

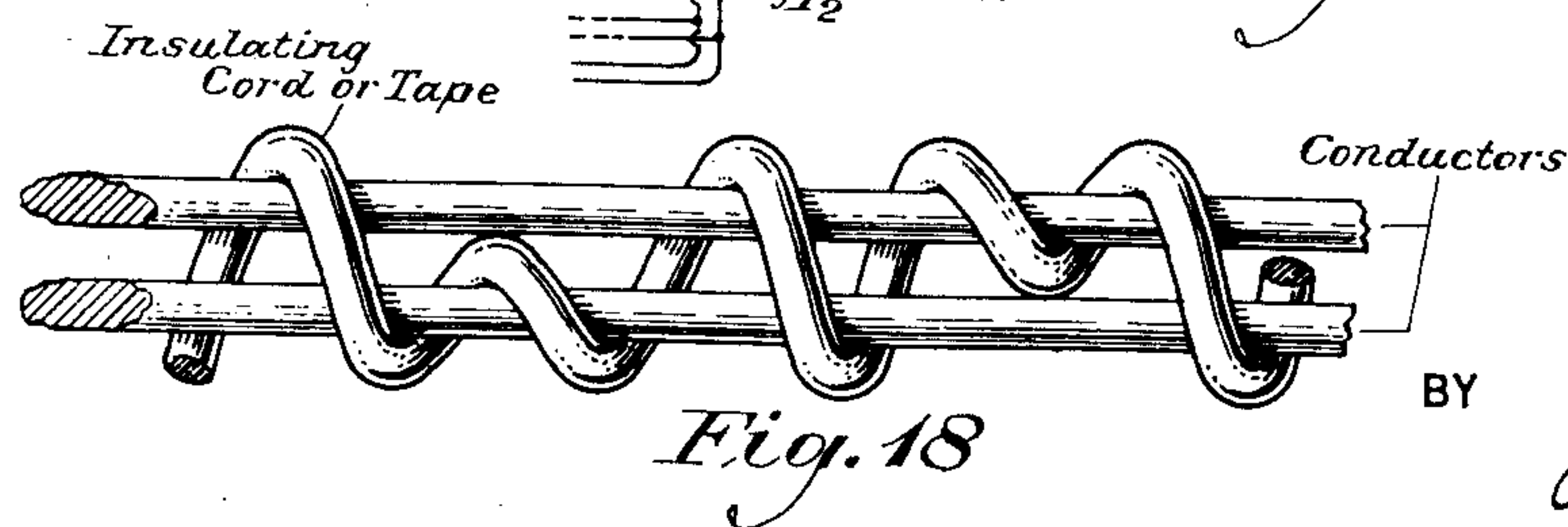
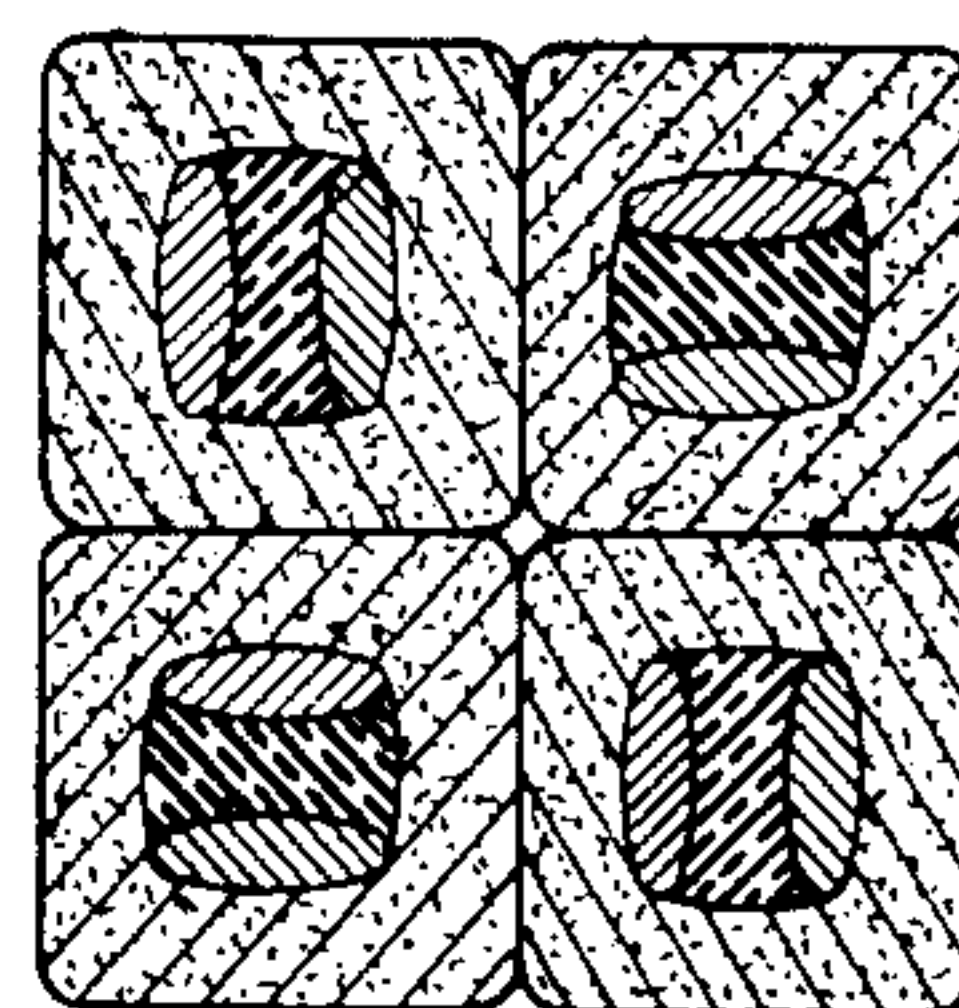
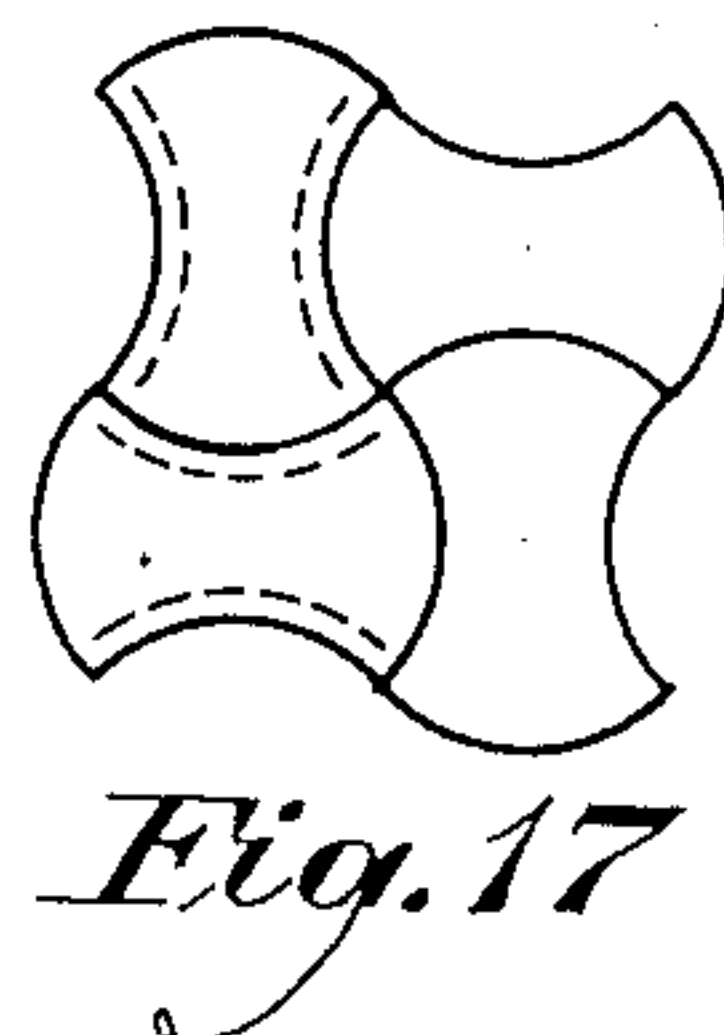
