United States Patent [19]

Davis

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[45] **June 12, 1973**

[54] **CONTINUOUS MANUFACTURE OF SHIELDED CONDUCTORS**

[75] Inventor: **Bayard C. Davis,** Lombard, Ill.

[73] Assignee: **Sensor Dynamics, Inc.,** Addison, Ill.

[22] Filed: **July 13, 1970**

[21] Appl. No.: **54,405**

[52] **U.S. Cl.** **29/624,** 29/613, 156/49, 156/55, 174/102.5

[51] **Int. Cl.** **H01b 13/26**

[58] **Field of Search** ..... 156/49, 50, 55; 29/624, 613; 18/13 A, 11; 124/9, 15; 264/47, 43, 61, 63; 174/102.5

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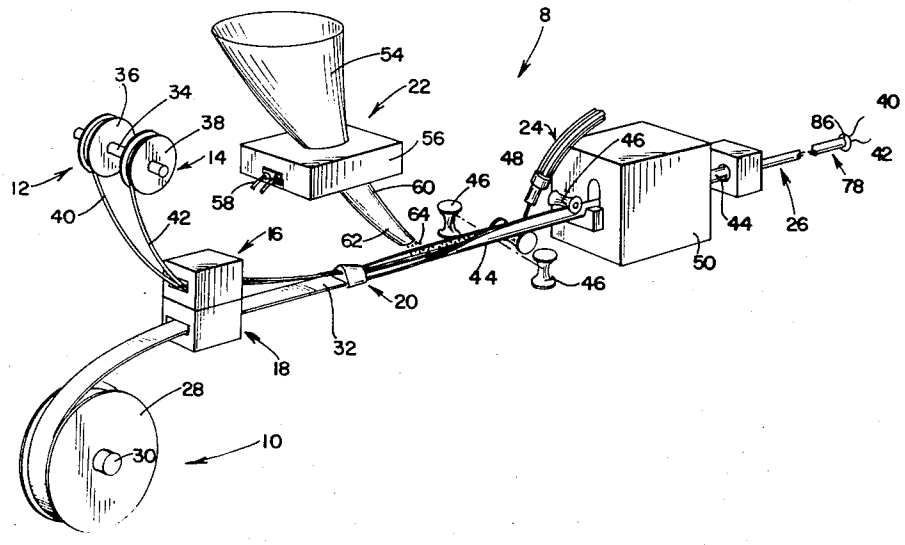
Primary Examiner—Charles W. Lanham
Assistant Examiner—Joseph A. Walkowski
Attorney—Alter, Weiss & Whitesel

[57] **ABSTRACT**

A method of making continuous lengths of a shielded electrical conductor having a rigid exterior sheath and at least one conductor element held in place therein and surrounded by finely divided and compacted electrical insulation. A supply of metal strip material is continuously removed from a storage roll, and cleaned and positioned by a guide so that, as the strip is formed into a tube, the tube will surround one or more wires or conductive elements which are simultaneously being removed from a storage roll, cleaned, and positioned within the tube being formed by another portion of the guide. During one stage of the tube formation, the insulating material is cleaned and deposited continuously on the strip material from which the tube is being formed, so that the tube will enclose the insulation, and the insulation will in turn aid in positioning the wire within the tube. After formation of the shielded conductor in this manner, the entire conductor is reduced in diameter to compact further the insulation. The formed lengths may thereafter be cut to desired lengths for use as shielded cable, electrical resistance heating elements or thermocouples for temperature detection.

Interior tube cleanliness is critical in shielded conductors; the method of the invention enables cleaning to be made more effective and consistent, and to be greatly simplified, and also permits high quality shielded conductors of virtually unlimited length to be made at low cost.

