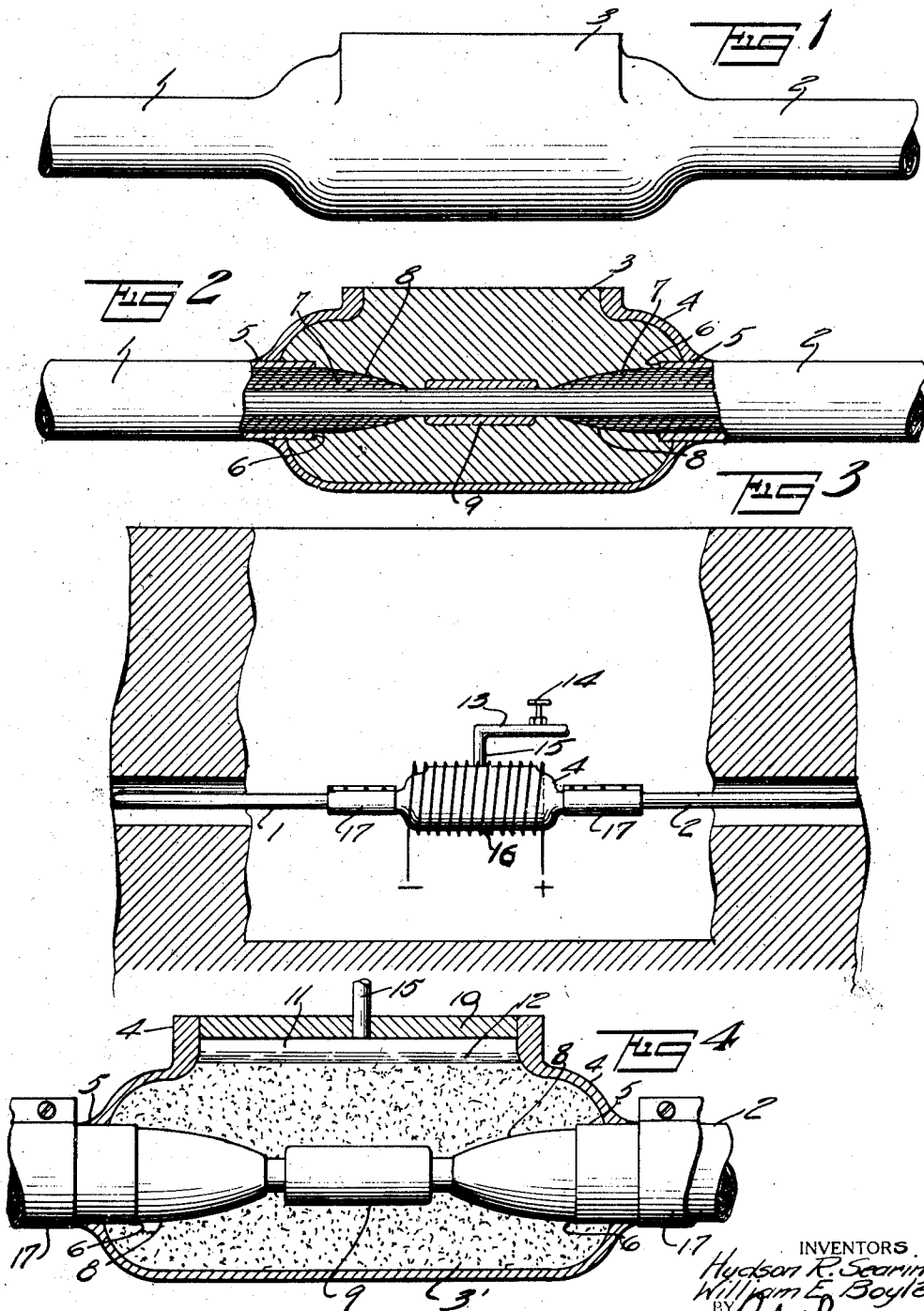


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SPLICES FOR UNDERGROUND SYSTEMS
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3 Sheets-Sheet 1



