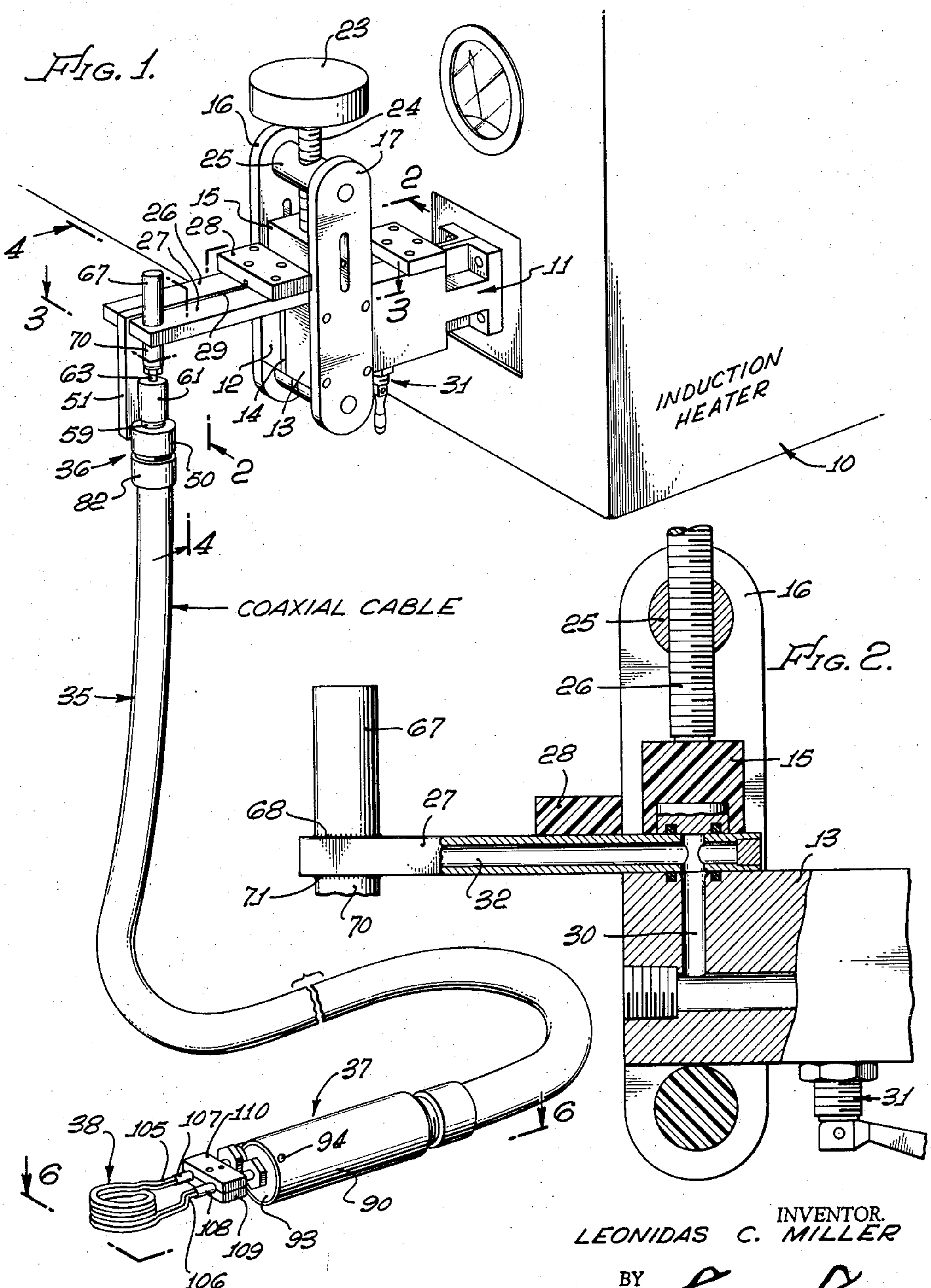
Feb. 20, 1962 L. C. MILLER 3,022,368

COAXIAL CABLE ASSEMBLY

Filed April 22, 1959 4 Sheets-Sheet 1



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COAXIAL CABLE ASSEMBLY

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