April 21, 1942. P. H. SMITH 2,280,200

CONCENTRIC CONDUCTOR TRANSMISSION LINE

Filed April 16, 1940

FIG. 1

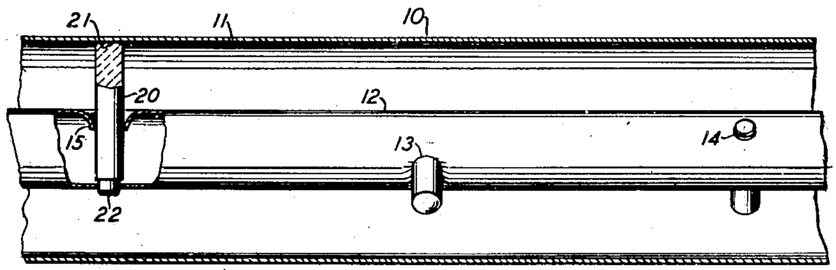



FIG. 4

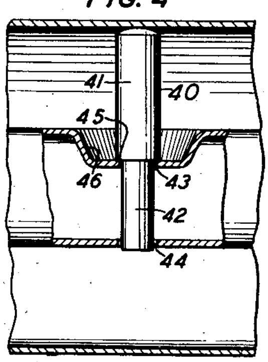



FIG. 2

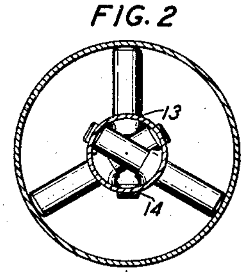



FIG. 5

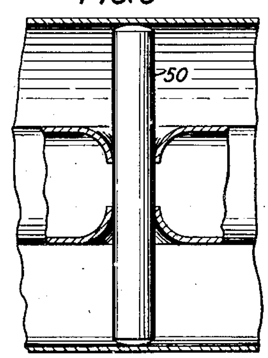
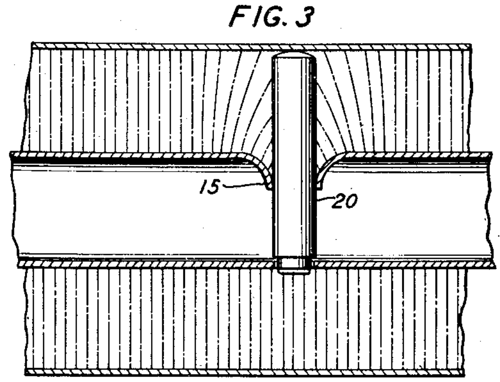



FIG. 3




INVENTOR
P. H. SMITH
BY H. A. Burgess
ATTORNEY

Patented Apr. 21, 1942 2,280,200

# UNITED STATES PATENT OFFICE

2,280,200

## CONCENTRIC CONDUCTOR TRANSMISSION LINE

Phillip H. Smith, Denville, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 16, 1940, Serial No. 329,862

3 Claims. (Cl. 174—28)

This invention relates to an improvement in concentric conductor transmission lines.

One form of concentric conductor line known heretofore comprises a tubular inner conductor disposed in a tubular outer conductor and spaced concentrically therefrom by insulating rings, or the like, mounted on the periphery of the inner conductor at intervals therealong. In such arrangements the insulating rings are held in place on the inner conductor in one of the following ways: (a) friction, (b) crimping the inner conductor on both sides of the insulating ring, (c) soldering metal rings on the inner conductor on both sides of the insulating ring, and (d) springing resilient wires on the inner conductor on both sides of each insulator.

Accordingly, these insulating rings create gaps between themselves and the inner conductor along a radial extending from the center of the line, and, in addition, introduce between the inner and outer conductors a relatively large mass of material which has a high dielectric constant compared to air or gas surrounding it and which, in addition to increasing the dielectric losses that are proportional to the mass of this material, alters the distribution of the electrostatic field and consequently the distribution of voltage gradient on the outer surface of the inner conductor. This distribution would be uniform for a line assumed to have a uniform air or gas dielectric intervening exclusively between the inner and outer conductors, or a line provided with insulators having a dielectric constant equivalent to that of the surrounding air or gas, if such were possible. However, since a solid material having a dielectric constant equivalent to that of air or gas is physically non-existent, the nearest approach to the desired condition of a uniform air or gas dielectric is realized with an insulator having minimum mass.

These alterations in the distribution of voltage gradient cause substantial increases of voltage gradient in the vicinity of the insulating rings and frequently result in the production of relatively steep voltage gradients on the outer surface of the inner conductor, particularly if any gaps intervene between the inner conductor and the insulating rings. Consequently, there may be produced in the vicinity of the insulating rings corona and flash-over by signaling voltages applied to the line and having magnitudes substantially less than those that would otherwise be required to produce corona and flash-over on a concentric line of the same cross-sectional dimensions and having air or gas dielectric intervening exclusively between the inner and outer conductors.