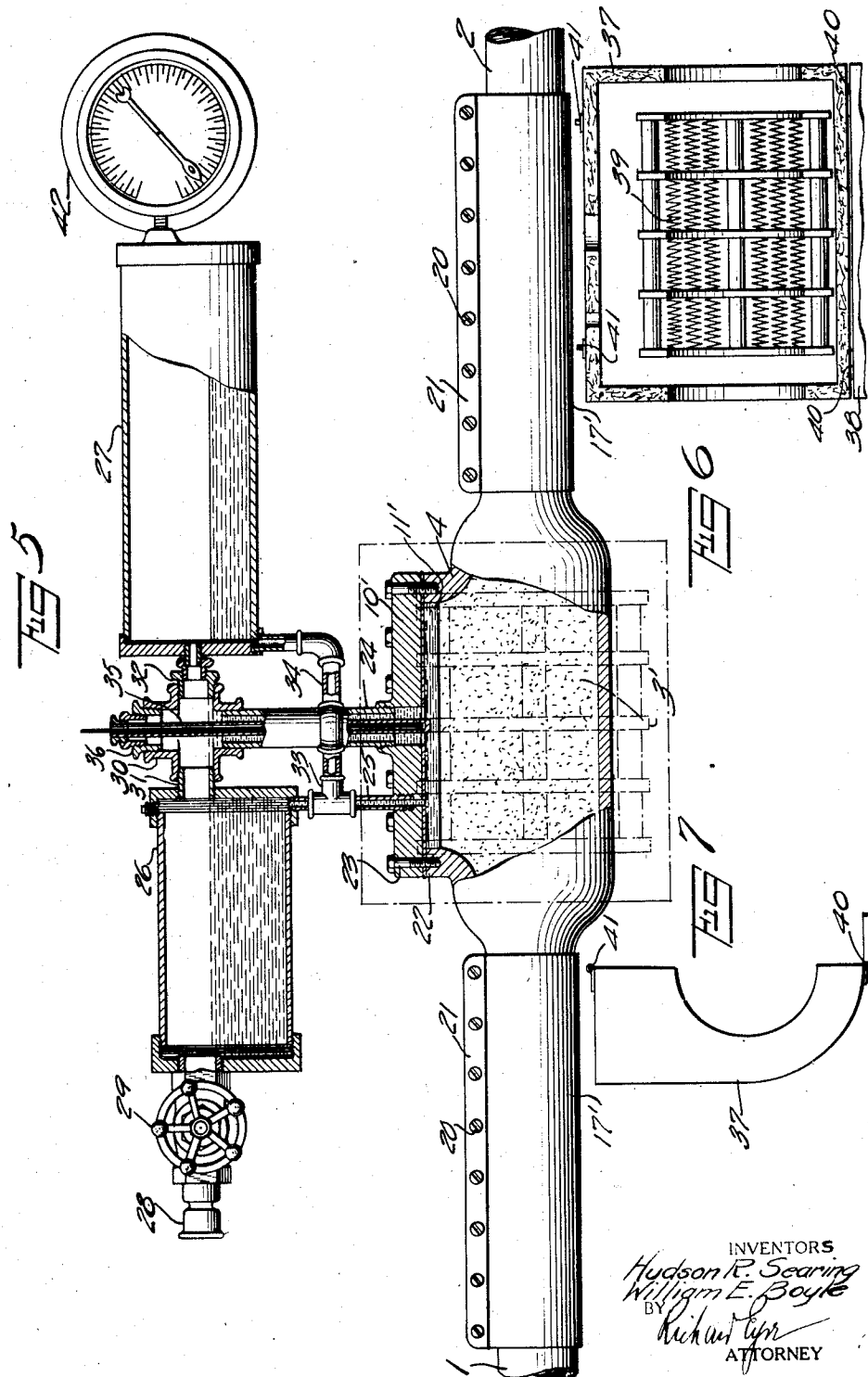
INVENTORS
Hudson R. Searing
William E. Boyle
BY
Richard E. Byrne
ATTORNEY

