CHAPTER 3. FIBERGLASS AND PLASTICS

SECTION 1. REPAIR OF LIGHT LOAD LAMINATE STRUCTURES

3-1. GENERAL. There is a wide variation in the composition and structural application of laminates, and it is essential that these factors be given major consideration when any restoration activities are undertaken. To a similar extent, there also exist many types of laminate structure repairs that may or may not be suitable for a given condition. For this reason, it is important that the aircraft or component manufacturer's repair data be reviewed when determining what specific type of repair is permissible and appropriate for the damage at hand.

NOTE: Review Material Safety Data Sheets for material to be used. When handling materials, prepreg fabrics, or parts with prepared surfaces, observe shelf life. Latex gloves and approved masks must be worn.

a. The materials used in the repair of laminate structures must preserve the strength, weight, aerodynamic characteristics, or electrical properties of the original part or assembly. Preservation is best accomplished by replacing damaged material with material of identical chemical composition or a substitute approved by the manufacturer.

b. To eliminate dangerous stress concentrations, avoid abrupt changes in cross-sectional areas. When possible, for scarf joints and facings, make small patches round or oval-shaped, and round the corners of large repairs. Smooth and properly contour aerodynamic surfaces.

c. Test specimens should be prepared during the actual repair. These can then be subjected to a destructive test to establish the quality of the adhesive bond in the repaired part. To make this determination valid, the specimens must be assembled with the same adhesive batch mixture and subjected to curing pressure, temperature, and time identical to those in the actual repair.

3-2. FIBERGLASS LAMINATE REPAIRS. The following repairs are applicable to fiberglass laminate used for non-structural fairing, covers, cowlings, honeycomb panel facings, etc. Prior to undertaking the repair, remove any paint by using normal dry sanding methods. Bead blasting may be used but caution must be exercised not to abrade the surfaces excessively.

NOTE: Chemical paint strippers must not be used.

NOTE: These repairs are not to be used on radomes or advanced composite components, such as graphite (carbon fiber) or Kevlar.

CAUTION: Sanding fiberglass laminates gives off a fine dust that may cause skin and/or respiratory irritation unless suitable skin and respiration protection is used. Sanding also creates static charges that attract dirt or other contaminants.

a. Check for voids and delamination by tap testing. (See chapter 5.) When the surface of a fiberglass laminated structure is scratched, pitted, or eroded; first wash with detergent and water to remove all of the dirt, wax, or oxide film. Then scrub the surface with an acceptable cleaner. After the surface is thoroughly cleaned, sand it with 280-grit sandpaper, and again use an acceptable cleanser to remove any sanding residue and moisture. This is essential, as any moisture remaining on the surface will inhibit the cure of the resin. Dry the fiberglass laminate thoroughly prior to bonding repair. Mix enough resin, using the manufacturer's instructions, to completely cover the damaged area, and apply one or two coats. Cover the resin with a peel ply to exclude all air from the resin while it is curing. After the resin has cured, remove the film and file or sand the surface to conform to the original shape of the part. Ensure that all edges of the laminate part are sealed to prevent water absorption. Then refinish it to match the rest of the structure.

b. Superficial scars, scratches, surface abrasion, or rain erosion can generally be repaired by applying one or more coats of a suitable low temperature resin, catalyzed to cure at room temperature, to the abraded surface. The number of coats required will depend upon the type of resin and the severity of the damage.

(1) Damage not exceeding the first layer or ply of fiberglass laminate can be repaired by filling with a putty consisting of a compatible room-temperature-setting resin and clean short glass fibers. Before the resin sets, apply a sheet of peel ply over the repair area and work out any bubbles and excess resin. After the resin has cured, sand off any excess and prepare the area for refinishing.

(2) Damage deep enough to seriously affect the strength of the laminate (usually more than the first ply or layer of fabric) may be repaired as illustrated in figure 3-1. Coat the sanded area with room-temperature-setting resin and apply contoured pieces of glass fabric soaked in resin. Apply a peel ply sheet over the repair and work out any bubbles and excess resin. After the resin has cured, scrape off the excess resin and sand the surface of the repair to the original contour.

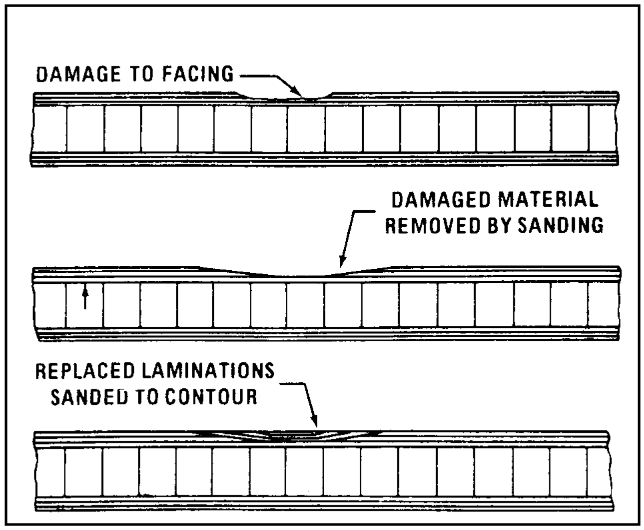

FIGURE 3-1. Typical laminate (facing) repair.

(3) Damage that extends completely through one facing and into the core requires the replacement of the damaged core and facing. A method for accomplishing this type of repair is shown in figure 3-2. An alternate method for repairing the facing is shown in figure 3-3. The damaged portion is carefully trimmed out to a circular or oval shape and the core material is removed completely to the opposite facing. Exercise caution so as not to damage the opposite facing or to start delamination between the facings and the core around the damage.

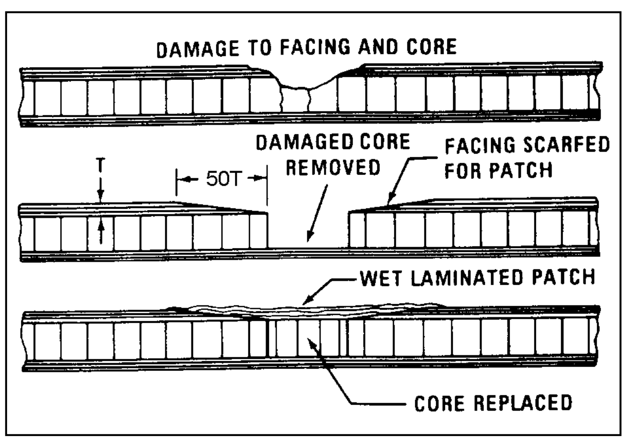

FIGURE 3-2. Typical core and facing repair.

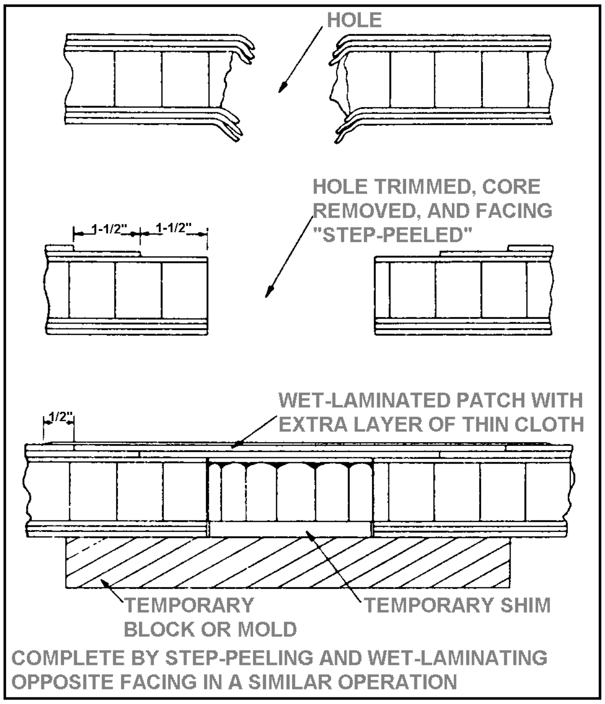

FIGURE 3-3. Typical stepped joint repair.

c. Use replacement core stock of the same material and density as the original (or an acceptable substitute) and cut it to fit snugly in the trimmed hole. Observe the direction of the original core. When all of the pieces of replacement facing laminations are cut and soaked in resin, coat all surfaces of the hole and the scarfed area with resin. Then coat all surfaces of the core replacement with resin and insert it into the hole. After all of the pieces of resin-impregnated glass-fabric facing are in place and lined up with the original fiber-orientation, cover the entire area with a piece of peel ply and carefully work down the layers of fabric to remove any air bubbles and excess resin. Apply light pressure by means of sand bags or a vacuum bag. When the resin has cured, sand the repair to match the original contour and refinish the surface.

3-3. REPAIRING HOLES.

a. Scarf Method. If the damaged area is less than 3 inches in diameter, the damage may be removed by either sanding with a power sander or hand sanding with 180-grit sandpaper.

(1) Scarf back the edges of the hole about 50 times the thickness of the face ply. Thoroughly clean out all of the sanding residue with a cloth wet with an acceptable cleanser.

(2) Prepare the patches by (see figure 3-4) laying the proper weight fiberglass cloth impregnated with resin on a piece of peel ply. A weight of resin equal to the weight of the patch provides a 50-percent ratio.

