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W. JACKSON, JR., ET AL
THERMISTOR SENSITIZED SERVOMECHANISM FOR AUTOMATIC
RECORDING OF VOLUME-TEMPERATURE
DISTILLATION DATA

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2 Sheets-Sheet 2

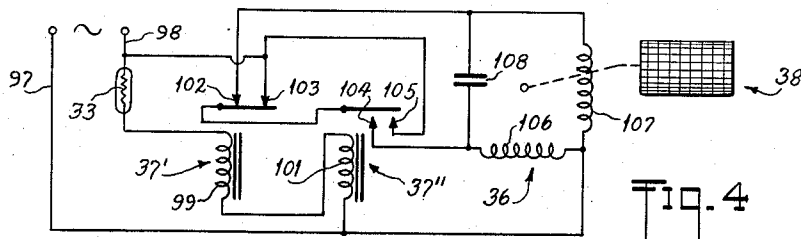


Fig. 4

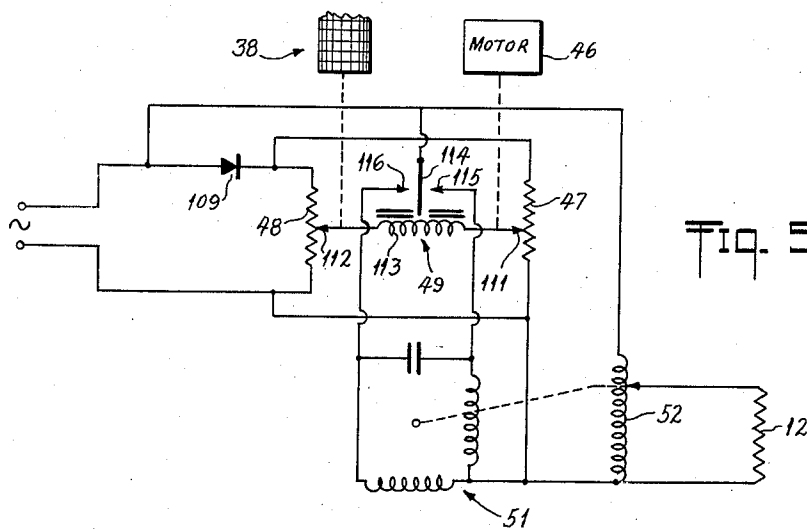


Fig. 5

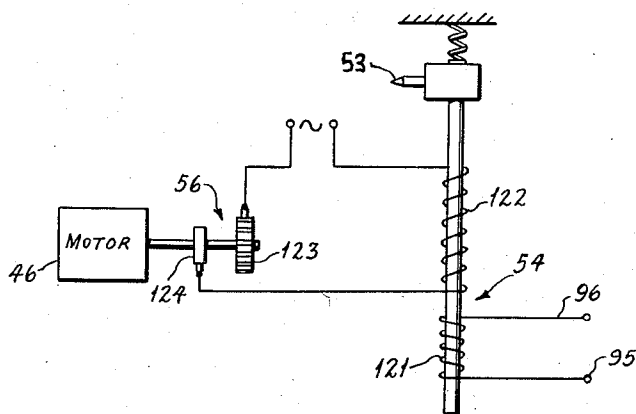


Fig. 6

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THERMISTOR SENSITIZED SERVOMECHANISM FOR AUTOMATIC RECORDING OF VOLUME- TEMPERATURE DISTILLATION DATA

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9 Claims. (Cl. 202—160)

The present invention relates to automatic distillation apparatus and, more particularly, to apparatus for distilling liquid under controlled conditions and for recording a temperature-volume distillation curve thereof.

In order to maintain uniform quality of products in the petroleum industry, a standard test method utilizing standard apparatus has been established and sponsored by the American Petroleum Institute and the American Society for Testing Materials and is known as the A. S. T. M. designation D86.

The apparatus employed in the manual execution of this test comprises a standard 100 milliliter Engler distillation flask having prescribed dimensions controllably heated by gas or electricity and connected through a condenser tube, which is immersed in an ice water bath, to a cylindrical 100 milliliter distillate-receiving graduate. A standard thermometer is mounted in the neck of the flask above the liquid and the receiving graduate is maintained within certain temperature limits.

