

Nov. 1, 1932.

H. A. AFFEL

1,885,168

CONCENTRIC CONDUCTING SYSTEM

Filed May 23, 1929

3 Sheets-Sheet 1

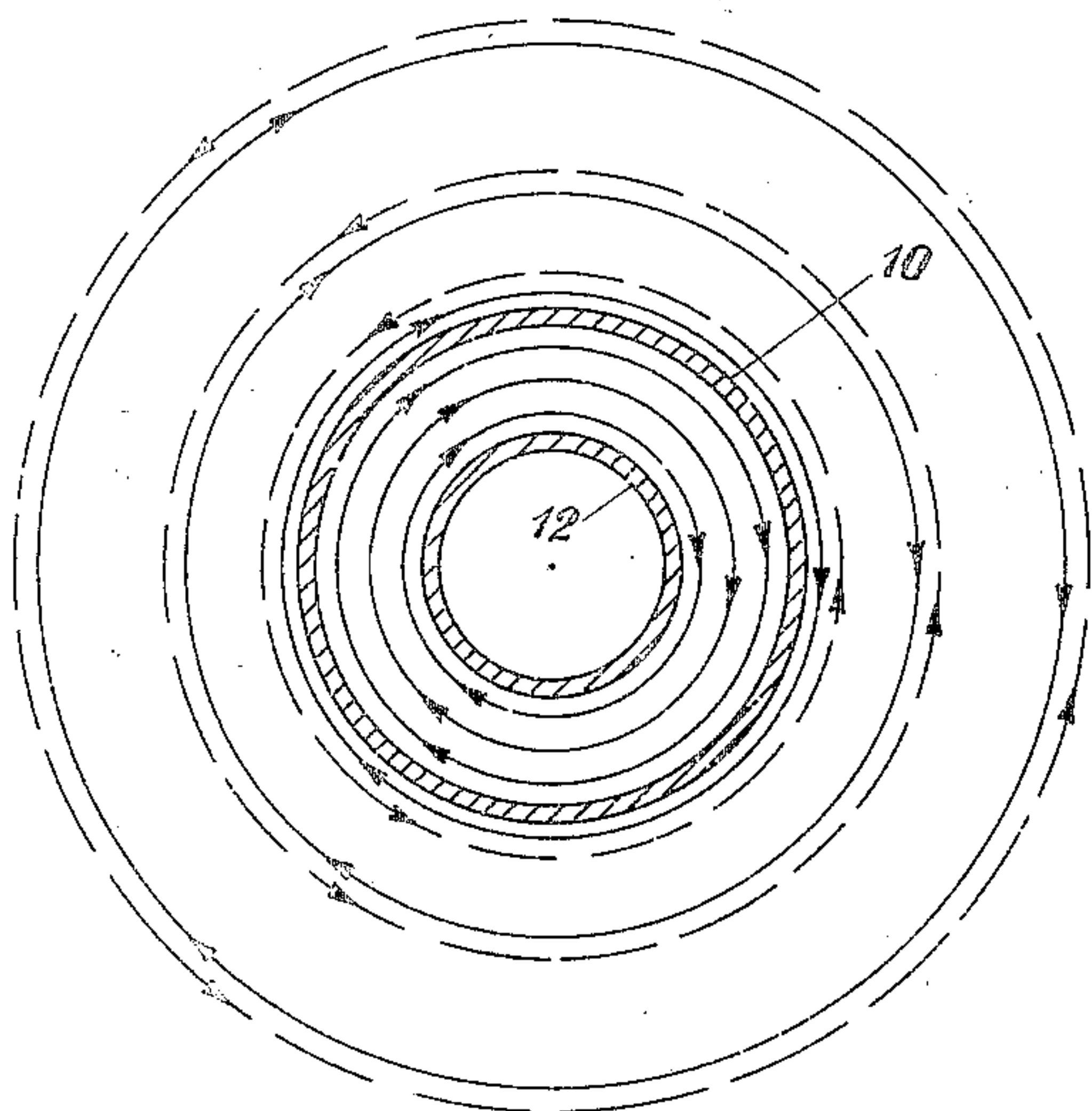


Fig. 1, Magnetic Field

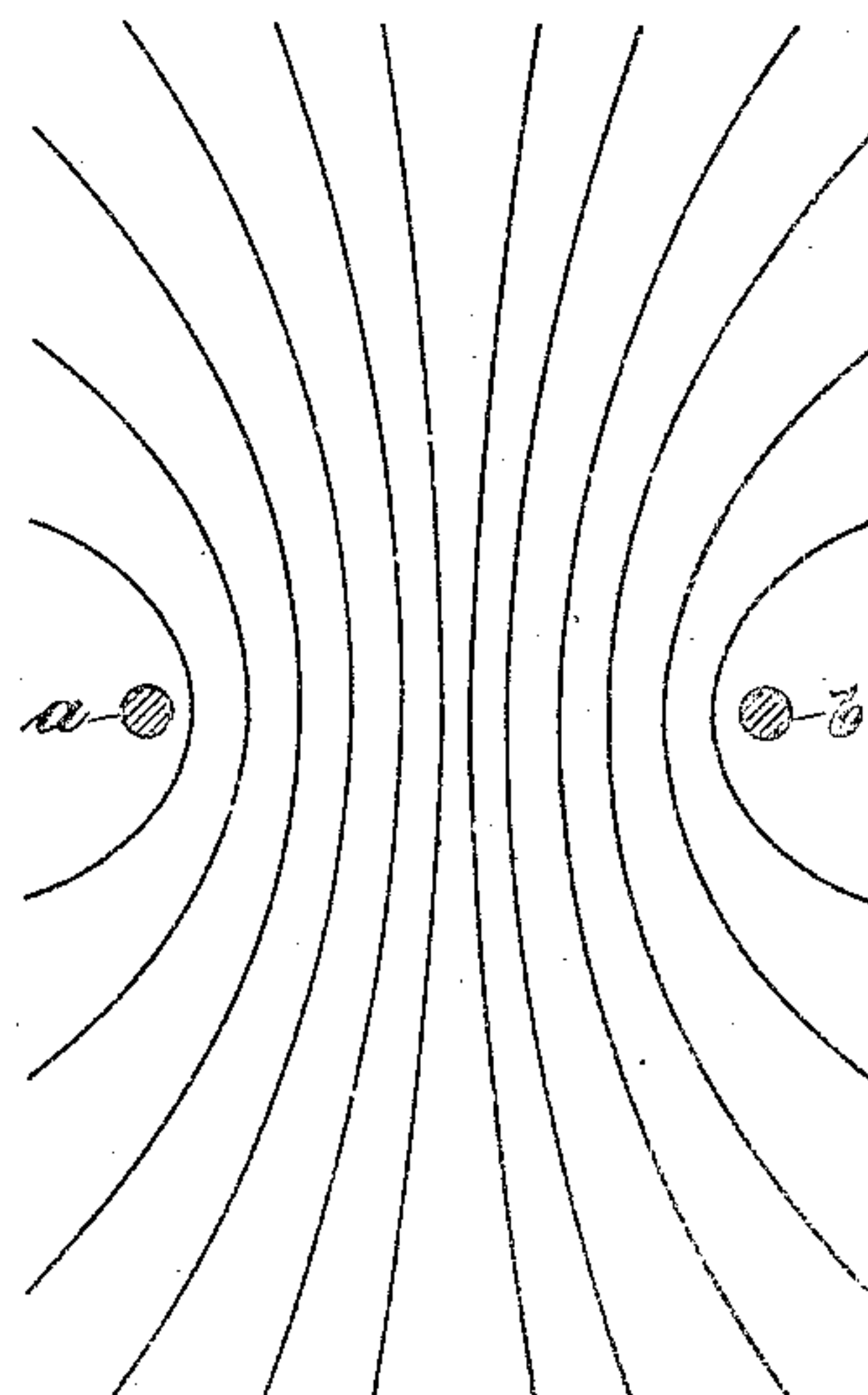


Fig. 2, Magnetic Field

