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MULTI-CONDUCTOR COAXIAL CABLE WITH CONDUCTORS STRANDED
IN ORDER OF RELATIVE IMPEDANCE

3,342,926

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2 Sheets-Sheet 1

FIG. 1

PRIOR ART

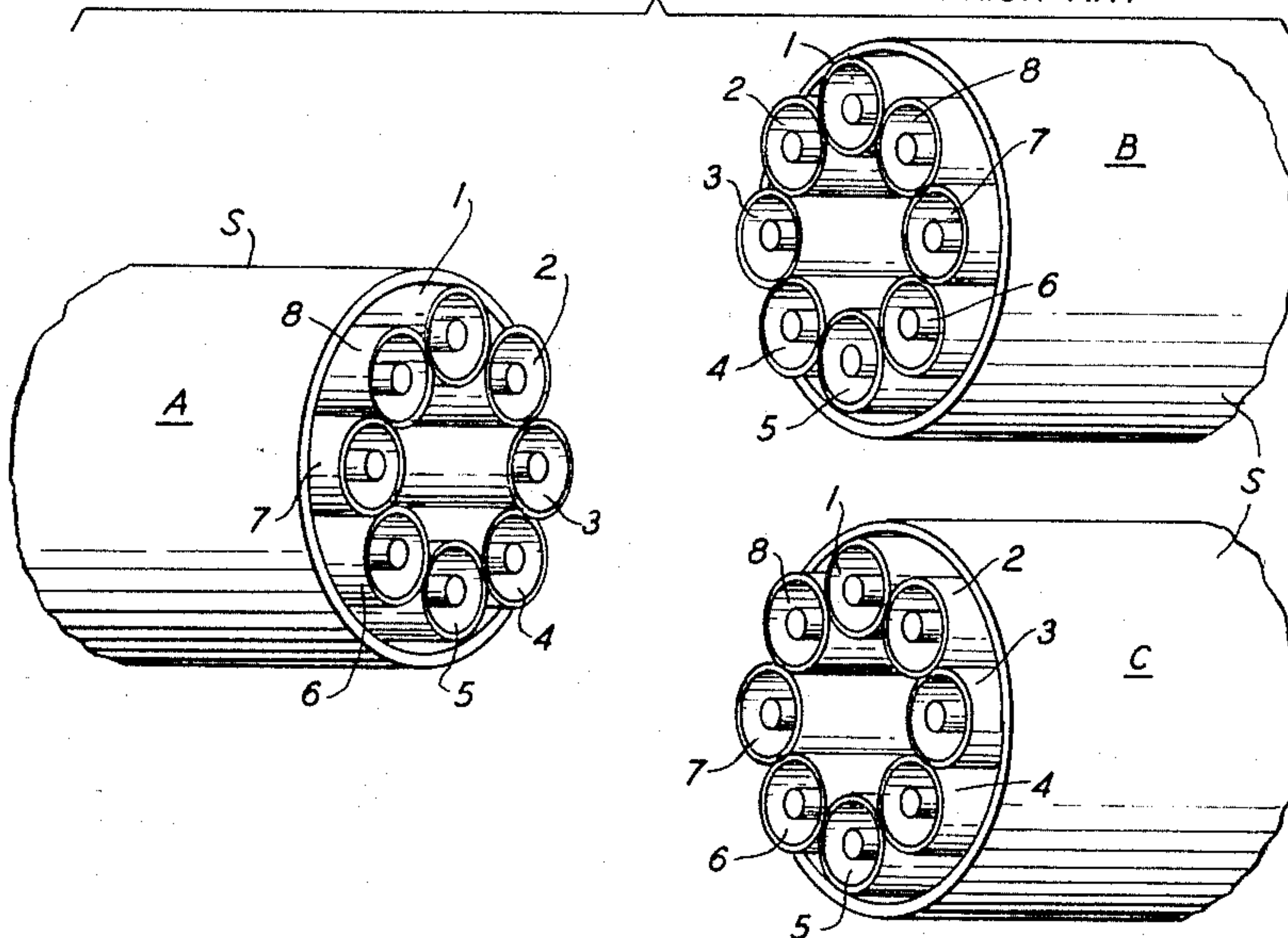
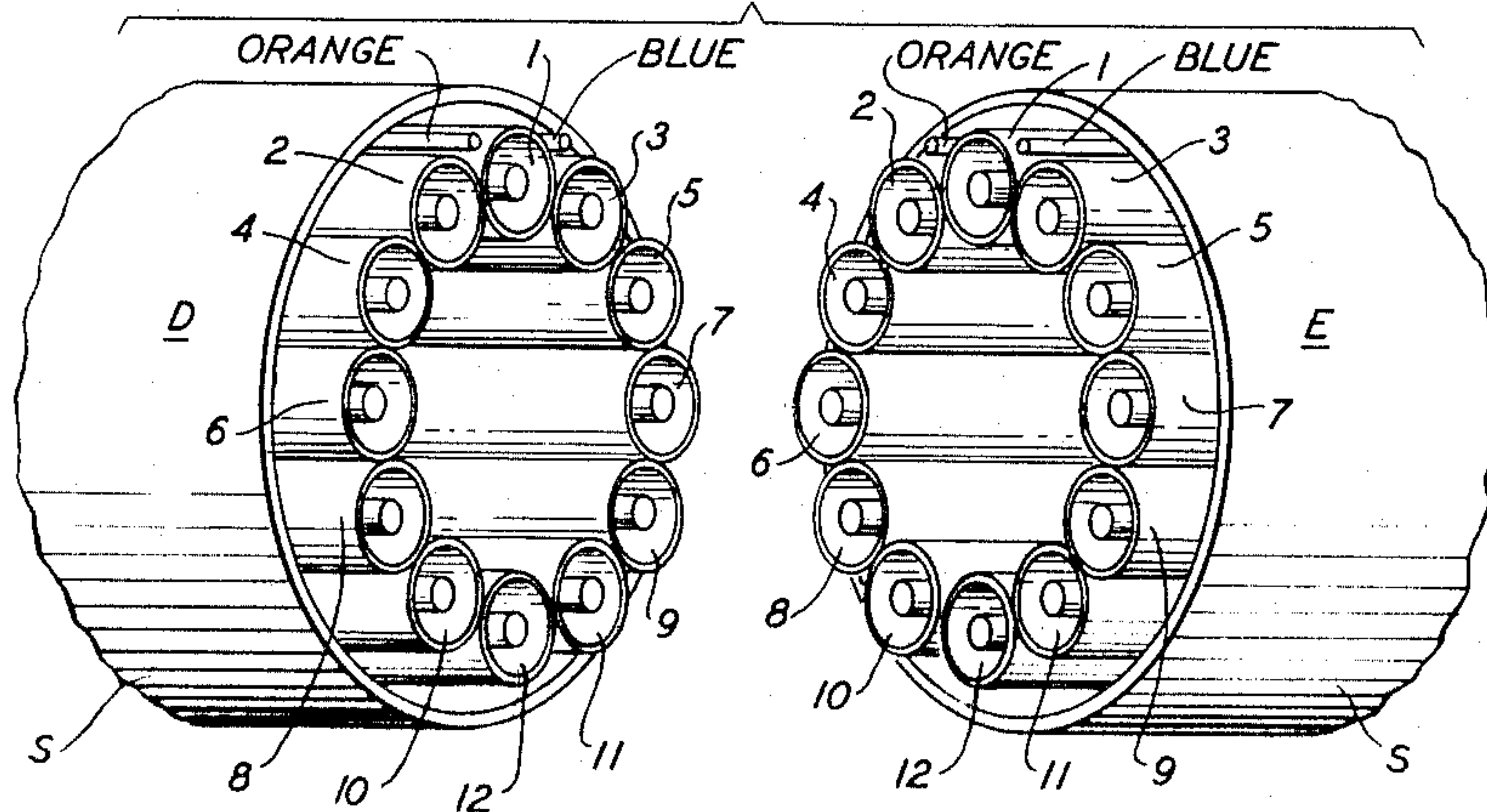