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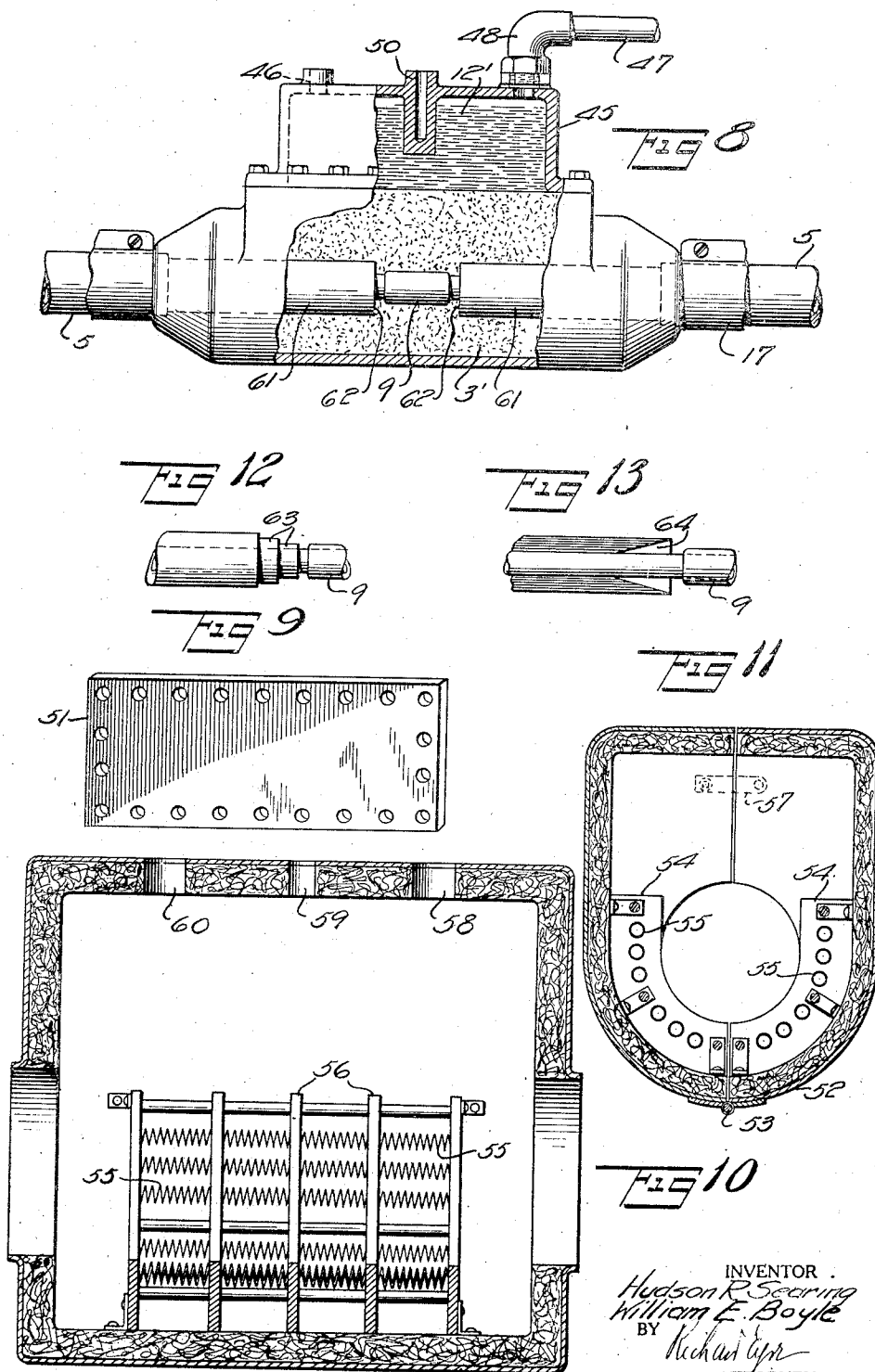
INVENTORS
Hudson R. Searing
William E. Boyle
BY
Richard L. Linn
ATTORNEY

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3 Sheets-Sheet 3



INVENTOR
Hudson R. Seering
William E. Boyle
BY
Richard L. Gyr
ATTORNEY

UNITED STATES PATENT OFFICE.

