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GB 1085633
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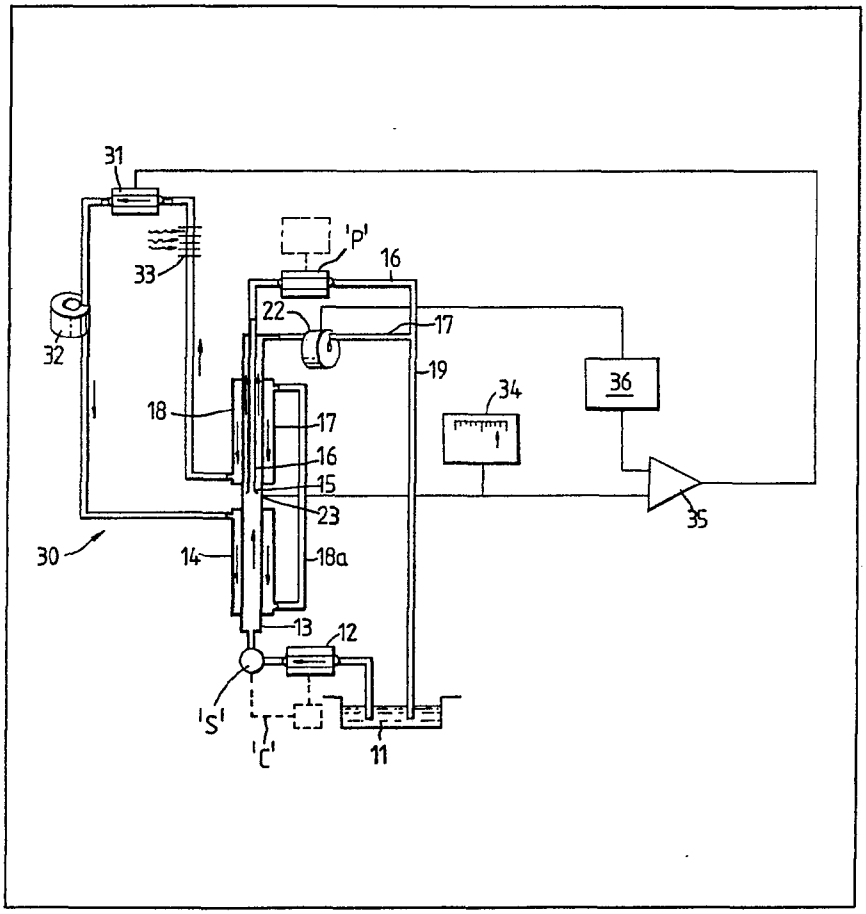
(54) Liquid metal monitor

(57) A liquid metal monitor of the by-pass plugging meter kind described in British Patent 1,308,466, is further provided with a pump P′ arranged to oppose flow through by-pass 16 thereby to provide a constant pressure difference across orifice 15 and improve the sensitivity of the instrument. The monitor estimates the impurity content in a liquid metal stream.



