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DETERMINATION OF CONTAMINATION OF LIQUID METALS

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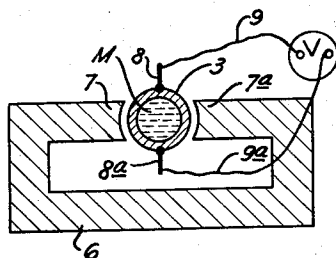
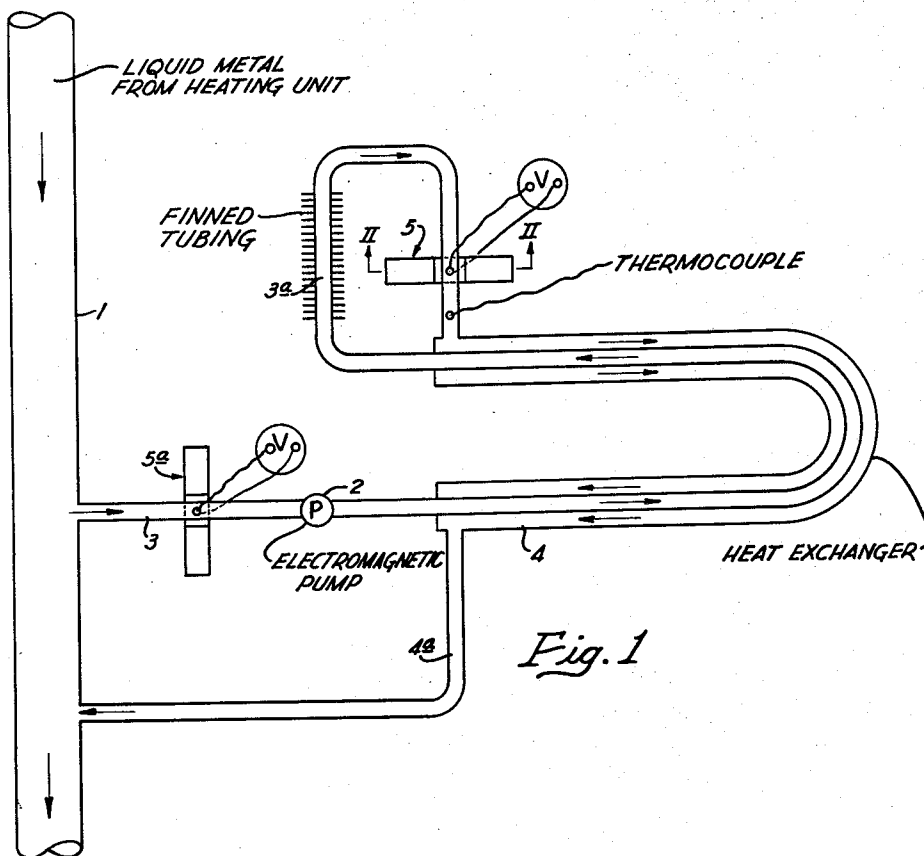


Fig. 2

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DETERMINATION OF CONTAMINATION OF LIQUID METALS

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10 Claims. (Cl. 324—65)

This invention relates to liquid metal heating systems, more particularly to the determination of impurities, such as oxide or other non-metallic impurities, present in the liquid metal.

Liquid metals are well known to have characteristics that render them important and highly desirable as heat transfer media. For example, their thermal conductivity may be as great as 50 to 150 times that of water, and in general the specific heats of liquid metals are lower than those of other heat transfer media so that they heat more quickly to operating temperatures. Furthermore, the liquid metals are characterized by high coefficients of heat transfer, and they are thermally stable relative to non-metallic transfer media wherefore the liquid metals are useful over a wider range of temperatures because of their stability. A particularly important characteristic of the liquid metals is that they possess low vapor pressures so that they may be operated at high temperatures under little or no pressure.

Liquid metals are particularly useful in closed loop systems in which the liquid metal is heated to operating temperature in a heating unit whence it passes to another unit, such as a heat exchanger, to do useful work in the performance of which the liquid metal becomes cooled, and it is then returned in its cooled but still liquid state to the heating unit. As long as the condition of the liquid metal remains unchanged, its performance is satisfactory. However, there is an ever present tendency for the liquid metal to pick up and accumulate impurity, especially non-metallic impurity, commonly oxide of the liquid metal. Such impurity may be formed in consequence of the production of metal oxide due to the presence of air in the system, or by reduction of metallic oxides in the conduit wall. Or, impurities may result from corrosion of the conduit.