The A. S. T. M. procedure for the D86 test requires that

(a) The heater be set to deliver heat at a uniform rate and be so regulated that the first drop of distillate falls from the condenser between 5 and 10 minutes after starting the heater cold,

(b) The distillation thermometer be read two minutes after heat is applied,

(c) The receiving graduate be moved after the first drop so that the nozzle of the condenser tube touches the side of the graduate,

(d) The heat be regulated so that the distillation proceeds at a uniform rate of between 4 and 5 milliliters per minute.

(e) The temperature be observed and recorded for every 10 milliliter of distillate collected or the amount of distillate be observed and recorded for every 10° C. rise in temperature,

(f) No adjustment to the heat be made when the liquid residue in the flask is approximately 5 milliliters,

(g) The end point maximum temperature be observed and recorded, and

(h) The temperature outside the collecting graduate be maintained between 55° and 65° F.

Automatic distillation apparatus has been disclosed by Albert H. Garrison and Francis B. Rolfson in Patent No. 2,577,615, granted December 4, 1951, for accomplishing all the prescribed distillation procedure. It is only necessary for an operator to initiate each distillation test inasmuch as the temperature-distillate volume curve is automatically recorded while the desired distillation rate is maintained. The apparatus resets itself to its original condition after completing a test.

The patented apparatus employs photo-sensitive devices to detect the first drop of distillate and to follow the level of the distillate as it rises in a receiving vessel. The apparatus, however, requires several sensitive electrical amplifiers and several light sources, one of which must be energized by a source of high-frequency voltage.

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It is an object of the present invention to provide automatic distillation apparatus which is relatively rugged, inexpensive and easy to service.

In accordance with the present invention an automatic system for controlling the distillation of a liquid and recording a temperature-volume distillation curve thereof is provided wherein a flask adapted to hold liquid is heated by an electrical heater and distillate after being condensed by a condenser is transferred into a liquid receiver of uniform cross-section. A temperature-sensitive resistor is mounted in the flask in order to respond to the temperatures above the liquid therein. The resistance of this temperature-sensitive resistor is balanced against the resistance of a potentiometer that is driven by an electric motor controlled in response to the differences in the two resistances. A second temperature-sensitive resistor is mounted near the lower end of a carriage member that is arranged for vertical movement above the distillate in the receiver. The second temperature-sensitive resistor is heated by current therethrough to render it sensitive to the marked difference between its thermal dissipation in liquid and in air or vapor. A second electric motor is adapted to move the carriage in response to resistance variations in the second resistor whereby the carriage tends to follow the rising level of the distillate in the receiver. The first electric motor actuates recording means as a function of temperature, and the second electric motor independently actuates the recording means as a function of distillate volume with the result that a temperature-volume curve of the liquid is recorded.

The apparatus, furthermore, includes a third temperature-sensitive resistor, which may be self-heated, mounted within the receiver and positioned to intercept the first drop of distillate delivered by the condenser. An electrically operated device responds to a change in the resistance of this third temperature-sensitive resistor to position the inner wall of the receiver against the discharge end of the condenser after the first drop of distillate falls and to mark the event on the recording means.

In order that the invention may be more clearly understood it will now be described in detail with reference to the accompanying drawings wherein:

Fig. 1 is a block schematic diagram of the automatic distillation apparatus of the present invention;

Fig. 2 is a circuit diagram of the temperature recording system;

Fig. 3 is a circuit diagram of apparatus for detecting the first drop of distillate, for moving the distillate receiver in response thereto and for recording the first drop;

Fig. 4 is a circuit diagram of apparatus for following the level of the distillate and for recording the volume thereof;

Fig. 5 is a circuit diagram of apparatus for predetermining the rate of distillation and for controlling the heat applied to the distillation flask to maintain the distillation rate constant; and

Fig. 6 is a circuit diagram of apparatus for generating uniformly spaced timing signals and for recording such signals and for indicating the initial boiling point as determined by the first drop of distillate.

