July 20, 1948. P. D. ZOTTU 2,445,380

COAXIAL TRANSMISSION LINE

Filed Feb. 16, 1944 3 Sheets-Sheet 1

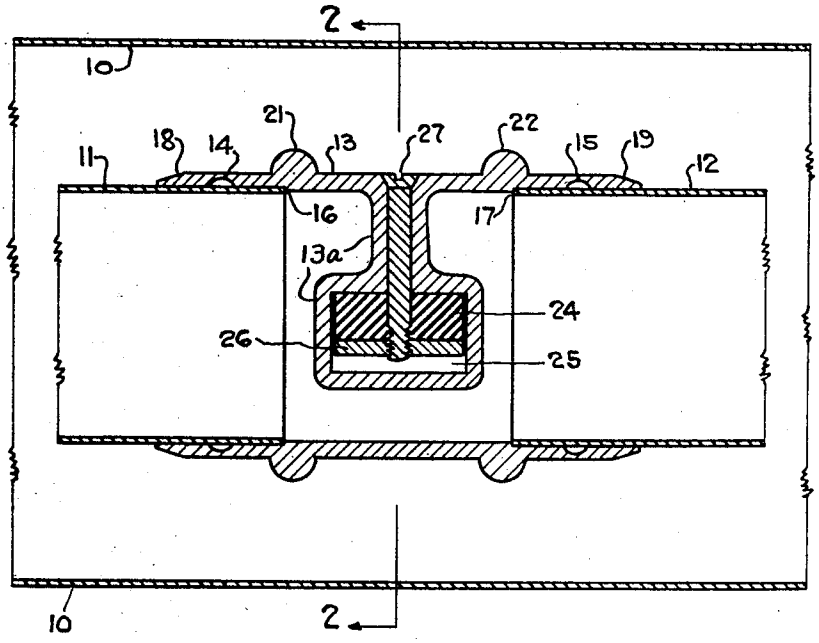


FIG. 1

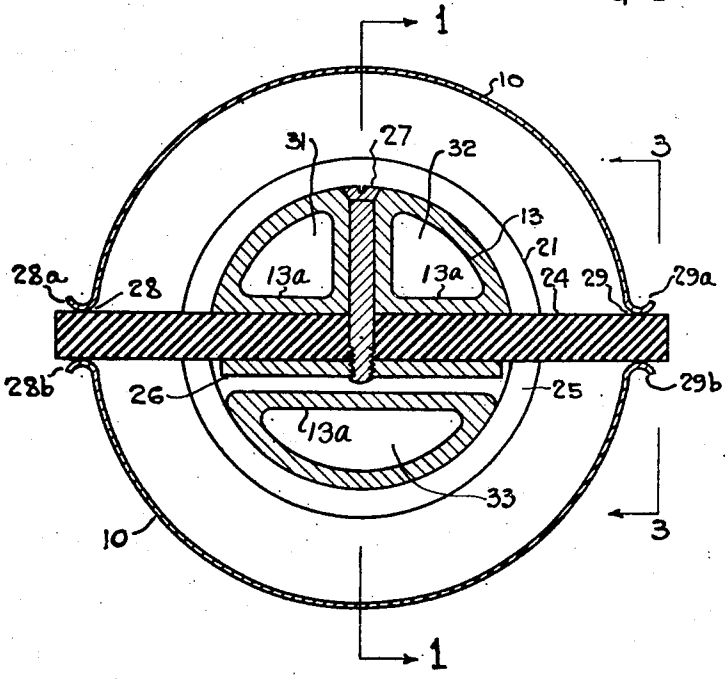


FIG. 2.

