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(54) Liquid level control and indication

(57) Apparatus for sensing liquid level comprises a heated probe (17) disposed in the liquid container, the presence of the liquid serving to maintain the probe relatively cool while its absence results in the temperature of the probe rising. The probe is associated with a temperature sensor (19), whose output serves to initiate, control of the liquid level and/or shut-down of the boiler or vessel and/or alarm. Such apparatus avoids a false "safe" signal being transmitted due to scale or deposits forming on the probe. The probe may be inclined and contain temperature sensors at each end of the heater.

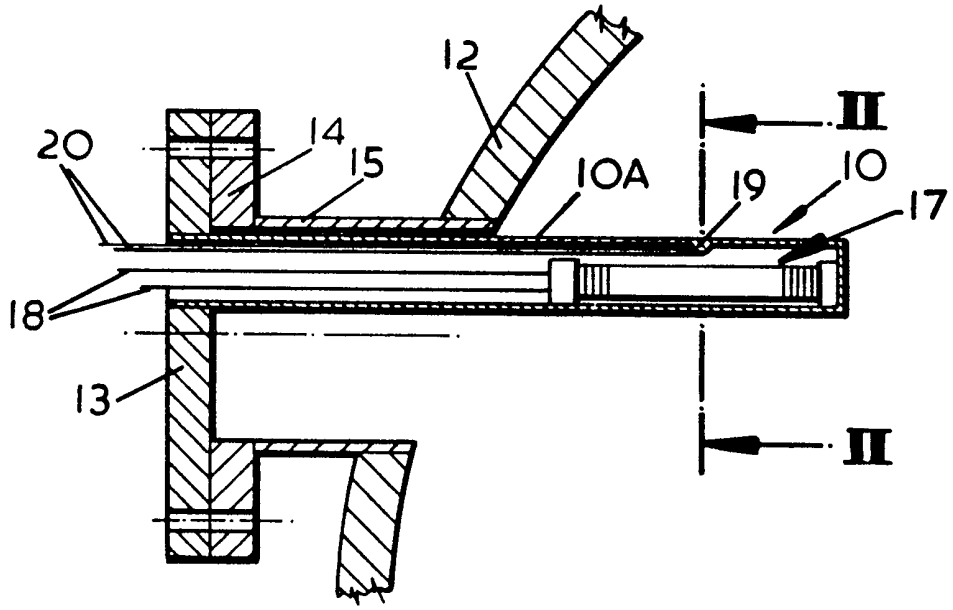

FIG. 1

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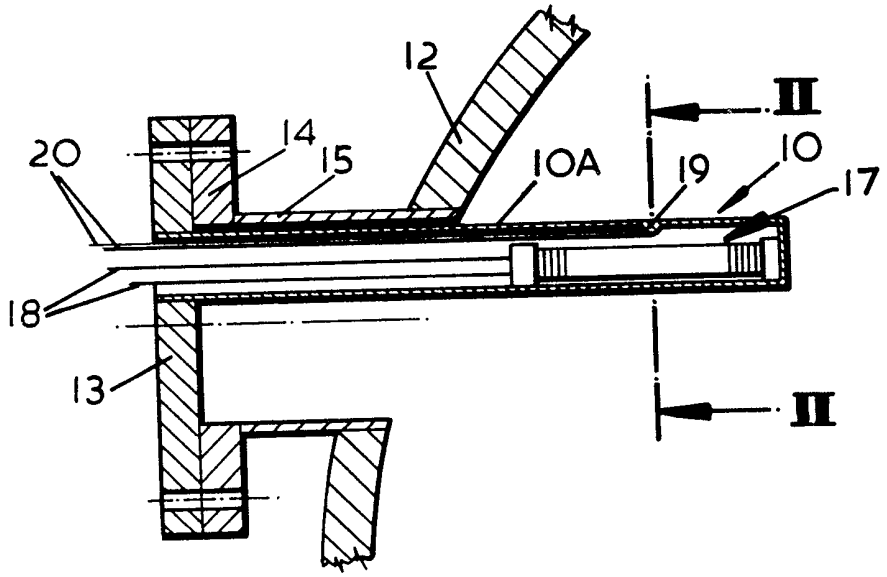