Referring now to Fig. 1, distillation apparatus is disclosed including a standard 100 milliliter Engler distillation flask 11 heated by an electrical resistor 12. The flask 11 has a removable stopper 13 which seals the neck 14 of the flask 11 and supports a rod 15. The rod 15 projects through an axial bore in the stopper 13 and extends down the neck 14, terminating opposite the junction of a vapor outlet tube 16 with the neck of the flask 11. A temperature-sensitive resistor or thermistor 17 is attached to the lower end of the rod 15 and is therefore in a position to be sensitive to the temperature of the vapor in the flask 11.

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The vapor outlet tube 16 is coupled to a condenser tube 18 which passes through a condenser jacket 19 normally filled with ice water and terminates in an outlet end 21 above a cylindrical distillate receiver 22. The dimensions and slope of the condenser tube 18 are prescribed by the A. S. T. M. test specification, and the outlet end 21 is cut off to form an acute angle in order to facilitate flow from the tube 18 and curved slightly back upon itself in order to insure contact with the wall of the receiver 22.

The distillate receiver 22 is mounted on a stand 23 that is laterally slidable in horizontal guideways 24. The lateral position of the receiver 22 is determined by a ring clamp 25. The plunger 26 of a solenoid 27, when the latter is energized, draws the receiver 22 against the tension of a spring 28 away from contact with the outlet end 21 of the condenser tube 18. A thermistor 29 is mounted on the inner end of a rod 31 which projects through the wall of the receiver 22 above the 100 milliliter level and directly below the outlet end 21.

At the initiation of each test, the solenoid 27 is energized by a relay 32 which is controlled by the thermistor 29. When the first drop of distillate falls from the outlet end 21, it strikes the thermistor 29 causing a sharp change in its resistance. The relay 32 is thereupon actuated, and the solenoid 27 is de-energized with the result that the spring 28 draws the wall of the receiver 22 into contact with the outlet end 21. The subsequently condensed distillate flows down the wall of the receiver 22 and rises from the bottom of the receiver 22 in a tranquil manner as a body of liquid.

The level of the distillate and, accordingly, its volume is determined by a thermistor 33 attached to the end of a vertical rack 34 which meshes with a pinion 35 driven by a volume servo motor 36. The motor 36 is under the control of a relay 37 which responds to the sharp change in the resistance of the thermistor 33 caused by the temperature change that results from the alteration in the thermal dissipation of the heated thermistor 33 depending upon whether it momentarily lies above or below the gradually rising liquid level in the receiver 22. The motor 36 is controlled in a direction such that it continuously seeks this liquid level and simultaneously drives a drum 38 upon which is mounted a recording chart 39.

The temperature of the vapor in the flask 11 is simultaneously indicated on the chart 39 by means of a pen 41 which is driven through a worm gear 42 axially of the drum 38 by a temperature servo motor 43. The motor 43 adjusts the movable contact of a follow-up potentiometer 44 in such manner as to balance the changes in the resistance of the thermistor 17 in the flask 11. The difference in the voltage drops across the thermistor 17 and the potentiometer 44 energizes a relay 45 which, in turn, controls the direction of the motor 43 with the result that the pen 41 is continuously displaced as a function of the vapor temperature.

The prescribed rate of distillation is determined by a constant speed synchronous motor 46 which rotates the movable contact of a reference potentiometer 47. A follow-up potentiometer 48 is mechanically coupled to the drum 38 and provides a voltage representing the actual volume of distillate. The output signals of the potentiometers 47 and 48 are applied to a differential relay 49 which determines the direction of a heating control motor 51 according to whether the actual distillate volume is greater or less than the prescribed distillate volume at a given moment. The motor 51 actuates a voltage control unit 52, such as a variable autotransformer, which determines the voltage applied to the heating resistor 12. The control direction is such that the heat is increased if the actual distillation rate is too low and decreased if the distillate rate is too high.

An auxiliary pen 53 is provided adjacent the edge of the drum 38 for indicating on the chart 39 uniformly spaced timing marks and also the time at which the first drop of distillate falls. The auxiliary pen 53 is actuated

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by a spring-loaded solenoid 54. The solenoid 54 receives an energizing pulse over a conductor 55 from the relay 32 when the same is actuated by the first drop of distillate. The temperature opposite this mark is considered to represent the initial boiling point. A commutator 56 is geared to the constant speed motor 46 and provides periodic timing pulses to the solenoid 54.

