tight over the enclosure since the pressure may distort the panel. It is preferable to allow room for the circulation of air between the cover and the plastic.

PART 6

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INSTALLATION PROCEDURES

GENERAL PRINCIPLES

1 There are a number of methods of installing plastic panels in aircraft. Which method the aircraft manufacturer uses depends on the position of the panel on the aircraft, the stresses to which it will be subjected and a number of other factors. In installing a replacement panel, follow the same mounting method used by the manufacturer of the aircraft.

NOTE

Where difficulty is encountered in rivet installations, bolts may be used in installing replacements when the manufacturers original design permits.

2 When subjected to large stresses (over a 1000 lbs. per sq.in.), acrylic plastics are apt to craze, lowering the transparency and strength of the panel. It is of prime importance, therefore, that these plastics be mounted and installed so that such stresses are avoided. Close examination of crazing suggests that it is likely to have the same effect on strength as scratching. In a heat treated sample in which the centre portion was painted with a solvent whilst under bend stresses, by looking through the edge, it can be seen that craze lines penetrate into the bulk of the material.

3 Never force any acrylic plastic panel out of shape to make it fit a frame. Acrylic panels are reasonably flexible but if they are forced into a frame, high or unequal stresses will be set up in certain areas of the panel. If a replacement part does not fit easily into the mounting, obtain a new replacement or heat and reform the old panel.

CAUTION

Do not heat and reform limited areas of the panel, for local heating methods are apt to be only superficial and not thorough enough to reduce stress concentrations.

4 In clamping or bolting acrylic panels into their mountings, do not place the plastic under excessive compressive stress. In other words, it is easy to develop more than 1000 lbs. per sq.in. on the plastic by drawing up the bolts "good and tight". Tighten each nut to a firm fit THEN BACK IT OFF ONE FULL TURN.

5 In bolt installations, spacers, collars, shoulders or stop nuts should be used to prevent tightening the bolt excessively. Wherever such devices are used by the aircraft manufacturer, they should be retained in the replacement installation.