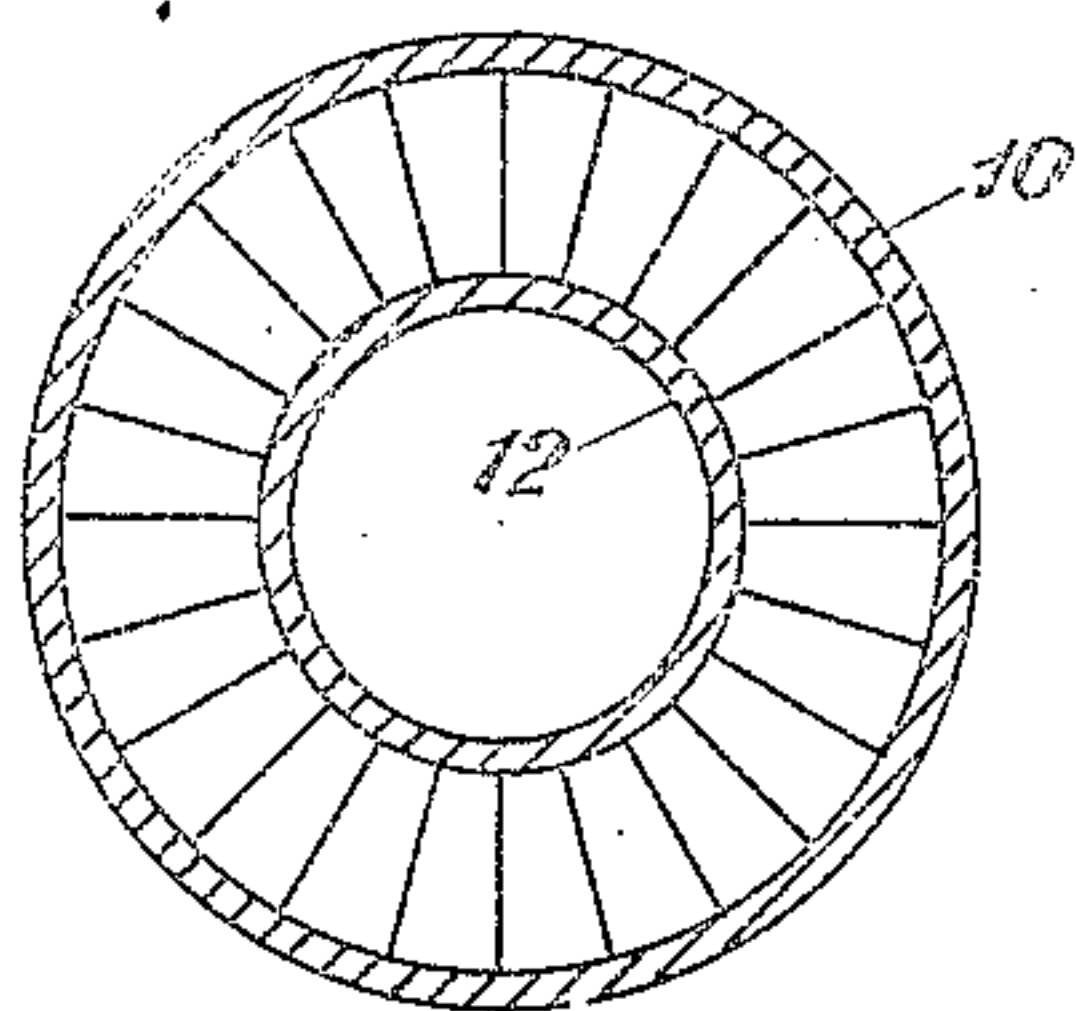


Fig. 3, Electric Field

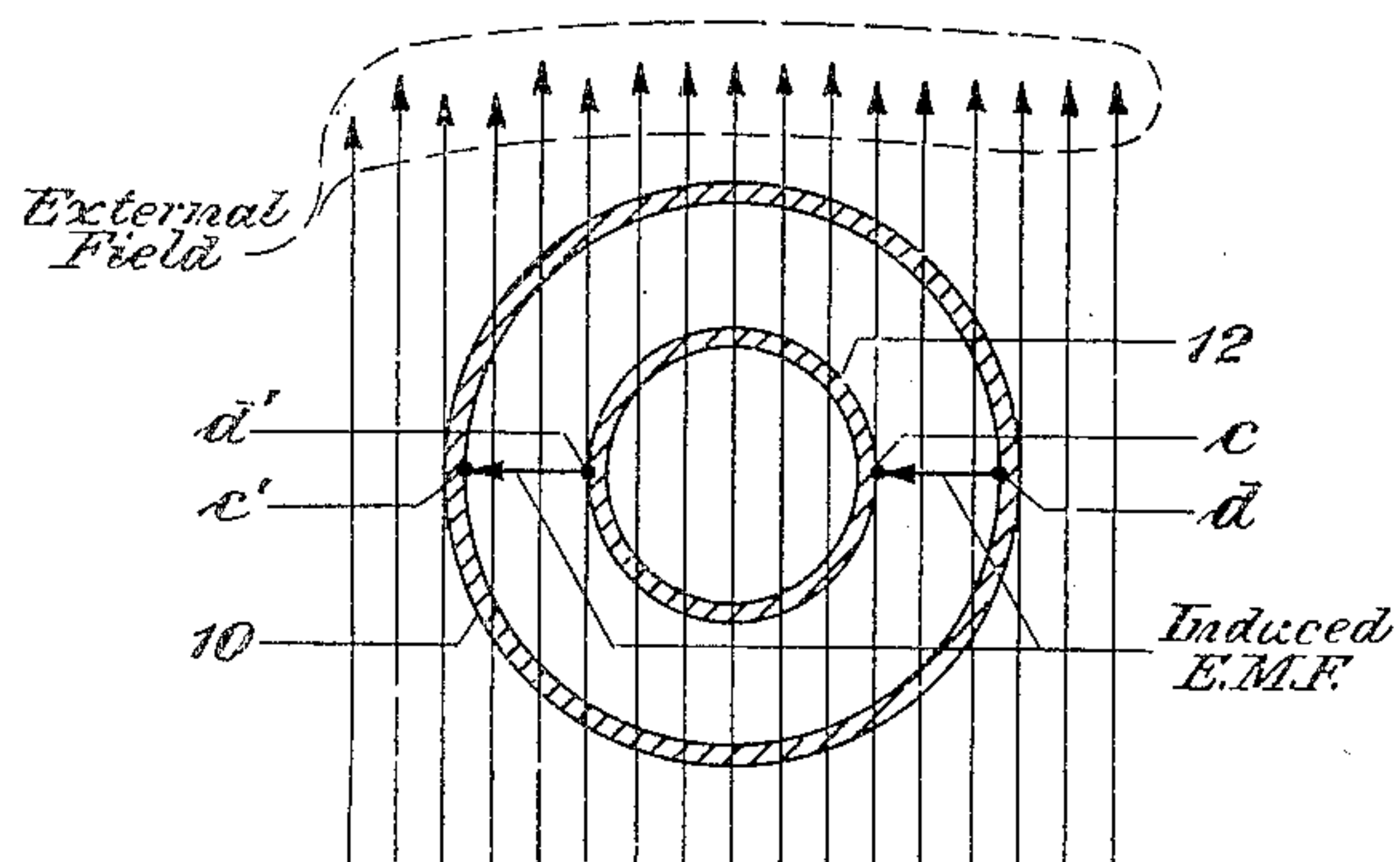


Fig. 5

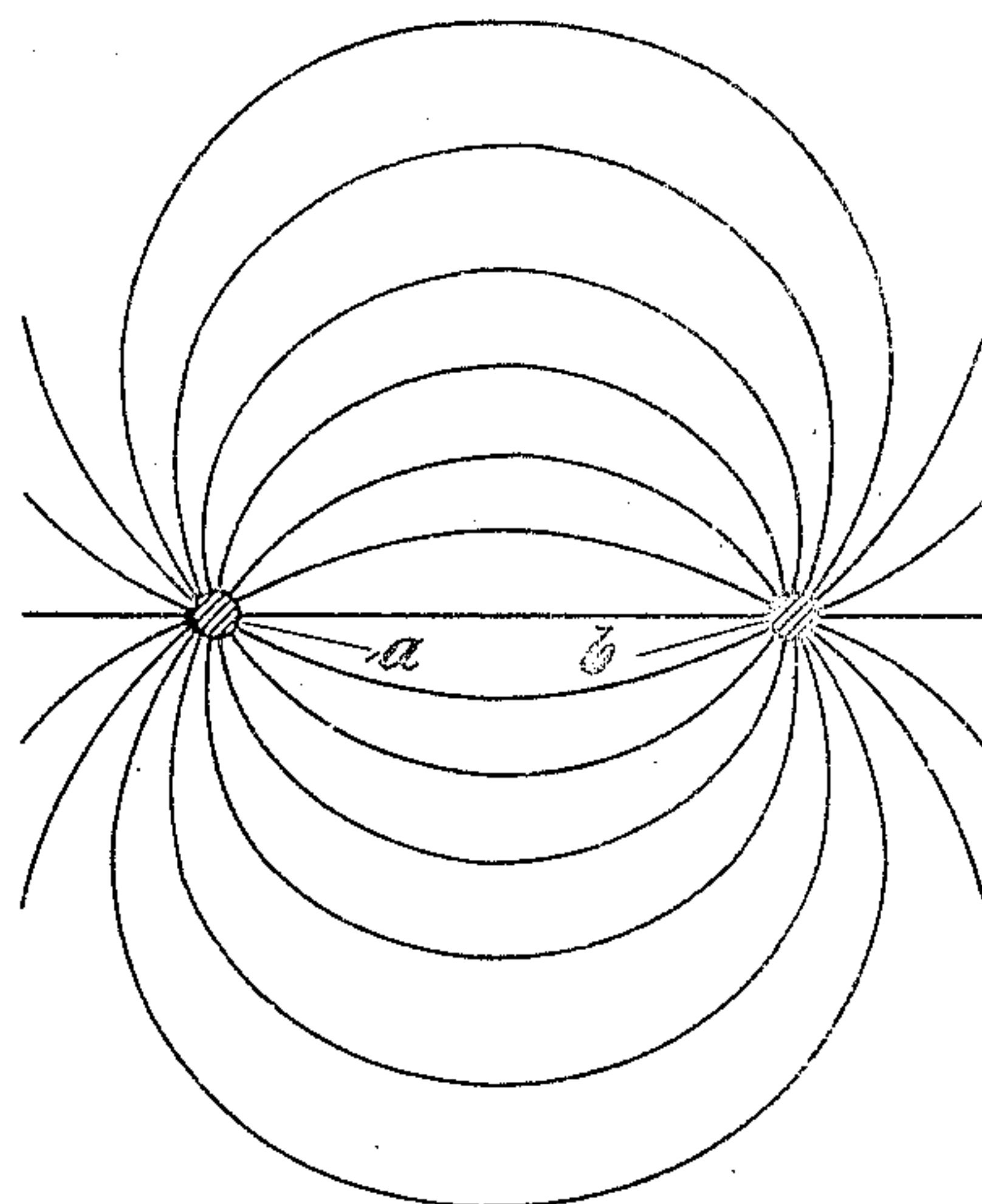


Fig. 4, Electric Field

INVENTOR
H. A. Affel
BY *J. H. S. H.*
ATTORNEY

