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EBR-II Data Digitization

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ABSTRACT

This work is aimed to initiate a process to generate a validation database from the collection of the operational data of the last nine years (1985-1994) of activity of the EBR-II reactor. In particular two tasks are here accomplished. First all the drawings of the reactor vessel internals, and primary loop are identified in terms of Idaho National Laboratory (INL) Electronic Document Management System (EDMS) Identification Number. Second, a detailed description of all the sensors and their positioning in the reactor is reported to allow for an accurate reproduction of the signals by numerical methodology.

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FIGURES

TABLES

ACRONYMS

ANL	Argonne National Laboratory
AMS	Average Magnitude Squared
BFTF	Breached Fuel Test Facility
cps	Counter Per Second
DAS	Digital data Acquisition System
DND	Delayed Neutron Detector
EBR	Experimental Breeder Reactor
FCF	Fuel Cycle Facility
FEF	Fuels and Examination Facility
FERD	Fuel Element Rupture Detector
FFTS	Failed Fuel Transfer System
FGM	Fission Gas Monitor
FPTF	Fuel performance Test Facility
FUM	Fuel Unloading Machine
GLASS	Germanium-Lithium Argon-Scanning System
IBC	Interbuilding coffin
IHX	Intermediate Heat Exchanger
INCOT	In-core Instrument Test Facility
INSAT	Instrumented Subassembly Test Facility
LCR	Log Count Rate
LMFBR	Liquid Metals Fast Breeder Reactor
MSA	Mine Safety Appliances
NIFT	Nuclear Instrument Test Facility
NRTS	National Reactor Test Station
RCGM	Reactor Cover Gas Monitor
RSCL	Radioactive Sodium Chemistry Loop
TIR	Test Instrument Room
TREAT	Transient Reactor Test Facility

EBR-II Data Digitization

1. Objectives

The goal of this report is to place the fundaments of the construction of a validation database based on operating experience of EBR II reactor.

More in detail this report has two objective, first to provide the information to assess the amount of work it will be required to generate CAD files from the EBR-II drawings, and second to provide the information needed to locate and characterize the sensors used to monitor the reaction operation.

The location and availability of the EBR-II drawings is investigated and where possible provided, more detailed information is provided for the sensors.

For the sensors, the document reports a rather detailed information collection, so that this document could be used directly to characterize the sensors both in term of response and location.

2. List of References

The following reports have been recorder, as part of this work, in electronic format and used as source of the information for the report.

1. EBR-II System Design Descriptions – Volume I, General Facilities [1]
2. EBR-II System Design Descriptions – Volume II, Primary System [2]
    a. Chapter 1. General Information
    b. Chapter 2. Reactor
    c. Chapter 3. Primary Cooling System
    d. Chapter 4. Primary Tank Assembly
    e. Chapter 5. Fuel Handling System
    f. Chapter 6. Instrumentation
    g. Chapter 7. Auxiliary Systems
3. EBR-II System Design Descriptions – Volume III, Secondary System [3]
4. EBR-II System Design Descriptions – Volume IV, Steam System [4]
5. EBR-II System Design Descriptions – Volume V, Electrical System [5]
6. EBR-II System Design Descriptions – Volume VI, Sensitive Systems [6]

In particular "EBR-II System Design Descriptions – Volume II" (Chapters 2 to 5) have been used to identify the IDs of the drawings that will need to be made into CAD files.

The information of the instrumentation in EBR-II primary system is stored in the "EBR-II System Design Descriptions – Volume II, Chapter 6. Instrumentation."

Along the text square brackets are used to identify the volume that is the source of the reported information.

3. EBRII Drawings

Drawing tables are cataloged and possibly electronically stored in the Idaho National Laboratory Electronic Document Management System (EDMS). EDMS uses the original drawing IDs (referred here as Alternate ID) and its own ID system. The "EBR-II System Design Descriptions – Volume II" has been used as source to collect the "Alternate ID" of the drawing of interest and the search engine of EDMS has been used to find, when possible the new IDs.

Table 1 reports the title, EDMS ID, and Alternate ID of the drawing of interest for the instrument and component in the vessel and internals, while Table 2 reports the same information for the primary loop.

In both tables, the red color indicate drawings that where not found referenced in the EDMS at all, the bold is used to indicate active drawings, and the standard characters indicate inactive drawings. Inactive drawings are drawings that have been cataloged but not made available in electronic format.

Table 1 Library IDs of Instruments and Components in Vessels and Internals

Title / Component Name (if Title is not given)	EDMS ID	Alternate ID
Installation in CRP #2	Not Existing	E0392-0009-DX
EBR-II ACRDS 2 SPEED GEAR TRAIN LAYOUT	**689675**	**E1983-0091-DE**
INSTALLATION IN CRP #8	**693838**	**E5190-0304-DE**
INSTALLATION IN CR POSITION #6	**694358**	**E5221-0001-DE**
INSTALLATION OF INSAT 5C1 CR POSITION NO. 11 (2 SHTS)	**695317**	**E5224-0001-DF**
SYSTEM SCHEMATIC ACRDS	**696244**	**E5257-0019-DE**
INNER BLANKET SUB-ASSEMBLY	**692790**	**EB-1-25056-E**
Gripper Drive Motor Assembly	692798	EB-1-25079-D
Rack Drive Motor Assembly	692820	EB-1-25101-D
Gear Housing Assembly	692842	EB-1-25123-B
Guide Tube of Control Rod Drive	692855	EB-1-25136-D
Rack Drive Housing	692871	EB-1-25154-C
Gripper and Sensing Shaft Bellows	692881	EB-1-25164-D
Rack Tube	692886	EB-1-25169-C
Connecting Rod	692887	EB-1-25170-B
Gripper and Sensing Data Transducers	693316	EB-1-25176-C
Nesting Bellows	693317	EB-1-25177-C
PRIMARY TANK ASSEMBLY	**693319**	**EB-1-25179-F**
EBR-II PRIMARY SYSTEM REACTOR INLET PIPING	**693365**	**EB-1-25231-F**
Thermocouples Inner Vessel	693380	EB-1-25260-D

OUTER BLANKET SUB-ASSEMBLY	**693382**	**EB-1-25264-E**
Thermocouples Inner Vessel Shell Outside Wall	693383	EB-1-25266-D
Thermocouples Outer Vessel	693388	EB-1-25272-D
Safety Rod Drive Beam	693389	EB-1-25273-D
Mark I Core Type Driver Fuel Assembly	693392	EB-1-25276-F
Shock Absorber Assembly	693406	EB-1-25295-F
Safety Rod Drive Unit	693466	EB-1-25359-E
Safety Rod Drive Lower Assembly	693902	EB-1-25381-F
Main Shafts of Safety Rod Drive Lower Assembly	693903	EB-1-25382-E
Shielding Tube	693906	EB-1-25385-D
Rack	693907	EB-1-25386-D
Bellows Seal	693916	EB-1-25395-D
Drive Shafts and Universal Joints	693925	EB-1-25407-C
Rack Housing Assembly	693927	EB-1-25409-D
EBR-II NEUTRON SHIELDING	**693934**	**EB-1-25416-F**
Rack Housing Assembly Shock Absorber Assembly	693954	EB-1-25442-E
INSTRUMENT PLUG	**694389**	**EB-1-25582-D**
INSTRUMENT PLUG	**694390**	**EB-1-25584-D**
“V” Nozzle Plug	694439	EB-1-25653-F
Mark IA Control Rod	694502	EB-1-25731-F
Mark I Safety Rod	694869	EB-1-25791-F
ASSEMBLY REACTOR VESSEL GRID	**694885**	**EB-1-25809-E**
J. NOZZLE OUTER PLUG "O" RING SPACER Fission Counter	**689623** 694898	**EB-1-25822-E**
Mark I Blanket Region type driver fuel assembly	693383	EB-1-25857-F
Latch Mechanisms	695378	EB-1-26025-D
REACTOR VESSEL SUBASSEMBLY	**695949**	**EB-1-26290-E**
Dummy Core Fuel Rod	695950	EB-1-26291-D
Gripper and Sensing Data Transducers	695954	EB-1-26295-C

Scram Mechanism	696791	EB-1-26588-D
Reactor Vessel Cover Labyrinth Seal	696827	EB-1-26625-C
Control Position Data Transmitter	697190	EB-1-26739-C
COVER - REACTOR VESSEL	**697236**	**EB-1-26799-F**
REACTOR VESSEL INTERNALS ASSEMBLY	**697641**	**EB-1-26954-E**
SHIELDING CAN LAYOUT	**698059**	**EB-1-27172-F**
PRESSURE & TEMPERATURE INSTRUMENTS - EBR-II VESSEL	**698442**	**EB-1-27312-E**
EBR-II PRIMARY SYSTEM PUMP MI PRESSURE SENSING INSTALLATION	**691522**	**EB-1-27564-D**
Blanket Region Core	691934	EB-1-27689-F
Ion Chamber	Not Existing	EB-1-28083-E
REACTOR VESSEL, PRESSURE & RESISTANCE THERMOMETER INSTRUMENTATION INSTALLATION	**695094**	**EB-1-29015-E**
REACTOR OUTLET PIPING INSTRUMENTATION INSTALLATION	**695095**	**EB-1-29016-E**
REACTOR INLET (PUMP) M2 PIPING INSTRUMENTATION INSTALLATION	**695096**	**EB-1-29017-E**
REACTOR INLET (PUMP) M-1 PIPING INSTRUMENTATION INSTALLATION	**695097**	**EB-1-29018-E**
THERMOCOUPLE INSTALLATION - REACTOR VESSEL LOWER PLENUM	**695098**	**EB-1-29019-E**
Thermocouples in Primary Pump	695099	EB-1-29020-F
REACTOR VESSEL THERMOCOUPLE INSTALLATION (0-180 DEGREES)	**695100**	**EB-1-29021-E**
REACTOR VESSEL THERMOCOUPLE INSTALLATION (180-360 DEGREES)	**695101**	**EB-1-29022-E**
PRIMARY TANK COVER PLUG-NOZZLE-INSTRUMENT ARRANGEMENT	**695128**	**EB-1-29049-E**
THERMOCOUPLE INSTALLATION - BULK SODIUM	**695155**	**EB-1-29079-E**
Blanket Region Core	696069	EB-1-29396-F
Inner Blanket Neutron Source	696112	EB-1-29444-D
Source Rod Lifting Tool	696131	EB-1-29463-C

Outer Blanket Neutron Source	696132	EB-1-29464-D
Filtering, Core	697353	EB-1-29894-E
Inner Blanket Filtering Subassembly	697365	EB-1-29906-E
Manual Operator Assembly	697377	EB-1-29919-D
Core Flux Wire	Not Existing	EB-1-33847-F
Inner & Outer Blanket Flux Wire	Not Existing	EB-1-33855-D
Dummy Plugged Inner Blanket	Not Existing	EB-1-35392-D
Dummy Control Rod	Not Existing	EB-1-35393-D
Dummy Safety	Not Existing	EB-1-35394-D
Neutron Source Storage Thimble	698633	EB-1-38154-D
Material Surveillance	691702	EB-1-38381-E
Mark I Oscillator Rod and Thimble	692158	EB-1-38560-D
Stainless Steel Drop Rod Dummy Control Rod	692544	EB-1-38685-F
Mark II Oscillator Rod and Thimble	Not Existing	EB-1-38743-D
Oscillator Drive Assembly	692654	EB-1-38798-F
Drive Shaft Assembly	692662	EB-1-38806-F
Oscillator Drive Assembly	Not Existing	EB-1-38859-E
Gripper Drive Assembly PROPOSED MODIFICATION TO EB-1-38859-F (LOWER DRIVE ASSY- OSCILL. ROD)	693086 721532	EB-1-38859-F
Bearing Carrier Overload Spring Assembly	693164	EB-1-38940-D
Sensing Rod Switch Assembly Gripper Shaft Switch Assembly Drive Shaft Obstruction Switch Assembly	693174	EB-1-38950-D
Mark IA & IB Core Type Driver Fuel Assemblies	693191	EB-1-38967-F
Oscillator Rod Drive	693198	EB-1-38974-E
Positioning Monitoring Assembly	693204	EB-1-38980-E
Mark IA Blanket Region Type Driver Fuel Assembly	693666	EB-1-39018-F
Mark IB Model IHE Control Rod	693718	EB-1-39081-F
Inner & Outer Blanket SRB	700604	EB-1-39200-E

Mark IIB Oscillator and Thimble Assembly	Not Existing	EB-1-39282-D
Mark II Core Type Driver Fuel Assembly	700740	EB-1-39338-F
Mark I Blanket Region Type Driver Fuel Subassembly	701022	EB-1-39348-F
Mark I Core Type Driver Fuel Subassembly	701025	EB-1-39351-F
Mark IIB Oscillator and Thimble Assembly	Not Existing	EB-1-39475-F
Fuel Rod used in Place of Mark II Oscillator Rod	701155	EB-1-39495-F
Non-Fueled Dummy Oscillator Rod	701591	EB-1-39690-D
Top Spacer of Model IHC Control assembly	701592	EB-1-39691-C
Higher Worth Control Rod	701850	EB-1-39914-F
Revised Drop Rod, Model RRR	702959	EB-1-50516-F
Tantalum Drop Rod, Model TAD	703885	EB-1-50854-F
Biological Shield	Not Existing	H.K. Ferguson Drwg. No. R-12 ~ R-22
Outlet Air duct from Thimbles J-2, J-3, O-1, O-2	Not Existing	HKF-R-300
Outlet Air duct from Thimbles J-1, J-4, O-3, O-4	Not Existing	HKF-R-303
Outer Blanket Instrument Tube	Not Existing	RE-1-33695-D
Inner Blanket Instrument Tube	Not Existing	RE-1-33703-D
Core Thermocouples	Not Existing	RE-1-33776-D
Inner Blanket Fission Foil Traverse	Not Existing	RE-1-33790-D
Outer Blanket Fission Foil Traverse	Not Existing	RE-1-34025-D
Dry Critical Oscillator Rod	Not Existing	RE-1-34361-E
Core Filter	Not Existing	RE-1-35395-D
Outer Blanket Filter	Not Existing	RE-1-35396-D

Table 2 Library IDs for Instrument in Primary Loop

Title	EDMS ID	Alternate ID
NO. 1 NUCLIDE TRAP ASSY PRIMARY PURIFICATION CELL	697485	E5171-0003-DE
EBR-II PRIMARY TANK SUPPORT STRUCTURE **EBR II UPPER SUPPORT STRUCTURE PARTS (ORIENTATION)**	**693347** **693349**	**EB-1-25208-F**

Primary Auxiliary Pump	693356	EB-1-25219-F
Thermocouples at Secondary Sodium Outlet Pipe	693373	EB-1-25250-C
Intermediate Heat Exchanger	693376	EB-1-25256-F
D-C Electromagnetic Pump	693452	EB-1-25344-E
REACTOR OUTLET PIPING INSTRUMENTATION INSTALLATION	**695095**	**EB-1-29016-E**
Piping within Primary Tank	696880	EB-1-29655-D
Surge Tank	697319	EB-1-29858-C
Thermocouples at Bottom Orifice Plate	Not Existing	Struthers-Wells Corp. Drwg. 59P8088D3
Thermocouples at Top Orifice Plate	Not Existing	Struthers-Wells Corp. Drwg. 59P8088D4
Tube Bundle	Not Existing	Struthers-Wells Corp. Drwg. 59P8088D6
Well Casing	Not Existing	Struthers-Wells Corp. Drwg. 59P8088D7
Shield Plug	Not Existing	Struthers-Wells Corp. Drwg. 59P8088D9
Thermocouples at Primary Sodium Outlet	Not Existing	Struthers-Wells Corp. Drwg. 59P8088D17

4. Locations of Sensors in EBR-II System

4.1 Identification Codes of Sensors

The location of sensors in the plant layout is shown in Figure 1. This figure, located in pp.6.1-7/8, Chapter 6, Volume II, shows the sketchy location of sensors in the plant. The instrumentations in the primary cooling system are shown in Figure 2. Each sensor and the associated signal are identified by its location, system, parameter, function, instrument number and point of measurement. How to read this identification code is described in EBR-II System Design Descriptions, Volume II, Chapter 6, section 6.3.3.1 Instruments. This document have been made available as part of this work as an electronic pdf file.

The structure of the code, the possible values of the code entries, theirs meaning are here reported in the following tables.

Table 3 Identification Code Structure [Vol. II, Chapter 6, P.6.3-5]

Position	Information content
1	Location (relative to building or section of plant where instrument is being located). One character.
2	System. Two digits integer.