11 Claims, 5 Drawing Figures



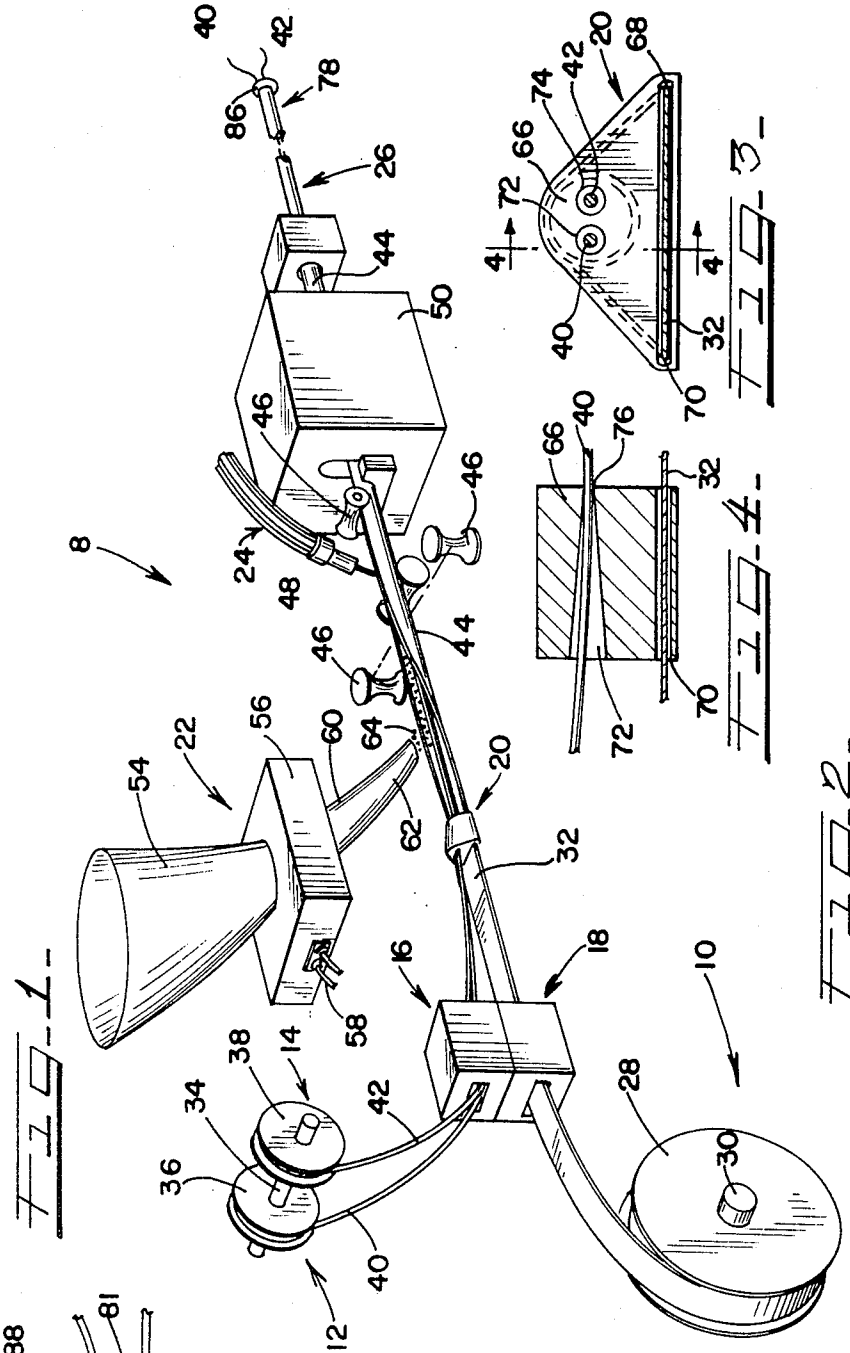


FIG-1-

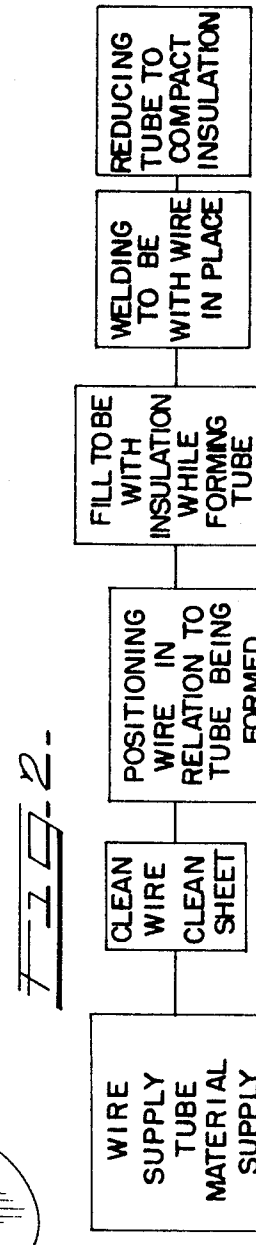


FIG-2-

FIG-3-

FIG-4-

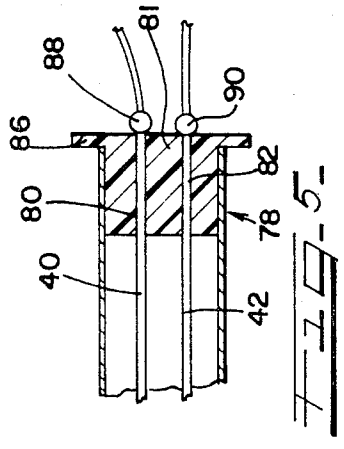


FIG-5-

INVENTOR
BAYARD C. DAVIS
BY Strist, Lockwood, Greenawalt & Dewey
ATT'YS.

CONTINUOUS MANUFACTURE OF SHIELDED CONDUCTORS

BACKGROUND OF THE INVENTION

Shielded conductors of the type with which the present invention is concerned have a number of important industrial and commercial uses.

For example, a thermocouple hot junction may be formed by joining together the adjacent ends of two extremely long electrical conductors sheathed within a continuous tube or shield and electrically insulated from each other and from the sheath.

The use of such thermocouples in the form of long probes for temperature detection in inaccessible regions is well known, and, because of their inherent simplicity and reliability, such thermocouples are very commonly used in a wide variety of industrial applications, including steel making installations, oil refineries, and even nuclear reactors and the like. Shielded conductors are also commonly used as electrical resistance heating elements and the like, and as sheathed cable for other applications.

However, in spite of the relatively large volume of shielded conductors made today, methods or processes commonly used for forming metal sheathed, metallic oxide insulated conductors have made the cost of these units very high in relation to their essentially simple nature. One reason for this high cost is the common essential requirement of satisfactory shielded conductors that highly reliable electrical insulation be provided, since, in the case of thermocouples, for example, short circuits cause faulty readings and/or a total lack of available voltage or current from which readings may be taken. In the case of heating elements, wherein large currents and significant voltage differences are present, short circuits create the possibility of electrical shock, fire, and other hazards.

One common prior art method of forming metal sheathed, metallic oxided insulated conductors and the like includes the steps of inserting wires or like conductors through axially extending openings in preformed, generally cylindrical oxide pallets, and inserting the wires and pellets as a unit into a carefully cleaned, previously formed tube, and then reducing the diameter of the tube to compact the oxide around the wires to insulate them electrically and position them in a desired, spaced apart relation from each other and from the sheath formed by the tube. In such an operation, the axial openings in the pellets would be several thousandths of an inch larger than the diameter of the wires, and the oxide pellets, which were customarily formed in one to six inch lengths, had an outside diameter which was a few thousandths smaller than the inside diameter of the tube so that the pellets could be inserted into the tube without difficulty. In this method, manufacture of substantial lengths of shielded conductor involve "stringing" the wire or other conductor through a long succession of pellets, and then inserting there pellets in succession into the preformed and precleaned tube.

A similar method is commonly used for making shielded conductors having only a single wire or other conductor, such a wire being normally centrally disposed within the pellet for best insulation value by reason of maximum spacing from the tubular sheath.