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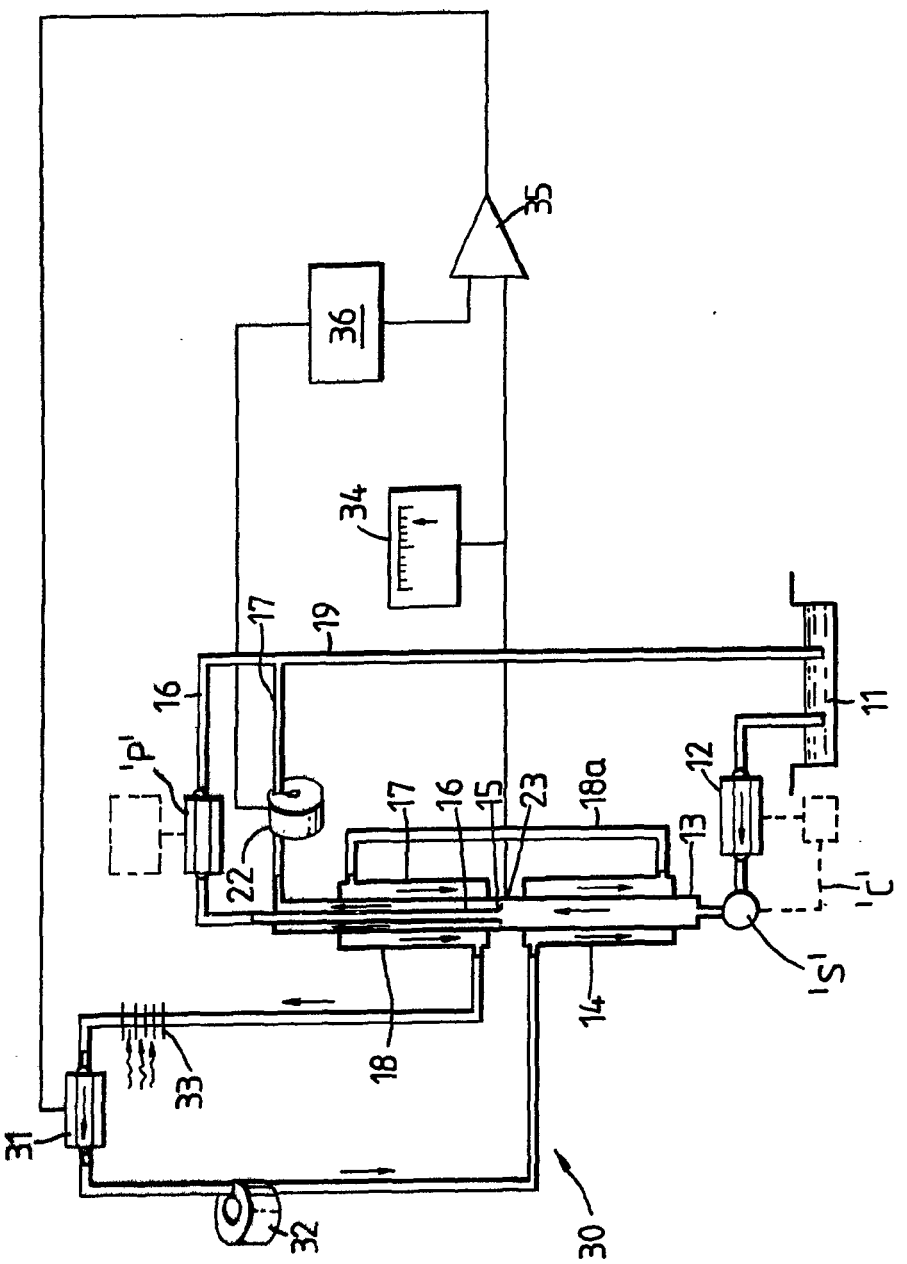
35
36
34
17
19
16
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'P'
17
16
15
23
18a
12
13
22
'C'
'S'
14
18
33
31
32
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SPECIFICATION

Liquid level monitors

This invention relates to liquid metal monitors used for estimating the impurity content (mainly oxygen in the form of the metal oxide) in a liquid metal stream. The invention is concerned with monitors known as "plugging meters". Such meters rely on the fact that there is a known relationship between temperature and the solubility of the impurity in the liquid metal. The temperature is measured at which impurity begins to precipitate (plugging) and at which it begins to redissolve (unplugging) and the mean value is taken as the true saturation temperature. A flow of hot liquid metal is established through a cooler and then through an orifice. If the temperature of the liquid metal passing through the orifice is progressively reduced while the flow rate is continuously measured a reduction in flow indicates that the orifice is being partially blocked or "plugged" by particles of impurity. If the temperature of the partially plugged orifice is progressively raised, the unplugging temperature can be observed.

A continuous indication of true saturation temperature can be obtained if the temperature at the orifice is controlled so that flow through a partially blocked orifice is maintained constant.

