CHAPTER 4

CABLE CONNECTIONS AND TERMINATIONS

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Introduction

1. Various methods have been employed in the past for making electrical joints and connections in aircraft electrical installations, and among the more widely used methods are those described below:—

(*a*) *Twist Connections*. A simple and rapid means of joining two conductors by removing the dielectric from the ends of the cores, twisting together the exposed conductors tightly (in some cases a light coating of solder may be applied to the twisted conductors for added security), then taping over the joint with a fabric insulating material.

(*b*) *Screw Connections*. Twisting the strands of a conductor together and trapping the twisted strands under the head of a compression screw. Breakage or escape of individual strands leads to loss conductor capacity and risk of short-circuits. A variant form of screw connection consists of looping the twisted strands of the conductor around a terminal stud and securing under a washer and lock-nut, or of securing the twisted strands in a terminal hole by a grub screw. Strand breakage and fraying may be avoided by dipping the twisted conductor in solder, but a connection of this kind lacks flexibility and is liable to fracture in conditions of vibration.

(*c*) *Soldering*. Direct soldering of conductors to equipment terminals is extremely effective if efficiently performed, but 'dry' joints, involving loss of conductivity, are hard to detect. Plate-type cable-ends also offer a sound method of connection, with the cable-end fitting secured under some form of compression screw after being soldered to the conductor of the cable, but weakness is always apparent at the entry point of a small cable to the end-fitting because of the "stiffness" of the soldered joint. Soldered end-fittings on large cables usually involve the use of considerable heat, with consequent risk of damage to the cable dielectric, but such connections, if expertly made, are extremely effective.

2. The above methods, when efficiently executed by skilled personnel with suitable equipment, are admittedly quite effective, but with varying standards of skill and experience in this rather specialized type of work there is always the risk of low-quality connections impairing the serviceability of an entire electrical installation. For this reason, almost all connections in the circuits of Service aircraft installations are made through the medium of solderless cable-end fittings which are mechanically "crimped" on to the ends of the cables by means of special tools. Given the correct equipment, such connections can be made with absolute uniformity and guaranteed quality by unskilled personnel, and they afford permanently effective connections even in the most "difficult" conditions of vibration, etc.

Solderless Cable-End Fittings

3. The range of solderless cable-end fittings is so comprehensive that virtually every requirement for cable-end fittings likely to arise in an aircraft electrical installation can be satisfied by "stock" items. This implies the supply of cable lugs of various types, for the various forms of screw-compression connections that are normal usage, suitable for use on the complete range of approved aircraft cables; plug pins and socket inserts, for an almost equally extensive range of cables, for use in plug-and-socket connections such as are found in the Plessey system of wiring; ferrules and ferrule adapters such as are used in the S.B.A.C. wiring system, and in-line connectors or splices for direct connection of individual lengths of cables of various types and ratings. Notwithstanding the vast number of individual items that constitute the full range of solderless cable-end fittings, each and every item in the range has one feature in common—in every case the fitting incorporates a crimping barrel which, after insertion of the bared end of the cable conductor, is deformed by a suitable compression tool so that conductor and barrel become a homogenous mass of excellent electrical conductivity and good mechanical strength. The actual design of the crimping barrel, and of the individual fitting in general, is dependent on the material used and the method of manufacture, e.g., whether the component is of copper, aluminium or brass, and is made from bar, tube, raised from strip metal, or cast—the design may also be influenced by other practical considerations, such as space limitations, in the installation.

4. There are two general categories of barrel deformation or "crimping", viz., indent crimping and confined crimping. In crimps of the former type, one or more indentations in the crimping barrel are produced by the crimping tool, and the metal displaced by the application of pressure escapes laterally. In the confined type of crimp, the barrel is totally enclosed during the crimping operation, and the actual operation compresses the barrel and conductor almost solid. Ideally the confined crimp should be round, but it has been found in practice that a hexagonal shape gives excellent results and also simplifies the manufacture of crimping dies—this form of crimp is uniformly applicable to large and small cable sizes, and to aluminium as well as copper conductors. To facilitate inspection of the crimped joint, the barrel is frequently made open at the tongue or plate end (cable-lug fittings) or is provided with an inspection hole (other fittings) through which an examination of the bared conductor—for adequate entry into the barrel—can be made.

5. When dealing with small cables the point of entry of the conductor into the crimping barrel may be a point of weakness where mechanical failure, as a result of strain or vibration, is liable to occur. This weakness may be eliminated by extending the barrel to encompass and support a length of the cable insulation. In the case of cable-end fittings made from rod or tube an extended barrel with a suitably enlarged bore extending over part of its length serves this purpose—the extension may either just support the insulation, or it may be crimped over it to provide additional grip. When dealing with fittings made from strip it is common practice to fit a suitable sleeve over the crimping barrel; in this way the insulation of the cable is supported adequately and at the same time the seam of the rolled-up barrel is prevented from spreading during the crimping operation. When crimping both conductor and insulation the appropriate crimping tools are usually designed to make both crimps simultaneously in a single operation of the tool.

6. The design of the tongue or plate of a solderless cable-lug depends on how and where the fitting is to be attached to the 'receiving' component—four typical forms of cable-lug are shown in Fig. 1. The most common form is the ring tongue, circular in outline with a hole to fit over a terminal stud or to take a securing screw; modifications of this basic design incorporate location holes or slots, or two stud-holes instead of one, to eliminate the risk of the lug swivelling about its anchorage. Slotted, fork, spade and hook-tongue lugs are also available; these types permit easy withdrawal of the lug from the terminal stud or screw, but are less resistant to vibration. Flag and various angled types of tongue provide connections to studs and screws not otherwise easily accessible.

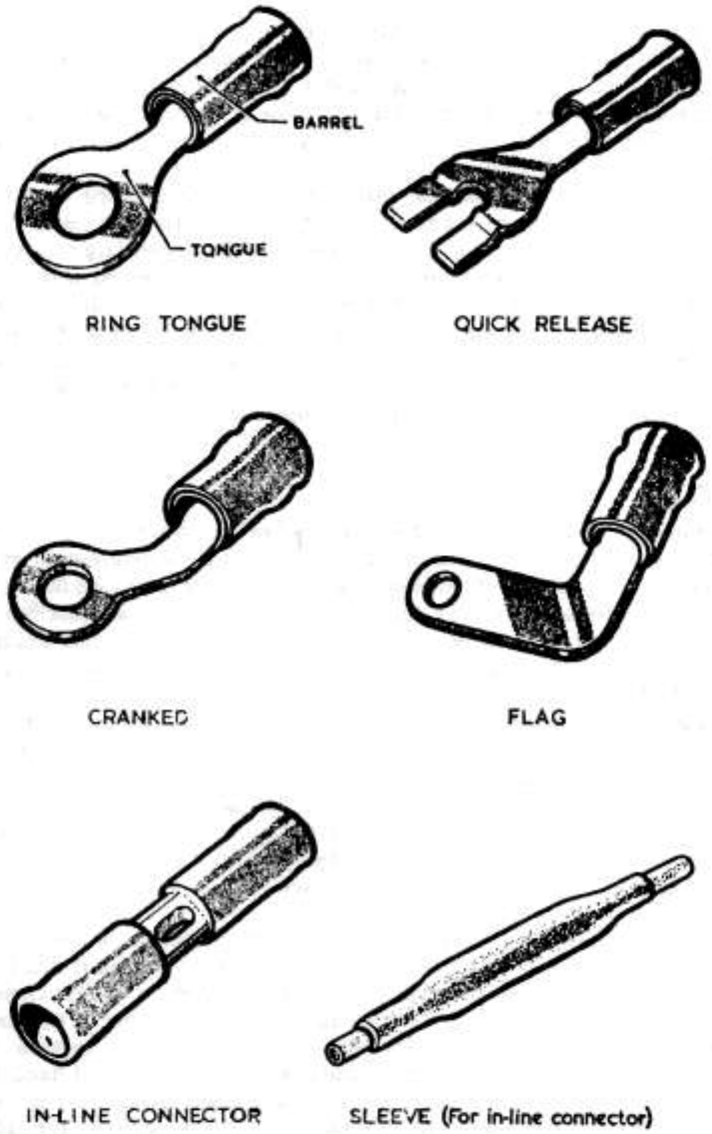

Fig. 1. SOLDERLESS CABLE LUGS AND IN-LINE SPLICES

7. The most widely used form of in-line connector or splice is the butt type shown at the bottom of Fig. 1; this is basically two standard crimping barrels set in series, with one conductor entering and being crimped in either barrel—a hole formed in the inter-barrel link provides for inspection of the bared conductors prior to the actual crimping operation being performed. An alternative form, the parallel splice, is less common; this is simply a single crimping barrel long enough to accept and be crimped on two conductors, which may enter from opposite ends or from the same end to lie parallel with each other in the barrel. Three-way and four-way splice units are also produced for industrial purposes, but these are not in general use for aircraft work.