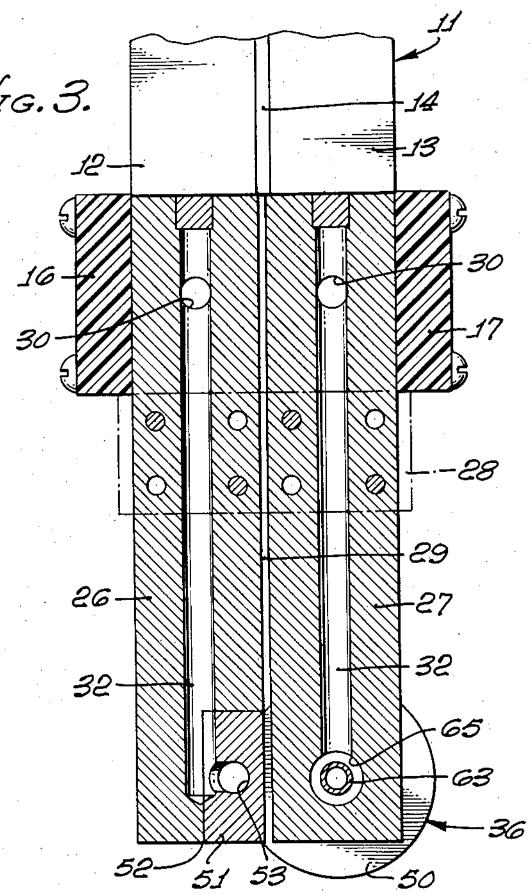

FIG. 3.

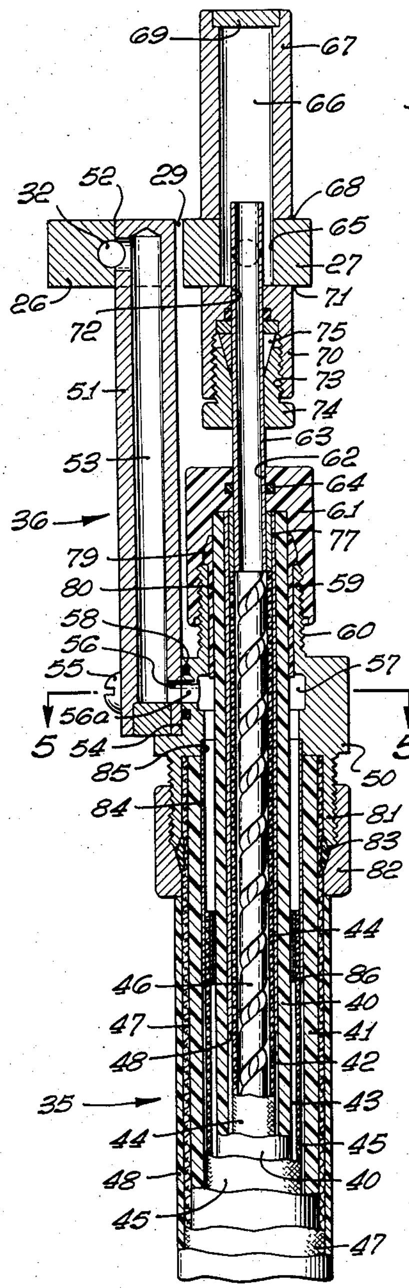

FIG. 4.

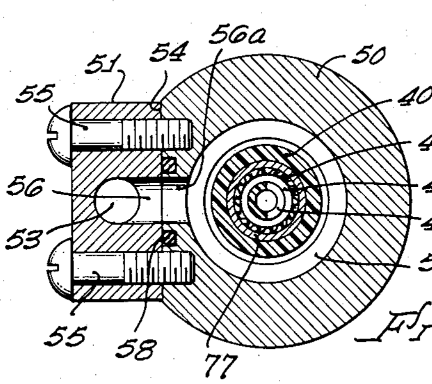

FIG. 5.

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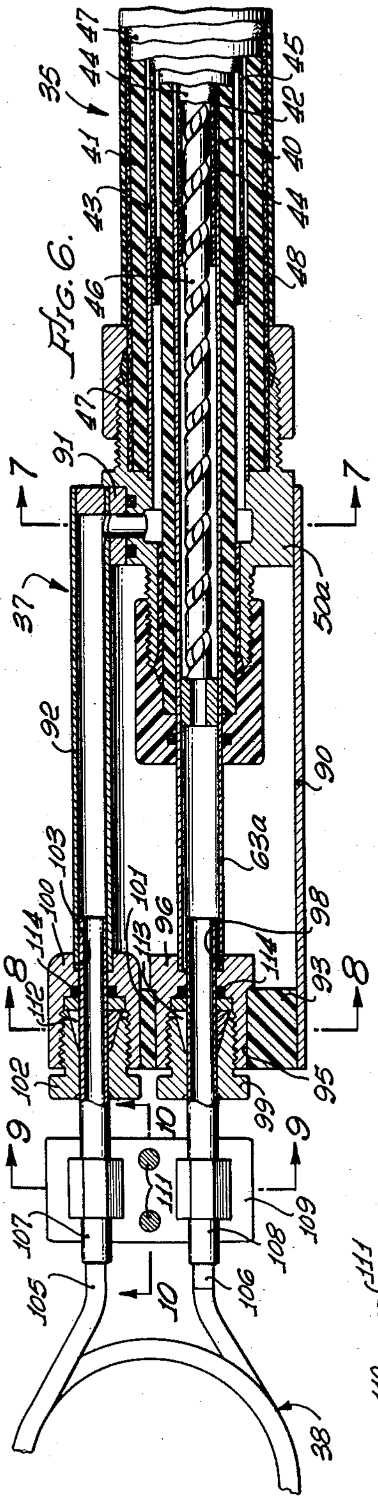

FIG. 6.