FIG. 2



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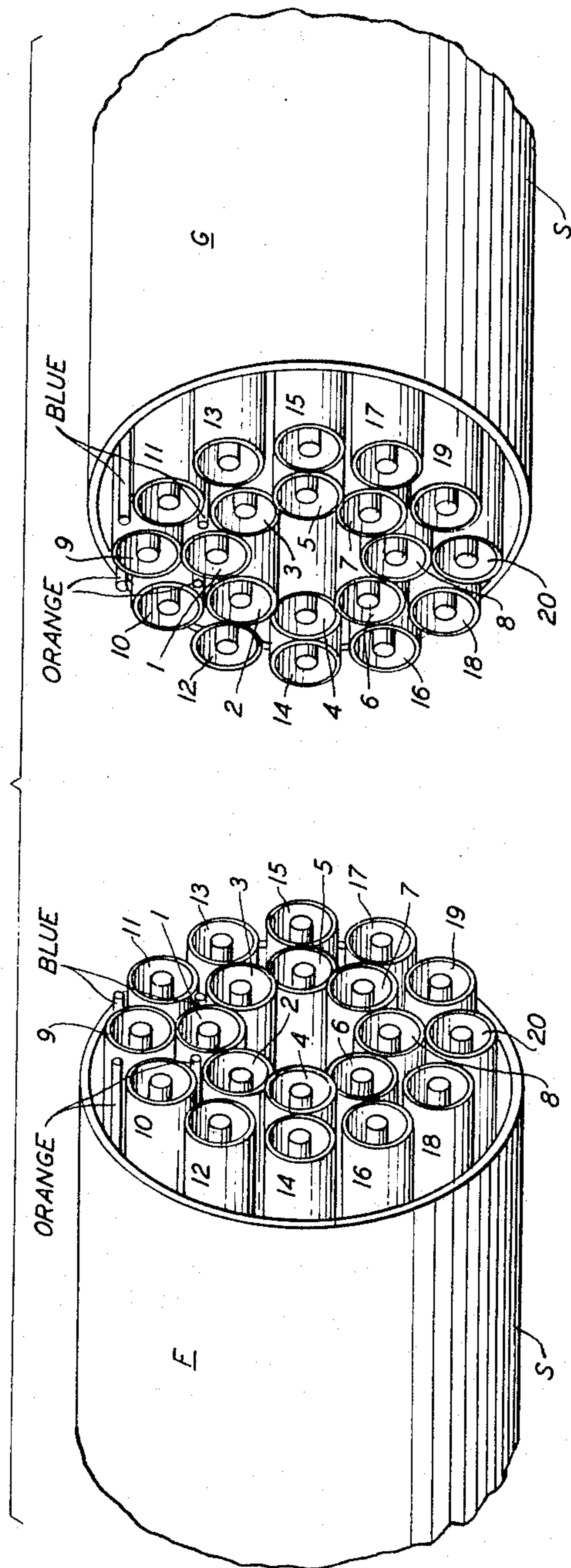
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2 Sheets-Sheet 2

FIG. 3



1

3,342,926

MULTI-CONDUCTOR COAXIAL CABLE WITH CONDUCTORS STRANDED IN ORDER OF RELATIVE IMPEDANCE

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8 Claims. (Cl. 174-68)

ABSTRACT OF THE DISCLOSURE

In a cable that includes a plurality of coaxial conductors, the conductors are physically arranged sequentially in correspondence with the impedance magnitudes of the conductors in order to reduce the possibility of introducing impedance mismatches during splicing.

This invention relates to electrical cable, and more particularly, to a sequence for stranding individual coaxial conductors in a multi-coaxial cable.

When one coaxial conductor is spliced to another, it is important to match the impedance of the two coaxials as nearly as possible. The minimization of impedance mismatch at the splice is necessary to prevent echoes.

This requirement has led to the practice in the cable industry of stranding the individual coaxial conductors of a cable in a known impedance sequence. The known sequence assists a splicer in keeping impedance mismatches to a minimum during splicing operations by providing a means for splicing a low impedance conductor in one cable to a low impedance conductor in another cable, and a high impedance conductor in one cable to a high impedance conductor in the other cable.

The usual sequence employed in stranding multi-coaxial conductor cable is to strand the individual conductors in an order of ascending impedance values. Thus, for example, if the end of a multiple-conductor cable were examined, the ends of the individual conductors would be displayed in a particular pattern; usually circular. The pattern is defined by the cross sections of the adjacent conductors. The sequence starts with the conductor of lowest impedance and proceeds around the pattern, each adjacent conductor having a larger characteristic impedance than the preceding one, until the full pattern has been completed.

