ORNL 1094
Reactors
9a

A MANUAL OF

HRE CONTROL AND INSTRUMENTATION

OAK RIDGE NATIONAL LABORATORY • U.S. ATOMIC ENERGY COMMISSION

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OPERATED BY
CARBIDE AND CARBON CHEMICALS COMPANY
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HRE CONTROL AND INSTRUMENTATION

L. R. Quarles
W. P. Walker

Date Issued

JAN 9 1952

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Introduction

The controls for the Homogeneous Reactor Experiment may be divided into three principal groups:

1. Reactor
2. Process or auxiliary
3. Power generation.

While these necessarily overlap somewhat because of the coupling between the various functions of the experiment, this classification does designate the primary functions of the controls.

Since the project is an experiment designed to furnish data which will aid in designing future large-scale homogeneous power-producing reactors there are numerous instruments and control features which would ordinarily be omitted. For example, the reactivity may be controlled in several ways so the most desirable method may be determined by operating experience.

The operating controls and instruments have been grouped to minimize the number of operating personnel for routine operation. Although it is realized that during experimental runs, several engineers will be needed, a two-man crew should be able to handle the entire plant for regular operation. All remote valve operators, automatic controllers, and operating instruments are located in the control room and are arranged according to frequency of use.

The general layout of the control room is shown in Figure 1. The console has all the manual controls which must be handled by the operator during start-up or at frequent intervals during operation. Control stations

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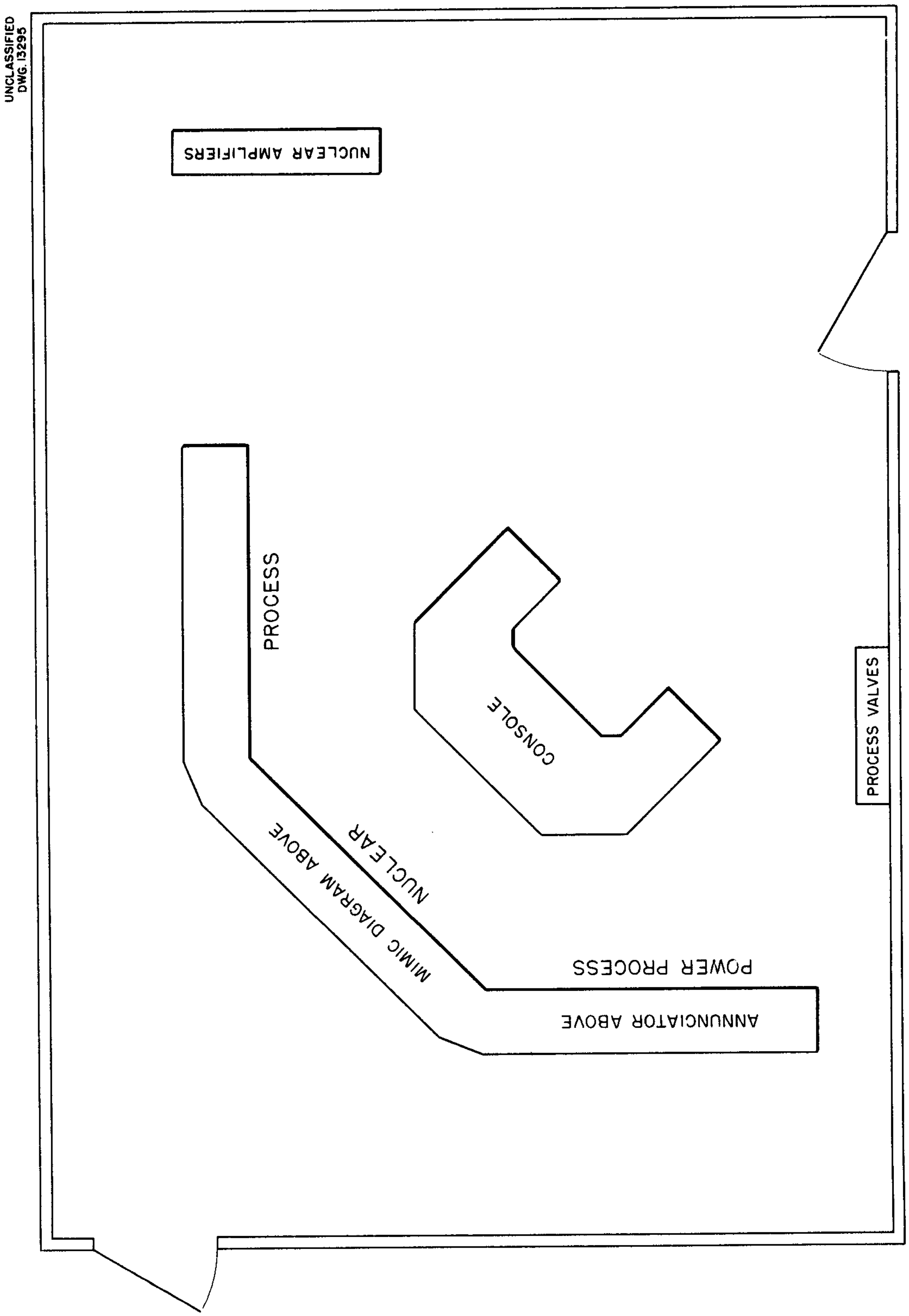

Fig. 1 – Control Room

for pneumatic valves which need to be changed infrequently are grouped on a panel located to one side so that the operator can check controller position and air pressure without leaving his seat. Switches for the various motors and electric heaters which do not require frequent changes are mounted on the left hand panel board. Thus the operator or his assistant may set up the correct valve positions and operation of auxiliaries before start-up and then the operator can bring the reactor to power, synchronize the generator on the line and continue operation from the control console.

The panel board instruments are grouped roughly according to general classification and according to their importance in operation. Thus the instruments indicating reactivity (CRM, log N, rod position, reflector level, etc.) are on the center panel directly in front of the operator. The instruments associated with power generation are on the panel at the operator's left and the process instruments on the one to his right. The detailed panel layout is shown in Figure 2. The console, shown in Figure 3, has the controls grouped in a similar manner. Principal reactor controls are at the operator's right, with less critical process controls at the extreme right, while the steam and electrical power controls are on the left.

In addition to the supervision provided by the instruments, the various alarms are registered on a two-light annunciator panel and the position of all remote-operation valves is shown on a mimic panel. The alarms give an audible signal, which may be stopped by the operator, and give two visual signals on the annunciator panel. The first of the visual signals will clear automatically when the fault clears, but the second one will continue until reset by the operator, thereby enabling him to spot and record even a momentary fualt. A

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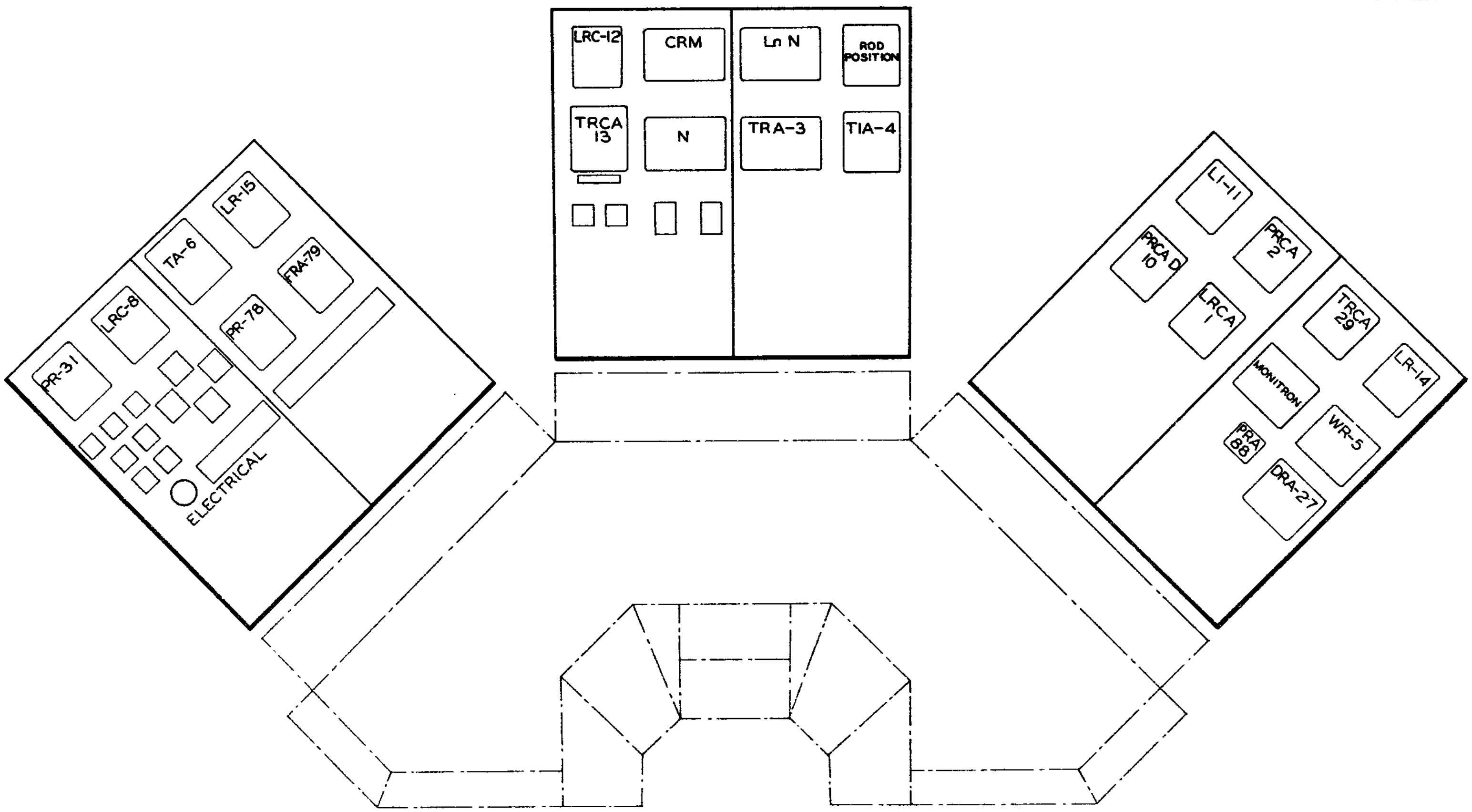

Fig. 2– Instrument Panels

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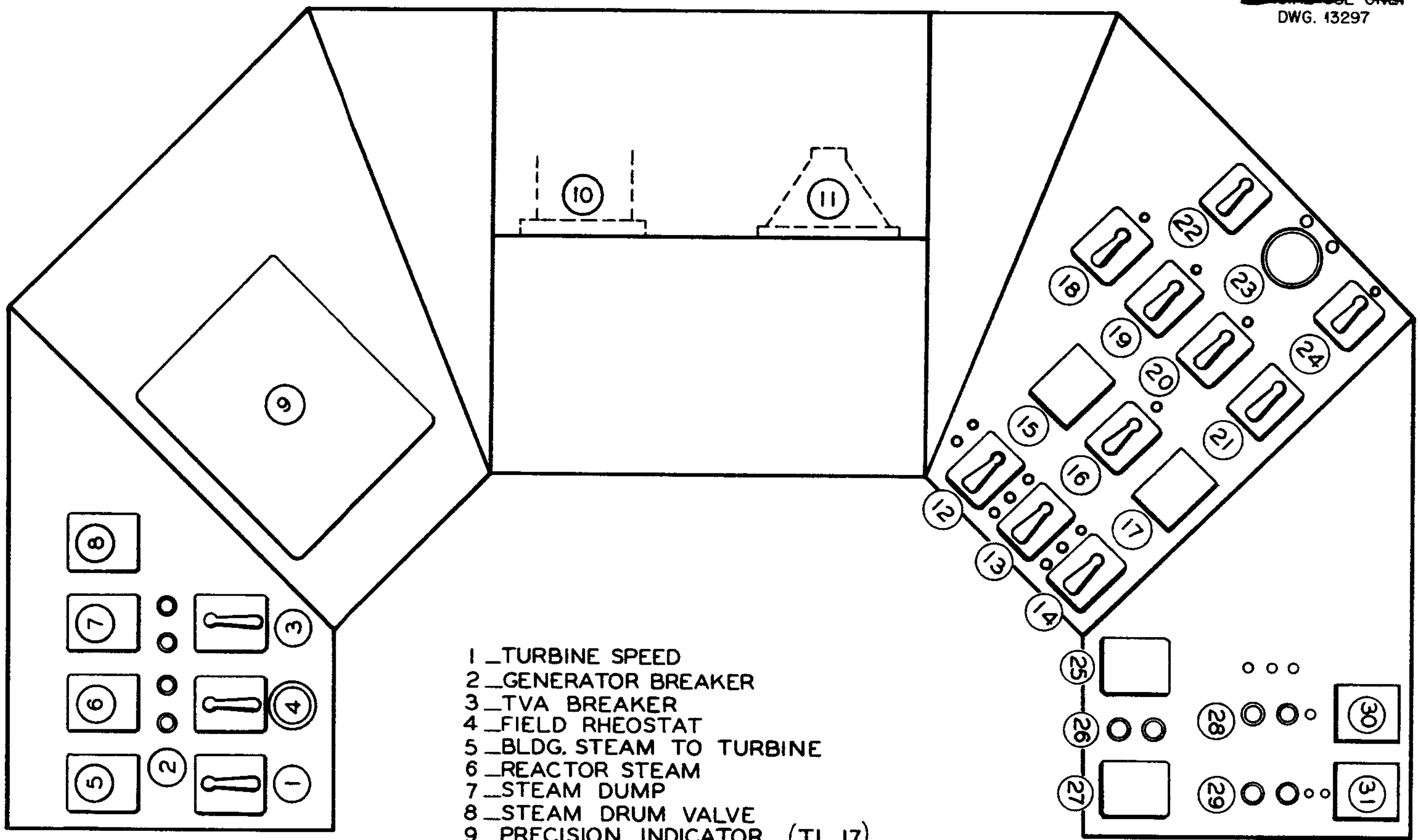

1 _TURBINE SPEED
2 _GENERATOR BREAKER
3 _TVA BREAKER
4 _FIELD RHEOSTAT
5 _BLDG. STEAM TO TURBINE
6 _REACTOR STEAM
7 _STEAM DUMP
8 _STEAM DRUM VALVE
9 _PRECISION INDICATOR (TI 17)
10 _PERIOD METER
11 _MONITORING SPEAKER & SELECTOR SWITCH
12 _CONTROL PLATE
13 _SHIM PLATE
14 _SAFETY PLATE
15 _DILUTE VALVE
16 _HOLD DUMP
17 _CONCENTRATE VALVE
18 _SOUP DUMP
19 _REFLECTOR DUMP
20 _MAGNET POWER
21 _LOWER ALL PLATES
22 _START-RUN
23 _LOW BOILER PRESSURE BY-PASS
24 _RUN-TEST
25 _NO. 1 PULSAFEEDER
26 _REFLECTOR CIRCULATING PUMP
27 _SOUP CIRCULATING PUMP
28 _NO. 2 PULSAFEEDER
29 _SOUP PULSAFEEDER
30 _PRESSURIZER BLEED VALVE
31 _SOUP PULSAFEEDER VENT

Fig. 3 – Console

mimic panel mounted above the center panel board is a simplified flow diagram showing principal piping and valves. The position of each valve is indicated on this diagram by colored lights, thus enabling the operator to check the system valving at a glance.

The flow sheet shown in Figure 4 shows all instrumentation except the reactor nuclear instruments and the building monitors. The nuclear instrumentation consisting of standard components is shown in the block diagram of Figure 5. The controls will be discussed in a general manner before considering the detailed operation of each instrument or control.

Basically, the HRE consists of three major system components - soup or fuel, reflector, and power generation. These may be considered by reference to Figure 4. The soup in the critical volume and heat extraction loop is maintained at a high pressure (design value of 1000 psi) by a steam pressurizer located in the upper part of the reactor assembly. The remainder of the soup system consists of the dump tanks, concentrating components, and gas handling components. The reflector and its heat extracting loop are operated at a pressure slightly above that of the soup. The dump tanks and off-gas equipment complete the reflector part. The power generation equipment is fairly standard from the heat exchanger on. The valving is somewhat complicated by the need for introducing steam from the building boiler for start-up heating and experimental work.

The nuclear instrumentation shown in Figure 5 is an adaptation of the "MTR" instruments. Two fission chambers are connected to counting rate

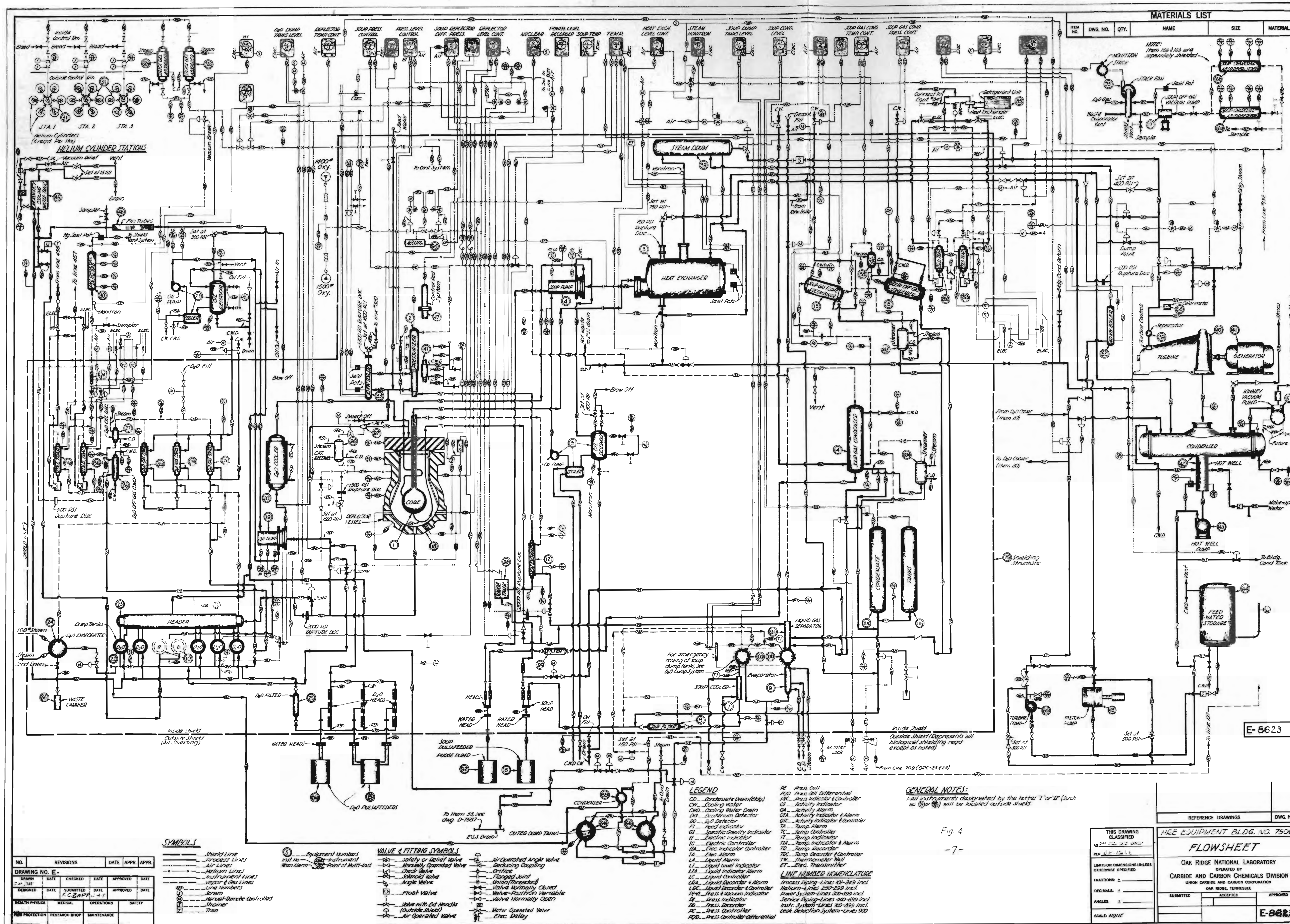
HELIUM CYLINDER STATIONS
STEAM DRUM
HEAT EXCHANGER
CORE
HEADER
CONDENSER
TURBINE
GENERATOR
FEED WATER STORAGE
HOT WELL PUMP
D2O PULSAFEEDERS
OUTER DUMP TANKS
MATERIALS LIST
ITEM NO. | DWG. NO. | QTY. | NAME | SIZE | MATERIAL
E-8623
LEGEND
CD__Condensate Drain (Bldg)
CW__Cooling Water
CWD__Cooling Water Drain
Dd__Deuterium Detector
DO__D2O Detector
FI__Feed Indicator
GI__Specific Gravity Indicator
II__Electric Indicator
IC__Electric Controller
IIA__Elec. Indicator Controller
IA__Elec. Alarm
LA__Liquid Alarm
LI__Liquid Level Indicator
LIA__Liquid Indicator Alarm
LC__Liquid Controller
LRA__Liquid Recorder & Alarm
LRC__Liquid Recorder & Controller
PI-VI__Press. & Vacuum Indicator
PI__Press. Indicator
PR__Press. Recorder
PC__Press. Controller
PC/D__Press. Controller-Differential
PE Press Cell
PE/D Press Cell Differential
PIC__Press Indicator & Controller
QI__Activity Indicator
QA__Activity Alarm
QIA__Activity Indicator & Alarm
QIC__Activity Indicator & Controller
TA__Temp. Alarm
TC__Temp. Controller
TI__Temp. Indicator
TIA__Temp. Indicator & Alarm
TR__Temp. Recorder
TRC__Temp. Recorder & Controller
TW__Thermometer Well
ET__Elec. Transmitter
LINE NUMBER NOMENCLATURE
Process Piping-Lines 101-249 incl.
Helium-Lines 250-299 incl.
Power System-Lines 300-399 incl.
Service Piping-Lines 400-699 incl.
Instr. System-Lines 700-899 incl.
Leak Detection System-Lines 900
GENERAL NOTES:
1. All instruments designated by the letter "T" or "R" (Such as ⓣ or ⓡ) will be located outside shield
SYMBOLS
VALVE & FITTING SYMBOLS
REFERENCE DRAWINGS
DWG. NO.
THIS DRAWING CLASSIFIED
LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED
FRACTIONS: ±
DECIMALS: ±
ANGLES: ±
SCALE: NONE
HRE EQUIPMENT BLDG. NO. 7500
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Fig. 4

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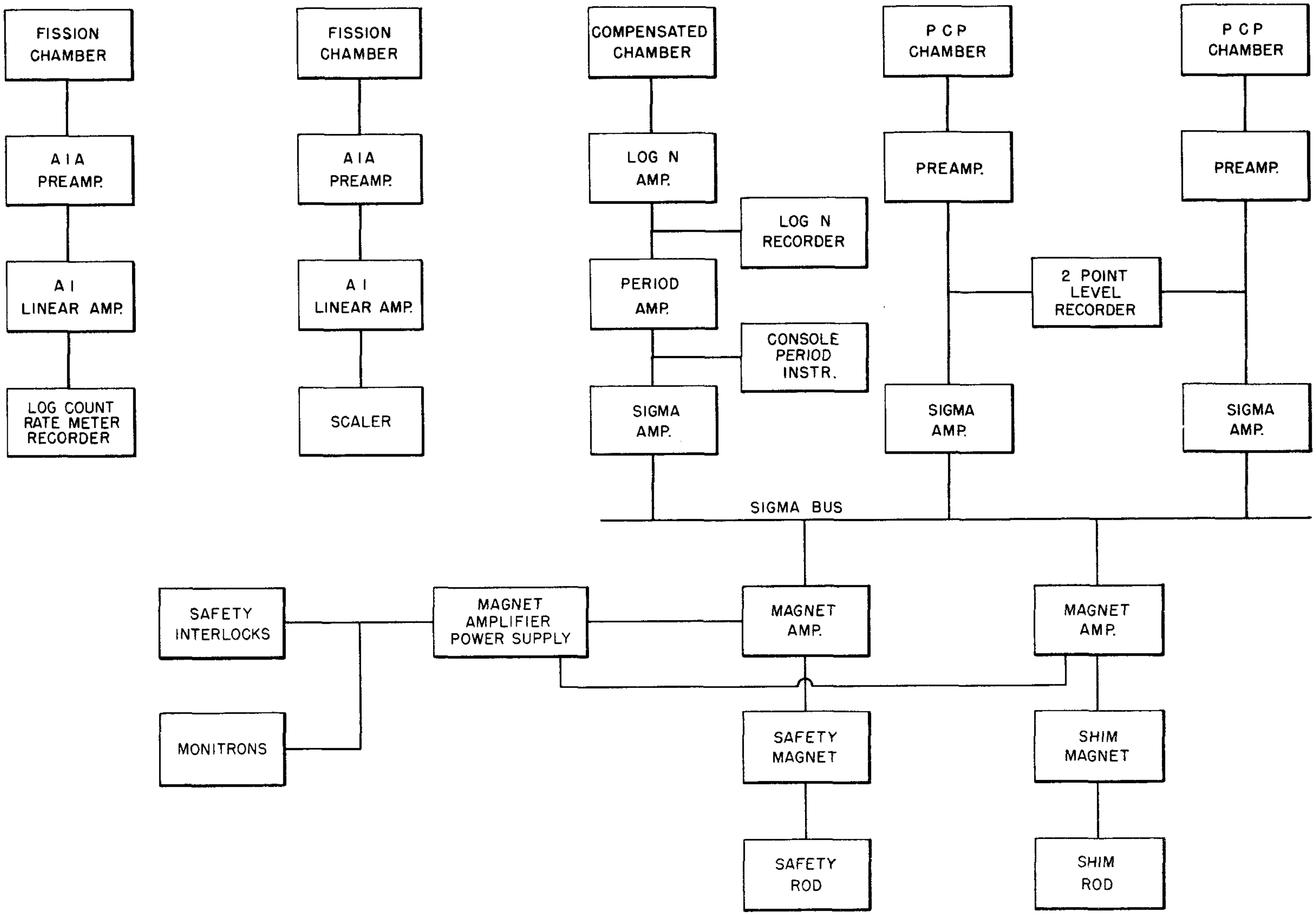

Fig. 5 — Nuclear Instrumentation

meters and a compensated ion chamber drives both a Log N and a period meter. Two PCP boron chambers are connected to a two point level recorder and to the conventional scram circuit. Several monitoring chambers are located on critical points to detect soup leaks, one on either side of the heat exchanger, one on the soup circulating pump cooling oil system, one on the D_2O off-gas system, and one on the stack.