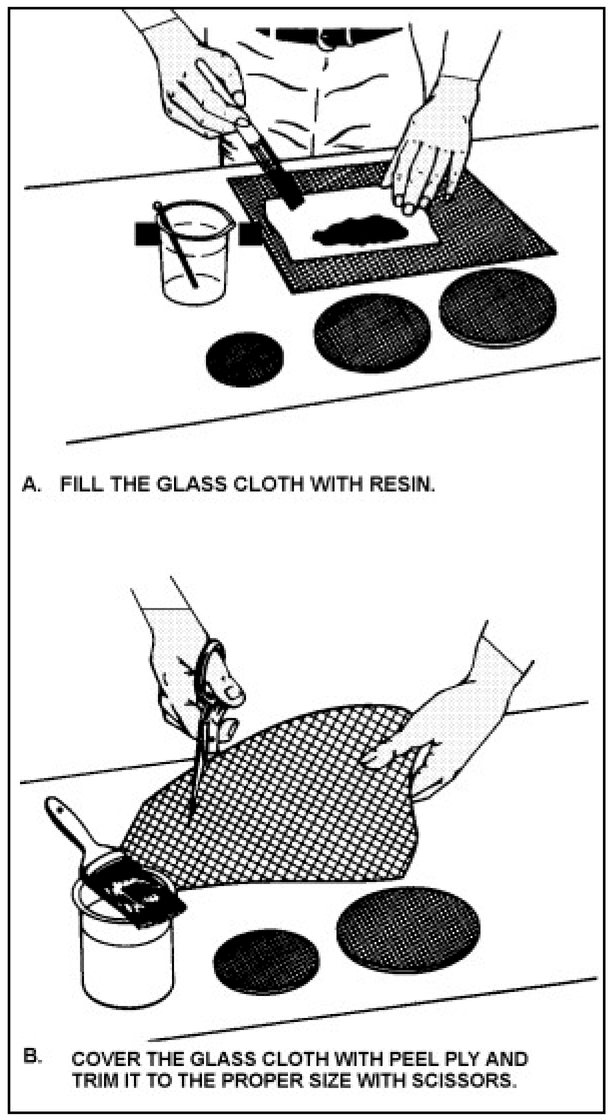

FIGURE 3-4. Preparing the fiberglass sandwich.

(3) Make a sandwich by laying a second layer of peel ply over the patch before cutting it to the required size and shape. Sandwiching will prevent the patch from raveling when cut. Brush a good coat of resin over the scarfed area. Remove one piece of peel ply from the first patch and lay the patch in place. Work all of the air out of the resin and remove the top peel ply. Cut the next larger patch so it will overlap the first patch by at least one-half inch. Remove one piece of peel ply from this patch and center the patch over the first one. Work all of the air out of the resin. Continue laying in patches, each overlapping the one below it by at least one-half inch, until you have the required number of layers (see figures 3-5 and 3-6) plus an extra ply to restore original strength to the repaired area.

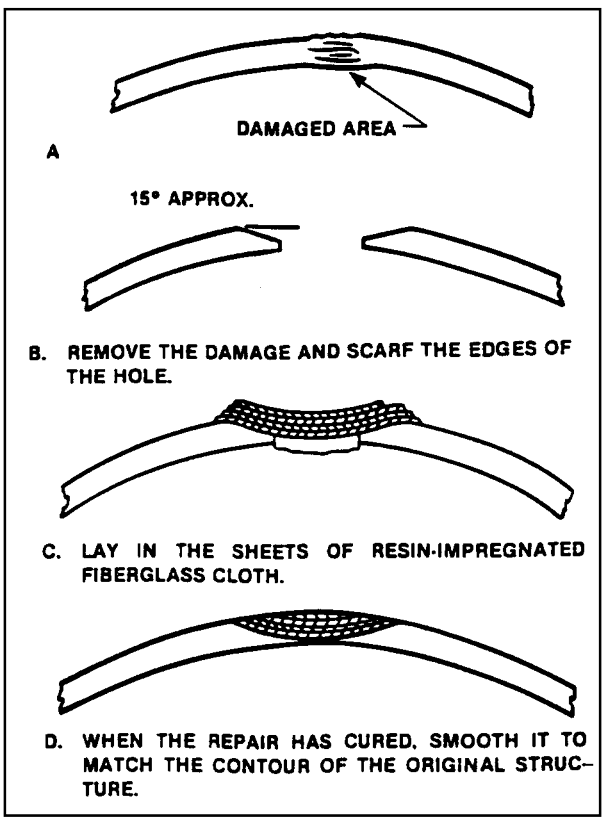

FIGURE 3-5. Scarfed repair to a nonstructural laminated fiberglass component.

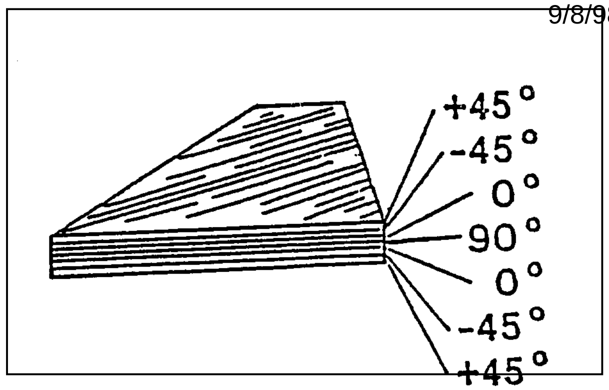

FIGURE 3-6. Symmetrical layup same as original number of plies, plus one extra ply.

(4) Cover the entire repair with peel ply and carefully work out all of the air bubbles from the resin. Apply pressure over the repair with tape or sandbags and allow it to cure. After the repair has cured, remove the excess resin by filing or sanding the surface to the contour of the original part. Smooth the surface with fine sandpaper and refinish it to match the original part.

(5) An alternate layup method that works equally well is to place the larger patch over the scarfed area first, and then each subsequent smaller patch over this. Both types of repair are finished in exactly the same way.

(6) The scarfed joint method (see figure 3-7) is normally used on small punctures up to 3 or 4 inches in maximum dimension and in facings that are made of thin fabric that is difficult to peel.

b. Step-Joint Method. The scarf method of repairing a laminated fiberglass face sheet of a honeycomb structure is the easiest method to use. In this type of repair, the damage is outlined with a compass. If a square or rectangular repair is more appropriate then the damage is outlined using a straight-edge and a compass to round out the corners.

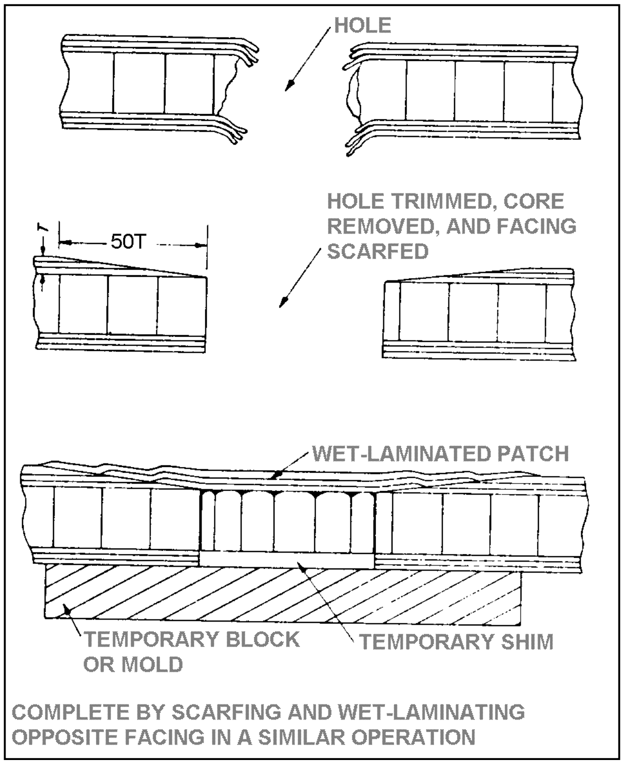

FIGURE 3-7. Typical scarf joint repair.

(1) The configuration of the repair should be that which will remove the least amount of sound material. Extend the cleaned-out area for a distance equal to the number of plies to be removed, less 1 inch. For example, if you must remove three plies, extend the repair for 2 inches beyond the cleaned-out area. Each layer should be 1 inch beyond the layer below. Use a sharp knife or other type of cutter to cut through the top layer, being careful not to damage the underneath layer. Use several passes with the knife rather than one deep cut. (See figure 3-8.)

(2) Begin with one corner of the patch and carefully pry it loose and peel it up until all of the layer is removed. Next, mark the exposed layer 1/2 inch inside the opening and carefully cut and remove it. Continue until you have removed all of the damaged or delaminated layers.

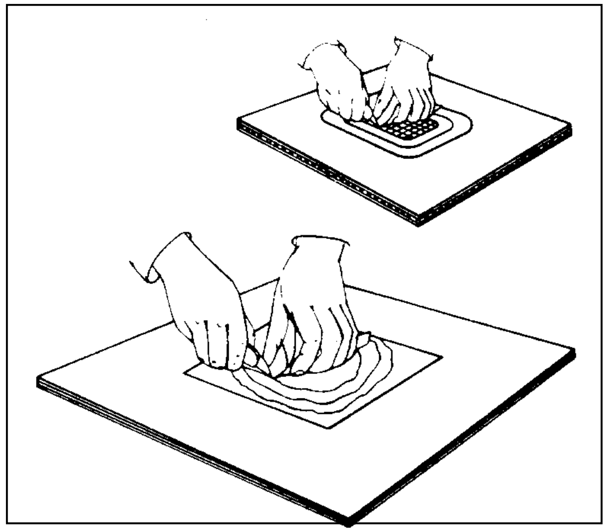

FIGURE 3-8. Carefully cut through each layer of fiberglass cloth and remove it from the damaged area.

(3) Lightly sand, then scrub the entire area with an acceptable cleanser. Prepare the patches exactly as you did for the scarf method, cutting each layer to exactly the size of the material removed. Brush in a coat of resin, lay in the patch of the smallest size, and carefully work out all of the air bubbles from the resin. Now, lay in the next larger size patch to lock the first layer of fiberglass cloth into place. Repeat the process until the damage area is filled.

