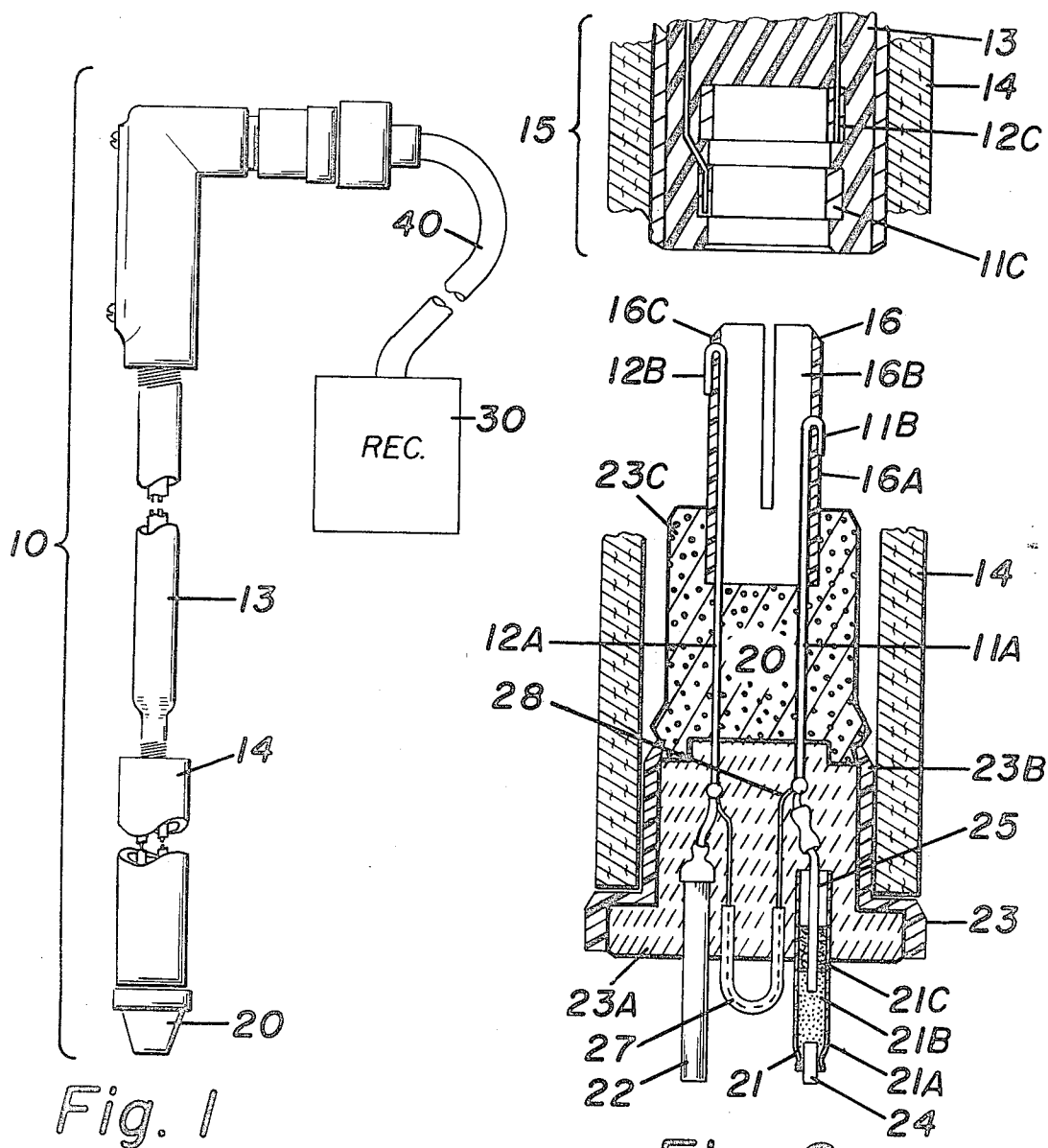


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ELECTRODE ASSEMBLY TO DETERMINE THE OXYGEN
CONTENT OF MOLTEN METAL
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**ELECTRODE ASSEMBLY TO DETERMINE THE
OXYGEN CONTENT OF MOLTEN METAL**
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5 Claims

ABSTRACT OF THE DISCLOSURE

An expendable, plug-in electrode assembly for insertion into a bath of molten material to form a galvanic cell comprised of solid state electrolyte connected on one side to a solid state reference electrode and on the other side connected to a connector electrode through a liquid containing a constituent in an amount to be determined. The electrode assembly is characterized by the inclusion of a thermal switch connected across the electrical leads to the electrodes for use in checking the continuity of plug-in electrical connections and a measuring circuit prior to immersing the electrode assembly into a bath of molten material.