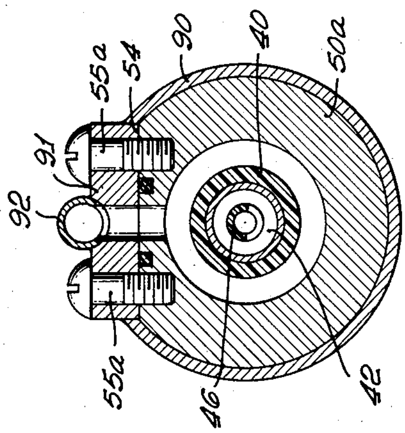

FIG. 7.

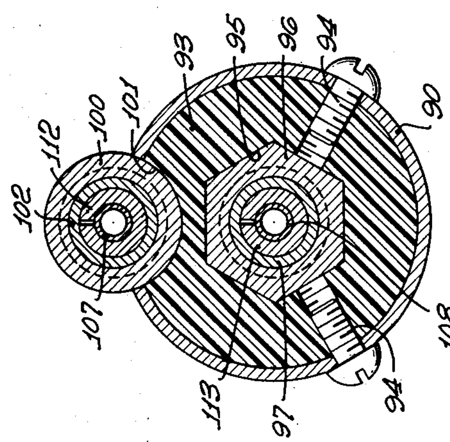

FIG. 8.

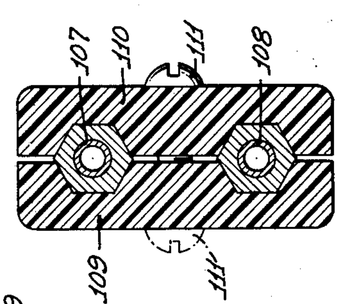

FIG. 9.

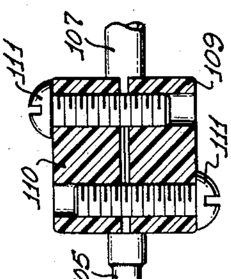

FIG. 10.

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COAXIAL CABLE ASSEMBLY

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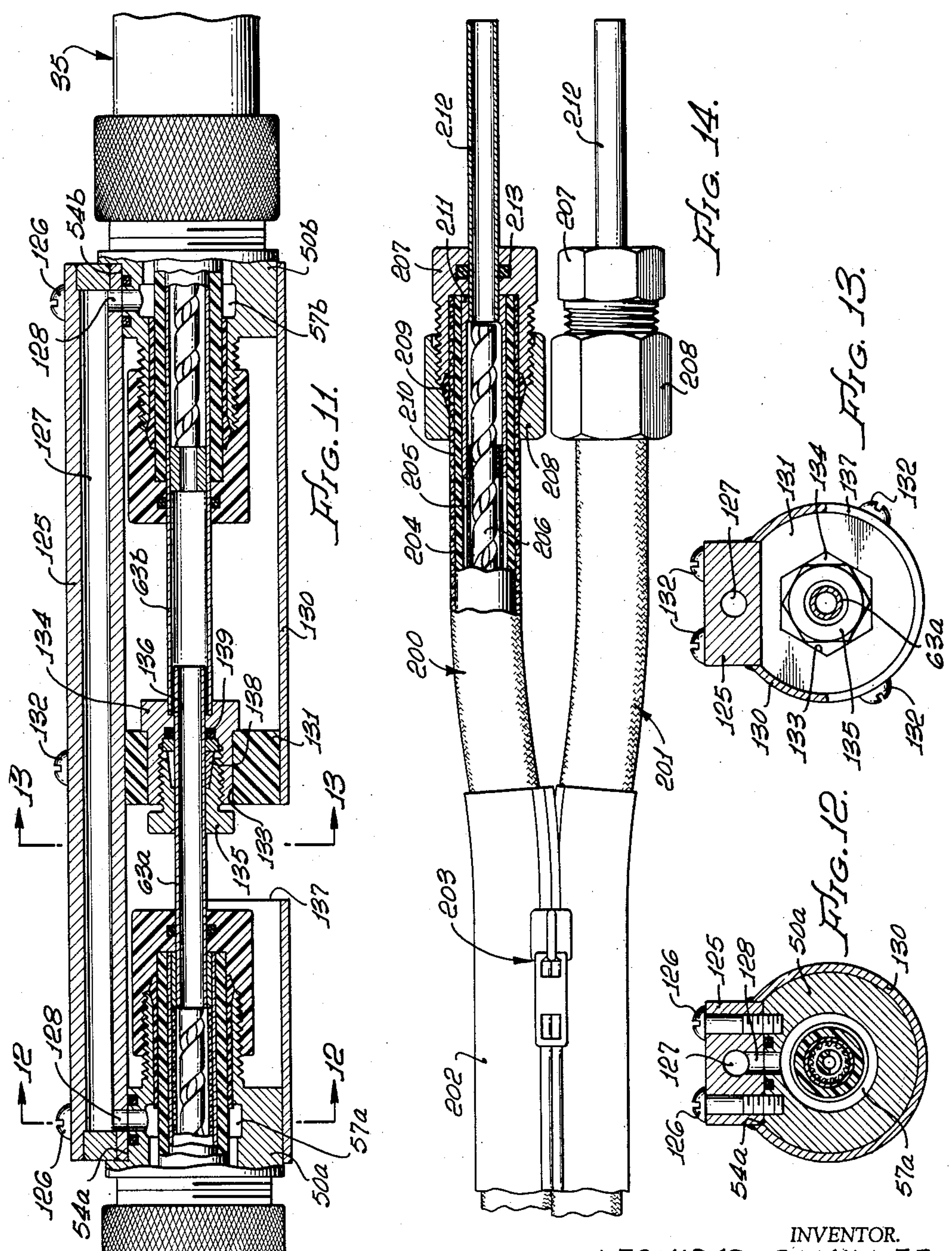