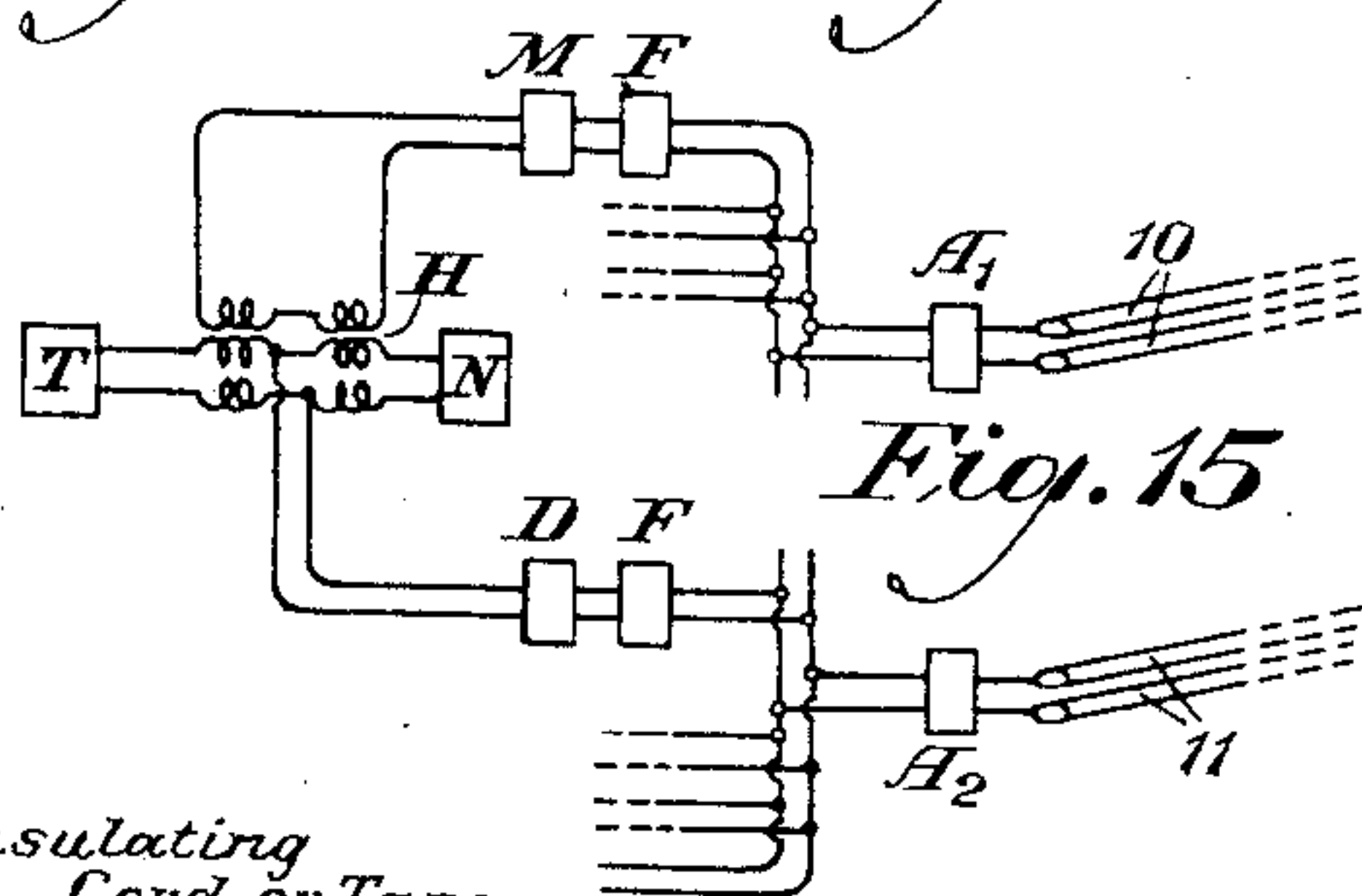
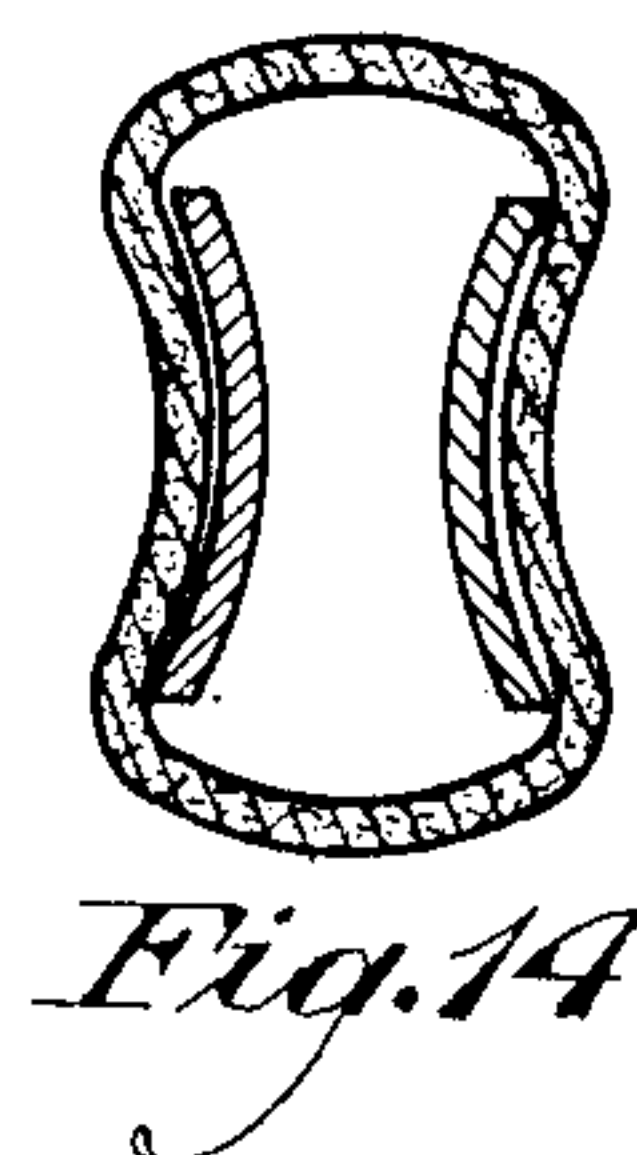
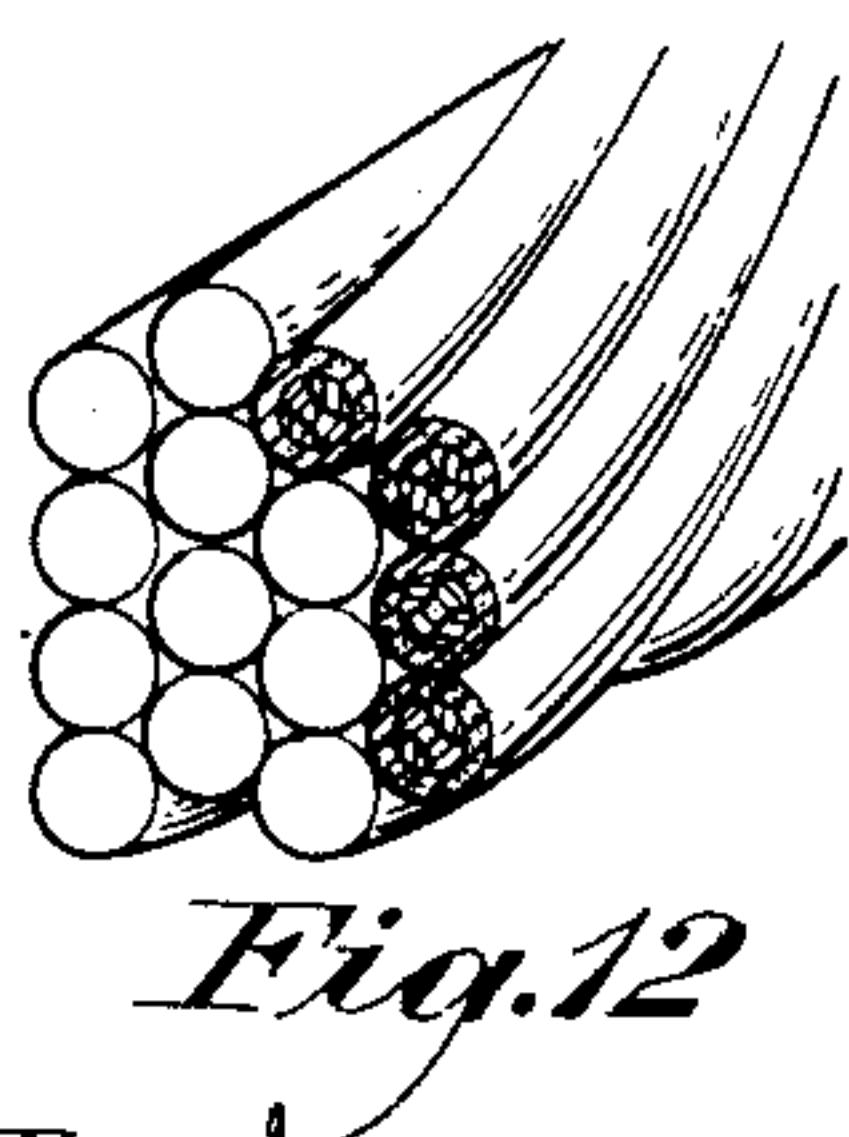
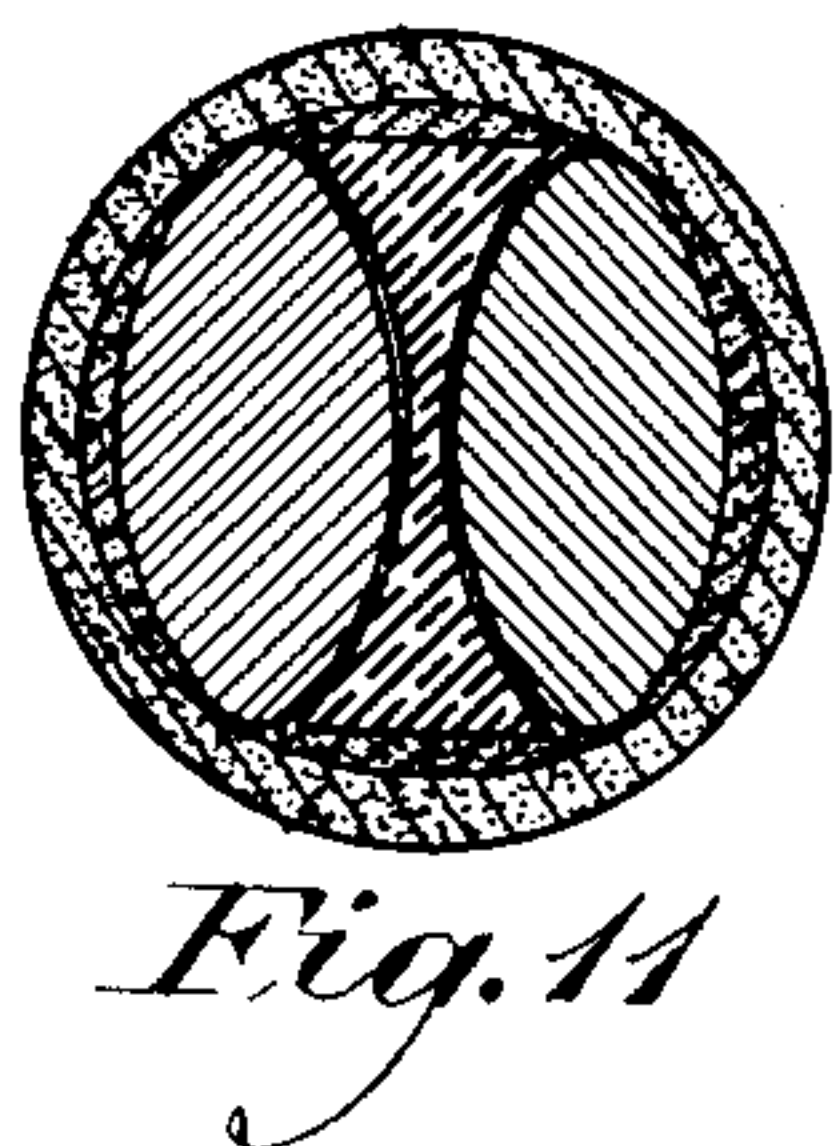
