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(54) **A long, lead-sheathed submarine power cable, and a process for producing the same.**

(57) A long, lead-sheathed, submarine power cable is made up of a number of cable units joined by the TIG welding process in an atmosphere of an inert gas. The cable units are supported in a horizontal position, and the lead sheathes (14) of adjoining cables are welded circumferentially (38). Welding is effected in a direction from the bottom towards the top of the sheath as viewed in cross-section. The welding operation is facilitated by the combined use of a robot (31) and the TIG welding process.

EP 0 171 920 A2

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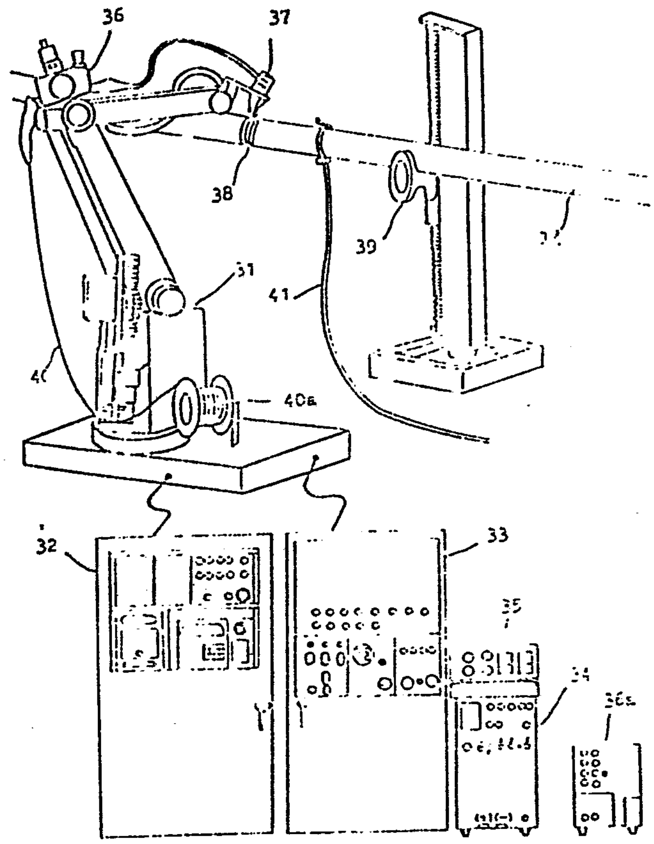
FIG. 1



"A LONG, LEAD-SHEATHED SUBMARINE POWER CABLE, AND A PROCESS FOR PRODUCING THE SAME"

This invention concerns a long, lead-sheathed, submarine power cable manufactured by joining a number of separate cable units or lengths in a factory by welding, and a process for producing the same.

As shown in Fig. 2 in cross-section, an oil-filled submarine power cable is made up, concentrically from the inside to the outside, of an oil passage 11, a layer of conductive wires 12, a layer of oil-impregnated insulating paper 13, a lead-sheath 14, bedding 15, a layer of winding iron wires 16 and a protective layer 17.

Cable units or lengths having such a structure are joined together, to produce a composite cable of a given or required length, in a factory before shipment. However, the trouble was that the joining of cable units had to be effected entirely manually. That is, as shown in Fig. 3, each of the adjacent ends of the lead-sheathed cable units to be joined is firstly opened and truncated so as to provide a V-shaped notch where the ends meet, and then lead is fed into the notch to manually fuse a base material (lead-sheath 14) and a lead welding rod 19, with a gas torch 20. Therefore, the following problems are very likely to arise, and joints are so apt to break, that fundamental improvement in the work has long been awaited.

(1) Because a gas torch is used, there is a tendency for air and a gas produced from combusion to be fed into the joints and form pinholes therein. Hence, the joints are inferior in mechanical strength.

That is, they are so poor in tensile strength and elongation that they break very often.

