

Underground Cables

An **underground cable** essentially consists of one or more conductors covered with suitable insulation and surrounded by a protecting cover.

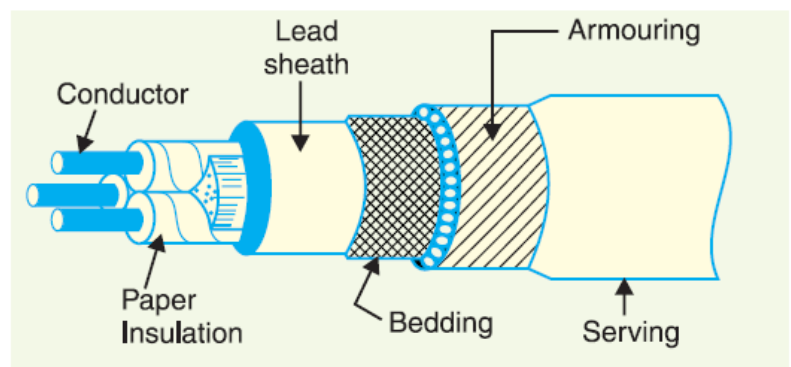
Although several types of cables are available, the type of cable to be used will depend upon the working voltage and service requirements. In general, a cable must fulfil the following necessary requirements :

- (i) The conductor used in cables should be tinned stranded copper or aluminium of high conductivity. Stranding is done so that conductor may become flexible and carry more current.
- (ii) The conductor size should be such that the cable carries the desired load current without overheating and causes voltage drop within permissible limits.
- (iii) The cable must have proper thickness of insulation in order to give high degree of safety and reliability at the voltage for which it is designed.
- (iv) The cable must be provided with suitable mechanical protection so that it may withstand the rough use in laying it.
- (v) The materials used in the manufacture of cables should be such that there is complete chemical and physical stability throughout.

Construction of Cables

Fig. 11.1 shows the general construction of a 3-conductor cable. The various parts are :

- (i) **Cores or Conductors.** A cable may have one or more than one core (conductor) depending upon the type of service for which it is intended. For instance, the 3-conductor cable shown in Fig. 11.1 is used for 3-phase service. The conductors are made of tinned copper or aluminium and are usually stranded in order to provide flexibility to the cable.
- (ii) **Insulation.** Each core or conductor is provided with a suitable thickness of insulation, the thickness of layer depending upon the voltage to be withstood by the cable. The commonly used materials for insulation are impregnated paper, varnished cambric or rubber mineral compound.
- (iii) **Metallic sheath.** In order to protect the cable from moisture, gases or other damaging liquids (acids or alkalis) in the soil and atmosphere, a metallic sheath of lead or aluminium is provided over the insulation as shown in Fig. 11.1





- (iv) **Bedding.** Over the metallic sheath is applied a layer of bedding which consists of a fibrous material like jute or hessian tape. The purpose of bedding is to protect the metallic sheath against corrosion and from mechanical injury due to armoring.
- (v) **Armoring.** Over the bedding, armoring is provided which consists of one or two layers of galvanised steel wire or steel tape. Its purpose is to protect the cable from mechanical injury while laying it and during the course of handling. Armoring may not be done in the case of some cables.
- (vi) **Serving.** In order to protect armoring from atmospheric conditions, a layer of fibrous

Insulating Materials for Cables

The insulating materials used in cables should have the following properties:

- (i) High insulation resistance to avoid leakage current.
- (ii) High dielectric strength to avoid electrical breakdown of the cable.
- (iii) High mechanical strength to withstand the mechanical handling of cables.
- (iv) Non-hygroscopic *i.e.*, it should not absorb moisture from air or soil. The moisture tends to decrease the insulation resistance and hastens the breakdown of the cable. In case the insulating material is hygroscopic, it must be enclosed in a waterproof covering like lead sheath.
- (v) Non-inflammable.
- (vi) Low cost so as to make the underground system a viable proposition.
- (vii) Unaffected by acids and alkalies to avoid any chemical action.

The principal insulating materials used in cables are rubber, vulcanised India rubber, impregnated paper, varnished cambric and polyvinyl chloride.