Also it may happen that either in slipping the outer conductor onto the inner conductor or in handling an assembled concentric conductor line in the field, the insulating rings would be subjected to longitudinal displacement on the inner conductor. Such movement tends to change the concentric relation between the inner and outer conductors, thereby causing further variation in the distribution of the voltage gradient on the outer surface of the inner conductor.

Concentric conductor lines may be used in the transmission of broad band signaling waves in the manner disclosed in the patent of L. Espenschied et al. No. 1,835,031 issued December 8, 1931.

According to this invention there is provided a concentric conductor line embodying pin-type insulators in which the flash-over factor of such insulators is higher than that of the line per se.

One object of the invention is to provide a concentric conductor system which, for a given cross-section and conductor diameter ratio, allows the efficient transmission of maximum signaling voltages, substantially equivalent to those that would be transmitted by a concentric conductor system of the same dimensions but embodying ideal insulating arrangements.

Another object is to provide highly efficient insulation for the transmission of signaling currents embracing a wide band of frequencies.

Another object is to provide a substantial reduction in the cost of manufacture.

A further object is to provide in effect a minimum disturbance of the dielectric intervening between the inner and outer conductors.

Another object is to improve the voltage flash-over factor of the insulators.

Another object is to reduce the voltage gradient on the surface of the inner conductor, in the vicinity of the points of engagement between the inner conductor and the insulators.

A further object is to provide for wide distribution of the electrostatic lines of force in the vicinity of the points of engagement between the inner conductor and the insulators.

In a preferred embodiment of the invention, a concentric conductor line comprises inner and outer conductors of which the inner conductor is provided with a plurality of pairs of diametrically aligned openings spaced therealong in such manner that adjacent aligned pairs are angularly disposed relative to each other. The openings of each aligned pair have different diameters and are arranged such that the opening of larger diameter is formed with an internally projecting perimeter. In each pair of aligned openings is disposed one end of an elongated insulator whose opposite end engages the inner surface of the outer conductor. This arrangement assures concentric spacing of the inner conductor within the outer conductor and at the same time improves the flash-over factor of the line in the vicinity of the individual insulators as a relatively low potential gradient is provided in the vicinity of the point of engagement between the internally projecting perimeter and the elongated insulator disposed therein.

This invention will be readily understood from the following description taken together with the accompanying drawing in which:

Fig. 1 is a sectional view of a concentric conductor line illustrating a preferred form of the invention;

Fig. 2 is an end of Fig. 1;

Fig. 3 is a sectional view showing a distribution of electrostatic lines of force obtained in accordance with the invention; and

Figs. 4 and 5 are modifications of Fig. 1.

Referring to Fig. 1, a concentric conductor line **10** comprises an outer conductor **11** and an inner conductor **12** and in which the latter is provided with a plurality of pairs of diametrically aligned openings **13** and **14** spaced at intervals therealong. Of each pair, opening **13** has a diameter which is preferably larger than that of opening **14**. Also, preferably each opening **13** is angularly disposed 120 degrees relative to adjacent openings **13** while each opening **14** is similarly disposed relative to adjacent openings **14** as shown in Fig. 2. The larger opening **13** of each aligned pair is formed with an internally projecting perimeter **15** for a purpose that will be presently explained. It is understood that adjacent pairs of aligned openings **13** and **14** may be disposed relative to each other in any suitable angular relation in addition to the manner mentioned above.

An electrical insulator **20** of an elongated type having a rounded end **21** and formed with a longitudinal projection **22** on the opposite end is positioned in each pair of aligned openings **13** and **14** such that the projection **22** is disposed in the opening **14** and the rounded end **21** engages the inner surface of the outer conductor as shown in Figs. 1 and 2.

Material of which insulators **20** are made has a dielectric constant which is high compared to that of the surrounding medium causing nearby electrostatic lines of force to pass through the insulators **20** in preference to the more direct radial path to ground through the surrounding medium. Due to the skin effect at high frequencies, however, or the tendency for current to crowd to the outermost edges and surfaces of the inner conductor, a concentration of lines of force in the vicinity of the point of engagement between the inner conductor **12** and the individual insulators **20**, which would otherwise exist, is avoided by means of the internally projecting perimeter **15**. Hence, there will be a relatively small amount of current flowing along the inner conductor at this point. In other words, the large surface area provided by the inwardly projecting perimeter **15** results in a relatively wide distribution of the electrostatic lines of force.

This eliminates a high voltage gradient in the vicinity of the points of contact between the inner conductor **12** and individual insulators **20** thereby reducing the tendency of flash-over along the surface of the individual insulators **20**. Such distribution of the electrostatic lines of force is illustrated in Fig. 3. Thus, the inwardly projecting perimeters **15** serve to control the flash-over factor of the individual insulators **20** which factor may be made higher, if desired, than the flash-over factor of the concentric conductor line per se. The radius of the perimeter **15** determines, for a given insulator and conductor diameter, whether the flash-over factor of the individual insulators **20** will be greater or less than that of the concentric conductor line. A sufficiently large radius is usually chosen for the perimeters **15** so that the flash-over factor of the individual insulators **20** will be higher than the flash-over factor of the concentric conductor line.