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H. A. AFFEL

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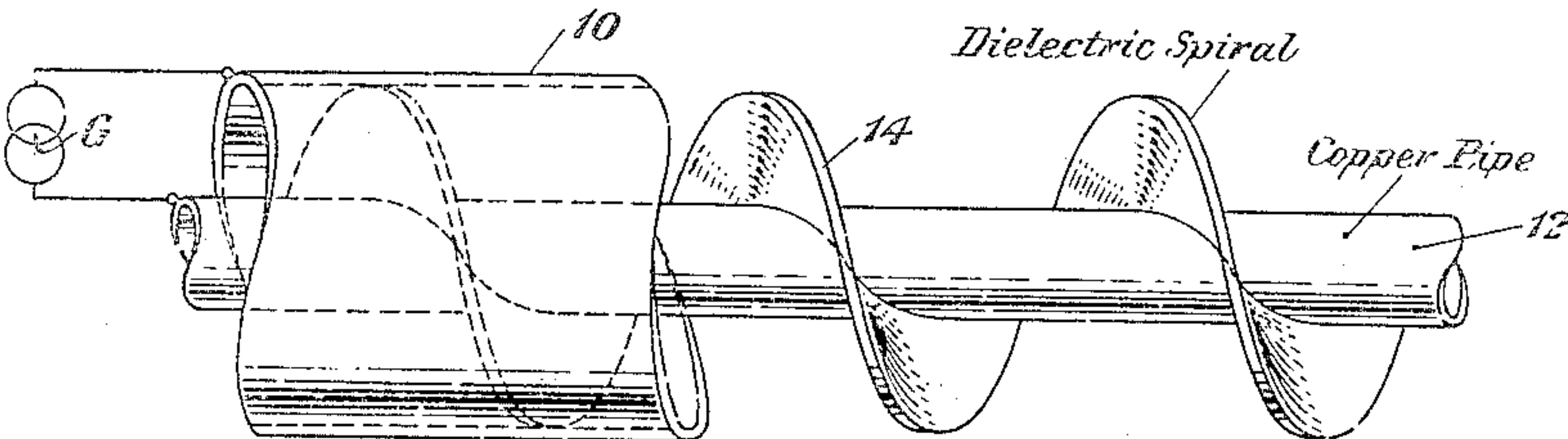
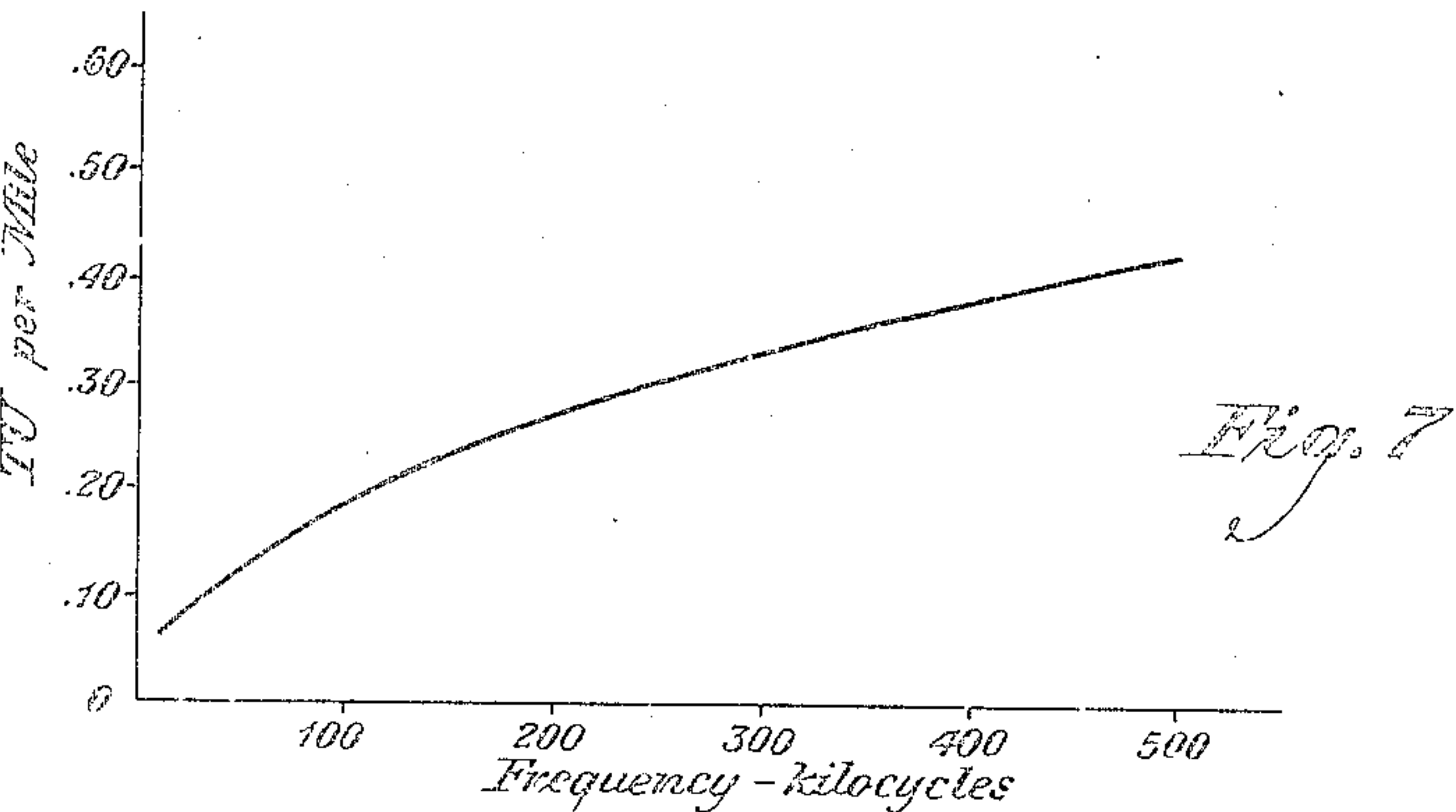
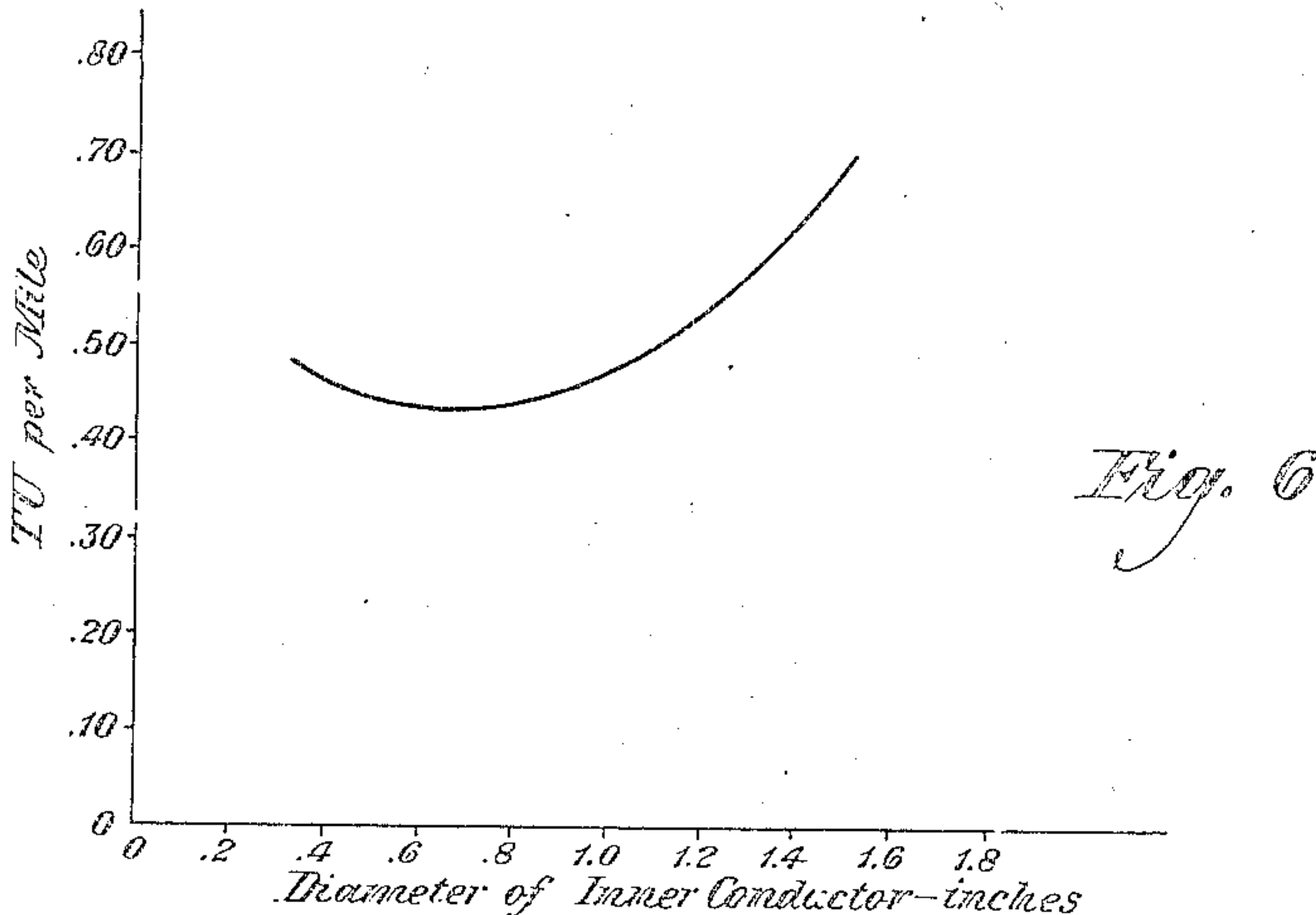