The straight ascending sequence described above, and in more detail subsequently, is sufficient to minimize impedance mismatches where straight-through splices are performed. A straight-through splice is made where the sequence looking at one end of a cable is of one hand, for example clockwise, and the sequence looking at the end of the other cable is of the opposite hand, counterclockwise. When the patterns are as described, the coaxial conductor of lowest impedance in one cable may be spliced directly to the coaxial conductor of lowest impedance in the other cable, and so forth throughout the entire pattern. In other words, each conductor in one cable is spliced directly to the conductor in the other cable that most nearly matches it in impedance without crossing one conductor over any of the other conductors.

However, there are a number of situations where straight-through splices can not be made. Such situations occur, for example, when one cable is installed backwards, when one cable is placed backwards on the reel, when the wrong end of a cable is marked, and other similar situations. When one of the above situations occurs, the impedance sequence looking at the ends of the cables to be spliced are both of the same hand; either both clockwise or both counterclockwise.

2

If a straight-through splice is attempted where one cable is reversed, the conductor of highest impedance in one cable will be spliced to the conductor of second lowest impedance in the other cable if the conductors of lowest impedance in both cables are spliced together. This situation may be unsatisfactory from an electrical standpoint.

Impedance mismatching in the above situation can only be minimized by cross-over splicing, if such is possible. A cross-over splice requires the splicer to identify the coaxial conductors of most equal impedance and splice them together by crossing the various conductors over each other. Such an operation is time consuming and costly.

The invention is embodied within a sequence that alleviates or minimizes all the problems suggested above. The conductors of cable manufactured in accordance with this new sequence may be spliced straight across to one another, no matter how the cable is reeled or placed, and still minimize impedance mismatches without requiring cross-over splices.

The invention will be better understood, its features and advantages more readily apparent from a study of the following detailed description and drawing in which:

FIG. 1 is a perspective view of the ends of cable manufactured according to the prior art; and

FIGS. 2 and 3 are perspective views of the ends of cable manufactured according to the invention.

FIG. 1 shows the ends of three cables that are manufactured according to the prior art. The cables comprise an enclosure or sheath S and eight coaxial conductors. The conductors are numbered by the consecutive integers 1 through 8 in order of increasing relative impedance. The coaxial conductor of least impedance is number 1, the coaxial conductor of next higher impedance is number 2, and so forth until the conductor of highest impedance is numbered 8.

The sequence of the conductors in cable A in FIG. 1 is clockwise. That is, the conductors are stranded in cable A so that when its right-hand end is inspected, the sequence of conductors according to increased impedance is clockwise. If the left-hand end of cable A had been shown, the sequence would have been counterclockwise. The left-hand end of cable A would appear exactly as the left-hand end of cable B that is shown in FIG. 1.

From an inspection of the ends of cables A and B and in particular, from an inspection of the impedance sequences shown, it is obvious that a straight-through splice between cable A and cable B can be made with a minimum of impedance mismatch. In other words, conductor 1 of cable A can be spliced directly to conductor 1 of cable B without crossing over any of the other conductors. Conductor 2 of cable A can be spliced directly to conductor 2 of cable B and so forth through all the conductors; each being spliced to its corresponding conductor in the other cable without crossing over any other conductor.

In contrast though, cable C represents a cable where the sequence has been reversed for one of the many reasons previously mentioned. As shown, when a cable is reversed, the sequence in the right end of cable A is of the same hand as that of the left end of cable C. If cable A were spliced straight through to cable C, conductor 1 in cable A would be spliced to conductor 1 in cable C and conductor 2 in cable A would be spliced to conductor 8 in cable C. The resultant splice would include a mismatch of six relative impedance values which might be sufficient to introduce deleterious electrical echoes.

The situation described above can be remedied in a number of ways; all of which are costly or impractical for one reason or another. For example, the cable represented by cable C in FIG. 1 can be removed and reinstalled with its ends reversed. This requires a great deal of

extra time and is impractical. Another remedy is to make a cross-over splice wherein the conductors of cable A and cable C are crossed over each other during the splicing operation in order to obtain better impedance matching. A cross-over splice requires a great amount of space and also requires the splicer to be able to identify each conductor in its relative sequence of impedance.