FIG. 1

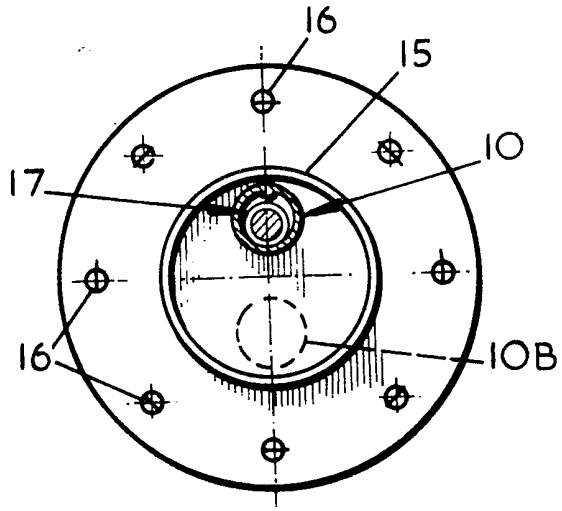

FIG. 2

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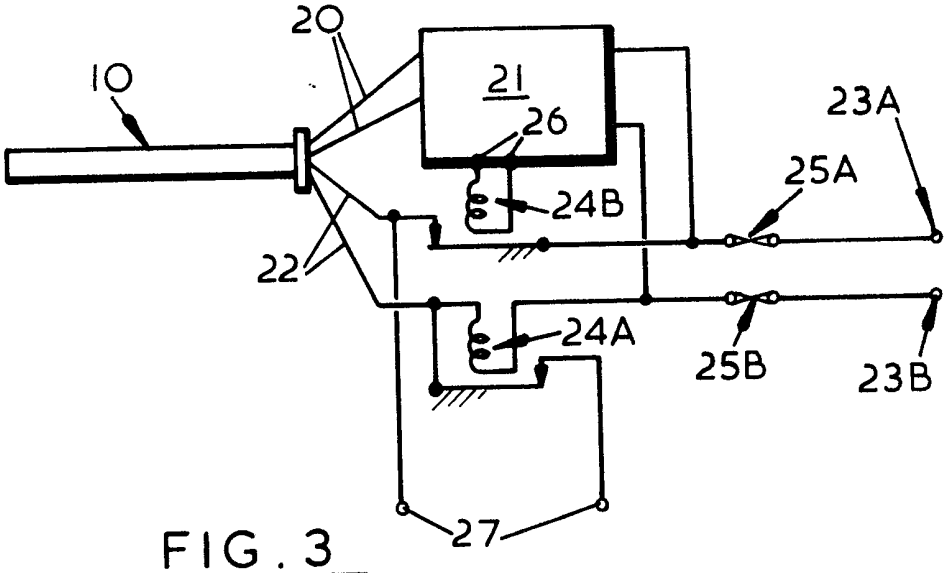