Insulation Sleeves

8. The crimping barrels of cable-end fittings, after crimping has been completed, are usually protected by insulating sleeves—in many instances these sleeves are also used as circuit-code markers. Various types of protective and marker sleeves are available in a comprehensive range of lengths and diameters: Helsyn sleeves are made of neoprene-based synthetic material, Helvin sleeves are of polyvinyl chloride (P.V.C.), and Hellerman sleeves are of mineralized rubber. Helsyn and Helvin sleeves are resistant to oil, gasoline, etc., and because of this ability they are also used for additional protection to cables exposed to such liquids (see Chap. 5 Para. 11). The fitting of sleeves is simplified by the use of a sleeve-fixing tool (see Chap. 2, Fig. 22)—these tools are available in small, medium and large sizes. The prongs of the tool should be lightly coated with Hellerine lubricant (supplied with the tool) before placing the sleeve over them; no other lubricant should ever be used for this purpose, since incompatible lubricants can give rise to rapid and total deterioration of the sleeve in service. To eliminate the sleeve-fixing operation, cable-end fittings of certain ranges are also manufactured with plastic insulation sleeves bonded to the metal of the fittings—conductor and cable dielectric can thus be crimped, and the joint insulated from external contact, in a single operation.

Crimping Tools

9. Good crimped joints cannot be made with makeshift crimping tools: a full range of properly-designed crimping equipment, capable of dealing effectively with every type and size of general-purpose cable and cable-end fitting used in aircraft installations, is standard workshop equipment for aircraft servicing, and there can never be any justification for using anything but the correct equipment for each individual job. For the smaller classes of work plier-type tools, such as are embodied in the Plessey, Hellerman, and Erma hand-crimping toolkits described later in this Chapter, are very convenient: tools of this type may have a fixed head with crimping jaws for one or more cable sizes, or the head may be designed to accommodate interchangeable insert dies for different sizes of cable. In certain instances the plier-type crimping tool incorporates a 'full-crimp' device to ensure completion of the crimping operation once the operator has started to make the crimp—the design is such that the tool cannot be opened until the full travel of the crimping head has been completed. The Lucas hand-crimping toolkit, also described in this Chapter, is based on a screw-operated tool equipped with interchangeable dies.

10. Because of the limited crimping force that can be exerted with hand-crimping tools, their use is restricted to cables up to cable group C6 (Pren 24 and equivalent), group C9, or group C10 (see Chap. 1 of this Section). For work on cables of higher cable groups it is necessary to use hydraulically-operated crimping equipment capable of producing the high crimping pressures needed to form a joint of the quality mentioned in para. 12. Various models of this form of equipment, which is available in both bench and hand-tool versions; are in current use. The Erma hydraulic portable crimping machine, for example, consists of a 15-ton crimping head and a set of eight interchangeable dies suitable for cables in groups C10 (minimum) to C18, a separate foot-pump, and the necessary high-pressure hose and connectors—the crimping head is designed for bench mounting. The Plessey hydraulic crimping kit, which is lighter and more compact than the Erma, has even greater applications, since it can be used on all Pren cables (and equivalents) from Pren 4 to Pren 280—the crimping head of the Plessey equipment is hand-held in operation.

11. Crimping equipment enables unskilled operators to make connections of excellent mechanical strength and first-class electrical conductivity, as well as of uniform quality and appearance. Such results are possible because the equipment is made to very high standards of accuracy and finish—it is, in fact, precision equipment, even if it is of very robust construction, and as such it must receive the careful handling and regular servicing that is the natural right of all precision equipment. Precise instructions for the use of each equipment is given in the container, and full instructions pertaining to individual crimping kits are pub-

lished in appropriate Chapters of A.P. 4343S, Vol. 1, Section 15: if in doubt as to the procedure applicable to a crimping set, consult these sources of information *before* commencing operations.

Quality of Crimped Joints

12. Every wiring connection in an aircraft electrical installation must be mechanically strong (to withstand disturbance and vibration), and its electrical resistance must be low and stable. Mechanical strength is assessed in terms of the force required to pull the crimped component from the conductor: a small fitting, properly crimped to a Pren 4/6 cable, should withstand a pull of about 10 lb. without damage to the connection, while a force of several tons should be needed to disturb crimped joints made on the larger sizes of cables, such as Pren 280. Electrical efficiency of connections is determined by measuring the voltage drop across the connection when it is carrying a stated current; this drop should not exceed that incurred in a length of cable equal to the length of the connection. Special fittings are prescribed for use in conditions that are more arduous than those normally associated with general aircraft service; these fittings have, in general, been type-tested for satisfactory behaviour in conditions of extremes of temperature, humidity, current overloading or cycling, or adverse chemical environment, or for combinations of these conditions.

Use of Aluminium

13. Special aluminium fittings are supplied for use with cables having aluminium cores, and it is most important that copper cable-end fittings are never, under any circumstances, used on aluminium conductors, or vice versa—a pronounced galvanic action, resulting in corrosion, is liable to develop between a copper/aluminium 'couple' if exposed to even slight humidity. Subject to certain simple precautions rendered necessary by the physical differences between aluminium and copper, i.e. the softness and lower density of aluminium as compared with copper, and the ready formation of aluminium oxide (an insulating compound which can give rise to unduly high resistance in connections), the actual crimping operation is identical and the same tools and dies may, in many instances, be used on copper and aluminium conductors and end-fittings. The formation of aluminium oxide in the crimped connection is discouraged by first cleaning the aluminium conductor with a wire brush (to remove existing oxide) at the 'strip-back' stage of preparation, then applying a special inhibitor to the conductor to prevent further oxidation—the inhibitor should be packed into the crimping barrel, and the 'tongue' end of the barrel sealed off with the finger-end while the conductor is being entered to ensure adequate penetration of the inhibitor into the strands. Crimping must be done immediately after cable preparation.

Lucas Hand Crimping Equipment

14. Lucas hand crimping equipment is designed primarily for crimping cable-end fitting, of S.B.A.C. design (see Chap 3 for full details of the S.B.A.C. wiring system) to the ends of suitable cables. The crimping equipment, like the components of the S.B.A.C. wiring systems was originally designed for use with the older types of general-purpose aircraft cables such as the -cel, -vin and -rubber ranges, but it can also be employed quite effectively with newer types of cables, such as -pren and -nyvin, of corresponding cable groups. Two tool kits are available in this range of crimping equipment: kit No. 1 is designed for crimping ferrules and ferrule adapters of 4-A to 37-A rating, while kit No. 2 is supplied for use on heavy-duty cable-end fittings of 63-, 138- and 183-A rating.

15. **No. 1 Kit.** The crimping tool of this kit is simply a phosphor-bronze die-carrier in which a two-part interchangeable crimping-die assembly is accommodated: the die assembly is spring-loaded to open, and the ferrule or ferrule adapter that is to be crimped to a cable is placed between the open jaws of the die. One component of the die assembly is static, and the other component is forced (against the action of the loading spring) towards the

static member by turning the tommy bar secured to the end of a threaded operating shaft in the clockwise direction; the resulting compression of the crimping barrel of the adapter or ferrule between the faces of the die produces a single indent crimp at the front of the barrel into the bared conductor of the cable (previously inserted into the barrel), and also crimps the back end of the ferrule barrel to the cable insulation. The kit contains five dies, each marked with the rating of the ferrules or adapters for which it is supplied, i.e. with the rating of the 'old-style' cable, such as -vin cable, which the crimping barrel can accommodate snugly: details of these dies, and their uses, are as follows:—

(*a*) Dies marked '4/7'; Ref. No. 5H/97 for use on 4-A and 7-A ferrules, Ref. No. 5H/100 for use on adapters taking -vin 4 and -vin 7 cables to 37-A connectors.

(*b*) Dies marked '19'; Ref. No. 5H/98 for use on 12-A and 19-A ferrules, Ref. No. 5H/101 for use ón adapters taking -vin 12 and -vin 19 cables to 37-A connectors.

(*c*) Die marked '37'; for use on 37-A ferrules and on adapters for taking -vin 37 cable to 19-A connectors.