Conventional portions of the distillation apparatus such as the means for maintaining the receiver 22 at a temperature within the prescribed range of 55° to 65° F. and limit switches to prevent operation of the motors beyond proper physical limits have not been illustrated inasmuch as they are not a part of the invention although normally utilized with the novel apparatus. It is to be understood, for example, that the operation of the heat control motor 51 is discontinued when the actual volume of distillate, as indicated by the potentiometer 48, reaches 95 milliliters since the A. S. T. M. specification requires that the heat remain constant during the last 5% of the distillation process. Also, arrangements may be provided for returning the automatic system to its initial position but such details, since they lie outside the scope of the claims, would unnecessarily burden the description.

Fig. 2 discloses a typical circuit diagram of the temperature recording portion of the apparatus shown in Fig. 1. A source of alternating voltage is impressed across conductors 61 and 62 and applied through a rectifier 63 to a current limiting resistor 64 in series with the thermistor 17 and also to a fixed resistor 65 in series with the potentiometer 44. The winding 66 of the relay 45 is connected between the junction of the resistor 64 with the thermistor 17 and the movable contact 67 on the potentiometer 44. The winding 66 is accordingly located in a position corresponding to the galvanometer in a Wheatstone bridge circuit. When the contact 67 is not at a point on the potentiometer 44 such that the voltage appearing thereon is equal to the voltage drop across the thermistor 17, current will flow through the relay winding 66 in a direction depending upon whether the voltage on the contact 67 is too great or too small. A contact arm 68 moved by the relay armature (not shown) is forced either against a fixed contact 69 or a fixed contact 71 according to the direction of current flow. The relay 45 is not polarized and, therefore, when no current energizes the same, the contact arm 68 rests in an intermediate position free from both contacts 69 and 71.

The motor 43 is illustrated as a split-phase induction motor having two windings 72 and 73 and a phase shifting capacitor 74. The conductor 61 from the source of alternating voltage is connected to a common junction of the windings 72 and 73 while the other conductor 62 from the power source is connected to the contact arm 68. The capacitor 74 is connected across the contacts 69 and 71, which are joined to the independent ends of the windings 73 and 72, respectively.

In the operation of the relay 45, the contact arm 68 when it touches the contact 69 causes the winding 73 to be directly energized by the power source and places the capacitor in series with the winding 72, causing the motor 43 to rotate in a given direction. When the contact 71 connects with the arm 68, it is the winding 72 that is directly energized by the power source, and the phase of the voltage across the winding 73 is shifted, causing motor rotation opposite to the given direction. The motor 43 drives the contact 67 to the point of balance and simultaneously moves the pen 41. The position of the pen 41 is a measure of the resistance of the thermistor 17 and hence the temperature of the vapor in the flask 11.

Fig. 3 discloses a typical circuit diagram of the portion of the apparatus shown in Fig. 1 that is adapted to detect the first drop of distillate, to move the distillate receiver in response thereto, and to transmit a pulse to the solenoid 54 simultaneously. A source of alternating voltage is impressed across a pair of conductors 75 and

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76 and applied to a series combination of the thermistor 29 and a winding 77 of a relay 32'. A relay contact 78, connected to the conductor 76, is associated with the relay 32' and is normally connected by a shorting bar 81 to a contact 79 except when the winding 77 is energized. A second relay 32'' is provided having a winding 82, which may be energized in two ways. One end of the winding 82 is connected to the conductor 75 of the power source, while the other end of the winding is connected to the relay contact 79 and also to a contact 83. The contact 83 is adapted to be short-circuited to a contact 84 by a shorting bar 85 that is actuated by the relay 32'' when the winding 82 is energized. The contact 84 is connected through the normally short-circuited contacts 86 of a reset push button 87 to the conductor 76 of the source.