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COAXIAL CABLE ASSEMBLY
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Filed Apr. 22, 1959, Ser. No. 808,201
9 Claims. (Cl. 174—15)

This invention relates to coaxial cables and is particularly directed to a flexible cable assembly for connecting an induction heater to a remote induction heating tool. The cable contains concentric electrical conductors as well as passageways for circulating a coolant through the cable and tool.

Induction heater devices are commonly used with tools of appropriate design for generating heat in a metallic part in a localized zone or zones. Joining of metal parts by induction brazing techniques is an example. Induction heating machines are relatively large and cumbersome and accordingly it is usually necessary to bring the work to the machine. With conventional tooling and attachments it has not been practicable to perform induction heating operations at any location remote from the induction heater machine. Accordingly, it has been necessary to accept penalties in design of certain component parts of present day aircraft because of inability to bring the induction heating machine to a location adjacent the parts to be heated.

The present invention overcomes these shortcomings by providing a flexible coaxial cable capable of carrying substantial amounts of energy for a considerable distance away from the induction heating machine. This makes it possible to form induction brazed connections in aircraft and other assemblies at locations difficult of access.

It is the principal object of the present invention to provide a flexible cable assembly for delivering high frequency electrical energy from an induction heater to a remotely positioned tool. Another object is to provide a flexible cable assembly of this type in which concentric tubular electrical conductors are provided, which conductors are formed of woven metallic material.

Another object is to provide such a coaxial cable assembly in which each electrical conductor is positioned within a coolant passageway defined by concentric tubes formed of insulating material. Another object is to provide a device of this type in which the concentric tubes are impervious to a coolant circulated therethrough and which have high electrical resistance. Another object is to provide a coaxial cable assembly of this type having the characteristic of very low impedance change due to flexure of the cable. Another object is to provide a coaxial cable assembly having novel forms of terminal fittings. Other and more detailed objects and advantages will appear hereinafter.

In the drawings:

FIGURE 1 is a perspective view showing a preferred embodiment of this invention and illustrating a connection to a conventional form of induction heater.

FIGURE 2 is a sectional view partly broken away and taken substantially on the lines 2—2 as shown in FIGURE 1.

FIGURE 3 is a sectional plan view partly broken away and taken substantially on the lines 3—3 as shown in FIGURE 1.

FIGURE 4 is a sectional elevation taken substantially on the lines 4—4 as shown in FIGURE 1.

FIGURE 5 is a transverse sectional view taken substantialy on the lines 5—5 as shown in FIGURE 4.

FIGURE 6 is a longitudinal sectional view taken substantially on the lines 6—6 as shown in FIGURE 1.

FIGURES 7, 8, 9 and 10 are sectional views taken substantially on the lines 7—7, 8—8, 9—9 and 10—10, respectively, as shown on FIGURE 6.

FIGURE 11 is a longitudinal sectional view illustrating details of a detachable connection permitting joinder of lengths of coaxial cable end-to-end.

