

July 12, 1938.

H. ROST

2,123,209

ELECTRIC CABLE

Filed Sept. 2, 1937

FIG. 1.

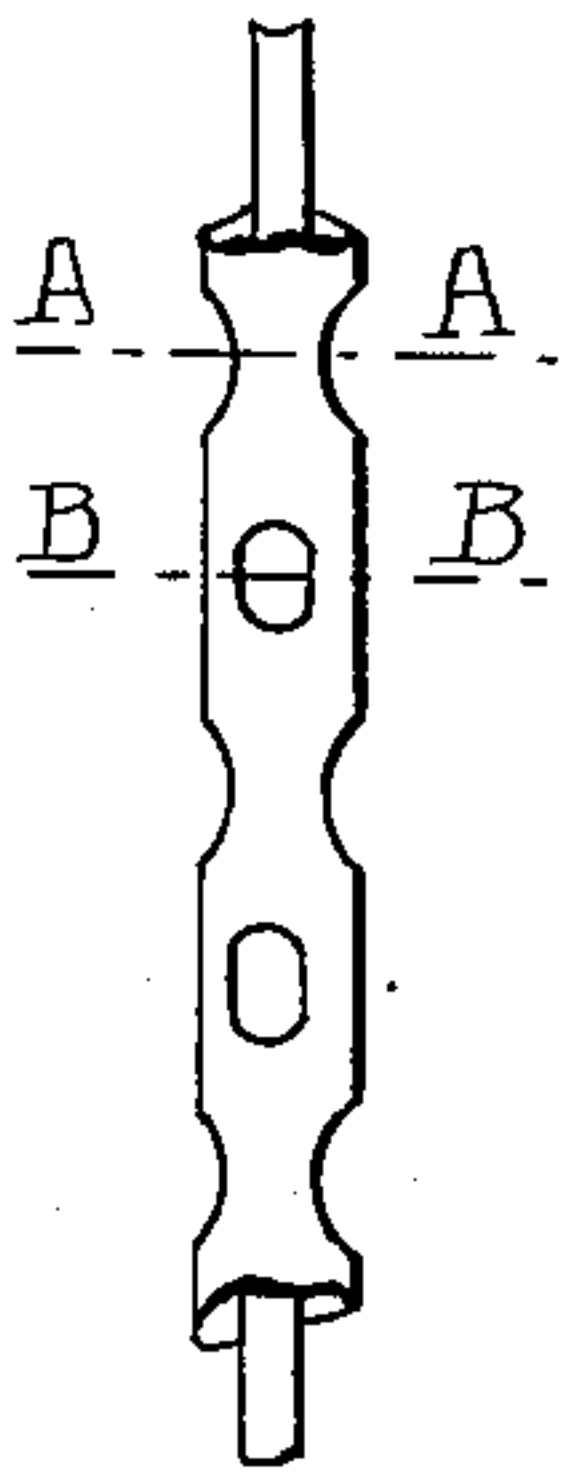


FIG. 2.



FIG. 4.

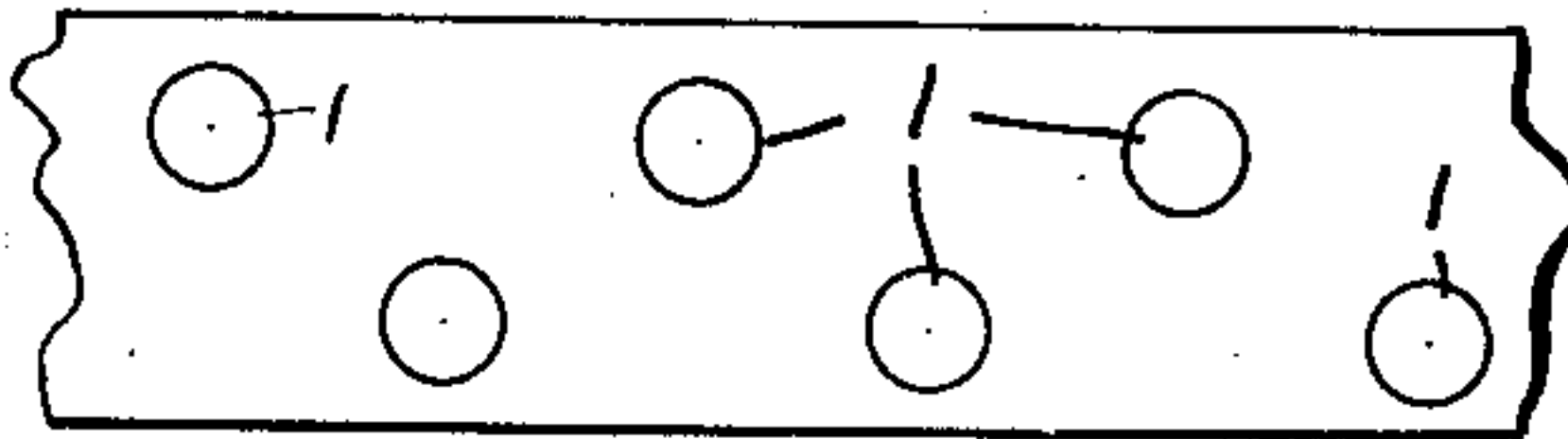


FIG. 3.