(2) Because welding cables is technically very difficult, it demands a high degree of skill, and the use of experts is indispensable.

(3) Because welding depends on manual work, variations in quality arise. That is, since workers, i.e. welders, differ from each other in skill, and the ease of welding differs from portion to portion on cables, the working standard, including the feed rate of a welding rod, the intensity or spread of a torch flame, and the position where workers should stand whilst welding, etc.,is difficult to specify quantitatively. These unspecified factors result in unevenness in the joint quality.

In order to solve these problems, it is of course possible to consider providing a factory with large equipment capable of producing a continuous submarine power cable. However, in reality, such equipment needs a huge sum of investment and it is very difficult to realize.

Under the circumstances, it is an object of this invention to provide a long, lead-sheathed submarine power cable with a number of joints which are qualitatively so stable that breaking seldom occurs. It is another object of this invention to provide a process for producing a long, lead-sheathed submarine power cable incorporating joints which contain effectively no such pinholes, so that their quality is fully guaranteed. It is still another object of this invention to provide a process for producing a long, lead-sheathed submarine power cable which does not need any special training of workers prior to joining cable units and makes it possible to stabilize the quality of joints by the combinative use of an automatically welding robot.

In order that the invention may be more fully understood, reference will now be made to the accompanying drawings, in which:-

Fig. 1 is a schematic illustration which shows the combined use of the TIG welding process and robotics, according to one embodiment of the invention,

Fig. 2 is a cross-sectional diagram which shows the outline structure of an oil-filled submarine power cable;

Fig. 3 illustrates a conventional way of welding a joint of cable units;

Fig. 4 illustrates the direction in which welding is made at a given rate according to this embodiment of the invention,

Fig. 5 illustrates that a welding torch is set at a certain angle to the circumference of a cable unit.

The present inventors have keenly felt that the mechanization or automation of welding is of paramount importance in stabilizing the quality of cable joints sufficiently so as to prevent them from breaking. Accordingly, they made an extensive comparative study of the MIG welding process and the TIG welding process as well as of various conventional welding processes utilizing a gas torch. As a result, they found that conventional welding processes are generally unsuitable for the mechanization or automation of welding cables because it is very difficult to control a lot of related factors, such as the amount of a gas to be fed into a torch, the intensity of a torch flame, its ignition cycles, etc. in a well specified condition. From the above, they felt the necessity of adopting an electric welding technique, such as the MIG or the TIG welding process, for the purpose of the automation. However, the MIG welding process requires such a high electric current that it proved unsuitable for joining lead-sheathed units at low temperatures. Eventually they keenly advanced their study on the TIG welding process because it requires a comparatively small electric current.

Nevertheless, when they started their study, gas welding processes which employ propane or hydrogen prevailed throughout the industry, because these processes are relatively satisfactory in relation to working efficiency, since welders can adjust the spread of a torch flame, or the rate of melting lead, whilst checking the welding condition visually.

Contrary to this, the TIG welding process had been employed entirely in welding steel materials at high temperatures for a short time. For this, an electric current of more than 50 amperes is usually used. The situation was that no one had any idea at all that the TIG welding process could be applicable to welding lead-sheathed cable units. The present inventors carefully examined the application of the TIG welding process in many ways, repeated experiments to create a new process, and finally accomplished it.

According to the new process, the most important of all conditions is to control a welding electric current in the range 10 to 30 amperes, provided that the optimum welding electric current is 16 amperes. As mentioned above, the TIG welding process commonly requires a large electric current of more than 50 amperes. However, it is one of the characteristics of this invention that a low electric current is applied to welding. Briefly, when the welding electric current is greater than 30 amperes, holes are apt to form in the lead-sheath of cables, or molten lead drops from joints being welding because too much lead melts. Conversely, when the welding electric current is less than 10 amperes, both the lead-sheath of cables and the welding rod are difficult to melt. From these, it is very important to use a welding electric current in the range of 10 to 30 amperes.

