

CHAPTER 5

WORKING AND REPAIR OF TRANSPARENT PLASTICS

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Introduction

1. This chapter gives information on machining and working transparent plastics, and then describes the various methods by which bullet-holes, cracks, etc., in transparent panels may be repaired. The cleaning and polishing of transparent plastics is described in A.P.2656A, Vol. I, Sect. 13.

Note . . . The plastics are referred to by the names of the materials of which they are made rather than by their trade names. For instance, "Perspex" is methyl methacrylate and conforms to D.T.D.339, so that it is included under the heading "Methyl methacrylate (D.T.D.339)".

WORKING OF TRANSPARENT PLASTICS

Methyl methacrylate (D.T.D.339)

Protective covering

2. Methyl methacrylate (D.T.D.339) has a delicate surface susceptible to scratching,

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and for this reason it is supplied with a protective covering of paper stuck on with a gelatine adhesive. Any working of the material, such as cutting and drilling, should be done with this protective paper in position, but the paper and all traces of adhesive must be removed before any shaping or moulding with accompanying heat is effected.

3. To remove the paper covering it should be raised at one corner and peeled off, after which any remnants of gelatine or paper should be washed off in warm soapy water (not warmer than 40°C.) and a final rinse given with clean water. The sheet should either be allowed to dry in air or should be rubbed dry with a soft leather—on no account should harsh fabrics be used. Washed sheets should not be placed in contact with one another. If it is necessary to pile or to stack washed sheets, wads of cotton wool should be used to separate the surfaces.

Cutting

4. Methyl methacrylate may be cut on any high-speed band or circular saw such as is used for cutting wood. The best results are obtained by the use of a fairly fine saw with about 14 teeth to the inch and very little "set". Dry cutting gives a good edge, but the finish is improved if water is used freely as a lubricant. The material should be slightly warmed if it shows a tendency to crack, but local overheating must be avoided.

5. Small pieces of the plastic may be cut with a fretsaw or a hacksaw, but the material tends to overheat and cause the saw to stick. Thin sheets, i.e. $\frac{3}{32}$ in. or less in thickness, may be scribed and broken along the scratch mark. Methyl methacrylate should not be guillotined or cut by shears.

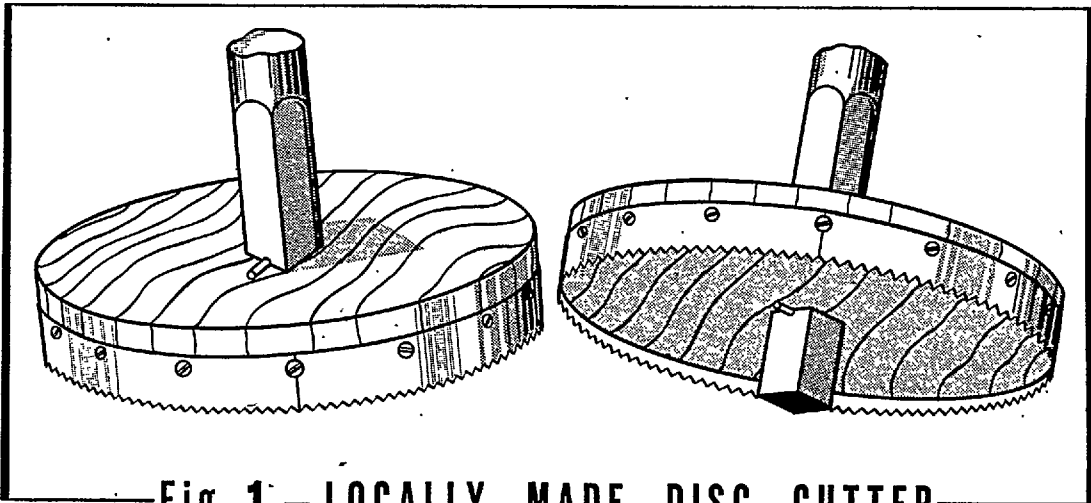


Fig. 1 — LOCALLY MADE DISC CUTTER

6. Thicker sheets should be cut by sawing. A hack-saw with a blade having from 18 to 24 teeth per inch, a jig-saw with a blade having about 10 teeth per inch and a cutting speed of 500 strokes per minute, a band-saw having 8 to 10 teeth per inch and running at about 2,500 ft. per min., and a carpenter's tenon saw, are all suitable tools for this purpose. When transparent panels are being sawn or drilled, the outline or position of the holes may easily be followed if a paper template is stuck to the under surface of the panel.