6 To help prevent stress concentrations in the plastic, the aircraft manufacturer may use

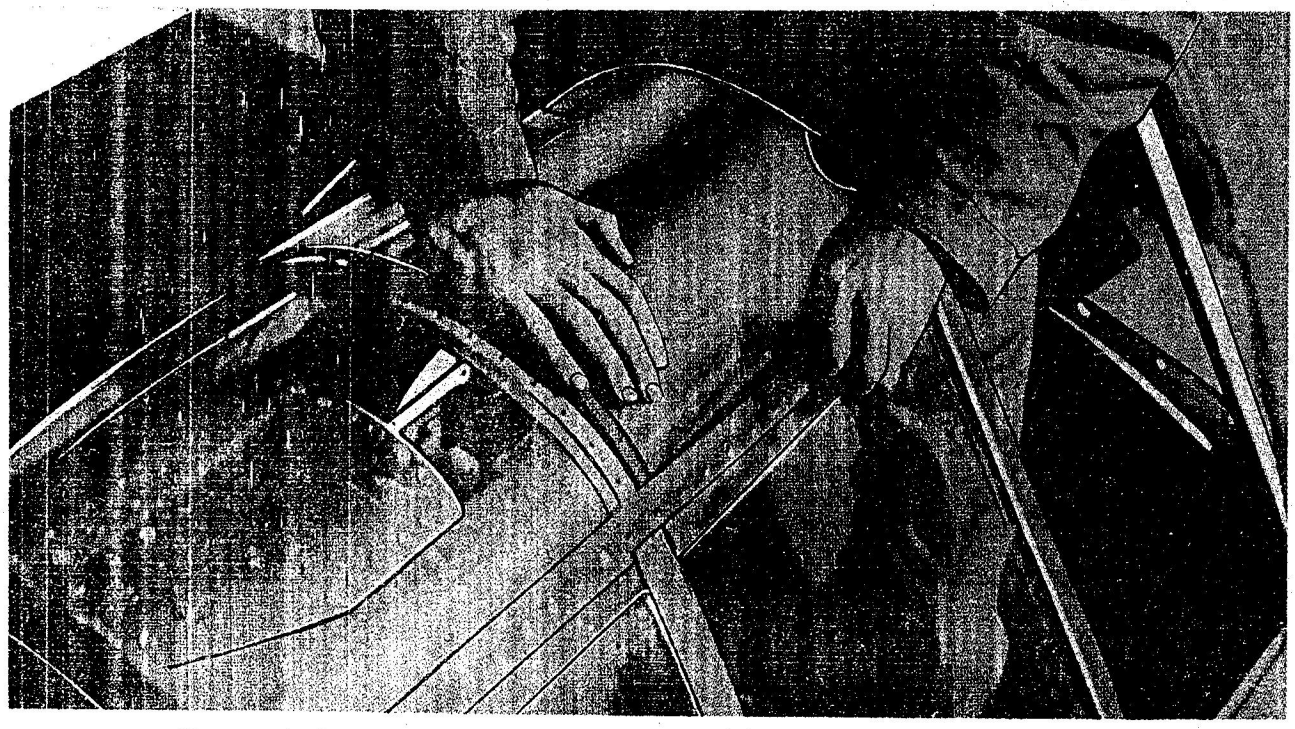

Figure 6-1 Wrong: Replacement Panels Should Fit Without Forcing

a number of bolts in a given installation. In making replacements, it is important that the same number of bolts complete with washers, spacers, etc, be used.

7 Acrylic plastic panels should be mounted between rubber, cork or other gaskets to make the installation waterproof, to reduce vibration and to help to a limited extent to distribute compressive stresses on the plastic (see Part 2 para. 9 of this order).

8 Since acrylic plastics expand and contract approximately three times as much as the metal channels in which they are mounted, suitable allowance for dimensional changes with temperatures must be made.

(a) Clearances of 1/8 inch minimum should be allowed all around the edges of the panel.

(b) If the installation involves bolts or rivets, the holes through the plastic should be oversize by 1/8 inch diameter and centered so that the plastic will not bind at the bolts. In large self supporting parts, such as nose sections, gun turrets, etc, old holes should be elongated radially.

(c) Panels should be mounted to a sufficient depth in the channel to avoid danger of falling out when it contracts at extremely low temperatures or when the panel is flexed. When the manufacturers original design permits, panels up to twelve inches long should be mounted to a minimum of 3/4 inch. Larger panels should be mounted to a minimum depth of 1 1/8 inches.

CHANNEL AND CLAMP MOUNTINGS

9 Wherever possible, avoid bolting or rivetting through holes drilled in the plastic channel. Clamp installations are definitely superior in distributing stresses.

10 In this type of mounting, the principal precautions are:

(a) The channel should be oversize to permit free linear expansion and contraction of the plastic relative to the frame.

(b) When installing acrylic plastics, care should be taken to keep the clamping action uniform over all the area clamped.

(c) The channels should be deep enough to hold the plastic securely despite flexing and thermal contraction. A safe rule is that plastic panels up to 12 x 12 in. in area should extend into the channel a minimum of 3/4 in. larger panels 1 1/8 in. minimum.