Next to the welding electric current, the direction of welding is important. In order to melt lead well and make a good joint, it is desirable to effect the welding, in terms of the cross-sectional view of the cable 14, from its bottom (lowest point) to its top (highest point), in the direction indicated by the arrows in Fig. 4. In this connection, welding may be effected in such a way that the circumference of a cable is divided into two parts as shown in Fig. 4 (A), or into four parts as shown in Fig. 4 (B). The more the circumference is divided, the easier it becomes to weld, because the curvature that a torch follows becomes gentle.

Other welding conditions will be listed as follows:

(1) The diameter of tungsten electrodes which are used is in the range of 1.0 to 3.0 mm, provided that their optimum diameter is 1.6 mm. When this diameter is smaller than 1.0 mm, the electrodes tend to wear down, necessitating frequent replacement. When the diameter is greater than 3.0 mm, it is difficult if not impossible to concentrate the arc on the spot to be welded.

(2) In effecting welding, the welding torch has to follow the welding rod. That is, in terms of the welding direction, the welding rod leads and the welding torch lags behind. If the two are transposed in position, the welding rod always comes after the melt pool formed by the welding torch. In such a case, a good weld is unlikely to be achieved, because the allowance of the feed rate of the welding rod becomes so narrowed that welding is slowed down.

(3) The distance between a base material (lead sheathed) and the welding torch is in the range of 1 to 4 mm, provided that the optimum distance is 2 mm. When this distance is greater than 4 mm, the lead-sheath does not melt but the welding rod melts. As a result, welding is impossible. When this distance is less than 1 mm, the welding rod comes into contact with the welding electrode and the arc disappears, with the result that welding cannot be continued.

(4) The moving speed of the welding torch is in the range of 5 to 20 mm/sec, provided that the optimum moving speed is 10 mm/sec. When this speed is less than 5 mm/sec, the melt pool grows too large to stay on the base material, with the result that it drops. When this speed is greater than 20 mm/sec, the lead-sheath does not melt sufficiently and as a result, welding becomes difficult.

(5) The feed rate of the welding rod is in the range of 2 to 8 mm/sec, provided that the optimum feed rate is 4.5 mm/sec. When this rate is less than 2 mm/sec, the surface of the welded joint becomes rugged or rough because the feed of the welding rod is too slow for the spread of the melt pool. When this rate is greater than 8 mm/sec, the feed of the welding rod is too fast, so that the welding rod cannot melt and fuse into the lead-sheath, which makes the joint surface rugged or rough, and pores form in the weld.

(6) The diameter of the welding rod is in the range of 1 to 4 mm, provided that the optimum diameter is 2 mm. When this diameter is less than 1 mm, the welding rod becomes too pliable to ensure a constant feed rate. When this diameter is greater than 4 mm, the feed rate must be made as slow as possible, with the result that controlled feeding becomes difficult.

(7) The angle of which the welding torch is held to the tangent to the circumference of the cables is in the range of 65° to 80°, provided that the optimum angle is 72°.

The above is a description of the conditions in welding when the TIG welding process is applied to this invention. It has been proved that, provided that the welders only keep strictly to the above welding conditions, and provided that they already have sufficient welding skills, they produce cable joints possessing a much more stable quality by using the TIG welding process than by using a conventional gas welding process. Despite this, it is difficult for the welders to acquire sufficient skill. Furthermore, even if they have the skill, irregularities are apt to form in a joint in terms of where they weld, i.e. to the right or left side, or upper or lower side, of the circumference of a cable, because they have to work in an unnatural position according to the portions to be welded.

Additionally, before commencing TIG welding, the welders have to wear a mask because they cannot directly look at an arc with their naked eyes. Therefore, before an arc is struck, it is difficult for them to place the welding torch in the right position, because they are hindered by the darkness caused by the mask.