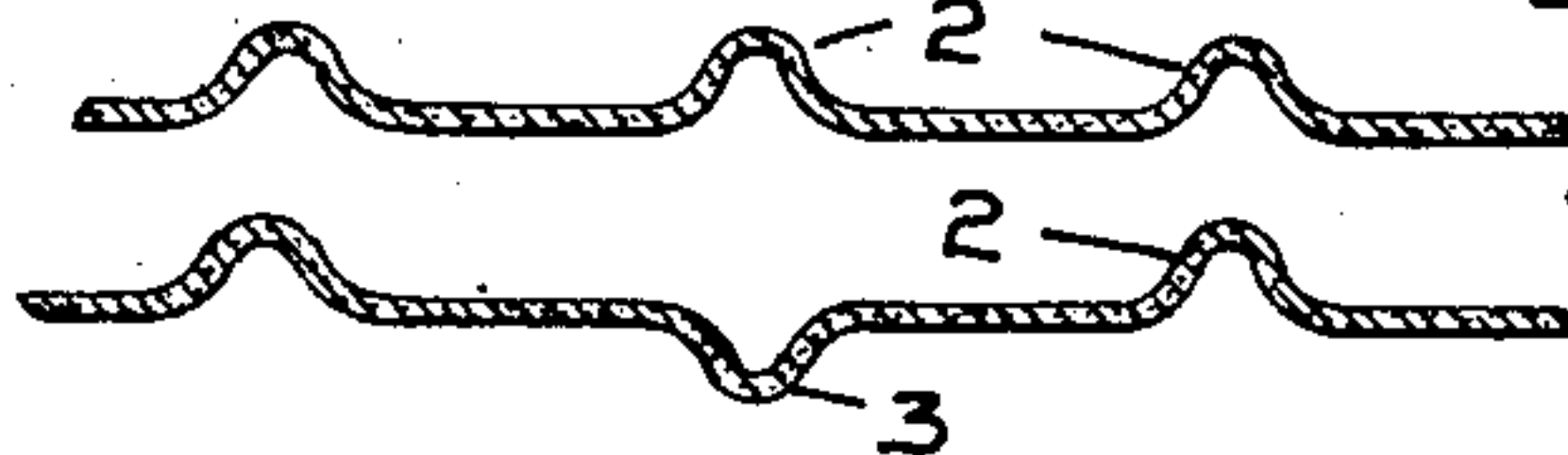


FIG. 5.

FIG. 6.

FIG. 8.

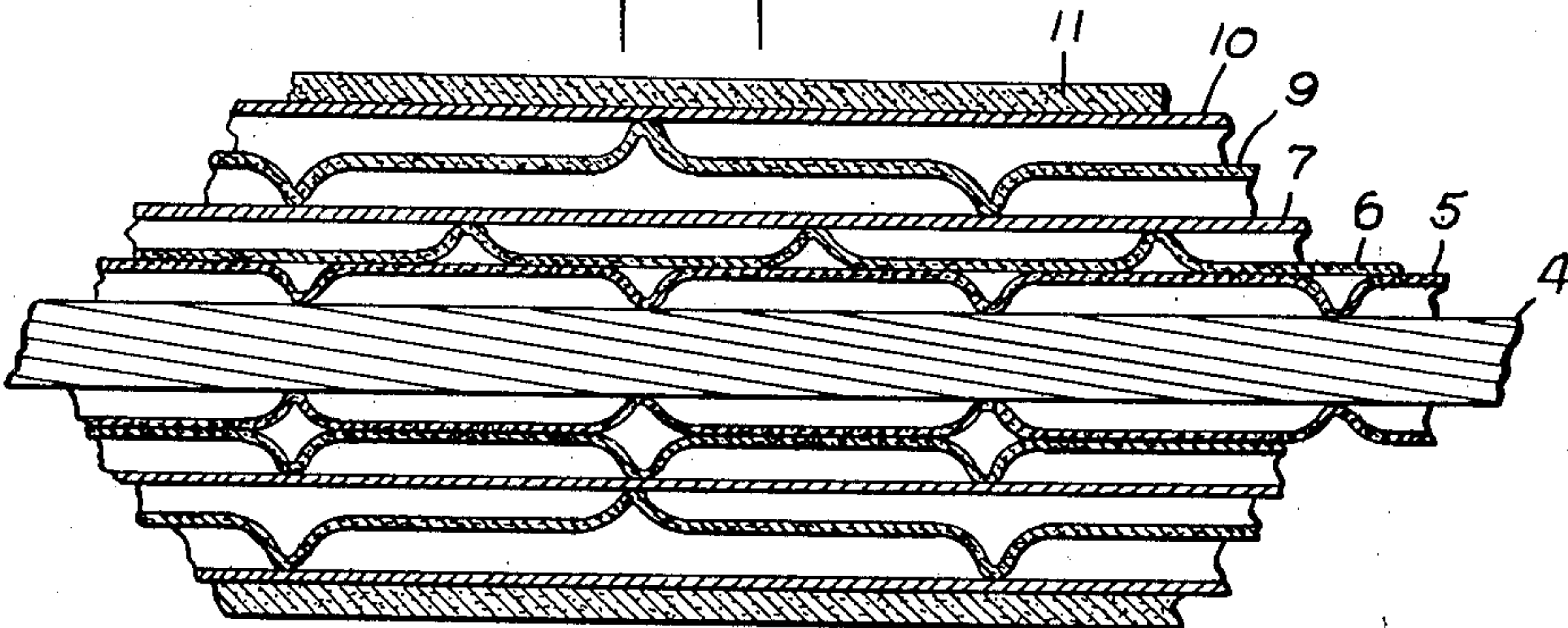


FIG. 9.

