INTRODUCTION

MEASUREMENT OF THERMODYNAMIC PROPERTIES OF SALINE SOLUTIONS

I. Objective

With the recent emphasis directed towards desalination of salt solutions, increasing attention is being focussed on its purification by an evaporation process. So far there has been no comprehensive data available on the thermodynamic properties of brines at temperatures in the range of evaporator operation.

The primary object of this project is to develop equations and charts to predict properties of brine with respect to

1. Specific Heat.
2. Vapour pressure.
3. Heat of Vapourization.
4. Specific Volume.
5. Enthalpy.
6. Entropy.

The independent variables for these functions are temperature, pressure and salt concentration. The equations and charts will offer the engineer a quick way to evaluate properties of brine, or brackish water, for pressures ranging from (0-5000) psig and for temperatures ranging from 32°F. to 350°F., and all salt concentrations ranging from zero to that for saturated solution.

To achieve the objectives a rather complex calorimeter had to be assembled. As needed modifications were made, and it became apparent that an operations manual of the calorimeter illustrating its salient features would be necessary for its use by new personnel unfamiliar with the equipment. The object of this report is to prepare such a Manual.

II. Plan of Attack

1. General Description of the Experiment:

This description consists of illustrating the following basic circuits:

1. Fluid Flow Circuit.
2. Electrical Circuit.
3. Thermocouple Circuit.
4. Pressure Recording Circuit.
5. Pressure Controlling Circuit.

2. Detailed Description of Each of the Above Circuits:

A detailed description of all the components used in the above mentioned circuits will be discussed, placed in the order of their occurrance in their respective circuits. The description of the circuits will involve description of the constructional and operational features. Any particular feature, if of special interest or importance, will be discussed in detail.

3. Operation of the System:

The operation of the system would include a breakdown on the sequence of actions that has to be followed to safely operate i.e. start, run and shut down the equipment.

4. Diagrams:

Inherent in all the discussions would be necessary figures and drawings to clarify and support the description.

SECTION II

FLUID FLOW CIRCUIT

FLUID FLOW CIRCUIT

Figure 1 shows a schematic of the fluid flow circuit. The components used are shown and will be described here in detail.

They will be discussed in the order in which they lie in the path of the fluid as it flows from the Ruska Pump, i.e., in the following order:

1. Ruska Positive Displacement Pump.
2. Storage Cells.
3. High Pressure Low Differential Recirculating Pump.
4. Preheater and Thermostatic Control of Preheater Temperature.
5. Calorimeter.
6. Condenser and Solenoid Valve.

Not shown in the schematic drawing is the cell or bath in which the calorimeter is placed and heated by Dowtherm vapor in the bath. This will be dealt with also.

7. Bath or Cell.

I. Ruska Positive Displacement Pump

(Ref: Figure 2 and catalog for details of construction and operation)

The main function of the Ruska pump is to act as an actuator for displacement of fluid stored in the storage cells and into the closed circuit containing the calorimeter. The positive displacement also creates a pressure which can be recorded on the two Heise Pressure Gauges.

The pump is an oil pump. It can be operated manually or electrically. The total displacement of the pump is 250 c.c. After each full stroke of the piston, the cylinder is replenished by oil from the oil reservoir placed at a height (Figure 1) so that the oil can easily flow into the cylinder as the piston moves backward. But before the piston is retracted, the stopvalve connecting to the main circuit should be closed. Care should also be taken that no air bubbles be drawn into the cylinder. To prevent this, the line from the reservoir to the cylinder should be free of air bubbles. If some air bubbles do exist in this line, slow retraction of the piston will prevent air bubbles from entering the cylinder.

If some air bubbles do enter the cylinder, a slight forward displacement of the piston will push them out of the cylinder. Then the piston can be slowly retracted.

Packing: The Ruska 15,000 psi hand pump uses synthetic "U" cup packing separated by nylon spacers. When replacing packing, the following procedure should be followed:

1. Crank plunger (11) all the way back until stop collar (13) bears against drive nut (15).

2. Bleed cylinder (2) to atmosphere.

3. Unscrew packing retainer nut (8) and cylinder retaining nut (4) completely. Slide packing follower ring (9) back on plunger.

4. Cylinder may now be withdrawn from pump base (10). It is sometimes beneficial to "pump" the cylinder out by cranking the plunger in. This helps to break loose the old packing from the packing chamber.

5. With the cylinder removed, the old packing set (5, 6, 7) is easily withdrawn. The junk ring (3) should also be removed for cleaning.

6. Clean packing chamber and plunger.

7. Lubricate packing and plunger with a heavy compound such as Esso XP-90 or equivalent, and slide junk ring and packing set (in order shown on drawing) onto plunger.

8. Replace cylinder noting proper position of outlet holes.

9. Tighten cylinder retaining nut in place.

10. Slide junk ring and packing into packing chamber, making sure that each piece seats into the bottom of the chamber.

11. Slide packing follower ring up against packing, and tighten packing retainer nut hand-tight plus a quarter turn of the wrench.

WARNING: Over-tightening may damage "U" cups.

Pump may now be pressured up. If leakage occurs, packing should be retightened by 1/8 turn increments.

CAUTION: NEVER TIGHTEN PACKING WITH PRESSURE IN PUMP CYLINDER.

Lubrication: Hand pumps are equipped with an oil cup (20) which supplies lubrication to the drive nut bearings. Pumps are pre-oiled at the factory.

Keep oil cup about half full at all times, using any good grade medium weight lubricant.

The plunger surface, including threads, should be cleaned as needed, and coated with Esso XP-90 or equivalent heavy lubricant. Run plunger in and out several times, without pressure on the pump, to distribute lubricant properly.

Note: Please give serial number in any correspondence concerning this pump.

II. Storage Cells

(Ref: Figure 3)

The oil stored in the cylinder of the Ruska oil pump displaces brine from the two cells. The cells are connected in such a manner that the calorimeter will receive salt solution until both cells are completely empty of brine (i.e., full of oil).

The oil being lighter always floats on top of brine, therefore the inlet, to both the cells, is placed at the top and the outlet at the bottom. This implies that oil will enter the pipe line only when both the cells are empty.

To determine when both cells are full of oil, the following data is required:

Volume of each cell 650 c.c.

Total volume of 2 cells = 1300 c.c.

Total volume displaced by pump per stroke = 250 c.c.

This means that four complete strokes of the pump can be safely taken without any replenishment of cells or any danger of oil entering the calorimeter line. Any further action of the pump will cause oil to be forced into the system.

Therefore, for using more than four strokes of the pump the following sequence of operation must be performed before the fifth stroke is commenced:

1. Open top cover and bottom connection.
2. Drain oil in the cells.
3. Clean the inside surface
4. Add fresh brine into both the cells.
5. Assemble and reconnect into the system.

After this, the fifth stroke may be commenced.

Note: These cells are high-pressure cells that depend on O-rings for sealing. Sometimes during the process of recapping, the O-rings may become twisted and the cap may not turn easily. The cap should be taken off, the twist of the seal should be straightened out, and the cover should then be fitted on to the body. The cap should not be forced to turn if there is a great deal of resistance to turning.

III. High Pressure Low Differential Recirculating Pump: (H.P.L.D.R. Pump)

(Ref: Figures 4 and 5)

The H.P.L.D.R. Pump is an Electro-magnetic type of pump consisting of a free floating piston made of an electro-magnetic corrosion resistant metal. The piston is actuated by two electric coils which are magnetized and demagnetized in sequence by a solid state switching device which energizes first one coil and then the other. This magnetization and demagnetization of the two coils in sequence causes the free floating piston to move to and fro.

The movement of the piston creates a region of low pressure on one side, thus causing the fluid flow into the cylinder from the supply line (c) (Figure 4). Meanwhile, on the other side the piston (P) pushes the fluid into the calorimeter due to the small pressure difference on the two sides of the piston. The flow backward from the pump cylinder into the supply line on the forward side of the piston or into the cylinder on the other side from the calorimeter is prevented by two check-valves (h-k and k-f) placed in series at the two ends of the cylinder.

Referring to the operational diagram shown in Figure 4, let coil m be magnetized (n being demagnetized at the same instant). Piston P moves towards (k-f) check valves. A region of low pressure is created to the left of the piston. Therefore fluid from c-b-h line will flow through the check valve h into r, part of the cylinder; fluid from d-g part is prevented from going into the cylinder by check valve g.

On the right side of the piston, the forward movement of the piston forces the fluid through section u-f-d onto the calorimeter. This fluid is prevented from flowing through section k-a-c by the check valve k.

Note: The H.P.L.D.R. Pump is a very delicate instrument. It was observed that minute particle contamination in the cylinder causes the piston to lodge. When the piston stops, the coils start heating up very fast and there is a danger of burning up of the system due to overheat. Hence, this pump should be carefully watched while in operation.

There is a light on the pump regulator board which blinks as one of the coil circuits gets switched on and off. When the piston lodges, there is an overload on the circuit and the light will not go out completely. This is a clear indication that the pump is not working properly. The same effect will also be observed when the speed regulator on the panel is turned so as to approach the maximum speed. In this condition, no fluid is being pumped and overheating may be expected.

While the pump is opened for cleaning or other purposes, it should be run dry to see whether it is working or not. Also, care should be taken while tightening the check valves to the ends of the cylinder. An extra tight joint will cause the piston to lodge.

Figure 5 shows the connection of the cyclinder to the check valves.

The electrical circuit operating the pump coils is shown in the section on "Electrical Circuits."

IV. <u>Preheater and Thermostatic Control of the Preheat Temperature</u>

(Ref: Figure 1)

The fluid from the recirculating pump goes to the main calorimeter. But before it enters the calorimeter it is heated by a coil (insulated wires) wrapped around the tubing. Along side the coil there is a temperature sensing thermocouple which operates the thermostat switch on the main panel. This thermostat can be set at any desired temperature. The thermocouple placed in the fluid media senses an emf depending upon the temperature of the fluid. If the temperature corresponding to the emf is greater than the thermostat setting, the current is cut off from the heating coils. This system regulates the temperature of the salt solution entering the calorimeter.

The accuracy of the thermostatic control is about 10-15°F, plus or minus.

To measure more accurately the temperature of the preheated water, another thermocouple is placed in the media. The emf generated is measured by the 8686 millivolt potentiometer.

Note: The power supply for the preheater temperature control is shown in the section on electric circuits.

V. Heat of Vaporization Calorimeter

The calorimeter is the heart of the whole set up. Figures 6, 7, 8, and 9 show the various parts of the calorimeter. The calorimeter contains the brine which is to be evaporated. As the solution gets hotter, its temperature rises. The temperature at various points in and on the body of the cell is measured by thermocouples inserted through holes in the body of the calorimeter.

With reference to Figure 7,

A - measures the vapor temperature.

B - measures the circulating fluid outlet temperature as does L. The outlet is placed diametrically opposite this thermocouple inlet.

K - measures the mid-level fluid temperature.

C - measures the inlet temperature.

There are two more thermocouples. One is placed on the outer body surface next to "C" to measure the temperature gradient across the metal at that section. A thermocouple on the outer body curface next to K measures the gradient at that location.

In Figure 7 offset (1) shows the recess at the two ends of the body where the seals have to be placed. This surface has to be very smooth if leakage is to be prevented at high pressure.

A. Top Plug (Ref: Figure 8)

The top and bottom plugs are inserted into the ends of the calorimeter body. The top plug (Figure 8) contains holes for vapor outlet and passage for level indicator probe.

B. Bottom Plug (Ref: Figure 9)

This contains openings for fluid inlet and passage for heater wires. The construction and description of the heater will be presented later.

C. Header Caps

The header caps hold the two plugs in place; they screw directly on to the body.

Note: The final tightening of the calorimeter is done with studs in the header caps. The following sequence of operation should be followed when tightening:

(1) Place the top plug on the body.

(2) Screw on the header cap until tight. There is no need of tightening this too much.

(3) The main tightening is done by 8 studs on the header cap. These are tightened by Allen wrenches in a particular order, i.e., in the same order as numbered (1 to 8). Repeat the process until all are tight to the same degree. If this is not done, leakage will occur no matter how much the other studs are tightened.

The way these studs seal the system is by pressing the top of the plugs which in turn deform the o-ring seal.

(4) The same process should be repeated for the bottom plug.

D. Level Indicator (Ref: Figure 10)

The probe consists of a conax 1/8" D. thermocouple. The two thermocouple wires are exposed with one leg 1/4 inch shorter than the other. Figure 10 illustrates the circuit; it can be closed only through the fluid.

OPERATION:

CASE A - The level of the fluid is below the two probe ends. No deflection is shown on the Ammeters, i.e., level of the fluid is low.

CASE B - Probe m is under the fluid surface and the circuit m-a-c-d-m is closed; Ammeter (1) will show deflection indicating level to be between (m) and (n).

CASE C - Both m and n are under the fluid surface; both Ammeters (1) and (2) will show a deflection indicating the level of the fluid to be too high.

E. Calorimeter Heater

Specification

1. Watts: (150 to 200) w.
2. Voltage: 36V maximum
3. Current: 4 to 5 A.
4. Fluid Flow Rate: 5 cc/min.
5. Heater Wire: No. 30 Nichrome Wire (.2548 mm diam).
6. Resistance of Wire: 6.750 Ω/foot.
7. Length of Wire: 12".

Placed inside the calorimeter is a small heater which is to be used to measure the energy required to vaporize the brine solution. The equipment and flow rate of the fluid determined the length, wattage, etc. of the heater.

Figure 11.A. shows the bottom plug upside down. The tube shown in Figure 11.C. fits in the opening with position "a" marked on the two drawings matching. Inside this tube about 12" of wire has to be placed such that the wire is insulated from the body of the tube.

Teflon was first considered for insulation in constructing the heater. However, teflon cannot stand temperatures beyond 500°F, and the red glowing wire easily cuts through the teflon.

Conax insulator tubes (shown in Figure 11.B.) were found ideal for this construction and following steps were executed to make the 12" wire fit in the tube which is 3 1/8" long:

(1) Conax insulators come in 2" lengths, so one of the insulators has to be cut in 1 1/8" size. It was found that an electric saw failed to cut the insulator properly but that large adjustable vice grip pliers would work. Place the insulator perpendicular to the U-shaped handle of the plier with the section of cut midway between the two edges of the U-section. Then press the other handle down on it. The insulator will snap with good accuracy. The length of the second piece should be 1 1/16" or a little less.

(2) Next, to increase the conductivity of heat from the wires, it is desirable to expose the heater wire; i.e., to remove insulation material, exposing the wire. To do this, the insulator has to be cut along its length on the side of each cylindrical hole. No saw available could perform this operation, because it is difficult to cut along a radial plane passing through the center of holes (ref: Figures 11.B. and 11.D.).

This can be done by inserting a loosely fitting copper wire through one of the holes. Hold the wire at one end by twisting. Take the other end in needle pliers and pull out along the radial plane through that hole. This will slit the hole almost like cutting paper.

Do not slit all the way but do it up to 1/8" of the other end for both pieces. For a small piece, start from the end which has been broken so that 1/8" covered hole remains at the other end.

(3) Insert wire through hole (1) (with reference to Figures 11.B. and 11.D.) and turn it around at the other end into hole (2) and again through (3) at the top and through (4) at the bottom.

The advantage of this kind of looping is that no short circuiting between various loops can occur. The total length of the wire in the tube should be 12" or slightly more. But total length taken should be about 18" to 24" so that some extension wire is left for further connections.

(4) It is evident from Figure 11.D. and 11.B. that both ends, and particularly the end which touches the closed end of the tube casing, will short circuit. Also, during heating the wires may expand and come out of the grooves and may touch the side walls of the casing.

To prevent this, Sauereisen mix was placed on the end touching the metal casing and on the grooves at several points (see Figure 11.D.) to prevent short circuiting of the expanded hot wire.

(5) The connection of the extension wire to the heater wires was accomplished in the following manner (Ref: Figure 11.E.):

The two extension wires are 4 or 5 strands of copper having very little resistance that are connected to the thin nichrome wires by twisting. Soldering can not be used because the heat will melt the solder.

After twisting, the joint is covered with Sauereisen mix and a teflon tube is placed over it. The Sauereisen makes a tight fit with the tube and prevents it from slipping. It also prevents the junction from touching the teflon tube and causing it to melt. The copper wire is not hot enough to melt teflon.

Figures 11.E. and 11.F. clearly show the rest of the connection.

The steps listed below were followed in testing the heater:

(A) The heater was connected to the D.C. power supply. To test the position of insulators and their effectiveness, 40V at 4.2 Amp. current was supplied for 1/2 hour. It was decided that the heater should not run for more than 1/2 hours because of the teflon insulation on the lead wires.

(B) The resistance of wire in the tube = 7Ω approx.

(C) Resistance across body (to check leakage) = 10 to 15 megaohms.

The circuit used to precisely measure the power input to the heater is described in the section on the Electrical Circuit.

VI. <u>Bath</u>

(Ref: Figures 12 and 13)

The calorimeter is suspended from the bath cover and suspended in the bath. The Dowtherm A liquid in the bath is heated by a bath heater which vaporizes the Dowtherm A and conducts heat to the calorimeter.

In using Dowtherm, it should be remembered that Dowtherm is flammable, highly aromatic, and a little toxic.

Also, to regulate the boiling temperature of Dowtherm, a vacuum is pulled on the bath. The pressure regulation circuit is shown in the section on Pressure Controlling Circuit.

Specifications of Heater:

Chromalox - 2000 watts, 120 volts.

VII. <u>Condenser and Solenoid Valve</u>

(Ref: Figures 1 and 13)

The evaporated fluid in the calorimeter is condensed in a counter-flow condenser brought to atmospheric pressure through a valve and then collected by either of two exhaust lines which are operated in sequence by a solenoid valve.

The next page shows the salient features of the solenoid.

Before vapor exits to the condenser, its vapor pressure is measured as illustrated in the section on Pressure Recording Circuit.

SECTION III

ELECTRICAL CIRCUIT

ELECTRICAL CIRCUIT

The fluid flow described in the last section has several elements which require electrical power to operate. The electrical circuit described in this section furnishes this power. The elements which require electrical power will be dealt with in the same order as they occur in the previous section:

1. General Description of Circuit.
2. Recirculating Pump - Coil Operation Circuit.
3. Preheater Circuit.
4. Calorimeter Heater Electrical Circuit.
5. Bath Heater Electrical Circuit.
6. Vacuum Pump.
7. Thermocouple circuit is described in the next section.
8. Condenser Solenoid Circuit.

I. General Description of the Electrical Circuit

(Ref: Figures 14 and 15)

The 110 v. A.C. power line available at the wall sockets in the room supplies current directly to the Ruska pump, speedomax recorder, regulated power supply. vacuum pump, potentiometer, and to the Adjust-A-Volt · (0-140) · V · (for the bath heater). An attempt should not be made to connect these lines to switches A (Figure 15) located at the back of the main panel because this may cause an overload and, consequently, the blowing of the fuse.

The rest of the equipment such as the thermostat control, powerstat (o-140) V, preheater, two Adjust-A-Volts (0-100)V, and time clock is supplied power through the transformer and through switches located in front of the panel.

The power first goes to the constant voltage transformer from where it is tapped in parallel (circuit) to the above mentioned items as shown in Figure 15.

The figure is self-explanatory as far as the circuit development is concerned.

II. High Pressure Low Differential Recirculating Pump Coil Circuit

(Ref: Figures 15 and 16)

The coils of the recirculating pump are actuated by the recirculating pump control shown in Figures 15 and 16.

The speed of the pump can be controlled by the "rate set" on the recirculating pump control panel. But as only 5 c.c./min. of fluid has to be pumped, the speed should be kept at its lowest setting. This speed can easily be checked by the rate of flickering of the light in the lamp marked as "cyclic rate" on the panel. Also, fast cyclic rate can cause the pump piston to stall.

The circuit involved in the instrument is shown in Figure 17. The transistors marked 2N1544A may burn out if fast rate is set or if the pump stalls. The transistors 2N1544A, 2N1192, 2N492 can all be replaced if they burn out without dismantling the assembly.

In order to check whether both the coils are operating properly or not, interchange the plug KK' and MM'. If they are working properly, the pilot lamp and cyclic rate lamp will both keep on operating. If not, the pilot lamp will go off, in which case the circuit connected to KK' is not working properly. Possibly one of the transistors has burned out. This test is based on the fact that the circuit essentially consists of two similar circuits in parallel with a switching device which supplies current to first the KK' circuit and then to the MM' circuit. The "cyclic rate" flickering lamp is connected to MM' side of the circuit and when it goes off, the current is only being supplied to the other circuit. A better arrangement would involve two lamps, one for each circuit.

III. Preheater Control Circuit

(Ref: Figure 15)

The preheater is essentially a mesh of insulated heater wires wrapped around the tubing. The power to the heater comes through the transformer into the switch shown, with accompanying lamp. The power, or the amount of current and voltage, can be regulated by an Adjust-A-Volt (0-140)V to meet the desired requirement.