Another method which is commonly used to manufacture shielded conductors and the like is to provide

a given length of tube and to position it vertically within a vibratory holder, and thereafter insert one or more wires or other conductors vertically therein in spaced apart relation to the tube. With the wires thus disposed, the tube is then filled with a very fine mesh metallic oxide powder, and vibrated so as to cause the powder to be compacted in place within the tube, thereby insulating the metal wires from each other and from the exterior metal sheath of the unit. This technique is quite commonly used in the preparation of electrical resistance heating elements. After the powder has been compacted around the wires or other conductors or wires, the tube may be further reduced, as by a drawing operation, and the oxide may be thereafter baked at a high temperature, typically 1,800° F. or more.

All of the above described methods have the common characteristic of utilizing a preformed cylindrical tube and a fine mesh powder or like oxide insulating material. Since the tube is ordinarily made by drawing, and since the tubing, after manufacture, is shipped and stored in the location where it will be formed into thermocouple stock or heating elements, for example, it is common for the interior of the tubing to have a residue of drawing oil or the like on the interior thereof, or to be contaminated with any other type of dirt to which it is exposed by reason of manufacture, transportation, storage, and handling.

As a consequence of the above, and since it is recognized that the presence of even the smallest amounts of contaminants may create so-called high resistance short circuits in the thermocouple stock or shielded cable, it has been found necessary in the shielded conductor industry to place great emphasis on cleaning of the interior of the tube immediately prior to manufacture of the composite element such as the shielded cable or thermocouple stock.

In those methods wherein the oxide pellets or cylinders are used, it is common to manufacture these pellets by wet mixing and extruding the material through a spider die. Extrusion produces a self-sustaining, highly viscous material of a consistency somewhat like that of a wet noodle; this material is then commonly cut into approximately 12 inch lengths and baked or fired while held in the "V" groove of an appropriate ceramic processing tray.

The material is then raised to a temperature which permits the pellet to attain a self-sustaining shape and become rigid enough to avoid being damaged during handling, while still being soft enough to permit the subsequent crushing and compacting which occurs when the exterior sheath is reduced in diameter. Normally, each one foot length of pellet material is further cut into pieces of a three inch or less length, with these individual pieces being examined for correct dimensions, including the size of the opening therein, the outside diameter, roundness and location of the openings.

In the event that during this handling, the oxide has picked up impurities, even in trace amounts such as the salt in sweat from human hands, the resulting heat treatment will fuse the sodium chloride into a form which will produce a high resistance short circuit path within the finished assembly. In other words, even the minute amount of salt present in the sweat which might be present on the hands of a worker is extremely undesirable, and creates a condition which must be carefully guarded against if a proper quality shielded conductor material is to be produced. As a result of the need for

cleanliness both during handling of the pellet material and manufacture of the final product from the tubing, the cost of the thermocouple stock, cable, or heating rod assembly is very great in relation to the cost of raw materials used to manufacture it.

Furthermore, in those cases where pellet manufacture does not comprise a step of the process, the length of tubing which may be made satisfactorily is severely limited because practical considerations place a limit of 18 to 25 feet on the length of stock which can be manufactured.

Another disadvantage of prior art systems which are capable of making substantial lengths of material, namely, the methods which use the pellets, is that manufacturers using this method must maintain a very large inventory of pellet material since a great number of different sizes of stock are commonly used. It is not uncommon, in fact, for a manufacturer to have an inventory of 200 different sizes and shapes of pellets within his inventory. The method used in cleaning the tubing itself also tends to place a limit on the maximum length of cable or other stock which can be manufactured, even using the pellet method. Since these cleaning methods commonly include successive cleaning steps with patches in the manner of cleaning a rifle bore, or involve blowing cotton wadding through the tube by pneumatic force, the use of specially prepared cleaning solutions, sand blasting, and the like, it can be appreciated that the expense of cleaning this tube is considerable in relation to the cost of the raw materials themselves.

It is also clear that the wires themselves must be carefully cleaned just prior to assembly, and that they may not thereafter be touched by human hands or other contaminated instrumentalities before being placed in the tubing.