Preparing blanks

7. Blanks can be machined with a circular cutter revolving at 1,000 r.p.m. for blanks of about $1\frac{1}{2}$ in. diameter. In other words, the cutting speed should be about 400 ft. per min. The cutter should be cooled with compressed air, water, soluble oil or paraffin.

8. If a tubular cutter or other tool suitable for cutting circular blanks is not available, a useful substitute (*see fig. 1*) may be made up with materials which are easily available locally. A disc of hard wood about $\frac{3}{4}$ in. thick and carefully turned to the required diameter, a short length of $\frac{3}{8}$ in. round scrap rod and a fine hack-saw blade are required.

9. The cutter should be made up as follows:—

- (i) The saw blade must be carefully annealed and twisted round the periphery of the hardwood disc to measure the length of blade required.
- (ii) Cut the blade at the correct point and drill holes suitable for $\frac{3}{8}$ in. round-head wood screws at intervals of $\frac{1}{2}$ in. along the length of the blade. In order that the butting ends of the blade may meet satisfactorily when the blade is screwed down around the periphery of the disc, file semi-circular recesses at each end of the blade, so that a wood-screw inserted into the disc between the blade ends will hold them down on to the disc.
- (iii) Screw the blade down carefully, and tighten the screws.
- (iv) File the length of scrap rod to square section for about 2 in. from the end, and drill a hole through the centre of the disc, filing it to a square suitable for the insertion of the rod.
- (v) Insert the rod, and pin it above and below the disc, as shown in fig. 1. The tool should now be ready for use with either a carpenter's brace or a fitter's hand drill.

Note . . . Units may find it more satisfactory, where such a tool would be frequently used, to make up cutters with an alloy instead of a wooden disc and to fasten the saw blade with setscrews.

Drilling

10. Owing to its brittle nature, methyl methacrylate should only be drilled when the hole is to be plugged or filled with a cemented patch. In other instances, holes should be bored with a hot wire or needle. When a hole is drilled the sheet should be packed to prevent its splitting.

11. Methyl methacrylate may be drilled with ordinary twist drills. The following drilling speeds are recommended:—

$\frac{1}{16}$ in. dia.	7,000 r.p.m.
$\frac{1}{8}$ in. dia.	1,800 r.p.m.
$\frac{1}{4}$ in. dia.	900 r.p.m.

12. To prevent the material from cracking when the drill emerges from the underside of the sheet, the twist drills should be ground rather flat. This reduces the cutting angle and the "corkscrew" effect of the drill drawing itself through the sheet. It is advisable to use a hand feed so that the feed can be instantly reduced if there is any sign of overheating.

13. If the drill is ground so that the point is slightly off centre, the resulting hole is larger than the nominal diameter of the drill, but there is less binding in the hole. This alteration to a standard drill is particularly useful when deep holes are being drilled.

14. When holes deeper than $\frac{1}{2}$ in. are drilled, the drill should be lubricated with water, paraffin, or water containing soluble oil, and should be frequently removed from the hole. Fluted drills are best for small diameter deep holes.

Turning and milling

15. Methyl methacrylate may be readily turned by hand or slide-rest lathes. For hand turning, standard wood-working tools with flat tops and ground to an angle of 55° are suitable, and for slide-rest turning a similar type of tool should be used set at an angle of 60° with the spindle. A cutting speed of 65 ft. per min., and a feed of 0.010 in. per revolution is recommended.

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16. Edge milling or bevelling can be done with standard tools such as are used for wood or metal working. Methyl methacrylate swarf should not be allowed to lie on the surface of the material as this may lead to crazing. It is usual to mill the material without a lubricant and the dry swarf can easily be blown away from the tool with compressed air.

Hand-planing

17. Methyl methacrylate may 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, or a scraper. During all cutting operations where the material has to be gripped in a vice, thick paper packing should be used to protect the delicate surface of the material from injury by the jaws of the vice.

REPAIR OF TRANSPARENT PLASTICS

Introduction

18. Observation panels should be repaired only as an emergency measure if there are no new panels available. A repaired panel should be discarded as soon as possible and replaced by a new one. This is necessary because the repair may produce a blind spot and it is dangerous to use an imperfect panel.