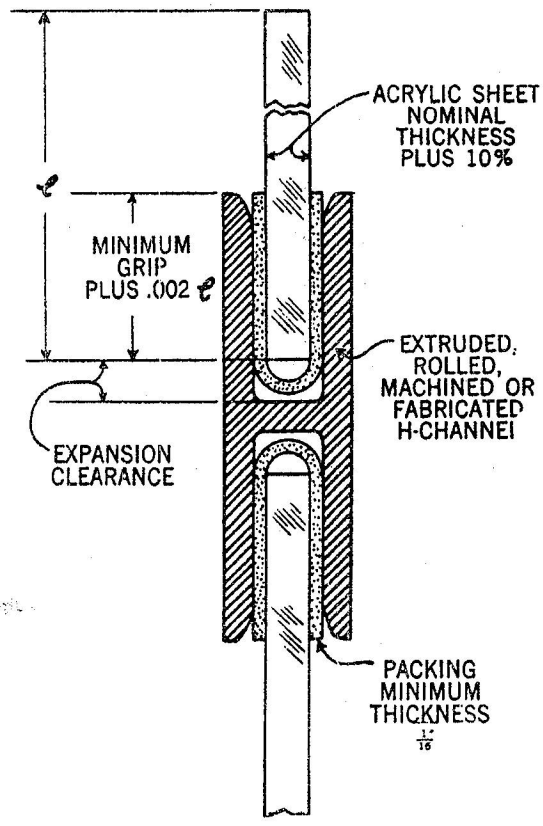

Figure 6-2 Simple Channel Installation

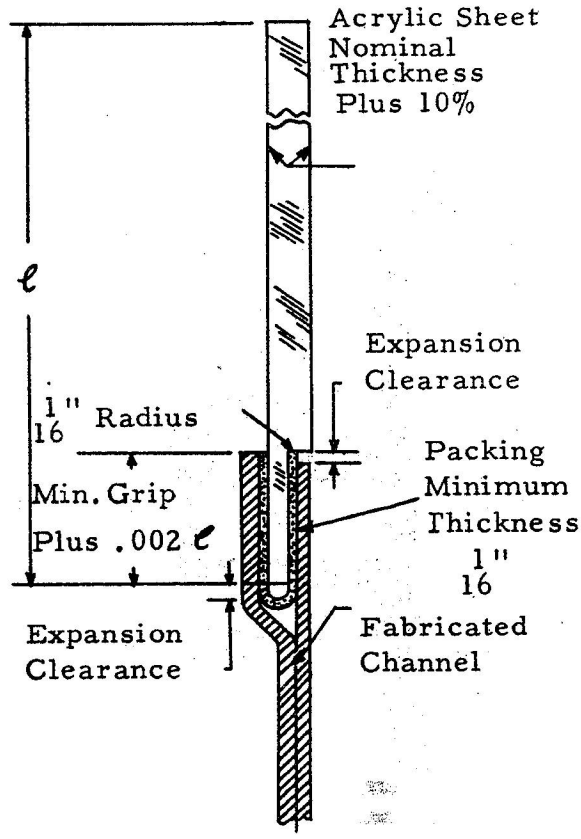

Figure 6-3 Channel Installation With Edge Routed to Permit Flush Mounting

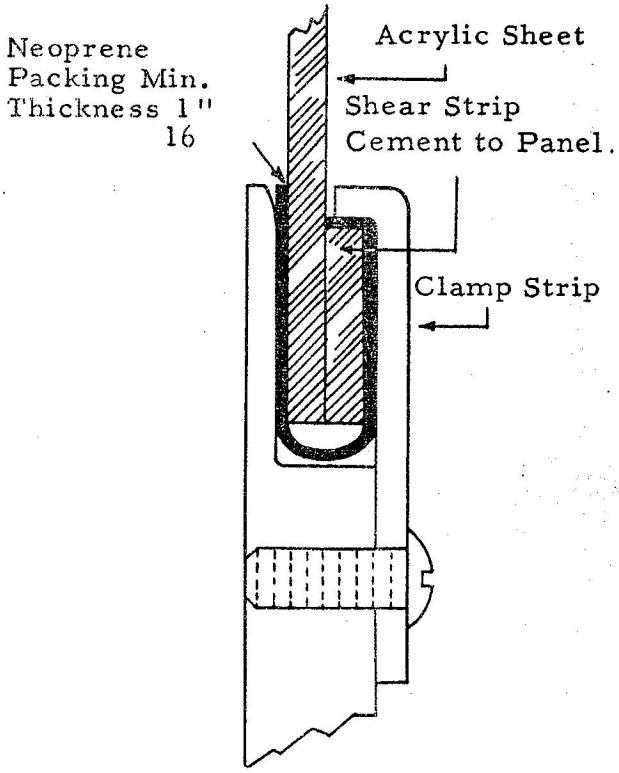

Figure 6-4 Clamp Installation With Reinforcing Rib

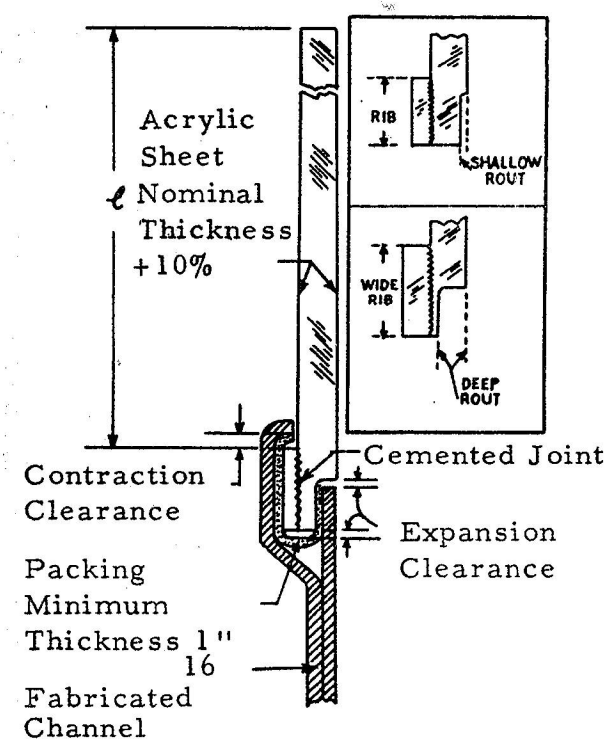

Figure 6-5 Clamp Installation With Reinforcing Rib Routed to Permit Flush Mounting