The instruments and controls on the power generation equipment are standard. On the steam side these include main heat exchanger water level, steam flow, and a throttling calorimeter. The electrical instruments are the usual voltmeters, ammeters, kilowattmeter, power factor meter, frequency meter, and synchroscope.

Reactivity Control

The HRE has a high negative temperature coefficient of reactivity (.0011 $\delta k/^{\circ}$ C, ORNL-730) so it is inherently self stabilizing, and hence does not require a servo system on the regulating rod. Any slight change in reactivity which would require servo correction in a low temperature coefficient reactor merely causes a small change in temperature of the HRE. This large temperature coefficient tends to make the reactor automatically respond to changes in power demand. A change of steam demand will produce a corresponding change in soup cooling in the heat exchanger so the soup temperature will drop for an increased steam demand or rise for a decreased demand. This temperature change produces a change of k so the power changes to meet the new demand and the reactor levels off at the new power and the same average temperature (all other k controls having been left fixed).

There are three methods provided for varying the reactivity - concentration of fuel solution, reflector level, and rods. These are interlocked so k can be increased by only one at a time. The reaction of the power demand through the temperature coefficient might be considered a fourth method.

Concentration control may be explained by reference to Figure 6, which shows a simplified version of the soup system. The component numbers correspond to those of the complete flow sheet of Figure 4. Soup from the dump tank is pumped into the core by the pulsafeeder and let down through the valve operated by a level controller on the pressurizer. Thus there is a continuous circulation at approximately 1.5 gpm between core and dump tanks. The circulating pumps give a flow of 100 gpm through the core-heat exchanger loop. The steam evaporator on the dump tank operates continuously, evaporating water from the soup in the tank. This resulting steam is condensed and if the concentrate valve is open the condensate returns to the dump tank. There is no net change of concentration in the system under this condition. If both the concentrate and dilute valves are closed the condensate is collected in the condensate tanks and the soup in the dump tanks becomes more concentrated. This in turn results in the core soup becoming more concentrated since there is continuous circulation. To lower concentration the dilute valve is opened, dumping the condensate into the pulsafeeder intake line and hence giving almost pure water into the core. Both concentrate and dilute valves are throttling valves controlled from the console by the operator, so the rate of concentration or dilution may be adjusted by the operator.

The maximum rates of response to concentration control may be readily computed if initial and final states are known. For dilution, a

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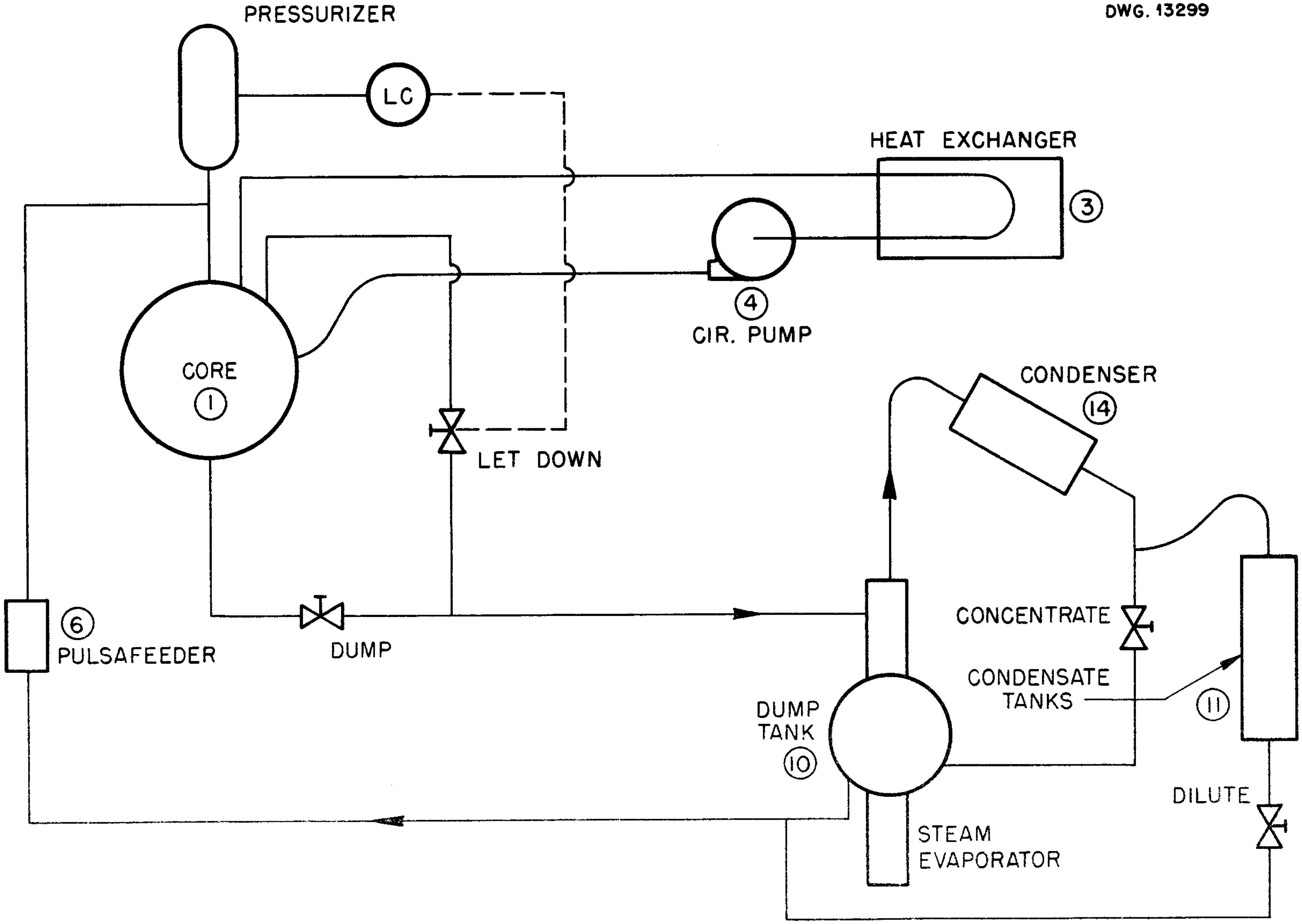

Fig. 6—Simplified Fuel System

fair approximation is to assume the dilution valve is fully open and the relative impedances to flow through the condensate line and the soup filter are such that practically pure water is pumped into the core by the pulsafeeder. Then,

$$\frac{d\ m_c}{dt} = -C_c f = -\frac{m_c}{V} f$$

where

m_c = uranium in the core

C_c = concentration in core

f = pumping rate

V = volume of core system ≈ 75 liters.

This gives

$$m_c = M_o\ e^{-ft/V}$$

or

$$C_c = C_o\ e^{-ft/V}$$

Typical values are:

Safe concentration at 20° C, C_c = 20 gm/l

Critical concentration, C_o = 35 gm/l

Pumping rate, f = 5.6 l/min.

The minimum time to dilute from the critical concentration to a safe volume is:

$$20 = 35\ e^{-\frac{5.6}{75}t}$$

$$t = 7.5 \text{ minutes.}$$

The soup in the core system should always be reduced to a safe concentration on any shutdown for which the reflector is dumped. Otherwise the soup may cool to a relatively low temperature and become critical upon restarting before the temperature interlocks function. The soup is automatically diluted when it is dumped.

The equations for soup concentration may be set up by a consideration of the material balance. With the concentration and dilution valves closed we can write:

$$V \frac{dC_c}{dt} = f\, C_D - fC_c$$

$$M = VC_c + (V_D - Bt)C_D$$

where

C_D = dump system concentration

V_D = dump system volume

t = time

B = evaporation rate

M = total uranium in the system, assumed as 4 kg.

Then,

$$C_D = \frac{M - VC_c}{V_D - Bt}$$

$$\frac{dC_c}{dt} + \frac{fC_c}{V}\, 1 + \frac{V}{V_D - Bt} = \frac{f}{V}\, \frac{M}{V_D - Bt}$$

The solution of this equation for various values of the parameters is presented in the form of curves in Figure 7.

The relation between concentration and k has been computed and is given as Figure II-1, ORNL-730. The concentration is measured indirectly by weighing the water in the condensate tanks. Knowing the initial charge of

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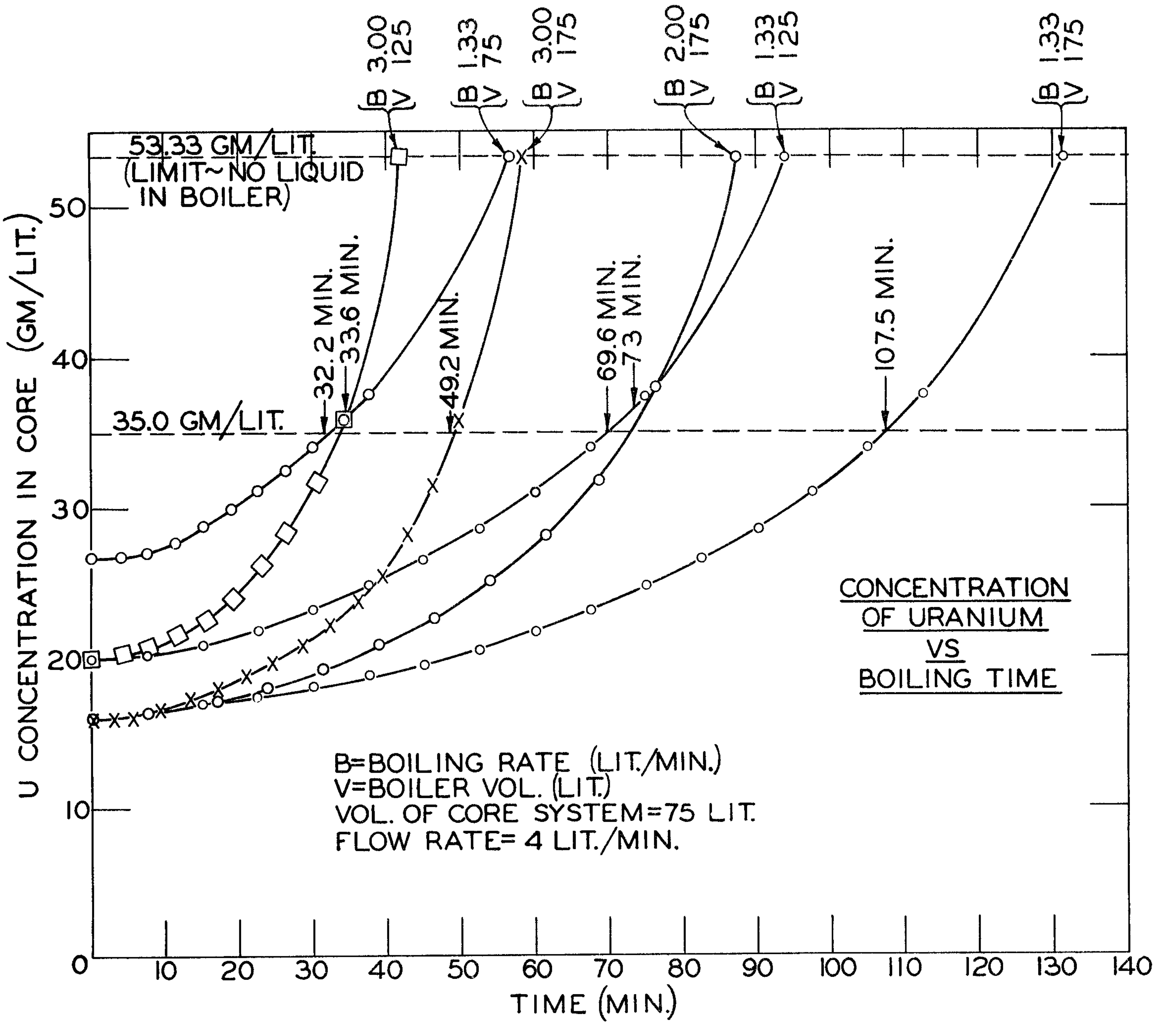

Fig. 7– Concentration Rate

water and uranyl sulphate the concentration is readily determined from the water hold-up so the weigh instrument may be calibrated in terms of concentration. As a check on the entire soup system, as well as the concentration instrument, the soup in the dump tanks is also weighed. This method of determining concentration is not an absolute determination since it cannot take into account any partial precipitation and hold-up of fuel in the system, nor is it capable of giving rapid measurements of concentration in the core itself. Fortunately, however, the reactor can be operated safely without knowing the values accurately.

The basic reflector flow sheet is given in Figure 8. D_2O is pumped into the reflector from the dump tank by means of pulsafeeder pumps. This water is circulated through the heat exchanger where its heat is extracted to preheat the feed water of the soup heat exchanger. Reflector level is maintained by a level controller by appropriate operation of the pulsafeeder pump and letdown valve. Any desired level from half full to full may be selected by the operator. Since the safety plates are not effective unless immersed in the D_2O, the reactor cannot be operated with less than half full reflector. Results presented in ORNL-730 indicate the reflector controls approximately 26% k_{eff}.

The control rods or plates consist of three sets; one of 2.5% $\frac{\delta k}{k}$ used as a safety; one of 2.5% used as a shim; and the third having 0.7% used as a regulating rod. These rods may be raised or lowered by constant speed drives requiring two minutes for full travel one way, thereby giving a maximum $\delta k/k$ rate of 1.3%/minute. The shim and safety rods are suspended from the drive mechanism with electromagnets so they may be released very quickly. The release time of the magnets is ~ 7 milliseconds, and the rods are spring

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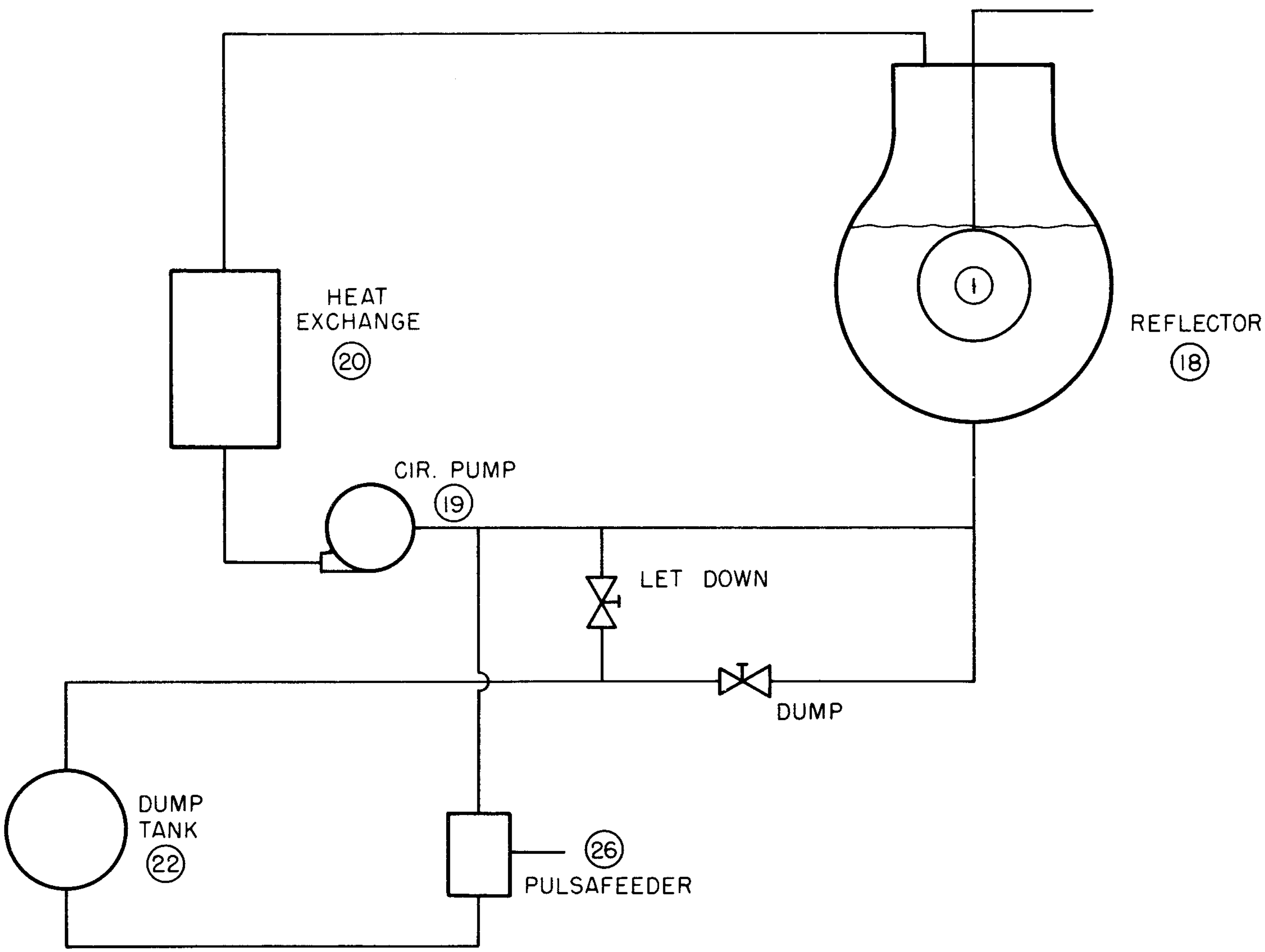

Fig. 8 — Reflector System

loaded to produce an initial acceleration of 5 g. On an emergency drop the rods reach one-third of their total insertion in ~50 milliseconds.

Nuclear Instrumentation

The nuclear instrumentation consists basically of the various chambers and associated circuits for monitoring the reactor proper and several monitrons monitoring components. Six thimbles are provided through the shielding and reflector so the neutron flux leaving the core may be determined with suitable chambers. With the exception of the period amplifier all components of these circuits are "standard" units as used for the MTR (ORNL-963), and so will not be discussed in detail.

Two fission chambers and associated A-1A pre-amplifiers and A-1 amplifiers are provided for counting rate measurements from source level ($\sim 10^{-11}$ N_F) to $\sim 10^{-6}$ N_F. One of these will be connected to a Brown strip recorder for a log CRM record, while the other will be connected to a scaler. The scaler and recorder may be interchanged by switches.

A compensated chamber is used in conjunction with a log amplifier and period amplifier to give Log N and period measurements and safety control. The Log N instrument is a Brown recorder covering the range 10^{-6} N_F to N_F. The period instrument is an indicating instrument mounted on the console. It gives a usable indication at a flux of $\sim 10^{-7}$ N_F. Mathematical analysis of the HRE (ORNL-730) has indicated that very rapid positive power surges with fast positive periods followed by a negative period will probably occur. It seems advisable, therefore, to modify the MTR period amplifier to include a negative period scram. Thus, if the positive surge does not last long enough to permit the safeties to act, the following negative period will scram the reactor and prevent an oscillation build-up. The negative period scram will also protect the reactor against a continued rapid rise of temperature since such a rise puts the reactor on a negative period.

The two PCP boron chambers and their amplifiers serve as flux instruments and safeties at the upper flux levels, 10^{-3} N_F to N_F. The safety signal is fed from both to the sigma bus, while the flux level is recorded on a two-point Brown recorder. This instrument is equipped with a second slide wire mechanically connected to the balancing motor. This slide wire is used as the load of a watt-hour meter so the meter register is a record of nvt for the reactor.

The monitrons supervising reactor components are remote chamber units with the chambers located at various critical points. The outputs are recorded on a six-point Brown strip chart recorder and the emergency levels actuate the appropriate contacts in the safety circuit as discussed below. QRC-23 and -26 monitor the heat exchanger for soup leaks. In addition to shutting the reactor down, these close valves 316A, 316B, 330, 323, and 321, thus isolating the heat exchanger. The steam drum provides enough steam hold-up ($\sim$4 seconds) to permit valve 316A, a quick-closing unit, to close before active steam can get outside the shield. QRC-24 monitors the D_2O off-gas and is tied into the safety circuit. QRC-25 checks the soup circulating pump oil for a soup leak and in an emergency dumps the soup. QRC-68 provides over-all stack supervision.

The chambers which are located inside the shield are lead and boral shielded to reduce the background noise so maximum sensitivity to leaks may be realized.

Rod Drive

The drive mechanisms for the three rods or plates are identical, but the method of holding the rods differs. The drive is a three-phase squirrel cage motor geared to a lead screw. The rod position indicator consists of a reciprocating magnet inside the pressure thimble, a magnetically operated switch on the outside of the thimble, and a stepping relay driven panel board indicator. The magnet is moved back and forth by a cam on the lead screw shaft so it operates the outside switch once each revolution. This switch in turn pulses a stepping relay mechanism arranged to drive a drum in the panel instrument. The drum moves a colored tape across the face of the instrument to indicate the position of the rod. This gives the rod location to 0.9% of its full travel, or for the control rod to $.006\% \; \delta k_{eff}$. The zero position may be checked by the limit switch signals at either end of the travel.

Process Instruments and Control

The operation of the instruments and controls will be discussed in groups on a functional basis rather than individually. Table 1 summarizes the control valve data. The numerical designation of instruments is rather arbitrary, so the order of this discussion is not necessarily that of instrument numbers, but they are listed in numerical order in the instrument index. The letter code used with the instruments gives the function of the instrument as follows:

[redacted]

TABLE 1

CONTROL VALVES

Valve Line No.	Body Connection & Size	Valve Body	Operator	Trim Material and Size	Trim Shape	Flowing Medium	Manual Control Station	Location Moore Station	Position Indicator	Valve Fails	Location of Valve/ Shield	Location on Flow Sheet
105	Welded ½	MH	MH	1/8 Stellite	= %	Soup	On Inst.	-	Yes	O	In	Lower left cent
106	Welded ½	FS	Fox	1/2 Stellite	on/off	Soup	Moore	Panel	Yes	O	In	Lower left cent.
113A	Welded ½	FS	Fox	1/2 St to St	on/off	Soup	Moore	Panel	Yes	C	In	Lower left cent.
113B	Welded ½	FS	Fox	½ 347 to St	on/off	Soup	Moore	Panel	Yes	C	Out	Lower left cent.
114	Welded ½	FS	Fox	½ 347 to/or St	on/off	H_2O	Moore	Console	Yes	O	In	Lower left cent.
120A	Welded ½	FS	Fox	½ 347 to St	on/off	Decont. Waste	Moore	Panel	Yes	C	Out	Lower left cent.
120B	Welded ½	FS	Fox	½ St to St	on/off	Decont. Waste	Moore	Panel	Yes	C	Out	Lower left cent.
125	Welded ½	FS	Fox	Special	Special	Gas and Steam	Moore	Console	Yes	C	In	Upper left cent.
126	Welded ½	FS	Fox	½ 347 to/or Stellite	on/off	H_2O	Moore	Console	Yes	O	In	Lower left cent.
131	Welded ½	FS	Fox	½ 347 to Stel	on/off	Pretreat & Soup	Moore	Panel	Yes	C	In	Upper right cent
132	Welded ½	FS	Fox	½ 347 to/or Stellite	on/off	Soup Gas	Moore	Panel	Yes	C	Out	Lower left cent.
136	Welded ½	FS	Fox	½ 347 to/or Stellite	on/off	Gas	Moore	Panel	Yes	O	In	Upper left
137	Welded ½	FS	Fox	½ 347 to/or Stellite	on/off	Gas	Moore	Panel	Yes	O	In	Upper left
139	Welded ½	FS	Fox	½ 347 to/or Stellite	on/off	Gas	Moore	Console	Yes	C	In	Lower left cent.
150	Welded 2	MH	MH	2 Stellite	on/off	D_2O	Moore & Solenoid	Panel	Yes	O	In	Lower l

[redacted]

TABLE 1 (CONTINUED)

Valve Line No.	Body Connection & Size	Valve Body	Operator	Trim Material and Size	Trim Shape	Flowing Medium	Manual Control Station	Location Moore Station	Position Indicator	Valve Fails	Location of Valve/ Shield	Location on Flow Sheet
155	Welded ½	MH	MH	1/8 Stellite	= %	D_2O	On Inst.	-	Yes	O	In	Lower left cent
159	Welded ½	FS	Special	½ 347 to 410	on/off	D_2O	Moore	Panel	Yes	C	In	Lower left
167	Screw 1/8	FS	MH	1/16 stainless	Needle	D_2O gas	Moore	Panel	Yes	O	In	Middle left
168	Screw 1/8	FS	MH	1/16 stainless	Needle	D_2O gas	Moore	Panel	Yes	O	In	Middle left
267A	Screw ½	MN 107	MN	1/16 stainless	Needle	He	See 270	-	No	O	In control rm.	Upper left
267B	Screw ½	MN 108	MN	1/16 stainless	Needle	He	See 150	-	No	C	In control rm.	Upper left
270	Welded ½	MH	MH	1/8 Stainless	= %	He	On Inst.	-	Yes	C	In	Lower left
309	Screw 1"	CS	MH	Stainless	= %	H_2O	On Inst.	-	Yes	C	Out	Upper rig
310	Screw 1¼"	CS	MH	1¼ Stainless	= %	H_2O	On Inst.	-	Yes	O	Out	Upper right
313	Screw 1"	CS	MH	1/8 Stellite	Parabolic	H_2O	On Inst.	-	No	C	Out	Upper right
316A	Flanged 4	CS	HD	4" Stellite	on/off	Steam	Moore & Solenoids	Console	Yes	C	Out	Upper right cent
316B	Flanged 4	CS	Leslie	4" Stellite	= %	Steam	Moore & Solenoids	Console	Yes	C	Out	Upper right
321	Screw 3/4"	FS	MN	¼" S. Steel	= %	H_2O	Moore & Solenoid	Panel	Yes	C	In	Upper right cent
323	Flanged 2"	CS	Leslie	2" Stellite	= %	Steam	Moore & Solenoid	Console	Yes	C	Out	Upper right
324	Flanged 1½"	CS	Climax	1½" S. Steel	= %	Steam	Moore	Console	Yes	C	Out	Upper right
330	Flanged 1"	CS	Leslie	5/8" Stellite	= %	Steam	See 323	See 323	Yes	C	Out	Upper ri

TABLE 1 (CONTINUED)

Valve Line No.	Body Connection & Size	Valve Body	Operator	Trim Material and Size	Trim Shape	Flowing Medium	Manual Control Station	Location Moore Station	Position Indicator	Valve Fails	Location of Valve/ Shield	Location on Flow Sheet
407	Screw 3	MH	MH	Butterfly		H_2O			Yes	O	Out	Upper left
438	Screw	MN 37's	MN	Stainless	V-port	H_2O	On Inst.	-	Yes	O	Out	Upper right cent.
440	Screw $\frac{1}{2}$ or 3/4	MN 37's	MN	Stainless	V-port	H_2O	On Inst.	-	No	O	Out	Upper right cent.
507	Screw	MN 37's	MN	Stainless	V-port	H_2O	On Inst.	-	No	O	Out	Upper right cent.
347	Screw 3/4"	MH	MH	1/2" S. Steel	= %	H_2O	See 316B	-	No	O	Out	Center right

Valves which are located in high flux regions are operated through air relays located in the D_2O compartment to prevent release of radioactive argon in the control room.

