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Kluge et al.

[11] **3,808,350**

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[54] **LIQUID COOLED HEAVY CURRENT CABLE**

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[51] **Int. Cl.**.. **H01b 7/34**

[58] **Field of Search**................ 174/19, 15 C, 47, 27; 339/112, 117; 219/130; 13/15, 16, 32

[56] **References Cited**

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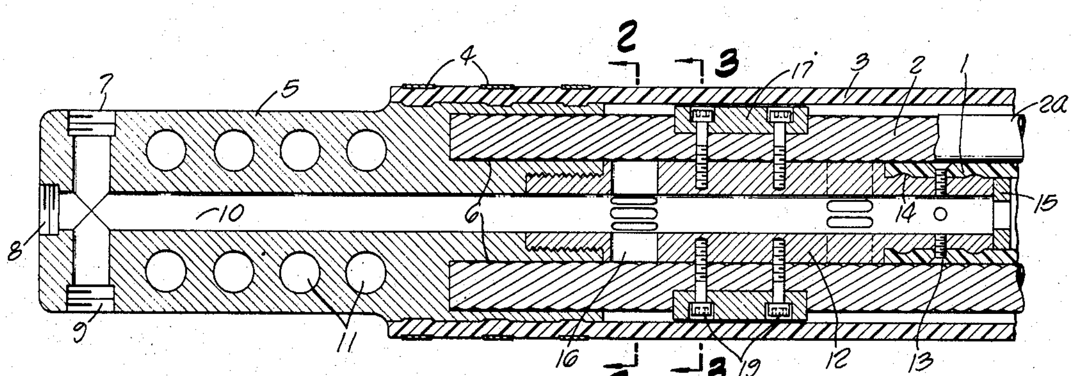
[57] **ABSTRACT**

A water-cooled cable with cable sockets at the ends. The cable has inner, preferably, resilient tube, conductors twisted on and extending along that tube, and an outer envelope. Rigid or flexible connector sleeves provide fluid conductive connection between ducts in the sockets and the inner tube, with lateral ports in the sleeves providing exclusive passage for coolant to and from the annular space between the tubes containing the conductors.

13 Claims, 4 Drawing Figures



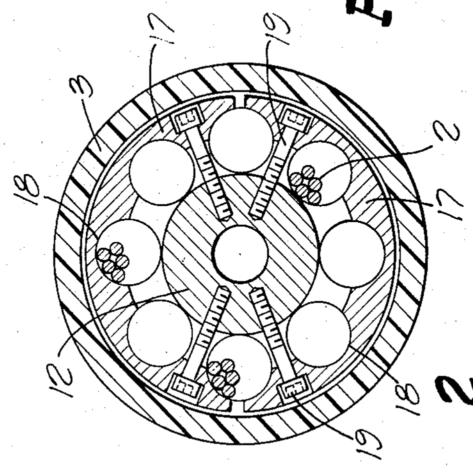


FIG. 3.

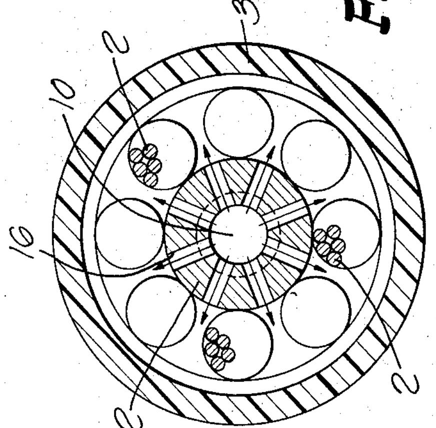


FIG. 2.

