AUSTRALIAN ATOMIC ENERGY COMMISSION

RESEARCH ESTABLISHMENT
LUCAS HEIGHTS

PHYSICAL INSTRUMENTATION OF THE REACTOR HIFAR

by

R. HICKS

August 1968

AUSTRALIAN ATOMIC ENERGY COMMISSION

RESEARCH ESTABLISHMENT

LUCAS HEIGHTS

PHYSICAL INSTRUMENTATION OF THE REACTOR HIFAR

by

R. M. HICKS

ABSTRACT

This manual gives a description of the physical instrumentation of the reactor HIFAR. The relevant principles of operation of the various types of primary elements, transducers and transmitters are given.

CONTENTS

continued...

CONTENTS (continued)

1. INTRODUCTION

To promote the safe and efficient operation of any process it is essential that the magnitude and/or condition of a variety of physical or chemical quantities be indicated, recorded or displayed in some form for the operating personnel. This report describes, in some detail, the instrumentation installed in HIFAR for this purpose.

Various devices ranging from self-contained measuring and indicating units (pressure gauges) to multi-element units (Dall tube - transducer - transmitter - indicator) are incorporated in the system. To simplify the presentation, the tag number of individual elements associated with either a single or multi-element unit has been given wherever possible, together with all available information. The principles of operation of the various types of primary elements, transducers and transmitters have been included.

2. DESCRIPTION OF INSTRUMENTATION

2.1 HEAVY WATER CIRCUIT

D_2O Flow

Primary Elements (1-FE-1, 2, 3 and 4) : 'KENT' Dall Tubes.

Fluid conditions	:	specific gravity 1.1 at 60°F. temperature 51°C (max. 60°C). pressure 5 p.s.i.g. (max. 35 p.s.i.g.).
Differential head	:	150 inches W.G. with a max. flow of 219 lb/sec. After 12th January 1966, 281 inches W.G. with a max. flow of 300 lb/sec.
Line size	:	7 inches
Pressure taps	:	½ inch
Location	:	1 each in the four downcomers from the reactor aluminium tank. Refer to Drawing No. WTA 2073.

Measuring Unit and Transmitter (1-FI-20) : 'FOXBORO' pneumatic D.P. cell.

Range	:	0-150 inches W.G.
Range	:	after 12th January, 1966, 0-300 inches W.G.
Diaphragm	:	stainless steel.
Body	:	18/8/1 stainless steel.
Output	:	3-15 p.s.i.g. proportional to square of flow.
Supply	:	20 p.s.i.g. dry oil-free air.
Location	:	D_2O Plant Room.

Receivers (a) 1-FI-20 'KENT' 12 inch dial indicator

(b) 1-FI-20 'KENT' 6 inch dial indicator

Calibration (a) 0-876 lb/sec (square root).

0-1200 lb/sec (square root) after 12th January, 1966.

(b) 3-15 p.s.i.g.

Location (a) Main Control Room, Panel No. 6 (Unit 9).

(b) Emergency Control Room. Panel adjacent to Plant Room mimic.

Pressure Switch (1-FIA-20) : K.D.G. SP33 pressure switch.

Range : 3-15 p.s.i.g.

Two have alarm settings operating at less than 90% flow M4.

Two have alarm settings operating at less than 70% flow M3.

D_2O Flow Through Ion Exchanger

Primary Element (1-FE-12) : 'KENT' orifice plate

Fluid conditions	:	specific gravity 1.1 at 60°F.
	:	temperature 51°C (max. 60°C).
	:	pressure 20 p.s.i.g. (max. 30 p.s.i.g.)
Differential head	:	25 inches W.G. with a max. flow of 4,500 lb/hr.
Orifice material	:	18/8/1 stainless steel.
Line size	:	1 inch
Location	:	inlet line to 1-L-3 immediately after liquid level pump in D_2O Plant Room.

Measuring Unit and Transmitter (1-FI-12) : 'FOXBORO' pneumatic D.P. cell

Range	:	0-25 inches W.G.
Diaphragm	:	18/8/1 stainless steel.
Body	:	18/8/1 stainless steel.
Output	:	3-15 p.s.i.g.
Supply	:	30 p.s.i.g. dry oil-free air.
Location	:	D_2O Plant Room adjacent to liquid level pumps.

Receiver (1-FI-12) : 'KENT' 6 inch dial indicator

Calibrated	:	0-10 gallons/minute square root.
Location	:	Reactor Basement, outside rear wall of Experimental Plant Room.

D_2O Weir Overflow

Primary Element (1-FE-5) : 'KENT' weir plate

Fluid conditions	:	specific gravity 1.1 at 60°F. temperature 51°C. pressure 6 inches W.G.

Weir plate will pass a flow of 3,300 lb/hour.
Material 18/8/1 stainless steel.
In the event of no flow, weir drains completely.

Measuring Unit (1-FI) : 'R. TRIST' float switch.

Float material	:	stainless steel.
Float range	:	$\frac{1}{2}$ inch.
Location	:	return line to 1V3.

No-flow operates S.P.D.T. switch, initiating visual audible alarm.

D_2O Level in Reactor

Primary Element and Transmitter (1-LLIA-1) : 'FOXBORO' D.P. cell

Fluid conditions	:	specific gravity 1.1 at 60°F. temperature 50°C. pressure 5 p.s.i.g. (max. 40 p.s.i.g.).
Range	:	0-215 cm.
Outlet	:	3-15 p.s.i.g.
Supply	:	20 p.s.i.g. dry oil-free air.
Diaphragm material	:	18/8/1 stainless steel.
Location	:	Face 7, 15 ft. floor level.

Receiver : 'KENT' 12 inch dial indicator.

Range : 0-215 cm

Location (a) Main Control Room Panel No. 8.
(b) Emergency Control Room, Panel adjacent to Plant Room mimic.

Alarm Switch : 'K.D.G.' SP33 pressure switch.

Range	:	3-15 p.s.i.g.
Diaphragm	:	beryllium copper
Alarm switch	:	micro S.P. switch assembly.
Alarm setting	:	182 cm.
Location	:	Rear of Panel 8, Main Control Room.

D_2O Drain Tank (1V5) Level 1-LG-4

Indicator	:	'KLINGER' sight glasses.
Location	:	1 top and 1 bottom of tank 1V5.

D_2O Storage Vessel (1V3) Level 1-LLIA-2

Primary Element :'FOXBORO' pneumatic D.P. cell

Fluid conditions	:	specific gravity 1.1 at 60°C. temperature 50°C. pressure 5 p.s.i.g. (max. 40 p.s.i.g.).
Range	:	0-240 cm.
Diaphragm material	:	stainless steel.
Supply	:	20 p.s.i.g. dry oil-free air.
Output	:	3-15 p.s.i.g.
Location	:	D_2O Plant Room.

Receiver : 'KENT' 12 inch dial indicator.

Range	:	0-240 cm.
Location	:	Control Room Panel No. 8 (Unit 11).

Alarm Switch: K.D.G. type SP33 pressure switch

Range	:	3-15 p.s.i.g.
Diaphragm material	:	beryllium copper.
Location	:	rear of Panel No. 8.

Alarm Setting :(a) Liquid level pump circuits M15, 11 cm.
(b)
(c) warning circuits M5

D_2O Conductivity 1-KA-1/1 - 1/3

Primary Element: 'KENT' 'P' type measuring cell

Fluid conditions	:	temperature 51°C (max. 60°C). pressure 3 p.s.i.g.
Electrodes	:	gold plated.
Cell material	:	stainless steel.

Location (a) 1 inch diam. over flow pipe from R.A.T.
(b) inlet to ion exchange column.
(c) outlet of ion exchange column.

Receiver : 'KENT' strip chart recorder

Range : (5×10^{-5}) mhos - (5×10^{-7}) mhos

Alarm settings (a) 2.5 μmho for 1 point only.

Location : Panel 15 in Reactor Basement.

D_2O Temperature Difference Inlet/Outlet R.A.T. 1-ΔTRT-2

Primary Element : 'HERAEUS' resistance thermometer

Material : platinum (glass enclosed).

Resistance : 100 ohms (nominal) at 0°C, 3 wire type.

Immersion : taken from o.d. of pipe to top of stainless steel pocket

inlet to R.A.T. 'N' $5\frac{1}{4}$ inches

'O' $5\frac{1}{4}$ inches

'P' $5\frac{1}{4}$ inches

outlet from R.A.T. 10 inch header,

'L', 'M', 'Q', 'R' - 7 inches

changed (1967) to inlet to heat exchanger, 'L', 'Q', 'R'.

Receiver : 'KENT' strip chart recorder

Range : 0-10°C.

Alarm settings : 8°C.

Location : Control Room Panel No. 6.

D_2O Reactor Outlet Temperature 1-TRT-3

Primary Element : As in 1-ΔTRT-2

Location : 'M' in the outlet of R.A.T. (10 inch header).

Receiver : (a) 'KENT' strip chart recorder

(b) 'KENT' strip chart recorder (Repeater)

Range : 0-100°C.

Alarm setting : 55°C.

Location (a) Control Room, Panel 6 (Unit 8).

(b) Basement on H_2O Header.

D_2O Main Circulator Motor Winding Temperature

Primary Element : Thermocouples

Type	:	chromel-alumel.
Location	:	(1) (2) Main Circulator motor windings. (3) D_2O Plant Room.

Indicator and Alarm : 'FOSTER' Milli-voltmeter type

Range	:	0-200°C.
No. of inputs	:	3, (switches automatically).
Alarm setting	:	62°C.
Location	:	Basement, adjacent to D_2O Plant Room, Panel 16.

D_2O Main Circulator 'A' Suction Pressure 1-PI-1

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	30 inches Hg - 0- 60 p.s.i.g.
Diaphragm material	:	stainless steel.
Location	:	Reactor Basement. D_2O Plant Room wall above D_2O Main Circulator Cubicle.
Connection	:	½ inch B.S.P.

D_2O Main Circulator 'B' Suction Pressure 1-PI-2

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	30 inches Hg - 0- 60 p.s.i.g.
Diaphragm material	:	stainless steel.
Location	:	Reactor Basement. D_2O Plant Room wall above D_2O Main Circulator Cubicle.
Connection	:	½ inch B.S.P.

D_2O Main Circulator 'C' Suction Pressure 1-PI-3

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	30 inches Hg - 0- 60 p.s.i.g.
Diaphragm material	:	stainless steel.
Location	:	Reactor Basement. D_2O Plant Room wall above D_2O Main Circulator Cubicle.
Connection	:	½ inch B.S.P.