BACKGROUND OF THE INVENTION

(1) Field of the invention

Applicants' invention is for use with galvanic cells. Such cells are classified in the U.S. Patent Office with items dealing with chemistry, electrical and wave energy and primarily are to be found in subclasses dealing with electrolysis or electrolytic apparatus for analysis and testing. Additionally, galvanic cells may be found in the class for batteries and particularly electrolytes for batteries. Thermal switches which may be useful in the practice of applicants' invention may be found in the U.S. Patent Office class relating to electric switches, electrothermally or thermally actuated switches with fusible, combustible or explosive material and/or those with fusible elements opening the circuit without employing mechanical contacts.

(2) Description of the prior art

During the past several years considerable time and money has been expended by many individuals in an effort quickly to determine and/or control the amount of one or more constituents in a bath of molten material by means of techniques utilizing a galvanic cell. Much has been accomplished towards the development of electrode assemblies suitable for insertion into a bath of molten metal such as liquid iron or steel to form therewith a galvanic cell for determination of the concentration of oxygen dissolved in the molten metal. The state of the art as of 1968 and a brief historical review of developments is set forth in a paper prepared for presentation at the 76th General Meeting of American Iron and Steel Institute, in New York, May 23, 1968, by E. T. Turkdogan and R. E. Fruehan entitled "Rapid Oxygen Determination in Liquid Steel." A copy of the paper is available upon request from the American Iron and Steel Institute, 150 E. 42nd Street, New York, N.Y. 10017.

In the Turkdogan et al. paper there is disclosed a disposable immersion type, plug-in unit including an electrode assembly for forming a galvanic cell in liquid steel and a thermocouple for measuring the temperature thereof. The plug-in electrical connections and thermocouple are like those used in disposable, i.e. expendable immersion thermocouples of the plug-in type disclosed in U.S. Pat. 2,999,121—H. G. Mead; 3,024,295—P. J. Moore; and 3,048,642—K. B. Parker. Expendable thermocouples are well known to those skilled in the arts wherein the temperature of a bath of molten material is to be meas-

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ured and particularly those skilled in the arts of producing steel and cast iron. Thermocouples of this type are plugged into a receptacle at the immersion end of a manipulator, sometimes referred to as a holder or a lance, which establishes an electrical connection to a measuring circuit which generally includes a recorder. Continuity of the entire measuring circuit is readily checked since a thermocouple, which consists of wires joined to form an electrical junction, is a device which completes the electrical circuit. On the other hand, however, an electrode assembly for insertion into a bath of molten material to form a galvanic cell is an open circuited device, that is to say, it does not conduct electricity until after it has been inserted into a bath of molten metal and its temperature raised sufficiently for the galvanic cell to become operable, hence it has heretofore been impossible to check the continuity of the plug-in electrical connections to the electrode assembly prior to insertion of the electrode assembly into a bath of molten material.

In accordance with applicants' invention this difficulty is overcome by the addition of a thermal switch to the electrode assembly.

SUMMARY OF THE INVENTION

It is an object of applicants' invention to provide a plug-in electrode assembly for galvanic cell, said assembly including a body structure supporting a reference electrode including a solid state electrolyte, and a connector electrode electrically insulated one from the other by material of the body structure and projecting from a face of the body structure. Each of the electrodes is connected to electrical conductors terminating at contacts of a plug-in connector, and means is provided for use in checking continuity of a measuring circuit including the contacts comprising a thermal switch supported by the body structure, said switch having electrically conductive means connected within the body structure to the electrodes to provide an electrically conductive path between them. The thermal switch has means exposed to heat externally of the body structure to be acted upon by the heat of molten material to open the conductive path between the electrodes upon insertion of the electrode assembly in a bath of molten material.

It is more specifically an object of applicants' invention to provide an expendable, immersion, plug-in electrode assembly for determining the oxygen content in a bath of molten steel wherein the assembly comprises: a body structure including electrical and heat insulating refractory material supporting a projecting reference electrode with a solid state electrolyte mounted in an immersion end thereof in electrical contact therewith. The assembly also includes a connector electrode supported by and projecting from said refractory material in a direction substantially parallel to said reference electrode. There is plug-in electrical contact means electrically connected with the electrodes accessible from a face of said body structure other than said immersion end, and the improvement consisting of a thermal switch comprised of an electrical conductor having an intermediate meltable portion thereof housed in a U-tube of heat transmitting, electrically insulating refractory material in projecting relation with respect to the immersion end of the body structure and with end portions of the electrical conductor connected within the body structure to the electrodes thereby to provide an electrically conductive path therebetween.