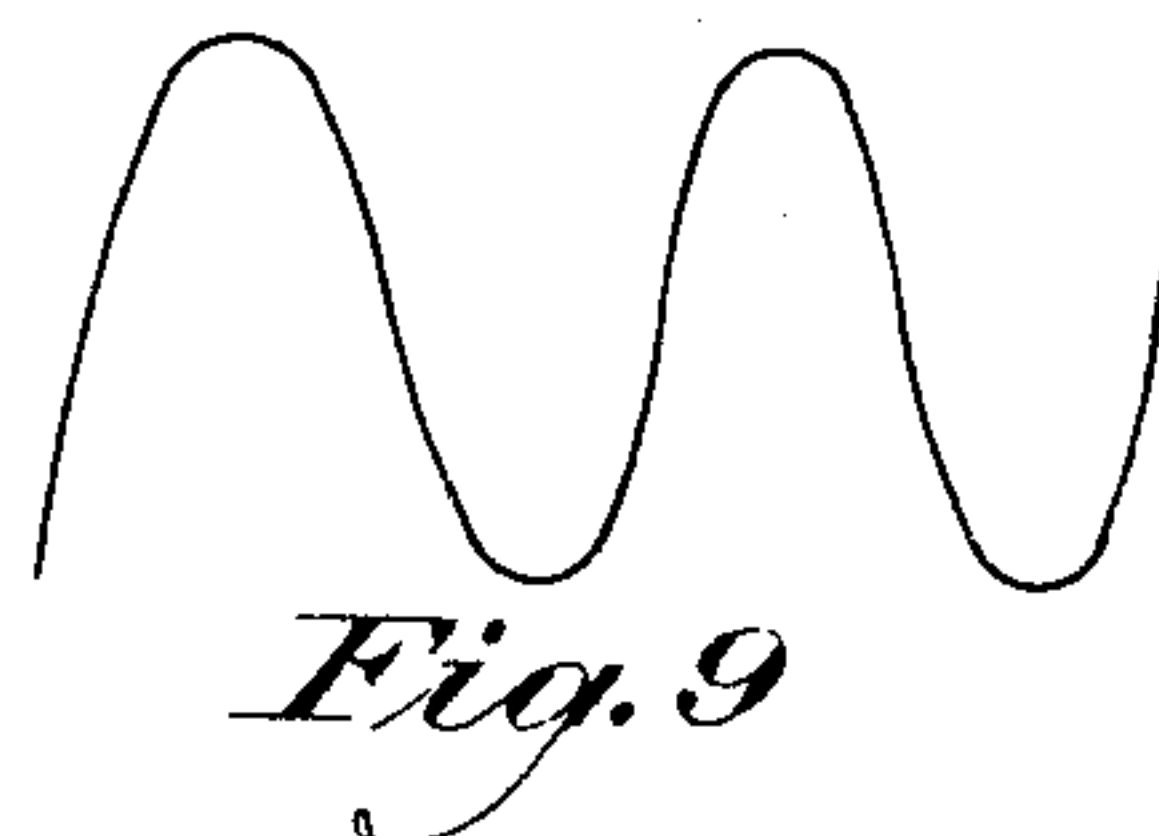
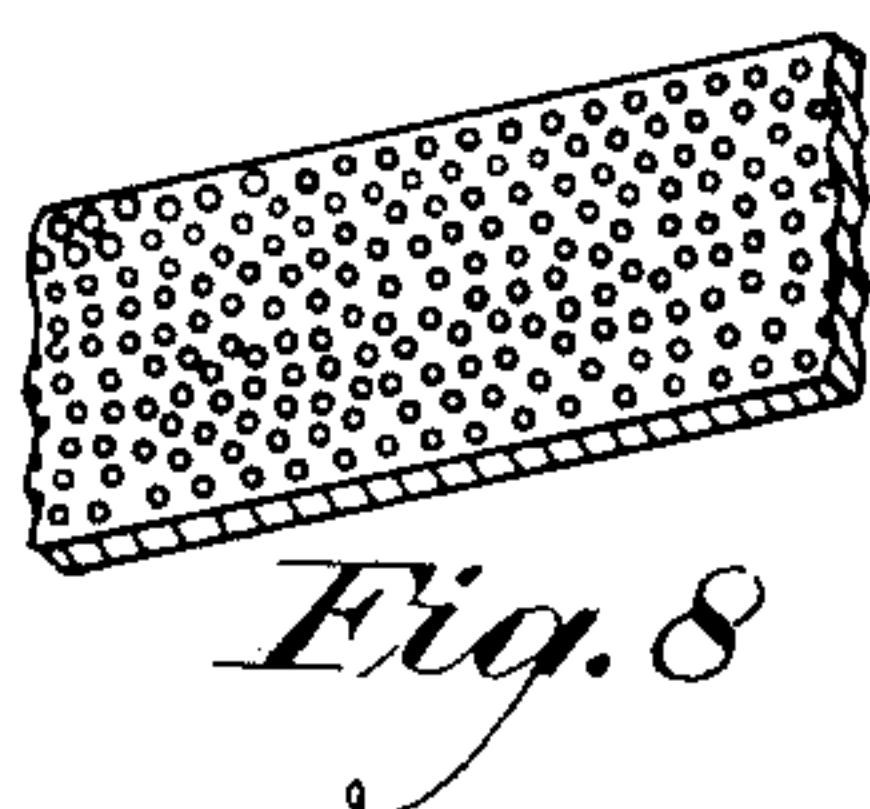
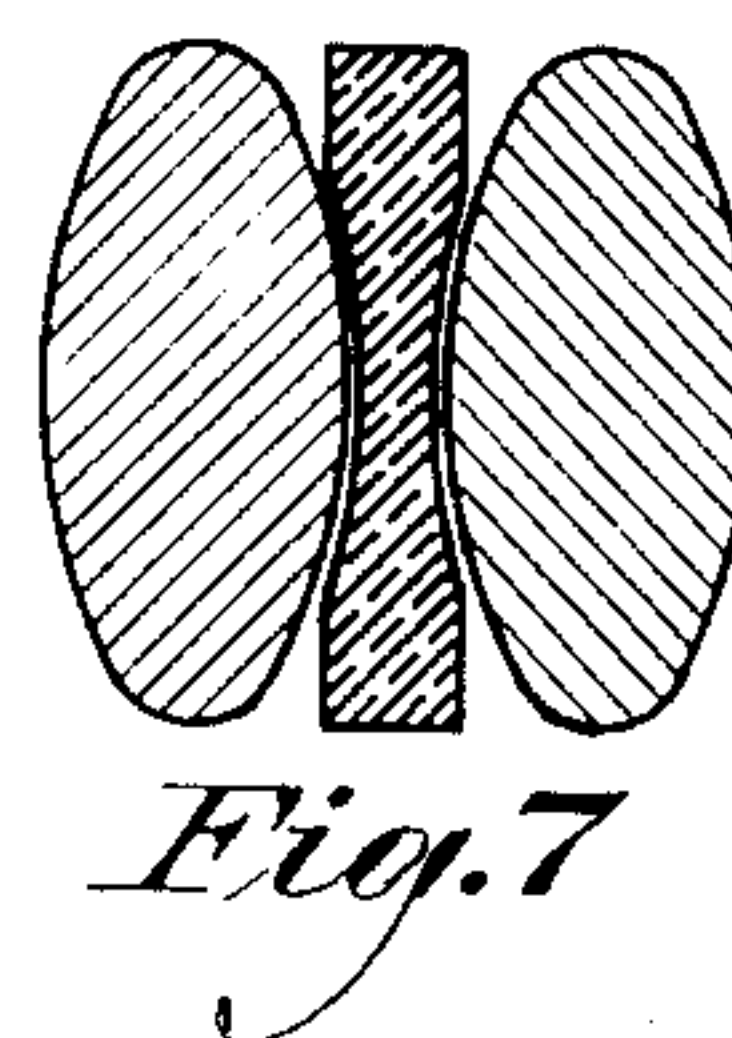
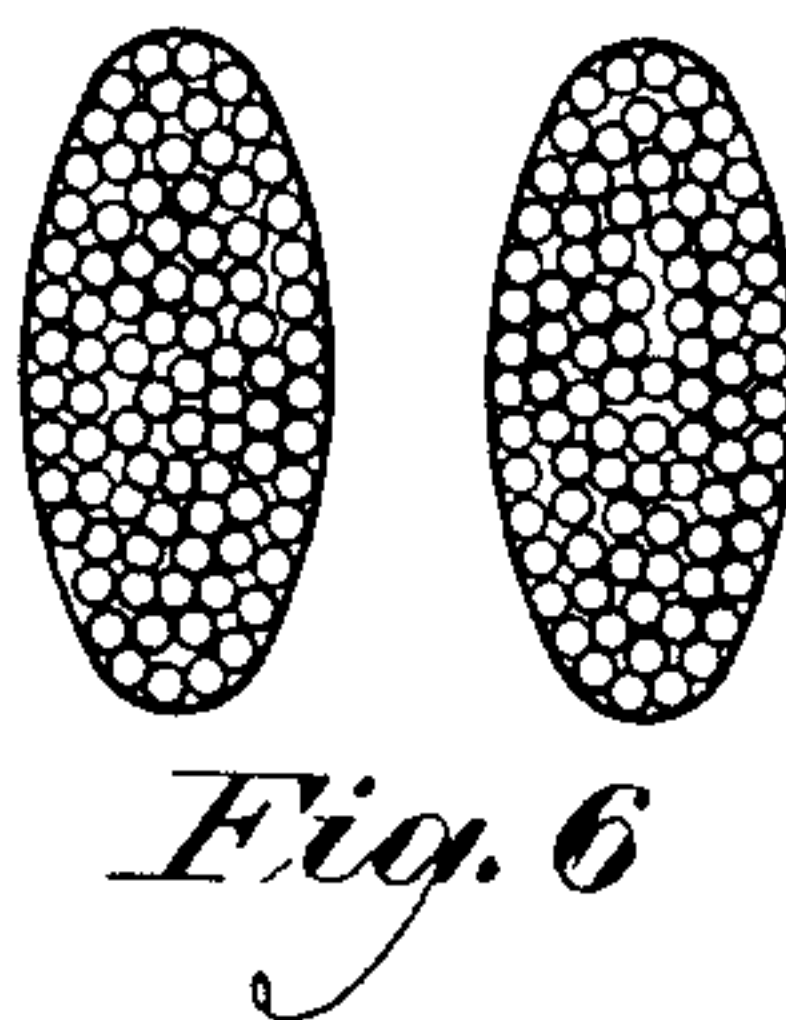