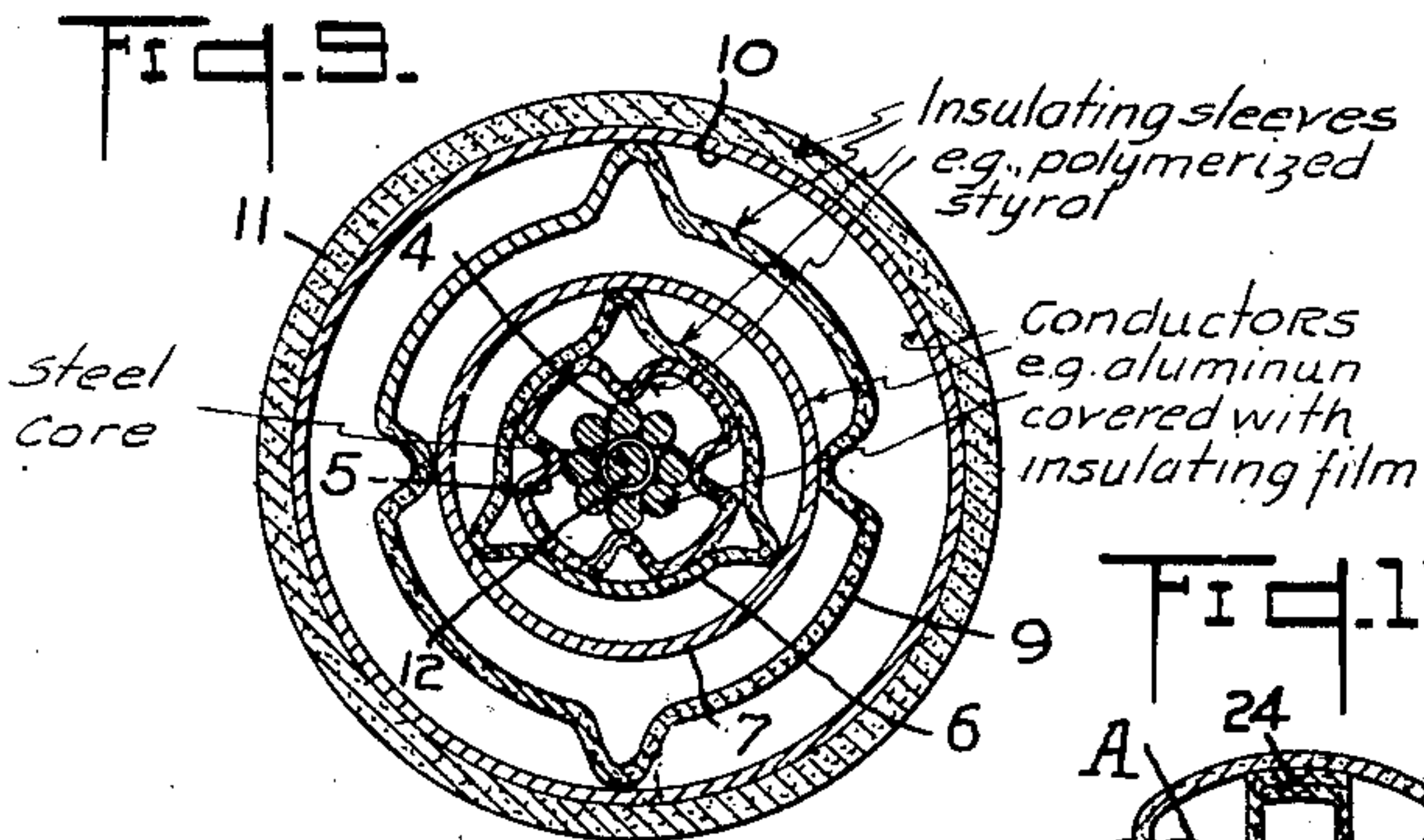


FIG. 10.

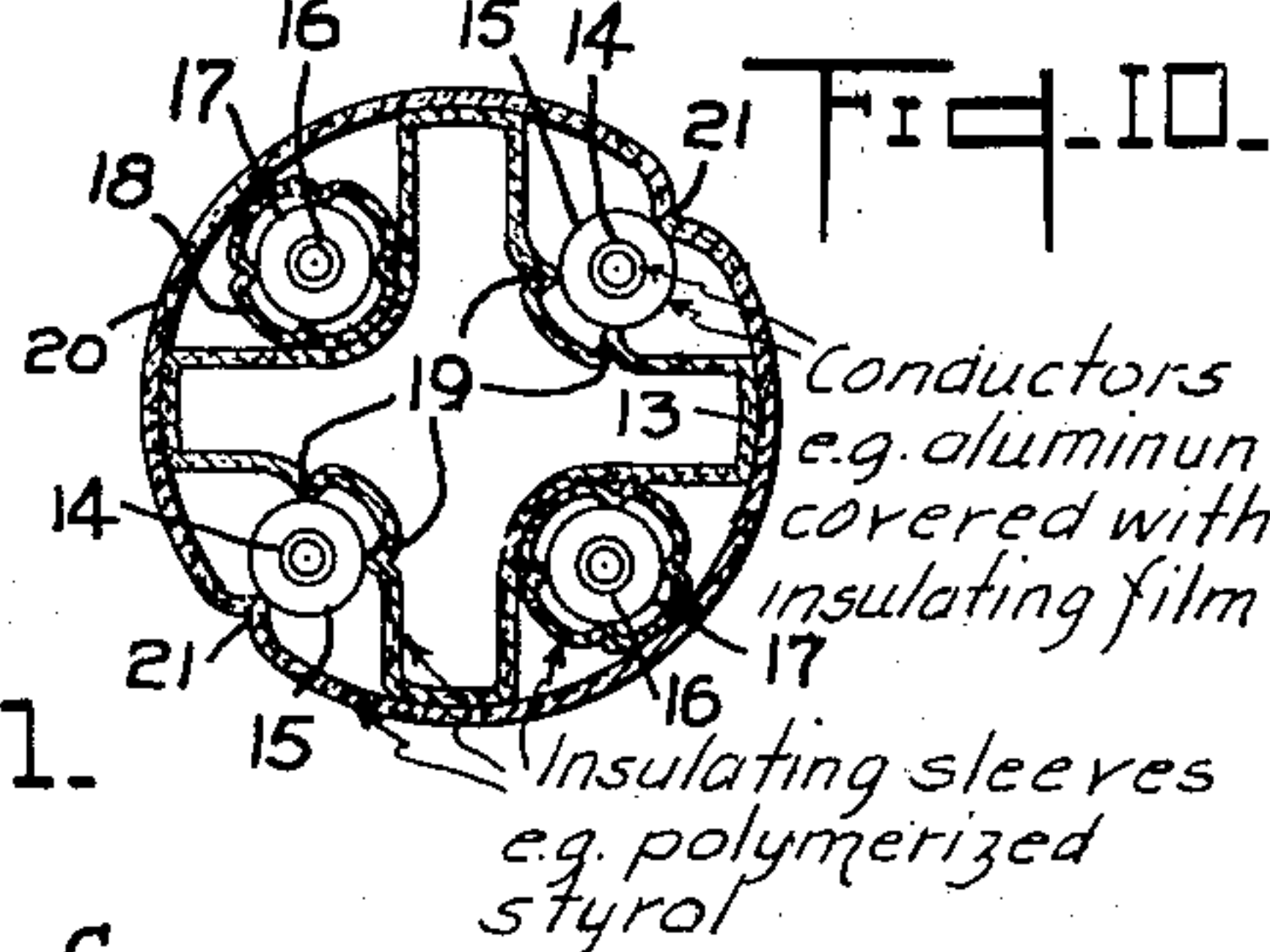


FIG. 7.