First Letter

D - Deuterium

F - Flow

G - Specific gravity

I - Electrical

L - Level

P - Pressure

Q - Activity

T - Temperature

W - Power

Following Letters

A - Alarm, visual and/or audible

C - Controller

/D - Differential

I - Indicator

R - Recorder

Z - Integrator

For sensing elements, TC indicates a thermocouple and PE a pressure element. Detailed data on various instruments are given in Tables 2 - 12. Valves are numbered according to the line in which they are located, letters A, B, etc., being used when a line contains more than one control valve.

The response times of the instruments and valves are not given, since in most cases these will be adjusted in the field for satisfactory control. In general, the Foxboro instruments can be adjusted for full-scale responses ranging from 1 to 12 seconds by changing the oil used. Brown strip chart instruments normally have a response time of 4.5 seconds, while the circular chart instruments have a response time of 12 seconds. Valve operating time may be adjusted from approximately 2 to 20 seconds by using positioners and boosters. Where emergency conditions require rapid opening or closing of a valve, a solenoid valve located near the main valve is used to control the pneumatic operator, thereby eliminating the delay of a long air line.

Pressurizer Level Control

This control is shown schematically in Figure 9, and the instrument data is summarized in Table 2. The notation used in this figure is common to all of the control drawings of this type. Line numbers and major component numbers are the same as in Figure 4; air lines are indicated by "A" and electrical connections by "E." The wavy breaks in various lines symbolize passage through the shield. Electrical junction boxes are shown as squares with a letter and one or more numbers, the letter referring to the box designation and the number to the particular terminals within the box.

The level control depends upon detecting a change of level in the pressurizer by means of a restrained float in a side chamber. This float is a section of stainless steel pipe, capped at both ends and supported by two rods as shown in Figure 10. This construction meets the various specifications for a sensing element at this point in the system - stainless steel for parts contacting liquid, high pressure operation, no dead ends which might be difficult to clear of pretreatment chemicals, and no materials subject to radiation damage. Changes of level produce small displacements of this float (approximately 30 mils full-scale) which are transmitted to the control instrument by an inductance around a small magnetic extension of the float. The inductance is

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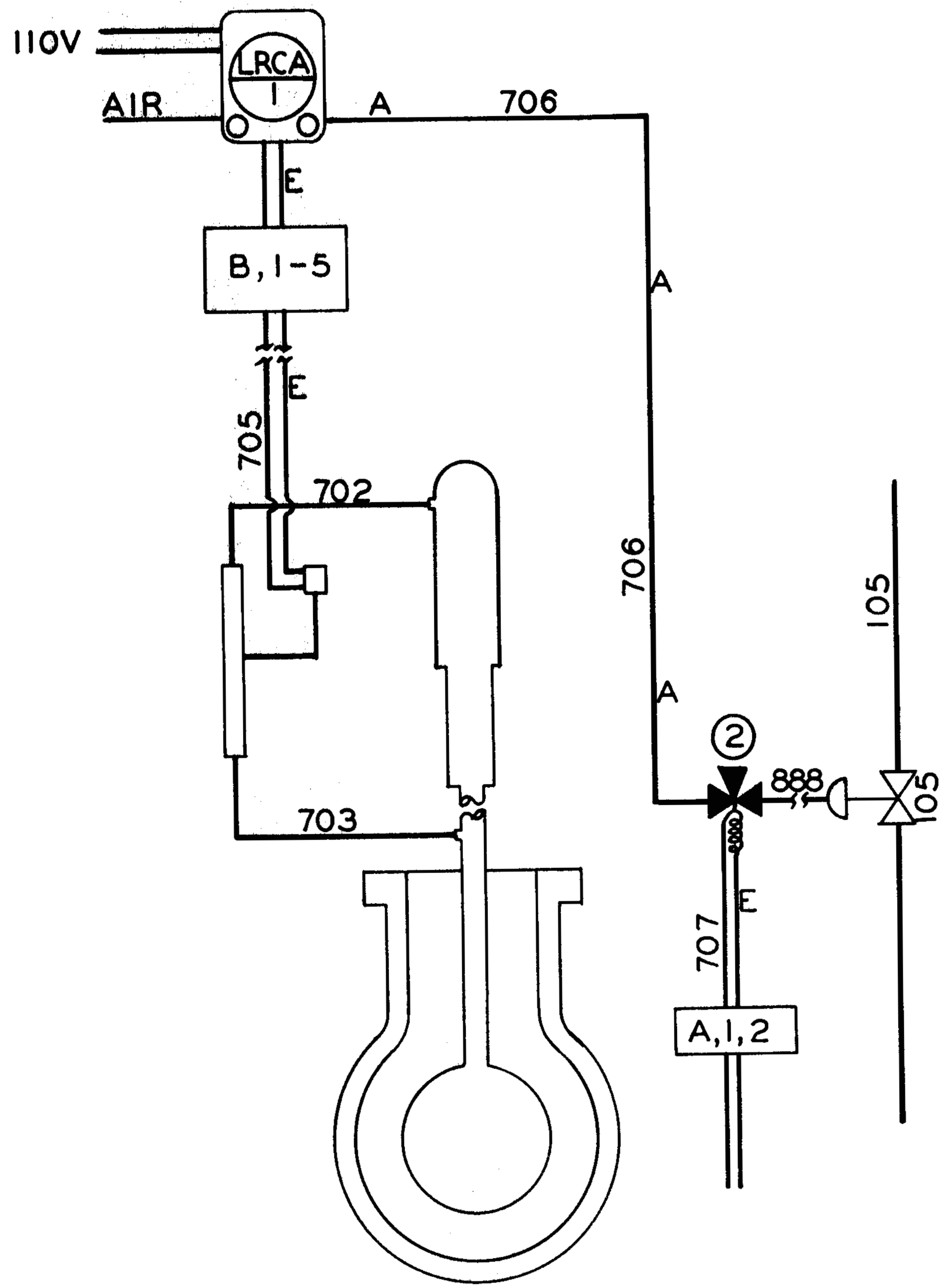

Fig. 9—Pressurizer Level

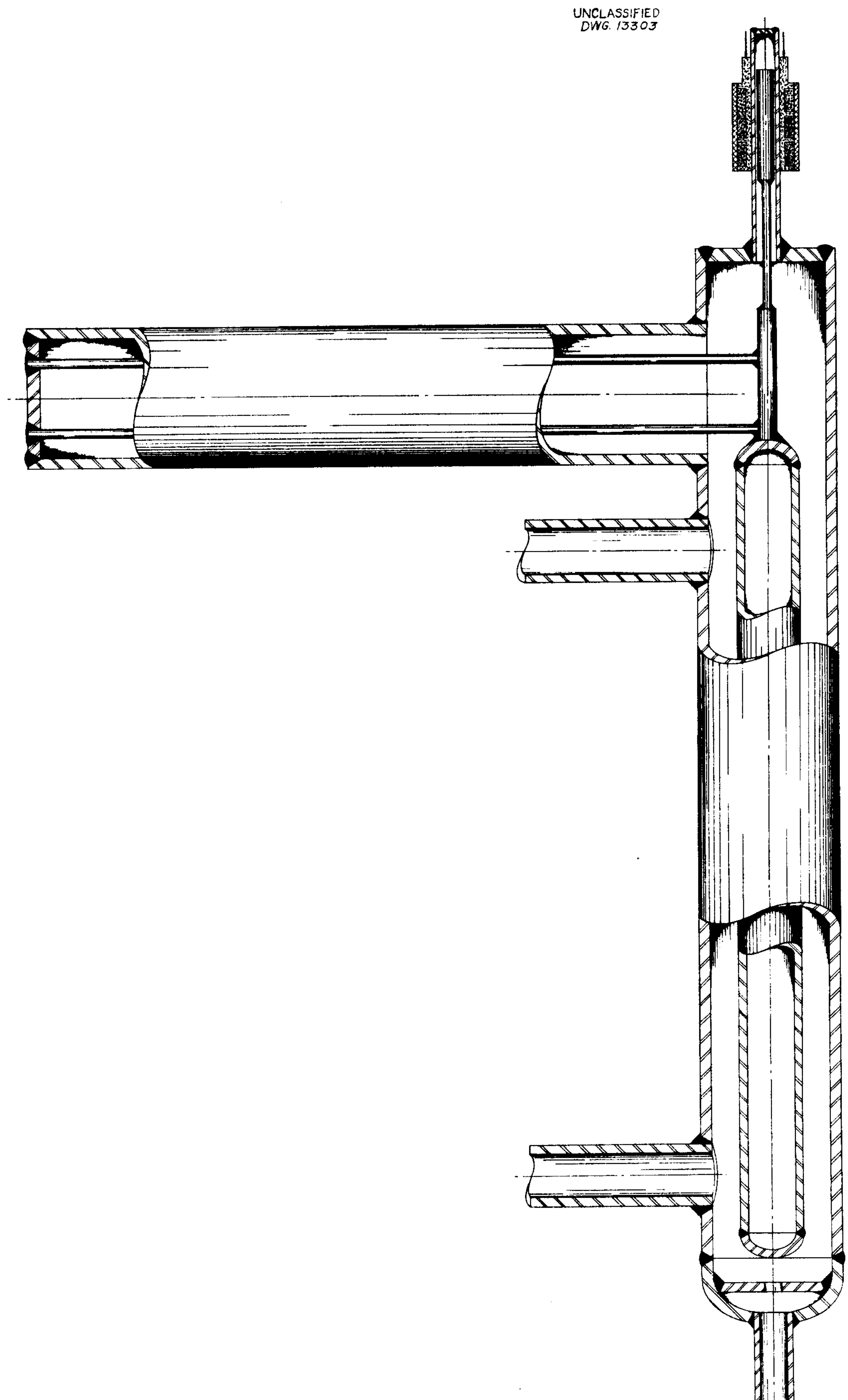

FIGURE 10
LEVEL CONTROL FLOAT

TABLE 2

PRESSURIZER LEVEL CONTROLLER

LRCA-1

Receiver - Foxboro Dynalog Circular Chart Controller for use with Wianco cell

range - 0-1 m.v/v
pen speed - 1 sec.
control - pneumatic-proportional, derivative, manual
chart speed - 4 hrs.
chart - 0-100 linear
mounting - flush
adjustments - span and zero
failure - up-scale
input circuit - Fig. 11A

Contacts*

1 CR - interlock (low level)
1 CD - alarm (high level) - F.O.

Location - panel board

Transmitter - Schevitz Microformer - MW level cell

type - 18 LCT
range - 0.8 volt/volt-inch
J. B. Terminals - B, 1-5

Location - Reactor compartment

Auxiliary Equipment

(105) - control element - 1/8" SS Belfield, fails open

Location - Soup cell

(2) - Solenoid valve - 1/4" Asco, fails open

J. B. Terminals - A4, 1-2

Location - north face of shield

* CR - close on rise
CD - close on drop
FO - fails open
FC - fails closed

a microformer connected as a center-tapped coil, which is in turn connected in a bridge circuit (Figure 11A) to a Foxboro Dynalog circular chart controller and recorder. Motion of the magnetic core attached to the float unbalances the inductance bridge, causing the instrument to operate to restore balance and thus control level. The instrument provides proportional control to the pneumatic operator of the let-down valve, (valve 105 of Figures 4 and 9).

In normal operation soup is pumped to the core from the dump tanks at approximately 1.5 gpm. For a constant level this must be bled from the core system back to the dump tanks. Changes in reactor power will cause corresponding changes in level in the pressurizer due to expansion of the liquid and to variations in the gas formation. These level changes cause the controller to adjust the throttling of the let-down valve to compensate for them. Thus, for example, increased gas formation forces more liquid into the pressurizer, the let-down valve opens more, allowing this extra gas to go through and thus restore level to the proper valve.

The level fluctuates with each stroke of the pulsafeeder pump so the instrument and valve are purposely slowed so they will not respond to these pulses. Too much delay will produce enough phase shift to cause oscillations. Some error is introduced by temperature effects, both by change of density of the liquid and to a lesser extent by change of the modulus of the float-supporting rods. Fortunately, the absolute level is not critical, so this temperature effect is not serious. If at some later date more accurate indication of absolute level is desired a temperature correction may be inserted in the circuit.

The let-down valve is not used normally for an emergency dump of the soup, but is used to back up the main dump valve. This is accomplished

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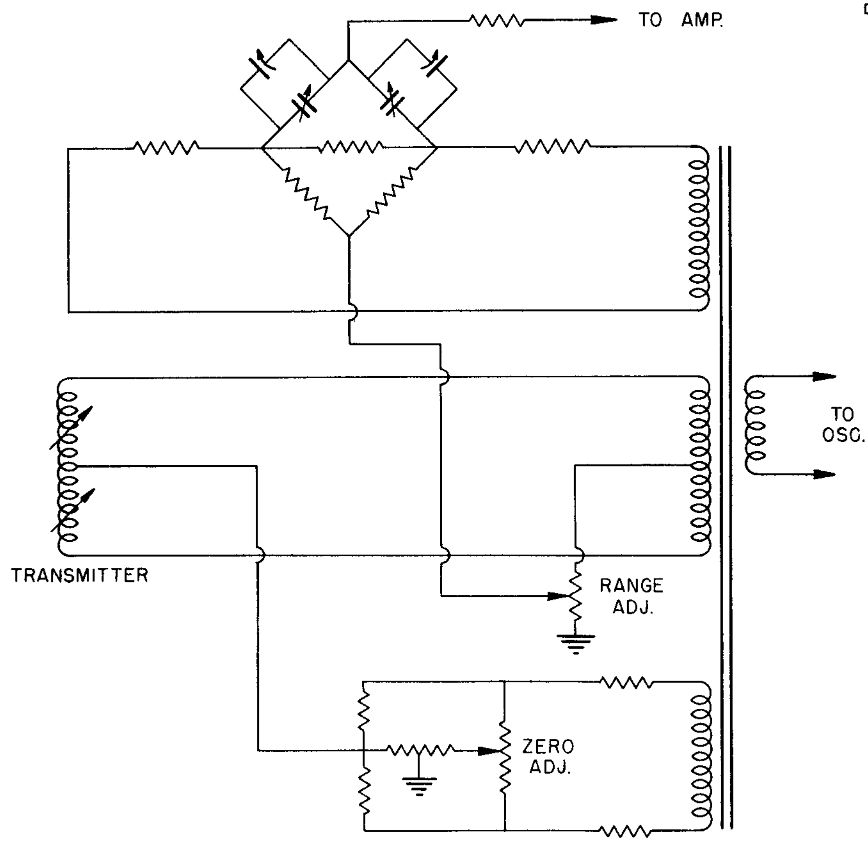

Fig 11A– Input Circuit

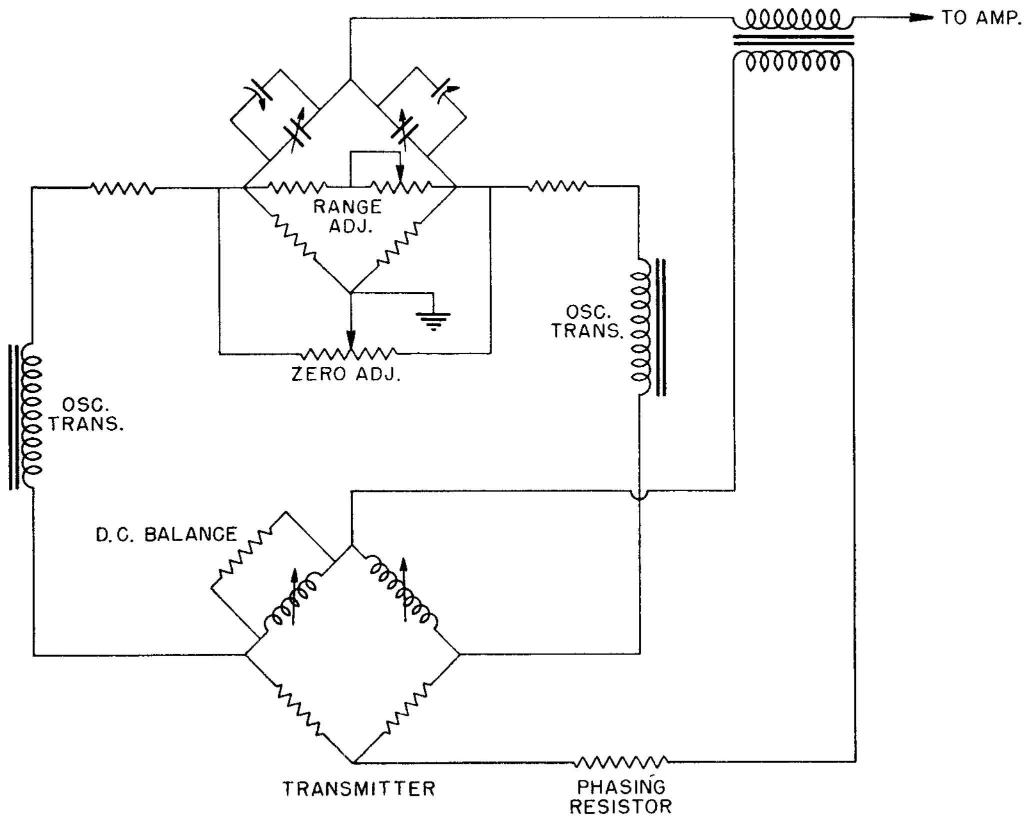

Fig. 11B – Input Circuit

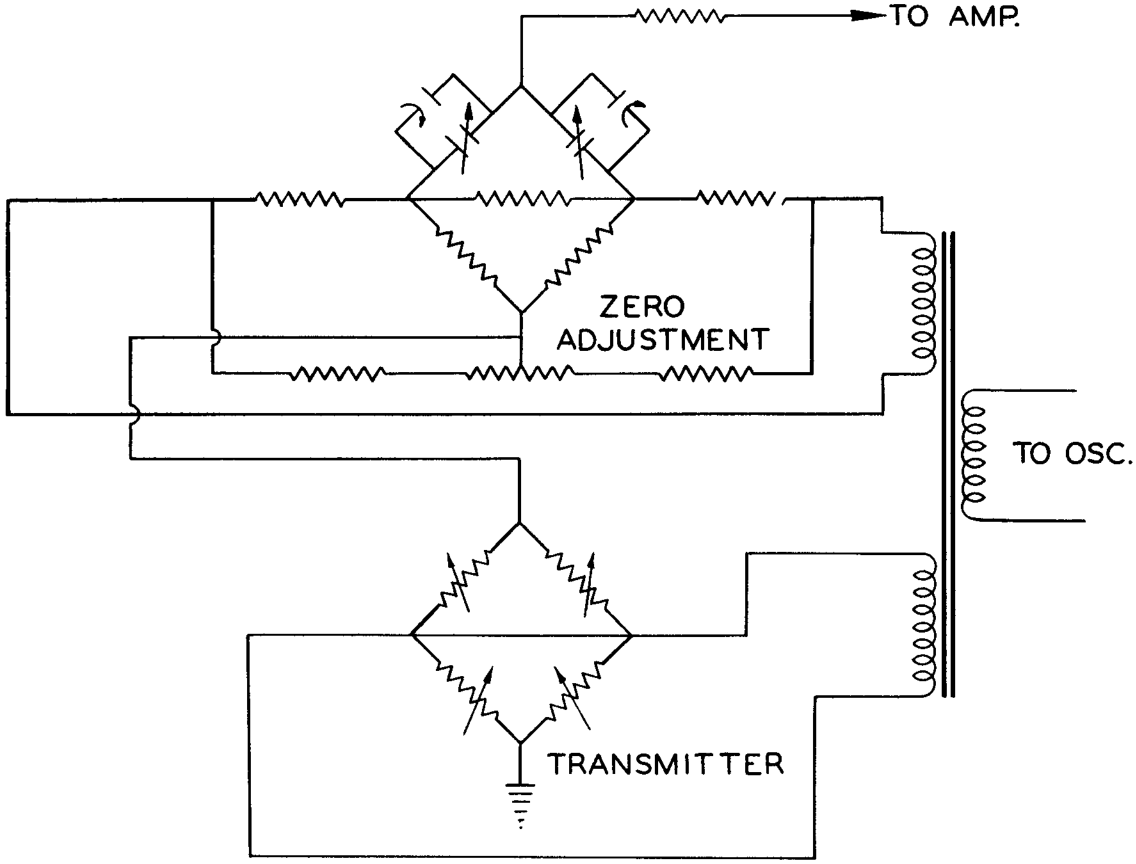

Fig. 11C— Input Circuit

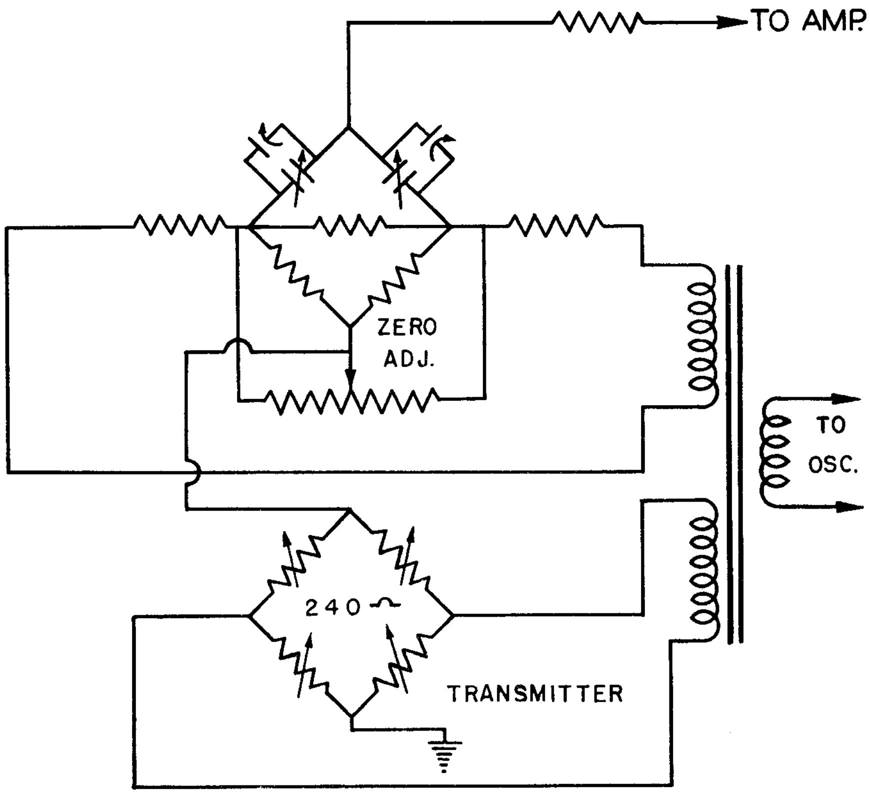

Fig. 11D— Input Circuit

by the solenoid valve designated as 2 in Figure 9. This valve is interlocked with the main dump valve so if the latter fails to open on an emergency signal, valve 2 operates to open the let-down valve, thereby dumping the soup through it.

Soup Pressure and Oxygen Feed

Figure 12 and Table 3 show the essential features of this phase of the reactor. While pressurization and oxygen feed serve different functions their controls are so interrelated that they are treated together.