It is also difficult for the welders to see if an appropriate amount of a lead-sheath or a welding rod is used in welding.

As apparent from the above, the manual work inevitably gives rise to unevenness or inconsistencies in the quality of joints in a long, lead-sheathed, submarine power cable.

In order to lessen such inconsistencies due to the various reasons mentioned above, the utilization or robotics to strictly maintain all the above conditions would result in the stabilization of the joint quality. However, in the combined use of robotics and a conventional gas welding process, it is difficult to control the amount of gas to be fed into the torch, and the spread, the intensity and the color of the torch flame. It is also difficult to extinguish the flame each time the torch is separated from the weld and ignite it each time the torch comes near the weld.

In contrast to this inconvenience, the combined use of robotics and the TIG welding process is very practical to achieve because, for example, the intensity of the torch flame is kept constant by adjusting the electric current. The torch flame can be ignited or extinguished automatically according to the distance between the weld and the torch. If the torch flame goes out by itself, the feed of the welding rod can be stopped by means of an interlocking mechanism. In this way, various control means may be put together so as to bring out their combined effect to the maximum extent.

Fig. 1 is a schematic illustration showing an apparatus comprising, in combination, a TIG welding device 34, and a multiarticulated robot 31 which is usually composed of five or more functional arms. Actually, it is preferable for the robot to have six articulated functional arms, namely, five common functional arms and one pneumatic 180° rotatable arm. The apparatus also includes a robot control panel 32; a panel 33 through which various welding conditions are input; a control panel 35 for the TIG welding device; an automatic feeding device 36 for a welding rod, provided with a control panel 36a; and a welding torch 37. The apparatus also includes a portion 38 where two cable units meet each other in such a way that their lead-sheath 14 can be subjected to welding; a roller 39 for supporting a cable in the horizontal position; a welding rod 40 which is fed from a reel 40a; and a grounding wire 41.

The welding of cables is performed in a factory by the use of all the above equipment. The working steps are outlined below:-

(1) The end of each cable unit is opened manually in a conventional manner by using tools.

(2) The robot 31 is manipulated by means of a teaching box incorporated in the robot control panel 32 so as to cause the robot to memorize every movement necessary for welding.

(3) All the conditions necessary for welding are determined, and input through the control panel 35 for the TIG welding device.

(4) The feed rate of the welding rod is determined for a certain condition, and input through the control panel 36a.

(5) Information relating to where and how to weld is input through the panel 33.

(6) A robot-actuating switch is switched on. Then

the robot proceeds with welding where required in perfect compliance with the set or predetermined conditions, producing a melt from the automatically fed welding rod 40 and the lead-sheath 14 (base material) in an inert gas by means of an arc produced from the top of the welding torch 37.

(7) Welding is repeated automatically by the robot and a good joint is formed between two cable units one after another.

The physical properties of joints formed in an inert gas by the TIG welding process, and by a conventional gas welding process, are shown in the following table, together with those of an unwelded lead plate for the sake of comparison.

	Tensile Strength	Elongation
Unwelded part	2.0 (kg/mm^2)	30-40 (%)
Gas-welded part	1.3-1.8 * "	10-20 "
TIG-welded part	1.8-2.0 ** "	25-35 "

* 65 - 90 percent of an unwelded part

** 90- 100 percent of an unwelded part

In the conventional gas welding process, pinholes form in the joints as referred to earlier. Outside, a variety of inconsistencies or unevenness comes into existence derived from the differences among individual skills, in the relative ease or difficulty with which welding may be carried out at particular positions on the circumference of cables, for example the upper, lower, right, or left side of the cables. Therefore, the physical properties of the joints are generally poor and have a wide spread. On account of these, joints are apt to break at their center in most cases. However, in the TIG welding process embodied in this invention, the quality of the joints is always so constant or consistent that their physical properties are not weaker than those of unwelded portions. Because the TIG welding process is carried out in an inert atmosphere, the welded joints are also quite free from pinholes, even if welding is effected manually. When the TIG welding process is combined with robotics, it is possible to put the distance between the welding torch and the base material, the distance between a welding torch and the welding rod, the welding speed, the welding temperature, etc. under such strict control that the joint quality is stabilized to a greater extent, and training workers to make them experts becomes unnecessary.