FIGURES 12 and 13 are transverse sectional views taken substantially on the lines 12—12 and 13—13, respectively, as shown on FIGURE 11.

FIGURE 14 is a plan view partly in section, showing a modification.

Referring to the drawings, the induction heater generally designated 10 is of conventional design and construction and is provided with electrical terminals and coolant circulating pipes which are connected to the terminal clamp assembly generally designated 11. This device is preferably of the form shown in my prior Patent No. 2,866,080. That device includes a pair of metallic body sections 12 and 13 mounted in a parallel back-to-back relationship and separated by a relatively thin insulator 14. A slide block 15 formed of insulating material is guided for longitudinal sliding movement between the upright insulator straps 16 and 17 and is moved vertically by means of the hand wheel 23 and screw 24 which is threaded through the cross bar 25. This slide block 15 serves to clamp laterally spaced parallel metallic bars 26 and 27 against the upper faces of the metallic body sections 12 and 13, respectively. The insulating bumper block 28 is connected to each of the parallel bars 26 and 27 and holds them in a spaced position with an air gap 29 therebetween. The bars 26 and 27 may be withdrawn as a unit laterally from the clamp assembly 11 upon turning of the hand wheel 23 in a direction to raise the clamping block 15.

The metallic body sections 12 and 13 are each provided with coolant passages 30 and the flow of coolant through these passages may be controlled through the shut-off valves 31. Each of the parallel bars 26 and 27 is provided with a coolant passage 32 which registers with one of the coolant passages formed in the metallic body sections 12 and 13. From this description it will be understood that the parallel bars 26 and 27 carry electrical energy from the induction heater 10 and also provide passages for circulating a coolant.

In accordance with my invention, I provide a coaxial cable assembly generally designated 35 having terminal connections 36 and 37 at the opposed ends thereof. The connection 36 includes the parallel bars 26 and 27 adapted to be received within the clamp assembly 11, described above. The terminal connection 37 provides a detachable coupling for the heating tool generally designated 38.

The coaxial cable assembly 35 includes a pair of concentric flexible tubes 40 and 41. Each of these tubes is imperforate and is formed of electrically insulating materials such as, for example, polyethylene, polyvinyl chloride or polytetracloroethylene. The interior of the inner tube 40 provides a passageway 42 for coolant and the annular space 43 between the concentric tubes forms another passageway for coolant. Positioned within the first passageway 42 is the electrical conductor 44 which may be tubular in form and positioned coaxially of the tubes 40 and 41. A second electrical conductor 45 is tubular in form and is positioned with the coolant passageway 43 between the tubes 40 and 41. Each of the electrical conductors 44 and 45 is flexible and is formed of woven metallic material, for example, woven copper strands.

A support member 46 is positioned within the interior of the electrical conductor 42. This support member 46 is formed of electrically insulating material similar to that of the imperforate tubes and preferably comprises a helical member having spaces or gaps between adjacent turns of the helix so that coolant may flow freely between the interior and the exterior thereof. The support member prevents collapse of the electrical conductor 42 upon flexure of the coaxial cable assembly.

A braided sheath 47 of non-conducting material encircles the outer tube 41 and provides reinforcement to prevent enlargement or bursting of the tube under internal pressure of a coolant. A suitable cover 48 of non-conducting materials may enclose the sheath 47.

From this description of the concentric parts of the coaxial cable, it will be understood that a construction is provided which minimizes impedance changes due to flexure of the cable assembly. Moreover, the outer diameter of the inner electrical conductor 42 is close enough to the inner diameter of the outer electrical conductor 45 to minimize electrical losses. In a particular commercial form of the invention it is possible to carry currents of several hundred amperes using water as a coolant. Air may also be used. In this particular device the outside diameter of the cover is slightly more than one inch in diameter. The terminal assembly 36 includes a body 50 connected by means of a vertical post 51 to the horizontal bar 26. The post 51 may be connected to the bar 26 by means of brazing 52 and is provided with a central passage 53 for coolant which connects with the passage 32 in the bar 26. In the particular form of the device shown in the drawings, the post 51 is rectangular in cross section and the lower end thereof contacts a flat surface 54 provided on one side of the body 50. Threaded fastenings 55 secure the post 51 to the body 50. Aligned ports 56 and 56*a* in the post 51 and body 50, respectively, establish communication between the coolant passage 53 in the post 51 and the central cavity 57 within the body 50. An O ring 58 prevents leakage at the joint.

The body 50 is provided with an upstanding annular projection 59 having threads 60 on its outer surface. An electrically non-conducting cap 61 is provided with internal threads which engage the threads 60 and this cap has a central opening 62 through which the metal tube 63 projects. An O ring 64 in the cap 61 prevents leakage. This metal tube 63 projects upward into the opening 65 within the horizontal bar 27 and into the chamber 66 formed within the tubular part 67. This tubular part 67 is fixed to the horizontal bar 27 by brazing 68 and is closed at its upper end by means of the disk 69.