3	Parameter. One or two characters.
4	Function. One character.
5	Instrument Number. 3 digits Number
6	Points of Measurement

For instance, Multi-point temperature indicator with alarm in steam system, located in the power plant is P3-TIA-503-24. This identification code is generated as following:

Table 4 Identification Code for Location

Location **[Vol. II, Chapter 6, P.6.3-6]**	
B	Boiler Plant – Wing
C	Cooling Tower
E	Electrical Substation
F	Process Plant
G	Guard House
K	Ambulance and Fire Station
L	Laboratory Building
M	Pump House and Well No.1
N	Pump House and Well No.2
P	Power Plant (including auxiliary boilers)
R	Reactor Plant
S	Sodium Plant – Wing
T	Temporary Facilities
W	Waste Treatment Plant
Y	Yard and Services (including fuel oil pumping station and main oil storage tank)

Table 5 Identification Code for System

System **[Vol. II, Chapter 6, P.6.3-6]**	
1	Primary System
2	Secondary System
3	Steam Power System
4	Shutdown Cooling
5	Feedwater System
6	Argon
7	Cooling Tower
8	Shield Air Cooling
9	Steam Heating System
10	Electrical
11	Suspect and Contaminated Gas
12	Waste Disposal
13	General Ventilation
14	Air Conditioning
15	Portable and Fire Water Systems
16	Fuel Oil System
17	Space Air Cooling
18	Water Treatment

Table 6 Identification Code for Parameter

Parameter **[Vol. II, Chapter 6, P.6.3-7]**	
N	Nuclear
T	Temperature
F	Flow
P	Pressure
L	Level
M	Radiation
pH	pH
Q	Current

V	Voltage
KW	Power
Va.	Volt. Amp.
dP	Differential Pressure
dT	Differential Temperature
C	Conductivity
B	Position
Y	Leak Detector
RH	Relative Humidity
S	Speed
G	Chlorine Concentration
X	Miscellaneous
A	Annunciator

Table 7 Identification Code for Function

Function **[Vol. II, Chapter 6, P.6.3-7]**	
R	Record
C	Control
I	Indicate
A	Alarm (or electrical contact)
s	Integrate (subletter)
Z	Analytical
D	Data Logging (only)

Table 8 Identification Code for Component

Component **[Vol. II, Chapter 6, P.6.3-8]**	
Q	Nuclear Detector
TC	Thermocouple
RT	Resistance Thermometer
TT	Temperature Transmitter (pneumatic)
PT	Pressure Cell

LT	Level Transmitter
AM	Amplifier
pHT	pH Cell
VT	Potential Trans.
QT	Current Trans.
E	Primary Element (dead ended)
FT	Flow Transmitter (except magnetic)
VC	Control Valve (pneumatic, hydraulic or electrical)
VS	Solenoid Valve
PS	Pressure Switch
KS	Power Supply
X	Miscellaneous
FM	Flow Transmitter (magnetic)
SD	Sodium Detector
LD	Leak Detector

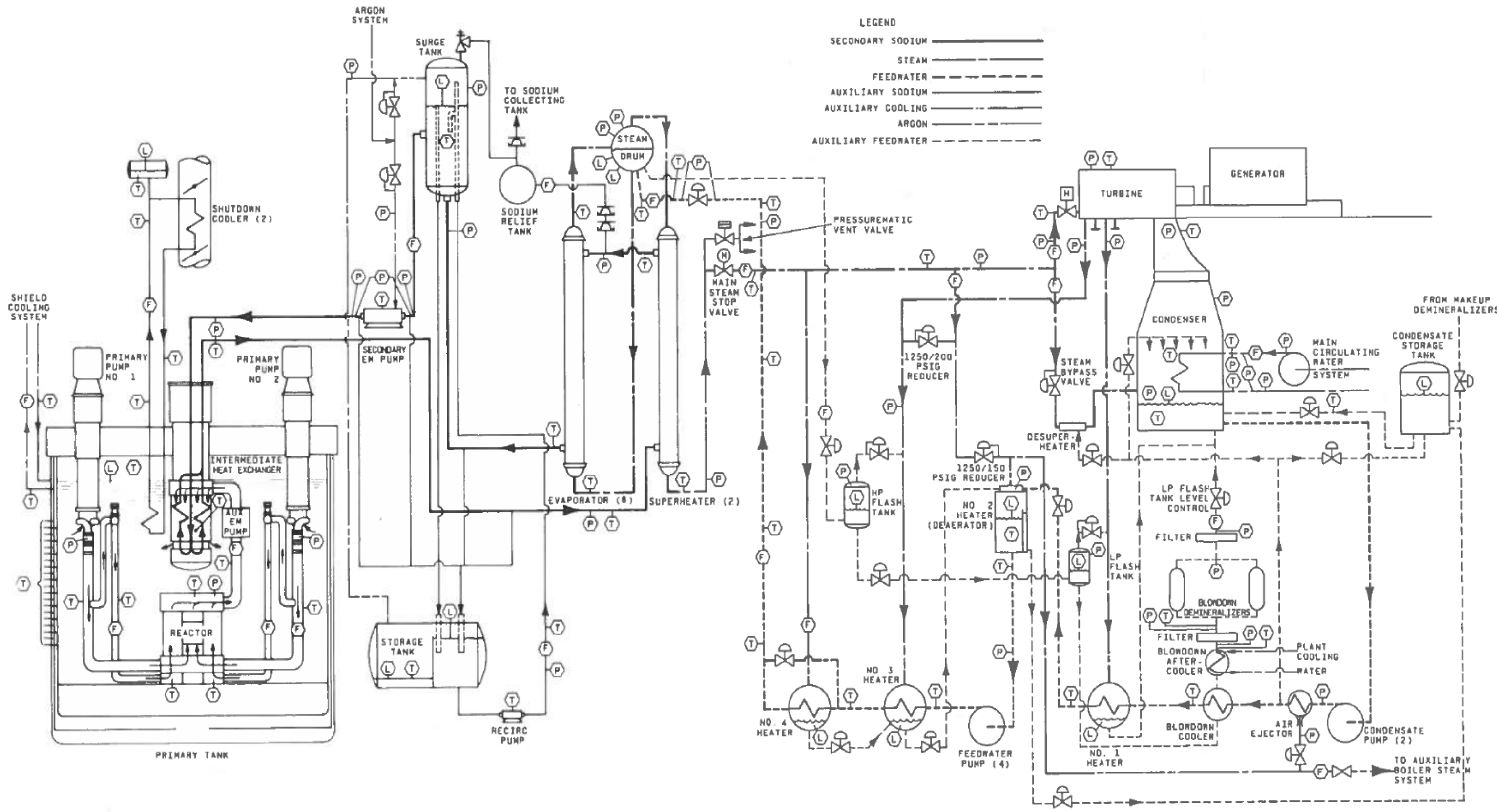

Figure 1 Figure 6.1-1 EBR-II Flow Diagram **[Vol. II, Chapter 6, pp.6.1-7/8]**

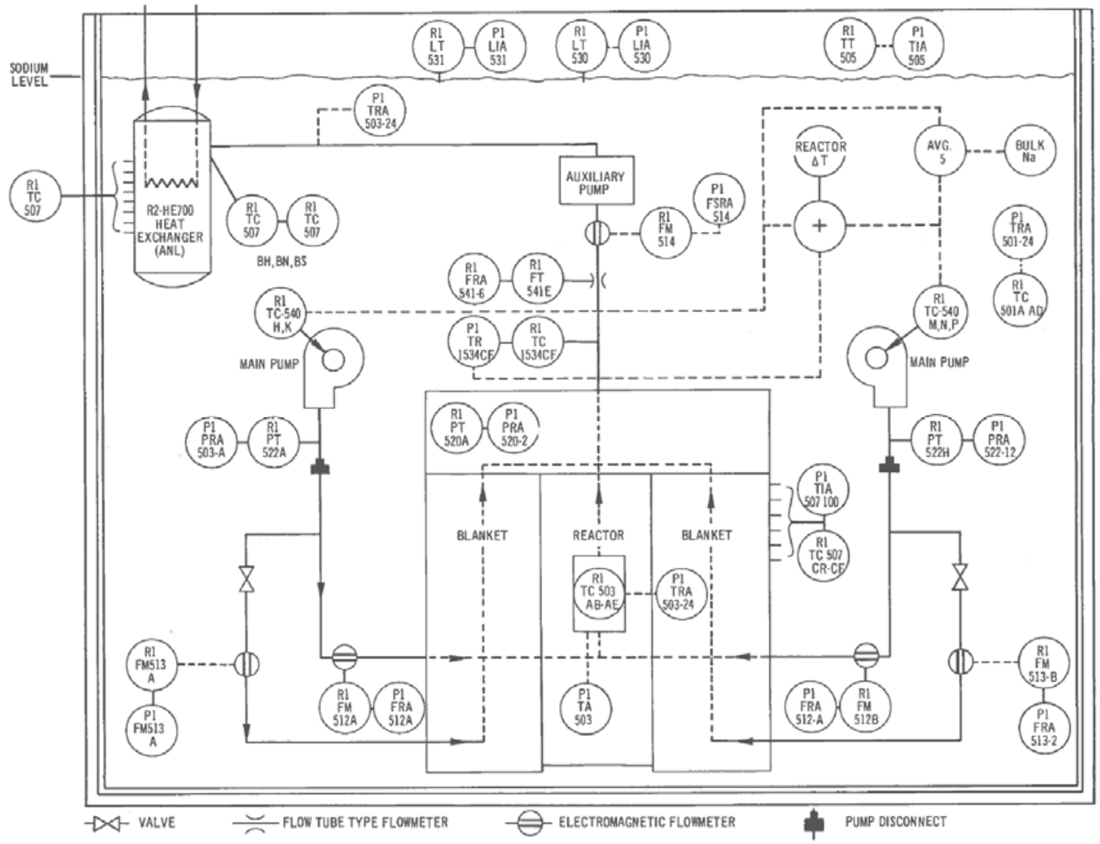

Figure 2 Figure 6.3-25 Primary Cooling System Instrumentation **[Vol. II, Chapter 6, p.6.3-57]**

4.2 Lists and Locations of Sensors

The nuclear instrument thimbles are installed into the reactor core to perform various experiments and to detect the physical conditions of the core. Figure 3 shows the top view of the primary tank and the locations of the nuclear instrument thimbles. The detailed information of sensors in each nozzle is reported in Table 9. Drawings of nuclear instrument thimbles and thimble cooling is shown in Figure 4. The type and location of instrument shown in Figure 4 are listed in Table 10. The specific drawings of "O", "J-1", J-2", "J-3" and "J-4" thimbles are shown in Figure 5, Figure 6 and Figure 7, respectively.

Instrument locations in the reactor vessel are shown in Figure 8. In addition, the location and description of each instrument are tabulated in Table 11 and Table 12. The instrument locations in the reactor vessel and the neutron shield are shown in Figure 9 and corresponding information of those instruments is tabulated in Table 13.

Schematic diagrams of primary tanks No.1 and 2 are shown in Figure 10 and Figure 11, respectively. In these figures, the types and locations of the sensors are presented. The type, location and number of each instrument in primary tank No. 1 and No. 2 are tabulated in Table 14 and Table 15, respectively.

Figure 12 shows the bulk sodium and Argon sensors in primary tank. The detailed locations of the sensors in Figure 12 are tabulated in Table 16.

Locations of thermocouples on the primary tank are shown in Figure 13. Totally 137 thermocouples are installed in the primary tank. The location and instrument number of the sensors are tabulated in Table 17.

Figure 14 shows the cross-sectional views of intermediate heat exchanger (IHX) and locations of the thermocouples in the IHX. The detailed information of the thermocouples in Figure 14 is tabulated in Table 18.

The instruments in shutdown coolers are presented in Figure 15. The locations of the instrument in shutdown coolers are tabulated in Table 19.

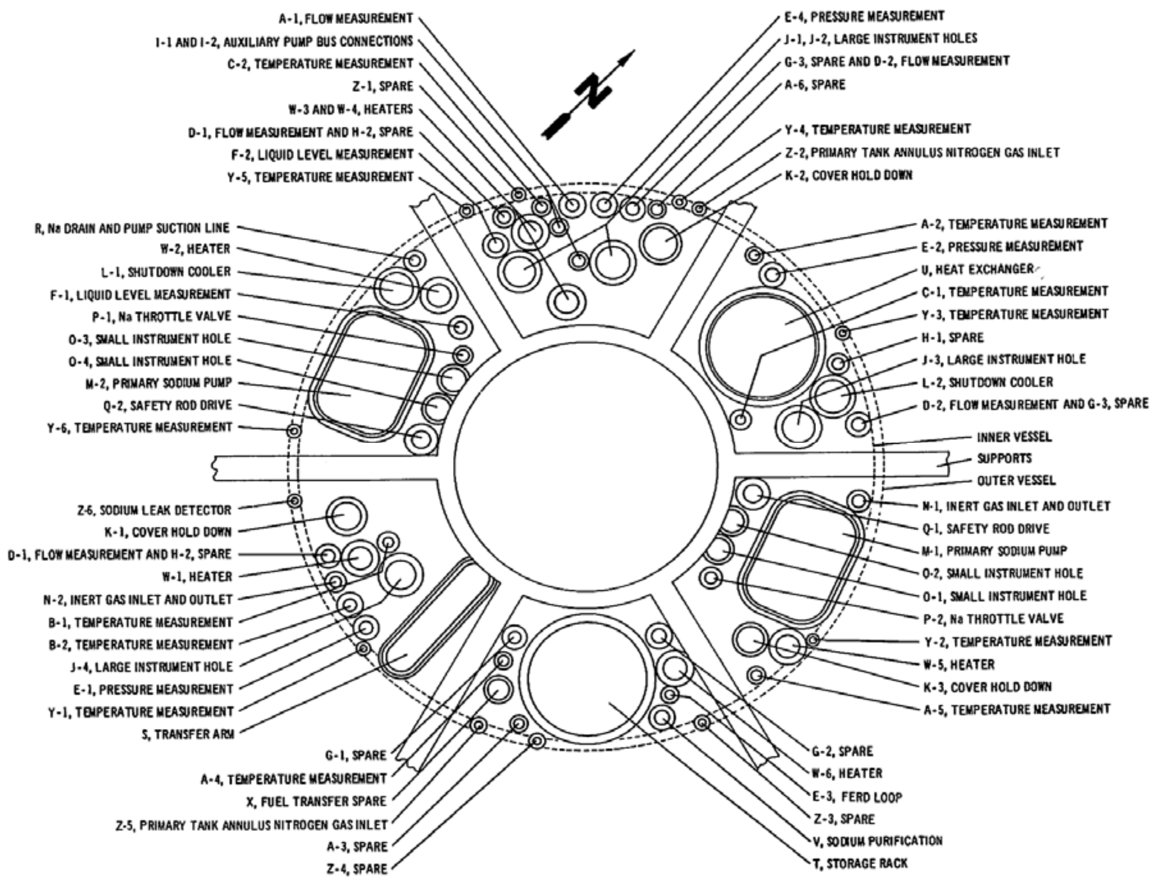

Figure 3 Figure 4.6-5 Primary Tank Nozzles (or Figure 6.3-24 Instrument Lead Penetration through Primary Tank Cover) **[Vol. II, Chapter 4, p.4.6-11 or Vol. II, Chapter 6, pp.6.3-55/56]**

Table 9 Figure 4.6-5 Primary Tank Nozzles (Figure 6.3-24 Instrument Lead Penetration through Primary Tank Cover) **[Vol. II, Chapter 4, p.4.6-11 or Vol. II, Chapter 6, pp.6.3-55/56]**

Nozzle	Instruments R1-	Layout Dwg. EB-1-
A-1	RT-502-A	29015-E
	RT-502B	29015-E
	RT-506	29016-E
	RT-506X	↓
	FM-514	
	FT-541E	
A-2	TC-530	29020-F
	TC-540Q	↓
	TC-540R	
	TC-540S	
	TC-540T	
	TC-540V	
	TC-540W	
	TC-540X	
	TC-540Y	
	TC-540Z	
	TC-540AA	
	TC-1534CF	29016-E
	TC-1534CG	29016-E
A-4	TC-540A	29020-F
	TC-540B	↓
	TC-540C	
	TC-540D	
	TC-540E	
	TC-540F	
A-5	TC-540G	29020-F
	TC-540H	↓
	TC-540K	
	TC-540AR	
	TC-540AS	
	TC-540AV	
B-1	TC-501A	29079-E
	TC-501B	↓
	TC-501C	
	TC-501D	
	TC-501E	
	TC-501F	
	TC-501G	
	TC-501H	
	TC-501K	
	TC-501M	
	TC-501N	
	TC-501P	
	TC-501Q	
	TC-501Y	
	TC-501AA	
	TC-501AD	
B-2	TC-507CR	29021-E
	TC-507CS	↓
	TC-507CT	
	TC-507DA	
	TC-507DB	
	TC-507DC	
	TC-507DK	
	TC-507DM	
	TC-507DQ	
	TC-507DR	
	TC-507FG	29079-E
	TC-507FH	↓
	TC-507FK	

Nozzle	Instruments R1-	Layout Dwg. EB-1-
C-1	RT-504A	29020-F
	RT-504B	29020-F
	TC-507CX	29022-E
	TC-507CY	↓
	TC-507CZ	
	TC-507DF	
	TC-507DG	
	TC-507DH	
	TC-507DP	
	TC-507DT	
	TC-507AB	29020-F
	TC-507AC	↓
	TC-507AD	
	TC-507AE	
	TC-507AM	
	TC-507AN	
	TC-507AP	
	TC-507AQ	
	TC-507AT	29019-E
C-2	TC-501R	29079-E
	TC-501S	↓
	TC-501T	
	TC-501V	
	TC-501W	
	TC-501X	
	TC-501Z	
	TC-501AB	
	TC-501AC	
	TC-507CV	29021-E
	TC-507CW	↓
	TC-507DD	
	TC-507DE	
	TC-507DN	
	TC-507DS	
	TC-540M	29020-E
	TC-540N	↓
	TC-40P	
H-2	FM-512B	29017-E
	FM-513B	↓
	FT-541B	
	FT-541D	
G-3	FM-512A	29018-E
	FM-513A	↓
	FT-541A	
	FT-541C	
E-1	PT-540A	29015-E
	PT-522E	29017-E
	PT-522F	↓
	PT-522G	
	PT-522Q	
E-2	PT-522B	29018-E
	PT-522C	↓
	PT-522D	
	PT-522K	
	PT-522P	29015-E
E-4	TC-505	29015-E
	PT-520B	↓
	PT-522M	
	PT-522N	
	PT-522R	
	PT-522S	

Nozzle	Instruments R1-	Layout Dwg. EB-1-
F-1	LT-531	29049-E
F-2	LT-530	29049-E
Y-1	TC-507A	25260-D
	TC-507B	↓
	TC-507C	
	TC-507D	
	TC-507E	
	TC-507F	
Y-2	TC-507G	25266-D
	TC-507H	↓
	TC-507K	
	TC-507M	
	TC-507N	
	TC-507P	
	TC-507Q	
	TC-507R	
	TC-507S	
	TC-507T	
Y-3	TC-507V	25266-D
	TC-507W	↓
	TC-507X	
	TC-507Y	
	TC-507Z	
	TC-507AA	
	TC-507AB	
	TC-507AC	
	TC-507AD	
	TC-507AE	
Y-4	TC-507AF	25260-D
	TC-507AG	↓
	TC-507AH	
	TC-507AK	
	TC-507AM	
	TC-507AN	
Y-5	TC-507AP	25266-D
	TC-507AQ	↓
	TC-507AR	
	TC-507AS	
	TC-507AT	
	TC-507AV	
	TC-507AW	
	TC-507AX	
	TC-507AY	
Y-6	TC-507AZ	25266-D
	TC-507BA	↓
	TC-507BB	
	TC-507BC	
	TC-507BD	
	TC-507BE	
	TC-507BF	
	TC-507BG	
	TC-507BH	
	TC-507FE	
M-1	PT-522A	27564-D
M-2	PT-522H	27564-D