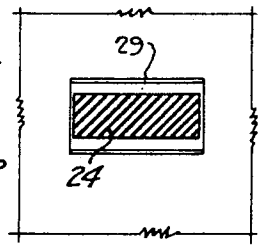


FIG. 3

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COAXIAL TRANSMISSION LINE

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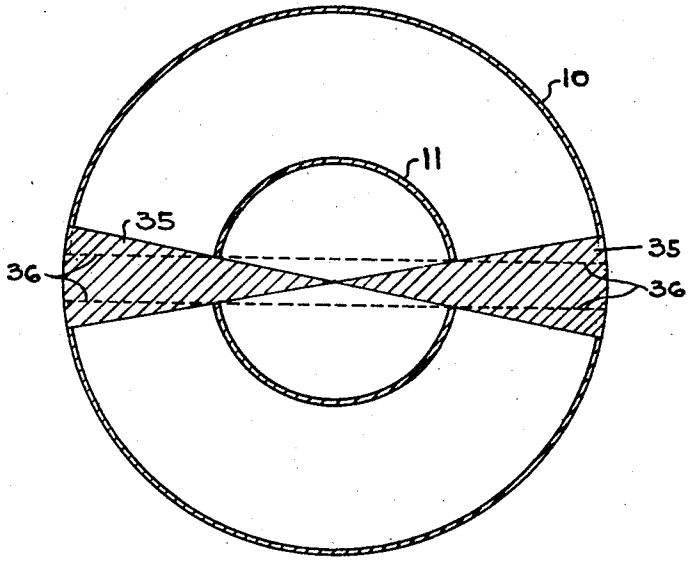


FIG. 4

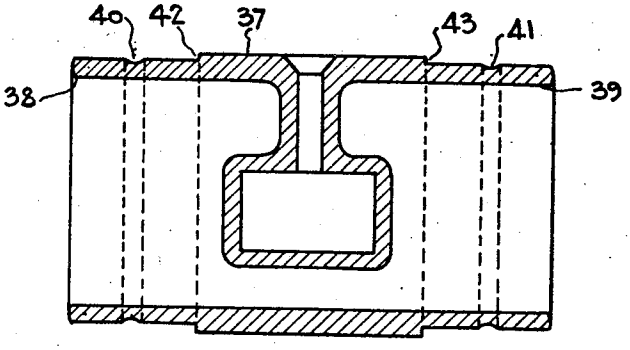


FIG. 5

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COAXIAL TRANSMISSION LINE

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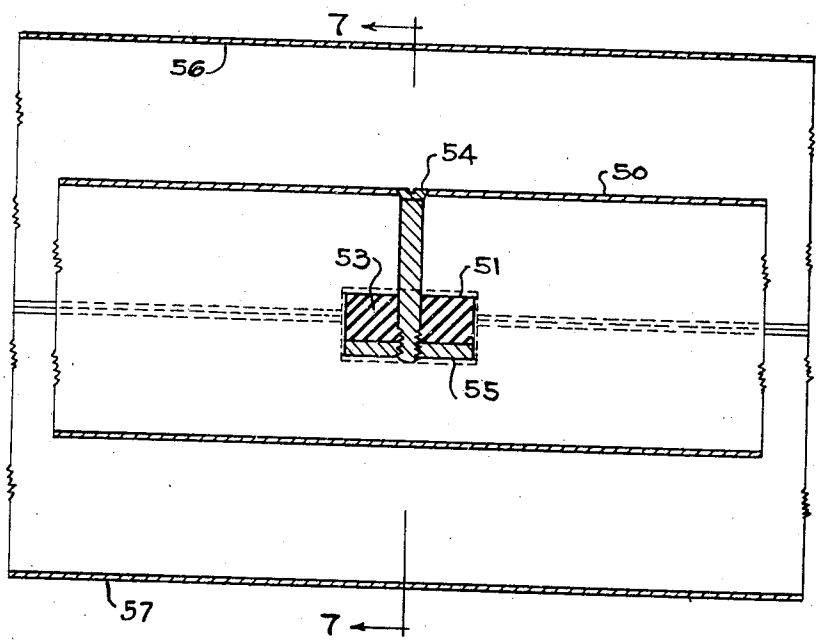