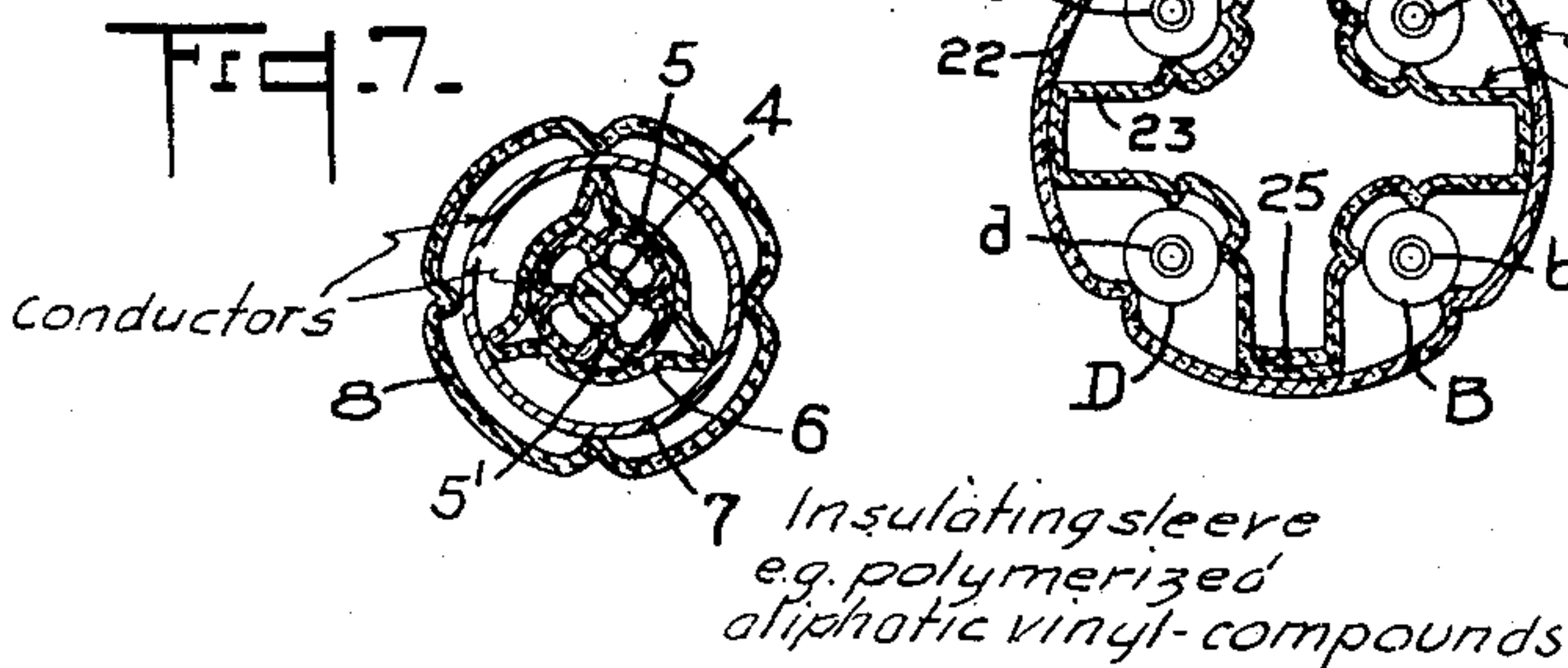
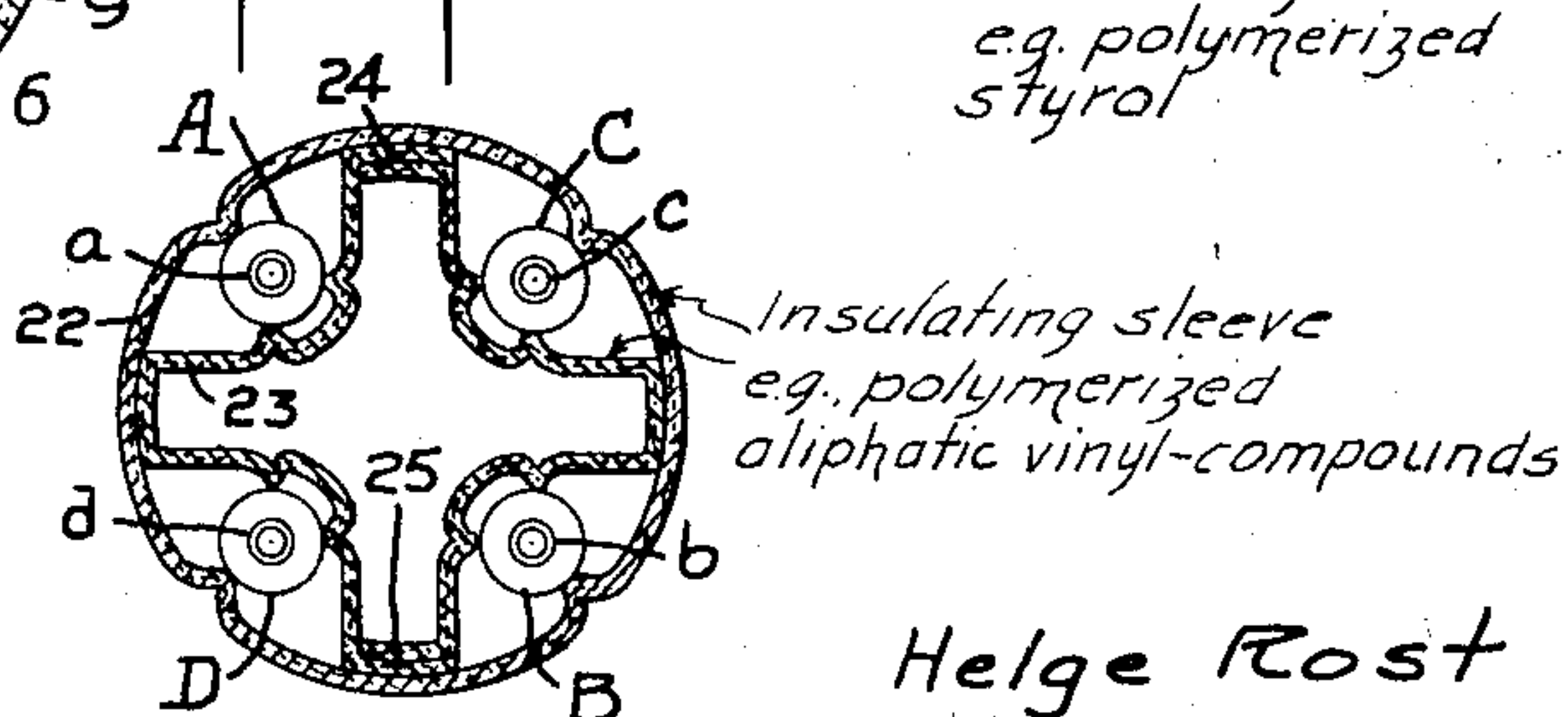


FIG. 11.



Helge Rost
INVENTOR

BY *Attorney*
his ATTORNEY.

UNITED STATES PATENT OFFICE

2,123,209

ELECTRIC CABLE

Helge Rost, Stocksund, Sweden

Application September 2, 1937, Serial No. 162,090
In Sweden July 26, 1932

3 Claims. (Cl. 173—265)

The present invention relates to improvements in electric conductors, cables and coaxial structures for transmitting with small attenuation electric currents, particularly alternating high frequency currents in communication systems.

The present application is a continuation in part of my copending applications Ser. Nos. 16,157, now Patent No. 2,092,025 and 681,136 now Patent No. 2,116,643 filed April 13, 1935, and July 19, 1933, respectively.

Several systems have been devised, which utilize the well known coaxial structures embodying concentric conductors having insulating means so formed, that the dielectric between adjacent surfaces of the conductors will be principally gaseous.