Along side the preheater is a thermocouple which sends a feedback signal to the "preheater thermostatic control." The thermostatic control can be set to any desired temperature from 0 to 800°F. If the feedback signal shows that the temperature corresponding to the feedback signal is greater than the setting, the thermostat automatically cuts off the power to the heater. When the preheater temperature goes below the setting, the thermostatic control reactivates the heater.

The accuracy of the thermostatic control was checked to be about 10 to 15°F.

Sometimes the wires in the thermostat become loose and it may then stop functioning. The first thing to do is to open the cover in front and check the connecting wires just behind it. For further checks, the catalog on this instrument should be consulted.

IV. Calorimeter Heater Electrical Circuit

(Ref: Figures 15 - 17)

Specification: (150-200)W Heater

36 Volts Max M D.C.

4 to 5 Amps.

The A.C. supply is converted into D.C. by the instrument "Regulated Power Supply" which also regulates the D.C. voltage and is not affected by the fluctuations in the A.C. Power Supply.

Figure 17 clearly shows the circuit. The power is supplied by the Regulated Power Supply via .01 ohm resistance and line "s-a-b-c-" where the power input splits into two circuits. The major part goes to the heater and the circuit is completed via "s-a-b-c-d-h-j-R".

The rest of the current goes through the standard resistors of 1000Ω, 1000Ω, and 1Ω, and circuit is completed via line s-a-b-c-d-e-t-g-h-j-R.

Tappings are made at a-b, c-j, and f-g to measure emf's of .01Ω cell, heater and 1Ω cell respectively. These tapped lines go to the rotary switch Nos. 10, 9, 11 respectively from where there is a common line to the potentiometer. The potentiometer can measure 11 emfs of different elements one at a time. This is done by turning the rotary switch to the desired number.

This electrical circuit enables one to accurately determine the power input into the heater. Below are tabulated the necessary calculations to determine this power input:

I_{tot} = Total Current

I_h = Heater Current

I_M = Current in measuring deg of parallel circuit

E_t = Voltage Drop Across Heater

E_L = Voltage Across Standard Resistance 1Ω to measure current in parallel leg

E_2 = Voltage Across Standard Resistance .01Ω

Now: $$I_{tot} = \frac{E_2}{.01} \text{ Amps} \qquad (1)$$

$$I_M = \frac{E_1}{1} \text{ Amps} \tag{2}$$

$$\therefore I_h = I_{tot} - I_M \quad \text{(By Kirchoff's Law)}$$

$$= \frac{E_2}{.01} - \frac{E_1}{1} \tag{3}$$

$$E_t = I_M(1+2000)$$

$$= \underline{E_1}(1+2000)$$

$$= 2001\ E_1 \tag{4}$$

$$\therefore P = \text{Power to the heater}$$

$$= E_t \cdot I_h$$

$$= 2001\ E_1\ (E_2/.01 - E_1/1) \quad \text{(Subst values from (4) and (3))}$$

$$= 200100 E_1 E_2 \tag{5}$$

Specifications

1. 1 ohm: L&N No. 4020B

   ±.001% up to .3 amperes

   & ±.02% up to 1 amps.

2. 1000 ohm: L&N No. 4035B

   ±.001% at .01 amps.

   & ±.02% at .03 amps.

3. .01 ohm: L&N No. 4222B

   ±.001% up to 10 amps.

   ±.05% to 30 amps.

Maximum Error:

$E_t + E_2 = 36$ volts

Then $I_M = 0.01792$ amps.

$I_{tot_{MAX}} = 5.5$ amps.

Percent error in power input at Max power = .1537%.

V. Bath Heater Circuit

(Ref: Figure 15)

Specification: 120 volts

3000 watts

The bath heater is supplied current directly from the power line from a wall outlet. The power goes through a controlling switch and a lamp. The lamp indicates whether the circuit is closed or not.

The power supplied is adjusted in magnitude by an Adjust-A-Volt (0-140)V placed in series along with a protecting fuse with an activating switch.

VI. Vacuum Pump Circuit

The vacuum pump is operated directly by the power line by plugging in the vacuum pump to the power line.

VII. Speedomax Recorder Circuit

The speedomax recorder also operates directly by the power line.

The details of thermocouple connections is dealt with in the section on thermocouple circuits.

See the catalog for detailed electrical circuitry involved inside the recorder.

VIII. Condenser Solenoid Circuit and Time Clock

(Ref: Figure 15)

The power is directly supplied to a controlling switch and lamp Q and from there to the two sockets placed in parallel.

The line is further extended from the socket to a knife switch. The knife switch may either be connected to the time clock or the solenoid valve.

Sometimes the solenoid may emit vibratory sound on starting. This may be due to air flowing through the passage or to the vibration of the plunger.

COIL REPLACEMENT (See other side for complete disassembly instructions)

1. All coils are clearly marked with an identifying code number and/or voltage and frequency. See tables.

A.C. COILS	VOLTS & CYCLES	115 V. 60 cy.	115 V. 50 cy.	115 V. 25 cy.	230 V. 60 cy.	230 V. 50 cy.	230 V. 25 cy.	208 V. 60 cy.	460 V. 60 cy.	550 V. 60 cy.	24V. 60 cy.
MARK OF IDENTITY	CLASS "A" (STD.)	801	802	**804**	801	903	**806**	808	306	805	807
	CLASS "H" (HI TEMP.)	901	902	**904**	904	903	**906**	908	906	905	907

D.C. COILS	VOLTS	6V.	12V.	24V.	32V.	110V.	220V.
MARK OF IDENTITY	CLASS "A" (STD.)	894	895	896	897	898	899
	CLASS "H" (HI TEMP.)	994	995	996	997	998	999

Spanner wrench

Note: Spanner wrench P/N 90-P600, furnished standard only with explosion-proof & watertight units. Available for other units from Distributor's stock.

2. Always make sure power supply is turned off.
3. The construction of alternating current (A.C.) and direct current (D.C.) solenoid valves are NOT the same. DO NOT attempt to replace a D.C. coil with one for A.C., or an A.C. coil with one for D.C. A complete new solenoid assembly is necessary for this situation.
4. Sever external electrical connections to coil lead wires.
5. Remove parts and replace them in the following order: (See exploded views, parts lists, and sectioned drawings)

GENERAL PURPOSE (NEMA 1) VALVES

2-WAY NORMALLY CLOSED FLOW PATTERN

A. Remove nut (16), lock washer (14) and name plate (15).

B. Lift off coil housing top (13), and grommet cap, where applicable (11).

C. Remove the spring washer (10), flux plate (9), top insulating washer (7), and coil (8). Make sure bottom insulating washer (7), and coil housing bottom (6), remain on the plunger tube assembly.

D. Place new coil in position, with taped lead wires running upward, or away from valve body.

E. Replace the top insulating washer, flux plate and spring washer.

F. Thread the leads through the grommet cap or conduit fitting (12). The grommet cap (or conduit fitting if necessary), should then be attached to the coil housing bottom.
With grommet connection make sure that leads do not cross each other inside housing.

G. Replace coil housing top, name plate, lockwasher, and nut. Tighten nut to draw housing down snugly to base of plunger tube assembly. 15 inch pounds torque is ample.

2-WAY NORMALLY OPEN, AND 3-WAY FLOW PATTERNS

A. Unmake pipe or tubing from connection adapter (16).

B. Remove connection adapter (16), and name plate (15) from valve.

C. Proceed with remaining steps as with a 2-way normally closed valve.

D. NO lockwasher (14) is included in assembly of the 2-way flow patterns.

EXPLOSION-PROOF & WATERTIGHT VALVES

2-WAY NORMALLY CLOSED FLOW PATTERN

A. Remove housing cap assembly (15) with hex spanner wrench provided with valve. See illustration of spanner.

B. Lift off coil housing (14), allowing lead wires to run out thru conduit hub.

C. Remove the spring washer (9), flux plate (8), top insulating washer (6), and coil (7). Make sure bottom insulating washer (6), remains on the plunger tube assembly (5).

D. Place new coil in position and replace parts in reverse order of removal.

E. DO NOT damage surfaces or corners of metal to metal joints of explosion-proof and watertight enclosures. These surfaces are machined to very close-fitting tolerances, which are essential to provide a flame-proof, or watertight seal. The explosion-proof joints are dry; the watertight joints have a coating of silicone grease, which should be renewed after handling.

2-WAY NORMALLY OPEN, AND 3-WAY FLOW PATTERNS

A. Unmake pipe or tubing from connection adapter (16).

B. Remove connection adapter (16). Remove housing cap assembly (15) with spanner wrench provided and proceed with remaining steps as with a 2-way normally closed valve.

SECTION IV

THERMOCOUPLE CIRCUIT

THERMOCOUPLE CIRCUIT

The thermocouple circuit has been primarily designed to give the maximum possible information regarding temperatures and temperature gradients in the calorimeter, i.e., in the two phases, in the liquid phase at different levels, and across the calorimeter wall.

The circuit is so designed that temperature recorded by individual thermocouples can be recorded along with continuous recording of the differential temperatures between thermocouple Nos. 1 and 2, 3 and 4, and 5 and 6.

The circuit will be discussed in detail in the following order:

1. Thermocouple Placement
2. Lead to Ice Junction
3. Lead to Potentiometer via Rotary Switch
4. Non-Thermocouple Leads to Potentiometer via Rotary Switch
5. Lead to Speedomax Recorder

I. Thermocouple Placement

(Ref: Figures 18 and 19)

The thermocouples are placed such that temperature recorded by them would offer maximum information.

Thermocouple No. 1: measures the vapor temperature in the center of the vapor region, i.e., its tip is on the central axis inside the calorimeter.

Thermocouple No. 2: measures the recirculating fluid outlet temperature. The tip of the T.C. is adjacent to the outlet passage.

Thermocouple No. 3: measures mid-level liquid temperature. At this level, the central portion of the calorimeter is occupied by the heater. Hence, the tip of the T.C. is located midway between the heater and calorimeter wall.

Thermocouple No. 4: measures the outer wall temperature at the same level as No. 3 so as to give information regarding temperature gradient across the wall at the level under consideration. The resulting differential emf is continuously recorded by the Speedomax Recorder.

Thermocouple No. 5: measures the inlet fluid temperature and its tip lies just above the inlet passage.

Thermocouple No. 6: gives the outer wall temperature at the level of No. 5.

Thermocouple No. 7: measures temperature of fluid entering the recirculating pump.

Note: This T.C. was initially installed but since then has been removed as it served no particular function.

Thermocouple No. 8: measures the temperature of the preheated fluid which is the temperature of fluid entering the calorimeter.

A. Fitting of Thermocouples

Type: The thermocouple numbers one to six are iron-constantan mineral insulated thermocouples.

Color Code: Iron (positive) - white color on top

Constantan (negative) - red color on top

Size: 1/8" in diameter with lead wires extending beyond the 18 inches of steel sheath. Reference catalog "Mineral Insulated Thermocouples"

Thermocouples 7 and 8 are special types. Refer to Autoclave Engineers catalog "High Pressure Information" for their exact specifications.

Figure 20.A. shows the joint of the thermocouple. In order to create the sealing effect, the thermocouple should be tightly gripped. To do this, the following procedure should be adopted:

1. Determine the length "L" through which the thermocouple will project beyond end a or a'. This can be done by knowing exactly where the tip is located inside the calorimeter.

2. Place the nut and then the ferrule as shown at the desired position. Care should be taken so that the length "L" is not altered.

3. Place the thermocouple in the threaded hole where it is to be placed and tighten, maintaining length L constant. As the nut is tightened, the surface of ferrule marked 1 - 2 will get crimped and will strongly clamp the thermocouple sheath.

4. Loosen the nut and it will be observed that ferrule cannot be moved. The sealing effect is created by a'-b' and a-b, pressing against each other.

NOTE: 1. As the process is irreversible, care should be taken in performing it correctly the first time.

2. The crimping of the ferrule can be done on any bolt or adaptor of similar dimension and shape as the hole in the calorimeter wall

B. Connection from Sheath Type Thermocouple to the Flexible Wire (Ref: Figure 20.B.)

The conax thermocouples were delivered with flexible wire attached to the end of the wires contained in the 18 inches of insulated metal sheath. Due to severe usage, the flexible wire broke and no leads were available for extending the thermocouple wires.

The only recourse was to strip the sheath of the insulation so that another connection could be made. The stripping should be done in the following manner: (Refer to Figure 20.B.)

1. File out about one inch length from the end on two diametrically opposite sides, the depth being as shown by the hatched lines in the side

view. This will cause the insulation (a white powdery material) to fall away and the two thermocouple wires will be visible.

2. Use cutting pliers to bend outward the remaining portion (i.e., section p and q) and cut it at section m. This will expose the leads.

To determine which is iron and which is constantan, bring a magnet near the wire. Iron will attract some of the filed particles lying on the magnet surface.

Iron, constantan sockets were connected to the thermocouples. Prongs were connected to the extension wires. This combination minimizes the problem of thermocouple breakage due to repeated flexing.

When the thermocouple's exposed lead wires were attached to the plug there was a danger of the joint breaking due to the rotation of the plug relative to the thermocouple. To overcome this, the Ferrule shown in Figure 20.C. was used and surface "a" was crimped on the metal sheath of the thermocouple. When the plug halves are tightened, the joint became extremely rigid. This has a two-fold advantage: one, that rotation is prevented and two, that any tension on the thermocouple sheath is transmitted to the plug and is not transmitted to the thin bare wires at the joint.

The flexible wire ends are attached to the socket end. The lead from the socket was filled with Bathtub Caulk to give extra rigidity to the flexible wires at this junction.

II. Lead to Ice Junction

The ice junction is essentially a bath of oil at the temperature of melting ice, i.e., 32°F. The components constituting the ice junction are a thermos flask in which eight test tubes filled with light oil are placed. In each test tube is one thermocouple lead pair. The test tubes are corked to prevent the wires from slipping out. Crushed ice is packed around the test tubes to create the desired temperature. The thermos flask is covered to prevent quick melting of ice.

Note: 1. The temperature of ice will not be 32°F unless it is made of distilled water and the pressure in the room is standard pressure. The charts are calibrated to 32°F. So the only way to correct the readings or to make it more accurate is to measure the actual temperature of ice and then calibrate the emf reading to the standard temperature of 32°F.

Example: Let the temperature of melting ice = 33°F.

Let emf reading by the potentiometer = 2.0 millivolt.

Temperature corresponding to 2.0 millivolts = 102°F.

∴ Actual temperature with reference to 32°F = 102 + (33-32)°F

= 103°F ---- ans.

2. The joint at the ice junction was soldered.

III. Lead to Potentiometer via Rotary Switch

The wires leading from the ice junction to the connecting junction are thermocouple wires. At the connecting junction these wires are connected to the same numbered rotary switch wires, maintaining the consistency in positive and negative wires.

Also, at this junction, leads for thermocouple numbers 1 through 6 are tapped and brought to "connecting junction for lead to recorder".

IV. Non-Thermocouple Leads to Potentiometer via Rotary Switch

(Ref: Figure 18)

Apart from the emf measurement of the 8 thermocouples, the potentiometer also measures the emf across the calorimeter heater, 1 ohm standard resistance, and .01 ohms standard resistance. These are connected to 9, 11, and 10 numbered switches respectively, maintaining the proper positive and negative connections.

The advantage of a 12-way rotary switch is that the lead to the potentiometer need not be changed every time a different emf is to be measured. All that needs to be done is to turn the dial on the rotary switch to the desired setting.

V. Lead to Speedomax Recorder

(Ref: Figure 18)

The function of the speedomax recorder is to continuously record the emf difference between thermocouple numbers 1 and 2, 3 and 4, 5 and 6. These differences will enable one to calculate the temperature gradient between vapor and liquid phase, between inner and outer walls at mid-level and lower level respectively.

The connecting junction for the lead to the recorder shows that the negative leads of one and two, three and four, and five and six are connected together at the junction. Only the positive ends of these pairs enter the recorder to form the differential lead.

The speedomax is constructed to measure 12 differential recordings, but as only 3 differential temperatures are recorded, the point made on the paper will denote differential temperatures in the following manner:

Differential Thermocouple No.	Thermocouple Used As Positive on Recorder	Thermocouple Used As Negative on Recorder
I	1	2
II	3	4
III	5	6

The points plotted are numbered one to 12. The table below will show what each number means in terms of differential temperature it denotes, i.e., whether it is I, II, or III.

Differential Thermocouple No.	Plot Numbers Denoting Same Diff$^{\underline{N}}$ Thermocouple Reading
I	1, 4, 7, 10
II	2, 5, 8, 11
III	3, 6, 9, 12

SECTION V

PRESSURE RECORDING CIRCUIT

PRESSURE RECORDING CIRCUIT

(Ref: Figures 1 and 21)

The items included in the pressure recording circuit are essentially two Heiss pressure gauges which record the pressure inside the calorimeter.

The tap for the pressure gage is taken from the vapor outlet line of the calorimeter. The vapor goes through a trap to condense salt and water particles being carried in the vapor.

The two pressure gauges record the same pressure; at lower pressures the (0-750) psig pressure gauge offers the more accuracy.

It is of interest to note the connection of the pressure gauges. When stop valve A is opened, pressure gauge 1 will register a pressure reading. Gauge 2 can be cut off from high pressures by closing stop valve C. The two pressure gauges may be exhausted by closing valve A and opening valves B and C.

Thus for pressure ranges of (0-750) psig in the calorimeter, both pressure gauges may be used to record pressure. But at pressures greater than 750 psig, pressure gauge 2 may be closed while operating pressure gauge 1. This step protects the bourdon tube of gauge 2.

I. Calibration

The two pressure gauges were calibrated with a dead weight tester. The m/c had an accuracy of 1 lb. per 1,000 lbs.

II. Results

A. Pressure Gauge (0-5000) psig

This pressure gauge required no calibration as it was correct to the fraction of the smallest division.

B. Pressure Gauge Range (0-750) psig

This pressure gauge required calibration and calibration curves are plotted on Figures 22.A., 22.B., 22.C., 22.D., and 22.E.

SECTION VI

PRESSURE CONTROLLING CIRCUIT

PRESSURE CONTROLLING CIRCUIT

(Ref: Figure 23)

The pressure controlling circuit provides a means of automatically maintaining a predetermined pressure in the calorimeter bath. As the absolute pressure can be controlled by the variation of controlling equipment, this system has been separately named as the Pressure Controlling Circuit.

The circuit essentially consists of a line from the bath connected via a controlling manostat to a vacuum pump. The vacuum pressure is measured by a U-TUBE mercury manometer. To set the monostat for operating pressures above atmospheric, a nitrogen cylinder is used to supply gas pressure to the manostat. This pressure is measured by the pressure gauge shown in Figure 23.

The equipment will be dealt with in the following order (refer to Figure 23):

1. Condenser
2. U-Tube Manometer
3. Cartesian Monostat #6A*
4. Vacuum Pump

I. General Operation

In order to create a vacuum in the bath, the following sequence of operations should be performed:

1. Close stop valve "a" and start the vacuum pump and wait till gurgling sound dies down; (check to make sure valves d and e are closed).

2. Open valve a and b; c remaining closed and set the manostat pressure.

3. Open valve f.

The U-TUBE manometer will automatically record the pressure to which the manostat has been set. The details of the manostat and its operation are described in the following pages.

In order to operate the bath at pressures above 1 atmosphere, the following sequence of operations should be performed (refer to Figure 23.A.):

1. Hook up the manostat as shown in Figure 23.A.

2. Connect the system to port marked <u>IN</u>.

3. Through the needle valve connect the pressure source to the system.

4. Connect the pressure gauge to the system.

5. Turn orifice adjustment knob halfway between the maximum and minimum positions.

6. Open the toggle-valve (i.e., ON-OFF valve at the bottom) needle valve being closed.

7. Keep one hand on toggle-valve and with the other very slowly start opening the needle valve (exhaust valve being closed).

8. When the desired position is approached, flick the toggle valve to the shut off position and open exhaust on-off valve.

9. Adjust needle valve to a fine bleed.

10. Set exact pressure by turning the orifice adjustment knob.

<u>To shut down the system</u>:

1. Close needle valve.

2. Open toggle valve.

3. Close exhaust on-off valve.

4. The manostat is now ready for starting up the system again by opening the needle valve.

A. Condenser

The purpose of the condenser is to condense any liquid particles contained in the vapor that is being sucked out. This is a safety feature as the fumes are somewhat toxic and is also essential in order to protect the vacuum equipment.

B. U-Tube Manometer

The manometer is a simple unit with excellent accuracy. The manometer measures the vacuum pressure of the bath.

When operating this manometer care should be taken to pressurize the manometer slowly. If atmospheric air is allowed to enter the system too quickly, the mercury in the manometer will be violently disturbed and some of the mercury may spill out of the leg open to the atmosphere.

C. Cartesian Manostat #6A*

(Ref: Figures 23 and 24)

The function of the cartesian manostat in the controlling circuit is to regulate the pressure in the bath. Without the manostat, the vacuum pump would automatically pull the maximum vacuum possible, i.e., about 28.5 in. of mercury. The manostat is used to regulate the pressure either above or below atmospheric pressure.