(4) Butt the top layer of cloth to the opening in the face ply and cover the entire repair with peel ply. Carefully work all of the air bubbles out of the resin and put pressure on the repair with either sandbags, or another appropriate method, such as vacuum bagging. (See figure 3-9.) After the top repair has hardened, repeat the process on the bottom.

3-4. SAMPLE BAGGING AND CURING PROCESS. Figure 3-9 shows a typical bagging arrangement for a localized repair in which patch plies of prepreg are cured with a layer of adhesive, and a heating blanket is used to supply heat.

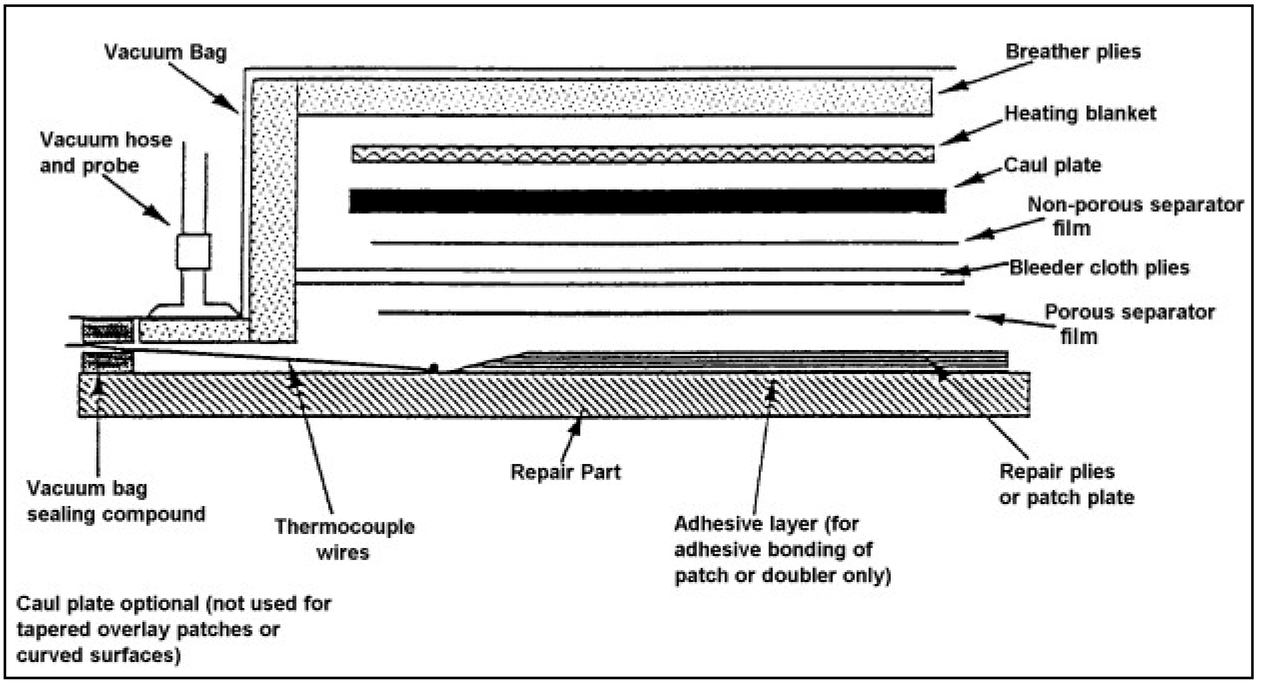

FIGURE 3-9. Sample bagging layup cross section.

a. The materials used for most bonded repairs require elevated temperatures and pressure, during their cure, to develop full strength. The following paragraphs describe the operations required to enclose the repair in a vacuum bag. When the part to be cured can be placed in an autoclave, additional pressure and heat can be applied. For cured-in-place parts, vacuum pressure and portable heat blankets usually suffice.

(1) When selecting materials, especially the parting agent film, the temperature at which the repair is to be cured must be known. Polyvinyl alcohol (PVA) film is ideal when the bonding temperature does not exceed 250 °F. PVA film has very high tear resistance and may be heat-sealed effectively. When the bond temperature is not above 180 °F, polyvinyl chloride film can be used. For temperatures up to 450 °F, a polyvinyl fluoride film is used. These three types of films are available in a variety of weights and widths. Most nylon bagging films are used for temperatures up to 400 °F.

(2) When all repair details are in place and ready to be cured, they are enclosed in a bag of plastic film or thin rubber. Air is removed from the bag by a vacuum source so that atmospheric pressure exerts a pressure on the repair as it is cured.

(3) To provide a path to draw off the air initially inside the bag, layers of fiberglass cloth or similar noncontaminating materials, known as breather plies, are placed inside the bag. When prepreg is being cured as part of the repair, it is sometimes necessary to bleed off excess resin. To do this, layers of fiberglass cloth or similar materials known as bleeder plies are placed over the prepreg. Some repairs have been made with a net resin prepreg that does not require bleeding, and therefore does not require bleeder plies. Porous separator plies or film are used between the prepreg and the bleeder and nonporous separator plies or film are used between the bleeder and breather plies to control the flow of resin.

(4) Small parts may be envelope bagged (i.e., enclosing the entire part in the bag). Larger parts with localized repairs can be bagged by sealing the surface completely around the repair areas with sealing tape and applying the bagging material to the sealing tape.

CAUTION: The whole panel must be vacuum bagged to prevent delamination in sandwich skins when using an oven or autoclave. Contoured parts must be restrained with tooling to prevent warpage.

b. When the heat for curing the repair is provided by a heat blanket, the blanket can be either inside or outside the vacuum bag. However, the blanket should be covered to minimize heat loss, and the blanket should be separated from direct contact with most bagging materials by layers of fiberglass cloth.

(1) This will prevent localized overheating that could damage the bag. It is sometimes helpful to place a thin aluminum sheet under the heating blanket to minimize localized heating. A thin rubber blanket can help smooth the surface of the material being cured. A pressure plate should be used when two or more heat blankets are applied to the same repair.

NOTE: Understanding that various resins behave differently during cure, the choice of bagging arrangements will often vary with the material being cured.

(2) The procedure for the bagging arrangement is as follows:

(a) Place a peel ply over the patch material to provide a surface finish for subsequent bonding or painting if not previously accomplished. Place a layer of porous separator cloth over the patch, extending beyond the prepreg and the adhesive. Smooth to avoid wrinkles.

(b) With the patch material in place, place the end of the thermocouple wire next to the edge of the prepreg. Tape the wire to the structure inside the bag with heat-resistant tape. The tape should not be in contact with the prepreg or the adhesive.

(c) Place bleeder plies as shown, extending 2 to 3 inches beyond the patch. The number of bleeder plies needed will vary with the type of resin and the resin content required.

(d) Place a layer of nonporous parting film over the bleeder plies, cut 1 inch smaller than the bleeder plies. This layer is intended to stop resin flow from bleeder plies into breather plies while still providing an airflow path when vacuum is applied.

(e) If a pressure plate is used, place it over the previous separator ply. The plate is frequently perforated with small holes to permit airflow to the breather plies. Bleeder plies may be necessary when using a pressure plate.

NOTE: Pressure on the repair will be reduced if the pressure plate does not conform to the repair.

(f) Place the heat blanket over the assembly, making sure it extends 3 to 4 inches beyond the material to be cured.

(g) One or more thermocouples should be in contact with the heat blanket to monitor its temperature. Additional thermocouples should be placed near the curing repair to monitor the temperature of the curing resin.

(h) When using a heat blanket as the heat source, four to six layers of fiberglass surface breather or the equivalent should be used over the heat blanket. This will insulate and prevent damage to the nylon bagging film. Ensure that the breather plies are in contact with the bleeder plies so that an air passage exists.

(i) Place a bead of sealing tape against the parent material around the edge of the breather plies. Seal the thermocouple wires to prevent vacuum leakage.

NOTE: Two layers of sealing tape may be required in order to provide a good seal.

(j) Cover with a suitable vacuum bag, smoothed to minimize wrinkles. Press the bag firmly onto the sealing tape to obtain an air-tight seal. Place pleats in vacuum bag to allow the bag material to stretch.

(k) Install two vacuum probes or sniffers through openings cut in the bag. One will be used for the vacuum gauge and the other will be connected to the vacuum source. The vacuum probe must sit on the breather plies, but must not touch the patch or adhesive.

NOTE: Place the vacuum gauge on the opposite side of the vacuum port, where applicable. Do not place vacuum probes near repair area.

(l) Connect the vacuum source and smooth the bag by hand pressure as the air is removed. Check for leaks and reseal as necessary. A minimum vacuum of 22 inches of mercury is required.

(m) Place insulating material over the vacuum bag to prevent heat loss.

(n) Apply power to the heat blanket and control its temperature as specified for the material being cured.

(o) Observe cure time requirements established by the product manufacturer.

3-5.—3-9. [RESERVED.]