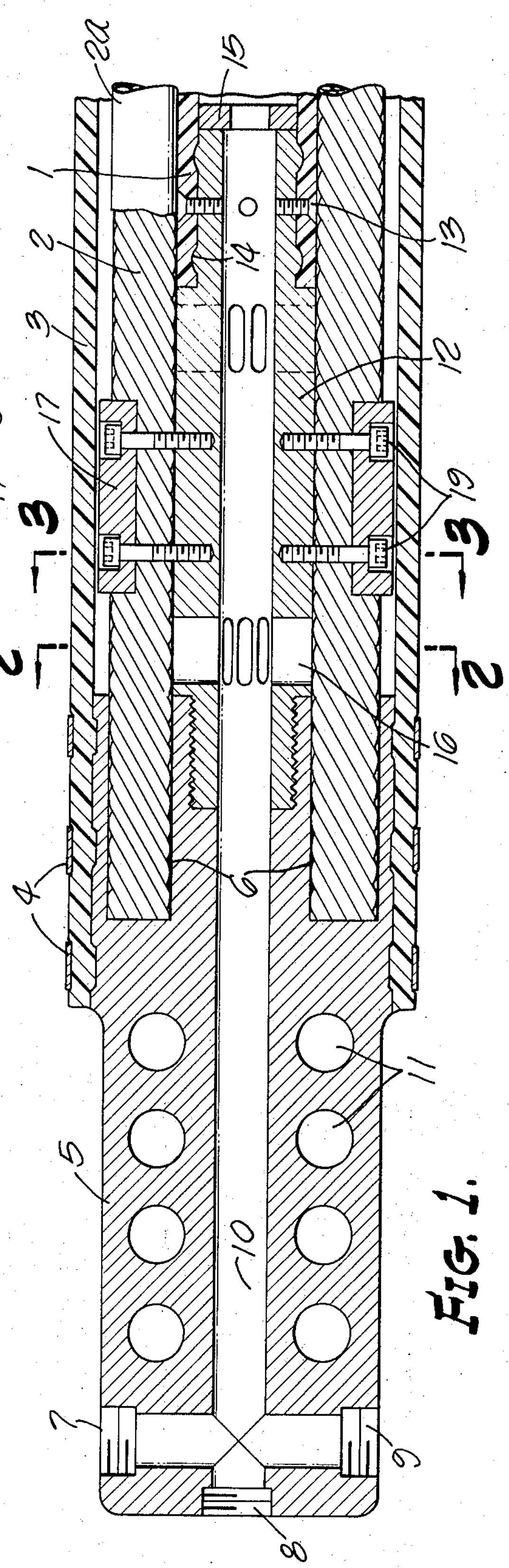


FIG. 1.