The relay 32'' also actuates shorting bars 88 and 89. The shorting bar 88 normally short-circuits a pair of contacts 91 in the connection of the solenoid 27 between the conductors 75 and 76. The shorting bar 89 normally short-circuits contacts 92 and 93. When the relay 32'' is energized, the shorting bar 89 moves to short-circuit contacts 92' and 93', which are connected to contacts 92 and 93, respectively. The conductor 75 is connected through a current limiting resistor 94 to the pair of contacts 92 and 92', while the conductor 76 of the source is connected to the opposite pair of contacts 93 and 93'. Conductors 95 and 96 are connected between the pairs of contacts 92, 92' and 93, 93' respectively, and the opposite ends of a winding 121 in the solenoid 54.

When the power is first connected to the conductors 75 and 76, current flows through the winding 77 of the relay 32' and the winding 82 of the relay 32''. The relay 32'' is fast acting and operates to short-circuit the contacts 83 and 84 and lock the relay 32'' in an energized condition before the connection is broken between the contacts 78 and 79.

In order to place the apparatus in condition for detecting the first drop of distillate, the reset push button 87 is pressed, thereby opening the contacts 86 and de-energizing the relay 32''. When the relay 32'' is thus de-energized, current may flow through the solenoid 27 by way of the short-circuited contacts 91.

When the first drop of distillate falls on the thermistor 29, the resistance thereof is abruptly increased with the result that the current through the winding 77 decreases sufficiently to de-energize the relay 32' and to permit the shorting bar 81 to again short-circuit the contacts 78 and 79. This action re-energizes the relay 32'', which quickly moves the shorting bar 85 against the contacts 83 and 84 and locks the relay 32'' in the energized condition. Simultaneously with the energization of the relay 32'', the solenoid 27 is de-energized permitting the spring 28, shown in Fig. 1, to draw the receiver 22 into contact with the outlet end 21 of the condenser tube 18. At the same time, the shorting bar 89 moves from the contacts 92 and 93 to the contacts 92' and 93'. In the brief interval when the shorting bar 89 is not making any contact, a voltage drop appears between the pair of contacts 92, 92' and the pair of contacts 93, 93'. A pulse of current is transmitted to the winding 121 of the solenoid 54 over the conductors 95 and 96.

After the first drop of distillate evaporates from the thermistor 29, the current through the winding 77 of the relay 32' returns to its normal value causing the shorting bar 81 to move away from the contacts 78 and 79. The relay 32'', however, remains energized because of the alternative connection through the shorting bar 85 to the power source. It will be noted that the evaporation of the first drop does not alter the de-energized conditions of the solenoid 27 and the winding 121.

Fig. 4 discloses the circuit arrangements for following the level of the distillate and for recording the volume thereof. A source of alternating voltage is impressed across conductors 97 and 98 and applied through the thermistor 33 to the windings 99 and 101 of relays

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37' and 37'', respectively. The same current thus acts on relays 37' and 37'', the former relay being adapted to operate in response to a lower current than that which energizes the latter relay. A pair of normally closed contacts 102 and 103 are opened when the relay 37' is energized, and a pair of normally open contacts 104 and 105 are closed when the relay 37'' operates.

The motor 36 is illustrated as similar to the split-phase induction motor 43 shown in Fig. 2 and has field windings 106 and 107 and a phase shifting capacitor 108. The common junction of the windings 106 and 107 is connected to the conductor 97 from the power source. The other ends of the windings 106 and 107 are attached to the contacts 104 and 102, respectively. The contacts 103 and 105 are both connected to the other conductor 98 from the power source.

In the operation of the circuit shown in Fig. 4, when the heated thermistor 33 is correctly positioned relative to the gradually rising liquid level, its resistance is at an intermediate value such that the current passing through the windings 99 and 101 is sufficient to energize the relay 37', opening the contacts 102 and 103, but insufficient to close the contacts 104 and 105.

In this condition no voltage is applied to the motor 36. When the thermistor 33 is below the liquid level its resistance increases, the contacts 102 and 103 close, and the motor 36 operates in a direction such as to raise the thermistor to the liquid level. On the other hand, if the thermistor 33 is displaced above the liquid level, the resistance of the same is decreased, and the current through the winding 101 reaches a value sufficient to close the contacts 104 and 105. Thereupon the direction of the motor 36 is reversed to drive the thermistor 33 down toward the liquid surface. Accordingly, the thermistor 33 seeks and maintains contact with the liquid level, which is indicated in terms of volume of distillate by the rotation of the drum 38.