SECTION 2. METALLIC SANDWICH SECONDARY STRUCTURE REPAIRS

3-10. REPAIRS TO METALLIC SANDWICH SECONDARY STRUCTURE. Magnesium, titanium, or stainless steel facings require special procedures that are not included in the following methods of repair. Aluminum alloys such as 7075-T6, 2024-T3, and 2014-T6 are commonly used for the repair of facings for sandwich structural parts having aluminum facings. For maximum corrosion resistance, use only clad aluminum for repairs to clad aluminum alloy facings.

a. Dents, scratches, or fractures, not exceeding 1/4 inch in largest dimension in aluminum facings, may be repaired with a suitable filler such as viscous epoxy resin. Dents that are delaminated shall not be filled but repaired. Thoroughly clean the repair area with fine sandpaper and acetone before applying the filler. After the resin has partially cured, remove any excess resin with a sharp plastic scraper. When the resin has completely cured, sand to the original contour. If the damage included a fracture, reclean the area around the filled hole and apply a surface patch.

b. Fractures or punctures in one facing and partial damage to the core of an aluminum-faced laminate may be repaired by several different methods. The technique used will depend upon the size of the damage, the strength required, and the aerodynamic loads of the area involved. If the repair requires aerodynamic smoothness, the facing surrounding the repair core cavity may have to be step cut to one-half its thickness. This can be done by using a router with an end mill bit and a template.

c. Damage that extends completely through the core and both facings may be repaired using the same general techniques as those used for repairing fiberglass laminates when both facings are accessible.

d. After locating the extent of the total damaged area by tapping or other nondestructive test methods, remove the damaged facing and that portion of the core material that is also affected. The depth to which the core must be removed will depend upon the type of core material and the method of repair. The replacement core material must be the same material and core cell size as the original. Fabricate core material to shape, keeping the same core ribbon or grain direction. When a substitution is permissible, wood or glass-fabric honey-comb cores are sometimes used in the repair of aluminum honeycomb cores, as they are generally easier to shape. Typical types of core replacements are shown in figure 3-10. Resin fills can be used to replace the core and facing where smaller core damage exists. Phenolic microballoons, low-density insulating materials, and/or other ingredients are added to lower the density and give greater flexibility.

e. For the repair of larger holes in which it is inconvenient to use a face patch because of aerodynamic smoothness requirements in that area, both the core and facing are sometimes replaced with glass-fiber fabric discs and resin. Undercut the core, as shown in figure 3-11, in order to obtain a better bonding of the fill with the facing. Fill the core cavity with accurately shaped resin-saturated glass cloth discs, and press each ply down to remove any air bubbles. Special care should be taken that the final plies fit well against the underside of the top facing. When the core cavity is filled, close the cutout in the facing with resin-impregnated glass fiber fabric discs that have been precut to size.

f. Overlap repairs, typically called scab patches, have a long history of use in repairing aircraft structures. These repairs simply cover the damaged area with patch material. Overlap repairs can be bonded and/or mechanically

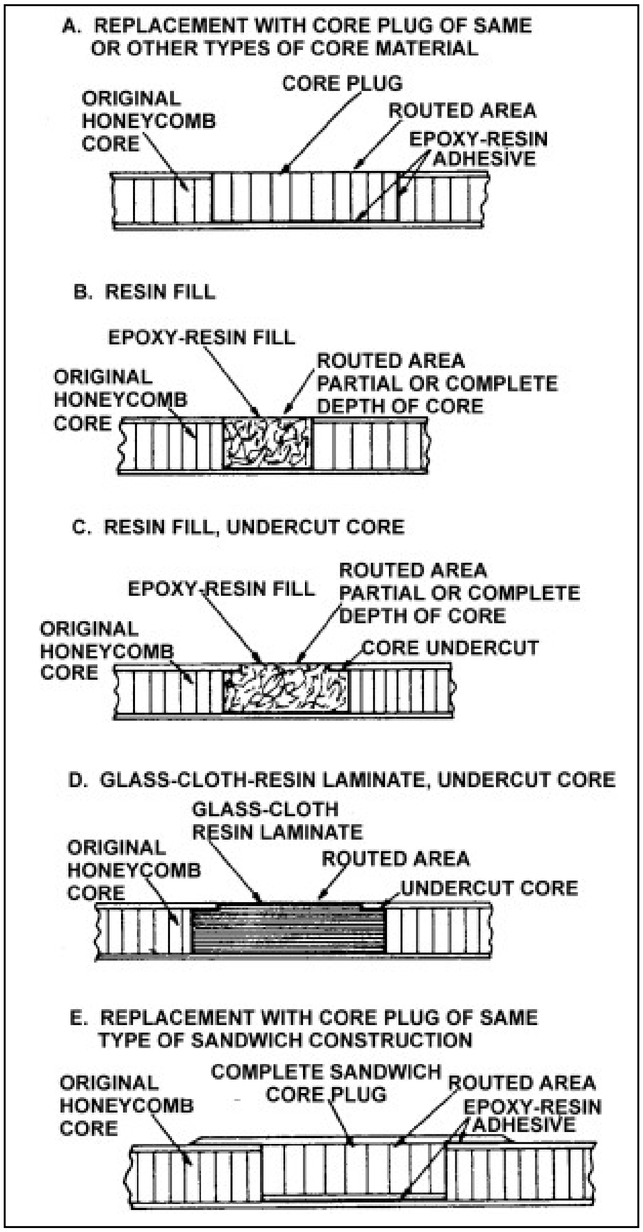

FIGURE 3-10. Typical types of core replacement.

fastened. Figure 3-12 shows a cross-section of a typical bonded and mechanically fastened repair. The damaged area may or may not need to be filled.

(1) Bonded overlap repairs work well on most structures. The overlap repair consists of a solid patch material such as metal, precured laminates, prepreg or wet layup material co-cured in place.

(2) Bolt or blind rivet. Mechanically fastened, bolted, or blind rivet repairs are primarily used for thick structures. Primary concerns include bolt/rivet spacing, fastener diameter, number of fasteners, and sealant type.

g. Core potting is the process of filling the core cutout with a curable paste filler material. If the damage is sustained in an area with an already-potted core, the replacement core should also be potted. In other cases, if the honeycomb or foam core is damaged, it may be potted rather than plugged if the damaged area is small (1 inch or less). Remove the face sheet with a power router, using a router template to prevent injury to undamaged face skin. The router may be adjusted to remove one of the face skins only, a face skin and part of the core, a face skin and all of the core, or both the face skins and the core. (See figure 3-13.)

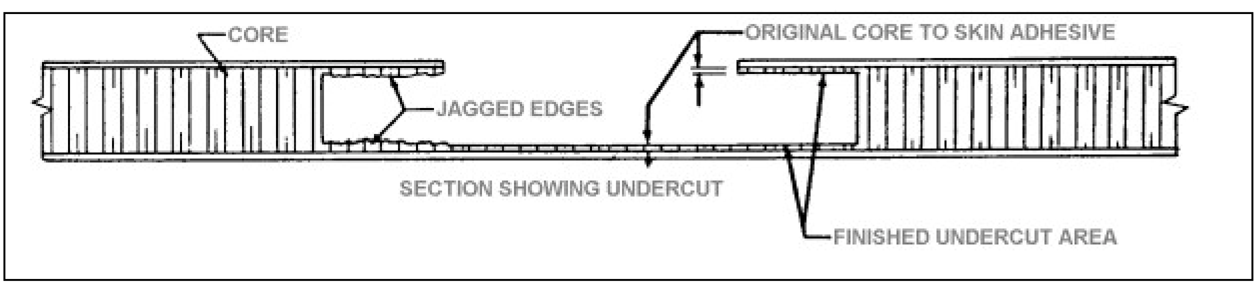

FIGURE 3-11. Typical undercut core material cavity.

(1) It may be necessary when routing a tapered section such as an aileron to use a wedge-shaped block between the routing template and the upper surface. This will allow the router to cut the core material parallel with the lower surface. (See figure 3-14.)

(2) Select the appropriate potting adhesive as recommended by the manufacturer. Mix a sufficient quantity of filler to fill the hole and add microballoons if they are needed to serve as a filler. When the resin and filler are thoroughly mixed according to the manufacturer's recommendations, pour the mixture into the hole filling all of the cells, then work out all of the bubbles with a toothpick. If performing an overlay repair fill the core cavity to slightly above the part's surface. If performing a flush repair, fill the core cavity to slightly above the original core.

(3) Cure the compound according to the manufacturer's directions. Trim the top of the cured potting compound flush with the surface, for the type of repair you are performing.

h. A core plug repair replaces damaged core material with a shaped piece of similar core material.

(1) Complete removal of core material to the opposite face generally requires some hand-cutting with a core knife. Figure 3-15 shows core material being removed with a core knife. The core can be peeled away from the skin bond using duckbill pliers. Sanding is then required to remove irregular accumulations of adhesive from the undamaged inner face. Remove only enough adhesive to produce a smooth finish.

CAUTION: Care should be used when peeling core material from thin-skin sandwich face sheets, because the skin can be damaged by pulling on the core.

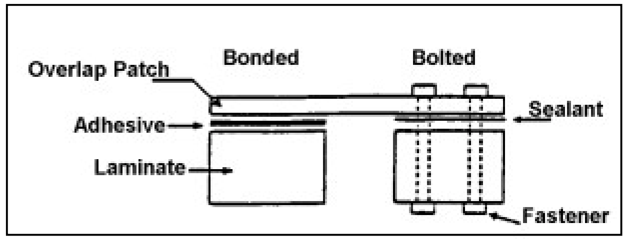

FIGURE 3-12. Cross section of bonded and bolted overlap repairs.

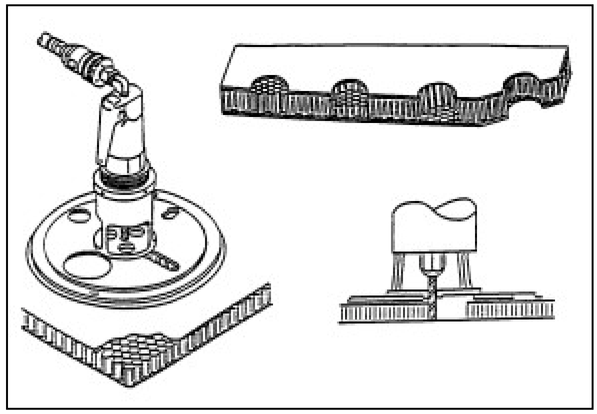

FIGURE 3-13. Honeycomb core removal.