D_2O Main Circulator 'A' Discharge Pressure 1-PI-4

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range : 0-60 p.s.i.g.

Diaphragm material : stainless steel.

Location : Reactor Basement. D_2O Plant Room wall above D_2O Main Circulator Cubicle.

Connection : $\frac{1}{2}$ inch B.S.P.

D_2O Main Circulator 'B' Discharge Pressure 1-PI-5

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range : 0-60 p.s.i.g.

Diaphragm material : stainless steel.

Location : Reactor Basement. D_2O Plant Room wall above D_2O Main Circulator Cubicle.

Connection : $\frac{1}{2}$ inch B.S.P.

D_2O Main Circulator 'C' Discharge Pressure 1-PI-6

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range : 0-60 p.s.i.g.

Diaphragm material : stainless steel.

Location : Reactor Basement. D_2O Plant Room wall above D_2O Main Circulator Cubicle.

Connection : $\frac{1}{2}$ inch B.S.P.

D_2O Emergency Shutdown Pump Discharge Pressure 1-PI-7

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range : 0-30 p.s.i.g.

Diaphragm material : stainless steel.

Location : Reactor Basement. D_2O Plant Room wall above D_2O Main Circulator Cubicle.

Connection : $\frac{1}{2}$ inch B.S.P.

D_2O Emergency Shutdown Pump Discharge Pressure 1-PI-8

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range : 0-30 p.s.i.g.
Diaphragm material : stainless steel.
Location : Reactor Basement. D_2O Plant Room wall above D_2O Main Circulator Cubicle.
Connection : $\frac{1}{2}$ inch B.S.P.

D_2O Level Pump Discharge Pressure 1-PI-11

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range : 0-60 p.s.i.g.
Diaphragm material : stainless steel.
Location : Reactor Basement. D_2O Plant Room wall above D_2O Main Circulator Cubicle.
Connection : $\frac{1}{2}$ inch B.S.P.

D_2O Level Pump Discharge Pressure 1-PI-12

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range : 0-60 p.s.i.g.
Diaphragm material : stainless steel.
Location : Reactor Basement. D_2O Plant Room wall above D_2O Main Circulator Cubicle.
Connection : $\frac{1}{2}$ inch B.S.P.

D_2O Level Pump Suction Pressure 1-PI-13

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range : 30 inches Hg - 0 - 15 p.s.i.g.
Diaphragm material : stainless steel.
Location : Reactor Basement. D_2O Plant Room wall above D_2O Main Circulator Cubicle.
Connection : $\frac{1}{2}$ inch B.S.P.

D_2O - H_2O Heat Exchanger Pressure Difference 1-ΔPIA-22

Primary Element and Transmitter : 'MASON NIELAN' Bourdon tube

Fluid Conditions:

Tube side	(a)	specific gravity 1.1 at 60°F. pressure 21 p.s.i.g. (max. 40 p.s.i.g.). temperature 44°C (max. 60°C).
Shell side	(b)	specific gravity 1.0 at 60°C. pressure 8 p.s.i.g. (25 p.s.i.g.). temperature 29°C (max. 60°C).

Range	:	0-20 p.s.i.g.
Output	:	3-15 p.s.i.g.
Supply	:	20 p.s.i.g. dry oil-free air.
Bourdon tube material	:	stainless steel.

Subtraction Relay : 'KENT' diaphragm type

Inputs (2) from Mason Nielan	:	3-15 p.s.i.g.
Output	:	3-15 p.s.i.g.
Supply	:	20 p.s.i.g. dry oil-free air.

Receivers (2) : 'KENT' (a) 12 inch and (b) 8 inch dial gauges

Input	:	3-15 p.s.i.g.
Calibration	:	0-25 p.s.i.g.
Location	(a)	Control Room Panel 8.
	(b)	Exterior of Experimental Plant Room. Rear wall adjacent to Panel 15.
Connection	:	½ inch B.S.P.

Alarm Switch : K.D.G. SP33 pressure switch

Range	:	3-15 p.s.i.g.
Diaphragm	:	beryllium copper.
Alarm switch	:	Micro S.P. switch.
Alarm setting	:	1.9 p.s.i.g.
Location	:	Control Room, rear of Panel 8.

H_2O Pressure at Shell Side of Heat Exchanger

Primary Element and Indicator : 'N.I.C.' Bourdon tube gauge

Range	:	0-30 p.s.i.g.
Bourdon material	:	beryllium copper.
Connection	:	$\frac{3}{8}$ inch B.S.P.
Location	:	D_2O Plant Room wall adjacent to Panel 15.

D_2O Pressure at Tube Side of Heat Exchanger

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	0-50 p.s.i.g.
Diaphragm material	:	stainless steel.
Connection	:	$\frac{1}{2}$ inch B.S.P.
Location	:	D_2O Plant Room wall adjacent to Panel 15.

2.2 HELIUM CIRCUIT

He Inlet Temperature to Recombiner 2-TI-12

Primary Element and Indicator : 'SUNVIC' bi-metal thermometer

Range	:	0-200°C.
Stem length	:	$5\frac{3}{4}$ inches.
Immersion	:	$1\frac{3}{4}$ inches.
Location	:	stainless steel pocket on 1 inch line.

He Inlet Temperature to Recombiner 2-TI-14

Primary Element and Indicator : 'SUNVIC' bi-metal thermometer

Range	:	0-200°C.
Stem length	:	$5\frac{3}{4}$ inches.
Immersion	:	$1\frac{3}{4}$ inches.
Location	:	stainless steel pocket on 1 inch line.

He Outlet Temperature from B.O.E. Unit 2-TI-33

Primary Element and Indicator : 'ROTOTHERM' bi-metal thermometer

Range	:	0-100°C.
Stem length	:	6 inches.
Immersion	:	$2\frac{1}{2}$ inches.
Location	:	stainless steel pocket on 2 inch line.

He Inlet Temperature to Heat Exchanger 2-TI-36

Primary Element and Indicator : 'ROTOTHERM' bi-metal thermometer

Range	:	0-160°C.
Stem length	:	6 inches.
Immersion	:	$2\frac{1}{2}$ inches.
Location	:	stainless steel pocket on 2 inch line.

He Outlet Temperature from Heat Exchanger 2-TI-7

Primary Element and Indicator : 'ROTOTHERM' bi-metal thermometer

Range	:	0-100°C.
Stem length	:	6 inches.
Immersion	:	$2\frac{1}{2}$ inches.
Location	:	stainless steel pocket on 2 inch line.
Alarm contacts	:	27°C.

He Pressure to D_2O Filling Station 2-PI-38

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	0-15 p.s.i.g.
Diaphragm material	:	stainless steel.
Location	:	D_2O filling station, Reactor Basement.
Connection	:	$\frac{1}{2}$ inch B.S.P.

He Pressure Drop Across Burner 2-ΔPI-23

Primary Element and Indicator : 'PAYNE AND GRIFFITH' Schaffer gauge

Range	:	0-10 inches W.G.
Diaphragm material	:	stainless steel.
Location	:	Reactor Basement Re-combiner.
Connection	:	$\frac{1}{2}$ inch B.S.P.

He Pressure in Reactor 2-PI-65

Primary Element and Transmitter : 'DRIMAC' D.P. cell

Range	:	0-40 p.s.i.g.
Output	:	0-40 p.s.i.g.
Supply	:	0-50 p.s.i.g.
Diaphragm material	:	316 stainless steel.
Location	:	8 inch He line to reactor.

Indicator Receiver : 'KENT' M40 12 inch dial indicator

Calibrated	:	(-15) - 0 - (+20) inches W.G.
Location	:	No. 1 Panel 8 Main Control Room.
		No. 2 Emergency Control Room in panel adjacent to Plant Room mimic.

Alarm Switches : K.D.G. SP33 pressure switch

Range	:	0-40 p.s.i.g.
Diaphragm material	:	beryllium copper.
Location	:	rear of Panel 8, Main Control Room.
Alarm settings	:	alarm at -5 inches W.G., Trip at +12 inches W.G.

He Pressure for Gasholder Protection PS-6/6A

Primary Element and Transmitter : 'DELTA-TECH' pressure switch

Range	:	0-15 inches W.G.
Bellows material	:	stainless steel.
Switch contacts	:	S.P. C/O.
Switch setting	:	12 inches W.G.
Location	:	8 inch He line to reactor.

Control Element : 'FISHER-GOVERNOR' pneumatic control valves

Valve size	:	2 inch single seat, reverse acting.
Operation	:	solenoid-operated exhaust valves.

Valves shut when pressure reaches 12 inches W.G.

He Flow to Recombiner 2-FI-7

Primary Element and Indicator : 'ROTAMETER' Type 107

Flow range	:	0-25 s.c.f.m.
Line size	:	1 inch.
Float material	:	aluminium.
Fluid	:	helium.
Alarm	:	no flow.
Location	:	Downstream of blower. Reactor Basement, storage block north-west wall.

He Flow to B.O.E. Unit 2-FIA-8

Primary Element and Indicator : 'ROTAMETER' Type 107

Flow range	:	2.5 - 25 s.c.f.m.
Line size	:	2 inches.
Float material	:	aluminium.
Fluid	:	helium.
Location	:	Downstream of blower, Reactor Basement, adjacent to 2V6.

He Level in Main Gasholder 2-LIAT-6

Primary Element and Actuator : 'ASHMORE, BENEAN AND PEASE' level limit switches

Alarm settings	:	10% capacity	- warning.
		5% "	- control reversal.
		80% "	- high level warning.

2.3 GRAPHITE REFLECTOR GAS CIRCUIT

He Level in Graphite Gasholder 3-LIAT-7

Primary Element and Actuator : 'ASHMORE, BENEAN AND PEASE' level limit switches

Alarm settings	:	Min. approx. 15 ft^3.
		Max. approx. 80 ft^3.

He Graphite Gasholder Pressure

Primary Element and Indicator : 'DELTA TECH' bellows type gauge

Range	:	0-12 inches W.G.
Bellows material	:	stainless steel.
Connection	:	$\frac{1}{2}$ inch B.S.P.
Location	:	Gasholder 2V7.

2.4 LIGHT WATER CIRCUIT

H_2O Outlet Temperature 5-E-2 H.E. 4-TI-35

Primary Element and Indicator : 'ROTOTHERM' bi-metal thermometer

Range	:	0-60°C.
Immersion	:	4 inches (Brass pocket screwed $\frac{1}{2}$ inch B.S.P.).
Location	:	Outlet line from 5-E-2 H.E.