Fig. 8, - Dielectric ribbon wound around inner pipe.

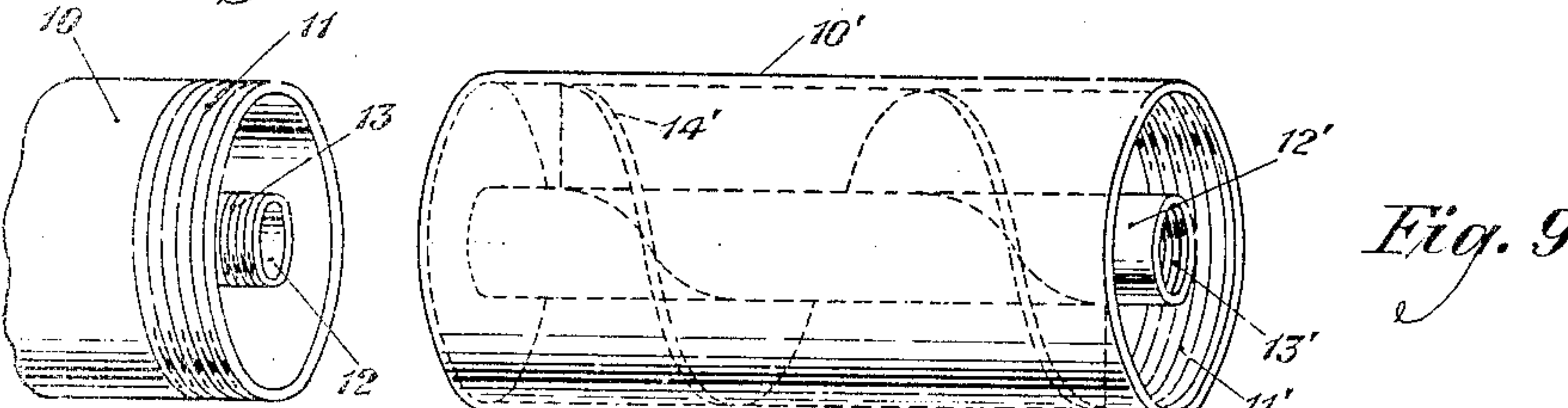


Fig. 9

INVENTOR
H. A. Affel
BY
ATTORNEY

Nov. 1, 1932.

