

## Chapter 6

# METHODS OF MAKING CABLE TERMINATIONS AND CONNECTIONS

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### Introduction

1. This chapter gives general information on cable terminations and various methods of making electrical connections, and describes the techniques involved. Particular details of terminations and tools available will be found in Chap. 5 of this section, together with instructions for making the connections.

### Methods of electrical connection

2. Various methods have been employed in the past for making electrical joints and connections. Among these are the following:—

- (1) Wire twisting. A simple and rapid means of joining two conductors. Usually requires taping.
- (2) Twisting of conductor strands around a terminal post or into a hole in a terminal post. Often awkward, and liable to lead to short-circuits or loss of conductor capacity through escape of strands while being clamped. Some disadvantages may be avoided by dipping conductors in solder, but connection still mechanically weak.
- (3) Looping of solid conductor around stud, followed by clamping with washers and lock-nut. Only partial contact, and may work loose through vibration.
- (4) Eyelets. Require excessive stripping length. Mechanically weak at entry to eyelet.

(5) Soldering. Satisfactory if efficiently performed, but dry joints hard to detect. Expensive when large conductor involved, and necessary heating may be a disadvantage.

(6) Spot welding. Requires expensive equipment and application of considerable heat to the joints.

3. When efficiently executed by skilled personnel with suitable equipment any of the above methods can be effective, but lack of skill can lead to a bad joint. For this reason, the approved Service method wherever possible is that of crimping, either to secure a termination to the end of a cable, or to join two lengths of cable by means of an in-line connector. Given the correct equipment, such connections can be made with absolute uniformity and guaranteed quality by unskilled personnel and afford a permanently effective connection.

### Solderless cable lugs

4. A solderless cable lug fulfils two functions; it provides a ferrule or crimping barrel bored to receive the conductor, and a tongue end for securing to the equipment concerned.

### Crimping barrel

5. The crimping barrel is the element of the terminal which fits over the conductor, and is deformed through the pressure applied by suitable crimping or compression tools, so that conductor and barrel become a homo-

geneous mass of good electrical conductivity and mechanical strength. The particular design of barrel will depend upon the material being used, e.g., copper, aluminium, or brass, and upon the method of manufacture, e.g., bar, tube, cast, or raised from strip; the design may also be dictated by space limitations of the installation.

6. In general there are two main categories of crimping configurations, namely indent crimping and confined crimping. In the former, one or more indentations are produced by the crimping tool in the crimping barrel, and the metal displaced by the application of pressure can escape laterally.

7. In the confined type of crimp, the barrel is totally enclosed during the crimping operation, which compresses the barrel and conductor almost solid. Ideally the confined crimp should be round, but in practice a hexagonal shape has been found to yield excellent results, at the same time lending itself conveniently to the manufacture of crimping dies. Moreover it is a form of crimp uniformly applicable to large and small cable sizes, and to aluminium as well as copper conductors. A photomicrograph of a cross-section of a hexagon crimped connection is shown in fig. 1. To facilitate inspection of the crimped joint, the barrel is frequently open at the tongue end or provided with an inspection hole through which the sufficient insertion of the conductor into the crimping barrel may be visually verified.

8. In small wires, the point of entry of the conductor into the crimping barrel may be a point of mechanical weakness and cause failure as a result of strain or vibration. This weakness can be overcome by extending the barrel to encompass and support a length of the cable insulation. In the case of terminals made from rod or tube an extended barrel with a suitably enlarged internal bore serves, and that extension, which is integral with the terminal, may either just support the insulation or may be crimped over it in order to grip it firmly. Where terminals are made from strip it is common practice to fit a sleeve over the crimping barrel which will at the same time prevent the seams of the rolled-up barrel from spreading during the crimping operation. When crimping both conductor and insulation the appropriate crimping tools are usually designed to effect both crimps simultaneously in one operation.

#### *Terminal tongues*

9. The design of the tongue end depends on where and how the terminal is to be attached. Typical terminals are illustrated in fig. 2; the most common form is the ring tongue, circular in outline with a hole to fit around a stud. Short of clamping a flat tongue without a hole, this design provides a connection in the smallest possible space. Other tongue shapes may be produced to meet special requirements, such as location holes or slots, or two stud holes instead of one, to prevent the risk of the terminal swivelling about its