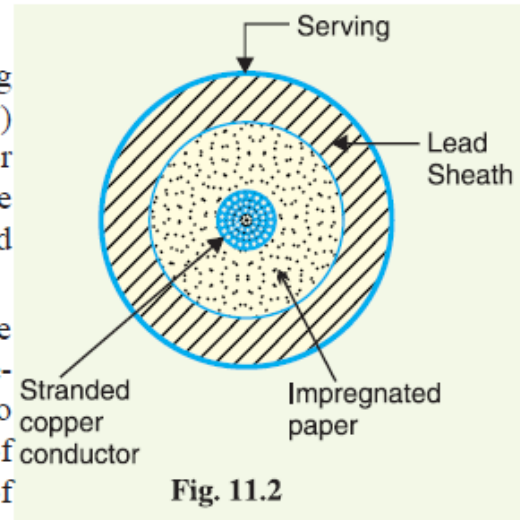
Classification of Cables

Cables for underground service may be classified in two ways according to (i) the type of insulating material used in their manufacture (ii) the voltage for which they are manufactured. However, the latter method of classification is generally preferred, according to which cables can be divided into the following groups :

- (i) Low-tension (L.T.) cables — upto 1000 V
- (ii) High-tension (H.T.) cables — upto 11,000 V
- (iii) Super-tension (S.T.) cables — from 22 kV to 33 kV
- (iv) Extra high-tension (E.H.T.) cables — from 33 kV to 66 kV
- (v) Extra super voltage cables — beyond 132 kV

A cable may have one or more than one core depending upon the type of service for which it is intended. It may be (i) single-core (ii) two-core (iii) three-core (iv) four-core etc. For a 3-phase service, either 3-single-core cables or three-core cable can be used depending upon the operating voltage and load demand.

Fig. 11.2 shows the constructional details of a single-core low tension cable. The cable has ordinary construction because the stresses developed in the cable for low voltages (upto 6600 V) are generally small. It consists of one circular core of tinned stranded copper (or aluminium) insulated by layers of



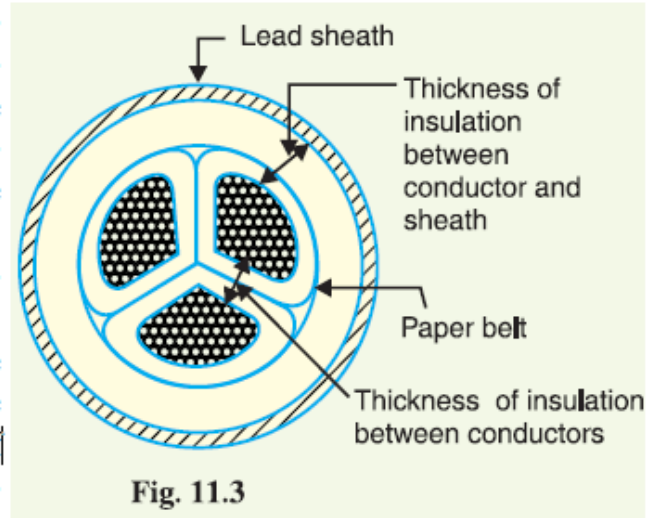
impregnated paper. The insulation is surrounded by a lead sheath which prevents the entry of moisture into the inner parts. In order to protect the lead sheath from corrosion, an overall serving of compounded fibrous material (jute etc.) is provided. Single-core cables are not usually armoured in order to avoid excessive sheath losses. The principal advantages of single-core cables are simple construction and availability of larger copper section.