FIG. 3

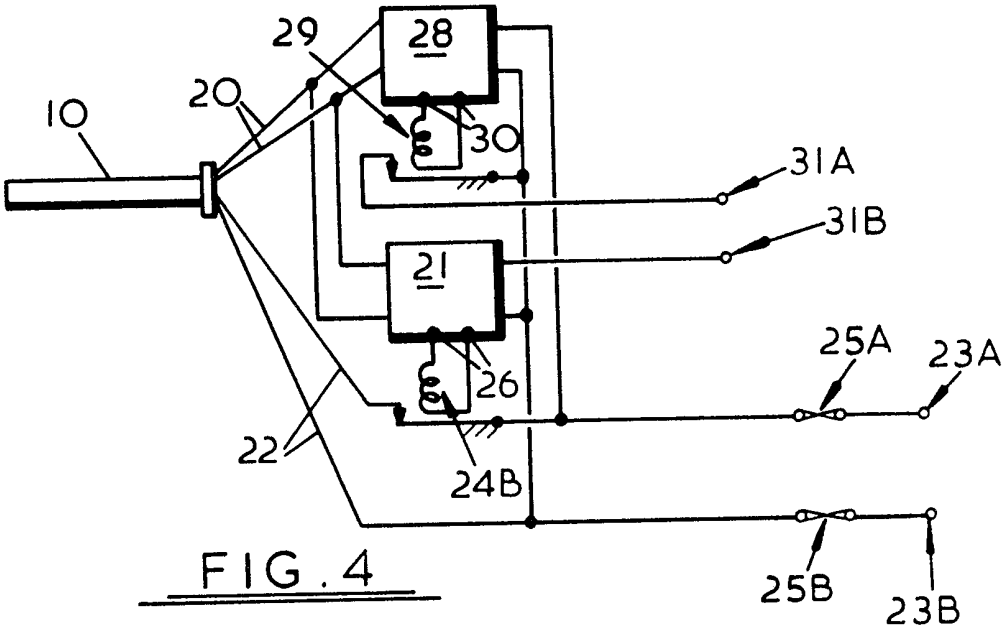

FIG. 4

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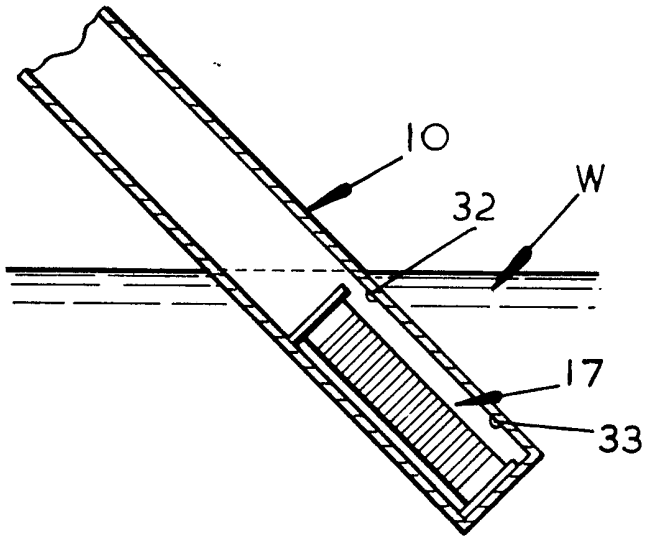

