Dec. 5, 1967 F. F. POLIZZANO ETAL 3,356,790

COAXIAL CABLE

Filed Feb. 18, 1966

FIG. 1.

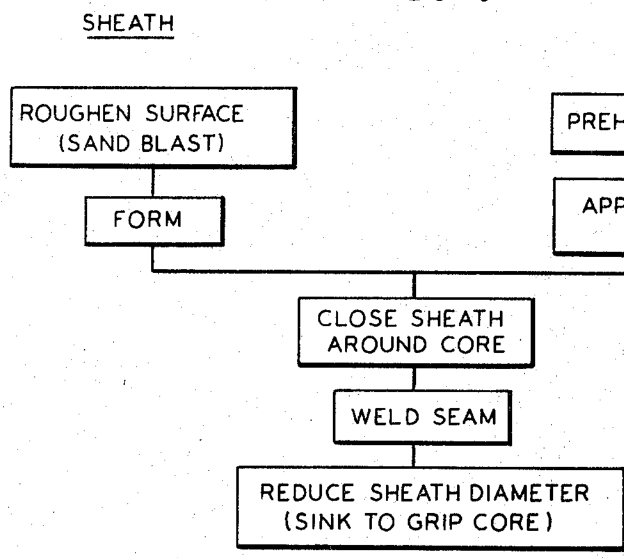


FIG. 2.

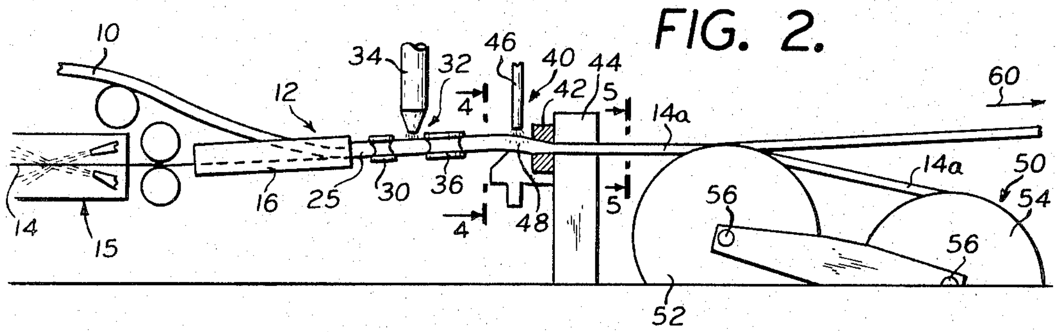


FIG. 3.

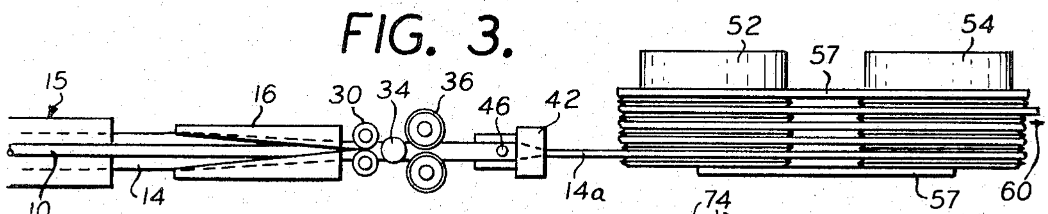
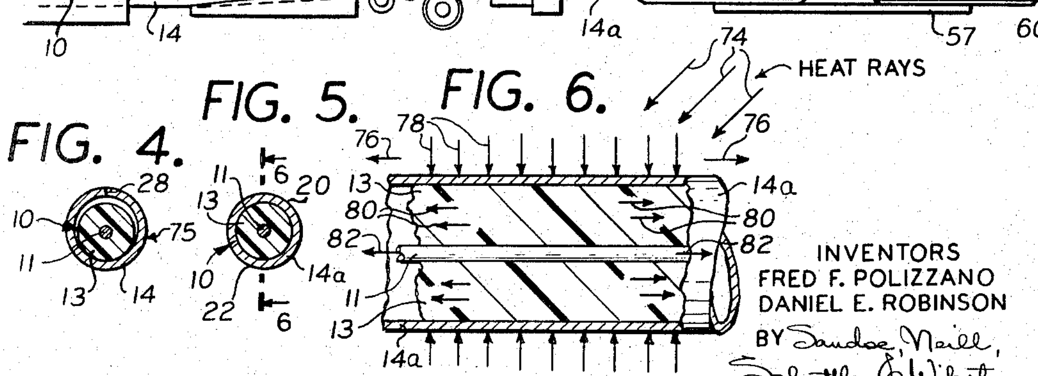


FIG. 4. FIG. 5. FIG. 6.