16. **Selection of Cable-End Fittings and Crimping Dies.** The 'nominal rating' of S.B.A.C. cable-end fittings is based on the 'old-style' cable (-cel, -vin and -rubber type) which, after being stripped back for a specified length, is a smooth fit in the crimping barrel of the component. The rating of a ferrule or ferrule adapter (37-A and under) can be determined by visual examination (see Chap. 3 for details), hence it is a simple matter to choose the appropriate ferrule or adapter for use on an 'old-style' cable; having selected the cable-end fitting, the correct die for crimping the fitting can be chosen (see previous paragraph). For example, a Univin 7 cable which is to be connected to a 19-A connector (the smallest of the S.B.A.C. connector range) must terminate in a 7-A ferrule, and the correct die for crimping this particular component is the '4/7' die Ref. No. 5H/97. The position is rather more complicated when cables such as -pren or -nyvin types are in use, since these cables are rated on a different basis. The recommended course of action is to determine the cable-group of the new-style cable (by cross-reference to A.P. 4343C, Sect. 5 and A.P. 4343, Vol. 1, Sect. 12, Chap. 5), then note the rating of 'old-style' cables in this cable-group: this rating is, of course, the rating of the crimping barrel of the S.B.A.C. ferrule or adapter for the 'new-style' cable in question. Let us assume, for example, that a Uninyvin 18 cable is to be connected to a 37-A S.B.A.C. connector. Nyvin 18 is in cable-group C4; old-style cables in this group are rated at 7-A (see Chap. 1, Para. 41 for confirmation), hence a 7/37 ferrule adapter must be crimped to the cable end—the appropriate die for crimping this component is the '4/7' die, Ref. No. 5H/100. It may be found that the cable-group of the new-style cable does not coincide with that of any old-style cable, as in the case of Uninyven 10: this particular cable is in cable-group C7, while the 'nearest' old-style cables are in group C6 (-vin 19) and C9 (-vin 37). A 19-A crimping barrel cannot take the bared conductor of a C7 cable, hence the only alternative is to make use of a fitting with a 37-A crimping barrel, but because of the excessive clearance between conductor and barrel a suitable sleeve, covering the bared conductor, is needed to achieve a sound crimped connection. Uninyvin 8 (cable-group C8) also requires a C9 (37-A) fitting, but in this case the clearance is not unduly excessive and an inner sleeve is not needed. Cables of group C1 (see Chap. 1, Para. 41 for particulars) constitute a special case; the conductors of these very small cables, after stripping back, are bent double before being inserted into 7-A crimping barrels.

17. **Cable Preparation.** As has already been stated, ferrules and ferrule adapters rated at 37-A and below are crimped to the bared conductor and also to the dielectric of the cable. The stripping back of the cable dielectric preparatory to crimping on ferrules and adapters must therefore be performed carefully; the conductor strands must not be damaged in any way, and the cable insulation must be removed for precisely the distances quoted below:—

(*a*) Cables in cable group C1 (for double insertion in 7-A crimping barrels)—$\frac{5}{8}$ in.

(*b*) Cables in cable groups C2 to C6 (for insertion in 4-A, 7-A, 12-A and 19-A crimping barrels)—$\frac{5}{16}$ in.

(*c*) Cables in cable groups C7 to C9 (for insertion in 37-A crimping barrels)—$\frac{11}{32}$ in.

18. Having selected the appropriate cable-end fittings and crimping die-assembly for the work in hand, assemble the die unit in the crimping tool—the spring-loaded component of the die-assembly *must* be nearest the threaded shaft of the tool. It is most important that each die in the tool kit is used only for crimping the specific types of ferrule or ferrule adapters for which it is designed, and for no other purpose. Cable entry for the horizontal dies (Ref. Nos. 5H/100 and 5H/101, for use with ferrule adapters other than 37/19 adapters) is from the side of the tool with the catch for locking the handle in position; the ferrule adapter should first be placed on the prepared cable end and then located endwise in the die assembly. When crimping with the vertical dies (all ferrules and 37/19 ferrule adapters) the cable, with end-fitting placed on the prepared cable end, is inserted to the maximum extent from the top of the die—location is automatic. Close the die by turning the tommy bar clockwise until the die faces meet, then reverse the turning action until the die opens sufficiently to allow the cable-end to be removed. Examine the crimped connection; the ferrule must not be unduly distorted, and shearing of the sides should not have occurred during the crimping process. Cut off any excess length of conductor protruding from the ferrule, and ensure by visual inspection that a firm and satisfactory crimp has been made.

19. **Servicing of Crimping Tools.** All dies should be checked periodically for satisfactory operation; no definite limits are laid down regarding maximum permissible wear of die faces. All moving parts of the crimping tool, the spherical top at the end of the screwed shaft, and the die-assemblies should be cleaned regularly and smeared lightly with good-quality grease.

20. **No. 2 Crimping Kit.** Heavy-duty S.B.A.C. cable-end fittings (i.e. fittings for attachment to the ends of 64-, 83- and 138-A cables of -cel, -vin or -rubber type, and other cables of cable-groups C10 to C16) are crimped by means of the No. 2 crimping kit. This kit contains separate crimping tools, with built-in dies, for each of the three sizes of crimping barrel used for heavy-duty S.B.A.C. components; the operation is very similar to that of the No. 1 crimping tool already described, with the important difference that a double-indent crimp is made on the conductor only—the cable insulation does not enter the crimping barrel of a heavy-duty fitting.

Hellermann Hand Crimping Kit

21. This kit is supplied for crimping Hellermann rolled-type compression terminals and in-line splices on cables up to and including -pren 24 and -nyvin 12 (cable groups C1 to C6 inclusive). The kit, comprises three sizes of the hand-compression plier-type tool shown in Fig. 2, three checking gauges for the compression tools, two sizes of sleeve-fitting tool, Hellerine lubricant for sleeving operations, and a selection guide to indicate the correct tools and terminals to be used with different cables.

22. **Hellermann Terminals.** Hellermann rolled-type terminals suitable for use with this crimping kit are made of plated copper, and the crimping element of the terminal consists, in every case, of a crimping barrel (for the reception of the bared end of the conductor) over which is clinched a long seamless ferrule; this ferrule extends well beyond the barrel and thus receives the unstripped portion of the prepared cable end when the latter is placed in the terminal shank. Adjacent compressions are applied simultaneously by the crimping tool to grip both conductor and insulation. Terminals are supplied in three barrel sizes, viz., size 0 for use on cables in groups C1 and C2, such as -pren 4 and -pren 6 or -nyvin 24, -nyvin 22 and -nyvin 20, size 1 for cables in groups C3 and C4 (-pren 9 and 12 or -nyvin 18 and 16), and size 2 for cables in groups C5 and C6 (-pren 18 and 24 or -nyvin 14 and 12):

each terminal is marked, on the tongue or palm, with its barrel size. Size 0 terminals are available in ring-tongue (size of hole 0 B.A. or $\frac{1}{4}$ in. to 6 B.A.) and quick-release types only; the larger sizes are available in ring-tongue ($\frac{5}{16}$ in. to 6 B.A. hole), quick-release, cranked and flag types.

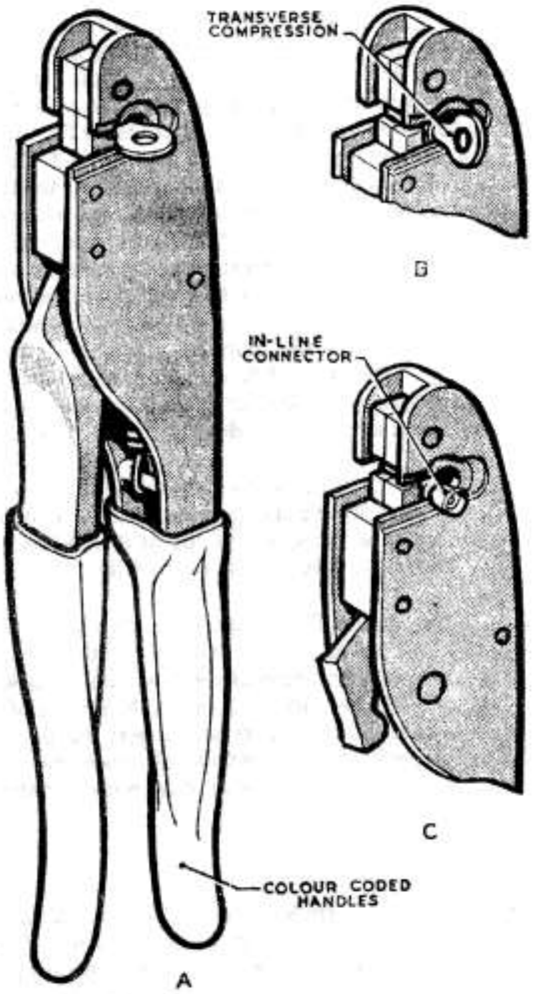

Fig. 2. HELLERMANN HAND CRIMPING TOOL

23. **Compression Tools.** The compression tools, an example of which is shown in Fig. 2, are each designed to crimp one size of crimping barrel over the ends of appropriate cables; for easy recognition the tool handles are coloured either green, red or blue for size 0, size 1 and size 2 crimping barrels respectively. Each tool has a built-in die, and it produces a crimp of irregular octagonal form that overlaps the cable insulation as well as the exposed conductor in the crimping barrel proper; in addition, the tool also reproduces the terminal size (0, 1 or 2) as a raised character on the surface of the crimp, as shown in Fig. 3. To ensure thorough crimping action, each tool incorporates a rachet mechanism which prevents the jaws of the tool opening until full travel of the dies has occurred to give complete crimping action. All tools are provided with location faces to control the position of the compression on the terminal barrel: for transverse compression, which may be required on certain terminals to enable