Pressurization is provided by heating the solution in the upper part of the pressurizer by means of a steam jacket. The system pressure is then determined by the vapor pressure of the solution, so by controlling the solution temperature the pressure may be controlled. Vapor pressurization is preferable to a gas pressurization system as it prevents the accumulation of an explosive mixture of hydrogen and oxygen in the pressurizer. Such an accumulation would be potentially one of the most dangerous conditions in which the reactor could be placed. An explosion would drive fuel from the pressurizer into the vortex and very closely approach a step increase in k corresponding in magnitude to the k value of the vortex plus the compressive value of the soup in the core. In the region in which the reactor will operate the vapor pressure changes so rapidly with temperature that pressure rather than temperature control is used. Consequently, the heaters of the 10 kw boiler are switched on and off by the pressurizer pressure controller to maintain the correct vapor pressure. These heaters are so connected electrically that the wattage being switched can be set manually to minimize pressure fluctuations.

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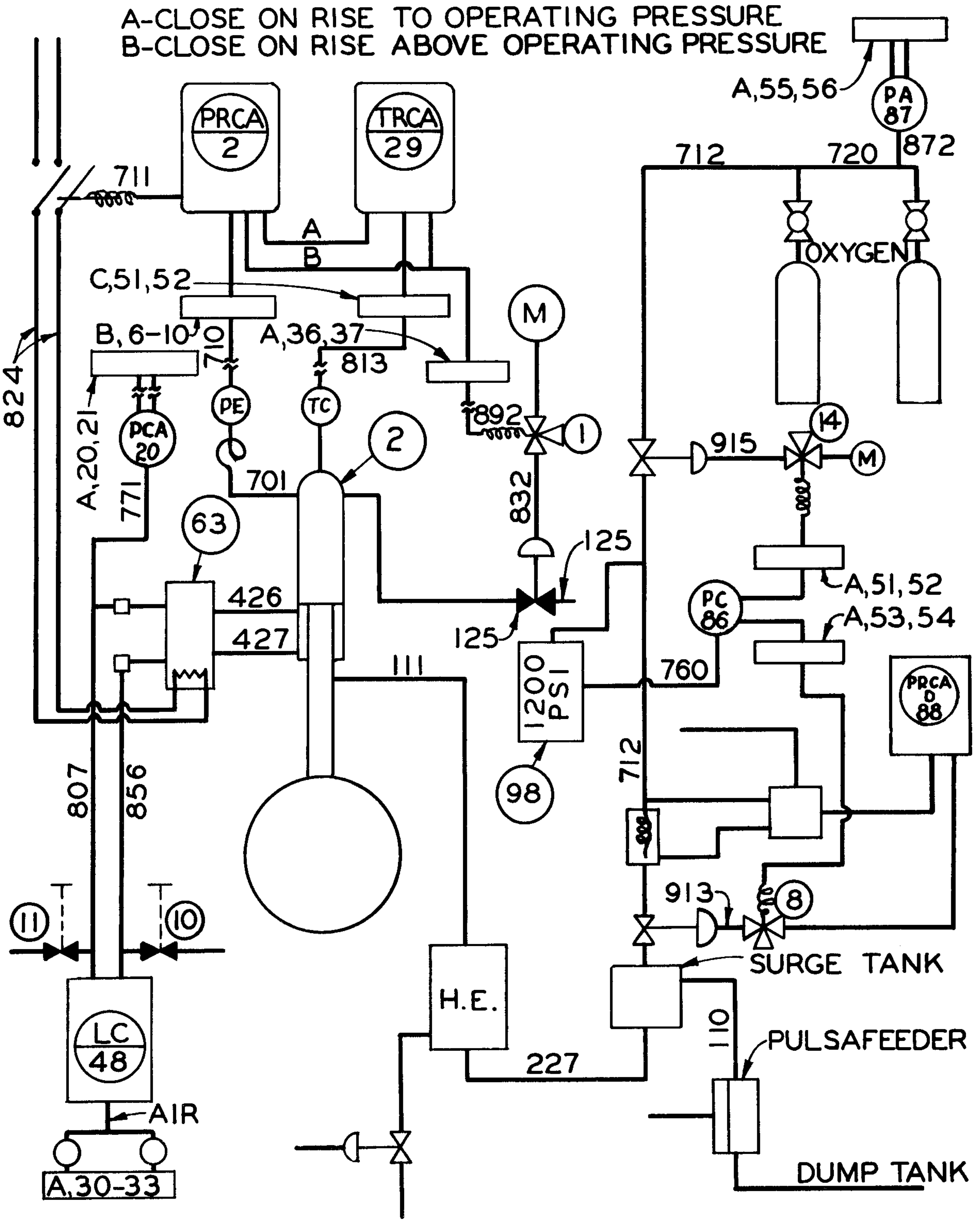

Fig. 12– Pressurizer

TABLE 3

SOUP PRESSURE

PRCA-2

Receiver - Foxboro Dynalog Circular Chart Controller for use with Baldwin cell

range - 0 - 1 m.v./v
pen speed - 3 sec.
control - electric, on-off
chart speed - 24 hours
chart - 0 - 2000
mounting - flush
adjustments - adjustable zero
failure - upscale
input circuit - Figure 11D

Contacts:

1 - CR - interlock (low)
1 - CR - bleed valve
1 - CR - bleed valve
1 - CD - alarm (high)

Location - Panel Board

Transmitter - Baldwin strain cell 0 - 2000 psi

range - 1 m.v./v 2000 psi
type - special, similar to Type C
J. B. terminals - B, 6 - 10

Location - Pressure cell

Auxiliary Equipment

(7) Sylphon in line 701
(125) De-gas valve - special Spline plug - Fulton Sylphon F. C.
Location - soup cell
(1) Solenoid valve - 1/4" Asco - F.C.
J. B. terminals A_1, 36 - 37
Location - north face of shield
(4) Moore manual station
Location - control room
(3) Special valve - F.C.
(2) Special valve - F.C.
(8) Solenoid valve - 1/4" Asco - F.C.
J.B. terminals A_1, 53 - 54
Location - north face of shield

TABLE 3 (CONTINUED)

Auxiliary Equipment

(9) Moore manual station
Location - control room
(13) Moore manual station
Location - control room
(15) Autoclave check valve in line 712

LC-48

Receiver - 3 - 15 psi gage 4-1/2", scale 0 - 100

Transmitter - Brown air output D/P cell

range - 0 - 20 - 600" water

Location - D_2O cell

Auxiliary Equipment

(5)	- Seal pot	Couple to 10 kw boiler
(6)	- Seal pot	A106 pipe nipple
(10)	- 1/8" Hoke	Mount close as possible to receiver
(11)	- 1/8" Hoke	Provide extension handle
(16)	- 2H air switches - 3 - 15 psi (J.B. A_1 30 - 33)	

1 - CR (Level) - interlock (heater)

1 - CD (Level) - interlock (heater)

PCA20

Receiver - Mercoid pressure switch (0 - 2000 psi)

Contacts:

1 CD - interlock (pickup at annunciator panel)
1 CD - alarm

Location - near LC-48

J.B. - A_1 - 20, 21

TRCA-29

Receiver - Brown Circular Chart Recorder

range - 0 - 300° C
pen speed - 24 sec.
control - electric on-off

[redacted]

TABLE 3 (CONTINUED)

Receiver

chart speed - 24 hr/rev
chart - 0 - 300
mounting - flush
adjustments - front set
failure - F.U.

Contacts:

1 CR alarm F.O.
1 CD alarm
1 CD control

Location - panel board

Transmitter - I.C. thermocouple
T. C. well designed in pressurizer

J.B. - C_1 - 51, 52

PA-87

Receiver - 0 - 1500 psi Mercoid pressure switch

Location - north face of shield

Contact:

1 CR alarm

J.B. A_1 - 55, 56

PC-86

Receiver - 0 - 1500 psi Mercoid pressure switch

Location - pressure cell compartment

Contact - SPDT

J.B. A_1 - 48 - 50

Auxiliary Equipment

(14) Solenoid valve - 1/4" Asco F.C.

J. B. Terminals A_1 - 51, 52

Location - north face of shield

[redacted]

The pressurizer can become gas-bound so the vapor pressure does not control the total pressure. Mock-up tests have demonstrated that the vapor controlled region is a rather thin layer (a few inches) just above the solution surface when appreciable gas is present. The bleed valve in line 125 and its controls are provided to care for the gas, either oxygen from the oxygenating system or decomposition gases from the solution. A thermocouple in the top of the pressurizer senses the temperature, and through TRC-29 uses this temperature to bleed off the gas through valve 125. The stratification of the gas and vapor will cause the thermocouple temperature to be below that corresponding to desired vapor pressure. This causes valve 125 to open and relieve the gas binding. When the system is being brought up to operating pressure this valve should be closed so the temperature-controlled contacts of TRC-29 are connected in series with pressure-controlled contacts of PRCA-2 so valve 125 opens automatically only when the pressure is correct and the temperature is low. Obviously, the temperature control point of TRC-29 must be set to correspond with the pressure control point of PRCA-2. Valve 125 also serves as a safety relief valve, opening when PRCA-2 indicates an abnormal pressure.

The 10 kw boiler, item 63, is protected by instruments LIA48 and PC20, the first for water level and the second for pressure protection. Both of these are located inside the shield for safety, since a leak from the pressurizer into the steam jacket would make them quite hot. LIA48 is a Foxboro differential pressure cell with air output operating the three switches. Since it is inside the shield three electrical signals are brought outside. The intermediate point is the fill point, while high and low contacts are connected in the heater control circuit so the heaters cannot operate if the water is low or if the boiler has been over-filled. PC20 is a 1500 psi pressure switch also connected in the heater circuit to prevent over pressure operation. Thus, subject to permission from water level and pressure instruments the boiler heaters may be switched as demanded by the pressurizer temperature.

Oxygen in the solution is necessary for chemical stability, so a means must be provided for introducing oxygen when the reactor is operated at such a low power level that it does not generate its own. This is cared for by the oxygen feed arrangement shown in Figure 12. Oxygen is metered into the system by valve 3 from the intermediate gas storage. This flow is measured with a differential pressure cell across an orifice, the cell in turn being connected to a recorder and controller. The oxygen flows into the surge tank, and an equilibrium liquid level will be reached when the absorption of the liquid surface and falling spray balances the feed rate. To meet the estimated stability requirement of approximately 25 ppm, the oxygen feed rate will be adjustable over a range of 1 to 15 cc/minute at operating pressure.

The double valving connection in the oxygen system is provided for activity safety. The intermediate cylinder is kept charged by the pressure switch and valve 3. This switch closes valve 2 before opening valve 3, so during the brief charging interval the oxygen supply to the reactor is shut off. Two oxygen supplies are manifolded to the system with a low pressure alarm as protection against failure of the oxygen supply.

<u>Soup Circulation and Heat Exchanger</u>

The instrumentation on the main soup circulating system, including the pump and heat exchanger is shown in Figure 13, with specifications in Table 4.

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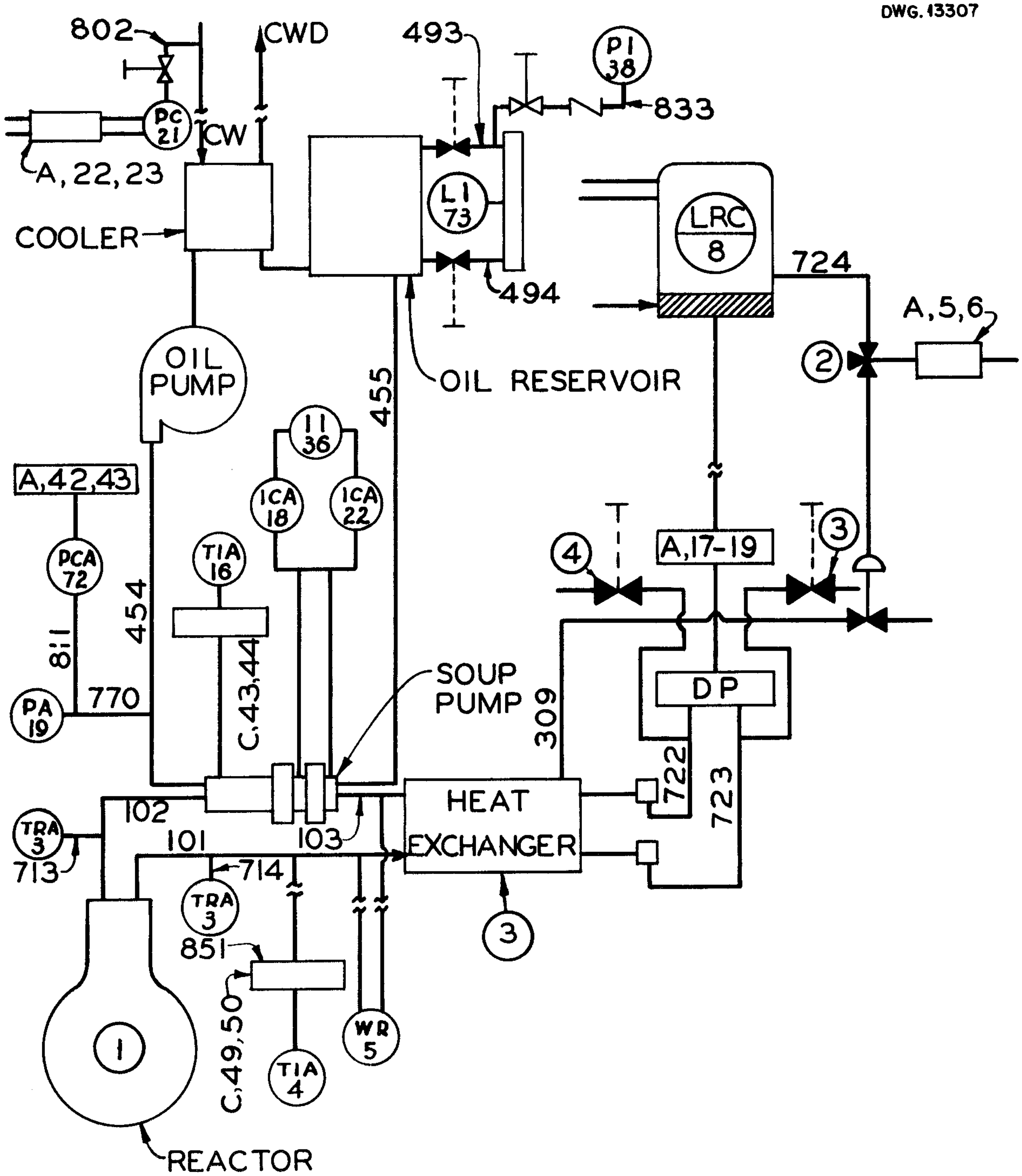

Fig. 13—Soup Circulation

TABLE 4

TIA-4

Receiver - Brown Circular Scale Contact Controller

range - 0-300° C
pen speed - 4-1/2 sec.
chart speed - 24 hr.
chart - 0-300 linear
mounting - flush
adjustments - front set
failure - fails upscale

Contacts: 1 CR interlock (differential adjustment)
1 CD (F.O.) (differential adjustment)

Location - panel board

Transmitter - I.C. thermocouple in line 101

J.B. C_1 - 49, 50

WR-5

Receiver - Brown Strip Chart Recorder

range - 0-3 mv.
pen speed - 24 sec.
chart speed - 10 inches/hr.
chart - 0-100 linear
mounting - flush

Location - panel board

Transmitter - I.C. T.C. lines 101, 102

J.B. C_1 - 53 - 56

Auxiliary Equipment - 1 contact T.C. adaptor (as built, insulated)

LRC-8

Receiver - Brown C.C. Recorder and Controller
Inductance bridge type

range - 0-20" H_2O
control - pneu-prop-reset-manual
chart speed - 24 hr/rev
chart - 0-20 linear
mounting - flush
adjustments - front set
failure - F.U.

TABLE 4 (CONTINUED)

LRC-8 (Continued)

Contacts: None

Location - panel board

Junction box: A_1 - 17 - 19

Transmitter - Brown Hg manometer inductance transmitter

range - 0-20" H_2O

Location - compartment in west face of shield

Auxiliary Equipment

(7) & (8) seal pots
(3) & (4) 1/8" Hoke valves with extension handles
(2) 1/4" ASCO solenoid valve (north face of shield)
J.B. A_1 - 5 - 6
(309) control element MH 1" valve (F.C.) (location in trench)

TIA-16

Receiver - Symplytrol Pyrometer with automatic reset

range - 0-500° F
mount - flush

Contacts: 1 CD alarm

Location - control room

Transmitter - I.C. couple with surface temp. adaptors
J.B. C_1 - 43-44

ICA-22

Receiver - G.E. Under current relay

range - 0-5 amps
mount - flush in draw-out case
type - IAC-55

Contacts: 1 normally closed - interlock
1 normally closed - alarm

Location - panel board

Auxiliary Equipment - current transformer 100/5 amps

(relay purchased as over current, changed to under current)

TABLE 4 (CONTINUED)

ICA-18

Receiver - G.E. Over current relay

type - PJC
range - 5 amps
mount - wall mount

Contacts: 1 N.C. interlock
1 N.C. alarm

Location - panel board

II-36

G.E. Ammeter

range - 0-5 amps
scale - 0-100 amps

PA-19

Receiver - MH pressure switch

range - 0-300 psi

Contacts: 1 CD alarm

Location - soup oil pump compartment

J.B. A_1 - 40, 41

PCA-72

Receiver - MH pressure switch

range - 0-300 psi

Contacts: 1 CR interlock
1 CR alarm

Location - soup oil pump compartment

J.B. A_1 - 42, 43

PC-21

Receiver - MH pressure switch

range - 0-150 psi

TABLE 4 (CONTINUED)

PC-21 (Continued)

Contacts: 1 CR interlock

Location - south face of shield

Auxiliary Equipment - 150 psi brass needle valve, line 802

PI-38

Receiver - 6" Clapp 0-300 psi

Location - west face of shield

Auxiliary Equipment - (5) 1/8" Hoke valve
(6) 1/8" Check valve

LI-73 - Sight Glass

Location - west face of shield

The measurements on the soup itself are confined to temperature determinations by thermocouples in wells welded to the main flow pipes. TI4 gives an indication of the temperature of the soup as it leaves the reactor. Both outlet and inlet soup temperatures are recorded by TRA-3, which is a multipoint Brown strip chart recorder. The other two thermocouples on the soup lines are connected differentially to WR5, a Brown circular recorder with an integrating attachment. Since the soup flow is constant, the differential temperature is a measure of power so WR5 is calibrated to read delivered reactor power.

The integrator associated with WR5 is a watt-hour meter connected to a second potentiometer in the recorder, as shown by Figure 14. The arm of this potentiometer is mechanically connected to the balancing motor of the recorder so its position corresponds to that of the recorder pen. It is seen that for a constant applied voltage, obtained from the regulated instrument supply source, the watt-hour meter will register the total delivered energy of the reactor.

Variations in soup flow may be detected by electrical measurements made on the pump motor, since any change of pumping load will reflect as a change in motor current. This current is indicated on an ammeter designated in Figure 13 as II36. Undercurrent and overcurrent are sensed by the current relays, ICA22 and ICA16. Both of these are connected into the reactor control circuit, as discussed later, so abnormal conditions will shut the reactor down. Gas binding of the pump, shaft breakage, or any other trouble which would remove the pump load but allow the motor to continue to run, would cause a drop in current and actuate the undercurrent relay. Any trouble, such as shaft binding, which would stop or even appreciably slow down the motor while voltage is still applied would cause an increase of motor current and the overcurrent relay would

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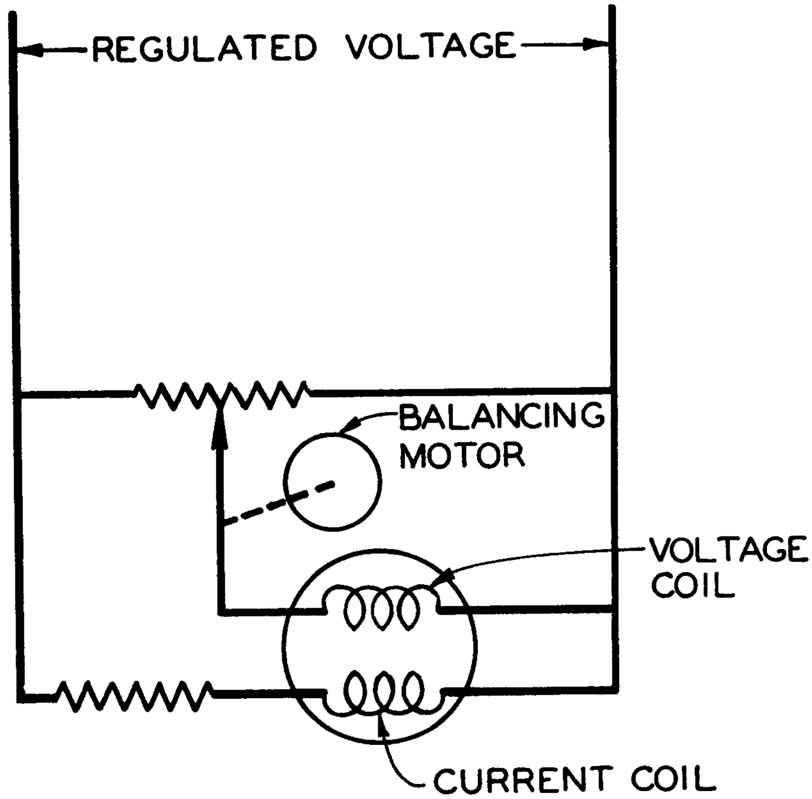

Fig. 14– Power Integrator

function. Both of these relays are quick operating. Thus, no stoppage of soup flow can occur without the reactor shutting down and consequently no serious overheating can occur from this cause.

The pump motor is oil-cooled and will quickly overheat if there is any interruption of oil flow. Over and under pressure switches PA19 and 72 on the delivery line of the oil pump provide alarm signals if trouble occurs in the oil system. Oil pump failure or low oil level will cause the low pressure alarm to function while plugging of the oil line or sludging in the oil will cause the high pressure alarm to operate. The cooling water supply is interlocked through pressure switch PC21 to the soup circulating pump motor so the pump cannot be started if cooling water is not flowing. Oil level in the reservoir may be checked by slight glass LI73 by opening the valves connecting the glass and reservoir. These valves are normally closed so radioactive material cannot get outside of the shield even if a leak from the soup system into the cooling oil does occur. Pressure gage PI38 gives an indication of any gassing due to radiation decomposition of the oil.

The circulating pump motor is further protected by a Simplytrol over-temperature alarm, TIA16, operating from a thermocouple on the motor casing.

The water level in the main heat exchanger is indicated and controlled by LIC8. This instrument consists of a Brown differential pressure cell and a pneumatic controller. The control point of the instrument may be adjusted at the instrument so level or rate of fill may be controlled manually. The controller operates the feed water valve in line 309 to regulate the supply from the feed water pump. However, this control may be overridden and the valve closed if excess activity is detected in the steam. This is accomplished through the solenoid valve in the air line. The operation of the monitor circuits will be discussed in a later section.

Concentration

The determination of concentration in the soup system is greatly complicated by the nature of the solution and system - a high pressure system containing a very radioactive solution which is gassing rather freely. A measurement scheme which may solve one difficulty generally fails to meet some other necessary specification.

The method used for the HRE is somewhat indirect and is subject to certain errors. The general operation of the concentration control has been discussed in connection with reactivity control, and schematic diagram of the actual measuring system is given in Figure 15. The condensate tanks are suspended from a Baldwin weigh cell which is in turn connected electrically to a Foxboro indicator. The specifications for this instrument are given in Table 5 .

The soup dump tank level measurement serves as a liquid balance check on the concentration calculations. A leak, whether due to structural failure or to a valve leakage to the outer dump tanks, will result in an error in concentration values. A leak out of the system should be detected promptly by one of the activity monitors, but one into the outer tanks would not show up except as a loss of level in the system. When the soup is dumped to the regular dump tanks the level indicator, LI14, serves as a check on the total soup in the system. When the reactor is operating, this instrument is not a very reliable monitor since the amount of soup in the core will fluctuate with power (and hence gassing).