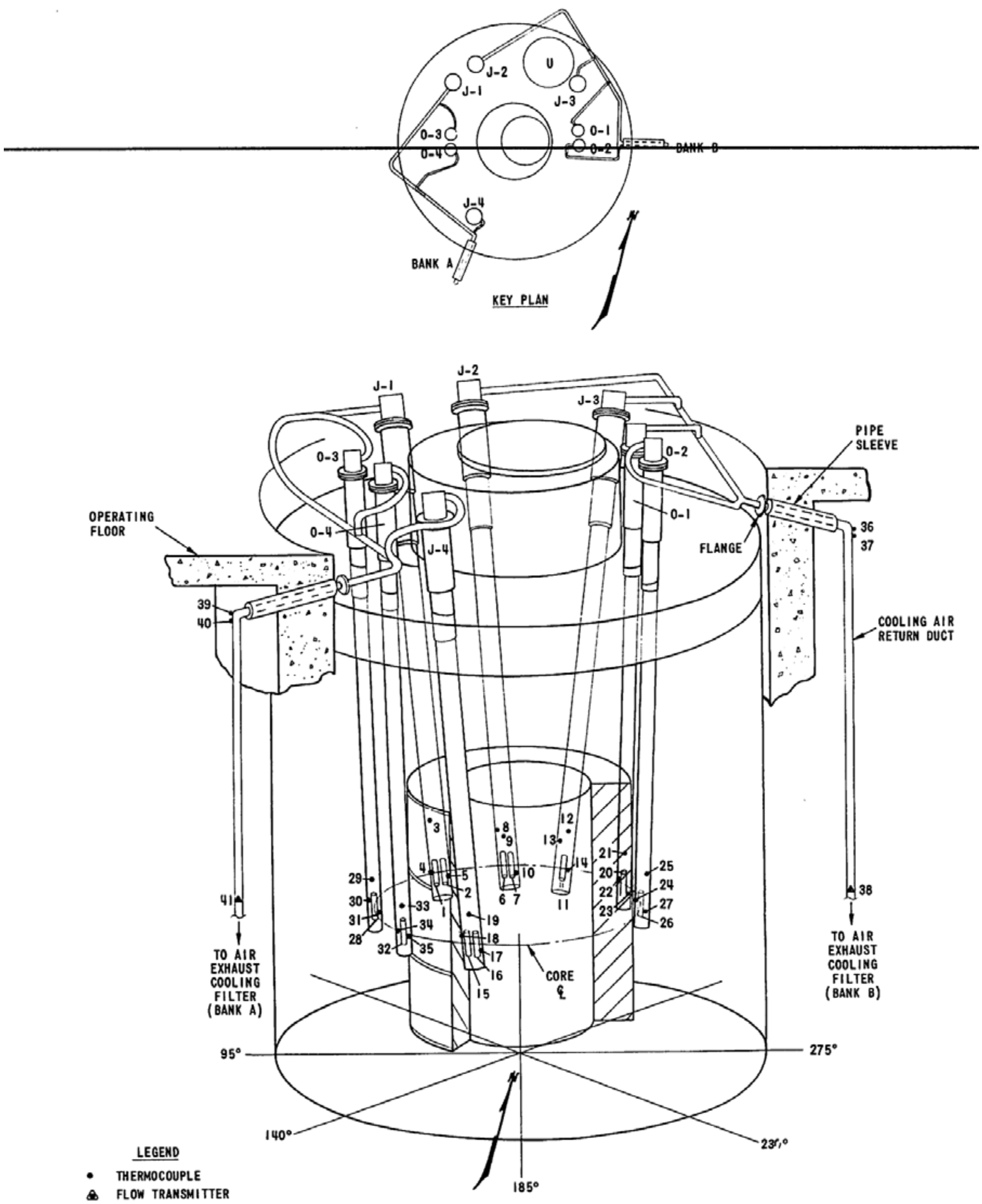

Figure 4 Figure 6.3-1 Nuclear Instrument Thimbles and Thimble Cooling **[Vol. II, Chapter 6, pp.6.3-13/14]**

Table 10 Figure 6.3-1 Nuclear Instrument Thimbles and Thimble Cooling **[Vol. II, Chapter6, pp.6.3-13/14]**

Thimble No.	REF. No.	Instrument No.	Description	Channel No.	Reference Drawing	Inst. No.	Point No.
J-1	1	R1-Q-580	Fission Counter	1	EB-1-25822-E		
	2	R1-Q-587	Ion Chamber	7A	EB-1-28083-E		
		R1-Q-583	Ion Chamber	4	↓		
	3	R4-TC-511-A	Thermocouple (Air)			511	1-2
	4	R4-TC-511-K	Thermocouple (Struct.)				
	5	R4-TC-511-V	Thermocouple (Struct.)				
J-2		NITF (Nuclear Instrument Test Facility)					
J-3		R1-Q-585	Ion Chamber	6			
	11	R1-Q-587	Ion Chamber	7			
		R1-Q-582	Fission Chamber	3			
	12	R4-TC-511-D	Thermocouple (Air)			511	1-5
	13	R4-TC-511-P	Thermocouple (Struct.)				
	14	R4-TC-511-Y	Thermocouple (Struct.)				
J-4	15	R1-Q-581	Ion Chamber	2			
	16	R1-Q-584	Ion Chamber	5			
	17	R4-TC-511-X	Thermocouple (Struct.)				
	18	R4-TC-511-N	Thermocouple (Struct.)				
	19	R4-TC-511-C	Thermocouple (Air)			511	1-4
O-1		NITF			EB-1-25846-F EB1-2-28083-E		
O-2	24	R1-Q-589	Ion Chamber	10	↓		
	25	R4-TC-511-H	Thermocouple (Air)			511	1-9
	26	R4-TC-511-T	Thermocouple (Struct.)				
	27	R4-TC-511-BH	Thermocouple (Struct.)				
O-3	28	R1-Q-588	Ion Chamber				
	29	R4-TC-511-E	Thermocouple (Air)	9		511	1-6
	30	R4-TC-511-Q	Thermocouple (Struct.)				
	31	R4-TC-511-Z	Thermocouple (Struct.)				
O-4	32	R1-Q-590	Ion Chamber	11			
	33	R4-TC-511-G	Thermocouple (Air)			511	1-8
	34	R4-TC-511-S	Thermocouple (Struct.)				
	35	R4-TC-511-BG	Thermocouple (Struct.)				
	36	R8-TC-646-A			HKF-R-300	646 A	
	37	R8-TC-511-BE	Outlet Air Duct from Thimbles J-2, J-3 & O-1, O-2		HKF-R-300	511	1-11
	38	R8-FT-521-B			HKF-R-303	521 B	
	39	R8-TC-646-B			HKF-R-300	646 B	
	40	R8-TC-511-BF	Outlet Air Duct from Thimbles J-1, J-4 & O-3, O-4		HKF-R-300	511	1-10
	41	R8-FT-521-A			HKF-R-303	521 A	

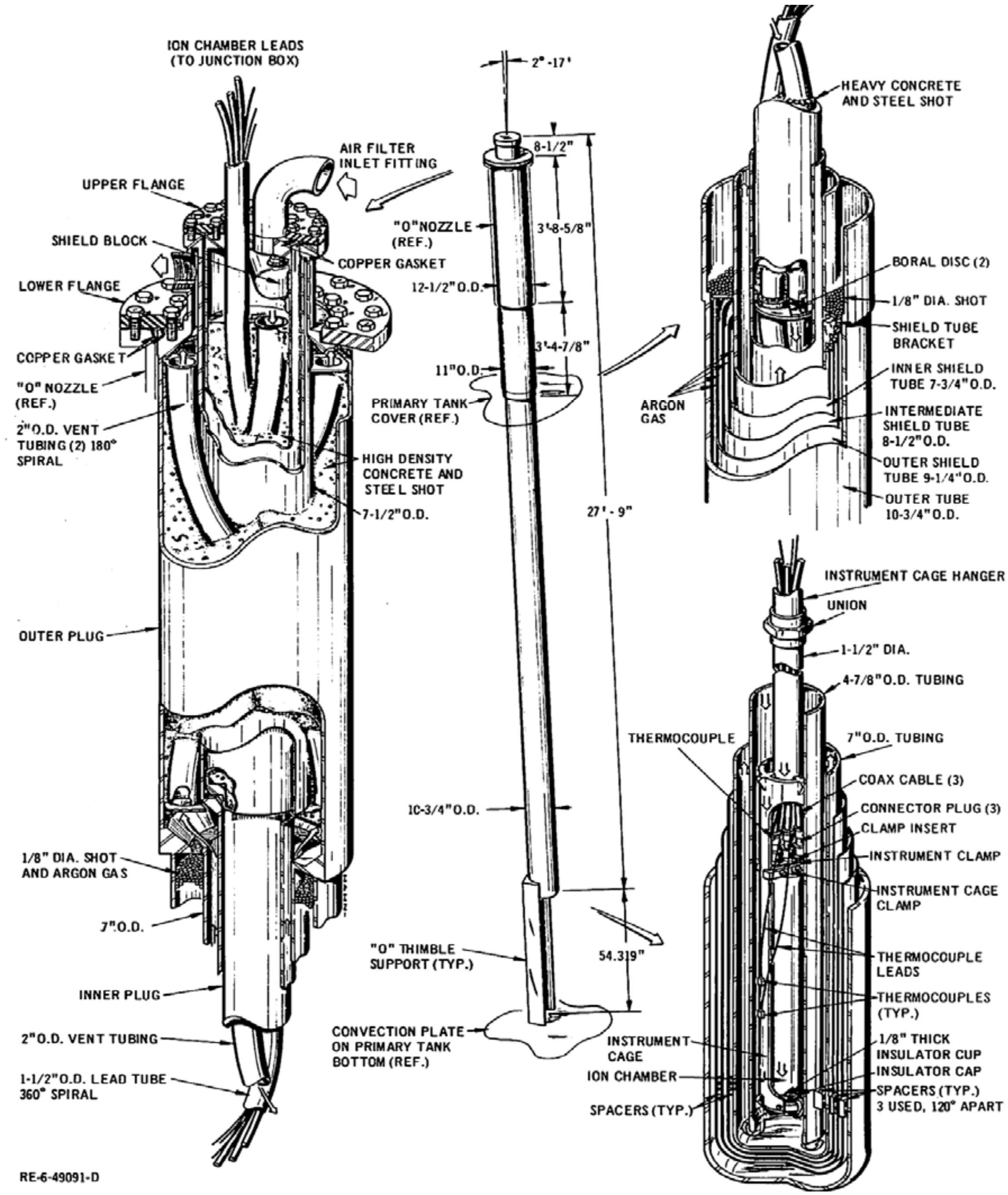

Figure 5 Figure 7.4-5 “O” Instrument Thimble Assembly (showing Original Instrumentation Arrangement) **[Vol. II, Chapter 7, p.7.4-11]**

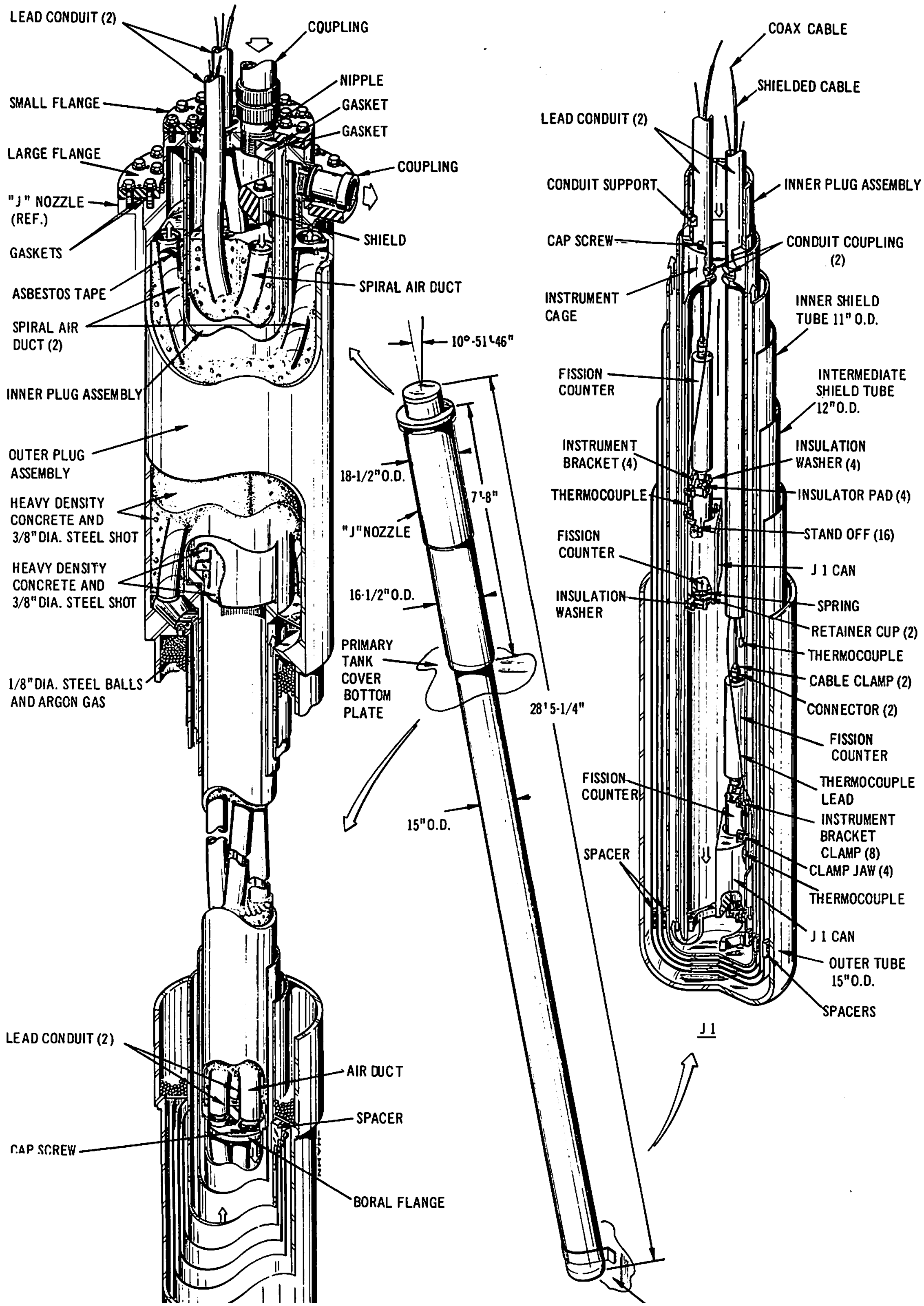

Figure 6 Figure 7.4-6 “J-1” Instrument Thimble Assembly (showing Original Instrumentation Arrangement) **[Vol. II, Chapter 7, p.7.4-14]**

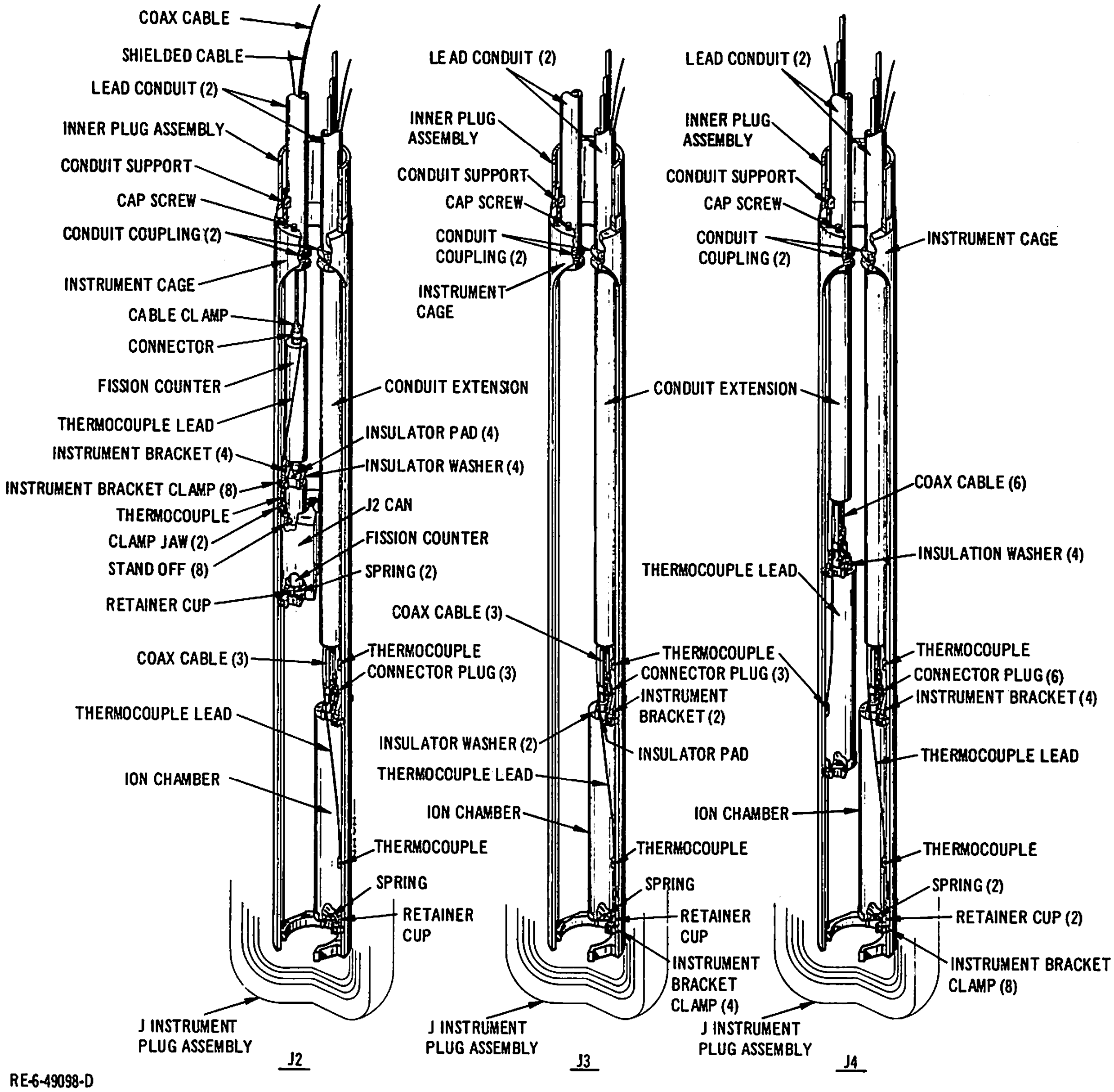

Figure 7 Figure 7.4-7 Original Instrument Cage Area Arrangement J-2, J-3 and J-4 Thimbles **[Vol. II, Chapter 7, p.7.4-16]**