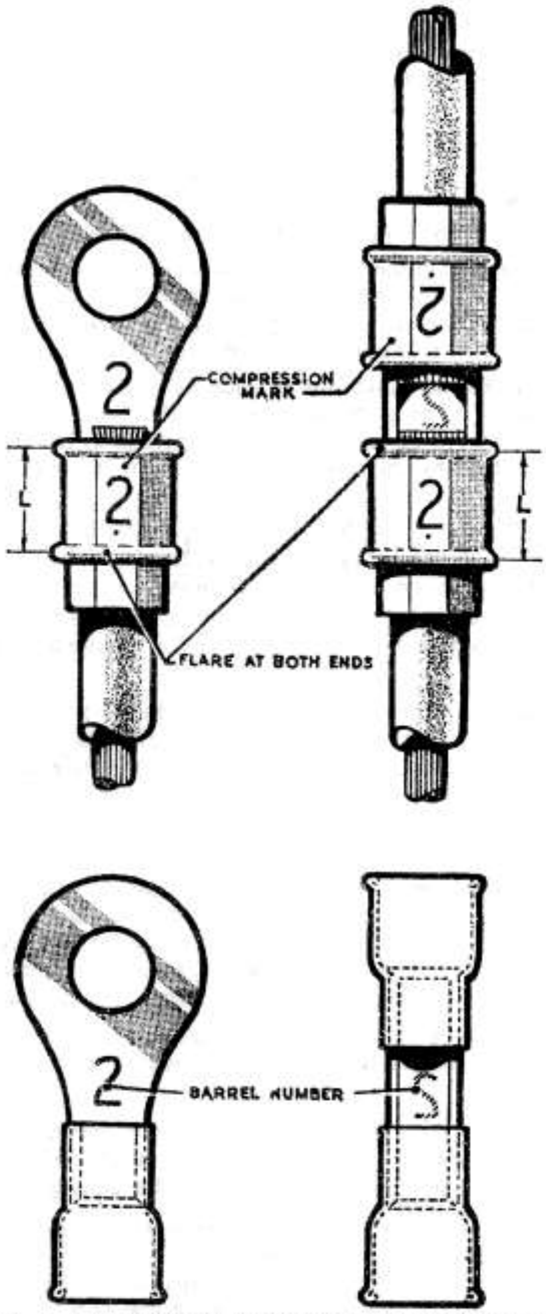

Fig. 3. IDENTIFICATION OF CABLE-END FITTINGS

them to be fitted in channelled cable entries, the tongue of the terminal can be turned through 90°, as shown at (B) in Fig. 2.

Note. *It is essential that these compression tools are used only on Hellerman rolled-type terminals and in-line splices; serious damage to the tools may be caused if they are used on any other type of terminal.*

24. **Crimping Procedure.**

(*a*) Determine the barrel size of cable-end fittings appropriate to the cable in use; select the compression tool for this particular barrel size; squeeze the tool handles together to release the ratchet and allow the handles to spring apart.

(*b*) Strip back the insulation at the end of the cable to a distance of $\frac{5}{32}$ in. to $\frac{3}{16}$ in. (size 0 terminal) or $\frac{3}{16}$ in. to $\frac{7}{32}$ in. (size 1 and size 2 terminals). Try prepared cable end for fit of insulation in barrel ferrule.

(*c*) If insulation is a loose fit in the ferrule, proceed as follows:—

(i) Hold the tool in the left hand with the moving handle towards the body; take the terminal by the tongue in the right hand, with the terminal tongue above the barrel, and pass the barrel through the gap between the punch and the die in the facing edge of the tool until it sits under the upper punch.

(ii) Holding the terminal square with the side of the tool, and pulling on the terminal tongue to keep the barrel against the locator and under the punch, gently close the tool until the first tooth of the ratchet is heard to engage—the terminal will then be held by the tool, and the hold on the terminal tongue may then be released.

(iii) Turn the tool in the left hand to face the entry side.

(iv) Insert the prepared cable end into the barrel with the right hand pushing gently to maintain position while continuing to close the handles.

(v) When the cable is felt to be held, bring the right hand to the tool handles and continue the closing action until the handles eventually release, indicating completion of the crimp.

(*d*) In-line splices are held by the free barrel and inserted in the tool in the manner described in (*c*), with the slot underneath engaging the side cheek of the tool, tilting the barrel under the punch. When making the second impression take care to keep the barrel against the location face, as positive location on both sides of the slot is then no longer possible.

(*e*) If the insulation is a reasonably close fit in the terminal ferrule, assemble the terminal on the prepared cable end and pass it through the side of the tool, again making sure that the barrel is held firmly against its location face and under the punch, then continue as described in (*c*). This method should be adopted whenever possible, as closure of the tool to the first tooth of the ratchet on the empty barrel, as in (*c*), slightly distorts the ferrule extension and may prevent entry of the insulation.

(*f*) Make a final check to ensure that the crimp has been correctly made, using the correct parts; the conductor should protrude beyond the open end of the barrel.

25. **Servicing.** The tools must be inspected at monthly intervals to ensure that the dies are closing to produce the correct configuration. First see that the punches and dies are clean and free from swarf, examine them for obvious cracks or other damage, then proceed as follows:—

(*a*) Close the tool slowly, and check that the pawl engages the first ratchet tooth and locks the handles firmly against return. Continue closing, and make sure that the handle will not return beyond the first tooth position until the pawl disengages the ratchet. When fully closed, release the handle and check that it returns smoothly to the open position, against the pin stop.

(*b*) Close the tool on an appropriate terminal assembled on a suitable cable until the ratchet releases the pawl: whilst held in this position check that the visible stop faces of the conductor punch and die come together.

(*c*) If the tool passes the test in (*b*), check the die gaps with the tool held shut against the stop pin, using cylindrical plug gauges inserted from opposite sides for conductor and insulation gaps. The die gaps must be within limits laid down in A.P. 4343S. The tool must be kept shut whilst gauging; closing the tool on a gauge may cause serious damage.

(*d*) If the tool fails to meet any of the foregoing requirements, it must be considered as unserviceable and the appropriate exchange action initiated.

Erma Hand Crimping Tool Kit

26. The Erma hand crimping tool kit is supplied for crimping hot pressed copper and aluminium cable-end fittings (lugs and in-line splices) on cables ranging from -pren 4 and equivalents (cable group C1) up to cables of group C10 (-pren 70, -prenal 50, -nyvin 6, -nyvinal 6, etc.). The kit contains two sizes of crimping tool, viz. 'Minor' and 'Standard', two sizes of Hellermann sleeve-fixing tool, and Hellerine lubricant: details of the two compression tools are as follows:—

(*a*) *Minor Tool*. This tool is designed for use on cable-end fittings used with cables of group C1 to C5 (-pren 4 to -pren 18, and equivalents). It has no separate dies but embodies three crimping notches coded HA, HB and HC, marked with the appropriate cable sizes—the cable size for each crimping notch is

(i) HA — -pren 4, -pren 6, -nyvin 22, -nyvin 20.

(ii) HB — -pren 9, -pren 12, -nyvin 18, -nyvin 16.

(iii) HC — -pren 18, -nyvin 14.

For all cables enumerated above the stripping length is $\frac{5}{16}$ in. A barrel stop provides for correct positioning of the crimp, which is made simultaneously on both conductor and cable dielectric.

(*b*) *Standard Tool*. This tool is for use on the larger sizes of cables (-pren 24 and upwards to -pren 70 and -prenal 50, and equivalents), and is provided with four sets of insert dies which are interchanged by means of a hexagon socket wrench supplied with the kit. Each set of dies consists of a short upper die and a longer lower die; the short die fits into the top of the tool head, and is located by a spindle connecting the two handles. The various sets of dies, like the crimping notches in the 'Minor' tool, are letter-coded; details of die coding are as follows:—

(i) HD — for use on -pren 24 and -nyvin 12 cables.

(ii) HE — for use on -pren 35 and -nyvin 10 cables.

(iii) HF — for use on -pren 50 and -nyvin 8 cables.

(iv) HG — for use on -pren 70 and -nyvin 6 cables.

The HF and HG dies are intended for limited use only; it is preferable to use the more powerful hydraulic crimping kits when dealing with such cables as -pren 50 and -pren 70.

Both tools are provided with full-closure mechanism to prevent the jaws being opened to release the crimped end-fitting until full compression pressure has been applied. Two go/no-go gauges are included in the kit for checking the crimping heads of the two tools.

27. **Method of Crimping (Minor Tool).**

(*a*) Select cable-end fitting of correct barrel size for cable in use; strip back insulation for $\frac{5}{16}$ in.

(*b*) Insert cable lug, tongue first, from side marked "Cable Entry" in the appropriate crimping notch, locating the end of the barrel of the lug against the stop.

(*c*) Grip lug lightly between crimping jaws and insert prepared end of cable (or assemble lug on cable, if cable insulation is a reasonably tight fit in the counterbored rear portion of barrel, before inserting lug between crimping jaws). A short length of conductor should protrude through the front end of the barrel.

(*d*) Close the handles of the tool until an audible click (from the full-closure mechanism) is heard—this click indicates that full crimping pressure has been applied to the barrel.

(*e*) Release pressure on the tool handles to remove the crimped fitting; the tool will return to the original condition ready for the next crimp.