A liquid metal monitor of this kind is disclosed in Patent 1085633 and in that monitor there is provided a by-pass for a fraction of the flow, the division of flow taking place immediately before the orifice. The by-pass plugging meter is more amenable to automatic control than the more conventional plugging meter because the total flow of liquid metal through the cooler remains approximately constant even when blockage of the orifice occurs. A development of the by-pass plugging meter is disclosed in Patent No 1308466 the development seeking greater heat economy by transferring heat energy from liquid metal upstream of the orifice to liquid metal down stream of the orifice through a closed cooling circuit. In addition, disturbances in the meter reading due to changes in the temperature of the sodium supply are reduced by making the rate of cooling of the liquid metal flow before the orifice a function of both flow through the orifice and temperature of liquid metal at the orifice.

An object of the present invention is to provide a by-pass plugging meter generally of the kind disclosed in Patent No 1308466 but having improved sensitivity.

According to the invention in a liquid metal monitor comprising an orifice in a liquid metal flow path which orifice can be at least partially plugged by impurity precipitated from liquid metal in the flow path, there being a division of the liquid metal flow at the orifice into two parts so that subsequently one of the paths passes through and the other part by-passes the orifice, and wherein heat transfer means are provided for transferring heat energy from the liquid metal in the flow path upstream of the orifice to liquid metal in the flow path downstream of the orifice is characterised in that the by-pass includes a pump arranged to oppose flow through the by-pass thereby to provide a constant pressure difference across the orifice. The arrangement according to the invention produces a greater change in flow for a given degree of blocking of the orifice.

In a preferred construction the pump is arranged to operate such that there is zero rate of flow through the by-pass in the unplugged condition so that all the flow is available for supplying impurities in which case the total flow can be approximately halved thereby reducing cooling requirements.

An embodiment of the invention is described by way of example with reference to the accompanying drawing which is a flow circuit diagram.

A channel 11 carries a supply of liquid metal sodium to be monitored. Such sodium is drawn from the channel 11 by means of electromagnetic pump 12 which serves to drive the sodium through a duct 13 by way of a flow meter 'S'. Downstream of the flow meter 'S' the duct is surrounded by a first jacket 14 through which a heat exchange medium, such as a mixture of liquid metal sodium and potassium, can be passed as will be described hereafter.

An orifice plate 15 is positioned in the duct 13 downstream of the first jacket and acts to divide sodium flow along duct 13 so that it either passes into a by-pass duct 16 or through the orifices in plate 15 into a duct 17. A thermocouple 23 is embedded in the duct wall in the region of plate 15. Downstream of orifice plate 15 the duct 17 is surrounded by a second jacket 18 which is coupled to the first jacket by pipe 18a and incorporated in the heat exchange medium circuit as will be hereinafter described.

By-pass duct 16 connects into a return line 19 leading back to the channel 11. The by-pass duct contains an electromagnetic pump 'P' acting in reverse so as to provide a constant pressure difference across the orifice. The pump P is designed to have a low flow restriction so that pressure difference is independent of by-pass flow.

Duct 17, also opening into return line 19, includes an electromagnetic flow meter 22 whose output (a function of the sodium flow through orifice plate 15) is used to control a pump 31 in a closed loop 30. The pump 31 is controlled by the output of the flow meter 22 and the thermocouple 23. The closed loop 30 contains a heat transfer medium consisting of a liquid metal sodium-potassium mixture which is driven around the loop by the pump 31 whose pumping rate can be varied. The liquid metal mixture in the loop is continuously cooled by the means of an air cooler 23 having vanes over which air is driven by a fan (not shown). An electromagnetic brake 32 serves to limit convection flow in the coolant liquid metal mixture which flow can otherwise persist in the loop with the pump 31 switched off.

The flow meter and thermocouple outputs are fed into a differential DC amplifier 35. The output

of the amplifier 35 is proportional to the differential of the two inputs and the varying output is used to effect correspondingly variable control of the pump 31. The saturation temperature represented by the output of thermocouple 23 is continuously recorded on a pen recorder 34. The ouput of the flow meter 22 is fed to the differential amplifier 35 by way of a controller 36.