1. Description of the Apparatus

The manostat essentially consists of a float which is closed at the top by a rubber seat which acts as a sealing surface. The "FLOAT" floats in column of mercury and moves up and down due to changes in pressure difference between P_1 and P_2 (reference Figure 24).

Inside the float is a central tube open at the top as shown and connected at the bottom through "ON-OFF valve" to the system (i.e., the bath in our case).

Above the float surface there is a movable orifice whose surface "c'" can be lowered or raised by the handle at the top. The orifice is connected to the vacuum pump and the atmosphere through valves "b'" and "c'".

The space outside the float is also connected to the system (shown by arrows) and to a U-tube manometer as shown.

2. Operation

The principle of operation of the manostat can be stated in one sentence: The Float rises when pressure P_2 is less than P_1 and falls down when pressure P_2 is greater than P_1.

Consider the case when the manostat has just been assembled. The entire system is at atmospheric pressure.

a. Close valve "c", open "f", "b", and "on-off valve".

b. Start the vacuum pump.

c. Initially the whole system is at atmospheric pressure. But as the vacuum is created, pressures P_1 and P_2 will drop. BUT WILL REMAIN EQUAL TO EACH OTHER. Therefore the Float will remain stationary.

d. The pressure at each instant will be shown on the U-Tube Manometer and when the desired vacuum pressure is reached, close the ON-OFF valve.

e. The vacuum pump will create more vacuum and pressure P_2 will drop but P_1 will remain fixed at the pressure at which ON-OFF valve was closed.

f. As soon as P_2 becomes less than P_1, the Float will rise and c surface a' on rubber seat will seal against c' surface of the movable orifice.

g. The sensitivity of the instrument tells the pressure gradient required for the float to rise and close the movable orifice. It is the measure of the instruments accuracy which is ±.2% or ±.2 mm, whichever is greater.

h. When the vacuum operation is complete and the system has to be brought to atmospheric pressure, close valve b" and open c slowly. Air from atmosphere will rush into the orifice and push the float down and P_2 will become greater than P_1. Thus float will go down and lower seat surface b' will seal the central tube opening. Then even if ON-OFF valve is opened, low pressure between central tube and float will cause the float to keep the opening sealed and the pressure setting will remain as before if operated again.

3. To Change Pressure Setting

a. To lower absolute pressure P_1 or increase vacuum pressure in the system:

(1) Set the unit in operation as before.

(2) When the previous pressure setting is reached, just open the ON-OFF valve momentarily. This will cause some more gas to be evacuated from inside the float and the float will fall. This will cause more air to be evacuated from the system until system pressure P_2 is lower than the new setting of P_1.

Care should be taken to open and close the ON-OFF valve quickly; otherwise too much air may be evacuated.

b. To raise the pressure setting P_1:

(1) The system is in the operating state. Close valve b" and open ON-OFF valve. This will equalize the pressure P_2 and P_1 and the float may be said to be in controlling condition.

(2) Open valve "c" and very slowly let air into the system. This air will enter into the inner and outer sides of the manostat and the whole system will be at atmospheric pressure and ready for a new setting.

(3) It was observed that the highest absolute pressure setting for vacuum operation with atmospheric pressure inside the float was 18.5 ins. of mercury.

Refer to Figure 23. Connected to one side of the ON-OFF valve is a pressure gauge and a nitrogen gas cylinder. To get a pressure setting lower than 98.5 ins. of mercury, follow the following procedure:

(a) Assume that the system is at atmospheric pressure.

(b) Open valve "e" and let gas enter the inner side of the float. Trap a higher than atmospheric pressure on the inner side by closing the ON-OFF valve at the desired pressure recorded by the pressure gauge.

(c) This is a hit or miss tactic as there is no calibration between pressure gauge reading and vacuum pressure which will be created in the system due to it.

4. Line from manostat to vacuum pump:

The line from manostat to the vacuum pump includes a reservoir (glass jar). This has been placed in the circuit so that any liquid particles in the system may condense here so that the vacuum pump will receive only saturated vapor.

D. Vacuum Pump

The catalog describes in detail various features of the pump. Some of the important features will be mentioned here, namely safety features:

1. Check oil level before operating the pump and check it occasionally during operation. Use clean vacuum pump oil (Precision Vac Pump Oil, Catalog #69100).

2. A stalled pump may result from introduction of metallic or glass particles into the pump unit.

3. When starting, close intake port and initially a gurgling sound will be heard. This sound should die out within a minute. If it does not, the pump is low on oil.

SECTION VII

SYSTEM OPERATION

SYSTEM OPERATION

(Ref: Figure 1)

In order to run the calorimeter, the sequence of operations described below should be of help and guidance. Exact operation will be determined on the basis of the particular experiment in mind.

I. Pre-Operational Tests

A. Check for leakage in the calorimeter in the following manner:

1. Before lowering the calorimeter in the bath, connect as shown in Figure 1, plugging the recirculating line. Keep the vapor line open to atmosphere and pressure gauges in the circuit.

2. Manually operate the pump to fill the calorimeter with fluid. Keep operating the pump until water comes out of the vapor line open to the atmosphere.

3. Now close the vapor line. The pressure gauge will record a pressure when sufficient water is injected into the system. Operate the pump electrically in this portion of the test.

4. Check all joints for leakage. The pressure should be raised a little beyond the maximum limit expected during the operation.

5. Open valve "d" (Figure 1) and retract the pump piston until the pressure recorded is almost atmospheric. Then open the vapor line to the atmosphere and retract the piston to the original starting point.

6. Check all electrical connections.

II. Assembly

A. Remove all connections for the above test and lower the cover to the calorimeter bath, checking to be sure the asbestos insulator is in place.

B. Tighten the cover connection as indicated by Figure 1.

C. Pump fluid into the calorimeter until level indicators indicate the proper level.

D. Stop pumping and start the bath heat and the preheater (set at 212°F).

E. Start the recorder thereby keeping continuous measurements of the temperatures.

F. Bring into operation the vapor condenser and pressure controlling circuit so as to create the desired pressure in the bath. Bath pressure depends on the desired test temperature. This pressure is determined from the vapor pressure curve for Dowtherm A.

G. It will probably take from 4 to 6 hours for the Dowtherm to start boiling. The calorimeter heater should only be used while conducting a test.

H. The level indicator will continuously monitor the fluid level in the calorimeter. If no leaks are present, this level will stabilize as soon as the temperature and pressure stabilize.

I. Once the fluid in the calorimeter starts boiling (observed when fluid outlet temperature and vapor temperature are equal) the calorimeter heater is brought into operation and recirculating may be started to maintain the level by replacing liquid lost through evaporation.

J. Depending upon the specific objective of the experiment, various temperature and pressure readings will have to be taken. Both the heat input into the calorimeter heater and the rate of evaporation of liquid must be measured in order to calculate the latent heat of evaporation.

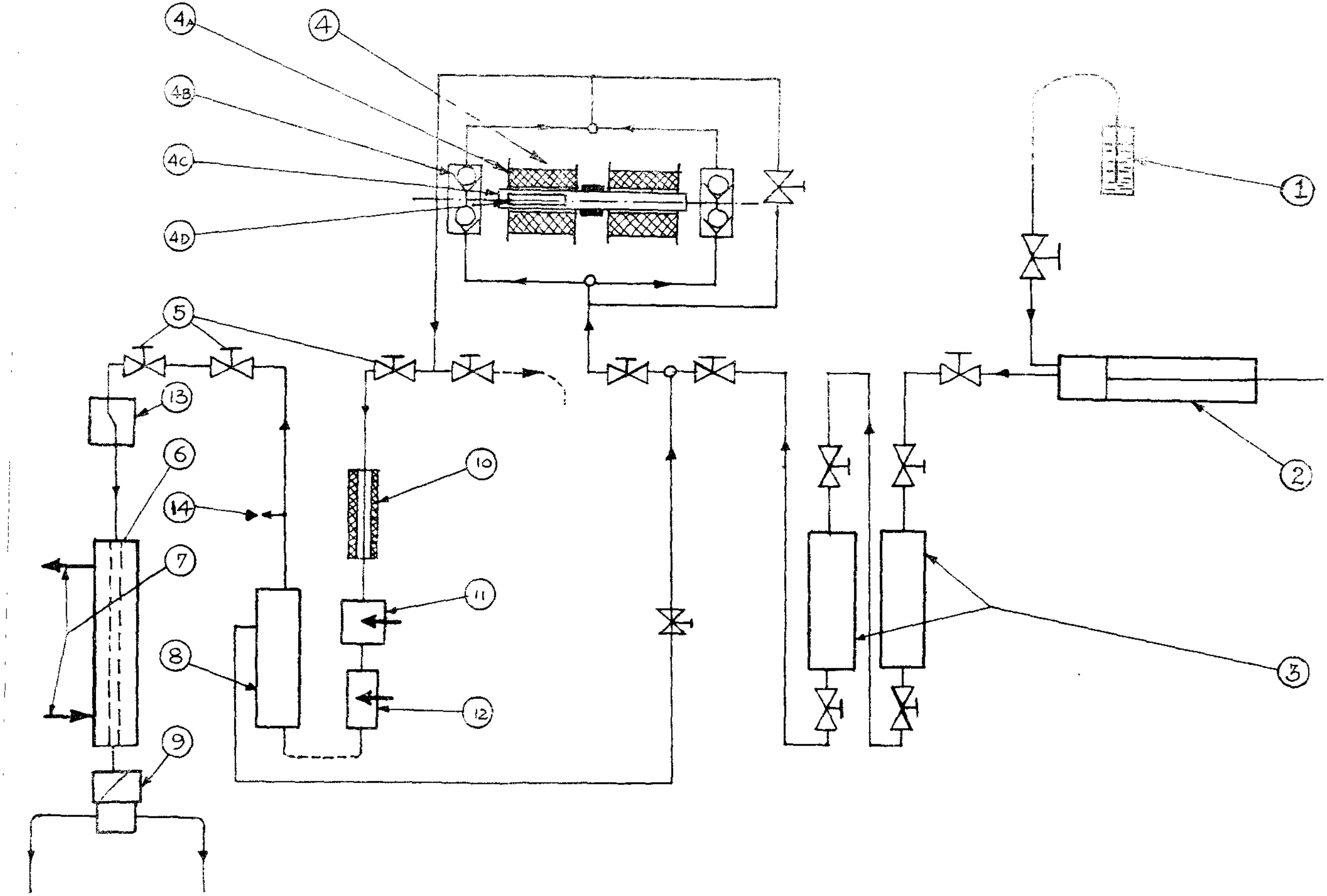


Figure 1. Fluid Flow Line

Figure 1 (con't.)

SL. NO.	ITEM	NO. OFF.	REMARKS
1	OIL RESERVOIR (FOR POSITIVE DISPLACEMENT PUMP)	1	
2	RUSKA POSITIVE DISPLACEMENT PUMP	1	
3	STORAGE CELL	2	
4	HIGH PRESSURE, LOW DIFFN. RECIRC. PUMP	1	
4a	MAGNETIC COILS	2	
4b	CHECK VALVE	2	
4c	CYLINDER	1	
4d	PISTON	1	
5	STOP VALVE	12	
6	VAPOUR CONDENSOR	1	
7	COOLING WATER FOR CONDENSOR		
8	CALORIMETER	1	
9	SOLENOID	1	
10	PREHEATER COILS	1	
11	THERMOCOUPLE	1	
12	THERMOSTATIC CONTROL OF PREHEAT TEMP.	1	
13	RELIEF VALVE	1	
14	LINE TO PR. GAUGE		

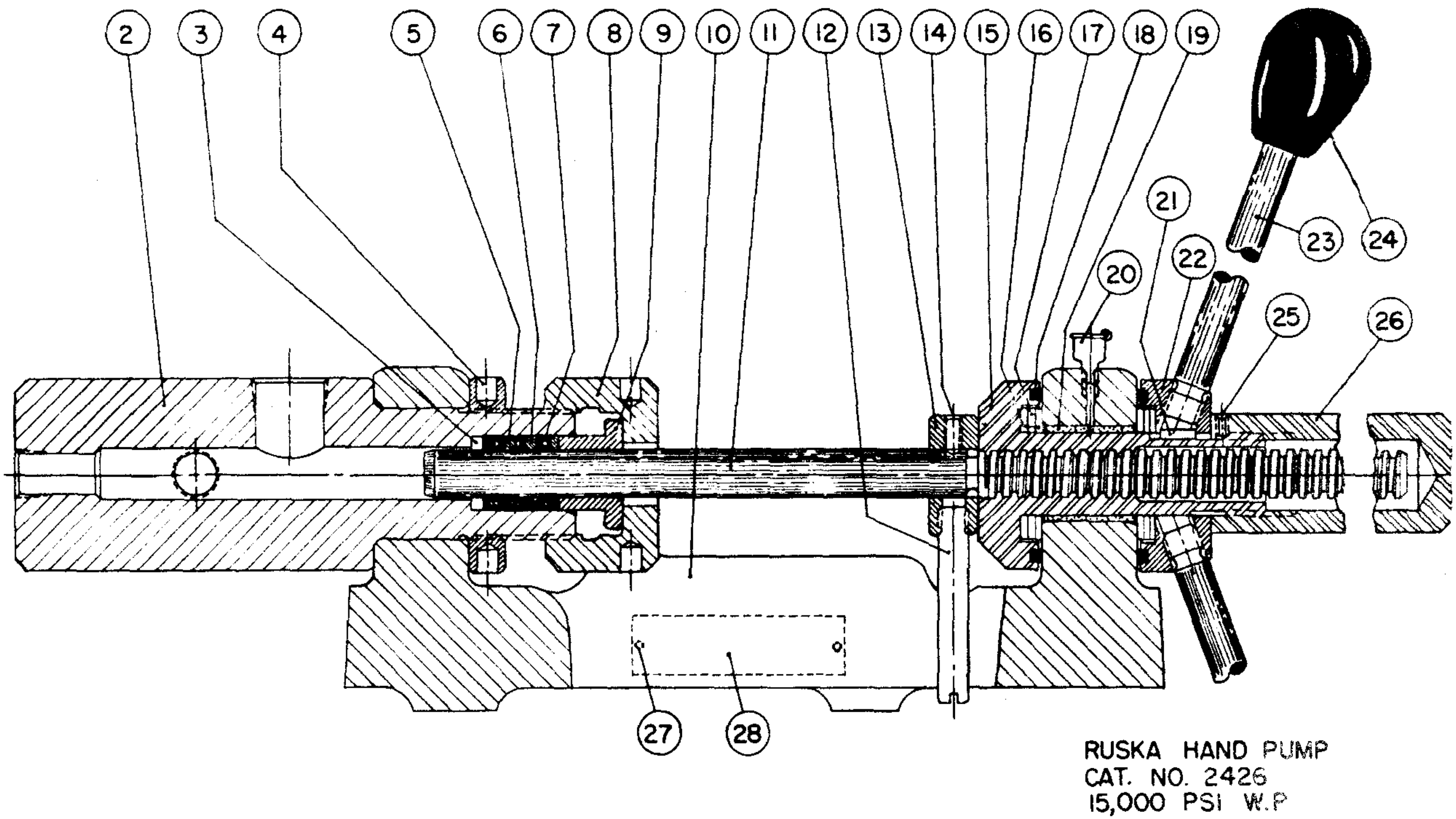


Figure 2. Ruska Hand Pump

PARTS LIST

RUSKA HAND PUMP, CAT. NO. 2426

No.	Name	No. Req'd.	Ruska Stock No.
1	Spanner Wrench	1	Williams #456
2	Cylinder	1	2426-1-6-1
3	Junk Ring	1	2425-3
4	Cylinder Retaining Nut	1	2426-1-4
5	Packing Ring	3	2425-19
6	Packing Spacer	1	2425-20
7	"U" Cup	3	CS-222-47
8	Packing Retainer Nut	1	2426-1-10
9	Packing Follower Ring	1	2426-1-11
10	Base	1	2426-1-1
11	Plunger	1	2426-1-5
12	Non-Rotation Pin	1	2426-1-8
13	Stop Collar	1	2426-1-3
14	Socket Set Screw	3	CS-31 HHSS #10 x 5/16 ST
15	Drive Nut	1	2426-1-2
16	Thrust Washer	4	CS-399-5
17	Thrust Bearing	2	CS-332-4
18	Square Felt	2	SS-371-43
19	Bearing	1	CS-330
20	Oil Cup	1	CS-197-1
21	Square Key	1	SS-56-6
22	Handle Hub	1	2426-1-7
23	Handle	2	2426-1-9
24	Handle Knob	2	CS-251-2
25	Socket Set Screw	2	CS-31 HHSS #5 x 3/16 ST
26	Thread Cover	1	2427-1-7
27	Drive Screw	2	CS-90
28	Number Plate	1	SS-236-2¼

Figure 2 (con't.)