19. It is, however, permissible to repair a damaged panel if the patch is so situated that it cannot impede the view—that is, if the panel is not used for anything but the admission of light.

Methyl methacrylate (D.T.D.339)

Identification markings

20. All methyl methacrylate (D.T.D.339) sheets and panels supplied to the Service bear an identification symbol, "D.T.D.339", stamped or inscribed near to one edge of the sheet or panel. This mark is in addition to any trade name such as "Perspex" which may appear on the material.

21. Where flat panels are made up by the Service from sheet material, this identification number must be inscribed in a position out of the range of vision and near to one corner, but so placed that it will not be obscured when mounted on the aircraft. The symbol is to be inscribed with a sharp pointed instrument, such as a scribe (Stores Ref. 1C/2187), in letters and figures not exceeding $\frac{1}{8}$ in. height and surrounded by a small circle. Care should be taken to ensure that, if the part of a stock sheet of material on which the specification number is inscribed is removed, the sheet is re-marked immediately.

Distortion of panels

22. No attempt should be made to remould distorted panels, since the application of heat, necessary for the process, causes 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.

Fitting panels to frames

23. Panels of methyl methacrylate (D.T.D.339) are subject to slight changes in area due to temperature variations. A permanent shrinkage of 0.1 per cent. in linear dimensions is usual after continued exposure to sunshine, and a further temporary shrinkage may occur during conditions of extreme cold. For this reason, holes drilled in methyl methacrylate (D.T.D.339) panels, for receiving fixing screws, bolts, or rivets, are given a clearance which may be from $\frac{1}{16}$ in. to $\frac{1}{8}$ in. or more on the diameter according to the size and estimated linear contraction of the panel. Care should be taken, when transparent panels are renewed, to ensure that these clearances are retained.

Repairing damaged panels

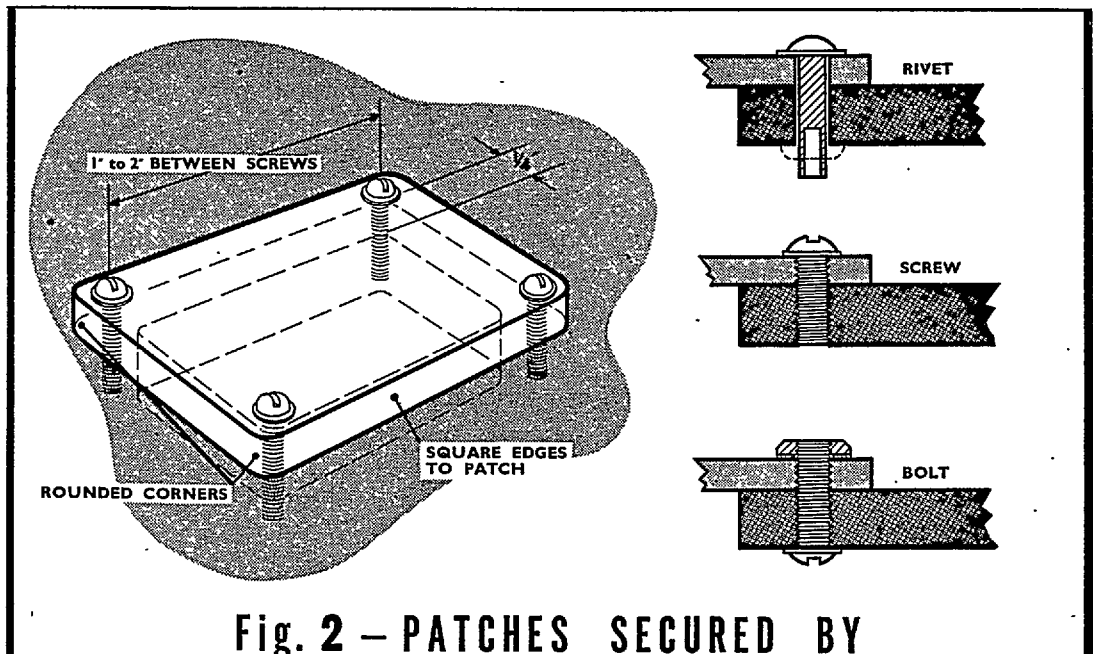
24. The repair by patching of transparent panels made of methyl methacrylate (D.T.D.339) may be grouped into three categories:—

- (i) Patches secured by screws or rivets.
- (ii) Inlay patches secured at the edges by cement.
- (iii) Overlay or lap joints secured by a cement.