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COAXIAL CABLE

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ABSTRACT OF THE DISCLOSURE

This specification discloses a coaxial cable with provision for transmitting longitudinal expansion of the sheath to the center conductor. In order to obtain this result, without compressing the insulation to a degree that impairs its electrical qualities, the invention roughens the inside surface of the sheath to increase the coefficient of friction between the sheath and the insulation. A sinking operation is used to bring the sheath into contact with the insulation with only moderate pressure between the sheath and insulation. The increased coefficient of friction is sufficient to transmit longitudinal thermal expansion of the sheath, as when subjected to strong sunlight, to the center conductor so that the connections are not pulled off the center conductor as sometimes occurs in the coaxial cables of the prior art as the result of unequal expansion of the conductors.

Brief description of the invention

This invention relates to coaxial cable, and more especially to cable in which the sheath is welded around the insulation that surrounds the center conductor and the sheath is then reduced in diameter by a sinking process in order to grip the insulation.

One of the problems that is presented by coaxial cable results from differences in thermal expansion of the metal sheath and the center conductor. For example: in certain areas of the country, fog conditions often exist in the morning; and when the fog dissipates, the cable sheath is subjected to a very sudden change in temperature, caused by the sun. The effect of subjecting the outer sheath to a fast rise in temperature is a longitudinal expansion of the sheath without corresponding expansion of the center conductor and with the result that the connectors are pulled off of the center conductor.

Electrical insulation between the sheath and the center conductor acts also as heat insulation and thus accentuates the temperature differences between the sheath and the center conductor when the cable is subjected to heating from an outside source.

It is an object of this invention to provide an improved coaxial cable in which the entire cable expands as a homogeneous mass, or substantially so. The coaxial cable of this invention is constructed so that longitudinal expansion of the sheath is transmitted through the insulation to the center conductor and stretches the center conductor to an increased length substantially equal to the increased length of the sheath.

In order to attain this new result, it is necessary to prevent the sheath from slipping on the insulation and to prevent the insulation from slipping on the conductor. The force to prevent such slippage can be increased by sinking the sheath to a degree that causes it to grip the insulation more tightly, but this is objectionable because it impairs the electrical qualities of the insulation.

It is another object of the invention to increase the axial force that can be transmitted from the sheath to the insulation, and through the insulation to the conductor, without impairing the electrical qualities of the insulation.

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The invention treats the surface of the sheath so as to produce a rough surface having a higher coefficient of static friction on the insulation than sheaths of the prior art and this increases the axial force that can be transmitted from the sheath to the insulation without increasing the pressure of the sheath against the insulation. The surface of the sheath is treated before the sheath is applied to the insulated core and the treatment is one on which the subsequent sinking of the sheath has no objectionable effect, and is one which does not result in internal reflection or standing waves which impair the signal transmission of the cable when used for television transmission. Both the inside and outside surfaces of the sheath may be roughened, as will be explained herein.

It is, therefore, another object of the invention to provide an improved method of making coaxial cable with a welded sheath around the insulation and reducing the diameter of the sheath by a sinking step to grip the insulation.

Other objects, features and advantages of the invention will appear or be pointed out as the description proceeds.

Brief description of the drawings

In the drawing, forming a part hereof, in which like reference characters indicate corresponding parts in all the views:

FIGURE 1 is a flow diagram showing the successive steps when making coaxial cable in accordance with this invention.