Notes. 1. The procedure when crimping in-line splices is similar to that for lugs except that the slot in the splice is located in the stop—in some cases the stop may have to be removed.

2. Erma-type lugs and in-line splices must always be used with the Erma minor tool, and it is imperative that the correct crimping notch is used for each size of crimping barrel—if the barrel is too small for the notch a satisfactory fully-compressed crimp cannot be obtained, while too large a barrel does not permit full closure of the jaws and the tool cannot, in consequence, be opened.

28. **Fitting Dies in Standard Tool.** The following procedure should be adopted when fitting die-assemblies in a 'Standard' Erma crimping tool:—

(*a*) Remove the grub screw in the collar of the bearing spindle and withdraw both collar and spindle, thus separating the two handles.

(*b*) Slip the upper (short) die through the hole in the lower part of the head and push right up against the top part of the head: locate the dimple in the die, and tighten the securing grub screw with the hexagon socket wrench.

(*c*) Slip the lower (longer) die through the hole in the lower part of the head and position it so that the code markings match each other, facing outward.

(*d*) Replace the spindle through the handles and the lower die, then replace the collar and the locking grub screw.

(*e*) Fit a barrel stop *carrying the same code markings as the dies* to the side of the head. The above procedure is reversed to remove a die-assembly and barrel stop.

29. **Crimping Procedure (Standard Tool)**

(*a*) Prepare end of cable by stripping back insulation for $\frac{5}{16}$ in. (-pren 24 or -pren 35 and equivalents), $\frac{11}{32}$ in. (-pren 50 and equivalents) or $\frac{15}{32}$ in. (-pren 70 and equivalents).

(*b*) Select the die-assembly and barrel stop appropriate to the barrel size of the cable-end fitting, and fit into the tool.

(*c*) Insert the cable lug into the crimping head and locate the tongue end of the lug barrel against the stop; close the handles lightly to grip the cable lug.

(*d*) Insert the prepared cable end into the lug barrel until a short length of conductor protrudes through the front end of the barrel.

(*e*) Close the handles of the tool until the full-closure mechanism clicks, thus forming a hexagonal crimp over the conductor (and over the cable dielectric when using the HD die-assembly). Open the handles to remove the crimped connection and examine for soundness and regularity.

The procedure for crimping in-line splices is similar to that for lug crimping, but the stop must be slid back or removed.

30. **Servicing.** The crimping notches and dies of the Minor and Standard crimping tools should be checked monthly, using the appropriate go/no-go gauges provided in the kit, to ensure that no appreciable wear has taken place.

Note. Full data concerning hot pressed copper and aluminium cable lugs for use with the Erma hand crimping kit is available in A.P. 4343, Vol. 1, Sect. Chap. 5. No other type of cable termination should be used with this kit. Insulation sleeves must be fitted over the crimped barrels of all cable lugs, and over the full length of in-line splices.

Plessey Hand Crimping Tool

31. The Plessey hand crimping tool was originally designed for crimping 4-, 7- and 19-A 'old-style' cables (i.e. -cel, -vin and -rubber types) to solderless plug pins, socket inserts and quick-release tags of the Plessey wiring system (see Chap. 2), but it can also be used for crimping -pren and other more recent types of cables of comparable cable groups (C1 to C6) to these terminations. The tool resembles a large pair of pliers, the jaws of which carry interchangeable crimping dies and are operated through a toggle linkage: the closure of the dies on the barrel of the cable termination produces two indentations, diametrically opposed to each other, which crimp the barrel of the termination to the cable conductor—the cable dielectric does not enter the barrel, and is not concerned in the crimping action. Four sets of dies are supplied with the tool: two sets, coded 106/108 and 152/154, are used for crimping the barrel of plug-pins and socket-inserts, while the other two sets, coded 146/148 and 188/192, are used on quick-release tags.

32. **Cable Terminations.** The range of Plessey cable-end fittings with which the Plessey crimping tool can be used is as follows:—

(*a*) 7-*A Plug Pins*. This type of plug pin (Ref. No. 5X/3238) has a crimping barrel which can accommodate

(i) The doubled conductor of group C1 cables (-vin 2·5, -pren 4, -nyvin 22, etc.);

(ii) Single conductor of cables of groups C2 and C3 (-vin 4, -pren 6, -nyvin 20, etc.) with a sleeve adapter (Ref. No. 5X/3148) fitted over the conductor.

(iii) Single conductor of cables in group C4 (-vin 7, -pren 9 and 12, -nyvin 18 and 16 etc.) without sleeve adapter.

(*b*) 19-*A Plug Pins*. These are in two types; one type (Ref. No. 5X/3240) has a crimping barrel which is identical with that described in (*a*), while the barrel of the other type (Ref. No. 5X/3242) can accommodate

(i) Single conductor of group C4 cables (see above) with a sleeve adapter (Ref. No. 5X/3146) fitted over the conductor.

(ii) Single conductor of group C5 cables (-vin 12, -pren 18 and -nyvin 14) with a sleeve adapter (Ref. No. 5X/3147) over the conductor.

(iii) Single conductor of group 6 cables (-vin 19, -pren 24 and -nyvin 12) without a sleeve adapter.

(*c*) 7-*A Socket Inserts*. Two types of 7-A socket insert (5X/2329 and 5X/7330) are available, the crimping barrel of both types being identical, so far as cable-acceptance is concerned, with the barrel of the 7-A plug pin described at (*a*)—the same type of sleeve adapter (5X/3148) must be fitted over the conductor of cables of groups C2 and C3.

(*d*) 19-*A Socket Inserts*. One type (Ref. No. 5X/7331) is available; the crimping barrel is similar to that of the 19-A plug pin (5X/3242), and the same sleeve adapters are used with cables of groups C4 and C5.

(*e*) *Quick-Release Tags*. These are available in 4-, 7- and 19-A ratings: the cable-acceptance abilities of the crimping barrels of the different tags are

(i) The 4-A tag takes single conductors of cables in groups C2 and C3 (see (*a*) for typical cables).

(ii) The 7-A tag takes either doubled conductors of cables in group C1 or single conductors of cables in group C4.

(iii) The 19-A tag takes single conductors of cable in group C5 with a sleeve adapter (5X/3147) or single conductors of cables in group C6 without adapter.

Outer thimbles are used with all Q-R tags of Plessey type.

33. **Identification of Terminations.** It is of the utmost importance that the various ratings of cable terminations are correctly identified prior to crimping to cables; the following points of identification are given as a guide:—

(*a*) The pin part of the 19-A plug pin is almost twice the diameter of that of the 7-A plug pin: the small-cable (C1 to C4) 19-A pin can be distinguished from the large-cable (C4 to C6) 19-A pin by the larger crimping barrel of the latter.

(*b*) 7-A and 19-A socket inserts are readily distinguishable by the difference in overall size.

(*c*) The 4-A Q-R tag is identified by the numeral 4 on the tongue; the 7-A tag, although very similar in general appearance and size, lacks any distinguishing numeral. The 19-A tag is easily distinguished from the other two by its larger crimping barrel. Be particularly careful not to confuse Hellermann Q-R tags, which must NOT be crimped with Plessey crimping pliers, with Plessey tags: the Hellermann fittings are all identifiable by a coded numeral (0, 1 or 2) on the tag tongue, and also have thimbles already attached to the barrels when issued.

34. **Selection of Crimping Dies.** As has already been mentioned, two sets of dies are supplied for use when crimping plug pins and socket inserts, and two further sets for crimping the barrels of quick-release tags. The individual sets of dies are to be used for the following purposes only:—

(*a*) Dies coded 106/108—for use on 7-A plug pins (5X/3238), small-barrel 19-A pins (5X/3240), and 7-A socket inserts.

(*b*) Dies coded 152/154—for use on large-barrel 19-A plug pins (5X/3242) and 19-A socket inserts.

(*c*) Dies coded 146/148—for use on 4-A and 7-A quick-release tags.

(*d*) Dies coded 188/192—for use on 19-A quick-release tags.

35. **Crimping Procedure.**

(*a*) Prepare the cable end by baring the conductor for a distance of $\frac{5}{16}$ in. or, in the case of group C1 cables—conductors of such cables must be doubled before insertion into the crimping barrel—for a distance of $\frac{5}{8}$ in.

(*b*) Select the appropriate termination for the cable in use.

(*c*) Select the appropriate dies for the termination to be crimped; remove the knurled screws in the jaws of the crimping tool, insert the dies, and replace the screws.

(*d*) Assemble the termination on the prepared cable end, using the appropriate sleeve adapter (if such is required) and the requisite outer thimble if a quick-release tag is to be crimped—check that the conductor extends up to the inspection hole in plug pins and sockets.

(*e*) Place the cable termination between the crimping dies, locating the part of the termination to be crimped centrally in the jaws.

(*f*) Fully close the pliers to complete the crimping action.

(*g*) Open the pliers to release the crimped termination; check by visual inspection that a satisfactory crimp has been made.

(*h*) Fit an insulating sleeve over the crimped connection.