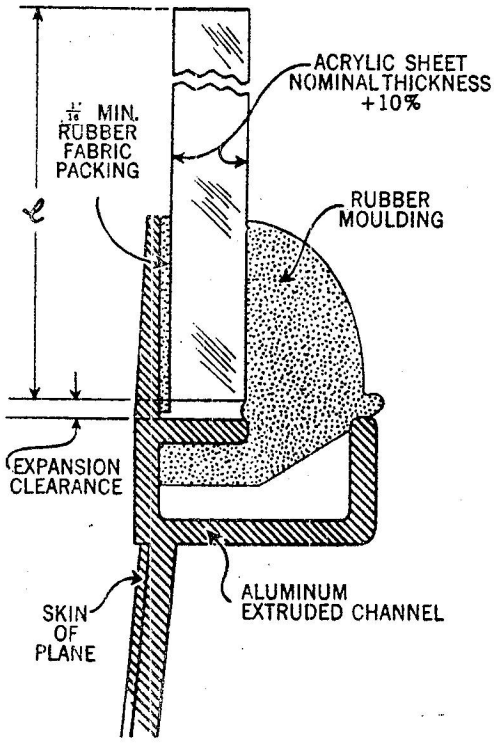

Figure 6-6 Patented (Hunter Sash) Mounting

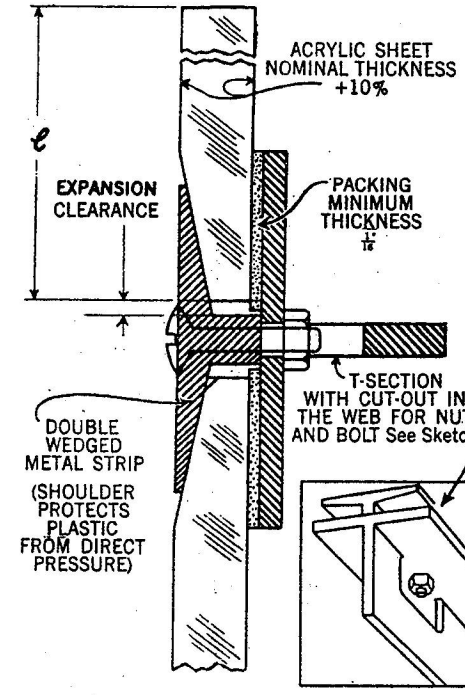

Figure 6-7 Wedge Section Installation

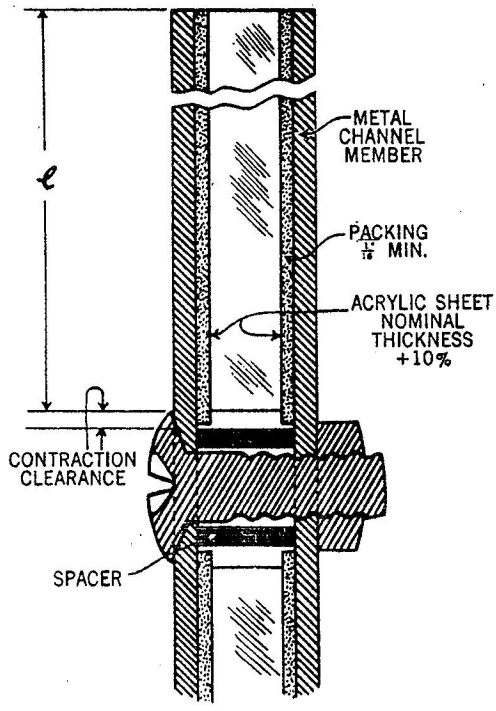

Figure 6-8 Bolt and Spacer Installation

(d) In calculating these allowances, remember that linear sawing tolerances for acrylic plastics are usually plus or minus .060 in. Tolerances of plus or minus .030 in. have been maintained when necessary of panels under twelve inches in length.

(e) The approved channel and clamp mountings are shown in Figs. 6-1 to 6-6.