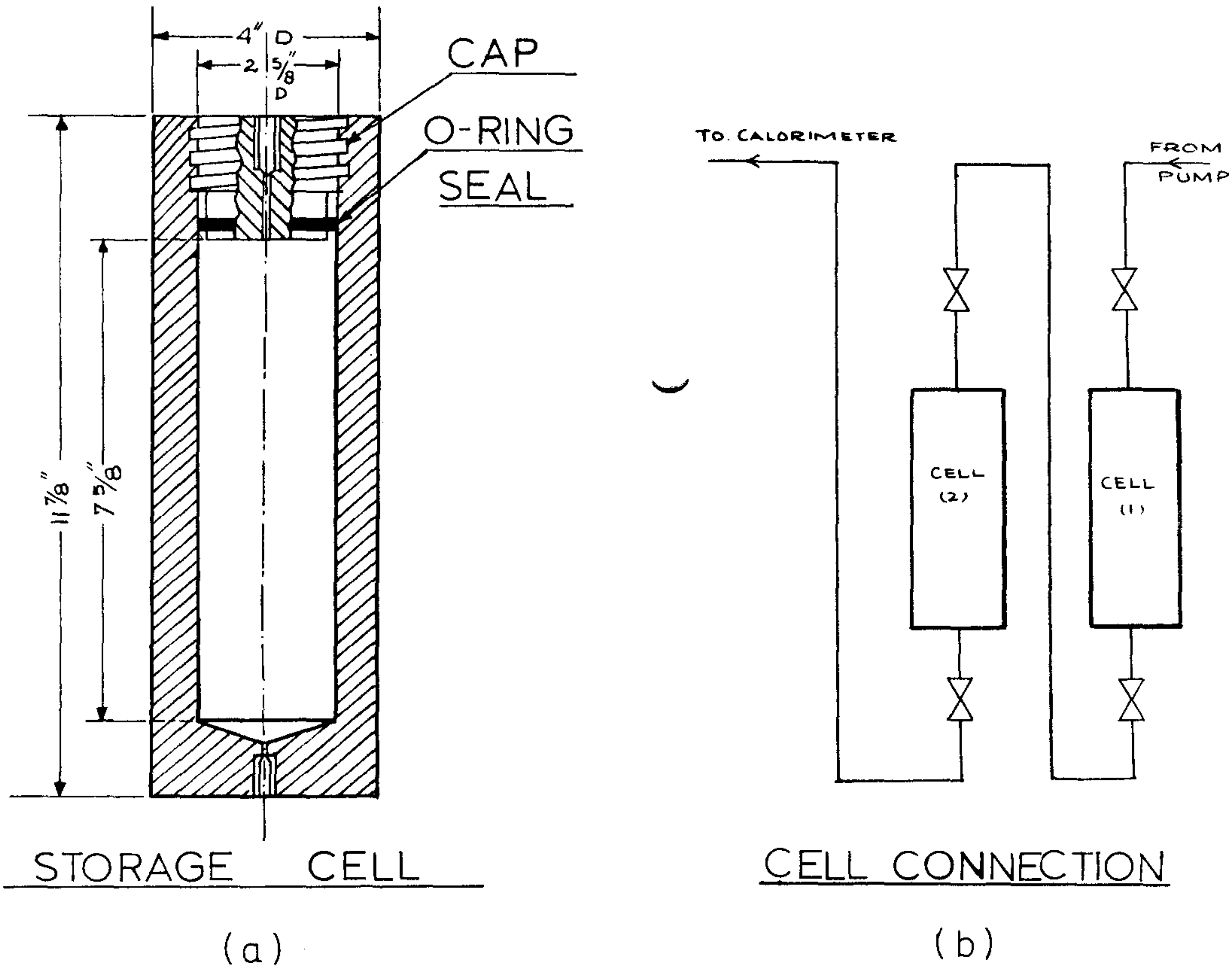


Figure 3. Storage Cell and Cell Connection

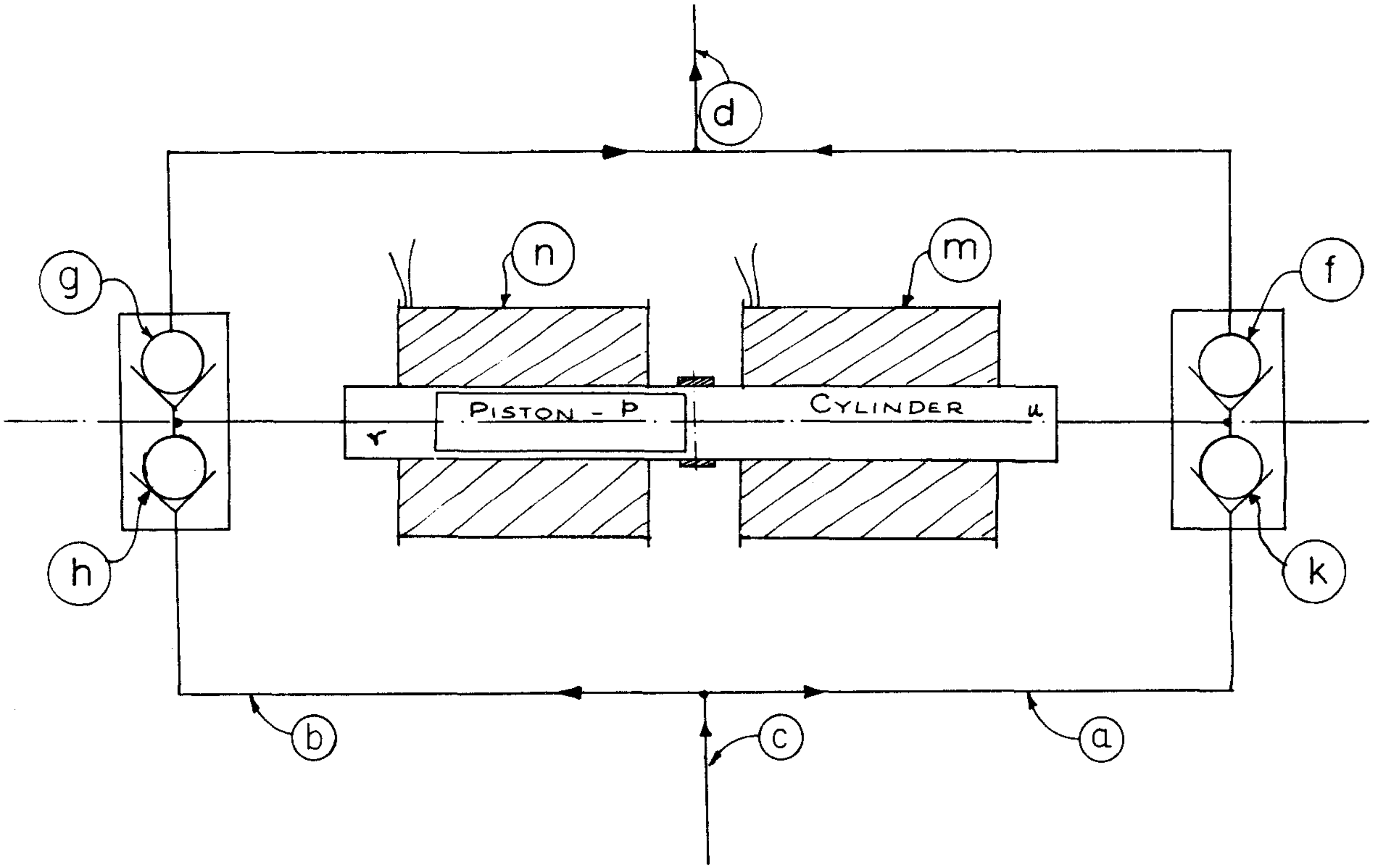


Figure 4. Schematic of Recirculating Pump

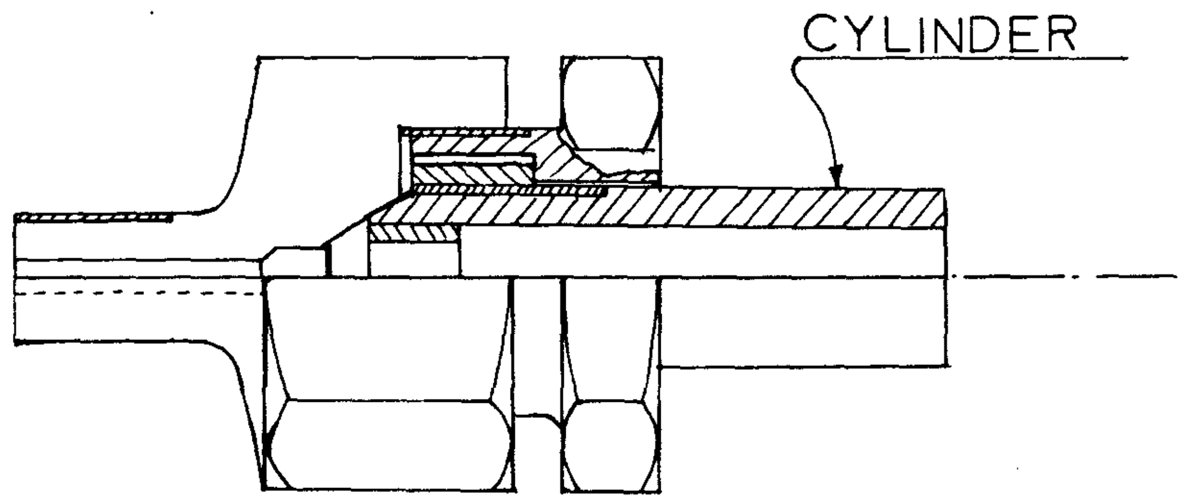


Figure 5. Section of Recirculating Pump Showing Joint for Connecting Check Valve to the Cylinder