Moulding repair patches

25. Methyl methacrylate is a thermo-plastic and may be satisfactorily remoulded, for making patches only, by the application of heat and light pressure. The plastic must be absolutely clean before it is remoulded. The temperature should be closely controlled. A temperature of 120–130°C. is suitable for remoulding material up to $\frac{1}{8}$ in. thick. The same temperature is suitable for material over $\frac{1}{8}$ in. thick, with oil or glycerin as the medium. The time required for heating depends on the thickness of the sheet— $\frac{1}{8}$ in. material needing 5 min., and material over $\frac{1}{4}$ in. thick needing about 30 min.

26. It is important that personnel handling the heated plastic should wear clean cotton gloves to avoid injuring the softened surface. When the patch is soft, it should be moulded by being pressed against the curved panel to which it is to be fitted, or else it should be placed in a mould made of wood or whitemetal. The surface of the mould should be covered with a stretchy fabric or with rubber latex. The pressure on the patch should be maintained until the material has cooled to room temperature, and the material should be quite cool before any attempt is made to polish it. Indeed, if it has been shaped properly, it should not need polishing.



**Fig. 2 — PATCHES SECURED BY
SCREWS, RIVETS, OR BOLTS**

Patches secured by rivets, bolts, or screws

27. Patches of transparent plastic may be secured to the panel by rivets, bolts, or screws. For panels up to $\frac{5}{32}$ in. in thickness, a patch of $\frac{3}{4}$ in. material should be used; for panels of

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greater thickness the patch should be of $\frac{5}{8}$ in. material. In all instances patches should be applied to the inside surface of a panel to minimise air resistance and erosion.

28. The holes for screws or rivets should be drilled at intervals of 1 to 2 in., and should not be less than $\frac{1}{4}$ in. from the edge of the patch (*see fig. 2*). Rivets should be tubular or semi-tubular, and should be $\frac{3}{32}$ in. or $\frac{1}{8}$ in. dia. The rivet holes for $\frac{3}{32}$ in. dia. rivets should be drilled $\frac{7}{64}$ in. dia. (No. 35 drill) and those for $\frac{1}{8}$ in. dia. rivets should be drilled $\frac{9}{64}$ in. dia. (No. 28 drill).

29. Patches may be secured by bolts or by setscrews. When bolts are used, fine clearance holes should be drilled in both patch and panel. For instance, for 6 B.A. bolts and nuts, a No. 33 drill should be used throughout. Setscrews require a clearance hole in the patch and a tapping hole in the panel. A 2 B.A. setscrew should be used in conjunction with a No. 13 drilled hole in the patch and a No. 24 drilled hole in the panel. The setscrew is passed through the hole in the patch and screwed tightly into the panel, after which the projecting end should be cut off and filed flush.

30. Washers should always be used with the screws or bolts. Direct contact between the undersides of the screw heads and the patches during tightening-up may cause damage to the patches and it is essential that suitable washers be inserted.

31. 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 in para. 25 should be followed.

Cements

32. The cement used for securing repair patches to methyl methacrylate is Cement, Perspex No. 6 (Stores Ref. 33C/888), which is supplied in pint cans. The cement is slow-hardening and a setting time should be allowed of about two hours. A piece of wood should not be used for stirring the cement as small bits break off and remain in it. A piece of metal, clean and free from rust, should be used instead. For the best results, only a second or two should elapse between the application of the cement and making the joint. When the cement is used in the open air, it becomes cloudy. The lid of the container should not be left off for any length of time.

33. When replacing the lid of the container, after the cement has been used, the operator should ensure that the lid is quite free of the adhesive, because the metal-to-metal bond is so strong that the lid cannot be removed.

WARNING.—Perspex No. 6 is inflammable and its fumes are poisonous, so that good ventilation is necessary. Smoking should not be allowed where the cement is being used owing to the risk of forming chlorine gas.

34. Where Perspex No. 6 is not available, an adhesive can be prepared by dissolving a quantity of methyl methacrylate in a solvent of the material, as follows:—

Prepare a solution of methyl methacrylate (D.T.D.339) filings in chloroform or benzene in the proportion of 4 per cent. of filings to 96 per cent. of chloroform or benzene. A higher concentration than 4 per cent. of the plastic in solution will cause the adhesive to become gelatinous. Even at the concentration recommended, a rapid increase in viscosity is liable to occur, and the adhesive should therefore be prepared immediately before it is required for use.