BOLT AND RIVET MOUNTINGS

11 When special considerations make channel and clamp mountings impractical, holes may be drilled in the plastic for bolt or rivet installations. Because of difficulties experienced with rivet installations, bolt mounting is preferable. To assure long service, special consideration should ge given the following factors:

(a) Use as many bolts or rivets as practical. Distribute the total stress as equally as possible among these bolts or rivets.

(b) The holes drilled in the plastic should be sufficiently larger than the diameter of the bolt to permit expansion and contraction of the plastic relative to the frame.

(c) The holes in the plastic should be concentric with the holes in the frame so that the greater relative expansion of the plastic will not cause binding at one edge of the hole.

(d) Use oversize tube spacers, shoulder bolts or rivets, cap nuts or some other device to protect the plastic from direct pressure.

12 .Possible bolt and rivet installations are shown in Figs. 6-7 and 6-8.

CELLULOSE ACETATE BASE MATERIALS

13 The co-efficient of expansion of cellulose acetate base plastic is greater than that of metals commonly employed for mounting structures and even exceeds the co-efficient of expansion of acrylic plastics. Cellulose acetate base plastics are affected by moisture and will change dimensionally as they absorb water. Allowance must be made in mounting acetate plastic if wide variations of temperature and humidity are to be encountered. In general, an allowance of about 1/8 inch per foot of panel length must be made for expansion and 3/16 inch per foot for contraction.

APPENDIX "1"

TABLE 1

APPROVED COMMERCIAL BUFFING COMPOUNDS AND RELATED MATERIALS

BUFFING COMPOUNDS	MANUFACTURE
Compound No. 771	Matchless Metal Polish Company, Glen Ridge, N.J., U.S.A.
Learock No. 832	Lea Manufacturing Company, Waterbury, Conn., U.S.A.
Compound 4M-30 (Gray) Compound 6M-157 (White)	Hanson-Van Winkle-Munning Co., Matawan, N.J., U.S.A.
Triple A Buffing Compound	McAleer Manufacturing Company, Rochester, Mich., U.S.A.
Plascor No. 705 (White) Plascor No. 1403 (White)	United Laboratories, Linden, N.J., U.S.A.
Newcomb No. 7	Newcomb Products Company, Cleveland, Ohio, U.S.A.
ASHING COMPOUNDS	**MANUFACTURER**
M37, Pre-buff Paste	O'Cedar of Canada Ltd., Toronto 3, Ontario.
Pumice, Grade FF or FFF	James H. Rhodes, Chicago, Illinois, U.S.A.
du Pont Rubbing Compound No. 45 (rough) du Pont Rubbing Compound No. 12 (fine)	E. I. du Pont de Memours Co. Inc., Wilmington, Del., U.S.A.
Learock No. 765	Lea Manufacturing Company, Waterbury, Conn., U.S.A.
TALLOW	**MANUFACTURER**
Buffing Tallow	McAleer Manufacturing Company, Rochester, Mich., U.S.A.

TABLE 2

APPROVED COMMERCIAL POLISHES AND CLEANERS FOR TRANSPARENT PLASTICS

POLISHES	MANUFACTURER
CIL No. 7	Canadian Industries Limited, Toronto, Ontario.
O'Cedar of Canada M37 Plastic	O'Cedar of Canada Limited, Toronto 3, Ontario.
Parko Gloss Polish and Cleaner No. 4E-L	Park Chemical Company, Detroit, Mich., U.S.A.
PL-464-A2	Minnesota Mining & Manufacturing Company, Detroit, Mich., U.S.A.
Ken-Glo	Ken-nite Company, Detroit, Mich., U.S.A.
Lincoln M-3828 Liquid Cleaner	Lincoln Motor Car Division, Fort Motor Company, Dearborn, Mich., U.S.A.
Turco L-567 Cleaner	Turco Products Inc., Los Angeles, Cal., U.S.A.
WILCO Scratch Removing Compound Nos. 55 & 35	WILCO Company, Los Angeles, Cal., U.S.A.
Simoniz Liquid Cleaner	Simoniz Company, Chicago, Illinois, U.S.A.
McAleer Plexi-Glo Cleaner and Polish	McAleer Manufacturing Company, Rochester, Mich., U.S.A.
Aerogroom Cleaner	The Autogroom Company, Inc., Woodside, Long Island, N.Y., U.S.A.
Crystal X Cleaner and Glaze	Crosdale & deAngelis, Upper Derby, Pa., U.S.A.
Triple Life Cleaner and Glaze	Franklin Research Company, Philadelphia, Pa., U.S.A.
Noxon Cleaner Polish	Nozon Inc., Ozone Park, N.Y., U.S.A.
Puritan's Plasti-Kleen	Puritan Chemical Company, Atlanta, Ga., U.S.A.