WILLIAM E. BOYLE AND HUDSON R. SEARING, OF NEW YORK, N. Y., ASSIGNORS, BY DIRECT AND MESNE ASSIGNMENTS, TO ENGINEERING PRODUCTS CORPORATION, INC., OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

METHOD OF FORMING HIGH-TENSION CABLE JOINTS OR SPLICES FOR UNDERGROUND SYSTEMS.

Application filed December 6, 1924. Serial No. 754,273.

This invention relates to high tension cable joints or the like, especially for underground systems.

The object of the invention generally is a novel and improved method for making a cable joint or splice for high tension underground systems and analogous applications which possesses marked resistance to electrical breakdown, is water proof, airtight and permanently stable, and is capable of being practically installed within the confined and reduced spaces of underground systems.

With the increase in voltage of underground transmission systems the forming of satisfactory cable joints or splices becomes increasingly difficult because of the small and circumscribed spaces within which the conductors are laid and of other special problems to be met which are peculiar to underground systems. The tendency has been generally to follow the practice in low tension systems of forming joints or splices of a tape or paper foundation immersed in a bath of an insulating compound, in some instances reinforced by fibrous insulating tubes immediately surrounding the tape or paper insulation. Joints of this character become unduly bulky for the higher voltages, and moreover experiments show that the dielectric strength and breakdown resistance of such joints are quite irregular and often fail to accord with expected results. This is believed due to the difficulty of excluding the presence of air and moisture and this difficulty is enhanced by the tendency of the filling compound to migrate or otherwise become depleted after installation. The latter difficulties may be partially avoided by the use of the usual so-called "hard" compound fillers which are poured around the insulated joint while hot and permitted to cool, but all such compounds with which we are familiar either fail to penetrate and fill the interstices of the joint or upon cooling leave numerous cracks and voids throughout the body thereof, or both, with resultant entrapment and penetration of air and moisture. Such "hard" compounds appear particularly incapable upon hardening of forming an air and water tight seal with the filling-in and cable insulation. In accordance with our novel method herein claimed we have devised a joint or splice

which is of the small dimensions demanded in practice and which is not only free of entrapped air and moisture but is permanently stable and resistant to air and water penetration indefinitely. We effect such a joint by forming around the bare conductor splice and the adjacent cable insulation a hard, solid, impenetrable body of insulating material of a character and in a manner to form a permanently close air and water tight seal with both the bare conductor and the cable insulation. The insulating body must be of such character and formed in such manner as to avoid injury to the bare conductor and the cable insulation during the process of formation and after formation it must withstand the severe temperature changes and moisture conditions experienced in underground systems without internal ruptures and disintegration. The insulating material which we have found suitable belongs generally to the synthetic resin class, though other materials such as specially treated natural resins may be later found to be suitable for our purpose. The preferred insulating material is a synthetic resin of the phenol-formaldehyde condensation type because we have found such an artificial resin, if properly selected, to possess properties peculiarly fitting it to the formation of such an impenetrable air and water tight joint including a close seal or union with both the bare splice and the cable insulation. Moreover, an insulating body of this character possesses temperature and heat conducting characteristics which render it especially suitable for use with the bare copper conductor splice with which it functions and enable it to resist rupture and fracture during severe service conditions.

More particularly our invention relates to the insulation of cable conductors in situ, and in one aspect involves incorporating the raw material about the bare splice and the interrupted cable insulation in the quantity desired, either before or after melting, and while subjecting it to heat and/or pressure in the usual manner of transforming similar materials into a hard infusible mass, localizing the pressure about the cable joint and thereby preventing the migration of the molten or plastic material during the treating and forming stage. In another aspect, our

novel method involves the introduction of an insulating oil bath about the joint or splice in a manner to thoroughly saturate the cable insulation prior to the formation of the solid mass of insulation about the joint.

For a better understanding of the invention, reference may be had to the accompanying drawings forming a part of this application, wherein:

Fig. 1 is a side view of a cable joint embodying our invention,

Fig. 2 is a longitudinal section there-through with enclosing casing,

Fig. 3 is a view indicating the method of forming the joint,

Fig. 4 is a longitudinal view partly in section illustrating a step in the formation of the joint,

Fig. 5 is a view illustrating apparatus which may be employed in carrying out our invention,

Figs. 6 and 7 are views of an electrical heating apparatus which may be employed.