BRIEF DESCRIPTION OF THE DRAWINGS

For an understanding of applicants' invention the following description and claims should be read with reference to the accompanying drawings wherein:

FIG. 1 is a side elevation of an immersion oxygen

sensing assembly with the electrical connections to a recorder shown diagrammatically,

FIG. 2 is an enlarged, exploded side elevation in section showing the construction of a sensor in accordance with applicants' invention and the manner in which it is electrically connected to a manipulator structure, and

FIG. 3 is a plan view of the immersion end of applicants' sensor.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. 1 reference numeral 10 designates an immersion oxygen sensing assembly comprised of a lance or manipulator 13 which has plugged into the immersion end thereof a combination electrode and thermocouple assembly 20 which is electrically connected to a measuring and recording device 30 by means of electrical conductors within a multi-conductor cable 40. In FIGS. 2 and 3 the assembly 20 is shown in greater detail with the thermocouple and a fusible cap omitted in order to simplify this disclosure since they form no part of applicants' invention. The thermocouple and cap may be of the types disclosed in the Mead, Moore, and Parker patents. A multi-conductor plug-in connector for a pair of thermocouples is disclosed in FIG. 6 of U.S. Pat. 3,455,164-G. P. Boyle. A connector of the same general construction will serve equally well for an assembly including a thermocouple and a pair of electrodes.

In FIG. 2 there is shown the lower or immersion end of manipulator 13, a device well known to those skilled in the art of expendable thermocouple pyrometry. In the immersion end of manipulator 13 is mounted the female portion 15 of a plug-in connector, of the type disclosed in FIG. 8 of the above mentioned Parker patent. This female portion is adapted to receive the male connector portion 16 which is part of electrode assembly 20. The lower end of manipulator 13 is surrounded by a protective tube 14 of cardboard or other suitable material that will withstand the action of a bath of molten steel or the like for the short time required to obtain a measurement. The lower or immersion end of the tube 14 has inserted therein and securely fastened thereto the electrode assembly 20. When measurement is to be made the tube is slid over the manipulator 13 and the male connector portion 16 of the plug-in connector is engaged with the mating female portion 15.

The electrode structures of assembly 20 may be any of several types known to those skilled in the art. The ones used for illustrative purposes comprise a reference electrode 21 supporting a solid electrolyte 24 in the immersion end thereof, and a connector electrode 22. Both electrodes are supported by and project from the immersion end of body structure 23.

The reference electrode 21 is desirably a tube 21A of fused quartz or Vycor glass having an end supported in a mass 23A of electrical and heat insulating refractory cement within a plastic sleeve 23B which are parts of body structure 23. At the immersion end of tube 21A there is secured a cylindrical plug 23 of solid electrolyte material such as calcium stabilized zirconium oxide. Within tube 21A and bridging the space between the mass of solid electrolyte 24 and the end of a molybdenum rod-like conductor 25 is a mixture 21B of chrome metal powder and chrome oxide powder which has been compacted within the tube to effect good electrical contact with the electrolyte and conductor 25. This chrome, chrome oxide powder serves to generate a stable oxygen reference potential. Between the upper end of tube 21A, as viewed in FIG. 2, and the compacted powder is a quantity of alumina and silica fibers 21C in the form of a wool to retain the powder in place. The rod-like conductor 25 extends from the upper end of tube 21A through a seal comprised of Hysol epoxy resin and is connected as by a crimp connector to an electrical conductor 11A which passes through the refractory cement and plastic tube 16A wherein it is reversely bent in a slot 16B to form elec-

trical contact 11B of the male connector portion 16 of the plug-in connector. The plastic tube 16A is supported in a counterbore in a member 23C of the body structure 23. The material of 23C is not critical since it need only support the connector at a location protected from heat. The electrical conductor 11A connected to rod 25 is, in the modification described, a material known to those skilled in the art as #11 alloy.