A boss 70 is fixed to the lower surface of the horizontal bar 27 by means of brazing 71 and is provided with a central opening 72 which receives the metal tube 63. The boss 70 is provided with internal threads 73 for reception of the threads of the nut 74. A split metal collet 75 encircles a portion of the metal tube 63 and contacts the outer surface thereof. When the nut 74 is tightened to wedge the collet 75 against the metal tube 63, an electrical connection is achieved between the horizontal bar 27 and the metal tube 63.

The lower end of the metal tube 63 extends into the upper end of the insulating tube 40 and is joined on the upper end of the electrical conductor 44. A metal tube 77 encircles the upper portion of the conductor 44 and extends downward through the interior of the body 50, terminating at 78. An electrical connection is thus established between the metal tube 63 and the woven copper conductor 44. The threaded cap 61 receives the enlarged end 79 of the insulating sleeve 80 and serves to clamp the insulating tube 40 and inner tubular conductor 42 in position relative to the body 50.

The body 50 includes an externally threaded skirt 81 which receives an internally threaded nut 82. A ring 83 formed of plastic material rests on the outer surface of the braided non-metallic sheath 47. This sheath and the insulator tube 41 extend upward into the interior of the body skirt 81 and are clamped in position by means of the nut 82.

A metallic sleeve 84 is fixed within a counter bore 85 on the body 50 and extends downward through the skirt 81 and nut 82 and terminates at 86. The upper end of the outer tubular conductor 45 extends upward into the interior of the metal sleeve 85 and forms an electrical contact therewith. Accordingly, an electrical connection is provided between the horizontal bar 26 and the outer woven copper conductor 45 by way of the post 51, body 50 and metal sleeve 84.

Parts of the terminal fitting 36 may be disconnected if desired in order to separate the coaxial cable assembly from the parallel horizontal bars 26 and 27. This may be accomplished by removal of the threaded fastenings 55 and by unthreading of the nut 74 to loosen the split collet 75 and thereby permit axial movement of the metal tube 63 downward through the boss 70 and nut 74.

From the above description, it will be understood that electrical energy is carried from the horizontal bar 26 to the outer electrical conductor 45, and from the horizontal bar 27 to the inner electrical conductor 44.

Coolant delivered to the passageway 32 in the horizontal bar 26 passes through the vertical post 51, through ports 56 and 57 into the body 50 and through the interior of the metal sleeve 84 and then to the annular space 42 between the concentric insulator tubes 40 and 41. Coolant returning through the interior of the insulator tube 40 passes upward through the metal tube 63 and into the space 66 and returns through passage 32 formed in the horizontal bar 27.

The terminal fitting 37 may be identical with the terminal fitting 36 except that the post 51 is omitted and the projecting metal tube 63*a* is somewhat shorter than the metal tube 63. A shell 90 is mounted on the terminal body 50*a* by means of the threaded fastenings 55*a* which serve to clamp the shoe 91 against the flat surface 54 on the body 50*a*. An axially extending tube 92 is joined to the shoe 91 and forms a part of the shell 90. A filler block 93 formed of electrically non-conducting material is mounted within the forward end of the shell 90 and is held in place by threaded fastenings 94, which are also electrically non-conductive. The filler block 93 has a non-circular opening 95 which receives a metallic receptacle 96 having internal threads engaged by the nut 97. The metal tube 63*a* is brazed within the counterbore 98 of this receptacle 96.

A second receptacle 100 is carried on the shell 90 and extends into an arcuate cut out 101 formed on the filler block 93. This receptacle 100 is provided with internal threads which are engaged by the nut 102. The tube 92 has its forward end brazed within the counterbore 103 of the receptacle 100.

The induction heating tool generally designated 38 may have one or more turns of hollow copper tubing and may be formed in any convenient or desirable shape to suit the particular job requirement. The ends 105 and 106 of the hollow copper tubing are brazed within parallel extension tubes 107, 108 respectively. These extension tubes are clamped in spaced relationship by means of the insulating clamping parts 109 and 110 and by means of threaded fastenings 111. The upper clamping part 110 is omitted from FIGURE 6 for clarity of illustration. The parallel extension tubes 107 and 108 are slidably mounted within the receptacles 100 and 103 respectively. Electrical contact is achieved by tightening the nuts 102 and 97 to cause the split collets 112 and 113 respectively to be tightened around the outer surface of the extension tubes 107 and 108 which telescope into the tubes 92 and 63*a* respectively, to establish communication for passage of coolant. O rings 114 prevents leakage at the joints.