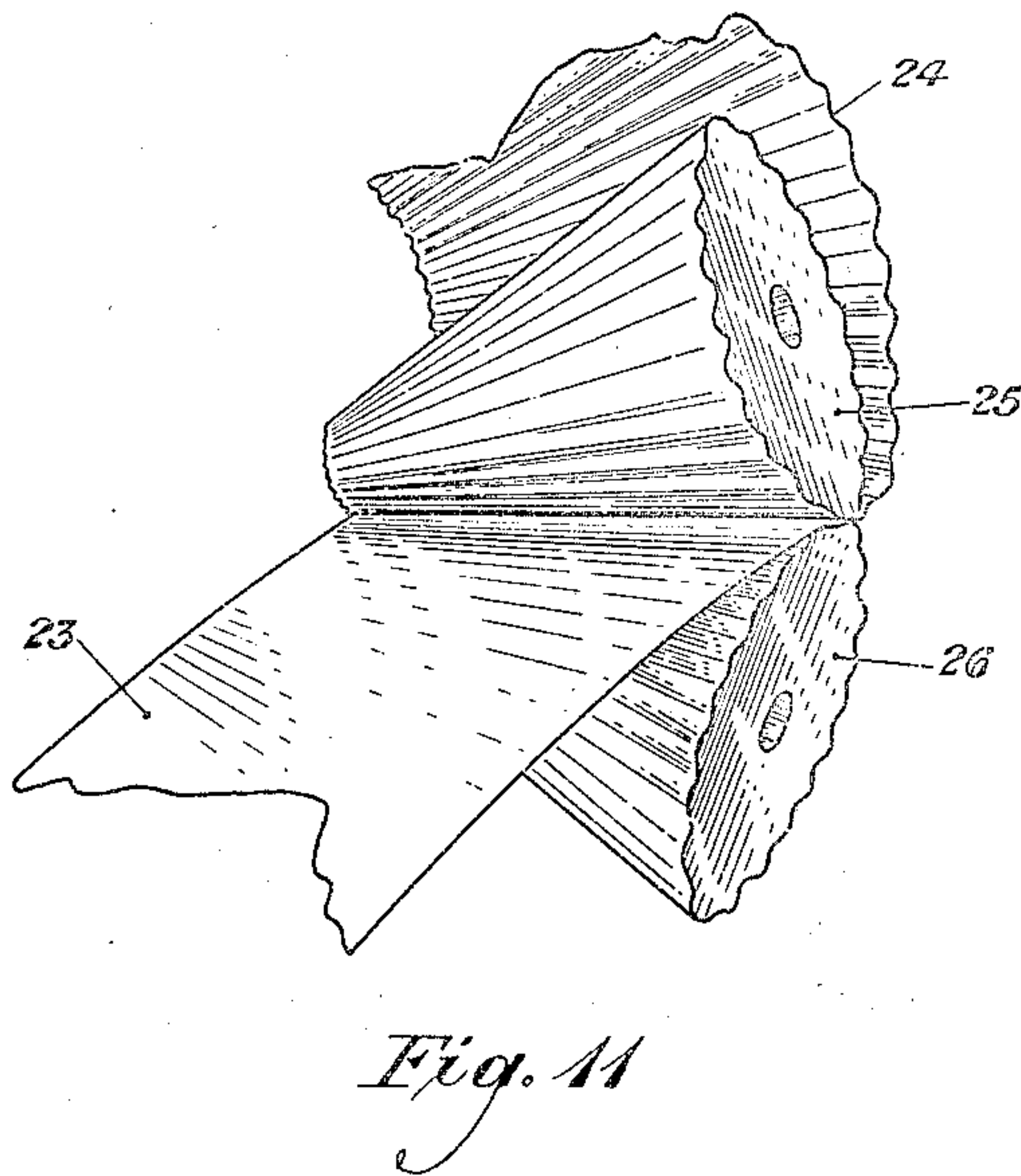
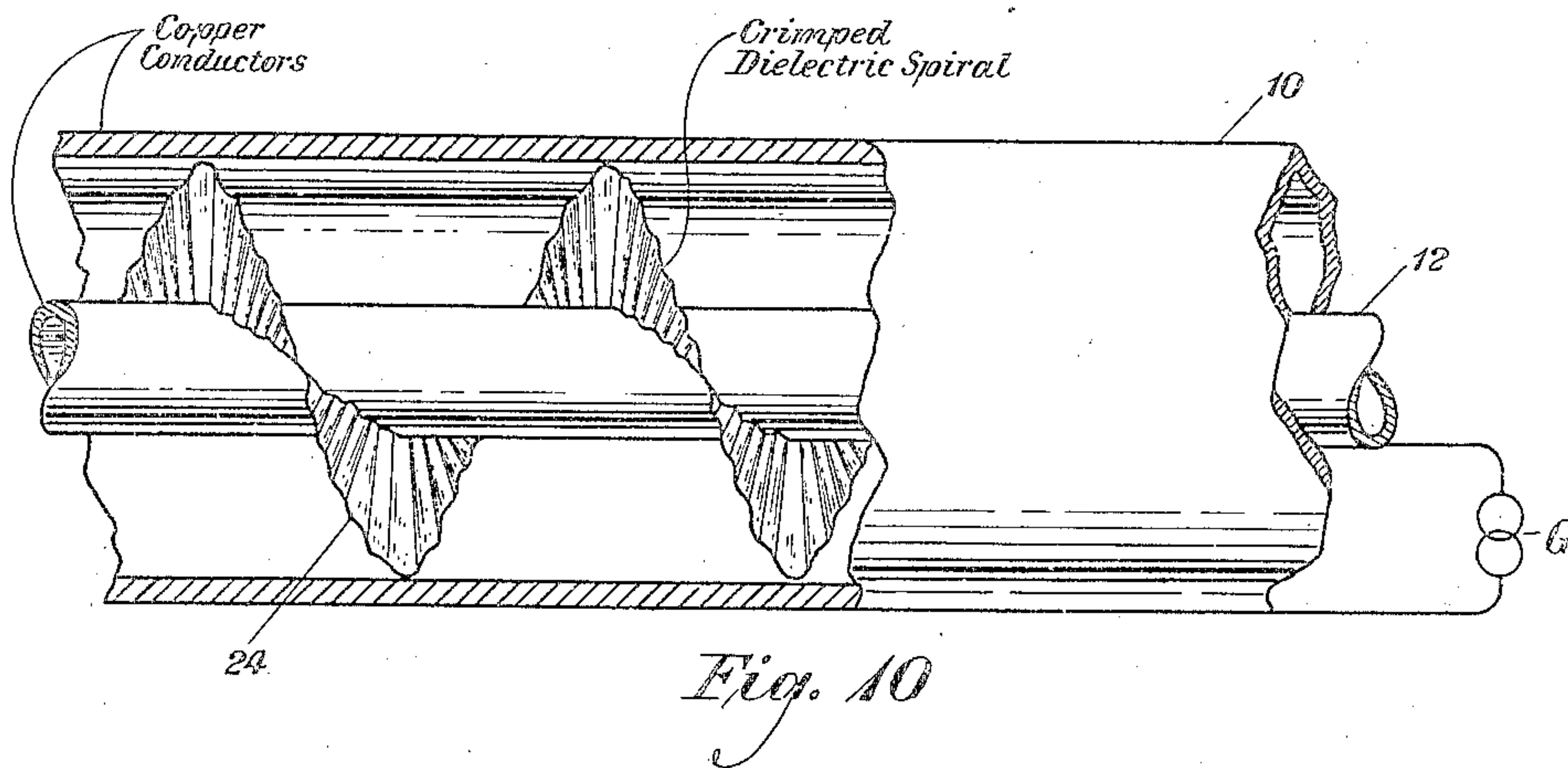
H. A. AFFEL

1,885,168

CONCENTRIC CONDUCTING SYSTEM

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3 Sheets-Sheet 3



INVENTOR
H. A. Affel
BY *J. V. 409*
ATTORNEY

UNITED STATES PATENT OFFICE

HERMAN A. AFFEL, OF RIDGEWOOD, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

CONCENTRIC CONDUCTING SYSTEM

Application filed May 23, 1929. Serial No. 365,521.

This invention relates to a conducting system for transmitting with small attenuation a band of frequencies whose upper limit extends well above the frequencies now employed in carrier transmission.

Modern developments in the art of communication render it highly desirable to have available for transmission purposes a system which will transmit without undue attenuation frequencies extending from the audio frequency range well up into the radio frequency range. For example, high grade circuits are now required for the transmission of programs over telephone lines to broadcasting stations. In order to transmit musical programs it is necessary to provide circuits that will transmit a band of frequencies extending well up toward 10,000 cycles, as compared with the voice range ordinarily employed in telephony, which did not exceed about 2,500 cycles. For the best quality of transmission of music it might be desirable to transmit over telephone lines frequencies up to the audio limit, which would be in the neighborhood of 15,000 or 20,000 cycles. Modern cable circuits are not adapted for transmission of such high frequencies, and the only commercial circuit now available which would be capable of transmitting frequencies of this order would be the open wire circuits which have heretofore been employed for high frequency multiplex carrier transmission.

Even for carrier transmission, open wire lines have been found uncommercial for the transmission of frequencies much above 30,000 cycles. If, therefore, an open wire line is used for the transmission of a high grade audio frequency program involving frequencies in the neighborhood of 15,000 or 20,000 cycles, the remnant frequency range above such audio band would be so narrow as to be of little use for carrier transmission. From this standpoint, therefore, it would be highly desirable to have available a circuit which would transmit without undue attenuation frequencies much higher than 30,000 cycles.