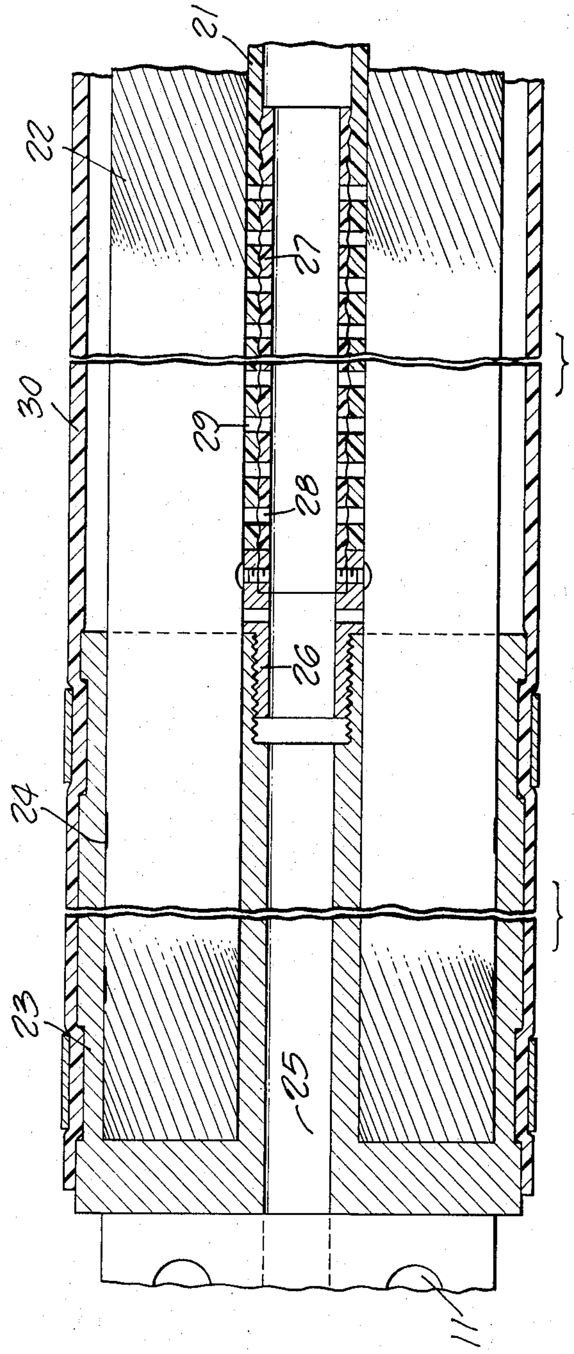


FIG. 4.

LIQUID COOLED HEAVY CURRENT CABLE

BACKGROUND OF THE INVENTION

The present invention relates to a liquid cooled heavy current cable particularly of the variety used for feeding electric current to an arc furnace. More particularly, the invention relates to a liquid cooled cable having an inner tube as conduit for the coolant, further having cable conductors on the inner tube and an outer tube or hose as envelope. Additionally, cable connectors, such as cable sockets or the like, are provided at the ends which serve also as inlet and outlet for the coolant.

Electric arc furnaces are used to an increasing extent for melting steel scrap, sponge iron or pre-reduced iron ore concentrates. The electric current fed to such a furnace is quite high and water-cooled cable is used for running the current, e.g., from a transformer to the furnace. Water-cooling is needed to increase the life of the cable. Aside from being capable of conducting a high current, the cable must meet additional conditions arising from this particular use. The load (furnace) develops extensive heat so that the cable is subjected to ambient temperatures, well above normal room temperatue. Also, mechanical wear, even abuse, was found to be considerable.

U.S. Pat. No. 3,551,581 discloses a flexible, heavy current cable of the type outlined above, wherein the outer envelope is very resistant mechanically. Not only is the cable to be cooled as a whole, but the inner tube is perforated so that coolant may flow around the insulated conductors on the outside of the inner tube. That inner tube has axial fins to separate the conductors from each other and to define channels for them individually. However, it is not believed that conductor cooling is adequately defined, but has some random character that depends on the passage of coolant through the perforations along the cable. No flow pattern is clearly defined but the cross flow between channels and the interior of the inner tube may depend on factors such as the suspension of the cable, its orientation to vertical and horizontal directions, vibrations etc. Additionally, this particular cable has individual sections which are more or less concatenated over the desired length of the cable connections and throttles are interposed at the joints for impeding somewhat the flow of coolant in the inner tube to enhence circulation through the ports to the conductors on the outside of the inner tube.

Another problem arises frequently in water-cooled cables in that upon strong and frequent flexing of the cable in the vicinity of the cable socket, the connection of the socket to the inner tube breaks quite readily.

DESCRIPTION OF THE INVENTION

It is an object of the present invention to improve the construction of liquid cooled cable, particularly as far as the cooling function is concerned. It is another object of the present invention to simplify the construction of such a cable and to provide for such a construction so that manufacturing can be mechanized.

It is another object of the present invention to improve the connection between a cable socket piece and the cable proper as far as resistance against breaking during flexing is concerned.

Generally speaking, the new cable is to have long life and must be safe in operation.