When it is desired to remove the induction heating tool 38 or to substiitute a different tool it is necessary only to unscrew the nuts 102 and 97 to allow loosening of the collets 112 and 113 and thereby permit axial movement of the tool 38 away from the shell 90. The shell 90 forms a convenient handle for manipulation of the tool 38.

FIGURE 11 shows how two lengths of coaxial cable embodying my invention may be joined end-to-end. The cable lengths and the major portions of the terminal fittings are substantially the same as previously described. Neither the post **51** nor the shell **90** is used, but instead a hollow rectangular bar **125** is employed to connect the terminal fitting bodies **50***a* and **50***b*. Threaded fastenings **126** at each end of the bar **125** hold a side face of the bar in contact with the flat surfaces **54***a* and **54***b*. The central passage **127** in the bar **125** and the lateral ports **128** establish a passage for coolant extending between the body cavities **57***a* and **57***b*, and the bar itself forms an electrical connection between the bodies.

A shell **130** is fixed to the bar **125** and has end portions which encircle parts of the bodies **50***a* and **50***b*. The shell **130** and bar **125** also enclose a non-metallic filler block **131** which is fixed to the shell and bar by means of threaded fastenings **132**. The filler block has a non-circular central opening **133** receiving a metallic receptacle **134** having internal threads engaged by a nut **135**. The metal tube **63***a* projecting from the body **50***a* passes through the central opening in the nut **135** and telescopes into the metal tube **63***b* which projects from the body **50***b*. The tube **63***b* is brazed within the counter bore **136** of the receptacle **134**. An opening **137** is provided in the tube **130** for wrench access to the nut **135**. When the nut **135** is turned the collet **138** is tightened above the outer surface of the tube **63***a* to form good electrical contact. The O ring **139** prevents leakage.

In the modified form of my invention shown in FIGURE 14, two separate conductor cables **200** and **201** are provided and they are not concentric. They may be enclosed within a common sheath **202** held together by a slide fastener assembly **203**. Each of the cables **200** and **201** are duplicates and each includes a single flexible imperforate tube **204** having a woven metallic conductor **205** positioned therein. A central helical support **206** of the type previously described extends through the interior of the tubular conductor **205**. A coolant passage is provided within the tube **204** which is formed of electrical insulating material. The terminal connections for each tube include a receptacle **207** having threads engaged by the clamping nut **208**. A non-metallic collet **209** is clamped by the nut against the fabric cover **210**. A metal sleeve **211** within the terminal is connected to the metallic conductor **205** and to the metal tube **212** which projects through the central opening in the receptacle **207**. The O ring **213** prevents leakage. The projecting metal tube **212** is thus connected in electrical contact with the flexible tubular conductor **205** and serves as a passage for coolant to or from the interior of the non-metallic flexible tube **204**. This form of my invention is economical to construct and may be used for cables carrying relatively low amounts of energy, but the electrical efficiency is not as great as the coaxial double conduit form of my invention previously described.

Having fully described my invention, it is to be understood that I do not wish to be limited to the details herein set forth, but my invention is of the full scope of the appended claims.

I claim:

1. In a coaxial cable assembly of the type described, the combination of: inner and outer concentric flexible imperforate tubes each formed of electrical insulating material, the tubes defining an annular passageway for coolant therebetween, the inner tube providing a second passageway for coolant, first and second concentric tubular electrical conductors, the first electrical conductor being positioned within said annular passageway, the second electrical conductor being positioned concentrically within the second passageway, a terminal fitting having a body, clamping means on the body securing each of said imperforate tubes thereto, a metal tube connected to and extending coaxially of the said second electrical conductor and projecting exteriorly of said body, the interior of said metal tube communicating with the interior of said inner imperforate tube, the body having a central cavity communicating with the said annular passageway, and the body having a lateral port communicating with said cavity.

2. In a coaxial cable assembly of the type described, the combination of: inner and outer concentric flexible imperforate tubes each formed of electrical insulating material, the tubes defining an annular passageway for coolant therebetween, the inner tube providing a second passageway for coolant, first and second concentric tubular electrical conductors, the first electrical conductor being positioned within said annular passageway, the second electrical conductor being positioned concentrically within the second passageway, a terminal fitting having a metallic body, means connecting said first electrical conductor to said body, clamping means on the body securing each of said imperforate tubes thereto, said clamping means including an insulating nut threaded on the body, a metal tube connected to said second electrical conductor and extending coaxially through the said insulating nut, the interior of said metal tube communicating with the interior of said inner imperforate tube, and the body having passage means including a lateral port communicating with the said annular passageway.