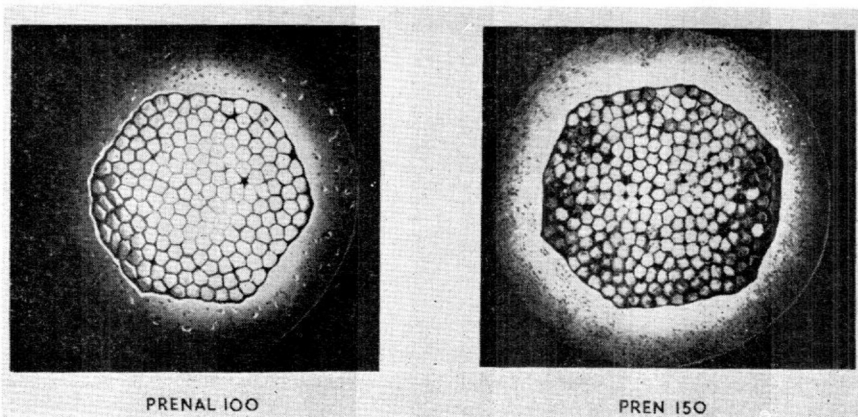


Fig. 1. Cross-section of hexagon crimped connection

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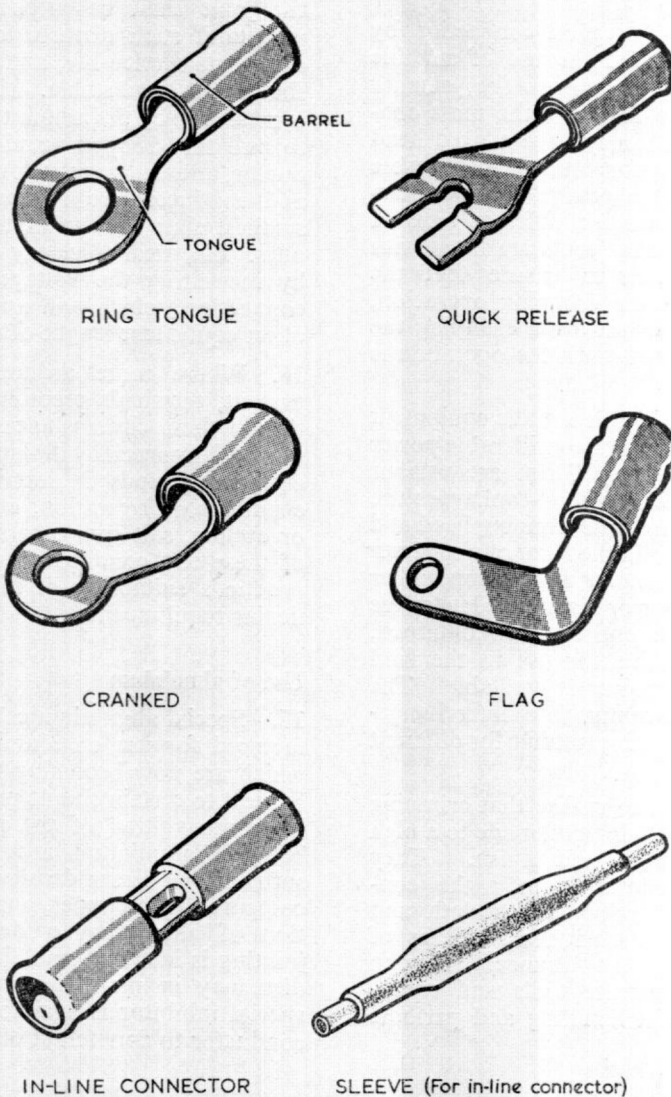


Fig. 2. Typical compression terminals

post. Slotted, fork, spade or hook tongues permit easy withdrawal from the attachment post without requiring its entire removal, but are not so resistant to vibration. Flag and various angle types of tongue provide connections to screws not otherwise readily accessible.

10. A variant is the in-line connector serving for the connection of two cables. The butt type, as illustrated, is essentially two crimping barrels in series, one conductor entering and being crimped at each end; the

parallel type is a single crimping barrel long enough to accept and be crimped on two conductors, which may enter from opposite ends or at the same end. Three or four-way connectors can also be designed.

#### Insulation of crimped joints

11. Crimped joints may be insulated by fitting a rubber or plastic insulation sleeve which may at the same time serve as a marker. Terminals have also been designed with a plastic insulation sleeve bonded to the terminal, permitting conductor and dielectric



to be crimped, and the joint insulated, in one operation.

### **Crimping tools**

12. The making of a good connection by crimping depends upon the use of suitable crimping equipment. For the smaller terminals plier type tools are the most convenient. These tools may have a fixed head with crimping jaws for one or more cable sizes, or a head arranged to receive interchangeable insert dies for different sizes of cable. Frequently these tools are fitted with a full closure device to ensure that the operator completes the crimping operation, since once he has commenced crimping the tool cannot be opened until the operation is complete.

13. For heavier cables, hydraulic equipment permits the application of considerable power within restricted space. There are various models, of the bench or hand-tool type; the latter are made either with crimping head and pump in one unit, or in the form of a separate head operated by hand or foot pump, either by the same operator or his mate. Hydraulic crimping tools are entirely self-contained, and eminently suitable for use in the field where no external power is available. The crimping heads accommodate interchangeable dies of various sizes, suitable for different cables.

14. It is important to realise that crimping tools are precision equipment, made to a high standard of accuracy and finish. They enable unskilled operators to make connections of great mechanical strength and good electrical conductivity, as well as of uniform quality and appearance. Though robustly constructed, the tools and equipment deserve careful handling and periodic servicing.

### **Quality of crimped joints**

15. For the vast majority of wiring connections the two necessary conditions are that the joint shall be mechanically strong to withstand such disturbances as may occur during its service life, and that its resistance shall be low and stable. Mechanical strength is measured by the amount of force necessary to pull the crimped terminal from the conductor, and will vary with the size of terminal and conductor from about 10 lb. for the smallest sizes to several tons for the larger ones. Electrical efficiency can be determined by measuring the voltage drop across the connection, which will approximate to that of an equivalent length of cable.

16. Where more arduous conditions are present, terminals recommended for operation in these circumstances will have passed successfully specially designed tests subjecting them to periods in humidity and hot air chambers, refrigeration, current overloading or cycling, salt spray, or such combinations of these test conditions as will indicate the product's suitability or limitations for particular requirements.

### **Use of aluminium**

17. Special aluminium cable lugs are manufactured for use on aluminium conductors, which are now becoming more widely used. Subject to certain simple precautions dictated by a recognition of the physical difference between aluminium and copper, i.e., the softness and lesser density of aluminium as compared with copper, and the ready formation of aluminium oxide, the method of jointing is identical and the same tools and dies may in many instances be used. A special inhibitor is available for coating the conductor to counteract oxidation.

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