36. **Servicing.** No servicing procedure is laid down for Plessey crimping tools. Moving parts of the tool should, of course, be kept well lubricated, and the efficiency of the tool should be checked periodically by making test crimps with each die and examining each crimp closely for regularity of form and soundness of connection. It must be stressed that this tool is designed for use with components of the Plessey wiring system; it must never be used for crimping any other kind of component.

CHAPTER 5

INSTALLATION AND SERVICING OF AIRCRAFT WIRING

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Introduction

1. When the wiring of an aircraft is first designed and installed, reasonable provision is generally made for subsequent extensions and modifications to the electrical installation. This provision, in the case of an aircraft wired on the Plessey system, consists of a number of spare conductors and socket inserts in certain of the cable assemblies, spare plug pins in the junction box plugs and bulkhead plugs, and spare terminals in the junction boxes and panels. There is, of course, a limit to what can be done in the way of making such provision, and it may eventually become necessary to install additional wiring under the terms of a Modification Leaflet. Modification work of this nature must never be of a slipshod character: full instructions as to the materials required and the method of performing the task are invariably given in the Leaflet that authorizes the work, and the finished job must bear comparison in effectiveness, safety, reliability and quality of workmanship with the wiring that it supplements. The same high standards must also be observed when work involving temporary or experimental equipment, authorized locally and not covered by a Modification Leaflet, is being carried out: there is no place in any aircraft electrical installation for any wiring, no matter how minor its function, that does not conform to the accepted standards, and no tradesman worthy of the name ever neglects his obligations by departing from those standards.

Installing Additional Wiring

2. Instructions for the installation of additional wiring, when given by Modification Leaflet, are detailed and precise—the one thing taken for granted by the issuing authority is that workmanship will be equally accurate and conscientious. In other circumstances a certain amount of responsibility in the choice of materials, routing of cables, etc., must inevitably fall upon the tradesman entrusted with the work, and in this connection the points mentioned in subsequent paragraphs may prove to be of some assistance to the inexperienced man.

3. **Choice of Cables.** The use of an unsuitable cable for supplementary wiring in aircraft is inexcusable: the range of aircraft cables is so extensive that a cable of suitable characteristics is available for virtually every possible job, and every cable is fully described in A.P. 4343C, Vol. 1. Section 5. The choice of a cable for a particular purpose must always be made in the light of two major considerations, viz.:—

(*a*) *Circuit Current.* Unduly large reductions in voltage at the terminals of consumer equipment must be avoided, particularly in 24-V installations. Cables of adequate rating must always be used; it is better to err on the generous side when deciding on the appropriate rating of cable than to risk excessive voltage-drop under full-load conditions.

(*b*) *Working Conditions.* The conditions under which a cable will be required to operate, and the service on which it is to be used, must be given full consideration. Modern general-purpose cables, such as the Pren range, are satisfactory for all except the most onerous or specialized duties, but their limitations must be recognized—a suitable special-purpose cable should be used if working conditions justify the increased expense or other disadvantages associated with a particular type.

4. **Choice of Route.** The following points should be considered when planning the route to be taken by supplementary wiring:—

(*a*) The shortest possible route has the advantage of keeping voltage-drop in the cables to a minimum, but this advantage may well be outweighed, except in heavy motor circuits, by considerations of accessibility, ease of installation, freedom from incidental damage, etc. A well-fitted accessible cable run is always preferable to a shorter but less workmanlike run, even if cables of somewhat higher rating have to be used to offset the added voltage-drop resulting from the increased length.

(*b*) Drilling or modification of the airframe structure in any way that might possibly affect the strength of the structure will never be acceptable to the Airframe trade, and it is a waste of time to plan a cable route that involves such procedures. Always consult the N.C.O. i/c Airframe when planning a cable route.

(*c*) Fuel and oil fillers, vents, and overflow pipes are bad company for electric cables—avoid them whenever possible, even if it means increasing the length of run.

(*d*) Cables for power services should not be run in common ducts with radio, ignition, or similar circuits; these different services should be kept apart whenever possible.

5. **Installing Cables.** The standards of reliability and safety in supplementary wiring must never be allowed to fall below the standards found in the original wiring of the aircraft, and this can only be guaranteed if conscientious workmanship is backed up by rigorous inspection as the work of installing the cables proceeds. Particular attention should be paid to the following points:—

(*a*) Cables must be adequately supported throughout their whole length; where cleating is used, ensure that the intervals between cleats, particularly in overhead work, do not allow sagging of the cables. Never try to eliminate sagging by straining cables; they should never be under tensional stress.

(*b*) Where cables are to be taken through holes in bulkheads, fairings, fabrics, etc., the holes must be effectively bushed to prevent chafing of the outer cover of the cable. The ends of conduits, through which cables are to be drawn, must be flared or bell-mouthed with clean smooth edges.

(*c*) Cables being drawn into conduits or similar fittings must be handled with care; every precaution must be taken to avoid kinking or twisting. It is always advisable to draw cable straight from the reel or drum into the conduit, turning the drum as necessary to prevent kinking.

6. **Cable Ends.** Whenever possible, crimping should be used in preference to soldering as a means of securing cable terminations (lugs, ferrules, etc.) to the conductors of cables. Aircraft cables, with few exceptions, are designed to have extreme flexibility, and soldering destroys this most desirable quality at the very point where it is of the greatest value, i.e., at the point of connection to the equipment terminals. Where soldering of cable terminations is unavoidable, the utmost care must be exercised to prevent the molten solder penetrating back along the flexible conductor: the soldered joint should subsequently be covered with a rubber sleeve to act as a shock-absorber, and the cable must be well supported at a point as near to the soldered portion as is possible.

7. **Compass Interference.** Since all cables, when carrying current, set up magnetic fields, every care must be taken when planning cable runs and installing supplementary wiring to

avoid interference with the functioning of aircraft compasses. Much can be done, in the case of two-pole wiring, by running positive and negative leads of each service adjacent to each other so that their magnetic fields are self-cancelling. In single-pole installations this practice of self-cancellation cannot, of course, be applied: here the only practicable solution is to route the cables as far away from the compasses as is reasonably possible, and to avoid any semblance of loops, which intensify magnetic effects. After new circuits have been installed, compass tests on various headings should be carried out, with the circuits energized, to ensure that compass deviation arising from electromagnetic interference does not exceed the permissible maximum laid down in A.P. 1275B.

Servicing of Aircraft Wiring

8. Aircraft wiring and associated components must be examined periodically in accordance with the relevant Servicing Schedules for the aircraft. Details of servicing applicable to the Plessey system of wiring, probably the most widely used system at present employed in aircraft of the Royal Air Force, are given in Chap. 2 of this Section: the points mentioned below apply to supplementary wiring and non-conduit plugless cable assemblies of the Plessey system, such as are used to connect minor consumer and control equipment to the main installation.

9. All soldered joints or connections should be examined closely at the point where the stiff soldered portion of the cable merges with the unsoldered flexible portion. If there are signs of strand breakage at this point, the conductor must be cut through, the outer covering of the cable stripped back a little further, and the joint re-made. Crimped connections are generally extremely reliable, but they must nevertheless be regularly inspected for security. Screw terminal connections should be examined for tightness to ensure that high-resistance conditions will not develop. All screws holding fixtures should be checked for tightness, and a close examination for potential short-circuits, caused by loose parts, stray ends of wire, dirt, swarf, etc., should be made in the vicinity of all "live" surfaces.

10. **Cables.** Deterioration of the insulation of cable may be caused by prolonged exposure, or by the action of heat or deleterious substances, such as oil or gasoline. Damage to cables may arise from accidental stresses or from chafing at the fixing points, at lead-in sections to instruments, conduits, or other points where the cables may come into contact with adjacent parts. Such points should, therefore, be examined regularly, and any looseness of the cleats should be rectified.

11. **Fitting of Sleeves.** Particular attention must be paid to all cables which are unavoidably exposed to the effects of heat, fuel or weather—such cables are particularly vulnerable at the entry points to electrical components. If any doubt exists as to the serviceability of insulation at such points, additional protection should be introduced by fitting synthetic rubber sleeves over the cores and outer sheath of suspect cables. The procedure for fitting sleeves is outlined below (Fig. 1 refers).

(*a*) Slit back the outer cable sheath for a distance of $\frac{1}{4}$ in. (see (A) of Fig. 1). Fit a synthetic rubber sleeve (1) over each core, pushing it as far as possible under the outer sheath.

(*b*) If the length of exposed core renders it desirable, fit a second sleeve (2) to overlap (1) by $\frac{1}{2}$ in.

(*c*) Fit an outer synthetic rubber sleeve (3) over the outer sheath, as shown at (B) of Fig. 1.

(*d*) Mark each core sleeve (2) to indicate the colour of the sheathed core.