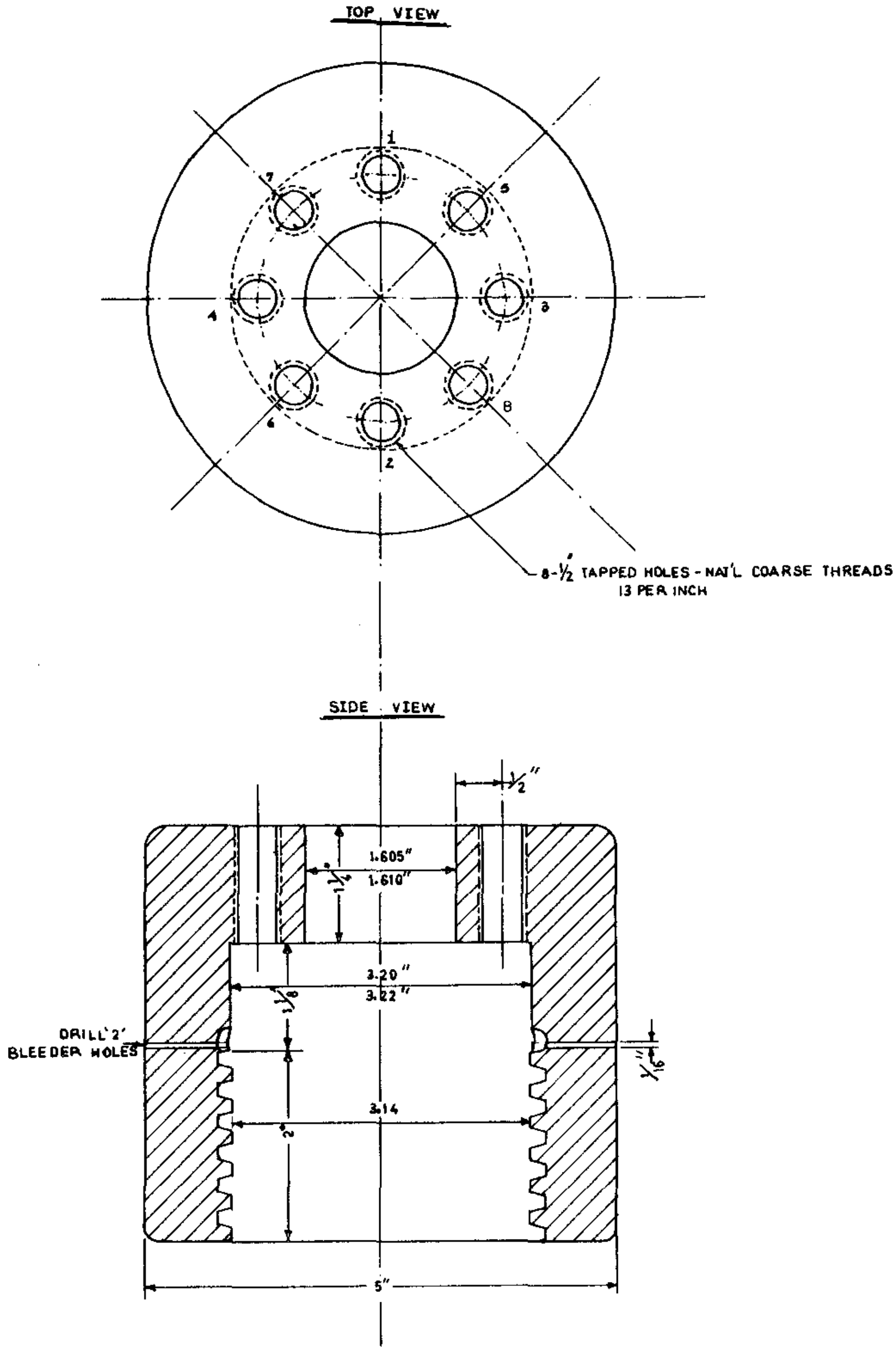


Figure 6. Header Caps for Calorimeter

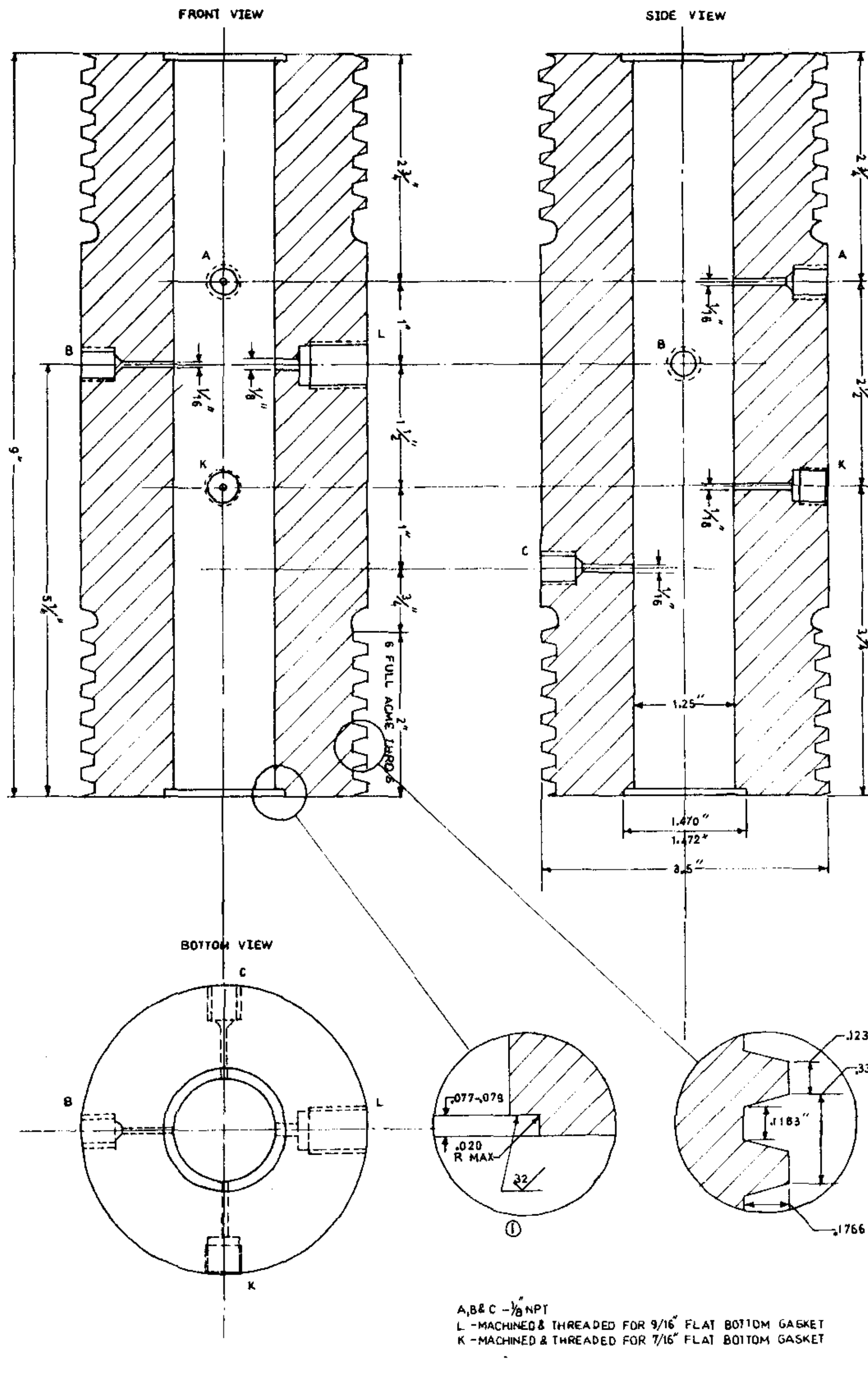


Figure 7. Calorimeter Body

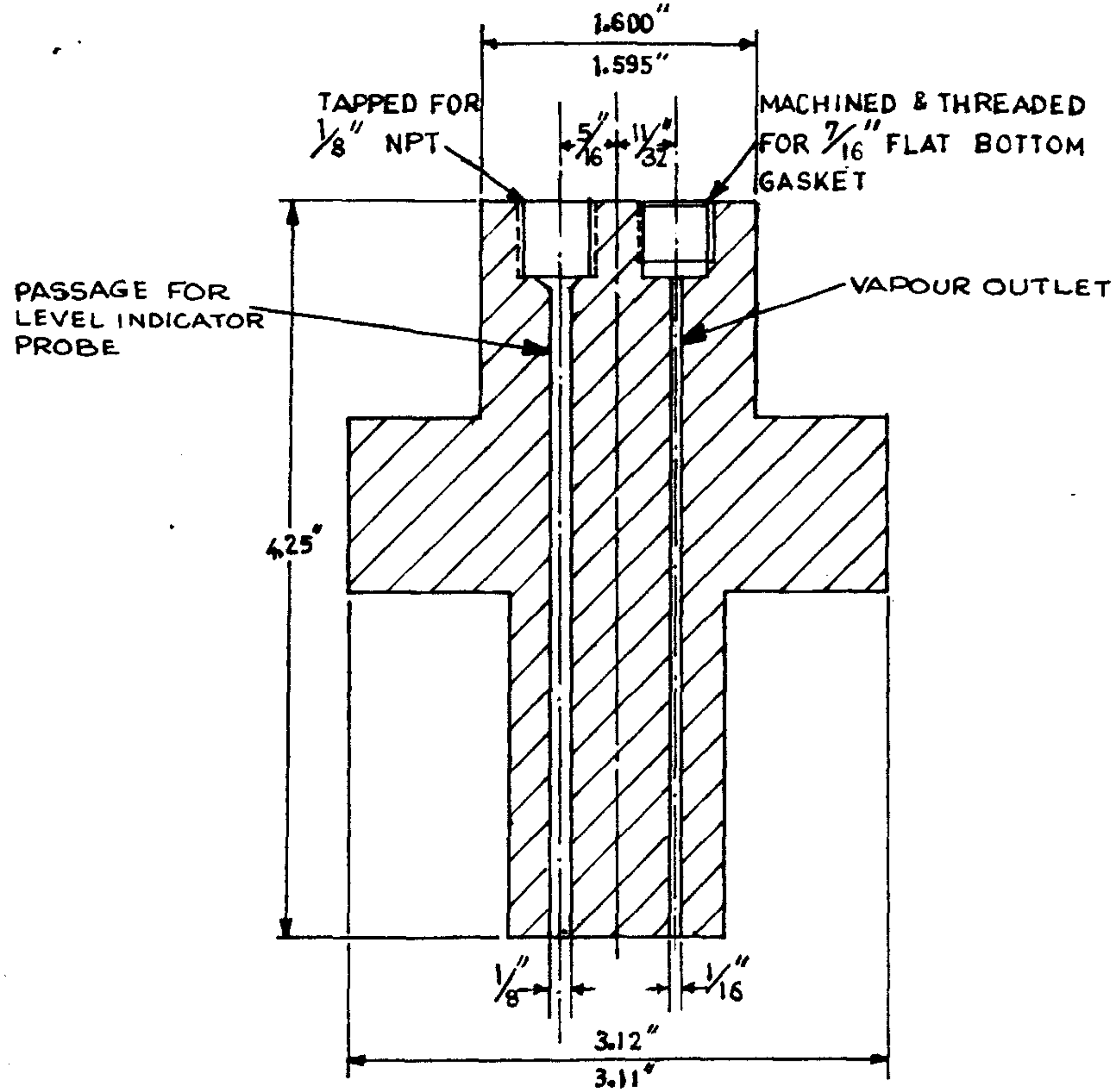


Figure 8. Top Plug

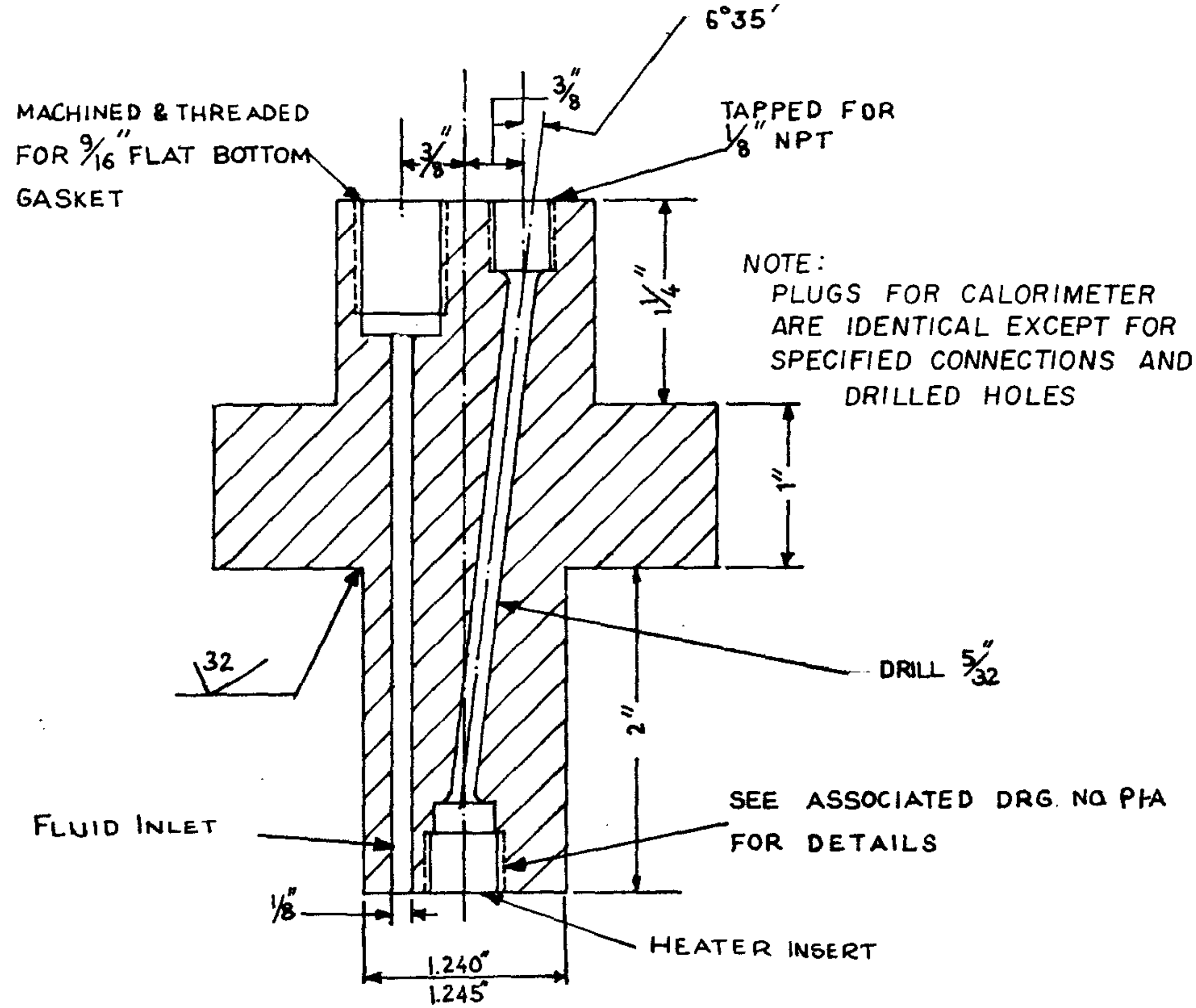


Figure 9. Bottom Plug

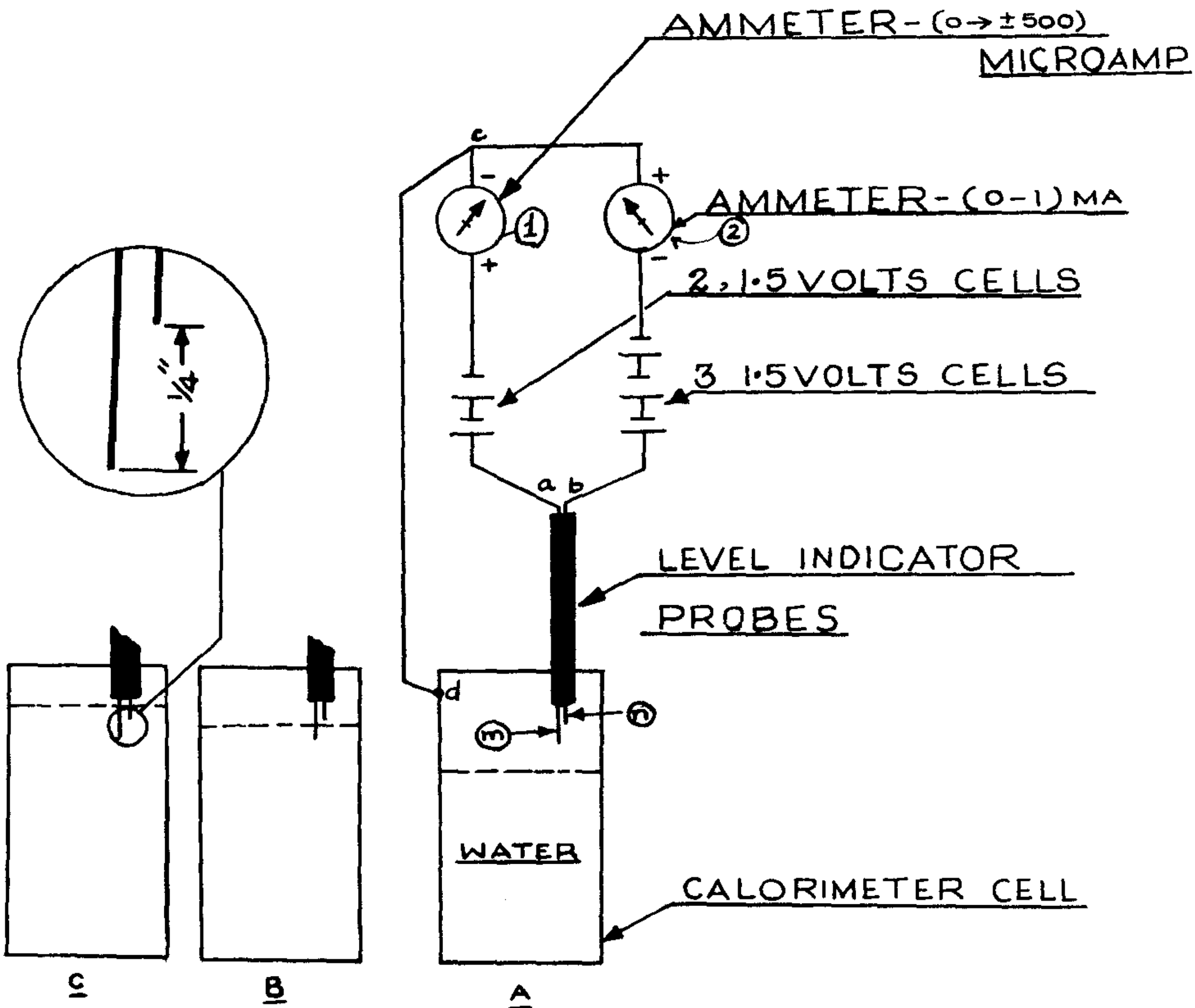


Figure 10. Fluid Level Indicator Circuit

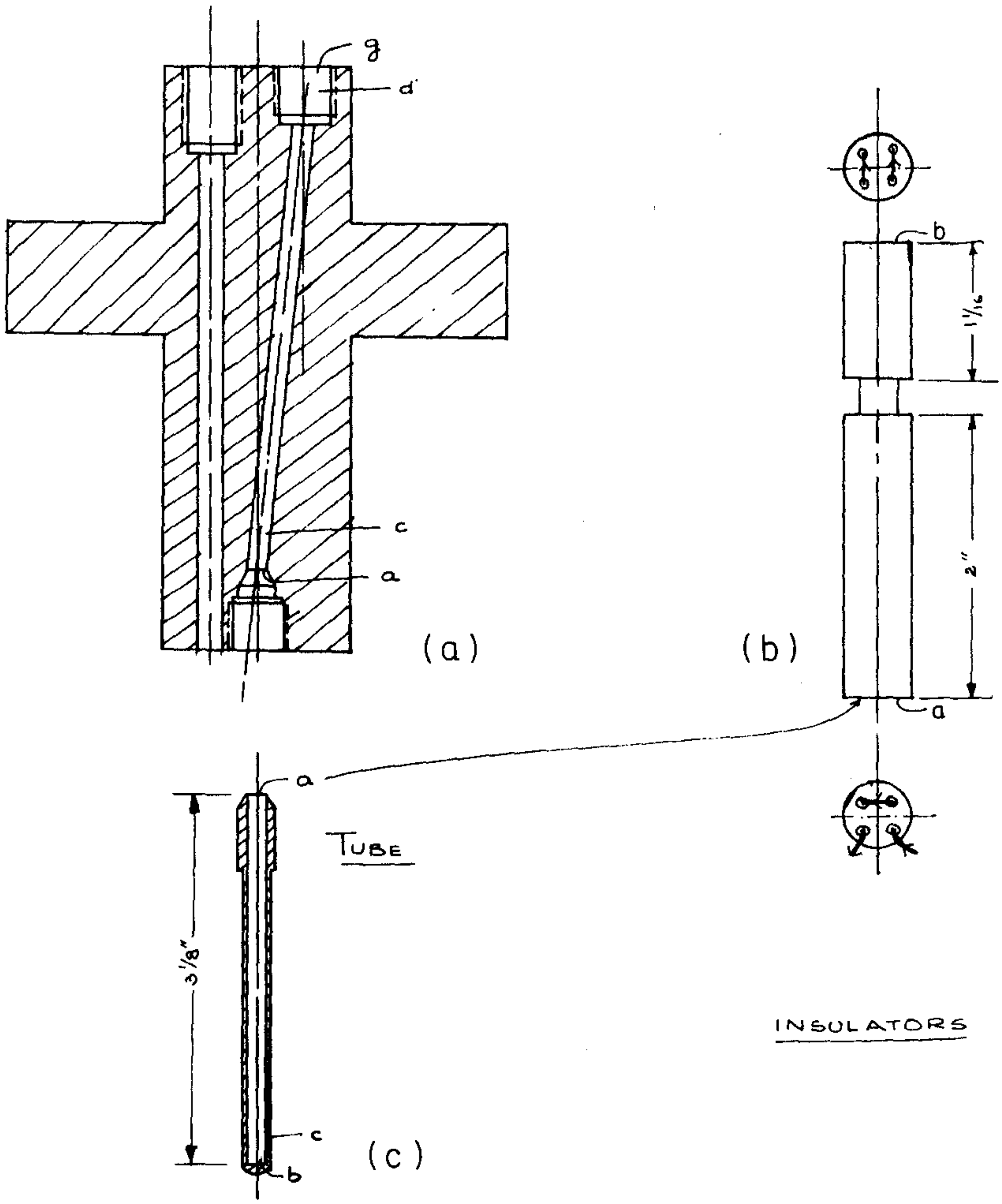
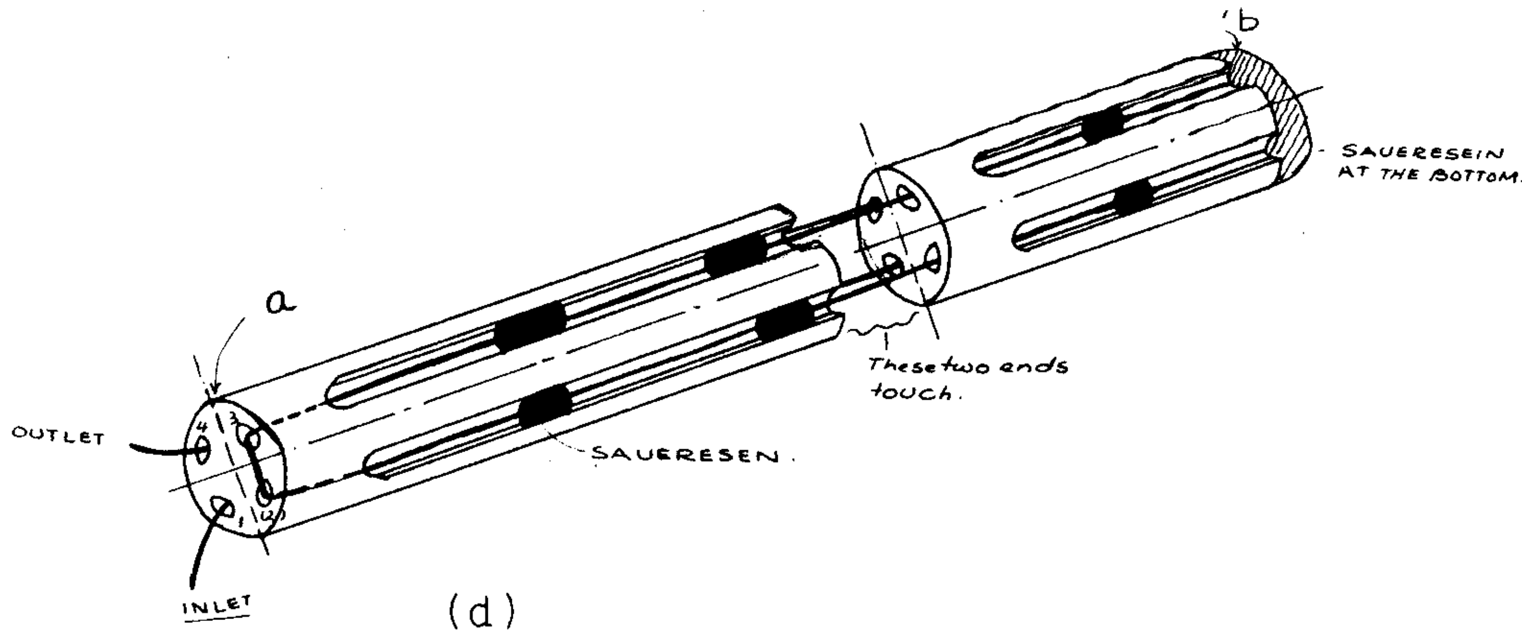
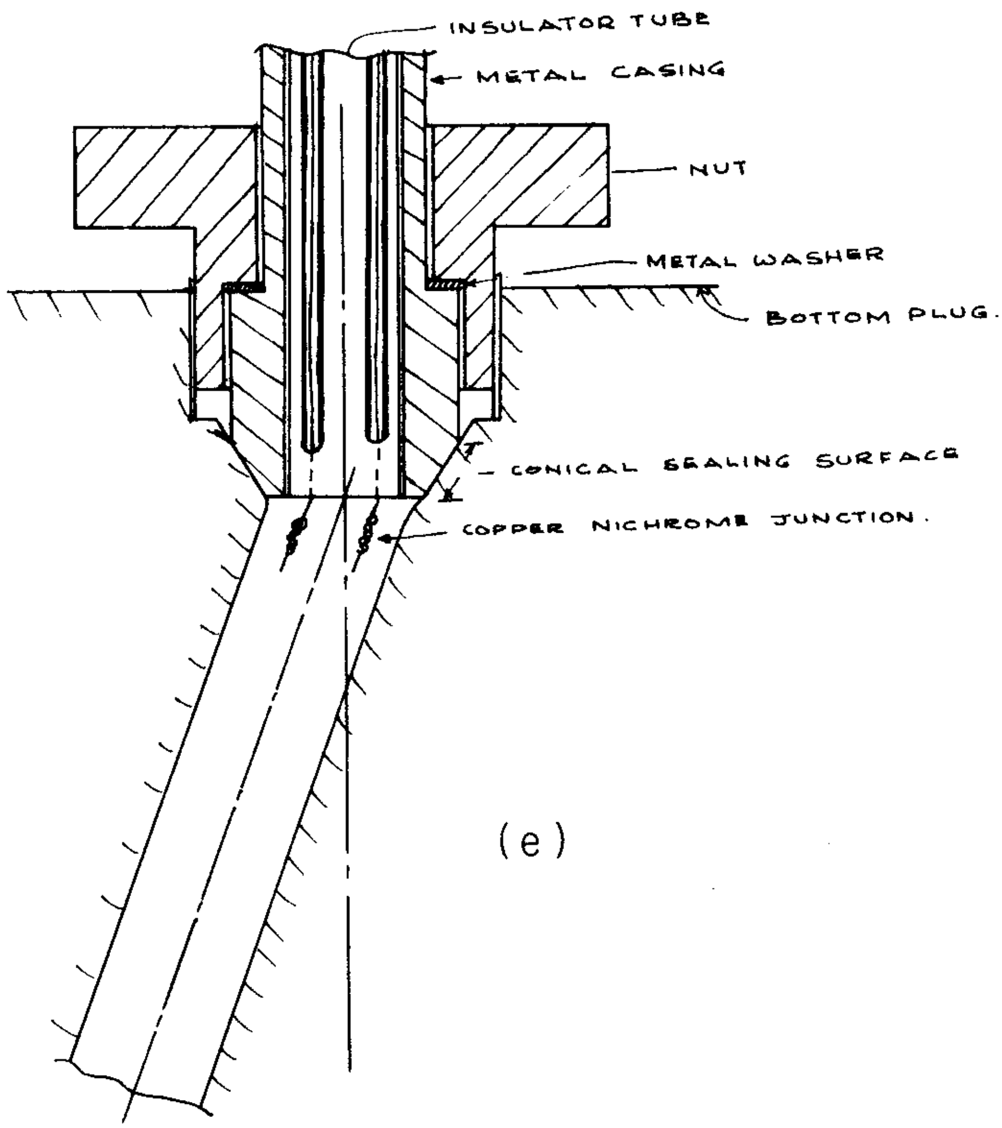


Figure 11. Bottom Plug and Heater



(d)



(e)

Figure 11 (con't.)