The modern development of television also introduces a new factor. Existing television systems which have been experimented with

have been limited to the transmission of a small image of a few square inches in area, and in such image the elements of the picture making up the entire image have been relatively large, so that the picture is not well defined. The mechanical problems involved in designing a television transmitting and receiving apparatus capable of picking up and receiving with excellent definition a representation of some large scene, such as a ball game or a theatrical performance, are probably capable of solution by known means, but the transmission of such a picture electrically involves the transmission of frequencies from zero up to the neighborhood of 500,000 cycles, and there is no telephone circuit now available which would commercially transmit any such range of frequencies because of the enormous attenuation involved at frequencies above about 30,000 cycles. It therefore becomes desirable to have available a conducting system which would transmit without undue attenuation a wide range of frequencies including the extremely high frequencies necessary for television, the circuit being at the same time available if necessary for the transmission of a very large number of carrier channels or for any desired number of bands of sufficient width for the transmission, without undue distortion, of high grade programs.

In accordance with the present invention a circuit having these desirable characteristics is obtained by employing concentric conductors of relatively large diameter, one acting as a return for the other. The two conductors may be insulated from each other and held in proper concentric relation by means of a ribbon of insulating material coiled spirally about the inner conductor and in edgewise relation thereto, with a considerable space between successive coils of the spiral. This insulating ribbon should preferably be of some suitable dielectric of small loss angle and low dielectric constant so as to introduce a minimum leakage loss between the conductors. By spacing the successive coils of the spiral relatively far apart the principal part of the dielectric between the two conductors will be air which, as is well known, involves

substantially no leakage loss. The conductors themselves may be made up of sections of copper pipe and the sections may be connected to each other by suitable pipe couplings, thereby enabling the conductor to be mounted upon the usual supports for overhead cable or to be pushed section by section through an ordinary underground cable conduit.

10 A conducting system such as above outlined has a number of advantages. It may be made waterproof, with the result that the leakage losses between the conductors (which in the case of ordinary open wire construction
15 vary greatly with weather conditions and at high frequencies contribute very substantially to the attenuation) may be made small and constant. Furthermore, the increase in conductor resistance with frequency due to
20 the skin effect is relatively small, so that the increase in the attenuation component due to resistance is much less rapid than for ordinary open wire construction. Also, the form of construction is such that interference from
25 nearby circuits and noise coming from external sources will be practically negligible. Moreover, the nature of the circuit is such that even though the outer conductor be grounded it will not be subject to interference
30 from ground currents. This enables the conductor to be laid directly on the metallic supports of an overhead cable system or underground in a conduit without any external insulation. Also the velocity of transmission
35 will be substantially uniform for all frequencies.

The invention will now be more fully understood from the following description when read in connection with the accompanying drawings of which Figures 1 to 7 are
40 curves illustrating the principles of the invention; Fig. 8 is a broken section of a portion of the conducting system in accordance with the present invention; Fig. 9 is a perspective view of the end of a conductor section together with a connector for joining
45 two sections of conductor together; Fig. 10 is a broken section showing a modified form of conductor system; Fig. 11 shows an arrangement for crimping the spiral dielectric used in Fig. 10.

Referring to Figs. 8 and 9 of the drawings, 10 designates an outer conductor which may be made up of sections of pipe of copper or
55 other conductive material screw threaded at the ends, as indicated at 11, to enable the conductor to be extended by sections to any desired length. A second conductor 12 is mounted concentrically with the outer conductor 10, the conductor 12 being also in the
60 form of sections of copper or other conductive pipe screw threaded at the ends, as indicated at 13. One of the conductors acts as a return for the other and not as a mere shield, this fact being indicated by the conventional

representation of a source of alternating electromotive force G with its terminals connected to the two conductors.

In order that the attenuation may be small at high frequencies the leakage loss between
70 the conductors must be as small as possible. As the leakage loss is due to the nature of the dielectric interposed between the conductors the dielectric should be principally of air, since air introduces no dielectric loss.
75 Accordingly, the two conductors are held in proper concentric relation and out of electrical contact with each other by means of a relatively thin ribbon 14 wound helically
80 about the inner conductor and arranged edge-wise thereto so that the outer conductor 10 may be slipped over the outer edge of the spiral. The successive coils of the insulator 14 should be separated from each other as
85 far as possible consistent with mechanical strength. The spiral insulator should also be composed of some dielectric of small loss angle and low dielectric constant since if these conditions are obtained, the leakage loss
90 (which in the ordinary open wire system comprises a large part of the attenuation) may be made so small as to be practically negligible. For example, the spiral insulating member 14 might be formed by shaving a spiral
95 ribbon from the edge of a hollow cylindrical mass of hard rubber of such dimensions that when stretched out, as shown in Fig. 8, the ribbon will assume the desired spiral shape. Or if preferred, the insulating member 14
100 may be constructed by molding pyrex glass or other good insulating material in the spiral form indicated, so that the spiral member may be relatively rigid.

In this connection it should be noted that
105 as the outer shell may be made watertight the insulating member 14 will be maintained dry and free from dirt or contamination so that the leakage loss will not increase or change with time. In ordinary open wire construction where the insulators are exposed to the
110 air and to the action of the elements the insulators become coated with a film of relatively high resistance conductive material which introduces large leakage losses, and these leakage losses are enormously increased
115 when the external surfaces of the insulators become wet. If it were possible to maintain an open wire line with its insulators in the dry and clean condition which characterizes them when they come from the factory the
120 attenuation component due to leakage would be so small as to be negligible. It will therefore be apparent that even if the dielectric material of which the insulating member 14 is composed is not the most perfect from the
125 standpoint of low loss angle and small dielectric constant, the attenuation due to the insulating member may still be practically negligible.

Since, as will be explained later, a conduct- 130

ing system of this type will be practically free from external interference even though the outer conductor is grounded, it is possible to mount the concentric conductor arrangement upon the metallic supports of an ordinary overhead cable construction, or to permit the arrangement to be buried directly in the ground or laid in a conduit such as might be employed for underground cable. In any case the transmission system might have to be made up of a plurality of sections of concentric tubular conductor material, but particularly in the case of underground conduit construction the sectional construction would be desirable. In this case the sections may be made of such length that a section may be inserted through a manhole and pushed into the conduit, the next section being then brought through the manhole and used to push the preceding section further into the conduit, after which it should be attached to the preceding section.

In order to accomplish this result an arrangement somewhat resembling a pipe coupling, as shown in Fig. 9, may be employed. This consists of two short pieces of tubing 10' and 12' concentrically arranged and interiorly threaded, as shown at 11' and 13', at each end. In order to maintain the two pieces of tubing in proper concentric relation a spacing insulator 14' of spiral form similar to that of the insulating member 14, may be employed. As each section of the concentric conductor is pushed into the conduit one of the coupling combinations 10'—12'—14' will be screwed to the end of the section, with the threads corresponding to 11' and 13' of the coupling mating with the external threads 11 and 13 of the conductor section. As the next section of conductor is pushed into the manhole its external threads corresponding to 11 and 13 will be caused to engage with the internal threads of the coupling and the joint will be pulled up until the joint between the outer shells of the coupling and the conductor sections will be made watertight. If desired, the outer coupling may be made watertight at the joints by the use of any well known waterproofing material. Also the joints may be soldered or welded if necessary, and unthreaded sleeves may be used for coupling the sections of pipe.

As has been previously pointed out, no insulation between the outer conductor and any external conductor is necessary in order to prevent interference. The insulation of the system, so far as it affects transmission, is confined entirely to the space between the two concentric conductors. Consequently, by making the external conductor waterproof the leakage due to the dielectric of which the insulating member 14 is composed will not change with wet weather, and the surfaces thereof will not deteriorate with time due to

accumulations of dirt or other foreign substances. The leakage loss of the system will therefore be confined to that leakage loss which will be due to the dielectric material of which the spiral member 14 is composed when it is new, clean and dry. If reasonably good dielectric material is employed the leakage loss due to the insulating member 14 will be practically negligible, and if a material of very low loss angle and dielectric constant is used, such for example as pyrex glass, the factor of attenuation which is due to leakage will be so small as to be practically negligible. In ordinary open wire construction (which has the lowest attenuation at high frequencies of any type of construction now employed in telephone practice) the attenuation due to leakage losses has been very large, and in wet weather becomes enormous. With the type of construction herein disclosed this factor of the attenuation becomes of little importance, and any attenuation due to this factor is fixed and unchangeable with variations in weather conditions.