APPROVED COMMERCIAL POLISHES AND CLEANERS FOR TRANSPARENT PLASTICS (Cont'd)

CLEANERS	MANUFACTURERS
Sinec. No. 2 Mark 2 Cleaner	O'Cedar Limited, Slough, England.
Sno-Flake No. 223 Cleaner	Snow Flake Products Company, Detroit, Mich., U.S.A.
Franklin High Gloss Cleaner	Franklin Research Company, Philadelphia, Pa., U.S.A.

TABLE 3

APPRCVED COMMERCIAL WAXES, MASKING TAPES, GASKET AND MASTIC MATERIALS, GREASES

WAXES	MANUFACTURER
Johnson's Industrial Wax No. 102-C	S.C. Johnson & Son Inc., Racine, Wisc., U.S.A.
Parko Eze-Wax	Park Chemical Company, Detroit, Mich., U.S.A.
Franklin Plexiglas Wax	Franklin Research Company, Philadelphia, Pa., U.S.A.
Simoniz Wax	Simoniz Company, Chicago, Illinois, U.S.A.
3M Auto Wax	Minnesota Mining & Mfg. Co., St Paul, Minn., U.S.A.
Permaseal	Commercial Chemical Company, Charlestown, Boston, Mass., U.S.A.

MASKING TAPES	MANUFACTURER
Scotch MFA (Flat Back Paper) or (Crepe Paper)	Minnesota Mining & Mfg. Co., St Paul. Minn., U.S.A.
Permacel XB-95	Industrial Tape Corporation, New Brunswick, N.J., U.S.A.

APPROVED COMMERCIAL WAXES, MASKING TAPES, GASKET AND MASTIC MATERIALS, GREASES (Cont'd)

GASKET MATERIALS	MANUFACTURER
Neoprene M-8831	U.S. Rubber Company, Detroit, Mich., U.S.A.
Neoprene Dome Gaskets	Vulcanized Rubber Company, Morrisville, Pa., U.S.A.
Fairprene No. 5545	E.I. duPont de Nemours & Company, Fairfield, Conn., U.S.A.
Grade GR-1 Synthetic No. 624 GN Synthetic A-086	B.F. Goodrich Company, Akron, Ohio, U.S.A.
Anchorite Buna S No. 200	Anchor Packing Company, Philadelphia, Pa., U.S.A.
Paraplex X-100, Stock JK-160 Paraplex X-100, Stock JK-161	Resinous Products & Chemical Company, Philadelphia, Pa., U.S A.
Freeze-Resisting Neoprene	Peerless-Key Imperial Company, Newark, NY., U.S.A.
Synthetic Glass Sealer No. 23212	Presstite Engineering Company, 3900 Chouteau Avenue, St Louis, Mo., U.S.A.

MASTIC MATERIALS	MANUFACTURER
3-M Mastic Compound EC-612 3-M Elastic Cement EC-373	Minnesota Mining & Mfg. Company, St Paul, Minn., U.S.A.
Synthetic Glass Sealer No. 23212	Presstite Engineering Company, 3900 Chouteau Avenue, St Louis, Mo., U.S. A.
RL-3774 Cockpit Enclosure Compound	W.P. Fuller & Company, 135 N. Los Angeles Street, Los Angeles, Cal., U.S.A.
Matiseal	Pittsburgh Plate Glass Company, Pittsburgh, Pa., U.S.A.

GREASES	MANUFACTURER
Cazar No. 2 Light Grade No. 3886 Die Lubricant	Esso Marketers and Associates 26 Broadway, New York 4, N.Y., U.S.A.
Gulf Precision Grease No. 1	Gulf Refining Company, Pittsburgh, Pa., U.S.A.