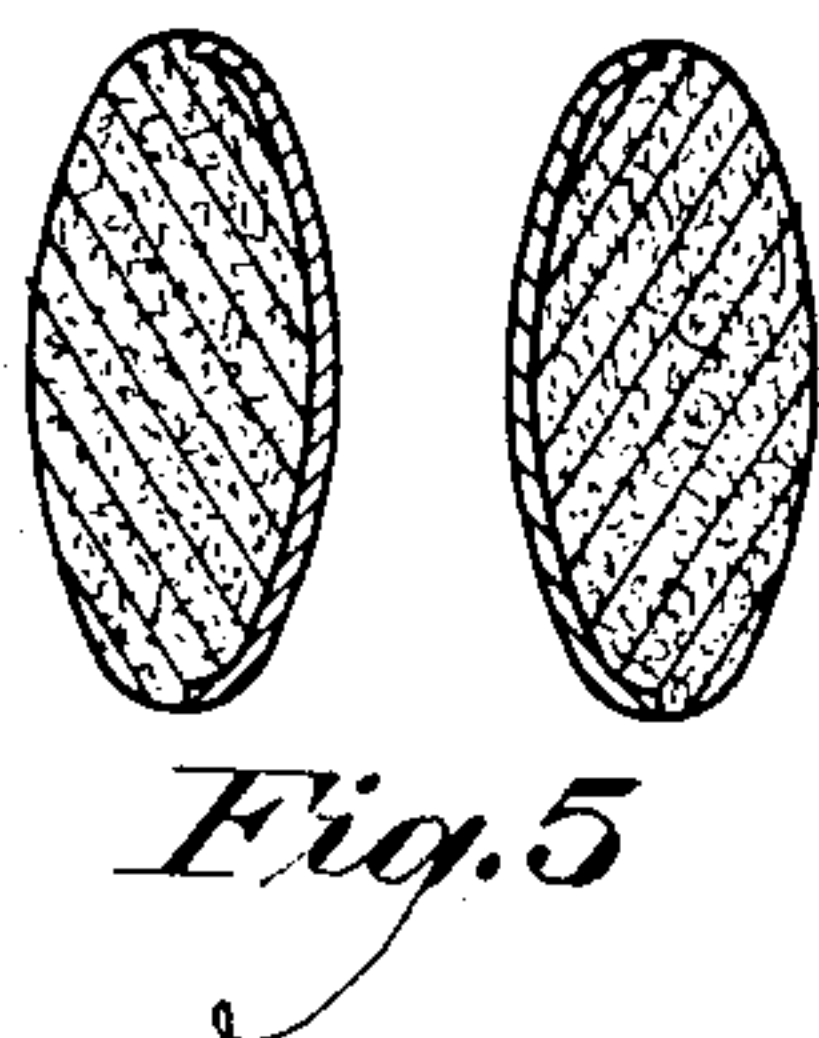
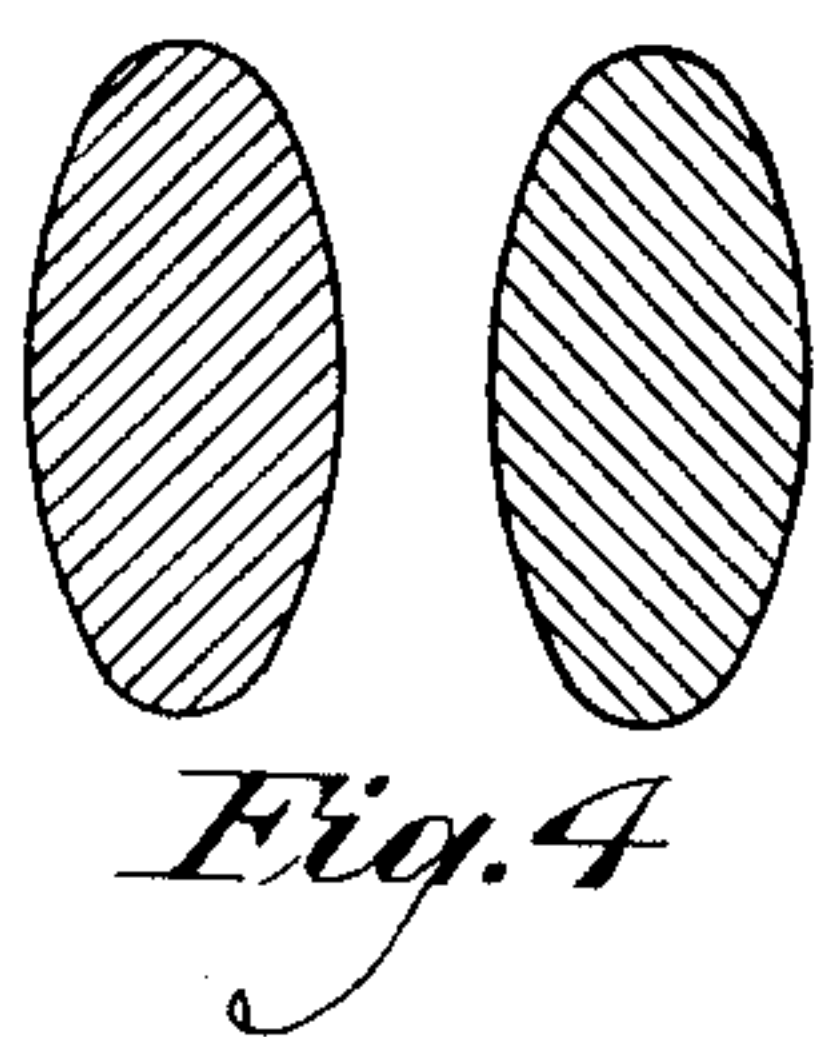
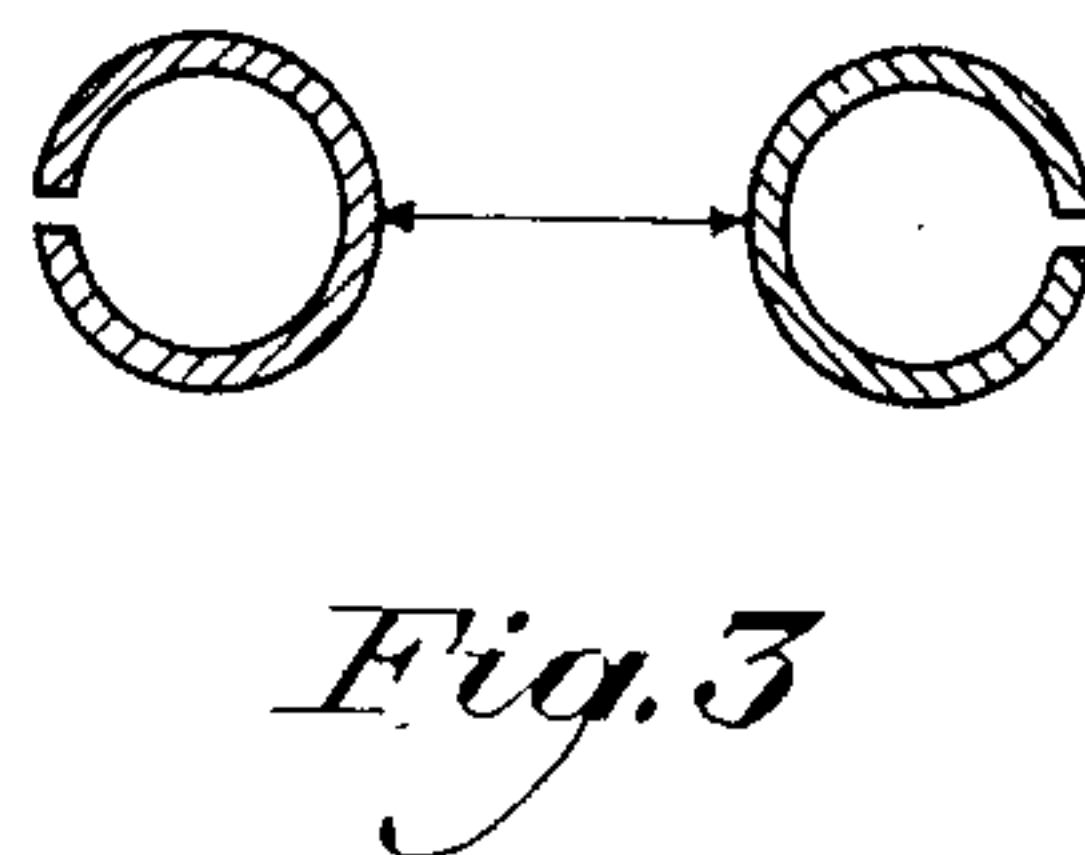