Heretofore such insulation has consisted of washers or of discs of hard rubber, steatite, pyrex glass, etc., placed at fairly wide intervals, between the rigid conductors generally in the form of tubes of copper or lead with the central conductor either of solid copper or in the form of a tube. A semi-flexible structure of small diameter has been made, having a solid central conductor with an outer conductor of overlapping copper strips, held in place with a binding of iron or brass tape spirally wound on the copper strips. In this case the insulation consisted of a cotton string wound spirally around the inner conductor.

The object of the present invention is to produce commercial flexible conductors, cables and structures, which can be handled on reels after the fashion of ordinary cables, which will be mechanically and electrically satisfactory, and which may be manufactured economically in a continuous process of fabrication.

Another object of the invention is to produce a new insulating compound for use in the cables according to this invention.

The structure according to this invention is suited to coaxial circuits of both small and large size conductors, without any danger of metallic contact between respective conductors, and still leaving ample air space between the insulation and the conductors, which are contacted by the insulation in a few isolated spots only. The coaxial structures of this invention will according to my preferred construction, be immensely lighter in weight and easier to handle than those now known.

By arranging several coaxial structures in the corners of perfect squares and by insulating them according to this invention, several combinations

of both balanced and unbalanced circuits offer wide possibilities for future transmissions.

According to this invention, it will not be necessary to use the highest band of frequencies with large size coaxial structures, but use can be made of the smaller sizes of coaxial structures, which when combined with highly balanced circuits, possible according to this invention, will render the same number of circuits as one large coaxial structure.

In this way several inconveniences of special large size coaxial structures would be eliminated, viz., standard type construction practice can be continued, repeater stations may be placed at longer distances from one another with the resulting lower initial and maintenance costs.

Furthermore, according to this invention, numerous limitations of existing balanced communication cables of today are eliminated, and a wider field is opened up for several carrier channels in both directions of the same cable, which so far has not been possible, without special shielding arrangements or the use of different cables for transmission in each direction.

The invention may be more fully understood from the following description, when read in connection with the accompanying drawing, in which—

Figure 1 is a side elevation of a conductor surrounded by an insulating sleeve;

Figures 2 and 3 are cross-sections along lines A—A and B—B of Figure 1;

Figure 4 is an elevation and Figures 5 and 6 longitudinal cross-sections of an insulating tape;

Figures 7, 9, 10 and 11 are transverse sections; and

Figure 8 is a longitudinal cross-section of coaxial cables in accordance with the present invention.

Figures 1, 2 and 3 show an insulating sleeve around a conductor provided with interior individual protuberances, said protuberances contacting the conductor at separated points in such a way, that the conductor is kept in the center of the sleeve. The point-like protuberances are arranged so that two protuberances A—A, Figure 1, are situated opposite to one another on each side of the conductor, while another pair of protuberances B—B are arranged at a suitable distance from A—A and are situated opposite to each other and at right angles to the protuberances A—A. Other protuberances A—A and B—B are alternately arranged along the conductor at suitable intervals.

Figures 4, 5 and 6 are views of tapes of in-

insulating and flexible material provided with individual point-like protuberances 1, 2 and 3, on one side (2) as in Figure 5, or on both sides (2 and 3), as in Figure 6.

Figure 7 is a substantially transverse sectional view of a coaxial structure, consisting of a central conductor 4, an insulating sleeve 5, provided with interior protuberances 5' as in Figures 1, 2 and 3; 6 denotes an insulating tape, see Figures 4 and 5, wound about the outside of the insulating sleeve 5, the tape having exterior point-like protuberances; 7 designates a concentric metallic conductor, preferably formed of one or several annealed tapes of aluminium, disposed parallel to the core and of such width, that the edges meet, or if necessary overlap, and the seams are welded according to any electric resistance welding principle, according to which the metal continuously melts or is fused between the electrodes, thus forming a perfect seam, while the core and the concentric conductor is passed through the welding machine.

It is not important that the weld be watertight, and as the conductor is not exposed to heavy mechanical tension strains, instead of welding by an electric resistance welding process, spot welding may also be used, or the edges of each tape may be held together simply by using a metal spraying device with aluminium as the sprayed metal and by this means a rapid and cheap welding of the longitudinal seam of the conductor can be made. If the aluminium tape is heavy enough, no welding is needed at all, as the edges can be laid side by side. In order to make the tubular conductor stiff enough, instead of pure aluminium tape, an alloy of for instance, silicon and aluminium can be used.

In order to decrease the attenuation due to the skin effect, the concentric conductor can be composed of several thin shells of metal, of which the first one can be arranged from a longitudinal tape as described above, and the remainder from tapes put on with longitudinal seams with or without welding, or wound spirally outside the first shell. Each shell or layer should be isolated from the others, either by a thin insulating film or if aluminium is used preferably by means of an insulating oxide film.

Figures 8 and 9 are substantially longitudinal and transverse sectional views, respectively, of a coaxial structure containing 3 concentric conductors, conveniently insulated from each other according to the principles of this invention. The central conductor can be solid, stranded or hollow, depending in each case upon how the coaxial structure shall be used. In the drawing a stranded conductor 4 is shown, said conductor being composed of several strands of wire, preferably of aluminium with steel-reinforced central strand 12. Eventually the individual wires of the conductor are provided with an insulating film. By using a steel-reinforced central strand conductor a greater stability is given to the whole coaxial structure, in which the reinforced aluminium steel strand will take up the longitudinal stresses of the coaxial structure, especially when the structure is being pulled into and out of an underground duct, or when said coaxial structure is placed as an aerial cable on existing pole structures. The coaxial structure with or without outside insulation can be attached to existing messenger wires and pole line hardware, but the coaxial structure can in certain cases be suspended without special messenger wires, using the cen-

tral conductor as messenger, which in such a case will take up the longitudinal stress. In these cases the whole manufacturing length of the coaxial structure is placed on the poles and attached to same by suitable fastening means, and at each end of such manufacturing lengths the steel reinforced central conductor is spliced to the corresponding central conductor of the next manufacturing length, and the other concentric conductors shall be spliced and insulated in a regular manner; suitable sleeves of somewhat larger diameter of both insulating and conducting materials must of course be used for such splices. Similar splices can be used for coaxial structures placed either on poles or underground.