FIG. 6

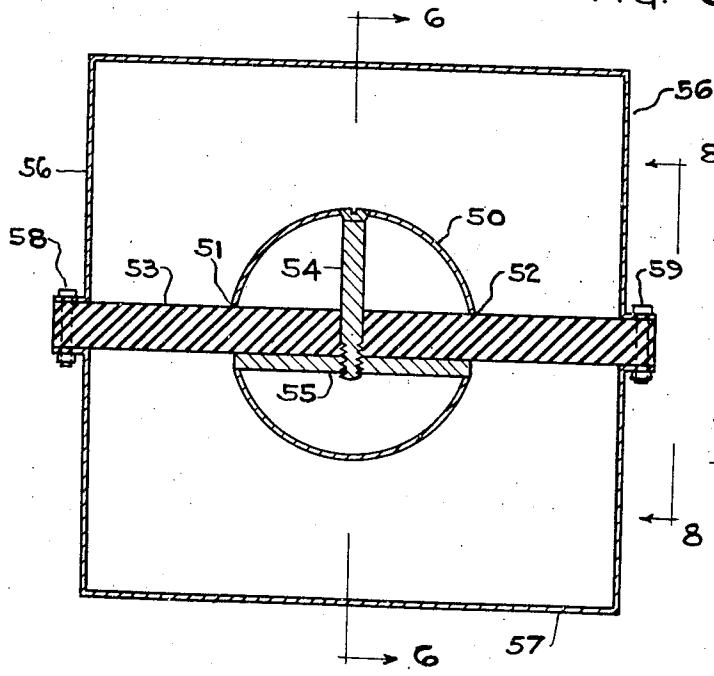


FIG. 7

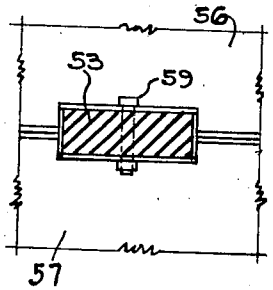


FIG. 8

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UNITED STATES PATENT OFFICE

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COAXIAL TRANSMISSION LINE

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Application February 16, 1944, Serial No. 522,647

12 Claims. (Cl. 174—28)

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This invention relates to coaxial or concentric transmission lines, more particularly to arrangements for supporting the inner conductor in rigid concentric relation with the outer conductor, and has for an object the provision of a supporting means which is electrically efficient, mechanically rugged, and relatively easy to manufacture.

Heretofore, in concentric lines a tubular inner conductor has been held in spaced relation with a tubular outer conductor by means of insulating rings; by small cylindrical members carried by the inner conductor with the ends contacting the inner surface of the outer conductor; and small cylindrical members have sometimes been secured to the outer conductor with the ends abutting against the inner conductor.

The inclusion of a supporting means between the inner and outer conductors alters the distribution of the voltage gradient and frequently causes substantial increases thereof in the vicinity of the insulating supporting means. The presence of a relatively steep voltage gradient results in flashovers, corona losses and general failure of the line at voltages much lower than it is designed and intended to withstand.

These problems are aggravated when the operating potentials are high, as in applications of high frequency to dielectric heating. For example, in such applications the high frequency voltage may be around 25,000 volts, peak, for the transmission of from one to three hundred or more kilowatts to a load. The frequencies may be of the order of from one million to ten million cycles per second, or more, or less.

In carrying out the present invention in one form thereof, the inner conductor of a concentric line is supported by means of a simple rectangular strip or bar of insulating material clamped to or carried by a fitting which interconnects adjacent sections of the inner conductor and forms an integral part thereof. The supporting bar has a configuration such that any change in the normal potential gradient existing between the inner and outer conductors is minimized. While of exceedingly simple construction, it has been found that a high voltage concentric inner conductor supported in accordance with the present invention operates in a highly satisfactory manner in contrast with inner conductors for like duties which when supported in conventional manner failed because of frequent flashovers.