The level instrument consists of a Wianco variable inductance transmitter connected to a Foxboro instrument. A small side chamber connected

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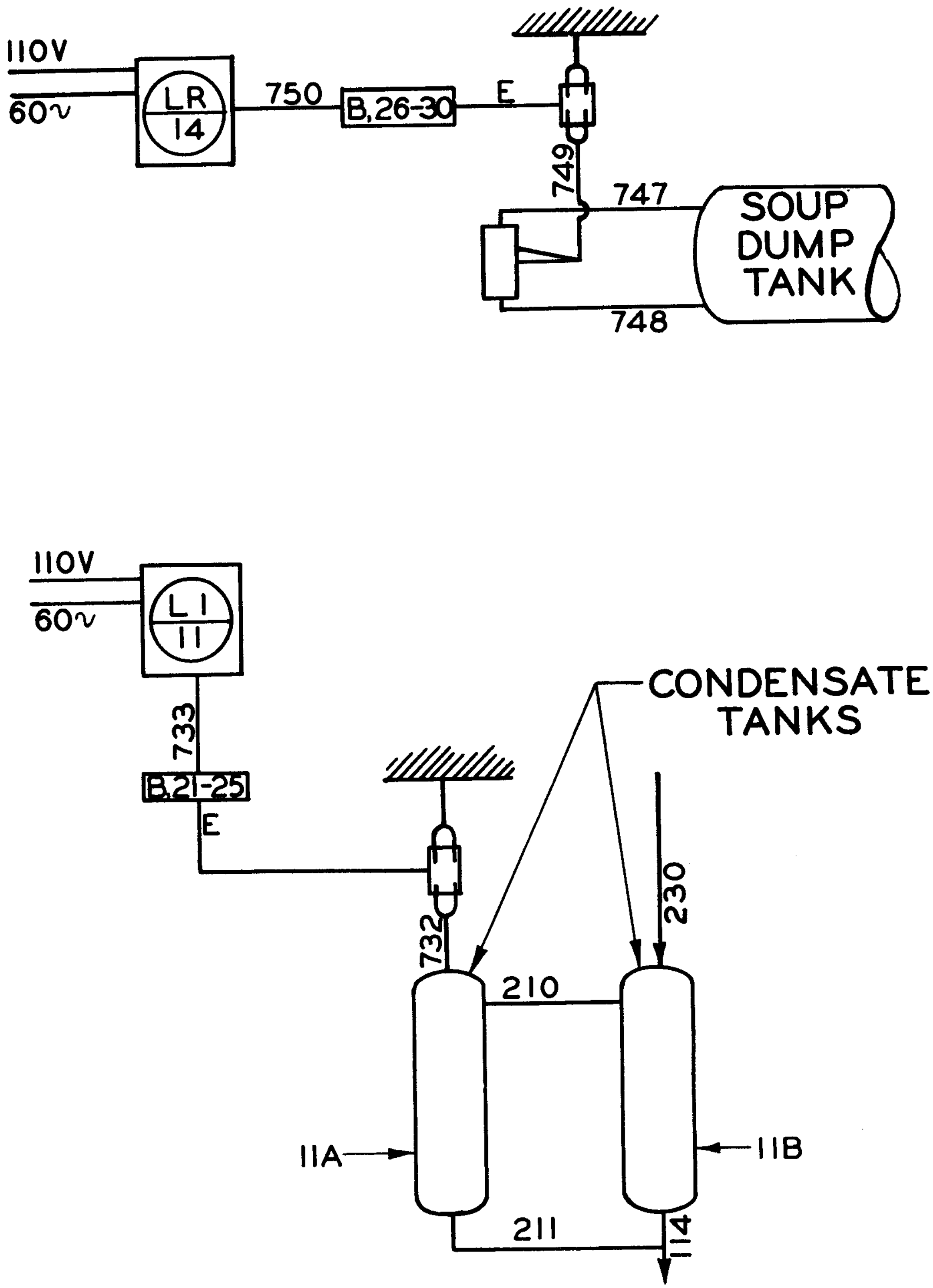

Fig. 15— Weight Systems

TABLE 5

LR-14

Receiver - Foxboro Dynalog C.C. Recorder for use with Wianco cells

range - 0-1 mv/v
pen speed - 3 sec.
chart speed - 24 hr/rev
chart - 0-100 linear
mounting - flush
adjustments - span and zero
input circuit - Fig. 11A

Location - panel board

Transmitter - Wianco cell (type 3FA15)

Location - soup cell

J.B. B_1 - 26 - 30

LI-11

Receiver - Foxboro C.C. Indicator for use with Baldwin Load Cell

range - 0-6 1/2 mv/v; 0-150 kg
pen speed - 3 sec.
mounting - flush
adjustments - zero adjustable to 500 pounds
input circuit - Fig. 11C

Location - panel board

Transmitter - Baldwin tension load cell
2 " lead shield

range - 0-180 kg
J. B. B_1 - 21 - 25

Location - soup cell

to the dump tanks by tubes serves as a weigh tank suspended from the Wianco unit. Thus, level is determined by weighing the liquid in this side tank.

Soup Off-Gas Recombiner

The soup off-gas recombiner system is given in Figure 16. Reference to Figure 4 will show that this is a detail of the system between the soup off-gas condenser and the cold traps. The instrument specifications are presented in Table 6.

The flow of gas and steam to the flame recombiner is metered by a Foxboro differential pressure cell and Dynalog controller across the orifice. This flow is used to control the cooling water to the off-gas condenser to prevent flash-backs from the recombiner to the condenser. At high gas flows the velocity in line 116 is high enough to prevent a flash-back, but at low gas flows it is necessary to increase the steam content. This is accomplished by decreasing the cooling water to the condensers. The absolute pressure in this line is recorded by PR-78, consisting of a Baldwin pressure cell and a Foxboro circular chart recorder.

The only other instrument control on the recombiner system is temperature control of the cooling water to the flame recombiner. The temperature of the gas between the flame and catalytic recombiners is sensed by a thermocouple which is connected to a Brown controller (TRC-6) which effectively maintains the correct steam and gas flow to the catalytic unit.

Numerous temperatures may be determined with thermocouples indicated as TI17, which are connected to a 48-point Brown precision indicator. In addition, the flame recombiner temperature is recorded on TRA-3. These various temperatures in conjunction with the cooling water flow meters, FI84 and FI 58, will furnish data for calculation of the gas recombination rate.

DWG. 13310

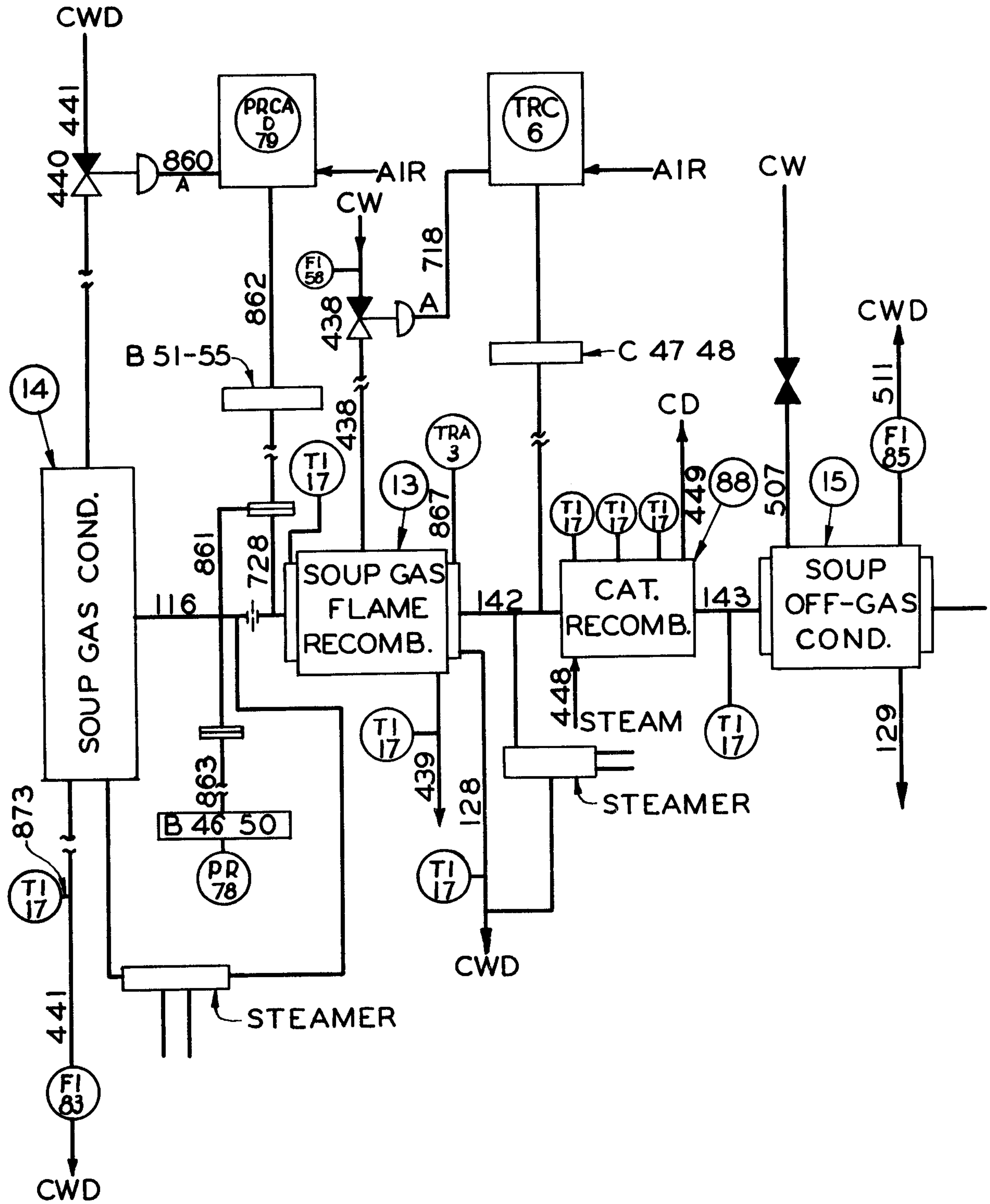

Fig. 16–Soup Off-gas

TABLE 6

PR-78

Receiver - Foxboro Dynalog C.C. Recorder for use with Baldwin pressure cell

range - 0-1/4 mv/v
pen speed - 1 sec.
chart speed - 24 hr/rev
chart - 0-50 psi
mount - flush
adjustment - zero
input circuit - Fig. 11D

Location - panel board

Transmitters - Baldwin pressure cell

range - 0-200 psi, 0-1 mw

Location - pressure cell compartment

J.B. B_1 - 46 - 50

PRCA/D-79

Receiver - Foxboro Dynalog C.C. Recorder Controller

range - 0-20"
pen speed - 3 sec.
chart speed - 24 hr/rev
control - pneu, prop, reset, manual
mounting - flush
chart - 0-20"
adjustments - front set and zero
failure - fail downscale
input circuit - Fig. 11D

Location - panel board

Contacts: 1 CD alarm

Transmitter - Foxboro D/P cell

range - 0-20"

Location - line 116 (soup cell)

J.B. B_1 - 51 - 55

Auxiliary Equipment - (440) Control element MH valve (F.O.)

TABLE 6 (CONTINUED)

FI-83

12 gpm water meter

Location - line 441

FI-85

12 gpm water meter

Location - line 511

TRA-3

(See Table 12)

TRC-6

Receiver - Brown C.C. Air-O-line Controller

range - 0-400° C
pen speed - 12 sec.
control - pneu, prop, reset, manual
chart speed - 24 hr/rev
chart - 0-400 linear
mount - flush
adjustments - front set
failure - upscale

Contacts: 1 CR alarm
1 CD alarm

Location - panel board

Transmitter - I.C. couple with T.C. weld line 142
J.B. C_1 - 47, 48

Auxiliary Equipment - (438) MV valve control element (F.O.)

FI-58

12 gpm water meter

Location - line 438

The pressure in this system is controlled by the mercury level in the seal pot shown in Figure 4 between the charcoal traps and the stack fan. For normal operation the vacuum pump is not in operation.

Reflector Pressure and Level

The reflector is pressurized with helium to a value slightly (approximately 50 psi) above the core pressure by the differential pressure controller, PRCA/D 10, Figure 17. Two Baldwin pressure cells, 4 and 5, are connected electrically to PRCA/D 10, a Foxboro Dynalog pressure controller. The pneumatic control signal from this instrument is applied to valves 267A and 270. Helium is supplied from cylinders manifolded to line 267 at the right of Figure 17. A pressure differential, other than the set-point of the instrument, between core and reflector will apply air to valve 267A or 270, depending upon the direction of the differential. Low reflector pressure will cause valve 267A to open and admit helium to the reflector space through the control rod housings (see Figure 4). Excess reflector pressure opens valve 270 and bleeds helium from the reflector to the dump tanks.

The requirements for proper pressure control during a dump of reflector or core are not met by the basic control just outlined. The two helium control valves are necessarily small to give suitably fine control, and hence cannot pass helium rapidly enough to keep pressures equalized during a dump. Actually, these valves have a Cv of .07 and the equation for valve flow,

$$Q = \frac{61\ Cv \sqrt{(P_1 - P_2)\ P_2}}{\sqrt{G}},$$

may be applied to get maximum flow. In this equation, Q is flow in scfh, P_1 and P_2 are pressures on either side in psi, and G is the specific gravity of the gas referred to air.

[redacted]Y
DWG. 13311

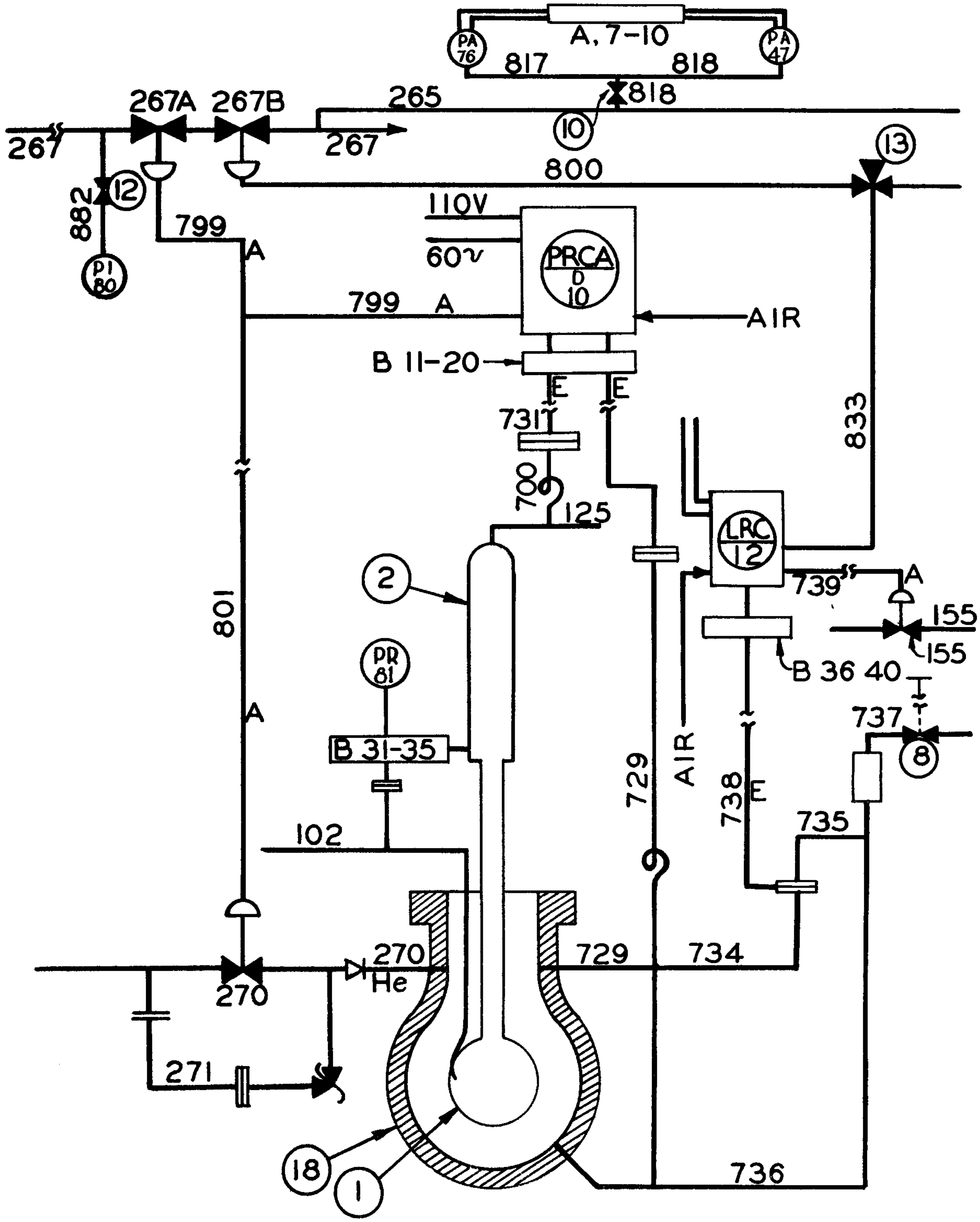

Fig. 17– Deflector

[redacted]

TABLE 7

PR-81

Receiver - To be supplied (scope)

Transmitter - Wianco pressure cell

range - 0-2000 psi
J.B. B-31 - 35

Location - reactor compartment

PI-80

Receiver - 0-1500 psi, 6" Clapp

Location - control room

Auxiliary Equipment - (12) 1/8" Hoke valve, line 882

PA-47

Receiver - Mercoid pressure switch 0-1500 psi (CD)

Location - north face of shield

Contact: 1 CD high alarm
J.B. A_1 - 7, 8

PA-76

Receiver - Mercoid 0-1500 psi press. switch

Location - north face of shield

Contacts: 1 CR low alarm
J.B. A_1 - 9, 10

Auxiliary Equipment - (10) 1/8" Hoke valve, line 818

PRCA/D-10

Receiver - Foxboro Dynalog C.C. Recorder Controller

range - 50 to + 150 psi
pen speed - 3 sec.
control - pneu, prop, derivative, manual
chart speed - 24 hr/rev
chart - 50 to + 150 linear
mount - flush
adjustments - zero
failure - upscale
input circuit - Fig. 11D

[redacted]

TABLE 7 (CONTINUED)

PRCA/D-10 (Continued)

Contacts: 1 CD interlock F.O.
1 CR alarm F.O.
1 Air switch closes on pressure rise-alarm

Location - panel board

Transmitters - (4) & (5) Baldwin pressure cells

range - 0-2000 psi
J.B. B_1 - 11 - 20

Location - pressure cell comp.

Auxiliary Equipment - Sylphons in lines 700 & 729
(267-A) control element - MN 108

Location - north face of shield

(270) control element - 1/8" Belfield (F.O.)

LRC-12

Receiver - Foxboro C.C. Recorder Controller for use with Foxboro D/P cells

range - 0-20, 0-30 inches H_2O
pen speed - 3 sec.
control - pneu, prop, reset, manual
chart speed - 24 hr/rev
chart - 0-100 linear
mounting - flush
adjustments - span & zero
failure - upscale
input circuit - Fig. 11B

Contacts: 1 CD interlock
2 CR Air switch (F.C.) interlock (move with control point)
1 CR interlock (half full point)

Location - panel board

Transmitter - (6) Foxboro 30" D/P cell

Location - south face of D_2O cell
J.B. B_1 - 36 - 40

TABLE 7 (CONTINUED)

LRC-12 (Continued)

Auxiliary Equipment - (7) gas chamber (1 1/2" SS pipe, 12" long)
(8) 1/8" Hoke valve, extension handle
(155) control element - 1/8" Belfield (F.O.)

Mounting Dimensions: top of reflector top flange to top of D/P cell - 5 1/16": top of D/P cell to full level - 9 5/16": top of D/P cell to zero level - 39 5/16": top of D/P cell to full level 49".

During a reflector dump without soup dump the pressure drops rapidly, the D_2O dumping in approximately 15 seconds. This causes valve 267A to open wide and 270 to close. In time this would admit enough helium into the vessel to bring the now empty reflector back to approximately 1050 psi, requiring approximately 16 cubic feet of gas at this pressure. Upon refilling the reflector, this helium would be blown into the dump tanks through valve 270. As the reflector is dropped for any shutdown of more than a few seconds duration, it is apparent that this loss of helium is very undesirable. Valve 267B is therefore interlocked through its solenoid valve to the dump valve, 150, so it closes on a dump and thus prevents flow of helium into the system. This valve is further interlocked with the reflector level controller so it will be closed whenever the reflector is below the half full point (minimum operating level). This feature is necessary because the dump valve closes when the reflector is empty and hence without the level interlock valve, 267B, would open and admit helium.

The rapid dump means an essentially adiabatic process, so the reflector pressure will drop to slightly over 100 psi, permitting a pressure differential across the core shell of 900 psi. Some D_2O should remain in the bottom of the vessel when the dump valve closes so its vapor pressure will soon reduce the differential pressure approximately 100 psi for rated operating temperature. However, the reactor will be operated during certain experiments at reflector temperatures below 175° C. While the core should withstand the expected 900 psi differential, it is strongly recommended that a normal shutdown procedure require the reactor to be made subcritical by lowering the concentration and that the core pressure then be reduced to approximately 500 psi, allowing PRCA/D-10 to bring the reflector pressure to a corresponding value before the reflector is dumped.

[redacted]

A core dump without reflector dump would apply a high differential pressure from the outside and might cause collapse of the core. Two precautions are provided to prevent this condition occurring. The reflector dump valve is interlocked with the core dump valve as discussed later under "Safety Circuit," so the reflector dumps simultaneously with the core. A back-up protection to care for this and also for a failure in the helium system is provided by connecting the reflector dump valve solenoid to PRCA/D-10 so excessive differential pressure from reflector to soup will open the D_2O dump valve and relieve the pressure.

Reflector level is controlled by LRC-12, consisting of a Foxboro D/P cell and Dynalog controller. Since the connection of the D/P cell is somewhat unorthodox it is discussed in conjunction with Figure 18. The gas chamber, 7, is provided to collect any gas which may get into lines 735 and 736. Periodically this gas can be bled off through valve 737 which is provided with an extension handle to the outside of the shield. If we assume an equilibrium condition with the reflector full and pressurized to P_o, the gas pressure in 7 being P_1, and other pressures being due to water columns, the pressure on the top of the cell is:

$$P = P_1 + P_3 - P_2.$$

If the level drops to a point corresponding to a hydrostatic pressure change of P_4, the new pressure is:

$$P' = P + P_3 - P_2 - P_4,$$

or the change of pressure is P_4. Thus, since the other side of the cell is maintained at P_o, the differential pressure change corresponds to the change of level. It is seen that the initial gas pressure, P_1, does not affect the instrument provided it does not cause the liquid level to drop below line 735.

[redacted]

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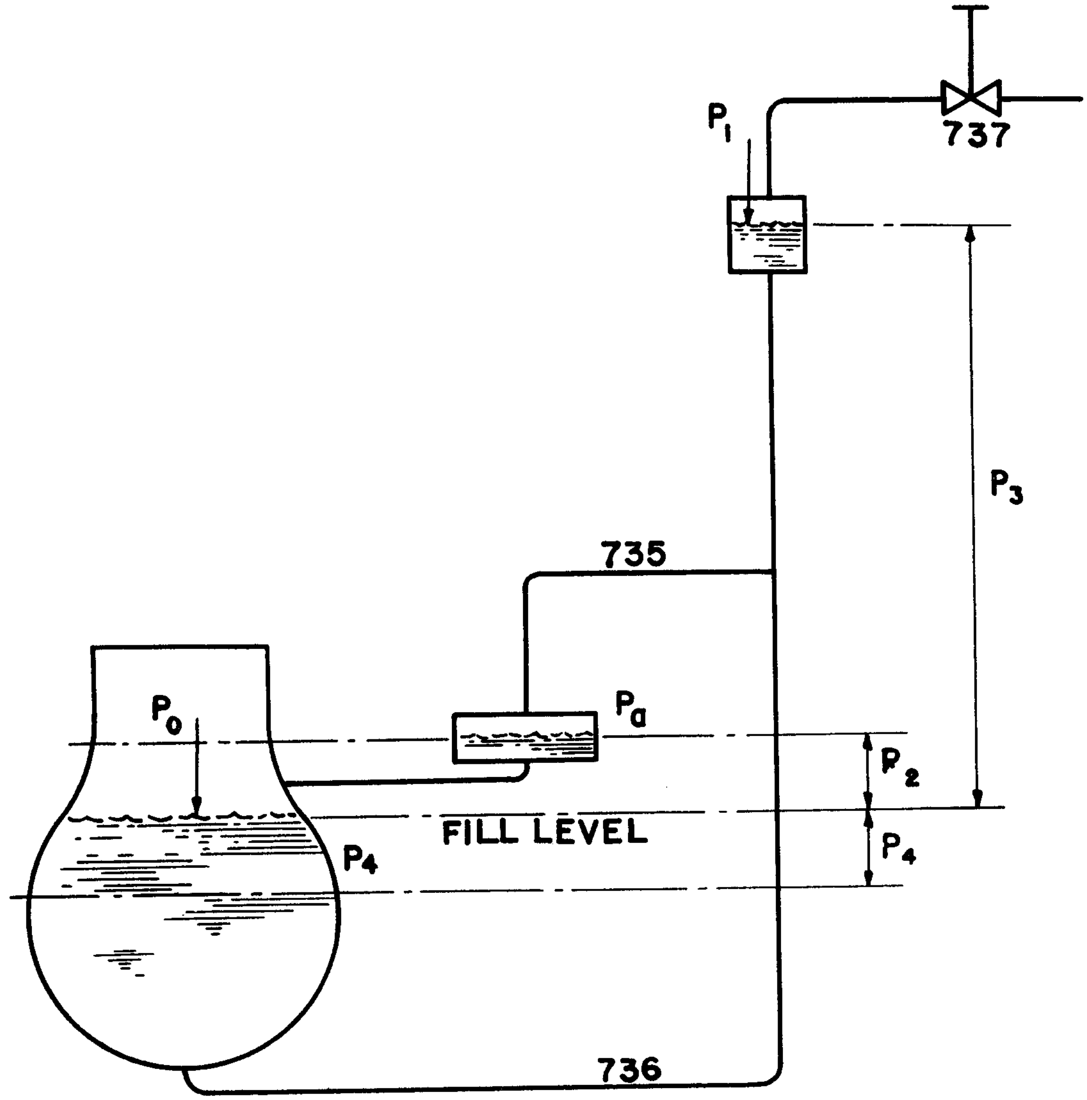

Fig. 18 — Reflector Level

Line 855 of Figure 17 is provided to remove condensate from line 734. Junction 11 of Figure 17 must be above the maximum water level because the instrument indications reverse if this junction is submerged.

The controller is provided with a proportional air control and several electrical contacts. The control point may be set at the instrument by the operator, subject to a lower limit of a half full reflector. This limit is provided by a blocking pin at half scale so the operator cannot run the reactor without sufficient reflector for safety. Excess D_2O is bled off through valve 155, which is actuated by the air signal when the level is too high. The pulsafeeder pump is controlled by two electrical contacts so it is started if the level falls to the lower one and is stopped when it reaches the upper one. The details of the electrical controls are shown in the safety circuit. In addition to these contacts, two others are provided for control during a reflector dump. One just below the half full point provides an interlock on the helium valve, 267B, as discussed above. The remaining contact is a lower limit control which operates the solenoid of the dump valve, 150, to close this valve before the reflector is completely empty.