FIG. 5

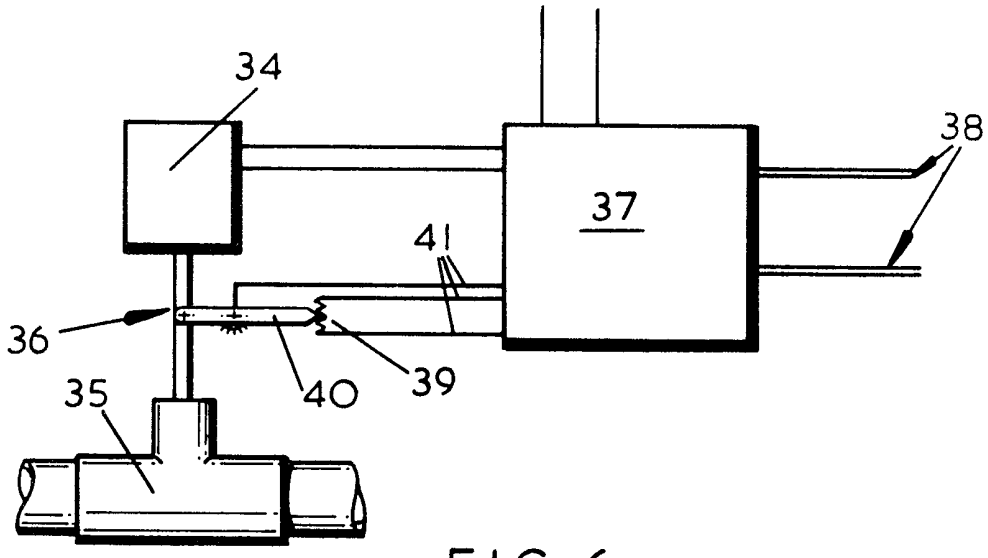

FIG. 6

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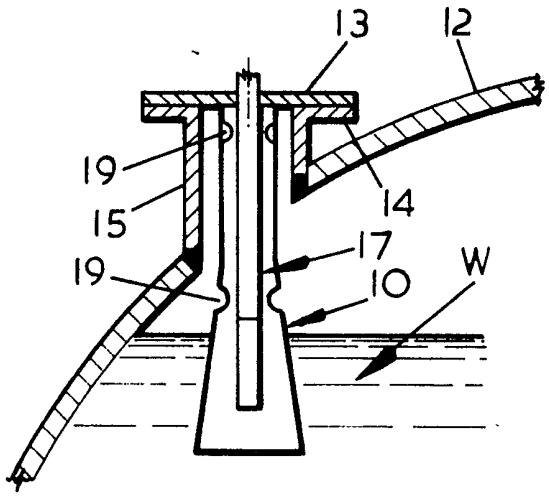

FIG. 7

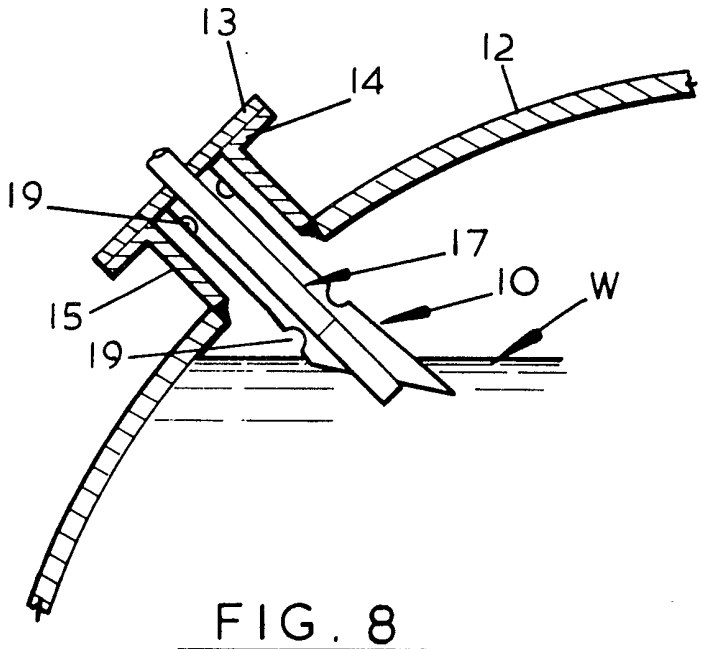

FIG. 8

SPECIFICATION

Apparatus for controlling liquid levels in vessels

This invention relates to apparatus for controlling liquid levels in vessels, and additionally, should an unsafe level of liquid occur, for initiating alarm and/or shut-down signals. Such an apparatus is required to control the level of water in a boiler for example since exposure of a heated surface resulting from a falling water level can result in damage to the boiler structure and possibly explosion.

Such liquid level control apparatus is known.

In one form a float arrangement is used to operate an electrical switch, the float being placed either in the boiler or vessel or more conveniently in an external chamber in liquid communication with the boiler or vessel.

This arrangement has the disadvantage that the float is subject to disturbances arising out of movements of the liquid which can be violent.

Float arrangements are also subject to the adverse affects of deposits arising from the liquid, which deposits can impede or render erratic movements of the float with again the aforesaid deleterious affects to the boiler structure. It is known to reduce the probability of such unsatisfactory float behaviour by "blowing down" the boiler or vessel (or alternatively the external chamber if provided) to obtain verification of correct float functioning. Such "blowdown" also has the effect of removing accumulated sludge from external float chambers which can unbalance liquid levels in such a chamber and its associated boiler or vessel and thus cause the float to give a false signal.

Another known liquid level control apparatus employs a leakage current from an electrode which terminates at the water or other liquid level. This apparatus is subject to the accumulation of scale or deposits (conducting or non-conducting) on the electrode which can give respectively false "safe" or "unsafe" signals.