In accordance with the preferred embodiment of the invention, it is suggested to provide an inner tube in smooth wall configuration and without perforations except possibly at the ends. Rigid or flexible sleeves are affixed to the tube ends, and these sleeves, in turn, are respectively fastened to connector pieces, i.e., cable sockets which have internal ducts providing passage to the sleeves. These sleeves have lateral apertures so that liquid can pass through to flow around, along and on the said tube. Conductors are disposed on this tube and are affixed to the cable sockets. The assembly of conductors on the said inner tube is disposed in a, preferably flexible envelope so that liquid flowing along the inner tube flows in the annular space between that tube and the outer envelope, around and along the conductors in that space. That annular flow space receiving the conductors is not partitioned by longitudinal ribs, nor does it communicate with the interior of the inner tube except at or near the ends thereof. If the cable is sectionalized, the several sections can be interconnected directly as the streams of coolant flow inside and outside of the inner tube are and remain separated at such joints.

One end of the cable will serve as coolant inlet, the other as outlet. The flow of coolant in the annular receiving space for the conductors is well defined by the aperture relation of passage into the inner tube and passage into the annular space. The absence of any cross flow between these flow spaces along the most part of the cable, is instrumental in rendering the cooling conditions more predictable.

In the preferred form, the outflow from the sleeve (at the coolant inlet side of the cable) is throttled to some extent as far as flow into the inner tube is concerned. As a consequence, coolant is forced out of the sleeve laterally and into the said annular space at a predetermined rage, to serve directly as coolant of the conductors along their extension in and as part of the cable assembly.

The apertures in the sleeves at the cable ends are preferably oriented to the disposition of the conductors so that each aperture is located between two conductors. The conductors each have stranded configuration but together they are also twisted on and along the inner core. The apertures are preferably offset to remain in that relative disposition to the conductors.

Depending on the overall configuration, the sleeve which connects the cable socket and its duct with the inner tube may be rigid or flexible. The latter is necessary if the sleeve is as long as a foot, otherwise the cable may easily break at the socket. If the sleeve is short enough to permit rigid configuration, it has preferably a corrugated or serrated end nozzle onto which the inner tube is slipped and held by enhenced friction. The tube may be clamped additionally to the sleeve. If the sleeve is flexible, then the inner tube is slipped onto the sleeve in its entirety and only in this case is it necessary to provide the inner tube with perforations which register with apertures in the sleeve.

DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention, it is believed that the invention, the objects and features of the invention and further objects, features and advantages thereof will be better understood from the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a section view into a cable end for a liquid cooled cable and improved in accordance with an example of the preferred embodiment of the invention;

FIGS. 2 and 3 are respectively section views along lines 2—2 and 3—3 in FIG. 1; and

FIG. 4 is a section view of a modified example of the preferred embodiment of the invention.

Proceeding now to the detailed description of the drawings, FIGS. **1, 2** and **3** illustrate a liquid cooled heavy current cable having an inner tube **1** such as elastomeric hose made, for example, of a material known under the designation neoprene. Flexible, stranded cable conductors **2** are disposed on the outside of tube **1** and extend axially there along; they are regularly distributed about the circumference of tube **1.** The entire arrangement is disposed in a tubular envelope **3** such as a rubber hose which is re-enforced by cloth or the like.

The individual stranded conductors are actually without insulation, because they all are at the same potential at any point along the cable. However, it may be advisable to jacket, e.g., every other conducor in an envelope which reduces friction among adjoining conductors. In case the cable is being twisted as a whole, the individual conductors may slide on each other and without further measures such sliding may damage individual strands. Anti-friction linings or envelopes **2*a*** prevent that damage.

Hose **3** is fastened to a connector piece or cable socket **5** by means of clamps **4.** The conductors **2** are affixed to socket **5** at points **6,** for example, by means of soldering. Socket **5** has bores **7, 8** and **9** which terminate in a cooling duct **10** in the interior of the socket. Coolant is fed into the cable (or discharged therefrom) via this duct system **7** to **10.** Not all of the inlets or outlets **7, 8, 9** have to be used, but one or the other may be plugged, depending on the location of the furnace and of the coolant feeder and discharge system feeding the cable. Bores **11** are provided for receiving bolts for connecting the cable socket to the respective current bus bar.