Masking tape

35. The cements used for securing repair patches are solvents of the plastic. If the cement is allowed to come in contact with any surfaces other than those being joined it destroys the smoothness. It is therefore necessary to protect the surfaces of the patch and the panel by the use of masking tape.

36. The tape should be applied round the edges of the repair in such a way that it covers all but the areas to be cemented and protects the rest of the panel from splashes and overflows of cement. The tape must be stripped off after one hour as otherwise it may cause crazing.

Inlay patches secured by cement

37. The use of inlay patches calls for a high degree of fitting skill. Surfaces to be cemented together must be in contact over their whole area, for the cement will not fill up cracks or gaps greater than 0.003 to 0.004. The material from which an inlay patch is made must always be the same as that of the panel. The method of repair by inlay patches may conveniently be divided into information for filling circular holes up to 1 in. or 2 in. diameter, and information for filling larger holes.

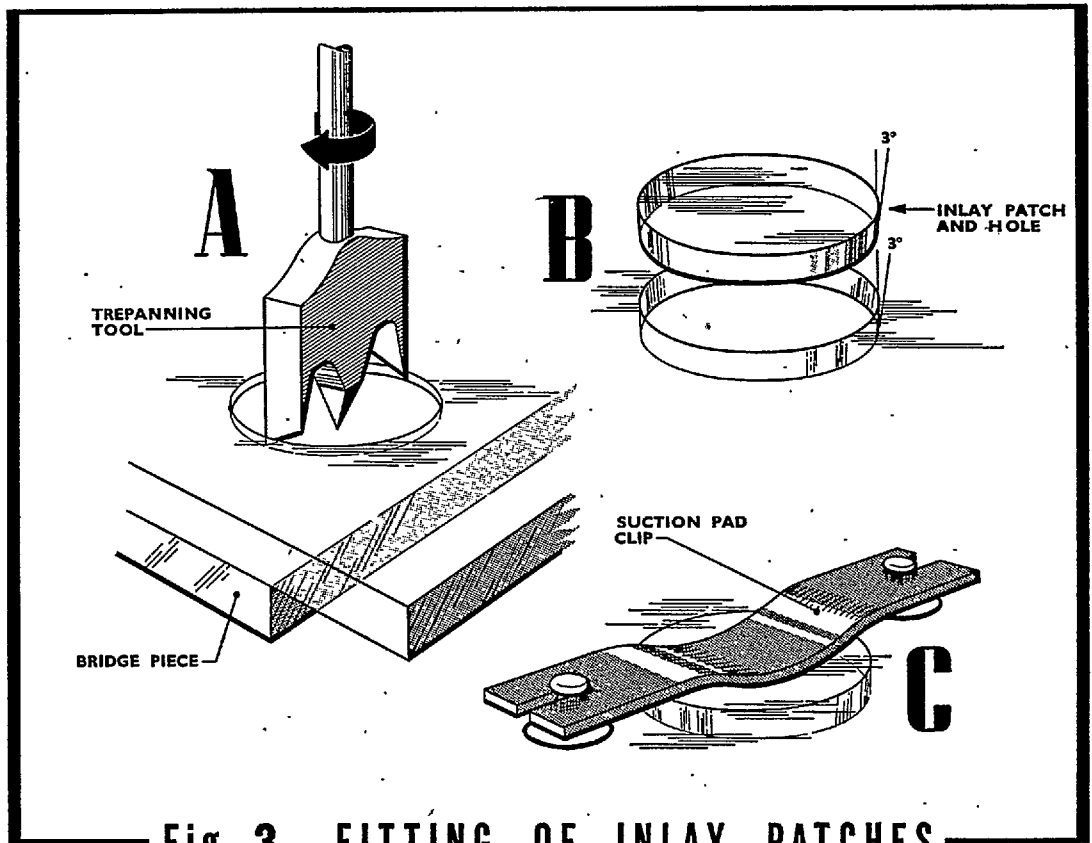


Fig. 3 - FITTING OF INLAY PATCHES

Preparing the hole—up to 2 in. diameter

38. Small holes, up to 1 in. or 2 in. diameter, should be made circular. Such holes may be cut with a drill (Stores Ref. 3B/1350 to 1601), a trepanning tool (see A, fig. 3), a centre bit (Stores Ref. 1A/122 to 132), 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, i.e., methyl methacrylate (D.T.D.:339), should be cemented across the hole (see A, fig. 3) as a bridge piece. If such material is not available a bridge piece may be made from a strip of any similar material, or of hardwood, and temporarily bolted to the panel. If the bridge piece is fixed on the reverse

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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.