As a result of the foregoing drawbacks and disadvantages of prior art methods for making shielded conductors such as thermocouple probes, resistance heating elements, and metal sheathed insulated cable, it is an object of the invention to provide an improved method of manufacturing shielded conductors.

Another object is to provide a method of making shielded conductors which is characterized by extremely low cost of manufacture.

Another object is the provision of a method which is not inherently limited as to the length of conductor able to be made thereby.

A still further object is the provision of a method for making shielded conductors which makes it possible to achieve superior cleanliness of components at reduced cost in comparison to prior art methods of making sufficiently clean conductors.

A further object is the provision of a method wherein the manufacturer's requirements of component inventory may be greatly reduced, and may be limited to bulk quantities of oxide powder, strip stock, and conductor elements.

A still further object is the provision of a method of making insulated conductors in which the number of operations is minimized in relation to prior art operations.

Still another object is the provision of a method which inherently produces a high quality shielded conductor of increased freedom from the possibility of high resistance short circuits and other failures and malfunctions.

A further object is the provision of a continuous manufacturing method for shielded conductors wherein one or more wire conductors are held in tension in a fixed relationship to a tube which is continuously being formed from flat stock in a desired location around the conductors after insulating material is placed within the tube being formed.

Another object is the provision of a method wherein a large, continuous supply of sheath stock is continuously cleaned while in a flat condition and is shortly thereafter formed into a tubular shape for welding so as to enclose one or more wires or like conductors disposed therein.

Another object is the provision of a method wherein wire conductors to be enclosed within a shielded conductor or cable may be cleaned immediately prior to their incorporation into the finished product.

The exact manner in which these objects, and other inherent objects and advantages of the invention are achieved will become more clear when reference is made to the accompanying detailed description of the preferred embodiments of the invention and to the accompanying drawings, in which like reference numerals indicate corresponding parts throughout.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view, partly diagrammatic, showing an apparatus which is adapted to perform the method of the invention, and including means for forming a tubular sheath, positioning conductors therein, depositing an insulating material therein prior to the time the tube is completely formed, and for reducing the diameter of the finally formed insulated conductor;

FIG. 2 is a block diagram showing the principal steps of the method of the invention;

FIG. 3 is an axial view, taken generally along lines 3—3, showing the guide means for positioning the wire conductors and the flat stock prior to tube formation;

FIG. 4 is a vertical sectional view of the guide of FIG. 3, taken along lines 4—4 thereof; and

FIG. 5 is a vertical sectional view showing the means for initially positioning the conductors within the tube.

DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

Before referring in detail to the description of the preferred method of the invention, the apparatus for carrying out the method and the characteristics of the shielded conductor produced thereby, it will be understood that only illustrative embodiments are intended to be shown for making the types of shielded conductors shown, and that the method of the invention may be equally suitable for performing other processes and making other articles whose general steps or characteristics, respectively, are similar to the method steps and articles resulting from operation thereof. Further, it will be appreciated that although numerous variations of the form of apparatus described may be used in practicing the invention, and that the process and resulting products need not be made in or be characterized by orientation along any particular axis or direction, and therefore, direction or orientation indicating words used in describing or claiming the method, apparatus and resulting products are not to be taken as indicating novel features or limitations of the invention per se.

Referring now to the drawings in greater detail, FIG. 1 shown an apparatus 8 which is useful in carrying out

the method of the invention, and, in particular, includes a number of elements or subassemblies, including means **10** for supplying a continuous strip of a flat metal material, means **12** and **14** for continuously supplying first and second electrical conductor elements, a wire or other conductor cleaning apparatus **16**, a flat strip cleaning apparatus **18**, and means **20** for positioning the strip and conductors in a manner to be described in further detail herein. The apparatus **8** also includes means **22** for continuously supplying finely subdivided insulating material to the strip as it is being formed into a tube, means **24** for forming a tube from the strip, and means **26** for reducing the diameter of the tube thus formed and thereby compacting the electrical insulation therein.