FIG. 2 shows the ends of two cables D and E that use the new conductor sequence. The cables both include twelve coaxial conductors that are arranged or grouped within the sheath S in a circular pattern. The pattern is described by the ends of the adjacent conductors.

The conductors are arranged in the pattern according to a predetermined sequence. The sequence is based upon the relative impedance values of the various coaxial conductors. In particular, in accordance with the invention, the sequence starts with the conductor of least impedance and continues around the pattern with alternate values of increasing conductor impedance. When the conductor of greatest impedance has been reached, the sequence then continues with the remaining conductors in decreasing values of impedance. For example, the sequence for the twelve conductor cables shown in FIG. 2 is 1, 3, 5, 7, 9, 11, 12, 10, 8, 6, 4, 2.

If cable using the new sequence is installed without reversing one of the cables, the sequence of the two ends that are to be spliced will be of opposite hands; that is, one will be clockwise and the other will be counterclockwise. A straight-through splice can be made between the corresponding conductors in each cable. The situation will be similar to that where cable A was spliced to cable B in FIG. 1. Number one conductor in one cable can be spliced to number one conductor in the other cable, number two conductor in one cable can be spliced to number two cable in the other cable and so forth throughout the entire sequence.

FIG. 2 represents the situation where one cable has been installed backwards, or in which the sequence has been reversed so that the sequence in both of the cable ends to be spliced is of the same hand. The impedance sequence in both cables D and E is clockwise. If conductor 1 in cable D is spliced to conductor 1 in cable E, the new sequence mates conductor 3 of cable D with conductor 2 of cable E; conductor 5 of cable D with conductor 4 of cable E and so forth throughout the sequence as shown in FIG. 2. A straight-through splice between cables D and E results in a maximum of one relative impedance mismatch. Since one relative impedance mismatch does not introduce sufficient impedance mismatch to alter the electrical performance of the cable, it is obvious that the new sequence allows a splicer to make straight-through splices no matter how the cables are installed. The only requirement imposed on the splicer is that conductor 1 of cable D be spliced to conductor 1 of cable E. A straight-through splice thereafter yields a splice with minimum impedance mismatch.

In order to identify the conductor of lowest impedance, the usual methods of color coding, tracer wires et cetera, may be used. For the purposes of illustration, FIG. 2 shows the conductor of lowest impedance between orange and blue tracer wires. If it is desired to disclose the actual sequence to the splicer, the fact that the sequence proceeds from the orange tracer toward the blue tracer may be made known to him.

The straight-through splice, described above, connects coaxial conductors 1 and 12 of cable D to coaxial conductors 1 and 12 of cable E. All other conductors are displaced by one relative impedance value. Because of the other interstitial conductors or power requirements of specific coaxials or other similar resources, the straight-through splice, described above, may not be desirable or electrically acceptable. The new sequence provides an alternative straight-through splice that also results in a minimization of relative impedance mismatch.

The alternative straight-through splice connects con-

ductor 1 of cable D to conductor 2 of cable E and conductor 3 of cable D to conductor 2 of cable E, and so forth throughout the sequence. An inspection of FIG. 2 shows that a difference of only one relative impedance value exists between each conductor in cable D and the conductor in cable E to which it is spliced.

As shown in FIG. 3, the invention may be used with cables wherein the number of conductors requires more than one layer of conductors. FIG. 3 shows two cables F and G in which the conductors are arranged in two layers of 8 and 12 conductors respectively. The pattern described by the adjacent conductor ends is of two concentric circles. The inner circle is defined by the 8 adjacent conductors and the outer circle is defined by the 12 adjacent conductors.

The conductors in each circle are arranged according to impedance in the new sequence. In particular, each sequence starts with the conductor of least impedance on the circle and continues around the circle with alternate values of increasing conductor impedance. When the conductor of greatest impedance has been reached, the sequence then continues with the remaining conductors in decreasing values of impedance. Thus, the sequence for the inner circles is 1, 3, 5, 7, 8, 6, 4, 2 and the sequence for the outer circle is 9, 11, 13, 15, 17, 19, 20, 18, 16, 14, 12, 10.