FIGURE 2 is a diagrammatic side elevation of apparatus for making coaxial cable by the method of this invention;

FIGURE 3 is a top plan view of the apparatus shown in FIGURE 2;

FIGURES 4 and 5 are sectional views, on a greatly enlarged scale, taken on the lines **4—4** and **5—5**, respectively, of FIGURE 2; and

FIGURE 6 is a greatly enlarged fragmentary, sectional view of the conductor shown in FIGURE 5, the section being taken on the diameter **6—6** of FIGURE 5.

Detailed description of the invention

The coaxial cable of this invention is made by first applying a sheath **14** to a core **10**, the latter consisting of a center conductor **11** (FIGURES 5 and 6), surrounded by electrical insulation **13**. This core is made in accordance with conventional practice by preheating the conductor **11** and extruding the insulation **13** over the heated conductor; these steps being illustrated at the right of the flow diagram shown in FIGURE 1.

The electrical insulation **13** bonds firmly to the conductor **11** because of the extrusion over the hot surface of the conductor. Where there has been relative movement of the center conductor and the sheath of a coaxial cable, as a result of differences in thermal expansion, the slippage has occurred between the outer sheath and the insulation **13** rather than between the center conductor **11** and the insulation **13**.

Referring to FIGURE 2, the insulated core **10** is fed to a forming station **12** where the metal sheath **14** is progressively formed into a tube around the core **10**. As the metal sheath **14** approaches the forming station **12**, it is subjected to a roughening operation. In the apparatus shown in FIGURE 2, the sheath **14** passes through a sand blast chamber **15**; but it will be understood that this sand blast chamber is merely illustrative of the preferred embodiment and in the broader aspects of the invention, is merely representative of means for treating the surface of the sheath **14** to increase its coefficient of static friction on the insulation that surrounds the core **10**. The surface which forms the outside of the sheath may be roughened also in the chamber **15**, the purpose of which will be explained. The forming of the metal sheath **14** is done in a forming die **16** which is merely representative of means for bending a flat strip into a tube with a longitudinal seam, preferably a butt seam.

The electrical insulation on the core **10** is preferably a plastic foam such as polyethylene, having a percent of air of about 45 to 55. These values are given by way of illustration. For any particular cable, the plastic foam is maintained substantially uniform in composition and diameter along the entire length of the cable since variations in the density of the foam, or other physical characteristics, affect the electrical characteristics of the cable. Any variations in the original diameter of the insulation produce resulting variations in the squeezing of the insulation by the sheath in the final cable.

The outside diameter of the insulation on the core **10** depends upon the diameter of the conductor **11** (FIGURES 5 and 6) and is preferably at least one and one half times as great as the diameter of the conductor. The radial thickness of the insulation **13** is preferably within a tolerance of 0.002 inch throughout the length of the cable for cores of less than ½″ in diameter, and the tolerance is somewhat greater for larger diameter cores.

The cable consisting of the conductor core **10** surrounded by the formed metal sheath is indicated by the reference character **25**. The formed sheath or tube, designated by the reference character **14′**, is of an inside diameter substantially larger than the outside diameter of the core **10**. The seam of the sheath is indicated by the reference character **28** and this seam is spaced from the insulation **13** so that the seam can be welded without having the welding heat damage the insulation **13**.

Beyond the forming die **16**, the cable **25** travels through a roll stand **30** at a welding station **32**. There is a torch **34** at the welding station in position to weld the seam **28** as the cable travels from the roll stand **30** to another roll stand **36**, spaced closely behind the roll stand **30** and the torch **34** at the welding station **32**.

Immediately beyond the roll stand **36**, there is a sizing station **40** which includes a bell or sinking die **42**, carried by a supporting frame **44**; and there is a pipe **46** immediately in front of the die **42** for pouring lubricant over the outside surface of the sheath **14′**.

The sizing and sinking step is performed by the single stationary die **42** in the illustrated apparatus, but can be done by successive dies.

An advantage of having the forming and welding station close to the sizing station is that the core **10** moves faster than the sheath **14′** before the tube has passed through the sinking die **42**. This is because the core **10** advances at the same speed as the reduced-diameter portion of the sheath beyond the sinking die and because of the elongation of the tube in the die **42**, the lineal speed of the sheath ahead of the die **42** is less than that beyond the die. The tube or sheath beyond the sinking die **42** is indicated by the reference character **14*a***.