Referring again to FIG. **1**, it will be seen that the strip supply means is in the form of a roll **28** which is rotatable about an axis defined by the axle **30**, and which contains a continuous length of a metal strip material **32** to which further reference will be made later. The strip cleaner **18**, which is shown in diagrammatic form in a preferred form of the invention, is preferably an ultrasonic cleaner of a known type. While the exact construction of such cleaner does not form a novel part of the invention per se, and may be of any construction suitable to accomplish the result of cleaning and drying the strip of material **32**, one preferred form of such unit has plural guide rollers and one or more solvent or other cleaning baths through which ultrasonic energy is communicated to the strip for cleaning the same. Ordinarily, the cleaner **18** also includes means for rinsing and drying the strip material **32**. After emerging from the cleaner **18**, the strip material passes through the positioning assembly **20** in a manner to be set forth in further detail herein.

Assuming, for example, that the shielded conductor to be manufactured will be a length of tubing having a pair of conductors in the form of two wires, held in insulated relation to each other and to the tube, and joined at their ends to form a thermocouple hot junction, the means **12** and **14** for supplying the conductors will be in the form of reels **36, 38**, rotatably positioned on a common axis by means of an axle **34**, with each reel **36, 38** having a supply of wire **40, 42** or like electrical conductor thereon. Preferably, the cleaner **16** for the wires **40, 42** is a unit similar to the ultrasonic cleaning apparatus **18** used for the strip **32**, that is, it may include one or more cleaners or solvents in liquid form disposed in tanks through which the wires **40, 42** are passed while the solution within the cleaner **16** is being agitated by the application thereto of ultrasonic energy such as by an electromechanical transducer in a manner well known in the art.

In the use of the apparatus **8**, the strip **32** and the wires **40, 42** simultaneously emerge from the ultrasonic cleaning units **18, 16** respectively, and enter the positioning or guiding means **20**, which serves to position the strip **32** for subsequent passage between opposed sets of hourglass rollers **46** which are positioned radially and axially of the strip **32** so as to form it into a tube **44**; the guiding means **20** also serves to position the wires **40, 42** so that they are disposed generally centrally of the tube **44** being formed. In this manner, the wires **40, 42** will be generally disposed centrally of, but still spaced apart from the walls of the tube **44**, as well as spaced apart from each other. Referring now to another element of the invention, namely, the means **22** for supplying a quantity of insulating material to the tube **44** while it is being formed, this unit **22** will be seen to include a hopper **54** having a heating unit **56** associated therewith and electrical cables **58** for supplying power thereto. Powdered insulation passing through the heater **56** is dried, and deposited on the strip **32** from a discharge nozzle **60** having an end portion **62** disposed immediately adjacent the rollers **46** forming the tube **44** from the strip **32**. The hopper **54** includes means (not shown) for controlling the flow or rate of deposition of insulating material **64** on the tube **44** being formed. Further disclosure of such flow control means is believed unnecessary, since such means are well known in and of themselves and do not form a part of the invention which is novel per se.

Referring now to FIGS. **3** and **4**, additional details of the positioning and guiding means **20** are shown. The guide **20** includes a body portion **66** having, in the lower portion thereof, inwardly directed wall portions **68** defining an aligning slot **70** for the passage of the strip **32**, which is to be formed into the configuration of a tube **44** after leaving the guide **20**. Positioned axially generally centrally of the body **66** and hence the tube **44** are a pair of tapered bores **72, 74** each having a forward outlet **76** for guiding wire **40** passing therethrough. In the event a form of shielded conductor other than the form shown herein is desired to be made, the number and disposition of the bores **72, 74** may be suitably altered. Likewise, the dimensions and the position of the slot **70** may be varied according to the thickness of the material to be used and the intended diameter of the tube to be formed therefrom. The guide **20** may be secured in position in relation to the other elements of the apparatus by conventional means (not shown) which permit ready removal and replacement thereof.