39. The edge of the hole should be bevelled to the full thickness of the panel at an angle of 3° . This enables the inlay patch to be fitted in the form of a wedge (*see B, fig. 3*) and prevents it from falling through the hole in the panel during the fitting and cementing processes. 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.

Preparing the blanks—up to 2 in. diameter

40. As the practicable size of circular inlay patches will not exceed 2 in. dia., the normal curvature of a transparent panel should not be such as to preclude their use, but where the curvature is complex the use of discs will be impracticable and repair will be only possible by means of moulded patches (*see para. 25*).

41. Circular blanks of methyl methacrylate (D.T.D.339) for inlay patches may be cut by means of a tubular cutter such as described in para. 7. The blank must be bevelled round the edge to its full thickness at an angle of 3° and carefully mated up to the hole it is required to fit. Smooth files and the blade of a penknife or some other sharp light cutting tool should be used to obtain smooth flat-fitting surfaces.

42. Before the patch is cemented in the panel, all traces of oil or grease should be removed with paraffin. The cleaned surfaces should then be left until they are thoroughly dry. The edges or surfaces to be joined should be rubbed with durex emery cloth to remove any roughness left by the cutter—there is no need to polish the surfaces. Masking tape should be applied on the upper and lower surfaces of both patch and panel to protect them from the surplus cement.

43. The cement should be applied with a camel-hair brush (Stores Ref. 1A/202). The cemented surfaces should not be fingered and the joint should be made immediately. When the patch has been pressed into position and all air excluded from the joint, it should be held in place with suction pad clips as shown at C, fig. 3.

44. The time taken for the joint to dry out will vary with the warmth and humidity of the atmosphere. A warm dry atmosphere hastens the drying process; a cool moist atmosphere prolongs it. Under normal conditions a joint should be ready for the removal of the clips after about an hour. After an hour, the masking tape should be removed, and after three hours any surplus adhesive still remaining should be cleaned off with Durex emery cloth. The surface of the plastic may tend to craze at first, but the effect should disappear, leaving a comparatively clean and clear union.

Repairs over 2 in. diameter

45. If an inlay patch is used for repairing a hole more than 2 in. diameter, the hole in the panel should be cut to a rectangular or square shape with rounded corners. A piece of the same material as the panel should be shaped to suit the hole. As with circular patches all the edges should be bevelled 3° 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 that described for circular patches in para. 38 to 44.

Overlay patches secured by cement

46. Cemented overlay patches must not be used in positions where clear vision is essential. Overlay patches on flat transparent panels require little fitting skill (*see A, fig. 4*). The patches can also be moulded to suit panels of complex curvature, the nature and extent of such repairs depending largely on the skill of the fitter.

47. The damaged portion of the panel should first be cut by means of a hacksaw and filed to a regular shape—circular, rectangular, square, etc. A repair patch of the same material as the panel should be prepared; this should be the same shape as the hole in the panel, but $\frac{1}{4}$ in. larger on superficial dimensions. The sharp edges of the patch should be retained. If radii are filed on the edges, a distorted view may be obtained when the patch is fitted to the panel. Where the patch requires moulding to conform to the curvature of the panel, the procedure described in para. 25 should be adopted.