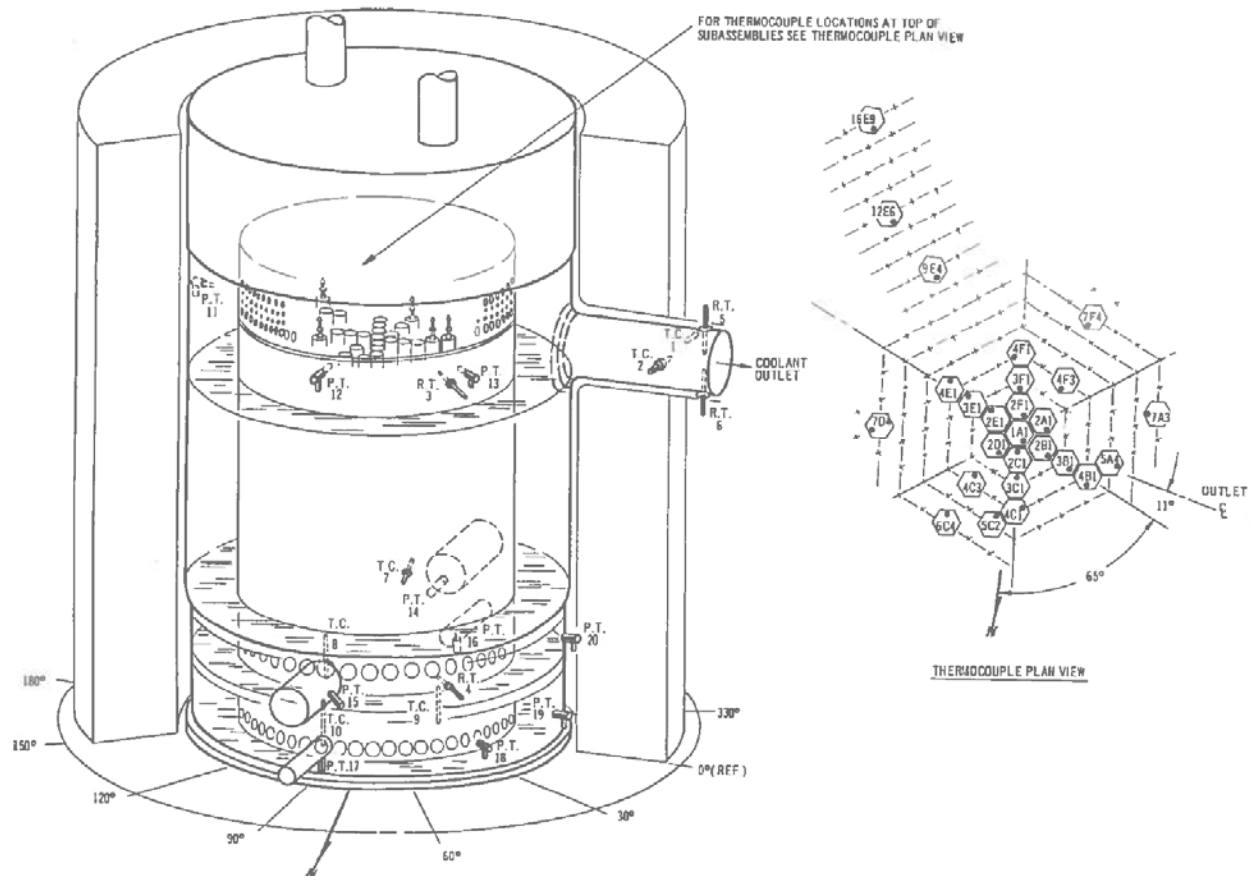

Figure 8 Figure 6.3-5 Instrument Locations in Reactor Vessel **[Vol. II, Chapter 6, pp.6.3-19/20]**

Table 11 Figure 6.3-5 Instrument Locations in Reactor Vessel **[Vol. II, Chapter 6, pp. 6.3-19/20]**

Ref. No.	Location	Instrument No.	Reference Drawing	Description
1	Na Outlet Pipe Jacket	R1-TC-1534-CG	EB-1-29016-E	Thermocouple
2	Reactor Coolant Outlet	R1-TC-1534-CF	EB-1-29016-E	Thermocouple
3	Reactor Coolant Outlet Annular Plenum	R1-RT-502-B	EB-1-29015-E	Res. Thermo.
4	Reactor Coolant High Press. Annular Plenum	R1-RT-502-A	EB-1-29015-E	↓
5	Reactor Coolant Outlet	R1-RT-506	EB-1-29016-E	
6	Reactor Coolant Outlet	R1-RT-506X	EB-1-29016-E	
7	Reactor Coolant High Press. Annular Plenum	R1-TC-540-At	EB-1-29016-E	Thermocouple
8	Reactor Coolant Low Press. Plenum	R1-TC-540-AV	EB-1-29016-E	↓
9	Reactor Coolant Low Press. Plenum	R1-TC-540-AR	EB-1-29016-E	
10	Reactor Coolant Low Press. Plenum	R1-TC-540-AS	EB-1-29016-E	
11	Reactor Coolant Outlet Annular Plenum	R1-PT-520-A	EB-1-27312-E	Press. Transm.
12	Reactor Coolant Outlet Annular Plenum	R1-PT-520-B	EB-1-27312-E	↓
13	Reactor Coolant Outlet Annular Plenum	R1-PT-522-R	EB-1-27312-E	
14	Reactor Vessel High Press. Inlet Pipe	R1-PT-522-F	EB-1-25231-F	
15	Reactor Vessel High Press. Inlet Pipe	R1-PT-522-C	EB-1-25231-F	
16	Reactor Vessel Low Press. Inlet Pipe	R1-PT-522-E	EB-1-25231-F	
17	Reactor Vessel Low Press. Inlet Pipe	R1-PT-522-D	EB-1-25231-F	
18	Reactor Coolant Low Press. Annular Plenum	R1-PT-522-S	EB-1-27312-E	
19	Reactor Coolant Low Press. Annular Plenum	R1-PT-522-M	EB-1-27312-E	
20	Reactor Coolant High Press. Annular Plenum	R1-PT-522-N	EB-1-27312-E	

Table 12 Figure 6.3-5 Instrument Locations in Reactor Vessel **[Vol. II, Chapter 6, pp. 6.3-19/20]**

Ref. No	Instrument No.	Ref. No	Instrument No.	Ref. No	Instrument No.
1A1	R1-TC-503-AA	3F1	R1-TC-503-T	5A4	R1-TC-503-Q
2C1	R1-TC-503-D	3B1	R1-TC-503-F	5C2	R1-TC-503-Y
2D1	R1-TC-503-A	4C1	R1-TC-503-B	6C4	R1-TC-503-N
2E1	R1-TC-503-P	4C3	R1-TC-503-AC	7F4	R1-TC-503-AE
2F1	R1-TC-503-K	4E1	R1-TC-503-Z	7A3	R1-TC-503-AB
2A1	R1-TC-503-H	4F1	R1-TC-503-V	9E4	R1-TC-503-R
2B1	R1-TC-503-E	4F3	R1-TC-503-S	12E6	R1-TC-503-X
3C1	R1-TC-503-C	4B1	R1-TC-503-G	16E9	R1-TC-503-W
3E1	R1-TC-503-M	7D4	R1-TC-503-AD		

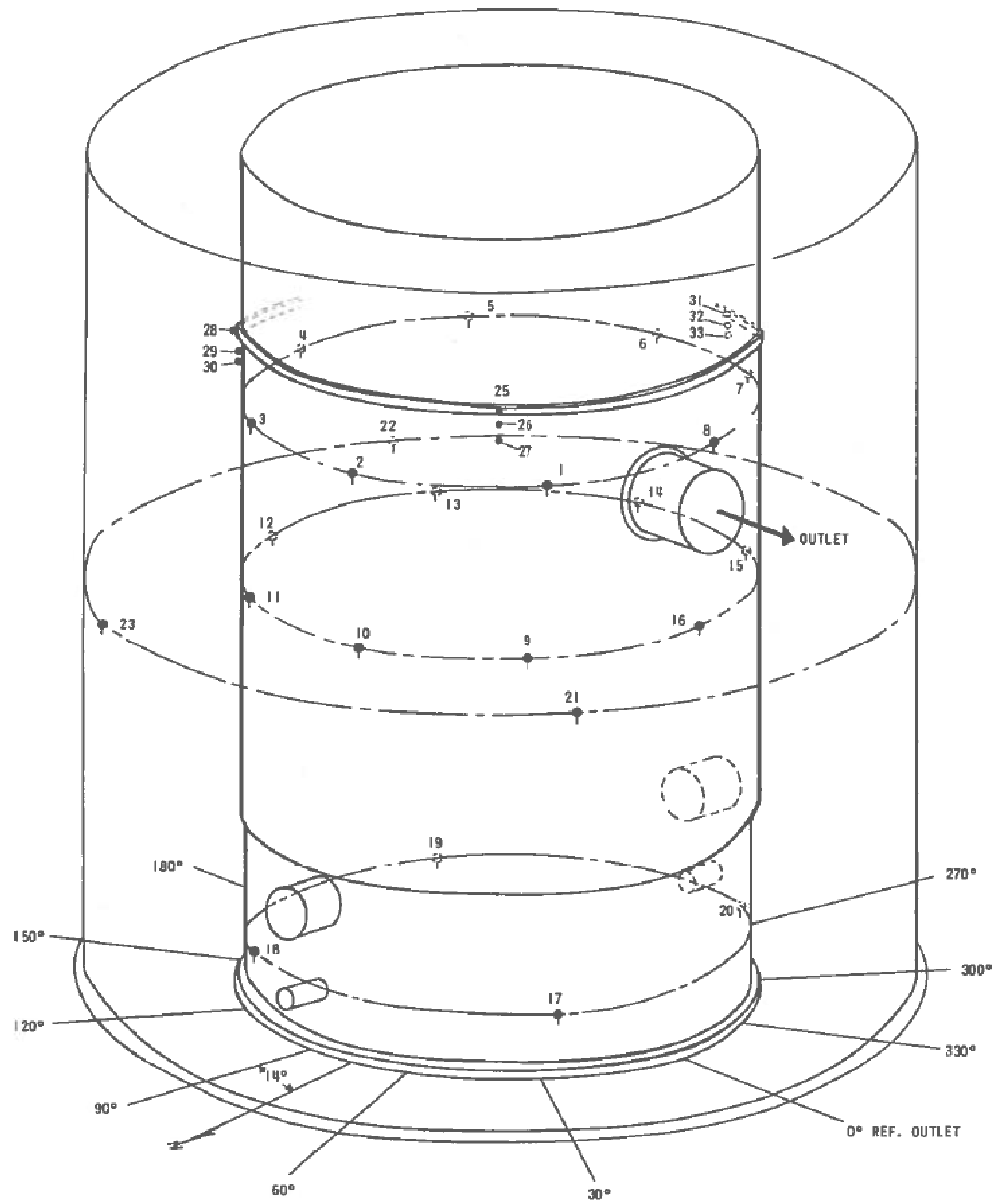

Figure 9 Figure 6.3-6 Reactor Vessel and Neutron Shield **[Vol. II, Chapter 6, pp.6.3-21/22]**

Table 13 Figure 6.3-6 Reactor Vessel and Neutron Shield **[Vol. II, Chapter 6, pp.6.3-21/22]**

Ref. No.	Location	Instrument No.	Reference Drawing	Point No. P1-TRA-507
1*	Reactor Vessel Outside Wall	R1-TC-507-DE	EB-1-29021-E	89
2		R1-TC-507-DF	EB-1-29022-E	90
3*	↓	R1-TC-507-DG	EB-1-29022-E	91
4		R1-TC-507-DH	EB-1-29022-E	92
5*		R1-TC-507-DA	EB-1-29021-E	85
6		R1-TC-507-DB	EB-1-29021-E	86
7*		R1-TC-507-DC	EB-1-29021-E	87
8		R1-TC-507-DD	EB-1-29021-E	88
9*		R1-TC-507-CW	EB-1-29021-E	81
10		R1-TC-507-CX	EB-1-29022-E	82
11*		R1-TC-507-CY	EB-1-29022-E	83
12		R1-TC-507-CZ	EB-1-29022-E	84
13*		R1-TC-507-CR	EB-1-29021-E	77
14		R1-TC-507-CS	EB-1-29021-E	78
15*		R1-TC-507-CT	EB-1-29021-E	79
16		R1-TC-507-CV	EB-1-29021-E	80
17*		R1-TC-507-DN	EB-1-29021-E	95
18		R1-TC-507-DP	EB-1-29022-E	96
19*		R1-TC-507-DK	EB-1-29021-E	93
20		R1-TC-507-DM	EB-1-29021-E	94
21	Reactor Vessel Neutron Shield Outer Wall	R1-TC-507-DS	EB-1-29021-E	99
22		R1-TC-507-DQ	EB-1-29022-E	97
23	↓	R1-TC-507-DT	EB-1-29021-E	100
24				
25	*Reactor Vessel Outside Wall Top Ring	R1-TC-540XX3	EB-1-29021-E	18
26		R1-TC-540XX1	EB-1-29021-E	16
27	↓	R1-TC-540XX2	EB-1-29021-E	17
28		R1-TC-540XX6	EB-1-29021-E	21
29		R1-TC-540XX4	EB-1-29021-E	19
30		R1-TC-540XX5	EB-1-29021-E	20
31		R1-TC-540XX9	EB-1-29022-E	24
32		R1-TC-540XX7	EB-1-29022-E	22
33		R1-TC-540XX8	EB-1-29022-E	23

* ON RX-T1-1535

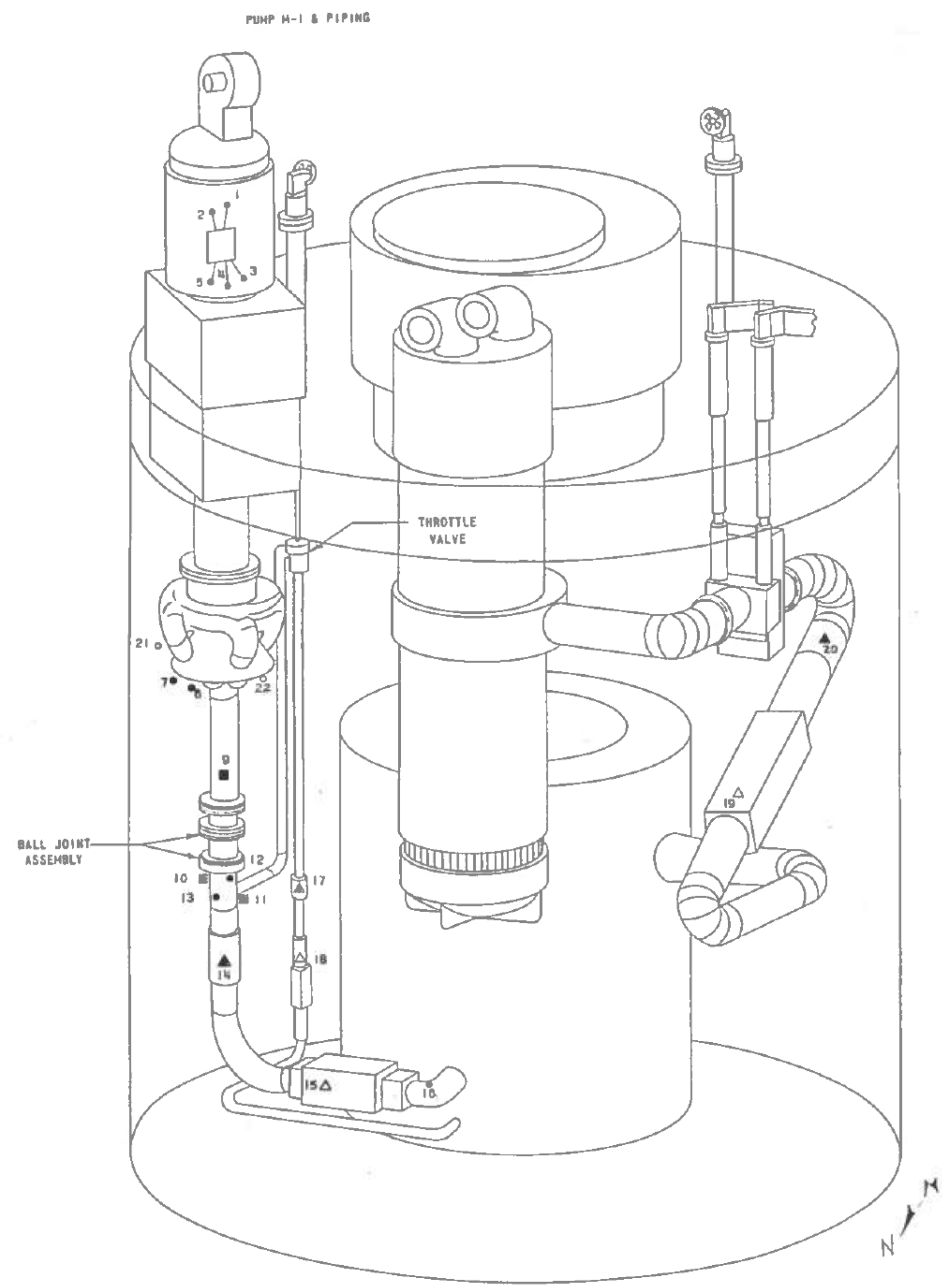

Figure 10 Figure 6.3-7 Primary Pump No.1 **[Vol. II, Chapter 6, pp.6.3-23/24]**

Table 14 Figure 6.3-7 Primary Pump No.1 **[Vol. II, Chapter 6, pp.6.3-23/24]**

Ref. No.	Instrument No.	Readout Inst.	Point No.	Location	Ref. Dwg. No.
1		Pump #1 Control Panel	11	Pump Motor upper Bearing	BYRON JACKSON 2E-1571
2		Pump #1 Control Panel	3	Pump Motor Winding	
3		Pump #1 Control Panel	9	Pump Flange	
4		Pump #1 Control Panel	10	Pump Motor Lower Bearing	
5		Pump #1 Control Panel	4	Pump Motor Air Outlet	
6	R1-TC-540-H	540	8	Pump Inlet	EB-1-29020-F
7	R1-TC-540-K	540	9	Pump Inlet	EB-1-29020-F
8	DELETED				
9	R1-PT-522-A	522	1	Pump Outlet Before Disc. Joint	EB-1-27564-D
10	R1-PT-522-B	522	2	Pump Outlet After Disc. Joint	EB-1-29018-E
11	R1-PT-522-P	SPARE		Pump Outlet After Disc. Joint	EB-1-29018-E
12	R1-TC-540-C	540	3	Pump Outlet After Disc. Joint	EB-1-29020-F
13	R1-TC-540-D	540	4	Pump Outlet After Disc. Joint	EB-1-29020-F
14	R1-FT-541-C	541	2	Pump Outlet High Press. Pipe	EB-1-29018-E
15	R1-FM-512-A	512A	--	Pump Outlet High Press. Pipe	EB-1-29018-E
16	R1-TC-540-B	540	1	Pump Outlet High Press. Pipe	EB-1-29020-F
17	R1-FT-541-A	541	1	Pump Outlet Low Press. Pipe	EB-1-29018-E
18	R1-FM-513-A	513	1	Pump Outlet Low Press. Pipe	EB-1-29018-E
19	R1-FM-514	P1-FsRA-514		Reactor Outlet Pipe	EB-1-29016-E
20	R1-FT-541-E	R1-FRA-541	5	Reactor Outlet Pipe	EB-1-29016-E
21	R1-RT-504-D	504	--	Pump Inlet	--
22	R1-RT-504-B	504	--	Pump Inlet	--