Cables for 3-Phase Service

In practice, underground cables are generally required to deliver 3-phase power. For the purpose, either three-core cable or *three single core cables may be used. For voltages upto 66 kV, 3-core cable (i.e., multi-core construction) is preferred due to economic reasons. However, for voltages beyond 66 kV, 3-core-cables become too large and unwieldy and, therefore, single-core cables are used. The following types of cables are generally used for 3-phase service :

1. Belted cables — upto 11 kV
2. Screened cables — from 22 kV to 66 kV
3. Pressure cables — beyond 66 kV.

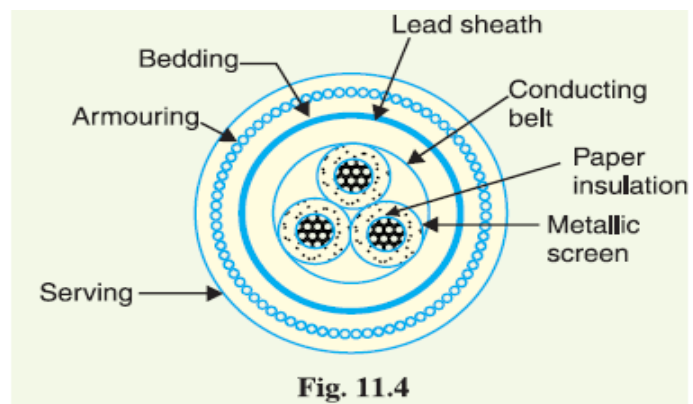
1. Belted cables. These cables are used for voltages upto 11kV but in extraordinary cases, their use may be extended upto 22kV. Fig. 11.3 shows the constructional details of a 3-core belted cable. The cores are insulated from each other by layers of impregnated paper. Another layer of impregnated paper tape, called *paper belt* is wound round the grouped insulated cores. The gap between the insulated cores is filled with fibrous insulating material (jute etc.) so as to give circular cross-section to the cable. The cores are generally stranded and may be of non-circular shape to make better use of available space. The belt is covered with lead sheath to protect the cable against ingress of moisture and mechanical injury. The lead sheath is covered with one or more layers of armouring with an outer serving (not shown in the figure).



2. Screened cables. These cables are meant for use upto 33 kV, but in particular cases their use may be extended to operating voltages upto 66 kV. Two principal types of screened cables are H-type cables and S.L. type cables.

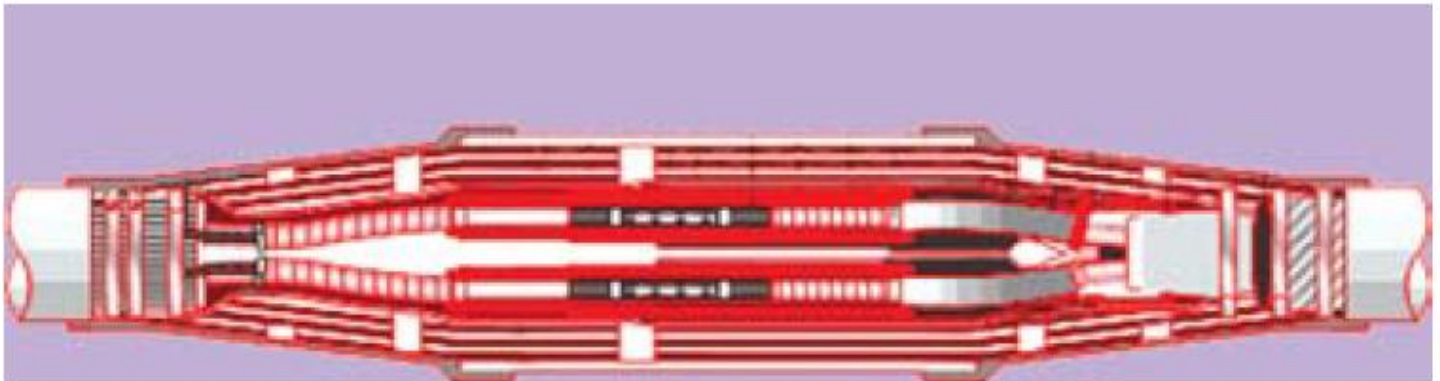
(i) H-type cables. This type of cable was first designed by H. Hochstadter and hence the name. Fig. 11.4 shows the constructional details of a typical 3-core, H-type cable. Each core is insulated by layers of impregnated paper. The insulation on each core is covered with a metallic screen which usually consists of a perforated aluminium foil. The cores are laid in such a way that metallic screens

make contact with one another. An additional conducting belt (copper woven fabric tape) is wrapped round the three cores. The cable has no insulating belt but lead sheath, bedding, armouring and serving follow as usual. It is easy to see that each core screen is in electrical contact with the conducting belt and the lead sheath. As all the four screens (3 core screens and one conducting belt) and the lead sheath are at earth potential, therefore, the electrical stresses are purely radial and consequently dielectric losses are reduced.