Fig. 5 shows the circuit arrangements for predetermining the rate of distillation and for controlling the heat applied to the distillation flask to maintain the distillation rate constant. The potentiometers 47 and 48 are connected in parallel through a rectifier 109 to a source of alternating voltage and have movable contacts 111 and 112, respectively, interconnected by the winding 113 of the nonpolarized relay 49. The potentiometers thereby form a bridge network and any difference between the voltages appearing on the contacts 111 and 112 causes current to flow through the winding 113 which actuates a contact arm 114 to close either with a contact 115 or a contact 116 according to the direction of the current. The contact arm 114 is connected to one terminal of the power source. The contacts 115 and 116 serve a function corresponding to the contacts 69 and 71 in Fig. 2 and control the split-phase induction motor 51 in the same manner as the motor 43 is controlled. The motor 51 adjusts the voltage control 52 which determines heat provided by the resistor 12. The servo system is completed through the vapor path from the flask 11 to the distillate receiver 22 and then through the volume detecting servo system including the thermistor 33 and the volume motor 36 which turns the drum 38.

Fig. 6 shows in somewhat greater detail than Fig. 1 the apparatus for generating uniformly spaced timing signals and for recording such signals together with a mark indicating the occurrence of the first drop of distillate. The time-marking solenoid 54 has two windings, 121 and 122. The winding 121 is connected to the conductors 95 and 96 associated with the relay 32'' shown in Fig. 3. A pulse of voltage is impressed on the winding 121 when the first drop of distillate falls, and the pen 53 is momentarily moved in contact with the chart 39. The winding 122 is energized from a power source through equi-angularly spaced conductive segments 123 of the commutator 56 which segments are connected to

a slip ring 124. The constant speed motor 46 drives the commutator 56 through suitable reduction gearing (not shown).

The circuit details shown in Figs. 2 to 6 are given by way of example and are not to be construed as limiting the invention, the scope of which is restricted solely by the appended claims.

We claim:

1. An automatic system for controlling the distillation of a liquid and recording a temperature-volume distillation curve thereof comprising a flask adapted to hold said liquid, an electric heater for said flask, a liquid receiver, a condenser for condensing and transferring distillate from said flask to said receiver, a first temperature-sensitive resistor in said flask responsive to the temperatures above the liquid therein, first electrical motive means, a potentiometer actuated by said electrical motive means in response to the difference in the voltages across said first temperature-sensitive resistor and said potentiometer to balance said voltages, a second temperature-sensitive resistor mounted for movement vertically above said liquid receiver, said second resistor being responsive to its thermal relation with its surroundings to exhibit an intermediate resistance value and opposite-sense variations therefrom when respectively positioned below and above the surface of said distillate, second electrical motive means for moving through a motion transmitting coupling said second temperature-sensitive resistor in response to said resistance variations in the same in a direction tending to restore said intermediate value whereby said second temperature-sensitive resistor follows the rise of the distillate surface in said receiver, and recording means independently responsive to said first and second electrical motive means for recording a temperature-volume distillation curve of said liquid.

2. An automatic system according to claim 1 further including a third temperature-sensitive resistor positioned to intercept the first drop of distillate delivered by the condenser, and means for marking the vapor temperature at which the first drop occurs.

3. An automatic system according to claim 2 including a spring-tensioned solenoid for so relatively positioning the receiver and the discharge end of the condenser that the first drop of distillate falls upon the third temperature-sensitive resistor, said solenoid being responsive to a change in the resistance of said third temperature-sensitive resistor for so altering the relative position of said receiver and the discharge end of said condenser that the inner wall of said receiver touches the discharge end of said condenser after the first drop of distillate falls.