In spaced, substantially parallel relation to the reference electrode 21 there is supported projecting from the mass 23A of refractory cement a connector electrode 22 which may be a piece of molybdenum rod about 1/8-inch in diameter secured to a copper conductor 12A as by a crimped connector. The conductor 12A extends through tube 16A and is reversely bent through a slot 16C to form electrical contact 12B of the male portion 16 of the plug-in connector. It may be noted that the contacts are positioned at different locations along the longitudinal axis of the connector portion 16 thereby to form plug-in contacts as described in the above mentioned Parker patent. While contact structures like those shown in FIG. 8 of the Parker patent are deemed desirable it is clearly to be understood that many other types of plug-in connector structures are known, any of which may be found satisfactory and that the materials used will be selected in accordance with those employed in the reference and connector electrodes. It is likewise to be understood that the electrode structures described are known to those skilled in the art and are not applicants' invention.

Since in the absence of applicants' invention no electrical circuit is completed by plugging the male portion 16 into female portion 15 of the plug-in connector applicants provide a circuit including a thermal switch temporarily to connect electrode 21 with electrode 22. A suitable circuit and switch is comprised of a refractory U-tube 27 projecting from and supported by the body structure 23 within which is an easily meltable wire 28 which may be of copper approximately 0.015 inch in diameter having portions which extend beyond the ends of the tube inwardly of the body structure and connected to conductors 11A and 12A respectively, thus to establish a conductive path between these conductors when the electrode assembly 20 is not in use. When the assembly 20 is plugged into the manipulator 13 which has conductors within cable 40 terminating in a connection with the recorder 30 a circuit is completed from the recorder, through the contacts 11C, 11B and 12C, 12B of connector elements 15 and 16 and conductor 28 of the thermal switch. Continuity of the circuit will be indicated by operation of the recorder in a particular manner.

As is known to those skilled in the art, when the electrode assembly 20 is inserted to a subsurface level of a bath of molten metal, such as steel, an electrical circuit is completed between the solid electrolyte 24 of reference electrode 21 and the connecting electrode 22, thus to form a galvanic cell. In order for the cell to be operable the circuit established by wire 28 must be opened. This is automatically and quickly effected when the assembly 20 is immersed in the molten steel bath by the intense heat transmitted through the walls of the refractory U-tube 27 which quickly melts the wire 28 to open the circuit which had existed by way of wire 28 connected to the conductors 11A and 11B. Thereafter as the intense heat of the bath heats the solid electrolyte 24 the galvanic cell becomes operable for its intended purpose.

While a specific embodiment of applicants' invention has been illustrated for a specific application it is to be understood that applicants' invention will be useful with other plug-in electrode assemblies for other high temperature galvanic cells and for applications other than sensing oxygen in molten steel.

What is claimed is:

1. A plug-in electrode assembly for a galvanic cell, said assembly including a body structure supporting a reference electrode including a solid state electrolyte and

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a connector electrode electrically insulated one from the other by material of the body structure and projecting from a face of the body structure, electrically conductive means from said electrodes terminating at electrical contacts of a plug-in electrical connector portion, and the improvement comprising a thermal switch supported by the body structure, said switch having electrically conductive means connected within said body structure to said electrodes temporarily to provide an electrically conductive path between them, and said switch having means exposed to heat exterior of said body structure to be acted upon by heat in a manner to open said conductive path upon insertion of said electrode assembly in a bath of molten material.

2. A plug-in electrode assembly in accordance with claim 1 wherein said thermal switch is comprised of an electrical conductor meltable by the heat of a bath and wherein each end of said conductor is attached to one of said electrodes to form said electrically conductive path and an intermediate portion of said conductor is exposed to heat exterior of said body structure through an electrically insulating heat transmitting element of refractory material.

3. A plug-in electrode assembly in accordance with claim 2 wherein said element of refractory material is a U-shaped tube with said intermediate portion of said conductor encased therein having its open ends mounted in said body structure and the bend of the U and portions adjacent thereto projecting outwardly of said body structure.

4. A plug-in electrode assembly according to claim 2 wherein said electrical conductor meltable by heat is a copper wire.

5. An expendable, immersion, plug-in electrode as-

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sembly for determining the oxygen content in a bath of molten steel, said assembly comprising:

a body structure including electrical and heat insulating refractory material supporting a projecting reference electrode with a solid state electrolyte mounted in an immersion end thereof in electrical contact therewith,

a connector electrode supported by and projecting from said refractory material in a direction substantially parallel to said reference electrode;

plug-in electrical contact means electrically connected with said electrodes accessible from a face of said body structure other than said immersion end, and

a thermal switch comprised of an electrical conductor having an intermediate meltable portion thereof housed in a U-tube of heat transmitting, electrically insulating refractory material mounted in projecting relation with respect to said immersion end of said body structure and with end portions of said electrical conductor connected to said electrodes within said body structure thereby to provide an electrically conductive path therebetween.

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