Referring now to FIGS. **1** and **5**, the manner in which the process of the invention is first started is somewhat schematically illustrated. Referring to FIG. **1**, and assuming that a tube **44** having two conductors **40, 42** positioned therein is desired to be made, a short length of the strip **32** is fed through the guide **20** and through the rollers **46** so as to be welded into a tube **44**, and the front end portion **78** thereof is then passed a short distance through the reducing die **26**. During this operation, which customarily involves the welding of only a few feet or more of tube **44**, the insulating material **64** is not allowed to flow into the strip **32**. After a short length of tubing **44** is formed, including the forward reduced diameter portion **78** thereof, feeding of the strip **32** is stopped, and the wires **40, 42** are fed through the bores **72, 74** in the body **66** of the guide **20**. Thereafter, the wires **40, 42** are inserted into that portion of the tube **44** which is already formed, and which is free from insulation **64**. These wires **40, 42** are then inserted through passages **80, 82** in a plug **84** placed in the reduced diameter forward end portion **78** of the tube **44** and there held against inward axial movement by reason of the plug shoulder **86**. The wires **40, 42** may be held in place by fasteners **88, 90** to prevent axial movement through the openings **80, 82** in the plug **84**. At this point, the strip **32** may again be advanced through the rollers **46** with the tube forming means **24** including the welder **48** being actuated, and the insulation **64** being fed from the hopper **54** through the end **62** of the nozzle **60**, and onto the strip **32**. It will be appreciated that, assuming that sufficient insulation **64** is placed on

the strip **32** to substantially fill the tube **44**, upon reduction in diameter of the tube **44** in the die **26**, the compaction of the insulation **64** brought about thereby will be sufficient to hold the wires **40, 42** under sufficient tension so as to cooperate with the bores **72, 74** in the guide **20** for maintaining accurate positioning of the wires **40, 42** within the tube **44** during continuous tube formation.

Referring now to the block diagram shown in FIG. **2**, the operation of the apparatus **8** which performs the method of the invention is illustrated. By reference to the diagram, it can be seen that the supply of one or more wires and the supply of tube material are fed to the wire and sheet material guide or positioning means at a controlled rate after being cleaned respectively by associated cleaning units. The tube is thereafter partially formed, during which the insulating material is supplied thereto, and thereafter, the complete tubular shape is imparted to the sheet of material, which is held by the hourglass rolls, as pointed out above, until welding thereof is complete. Thereafter, tube is reduced in diameter and the insulation is compacted by passing the tube containing the insulation and wires through the reducing die **26**.

From the foregoing description, it will be apparent that the length of material formed by this process is theoretically limited only by the amount of materials which may be supplied to the rolls **28, 36, 38** and to the hopper **54**.

One of the number of advantages provided by the present invention is that only a minimum number of sizes of strip material and only a minimum number of sizes of conductors **40, 42** need be kept on hand in the manufacturer's inventory. The insulation material may be purchased and stored in bulk form, and, if chemically pure (C.P.), it need only be dried before being supplied to the strip before the tube **44** is formed. Consequently, the previously used methods and apparatus for manufacturing oxide pellets need not be used, and all prior art steps involved in the manufacture, handling, and inspection thereof may be dispensed with. Because of the continuous nature of manufacture employed by the present invention, excellent uniformity and quality control are attainable. The provision of appropriate cleaning means, such as the ultrasonic cleaners **16** and **18** is a particular advantage of the invention. This is not only because an economical and very thorough and effective cleaning of the strip stock **32** and the wires **40, 42** is made possible, but also, because cleaning with these units takes place immediately prior to manufacture of the shielded conductors, thereby eliminating the problem of possible recontamination of previously cleaned elements of the conductor.

Since there is no practical and economical method of cleaning the interior of substantial lengths of preformed tubing, the use in the present invention of a method enabling the stock from which the tube or sheath is made to be cleaned while it is in the form of a flat strip constitutes a definite advantage of the invention.