H_2O Outlet Temperature Cooling Tower Weir 4-TIA-37

Primary Element and Indicator: 'ROTOTHERM' bi-metal thermometer

Range	:	0-30°C to + 60°C.
Immersion	:	8 inches (brass pocket screwed $\frac{1}{2}$ inch B.S.P.).
Alarm setting	:	high + 36°C, low + 4°C.
Location	:	Pump house, right hand of suction header.

H_2O Outlet Temperature Main Heat Exchangers 4-TIA-39

Primary Element and Indicator : 'ROTOTHERM' bi-metal thermometer

Range	:	0-100°C.
Immersion	:	8 inches (brass pocket screwed $\frac{1}{2}$ inch B.S.P.).
Alarm setting	:	50°C.
Location	:	junction of 20 inch pipe and outlet header, Reactor Basement.

H_2O Inlet Temperature Main Heat Exchangers 4-TRA-42

Primary Element : 'HERAEUS' resistance thermometer

Material	:	platinum (glass enclosed).
Resistance	:	100 ohms (nominal) at 0°C, 3 wire type.
Immersion	:	10 inches - taken from o.d. of pipe to top of stainless steel pocket.
Location	:	junction of 20 inch pipe and inlet header, Reactor Basement.

Receiver : 'KENT' strip chart recorder (refer manual AAEC/M36) twin range

No. of channels	:	2
Range	:	0-10°C and 0-40°C.
Location	:	Control Room Panel No. 5.
Alarm settings	:	38°C.

H_2O Temperature Difference Across 1E1/1, 2 and 3 H.E. 4ΔTRA-

Primary Elements : 'DEGUSSA' (Type P7) resistance thermometer

Material	:	platinum (glass encapsulated).
Resistance	:	100 ohms at 0°C (nominal), 3 wire type.
Immersion	:	Approx. 3 inches in a $\frac{1}{8}$ inch thick brass pocket.
Location	:	10 inch line between Inlet/Outlet header and D_2O Plant Room.

<u>Receiver</u> : 'KENT' strip chart recorder, (refer manual AAEC/M36) twin range

No. of channels	:	2
Range	:	0-10°C, 0-40°C, each pair may be selected via a selector switch mounted in recorder case.
Location	:	Main Control Room Panel No. 5.

<u>H_2O Temperature Difference Across Inlet and Outlet Header 4ΔTRA-</u>

<u>Primary Elements</u> : 'DEGUSSA' (Type P7) resistance thermometer

Material	:	platinum (glass encapsulated).
Resistance	:	100 ohms at 0°C (nominal), 3 wire type.
Immersion	:	Approx. 3 inches in a $\frac{1}{8}$ inch thick brass pocket.
Location	:	Junction of 20 inch pipe and Inlet/Outlet header, Reactor Basement.

<u>Receiver</u> : 'KENT' strip chart recorder, (refer manual AAEC/M36) twin range

No. of channels	:	2
Range	:	0-10°C, 0-40°C, each pair may be selected via a selector switch mounted in recorder case.
Location	:	Main Control Room Panel No. 5.

<u>H_2O Pressure Cooling Tower Pump 4-P-6/1 Discharge 4-PI-44</u>

<u>Primary Element and Indicator</u> : 'BUDENBURG' Schaffer gauge

Range	:	0-30 p.s.i.g.
Diaphragm material	:	stainless steel.
Connection	:	$\frac{1}{2}$ inch B.S.P.
Location	:	Pump 4-P-6/1.

<u>H_2O Pressure Cooling Tower Pump 4-P-6/2 Discharge 4-PI-45</u>

<u>Primary Element and Indicator</u> : 'BUDENBURG' Schaffer gauge

Range	:	0-30 p.s.i.g.
Diaphragm material	:	stainless steel.
Connection	:	$\frac{1}{2}$ inch B.S.P.
Location	:	Pump 4-P-6/2.

H_2O Pressure Cooling Tower Pump 4-P-6/3 Discharge 4-PI-46

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	0-30 p.s.i.g.
Diaphragm material	:	stainless steel.
Connection	:	$\frac{1}{2}$ inch B.S.P.
Location	:	Pump 4-P-6/3.

H_2O Pressure Cooling Tower Pump 4-P-6/4 Discharge 4-PI-47

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	0-30 p.s.i.g.
Diaphragm material	:	stainless steel.
Connection	:	$\frac{1}{2}$ inch B.S.P.
Location	:	Pump 4-P-6/4.

H_2O Pressure Cooling Tower Pumps 4-P-6/1-4 Suction 4-PI-48

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	30 inches Hg - 0 - 30 p.s.i.g.
Diaphragm material	:	stainless steel.
Connection	:	$\frac{1}{2}$ inch B.S.P.
Location	:	Pump 4-P-6/1-4.

H_2O Pressure - Shutdown Pump 4-P-8/1 and 2 Suction

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	30 inches Hg - 0 - 30 p.s.i.g.
Diaphragm material	:	stainless steel
Connection	:	$\frac{1}{2}$ inch B.S.P.
Location	:	Pump 4-P-8/1-2.

H_2O Pressure Shutdown Pump 4-P-8/1 Discharge 4-PI-49

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	0-30 p.s.i.g.
Diaphragm material	:	stainless steel.
Connection	:	$\frac{1}{2}$ inch B.S.P.
Location	:	Pump 4-P-8/1.

H_2O Pressure Shutdown Pump 4-P-8/2 Discharge 4-PI-50

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	0-30 p.s.i.g.
Diaphragm material	:	stainless steel.
Connection	:	½ inch B.S.P.
Location	:	Pump 4-P-8/2.

H_2O Pressure Differential Across In-line Strainers 4-PI-81, 82, 83

Primary Element and Indicator : 'BUDENBURG' Bourdon tube gauge

Range	:	10 inches Hg - 0 - 10 p.s.i.g.
Bourdon tube	:	beryllium copper.
Location	:	Upstream of headers - Reactor Basement, in pipe-lines between headers and D_2O Plant Room wall.

H_2O Cooling Water Flow to Main Heat Exchangers 4-FIA-15

Primary Element : 'KENT' Dall tube

Fluid conditions	:	specific gravity 1.0 at 60°F. temperature 21°C (max. 32°C). pressure 22 p.s.i.g. (max. 30 p.s.i.g.).
Differential head	:	106 inches W.G. at a flow of 3.6×10^6 lb/hour.
Line size	:	19.875 inches.
Throat material	:	gunmetal.
Location	:	20 inch pipe upstream of main inlet isolating valve.

Measuring Unit and Transmitter : 'FOXBORO' pneumatic D.P. cell

Range	:	0-106 inches W.G.
Output	:	3-15 p.s.i.g.
Supply	:	20 p.s.i.g. clean dry oil-free air.
Diaphragm material	:	beryllium copper.
Location	:	adjacent to Dall tube.

Receiver : 'KENT' circular scale indicator, refer to manual AAEC/M29.

Calibration	:	0-1000 lb/second.
Location	:	Control Room Panel No. 4.

Alarms : 'K.D.G.' SP33 pressure switch

Range	:	3-15 p.s.i.g.
Alarm setting	:	less than 80%.

H_2O Flow Shield Cooling Heat Exchangers Outlet 4-FE-21

Primary Element : 'KENT' orifice plate

Flow conditions	:	specific gravity 1.0 at 60°F. temperature 25.6°C. pressure 30 p.s.i.g.
Differential head	:	50 inches W.G. at 90,000 lb/hour.
Line size	:	4 inches.
Pressure tappings	:	D and D/2, $\frac{1}{2}$ inch B.S.P.
Material	:	stainless steel.
Location	:	Outlet line above Shield Cooling Pumps.

H_2O Level Cooling Tower Basin 4-LCA-10

Primary Element : 'LONDEX' Electrodes (4)

Control range	:	6 inches.
Alarm range	:	9 inches.
Alarm settings	:	9 inches.

2.5 SHIELD COOLING CIRCUIT

Temperature Shield Cooling Water Inlet 5-TI-9

Primary Element and Indicator : 'ROTOTHERM' bi-metal thermometer

Range	:	0-100°C.
Immersion	:	3 inches, copper pocket screwed $\frac{1}{2}$ inch B.S.P.
Alarm setting	:	60°C.- 70°C.
Location	:	Outlet from 5-E-2 H.E.

Temperature Shield Cooling Bulk Water Outlet 5-TI-10

Primary Element and Indicator : 'ROTOTHERM' bi-metal thermometer

Range	:	0-100°C.
Immersion	:	3 inches, copper pocket screwed $\frac{1}{2}$ inch B.S.P.
Alarm setting	:	57°C ± 2°C.
Location	:	Reactor Basement, north wall of Experimental Plant Room.

Temperature Cooling Water Outlet Shield Top 5-TI-8

Primary Element and Indicator : 'ROTOTHERM' bi-metal thermometer

Range	:	0-100°C.
Immersion	:	3 inches, copper pocket screwed $\frac{1}{2}$ inch B.S.P.
Alarm setting	:	71°C.
Location	:	Reactor Basement, north wall of Experimental Plant Room.

Temperature Cooling Water Outlet Shield Bottom 5-TI-15 and 40

Primary Element and Indicator : 'ROTOTHERM' bi-metal thermometer

Range	:	0-100°C.
Immersion	:	3 inches, copper pocket screwed $\frac{1}{2}$ inch B.S.P.
Alarm setting	:	70°C.
Location	:	Reactor Basement, north wall of Experimental Plant Room.

Temperature Cooling Water Outlet Radial Shield 5-TI-41, 43, 44, 45

Primary Element and Indicator : 'ROTOTHERM' bi-metal thermometer

Range	:	0-100°C.
Immersion	:	3 inches, copper pocket screwed $\frac{1}{2}$ inch B.S.P.
Alarm setting	:	71°C.
Location	:	Reactor Basement, north wall of Experimental Plant Room.

Temperature Cooling Water Outlet Thermal Column 5-TI-46

Primary Element and Indicator : 'ROTOTHERM' bi-metal thermometer

Range	:	0-100°C.
Immersion	:	3 inches, copper pocket screwed $\frac{1}{2}$ inch B.S.P.
Alarm setting	:	70°C.
Location	:	Reactor Basement, north wall of Experimental Plant Room.

Pressure Shield Cooling Pump Suction 5-PI-39

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	0-25 p.s.i.g.
Diaphragm material	:	stainless steel.
Location	:	Pump.