Several other instruments are provided on this system, but do not serve as controls. PA47 and PA76 are pressure switches on the helium supply to give an alarm on the annunciator if trouble develops in this supply. PI80 is a pressure gage giving the absolute pressure in the reflector.

Reflector Temperature

The reflector temperature is maintained at the desired value by circulating the D_2O through a heat exchanger whose cooling water is controlled by valves 310 and 313. The instrument connections are shown in Figure 19, and the specifications are given in Table 8. Reference to the complete flow sheet

[redacted]
DWG. 13313

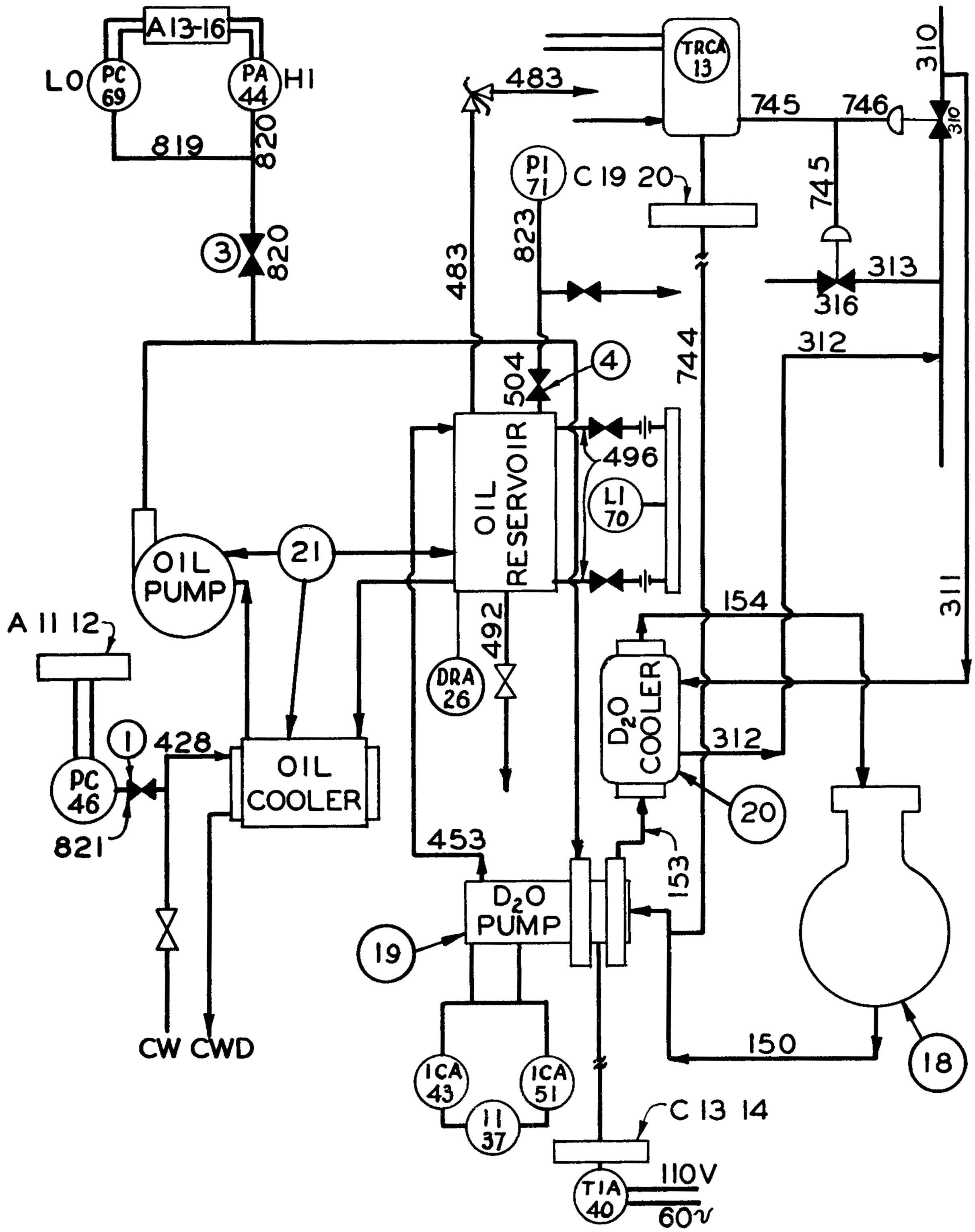

Fig. 19 — D_2O Circulation

[redacted]

TABLE 8

TRCA-13

Receiver - Brown C.C. Air-O-line Controller

range - 0-300° C
pen speed - 12 sec.
chart speed - 24 hr/rev
chart - 0-300
control - pneu, prop, reset, manual
mount - flush
adjustment - none
failure - downscale

Contacts: 1 CR alarm (F.O.)

Location - panel board

Transmitter - I.C. couple & T.C. well

Location - line 152

J.B. C_1 - 19, 20

Auxiliary Equipment - (313) control element 1" MH valve, line 313
(310) control element 1 1/4" MH valve, line 310

II-37

G.E. Ammeter

range - 0-5 amps
scale - 0-50 amps

Location - panel board

TIA-40

Receiver - Symplytrol Indicator Pyrometer

range - 0-500° F

Location - panel board

Contacts: 1 CD alarm

Transmitter - I.C. couple, surface adaptor

Location - D_2O circulating pump

J.B. C_1 - 13, 14

[redacted]

TABLE 8 (CONTINUED)

ICA-43

G.E. Under current relay

Type IAC
(converted from overcurrent to undercurrent)

Contacts: 1 normally closed

Location - panel board

ICA-51

G.E. Overcurrent relay

Type PJC

Contacts: 1 normally closed

Location - panel board

PA-44

Receiver - MH pressure switch 0-300 psi

Location - D_2O oil pump platform

Contact: 1 CD alarm
J.B. A_1 - 13, 14

Auxiliary Equipment - (3) 1/4" brass needle valve, line 820

PC-46

Receiver - MH pressure switch 0-150 psi

Location - D_2O oil pump platform

J.B. A_1 - 11, 12

Contact: 1 CR interlock

Auxiliary Equipment - (1) 1/4" brass needle valve

PCA-69

Receiver - MH pressure switch 0-300 psi

Location - D_2O oil pump platform

J.B. A_1 - 15, 16

TABLE 8 (CONTINUED)

LI-70 - Sight glass

Location - D_2O oil reservoir

PI-71

Receiver - 6" Clapp 0-300 psi

Location - D_2O oil reservoir

Auxiliary Equipment - (4) 1/4" brass needle valve

DA-26

Receiver - B-W conductivity alarm

Location - D_2O oil pump platform

Contact: 1 normally closed

of Figure 4 will show that the cooling water is supplied by the feed water pumps of the reactor heat exchanger, thus the heat removed from the D_2O is used to preheat the feed water. The temperature is determined by a thermocouple in line 152 connected to a Brown circular chart controller. The pneumatic control signal from this actuates valves 310 and 313. If both of these valves are closed the flow through the D_2O heat exchanger will be determined by the demand of the soup heat exchanger. This condition holds if this feed water demand is just right to maintain the correct D_2O temperature. If the flow to the main heat exchanger is too low the D_2O temperature rises and the controller opens valve 313, allowing additional flow through the D_2O exchanger. If the soup heat exchanger demands more water than that necessary to remove the D_2O heat, the D_2O cools and the controller opens valve 310, thus allowing part of the flow of feed water to by-pass the D_2O exchanger.

The D_2O circulating pump is similar, except for size, to the soup circulating pump and the motor protection is the same as that provided for the soup pump with the exception of the pump leak detection. The oil reservoir is equipped with a spark plug at its lowest point. This plug is connected to a conductivity alarm, DA26, so any D_2O leakage will be detected when the D_2O collects across the plug contacts.

D_2O Dump System

The D_2O inventory in the dump tanks is monitored by a load cell similar to that discussed for the soup dump tanks. The connections are shown in Figure 20, and instrument data is given in Table 9.

There are no control instruments on the dump system, but temperature measurements are provided for at several points, as shown on the flow sheet.

[redacted]

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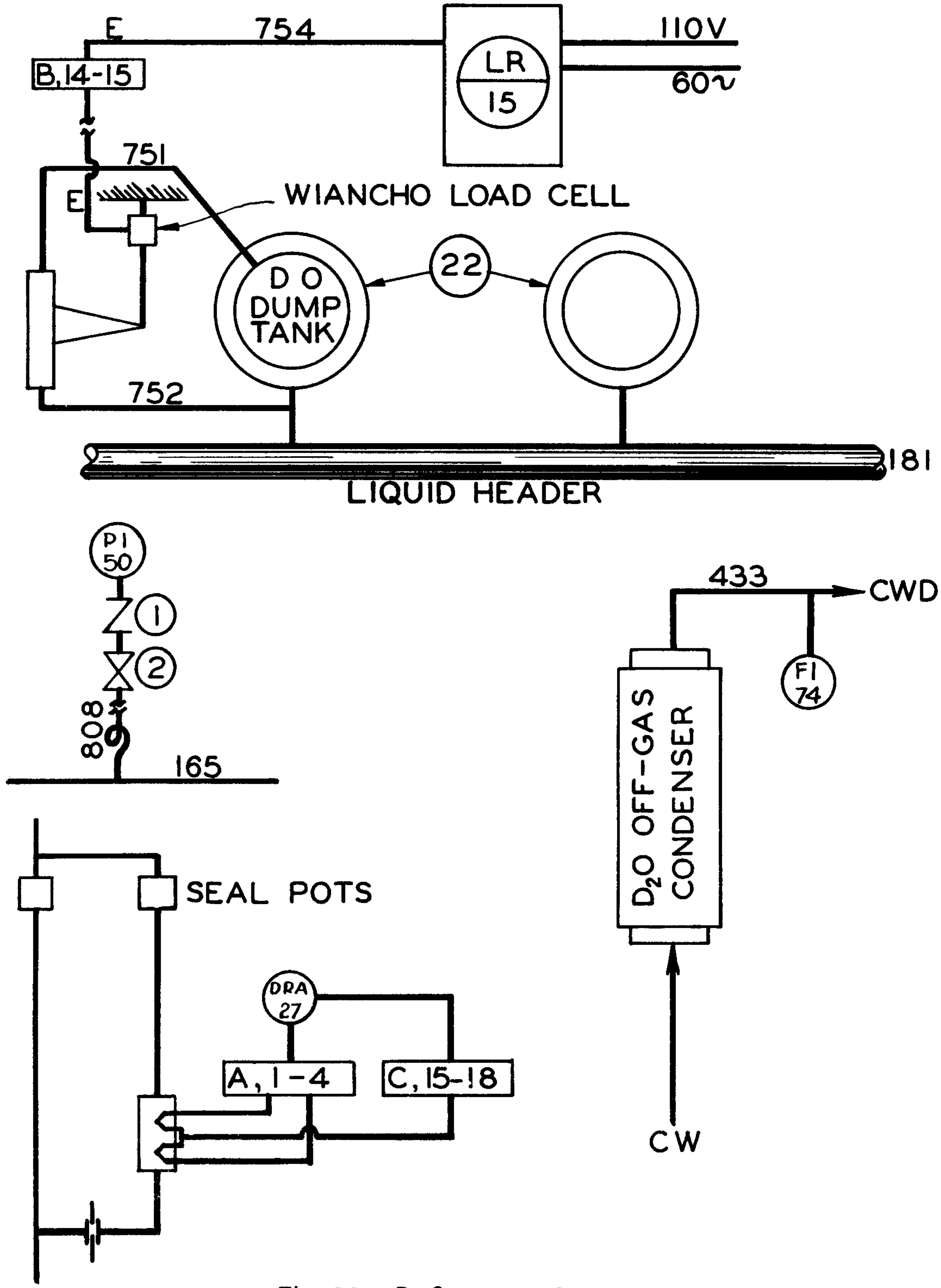

Fig. 20– D_2O Dump System

TABLE 9

LR-15

Receiver - Foxboro dynalog circular chart recorder for Wianco cell

range - 0-1 mv/v
pen speed - 3 sec.
chart speed - 24 hr/rev
chart - 0-100 linear
mounting - flush
adjustments - span & zero
input circuit - Fig. 11A

Location - panel board

Transmitter - Wianco cell, type 3FA15

Location - soup cell

J.B. - B_1 - 41, 45

DRA-27

Receiver - Brown C.C. Recorder

range - 0-1 mv
pen speed - 24 sec.
chart speed - 24 hr/rev
chart - 0-100 linear
mounting - flush

Location - panel board

Contacts - 1 CD alarm

Transmitter - platinum detector as built

Location - D_2O cell

J.B. C_1 - 15 - 18 (T.C.)

A_2 - 1 - 4 (heaters)

Auxiliary Equipment - (1) and (2) Hg seal pots
(3) flat plate orifice, line 168

Pl-50

Receiver - 6" Clapp, 0-500 psi

Location - north face of shield

TABLE 9 (CONTINUED)

P1-50 (Continued)

Auxiliary Equipment - (1) 1/8" check valve
(2) 1/8" Hoke valve
(3) Sylphon, line 808

FI-74

12 gpm water meter

Location - east face of shield

The thermocouples are connected to the 48-point precision indicator on the operating console. These temperatures in conjunction with the water flows in the condensers, measured by water meters, give data to compute vapor and gas flows in the off-gas system. Pressure measurement is provided by a pressure gage, PI50, on the condenser header.

The catalytic recombiner temperature is a good indicator of the D_2 - O_2 percentage in the helium off-gas. If the recombiner were perfectly insulated its only coolant would be the helium flowing through it, while its source of heat would be the recombination of the deuterium and oxygen. The resultant catalyst temperature would then be an excellent indication of the net effect of these two processes. While the recombiner insulation is not perfect, the temperature is expected to yield an accurate determination of gas composition. The unit will be calibrated for this purpose before installation.

As a check on the recombiners a deuterium detector is being developed and will be installed in the off-gas line 168 as item 94 (Figure 4). The basic detector is a Davis hydrogen detector which is essentially a platinum filament operated at about 500° C and having a thermocouple attached so its temperature may be determined. The platinum serves as a catalyst for the recombination of hydrogen and oxygen, and is in turn heated by the reaction. This rise of temperature is a measure of the amount of recombination. To apply this device to the present system it must be modified to operate over a wide range of flow rates, ranging from a low of a few cc/minute due to helium valve leakage up to 15 scfm during a dump. To compensate for variable cooling with variable flow, a second filament of a non-catalytic material is used and its thermocouple connected in opposition to that of the platinum. Tests indicate that alumel is one of the more suitable materials for this, but due to differences in emissivity of it and platinum it does not compensate over the full range of flows. The rate of flow will therefore be controlled by use of mercury seal pots and orifice as shown in Figure 20. Pot 1 is set for a slightly higher pressure than 2, so for low flow rates the flow is entirely through the detector, while for high flows the orifice restricts the detector flow so most of the gas flows through pot 1. An experimental curve of the flow characteristics of the detector is shown in Figure 21.

The vacuum break provided between the helium supply and the off-gas line is a standard acetylene regulator backed by an instrument-type pressure regulator set to maintain a low gage pressure in the off-gas line. This relieves the vacuum formed after a dump has occurred and the vapor pressure has dropped due to the condensers and cold traps. The seal pot in the off-gas line is set to relieve at slightly above this regulated pressure.

Steam Instrumentation

Two auxiliary sources of steam are provided, one the house boilers and the other the electrically-heated 40 kw high pressure boiler. The valving for these is shown in Figure 4, and except for safety interlocks the control is manual. The interlocks are discussed later under "Activity Monitors."

The instrumentation of the 40 kw boiler is given in Figure 22 and Table 10. The level instrument is a Brown 20 inch mercury manometer connected to a Brown flow recorder. The high and low level contacts of the recorder are connected to the boiler heater circuit so the heaters cannot operate if the level is outside the limits. PCA45 is a pressure switch also connected to disconnect the heaters if the pressure gets too high. The steam pressure is indicated by a conventional pressure gage.

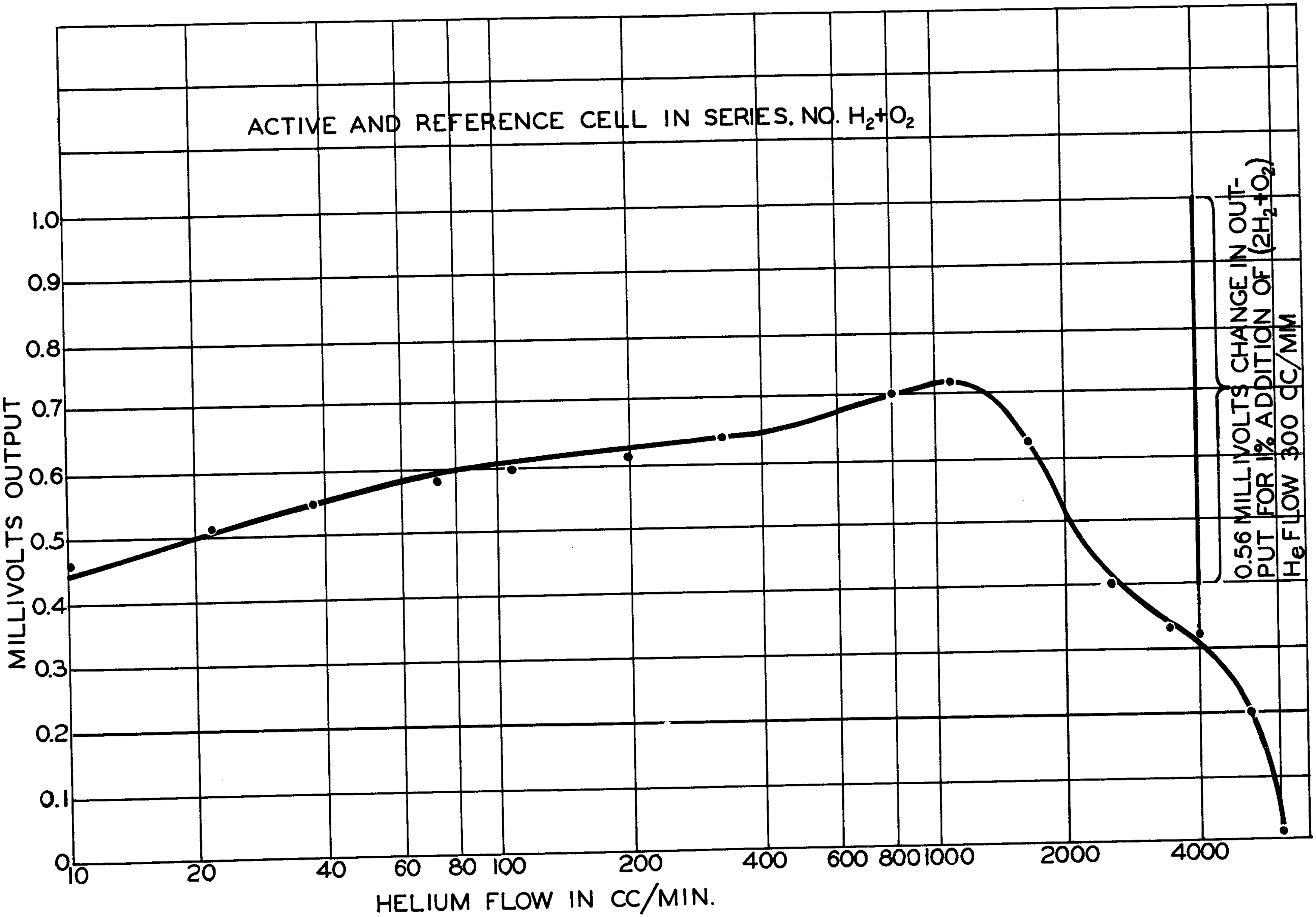

Fig. 21- D_2O Detector

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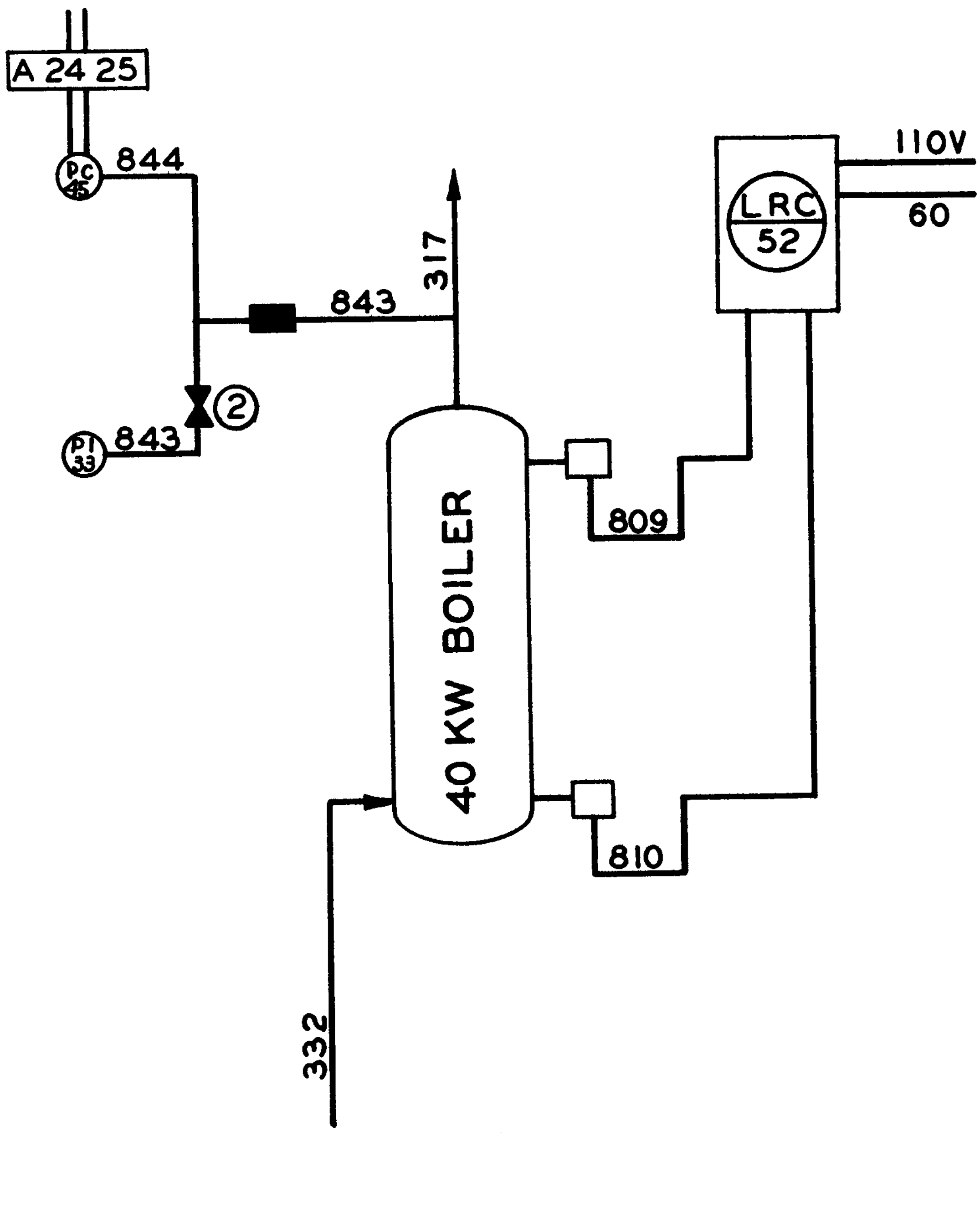


Fig. 22–40 kw Boiler

TABLE 10

PI-33

Receiver - 6" Clapp 0-1000 psi

Location - west face of shield

Auxiliary Equipment - (2) 1/8" Hoke valve, line 843
(1) autoclave check valve, line 843

PCA-45

Receiver - 0-1500 Mercoid pressure switch

Location - west face of shield

Contact: 1 CD high alarm
J.B. A_1 - 24, 25
1 CD interlock (pickup on annunciator)

LRC-52

Receiver - Brown Hg Manometer

range 0-20 inches H_2O
chart speed - 24 hr/rev
chart - 0-100 linear
mount - flush
failure - upscale

Contacts: 1 CD interlock (F.O.)
1 CR interlock
J.B A_1 - 26 - 29

Location - panel board

Auxiliary Equipment - (3) & (4) Seal pots (connect to 40 kw boiler with A106 3/4" pipe)

The several pressure indicators on the steam system shown in Figure 4 are standard and data is given in Table 11. The steam pressure and flow from the heat exchanger are metered by a regular pressure connection and a Brown mercury manometer transmitter across an orifice in the steam line connected to a two-pen Brown recorder, PR31. This instrument gives the delivered power of the reactor.

PC30 is a pressure switch to provide an interlock for the safety circuit in the event of a line break.

Valve 347 is interlocked through a time delay with valve 316B so the condensate return may be switched from the heat exchanger line to the building line when the steam source is switched.

Cold Traps

The cold traps for the soup and D_2O systems have identical controls as shown in Figure 23. Besides the compressor controls, the traps themselves are provided with various control valves. The refrigerant is regulated by float valves rather than expansion valves and may be shut off from either trap by the solenoid valve for defrosting. The connection of the electrical switches and the solenoids is arranged to prevent both traps being defrosted at the same time. However, both may be refrigerated at the same time. Thermostats on the cold traps are connected in parallel with the valve position relay contacts to sound an alarm if gas is valved through a warm trap.