Referring now to some of the materials which are preferably used to make shielded conductors according to the invention, assuming that it is desired to make a thermocouple probe of the shielded conductor type, that is, one in which two conductors are joined at one end to form a hot junction and in which the conductors are wires held in an insulated relation from each other and from the sheath which encloses them, the strip material may be a number 304 stainless steel, one of the wire conductors may be an Alumel (aluminum-nickel alloy) wire and the other a Chromel (chromium-nickel alloy) wire. The insulation may be a finely subdivided (200 mesh) chemically pure, anhydrous metallic oxide, such as magnesium oxide. In the event the shielded conductor is intended to be used as a resistance heater, one or more high resistance wires, such as Nichrome (nickel-chromium alloy) wire may be used. Other materials may be used for the conductors, depending on the intended use thereof, such as copper, aluminum, steel, or various alloys. With suitable modifications, a central wire core of a helical form may also be made by the method of the present invention. In the prior art, shielded conductors of this type were made by surrounding a helix of wire with an oxide pellet having a suitably sized central opening therein, placing a suitably sized solid oxide pellet within the helix of wire, then inserting the pellets and wire within the tube, and reducing the tube diameter to crush the oxide pellets and thereby compact the insulation and locate the wire in place within the tube. The method of the present invention also greatly simplifies manufacture of this type of shielded conductor.

It will thus be seen that the present invention provides a novel method for the continuous manufacture of shielded conductors, and in particular, a method having a number of advantages and characteristics, including those pointed out herein and others which are inherent in the invention.

I claim:

1. A method of continuous manufacture of shielded electrical cable suitable for use in hot environments, comprising positioning at least two continuous electrical conductor means spaced apart from each other, advancing said at least two electrical conductor means from a starting position through a given region lying generally forwardly and axially of the starting position while maintaining the spaced apart relationship, simultaneously moving a continuous length of said wire into said region, advancing a continuous strip of flat metal material past tube forming means so as to form a continuous tube therefrom in a position surrounding said given region, while concurrently depositing a sufficient amount of fluent ceramic insulating material on at least a portion of said strip for enclosure thereof within said tube to fill said tube as said tube is formed, and thereafter advancing said tube, said insulation contained therein and said conductors through means for reducing the diameter of said tube and applying tension to said two conductors thereby maintaining the spaced apart conditions to compact said insulation and permanently position said two conductors therein in the spaced apart condition.

2. A method as defined in claim **1** in which said strip material is continuously cleaned immediately prior to deposition thereof of said insulating material.

3. A method as defined in claim **1** in which said conductor means are cleaned immediately prior to being positioned for inclusion within said shielded conductor.

4. A method as defined in claim **1** in which said tube forming means includes a plurality of sets of hourglass rollers and welding means for permanently joining adjacent edges of said flat material together.

5. A method as defined in claim 1 in which said fluent insulating material comprises a finely subdivided metallic oxide material.

6. A method as defined in claim 1 in which said conductor means comprises two electrically conductive wires or differing composition.

7. A method as defined in claim 1 in which said conductor means comprises two wires of differing compositions said wires being adapted, when joined at their adjacent end portions, to form a thermocouple junction.

8. A method as defined in claim 1 in which said flat metal material comprises stainless steel.

9. A method as defined in claim 1 in which said electrical conductor means comprises at least one electrical resistance heating element.

10. A method as defined in claim 2 in which said cleaning is accomplished by application of ultrasonic energy to said strip.

11. A method as defined in claim 3 in which said cleaning is accomplished by application of ultrasonic energy to said conductor means.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,737,997
DATED : June 12, 1973
INVENTOR(S) : BAYARD C. DAVIS

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 8, line 42	Cancel "a continuous length of said wire" insert instead -- said at least two continuous conductor means --
line 43	Cancel "," insert instead -- and --

Signed and Sealed this

Thirtieth Day of *May 1978*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

LUTRELLE F. PARKER
Acting Commissioner of Patents and Trademarks

UNITED STATES PATENT AND TRADEMARK OFFICE

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[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

LUTRELLE F. PARKER
Acting Commissioner of Patents and Trademarks