Pressure Shield Cooling Pump Discharge 5-PI-40, 41

Primary Element and Indicator : 'BUDENBURG' Schaffer gauge

Range	:	0-60 p.s.i.g.
Diaphragm material	:	stainless steel.
Location	:	5-PI-40 on Pump 5P-7/1.
		5-PI-41 on Pump 5P-7/2.

Flow Shield Cooling Water Outlet from 5E-2 H.E. 5-FIA-14

Primary Element : 'R and G' percentage indicator set at 18%

Level Cooling Water Shield Tank 5-LA-8

Primary Element and Alarm : 'TRIST' float switch

Range	:	2.6 feet (float travel).
Float material	:	copper.
Float diameter	:	4 inches.
Alarm settings	:	high at 90 gallons.
		low at 40 gallons.
Location	:	shield cooling tank.5V9.

H_2O Pressure - Shield Cooling Inlet 5-PI-1/8

Primary Element and Indicator : 'N.I.C.' Bourdon gauge

Range	:	0-30 p.s.i.g.
Bourdon tube	:	beryllium copper.
Connection	:	$\frac{3}{8}$ inch B.S.P.
Location	:	Inlet lines, Experimental Plant Room wall opposite shield cooling pumps.

H_2O Pressure - Shield Cooling Outlet 5-PI-9/16

Primary Element and Indicator : 'N.I.C.' Bourdon gauge

Range	:	30 inches Hg - 0 - 30 p.s.i.g.
Bourdon tube	:	beryllium copper.
Connection	:	$\frac{3}{8}$ inch B.S.P.
Location	:	Outlet lines, Reactor Basement, opposite shield cooling pumps.

2.6 FLASK

Temperature Flask Coolant Heat Exchanger Inlet 9-TI-5

Primary Element and Indicator : 'TAYLOR' gas-filled thermometer

Range	:	0-400°C.
Capillary length	:	15 feet, PVC covered.
Bulb length	:	$5\frac{7}{8}$ inches.
Bulb material	:	stainless steel, type 23.

Temperature Flask Coolant Heat Exchanger Outlet 9-TI-6

Primary Element and Indicator : 'TAYLOR' gas-filled thermometer

Range	:	0-100°C.
Capillary length	:	15 feet, PVC covered.
Bulb length	:	$5\frac{7}{8}$ inches.
Bulb material	:	stainless steel, type 23.

Pressure Flask Coolant Pump Suction 9-PI-35

Primary Element and Indicator : 'DELTA TECH' Schaffer gauge

Range	:	0-15 inches W.G.
Diaphragm	:	stainless steel.
Connection	:	$\frac{1}{2}$ inch B.S.P.

Flow Air to Flask 9-FIA-17

Primary Element and Indicator : 'Rotameter'

Fluid conditions	:	air.
		pressure 20 inches W.G. (2 p.s.i.g.).
		temperature 30°C (max. 50°C).
Flow rate	:	0-150 lb/hour.

2.7 CONTROL INSTRUMENTATION

Temperature Graphite Reflector and Biological Shield 11-TI-50

Primary Element : 'PYROTENAX' thermocouples

Type	:	iron/constantan.
Insulation	:	magnesium oxide.
Sheath	:	galvanised mild steel.
Location	:	refer A.A.E.C. drawings AE95079 and AE95080.

Receiver : 'KENT' strip chart recorder and switch box

Range	:	0-200°C single point.
No. of switch box inputs	:	50.
Connections	:	Via twin 3/036 iron/constantan extension cable, yellow-positive, blue-negative.
Alarm settings	:	high at 160°C.
Location	:	Control Room Panel 9.

Temperature Fuel Elements

Primary Elements : thermocouples

Type	:	chromel/alumel mineral insulated, metal sheathed.
Insulation	:	magnesium oxide.
Sheath	:	stainless steel 18/8/1 Ti.
Diameter	:	0.084 inches.

Receiver : 'KENT' strip chart recorder (two)

Range	:	0-150°C.
No. of inputs	:	12.
Alarm setting	:	65°C.
Connections	:	Via C/A compensating cable, brown-positive, blue-negative.
Location	:	Panel 8, Main Control Room.

Temperature, Centre Fuel Element

Primary Elements : thermocouples

Type	:	chromel/alumel mineral insulated, metal sheathed.
Insulation	:	magnesium oxide.
Sheath	:	stainless steel.
Diameter	:	0.084 inches.

Receiver : 'KENT' strip chart recorder

Range	:	0-150°C, 0-750°C.
No. of inputs	:	1.
Alarm settings	:	70°C.
Connections	:	Via C/A compensating cable, brown-positive, blue-negative.

3. PRINCIPLES OF OPERATION

The following notes describe briefly the principles of operation of the particular types of process instruments installed in HIFAR. A number of simple devices such as pressure switches, sight glasses, float switches, reducing valves and filters have been omitted.

3.1 Flow

Of the many types of flow meters available, the most frequently used is the differential pressure or head meter. It is usually preferred because of its simplicity, flexibility, ease of installation or replacement, and minimum maintenance. It is also readily adaptable to electric or pneumatic transmission and control.

All differential pressure meters operate on the same principle. A restriction is installed in the flow line (Figure 1) to create an artificial pressure drop which bears a relationship to the rate of flow. This relationship is expressed mathematically by the formula $Q = K \sqrt{H}$, where Q is the quantity flowing, K is a constant depending on conditions specific to each installation, and H is the pressure drop which is commonly called the differential.

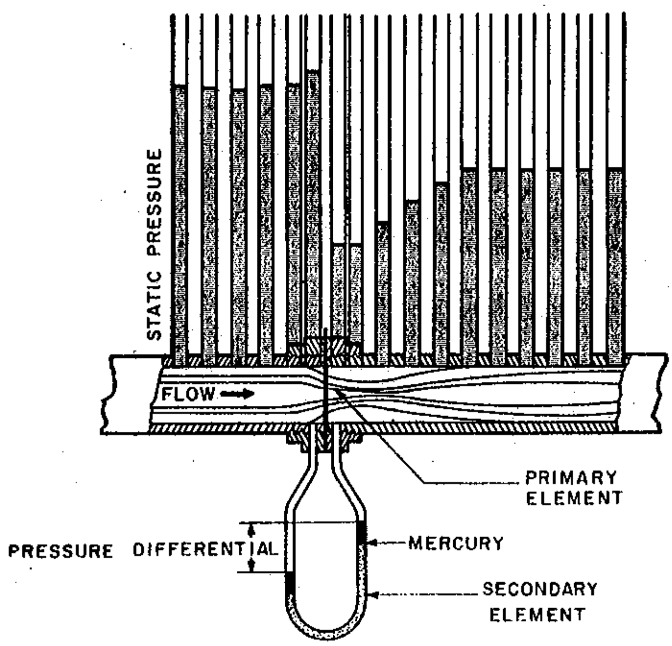


FIGURE 1. ELEMENTS OF HEAD FLOW METER.
Shaded vertical columns along top of pipe show relationship of static pressures existing at points up- and downstream from restriction. (Considine 1957, p. 4.5)

The restriction in the flow line used to produce the differential is called a primary element. A primary element can be an orifice plate, venturi tube, flow nozzle or Dall tube and the selection depends on the application.

3.1.1 Orifice plate

The most important characteristics of the orifice plate (Figure 2) favouring its choice as a primary device for head meters, are its economy of manufacture, reproducibility and ease of installation and replacement. Extensive application and research have provided highly reliable co-efficients for its use, with the result that orifices can be designed for the accurate measurement of most fluids.

A relatively large pressure drop is the major disadvantage incurred by their use. B.S. 1042 : 1964, gives a curve of pressure losses in terms of percentage of the differential pressure and the ratio of the orifice to pipe diameter. Taking a typical value of 0.6 for orifice to pipe diameter ratio, the loss works out at 40 per cent of the differential pressure.

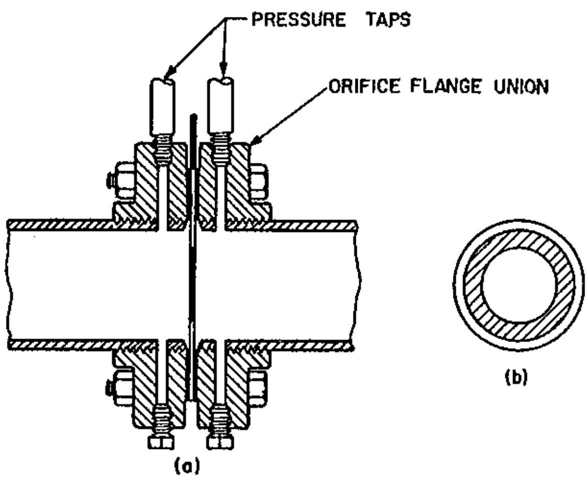


FIGURE 2. (a) THIN-PLATE SQUARE- OR SHARP-EDGED ORIFICE ASSEMBLY.
(b) PIPE CROSS SECTION SHOWING ORIFICE PLATE (shaded).
(Considine 1957, p. 4.9)

3.1.2 Dall tube

The Dall tube (Figure 3) was developed to give a much higher pressure recovery than that obtained with a Venturi tube and orifice plate. At the same time the overall length of the Dall tube is very much less than that of the equivalent size of Venturi tube.

The main features of the Dall tube are two truncated cones separated by a narrow throat. The inlet cone has an included angle between 40° and 50°, and the outlet cone between 12° and 17°. The diameter of the inlet cone is less than that of the pipe, resulting in a sharp step. This creates an impact pressure which is additional to the static pressure at the step. The higher upstream pressure connection is made just in front of the step. The other connection is made at the throat where the relatively abrupt change in area results in a marked static pressure depression.