Further objects and advantages of the present invention will become apparent, and will be pointed out, in the following detailed description,

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to be taken in conjunction with the accompanying drawings in which:

Fig. 1 is a sectional elevation, taken on the line 1—1 of Fig. 2, of a concentric line embodying the present invention;

Fig. 2 is a sectional view of the concentric line of Fig. 1 taken on the lines 2—2;

Fig. 3 is a fractional view taken on the lines 3—3 of Fig. 2;

Fig. 4 is a sectional elevation of a concentric line in which there is diagrammatically indicated an approximately ideal cross-section of a suitable supporting bar;

Fig. 5 is a sectional elevation of a modified form of the invention;

Fig. 6 is a sectional elevation, taken on the lines 6—6 of Fig. 7, of a modification of the invention;

Fig. 7 is a view taken on the lines 7—7 of Fig. 6 in which the outer conductor is rectangular; and

Fig. 8 is a fractional view taken on the lines 8—8 of Fig. 7.

Referring to the drawings, one form of the invention is shown as comprising an outer tubular conductor 10 within which there is supported coaxially or concentrically an inner tubular conductor. As shown in Fig. 1, the inner conductor is mechanically divided into two parts 11 and 12, which are interconnected by a coupling 13. Electrically the inner conductor is continuous. Thus, in assembling the inner conductor, the coupling 13 is moved over the end of the conductor 11 and soldered thereto, a solder groove 14 being provided for that purpose. Similarly the conductor 12 is moved into position in the opposite end of the coupling 13 and soldered thereto with the aid of the groove 15. Preferably shoulders as indicated at 16 and 17 are provided to fix the positions of the conductors 11 and 12 within the coupling 13.

It will be observed the overlying ends 18 and 19 of the coupling 13 are rounded towards the conductors 11 and 12 in avoidance of sharp corners the presence of which would result in an increase in the voltage gradient. Further to reduce a voltage gradient in the region of the supporting bar 24, gradient rings 21 and 22 are provided. These may be formed integrally with, or separate from, the coupling 13.

The inner conductor 11—12—13 is supported within the outer conductor 10 by means of the insulating bar 24 which extends through an opening 25 formed centrally and transversely of the coupling 13 by the internal structure 13a thereof. The supporting member or bar 24 is clamped against the upper surface or wall of the opening

25 by means of a plate 26, which may be of brass. The plate 26 is provided with a threaded opening into which there extends the threaded end of a clamping screw 27. Its outer end smoothly fits within a countersunk opening provided in the fitting 13. No sharp edges are present at the surface or around or near the bar 24.

As shown in Fig. 2, the insulating support 24 extends outwardly of the fitting 13 and through rectangular openings 28 and 29 provided in the outer conductor 10. These openings are preferably made by cutting the outer conductor along single lines so that the adjacent wall portions may be bent outwardly into curved portions as indicated at 28*a*, 28*b*, and 29*a*, 29*b*. If desired, a screw or a pin (such as shown at 58 and 59, Figs. 7 and 8) may extend between these rounded or curved portions which engage the support 24. It will thus be seen that the inner conductor is held securely and concentrically in position with reference to the outer conductor 10. Additional couplings 13 are provided along the length of the conductor system of transmission line. Some of the bars may be disposed at a ninety degree angle with respect to other supporting bars. For example, they may alternate in their direction of support. They function equally well whether the coaxial line be horizontal or vertical or at positions therebetween. For outer conductors of rectangular shape, the bars may extend diagonally thereacross.

The positions of the gradient rings 21 and 22 may be varied, and their height may be adjusted as the outer conductor is made larger or smaller. In general, high voltage transmission lines of this character are thoroughly tested under simulated or actual operating conditions and final adjustments of this character are then made.