○	Resistance Thermometer
●	Thermocouple
◙	Pressure Sensor
△	EM Flow Meter
▲	Foster Flowmeter (Flow Tube)

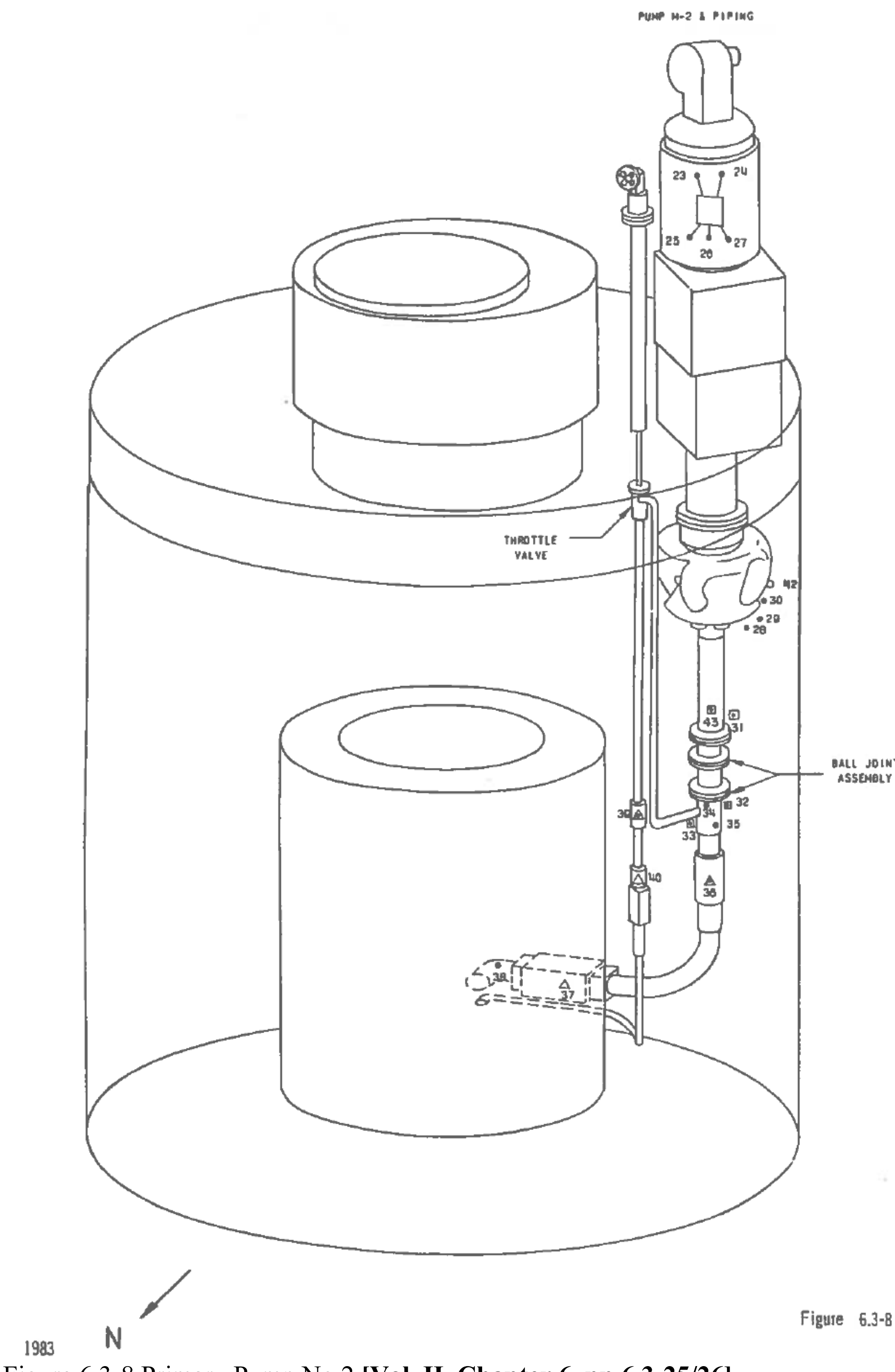

Figure 11 Figure 6.3-8 Primary Pump No.2 **[Vol. II, Chapter 6, pp.6.3-25/26]**

Table 15 Figure 6.3-8 Primary Pump No.2 **[Vol. II, Chapter 6, pp.6.3-25/26]**

Ref. No.	Instrument No.	Readout Inst.	Point No.	Location	Ref. Dwg. No.
23		Pump #2 Control Panel	11	Pump Motor upper Bearing	BYRON JACKSON 2E-1571
24		Pump #2 Control Panel	3	Pump Motor Winding	
25		Pump #2 Control Panel	9	Pump Flange	
26		Pump #2 Control Panel	10	Pump Motor Lower Bearing	
27		Pump #2 Control Panel	4	Pump Motor Air Outlet	
28	R1-TC-540-M	540	10	Pump Inlet	EB-1-29020-F
29	R1-TC-540-N	540	11	Pump Inlet	EB-1-29020-F
30	R1-TC-540-P	540	12	Pump Inlet	EB-1-29020-F
31	R1-PT-522-H	522	8	Pump Outlet Before Disc. Joint	EB-1-27564-D
32	R1-PT-522-G	522	7	Pump Outlet After Disc. Joint	EB-1-29017-E
33	R1-PT-522-O	SPARE		Pump Outlet After Disc. Joint	EB-1-29017-E
34	R1-TC-540-F	540	6	Pump Outlet After Disc. Joint	EB-1-29020-F
35	R1-TC-540-E	540	5	Pump Outlet After Disc. Joint	EB-1-29020-F
36	R1-FT-541-D	541	4	Pump Outlet High Press. Pipe	EB-1-29017-E
37	R1-FM-512-B	512B	-	Pump Outlet High Press. Pipe	EB-1-29017-E
38	R1-TC-540-A	540	2	Pump Outlet High Press. Pipe	EB-1-29020-F
39	R1-FT-541-B	541	2	Pump Outlet Low Press. Pipe	EB-1-29020-F
40	R1-FM-513-B	513	2	Pump Outlet Low Press. Pipe	EB-1-29020-F
41	DELETED	--	--		--
42	R1-RT-504-E	504	--	Pump Inlet	--
43	R1-PT-522-HX	DAS		Pump Outlet Before Disc. Joint	1982-O118-ED-00
○		Resistance Thermometer			
●		Thermocouple			
▣		Pressure Sensor			
△		EM Flow Meter			
▲		Foster Flowmeter (Flow Tube)			

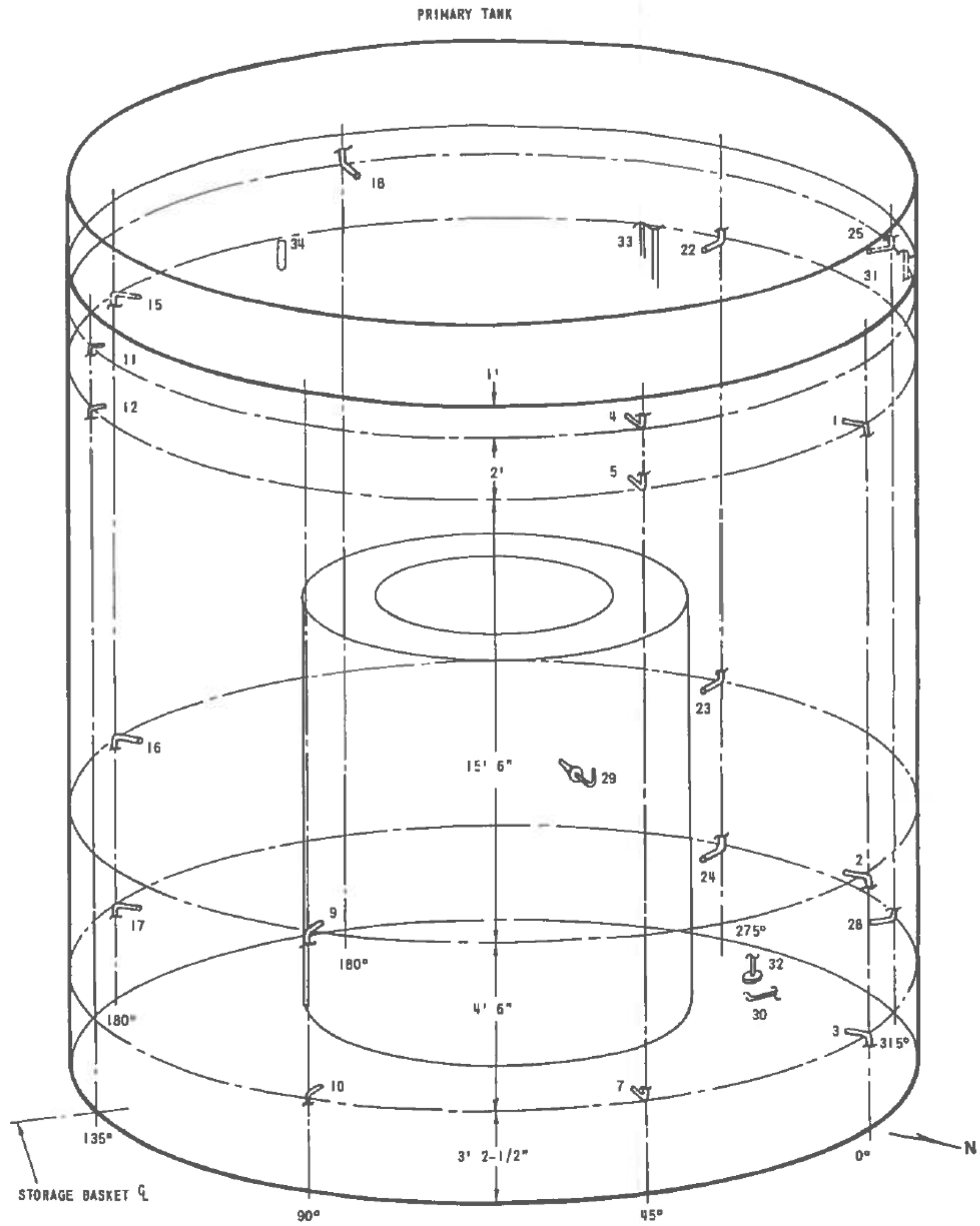

Figure 12 Figure 6.3-9 Bulk Sodium and Argon Sensors in Primary Tank **[Vol. II, Chapter 6, pp.6.3-27/28]**

Table 16 Figure 6.3-9 Bulk Sodium and Argon Sensors in Primary Tank **[Vol. II, Chapter 6, pp.6.3-27/28]**

Ref. No.	Location	Instrument No.	Reference Drawing	Point P1-TRA-501
1	Bulk Sodium	R1-TC-501-T	EB1-2-29079-E	
2	Bulk Sodium	R1-TC-501-V		
3	Bulk Sodium	R1-TC-501-W		
4	Argon Blanket (Spare)	R1-TC-501-EX		
5	Argon Blanket (Spare)	R1-TC-501-X		18
7	Argon Blanket (Spare)	R1-TC-501-Z		21
9	Bulk Sodium	R1-TC-501-H		8
10	Bulk Sodium	R1-TC-501-Q		13
11	Argon Blanket in Scram Circuit (Gas Blanket Scram)	R1-TC-501-Y		
12	Bulk Sodium	R1-TC-501-AA		
15	Bulk Sodium	R1-TC-501-D		4
16	Bulk Sodium	R1-TC-501-E		5
17	Bulk Sodium	R1-TC-501-F		6
18	Argon Blanket (Spare)	R1-TC-501-FG		
22	Argon Blanket (Spare)	R1-TC-501-M		
23	Bulk Sodium	R1-TC-501-N		16
24	Bulk Sodium	R1-TC-501-P		11
25	Argon Blanket (Spare)	R1-TC-501-FH		12
29	Argon Blanket (Spare)			
30	Temperature Comp. For R1-LT-530	R1-TC-530	EB-1-29020-F	
31	Argon Blanket (In T/C Well) No Readout	R1-TC-505	EB-1-29015-E	
32	Bulk Sodium (Level dP Type)	R1-LT-530	EB-1-25584-D	
33	Bulk Sodium (Level Probe Type)	R1-LT-531	EB-1-25582-D	
34	Bulk Sodium (Level Float Type)	R1-LT-530R		

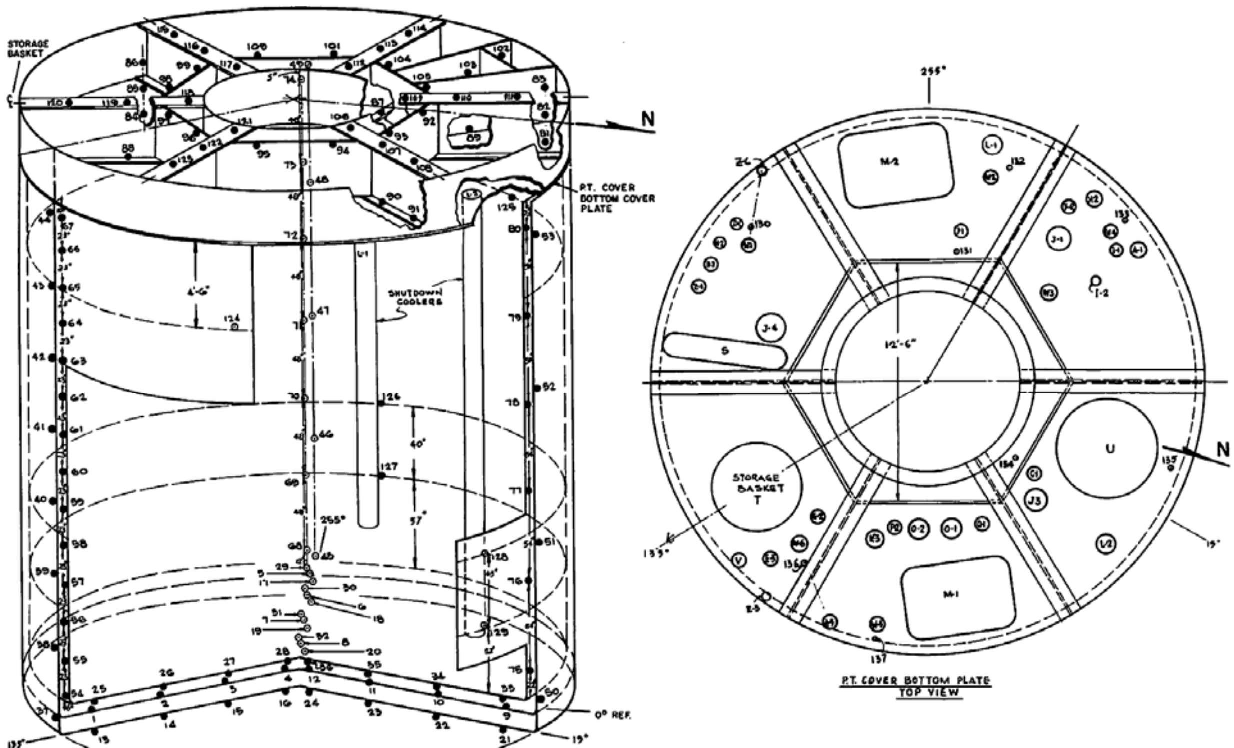

Figure 13 Figure 6.3-10 Thermocouples on Primary Tank **[Vol. II, Chapter 6, pp.6.3-29/30]**

Table 17 Figure 6.3-10 Thermocouples on Primary Tank **[Vol. II, Chapter 6, pp.6.3-29/30]** (1/4)

Ref. No.	Location	Instrument No.		Ref. Dwg.	Readout Inst. Point Numbers
1	Outer Vessel Inside Bottom	R1-TC-507A	□	EB-1-25272-D	1
2	↓	R1-TC-507B	□	↓	2
3	↓	R1-TC-507C	□	↓	3
4	↓	R1-TC-507D	□	↓	4
5	↓	R1-TC-507E	□	↓	27
6	↓	R1-TC-507F	□	↓	28
7	↓	R1-TC-507DV	□	↓	5
8	↓	R1-TC-507DW	□	↓	6
9	↓	R1-TC-507DX	□	↓	29
10	↓	R1-TC-507DY	□	↓	30
11	↓	R1-TC-507DZ	□	↓	31
12	↓	R1-TC-507EA	□	↓	32
13	Outer Vessel Outside Bottom	R1-TC-540FR	▲	↓	72
14	↓	R1-TC-540FS	▲	↓	73
15	↓	R1-TC-540FT	▲	↓	74
16	↓	R1-TC-540FV	▲	↓	75
17	↓	R1-TC-540FW	▲	↓	76
18	↓	R1-TC-540FX	▲	↓	77
19	↓	R1-TC-540FY	▲	↓	78
20	↓	R1-TC-540FZ	▲	↓	79
21	↓	R1-TC-540GA	▲	↓	80
22	↓	R1-TC-540GB	▲	↓	81
23	↓	R1-TC-540GC	▲	↓	82
24	↓	R1-TC-540GD	▲	↓	83
25	Inner Vessel Outside Bottom	R1-TC-507BB	□	EB-1-25260-D	44
26	↓	R1-TC-507BC	□	↓	45
27	↓	R1-TC-507BD	□	↓	46
28	↓	R1-TC-507BE	□	↓	47
29	↓	R1-TC-507AP	□	↓	33
30	↓	R1-TC-507AQ	□	↓	34
31	↓	R1-TC-507AR	□	↓	35
32	↓	R1-TC-507AS	□	↓	36
33	↓	R1-TC-507AB	□	↓	23
34	↓	R1-TC-507AC	□	↓	24
35	↓	R1-TC-507AD	□	↓	25
36	↓	R1-TC-507AE	□	↓	26
37	Outer Vessel Shell Outside Wall	R1-TC-540GE	▲	EB-1-25272-D	84
38	↓	R1-TC-540GF	▲	↓	85
39	↓	R1-TC-540GG	▲	↓	86
40	↓	R1-TC-540GH	▲	↓	87
41	↓	R1-TC-540GK	▲	↓	88