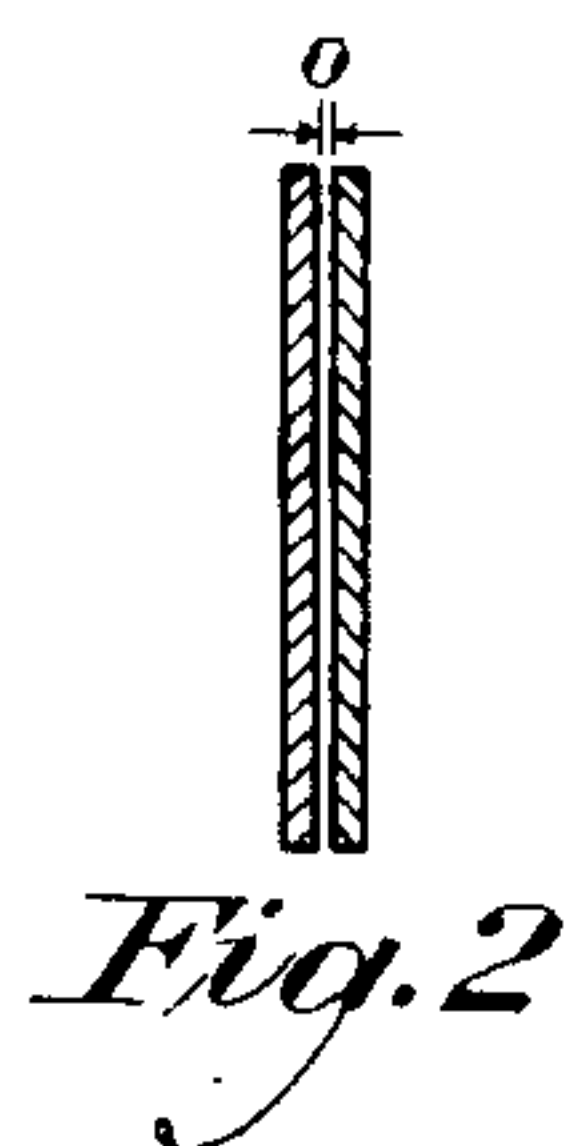
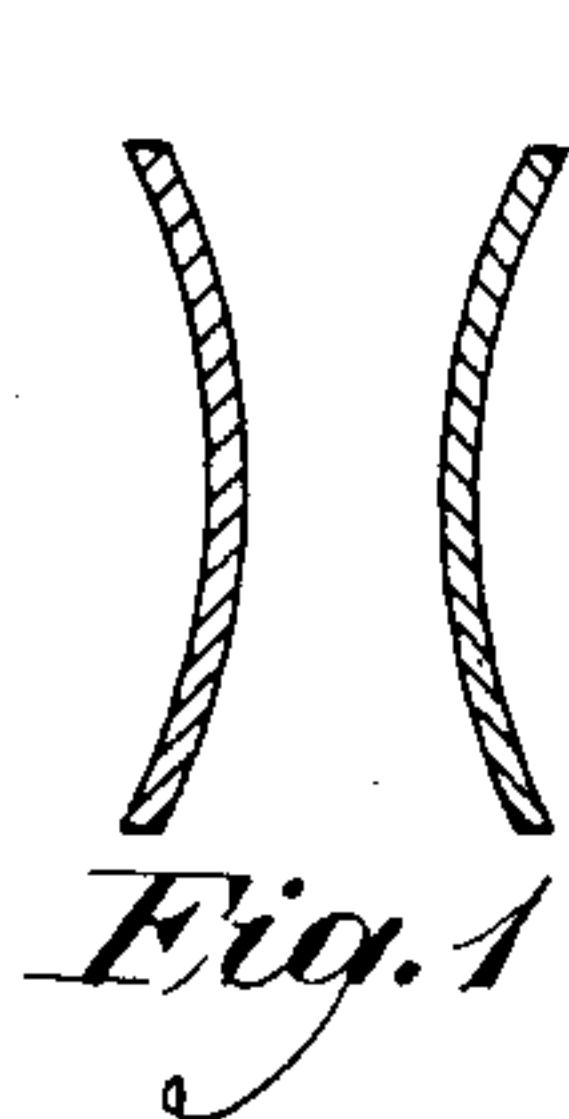
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H. A. AFFEL