Further, in accordance with the invention, a cooling fluid may be circulated through the inner conductor. For this purpose, the coupling 13 is provided with openings 31, 32, and 33 which extend through internal structure 13*a* in directions parallel to the axis of the coupling 13 and of the inner conductor. Thus it will be seen that the coupling 13 electrically interconnects adjacent sections 11 and 12 of the inner conductor and forms a fluid-tight connection therebetween with flow channels for circulation of a cooling fluid, either gas or liquid, through the hollow inner conductor. The couplings further serve to support the insulating bars by means of the other opening extending transversely of the fluid openings and sealed therefrom. The bars themselves serve mechanically to interlock the outer and inner conductors while insulating them one from the other with a minimum change in the voltage gradient therebetween.

Referring to Fig. 4, it will be understood by those skilled in the art that the electric field surrounding the inner conductor extends radially therefrom and at right angles to the magnetic field. For the production of a minimum change in the voltage gradient each supporting bar may be made with its boundaries parallel to radial lines taken from the center of the inner conductor. For example, it may be given a shape as shown at 35. Of course in the region within the inner conductor 11 the bar 35 need not decrease in cross section but it is so illustrated the better to emphasize the overall shape. However, it has been found that this approximately ideal shape is not necessary to all applications and that a compromise will be reasonably and commercially satisfactory. In consequence, the bar 24 of Figs. 1–3 is made rectangular, as indicated by the broken lines 36 in Fig. 4. Though there is some deviation from the ideal design outside of the inner conductor, yet the rectangular design is a reasonable compromise and a satisfactory one. Even though there is interposed in the electric field an insulating member, there are no regions where the voltage gradient is excessive. On the contrary, it is kept low.

In accordance with a modification of the invention, illustrated in Fig. 5, a coupling or fitting 37 is arranged for the projection of the ends of the inner tubular conductor over extensions 38 and 39. Soldering grooves 40 and 41 are provided, as well as shoulders 42 and 43 against which the ends of the inner conductor abut. This construction is entirely satisfactory when the inner diameter of the conductor is of uniform dimension. Ordinarily, however, copper tubing is manufactured with a relatively fixed dimension for its outside diameter. Variations in the wall thickness are reflected by a varying internal diameter. For this reason, the coupling or fitting 13 of Figs. 1 and 2, made of brass or copper, is preferred for tubing inasmuch as there will always be an assurance of an accurate fit between the outer surface of the tubular conductor and the inner surface of the ends of the coupling 13.

As may be inferred from the foregoing description, the inner conductor may be provided with elongated slots, thereby eliminating the need for a separate fitting. For example, as shown in Figs. 6 and 7, the inner conductor 50 is provided with axially elongated slots 51 and 52 through which an insulating bar 53 extends. The central part of the bar 53 has an opening through which a locking screw 54 extends, the end of this screw threadedly engaging a clamping bar 55. The head of the screw 54 is countersunk into the inner conductor 50 and the supporting bar 52 is rigidly held in place by action of the clamping bar 55 and the upper edges of the slots 51 and 52 as viewed in Fig. 7. In this modification of the invention as well as those above described, the outer conductor may be made in two parts. Both the upper and lower sections 56 and 57 of the outer conductor may terminate in flanges or outturned ends through which there extends fastening bolts 58 and 59. The outside conductor may be cylindrical although it is shown as rectangular. As in Fig. 2, the flanges have been bent away to provide room for the insertion of the supporting bar 53.

In every form of the invention the change in the voltage gradient in and near the regions of support is minimized. The insulating bar is made of insulating material of high dielectric efficiency, such for example as an insulating material known in the art under a familiar trade name, and comprising a glass-bonded mica insulating material. Because of the relatively thin or narrow rectangular shape of the bar 24 of Fig. 1 or the bar 51 of Fig. 6, the voltage gradient does not rise abruptly in or near the region of support of the inner conductor. Yet adequate strength is provided due to the dimension lengthwise of the conductor or coupling, that is, the greater axial width of each supporting bar. All air spaces between the inner conductor and the insulating bar have been eliminated. Small air gaps such as are inherently present with supporting members of the disc or washer-type have contributed to electrical failure with relatively low operating voltages but in accordance with this invention, such air gaps have been eliminated and the coaxial transmission line

functions satisfactorily at high voltages because of the absence of high voltage gradients on any small or large portion of the supporting structure.