TABLE 4

LIST OF SPECIFICATIONS FOR MATERIALS RECOMMENDED FOR USE IN THE FABRICATION AND REPAIR OF ACRYLIC AND CELLULOSE ACETATE BASE PLASTIC

NOMENCLATURE	REF. NO.	CANADIAN OR BRITISH SPECIFICATION	AMERICAN SPECIFICATION
Synthetid Resin Sheet Transparent, Clear (Acrylic Sheets)			
Sizes 3/32 inches	33C/202	DTD 339B	MIL-P-6886 (AN-P-44)
1/ 8 "	33C/203	"	" "
5/32 "	33C/204	"	" "
3/16 "	33C/205	"	" "
7/32 "	33C/206	"	" "
1/ 4 "	33C/207	"	" "
5/16 "	33C/208	"	" "
3/18 "	33C/209	"	" "
CELLULOSE Acetate Plastic Sheets, Transparent clear			
Sizes 0.006	33C/336	C-6-56	MIL-P-6887 (AN-P-84)
0.020	195	"	" "
0.030	196	"	" "
0.040	197	"	" "
0.060	198	"	" "
0.080	199	"	" "
0.093	322	"	" "
0.100	200	"	" "
0.120	201	"	" "
0.125	323	"	" "
0.156	324	"	" "
0.187	325	"	" "
0.218	326	"	" "
0.250	327	"	" "
0.312	328	"	" "
0.375	329	"	" "
CEMENTS			
Adhesive, Cement, Acrylic Resit	33C/309	-	MIL-C-3116
Methylene Chloride	33C/583	-	MIL-M-6998
Glacial Acetic Acid	14B/27		-
Acetone	33C/417	AN-O-A-51	Fed O-A-51(b)
BUFFING COMPOUNDS	33C/		
POLISHES	33C/284	DTD 770	MIL-C-5547
WAXES	33C/		NAV Aer C-7(a)-1

NOMENCLATURE	REF. NO.	CANADIAN OR BRITISH SPECIFICATION	AMERICAN SPECIFICATION
TAPE masking paper barked			
Sizes 1/2 in. wide	32B/96		UU-T-106A
1 in. wide	32B/59		" " "
2 in. wide	32B/60		" " "
PAPER abrasive waterproof			
320A	29/		Fed PP 101-1
360A	29/1868		Fed PP 101-1
400A	29/1867		Fed PP 101-1
500A	29/		Fed PP 101-1
600A	29/		Fed PP 101-1
GREASES	34A/178	3GP-682 DTO 783	AN-G-15A
LEATHER Chamois 26" x 26"	32B/36		Fed KK-S-416 Type A
CLEANERS			
Aliphatic Naptha	33C/		TT-N-95
Dry cleaning solvent			
Stoddard Solvent	33C/182	3-GP-8	Fed P-S-661(a)-1

APPENDIX "2"

GLOSSARY OF TERMS ASSOCIATED WITH THE USE OF TRANSPARENT PLASTICS IN AIRCRAFT

Acrylic Plastic (also known as acrylate of methacrylate base)	Thermoplastic material produced by a complex chemical reaction of the monomeric derivatives of acrylic acid.
Ashing	The process of removing scratches or other surface defects from a plastic by the mild abrasive action of a pumice paste or similar material applied to the plastic surface with a rotating cloth wheel. This process, sometimes used instead of sanding, leaves a cloudy surface which may be brought to a high polish by buffing.
Astrodome	A shallow acrylic plastic dome, carefully formed to meet critical optical specifications, through which a navigator makes his observations.
Bexoid	Trade name for a cellulose acetate base plastic of British manufacture.
Buffing	The process by which the ashed or sanded surface of a plastic is brought to a high polish. It usually consists of the application to the plastic surface of a polishing or "buffing" compound by means of a rotating cloth wheel.
Catalyst	A substance which in very small amounts, accelerates a chemical reaction without itself entering into the reaction.
Cellulose Acetate	A thermoplastic material formed by the action of glacial acetic acid, acetic anhydride and concentrated sulphuric acid on cellulose, derived from cotton or wood.
Cold-Forming	Bending or shaping plastics without first heating. This practice is permissible with cellulose acetate base plastics but not with acrylic plastics.
Crazing	A number of small surface cracks which interfere with vision.

GLOSSARY OF TERMS ASSOCIATED WITH THE USE OF TRANSPARENT PLASTICS IN AIRCRAFT (Cont'd)