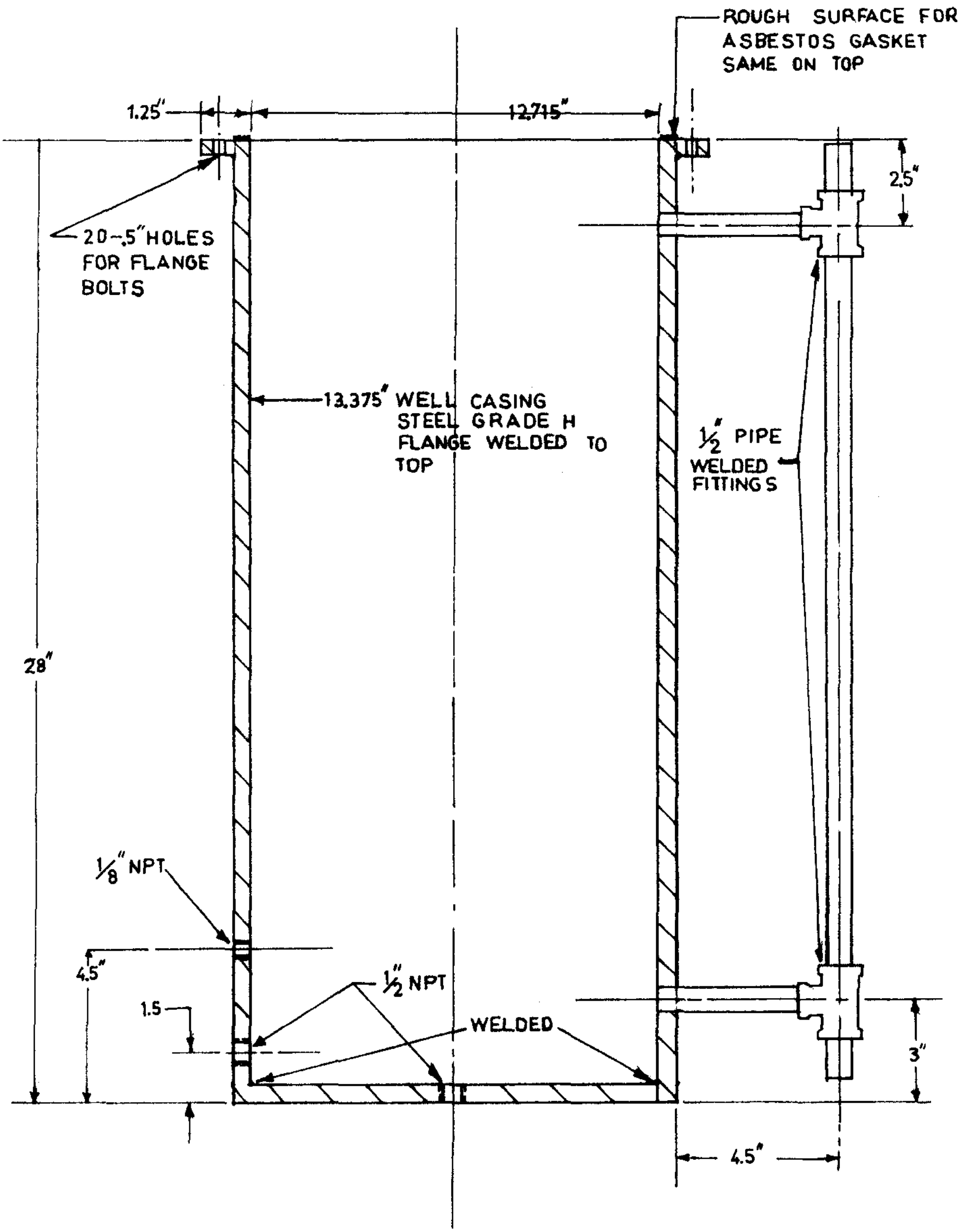


Figure 12. Calorimeter Bath - Designed for 200 PSIG and 750°F

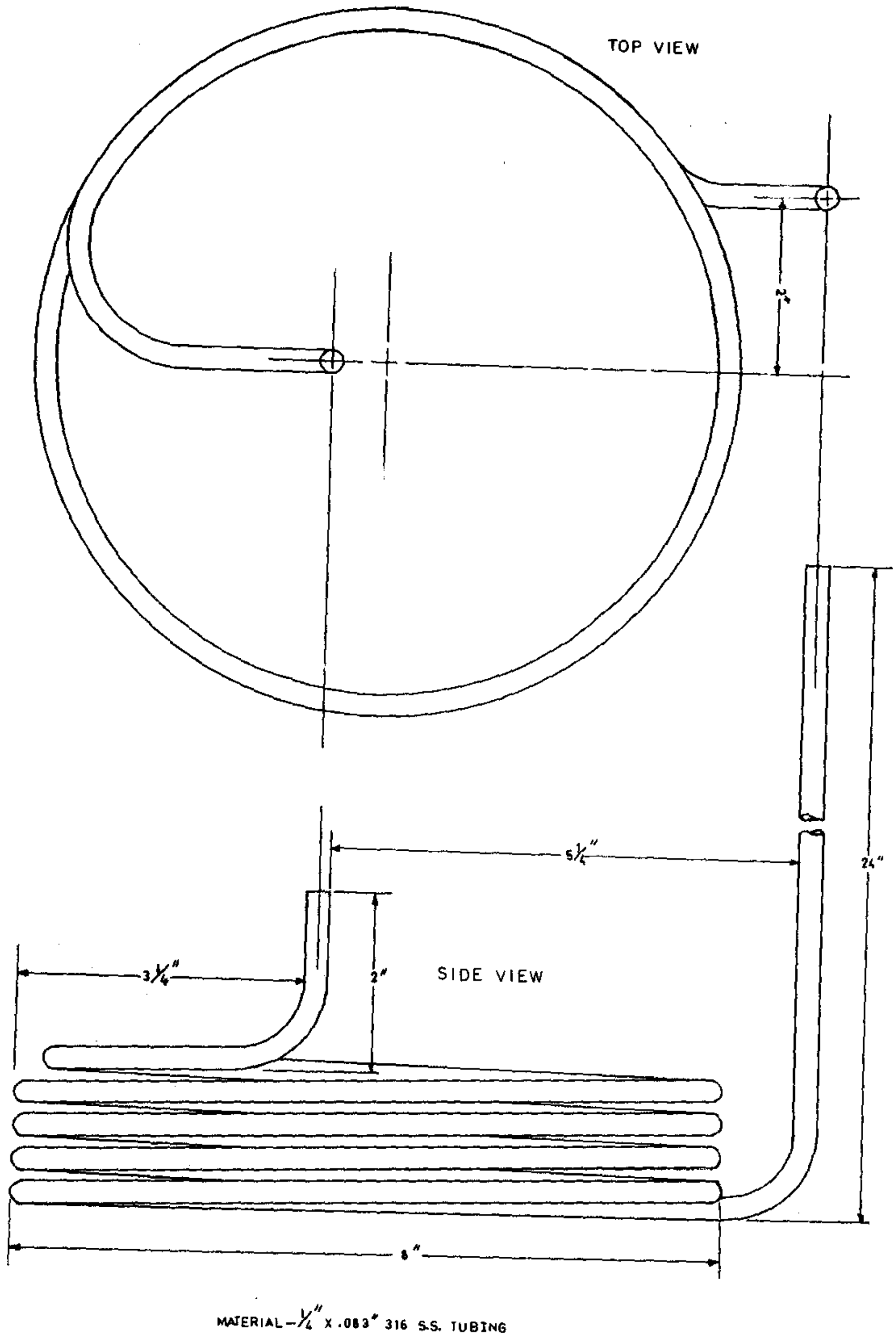


Figure 13. Heater Coil for Calorimeter

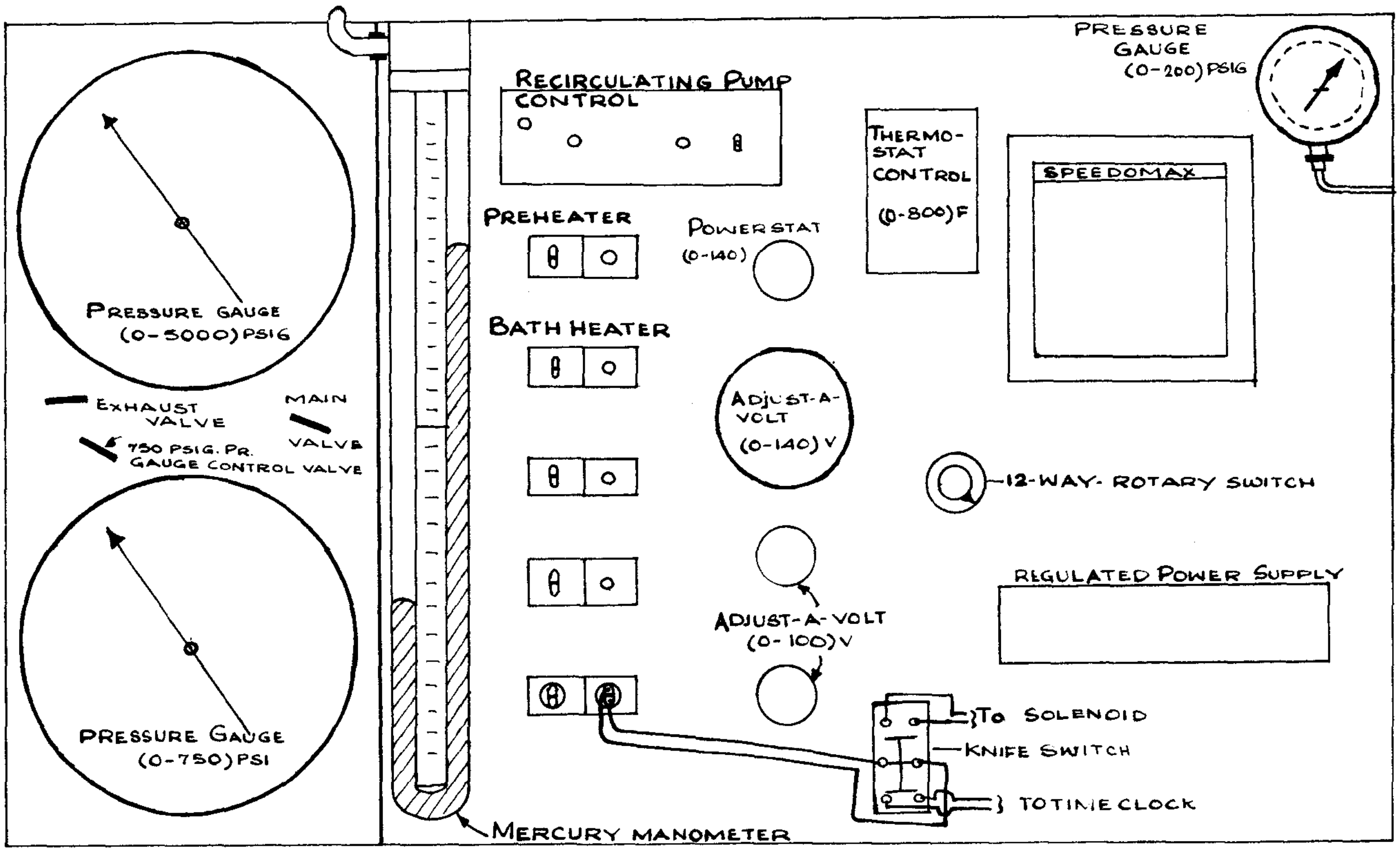


Figure 14. Instrument Panel

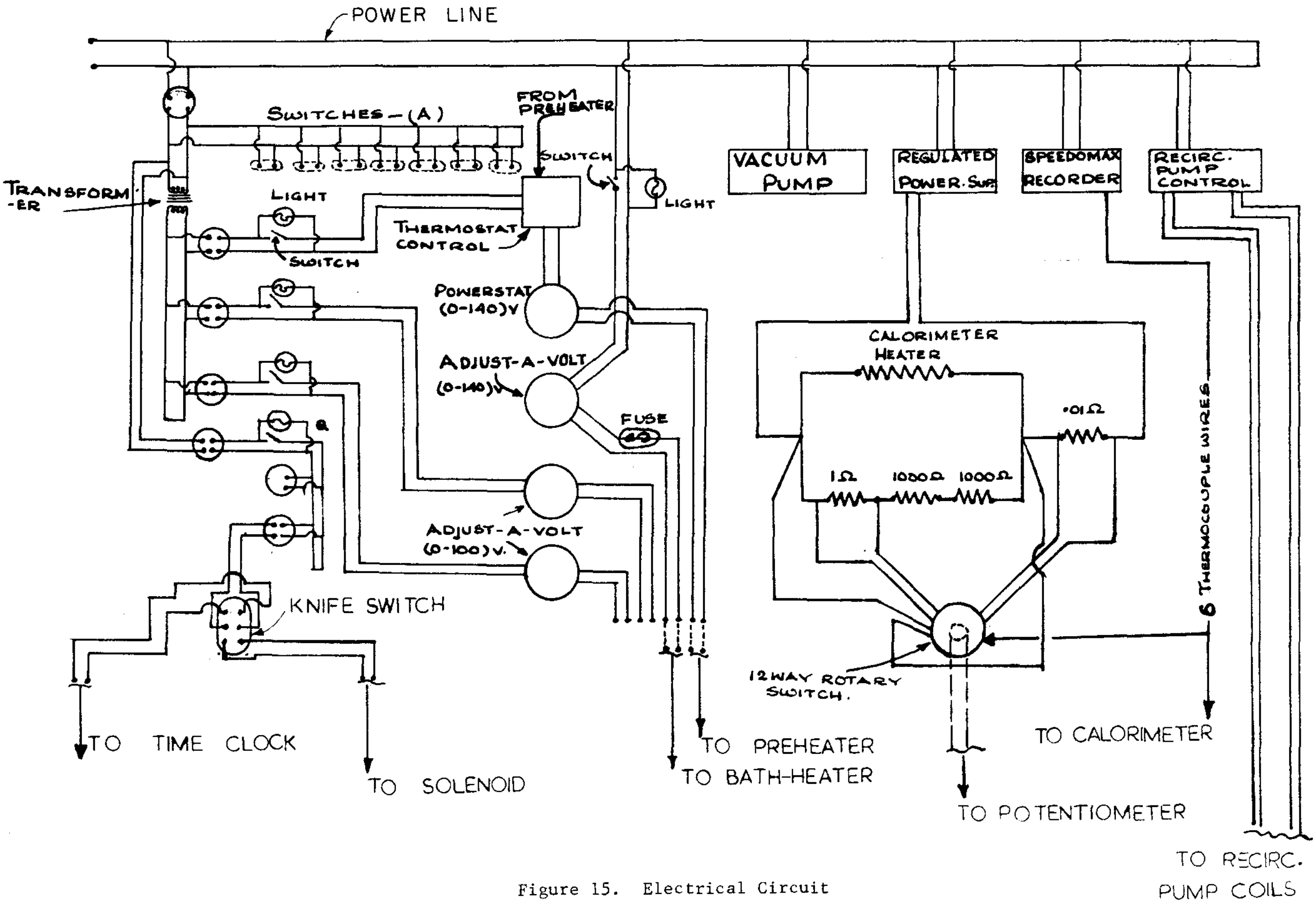


Figure 15. Electrical Circuit

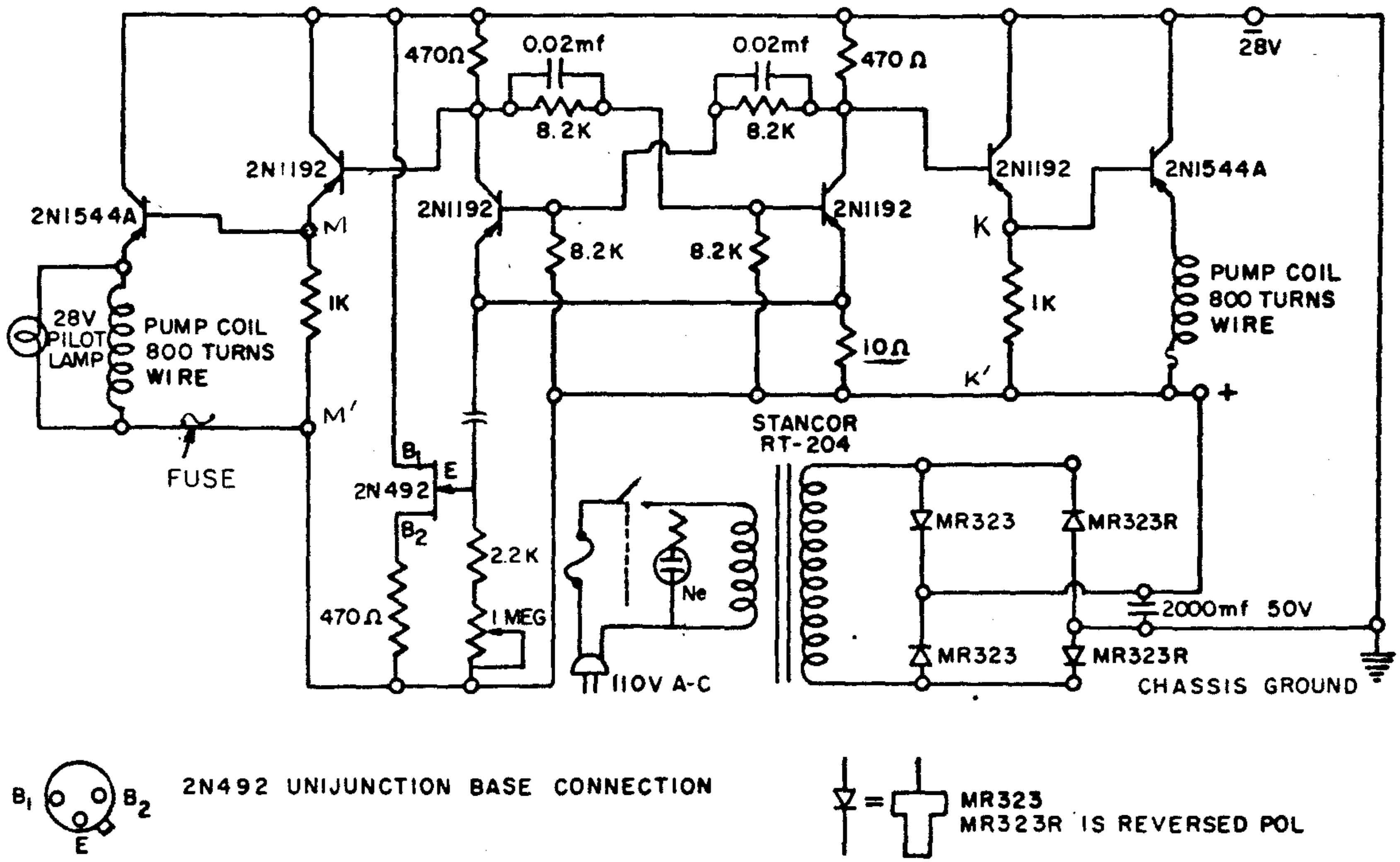


Figure 16. Circuit Diagram for Magnetic Drive Circulating Pump

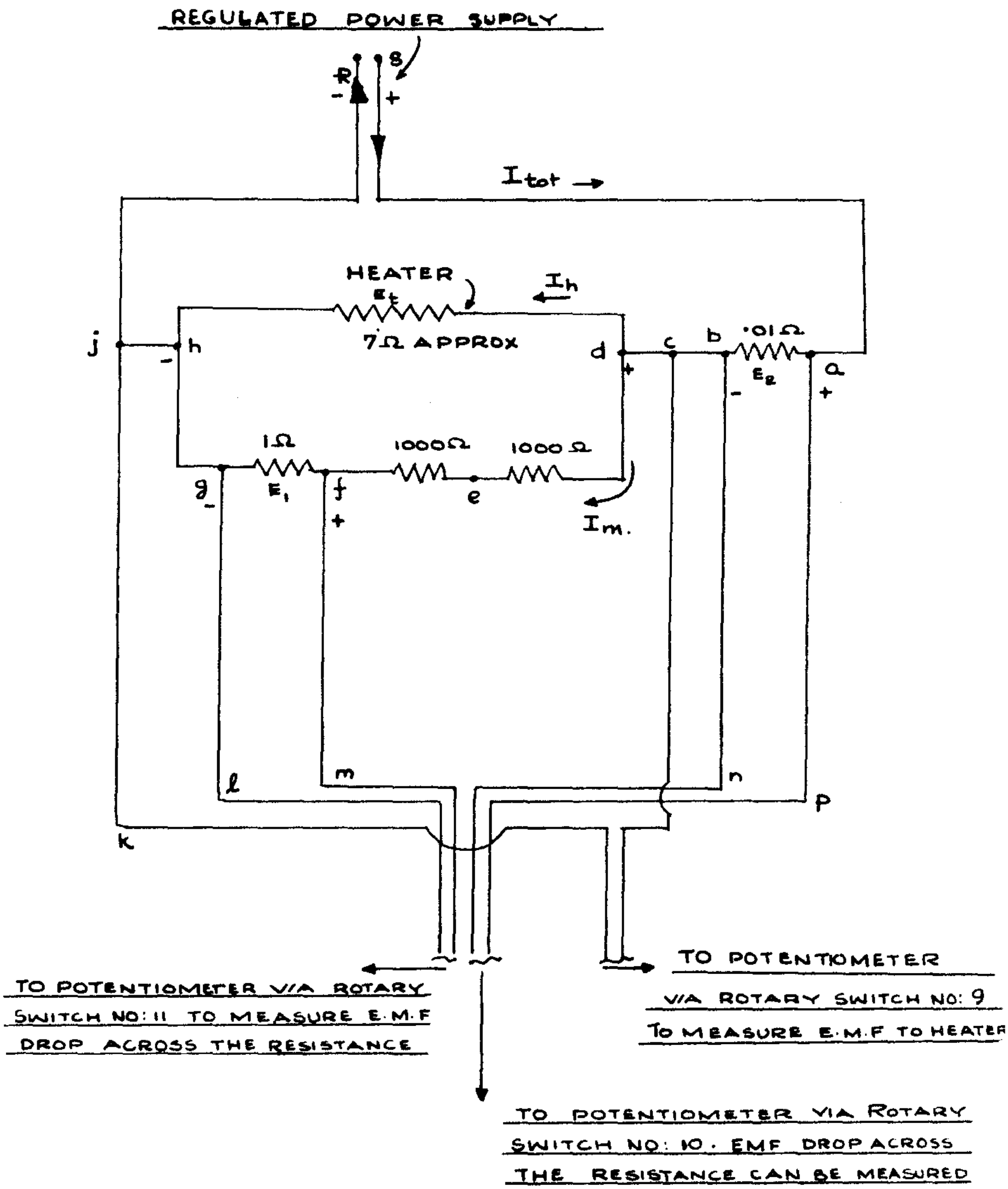


Figure 17. Calorimeter Heater Circuit

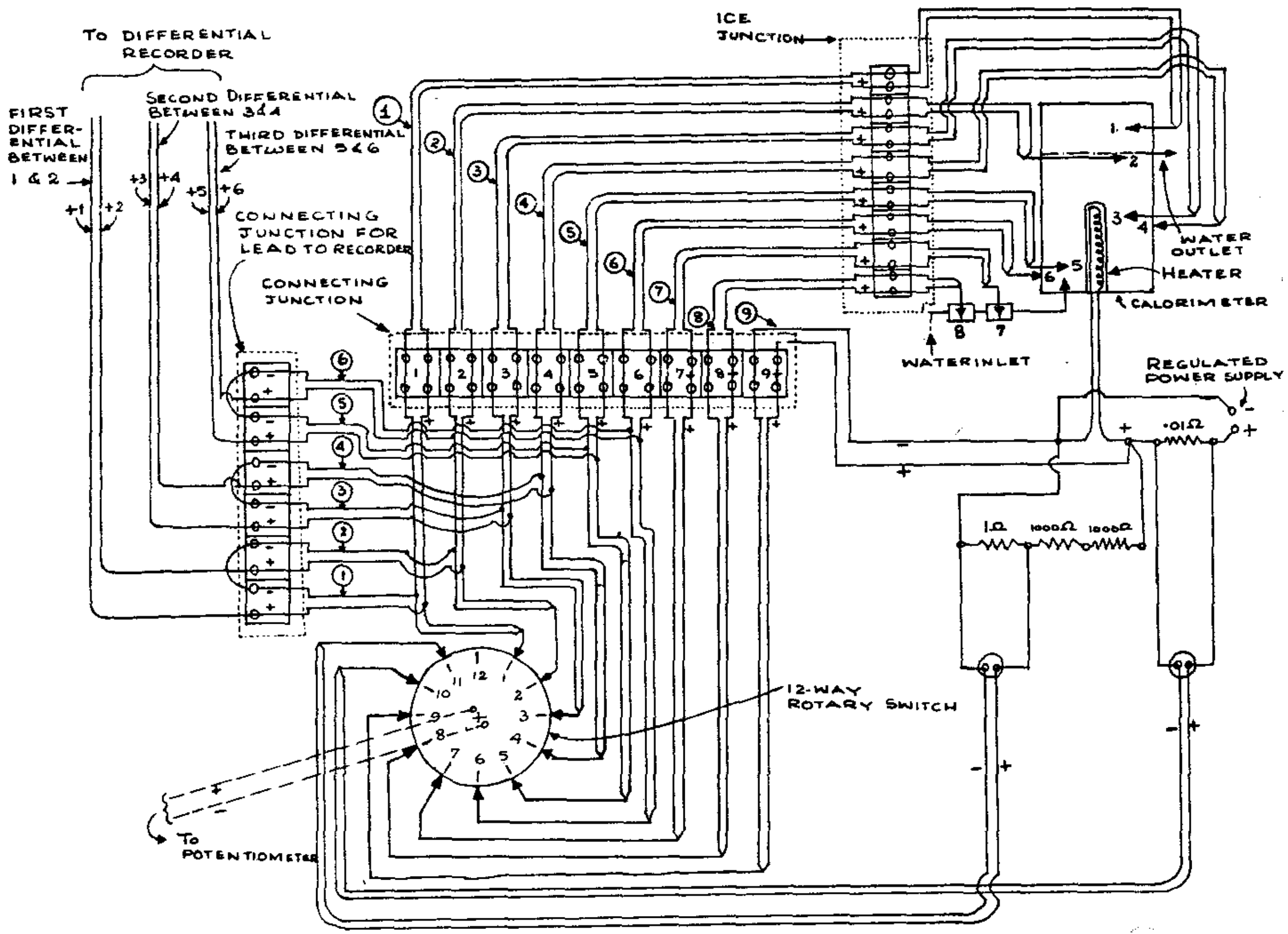
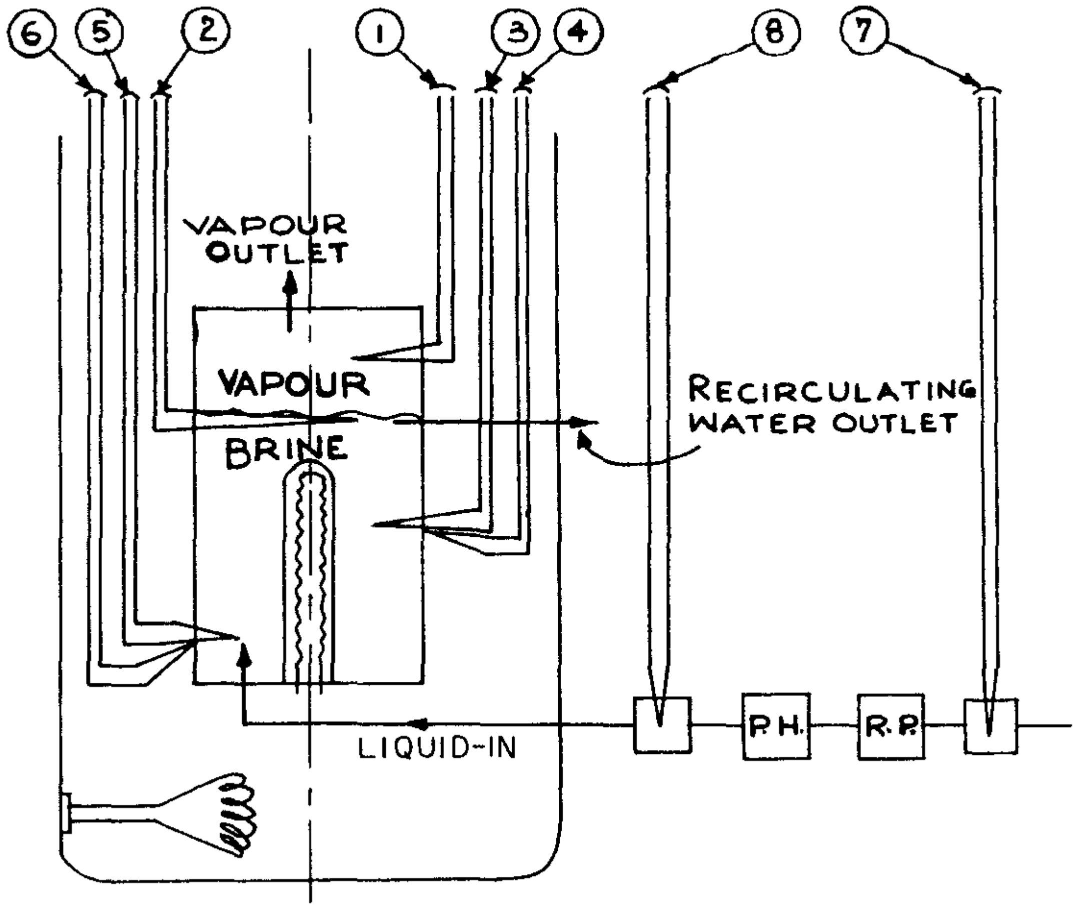