Figs. 8-11 and 12-13 are views illustrating a modified form of apparatus and a slightly modified method of procedure respectively.

Referring to Fig. 1 we have indicated the cable ends 1 and 2 which are to be joined together and insulated in accordance with our invention. The joint resulting from our invention includes a body of hard infusible and permanently stable insulating resin-like material 3 which is formed around the splice and is of a character to form an air and watertight seal and joint with both the bared conductor ends and the cable insulation coverings, and to permanently exclude both air and moisture from the joint. We have found that a material of the phenol-formaldehyde condensation type, if properly selected and treated, is especially suited for insulating cable joints, particularly in that such a material may be treated and operated upon so as to form a permanently solid air and water proof insulating mass about both the bared metallic conductor, and the cable insulation. Its insulation and dielectric strength are such that joints of this character may be employed for the highest voltages in use in underground systems without unduly increasing the dimensions of the cable at the joint, and its temperature, heat conducting and other physical properties are such that its structure remains firm and intact indefinitely, notwithstanding the severe service conditions to which it is subjected in underground systems.

In Fig. 2 we have shown a casing 4 surrounding the body of insulation 3, the casing 4 forming a wipe joint with the lead sheath 5 of the cable. The lead sheath 5 is illustrated as cut off to the point 6 and the exposed insulation 7 of the cable may, if desired, be beveled off along the surface 8. The bared ends of the conductors of the cable ends 1 and

2 are joined together by a metallic sleeve 9 in the usual manner. The body of insulating material 3 is observed to adhere to both the cable insulation 7 and the bared conductor ends and copper sleeve 9, and to fill all the crevices and interstices within the casing 4 and about the splice.

One embodiment of our method of formation and insulation of the joint in situ is indicated in Figs. 3 and 4. Fig. 3 indicates the conventional manhole having the cables 1 and 2 leading thereto which cables are to be joined and insulated according to our invention. The casing 4 is passed over one of the cable ends 1 or 2 before the bared conductor ends are joined by the copper sleeve 9 and after the anchoring of the sleeve 9 in position about the abutting ends of the bared conductors, the casing 4, which is indicated as of cylindrical form with an opening on its upper side, is then slipped into position to surround the copper splice 9. The ends of the casing 4 are then sealed to the lead sheath 5 of the cables in any suitable manner, as for example by the usual wipe joint. The casing 4 is then filled or almost filled with the insulating material which is ultimately treated to form the resin-like body 3 about the cable splice. We prefer to use for our purpose a phenol-formaldehyde condensation product which, before it is melted and treated, is in a granular, flaky, lump-like or plastic form. This material is introduced through the opening in the upper side of the casing 4 and preferably in the melted form. It can be easily melted by the application of moderate heat in a suitable vessel (omitted from the drawings for convenience in illustration) and after melting or bringing it to a liquid or plastic state it is then poured into the casing. A cover 10 is indicated more or less diagrammatically for closing the opening in the casing 4 and between the cover 10 and the melted raw material 3' there is a chamber 11 to provide for the application of suitable fluid pressure during the process of treatment. In the preferred embodiment a layer of oil 12 of suitable depth completely covers the material 3' which serves to shield the material from direct contact with the pressure fluid applied to the top thereof. The oil used does not mix with or penetrate into the body of phenol resin product 3'. Pressure and heat are then simultaneously applied to the melted material 3' for a suitable length of time to convert and transform the same into the hard infusible resin-like body 3 of Figs. 1 and 2. Fluid pressure such as CO₂ or the like may be applied through a pipe line 13 controlled by a valve 14, the pipe 13 having a connection leading down through the cover 10 to the chamber 11 above the raw material or substance 3'. Heat may be applied in any suitable manner, but I have indicated diagram-