At regions where the core **10** and the sheath tube **14′** move at different speeds, there is friction between the contacting surfaces of the core **10** and the sheath tube **14′**. This friction contact is against certain areas of the core and not against the upper areas where there is clearance between the conductor core and the tube. It is, therefore, desirable to reduce to a minimum the travel of the conductor core while in contact with the tube and while moving at a different speed from the tube so as to avoid wear, and especially uneven wear, around the circumference of the insulation. This is particularly true of the present invention, which has a rough surface on the sheath in contact with the core.

The reduction in the diameter of the tube or sheath **14′** in the sinking die **42** is preferably between about 5% and 40%; the amount of reduction depending upon the original width of the metal sheath **14**, as compared to the circumference of the core **10**. It is desirable that the tube or sheath **14′** be reduced in diameter sufficiently to contact with the core **10** around the entire circumference of the core and to impart some squeeze to the insulation on the core **10** so as to provide friction between the sheath and the insulation.

The wall thickness of the sheath is not reduced by its passage through the sinking die **42** and the effect of the die is merely to lengthen the tube as the diameter reduces. This is a "sinking" operation, as distinguished from a "drawing" process, which would reduce the sheath thickness as well as its diameter. It is, of course, necessary to use a metal strip for the sheath which has a composition and temper that will elongate in the sinking die **42** in the manner required by the method of this invention, but such sinking operations on tubes are well understood by those skilled in the art.

If the sheath **14** is made from a fully annealed aluminum strip of electrical conductive grade, the working of the metal in the sinking die **42** results in a harder tube, up to medium or half hard, depending upon the diameter reduction.

The effect of squeezing of the insulation on the core **10** by the reduced-diameter sheath is critical with respect to the electrical properties of the insulation. Excessively squeezing cores produce poor SRL (structural return loss) values which drop sharply with increase in squeeze. The squeeze for a core of approximately one half inch in diameter, with a .098 inch conductor, should not be more than about 15 mils.

The squeeze also affects the impedance value of the insulation. Greater squeezing results in lower impedance, and lesser squeezing results in higher impedance. To obtain the desired electrical properties, therefore, the cable core must be properly designed in accordance with the intended reduction in diameter of the sheath after welding and with a range of squeeze between about 5 and 15 mils. Minimum SRL is 26 db, and preferably about 32 db for 8 to 220 megacycles.

A more highly squeezed core has more resistance to slippage of a sheath on the insulation and can, therefore, transmit more axial force to the insulation; but this invention obtains the same result with lighter squeeze by providing the rough surface on the inside of the sheath so that the greater axial force can be transmitted from the sheath to the insulation without impairing the electrical properties of the insulation by resorting to higher squeeze.

A capstan **50** pulls the cable **14*a*** with sufficient force to advance the welded sheath continuously through the sinking die **42** at uniform speed. The capstan **50** includes two drums **52** and **54** mounted for rotation about parallel axles **56** carried by a fixed frame **57**. The drums **52** and **54** preferably have suitable grooves for receiving the cable **14*a***, and the drums **52** and **54** are driven by power with any conventional capstan drive. A pull is exerted on the cable **14*a***, where it comes off the capstan, as indicated by the arrow **60**, so as to keep the convolutions of the cable **14*a*** tight on the drums.

Because of the substantial length of the cable **14*a*** on the drums **52** and **54**, and the angle of wrap of the cable around the drums, a substantial friction is developed which advances the cable with uniform speed and without slippage on the drums **52** and **54**, even though the outside of the cable remains coated with lubricant from the lubricant supply pipe **46**.

Other means for advancing the cable through the sinking die **42** can be used and the capstan illustrated is representative of means for advancing the cable without putting any periodic dents or other imperfections in the sheath such as are sometimes formed by grippers. Any periodic variations in the sheath diameter, even though of small degree, are objectionable for coaxial cable because they produce internal reflections and standing waves which impair the transmission of television signals by the coaxial cable.

FIGURE 6 illustrates the principle of operation of this invention when the outer sheath **14***a* is subjected to heat, as from heat rays **74**. These heat rays **74** strike the outer sheath **14***a* and cause longitudinal expansion of the sheath in an axial direction, as indicated by the arrows **76**.