1,996,186

TRANSMISSION LINE CONDUCTOR

Filed Oct. 5, 1932



INVENTOR
H.A. Affel
BY
g e f o r
ATTORNEY

UNITED STATES PATENT OFFICE

1,996,186

TRANSMISSION LINE CONDUCTOR

Herman A. Affel, Ridgewood, N. J., assignor to
American Telephone and Telegraph Company,
a corporation of New York

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17 Claims. (Cl. 173—81)

This invention relates to conductors for use in transmission lines and more particularly those transmission lines used for communication in which the frequencies to be transmitted rise to high values.

Its purpose is to so design the cross-section of and arrange the spacing between a pair of conductors as to reduce the skin and edge effects characteristic of alternating currents flowing in conductors.

Another purpose is to make the attenuation of the line as low as possible by a design of conductors which will give as small a distributed capacity and as large a distributed inductance as is consistent with the amount of metal at hand and the space available.

Another purpose is to provide a conductor which is extremely efficient with respect to its ability to transmit high frequency currents and which is at the same time substantially balanced to ground. Still another purpose is to so support a pair of conductors of the kind referred to above by such means and in such manner that the average dielectric constant along the transmission line between the conductors shall be as low as possible, and which will, at the same time, permit twisting of the conductors to reduce inductive effects.

The invention will be better understood by reference to the following specification and the accompanying drawing in which Figures 1 to 14 and 18 show the conductors in cross-section or various parts of insulation in detail. Fig. 15 shows the connections of a pair of transmission lines made up of my conductors for multiplex signaling purposes, and Figs. 12, 16 and 17 illustrate how a plurality of pairs of conductors may be laid up together to form a cable.

In determining the best conductor for high frequency transmission systems there are two outstanding characteristics to be considered: (1) a low attenuation, that is low losses consistent with desirable size and mechanical properties; and (2) a construction which will have the maximum freedom from external electrical disturbances, such as cross-talk from other conductors in the vicinity or noises from other stray electrical fields.

Considerable work has been done in the way of providing compact, well-shielded conductors for high frequency transmission purposes, such as carrier frequency systems, television, etc. These efforts have chiefly taken the form of cable pair construction using wires of a circular cross-section of the form now well known in the

art, or of coaxial conductor arrangements of the kind disclosed in a patent to Espenschied and Affel, 1,835,031, December 8, 1931.