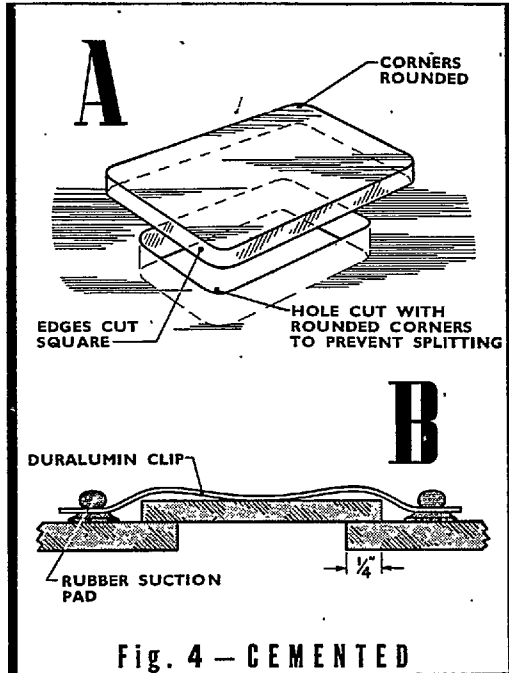


Fig. 4 - CEMENTED OVERLAY PATCH

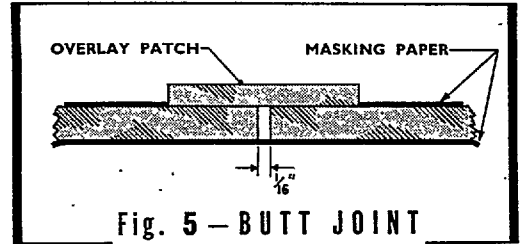


Fig. 5 - BUTT JOINT WITH OVERLAY

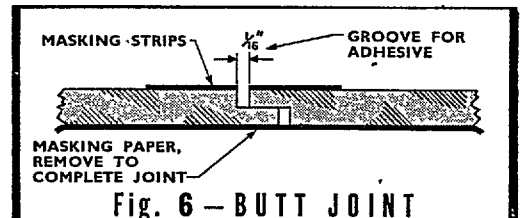


Fig. 6 - BUTT JOINT WITHOUT OVERLAY

48. The degree of accuracy required is such that when the patch is laid in position a 0.002 in. feeler will just enter, but not pass through, any part of the joint. If a larger feeler should enter, or the 0.002 in. feeler pass through at any point, the results will be poor and the joint should not be made until a better fit has been obtained. When the patch is ready for cementing, both this and the panel should be cleaned with paraffin.

49. Masking tape should be applied to any surfaces likely to be accidentally covered with the cement. The cement should then be spread on the mating surfaces with a camel-hair brush (Stores Ref. 1A/202). The patch should be carefully pressed into position by hand and secured by means of duralumin suction clips (see B, fig. 4). After one hour the masking tape should be removed, and the surfaces cleaned and polished if necessary.

Butt joints with overlay

50. The edges of the panels to be joined should be milled to ensure that the mating surfaces are parallel. The panels should be brought together until a gap of only $\frac{1}{16}$ in. remains between their edges (see fig. 5). This gap can be maintained by laying the panels on a strip or strips of masking tape. An overlay patch of similar composition and thickness to the panels (i.e. $\frac{1}{8}$ in. thick methyl methacrylate (D.T.D.339) panel) and $\frac{3}{4}$ in. to $1\frac{1}{2}$ in. in width, should be cut and laid in position on the panels to be joined.

51. The surfaces of the panels immediately on either side of the patch should be covered with masking tape to protect them from the cement. The patch should now be removed and an excessive amount of the cement should be poured on the margins of the panels on which the

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patch is to be placed, and in the $\frac{1}{8}$ in. groove, care being taken to prevent the formation of bubbles. The joint should now be made by placing one end of the patch in position and gently lowering the remainder until contact is made along its whole length. A light pressure should be applied with the fingers to remove air bubbles and excess cement. After a period of one hour has elapsed, the masking tape should be removed and the joint baked for 24 hours at 40 to 60°C.

Butt joints without overlay

52. Butt joints without overlay should only be used where no increase in thickness can be permitted. The panels to be joined should first be milled on their edges so as to leave a groove $\frac{1}{16}$ in. wide on each side of the assembly when the two panels are brought together (see fig. 6). Masking tape should be used as described in para. 50. The procedure is similar to that described for butt joints with an overlay patch.