The inner tube **1** is provided as a smooth wall element with closed, i.e., unperforated wall structure. The ends of tube **1** are slipped onto sleeves such as sleeve **12** and bolted thereto by means of bolts **13.** Sleeve **12** is threaded into an end socket of cable socket **5.** Sleeve **12** has a nipple end of reduced diameter to receive tube **1** so that the outer surface of tube **1** is about flush with the remainder or main part of sleeve **12.** Additionally, tube **1** is held on sleeve **12** by serrations or corrugation crests **14.** This way, added friction is established between tube **1** and sleeve **12** to obtain a secure connection to tube **1.** The cable as a whole is readily cooled even if overloaded.

Sleeve **12** is provided with an end piece **15** which reduces drastically the cross section of the liquid passage from duct **10** to the interior of tube **1.** Throttling disk **15** may be soldered, welded onto or threaded into sleeve **12.** Due to flow throttling by disk **15** a considerable portion or even most of the coolant (e.g., water) passes laterally out of sleeve **12** through passages and bores **16,** communicating with the annular space between hose **3** and sleeve **12,** as containing the ends of cable conductors. The coolant flows axially along tube **1** and is, for example, discharged at the other end of the cable which is provided with a similar construction. As stated, the FIGS. **1, 2** and **3** can be interpreted as inlet or outlet for coolant. At the outlet, the coolant is pumped out of the cable to maintain a flow producing pressure gradient therein.

As can be seen particularly from FIG. **2,** openings **16** are provided in-between respective two conductors **2,** as far as their azimuthal distribution and position is concerned. Thus, the openings **16** are not covered by conductors so that coolant can flow freely into the annular space between the concentric tube arrangement.

The conductors **2** are preferably stranded as a group exhibiting particular helical pitch. The openings **16** should match that twist.

As shown particularly in FIG. **3,** two part clamps **17** are provided as strain relief for the conductors as soldered to socket **5.** Clamps **17** have indents **18** for receiving the conductors. Hexagon head cap screws **19** are used to fasten clamps **17** to sleeve **12.**

The arrangement as shown in FIGS. **1, 2** and **3** is assembled as follows, whereby the assemblies for both cable ends are made in the same manner. At first, sleeve **12** is threaded into socket **5.** Next, the conductors are run into the axial openings in socket **5** as provided for that purpose and are soldered thereto. Next, clamps **17** are provided to engage the conductors and tightened to sleeve **12** for fastening the conductors to sleeve **12** as strain relief for the solder points.

Next, rubber hose **1** is slipped onto the nipple end onto the nipple end of sleeve **12,** over the serrations and is secured thereto by the clamps **13.** The same operation is repeated at the other end, except for securing the tube **1** to to the other sleeve **12.** Now, the conductors are twisted on tube **1** to obtain their final position on tube **1,** whereupon the other tube **1** is also fastened to a sleeve **12** thereat. Tube **1** should not follow that twist. Thereafter, the several parts are secured into position.

The throttling piece **15** has been previously soldered, welded, bolted or threaded onto the nipple end of sleeve **12.** Piece **15** is a simple washer made of plastic or metal. However, one could provide here a controllable valve of the type traded under the designation GD 10 Ermeto. It is preferred to have the distribution of coolant as between inside and outside of tube **1** adjusted on location in this manner.

In the example of FIGS. **1, 2** and **3,** tube **1** has no perforations at all, as coolant is fed to and discharged from the annular between tubes **1** and **3** through apertures **16** in the end sleeves only.

Another example of the preferred embodiment of the invention is shown in FIG. **4,** and again, there is an inner tube **21,** such as a neoprene hose, which has perforations or apertures **29** but only at the end. The main part of tube **21** is free from any radial passage. Conductors **22** are disposed on tube **21.** A fiber re-enforced rubber hose **30** is used as envelope above and around the conductors.