It is characteristic that such impurities in liquid metals are of highly restricted solubility; the solubility in general decreases very rapidly with lowering of temperature. By way of example, at 1000° F. metallic sodium is capable of dissolving sodium oxide equivalent to 0.2 percent of oxygen but the solubility decreases to about 0.08 percent oxygen equivalent at 800° F., and at 300° F. sodium oxide is virtually insoluble in metallic sodium.

Pick up of impurities by liquid metal heat transfer media at points where unsaturation occurs is attended by objectionable consequences. For example, at constant power input to a circulating pump, the metal flow rate decreases as oxygen or oxide dissolves in the liquid media with resultant impurity deposition at points where saturation occurs due to a lower temperature, since there is a common tendency for these impurities to precipitate out on the conduit walls where cooling is taking place, with impairment to flow and heat transfer.

In the case of some liquid metals these impurities can be rendered innocuous. For instance, in the case of sodium or sodium-potassium alloys "getters" such as metallic magnesium or calcium, may be introduced, or cold trapping may be used, to eliminate oxide carried by

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the liquid metal. However, heretofore it has been difficult to determine when the use of getter is needed, and the proper dosage. These and related matters have militated, accordingly, against the more wide spread use of liquid metal heating systems.

A primary object of this invention is to provide a method of detecting the presence of impurity in circulating liquid metal that is applicable particularly to doing so before the concentration of impurity exerts a detrimental effect upon the metal circulation, as in a closed loop system.

Another object is to provide such a method that is simple, easily performed, does not interfere with normal circulation of the metal, is of good sensitivity, is adapted to indicate, by automatic means, when such impurity reaches a predetermined value, whereby steps may be taken to reduce or eliminate the impurity content, and which requires only simple and readily available devices.

Yet another object is to provide simple and inexpensive apparatus for performing the method of the foregoing objects.

Other objects will appear from the following description.

The invention will be described with reference to the accompanying drawing in which Fig. 1 is a schematic representation of its preferred embodiment as applied to a closed loop heating system; and Fig. 2 a sectional view, on an enlarged scale, taken on line II—II, Fig. 1.

The method provided by the invention is based on the fact that when impurity in liquid metal is present in excess of its solubility at a given temperature it will be precipitated and will deposit on the metal conduit walls. In the practice of our method the presence of solid impurity is detected by subjecting a portion of a metal conduit carrying circulating liquid metal to a substantially constant magnetic field flowing across the conduit perpendicular to the direction, or axis, of metal flow, whereby the cutting of the lines of magnetic force by the metal flow creates an E. M. F. a portion of which may be measured by appropriate means, preferably by a pair of electrodes connected to the conduit in a plane perpendicular both to that of the magnetic field and also to that of metal flow. All of the E. M. F. generated will not appear on the surface of the conduit because the conduit, being a conductor of electricity, will cause a shorting effect and thus reduce the output voltage by the IR drop of the internal resistance of the generator. As long as the condition of the liquid metal relative to impurity content remains the same, the E. M. F. appearing on the outside surface of the conduit will remain constant. However, the deposition of impurities on the inside surface of the conduit, due to exceeding the solubility limit at the constant temperature or in consequence of lowering of the liquid metal temperature will cause the E. M. F. output signal to drop as a result of the deposit with considerable lower electrical conductivity than the liquid metal, thus, in effect, inserting a high resistance between the generator and the load. Thus means are provided for determining the occurrence of such a condition. Likewise, by the development of appropriate calibration curves the E. M. F. measurements may be used as a quantitative measure of the amount of impurities present, provided that constant temperature and flow rate are maintained.

The practice of that simple embodiment will not indicate the occurrence of impurity trouble until it has become an actual problem in the operation of the liquid metal heating system, as by impairment of metal flow or of heat transfer. For most purposes detection of the imminence of trouble, i. e., deposition of impurities as solids, is desired, and accordingly to obtain this prediction the measurement must be made at a temperature

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below that in the operating loop. To this end we now prefer to by-pass a small portion of the main streams through a by-pass line in which it is cooled to a selected temperature where it is exposed to an electromagnetic device of the type described above. As long as the E. M. F. generated is constant, satisfactory operating conditions prevail but lowering of the E. M. F. signal from the outside surface of the conduit indicates the impurity content of the main stream has reached a concentration such that future deposition in it may be expected. Steps may then be taken, as indicated above, to correct the situation.