While particular embodiments of the invention have been shown, it will be understood many modifications may be made. It is therefore intended by the appended claims to cover any such modifications as fall within the spirit and scope of the invention.

What is claimed is:

1. A transmission line comprising an outer hollow conductor, an inner hollow conductor having a slot elongated lengthwise thereof, means for supporting said inner conductor in fixed spaced relation within said outer conductor comprising an insulating bar having a materially greater width than thickness and extending through said slot with the ends of said bar supported by said outer conductor, clamping means within said inner conductor for clamping said bar against the side of said slot, said bar in its clamped position extending symmetrically across said inner conductor, and means for securing in fixed position at least one end of said bar to said outer conductor.

2. A coaxial transmission line comprising a hollow outer conductor and a hollow inner conductor, said inner conductor including a hollow coupling provided with inwardly extending internal structure having a centrally located opening extending transversely thereof and axially elongated with respect thereto, a rectangular supporting bar of insulating material extending through said opening in supporting relation with said coupling and transversely of said inner and outer conductors, said bar having a width axially of said coupling substantially greater than its thickness transversely thereof, means within said coupling for rigidly holding said bar and coupling in fixed position one with the other, and means for attaching the respective ends of said bar to said outer conductor.

3. In a transmission line formed by an inner conductor and an outer conductor radially spaced therefrom, the combination of means for supporting said inner conductor from said outer conductor comprising a coupling having end portions connected to and forming part of the inner conductor, said coupling having walls extending inwardly thereof and having a rectangular opening extending diametrically across said coupling, an insulating member of rectangular cross-section disposed within said opening and extending diametrically across said inner and outer conductors with its wider cross-sectional dimension parallel to the axes of said conductors, said outer conductor having means for supporting said insulating member at the respective ends thereof, and means for clamping said insulating member against said coupling.

4. A fluid-cooled transmission line comprising an inner conductor through which cooling fluid may be circulated and an outer conductor concentric therewith, a hollow coupling forming an integral part of said inner conductor, said coupling having structure within and extending transversely across said coupling, said structure having an opening for the passage of fluid from one side of said structure to the other side thereof and longitudinally of said inner conductor, said structure also having a separate opening which extends transversely thereof and transversely of said inner conductor along a diametrical plane thereof, an insulating bar extending through said last mentioned opening and outwardly into supporting engagement with said outer conductor, and means carried by said coupling for holding said bar in fixed position within said separate opening.

5. For a high-frequency electrical transmission line of the coaxial type, a supporting and coupling member for the inner conductor of the line comprising a body portion having end portions for engaging and supporting adjacent ends of the inner conductor, said member including internal structure having at least one fluid passage extending lengthwise thereof, and a separate opening elongated axially and diametrically of said member and extending transversely therethrough and isolated from said fluid passage, and means within said separate opening for clamping a supporting member therein.

6. In a conductor system including coaxial inner and outer conductors, the combination of a coupling forming a part of said inner conductor, said coupling having inwardly extending walls having an opening centrally thereof and extending transversely of the longitudinal axis of the inner conductor, an insulating member of relatively small cross-sectional area disposed within said opening with opposite ends thereof extending to said outer conductor, said outer conductor including means for supporting said opposite ends, and means for clamping said insulating member against a wall of said opening with the cross-sectional area of said member symmetrical with respect to a diametral line of said member and of said inner and outer conductors.