Cable Repairs

12. Damaged or broken cables should be entirely renewed wherever complete replacement is reasonably practicable, but to obviate the removal of cables from long looms or from bulk-

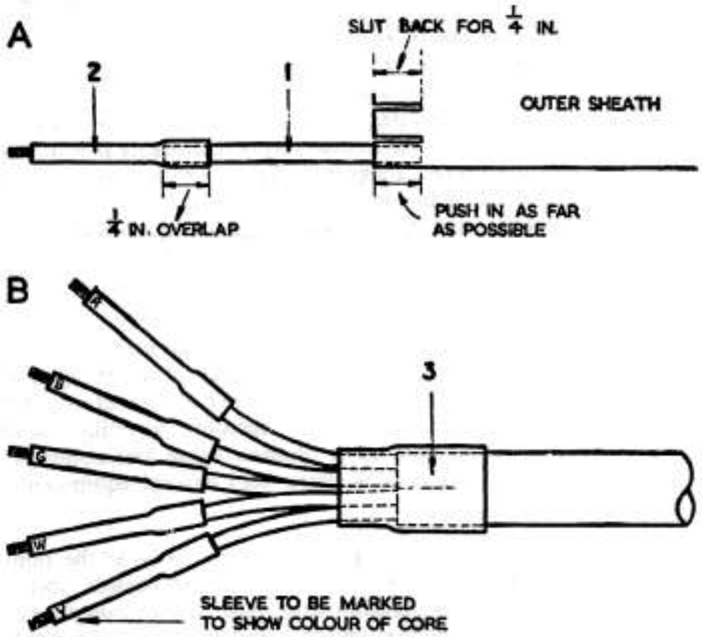

Fig. 1. METHOD OF PROTECTING DETERIORATED CABLES

head sealing components it is permissible, in certain circumstances, to make joints in cables by means of in-line crimped connectors (see Chap. 4 of this Section). A comprehensive range of connectors, each suitable for use with a specified size of cable up to Pren 70 and equivalent, is available for repair work; full details of the range are given in A.P. 4343, Vol. 1, Section 12, to which reference should be made before commencing operations, to ensure that the correct connector is used, that cable ends are "stripped back" to precisely the right length, and that the appropriate crimping tool or die is used for each operation in the repair.

13. The method of fitting in-line crimped connectors is shown, in stages, in Fig. 2—parts A, B and C of this diagram refer to the jointing of Pren 4—6, 9—12, 18 and 24 cables, while parts D, E and F are concerned with heavier cables, i.e. Pren 35, 50 and 70. The full procedure of making a joint with in-line connectors is as follows:—

(*a*) Cut off the damaged end or, if damage is away from the ends of the cable, remove the damaged section. Provide a new length of cable similar in dimensions and type to that removed.

(*b*) Strip back the dielectric from the cable ends to be joined to the distance stipulated for the particular connector (shown as W in Fig. 2). Be careful not to cut or damage the strands.

(*c*) Fit an insulating sleeve (see A.P. 4343 for correct Ref. No.) over one end of the prepared cable and slide clear of the end.

(*d*) Fit the prepared cable ends into the in-line connector. During this operation ensure that all the strands of wire are entered into the inner barrel of the connector, and that the cable ends butt against each other in the centre of the connector—this can be verified through the inspection hole in the centre.

(*e*) Make hexagon crimps at position A (Fig. 2) on the connector, using heavy-duty crimping pliers for Pren cables 4–24 or the hydraulic crimping tool for Pren cables 35–70—ensure that the correct size dies are fitted to the tool.

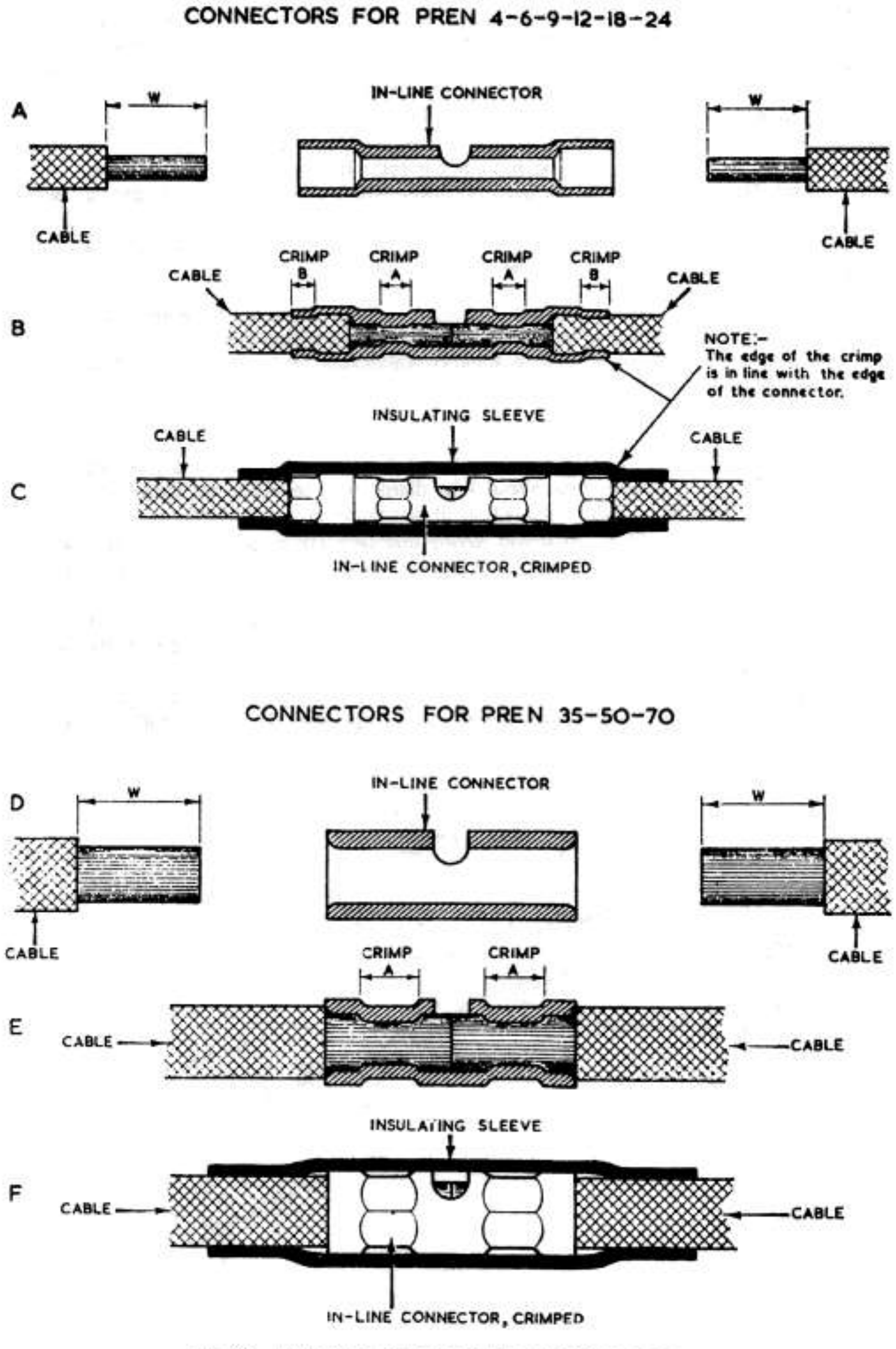

Fig. 2. FITTING OF IN-LINE CONNECTORS

(*f*) For Pren cables 4–24 (and equivalents) make further crimps at position B on the connector, using the next size larger crimp dies in the hand tool. It is most important when making this dielectric crimp to ensure that the edge of the die is in line with the edge of the connector—this ensures maximum effectiveness of this crimp in holding in the dielectric, and also prevents the connector end belling out.

(*g*) Inspect the newly-made joint for the following:—

(i) That the cable ends are butting at the centre of the connector.

(ii) That the crimps have been made correctly and are in the right position.

(iii) That no "flashes" have been produced which may pierce the insulating sleeve —any flashes found are to be removed.

(*h*) Re-position the insulating sleeve so that it fits over the in-line connector with an equal amount of sleeve covering the dielectrics of the joined cables.

14. If more than one cable is damaged in a loom and the cables are to be repaired by the method just described, the joints must be made in a pattern which allows the connectors to be staggered in the loom. So far as is reasonably practicable, no two connectors should ever lie adjacent to one another in a loom.

Repairs to P.V.C. Tubing

15. Damaged P.V.C. tubing may be repaired quite successfully if the damage is not excessive, e.g., if holes are not larger than about ⅜ in. diameter or tears are not longer than 4 in. Fig. 3 shows the method of repair: the details of procedure are as follows:—

(*a*) Cut a patch of P.V.C. to shape, giving adequate coverage of the damaged area.

(*b*) Clean both patch and the surface of the tube around the damage with a rag dipped in gasoline, then dry thoroughly.

(*c*) Apply Titebond 22 to both patch and tubing surface, and put the patch in place, pressing down firmly to give good adhesion—a slight chamfer on the edge of the patch helps to make a good joint.

(*d*) *Warm* a clean smooth soldering iron and run it gently round the edges to weld the patch into place—do not overheat the iron, otherwise the P.V.C. will be charred and the Titebond will lose its grip.