Fig. 4 is generally similar to Fig. 1 and illustrates an insulator **40** comprising a cylindrical portion **41** of one diameter and a cylindrical portion **42** of a smaller diameter. The portion **42** is disposed in a pair of diametrically aligned openings **43** and **44** provided in the inner conductor. Shoulder **45** formed by the junction of the portions **41** and **42** engages the periphery of the inner conductor in a cup-shaped portion **46** in which the opening **43** is embodied. Preferably, the shoulder **45** assumes a curvilinear shape that lends itself in a ready fit to the curvature of the outer surface of the inner conductor.

Fig. 5 is similar to Fig. 1 except that both diametrically aligned openings are formed with internally projecting perimeters and a unitary insulator **50** extends therethrough.

In the above arrangements, it is obvious that the insulators are precluded from longitudinal displacement on the inner conductor during the operations of (*a*) slipping the outer conductor onto the inner conductor, and (*b*) in handling an assembled concentric conductor line in the field. Consequently, the concentric relation between the inner conductor and outer conductor is retained at all points along the line.

In addition, pin-type insulators with their minimum mass of high dielectric material intervening between the inner and outer conductors tend to cause minimum dielectric losses and also minimum disturbances in the distribution of the potential gradient on the outer surface of the inner conductor. This obviates the production of relatively steep voltage gradients on the outer surface of the inner conductor in the vicinity of the insulators. Consequently, signaling voltages that are substantially equivalent in magnitude to voltages allowed by a line of the same dimensions having air or gas dielectric intervening exclusively between the inner and outer conductors, or an air or gas dielectric line of the same dimensions provided with ideal insulators for maintaining concentric spacing therebetween, may be applied to the line without causing the production of corona or flash-over.

Furthermore, it is evident that a pin-type insulating arrangement lends itself to the facile assembly of a concentric conductor line or the expeditious replacement of defective insulators. In the latter event, a defective insulator can be removed and replaced without disturbing the other insulators, which is not so in the case of ring-type insulators as all insulators leading to the defective one must be removed before the latter can be replaced. In addition, the inwardly projecting perimeters obviate the need of accurately fitting the insulators as the extent of the air-gaps intervening between the latter and the inner conductor is unimportant. Consequently, concentric conductor lines according to this invention involve substantially reduced costs.

While the invention is particularly described in connection with a concentric conductor line having a tubular inner conductor, it is obvious that it is equally well suited to concentric conductor lines provided with solid inner conductors.

It is understood that the invention is capable of modifications other than those disclosed herein, and the scope thereof together with such modifications is defined in the appended claims.

What is claimed is:

1. A concentric conductor transmission line comprising tubular inner and outer conductors, said inner conductor having a plurality of pairs of diametrically aligned openings, each of said pairs comprising openings having different diameters, the opening of larger diameter being provided with a perimeter depressed below the outer surface of the inner conductor, and insulators to maintain concentric spacing between said conductors, each insulator comprising two portions of different diameters and a shoulder formed at the junction of said two portions, each insulator being disposed in one of said pairs of aligned openings such that the portion of the smaller diameter is positioned in the opening of smaller diameter and is terminated on one end substantially at the outer surface of the inner conductor with the shoulder in engagement with a portion of the inner surface of the inner conductor in the vicinity of the opening of the smaller diameter, and such that the portion of the larger diameter is positioned in the opening of larger diameter to engage the depressed perimeter thereof and extend from the shoulder to the inner surface of the outer conductor.

2. A concentric conductor transmission line comprising tubular inner and outer conductors, said inner conductor having a plurality of pairs of diametrically aligned openings, one opening of each of said aligned pairs having its perimeter depressed below the outer surface of the inner conductor, and insulators to maintain concentric spacing between said conductors, each insulator comprising two portions of different diameters and a shoulder formed at the junction of said two portions, each insulator being positioned such that the portion of smaller diameter is disposed in one of said pairs of aligned openings and is terminated on one end substantially at the outer surface of the inner conductor with the shoulder in engagement with the inner conductor, and such that the portion of larger diameter extends from at least the depressed perimeter to a substantially diametrically opposite portion of the inner surface of the outer conductor.

3. A concentric conductor transmission line comprising tubular inner and outer conductors, said inner conductor having a plurality of pairs of diametrically aligned openings, one opening of each of said pairs having its perimeter depressed below the outer surface of the inner conductor, and insulators to maintain concentric spacing between said inner and outer conductors, each insulator comprising two portions of different diameters and a shoulder formed at the junction of said two portions, each insulator being positioned in one of said pairs of aligned openings such that the portion of smaller diameter extends substantially between the outer surface of the depressed perimeter and the outer surface of a substantially diametrically opposite portion of the inner conductor with the shoulder in engagement with the outer surface of the depressed perimeter, and such that the portion of larger diameter extends from the shoulder to the inner surface of the outer conductor.

PHILLIP H. SMITH.