The present invention adopts a different and more reliable solution to this problem of satisfactory liquid level control. The solution is a thermal one, and in its broadest form comprises a heated probe disposed in the water or other liquid, whereof the level is to be controled, the presence of which water or other liquid serves to maintain the probe relatively cool while its absence results in the temperature of the probe rising and the probe being associated with a temperature sensor, whereof the output serves to initiate, through the intermediary of electrical circuitry, control of the liquid level and/or shut-down of the boiler or vessel and/or alarm (visual and/or audible).

Such a thermal liquid level control apparatus avoids a false "safe" signal being transmitted due to scale or deposits forming on the probe since the effect of any such scale or deposits will be to increase the probe temperature leading to the transmission of an "unsafe" signal and initiation of control, shut-down and/or alarm. Failure of this form is thus to "safety".

A side benefit of employing such a heated probe is that it signals the formation of scale or deposits in the boiler or vessel which, as is known to those skilled in the art, is unsatisfactory and detrimental to the boiler or vessel structure.

More specifically, a liquid level control apparatus comprises a probe for insertion into a water boiler (for convenience, reference is hereinafter made simply to "water boilers") at a predetermined location and in a predetermined attitude and incorporating, or having otherwise associated with it a heating element, preferably an electrical heating element adapted to be supplied with a predetermined voltage, and temperature-sensing means thermally coupled to the probe in the region of the heating element.

Preferably, the temperature-sensing means is connected to relays or solid state devices adapted to signal and effect operation, for example, of a pump or valve controlling water supply to the boiler and/or to shut-down the plant of which the boiler forms part and/or to give an alarm.

The temperature-sensing means may *inter alia*, be a thermocouple, a thermistor, a resistance thermometer or a thermal expansion device.

Alternatively, the heating element may constitute its own temperature sensor by employing its inherent resistance/temperature coefficient. In this case, a continuous monitoring of the resistance of the heating element using, for example, a Wheatsone's Bridge circuit, is preferably effected.

A liquid level control apparatus according to the present invention will cause shut down of a plant incorporating a water boiler to which the apparatus is applied in the following circumstances.–

1. The temperature sensor detecting a high probe temperature due to low liquid level or scale formation of sufficient thermal resistance on the external surfaces of the probe.
2. Accidental detachment of the temperature sensor from the probe surface.
3. Short circuit of the temperature sensor (if electrical), or of the heater element.
4. Open circuit of the temperature sensor or the heater element.
5. Failure of electrical or other energy supply.

The apparatus always operates to fail safe.

The control circuitry operated by signals from the temperature sensor may take different forms. For example, a thermocouple, on rising temperature, generates a direct EMF measured in millivolts so that amplification of

the signal is required and it is preferred to use a solid state thermocouple amplifier for this purpose.

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:–

Figure 1 is a fragmentary sectional view of a boiler with a thermal probe according to the invention;

Figure 2 is a section of the line II–II of Fig. 1;

Figure 3 is an electrical diagram showing an alarm or cut-out mode;

Figure 4 is an electrical diagram showing a pump or valve control mode;

Figure 5 is a fragmentary sectional view of an alternative probe construction;

Figure 6 is an electrical diagram showing an alternative valve control mode; and

Figures 7 and 8 show respectively vertical and inclined probe arrangements.

Referring to Figs. 1 and 2, the liquid level control apparatus comprises a steel probe 10 closed at its end 11 to prevent ingress of water contained in the boiler 12. The probe 10 is fixed to a flange 13 which mates with flange 14 fixed to a standpipe 15, in turn, fixed to the boiler 12. Bolts 16 secure the flanges 13 and 14 together. The top surface 10A of the probe 10 is arranged to coincide with the desired water level sufficient adjustment being possible by rotating the flange 13 relative to the flange 14, there being five possible positions, the lowest of which is indicated as 10B.

The probe 10 is fitted internally with an electrical heater element 17 consisting of "nichrome" (Registered Trade Mark) or similar wire. Leads 18 connect the heater element 17 with an electrical supply from a control system (not shown). A thermocouple 19 is fixed in intimate thermal contact with the probe 10, leads 20 being taken to the control system shown in Fig. 3.