Continuing the description of Figures 8 and 9, (5) is an insulating sleeve as per Figures 1, 2 and 3, holding the central conductor in the center of said sleeve. 6 denotes an insulating sleeve directly outside sleeve 5 with outside point-like protuberances as per Figure 5, in order to give to the concentric conductor 7 convenient insulating air space. The insulating sleeves 5 and 6 could of course be substituted by a single sleeve with protuberances on both sides as in Figure 6, whereby said sleeve can be made up by overlapping longitudinal or spirally wound tape with protuberances on both sides of the tape. 9 designates an insulating sleeve with individual point-like protuberances on its inside and outside surfaces. 10 denotes a third concentric conductor of annealed aluminium tape as above described, and 11 designates an outside mechanically and electrically insulating flexible and resilient sleeve of the same linear coefficient of expansion, as the inside insulating sleeves, said outside sleeve of sufficient mechanical strength to withstand crushing action from exterior sources, and have sufficient tensile strength together with the steel-reinforced central conductor to withstand normal longitudinal stresses, 12 being the steel strand of the central conductor.

Figure 10 is a substantially transverse sectional view of four groups of coaxial structures (14—15) and (16—17) arranged in a perfect square (so-called quad-formation) and held at equilateral distances from each other by means of a hollow insulating core 13 with or without point-like protuberances 19, to keep the coaxial structures principally in air. Instead of providing the insulating core with protuberances, it may be constructed with smooth surface in which case each coaxial structure may be provided with an outside insulation (18), in the same manner as (8) in Figure 7, the whole coaxial structure in such a case having a form as shown in Figure 7. The conductors 14 and 15, 16 and 17 are of course separated by insulating sleeves as previously shown, although not marked in the figure. The hollow insulating core may be made in one operation by a thermo-plastic extruded insulating material, the hollow core being twisted spirally with suitable devices in order to give to the coaxial conducting structures a transposed position in relation to outside inductive disturbances. If deemed necessary the whole quad-structure may be provided with a common insulating sheath (20), eventually with interior protuberances (21) and an outside metallic sheath or armour against outside inductive disturbances (the latter not being shown in the drawing). Figure 11 is a substantially transverse sectional view of four groups of coaxial structures with conductors (A—a), (B—b), (C—c) and (D—d) arranged in a perfect square and held at equilateral distances from

each other by means of a hollow insulating core. This core is made preferably of one, two or more pieces, as 20 in Figure 10, or 22 and 23 in Figure 11, which afterwards are pasted or held together as shown at 24 and 25. Should the insulating core be provided with point-like protuberances as shown, it will be easier to make these protuberances before the integral pieces are assembled.

Insulating materials

The materials preferably to be used according to this invention for the insulating sleeves shall consist of a synthetic, organic homogeneous and isotropic, chemical reaction product, without heterogeneous inclusions, as according to the experience of the inventor only such homogeneous chemical reaction products of definite organic linkages, that contain no foreign or heterogeneous inclusions, such as water, acids, salts, air, fillers, etc., show the lowest dielectric constants and lowest dielectric losses, due to the fact that conductivity through the dielectric does not exist, contrary to what takes place in other dielectrics used heretofore, such as rubber-compounds, resins with heterogeneous plastifiers and fillers, etc.

By using pure homogeneous insulating products as above specified, the capacity between the respective conductors is reduced to a minimum at zero frequency, which minimum is further reduced with increased frequency, wherefore the material here specified is specially suitable for the insulation of coaxial conductors with the high frequencies to be passed through them. This is specially the case, as most of these materials are non-hygroscopic. The organic chemical reaction products to be used according to this invention are generally obtained by polymerization or condensation processes of hydrocarbons or derivatives thereof, or by combination of both of said processes, although also other products can be used.

The chemical compounds should preferably be stable and final. The following examples of suitable compounds will illustrate the variety of combinations that can be made:

45 Polymerized aliphatic vinyl-compounds, like polymerized vinyl acetate, polymerized vinyl halides, polymerized vinyl alcohol. Another compound which may be used, although not aliphatic, is polymerized styrol.

50 Aldehyde-derivatives like diphenylol-propan-formaldehyde, cresol-formaldehyde, diphenyl-cyclohexane-formaldehyde, etc.

Example of polymerization and condensation products:

55 Dibenzyl-idene-acetone of the formula



Cellulose derivatives:

60 Cellulose esters like cellulose acetate, cellulose butyrate, cellulose benzoate; cellulose ethers like methyl cellulose, ethyl cellulose, benzyl cellulose, etc.

Further examples of homogeneous, isotropic compounds and derivatives of organic linkage, preferably used in connection with this invention are the following:

70 Polymerized, electrically symmetrical aliphatic hydrocarbons, their isomers, homologues and substitution products of the methane series from methane to tetrahexacontane of the type $\text{C}(a)_4$, where the central carbon is located in the center of a regular tetrahedron, the atoms or radicals (a) being situated at the four apices, for instance: Carbon-tetravinyl-chloride, $\text{C}(\text{CH}_2\text{CHCl})_4$; carbon-tetraallyl-chloride, $\text{C}(\text{CH}_2\text{CH}_2\text{CHCl})_4$.

Electrically symmetrical derivatives of the alkyl hydro-carbon series, their addition, substitution and polymerized products of unsaturated alkyl-hydrocarbons, such as acetylene-, vinyl-, allyl-, propylene-, butylene-, amylene-, etc. 5 -halides. Example: trans-1:2-acetylene-dichloride $\text{C}_2\text{H}_2\text{Cl}_2$.

Electrically symmetrical hydrocarbon and derivatives of the carbo-cyclic compounds and their symmetrical addition, substitution and 10 polymerization products of the benzene, diphenyl, naphthalene and anthracene compounds, like polymerized mono-vinylhalide-benzene like



polymerized para-divinyl-benzene,



etc.

The following benzene derivatives with symmetrically arranged substituents in the side-chains are not known as insulators and on account of their symmetrically built molecules, they are specially suitable for insulating purposes: Alkylene-radicals, their halogen- or other derivatives, isomers and homologs attached to the benzene ring in symmetrical substitution positions, like: di-para-; tri-(1:3:5)-; tetra-(2:3:5:6)-positions and hexa-positions. If the radicals attached are not located in the same plane, they should be located in trans-positions in such a manner, that an electrically symmetrical structure is obtained. Examples: para- $\text{C}_6\text{H}_4(\text{CH}_2\text{CH})_2$; para- $\text{C}_6\text{H}_4(\text{CH}_2\text{CHCl})_2$; para- $\text{C}_6\text{H}_4(\text{CH}_2\text{CH}_2\text{CHCl})_2$; para- $\text{C}_6\text{H}_4(\text{CH}_2\text{Cl})_2$; para- $\text{C}_6\text{H}_4(\text{CH}_2\text{CH}_2\text{Cl})_2$; para- $\text{C}_6\text{H}_4(\text{Cl}_7\text{C}_3)_2$; 1:3:5- $\text{C}_6\text{H}_3(\text{CH}_2\text{CH})_3$; 1:3:5- $\text{C}_6\text{H}_3(\text{CH}_2\text{CH}_2\text{Cl})_3$; 1:3:5- $\text{C}_6\text{H}_3(\text{CH}_2\text{CH}_2\text{CHCl})_3$; 1:3:5- $\text{C}_6\text{H}_3(\text{CH}_2\text{Cl})_3$; 1:3:5- $\text{C}_6\text{H}_3(\text{CH}_2\text{CH}_2\text{Cl})_3$; 1:3:5- $\text{C}_6\text{H}_3(\text{Cl}_7\text{C}_3)_3$;