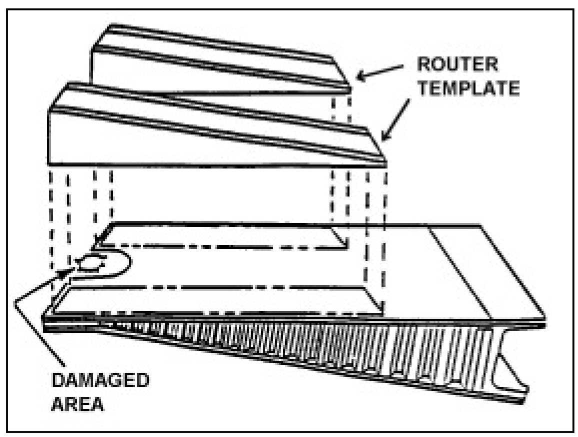

FIGURE 3.14 — Removing honeycomb core from a tapered control surface.

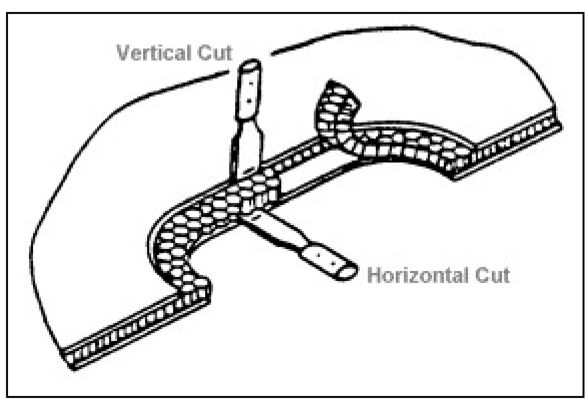

FIGURE 3-15. Removal of core with core knife.

(2) A core plug should be fabricated as follows. Select the core density. Cell size and ribbon direction and thickness should be at least the same as that used in the original construction. Trim the sides of the plug to a loose fit in the routed cavity. Trim the plug height so the top of the plug sits .001 inch higher than the level of the original surface. The core will compress and set during cure thereby requiring the extra height. Carefully remove the trimmed core plug from the machined cavity. Use a vacuum cleaning device to remove any dust or particles remaining on the core plug or in the repair area. Clean the core plug by rinsing with an approved solvent and wrap the plug in a clean polyethylene bag until needed for assembly.

CAUTION: When handling film adhesives, prepreg fabrics, or parts with prepared surfaces, latex gloves must be worn.

(3) Using a film adhesive, the core plug should be installed as follows. Select the appropriate adhesive film. Cut one disk of adhesive to the same shape and size as the perimeter of the repair cutout if the repair extends through the entire core thickness. Cut two disks if a partial depth core repair is being made. Cut one strip of core splice adhesive to wrap around the core perimeter to its full depth. For a partial depth core repair, also cut out a fiberglass or aluminum disk, again matching the size and the shape of the repair cutout. Figure 3-16 shows the details of a partial depth core repair. Preassemble the pieces.

(4) Wipe the bottom and sides of the cutout area with solvent. Allow the area to dry. Insert the core plug assembly with splice adhesive applied to the perimeter into the core cutout. Ensure the core plug ribbon direction matches that of the parent core. In the case of a partial depth core repair, the plug and disk

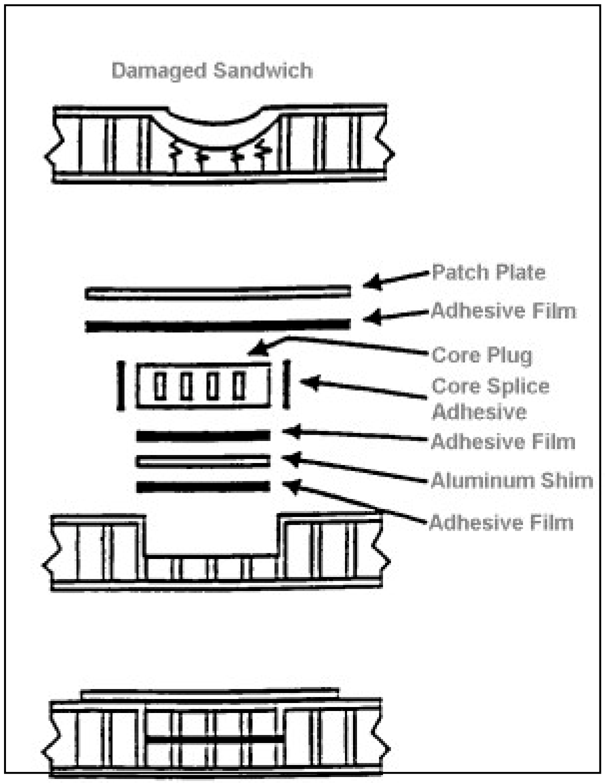

FIGURE 3-16. Details of core repair.

may be cured to save time. Some restraining method, such as vacuum bagging, may be desirable over the core splice adhesive as this material usually foams up and out during cure. Cure the adhesive according to the manufacturer's directions and allow the area to cool.

(5) Trim the top of the cured core plug flush with either the original core or the mold line, depending on the type of laminate repair to be performed. Proceed with laminate repair.

3-11. FINISHING. The type of finish coating applied to a metallic sandwich repair will normally be determined by the exposed material and the application of the part or assembly. Rain erosion of plastic parts, the need for electrical or dielectric properties, and/or the necessity for anti-corrosion coatings must be considered when the choice of finish is made. Plastic-faced parts such as radomes are finished primarily for rain erosion while aluminum- or other metal-faced laminates are finished for corrosion protection. For coatings to perform their function properly, it is essential that they be applied to surfaces that are clean, free of voids, and smooth. The edges of all parts not protected by a bonding of aluminum or glass-fabric laminate must be sealed to reduce the rate of moisture absorption.

3-12.—3-17. [RESERVED.]

SECTION 3. TRANSPARENT PLASTICS

3-18. GENERAL. Plastics cover a broad field of organic synthetic resin and may be divided into two main classifications – thermoplastics and thermosetting plastics.

a. Thermoplastics. Thermoplastics may be softened by heat and can be dissolved in various organic solvents. Two kinds of transparent thermoplastic materials are commonly employed in windows, canopies, etc. These materials are known as acrylic plastics and cellulose acetate plastics.

(1) Cellulose acetate was used in the past but since it is dimensionally unstable and turns yellow after it has been installed for a time, it has just about passed from the scene and is not considered an acceptable substitute for acrylic.

(2) Acrylic plastics are known by the trade names of Lucite or Plexiglas and by the British as Perspex and meet the military specifications of MIL-P-5425 for regular acrylic, MIL-P-8184 for craze-resistant acrylic.

b. Thermosetting Plastics. These plastics do not soften appreciably under heat but may char and blister at temperatures of 240 to 260 °C (400 to 500 °F). Most of the molded products of synthetic resin composition, such as phenolic, urea-formaldehyde, and melamine formaldehyde resins, belong to the thermosetting group. Once the plastic becomes hard, additional heat will not change it back into a liquid as it would with a thermoplastic.

3-19. STORAGE AND HANDLING. Because transparent thermoplastic sheets soften and deform when they are heated, they must be stored where the temperature will never become excessive. Store them in a cool, dry location away from heating coils, radiators, or steam pipes, and away from such fumes as are found in paint spray booths or paint storage areas.

a. Paper-masked transparent sheets must be kept out of the direct rays of the sun, because sunlight will accelerate deterioration of the adhesive, causing it to bond to the plastic and making it difficult to remove.

b. Plastic sheets should be stored with the masking paper in place, in bins that are tilted at a ten-degree angle from the vertical. This will prevent their buckling. If the sheets are stored horizontally, take care to avoid getting dirt and chips between them. Stacks of sheets must never be over 18 inches high, with the smallest sheets stacked on top of the larger ones so there will be no unsupported overhang. Leave the masking paper on the sheets as long as possible, and take care not to scratch or gouge the sheets by sliding them against each other or across rough or dirty tables.

c. Formed sections should be stored with ample support so they will not lose their shape. Vertical nesting should be avoided. Protect formed parts from temperatures higher than 120 °F (49 °C), and leave their protective coating in place until they are installed on the aircraft.

3-20. FORMING PROCEDURES AND TECHNIQUES. Transparent acrylic plastics get soft and pliable when they are heated to their forming temperatures and can be formed to almost any shape. When they cool, they retain the shape to which they were formed. Acrylic plastic may be cold-bent into a single curvature if the material is thin and the bending radius is at least 180 times the thickness of the sheet. Cold bending beyond these limits will impose so much stress on the surface of the plastic that tiny fissures or cracks, called crazing, will form.

3-21. HEATING. Before heating any transparent plastic material, remove all of the masking paper and adhesive from the sheet. If the sheet is dusty or dirty, wash it with clean water and rinse it well. Dry the sheet thoroughly by blotting it with soft absorbent paper towels.

NOTE: Wear cotton gloves when handling the plastic to eliminate finger marks on the soft surface.

a. For the best results when hot-forming acrylics, use the temperatures recommended by the manufacturer. A forced-air oven should be used–one that is capable of operating over a temperature range of 120 to 374 °F (49 to 190 °C). If the part gets too hot during the forming process, bubbles may form on the surface and impair the optical qualities of the sheet.

b. For uniform heating, it is best to hang the sheets vertically by grasping them by their edges with spring clips and suspending the clips in a rack. (See figure 3-17.) If the piece is too small to hold with clips, or if there is not enough trim area, lay the sheets on shelves or racks covered with soft felt or flannel. Be sure there is enough open space to allow the air to circulate around the sheet and heat it evenly.

c. Small forming jobs, such as landing light covers, may be heated in a kitchen baking oven. Infrared heat lamps may be used if they are arranged on 7-or 8-inch centers and enough of them are used in a bank to heat the sheet evenly. Place the lamps about 18 inches from the material.