matically an electrical heating coil 16 surrounding the casing 4 for externally applying heat to the substance 3'. Before the pressure and heat are applied, binding means such as clamps 17 are applied to the cables 1 and 2, these clamps 17 being indicated as binding very tightly about the cables 1 and 2 and functioning to localize the pressure within the immediate neighborhood of the joint. Migration of the resinous material along the bare conductors and through the cable insulation beyond the joint is thereby avoided. Sufficient heat is then applied to the substance 3' to convert it to a hard resin-like body 3 and at the same time pressure is applied and maintained thereon during the heating step. A pressure of from 100-125 pounds upon the material 3' and a temperature of 125-135° C. are suitable for most phenol condensation products with which we have worked, although satisfactory results may be obtained with considerable variations in pressures and temperatures. The pressure and heat are preferably applied continuously for four or five hours which is ordinarily sufficient to convert the raw material 3' into the hard infusible resistant resin-like body 3 which under this treatment closely surrounds and binds tightly both the bared conductor splice and the insulation. The process also results in the impregnation of the insulation 7 by the raw material 3' before it hardens and it penetrates all the interstices and crevices about the joint and within the casing 4 to form an airtight insulated joint with no voids and interstices therein. The binding means 17 function to prevent the bursting of the cable sheath 5 during the application of pressure and to relieve the joint of bending strains, and enables the maintenance of suitable pressure and prevents the penetration of the fluid material (before it hardens) therebeyond.

We have found it advantageous to thoroughly saturate the joint with oil before the introduction of the raw material 3' and this may be readily effected by temporarily filling the casing 4 with oil and then applying pressure, say of 100 pounds thereon for a brief period to impregnate the insulation and cause the oil to thoroughly penetrate the interstices and crevices thereof. The oil is then removed from the casing and the raw material 3' introduced as above indicated for forming about the joint. Preferably the oil bath is removed entirely before the introduction of the raw material 3', including the wiping of the bare conductor to remove the oil film, but it would of course be possible to introduce the material 3' directly into the oil bath since the resin would supplant the oil and cause it to rise to the top.

It is possible to form a fairly satisfactory joint by treating a properly selected resin at approximately 60° C. and at atmospheric

pressure, but the joint prepared as above described, is preferred, and moreover the time required for treatment (120-300 hours) at atmospheric pressure renders this practically prohibitive.

The joint thus formed forms a permanent insulating body about the splice which resists disintegration and air and moisture penetration and remains in its intact, homogeneous, voidless form indefinitely. Its heat conducting characteristics render it particularly free of internal stresses due to changes in temperature with the consequent reduction of tendency to rupture and form cracks and crevices therein.

Referring to Fig. 5 of the drawings we have illustrated an apparatus for practicing our invention. The casing 4 is positioned around the splice and is sealed to the lead sheath of the cables 1 and 2 in the manner above indicated, and on opposite sides of the casing 4 in which the insulating body is to be formed are disposed the elongated clamps 17', the latter having securing and binding means 20 for engaging the adjacent edges 21 of the clamps 17'. By this means the clamps 17' may be caused to bind the cables 1 and 2 very firmly and tightly to enable the maintenance of the pressure within the casing 4 and to prevent the migration of the phenol condensation products during the treatment. The casing 4 is provided with a cover 10' which rests upon the peripheral edge 22 of the opening in the casing 4 and is secured firmly thereto by bolts 23. The cover 10' is provided with openings for the reception of the pressure intake pipes 24 and 25, these being attached thereto in any suitable manner, as for example by the screw-threaded connections illustrated. A pair of expansion and pressure equalizing tanks 26 and 27 are carried by these intakes 24 and 25 and the tank 26 has an intake 28 with a control valve 29 therein for admitting fluid pressure such as air, CO₂ and such like for applying pressure to the phenol products 3' under treatment. The intake pipe 24 which is centrally disposed with reference to the cover 10' carries on its upper end a double T connection 30, the horizontal connections of this T leading to the tanks 26 and 27 through connections 31 and 32 respectively. The connections 32 are indicated as consisting of three telescopically arranged screw-threaded devices as indicated. The lower connection of this T connection 30 communicates with the pipe 24 and thence with the chamber above the products 3'. Tanks 26 and 27 are therefore in communication with the casing 4 through the pipes 24 and 25. Preferably there is an equalizing connection 33 between the vertical pipes 24 and 25 and similarly there is a connection 34 leading from the vertical pipe 24 to the bottom of the tank 27 near the left-hand end