□ Readout Inst. P1-TIA-507-100 △ Readout Inst. R1-TI-540-100 ▲ Readout Inst. Rx-TI-1535-100 ○ Readout Inst. P1-TRA-501-24

Table 17. Figure 6.3-10 Thermocouples on Primary Tank **[Vol. II, Chapter 6, pp.6.3-29/30]** (2/4)

Ref. No.	Location	Instrument No.		Ref. Dwg.	Readout Inst. Point Numbers
42	Outer Vessel Shell Outside Wall	R1-TC-540GM	▲	EB-1-25272-D	89
43	↓	R1-TC-540GN	▲	↓	90
44		R1-TC-540GP	▲		91
45		R1-TC-540GQ	▲		92
46		R1-TC-540GR	▲		93
47		R1-TC-540GS	▲		94
48		R1-TC-540GT	▲		95
49		R1-TC-540GV	▲		96
50		R1-TC-540GW	▲		97
51		R1-TC-540GX	▲		98
52		R1-TC-540GY	▲		99
53		R1-TC-540GZ	▲		100
54	Inner Vessel Shell Outside Wall	R1-TC-507BF	□	EB-1-25266-D	48
55	↓	R1-TC-507BG	□	↓	49
56		R1-TC-507BH	□		50
57		R1-TC-507BK	□		51
58		R1-TC-507G	□		7
59		R1-TC-507H	□		8
60		R1-TC-507K	□		9
61		R1-TC-507M	□		10
62		R1-TC-507N	□		11
63		R1-TC-507P	□		12
64		R1-TC-507Q	□		13
65		R1-TC-507R	□		14
66		R1-TC-507S	□		15
67		R1-TC-507T	□		16
68		R1-TC-507AT	□		37
69		R1-TC-507AV	□		38
70		R1-TC-507AW	□		39
71		R1-TC-507AX	□		40
72		R1-TC-507AY	□		41
73		R1-TC-507AZ	□		42
74		R1-TC-507BA	□		43
75		R1-TC-507V	□		17
76		R1-TC-507W	□		18
77		R1-TC-507X	□		19
78		R1-TC-507Y	□		20
79		R1-TC-507Z	□		21
80		R1-TC-507AA	□		22
81	Cover SHLDG Balls	R1-TC-540AW	△	EB-1-25179-F	39
82	↓	R1-TC-540AX	△	↓	40

□ Readout Inst. P1-TIA-507-100 △ Readout Inst. R1-TI-540-100 ▲ Readout Inst. Rx-TI-1535-100 ○ Readout Inst. P1-TRA-501-24

Table 17. Figure 6.3-10 Thermocouples on Primary Tank **[Vol. II, Chapter 6, pp.6.3-29/30]** (3/4)

Ref. No.	Location	Instrument No.		Ref. Dwg.	Readout Inst. Point Numbers
83	Cover SHLDG Balls	R1-TC-540AY	△	EB-1-25179-F	41
84	↓	R1-TC-540AZ	△	↓	42
85		R1-TC-540BA	△		43
86		R1-TC-540BB	△		44
87	Bottom of Cover	R1-TC-540EQ	▲		50
88	↓	R1-TC-540ER	▲		51
89		R1-TC-540BE	△		47
90		R1-TC-540ES	▲		52
91		R1-TC-540ET	▲		53
92	Top of Cover	R1-TC-540BH	△		50
93	↓	R1-TC-540BK	△		51
94		R1-TC-540EE	▲		42
95		R1-TC-540EF	▲		43
96		R1-TC-540EG	▲		44
97		R1-TC-540EH	▲		45
98		R1-TC-540EK	▲		46
99		R1-TC-540EM	▲		47
100		R1-TC-540EN	▲		48
101		R1-TC-540EP	▲		49
102		R1-TC-540BC	△		45
103		R1-TC-540BD	△		46
104		R1-TC-540BF	△		48
105		R1-TC-540BG	△		49
106		R1-TC-540EV	▲		54
107		R1-TC-540EW	▲		55
108		R1-TC-540EX	▲		56
109		R1-TC-540EY	▲		57
110		R1-TC-540EZ	▲		58
111		R1-TC-540FA	▲		59
112		R1-TC-540FB	▲		60
113		R1-TC-540FC	▲		61
114		R1-TC-540FD	▲		62
115		R1-TC-540FE	▲		63
116		R1-TC-540FF	▲		64
117		R1-TC-540FG	▲		65
118		R1-TC-540FH	▲		66
119		R1-TC-540FK	▲		67
120		R1-TC-540FM	▲		68
121		R1-TC-540FN	▲		69
122		R1-TC-540FP	▲		70
123		R1-TC-540FQ	▲		71

□ Readout Inst. P1-TIA-507-100 △ Readout Inst. R1-TI-540-100 ▲ Readout Inst. Rx-TI-1535-100 ○ Readout Inst. P1-TRA-501-24

Table 17. Figure 6.3-10 Thermocouples on Primary Tank **[Vol. II, Chapter 6, pp.6.3-29/30]** (4/4)

Ref. No.	Location	Instrument No.	Ref. Dwg.	Readout Inst. Point Numbers
124	P.T. Wall at Electric HTR. Plug W-5 4'-6" Below P.T. Cover Bottom Plate	R1-TC-501A ○	EB-1-29079-E	1
125	P.T. Wall at Electric HTR. Plug W-4 4'-6" Below P.T. Cover Bottom Plate	R1-TC-501R ○	EB-1-29079-E	14
126	P.T. Wall 97" Above Bottom Plate of Bottom Structure to Shutdown Cooler Plug L-1	R1-TC-540T △	EB-1-29020-F	16
127	P.T. Wall 57" Above Bottom Plate of Bottom Structure, close to Shutdown Cooler Plug L-1	R1-TC-540V △	EB-1-29020-F	17
128	P.T. Wall 97" Above Bottom Plate of Bottom Structure to Shutdown Cooler Plug L-2	R1-TC-540Z △	EB-1-29020-F	21
129	P.T. Wall 52" Above Bottom Plate of Bottom Structure, close to Shutdown Cooler Plug L-2	R1-TC-540AA △	EB-1-29020-F	22
130	P.T. Cover Bottom Plate 8" out from Side of W-1 HTR. Plug on Line between CTRS of W-1 * Z-6 Nozzles	R1-TC-501G ○	EB-1-29079-E	7
131	P.T. Cover Bottom Plate 12" from Center of P-1 Nozzle toward Center of P.T.	R1-TC-540R △	EB-1-29020-F	14
132	P.T. Cover Bottom Plate near W-2 HTR.	R1-TC-540Q △	EB-1-29020-F	13
133	P.T. Cover Bottom Plate between W-4 HTR. and P.T. Wall	R1-TC-501AB ○	EB-1-29079-E	19
134	P.T. Cover Bottom Plate at Point 15" from Center of C-1 Nozzle toward Center of P.T.	R1-TC-540X △	EB-1-29020-F	19
135	P.T. Cover Bottom Plate at Pointe between Heat Exchanger and P.T. Wall	R1-TC-540W △	EB-1-29020-F	18
136	P.T. Cover Bottom Plate at Point 6" out from Side of W-6 HTR. Plug toward A-5 Nozzle	R1-TC-501AC ○	EB-1-29079-E	10
137	P.T. Cover Bottom Plate at Point between W-5 HTR. Plug * P.T. Wall	R1-TC-540G △	EB-1-29020-F	7

□ Readout Inst. P1-TIA-507-100 △ Readout Inst. R1-TI-540-100 ▲ Readout Inst. Rx-TI-1535-100 ○ Readout Inst. P1-TRA-501-24

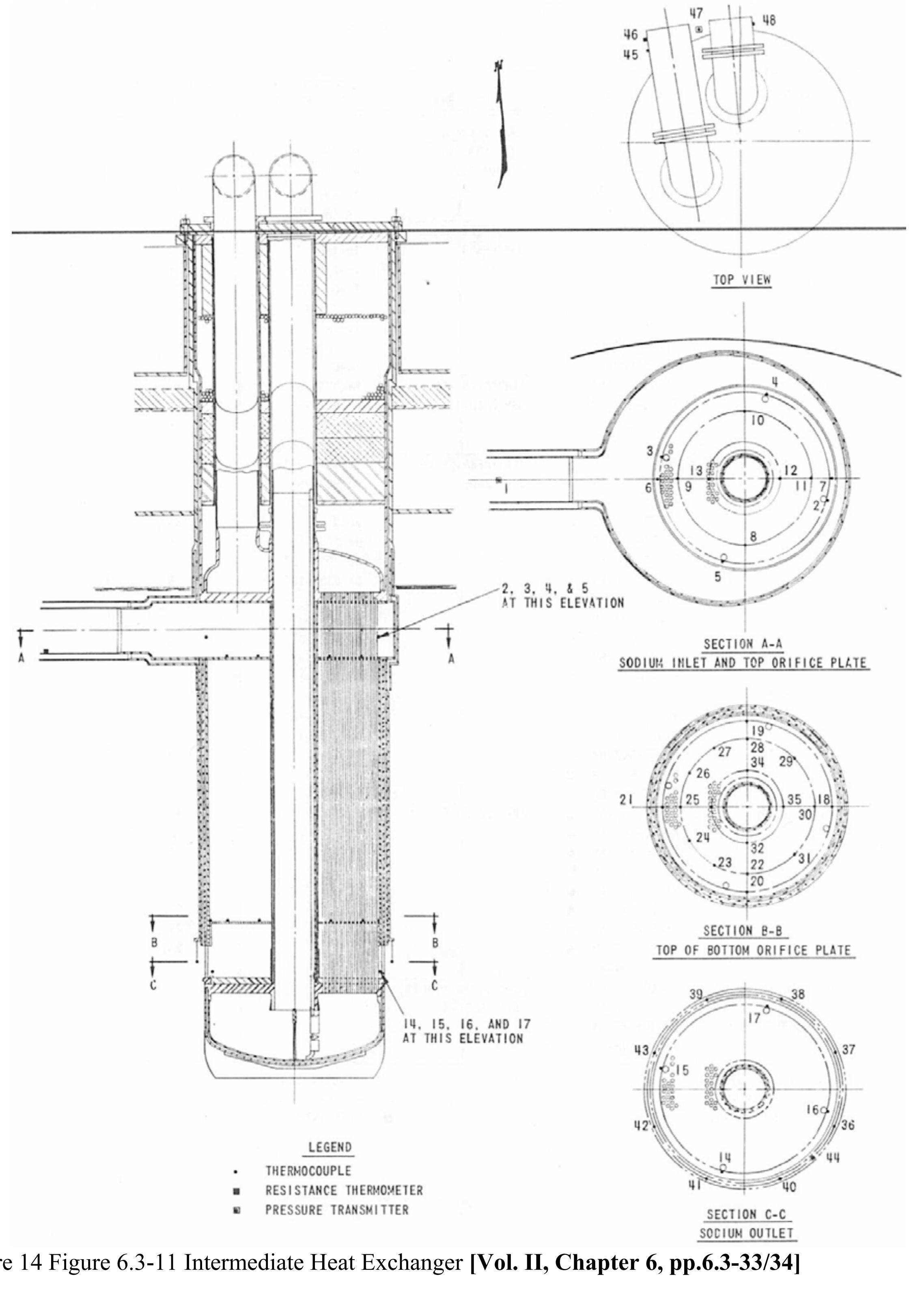

Figure 14 Figure 6.3-11 Intermediate Heat Exchanger **[Vol. II, Chapter 6, pp.6.3-33/34]**

Table 18 Figure 6.3-11 Intermediate Heat Exchanger **[Vol. II, Chapter 6, pp.6.3-33/34]**

Ref. No.	Location	Instrument No.	Ref. Dwg.	Struthers Wells T.C. MK. No.	Readout Inst. Point No.
1	PRI. Na Inlet	R1-PT-522-K ■	EB-1-29016-E		9
2		R1-TC-507-BQ △	Struthers-Wells 59P8088D17	Na IN-195”	55
3		R1-TC-507-BKA ⍍		Na IN-15”	9
4		R1-TC-507-BN △	↓	Na IN-105”	53
5		R1-TC-507-BS △		Na IN-285”	57
6	Top Orifice Plate	R1-TC-507-CP △	Struthers-Wells 59P8088D4	To-0°-25”	75
7		R1-TC-507-CQ △		To-180°-25”	76
8		R1-TC-507-EQ ⍍	↓	To-270°-19”	8
9		R1-TC-507-CM △		To-0°-19”	73
10		R1-TC-507-EP ⍍		To-90°-19”	7
11		R1-TC-507-CN △		To-180°-19”	74
12		R1-TC-507-CK △		To-180°-9”	72
13		R1-TC-507-CH △		To-0°-9”	71
14	PRI. Na Outlet	R1-TC-507-BT △	Struthers-Wells 59P8088D17	Na Out-285°	58
15		R1-TC-507-BM △		Na Out-15°	52
16		R1-TC-507-BR △	↓	Na Out-195°	56
17		R1-TC-507-BP △		Na Out-105°	54
18	Bottom Orifice Plate	R1-TC-507-CF △	Struthers-Wells 59P8088D3	Bo 180°-25”	69
19		R1-TC-507-CA △		Bo 90°-25”	64
20		R1-TC-507-CG △	↓	Bo 270°-25”	70
21		R1-TC-507-BZ △		Bo 0°-25”	63
22		R1-TC-507-CE △		Bo 270°-19”	68
23		R1-TC-507-EM ⍍		Bo 300°-19”	5
24		R1-TC-507-EN ⍍		Bo 330°-19”	6
25		R1-TC-507-BX △		Bo 0°-19”	61
26		R1-TC-507-EF ⍍		Bo 30°-19”	1
27		R1-TC-507-EG ⍍		Bo 60°-19”	2
28		R1-TC-507-BY △		Bo 90°-19”	62
29		R1-TC-507-EH ⍍		Bo 135°-19”	3
30		R1-TC-507-CD △		Bo 180°-19”	67
31		R1-TC-507-EK ⍍		Bo 225°-19”	4
32		R1-TC-507-CC △		Bo 270°-9”	66
33		R1-TC-507-BV △		Bo 0°-9”	59
34		R1-TC-507-BW △		Bo 90°-9”	60
35		R1-TC-507-CB △		Bo 180°-9”	65
36	PRI. Na Outlet	R1-TC-540-AQ ▲	EB-1-29020-F		34
37		R1-TC-540-AP ●	↓		33
38		R1-TC-540-AN ▲			32
39		R1-TC-540-AM ●			31
40		R1-TC-540-AE ●			26
41		R1-TC-540-AD ▲			25
42		R1-TC-540-AC ●			24
43		R1-TC-540-AB ▲			23
44		R1-RT-504-A ○			1
45	SEC. Na Outlet Pipe	R2-TC-508-F ⦿	R2-RT-533B(Inlet)		
46		R2-RT-533-A ⊗	EB-1-25250-C		
47	SEC. Na Inlet-Outlet Pipes	R2-dPT-525-A □	↓		1
48	SEC. Na Inlet Pipe	R2-TC-508-G ⦿			

△Readout Inst. P1-TIA-507-100 ▲ Readout Inst. R1-TI-540-100
⍍ Readout Inst. RX-TI-1535-100 ● Readout Inst. DAS
○ P1-dTRA-504 □ P2-PRA525-12 & S2-PRA525-12 ■ P1-PRA522-12