Two principal advantages are claimed for H-type cables. Firstly, the perforations in the metallic screens assist in the complete impregnation of the cable with the compound and thus the possibility of air pockets or voids (vacuous spaces) in the dielectric is eliminated. The voids if present tend to reduce the breakdown strength of the cable and may cause considerable damage to the paper insulation. Secondly, the metallic screens increase the heat dissipating power of the cable.

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H-Type Cables

(ii) *S.L. type cables*. Fig. 11.5 shows the constructional details of a 3-core *S.L. (separate lead) type cable. It is basically *H*-type cable but the screen round each core insulation is covered by its own lead sheath. There is no overall lead sheath but only armouring and serving are provided. The S.L. type cables have two main advantages over *H*-type cables. Firstly, the separate sheaths minimise the possibility of core-to-core breakdown. Secondly, bending of cables becomes easy due to the elimination of overall lead sheath. However, the disadvantage is that the three lead sheaths of S.L. cable are much thinner than the single sheath of *H*-cable and, therefore, call for greater care in manufacture.

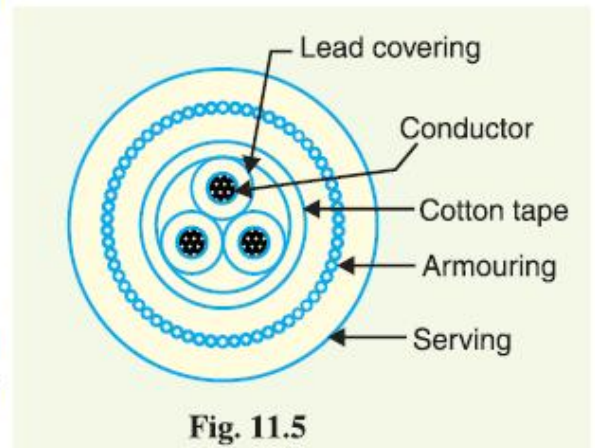


Fig. 11.5

3. Pressure cables For voltages beyond 66 kV, solid type cables are unreliable because there is a danger of breakdown of insulation due to the presence of voids. When the operating voltages are greater than 66 kV, *pressure cables* are used. In such cables, voids are eliminated by increasing the pressure of compound and for this reason they are called pressure cables. Two types of pressure cables *viz* oil-filled cables and gas pressure cables are commonly used.

(i) Oil-filled cables. In such types of cables, channels or ducts are provided in the cable for oil circulation. The oil under pressure (it is the same oil used for impregnation) is kept constantly supplied to the channel by means of external reservoirs placed at suitable distances (say 500 m) along the route of the cable. Oil under pressure compresses the layers of paper insulation and is forced into any voids that may have formed between the layers. Due to the elimination of voids, oil-filled cables can be used for higher voltages, the range being from 66 kV upto 230 kV. Oil-filled cables are of three types *viz.*, single-core conductor channel, single-core sheath channel and three-core filler-space channels.

Fig. 11.6 shows the constructional details of a single-core conductor channel, oil filled cable. The oil channel is formed at the centre by stranding the conductor wire around a hollow cylindrical steel spiral tape. The oil under pressure is supplied to the channel by means of external reservoir. As the channel is made of spiral steel tape, it allows the oil to percolate between copper strands to the wrapped insulation. The oil pressure compresses the layers of paper insulation and prevents the possibility of void formation. The system is so designed that when the oil gets expanded due to increase in cable temperature, the extra oil collects in the reservoir. However, when the cable temperature falls during light load conditions, the oil from the reservoir flows to the channel. The disadvantage of this type of cable is that the channel is at the middle of the cable and is at full voltage *w.r.t.* earth, so that a very complicated system of joints is necessary.