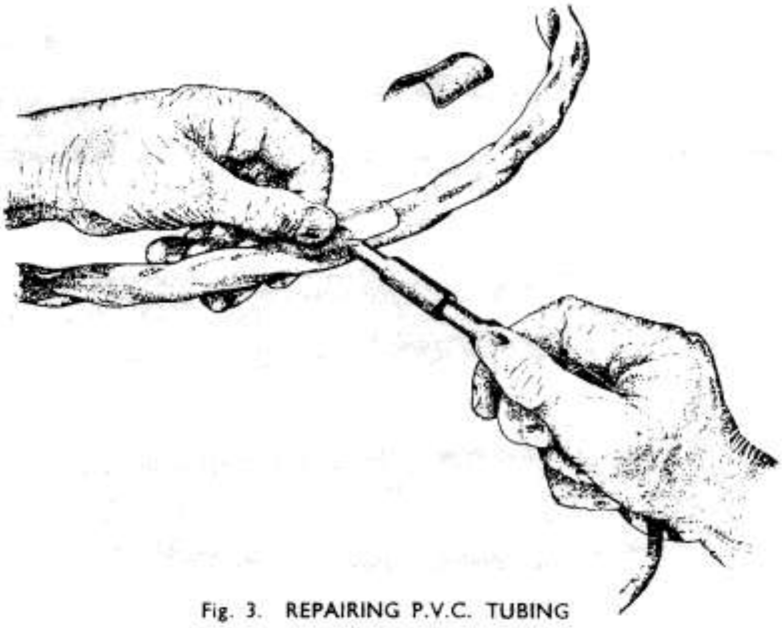

Fig. 3. REPAIRING P.V.C. TUBING

CHAPTER 6

BONDING AND SCREENING

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Principle of Bonding

1. Electrostatic charges are acquired by the metallic parts of an aircraft during flight, and any intermittent contact between parts which may happen to be at different electrical potentials is liable to set up sparking, which in turn may give rise to radio interference or may cause fires. There is thus an obvious case for ensuring that all metallic parts and components of an aircraft are always at the same electrical potential, and to this end all such parts are "bonded" or connected together to form an electrically continuous system of low and unvarying resistance. In addition to reducing the risk of fire and the propagation of radio interference from static causes, bonding also promotes increased radio efficiency by providing a large and constant capacitance for the radio "earth".

Methods of Bonding

2. **All-Metal Aircraft.** Bonding is a relatively simple matter in aircraft where the primary structure, including mainplanes and tail unit, is wholly of metal. The structure itself forms the necessary continuous connection or bond, and the required continuity between the primary bond and such components as seats, tanks, etc., is generally assured if clean metal-to-metal joints, protected from corrosion and incapable of making intermittent contact, are used to fix the various metallic components. External bonding is required only for moving components, such as control surfaces, trimming tabs, etc.; the electrical continuity through lubricated pivots or bearings can never be of a very high order, and it must necessarily be supplemented, in some cases, by flexible bonding strips attached to the structure and the moving unit. Where lengths of piping are joined together by means of rubber or other flexible connectors, continuity throughout the run of piping is preserved by brass contact strips which are held in metallic contact with the pipes at either side of the connectors by clamps or clips.

3. **Composite Aircraft.** In certain types of light aircraft the fuselage is largely constructed from processed wood, while the mainplanes, tail unit, etc., are of all-metal construction. These latter parts may be considered, for bonding purposes, as electrically continuous, and only the precautions applicable to all-metal aircraft, as described in the previous paragraph, are required. In the fuselage section, however, a full conducting network must be provided to link the all-metal parts of the aircraft with the fuselage components so that all are maintained at the same electrical potential. This network might consist, for example, of four copper main strips which, disposed symmetrically around the fuselage, extend throughout its length and are connected together at the fore-and-aft extremities. Fixed components are connected to the main bond by copper branch strips, while pipes, controls, etc., are similarly connected through copper braids to permit the necessary degree of freedom in movement.

4. **Ground Contact.** To ensure that no static electrical charge, with its risk of sparking, remains on metallic parts of the aircraft, the main bond must be brought into instantaneous

electrical contact with the ground as the aircraft touches down. This is achieved by fitting the nose (or tail) wheel with a tyre made from a special rubber compound which has comparatively low electrical resistance. The tyre is in contact with the main bond through the wheel bearings, and any static charge held by the bond is dissipated to earth as the touch-down is made.

Installation of Bonding

5. The following points are of importance when bonding is being installed or replaced:—

(*a*) Whenever circumstances permit, bonds of copper or brass strip should be used in preference to flexible braid bonds.

(*b*) Strips for bonding purposes must be of annealed copper or brass; the minimum acceptable cross-section is ¼ in. by 26 s.w.g.

(*c*) Braid for flexible bonding connections must contain not less than 64 strands of wire; the minimum cross-sectional area of the smallest braid is 0·0015 sq. in.

(*d*) Flexible connections should not exceed six inches in length; this must allow sufficient slack for working purposes.

(*e*) Connections in or to the main bond of a composite aircraft must be soldered. An acid-free flux must be used for soldering, and the connection, after being thoroughly cleaned, must be coated with an approved protective finish.

(*f*) Bonds should not be soldered directly to components unless there is no alternative method of connection.

(*g*) Contacting faces of bonding strips and of parts to be bonded must be quite clean; rust, protective finish, etc., should be removed by scraping, not by the use of emery cloth.

(*h*) Metal pipes and metal-braided cables must be supported in clamps of approved type. These clamps are designed to provide all-round contact with the pipes or cables to ensure unvarying contact resistance, and every care must be taken to ensure that every pipe or cable is gripped firmly by both sides of the clamp, and that the clamp itself is in effective contact with the main bond.

(*j*) Every run of piping must be bonded at its extremities and at intermediate points not more than five feet apart: metal-braided cables must be bonded at intervals of not more than 18 in.

(*k*) Bonding strips or braid must never, in any circumstances, be soldered to the metal braiding of cables.

(*l*) After replacing a bonding clip or clamp, always apply the approved protective covering to prevent corrosion.

Screening

6. In addition to radio interference originating in static charges acquired by the metal masses of an aircraft in flight, high-frequency disturbances in radio circuits may also be set up by the operation of certain forms of electrical equipment. This form of interference can be counteracted by fitting suppressors of suitable type in the cables connected to the source of interference, and by total enclosure of the offending item and its cables, up to and including the suppressor, in a continuous metallic sheath. This latter process is known as "screening": it is required for the following types of circuits:—

(*a*) High-tension and low-tension ignition wiring.

(*b*) Direct-current generators.

(*c*) All direct-current motors that may be required to operate continuously during flight.

(*d*) Slip-rings running at speeds in excess of 200 r.p.m.

(*e*) High-tension and low-tension booster coils.

(*f*) Apparatus making and breaking a circuit at a rate exceeding 10 cycles per minute.

7. D.c. generators, screened d.c. motors, screened slip-rings, and screened make-and-break components all require interference suppressors, which themselves are completely screened. The suppressor should be mounted as close to the screened component as is practicable, and the connecting cables, which must enter the suppressor at the entry marked SCREENED, must be totally enclosed by metal which is in sound electrical contact with the suppressor and the screened component. The required screening effect for the connecting cables is obtained, in the majority of cases, by using a suitable type of metal-braided cable. Various types of end-fitting are used to ensure continuity between the metal braiding and the metal casings of the suppressor and the screened component. Where the use of metal-braided cable is not practicable, suitable cables of unscreened type may be enclosed in metal conduits. The conduit may be of rigid or flexible construction, according to circumstances: if flexible conduit of interlock section is used it must have a closely-woven tight-fitting cover of braided tinned copper or phosphor-bronze wire. Bare, spirally-wound metallic tubing is unsuitable for screening purposes, owing to the variable nature of the electrical resistance between convolutions.

8. Screening of the ignition system used on aero-engines of piston type must be very comprehensive if it is to be really effective, and in most cases screening "harness", designed specifically for the particular type and mark of engine, forms an integral part of the engine equipment. The harness consists of an assembly of rigid and/or flexible metallic tubing which affords an effective screening enclosure for the high-tension cables that connect the magnetos to the screened sparking plugs, with unions designed to ensure a high degree of electrical continuity between the various conduits, the screen casings of the magnetos, and the screens of the sparking plugs. Ignition switches are of all-metal construction to give adequate screening, and low-tension wiring of the ignition system is usually carried out with metal-braided cable of suitable type. Interference is likely to be caused by ignition cables coming into close proximity with pipe lines, flexible-drive casings, and similar parts; whenever possible the ignition wiring should be kept at least one foot away from such components.

9. **Servicing.** All screened cable and conduit bonding clips and clamps should be checked regularly for tightness. Terminal connections and screened cable joints at suppressors and screened sources of interference must be inspected periodically and tightened if this is found to be necessary. Particular attention must be paid to all joints of the ignition screening system—screen joints in the immediate vicinity of the sparking plugs, in particular, are liable to prove troublesome, and these should be dismantled, thoroughly cleaned, and re-assembled at regular intervals.