hexa - vinyl - benzene; hexa - vinylchloride-benzene; hexa-allyl-chloride-benzene; hexa-1:2-dichlorethane - benzene; hexa - octachloropropane-benzene. Innumerable substitution products can in likewise manner be obtained changing the substitution atom, radical or chain.

Electrically symmetrical products of unsaturated aliphatic compounds, their derivatives and polymerization products, for instance: Substituted, added or polymerized products of butadien, like trans-2:3-dimethyl-butadien; trans-2-phenyl-butadien, $\text{C}_6\text{H}_5.\text{CH}:\text{CH}.\text{CH}:\text{CH}.\text{C}_6\text{H}_5$; trans-2-phenyl-2:3-trans-chloro-butadien,



para-2:3-trans-dichlor-butadien-benzene,



para-di-butadien-benzol,



2:3-tetrachlor-butadien, $\text{H}_2\text{C}.\text{CCl}_2.\text{CCl}_2.\text{CH}_2$; polymerization products of: cyclo-pentadien; cyclohexadien; diphenyl-ethylene; etc.

Polymerization and condensation products, like di-substituted ureas and thioureas, such as polymers of s-diphenyl-urea and s-diphenyl-thiourea.

I have discovered that especially favorable results may be obtained by using chemical reaction products for insulation purposes. In other words, insulation materials should be chemical compounds and not physical mixtures of different ingredients or dispersion. Preferably, the insulation material is constructed in the form of flexible, preferably thin tapes of a non-hygroscopic, homogeneous, synthetic organic compound, which

are loosely and spirally wound around the conductor, with or without the application of adhesive to the overlap, preferably in the form of a solvent of the film, or alternatively the insulation may consist of one or more continuous sleeves of cylindrical or other section of such insulating material placed over the conductor, which sleeves are formed by means of one or more mouthpieces by extrusion of the compound, which at high temperatures is plastic and when cooled becomes solid. Between the conductor and respective sleeves air spaces can be left. Depending upon the material one sleeve can be extruded at a time or several simultaneously by one or several mouthpieces.

The insulating material consists of an organic tough, flexible, homogeneous, waterproof and plastic compound of synthetic origin, which is non-hygroscopic, and contains no hydroxyl groups, for instance:

Polymerization products obtained from chemical hydrocarbon compounds or derivatives thereof comprising the vinyl group ($-\text{CH}:\text{CH}_2$), like polymerized vinyl-benzene, polystyrol, polymerized vinyl acetate, polymerized vinyl halides, etc.

The before mentioned polymerization products and particularly those which like polymerized vinyl benzene belong to the group of substituted benzenes of which each substitute radical comprises a vinyl group are especially suitable insulating materials for conductors for communication purposes in accordance with the present invention.

Particularly suitable are also those substances which like polystyrol belong to the group of aryl olefines. These materials, in the pure state, have a very high insulating resistance, an extraordinary low phase angle difference, and an exceptionally low dielectric constant thus causing very small dielectric losses.

Moreover, the above mentioned materials are substantially non-hygroscopic and therefore have stable electric properties, which remain unchanged by moisture.

The great advantages possessed by cables made in accordance with the present invention are as follows:

The insulating material is a non-hygroscopic one, for instance polystyrol, vinyl-benzene, etc.

In this manner all drying processes are eliminated and there is no danger of the insulation absorbing moisture from the air. On account of the good and homogeneous electrical insulation properties a better and more constant transmission is obtained than with paper insulation, and unbalance will be greatly reduced.

Polystyrol like other insulating materials which according to this invention proved very superior insulators could not be used heretofore in their pure state because of great hardness and brittleness. Cables, on the other hand, must be flexible. Nor has pure polystyrol been used heretofore for flexible conductors in the form of a chemical compound. The use of a physical mixture of substances instead of a chemical compound will produce results far inferior to those of the present invention. I discovered that by cutting polystyrol or any other pure insulating compound according to this invention in thin foils, during its manufacture, it is possible to produce pure insulation of perfect flexibility. The procedure corresponds to that used in the artificial silk and cellulose industry when manufacturing viscose-cellulose and

cellulose acetate, etc. The polystyrol and like insulating compounds are thus rendered flexible by stretching the thread or film while the compound is squirted hot from the nozzle in a semi-liquid state and before it is cooled. As already stated, it should be borne in mind that for best results, the polystyrol should be pure, free from solvent, and preferably polymerized to such a degree that unpolymerized molecules do not exist in the melt. In other words, the polystyrol should be sufficiently polymerized, so that the same will be homogeneous.

Sufficient polymerization is important because otherwise polymerization continues upon exposure to sun and light causing discoloration, while the internal tension in the material will produce cracks and breakage. I have found that polystyrol, even if partly polymerized, possesses valuable insulating properties.

The insulating foil generally delivered from the casting machine in broad continuous tape form, after having passed between smooth or special rolls for embossing, can immediately pass through a cutting machine, which will cut the thin foil in the necessary number of foils of desired width.

From the cutting machine the individual foils can be passed through a forming machine where each individual foil is formed by means of a mouthpiece into a cylindrical tube around each corresponding electrical conductor, which is passed through the mouthpiece at the same time as the tube is formed.

When forming the cylindrical insulation tube around the conductor, the edges of the foil overlap and can be stuck together by simultaneously adding a suitable solvent to one of the edges, whereafter the edges are pressed together and the conductor is now insulated and can, after the solvent has evaporated, be rolled on a spool.

Should more insulating layers or tubes be needed, the process can be repeated and a conductor already provided with one layer can pass through another forming machine where more tape-foil is formed and eventually glued around the already insulated conductor. When the capacity of the cable is smaller, or if otherwise so desired, the tape foil can be placed on spools and be employed in one or more layers in the same way as paper insulated conductors are now covered in modern cable works with sufficient overlap with or without application of adhesives to the overlap, or the tubes can be formed with longitudinal overlapped glued seams parallel to the conductor, in the same way as in the continuous process above described.