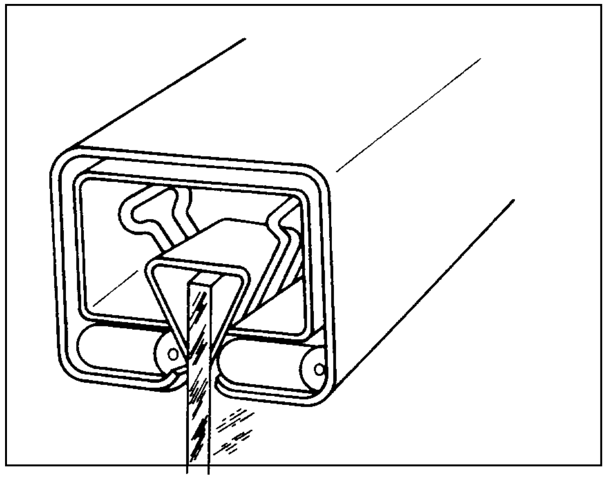

FIGURE 3-17. Hanging of acrylic sheets.

d. Never use hot water or steam directly on the plastic to heat it, because this will likely cause the acrylic to become milky or cloudy.

3-22. FORMS. Heated acrylic plastic will mold with almost no pressure, so the forms used can be of very simple construction. Forms made of pressed wood, plywood, or plaster are adequate to form simple curves, but reinforced plastic or plaster may be needed to shape complex or compound curves.

a. Since hot plastic conforms to any waviness or unevenness, the form used must be completely smooth. To ensure this, sand the form and cover it with soft cloth such as outing flannel or billiard felt.

b. The mold should be large enough to extend beyond the trim line of the part, and provisions should be made for holding the hot plastic snug against the mold as it cools.

c. A mold can be made for a complex part by using the damaged part itself. If the part is broken, tape the pieces together, wax or grease the inside so the plaster will not stick to it, and support the entire part in sand. Fill the part with plaster and allow it to harden, and then remove it from the mold. Smooth out any roughness and cover it with soft cloth. It is now ready to use to form the new part.

3-23. FORMING METHODS. (See table 3-1.)

a. Simple Curve Forming. Heat the plastic material to the recommended temperature, remove it from the heat source, and carefully drape it over the prepared form. Carefully press the hot plastic to the form and either hold or clamp the sheet in place until it cools. This process may take from ten minutes to one-half hour. Do not force-cool it.

b. Compound-Curve Forming. This type of forming is normally used for such parts as canopies or complex wingtip light covers, and it requires a great deal of specialized equipment. There are four commonly used methods, each having its advantages and disadvantages.

c. Stretch Forming. Preheated acrylic sheets are stretched mechanically over the form in much the same way as is done with the simple curved piece. Special care must be taken to preserve uniform thickness of the material, since some parts will have to stretch more than others.

d. Male And Female Die Forming. This requires expensive matching male and female dies. The heated plastic sheet is placed between the dies which are then mated. When the plastic cools, the dies are opened.

e. Vacuum-Forming Without Forms. Many aircraft canopies are formed by this method. In this process a clamp with an opening of the desired shape is placed over a vacuum box and the heated sheet of plastic is clamped in place. When the air in the box is evacuated, the outside air pressure will force the hot plastic through the opening and form the concave canopy. It is the surface tension of the plastic that shapes the canopy.

f. Vacuum-Forming With A Female Form. If the shape needed is other than that which would be formed by surface tension, a female mold, or form must be used. It is placed below the plastic sheet and the vacuum pump is connected. When air from the form is evacuated, the outside air pressure will force the hot plastic sheet into the mold and fill it.

g. Sawing And Drilling.

(1) Several types of saws can be used with transparent plastics, however circular saws are the best for straight cuts. The blades

TABLE 3-1. Typical temperatures for forming acrylic sheets.

Thickness of sheet (in.)	0.125		0.250		0.125		0.250	
Type of forming	Regular acrylic plastic. MIL-P-6886				Heat-resistant acrylic plastic, MIL-P-5425, and craze-resistant acrylic plastic, MIL-P-8184			
	°C	°F	°C	°F	°C	°F	°C	°F
Simple curve	113	235	110	230	135	275	135	275
Stretch forming (dry mold cover)	140	284	135	275	160	320	150	302
Male and female forming	140	284	135	275	180	356	170	338
Vacuum forming without form	140	284	135	275	150	302	145	293
Vacuum forming with female form	145	293	140	284	180	356	170	338

should be hollow-ground or have some set to prevent binding. After the teeth are set, they should be side-dressed to produce a smooth edge on the cut. Band saws are recommended for cutting flat acrylic sheets when the cuts must be curved or where the sheet is cut to a rough dimension to be trimmed later. Close control of size and shape may be obtained by band sawing a piece to within 1/16 inch of the desired size, as marked by a scribed line on the plastic, and then sanding it to the correct size with a drum or belt sander.

(2) Unlike soft metal, acrylic plastic is a very poor conductor of heat. Make provisions for removing the heat when drilling. Deep holes need cooling, and a water-soluble cutting oil is a satisfactory coolant since it has no tendency to attack the plastic.

(a) The drill used on acrylics must be carefully ground and free from nicks and burrs that would affect the surface finish. Grind the drill with a greater included angle than would be used for soft metal. The rake angle should be zero in order to scrape, not cut. (See figure 3-18.)

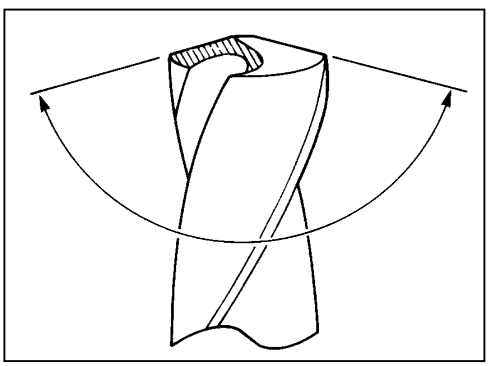

FIGURE 3-18. Drill having an included angle of approximately 150°, used to drill acrylic plastics.

(b) The patented Unibit (see figure 3-19) is good for drilling small holes in aircraft windshields and windows. It can cut holes from 1/8-to 1/2–inch in 1/32–inch increments and produces good smooth holes with no stress cracks around their edges.

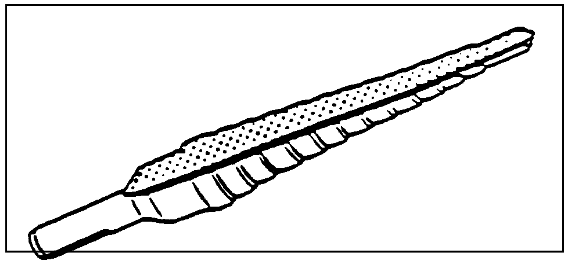

FIGURE 3-19. Unibit drill for drilling acrylic plastics.

h. Polymerizable Cements. Polymerizable cements are those in which a catalyst is added to an already thick monomerpolymer syrup to promote rapid hardening. Cement PS-30 and Weld-On 40 are polymerizable cements of this type. They are suitable for cementing all types of PLEXIGLAS acrylic cast sheet and parts molded from PLEXIGLAS molding pellets. At room temperature, the cements harden (polymerize) in the container in about 45 minutes after mixing the components. They will harden more rapidly at higher temperatures. The cement joints are usually hard enough for handling within 4 hours after assembly. The joints may be machined within 4 hours after assembly, but it is better to wait 24 hours.

(1) PS-30 and Weld-On 40 joints retain excellent appearance and color stability after outdoor exposure. These cements produce clear, transparent joints and should be used when the color and appearance of the joints are important.

(2) PS-30 and Weld-On 40 should be used at temperatures no lower than 65 °F. If cementing is done in a room cooler than 65 °F, it will require a longer time to harden and the joint strength will be reduced.

(a) The cement should be prepared with the correct proportions of components as given in the manufacturer's instructions and thoroughly mixed, making sure neither the mixing container nor mixing paddle adds color or affects the hardening of the cement.

Clean glass or polyethylene mixing containers are preferred.

(b) Because of their short pot life (approximately 45 minutes) Cement PS-30 and Weld-On 40 must be used quickly once the components are mixed. Time consumed in preparation shortens the effective working time, making it necessary to have everything ready to be cemented before the cements are mixed. For better handling pour cement within 20 minutes of mixing.

(c) For maximum joint strength, the final cement joint should be free of bubbles. It will usually be sufficient to allow the mixed cement to stand for 10 minutes before cementing to allow bubbles to rise to the surface. (See figure 3-20.)

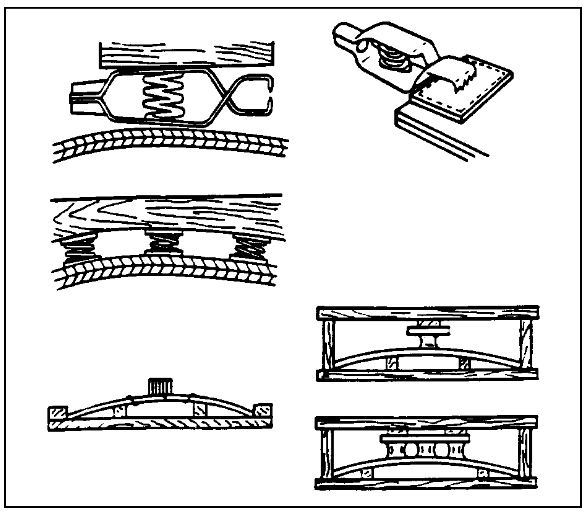

FIGURE 3-20. Applying pressure to acrylic plastics.

(d) The gap joint technique can only be used with colorless PLEXIGLAS acrylic or in cases in which joints will be hidden. If inconspicuous joints in colored PLEXIGLAS acrylic are needed, the parts must be fitted closely, using closed V groove, butt, or arc joints.

(3) Cement forms or dams may be made with masking tape as long as the adhesive surface does not contact the cement. This is easily done with a strip of cellophane tape placed over the masking tape adhesive. The tape must be chosen carefully. The adhesive on ordinary cellophane tape prevents the cure of PS-30 and Weld-On 40. Before actual fabrication of parts, sample joints should be tried to ensure that the tape system used will not harm the cement. Since it is important for all of the cement to remain in the gap, only contact pressure should be used.