Referring now to Fig. 3 the leads 20 are connected to a temperature controller 21, the operating temperature of which can be adjusted to suit the temperature and pressure of the water. Leads 22 connect the heating element 17 to an electric supply at inputs 23A, 23B *via* relays 24A, 24B and fuses 25A, 25B. With power supplied to the heating element 17, the probe 10 will increase in temperature to a value determined by the temperature of the water provided the water is in contact with the probe 10. The operating temperature of the controller 21 is set at a value above the water temperature. If the water level falls and contact is lost, the temperature of the probe 10 increases and causes the controller 21 to operate so as to de-energise relay 24b *via* connections 26. Relay 24B is energised to close the circuit to the heating element 17 so that, when the probe 10 reaches the pre-set temperature and the relay 24B is de-energised, the electric supply to the heating element is broken. The relay 24A also energised to close, opens, and the probe 10 cools. When closed the relay 24A signals the equipment under control to operate which equipment could typically be a combustion appliance. When the relay 24A opens, there is no signal from terminals 27 and the boiler ceases to operate until the water level is restored. Should the heating element 17 fail by short circuit, the fuses 25A, 25B, or one of them, will blow and there will be no output from the terminals 27, the boiler thereby reacting to a safe condition. Should the heating element 17 fail by open circuit, again there will be no signal at terminals 27. Since the probe 10 cools when the relay 24B opens, the temperature controller 21 will, at the set point cause the relay 24B to close restoring current to the heating element 17. In the absence of coolant water in contact with the probe 10, its temperature will again increase and the relay 24B open. There is thus a cyclic action, the frequency of which will depend on the thermal inertia of the probe 10 on the liquid temperature, and on the temperature set in controller 21. This cyclic action prevents the probe temperature rising to a value at which it may be damaged. The cyclic action will not however cause a similar reaction in the boiler plant where an alarm or cut-out is provided since such devices, once de-energised, cannot be restored until manually re-set, and will trip out again if the circumstances causing the alarm or cut-out persist.

Where however the liquid level controller is used to switch a pump on or off, or to open or close a valve, manual re-set trips are not appropriate. The arrangement shown in Fig. 3 would cause such a valve or pump to cycle at the same frequency, and this is not normally acceptable, giving rise to excessively frequent stopping and starting of the electric motors concerned. This action can be suppressed by the provision of a second temperature controller similar to 21 or by the inclusion in controller 21 of an extra set point.

Referring to Fig. 4, a temperature controller 28 is connected to thermocouple leads 20 in parallel with the temperature controller 21. Power supply is common to both controllers. The output from the controller 28 is used to operate a relay 29 in the same mode as the relay 24A, the relay 29 being connected to the controller 28 *via* connections 30. Relay 30 is connected to the electric supply at terminals 23A, 23B and when closed provides an output signal at 31A, 31B. The relay 24A is omitted and the set point of the controller 21 is raised above that of the controller 28 which is set to a point corresponding to the temperature controller 21 as used in Fig. 3. The set point of the controller 21 in Fig. 4 is adjusted to be high enough to prevent interaction with

the controller 28 and low enough to prevent overheating of the probe 10.

The arrangement of Fig. 4, as described so far, will either operate a valve to shut off the feed water supply to the boiler, when the demand has been satisfied or open the valve at the onset of demand. Alternatively, and more usually, it will switch the feed pump on or off. In many cases, however, it is preferable that the valve be adjusted to a position such that the rate of water supply approximates to the change of water level from a pre-set value so as to keep this constant. To meet this condition the probe arrangement is inclined (Fig. 8) or placed vertically (Fig. 7) relative to the water level *W* and in the case of thermocouples or thermistors two temperature sensors are used or use is made of the sensing resistance of the heater element 17. In this case of thermocouples these are connected in series so that their outputs are in opposition.