Cushion	The soft surface layer formed on an acrylic plastic when immersed in a cement during soak cementing.
Electrostatic Charge	A property acquired by plastics that is caused by friction. It has the tendency to draw certain materials to it, such as dust particles.
Fibestos	Cellulose acetate base plastic manufactured by Monsato Chemical Company, U.S.A.
Fillet	A curved section of small radius which forms a corner between two surfaces at right angles to each other. This radius is preferable to a sharp corner since it does not permit a concentration of stress at one point.
Gasket	Rubber, synthetic rubber or cork packing placed between plastic panels and their mounting frames to make an installation waterproof.
Haze	Any turbidity within the sheet or on the surface which reduces visibility through the sheet.
Heat Treating	The heating of a cemented joint to reduce the concentration of trapped solvent to a minimum and to develop maximum strength in the joint. In the case of a monomer cement, heating also completes the polymerization or hardening of the monomer to a solid plastic.
Hydrometer	A device for measuring the specific gravity of liquids, usually consisting of a calibrated float operating inside a glass tube into which a sample of the liquid is drawn by means of a rubber bulb.
Lucite	Trade name for acrylic plastic manufactured by E.I. duPont deNemours and Co., Inc.
Lumarith	Trade name for cellulose acetate base plastic manufactured by Celanese Cellulose Corporation.
Mark Off	Surface imperfections produced by transfer or mould surface defects to the plastic during moulding or forming operations.
Masking	The process of protecting a highly polished plastic surface, usually accomplished by the application of heavy kraft paper to the surface with a pressure sensitive adhesive which is not harmful to the plastic.

GLOSSARY OF TERMS ASSOCIATED WITH THE USE OF TRANSPARENT PLASTICS IN AIRCRAFT (Cont'd)

Mastic	Soft, putty-like materials packed around plastic panels to make an installation waterproof.
Monomer	Monomeric methyl methacrylate. This is the liquid from which acrylic plastic is originally made. As fluid as water at room temperature, it thickens and hardens (polymerizes) under influence of heat, light and certain chemicals called catalysts. When used as a cement, this same process can be made to occur in the joint.
Novellon	Trade name for a cellulose acetate base plastic of British manufacture.
Perspex	Trade name for acrylic plastic manufactured by Imperial Chemical Industries, Ltd., England.
Plastacele	Trade name for cellulose acetate base plastic manufactured by E.I. duPont deNemours and Co., Inc.
Plexiglas	Trade name for acrylic plastic manufactured by Rohm & Haas Company.
Polymerization	The process by which individual molecules of a compound (such as monomeric methyl methacrylate) link together in long chains. It is by this process that a monomer changes from a free-flowing fluid to a thick syrup and then to a hard transparent solid.
Rabbet	A rectangular groove, usually around the edge of a plastic panel, to permit flush mounting in a channel frame. Also called "step rout".
Rhodoid	Trade name for a cellulose acetate base plastic of British manufacture.
Routing	The operation of cutting a plastic on a router. This may involve step-routing (see Rabbet), trimming to size, or the cutting of special cross-sections for reinforcing ribs.
Scratches	Any marks or tears resulting from contact with a sharp or a rough instrument or particle, or from use of abrasive cleaners.
Sheeter Marks	Very fine, closely spaced, parallel lines on the surface of cellulose acetate base sheeting, caused by minute imperfections on the knives which are used to cut the sheeting from the blocks in which it is made.

GLOSSARY OF TERMS ASSOCIATED WITH THE USE OF TRANSPARENT PLACTICS IN AIRCRAFT (Cont'd)

Slip Forming	A method of forming three dimensional parts in which thinning out is reduced by allowing the excess plastic sheeting to slip through the clamping rings while the sheet is being stretched during forming.
Sighting Panel	An acrylic plastic section formed to meet critical optical specifications and inserted into a gun turret or nose section. The gunner sights through this panel in combat.
Snap-Back Forming	A method of forming based on the tendency of acrylic plastic sheets to return to their flat sheet form as long as they are hot.
Soak-Cementing	The method of cementing acrylic plastics which includes immersing one of the two parts to be joined in a cement.
Solvent	Any liquid which attacks and dissolves certain solids with which it comes in contact. Used in this handbook to designate solvents for acrylic and acetate base plastics, such as acetone, benzene, carbon tetrachloride, fire-extinguisher and de-icing fluids, lacquer thinners, aviation and ethyl gasolines and glass cleaning compounds.
Solvent Cements	A solvent or mixture of solvents which soften a plastic so that two or more pieces may be bonded.
Specific Gravity	The ration of the weight of a given volume of a solid or liquid to that of the same volume of water.
Syrup Cement	A thick cement made as needed by adding clear acrylic plastic shavings to either monomer or solvent cements.
Thermoplastic	A plastic which upon being heated, becomes soft and pliable, and which will harden when cooled. This process may be repeated a number of times without changing the properties of the material.
Veneer Saw	A portable saw used for trimming formed parts.
Waviness	A wave-like unevenness or cut-of plane area in the surface of a plastic.