CLAIMS

1. A lead-sheathed, submarine power cable, which is characterized by having one or more lead-sheathed joints made by the application of the TIG welding process.

2. A process for producing a lead-sheathed, submarine power cable in a factory by joining cable units or lengths one after another by welding, which is characterized in that the welding is effected in a direction from the bottom (lowest part) towards the top (highest part) in terms of the cross-sectional view of generally horizontally supported cable units by using a 10 to 30 ampere electric current by the application of the TIG welding process in an atmosphere of an inert gas.

3. A process as claimed in claim 2, which is characterized in that said welding is effected automatically by the use of a robot (31) provided with five or more articulated functional arms.

FIG. 1

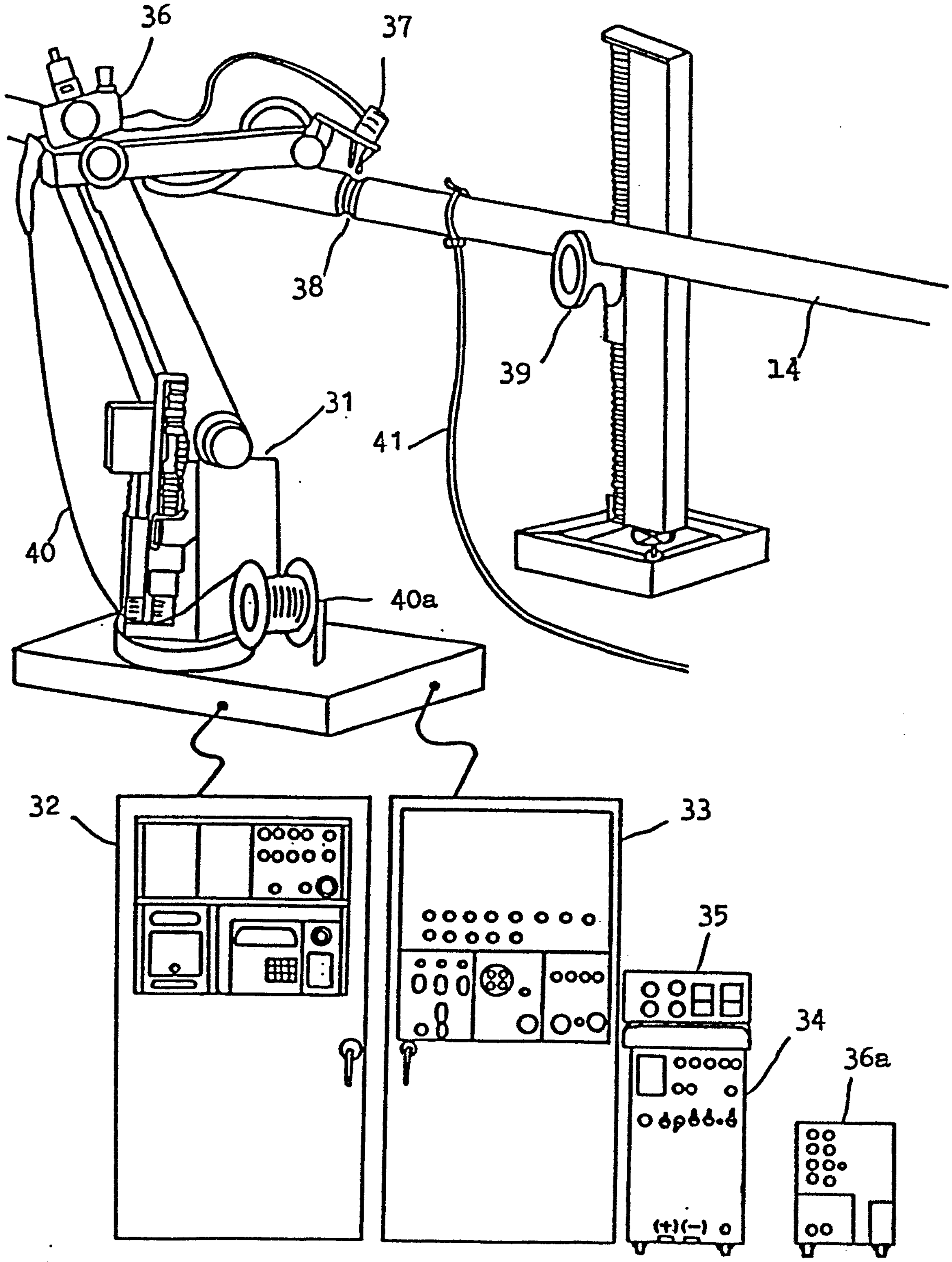


FIG. 2

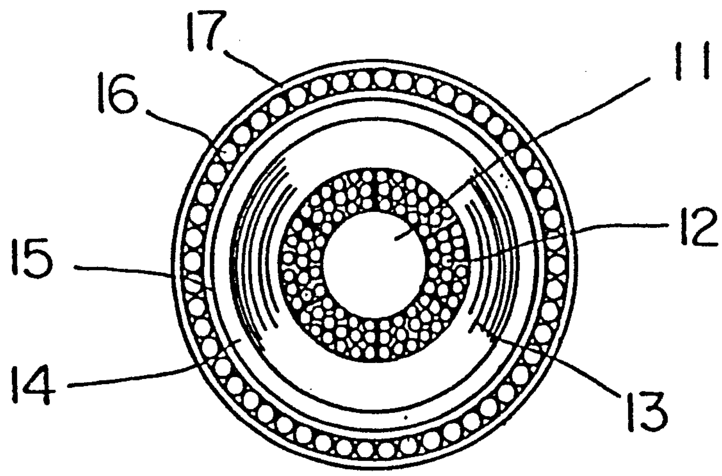


FIG. 3

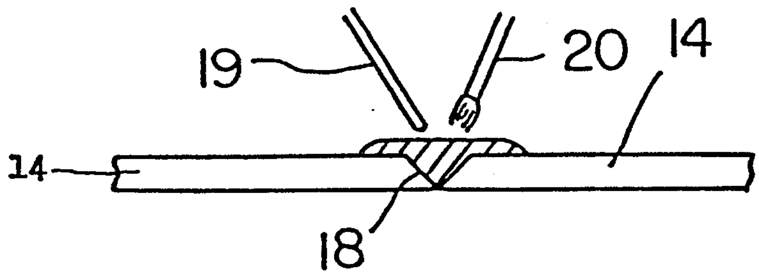


FIG. 4

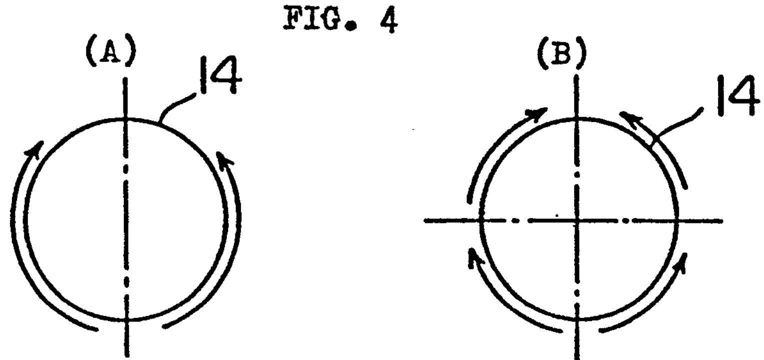


FIG. 5