Conductors **22** are, for example, soldered, welded or glued to a cable socket **23** at locations **24.** Socket **23** is provided with a central cooling duct for passing coolant such as water from or to the exterior, to or from the hose **21.**

Tube or hose **21** is fastened to socket **23** by means of a threaded fitting or sleeve **26** to which is connected a flexible tube **27**. Elements **26** and **27** are preferably interconnected by means brazing, soldering or welding. Tube **27** is, for example, a bronze hose, or a corrugated tube made of sheet metal or may have any other configuration that provides sufficient flexibility.

Tube **27** is provided with apertures **28** which register with the apertures **29** in hose **21**. Accordingly, liquid coolant may pass from tube **27** through apertures **28/29** into the annular space between inner and outer tubes as containing the cable conductors **22**. As a consequence, definite amounts of coolant enter (or are discharged from) that annular space.

The example of FIG. **4** has the advantage that the cable may bend right up to the shoe, even if the sleeve (**27**) is 250 to 350 mm (about a foot, plus or minus a few inches) long. A heavy current cable of this type may usually, or often be suspended and assumes U-shaped configuration. One socket is rigidly connected to the power supply, the other socket connects usually displacably to or on a movable part of the furnace, e.g., its cover. When the furnace cover is moved, the cable must follow that motion so that the angle of suspension changes, and the cable will bend right at the socket. For this reason, adequate flexibility is to be provided for and this example of FIG. **4** readily permits cable flexing at the shoes without breaking.

The invention is not limited to the embodiments described above but all changes and modifications thereof not constituting departures from the spirit and scope of the invention are intended to be included.

We claim:

1. Electrical, liquid cooled heavy current cable comprising:

- a first tube of smooth wall configuration, the first tube having for at least most of its extension no lateral perforations for passage of liquid between its interior and its exterior;
- a connector socket respectively for one of the ends of the tube, and having at least one internal duct;
- a connecting sleeve in telescopic connection with the one tube end and fastened thereto and further connected to the connector socket to provide a fluid connection between the tube, through the sleeve and through the duct;
- plural conductors affixed to the connector socket and disposed on and along said first tube;
- a tubular envelope around, receiving the first tube and defining therewith an annular space in which the conductors are located; and
- the sleeve being provided with lateral apertures communicating with said annular space for providing exclusive passage for fluid between the duct and the sleeve, and said space ahead of the first tube as unperforated and through which flows the remainder of the fluid from the duct to establish a fluid path between the duct and the said annular space.

2. Cable as in claim **1**, the first tube slipped over part of said sleeve, the remainder of the sleeve provided with the apertures as the exclusive passage for fluid between the interior of the sleeve and the annular spaces.

3. Cable as in claim **2**, said conductors located in azimuthal displaced relationship to the apertures so that the fluid passage through any of the apertures leads in-between respective two of said conductors.

4. Cable as in claim **3**, wherein the conductors are arranged on the first tube with a twist, the said disposition of the apertures following that twist.

5. Cable as in claim **4**, the throttling means being releasably secured to the sleeve.

6. Cable as in claim **1**, the end of the first tube provided with apertures and being slipped onto the sleeve, the apertures of the sleeve registering with the apertures of the first tube to thereby establish the exclusive passage for fluid between the duct and the annular space.

7. Cable as in claim **6**, the sleeve being flexible.

8. Cable as in claim **7**, the sleeve being corrugated.

9. Cable as in claim **1**, at least some of the conductors being covered with an anti friction envelope.

10. Cable as in claim **1**, including a said sleeve threaded into the connector socket and fastened to said connecting sleeve.

11. Cable as in claim **1**, said sleeve having an end portion of reduced diameter onto which the first tube end has been slipped to be substantially flush with the remainder of the sleeve.

12. Cable as in claim **11**, said reduced diameter end portions being provided with surface contour to increase friction engagement between it and the first tube.

13. Cable as in claim **1**, including fluid flow throttling means at the end of the sleeve where facing the interior of the first tube.

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