7. In a conductor system including coaxial inner and outer conductors, the combination of a coupling forming a part of said inner conductor, said coupling having inwardly extending walls which define an opening centrally and transversely thereof, which opening is wider lengthwise of said coupling than is its height, said inwardly extending walls having at least one additional opening separate and isolated from said transverse opening for flow of fluid longitudinally of said coupling, an insulating member wider lengthwise of said coupling than its thickness disposed within said transverse opening with opposite ends thereof extending to said outer conductor, said outer conductor including means for supporting said opposite ends, and means for clamping said insulating member against a wall of said transverse opening and in a position symmetrical with respect to a common diametral line of said member, of said coupling and of said outer conductor.

8. A coupling member for the inner conductor of a coaxial transmission line comprising a body portion having an opening extending transversely thereof and diametrically elongated lengthwise of said member, end-portions mechanically and electrically connected to said inner conductor, a rectangular insulating bar extending through said opening and outwardly from said member having a thickness radially of said member which is small compared with the width thereof along the longitudinal axis of said member, a clamping member, and means carried by said coupling member for holding said clamping member against said bar to secure it in a fixed position within said opening.

9. A supporting and coupling member for the inner conductor of a coaxial transmission line comprising a body portion having opposite end-portions connected to and forming an integral part of said inner conductor, said member having an opening extending therethrough transversely

of the longitudinal axis thereof and elongated along said axis, means including a rectangular insulating member fastened in, and extending outwardly from, said opening for supporting said inner conductor, and gradient rings so disposed on opposite sides of said opening as to reduce the voltage gradient in the region where said member extends outwardly from said opening.

10. In a coaxial transmission line having an inner tubular conductor formed by a plurality of tubular elements, and an outer tubular conductor, the combination of a coupling member having a body portion and opposite end-portions disposed in overlapping mechanical and electrical engagement with adjacent tubular elements, said body portion having an opening extending transversely thereof and therethrough and elongated along the axis thereof, an insulating bar having a thickness relatively small as compared with the diameter of said coupling member and extending through said opening and outwardly from said coupling member, a clamping member disposed within said opening and engaging one side of said bar, means for pressing said clamping member against said bar to hold it in place against the opposite side of said opening, and means for securing in fixed position to said outer conductor at least one end of said bar.

11. A transmission line comprising an outer hollow conductor, an inner hollow conductor having an opening elongated lengthwise thereof and extending diametrically thereof, means for supporting said inner conductor in fixed relation within said outer conductor comprising an insulating bar extending through said opening, means for fastening the ends of said bar to said outer conductor, said bar having a rectangular cross-sectional area elongated lengthwise of said inner conductor, and clamping means including a first member engaging said inner conductor and a second member rotatable to apply pressure to said first member and to said bar to clamp it against one side of said opening, said bar in its clamped position extending symmetrically across said inner conductor.

12. A high-voltage high-frequency electrical transmission line comprising an outer hollow conductor, an inner conductor of substantially smaller diameter than said outer conductor, said

conductors being adapted for operation with a high voltage therebetween, the electric field resulting from said high voltage extending in radial lines between said conductors, said inner conductor having in diametrically opposite sides thereof aligned slots elongated lengthwise of said inner conductor, means for supporting said inner conductor in centered relation with said outer conductor in avoidance of distorted high potential gradients at the supporting regions in the vicinity of said slots comprising an insulating bar disposed within said slots and extending outwardly into supporting engagement with said outer conductor, said bar having a thickness which is small relative to its width lengthwise of said inner conductor, means for holding said bar in said slots in a symmetrically fixed position with respect to said inner conductor, said thickness of said bar between said inner conductor and said outer conductor being such that the wide flat surfaces of said bar depart but slightly from said radial lines in avoidance of distortion of said field and in avoidance of said distorted potential gradients, and said width of said bar lengthwise of said inner conductor being adequate to provide the requisite strength for said support of said inner conductor within said outer conductor.

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