In the ordinary type of conductor system, either open wire or cable, where one solid wire acts as a return for another solid wire, the component of the attenuation which is due to the skin effect is of great importance at high frequencies. As is well known, where a solid conductor is employed, as the frequency becomes higher more and more of the current tends to flow at or near the surface of the conductor, so that the conductive material near the center of the conductor takes but little part in the action at high frequencies. As a consequence, the conductor resistance increases with frequency as a smaller and smaller part of the cross-section of the conductor is usefully employed. If the same amount of conductor material is arranged in the form of a relatively thin shell, the resistance at any given high frequency is very much reduced because now more nearly all of the material of the conductor is usefully employed in transmitting current. With a system of concentric conductors, such as described in connection with the present invention, both conductors, being in the form of thin hollow shells offer a much less resistance at high frequencies due to the skin effect for the same amount of conductive material than in the case of an ordinary transmission circuit consisting of two solid wires. In fact, with a system of concentric conductors such as herein disclosed, the current at higher frequencies tends to flow more and more at the inner surface of the outer conductor and the outer surface of the inner conductor, due to the well known skin effect. The result is that while that component of the attenuation which is due to the conductor resistance increases with frequency, the rate of increase is very much less than in the case of an open wire line. By means of the

construction above described, therefore, we have the one component of the attenuation which is due to leakage losses or the so-called "shunt effect" reduced to practically negligible proportions by reason of the fact that the dielectric between the conductors is very largely of air and such other dielectric as is employed introduces but little leakage, while the other component of attenuation, namely, that due to the conductor resistance or so-called "series effect" is very much reduced as compared with the ordinary type of conducting system for any given frequency.

The form of construction herein disclosed also has the advantage that it does not produce material interference in a neighboring circuit and, conversely, is substantially free from interference from nearby circuits and noise coming from external sources.

In order to understand this more clearly it should be remembered that the interference between any two circuits is due to the fact that the one circuit lies within either the electric field or the magnetic field or both, of the other circuit. Considering first the magnetic field, let us consider two conductors a and b circular in cross-section and arranged side by side, one acting as a return for the other. These conductors are shown in section in Fig. 2. The lines of force due to the magnetic field surround each conductor and are crowded together in the space between the two conductors. Any other conducting system introduced at a point where the conductors of such other system will be cut by these lines of force will have induced therein crosstalk from the conductor system $a-b$. If, now, we have two conductors 10 and 12, as shown in Fig. 1, in the form of hollow shells concentrically arranged and the one acting as a return for the other, each conductor has lines of magnetic force surrounding it, each successive line of force being of larger radius and all of the lines, due to the current flowing in the particular conductor, such as 12, being external thereto. As the current flows in one direction through the conductor 12 and in the opposite direction through the conductor 10, the lines of magnetic force due to the current through the conductor 12 are in one direction, as indicated by the arrows, while those due to the current flowing in the conductor 10 are in the opposite direction. Now, an inspection of Fig. 1 shows that some of the lines of force due to the current in the conductor 12 are within the conductor 10, but none are within the conductor 12. On the other hand, all of the lines of force due to the current flowing in the conductor 10 are external to said conductor, and the two magnetic fields produced by the currents flowing in the two conductors tend to oppose each other outside of the conductor 10. The resultant field of magnetic force external to the conductor 10 is, therefore, very

small, and the only effective magnetic field lies within the space between the two conductors. Since the external magnetic field is very small it is obvious that another conductive system external to the conductor 10 will not receive any appreciable amount of crosstalk interference from the conducting system 10-12.

In so far as the electric field is concerned, the distribution of the field in the case of two parallel conductors a and b is as indicated in Fig. 4, so that any external conductor which is cut by the lines of electric force between a and b will have crosstalk induced therein. In the case of the two concentric conductors 10-12, however, the electric field set up due to currents flowing in the two conductors is entirely between the adjacent surfaces of the two conductors, as indicated in Fig. 3. No external conductor can possibly be cut by any of the lines of the electric field due to current flowing in the conductor 12 and returning in the conductor 10, or vice versa, and hence so far as the electric field is concerned, no possible external interference can take place.

The concentric arrangement not only has the advantage that it produces substantially no external field to interfere in other circuits, but it is practically free from interference due to any external source. For example, referring to Fig. 5, let us assume that some external force produces a field as represented by the arrows. The lines of force cutting the two concentric conductors produce differences in potential between points of the two conductors. For example, consider the points c and d , the one on the outer surface of the conductor 12 and the other on the inner surface of the conductor 10. The lines of force cutting the two conductors produce an induced E. M. F. between these points in the direction and having the value indicated by the arrow $c-d$. Since the same number of lines of force cut the two conductors on the opposite side of the diagram, a difference in potential indicated by the arrow $c'-d'$ will be produced between the two points c' and d' . The induced potential $c-d$, however, tends to produce a current flow equal to and opposite that induced by the difference of potential at $c'-d'$, so that a balance is obtained. Due to the symmetry of the conducting system with respect to the cutting lines of force, all differences in potential induced between any other two points of the two conductors will be balanced by similar differences of potential induced at corresponding points on the opposite side, so that if the interfering field is evenly distributed through the cross-sectional area of the conducting system (as would be the case where the interfering source is not too near the system) substantially no interfering effect would result in the conducting system 10-12.

While the foregoing explanation only applies to fields perpendicular to the axis of the conducting system, field components parallel to the axis are also prevented from causing interference. This is because the skin effect in the outer conductor furnishes protection against such fields.

As has been previously stated, the concentric conducting system is free from external interference even though the outer conductor be grounded, and hence there is no necessity for insulating the outer conductor from metallic supports in case it is mounted like an overhead cable, or from ground in case it is placed in a conduit. The reason for this is that a ground return circuit is noisy, due to the fact that a wire supported above ground forms with the ground a loop to pick up stray fields. But from the diagram of Fig. 5 it is evident that if the outer conductor such as 10 is grounded so that it in effect becomes a ground return for the tube 12, it is only the space between the two concentric conductors that acts as the loop to pick up stray fields. Hence, as has been just explained in connection with Fig. 5, substantially no interfering currents are induced in the conductors 10—12.

In order that a conducting system such as herein disclosed may have as small attenuation as possible at high frequencies, the diameters of the two concentric conductors should be made as large as possible. However, due to practical considerations it may be desirable that the system should be of such character that it might be used in existing cable ducts or in connection with present aerial cable construction. For these reasons, in practice, it is convenient to make the diameter of the external conductor not much greater than about two and five-eighths inches, if the conductor is to be used in the existing telephone plant. For mechanical reasons the thickness of the conductors should be made as small as is consistent with securing proper values of electrical resistance and mechanical strength. In general, it has been found that if the tubing is made thick enough to satisfy the mechanical requirements, the electrical resistance is not a limiting factor in the attenuation at high frequencies. This is due to the skin effect or proximity effect, which, as previously described, causes the current to crowd to the outer surface of the inner conductor and the inner surface of the outer conductor as the frequency increases, thereby rendering the remaining cross-sectional area of little utility for carrying current.

As the outer conductor is, or at least can be made watertight, the leakage losses can be reduced to very low values by the use of pyrex or other insulation where mechanical support is necessary, with the largest possible air space between the two conductors. Under

these circumstances the leakage loss will not change with weather conditions. For zero leakage (a condition which would be approximately obtained) the attenuation equals

$$\frac{R}{2} \sqrt{\frac{C}{L}}$$

at high frequencies, where R represents the resistance, C the capacity and L the inductance. From this expression it is evident that the values of R and C should be as small as possible. At high frequencies R is inversely proportional to the diameter of the conductor, and hence the attenuation will be smaller at any given frequency the larger the diameter of the conductor. The capacity C also is an inverse function of the diameter and decreases as the difference between the diameters of the inner and outer conductors increases. Consequently, if the diameter of the outer conductor is fixed, as the diameter of the inner conductor increases from some small value the resistance of the conducting system decreases, while at the same time the capacity increases. The decrease in resistance tends to reduce the attenuation, while the increase in capacity tends to increase the attenuation. For a given diameter of the inner conductor these two effects balance and the attenuation becomes a minimum.