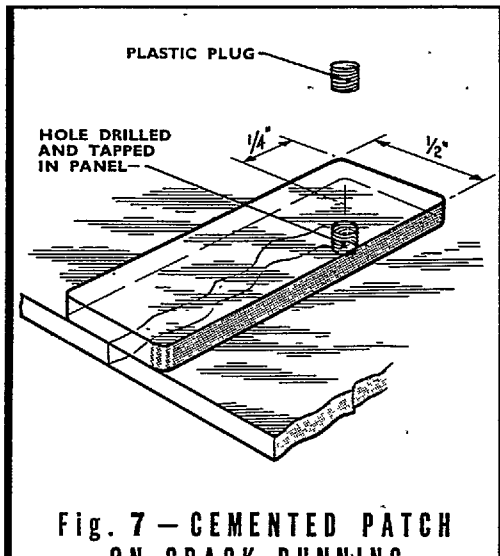


Fig. 7 — CEMENTED PATCH
ON CRACK RUNNING
FROM PANEL EDGE

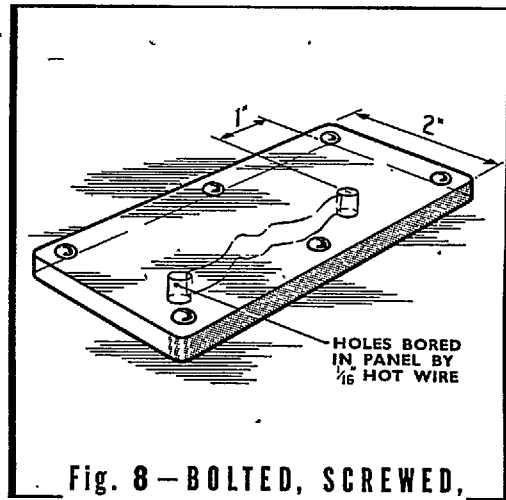


Fig. 8 — BOLTED, SCREWED,
OR RIVETED PATCH

Preventing cracks from spreading

53. Cracks in a transparent panel may be prevented from spreading if a hole is burnt at each end of the crack with a $\frac{1}{16}$ in. dia. hot wire or needle. The crack should be then covered by securing a covering strip of methyl methacrylate (D.T.D.339) or by one of the following methods:—

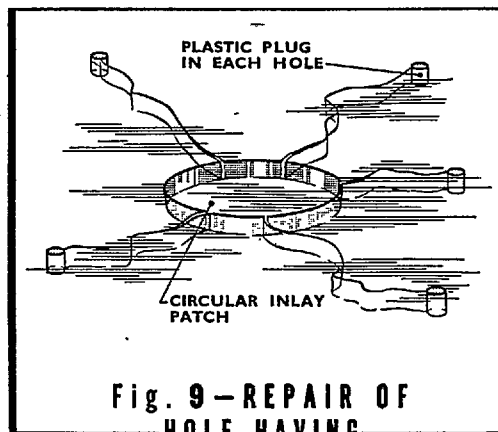
- (i) Cut a strip of the transparent material $\frac{1}{2}$ in. wide and long enough to cover the crack plus $\frac{1}{4}$ in. overlap at each end of the crack. With the covering strip in position and using a No. 27 drill, drill a hole through one end of the crack and through the strip. Repeat for the other end of the crack and, if the length of the crack is more than 3 in., drill one or more intermediate holes of the same diameter through both the crack and the strip. Apply cement to the whole of one surface of the strip and to the area it covers surrounding the crack. Clamp the strip to the panel with two or three 4 B.A. bolts and washers through the holes. When the cement is set, remove the bolts and washers, tap the holes 2 B.A., and plug them with pieces of rod made of methyl methacrylate threaded 2 B.A. and dipped in the cement (see fig. 7). Clean and polish the surface.

- (ii) Cut a strip of the transparent material 2 in. wide and long enough to cover the crack, plus about 1 in. overlap at each end of the crack. The strip should be bolted or riveted to the panel, the holes being drilled well clear of the crack in the panel (*see fig. 8*).

Cracks starting at the edge of the panel

54. If cracks appear at the edge of a panel when it is fitted into its frame, satisfactory repairs may be effected as follows:—

- (i) Cover the crack with masking tape on both sides of the panel and slit the tape by inserting a razor blade into the crack, as near the edge of the panel as possible.
- (ii) Using a fine camel-hair brush, paint the surface with cement, allowing it to run down into the crack. On no account attempt to flex the panel in order to separate the faces of the crack for the insertion of the brush, as this would extend the crack.
- (iii) When the cement becomes tacky, withdraw the blade and allow the faces of the crack to come together. Leave the cement to dry for an hour, then remove the masking tape.



**Fig. 9 — REPAIR OF
HOLE HAVING
RADIATING CRACKS**

Repair of hole with radiating cracks

55. The hole should be repaired with a circular inlay patch (*see fig. 9*) as described in para. 37. The extremity of each crack should be drilled and tapped 2 B.A. The holes should then be plugged with methyl methacrylate rod, threaded 2 B.A. and dipped in cement. The cracks should be painted with cement (*see para. 54*). When the cement is dry, the surface should be cleaned and polished.

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