4. An automatic system for controlling the distillation of a liquid and recording a temperature-volume distillation curve thereof comprising a flask adapted to hold said liquid, an electric heater for said flask, a liquid receiver of uniform cross section, a condenser for condensing and transferring distillate from said flask to said receiver, a first temperature-sensitive resistor in said flask responsive to the temperatures above the liquid therein, a first electrical motor, a potentiometer actuated by said first electrical motor, a first control means responsive to the difference in the resistances of said first temperature-sensitive resistor and said potentiometer for energizing said first electrical motor, a carriage member arranged for vertical motion above the distillate in said receiver, a second temperature-sensitive resistor mounted substantially at the lower end of said carriage member, said second resistor being responsive to its thermal relation with its surroundings to exhibit an intermediate resistance value and opposite-sense variations therefrom when respectively positioned below and above the surface of said distillate, a second electrical motor for moving said carriage member vertically, a second control means responsive to said resistance variations in said second resistor for energizing said second motor in a direction tending to restore said intermediate value whereby said carriage member

follows the rise of the distillate surface in said receiver, and recording means independently responsive to said first and second electrical motors for recording a temperature-volume distillation curve of said liquid.

5. An automatic system for controlling the distillation of a liquid and recording a temperature-volume distillation curve thereof comprising a flask adapted to hold said liquid, an electric heater for said flask, a liquid receiver of uniform cross section, a condenser for condensing and transferring distillate from said flask to said receiver, a first thermistor in said flask responsive to the temperatures above the liquid therein, a first electrical motor, a potentiometer actuated by said first electrical motor, a first relay responsive to the difference in the resistances of said first temperature-sensitive resistor and said potentiometer for energizing said first electrical motor, a carriage member arranged for vertical motion above the distillate in said receiver, a second thermistor mounted substantially at the lower end of said carriage member, said thermistor being responsive to its thermal relation with its surroundings to exhibit an intermediate resistance value and opposite-sense variations therefrom when respectively positioned below and above the surface of said distillate, a second electrical motor for moving said carriage member vertically, a second relay responsive to said resistance variations in said second thermistor for energizing said second motor in a direction tending to restore said intermediate value whereby said carriage member follows the rise of the distillate surface in said receiver, a third thermistor mounted within said receiver and positioned to intercept the first drop of distillate delivered by said condenser, and recording means independently responsive to said first and second electrical motors and said third thermistor for recording a temperature-volume distillation curve of said liquid and the temperature at which the first drop of distillate is delivered.

6. An automatic system according to claim 5 including a movable support for positioning the receiver under the discharge end of the condenser so that the first drop of distillate falls upon the third thermistor, a spring-tensioned solenoid coupled to said movable support and responsive to an abrupt change in the resistance of said third thermistor for moving said support to position the inner wall of said receiver against the discharge end of said condenser after the first drop of distillate falls.

7. A liquid level follow-up system comprising, a temperature-sensitive resistor mounted for vertical movement in a path including and extending from below to above the liquid level to be followed, said resistor being responsive to its thermal relation to its surroundings to exhibit an intermediate resistance value and opposite-sense variations therefrom when respectively positioned below and above said liquid level, electrical motive means, a motion transmitting coupling between said motive means and said resistor, and means responsive to said variations for actuating said motive means to move said resistor through said coupling in a direction tending to restore said intermediate value to said resistance whereby said resistor follows said liquid level.

8. A liquid level follow-up system comprising, a temperature-sensitive resistor mounted for vertical movement in a path including and extending from below to above the liquid level to be followed, said resistor being responsive to its thermal relation to its surroundings to exhibit an intermediate resistance value and opposite-sense variations therefrom when respectively positioned above and below said liquid level, a split-phase reversible motor, separate low-current responsive and high-current responsive relay means connected in circuit with said resistor to both receive current in accordance with the resistance value of said resistor, said relay means being adapted to deenergize said motor and to energize the same in one and another of two opposite-motion producing phase relations for, respectively, said intermediate resistance

value and one and the other of said opposite-sense variations therefrom, and a motion transmitting coupling for converting movement of the energized motor into movement of said resistor in directions tending to restore said resistor to said intermediate value whereby said resistor follows said liquid level.

9. In apparatus provided with means for recording the volume of a liquid after appearance of the first drop thereof the improvement comprising, a temperature-sensitive resistor positioned to receive said first drop upon its surface, said first drop by changing the thermal relation of the resistor to its surroundings causing a resistance change in said resistor, and means responsive to said resistance change for actuating said recording means to

provide a record which establishes when said first drop occurred.

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