In the ordinary cable pair construction where two wires are twisted together with paper or wood pulp for insulation, low shunt losses are obtained by insuring that the dielectric is dry and approaches an air dielectric condition as closely as possible. Minimum series losses in the conductor are approached by having the dielectric constant of the insulating material as low as possible in order that the characteristic impedance of the circuit may be relatively high. The conductors are otherwise proportioned with respect to size and spacing so that a reasonable balance is achieved between the series and shunt losses. The series losses in such a conductor, however, tend to be large because as the frequency is increased "skin effect" plays its part in increasing the effective resistance of the conductor. The situation is further complicated by the "proximity effect" in which the current tends to avoid those portions of going and return conductors which are farthest from each other. In other words, the current tends to take the path of minimum impedance. This crowding of the current toward the return conductor and the skin effect avoidance of the interior of the conductor cross-section means that even in relatively small conductors the alternating current resistance is several times that of the same conductor for direct current.

In an effort to improve the efficiency of transmission, stranded conductors have been employed in which the individual strands are insulated from each other, and by a suitable twisting and braiding of the strands a more equal distribution of current in the cross-section is achieved. Stranded forms of conductors, however, have certain disadvantages. They are relatively expensive, and also in the stranding there is a problem of insulating the individual strands. Also, even though insulated, the capacity between the individual strands in close proximity tends to disturb the ideal current distribution at the higher frequencies.

For a solid construction with the conductor in free space remote from the return conductor, a pipe shape in which the conducting material is relatively thin and in circular cross-sectional form, is a more ideal construction, and by making the walls sufficiently thin the A. C. resistance can be made to closely approach the D. C. resistance. The higher the frequency, the thinner should the walls be. When the outgoing and

return conductors are relatively close together, although the skin effect can be made smaller, the proximity effect is still serious unless the going and return conductors are of pipe form of different size and coaxially related, preferably being supported by spacers at intervals so that the dielectric is largely air. Such an arrangement is disclosed in the patent to Espenschied and Affel, referred to above, and constitutes a very desirable form of high frequency conductors from an attenuation standpoint.

In electrical signaling there are two chief methods of taking care of cross-talk or induction problems. In an ordinary cable pair construction, the symmetry of the construction insures a fair balance to ground which makes the circuit relatively free from induction effects, and the system is given its final degree of improvement by transposing or twisting the pairs regularly, and, by using different degrees of twist, pairs in close proximity may be kept from cross-talking into one another to a fair degree. However, the ordinary cable construction, with its many pairs twisted and crowded together under a single sheath and with relatively loose paper insulation, suffers considerably from lack of rigidity and a nice mechanical separation of the pairs, so that there are appreciable random variations in the relations of the different pairs one to another. Inductive effects may be further reduced by means of external shielding, that is, enclosing the conductors in a metallic shield which effectively forms a by-passing path for electrostatic fields which are external to the conductor and, if the shield be of magnetic material will also by-pass any magnetic field which may tend to produce E. M. F.'s in the conductor. In the case of a coaxial conductor the very form of the conductor itself with a concentric external return conductor, provides a shield. However, the effectiveness of the shield depends on its thickness and it may be necessary to employ more metal in providing the desired degree of shielding than is necessary to provide for the conductor transmission itself. Furthermore, the coaxial form of construction does not readily lend itself to transposing or twisting.

It is with the considerations given above regarding various types of conductors that the form of conductors constituting this invention and described hereinafter deal. In brief, the invention consists in using conductors which are no longer of circular cross-section, but in which the shape of the conductor is such that proximity and skin effects are minimized. Fig. 1 shows the two conductors in the form of curved flat strips. These strips may be very thin if quite high frequencies are to be transmitted, and their contour will be adjusted in such a way that the current will distribute itself substantially uniformly over the whole strip, in other words, that each equivalent conducting element of the strip has a reactance which is the same as that for every other element. The exact shape which the conductors will take will depend on the nature of the dielectric between the two strips and their distance apart. This becomes evident when one considers the distribution of current in a single insulated flat strip. Even though the strip be quite thin so that "skin effect" is not present, there will be a large edge effect due to the tendency of the current to concentrate at the edges. If two such strips are placed adjacent to each other, the proximity effect neutralizes, at least in part, this edge effect. If

the two strips are close together (which would be a relatively undesirable proportioning of the parts because of the high capacity), the two strips should be practically flat, as shown in Fig. 2. On the other hand, if the two strips are very far apart, the optimum contour approaches the form of a pipe shape, as shown in Fig. 3. The practical contour for strips where the distance apart is of the order of the width, is approximately the arc of a circle of fairly large radius, or, more specifically, an arc of an ellipse, as indicated in Fig. 1. Whether in any specific case the contour be made strictly that of an arc of a circle or an arc of an ellipse will depend, among other things, on the spacing and on the nature of the intervening and surrounding dielectric, and hereinafter, for the purpose of simplicity, the term "ellipse" will be taken to include that special case of the ellipse more commonly called a circle.

Practical considerations will change the exact shape of the conductor somewhat. Thus, to provide for twisting or spiraling, it is frequently desirable that the total cross-sectional area of the transmission line, including the conductors and their insulating and supporting material, should be substantially circular in form. This means that one practical form which my conductor may take will be that shown in Fig. 4 in which the two conductors are of approximately elliptical cross-section of considerable eccentricity. Solid metallic conductors of the form shown in Fig. 4 represent a substantial improvement over the more common conductors of circular cross-section. On the other hand, in view of the skin effect and proximity effects, the interior of such conductors would not carry much current and these conductors may, therefore, be hollow. Also, for the sake of mechanical rigidity, these hollow conductors may be filled with some cheap non-conducting or other material. Even in this case it will be recognized that the back surface of each conductor would carry less than its fair share of current and might, therefore, be replaced by some cheaper metal or non-conductor for mechanical support. This is illustrated in Fig. 5 in which the main conducting strips are portions of elliptical surfaces, the convex surfaces being adjacent to each other, and the remainder of the ellipse being of any other material for mechanical support. Still further, the whole elliptical cross-section of each conductor may be taken up by stranded or braided conductors, as shown in Fig. 6, and a pair of conductors so constructed will show an appreciable improvement over conductors of circular cross-section.

To insure the proper separation of the two conductors, several alternatives are possible. If, for instance, the conductors are of the form shown in Figs. 4 to 6 they may be held in proper relation to each other by a flat perforated moderately compressible material, such as wood pulp, as shown in Fig. 7. Such insulating material may be of a form such as shown in Fig. 8, being made of wood pulp or similar material perforated to a very considerable extent, such that the dielectric constant of the medium between the conductors shall approach as nearly as feasible that of an air dielectric. Still another method which I find suitable for proper spacing of the two conductors is shown in Figs. 9 and 10, the first of these representing the general appearance of a zigzag strip of insulator as seen from the side of Fig. 7, and Fig. 10 showing

grooves in this zigzag strip in which the elliptical conductors may be seated to increase their relative rigidity.

Such a pair of conductors as shown in Fig. 7 may be bound together by a serving of paper or fabric, as shown in Fig. 11, thus giving a compact unit of approximately circular cross-section which can be spiralled and, if necessary, made to lie in a cable close to other similarly formed conductors, as shown in Fig. 12.

An alternative construction is shown in Fig. 13 in which each conductor is an arc of an ellipse, the two being supported in proper relationship and given practically an air dielectric condition, as shown in that figure. The two conductors are shown as supported on the inside of an insulating pipe-like structure which can be pieced together or extruded in the desired shape, and which provides both the shell and the support for the conductors. This insulating shell may be spiralled to give the necessary transposing effect, as shown in Fig. 12, or the conductors within the shell may be spiralled.

Fig. 14 shows an alternative shell supporting structure in which the shell is externally indented to give the necessary contour for support of the conductor.

Still another alternative construction would consist of a continuous spiralled serving of cord or tape which binds the two conductors together but which is looped between the two conductors at intervals in order to maintain the required degree of separation, at the same time providing a dielectric medium which is largely air, is shown in Fig. 18.