Fig. 6 is a curve showing how the attenuation varies with diameter of the inner conductor at 500,000 cycles, with the inner diameter of the outer conductor fixed at two and one-half inches. This curve shows a minimum attenuation of .43 transmission units per mile for an inner conductor diameter of about .7 inch. As will be clear from the curve, either an increase or decrease of the diameter of the inner conductor from the foregoing value results in an increase in the attenuation. In Fig. 7 is shown a curve of the attenuation at various frequencies of a concentric conductor system whose outer conductor has a diameter of two and one-half inches and the inner conductor has the optimum diameter of about .7 inch. It will be observed from this curve that while the attenuation increases with frequency, the slope of the curve is not steep and the increase in attenuation is very much less than would be the case for an open wire line.

At 500,000 cycles the attenuation per mile of a 165 open wire circuit with a spacing of 12 inches between wires is about 1.67 transmission units, which compares with 0.43 transmission units per mile for the concentric conductor system. The advantages of using the latter are even greater than would appear from these figures on account of the lower levels to which the current may be attenuated before a repeater is necessary. This is due to the absence of coupling to external fields and results in a very low noise level. On an open wire circuit the level could

not be allowed to go below -50 transmission units, while with the concentric conductor system it might be permitted to fall as low as -80 transmission units. If the repeaters are adjusted to give an output of +10 transmission units this would result in a repeater spacing of thirty-six miles for the open wire circuit and 210 miles for the concentric return circuit. It appears to be impractical to devise a transmission system for an open wire circuit at such high frequencies, and the high frequency crosstalk would limit its use to one circuit on a given lead. Due to the absence of couplings to other circuits this limitation would not apply to the tubular conductor system, and any desired number of such conductor systems might be mounted upon the same pole line or carried in adjacent conduits without undue interference.

It follows, therefore, for the transmission of frequencies up to 500,000 cycles an open wire circuit would be quite unsuitable, whereas the concentric conductor system would carry frequencies as high as 1,000,000 to 2,000,000 cycles or even higher, without undue attenuation. A carrier telephone system could be operated over such a conductor with as many as one to two hundred two-way channels, allowing 5,000 cycles for each channel in each direction. This is comparable to the number of circuits which might be obtained from the pairs of wires in a cable of equivalent size. Any particular circuit in the cable could not be used for the transmission of frequencies much above the ordinary telephone range, and hence could not be employed for the transmission of musical programs involving frequencies up to the audio limit without using a very expensive loading system. A cable circuit could not conceivably be loaded to transmit frequencies high enough for good television transmission. The concentric conductor system, on the other hand, may be employed for either program transmission or television.

Fig. 10 illustrates a modified form of concentric conductor arrangement employing a spiral dielectric of such form that the amount of dielectric material other than air between the conductors will be even less than in the case of the arrangement of Fig. 8. Here the dielectric ribbon 24 is made thinner than in the case of Fig. 8 and is spirally wound about the inner conductor 12 so as to be interposed edgewise between the inner conductor 12 and the outer conductor 10. In order to give the spiral ribbon the necessary rigidity it is crimped as shown in the figure. As the outer edge of a single spiral has a greater length than the inner edge which is adjacent to conductor 12, the convolutions or folds are more widely spaced at the outer edge and gradually diminish in spacing towards the inner edge.

A crimped ribbon adapted to be spirally

wound as indicated in Fig. 10 may be produced as shown in Fig. 11. Here a very thin plain ribbon 23 of some suitable dielectric material is run between two rollers 25 and 26 of a generally conical form, the rollers being corrugated upon their outer mating surfaces as indicated, the corrugations being more widely spaced at that portion of the roller which is of largest diameter and the spacing gradually diminishing toward the smaller part of the roller. The corrugations in the two rollers mate each other so that as the ribbon 23 passes between the rollers it is crimped as shown at 24.

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

What is claimed is:

1. In a conducting system for the communication of intelligence, two conductors connected one as a return for the other, each conductor being cylindrical in form and the two conductors being arranged concentrically, means to separate the two conductors electrically and maintain them in concentric relation, said means comprising a strip of insulating material coiled spirally edgewise about the inner conductor with its outer edge supporting the outer conductor, said strip being of such thin cross-section and the successive coils thereof being so spaced that the dielectric in the space between the conductors is largely gaseous.

2. In a conducting system for the communication of intelligence, two conductors connected one as a return for the other, each conductor being hollow and cylindrical in form and having a diameter large as compared with its wall thickness so that its attenuation will be relatively small at high frequencies, said conductors being arranged concentrically, means to separate the two conductors electrically and maintain them in concentric relation, said means comprising a strip of insulating material coiled spirally edgewise about the inner conductor with its outer edge supporting the outer conductor, said strip being of such thin cross-section and the successive coils thereof being so spaced that the dielectric in the space between the conductors is largely gaseous.

3. In a conducting system for the communication of intelligence, two cylindrical electrical conductors having a common axis and separated by insulating material arranged in the form of a thin corrugated helix between the said conductors.

4. In a conducting system for the communication of intelligence, two conductors connected one as a return for the other, each conductor being cylindrical in form and the two conductors being arranged concentrically

ly, means to separate the two conductors electrically and maintain them in concentric relation, said means comprising a thin strip of insulating material corrugated transversely and coiled spirally about the inner conductor, said strip being of such cross-section and the successive coils thereof being so spaced that the dielectric in the space between the conductors is largely gaseous.

5. In a conducting system for the communication of intelligence, two conductors connected one as a return for the other, each conductor being cylindrical in form and the two conductors being arranged concentrically, means to separate the two conductors electrically and maintain them in concentric relation, said means comprising a thin strip of insulating material corrugated transversely and coiled spirally edgewise about the inner conductor with its outer edge supporting the outer conductor.

6. In a conducting system for the communication of intelligence, two conductors connected one as a return for the other, each conductor being cylindrical in form and the two conductors being arranged concentrically, means to separate the two conductors electrically and maintain them in concentric relation, said means comprising a thin strip of insulating material coiled spirally edgewise about the inner conductor with its outer edge supporting the outer conductor, said strip being corrugated transversely, the corrugations being more widely spaced nearer the outer edge and the spacing gradually diminishing as the edge adjacent the inner conductor is approached.

7. In a conducting system for the communication of intelligence, two conductors connected one as a return for the other, each conductor being cylindrical in form and the two conductors being arranged concentrically, means to separate the two conductors electrically and maintain them in concentric relation, said means comprising a thin flat strip of insulating material coiled spirally about the inner conductor and disposed edgewise thereto at a plurality of points about said conductor, the inner edge of said strip supporting the inner conductor at some of said points, and said strip being of such thin cross-section and the successive coils thereof being so spaced that the dielectric in the space between the conductors is largely gaseous.

8. In a conducting system for the communication of intelligence, two conductors connected one as a return for the other, each conductor being cylindrical in form and the two conductors being arranged concentrically, means to separate the two conductors electrically and maintain them in concentric relation, said means comprising a thin flat strip of insulating material coiled spirally about the inner conductor, said strip having its

longer cross-sectional dimension arranged radially between said conductors at a plurality of points along said inner conductor and being adapted to support said inner conductor at a plurality of points about its circumference, said strip being of such thin cross-section and the successive coils thereof being so spaced that the dielectric in the space between the conductors is largely gaseous.

9. In a conducting system for the communication of intelligence, two conductors connected one as a return for the other, each conductor being cylindrical in form and the two conductors being arranged concentrically, means to separate the two conductors electrically and maintain them in concentric relation, said means comprising insulating material in the form of a flat strip disposed about the inner conductor, said material being arranged endwise to said inner conductor at a plurality of points along said conductor and being adapted to support said inner conductor at a plurality of points about its surface, and said material being of such thin cross-section and so spaced that the dielectric in the space between the conductors is largely gaseous.

10. In a system for the transmission of intelligence, a transmission circuit comprising two cylindrical conductors arranged one as a return for the other, said conductors being arranged in coaxial relation to one another, and means to separate the two conductors electrically and maintain them in coaxial relation, said means comprising insulating material coiled spirally about said inner conductor, the cross-sectional dimensions of said insulating material being less when measured in certain directions than when measured in other directions, said insulating material being so arranged that it supports said inner conductor only at points where the greatest cross-sectional dimension of the insulating material lies in a radial position, said insulating material occupying a relatively small portion of the space between conductors, and the material occupying the remainder of said space being substantially gaseous.

In testimony whereof, I have signed my name to this specification this 20th day of May 1929.

HERMAN A. AFFEL.