Similar to the cables shown in FIG. 2, the conductor of lowest impedance on each circle is indicated by orange and blue tracer wires and the sequence proceeds from the orange toward the blue. The cables F and G, shown in FIG. 3, also represent the situation where the sequences in one cable have been reversed during its installation, or for some other reason, and in which all sequences in both cables are of the same hand. If conductors 1 and 9 of cable F are spliced to conductors 1 and 9 of cable G, a straight-through splice between all the rest of the conductors will allow, as a maximum, one relative impedance mismatch as previously described with the cables shown in FIG. 2.

The alternative straight-through splice previously described with respect to the cables shown in FIG. 2 may also be used with the cables shown in FIG. 3. The alternative splice is made by connecting conductor 1 of cable F to conductor 2 of cable G and conductor 9 of cable F to conductor 10 of cable G. The remaining conductors are then spliced straight across, in sequence to each other. An inspection of FIG. 3 shows that a difference of only one relative impedance value will exist between each conductor in cable F and the conductor in cable G to which it is spliced.

Although it is suggested in FIG. 3 that all of the conductors in the inner circle are of less impedance than those in the outer circle, the same results will be obtained if all the conductors on the inner circle are of greater impedance than those in the outer circle. The new sequence will yield the same results if there is no relationship between the impedance values in one layer to those of another layer as long as the sequence is followed consistently in each layer.

Though the invention has been disclosed in terms of cables having even numbers of conductors, it is equally applicable to cables having odd numbers of conductors. For example, the sequence in a seven conductor cable would be 1, 3, 5, 7, 6, 4, 2.

In all the figures of the drawing, the conductors are grouped or arranged within the enclosure or sheath S in a pattern, in particular, a circular pattern. Though a circular pattern is shown, the invention may be practiced with patterns other than circular patterns. For example, the invention may be used in a pattern where the adjacent conductor ends describe a generally closed curve or a combination of closed curves.

Notwithstanding the disclosure of the invention in terms of electrical coaxial conductors, it is within the scope of the invention to apply it to situations involving

5

other than electrical conductors. For example, the invention may be practiced in any situation where it is necessary to match and then interconnect a plurality of elements. The invention can be used for interconnecting pipes, hydraulic systems, ropes, strands in cables and other similar applications.

It is obvious to those skilled in the art that numerous changes and modifications can be made to the embodiment of the invention as it has been disclosed above. Such changes and modifications can be made without departing from the spirit and scope of the invention as set forth in the above specification and the appended claims.

What is claimed is:

1. A cable comprising a plurality of conductors arranged within an enclosure, one group of said conductors positioned adjacent to one another according to alternate values of increasing conductor impedance followed by the remaining conductors in order of decreasing values of conductor impedance.

2. A cable comprising a plurality of conductors arranged to form a pattern within an enclosure, said pattern being generally a closed curve in cross section of said cable, one group of said conductors positioned adjacent to one another according to alternate values of increasing conductor impedance followed by the remaining conductors in order of decreasing values of conductor impedance.

3. A cable comprising a plurality of conductors grouped to form a pattern within an enclosure, said pattern being generally circular in shape in cross section of said cable, said pattern including an ordered sequence of adjacent conductors, said sequence starting with the conductor of least impedance, said sequence continuing with conductors of alternate values of increasing conductor

6

impedance followed by the remaining conductors in decreasing order of conductor impedance.

4. A cable comprising a plurality of conductors arranged to form a pattern within an enclosure, said pattern including at least one generally closed curve in cross section, said conductors positioned adjacent to one another according to alternate values of increasing conductor impedance followed by the remaining conductors in order of decreasing values of conductor impedance.

5. A cable comprising a plurality of conductors grouped to form a pattern within an enclosure, said pattern in cross section including a plurality of closed circular curves, each of said curves including an ordered sequence of adjacent conductors, each sequence starting with the conductor on said curve of least impedance, continuing with conductors of alternate values of increasing conductor impedance followed by the remaining conductors in decreasing order of conductor impedance.

6. The cable described in claim 5 wherein said circular curves are concentric curves.

7. The cable described in claim 6 wherein each conductor located on an encircling curve is of greater impedance than each conductor located on an encircled curve.

8. The cable described in claim 6 wherein each conductor located on an encircled curve is of greater impedance than each conductor located on an encircling curve.

References Cited

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DARRELL L. CLAY, *Primary Examiner*.