Most suitably in this embodiment the cooled metal after it leaves the electromagnetic detector moves in heat exchange relationship with the incoming by-passed metal so as to minimize heat loss in returning the cooled by-pass stream to the main stream. Likewise, a second detector is located in the incoming by-pass line where there is little or no temperature drop; when the output of the detector at the cooled region falls off suddenly relative to that at or near the main stream temperature, the desired indication is had even though the main stream flow rate and temperature are changing.

Having reference now to the drawing, a main stream of heated liquid metal circulates, as indicated by arrows, in one branch 1 of a closed loop system. A small by-pass stream is drawn, as by an electromagnetic pump 2, into a by-pass conduit 3 having a portion 3a provided with metallic fins. From portion 3a the metal passes into a conduit 4 co-axially surrounding conduit 3 and from which an extension 4a returns the by-pass stream to conduit 1 down stream of the intake 3. As appears from the drawing, conduits 3 and 4 provide a heat exchanger in which the cooled metal from 3a picks up heat from the hot metal entering in 3, thus conserving heat.

In accordance with the invention an electromagnetic detector element 5 is associated with conduit 3 beyond but adjacent portion 3a. It comprises an electromagnet 6, Fig. 2, mounted so that conduit 3 is disposed centrally of the air gap between its poles 7 and 7a and so that the lines of force pass through the conduit normal to the direction of flow of the liquid metal M. A pair of electrodes 8 and 8a are mounted in diametrically opposed position in the wall of conduit 3 to lie in a plane normal to that of the lines of force from the magnet 6 and also normal to the direction of flow of the metal M in the conduit. The electrodes are connected by leads 9 and 9a to conventional means, such as a voltmeter V, for measuring the E. M. F. generated and changes therein. A second detector element 5a like that just described is associated similarly with conduit 3 adjacent the main stream so that there is little or no temperature drop between the main stream in conduit 1 and the by-pass metal where detector 5a is located.

Finned section 3a serves to cool the by-passed metal as it moves through it. If further cooling is needed or desirable, an air blast may be directed upon the fins.

Assuming that pure liquid metal, or liquid metal containing an unobjectionable amount of impurity, flows at a constant rate and temperature through the closed by-pass loop system, the E. M. F. generated by detectors 5 and 5a will remain constant. As impurities, such as oxide, form they will eventually reach a point at which the amount exceeds the solubility at the lower temperature prevailing just beyond portion 3a of the by-pass circuit, i. e., where detector 5 is mounted. This will be promptly reflected by a lowering of the E. M. F. output of detector 5 relative to that of detector 5a.

By operating such a system with successive additions of a normal impurity, such as sodium oxide in the case of metallic sodium, and measuring the resultant E. M. F. change at detector 5 due to the successive increases of oxide content vs. prevailing temperature, a calibration curve can be set up from which knowing the prevailing temperature the E. M. F. output can be used as a measure

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of the amount of oxide present. The E. M. F. change is dependent upon the quantity of impurity deposited at the detector, not the composition of oxide in the liquid, as long as saturation is reached. The range of temperature covered by the calibration curve is inversely proportional to the size of the system.

The metallic conduit tends to short out the E. M. F. generated by the liquid flow but experience has shown that even so sufficient E. M. F. is generated for adequate measurement, and in any event the various amplifying circuits and devices available can be used, if need be.

As indicating the sensitivity of our method, sodium containing oxide equivalent to 0.15 percent of oxygen generated an E. M. F. of 3.5 millivolts at about 850° F., while at 800° F. the E. M. F. was but about 1.6 millivolts. At 0.23 percent of oxygen and 900° F., the E. M. F. was 3 millivolts, whereas it was but 1 millivolt at 800° F. The occurrence of such abrupt breaks, or changes, in E. M. F. thus affords an accurate mode of determining when an impurity has exceeded its solubility at a given temperature, and thus when it will interfere with efficient flow and heat transfer.

Various changes may, of course, be made. For instance, the magnet 6 may be a permanent magnet or an electromagnet, while if needful or desired for any reason, an alternating current field may be substituted for the direct current field described. And as will be understood, the measurement of the E. M. F. may be manual at repeated intervals, or the leads from the electrodes may be associated with ultimate recording means that may, if desired, be adapted to operate a warning signal of any type upon the occurrence of a predetermined impurity condition. Also, sensitivity may be increased by the use of cooled electrodes, especially where very low impurity contents are involved.

Experience has shown that once a measuring device of the type shown and described has been calibrated for a given liquid metal and pipe size, it may be used for the same metal with other pipes of the same size and metal.