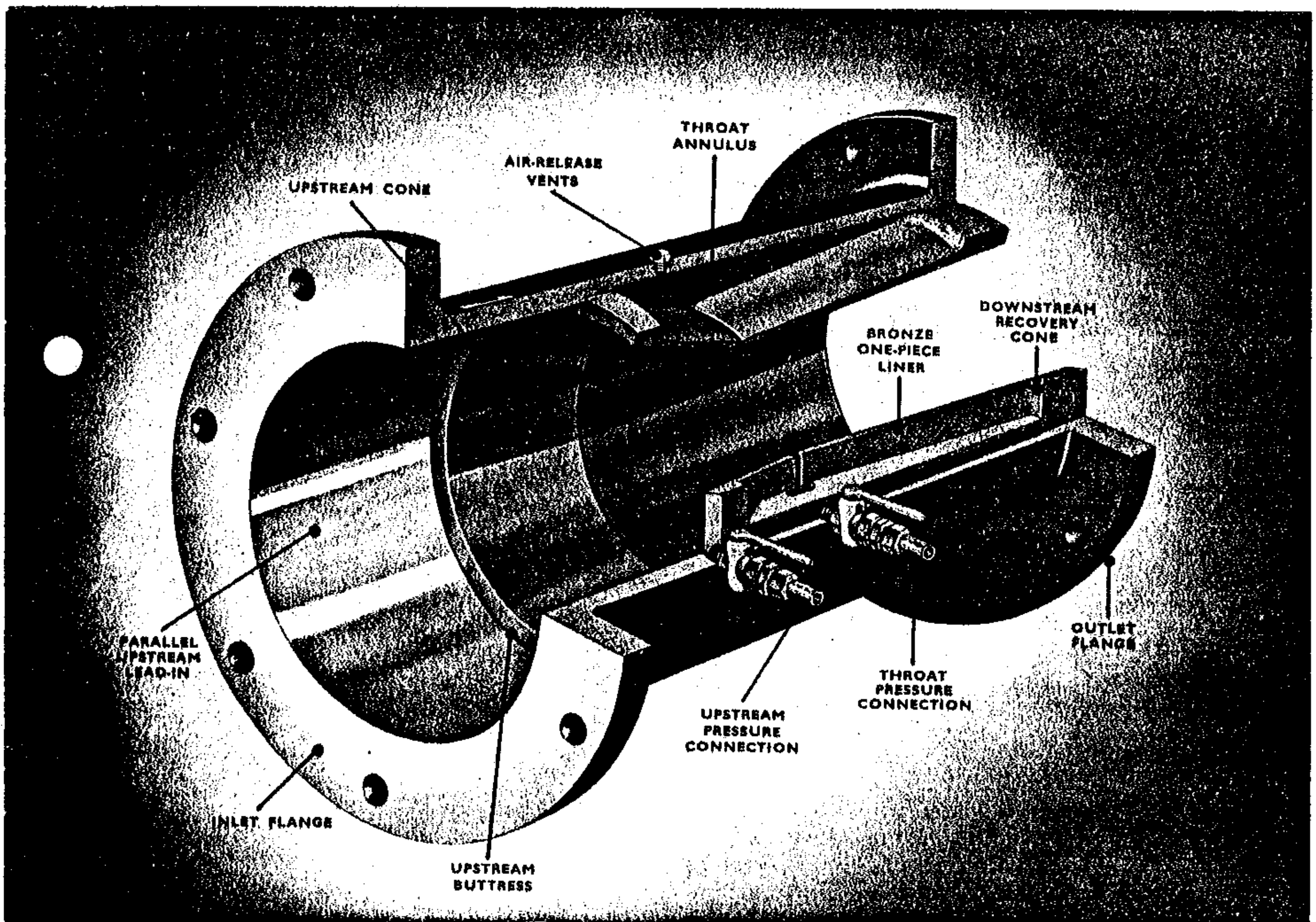


FIGURE 3. THE DALL TUBE

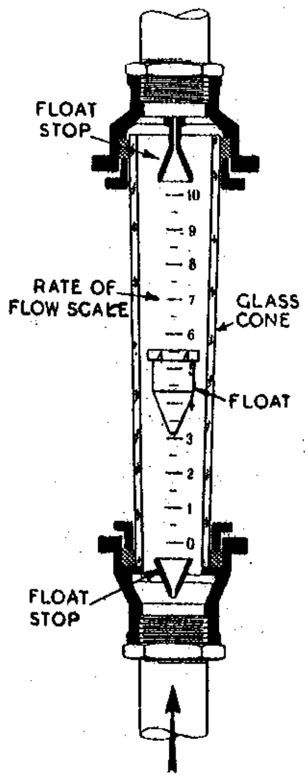
(George Kent Ltd.)

Depending on the ratio of the orifice to pipe diameter an average figure for the pressure loss is 5-6 per cent of the differential pressure generated.

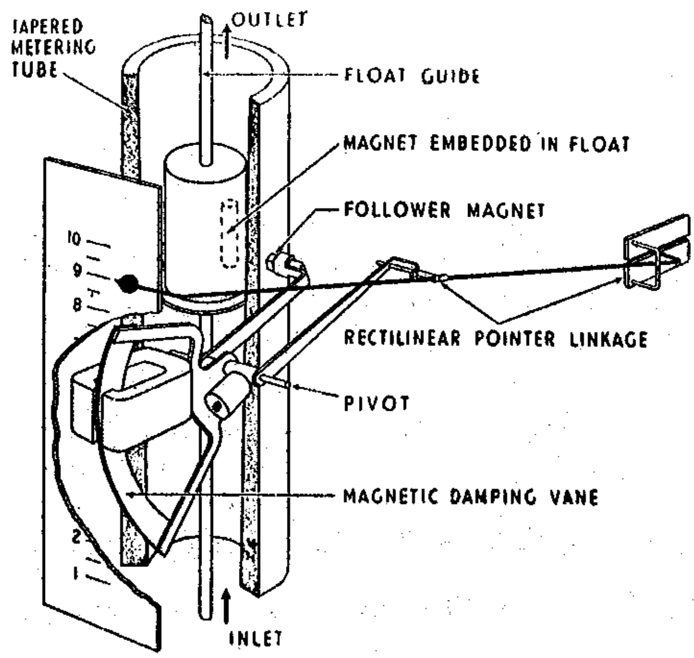
3.1.3 Rotameter

A rotameter or variable area flow meter operates on the same basic principle as other differential head meters such as those employing orifices. In the orifice meter there is a fixed aperture, and flow is indicated by a change in differential pressure. In the area meter (rotameter) there is a variable orifice and a relatively constant pressure drop. Thus in the area meter,flow is indicated by the area of the annular opening through which the fluid must pass.

As its name implies, this meter is a tapered tube forming an upward flow passage with its smallest diameter at the bottom (Figures 4 and 5).



Tapered Tube and Float



Magnetic Form

FIGURES 4 and 5. VARIABLE APERTURE METERS

(The Instrument Manual pp. 158, 160)

As the flow increases, the float rises within the tapered tube to a position where the pressure loss across the annular orifice just balances the weight of the float, and any mechanism which is attached to it. The float attains a position of equilibrium and the distance from the stop to the float is a measure of the flow rate.

The main characteristics of area meters are:

(a) minimum piping requirements (an area meter can usually be installed without regard to the fittings or length of straight pipe preceding or following the meter),

(b) linear scale, and

(c) small size. (Area meters are obtainable which are suitable for the flow ranges below those for which an orifice meter would be practical.)

3.2 Pressure

The measurement of absolute or gauge pressure on the reactor circuits is accomplished almost exclusively by primary sensing elements in the form of Bourdon tubes, diaphragms or bellows. Although available in a variety of types and construction, the following description and illustrations are representative of the installed instruments.

3.2.1 Bourdon tube gauge

This is one of the oldest pressure instruments, the tube having been patented by Bourdon in 1851. It has remained practically unchanged to this day and is one of the most common mechanisms in use.

Its action depends on the two sides of an elliptical cross section tube being forced apart when the internal pressure is increased. If a tube of this section is bent into a coil it tends to uncoil and straighten under pressure. When one end of the tube is fixed, the uncoiling effect causes the free end to move a pointer on a scale indicating the pressure applied to the tube. This tube can take several forms but the 'C' shape (Figure 6, see page 28) is the most widely used.

3.2.2 Schaffer diaphragm gauge

The Schaffer gauge is actuated by a stainless steel corrugated diaphragm (Figure 7, see page 28) which is clamped around its edge by flanges, leaving the control portion free to deflect when pressure is admitted from below. The deflection is connected by ball joint to the pointer, in the same manner as in a Bourdon tube gauge.

This type of gauge is preferred to the Bourdon tube gauge in applications involving sudden pressure surges, sustained overload pressures and in the lower pressure ranges below 16 p.s.i.g.

Budenberg: The Bourdon Pressure Gauge

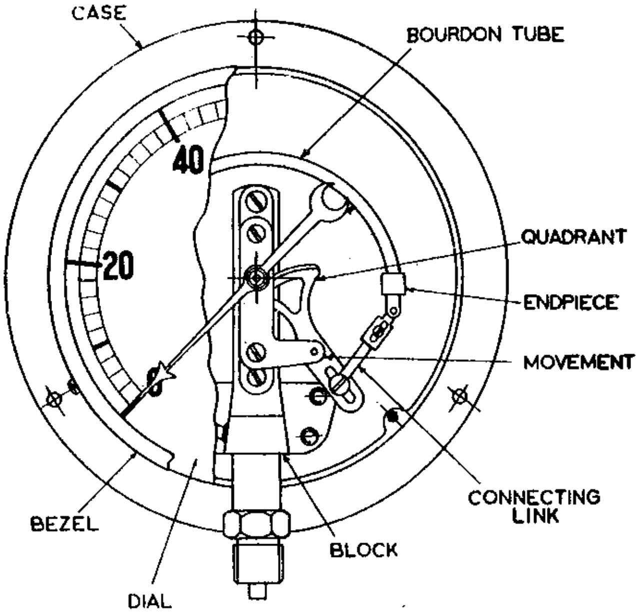
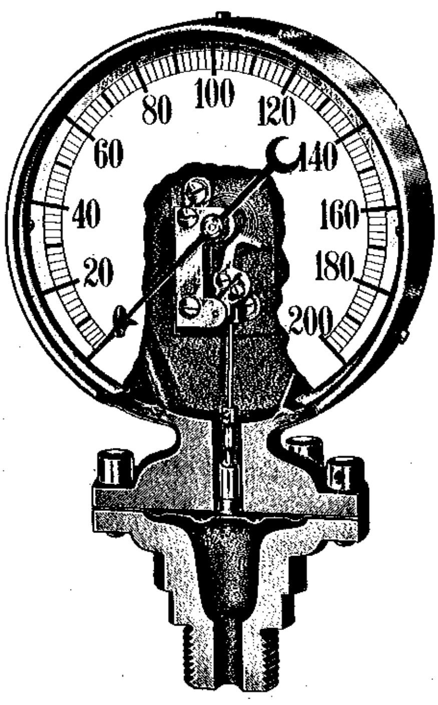


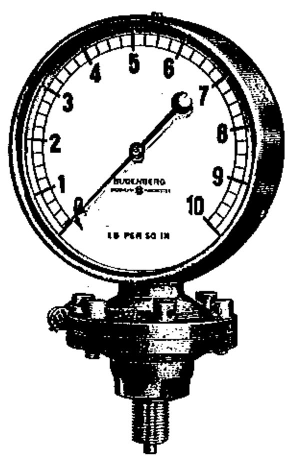
FIGURE 6. TYPICAL ARRANGEMENT OF BOURDON GAUGE

(Budenberg 1956)

Graduated 3 to 400 lb/in² **4in. to 10in. dials**



Part–section



Direct Mounting For
air, water, steam, oil, etc.