Alarm Annunciator and Mimic Panel

The alarm annunciator uses a circuit similar to that used in the MTR, as shown in Figure 24. The panel contains fifty-four stations to provide the alarms shown in Table 13 and necessary spares for future needs. The operation

TABLE 11

PC-30

Receiver - 0-1500 psi MH pressure switch

Location - west face of shield

Contacts: 1 CR - interlock
J.B. A_1 - 44, 45

Auxiliary Equipment - 1/8" Hoke valve

PI-31

Receiver - Brown C.C. Recorder (2 pens)

range - 0-400 psi (0-200 inches H_2O)
chart drive - 24 hr/rev
chart - 0-200 linear
mounting - flush
adjustments - none

Location - panel board

Transmitters - Hg manometer with electric transmission

range - 0-20 inches H_2O
0-200 inches H_2O

Auxiliary Equipment - Autoclave check valve (line 840)
Flat plate orifice (line 316) (steam capacity 3000 #/hr)

PI-32

Receiver - 6" Clapp, 0-600 psi

Location - turbine gage board

Auxiliary Equipment - 1 autoclave surge check valve
1 1/8" Hoke
1 sylphon, line 841

FI-53

Flat plate orifice and manometer

Location - turbine gage board

TABLE 11 (CONTINUED)

PI-77

Receiver - 6" Clapp 0-1000 psi

Location - turbine gage board

Auxiliary Equipment - 1 - 1/8" Hoke valve

P1-34

Receiver - 4 1/2" Clapp, 0-75 psi

Location - on turbine gage board

Auxiliary Equipment - 1 - 1/4" brass needle valve

P1-35

Receiver - 4 1/2" Clapp, 0-100 psi

Location - west face of shield

Auxiliary Equipment - 1 - 1/8" check valve
1 - 1/4" brass needle valve
1 - Sylphon, line 834

P1-39

Receiver - 6" Clapp, 30" vacuum to 50 psi

Location - turbine gage board

Auxiliary Equipment - 1 - 1/4" brass needle valve
1 - 1/8" check valve
1 - Sylphon

P1-41

Receiver - 6" Clapp, 0-100 psi

Location - west face of shield

Auxiliary Equipment - 1 - 1/4" brass needle valve
1 - 1/8" check valve
1 - Sylphon, line 805

[redacted]

TABLE 11 (CONTINUED)

P1-42

Receiver - 4 1/2" Clapp, 0-1000 psi

Location - turbine gage board

Auxiliary Equipment - 1 - 1/8" Hoke valve

[redacted]

TABLE 12

TRA-3

Receiver - Brown Strip Chart 0-400° C

range - 0-400° C
pen speed - 4 1/2 sec.
chart speed - 30, 60, 90, 120 in/min
chart - 0-400
mounting - flush
adjustments - none
failure - none

Contacts: 1 CD high alarm (line 712)
1 CR low alarm (line 715)

Location - panel board

Transmitter - Five I.C. thermocouple bayonets

Location -

J. B. Terminals - C_1 - 1 - 12

Auxiliary Equipment - 3 T.C. wells
2 surface adaptors

TI-17

Receiver - Brown Precision Indicator (48 points)

range - 0-300° C
speed - 12 sec.
scale - 0-300
mount - flush

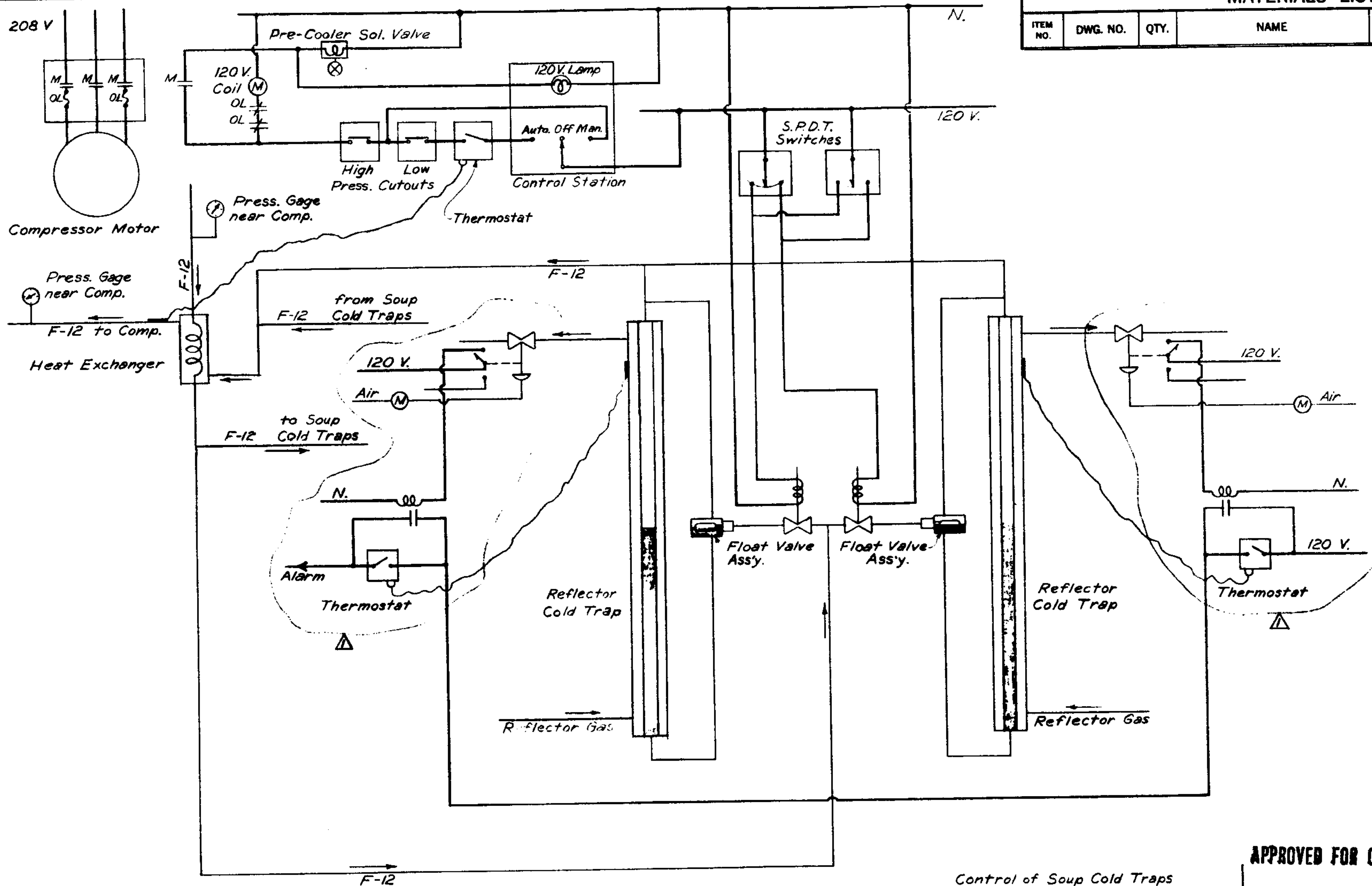
Location - panel board

Transmitter - I.C. couples

[redacted]

ITEM NO.	DWG. NO.	QTY.	NAME	SIZE	MATERIAL

MATERIALS LIST



Control of Soup Cold Traps is identical with Reflector Cold Traps.

SCHEMATIC FLOW DIAGRAM

Fig. 23

-80-

APPROVED FOR CONSTRUCTION

REFERENCE DRAWINGS	DWG. NO.

NO.	REVISIONS	DATE	APPR.	APPR.
1	changed reflector gas controls - added alarm	9-21-51		

DRAWING NO. C-9600

DRAWN	DATE	CHECKED	DATE	APPROVED	DATE
Brown	8-13-51		9-5-51		
DESIGNED	DATE	SUBMITTED	DATE	APPROVED	DATE

HEALTH PHYSICS	MEDICAL	OPERATIONS	SAFETY
FIRE PROTECTION	RESEARCH SHOP	MAINTENANCE	

THIS DRAWING CLASSIFIED AS [redacted] PER C. L. [illegible]

LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED

FRACTIONS: ±

DECIMALS: ±

ANGLES: ±

SCALE: None

H.R.E. EQUIPMENT - BLDG. 7500

COLD TRAP CONTROLS

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
CARBIDE AND CARBON CHEMICALS DIVISION
UNION CARBIDE AND CARBON CORPORATION
OAK RIDGE, TENNESSEE

SUBMITTED	ACCEPTED	APPROVED

C-9600

R:

UNCLASSIFIED
DWG. 13317

CIRCUIT DEENERGIZED
NO TROUBLE

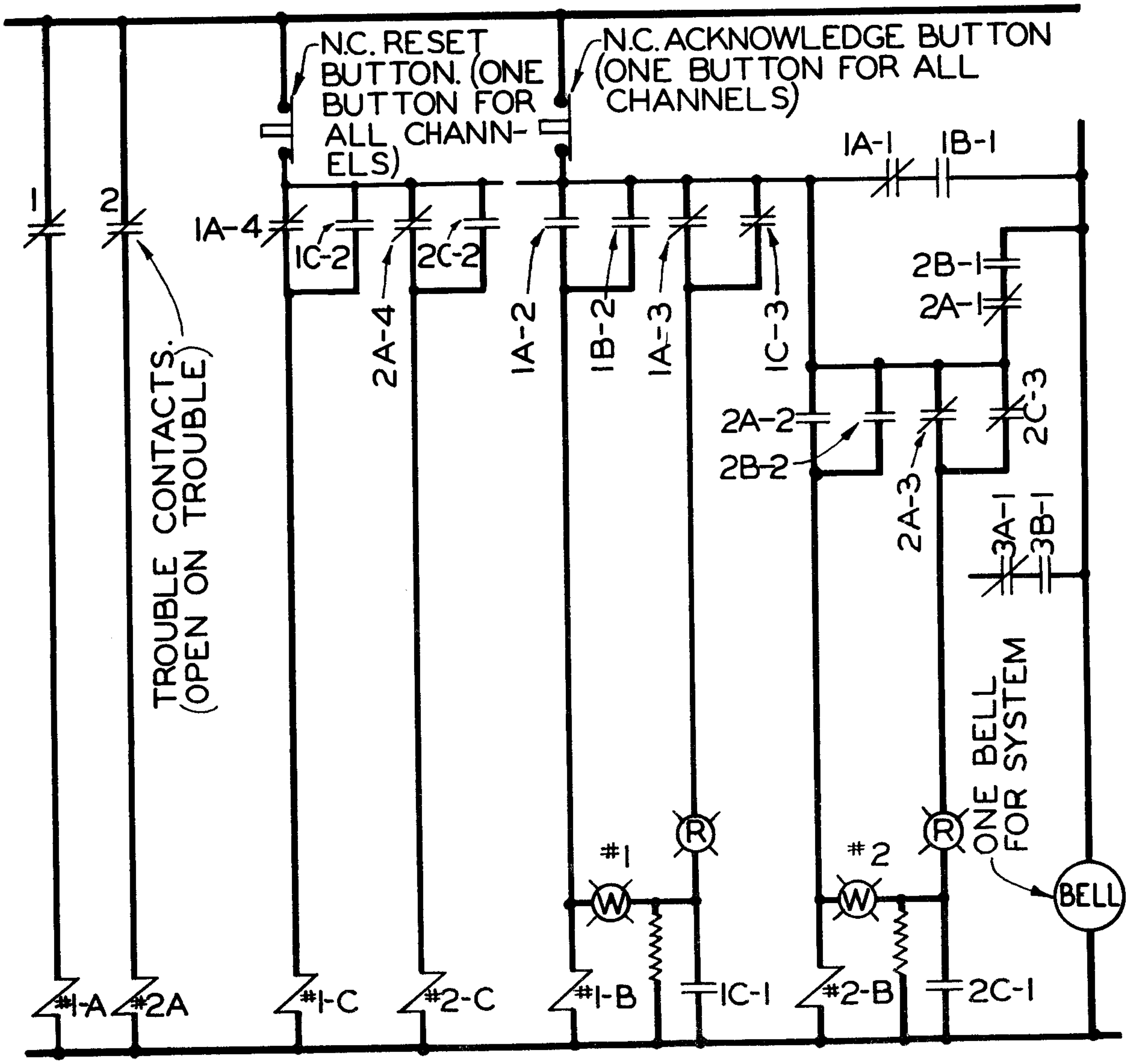


Fig. 24–Alarm Annunciator

TABLE 13

Inst. No.	Code	Function	High Alarms (CD)	Low Alarms (CR)
1	LECA	Pressurizer level	X	
2	PRCA	Soup pressure	X	
3	TRA	Multipoint soup temp.	X	X
4	TIA	Soup temp.	X	
10	PRCA/D	Soup-D_2O differential press.	X	X
13	TRCA	Reflector temp.		X
16	TIA	Soup pump temp.	X	
18	ICA	Soup pump overcurrent	X	
19	PA	Oil pressure to soup pump	X	
20	PCA	10 kw pressure	X	
22	ICA	Soup pump - undercurrent		X
26	DdA	D_2O detector - D_2O pump oil		
27	DdA	D_2 detector - D_2O off-gas	X	
29	TRCA	Pressurizer temp.	X	X
40	TIA	D_2O pump temp.	X	
43	ICA	D_2O pump undercurrent		X
44	PA	Oil to D_2O pump	X	
45	PCA	40 kw pressure	X	
47	PA	Helium to reactor	X	
51	ICA	D_2O pump overcurrent	X	
69	PCA	D_2O oil pressure		X
72	PCA	Soup pump cooling oil		X
76	PA	Helium to reactor		X
79	PRCA/D	Soup off-gas flow	X	
23	QRC	Monitrons: Steam	X	
24	QRC	D_2O off-gas	X	
25	QRC	Soup oil	X	
66	QRC	Bldg. vent	X	
68	QRC	Stack	X	
90	PCA	Building air pressure		X
89	PCA	Building water pressure		X
87	PA	Oxygen pressure		X
		Pulsafeeder flow		X
		Catalyst (soup) temp.	X	X
		Catalyst (D_2O) temp.	X	X
62	QIC	Period	X	
63	QRC	Safety	X	
59	QRC	CRM		X
		D_2O pump stop		X

of the circuit can be seen by reference to Figure 24 and Table 14. Basically, the alarm indication consists of two lights and a bell. For normal operation of the monitored circuit both lamps are dim, thereby giving a continuous check on the lamps. Occurrence of trouble changes both lamps to bright and sounds the bell. Acknowledgment stops the bell but leaves the red light on. If the trouble clears, the bell stops and the red light is turned off; the white, however, stays on bright. After the operator has made the necessary log entries the circuits are returned to normal by pressing the reset button.

A simplified flow sheet showing the principal process lines and the remotely operated valves is used for a mimic panel mounted above the center panel board in the control room. The valve operators have SPDT microswitches mounted on them so the switch is operated by movement of the valve stem. These switches in turn control the two lights, white and green, at each valve symbol on the mimic panel. The open or closed position of all valves is thus indicated by the appropriate light on the board. For valves which may be throttled the degree of operation is indicated by the pressure gage on each air switch.

Additional supervision of the over-all condition of the process equipment is provided by a microphone and speaker system. Carbon microphones are located in each of the major compartments and contact microphones are mounted on the two circulating pumps. These are connected to suitable amplifiers and a speaker on the operating console. A selector switch permits the operator to monitor any microphone at will. Mock-up tests have shown this system to be especially useful in picking up incipient failure of pump bearings.

TABLE 14

SCHEDULE OF OPERATION

	Field Contact	Relays			Lights		
		A	B	C	White	Red	Bell
Normal	Closed	Energized	Energized	De-energized	Dim	Dim	Silent
Trouble	Open	De-energized	"	Energized	Bright	Bright	Rings
Acknowledge	Open	"	De-energized	"	Off	Bright	Silent
Clears	Closed	Energized	Energized	"	Bright	Off	
Recurs	Open	De-energized	"	"	"	Bright	Rings
Acknowledge	Open	"	De-energized	"	Off	"	Silent
Reset - Still Trouble	Open	"	"	"	"	"	"
Clears	Closed	Energized	Energized	"	Bright	Off	"
Reset	Closed	"	"	De-energized	Dim	Dim	"

Safety Circuit

The various reactivity controls, nuclear instruments and process instruments are connected in an interlocked circuit so start-up and shutdown, either routine or scram, can occur only in an orderly and safe fashion. The experimental nature of this reactor has necessarily made this safety circuit somewhat more cormplicated than would be necessary if the reactor were designed solely as a power producer. It is also realized that in some instances the design may appear to "lean over backwards," but it seems best to include as many safety features as possible, and later remove them if operating experience proves them unnecessary. The goal has been to so interlock functions that the reactor can always shut down to a safe condition at any point in its start-up or operation; to arrange the components so they are adequately protected against faulty operating conditions; and to assure that abnormal nuclear conditions, operating conditions harmful to equipment, or failure of components will shut the reactor down in an orderly manner.

The block diagrams of the operating sequences for start-up or power increase are shown in Figure 25. For operation the console power switch must, of course, be unlocked, thereby energizing the various controls. Filling of the core with dilute soup and soup circulation through the heat exchanger are the only operations permitted without a cocked safety rod. This rod is raised through an independent circuit and its clutch and limit switches are then used through appropriate relays to assure that the rod is up before the reactor can be brought critical.

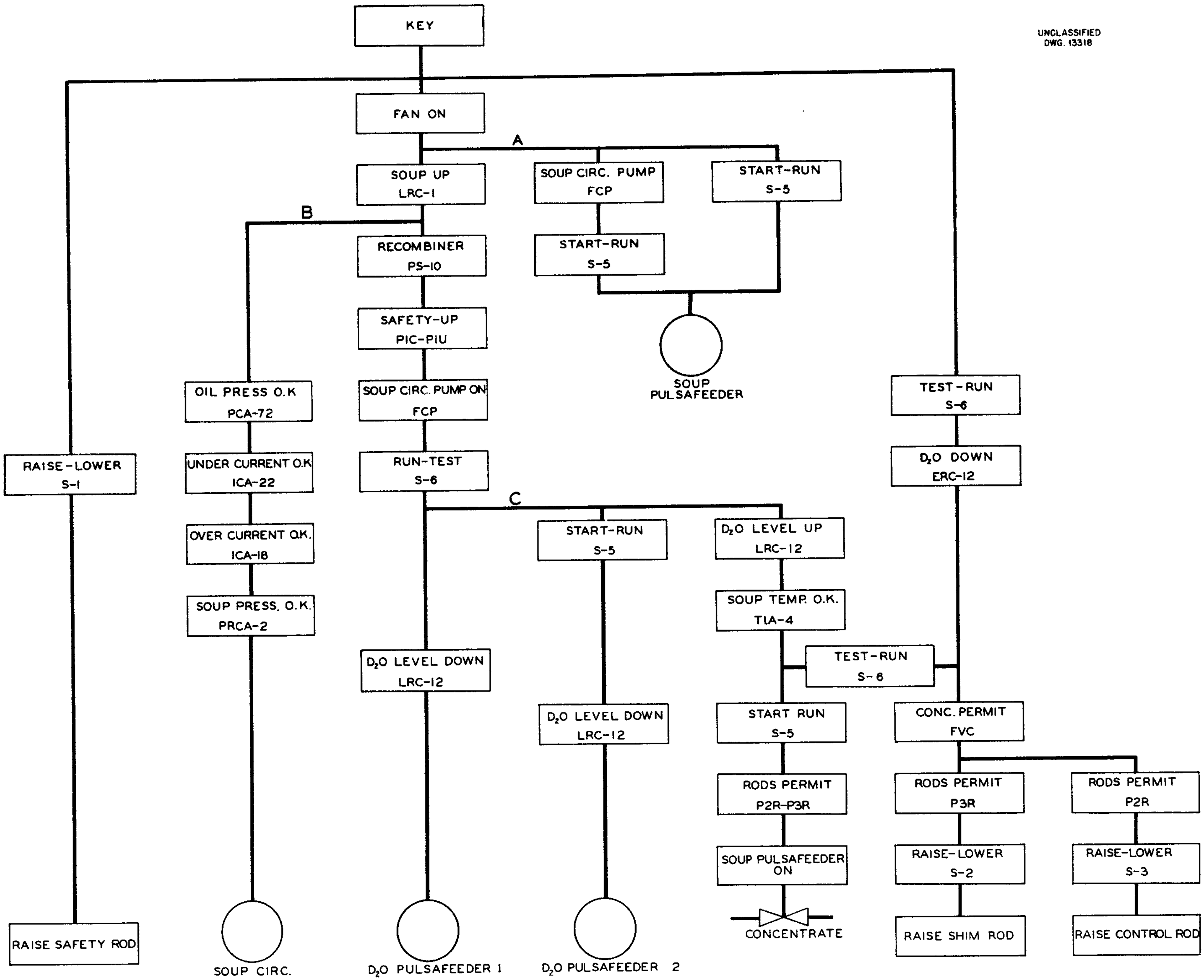


Fig. 25– Block Diagram – Start Up

The soup pumps may be operated if the stack fan is on. During operation the pulsafeeder pump should not operate unless the circulating pump is also operating to assure a uniform concentration throughout the system. However, for initial filling of the core the pulsafeeder must operate alone. This and other "start" functions are provided by the "start-run" switch. In the diagram, switch positions are indicated by underlining the proper word. With this switch in the "start" position the pulsafeeder pump may be operated without the circulating pump but other contacts on the switch block operations which might make the reactor go critical. As soon as the core system is filled and pressurized the circulating pump may be started and the pulsafeeder will operate with the switch in the "run" position. Oil pressure and motor current of the circulating pump must be within satisfactory limits in order to protect the motor. Soup pressurization is necessary to protect the bearings and impeller of the circulating pump, the manufacturer's specifications calling for a positive head of 200 psi, thus putting a lower limit on the pressures at which experiments may be performed.

With the soup circuit functioning, the safety rod cocked and recombiner on, the reflector may be brought up to operating level. During the initial filling of the reflector the "start-run" switch is in the "start" position, thus allowing both the 1 gpm and 2 gpm pumps to operate. Once the level reaches the point of the reflector level instrument (LRC-12) both pumps are automatically stopped and the 2 gpm one will not restart unless manually started, and then only if the switch is still on "start." The 1 gpm pump maintains level under control of the level instrument.

Not only must the reflector be up, but the soup temperature must be at the proper value before the soup may be concentrated or the shim and regulating rods moved. These three controls are interlocked so only one at a time may be varied. Concentration is further blocked unless the soup pulsafeeder is operating, thereby preventing excessive build-up of concentration in the dump tanks. Concentration interlock is obtained by an overriding solenoid valve in the air line to the "concentrate" valve.

The reactor cannot reach criticality without the reflector up, so it is safe to make tests of the rod drive circuits when the reflector is empty. This facility is provided by the "test" position of the "test-run" switch through the bottom limit of the reflector level instrument.

The block diagram of Figure 26 shows the numerous parallel paths by which the reactor may be shut down.

A manual shutdown may be made by lowering the rods with the motor drive, by releasing the magnets, or by dumping reflector or soup. The rods may be run down individually or all together by using the appropriate motor switch. These various methods of shutdown give rise to different conditions and initiate different follow-up operations.

Motion of the shim or regulating rods does not initiate any automatic sequence, but any lowering of the safety rod, whether by run-down or magnet drop, starts the D_2O timer. Unless the operator manually blocks the timer, the D_2O is automatically dumped at a fixed time after the rod moves. This effectively shuts the reactor down. The several signals which will automatically drop the rods and give this type scram are indicated on the block diagram.

There are several signals which indicate a soup leak, and these cause immediate dumping of the soup and reflector, as well as dropping of the rods and subsequent operations.