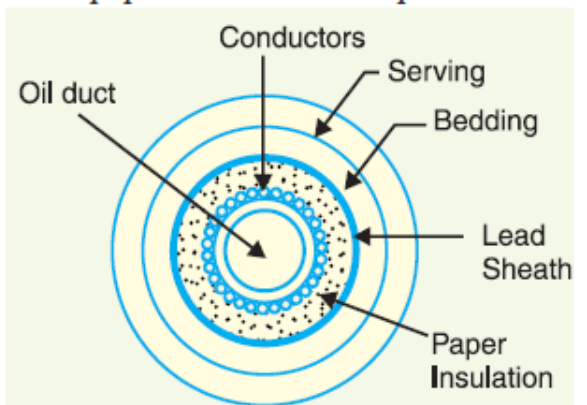


Fig. 11.6 Single-core conductor channel, oil-filled cable

Fig. 11.7 shows the constructional details of a single-core sheath channel oil-filled cable. In this type of cable, the conductor is solid similar to that of solid cable and is paper insulated. However, oil ducts are provided in the metallic sheath as shown. In the 3-core oil-filler cable shown in Fig. 11.8, the oil ducts are located in the filler spaces. These channels are composed of perforated metal-ribbon tubing and are at earth potential.

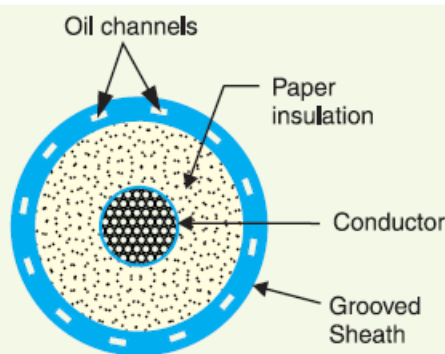


Fig. 11.7

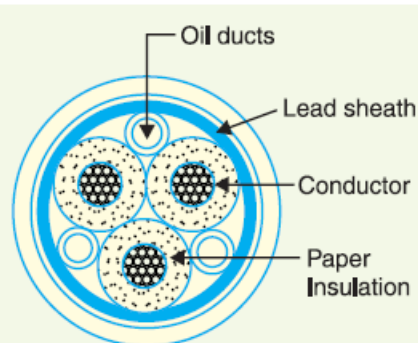


Fig. 11.8

(ii) **Gas pressure cables.** The voltage required to set up ionisation inside a void increases as the pressure is increased. Therefore, if ordinary cable is subjected to a sufficiently high pressure, the ionisation can be altogether eliminated. At the same time, the increased pressure produces radial compression which tends to close any voids. This is the underlying principle of gas pressure cables.

Fig. 11.9 shows the section of external pressure cable designed by Hochstadter, Vogal and Bowden. The construction of the cable is similar to that of an ordinary solid type except that it is of triangular shape and thickness of lead sheath is 75% that of solid cable. The triangular section reduces the weight and gives low thermal resistance but the main reason for triangular shape is that the lead sheath acts as a pressure membrane. The sheath is protected by a thin metal tape. The cable is laid in a gas-tight steel pipe. The pipe is filled with dry nitrogen gas at 12 to 15 atmospheres. The gas pressure produces radial compression and closes the voids that may have formed between the layers of paper insulation. Such cables can carry more load current and operate at higher voltages than a normal cable. Moreover, maintenance cost is small and the nitrogen gas helps in quenching any flame. However, it has the disadvantage that the overall cost is very high.

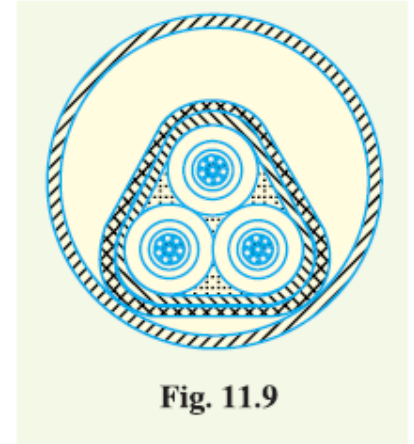


Fig. 11.9