(4) Bubbles will tend to float to the top of the cement bead in a gap joint after the cement is poured. These cause no problem if the bead is machined off. A small wire (not copper), or similar objects may be used to lift some bubbles out of the joint; however, the cement joint should be disturbed as little as possible.

(5) Polymerizable cements shrink as the cement hardens. Therefore, the freshly poured cement bead should be left above the surfaces being cemented to compensate for the shrinkage. If it is necessary for appearances, the bead may be machined off after the cement has set.

3-24. REPAIR OF PLASTICS. Replace, rather than repair extensively damaged transparent plastic, whenever possible, since even a carefully patched part is not the equal of a new section, either optically or structurally. At the first sign of crack development, drill a small hole with a # 30 or a 1/8-inch drill at the extreme ends of the cracks as shown in figure 3-21. This serves to localize the cracks and to prevent further splitting by distributing the strain over a large area. If the cracks are small, stopping them with drilled holes will usually suffice until replacement or more permanent repairs can be made. The following repairs are permissible; however, they are not to be located in the pilot's line of vision during landing or normal flight.

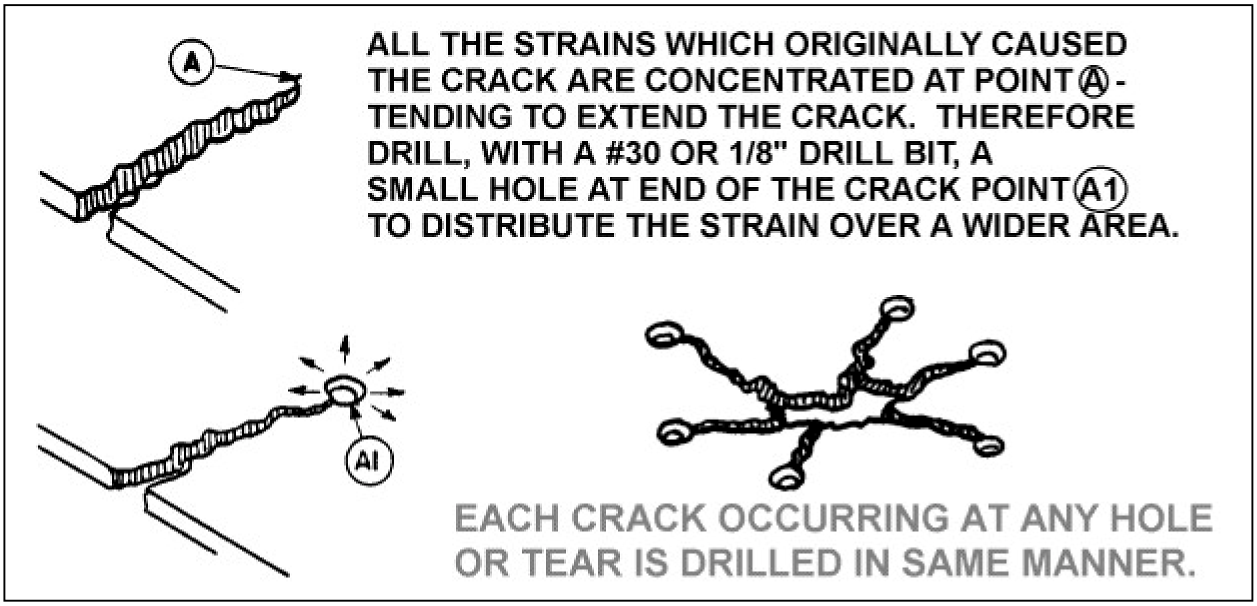

FIGURE 3-21. Stop-drilling cracks.

a. Surface Patch. If a surface patch is to be installed, trim away the damaged area and round all corners. Cut a piece of plastic of sufficient size to cover the damaged area and extend at least 3/4 inch on each side of the crack or hole. Bevel the edges as shown in figure 3-22. If the section to be repaired is curved, shape the patch to the same contour by heating it in an oil bath at a temperature of 248 to 302 °F, or it may be heated on a hot-plate until soft. Boiling water should not be used for heating. Coat the patch evenly with plastic solvent adhesive and immediately place it over the hole. Maintain a uniform pressure of 5 to 10 psi on the patch for a minimum of 3 hours. Allow the patch to dry 24 to 36 hours before sanding or polishing.

b. Plug Patch. When using inserted patches to repair holes in plastic structures, trim the holes to a perfect circle or oval and bevel the edges slightly. Make the patch slightly thicker than the material being

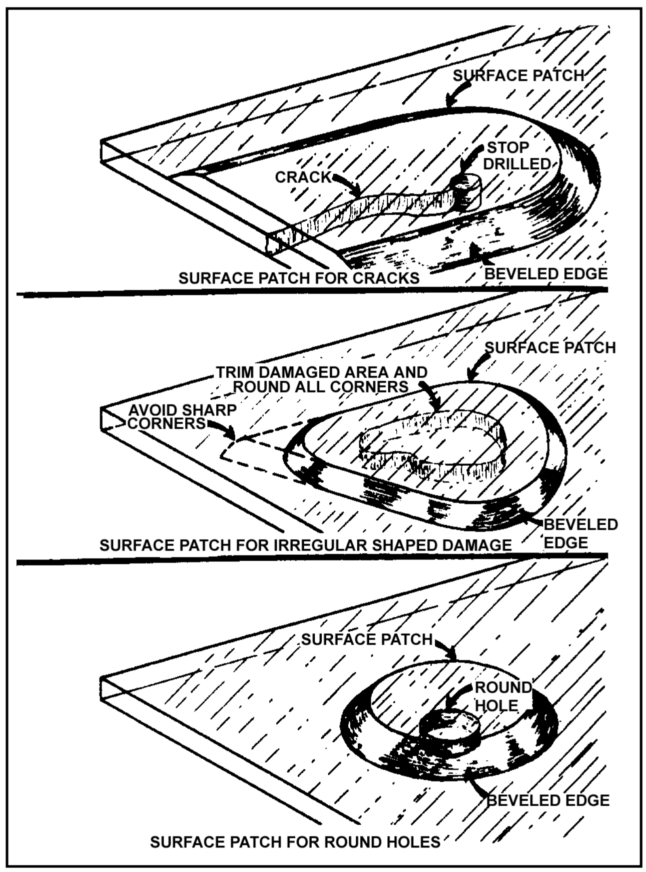

FIGURE 3-22. Surface patches.

repaired and similarly bevel its edges. Install patches in accordance with figure 3-23. Heat the plug until soft and press it into the hole without cement and allow to cool to make a perfect fit. Remove the plug, coat the edges with adhesive, and then reinsert in the hole. Maintain a firm light pressure until the cement has set. Sand or file the edges level with the surface, then buff and polish.

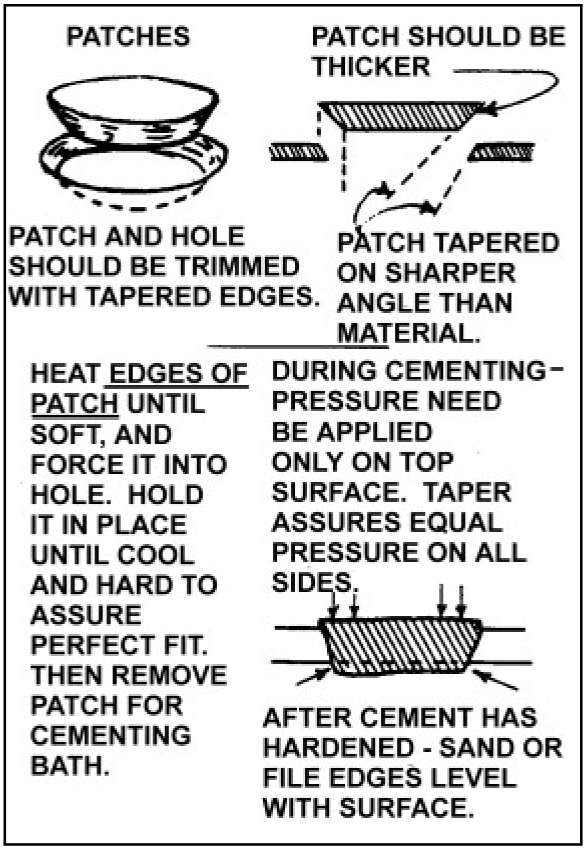

FIGURE 3-23. Plug patch repair.

3-25. CLEANING AND POLISHING TRANSPARENT PLASTIC. Plastics have many advantages over glass for aircraft use, but they lack the surface hardness of glass and care must be exercised while servicing the aircraft to avoid scratching or otherwise damaging the surface.

a. Clean the plastic by washing it with plenty of water and mild soap, using a clean, soft, grit-free cloth, sponge, or bare hands. Do not use gasoline, alcohol, benzene, acetone, carbon tetrachloride, fire extinguisher or deicing fluids, lacquer thinners, or window cleaning sprays. These will soften the plastic and cause crazing.

b. Plastics should not be rubbed with a dry cloth since this is likely to cause scratches, and also to build up an electrostatic charge that attracts dust particles to the surface. If after removing dirt and grease, no great amount of scratching is visible, finish the plastic with a good grade of commercial wax. Apply the wax in a thin even coat and bring to a high polish by rubbing lightly with a soft cloth.

c. Do not attempt hand polishing or buffing until the surface is clean. A soft, open-type cotton or flannel buffing wheel is suggested. Minor scratches may be removed by vigorously rubbing the affected area by hand, using a soft clean cloth dampened with a mixture of turpentine and chalk, or by applying automobile cleanser with a damp cloth. Remove the cleaner and polish with a soft, dry cloth. Acrylic and cellulose acetate plastics are thermoplastic. Friction created by buffing or polishing too long in one spot can generate sufficient heat to soften the surface. This condition will produce visual distortion and should be avoided.