FIGURE 7. SCHAFFER DIAPHRAGM GAUGES

(Budenberg Gauge Co. Ltd.)

3.2.3 Differential pressure cells

The differential pressure cell transmitter is a force balance type of device which detects pressure and transmits information pneumatically or electrically to a receiver calibrated in terms of the measurement. The transmitter output is 3-15 p.s.i.g. for the pneumatic model and 4-20 or 10-50 milliamps for the electrical model.

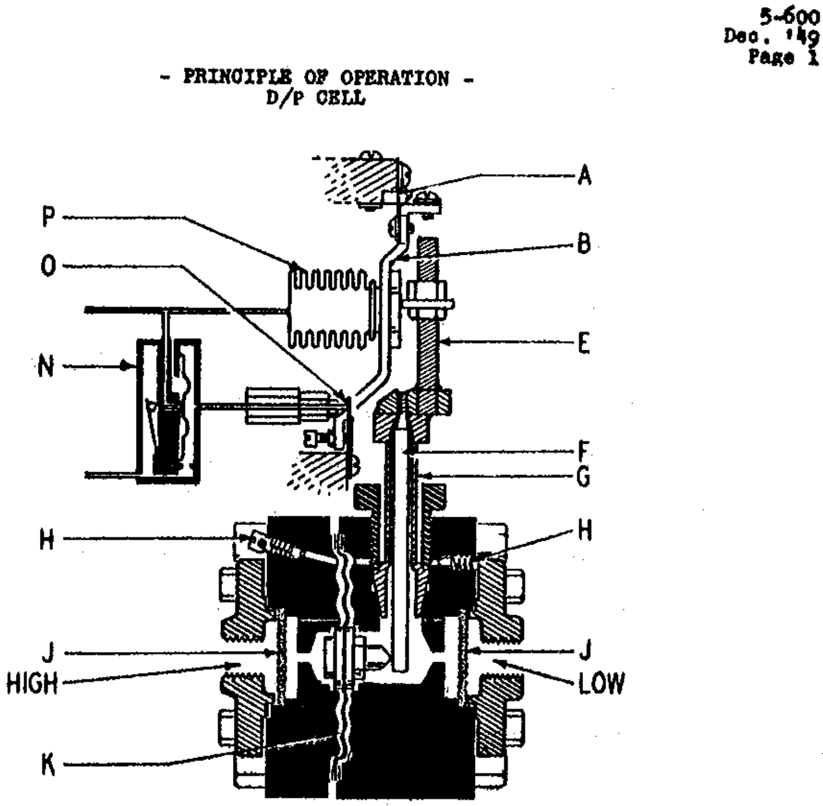


FIGURE 8. SCHEMATIC DIAGRAM OF DIFFERENTIAL PRESSURE CELL

(Foxboro-Yoxall Ltd.)

The basic components, the body, force-balance transmitter system and air connection block are shown schematically in Figure 8. The diaphragm (K) is securely clamped between separable sections of the body and separates the high and low pressure chambers in the body. The flexure tube (G) seals off the measuring cavity and also acts as a positive fulcrum for the force bar (F) and range rod (E). The range rod imposes on the intermediate lever (B) a force which is exactly proportional to the pressure on the diaphragm. Any tendency of the lever (B) to move is detected by the flapper nozzle (O).

Pressure established by the flapper nozzle is amplified by the relay (N) and led to the feed back bellows (P) and to the output.

Differential pressure cells are used extensively in process instrumentation systems and provide an accurate and extremely reliable measurement of differential, absolute or gauge pressure.

3.3 Temperature

Temperature is the most commonly measured physical variable in a nuclear reactor system and an extensive range of industrially proven sensors is available. In nuclear radiation environments 'chromel-alumel' mineral insulated metal sheathed thermocouples are generally preferred because of their resistance to radiation damage and their availability in a range of physical sizes, hot junctions and sheath materials.

3.3.1 Resistance thermometers

The resistance thermometer depends upon the inherent characteristics of metals to change in electrical resistance when they undergo a change in temperature. Resistance thermometer bulbs are usually made of platinum, copper or nickel and are available in many forms and shapes depending upon their intended application. A typical industrial form is shown in Figure 9. For pure metals the change in resistance with temperature is practically linear over a portion of the resistance-temperature curve and can be expressed as:

$$R_t = R_o (1 + at + bt^2 + ct^3 + \ldots\ldots) ,$$

where R_o = resistance at 0°C (ohms).

R_t = resistance at temperature t (ohms).

a, b, c = coefficients calculated from resistance-temperature values spaced over the working range.

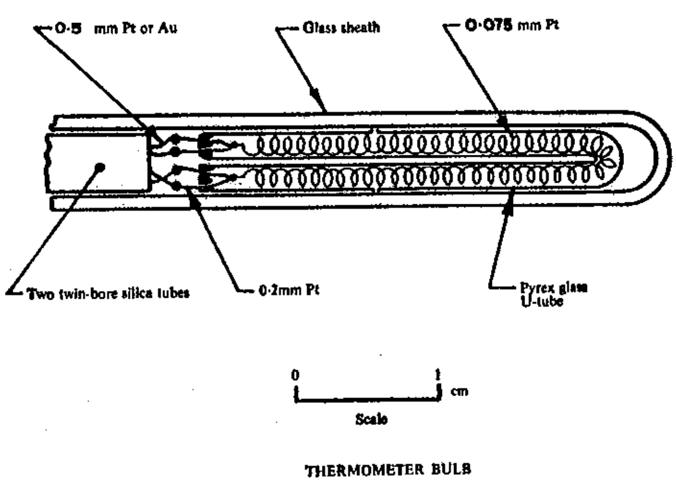


FIGURE 9. A PLATINUM RESISTANCE THERMOMETER DESIGN
(National Physical Laboratory 1957)

Platinum, obtainable in a highly pure form, maintains constant dependable values of the temperature coefficient and resistivity and is the most suitable of all metals for resistance thermometry. The useful temperature range of a platinum resistance bulb is -250°C to 600°C.

3.3.2 Gas filled thermometers

The filled system thermometer is designed to provide an indication or record of temperature some distance away from the point of measurement.

The system operates according to Charles' Law which states that the absolute pressure of a confined gas is proportional to the absolute temperature. In practice the capillary and Bourdon volume (Figure 10) is kept small compared with the bulb volume, thus preventing an appreciable percentage of the gas mass within the bulb from flowing out as the temperature is increased across the range.

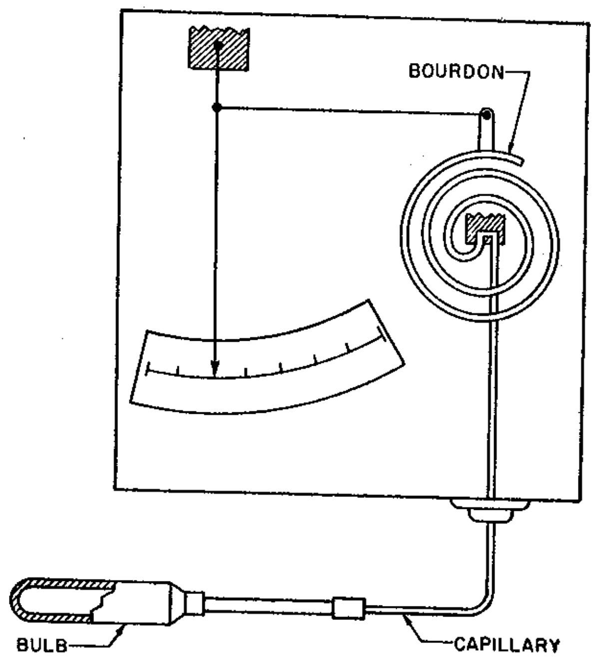


FIGURE 10. FILLED-SYSTEM THERMOMETER

(Considine 1957, p.2.68)

Its main advantages are simplicity and rugged construction combined with a sensitivity, response time and accuracy generally equal to other industrial temperature measuring systems. Its major limitation is the relatively large bulb size.

3.3.3 Bi-metal thermometers

The bi-metal thermometer is actuated by thermostatic bi-metal which can be defined as a material made up of strips of two or more metals fastened together, which because of the different expansion rates of the components, tends to change its curvature with change in temperature. If a strip of material is wound into a helix or spiral and one end is fixed, the other end will rotate when heat is applied. The angular deflection varies directly with the temperature change and the length of the strip, and inversely with the thickness of the material.

The general construction is illustrated in Figure 11. Its useful range is -150°C to 500°C with an accuracy of the order of 2 per cent. The stems containing the bi-metal element are available in a variety of forms depending on the application. The major disadvantage is again the relatively large element.

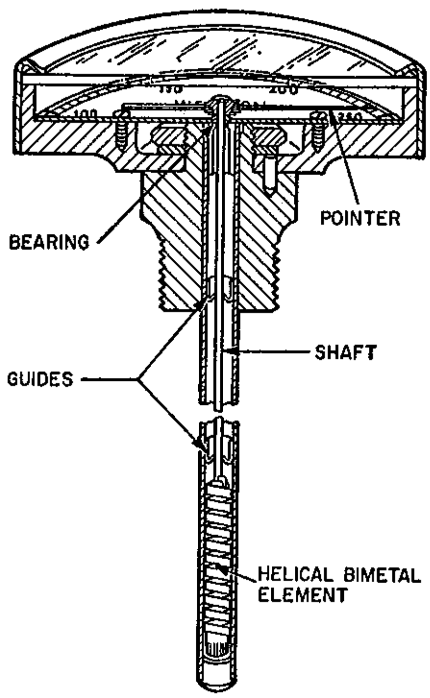


FIGURE 11. SECTIONAL VIEW OF INDUSTRIAL THERMOMETER USING HELICAL-TYPE BIMETAL ELEMENT.
(Considine 1957, p. 2.86)

3.3.4 Thermocouples

A thermocouple consists essentially of two dissimilar conductors, either or both of which may be pure metals, alloys or non-metals, which have a common junction at which the conductors are in good thermal and electrical contact. When the temperature of the common junction (the hot junction) differs from that of the other two ends of the conductors (the cold junction) an electromotive force is generated which can be represented by:

$$E = a + bt + ct^2 ,$$

where E = e.m.f.

t = temperature

a, b, c = constants.