According to the provisions of the patent statutes, we have explained the principle of our invention and have illustrated and described what we now consider to represent its best embodiment. However, we desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

We claim:

1. In the operation of a liquid metal heating system in which the metal is circulated through conduits from and to a heat source, the method of determining non-metallic impurity in said metal comprising subjecting a portion of said conduit to a substantially constant magnetic field flowing across the conduit perpendicular to the direction of metal flow, providing a pair of electrodes at opposite sides of said conduit portion in a plane perpendicular to said magnetic field and said direction of metal flow, and connecting said electrodes to means for indicating the E. M. F. induced in the metal flowing through said portion, lowering of said E. M. F. at a given metal temperature indicating the said impurities to be in excess of solubility at that temperature.

2. A method according to claim 1, said metal being selected from the group consisting of sodium and sodium-potassium alloys.

3. In the operation of a liquid metal heating system in which the metal is circulated through conduits from and to a heat source, the method of determining non-metallic impurity in said metal comprising subjecting a portion of said conduit to a substantially constant magnetic field flowing across the conduit perpendicular to the direction of metal flow, providing a pair of electrodes at opposite sides of said conduit portion in a plane perpendicular to said magnetic field and said direction of

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metal flow, and connecting said electrodes to means for indicating the E. M. F. induced in the metal flowing through said portion, lowering of said E. M. F. at a given metal temperature indicating the said impurities to be in excess of solubility at that temperature, and determining the temperature at which lowering occurs.

4. In the operation of a liquid metal heating system in which the metal is circulated through conduits from and to a heat source, the method of determining non-metallic impurity in said metal comprising subjecting a portion of said conduit to a substantially constant permanent magnetic field flowing across the conduit perpendicular to the direction of metal flow, providing a pair of electrodes at opposite sides of said conduit portion in a plane perpendicular to said magnetic field and said direction of metal flow, and connecting said electrodes to means for indicating the E. M. F. induced in the metal flowing through said portion, lowering of said E. M. F. at a given metal temperature indicating the said impurities to be in excess of solubility at that temperature.

5. A method according to claim 4, said liquid metal being of the group consisting of sodium and sodium-potassium alloys.

6. A method according to claim 5 in which said impurity comprises sodium oxide.

7. In the operation of a liquid metal heating system in which a main stream of the metal is circulated through a main conduit from a heat source, the method of determining non-metallic impurity in said metal comprising by-passing a portion of said main stream in a closed loop conduit from and to said main conduit, cooling the by-passed stream in a portion of the loop circuit, subjecting the cooled stream to a substantially constant magnetic field flowing across the loop conduit perpendicular to the direction of metal flow, providing a pair of electrodes at opposite sides of said loop conduit portion in a plane perpendicular to said magnetic field and said direction of metal flow, and connecting said electrodes to means for indicating the E. M. F. induced in the metal flowing through said loop conduit portion, lowering of said E. M. F. at a given metal temperature indicating the said impurities to be in excess of solubility at that temperature.

8. In a circulating liquid metal heating system in which the metal is passed through a conduit from a heat source

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through a conduit, the combination with said conduit of a closed loop conduit for circulating a by-pass stream from and to the conduit, means associated with a portion of said by-pass conduit for cooling metal flowing through it, a detector associated with said by-pass conduit beyond and adjacent said cooling means and comprising an electromagnet disposed so that its field flows thereacross perpendicular to the direction of metal flow, a pair of electrodes connected at opposite sides to the conduit in a plane perpendicular to said field and direction of metal flow.

9. In a circulating liquid metal heating system in which the metal is passed through a conduit from a heat source through a conduit, the combination with said conduit of a closed loop conduit for circulating a by-pass stream from and to the conduit, means associated with a portion of said by-pass conduit for cooling metal flowing through it, a detector associated with said by-pass conduit beyond and adjacent said cooling means and comprising an electromagnet disposed so that its field flows thereacross perpendicular to the direction of metal flow, a pair of electrodes connected at opposite sides to the conduit in a plane perpendicular to said field and direction of metal flow, means for indicating the E. M. F. generated by the detector, and connections between the electrodes and said means.

10. Apparatus according to claim 9 in which the portion of said by-pass conduit beyond said cooling means is disposed around a corresponding portion of the incoming by-pass conduit for heat exchange between incoming hot metal, and outgoing cooled metal, and a second said detector element is similarly associated with said incoming portion adjacent the main conduit.

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