Because of the pressure of the sheath **14***a* against the insulation **13**, as indicated by the arrows **78**, friction is present along the entire area of contact of the sheath **14***a* with the circumference of the insulation **13**. This friction causes the axial movement of the sheath **14***a* to be transmitted to the insulation **13** so that the insulation moves axially with the sheath **14***a*, as indicated by the arrows **80**.

If the total squeeze of the sheath against the confronting area of the insulation is "C" pounds, then the longitudinal force "F" that can be transmitted to the insulation and to the conductor **11** equals C (coefficient of friction) pounds and this must be greater than the force required to stretch the center conductor **11**. Cable made by this invention slips in the sheath more easily in one direction than the other. The coefficient of static friction considered must always be that in the direction least resistant to slip.

Since the insulation **13** is firmly bonded to the center conductor **11**, the movement of the insulation, as indicated by the arrows **11**, is transmitted to the conductor **11** and results in an expansion or stretching of the conductor **11** corresponding to the axial movement of the sheath **14***a*, this axial movement of the conductor **11** being indicated by the arrows **82**.

From the above description, it will be apparent that thermal expansion of the sheath **14***a*, resulting from external heating by the heat rays **74**, produces a motion which is transmitted through the insulation **13** to the conductor **11**, even though the conductor **11** is insulated from the heat by the insulation **13**. The actual elongation of the conductor **11**, as compared to that of the sheath **14***a*, can be described as being substantially the same, though actually there is some lost motion in the insulation **13**. However, the amount of lost motion is small because of the fact that the force transmitted from the sheath to the center conductor is distributed through the entire cross section of the insulation **13** and is also distributed along the length of the insulation **13**.

From the above description, it will be apparent that the cable expands as a substantially homogeneous mass when subjected to heat from an outside source; and it will also be apparent that the coefficient of friction of the sheath **14***a* on the circumference of the insulation **13**, must be high enough so that with only moderate squeeze of the insulation by the sheath, there is sufficient force to stretch the conductor **11**. This stretching of the conductor **11** may stretch the conductor beyond its elastic limit so that when the sheath **14***a* cools and contracts, the conductor **11** may have a somewhat wavy contour; and on subsequent expansions and elongations of the sheath, the center conductor will pull taut without undergoing subsequent permanent stretching.

The invention is applicable to popular sizes of coaxial cable. It will be evident that large sizes of cable having center conductors of large cross section could not be stretched by forces which could be transmitted through the insulation surrounding the center conductor. Also, the friction between the sheath and the core insulation could not be made high enough, without excessive squeezes of the insulation to transmit axial forces sufficient to stretch center conductors of heavy cross section.

Coaxials are commonly made with copper conductors and aluminum sheaths. This invention is especially valuable for such combinations of metal because the coefficient of lineal expansion of aluminum is 24×10^{-6} whereas that of copper is 14×10^{-6}. Even though the heating of the cable is so rapid that substantially no heat reaches the inner conductor, there is still a substantial differential

expansion between the sheath and the center conductor when the former is made of aluminum, and the latter is made of copper. This invention prevents such differential expansion which often results in the conductor pulling out of its connectors. Other combinations of metal can be used. The center conductor and sheath can both be made of aluminum or the center conductor made of aluminum with copper coating; or the sheath can be made of copper; and materials other than aluminum and copper can be used, though usually they are no commercially practical.

The electrical insulation described herein is a foam insulation but the invention is not limited to foam insulation. It can be used with solid insulation or with semi-solid insulation other than foam, for example: with disc or helix insulation.

Although sand blasting is a preferred step for roughening the surface of the sheath with a random roughening, it is merely representative of the step of roughening the surface insofar as the broader aspects of the invention are concerned. Where sand blasting is used, good results have been obtained by blasting aluminum strip with 80 mesh alumina at 40 pounds air pressure. When the sheath is blasted to roughen one surface, it can be blasted on both surfaces at the same time and this has an advantage if the coaxial cable is to have a jacket extruded over the sheath. The jacket adheres more tenaciously to the roughened surface. Other methods of houghening the surface include chemical treatment, electrochemical treatments, wire brushing, or the use of rolls having rough surfaces; but this latter method involves the hazard of periodic geometric changes in the sheath as compared to the random roughening which is obtained with a sand blast.