Thermocouples are available in a wide variety of forms and materials and are the most commonly used temperature sensor in the range of -270°C to 2000°C. (See 'Thermocouples - Notes on their properties and applications' A.A.E.C. unpublished report.)

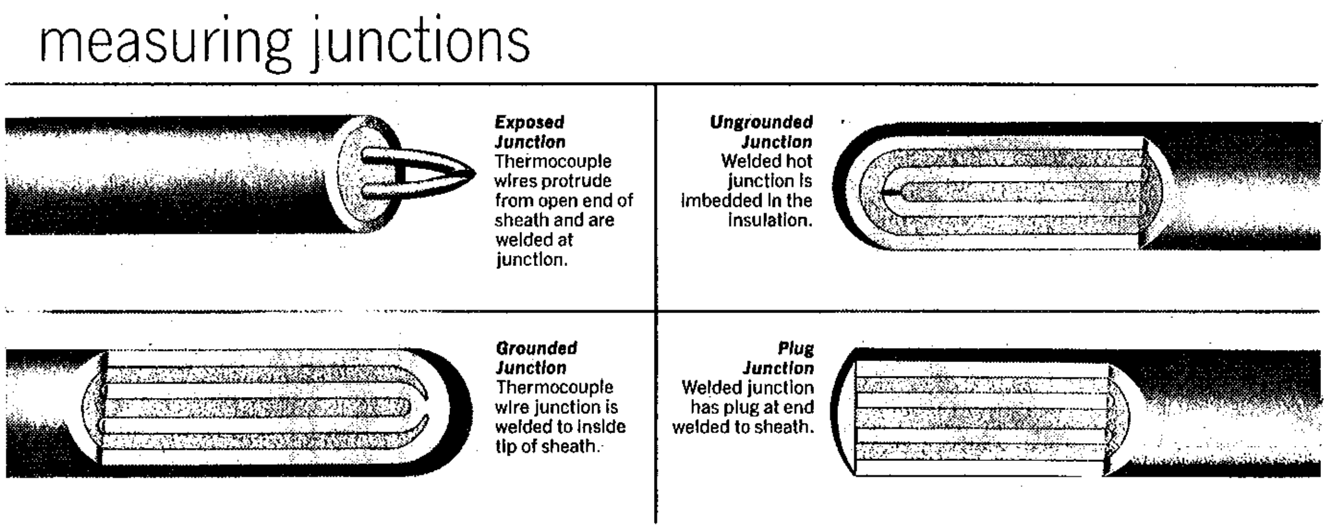


FIGURE 12. TYPICAL METAL SHEATHED MINERAL INSULATED THERMOCOUPLES

(Engelhard Industries Inc.)

3.4 Level

The determination of liquid level resolves itself into a measure of either (i) the position (height) of a liquid surface above a datum line or (ii) the hydrostatic head (pressure) developed by the liquid whose level is being ascertained. Sight glasses and floats used in the first case require no further

description and the pressure measuring devices previously described, especially D.P. cells, are suitable for level applications.

3.5 Conductivity Measurement

3.5.1 'P' type cells

Interest in the measurement of electrolyte conductivity arises chiefly from its usefulness as a measure of the ion concentrations in water solutions. The conductivity of a water solution is, in practice, almost exclusively due to dissolved electrolyte rather than to the solvent (water) ions and thus a criterion for electrolyte concentration can be established.

The determination of electrical conductivity (specific electrical conductance) is basically a measurement of the a.c. resistance of a column of solution. A typical measuring cell with gold plated electrodes is shown in Figure 13. The range of practical conductivity measurement extends from a fraction of a micromho to more than 1 mho.

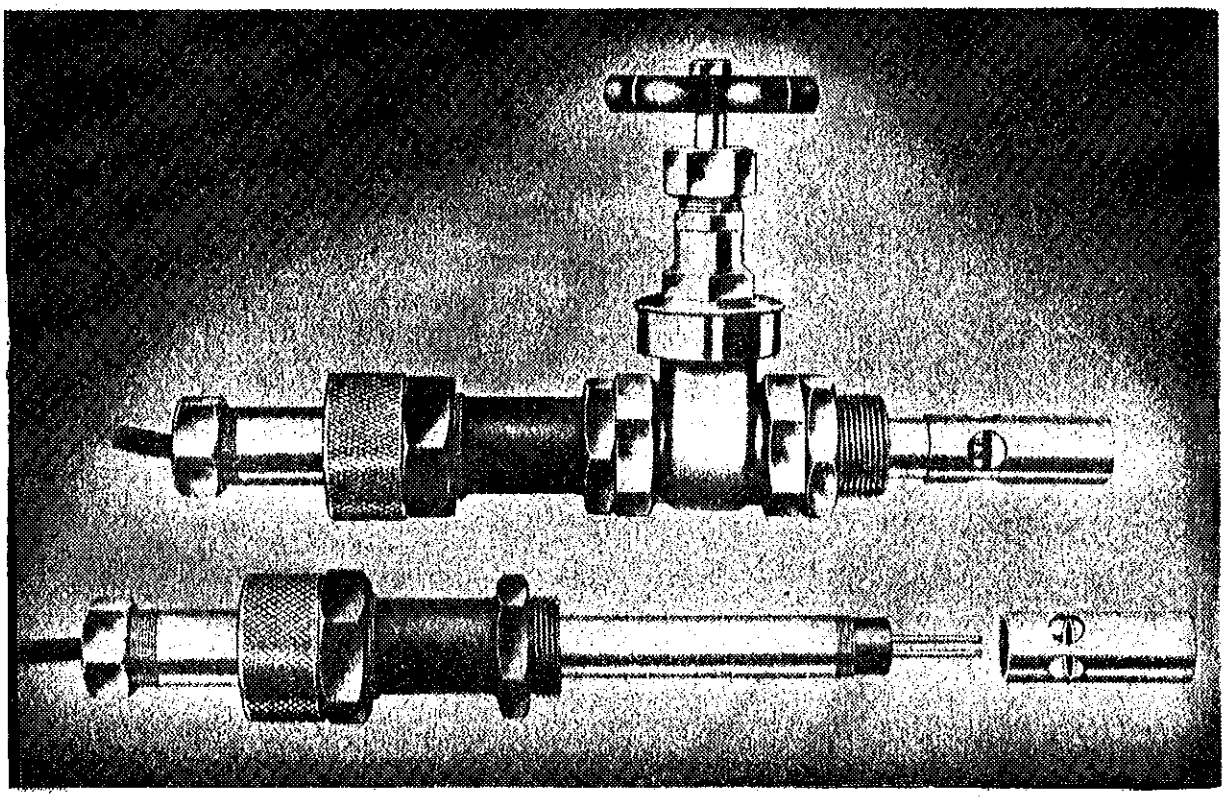


FIGURE 13. A TYPICAL 'P' TYPE CONDUCTIVITY CELL

(The Instrument Manual p. 98)

junction at which the conductors are in good thermal and electrical contact. When the temperature of the common junction (the hot junction) differs from that of the other two ends of the conductors (the cold junction) an electromotive force is generated which can be represented by:

$$E = a + bt + ct^2 ,$$

where E = e.m.f.

t = temperature

a, b, c = constants.

Thermocouples are available in a wide variety of forms and materials and are the most commonly used temperature sensor in the range of -270°C to 2000°C. (See 'Thermocouples - Notes on their properties and applications' A.A.E.C. unpublished report.)

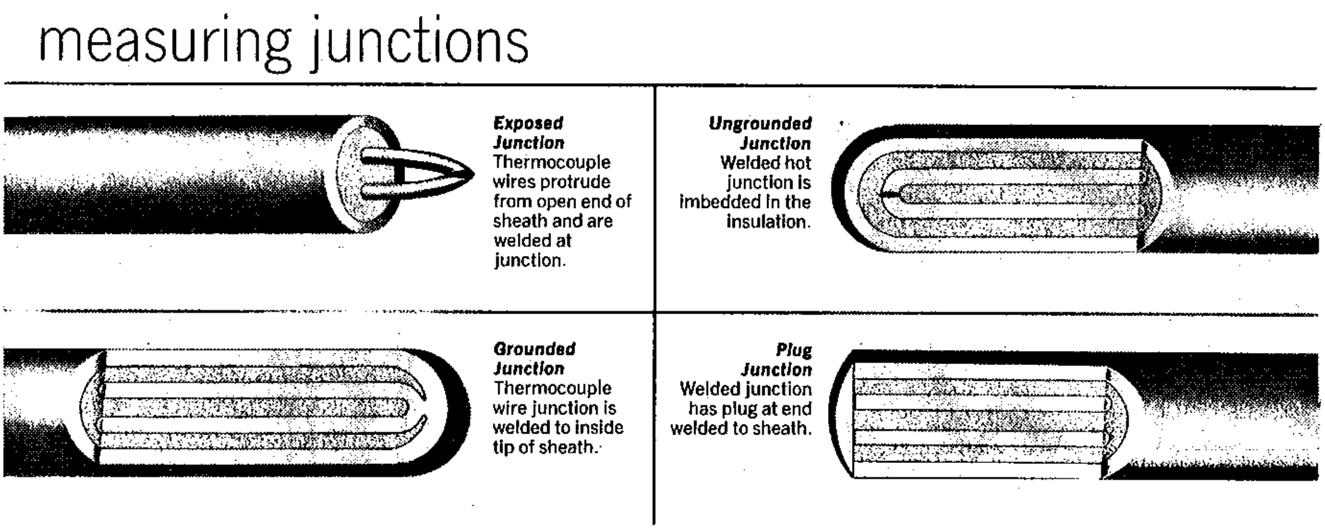


FIGURE 12. TYPICAL METAL SHEATHED MINERAL INSULATED THERMOCOUPLES

(Engelhard Industries Inc.)

3.4 Level

The determination of liquid level resolves itself into a measure of either (i) the position (height) of a liquid surface above a datum line or (ii) the hydrostatic head (pressure) developed by the liquid whose level is being ascertained. Sight glasses and floats used in the first case require no further

4. REFERENCES

Budenberg, C. F. (1956). - The Bourdon pressure gauge. Trans. Soc. Inst. Tech. 8(2) : 75-88.