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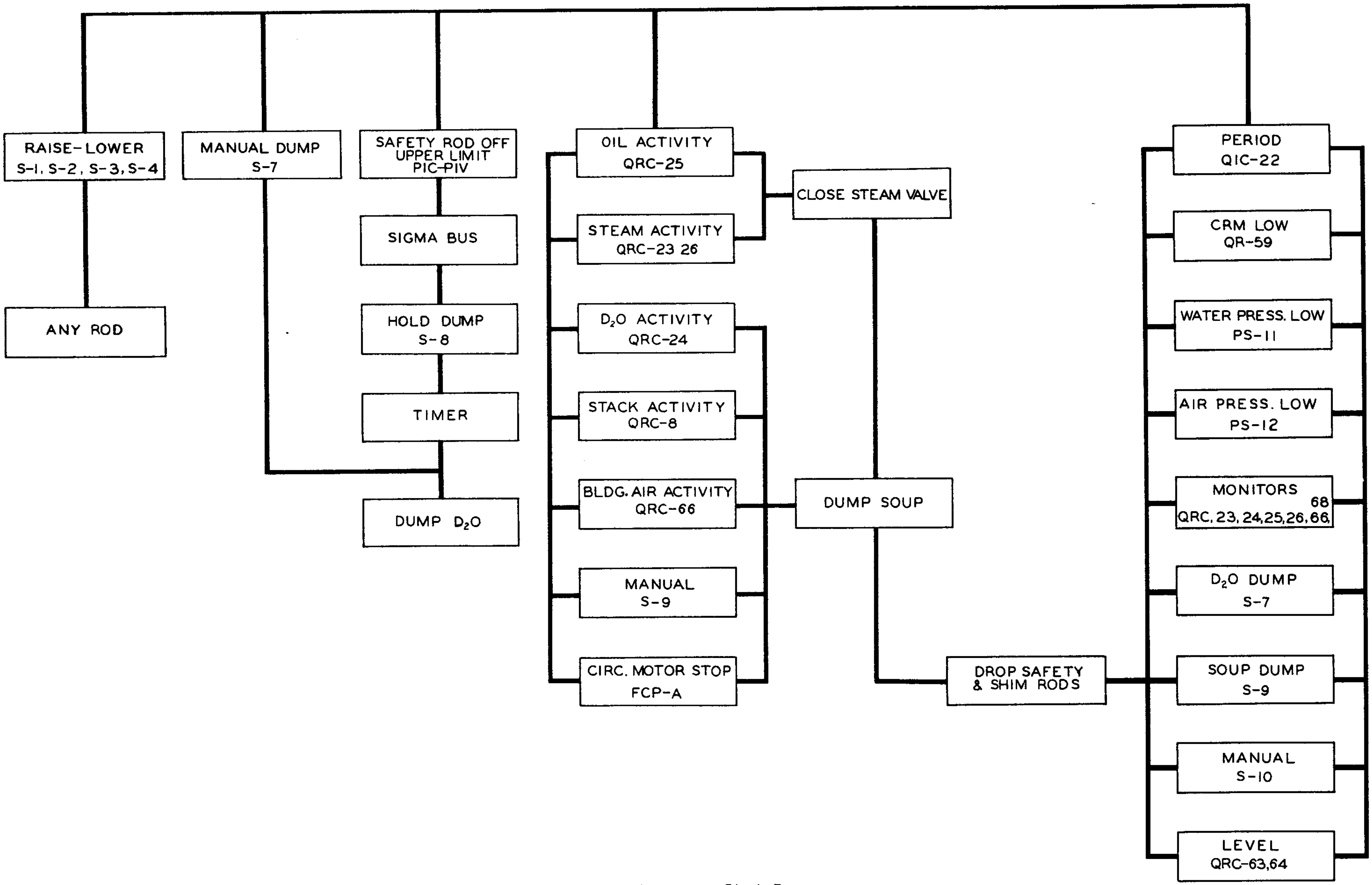


Fig. 26 – Block Diagram – Shut Down

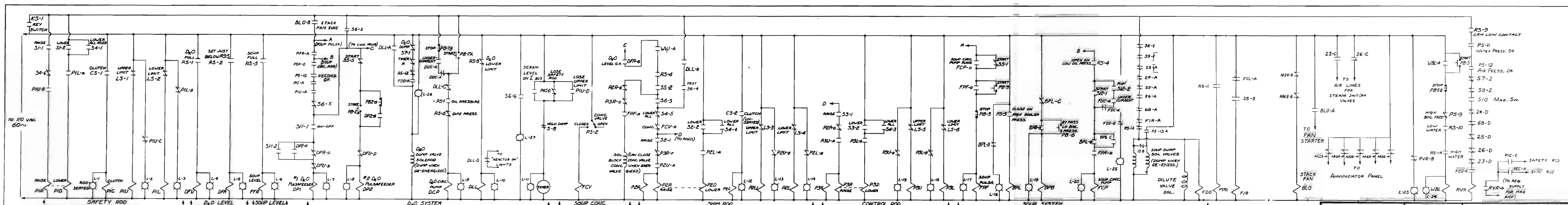
The details of the circuits which provide the safety interlocks are shown in Figure 27. The key to relay and instrument contact notation is given in Table 15. The exact functioning of the various relays is discussed in connection with the start-up and shutdown operations.

Typical Operations

Some discussion of the start-up, running, and shutdown of the reactor will serve to illustrate the operation of the safety circuits and, at the same time, present some of the considerations which dictated the particular solution to certain problems. There are possible variations in the procedures which may be used with the present instrumentation and control. Furthermore, it is highly probable that operating experience will suggest future changes in the circuitry and procedures.

The reactor is assumed to be in a completely shutdown state, reflector and soup in their respective dump tanks and at ambient temperature, and the operation is started from this point.

The operations discussed are based on a conventional run as certain experiments will require modifications of the safety devices. While such a procedure is necessary in order to get the maximum information from the HRE, it is absolutely essential that some control procedure be established to assure safe operation. As a minimum requirement, no change should be permitted until reviewed by the proper control and operation engineers; all such changes should be recorded in a permanent log; and no start-up of any kind should be permitted without first checking this log.



NOTES:

1. Relay contacts are shown in the de-energized position.
2. Switch contacts, where possible, are shown in non-actuated position.

S1 - Safety Rod Switch

Contact	Raise	Off	Lower
1	X		
2			X

Spring return from raise

S2 - Shim Rod Switch

Contact	Raise	Off	Lower
1	X		
2			X

Spring return from raise

S3 - Control Rod Switch

Contact	Raise	Off	Lower
1	X		
2			X

Spring return from raise & lower

S4 - Lower All Rods Sw.

Contact	Off	Lower
1		X
2		
3		X
4		X
5	X	
6	X	

S5 - Start-Run Switch

Contact	Start	Run
1	X	
2		X
3		X
4		
5	X	

S6 - Test-Run Switch

Contact	Run	Pl. Test	Refl. Test
1	X	X	
2			X
3	X		
4		X	
5	X		
6		X	X

S9 - Soup Dump Switch

Contact	Dump	Closed	Dump
1		X	
2		X	

S-7 D2O Dump Switch

Contact	Dump	Closed	Dump
1		X	
2		X	

S11 - #1 D2O Pulsafeeder

Contact	Off	On	Jog
1		X	X
2			X

S12 - Soup Circ. Pump

Contact	Jog	Stop	Run	Start
1				X
2			X	X
3	X			

MONITRONS
23 - Steam
24 - D2O off Gas
25 - Soup Circ. Oil
66 - Ventilators
68 - Stack Gases
26 - Reverse Flow Steam

Fig 27- Safety Circuit

-91-

NOT CLASSIFIED

REVISIONS

Date		Change	
6-12-51		Misc. changes.	
8-27-51		" "	
9-20-51		" "	

Designed: INGLIS
Drawn by: VANSANT
Finished: 2-12-51

OAK RIDGE NATIONAL LABORATORY
INSTRUMENT DEPARTMENT

H. R. E
ELECTRICAL CONTROL CIRCUIT

Scale: NONE | Q-1139-1 | A

TABLE 15

SAFETY CIRCUIT LEGEND

RELAYS

Safety Rod: P1

- P1R - raise rod
- P1C - clutch
- P1U - upper limit
- P1L - lower limit
- P1D - lower rod

Shim Rod: P2

- P2R - raise
- P2A - auxiliary relay for raise
- P2D - lower
- P2U - upper limit
- P2L - lower limit

Control Rod: P3

- P3R - raise
- P3A - auxiliary relay for raise
- P3D - lower rod
- P3U - upper limit
- P3L - lower limit

Soup System: F

- FFR - soup full
- FCV - conc. valve closed
- FPF - soup pulsa
- BPL - low b.p. detector
- BPB - by-pass low b.p.
- FCP - soup circ. pump
- FUC - undercurrent
- FPR - soup pressure
- FOC - overcurrent
- FIR - fuel circulation

D_2O System: D

- DFU - D_2O full up
- DFA - D_2O almost full
- DP1 - D_2O pulsa #1
- DP2 - D_2O pulsa #2
- DCP - D_2O circ. pump
- DLL - lower limit
- DUC - D_2O undercurrent

Miscellaneous:

- WBL - water boiler 40 kw
- ROL - reactor on
- RVP - reg. volt supply
- BLO - stack fan

Switches:

- PB - push button
- LS - limit
- RS - recorder
- PS - process

TABLE 15 (CONTINUED)

CONTROLLER SWITCHES

SW	ACTION	INSTRUMENT
RS-1	Closes on D_2O full, at the desired level. (In reflector)	LRC-12
RS-2	Closes on D_2O almost full, just below RS-1.	LRC-12
RS-3	D_2O lower limit. Closes when uncovered.	LRC-12
RS-4	Closes when some desired value of soup temperature is reached. ($\sim 200^{\circ}$ C)	TIA-4
RS-5	Closes when core is full of soup. (Pressurizer level)	
RS-6	Opens when soup-D_2O diff. pressure exceeds some value.	PRCA/D-10
RS-9	Opens on too-low reading of CRM.	QR-59
RS-10	Closes on too-low value of water level to 40 kw water boiler.	LRCA-52
RS-11	Closes when soup pressure reaches some minimum required value. ($\sim$200 psi)	PRC-2
RS-12	Opens on some undesirably high value on safety recorder.	QR-61
RS-13	Opens on high soup temperature.	TIA-4

PROCESS SWITCHES FOR HRE ELECTRICAL CONTROL CIRCUIT

PS-1	Opens when oil pressure to D_2O circulating pump drops below a desired value.	
PS-2	Position of soup conc. valve. (Closes when valve closes)	
PS-3	Opens on low steam pressure in main steam boiler. Closed on normal operating pressure.	
PS-4	Opens when oil pressure to soup circulating pump drops below a certain desired value. (Close when valve closes)	
PS-9	Opens to too-high value of boiler pressure in 40 kw water boiler.	

TABLE 15 (CONTINUED)

PROCESS SWITCHES FOR HRE ELECTRICAL CONTROL CIRCUIT

SW	ACTION	INSTRUMENT
PS-11	Opens on low cooling water pressure.	
PS-12	Opens on low instrument air pressure.	
PS-13	Opens when 1/2" soup dump valve is open.	
PS-14	Closes when 1/2" soup dump valve is open.	

Manually-operated valves controlling various cooling water flows and electrical switches controlling auxiliaries are set by the operator before starting the reactor itself.

Controlled motors and heaters are actually switched by magnetic contactors which are controlled by the relays shown in the safety circuit.

The safety rod is raised to the upper limit before any other normal operational step is taken. This is indicated by clutch and upper limit switches and other controls interlocked through the proper relays, PIC and PIU.

A possible variation, as far as interlocks are concerned, is to pump up the soup and even bring it to operating temperature before the safety rod is raised. In either case, the soup may be pumped up only when the stack fan is operating. As previously mentioned, the soup circulating pump must operate when the pulsafeeder does, in order to prevent excessive concentration differentials. For this discussion, we shall assume the rod is raised first.

The stack fan is one of the auxiliaries which is normally started before beginning operations so its interlock through relay BLO is satisfied. The soup may then be pumped up and brought to proper temperature and pressure. The "start-run" switch must be in the "start" position. The soup pulsafeeder control relay, FPF, is actuated by the push-button on the console and is locked in by the control relay contacts FPF-D. During this pump-up process, the soup let-down valve is closed by the level controller until the level reaches the control point when LRC-1 throttles the let-down valve to maintain level at the proper point. If gas in the system is compressed in the pressurizer to exceed the operating pressure, the pressure controller, PRC-2, will open valve 125 to relieve the gas binding.

The next step is to pressurize the soup system. This is accomplished by setting the temperature and pressure controllers, TRC-29 and PRC-2, to the desired values and switching the 10 kw boiler heaters on.

As soon as the soup level and pressure are correct, the soup circulating pump may be started by actuating relay FCP through its "start" button. This relay is subject to several permissive controls - soup level up given by LRC-1 through relay FFR, load within proper limits given by over and under current relays FOC and FUC, soup pressure high enough to prevent pump damage given by PRC-2 through relay FPR, and steam pressure satisfactory given by the combination of BPL and BPB. This last permission is included to care for the possibility of a steam line break. At start-up, the steam pressure is zero, but if while running this pressure returns to zero, it indicates a break and so the reactor must be scrammed. In order to prevent too rapid cooling of the soup, this scram is initiated by first stopping circulation. When starting with low boiler pressure, PS-3 is open and BPL is de-energized, so contacts BPL-C are closed and relay BPB may be closed by PB-6 and will lock in. Thus the soup circulating pump has permission through contacts BPB-C. As the reactor comes up to power and steam pressure builds up in the system, PS-3 closes, thus dropping out BPB through contacts BPL-C. However, contacts BPL-A now permit the soup pump to continue to operate. If a steam line breaks the steam pressure drops, relay BPB drops out and both contacts BPL-A and BPB-C are now open, and the circulating pump stops, initiating a scram, as discussed below.

To reduce the number of unnecessary scram possibilities, the circulating pump motor is not automatically protected against over temperature or lack of cooling oil. However, the cooling oil pump starts from the same switch as the circulating pump, subject to water pressure on the oil cooler, and improper values of oil pressure give an alarm. It is believed that these alarms are preferrable to the system of automatic protection since a false signal in the automatic system would stop the pump and thereby shut the reactor down completely.

The soup may now be brought to the desired operating temperature by passing steam through the water side of the heat exchanger. This process is a straightforward one of setting up the correct valves for the source of steam to be used and involves no safety interlocks.

Meanwhile, the reflector may be brought up to operating level. This operation is now permitted by the soup up relay contacts FFR-A, circulating relay contacts FCP-D, recombiner ignition on contacts PS-10, and the safety rod relay contacts PIC-A and PIU-A. The "Test-Run" switch, S-6, must be in the "Run" position for regular start-up so contacts S6-1 are closed. The two pulsafeeder pumps may be started by the respective motor start switch and pushbutton. They now run under control of the reflector level instrument, LRC-12, through relays DFU and DFA. Relay DFA is controlled by the "almost full" contact, RS-2 of LRC-12, picking up when the level reaches this value. DFU is controlled in a similar manner by the "full" contact, RS-1. When the pumps first start, these contacts are open and both relays de-energized so contacts DFA-A, DFU-B, and DFU-D are all closed. The holding contacts, DP1-A and DP2-B, of the motor relays close when the motors are started. As the level comes up, relay DFA picks up, opening contacts DFA-A, but the motor relay is held in by contacts DP1-A. At full level, relay DFU picks up and stops both pumps. Pump 2 will not restart unless its start button is again pressed, so it is effectively removed from instrument control as soon as the reflector is up. It is completely blocked when the "Start-Run" switch is thrown to "Run," opening contacts S5-5. Pump 1 is still on instrument control since its starting switch is not a spring return type. This pump will therefore start each time the level drops to the "almost full" point, and stop when the level reaches the "full" value. Switch S-11 provides a manual means of "inching" the level for certain experiments. While it is not a part of the safety circuit, it may be noted that instrument LRC-12 operates the let-down valve 155 to bleed off D_2O if the level is too high. Thus, if the operator wishes to operate with a lower reflector, he merely changes the control point of the instrument and the excess D_2O is bled off and the pumps function to maintain level at the new value.

If operational experience indicates that the slightly fluctuating level of this scheme is unsatisfactory, or if the let-down valve leaks excessively, the operation may be readily modified to correct the trouble. The control of pump 1 can be changed to keep it operating continuously, and the level maintained by throttling valve 155. The pump would then be subject to instrument shutdown only if the level exceeded a safe upper limit, set slightly above the control point of valve 155.

As soon as the reflector level has reached the half-full value, the interlock on the helium valve, 276B, is released so helium can be supplied for pressurizing the reflector. Thus, as the pulsafeeder pumps fill the reflector, instrument PRC-10 controls the admission of helium to bring the pressure to the proper value.

The D_2O circulating pump may be started when the level has reached the lower limit (corresponding to the bottom of the core), as indicated by opening of contacts RS-3 of LRC-12. This de-energizes relay DLL so contacts DLL-C close. Correct pressure permission is given through RS-6 by instrument PRCA/D10. The motor is protected against overcurrent, undercurrent, low oil pressure, and overheating by contacts DOC-A, DUC-A, PS-1 and PS-8.

At this stage the reactor is set up to be carried critical so the "Start-Run" switch is thrown to "Run" and the reactivity controls manipulated to bring the reactor to power. This operation has been blocked by the requirement for proper reflector level, contacts DFA-B, and proper soup temperature, RS-4 of TIA-4. Indirectly, all of the operations discussed so far, except D_2O circulation, are required since throwing S5 to "Run" would have dumped the soup unless the soup pump were operating properly.

The first reactivity control is concentration increase, which has been blocked until now by the various open contacts in the blocking solenoid valve circuit. Concentration cannot be changed unless the soup pulsafeeder pump is operating, closing contacts FPF-A, and the rods are stationary so contacts P2R-E and P3R-D are closed. These last two are to block simultaneous operation of two or more k increasing devices. With the block removed, the concentration valve, 126, may be operated at will from the valve station on the console. As the concentration increases, the nuclear instruments give continuous monitoring of the reactivity, and if the operation is carried too far will scram the reactor. The reactor may be brought all the way to power with concentration control, or the final stage may be done with the rods. For safety it is recommended that the rods be used so they will be up and can serve as additional safety rods. Fine concentration control is obtained by throttling valve 126.

When the concentration has reached the desired value, the rods may be raised to further increase reactivity. Of course, the rods may be raised before concentrating to the final value and the reactor then brought to the desired level with concentration control. It is believed that this is the safer method. A switch on the concentration valve controls relay FCV so the shim and control rods cannot be raised while the fuel is being concentrated.

As the reactor is brought up in power a point is reached when heat no longer needs to be supplied from the steam to maintain soup temperature, and actually a steam load must be extracted to prevent overheating. At this change over it is important that there be no sudden cooling of the soup (and hence increase of reactivity) by the admission of feed water to the heat exchanger. At least two procedures suggest themselves. The first is to close the drain valve and very slowly fill the heat exchanger from the feed water pumps by gradually increasing the control point of LIC-8. With steam still supplied and soup circulating through the exchanger, this should result in the water being heated to almost steam temperature as it is admitted, and thus cause no appreciable change of soup temperature. The second method is to close the drain valve and allow the condensate to fill the heat exchanger. With some operating experience the operator should be able to estimate when the drain valve should be closed to have sufficient water when the reactor starts delivering power. In any event, the control point of LIC-8 should correspond to the level of condensate when the feed water pumps are started and the instrument is allowed to take over control. The second method is probably the safer from the standpoint of sudden temperature changes, but either should be entirely satisfactory if the operator exercises normal care.

The reactor may be shutdown or reduced in power, at the option of the operator, by means of any of the reactivity controls. It may be shutdown automatically by any of several emergency conditions, as indicated in Figure 26 and detailed in Figure 27.

In general, a reduction by the operator in the operating level will be by rods or concentration for fine control, and by reflector level for large shim control. The rods may be manipulated to reach a new power level without any restrictions other than the requirement that only one reactivity control is increasing reactivity at a given moment. To reduce reactivity by dilution of the fuel the concentration valve and the dilution valve are both opened, thereby stopping the collection of condensate and feeding water from the condensate tanks to the core. The reflector shimming action is controlled by varying the control point of the level controller, LRC-12. The pulsafeeder pump control contacts and the let-down valve control function at any setting of the control point, so the operator merely changes the point and the instrument does the rest.

There are several methods available to the operator for shutting the reactor down, and various combinations of these could be used. However, all of these do not make restarting equally easy. For an emergency calling for quick shutdown, the rods are dropped and will be followed automatically by a reflector dump. If the emergency involves the soup system, the operator may dump the soup by operating the soup dump switch, S-9. Reflector may be dumped by switch S-7.

For a routine shutdown, it is suggested that the fuel be diluted to a value which will make the reactor sub-critical at room temperature. This operation will require about seven minutes with the dilute valve wide open. The rods are then run down and the reflector allowed to dump. This leaves the reactor in an "ever-safe" condition with the soup in the core system. Experience may indicate that this procedure may be modified; for example, complete dilution of the soup may not be necessary, and thus the concentration time at start-up may be shortened. In this event, the operator must realize that the reactor may become critical as the reflector is raised, so the necessary care must be exercised in raising the reflector. When the reactor is to be down for a long period, it is probably preferable to dump the soup as well as the reflector.

There are several interlocks on the shutdown devices. Whenever the safety rod leaves the cocked position, whether by drop or run-down, the reflector timer is started by the clutch or upper limit switch. After a definite time interval, presently considered as 30 seconds, the timer opens the D_2O dump valve. During the time delay interval, the operator may block the reflector dump by means of the "hold dump" switch, S-8. This feature is provided so the operator may survey the situation when the rods are dropped, and if he finds the drop is a false scram, or that conditions warrant it, he may prevent a complete scram and the resultant long start-up period. In addition to the rod actuation of the timer, a scram signal on the sigma bus of the magnet amplifiers will start it, so if a nuclear condition calls for a scram and the rods fail to drop, the reflector cycle is started, nevertheless. Should the operator hold S-8 (a spring return switch), and then decide he needs a quick dump, he may operate the dump switch, S-7, and not wait for the timer cycle.

As mentioned previously, the soup dump is interlocked with the reflector dump so a high reflector-to-core pressure cannot occur when the fuel is dumped. This is accomplished through relay FDD and is parallel with the fuel dump valves, so when these solenoids are de-energized contacts FDD-A in the D_2O dump valve circuit open and dump the reflector simultaneously. The core will dump in $\sim$25 seconds, but the inside pressure is reduced to $\sim$500 psi (corresponding to operating temperature), as soon as the solution drops below the steam jacket in the pressurizer. As a back-up for the fuel dump valve, the let-down valve is interlocked so if the dump valve fails to open the let-down valve is opened. This latter valve is not opened for normal dumping in order to reduce the erosion on the valve trim.

Several emergency signals will initiate this soup dump. Any of the monitrons, QRC 23, 24, 25, 26, or 68, which detect leaks will initiate such a dump. Any failure of the soup circulation, as indicated by the electrical condition of the pump motor, will also dump the fuel. Over or under current in this motor will indicate an abnormal pump load and open the supply line to the motor. Voltage relay FCL is connected across the line on the motor side of the contactor, so loss of motor voltage for any reason operates relay FIR and causes a dump. This feature must be blocked during initial filling so contacts of the "start-run" switch, S-5, are connected in the circuit of relay FIR. An additional interlock on the soup dump is provided to open the dilution valve and thus reduce the concentration to a safe value for the next start-up.

The monitrons, QRC 24 and 56, which detect abnormal activity in the shield also stop the stack fan, leaving the shield under stack draft only so an excessive amount of activity will not be passed up the stack.

The safety and shim rod magnets are tripped by many emergency signals. The normal safety and period trips are provided through the sigma bus of the amplifiers so dangerous nuclear conditions can initiate a scram without the delay associated with mechanical relays. Less critical conditions open the magnet amplifier power supply. Contacts RS-9 on the counting rate meter prevent a start-up without an adequate source. Low water or air pressure drops the rods through pressure switches PS-11 and PS-12. Because of the start-up safety interlocks, the rods should be dropped whenever the reflector is dumped. This is provided for by switch S7-2 and relay contact FDD-B. The various monitrons function through the contacts shown as 23-D, 24-D, 25-D, 26-D, and 68-D.

A "test-run" switch is provided so the rods or reflector may be tested when conditions are safe. The reactor cannot go critical when the reflector is down so the rod motors can be energized through S6-4, if the reflector low level contacts, DLL-B, indicate an empty reflector. The reflector pumps may be operated at will if the core is empty. This conditions is given by the "reflector test" position of S-6 when contacts S6-2 energize the pump motor circuits and

S6-1 opens the dump valves.

Operation and Loading of the Generator

Under normal conditions the reactor is loaded by operating the turbo-generator on the TVA system. The characteristic behavior of an alternator operated in parallel with a fixed frequency and voltage system makes load control rather simple. With this connection the frequency of the alternator, and hence its speed, cannot change, so the only way its load can be altered is by changing the setting of the governor. Contrary to the case of d.c. generators operated in parallel, changing the generator field does not change its load. Rather, a change of field produces a change of induced voltage which permits a circulating component of current to flow, which in turn adjusts the terminal voltage of the alternator to that of the fixed system. The net effect of this is a change in alternator power factor. There is a small change of delivered power due to a change in alternator resistance loss with the new current, but this load change is completely negligible. Thus, once the generator is synchronized on the line its load is adjusted by adjusting the turbine governor by means of the governor control on the console. The power factor is adjusted with the field rheostat on the console, or for extreme variation it may be necessary to use the field rheostat on the panel board. Normal power factor will be unity.

The turbine is brought up to speed gradually by admitting steam slowly through the appropriate valve from either the house supply or the reactor. The speed of the turbine is indicated on the frequency meter, 60 cycles representing rated speed. For normal operation the governor should be set by the governor control switch to give rated speed with the steam valve fully open. If the turbine is operating from one steam source and it is desired to transfer to the other, this may be done by opening the valve in the line to the second supply and closing that to the first, the check valve in the building steam line preventing any back-up of reactor steam into the building system.

After the turbine is warmed up the generator may be synchronized on the line by standard procedures. The synchroscope is turned on by the switch on the panel board. Output voltage of the alternator is adjusted to the line value, these being indicated by alternator and line voltmeters, by the field rheostat on the console. The turbine governor is adjusted so the synchroscope rotates very slowly. (This rotation should be slow enough to permit the operator to close the circuit breaker before the machine can get out of synchronism.) If the frequency is initially very far from correct it is easier to adjust the speed approximately by using the frequency meter as an indicator. With the alternator and line voltages equal and the synchroscope rotating very slowly, preferably with the local frequency above TVA frequency (synchroscope rotating in the "fast" direction), the generator breaker should be closed as the synchroscope goes through the synchronous position. Practically, this means the operator should throw the breaker switch just before synchroscope pointer reaches the vertical position, so the breaker will actually close as the pointer goes through the vertical position. If the generator and line voltages are too far out of synchronism the rush of current when the breaker closes will immediately trip it out and at the same time subject the alternator to undesirable stress.

[redacted]

Conclusion

This report has been prepared before the reactor design and construction are completed and it is expected that some minor modifications in instruments and controls will be necessitated as the work progresses. These will be covered in later reports or in a supplement to this report. Finished control drawings are not yet available, but will be issued as series Q-1139 for nuclear and safety circuits, and Q-1220, Q-1221, Q-1222, Q-1223, and Q-1224 for process instruments and installations.

The work covered by this report is the result of valuable contributions by many people on the Laboratory staff. While individual acknowledgment of each contribution is not practicable, a major portion of the work was done by L. P. Inglis, C. A. Mossman, J. E. Owens, and B. P. White.

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