3-26. REPLACEMENT PANELS. Use material equivalent to that originally used by the manufacturer of the aircraft for replacement panels. There are many types of transparent plastics on the market. Their properties vary greatly, particularly in regard to expansion characteristics, brittleness under low temperatures, resistance to discoloration when exposed to sunlight, surface checking, etc. Information on these properties is in MIL-HDBK-17A, Plastics for Flight Vehicles, Part II—Transparent Glazing Materials, available from the Government Printing Office (GPO). These properties are considered by aircraft manufacturers in selecting materials to be used in their designs and the use of substitutes having different characteristics may result in subsequent difficulties.

3-27. INSTALLATION PROCEDURES. When installing a replacement panel, use the same mounting method employed by the manufacturer of the aircraft. While the actual installation will vary from one type of aircraft to another, consider the following major principles when installing any replacement panel.

a. Never force a plastic panel out of shape to make it fit a frame. If a replacement panel does not fit easily into the mounting, obtain a new replacement or heat the whole panel and reform. When possible, cut and fit a new panel at ordinary room temperature.

b. In clamping or bolting plastic panels into their mountings, do not place the plastic under excessive compressive stress. It is easy to develop more than 1,000 psi on the plastic by over-torquing a nut and bolt. Tighten each nut to a firm fit, then back the nut off one full turn (until they are snug and can still be rotated with the fingers).

c. In bolted installations, use spacers, collars, shoulders, or stop-nuts to prevent tightening the bolt excessively. Whenever such devices are used by the aircraft manufacturer, retain them in the replacement installation. It is important that the original number of bolts, complete with washers, spacers, etc., be used. When rivets are used, provide adequate spacers or other satisfactory means to prevent excessive tightening of the frame to the plastic.

d. Mount plastic panels between rubber, cork, or other gasket material to make the installation waterproof, to reduce vibration, and to help to distribute compressive stresses on the plastic.

e. Plastics expand and contract considerably more than the metal channels in which they are mounted. Mount windshield panels to a sufficient depth in the channel to prevent it from falling out when the panel contracts at low temperatures or deforms under load. When the manufacturer's original design permits, mount panels to a minimum depth of 1-1/8 inch, and with a clearance of 1/8 inch between the plastic and bottom of the channel.

f. In installations involving bolts or rivets, make the holes through the plastic oversize by 1/8-inch diameter and center so that the plastic will not bind or crack at the edge of the holes. The use of slotted holes is also recommended.

3-28.—3-39. [RESERVED.]

SECTION 4. WINDSHIELDS, ENCLOSURES, AND WINDOWS

3-40. GENERAL. These repairs are applicable to plastic windshields, enclosures, and windows in *nonpressurized airplanes*. For pressurized airplanes, replace or repair plastic elements in accordance with the manufacturer's recommendation. When windshields and side windows made of acrylic plastics are damaged, they are usually replaced unless the damage is minor and a repair would not be in the line of vision. Repairs usually require a great deal of labor. Replacement parts are readily available, so replacement is normally more economical than repair.

a. Minor Repairs. There are times, however, when a windshield may be cracked and safety is not impaired. In that case, repairs can be made by stop-drilling the ends of the crack with a # 30 drill (1/8 inch) to prevent the concentration of stresses causing the crack to continue. Drill a series of number 40 holes a half-inch from the edge of the crack about a half-inch apart, and lace through these holes with brass safety wire (see figure 3-24) and seal with clear silicone to waterproof.

b. Temporary Repairs. One way to make a temporary repair is to stop-drill the ends of the crack, and then drill number 27 holes every inch or so in the crack. Use AN515-6 screws and AN365-632 nuts with AN960-6 washers on both sides of the plastic. This will hold the crack together and prevent further breakage until the windshield can be properly repaired or replaced. (See figure 3-24.)

c. Permanent Repairs. Windshields or side windows with small cracks that affect only the appearance rather than the airworthiness of a sheet, may be repaired by first stop-drilling the ends of the crack with a # 30 or a 1/8-inch drill. Then use a hypodermic syringe and needle to fill the crack with polymerizable cement such as PS-30 or Weld-On 40, and allow capillary action to fill the crack completely. Soak the end of a 1/8-inch acrylic rod in cement to form a cushion and insert it in the stop-drilled hole. Allow the repair to dry for about 30 minutes, and then trim the rod off flush with the sheet.

d. Polishing and Finishing. Scratches and repair marks, within certain limitations, can be removed from acrylic plastic. No sanding that could adversely affect the plastic's optical properties and distort the pilot's vision should be done on any portion of a windshield.

(1) If there are scratches or repair marks in an area that can be sanded, they may be removed by first sanding the area. Use 320- or 400-grit abrasive paper that is wrapped around a felt or rubber pad.

(2) Use circular rubbing motions, light pressure, and a mild liquid soap solution as a lubricant. After the sanding is complete, rinse the surface thoroughly with running water. Then, using a 500-grit paper, continue to sand lightly. Keep moving to higher grit paper and sand and rinse until all of the sanding or repair marks have been removed.

(3) After using the finest abrasive paper, use rubbing compound and buff in a circular motion to remove all traces of the sanding.

e. Cleaning. Acrylic windshields and windows may be cleaned by washing them with mild soap and running water. Rub the surface with your bare hands in a stream of water. Follow with the same procedure but with soap and water. After the soap and dirt have been flushed away, dry the surface with a soft, clean cloth or tissue and polish it with a

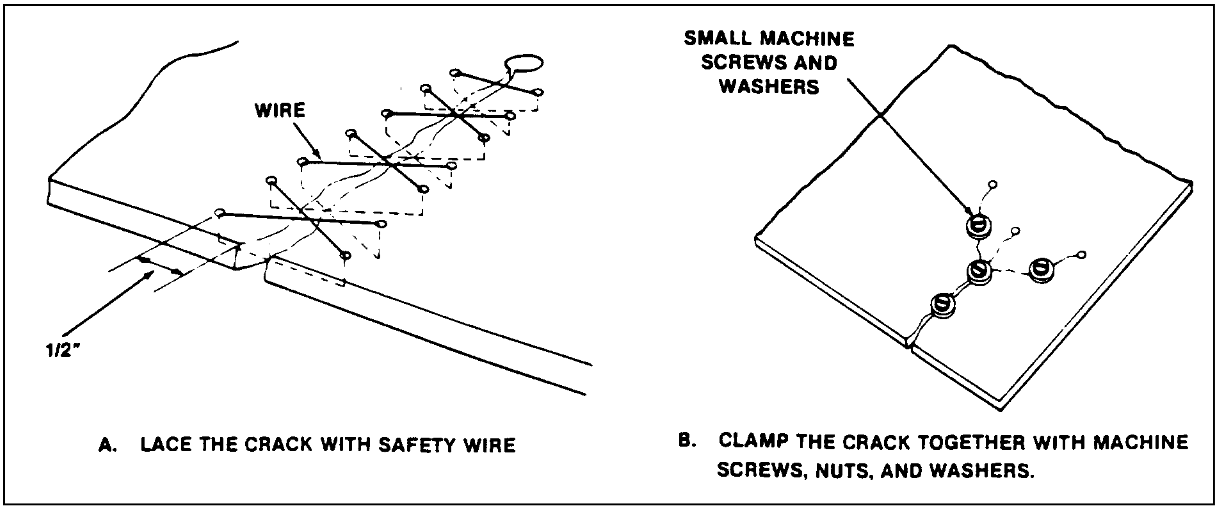

FIGURE 3-24. Temporary repairs to cracked windshields or windows.

windshield cleaner especially approved for use on aircraft transparent plastics. These cleaners may be purchased through aircraft supply houses.

f. Waxing. A thin coating of wax will fill any minute scratches that may be present and will cause rain to form droplets that are easily blown away by the wind.

3-41. PROTECTION. Acrylic windshields are often called "lifetime" windshields, to distinguish them from those made of the much shorter-lived acetate material. However, even acrylic must be protected from the ravages of the elements.

a. When an aircraft is parked in direct sunlight, the windshield will absorb heat and will actually become hotter than either the inside of the aircraft or the outside air. The sun will cause the inside of a closed aircraft to become extremely hot, and this heat is also absorbed by the plastic windshield.

b. To protect against this damage, it is wise to keep the aircraft in a hangar. If this is not possible, some type of shade should be provided to keep the sun from coming in direct contact with the windshield. Some aircraft owners use a close-fitting, opaque, reflective cover over the windshield. In many cases, this has done more harm than good. This cover may absorb moisture from the air and give off harmful vapors, and if it touches the surface of the plastic it can cause crazing or minute cracks to form in the windshield. Another hazard in using such a cover is that sand can blow up under the cover and scratch the plastic.

3-42. WINDSHIELD INSTALLATION. Aircraft windshields may be purchased either from the original aircraft manufacturer or from any of several FAA-PMA sources. These windshields are formed to the exact shape required, but are slightly larger than necessary so they may be trimmed to the exact size.

a. After removing the damaged windshield, clean all of the sealer from the grooves and cut the new windshield to fit. New windshields are covered with either protective paper or film to prevent damage during handling or installation. Carefully peel back just enough of this covering to make the installation. The windshield must fit in its channels with about 1/8- to 1/4-inch clearance to allow for expansion and contraction. If any holes are drilled in the plastic for screws, they should be about 1/8 inch oversize.

b. Place the sealing tape around the edges of the windshield and install the windshield in its frame. Screws that go through the windshield should be tightened down snug and then backed out a full turn, so the plastic can shift as it expands and contracts.

c. Do not remove the protective paper or film until the windshield is installed and all of the securing screws are in place.

3-43.—3-47. [RESERVED.]