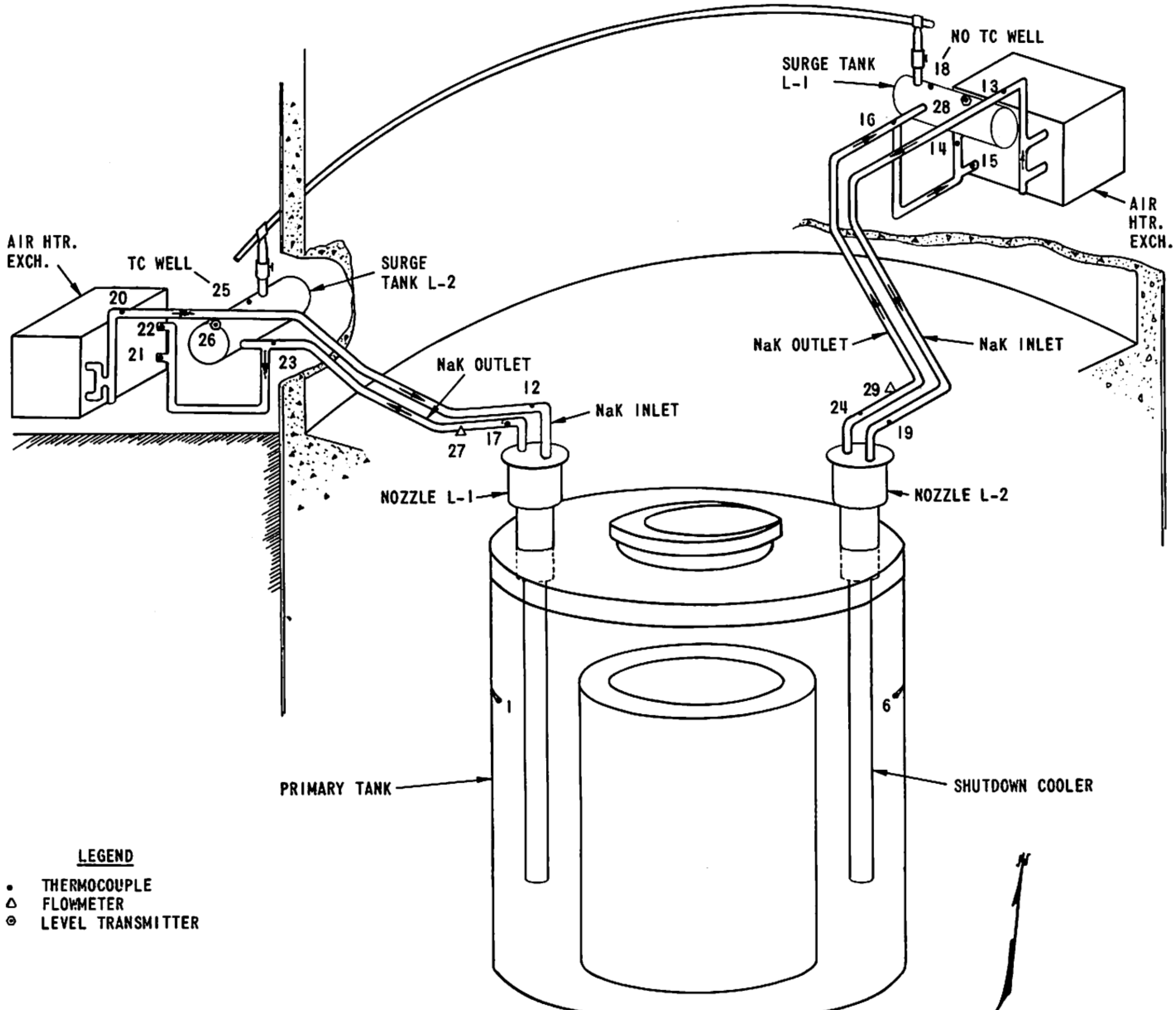

Figure 15 Figure 6.3-18 Shutdown Coolers **[Vol. II, Chapter 6, pp.6.3-43/44]**

Table 19 Figure 6.3-18 Shutdown Coolers **[Vol. II, Chapter 6, pp.6.3-43/44]**

Ref. No.	Location	Instrument No.	Reference Drawing	Inst. No.	Point. No
1	Near L1- Shutdown Cooler	R1-TC-540-S	EB-1-29020-F	540	15
6	Near L-2 Shutdown Cooler	R1-TC-540-Y	EB-1-29020-F	540	20
12	NaK Inlet to L-1 Shutdown Cooler	R4-TC-511-AG	HKF-R803, R806	511	3, 2
13	NaK Outlet from L-2 Air HTR Exch.	R4-TC-511-BD	↓	↓	3, 15
14	NaK Inlet to L-2 Air HTR Exch.	R4-TC-511-AR	↓	↓	3,10
15	NaK Inlet to L-2 Air HTR Exch.	R4-TC-511-AS	↓		
16	NaK Inlet to L-2 Air HTR Exch.	R4-TC-511-AV	↓		
17	NaK Outlet from L-1 Shutdown Cooler	R4-TC-511-AK	↓	511	3,5
18	Loose in Cooler #2	R4-TC-511-AN	↓	↓	3, 7
19	NaK Inlet to L-2 Shutdown Cooler	R4-TC-511-AF	↓	↓	3, 1
20	NaK Outlet from L-1 Air HTR Exch.	R4-TC-511-BC	↓	↓	3, 14
21	NaK Inlet to L-1 Air HTR Exch.	R4-TC-511-AQ	↓		
22	NaK Inlet to L-1 Air HTR Exch.	R4-TC-511-AP	↓	511	3,8
23	NaK Inlet to L-1 Air HTR Exch.	R4-TC-511-AT	↓		
24	NaK Outlet from L-2 Shutdown cooler	R4-TC-511-AH	↓	511	3, 4
25	Loose in Cooler #1	R4-TC-511-AM	↓	↓	3, 6
26	On Surge Tank L-1 Air HTR Exch.	R4-LT-529-A	↓	529A	
27	NaK Outlet from L-1 Shutdown Cooler	R4-FM-518-A	↓	518A,555A	
28	Surge Tank Level L-2 Air HTR Exch.	R4-LT-529-B	↓	529B	
29	NaK Outlet from L-2 Shutdown Cooler	R4-FM-518-B	↓	518B, 555B	

5. Drawings of Sensors in EBR-II System

To measure the reactor conditions, five types of instruments are employed. Thermocouples and resistance thermometers were used to measure the temperatures in the reactor system. The flow rate of the reactor coolant was measured by the magnetic flowmeters. Volumetric pressure sensing elements and differential pressure sensing elements were used to detect the system pressures. Fission-counter and ion-chamber were installed in the thimble to detector the neutron flux. The physical drawings of each instrument are shown in following sections.

5.1 Thermocouples and Thermometers

Figure 16 and Figure 17 show the pipe surface thermocouple assembly and pipe surface thermocouple mounting, respectively.

Figure 18 shows thermocouple assembly for the thermowell. Figure 19 and Figure 20 show the schematic of typical thermowell and typical thermowell type thermocouple mounting, respectively.

Figure 21 shows the special thermocouple assembly. Figure 22 shows the “type A” and the “type B” of special thermocouple, respectively.

Resistance thermometers were used to measure the temperatures of Sodium coolant and air. The thermometers for the Sodium and the air are shown in Figure 23 and Figure 24, respectively.

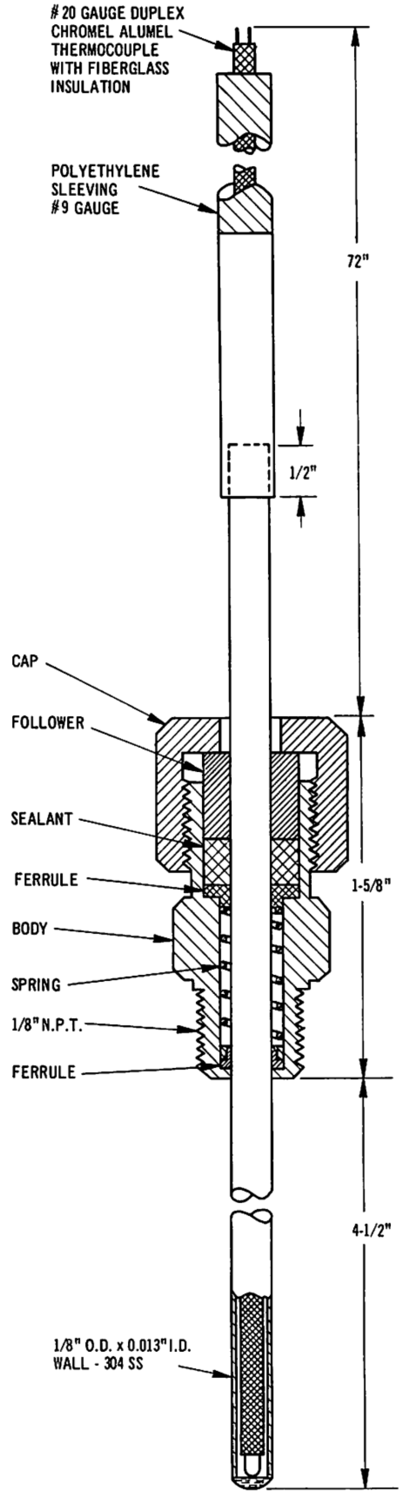

Figure 16 Figure 6.9-2 Pipe Surface Thermocouple Assembly **[Vol. II, Chapter 6, p.6.9-5]**

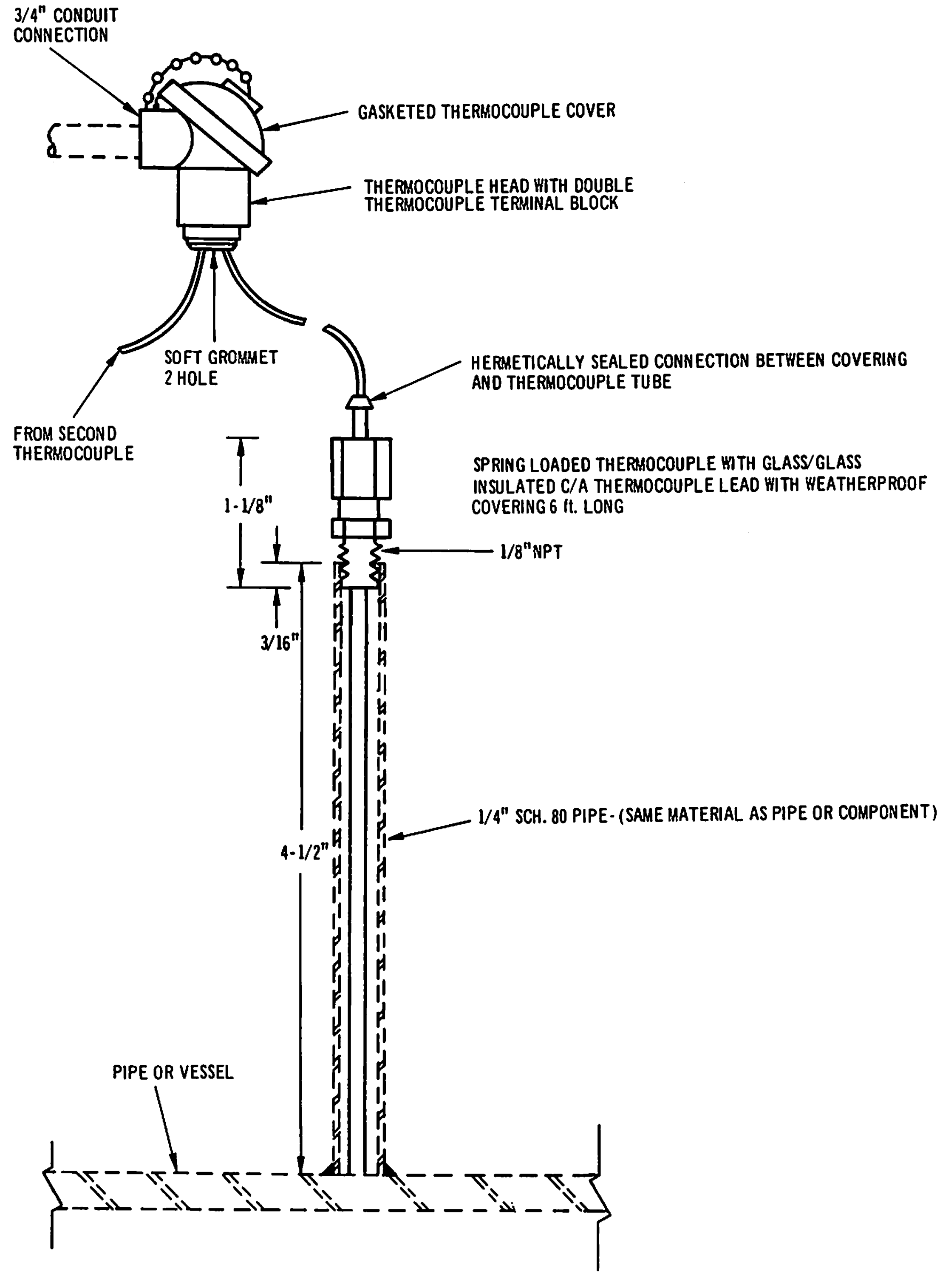

Figure 17 Figure 6.9-3 Pipe Surface Thermocouple Mounting **[Vol. II, Chapter 6, p.6.9-6]**

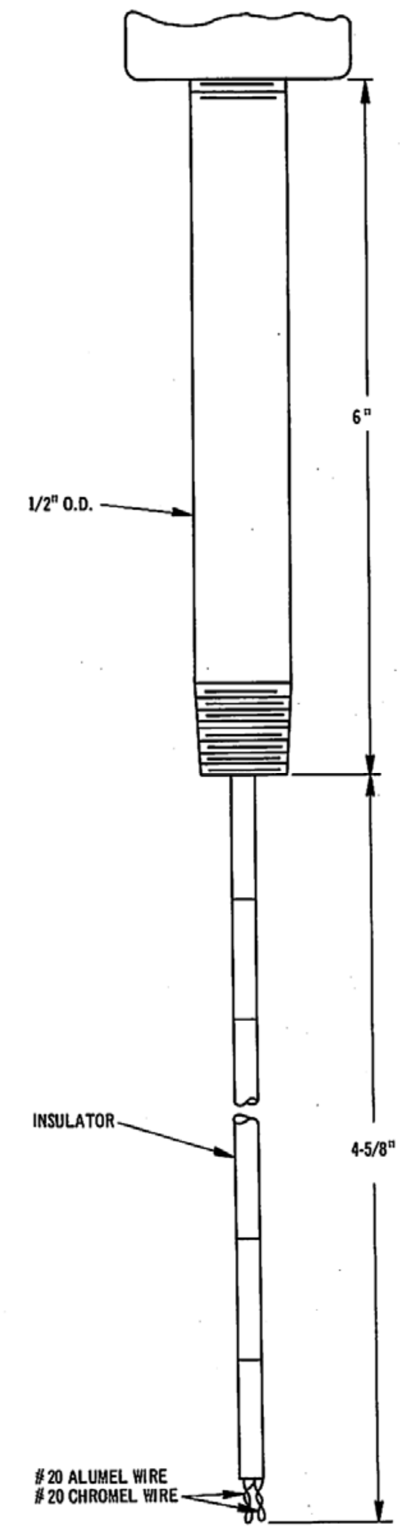

Figure 18 Figure 6.9-4 Thermocouple Assembly for Thermowell **[Vol. II, Chapter 6, p.6.9-7]**

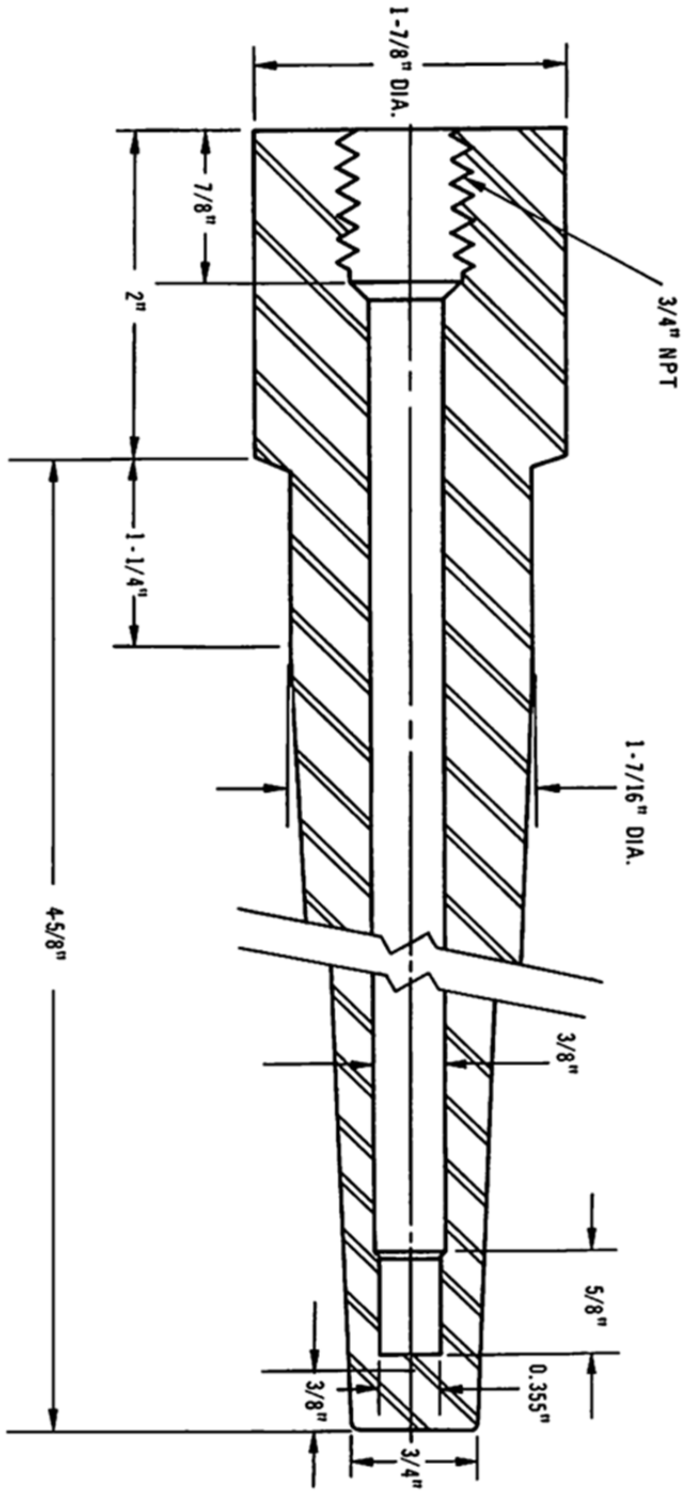

Figure 19 Figure 6.9-5 Typical Thermowell [**Vol. II, Chapter 6, p.6.9-9]**

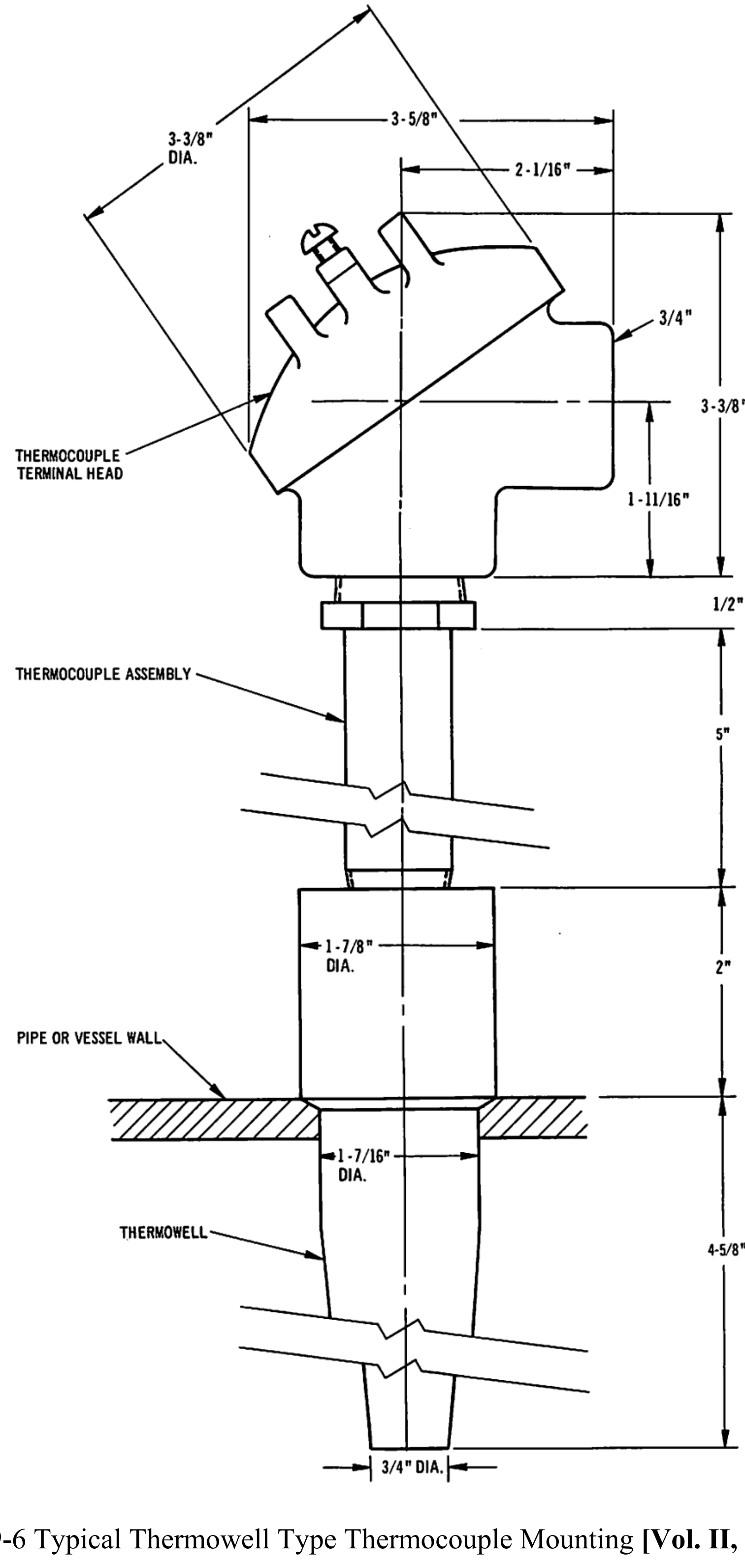

Figure 20 Figure 6.9-6 Typical Thermowell Type Thermocouple Mounting **[Vol. II, Chapter 6, p.6.9-10]**