thereof. The connection 24 is observed to lead into the tank 27 substantially centrally thereof in line with its longitudinal axis and into the tank 26 at a point above the center thereof, while the pipe 25 leads into the bottom of tank 26. The upper connection of the member 30 is provided for the purpose of inserting a thermometer casing 35 into the casing 4, the casing 35 being in the form of an elongated tube having its lower end closed. It is carried by the telescopically arranged screw-threaded sleeves 36, the lower one of these sleeves being carried directly by the T connection 30. This casing 35, therefore, extends centrally through the intake pipe 24 and to casing 4 and a thermometer as indicated, may be inserted therein for the purpose of determining the degree of heat to be applied.

In Figs. 6 and 7 we have indicated views of an electrical heating unit which is in the form of two similar mating parts 37 and 38 which may be clamped externally about the casing 4 in close proximity thereto for applying the heat to the casing 4. One of these halves 38 is shown as broken off and only partially illustrated. Both are provided with electrical heating coils 39 (only one group shown) which may be supplied with electrical energy after the assembly thereof about the casing 4. They are hinged at their lower edges as indicated at 40 and have suitable latches 41 on their upper portions for fastening them together after assembly about the joint. At 42 is indicated a pressure gauge for indicating the pressure applied to the system.

In the particular embodiment illustrated not only the chamber 11 above the condensation product 3' is filled with a neutral fluid like oil, but this oil is filled in in quantities sufficient to raise the level thereof to substantially the top of the intake pipe 24 and to a point slightly above the central axis of the tank 26 and slightly below the central axis of the tank 27. With the melted or plastic material 3' contained in the casing 4 and the parts assembled as indicated with the body of oil for shielding the material 3' against the direct influence of the fluid pressure, the pressure and temperature are raised to the desired degrees and continued for the desired period necessary to convert and transform the product 3' into a solid, infusible permanently stable insulating body. After the continuation of this treatment for the desired period, the pressure and the heat energy supply are removed from the system and the insulating body 3 thus obtained forms a permanent solid insulator about the cable splice of marked electrical resistance and dielectric strength. If desired, the cover 10 may be removed from the casing 4 with the other parts, or it may be permitted to remain there indefinitely. Similarly the binding devices

17' may be permitted to remain or they may be removed and used in the formation of other cable splices and joints.

In Figs. 8 and 9 we have shown a simplified and preferred apparatus for carrying out our invention. The casing or sleeve 4' which surrounds the joint and is sealed to the lead sheath 5 of the cable by the usual wipe joint is similar to the casing 4 described above. Instead of a flat casing plate 10, 10', however, we employ an elongated chambered cap 45 which may be tightly fastened over the opening of the casing 4' as by means of the series of fastening bolts indicated. This casing is provided on its top with an intake opening 46 with a suitable closing cap thereon whereby, upon removing the cap, insulating oil may be introduced therein to saturate the joint before the introduction of the material 3' or to form a body of oil which is interposed between the point of application of the fluid pressure and the body of raw material 3'. The fluid pressure is supplied by the pipe 47 from any suitable source and pressure, not indicated herein, as for example CO₂ tanks which are conveniently arranged adjacent the manhole and joint to be made. The pipe 47 leads through the connection 48 and an opening 49 above the body of oil 12' carried within the cap 45. A socket 50 is provided for insertion of a thermometer to serve as a guide for maintaining the proper treating temperature within the casing 4'. The method of treatment is similar to the method described above in connection with Figs. 1-5 inclusive. After the required treatment which results in the transformation of the raw material 3' into a hard infusible mass tightly gripping both the bared conductor and adjacent insulation and penetrating into the crevices and interstices to form a solid mass thereabout, the application of pressure and heat may be removed and the cap 45 exchanged for the permanent plate 51, illustrated in Fig. 9. This plate 51 is in the form of a flat plate which may be secured to the casing 4' by the same attaching bolts illustrated in Fig. 8. This plate 51 forms a permanent closure for the casing 4' during the life of the joint.