Budenberg Gauge Co. Ltd. (1957). - Catalogue, Section 1C pp.45-68. Test gauges and gauges for special purposes. Budenburg Gauge Co. Ltd., Broadheath near Manchester.

Considine, D. M. (Editor). (1957). - Process Instruments and Controls Handbook. McGraw-Hill, New York.

Engelhard Industries Inc. (n.d.). - Data sheet. Enclad mineral insulated thermocouples and conductors. Engelhard Industries Inc. New Jersey.

Foxboro-Yoxall Ltd. (n.d.). Instruction book for D.P. Cell Transmitter Type 3A. Foxboro-Yoxall Ltd. London.

George Kent Ltd. (n.d.). - Dall flow tube. Publication 275/1057. George Kent Ltd. Luton, England.

National Physical Laboratory. (1957). - Calibration of temperature measuring instruments. Notes on Applied Science, No. 12. H.M.S.O. London.

United Trade Press Ltd. (1960). - The Instrument Manual. United Trade Press Ltd. London.

APPENDIX 1

REACTOR HIFAR - LIST OF INSTRUMENTATION MANUALS

	M1	Introduction to Guard and Safety Circuits
	M2	Complete Shutdown Circuits
	M3	Trip Circuits
	M4	Control Reversal Circuits
	M5	Warning Circuits
*	M6	Primary Search Unit
	M7	Start Guard Circuits
*	M8	Flux Trip Circuits
*	M9	Safety Rod Circuits
*	M10	Coarse Control Arm Circuits
*	M11	Fine Control Rod Circuit
*	M12	Dump Valve Circuit
	M13	Main Heavy Water Pump Circuit (S1)
	M14	Shutdown Heavy Water Pump Circuit (S2)
*	M15	Transfer and Liquid Level Pump Circuits (S3 and S4)
*	M16	Main H_2O Pump Circuits (S6)
*	M17	H_2O Shutdown Circuits (S8)
*	M18	Cooling Tower Fan Circuits (G8)
*	M19	Shield Cooling Pump Circuits (S7)
*	M20	Experimental Pump Circuits (S9)
*	M21	Fine Control Rod Pump Circuits (S12)
*	M22	Miscellaneous Circuits 24V circuits — 4-LLA-10 circuit 50V d.c. circuits — 4-L-15 circuit 240V circuits — Panel N
	M23	Trip and Warning Alarm Circuits
*	M24	Ventilation Flow Diagram Circuit
*	M25	Main Flow Diagram and Cooling Tower Lamp Circuits
*	M26	Annunciator Lamp Circuits
*	M27	Fault Analysis Lamp Circuits
*	M28	Principles of Operation of the Nucleonic Instruments
	M29	The Control Room
*	M30	The Coarse Control System

continued...

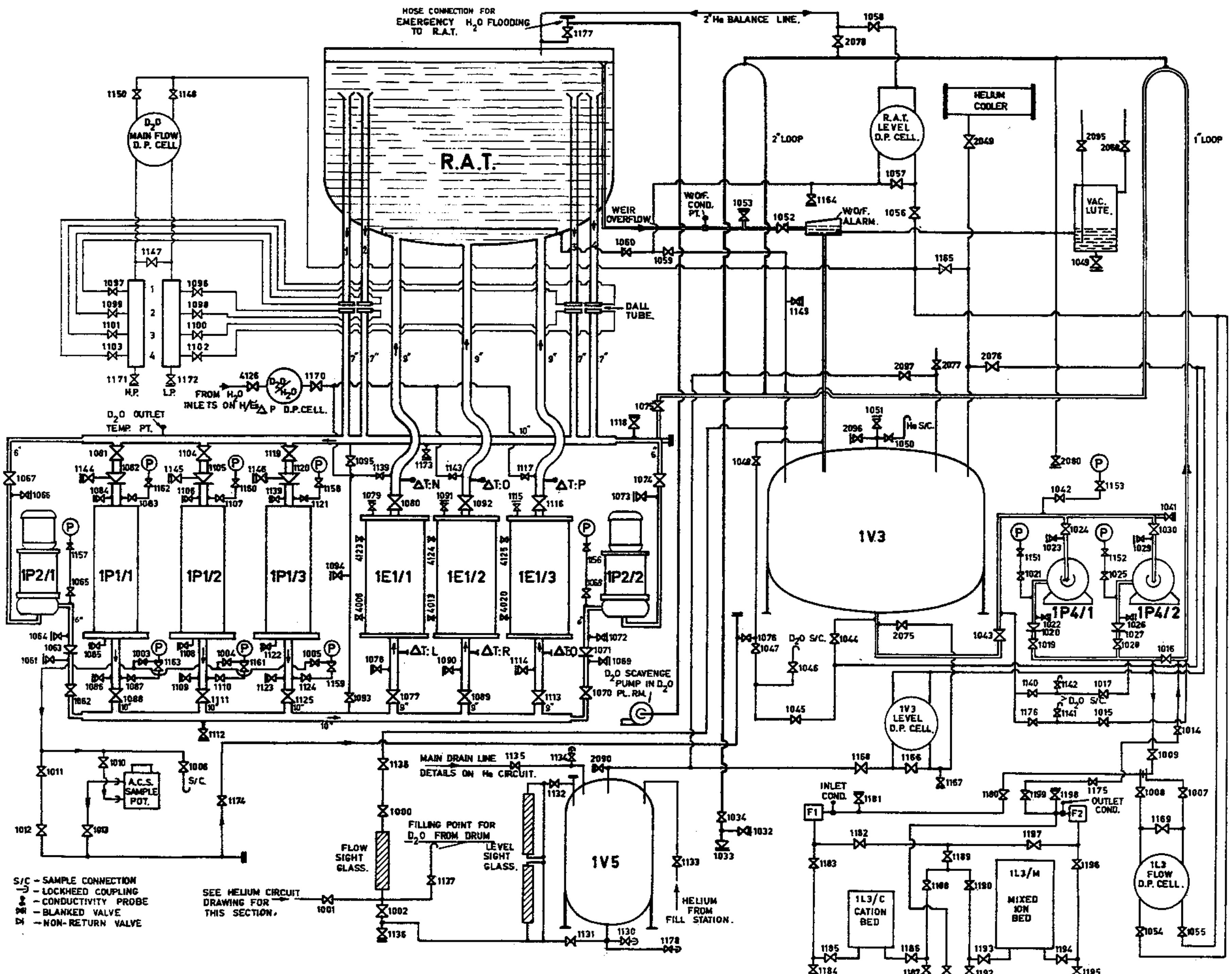


FIGURE 14. HEAVY WATER CIRCUIT OF HIFAR

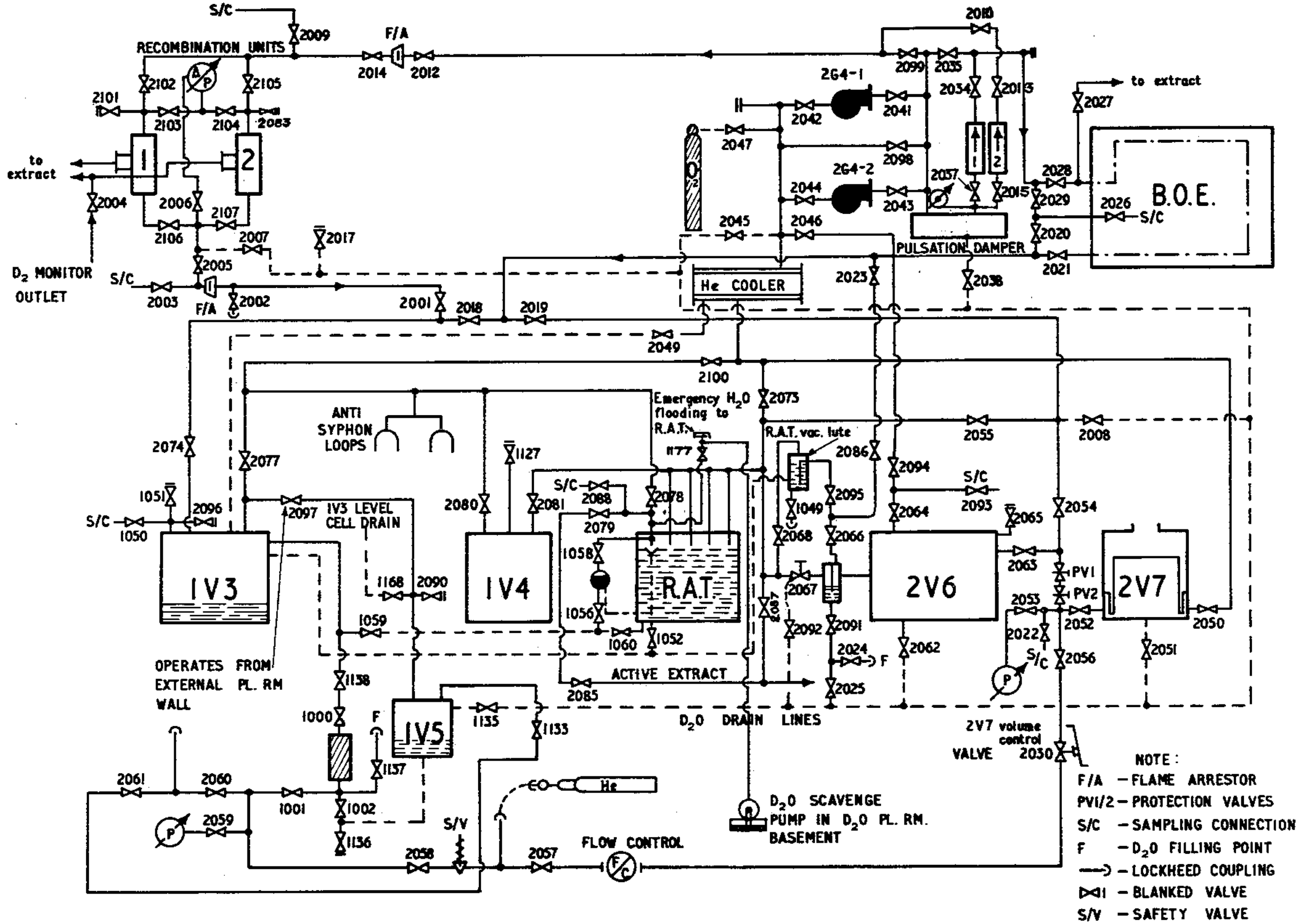


FIGURE 15. HELIUM CIRCUIT OF HIFAR