The principles of the monitor are adequately discussed in Patent No 1085633. Sodium metal from channel 11 is driven through duct 13 by means of pump 12. Cooling of the sodium metal in duct 13 occurs by heat exchange with liquid sodium potassium mixture driven through the first jacket 14. Cooled sodium in duct 13 then arrives at the orifice plate 15 and divides into two parts, one part passing into by-pass duct 16 and the other part passing through the orifices of plate 15 into the duct 17. Both orifice and by-pass flows receive heat in passing through the part of the duct 17 surrounded by second jacket 18. This jacket receives by way of pipe 18a the hot sodium potassium mixture from first jacket 14 which serves to receive heat from liquid sodium upstream of orifice plate 15. Liquid sodium in orifice duct 17 is then returned to channel 11 by way of return line 19 after passing through the electromagnetic flow meter 22. Flow through the duct 16 is governed by the 'reverse' pump 'P'. The pressure of the reverse pump 'P' is adjusted so that the flow in the by-pass is zero in the unplugged condition, the total liquid metal flow being available for supplying impurity. The initial condition of zero flow in the by-pass is set up by equating the flow through the orifice duct 17 in the unplugged condition with the total flow as indicated by the flow meter 'S'. The flow meter 'S' may also be connected in a loop control (designated 'C' in the drawing) with the pump 12 to keep the total flow constant.

In the embodiments of plugging meter disclosed in Patent No 1308466 and in the present embodiment which is generally similar, the output of flow meter 22 is fed by way of controller 36 into differential amplifier 35 together with the output of thermocouple 23. In this way the rate of cooling provided by the sodium potassium mixture in its closed loop 30 in passing through the jackets 14, 18 is made a function of both flow through the orifice plate and the temperature of liquid metal in the region of the orifice plate.

When the temperature of the supply sodium remains constant, automatic control of the instrument operates around the loop comprising orifice flow meter 22, controller 36, differential amplifier 35 and the coolant pump 31. This control loop is similar to that described in UK Patent 1085633. The effect of the orifice thermocouple connection is to introduce a degree of negative feedback.

When the temperature of the supply sodium varies, the temperature in the region of the orifice (which is displayed as the saturation temperature) will also vary although the actual impurity saturation temperature may have remained constant. Changes in the orifice temperature are communicated to the differential amplifier 25 which in turn controls the pump 31. The pump (and hence the coolant flow and orifice temperature) is adjusted in such a way as to reduce the original orifice temperature excursion, thus the error in the saturation temperature reading caused by a change in inlet sodium temperature, is reduced by the application of the feedback.

Controller 36 embodies an adjustable "set point" the position of which determines the value of the restricted orifice flow. It also embodies the variable terms for optimising control loop performance.

By providing a constant pressure difference across the orifice plate by means of the reverse acting pump 'P' a greater change in flow is produced by a given degree of blocking so that improved sensitivity is achieved.

By adjusting the flow through the by-pass duct 16 so that it is zero in the unplugged condition of the orifice the total flow of liquid metal is approximately halved thereby reducing the cooling air requirement for the cooler 33.

CLAIMS

1. A liquid metal monitor comprising an orifice in a liquid metal flow path which orifice can be at least partially plugged by impurity precipitated from liquid metal in the flow path, there being a division of the liquid metal flow at the orifice into two parts so that subsequently one of the paths passes through and the other part by-passes the orifice, and wherein heat transfer means are provided for transferring heat energy from the liquid metal in the flow path upstream of the orifice to liquid metal in the flow path downstream of the orifice, characterised in that the by-pass includes a pump arranged to oppose flow through the by-pass thereby to provide a constant pressure difference across the orifice.

2. A liquid metal monitor according to claim 1 wherein the pump is arranged to operate such that there is zero rate of flow through the by-pass in the unplugged condition.

3. A liquid metal monitor substantially as hereinbefore described with reference to the accompanying drawings.

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