The means for applying heat energy to maintain the proper temperature within the casing 4' during the treatment of the raw material 3' may be effected by an electric heating apparatus illustrated in Figs. 10 and 11, which is of the general character indicated diagrammatically in Figs. 6 and 7. This heating unit comprises the two casing halves 52 which are hinged at 53 and each half 52 carries therewithin near the bottom thereof a heating element 54, these elements 54 being adapted to closely surround the bottom and sides of the casing 4'. In the particular structure illustrated each of these heaters 54 comprises a series of six coils 55 which are

carried by the spacing insulating members 56, suitably secured to the casing parts 52 and these coils may be connected up in the usual manner to supply electrical energy thereto through any suitable connections passing out through the casings 52,—these connections not being shown for convenience in illustration. The two hinged halves 52 may be retained in mating relation in any suitable manner as for example by means of the latches 57 secured to the adjacent ends thereof. These casings 52 are also provided with semi-circular mating grooves 58, 59 and 60 on their upper meeting edges to form openings for accommodation of the pipe connection 48, the thermometer socket 50 and the closing cap 46.

Referring to Fig. 8 it is observed that the cable insulation 61 is not tapered or beveled off as is done in Figs. 1-4 inclusive, but instead a cylindrical section of insulation is removed from each end of the cable so as to provide end surfaces 62 at right angles to the cable. In Fig. 12 we have indicated a slight modification wherein the insulation is removed in series of steps 63 adjacent the cable ends, the creepage surface being slightly larger than the surface in Fig. 8. In Fig. 13 we have indicated the cable insulation adjacent the cable end as being undercut or tapered in the inverse manner to that shown in Figs. 1 and 4, a conical section of the insulation being removed to form the tapered undercut chamber 64. In forming the cable joint the resin is caused to enter and fill up the chamber 63 and also to closely surround the insulation immediately thereabout, but the present preferred method is to remove a cylindrical block of insulation, as indicated in Fig. 8,—it having been found that this is entirely satisfactory for practical purposes.

We have shown our invention as applied to the insulation of cable splices to which it is particularly adapted, but certain features thereof are of advantage in the formation of pot head joints and similar applications.

Having thus described our invention, what we claim and desire to protect by Letters Patent is:

1. The method of insulating a cable conductor splice in situ which consists in forming a casing around the splice, introducing a quantity of raw material into the casing, said material being capable of being transformed into a solid impermeable insulating mass binding the cable on opposite sides of the casing and then subjecting the material to

combined pressure and heat to transform it into a solid impermeable insulating mass surrounding the splice.

2. The method of insulating a cable conductor splice in situ which consists in forming an enclosing casing around the splice, introducing an insulating oil in the casing and applying pressure to thoroughly saturate the cable insulation adjacent the splice, and then forming around the splice and within the casing a solid body of insulating material.

3. The method of insulating a cable conductor splice in situ which consists in forming an enclosing casing around the splice, introducing an insulating oil bath within the casing and applying pressure thereto to saturate the cable insulation therewithin, then removing the oil bath and introducing a quantity of raw material into the casing which is capable of transformation by treatment into a solid impermeable insulating mass, and subjecting the material to combined pressure and heat treatment to transform it into a solid impermeable insulating mass surrounding the splice and filling the crevices and interstices within the casing and about the joint.

4. The method of insulating a cable conductor splice in situ which consists in forming an enclosing casing around the splice, introducing an insulating oil bath within the casing and applying pressure thereto to saturate the cable insulation therewithin, then removing the oil bath and introducing a quantity of raw material into the casing which is capable of transformation by treatment into a solid impermeable insulating mass, and then subjecting the material to treatment to transform it into a solid impermeable mass surrounding the splice and filling the crevices and interstices within the casing and about the joint.

5. The method of insulating a cable conductor splice in situ which consists in forming a casing around the splice, introducing a quantity of material into the casing which is capable of being formed into a solid impermeable insulating mass by a treatment including the application of pressure, binding the cable on opposite sides of the casing chamber and then subjecting the material to a treatment including the application of pressure to transform it into a solid impermeable insulating mass surrounding the splice.

In testimony whereof, we have signed our names to this specification.

WILLIAM E. BOYLE.
HUDSON R. SEARING.