Figure 18. Thermocouple Circuit



SYMBOL	DESCRIPTION OF THE SYMBOL
1	THERMOCOUPLE MEASURING VAPOUR TEMPERATURE
2	THERMOCOUPLE MEASURING WATER OUTLET TEMP.
3	THERMOCOUPLE MEASURING MIDLEVEL WATER TEMP.
4	THERMOCOUPLE MEASURING OUTER WALL TEMP. CORROSPONDING TO T.C. NO. 3.
5	THERMOCOUPLE MEASURING INLET WATER TEMP.
6	THERMOCOUPLE MEASURING OUTER WALL TEMP. CORROSPONDING TO T.C. NO. 5.
7	THERMOCOUPLE MEASURING LIQUID TEMP. IN THE RECIRCULATING PUMP.
8	THERMOCOUPLE MEASURING LIQUID TEMP. AFTER PREHEATER
P.H.	PREHEATER
R.P.	RECIRCULATING PUMP

Figure 19. Thermocouple Placement

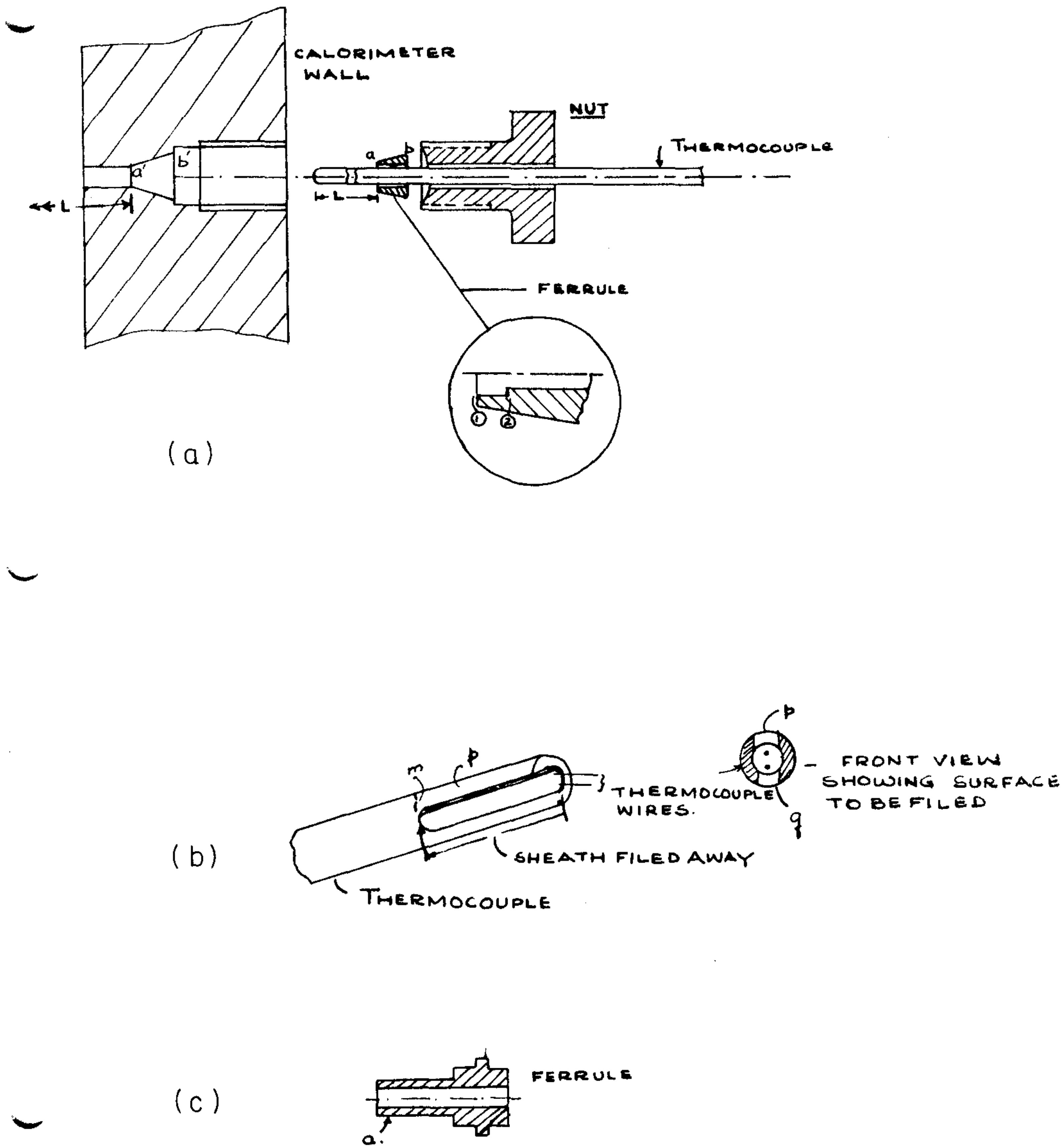


Figure 20. High Pressure Thermocouple Seal

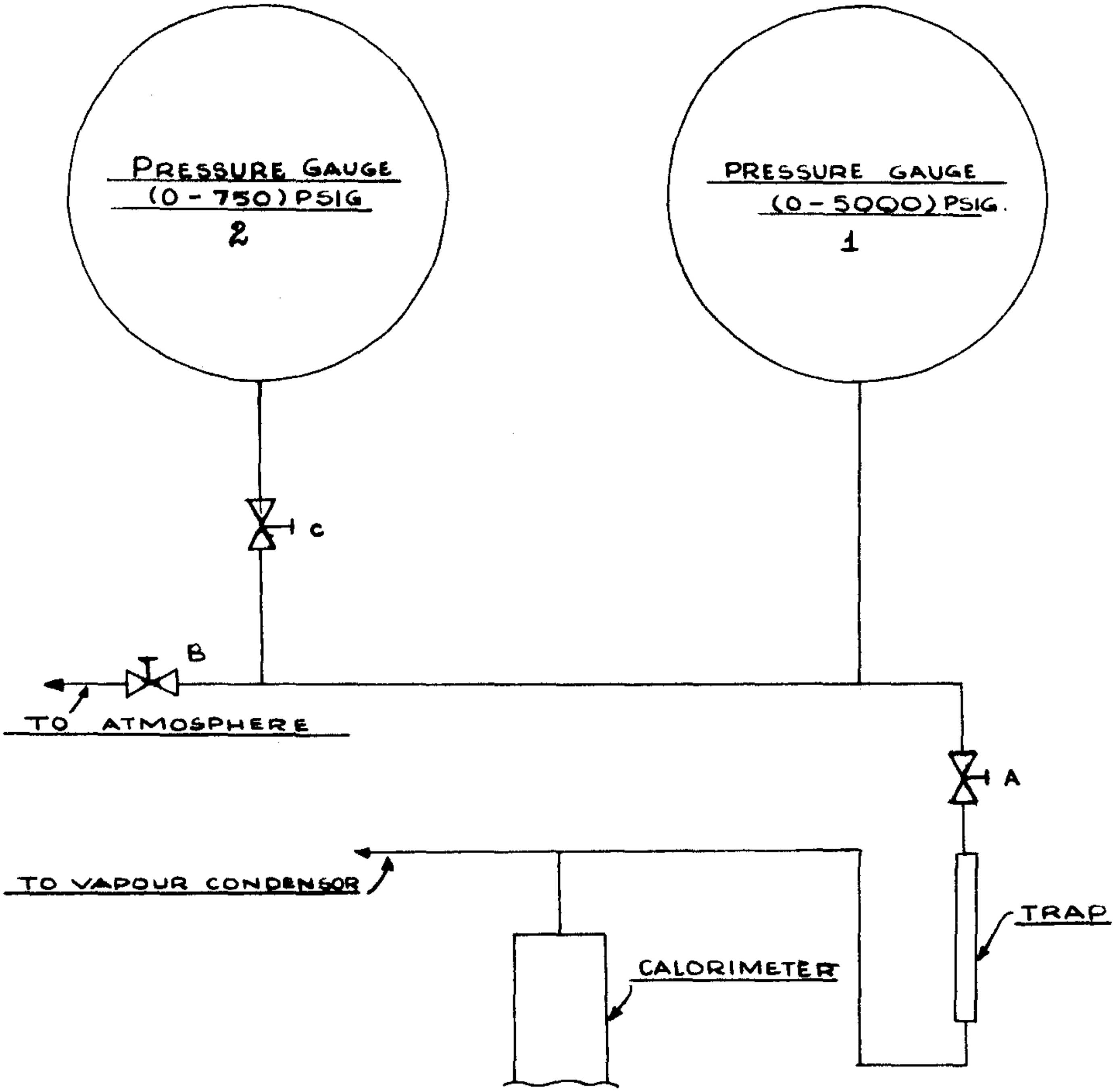


Figure 21. Pressure Recording Circuit

CHART I [(0-750) PSI GAUGE]

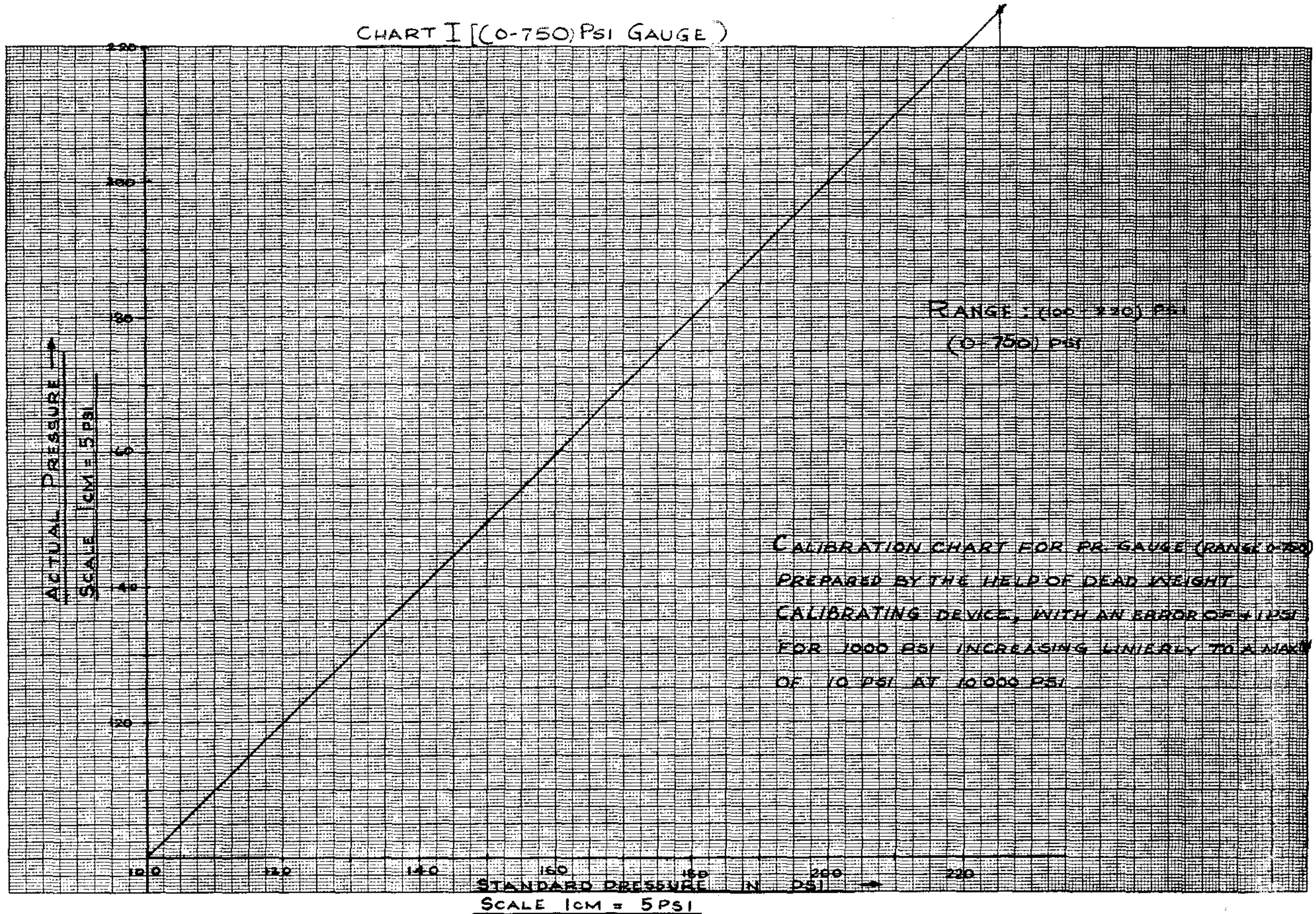


FIG - 22A

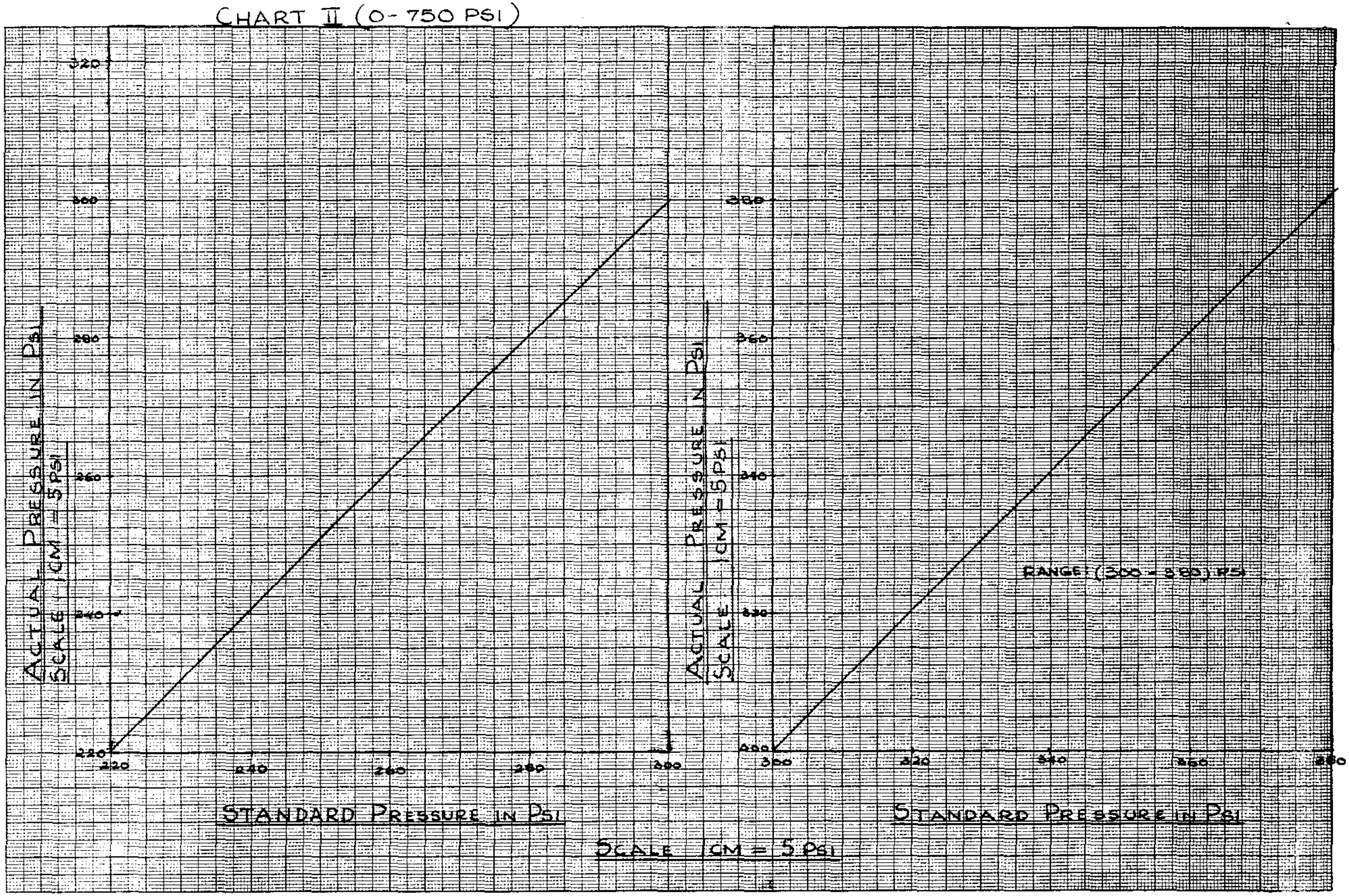


CHART II (0-750 PSI)
ACTUAL PRESSURE IN PSI
SCALE 1CM = 5 PSI
320
300
280
260
240
220
220
240
260
280
300
STANDARD PRESSURE IN PSI
ACTUAL PRESSURE IN PSI
SCALE 1CM = 5 PSI
380
360
340
320
300
300
320
340
360
380
RANGE: (300 - 380) PSI
STANDARD PRESSURE IN PSI
SCALE 1CM = 5 PSI