In addition to the characteristics of my transmission line, pointed out above, I find that an excellent one is that a plurality of such transmission lines may be readily laid up to be largely non-inductive with respect to each other. This is illustrated in Fig. 16 in which the line joining the centers of one pair of conductors are perpendicular to the line joining the centers of the adjacent pairs of conductors. It will be noted that the fields set up by any one pair of conductors are substantially perpendicular to the fields set up by the adjacent pair, and the coupling between the pairs is therefore relatively low. This is illustrated further in Fig. 17, as applied particularly to the structure of Fig. 14. The outside contour of Fig. 14 may be made up of four surfaces, each substantially a quarter of a circle, and in this case the plurality of pairs of conductors may be laid up indefinitely in a compact manner, as shown in Fig. 17. The conductors in two of the pairs are shown in dotted lines and the orthogonal nature of the fields of two adjacent pairs is evident. Such a grouping of conductors lends itself, also, readily to a slow spiralling which is desirable for transposition effects. It is evident that the four pairs of conductors shown in either Figs. 16 or 17 may constitute a transmission group unit which could, if desired, be spiralled with respect to other similar groups as in the case of "quads" in an ordinary cable.

Fig. 15 shows, for illustrative purposes, one application of such transmission lines for communication purposes. Thus, the pair of transmission lines, 10 and 11, each comprising two conductors of the type described, are shown as connected for multiplex signaling in both directions, in a manner now well understood in the art. In this figure T represents a source of telephone currents, such as a subscriber set, which is connected

through a hybrid coil H to a modulator M and filter F to the line 10, through suitable amplifiers A₁. This line 10 may be used for a plurality of channels employing different carrier frequencies as indicated in the figure. Signals coming from the other direction over the line 11 pass through appropriate amplifiers A₂, filter F, and demodulator D through the hybrid coil to the subscriber set at T, this transmission line being also adapted for a plurality of channels.

It is evident that numerous variations and changes may be made in the structures which are shown, those given being for illustrative purposes only.

What is claimed is:

1. In a transmission circuit for high frequency currents, a pair of going and return conductors, the cross-sections of which are substantially portions of elliptical sheets greater in one dimension than in the other, the two conductors being held parallel along their major axes and with the convex surfaces disposed to each other, such surfaces being so shaped as to provide substantially uniform current density throughout for alternating currents.

2. In a transmission line for high frequency currents, a pair of conductors, each conductor being of approximately elliptical non-circular cross-section, the conductors of the pairs being disposed with the convex surfaces toward each other and with the major axes parallel to each other and perpendicular to the line joining the centers.

3. In a transmission line for alternating currents, a pair of conductors, each conductor being a thin, broad elliptical strip of metal, the two conductors being parallel to each other, and the planes of the conductors being substantially perpendicular to the axial plane joining the centers of the conductors with the convex surfaces disposed toward each other, the distance between the conductors being adjusted to cause substantially uniform alternating current density throughout the cross-section of the conductors.

4. In a transmission line for high frequency currents, a pair of conductors, each conductor being a thin sheet of metal with a cross-section approximately an arc of an ellipse, the two conductors being parallel to each other, and the planes of the conductors being substantially perpendicular to the axial plane joining the centers of the conductors with the convex surfaces disposed toward each other.

5. In a conducting system for communication of intelligence, two conductors connected one as a return for the other, each conductor having a non-rectilinear cross-section whose dimensions are substantially greater in one direction than the other, the conductors being placed with broad convex curved surfaces towards each other and with the greater dimension perpendicular to the axial plane passing through the conductors.

6. In a conducting system for communication of intelligence, two conductors connected one as a return for the other, each conductor being in the form of a thin, curved sheet, the conductors being placed with convex surfaces towards each other, the chords of the curved surfaces being perpendicular to the axial plane passing through the conductors.

7. In a conducting system for communication of intelligence, two conductors connected one as a return for the other, each conductor having a non-rectilinear cross-section whose dimensions are substantially greater in one direction than the other, the conductors being placed with broad

convex curved surfaces towards each other and with the greater dimension perpendicular to the axial plane passing through the conductors and insulating means of low dielectric constant for supporting the conductors.

8. In a conducting system for communication of intelligence, two conductors connected one as a return for the other, each conductor being in the form of a thin, curved sheet, the conductors being placed with convex surfaces towards each other, the chords of the curved surfaces being perpendicular to the axial plane passing through the conductors and insulating means of low dielectric constant for supporting and separating the conductors.

9. In a conducting system for communication of intelligence, two conductors connected one as a return for the other, each conductor being in the form of a thin, curved sheet, the conductors being placed with convex surfaces towards each other, the chords of the curved surfaces being perpendicular to the axial plane passing through the conductors, and insulating means of low dielectric constant for supporting and separating the conductors, the insulating means for spacing the conductors being so formed that the dielectric between adjacent surfaces will be principally gaseous, and terminal apparatus for the conductors for supplying thereto and receiving therefrom signal frequencies.

10. In a conducting system for communication of intelligence, two conductors connected one as a return for the other, each conductor having a non-rectilinear cross-section whose dimensions are substantially greater in one direction than the other, the conductors being placed with broad convex curved surfaces towards each other and with the greater dimension perpendicular to the axial plane passing through the conductors and insulating means of low dielectric constant for supporting and separating the conductors, the outside form of the pairs of conductors with its insulation being such that a plurality of pairs may be laid up and the combination given a twist to reduce interfering inductive effects.

11. In a conducting system for communication of intelligence, two conductors connected one as a return for the other, each conductor being in the form of a thin, curved sheet, the conductors being placed with convex surfaces towards each other, the chords of the curved surfaces being perpendicular to the axial plane passing through the conductors, insulating means of low dielectric constant for supporting and separating the conductors, the insulating means for spacing the conductors being so formed that the dielectric between adjacent surfaces will be principally gaseous, and terminal apparatus for

the conductors for supplying thereto and receiving therefrom signal frequencies, the outside form of a pair of conductors with its insulation being such that a plurality of pairs may be laid up and the combination given a twist to reduce interfering inductive effects.

12. The combination of two pairs of conductors as set forth in claim 5, with the axial planes of the pairs perpendicular to each other.

13. The combination of a plurality of pairs of conductors as set forth in claim 5, with the axial planes of any two adjacent pairs perpendicular to each other.

14. In a conducting system for communication of intelligence, two conductors connected one as a return for the other, each conductor being in the form of a thin, curved sheet, the conductors being placed with convex surfaces towards each other, the chords of the curved surfaces being perpendicular to the axial plane passing through the conductors, and insulating means of low dielectric constant for supporting and separating the conductors, the cross-section of the curved surfaces and their distance apart being such that the edge effect and the proximity effect substantially neutralize each other.

15. In a conducting system for communication of intelligence, two conductors connected one as a return for the other, each conductor being in the form of a thin, curved sheet, the conductors being placed with convex surfaces towards each other, the chords of the curved surfaces being perpendicular to the axial plane passing through the conductors, and insulating means of low dielectric constant for supporting and separating the conductors, the cross-section of the curved surfaces being substantially the arc of an ellipse, and their spacing being such that the edge effect and the proximity effect substantially neutralize each other.

16. In a transmission line for alternating currents, a pair of conductors each conductor being a thin, broad elliptical strip of metal, the two conductors being parallel to each other, the pair being bound by continuous spiralled serving of cord or tape which is looped between the two conductors at intervals sufficient to provide the desired separation.

17. In a transmission line for alternating current, a pair of going and returning conductors, each conductor being a thin, broad elliptical strip of metal, the two conductors being disposed with the convex surfaces toward each other and being held apart by a continuous tape of porous insulating material and being bound together by a continuous serving of insulating tape or cord.

HERMAN A. AFFEL.