Other changes and modifications can be made and some features can be used in different combinations without departing from the invention as defined in the claims.

What is claimed is:

1. A coaxial cable comprising a center conductor, insulation surrounding the conductor, an outer metal sheath formed of a strip curved to surround the insulation and said sheath being of substantially uniform cross-sectional periphery throughout its length, the inside surface of the sheath being roughened and the sheath maintaining some pressure on the insulation continuously along the length of the insulation so as to provide friction between the insulation and the sheath, the roughened surface having a coefficient of static friction between the sheath and the insulation that transmits the motion of longitudinal thermal expansion of the sheath to the insulation, the insulation being of sufficient shear strength with respect to the elasticity and cross section of the center conductor to transmit the motion of longitudinal expansion of the sheath to the center conductor to lengthen said conductor in accordance with changes in the length of the sheath when the sheath is heated to a higher temperature than the conductor.

2. The coaxial cable described in claim **1** characterized by the squeeze of the insulation between the sheath being correlated with the coefficient of static friction of the sheath and the insulation, and with the elasticity of the center conductor, so that the product of the squeeze times said coefficient of static friction is greater than the force required to stretch the conductor axially in response to any axial elongation of the sheath.

3. The coaxial cable described in claim **2** characterized by the product of the squeeze times said coefficient of static friction being greater than the product of the cross section of the conductor time the elastic limit of the conductor.

4. The coaxial cable described in claim **1** characterized by the insulation being a plastic foam insulation that is bonded to the conductor and held in the sheath merely by the friction grip of the sheath on the insulation, the inside surface of the sheath being roughened with a random roughening.

5. The coaxial cable described in claim **4** characterized by the squeeze of the foam insulation by the sheath being less than approximately 3.76%.

6. The coaxial cable described in claim **1** characterized by the cable having a sheath that withstands less axial pull in one direction than the other before slipping on the insulation, and the coefficient of static friction that transmits the motion to the conductor being the coefficient of friction in the direction in which the sheath has the lower resistance to slippage on the insulation.

7. The coaxial cable described in claim **1** characterized by the sheath being roughened on both its inside and outside surfaces, and closed by a longitudinal welded seam with a tube wall reduced in diameter by sinking.

8. The coaxial cable described in claim **1** characterized by the sheath being made of material having a coefficient of linear thermal expansion which is substantially higher than that of center conductor.

9. The coaxial cable described in claim **8** characterized by the sheath being made of aluminum and a center conductor being made of copper.

10. The method of making a coaxial cable which comprises applying and bonding electrical insulation to a center conductor, treating at least one surface of a metal strip to roughen the surface, applying the strip lengthwise to the insulation, forming the strip progressively around the insulation as a tube having an inside diameter greater than the outside diameter of the insulation, securing the opposite edges of the tube together as a longitudinal seam, pulling the tube through a sinking die that reduces the diameter of the tube to squeeze the insulation and exert some pressure on said insulation, the shear strength of the insulation being correlated with the elasticity and cross section of the center conductor, and the squeeze being correlated with the coefficient of static friction of the roughened surface on the insulation, to transmit thermal elongation of the sheath through the insulation to the center conductor.

11. The method of making a coaxial cable as described in claim **10** characterized by the strip being sand blasted to roughen it, and the sheath being welded to close the seam.

12. The method of making coaxial cable as described in claim **11** characterized by the conductor being preheated and the insulation being extruded over the preheated conductor to bond the insulation to the conductor, the sheet being roughened on both sides, and extruding a plastic jacket over the outside surface of the sheath and bonding the plastic jacket to the sheath.

References Cited

UNITED STATES PATENTS

1,756,319	4/1930	Wentz	174—128 X
3,031,523	4/1962	Howard	174—107 X
3,173,990	3/1965	Lamons	174—102

OTHER REFERENCES

Croft: Aluminum Sheathed Cables in Wire and Wire Products, July 1953, pp. 682–687.

German printed application No. 1,029,896, Siemens, May 14, 1958.

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