FIG: 22B

CHART III-(0-750) PSI GAUGE

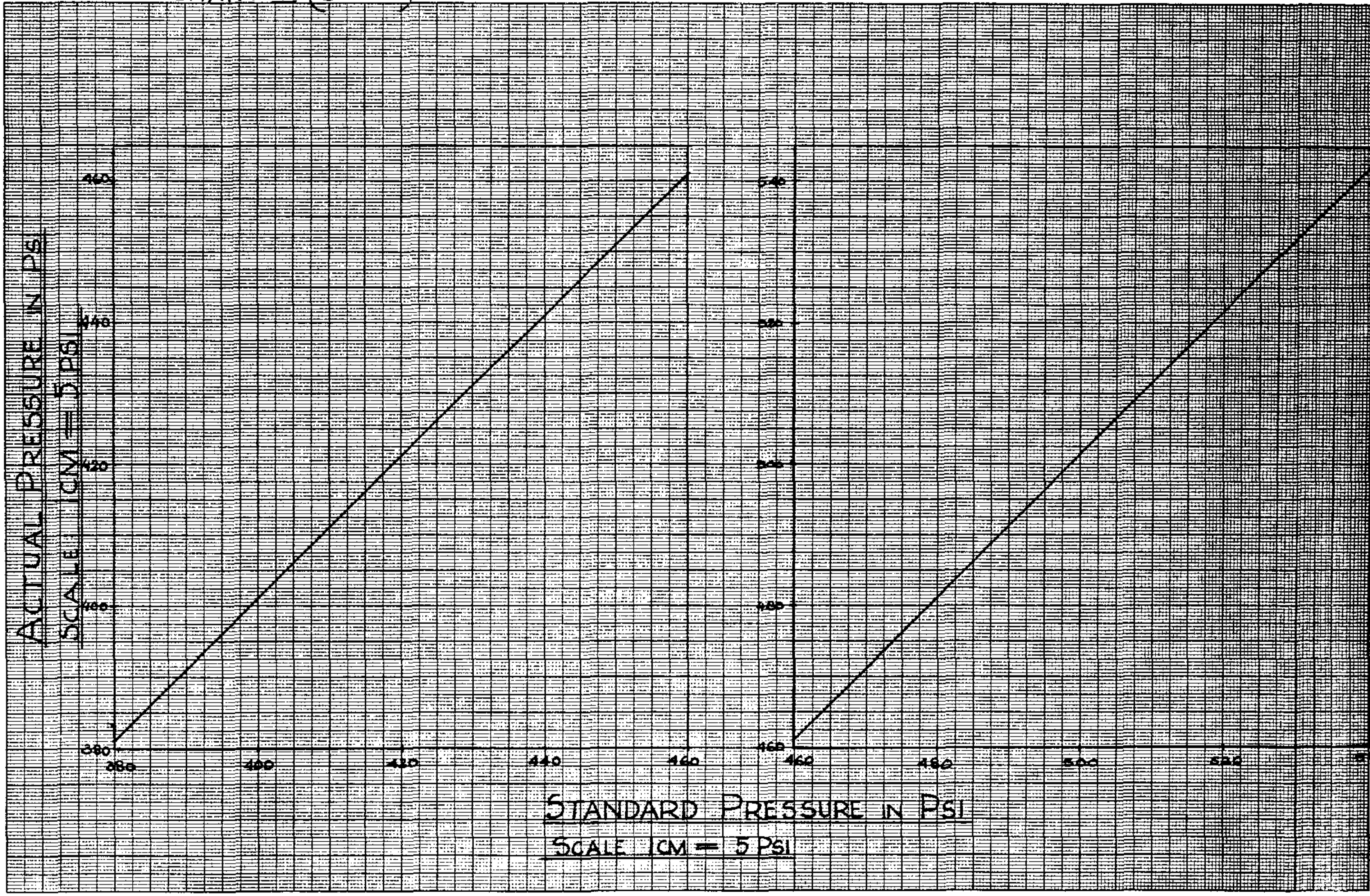


FIG: 22C

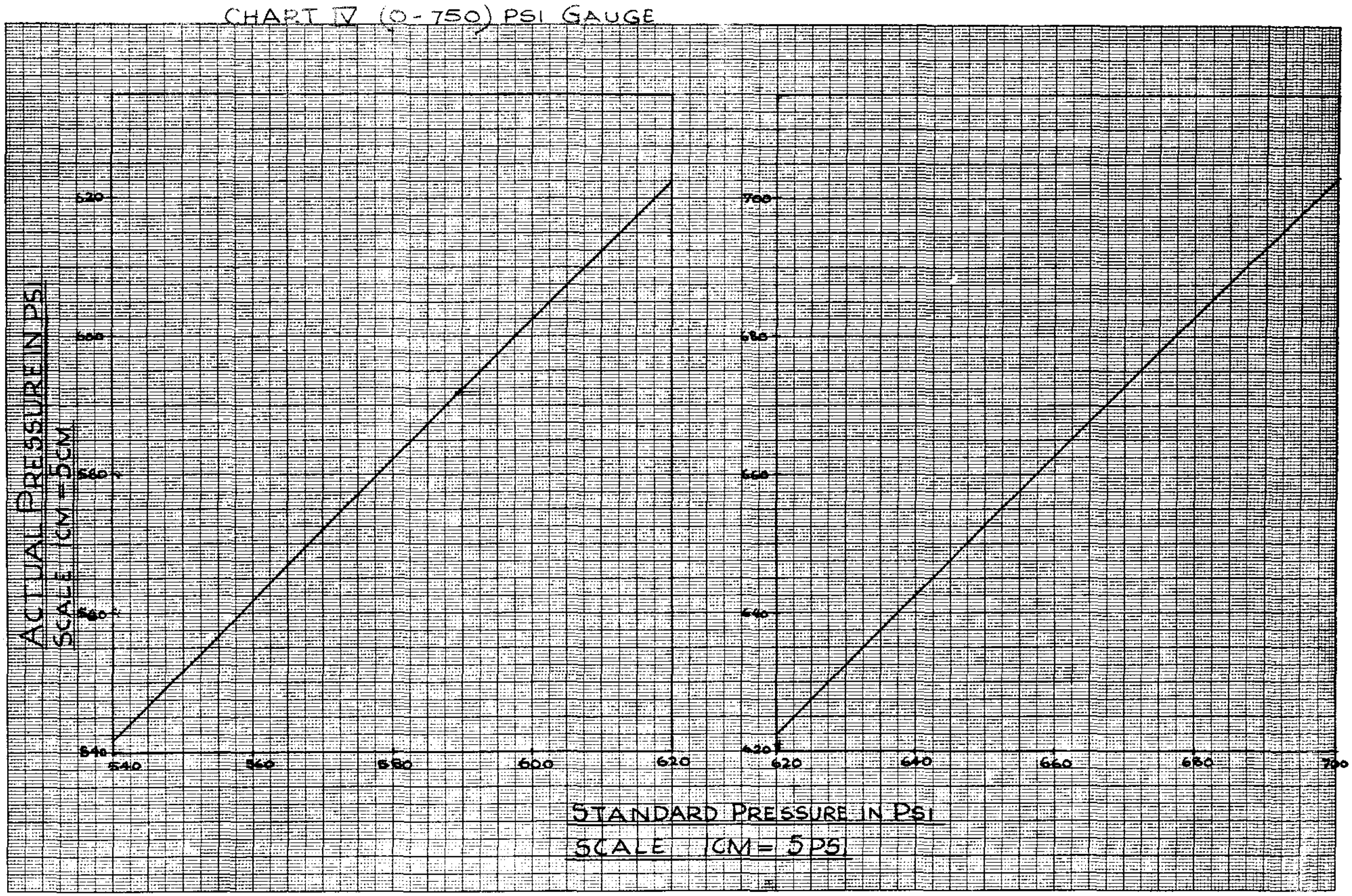


CHART IV (0-750) PSI GAUGE
ACTUAL PRESSURE IN PSI
SCALE 1CM = 5CM
620
600
580
560
540
700
680
660
640
620
540
560
580
600
620
620
640
660
680
700
STANDARD PRESSURE IN PSI
SCALE 1CM = 5PSI

FIG: 22D

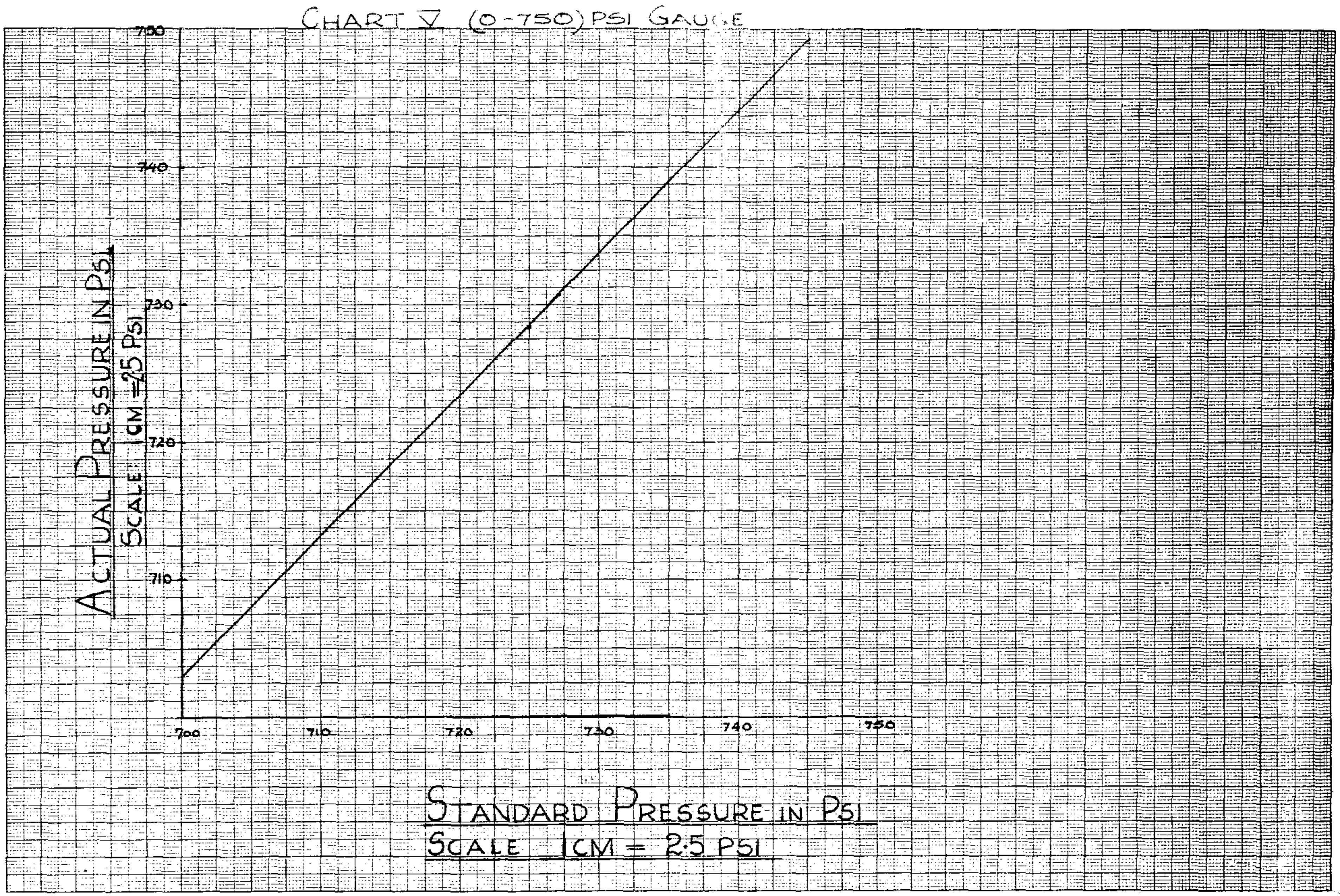


CHART V (0-750) PSI GAUGE
ACTUAL PRESSURE IN PSI
SCALE 1CM = 2.5 PSI
750
740
730
720
710
700
710
720
730
740
750
STANDARD PRESSURE IN PSI
SCALE 1CM = 2.5 PSI

FIG: 22E

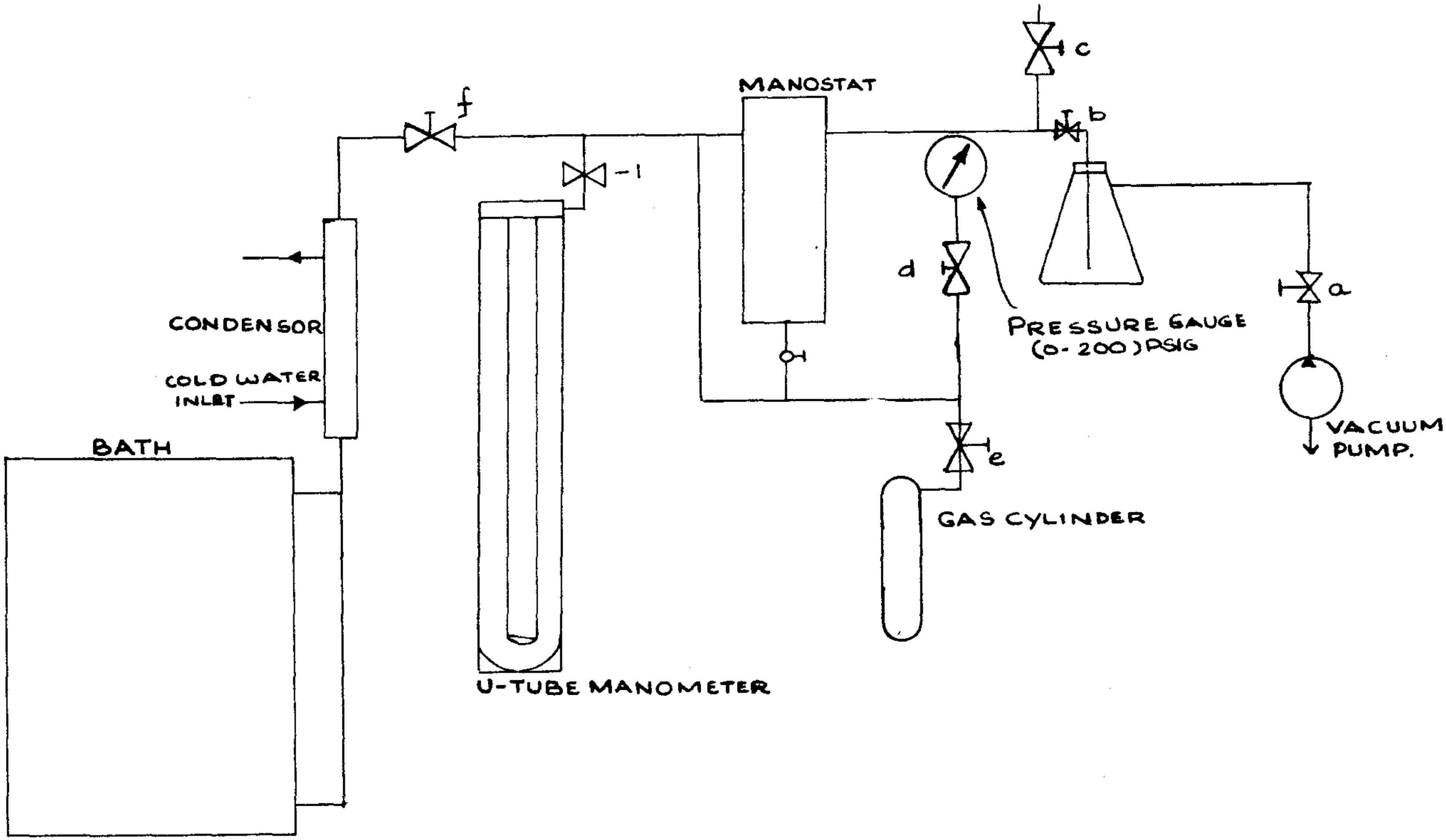


Figure 23. Pressure Controlling Circuit

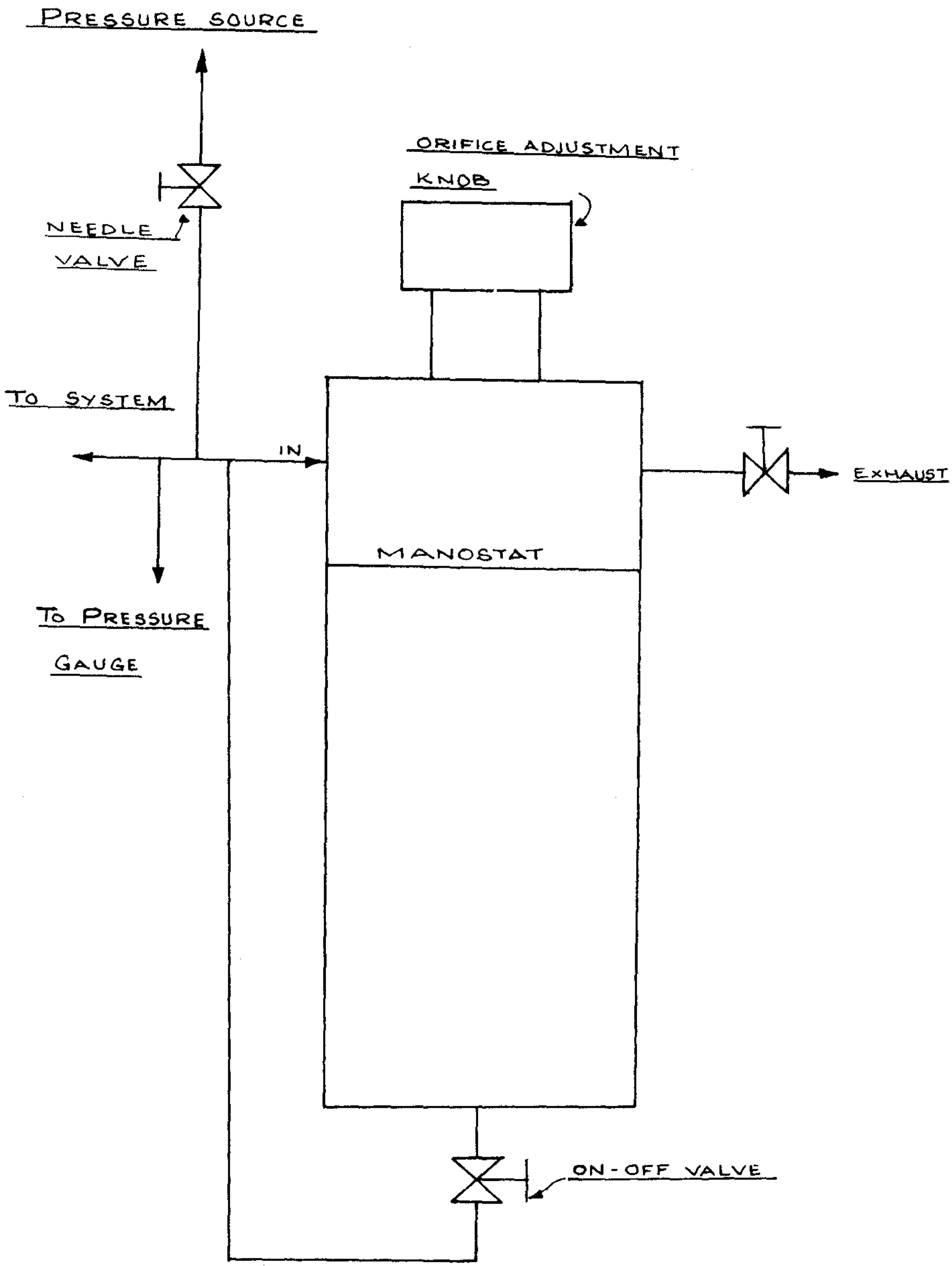


Figure 23.A. Pressure Control Operation

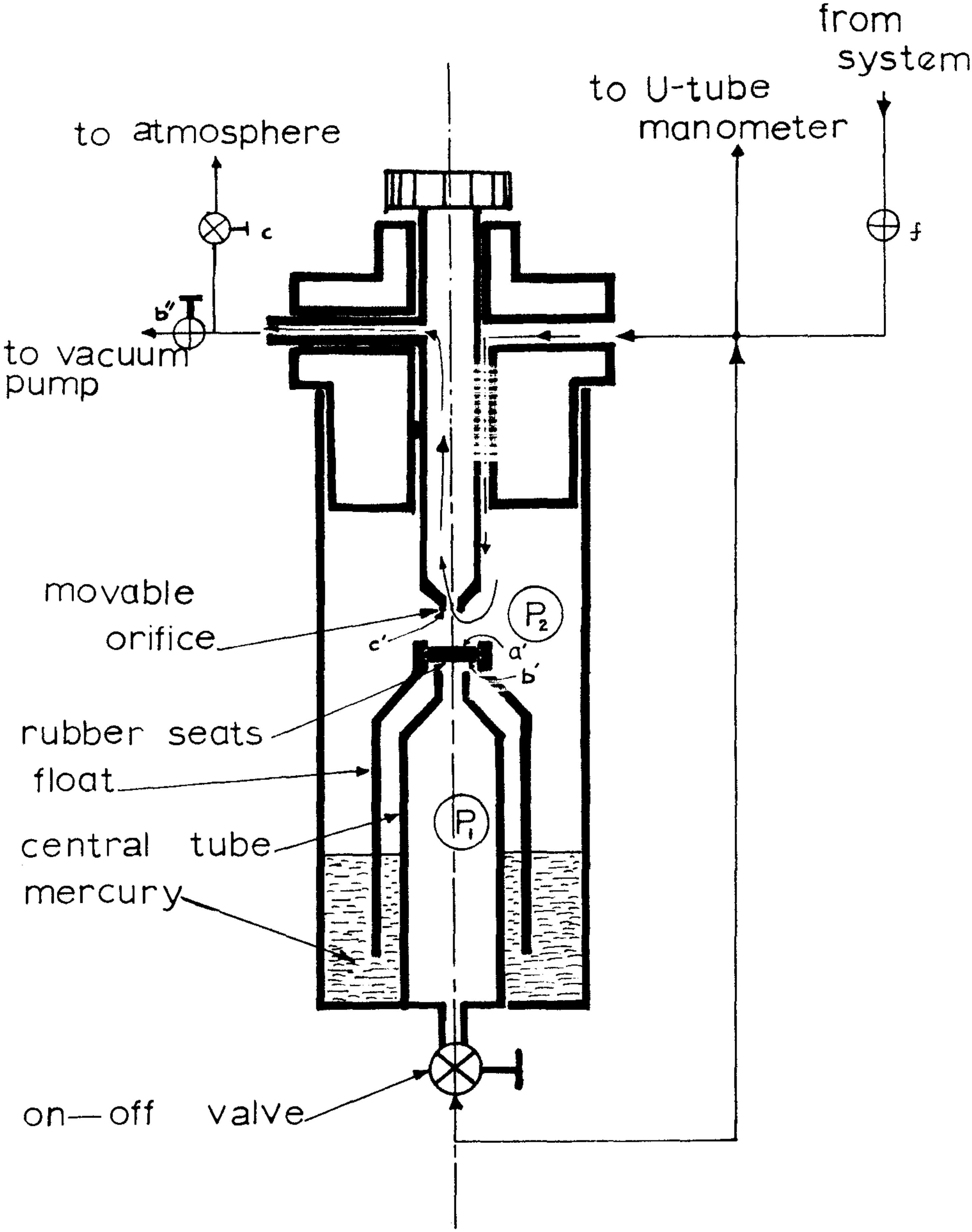


Figure 24. Operational Diagram of Manostat

APPENDIX A

SECTION I

INTRODUCTION