Referring now to Fig. 5, thermocouples 32, 33 are positioned near the extremities of the heating element 17 in the probe 10. The desired water level *W* is just above the thermocouple 32 and the probe 10, in the region of the heating element 17 will be at a substantially uniform temperature and the net output of the thermocouples 32, 33 will be at or near zero. There will thus be no signal for the control valve to move. If the water level *W* should fall the cooling effect of the water on the probe 10 in the region of thermocouple 32 will be reduced, since the heat transfer to the steam above the water level is less than that to water. The output of the thermocouple 32 will therefore exceed that of the thermocouple 33 thus giving a significant electrical output from the pair. This is amplified by a temperature controller similar to 21 to cause a servomotor to move and to open the valve. It will be noted that the probe 10 needs to be in an inclined or vertical position for this application in which case adjustment of the depth of immersion can be done by shims.

Referring finally to Fig. 6, a servomotor 34 drives a control valve 35 by means of a rod or linkage 36, the motor 34 receiving its signal from a control box 37. This in turn receives its signal from the thermocouples 32, 33 *via* connections 38. A variable voltage divider 39 is connected mechanically to the rod or linkage 36 by a linkage 40. Voltage divider 39 is electrically connected to the control box 37 whence it is supplied with a small D.C. voltage a proportion of which is fed back to the control box 37, the electrical connections between the control box 37 and voltage divider 39 being shown at 41. This feed-back voltage, modified in control box 37 is arranged to oppose the net output of thermocouples 32, 33. As the linkage 36 moves the valve 35, the centre arm of the voltage divider 39 moves so that the feed-back voltage to the control box 37 approximates to the net output from the thermocouples 32, 33 and is in opposition to it. Thus when the demand has been satisfied, the signal initiating valve movement is cancelled and the valve 35 ceases to move. If the water level rises, then the net output from the thermocouples 32, 33 and feed-back circuit is reversed, and the valve 35 is caused to close, so reducing the feed-back voltage until the balance is again restored.

CLAIMS

1. Apparatus for controlling liquid levels in vessels, and, additionally should an unsafe level of liquid occur, for initiating alarm and/or shut-down signals, the apparatus comprising a heated probe disposed in the liquid, whereof the level is to be controlled, the presence of which liquid serves to maintain the probe relatively cool while its absence results in the temperature of the probe rising and the probe being associated with a temperature sensor, whereof the output serves to initiate, through the intermediary of electrical circuitry, control of the liquid level and/or shut-down of the boiler or vessel and/or alarm (visual and/or audible).

2. A liquid level control apparatus comprising a probe for insertion into a water boiler at a predetermined location and in a predetermined attitude and incorporating, or having otherwise associated with it a heating element, and temperature-sensing means thermally coupled to the probe in the region of the heating element.

3. Apparatus as claimed in claim 2, in which the heating element is an electrical heating element adapted to be supplied with a predetermined voltage.

4. Apparatus as claimed in claim 2 or 3, in which the temperature-sensing means is connected to relays or solid state devices adapted to signal and effect operation, for example, of a pump or valve controlling water supply to the boiler and/or to shut-down the plant of which the boiler forms part and/or to give an alarm.

5. Apparatus as claimed in any one of claims 2 to 4 in which the temperature-sensing means may *inter alia*, be a thermocouple, a thermistor, a resistance thermometer or a thermal expansion device.

6. Apparatus as claimed in any one of claims 2 to 4, in which the heating element constitutes its own temperature sensor by employing its inherent resistance/temperature coefficient.

7. Apparatus as claimed in claim 6, comprising a continuous monitoring of the resistance of the heating element using, for example, a Wheatstone's Bridge circuit.

8. Apparatus as claimed in any one of claims 1 to 7, in which control circuitry operated by signals from the temperature sensor comprises a thermocouple which, on rising

temperature, generates a direct EMF measured in millivolts, and a solid state thermocouple amplifier for amplification of the signal.

9. Apparatus for controlling liquid levels in vessels, and, additionally should an unsafe level of liquid occur, for initiating alarm and/or shut-down signals, the apparatus being substantially as hereinbefore described with reference to the accompanying drawings.

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