3. In a coaxial cable assembly of the type described, the combination of: inner and outer concentric flexible imperforate tubes each formed of electrical insulating material, the tubes defining an annular passageway for coolant therebetween, the inner tube providing a second passageway for coolant, first and second concentric tubular electrical conductors, the first electrical conductor being positioned within said annular passageway, the second electrical conductor being positioned concentrically within the second passageway, a terminal fitting having a metallic body, means connecting said first electrical conductor to said body, clamping means on the body securing each of said imperforate tubes thereto, said clamping means including an insulating nut threaded on the body, a metal tube connected to said second electrical conductor and extending coaxially through the said insulating nut, the interior of said metal tube communicating with the interior of said inner imperforate tube, the body having a central cavity communicating with the said annular passageway, the body having an external surface prepared to receive a connecting part, and the body having a lateral port interrupting said external surface and communicating with said cavity.

4. In a terminal fitting for a coaxial cable assembly having inner and outer concentric flexible imperforate insulator tubes defining an annular passageway for coolant therebetween, the inner tube providing a second passageway for coolant, and having first and second concentric tubular electrical conductors, the first electrical conductor being positioned within said annular passageway, the second electrical conductor being positioned concentrically within said second passageway, the improvement comprising, in combination: a metallic body, means for connecting said first conductor to said body, first clamping means on the body for securing the outer of said imperforate tubes thereto, second clamping means on the body including an insulating nut, for securing the inner of said imperforate tubes thereto, a metal tube connected to said second conductor and extending coaxially through said insulating nut, the interior of said metal tube being adapted to communicate with the interior of the inner imperforate tube, the body having a central cavity adapted to communicate with the said annular passageway, and the body being provided with a lateral port communicating with said cavity.

5. The combination set forth in claim 4 wherein the body is provided with an external surface prepared to receive a connecting part, and wherein the lateral port interrupts said surface.

6. In a coaxial cable assembly, the combination of: inner and outer concentric flexible imperforate insulator tubes defining an annular passageway for coolant therebetween, the inner tube providing a second passageway

for coolant, first and second concentric flexible tubular electrical conductors, the first electrical conductor being positioned within said annular passageway, the second electrical conductor being positioned concentrically within said second passageway, a metallic body having oppositely extending coaxial threaded projections, means including a nut engaging one of the threaded projections for clamping the outer of said insulator tubes to the body, means including an insulating nut engaging the other of the threaded projections for clamping the inner of said insulator tubes to the body, means for connecting said first conductor to said body, a metal tube connected to said second conductor and extending coaxially through said insulating nut, the interior of said metal tube being adapted to communicate with the interior of the inner imperforate tube, the body having a central cavity adapted to communicate with the said annular passageway, and the body having a lateral port communicating with said cavity.

7. In a terminal fitting for a coaxial cable assembly having inner and outer concentric flexible imperforate insulator tubes, and having first and second flexible concentric tubular electrical conductors, the first being positioned outside the inner insulator tube and the second being positioned inside thereof, the improvement comprising, in combination: a metallic body having oppositely extending coaxial threaded projections, means including a nut engaging one of the threaded projections for clamping the outer of said insulator tubes to the body, means including an insulating nut engaging the other of the threaded projections for clamping the inner of said insulator tubes to the body, means for connecting said first conductor to said body, a metal tube connected to said second conductor and extending coaxially through said insulating nut, the interior of said metal tube being adapted to communicate with the interior of the inner insulator tube, the body having a central cavity adapted to communicate with the annular space between the insulator tubes, and the body having a lateral port communicating with said cavity.

8. In a terminal fitting for a coaxial cable assembly having inner and outer concentric flexible imperforate insulator tubes, and having first and second concentric flexible tubular electrical conductors, the first being positioned outside the inner insulator tube and the second positioned inside thereof, the improvement comprising, in combination: a metallic body having oppositely extending coaxial threaded projections, means including a nut engaging one of the threaded projections for clamping the outer of said insulator tubes to the body, means including an insulating nut engaging the other of the threaded projections for clamping the inner of said insulator tubes to the body, means for connecting said first conductor to said body, and a metal tube connected to said second conductor and extending coaxially through said insulating nut, the inner insulator tube serving to insulate the said metal tube from said metallic body.

9. In a coaxial cable of the type described, the combination of: inner and outer concentric flexible imperforate tubes each formed of electrical insulating material, the tubes defining an annular passageway for coolant therebetween, the inner tube providing a second passageway for coolant, first and second concentric tubular electrical conductors each formed of woven metallic material, the first electrical conductor being positioned within said annular passageway, the second electrical conductor being positioned concentrically within the second passageway, and non-metallic support means within the interior of said second electrical conductor to prevent collapse thereof upon flexure of the cable, said support means comprising a generally tubular member having passage means in the tubular wall thereof permitting coolant to pass therethrough.

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