Most of the above specified synthetic resins have excellent electric qualities, which specially fit them for insulation purposes.

Outside sheath

The outside electrically and mechanically insulating sheath around the outside concentric conductor in a concentric structure, or around a quad group of concentric conductors as per Figures 10 and 11, shall preferably be made of the same synthetic organic reaction products as the individual insulating sleeves between the respective conductors, as in that way the linear coefficient of expansion will be alike for the inside and the outside insulation, no serious or dangerous mechanical stresses taking place, due to temperature variations. By choosing aluminum for the respective conductors, the difference between

the linear coefficients of expansion of the conductors and the insulating material will be less, than if copper or other conducting material were used.

Thanks to the few point-like protuberances of the elastic insulating sleeves, contacting the conductors, said conductors will slide over said protuberances, thus facilitating bending and internal movements due to temperature changes, which is an important point in these semi-flexible structures.

Thanks to the outside insulating sheath, these cable structures will be immune against electrolysis or vagabond currents in the ground.

Distribution of frequencies

Unless the shell of an outer conductor of a coaxial structure for high frequency transmission is sufficiently thick, adequate shielding is not obtained for the lower part of the frequency spectrum.

Messrs. L. Espenschied and M. E. Strieby in their paper on "Systems for wide band transmission over coaxial lines" published in "The Bell System Technical Journal" October 1934, therefore propose to suppress the lowest 5 or 10% of the frequency range, not using it for signal transmission. As it besides appears to be impractical to design repeaters, that will satisfactorily transmit a broad band of both high and low frequencies, the suppression of the lowest 5 or 10% of the frequency range is resorted to in the proposed transmission system over coaxial structures, according to Messrs. Espenschied and Strieby.

According to this invention said lower part of the frequency spectrum can be utilized to great advantage, without any of the drawbacks encountered by Messrs. Espenschied and Strieby, by simply arranging four groups of concentrically arranged conductors in a square with means of holding said groups at equilateral distance from each other, see Figures 10 and 11, and grouping the respective conductors according to balanced systems in forms of quads, whereby ordinary repeaters now used in cables with balanced conductors can be used. The shielding problem for the lower frequencies, transmitted through coaxial conductors will entirely disappear and additional valuable advantages will be obtained, which present day balanced cable conductors are lacking, as I will presently show.

By arranging four coaxial structures as shown in Figures 10 and 11, a lower part of the high frequency spectrum can be used repeatedly with the same result as if a broad band of say 1,000,000 cycles should be transmitted through one structure. Instead of for example, transmitting one million cycles' band through one large coaxial structure with 10-mile spacing of the repeaters, the same number of channels can be transmitted, according to this invention, over four smaller coaxial structures, each one with a band of up to 250,000 cycles. In this case repeaters are needed at every 20 miles only, which means a considerable saving of repeaters and maintenance costs.

For a coaxial circuit with about 0.3" inner diameter of the outer conductor, a 20-mile repeater spacing will enable a frequency band up to 250,000 cycles to be transmitted over each coaxial circuit. In order to avoid interference on the lower part of the spectrum, it is proposed according to this invention to use 4 coaxial circuits arranged in quad form, each coaxial cir-

cuit to transmit a frequency band from about 50,000 to 250,000 cycles.

The lower end of the frequency spectrum up to about 50,000 cycles can be transmitted over 4 balanced circuits, each one transmitting a band of about 50,000 cycles, from which we see, that with a structure as proposed according to this invention more than 200 telephone circuits (corresponding to a frequency band of 1,000,000 cycles over one coaxial line) can be obtained with 20-mile repeater spacing or more.

If instead of 2 concentric conductors, 3 such conductors are used in each coaxial structure, with of course a larger diameter of the complete quad-cable, still further circuits and combinations could be obtained.

The following balanced circuits for the transmission of the lower part of the frequency spectrum can eventually be obtained, (see Figure 11):

A—B, using the upper side band of carrier,

C—D using the upper side band of carrier,

a—b using the lower side band of carrier,

c—d using the lower side band of carrier.

Phantom A—B—C—D for talking frequency and eventually using the upper side band of carrier.

Phantom a—b—c—d for carrier telegraph and eventually using the lower side band. In order to obtain the best results, the carrier wave should be suppressed in above cases.

Thanks to the high symmetry and stable insulating conditions of the transmitting system according to this invention, the transmission of the same frequencies over the balanced circuits is entirely feasible.

Attention is called to the peculiar feature of this invention, according to which two extra balanced transmission circuits are obtained from two coaxial two-conductor circuits, one balanced circuit inside the other balanced circuit and shielded by same.

Another important feature of the invention consists of the fact that although said balanced circuits are parallel and its conductors run side by side, transmission interference between both circuits is avoided, although the same frequencies are transmitted over both conductors, simply by using the upper side band for one circuit and the lower side band for the other circuit.

Apart from above mentioned four single balanced circuits, two extra balanced phantom circuits can be obtained, one within the other and shielded by same, which circuits will allow at least one low frequency talking circuit, one alternating power circuit for the feeding of the repeaters, one frequency range up to 50,000 cycles using the upper side band, and another similar frequency range using the lower side band.

According to need, different structures of both the unbalanced coaxial and the balanced symmetrical circuits can be chosen for transmission in one or the other direction, sufficient shielding effect between the different circuits existing to avoid interference due to high gain of the repeaters.

It will be obvious, that the general principles herein disclosed may be embodied in many other combinations different from those here mentioned without departing from the spirit of the invention as defined in the following claims.

What I claim is:—

1. In an electric cable for transmission of high frequency currents in communication systems, an insulating sleeve and an electric conductor dis-

posed within said sleeve, the latter consisting of a pure, homogeneous, substantially completely polymerized product of an aliphatic, vinyl ester of a saturated acid, said sleeve being sufficiently thin
5 so as to possess inherent flexibility and being free from extraneously added plasticizers.

2. In an electric cable for transmission of high frequency currents in communication systems, an insulating sleeve and an electric conductor dis-
10 posed within said sleeve, the latter consisting of a pure, homogeneous, substantially completely polymerized product of an aliphatic vinyl halide, said sleeve being sufficiently thin so as to possess

inherent flexibility, and being free from extraneously added plasticizers.

3. In an electric cable for transmission of high frequency currents in communication systems, an insulating sleeve and an electric conductor dis- 5 posed within said sleeve, the latter consisting of a pure, homogeneous, substantially completely polymerized product of an aliphatic vinyl acetate, said sleeve being sufficiently thin so as to possess inherent flexibility, and being free from extrane- 10 ously added plasticizers.

HELGE ROST.