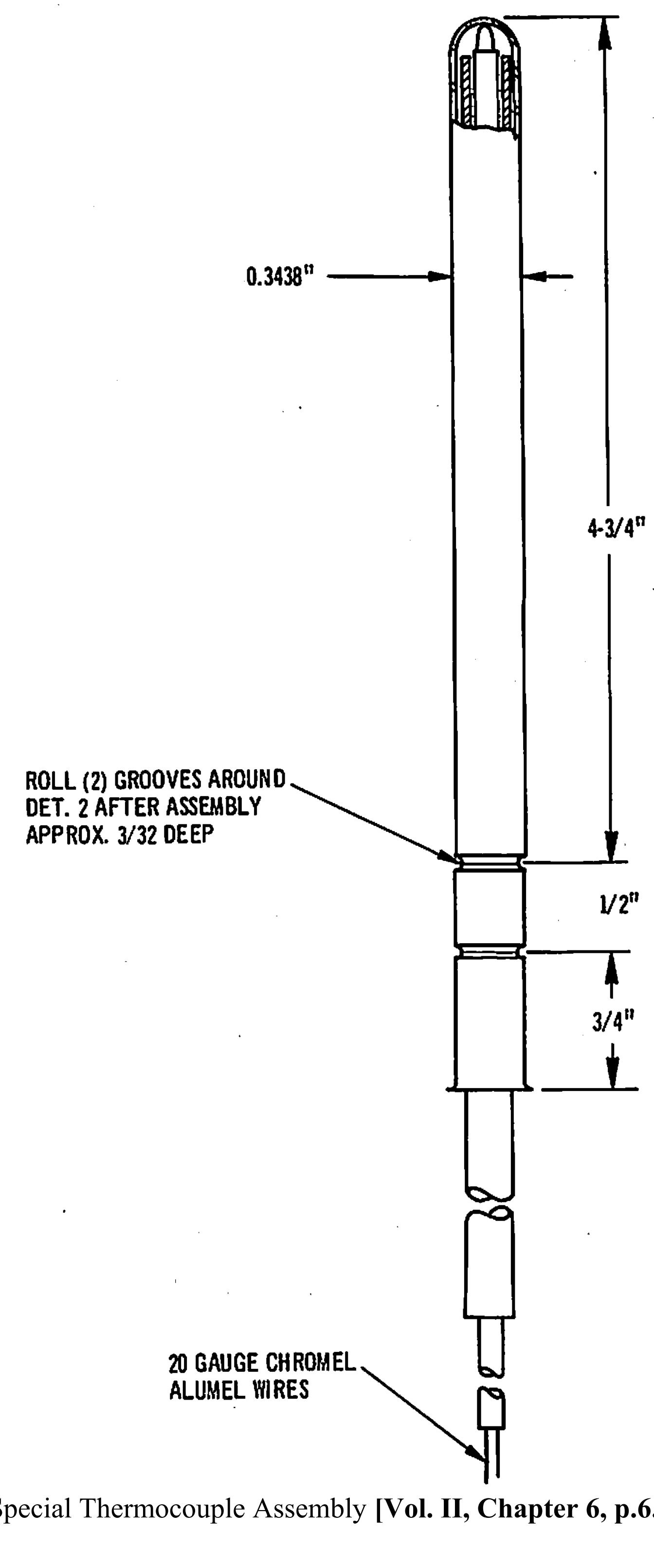

Figure 21 Figure 6.9-7 Special Thermocouple Assembly **[Vol. II, Chapter 6, p.6.9-11]**

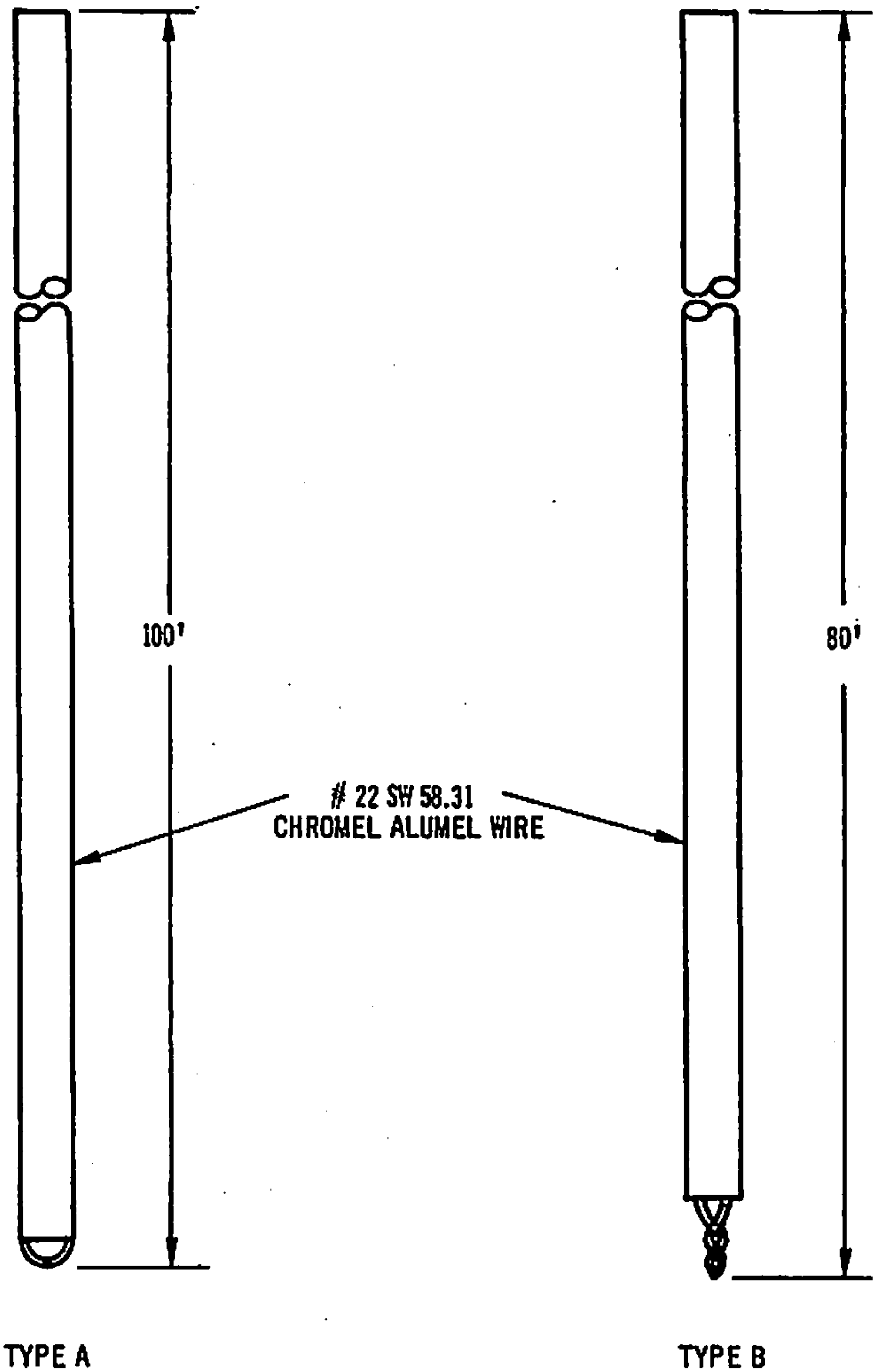

Figure 22 Figure 6.9-8 Special Thermocouple **[Vol. II, Chapter 6, p.6.9-13]**

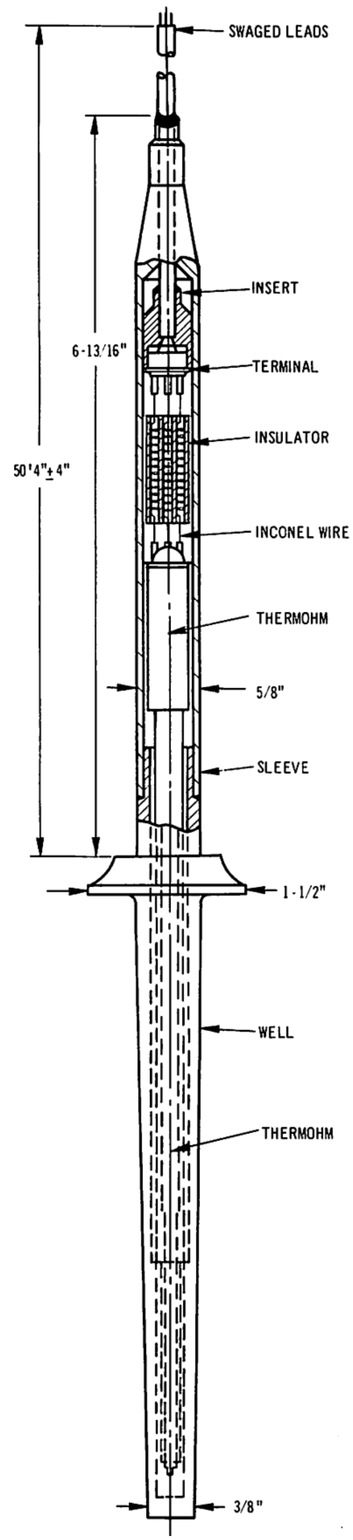

Figure 23 Figure 6.9-35 Typical Resistance Thermometer for High Temperature Use in Sodium **[Vol. II, Chapter 6, p.6.9-103]**

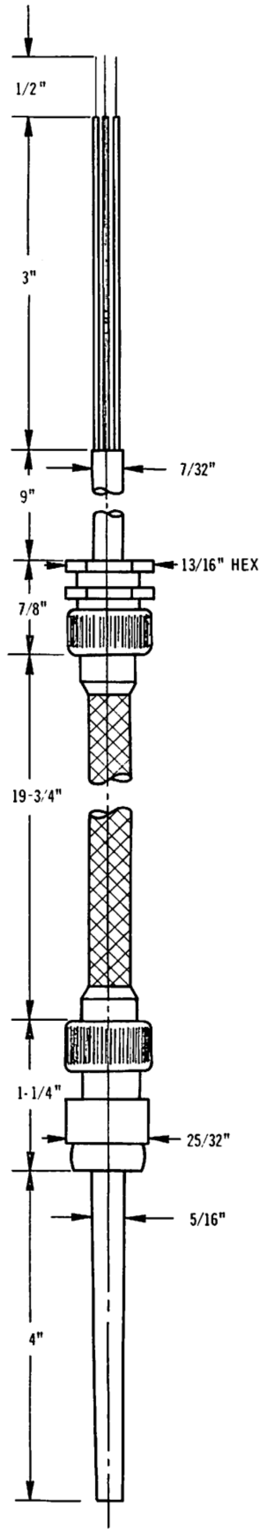

Figure 24 Figure 6.9-36 Resistance Thermometer for Sensing Air Temperatures **[Vol. II, Chapter 6, p.6.9-103]**

5.2 Pressure Sensors

NaK filled volumetric pressure sensing element manufactured by Taylor Instrument Co. was used to measure the local pressures in the reactor system. The differential pressure sensing head was used to detect the differential pressure in the primary system components. NaK filled volumetric pressure sensing elements and differential pressure sensing head are presented in Figure 25and Figure 26, respectively.

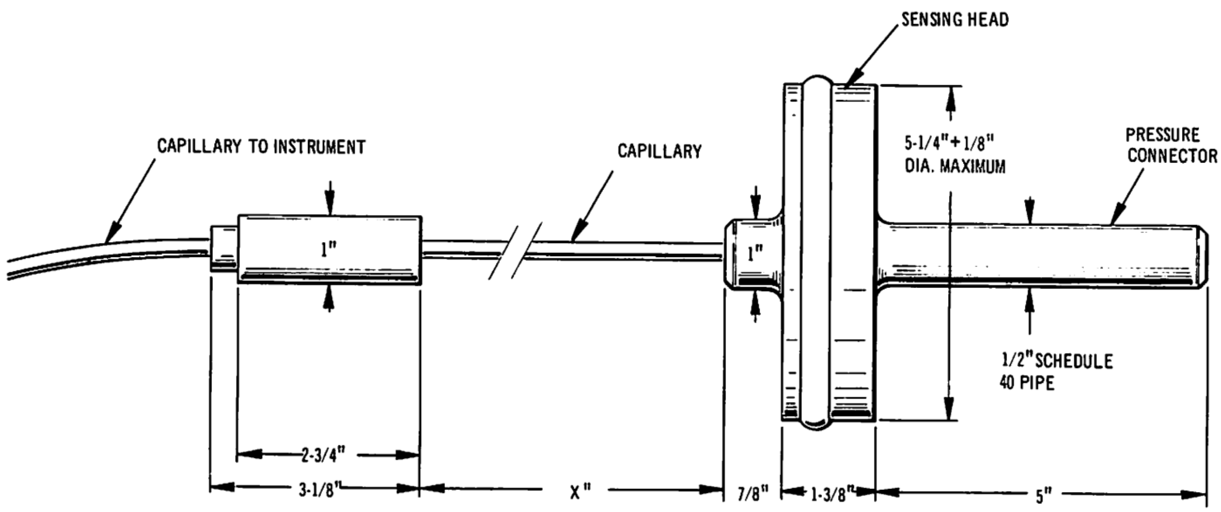

Figure 25 Figure 6.10-2 NaK Filled Volumetric Pressure Sensing Element **[Vol. II, Chapter 6, p.6.10-5]**

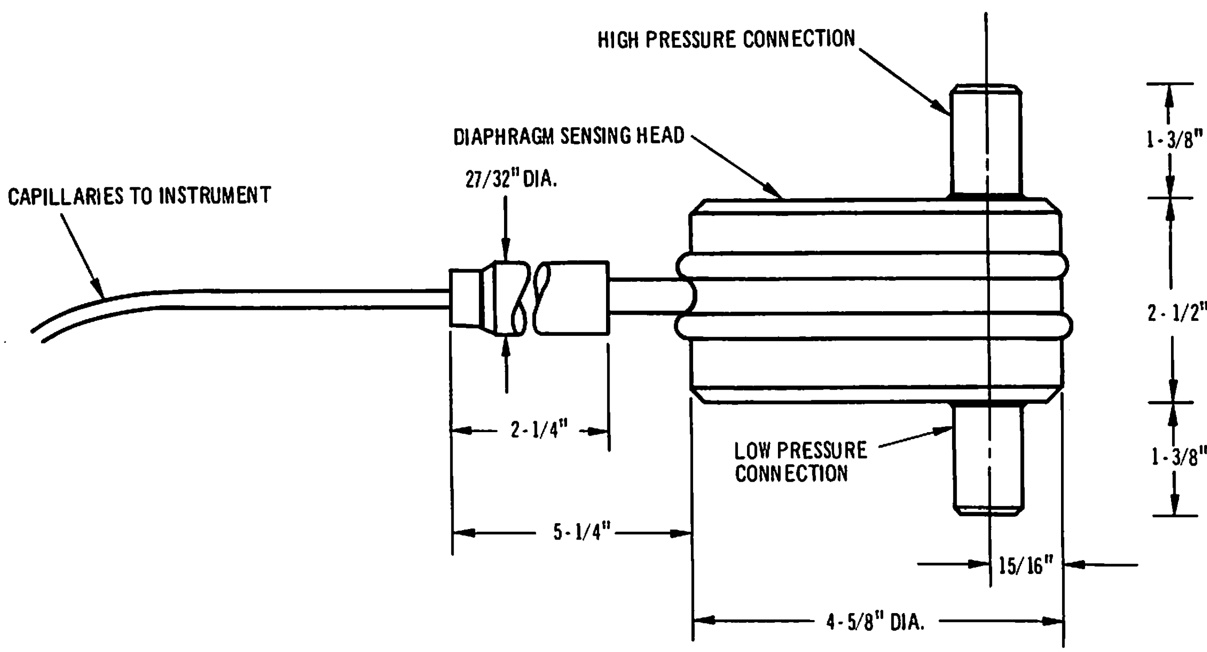

Figure 26 Figure 6.10-5 Differential Pressure Sensing Head **[Vol. II, Chapter 6, p.6.10-13]**

5.3 Flowmeters

Magnetic flowmeter and flow tube are used to measure the flow rate of Sodium coolant in primary system. Figure 27 shows the magnetic flowmeter installation for large sodium cooling pipe. Small magnetic flowmeter was installed in the sodium purification system as shown in Figure 28. Figure 29 shows the magnetic flowmeter installed below the capsule bundle to measure Sodium flow through the subassembly.

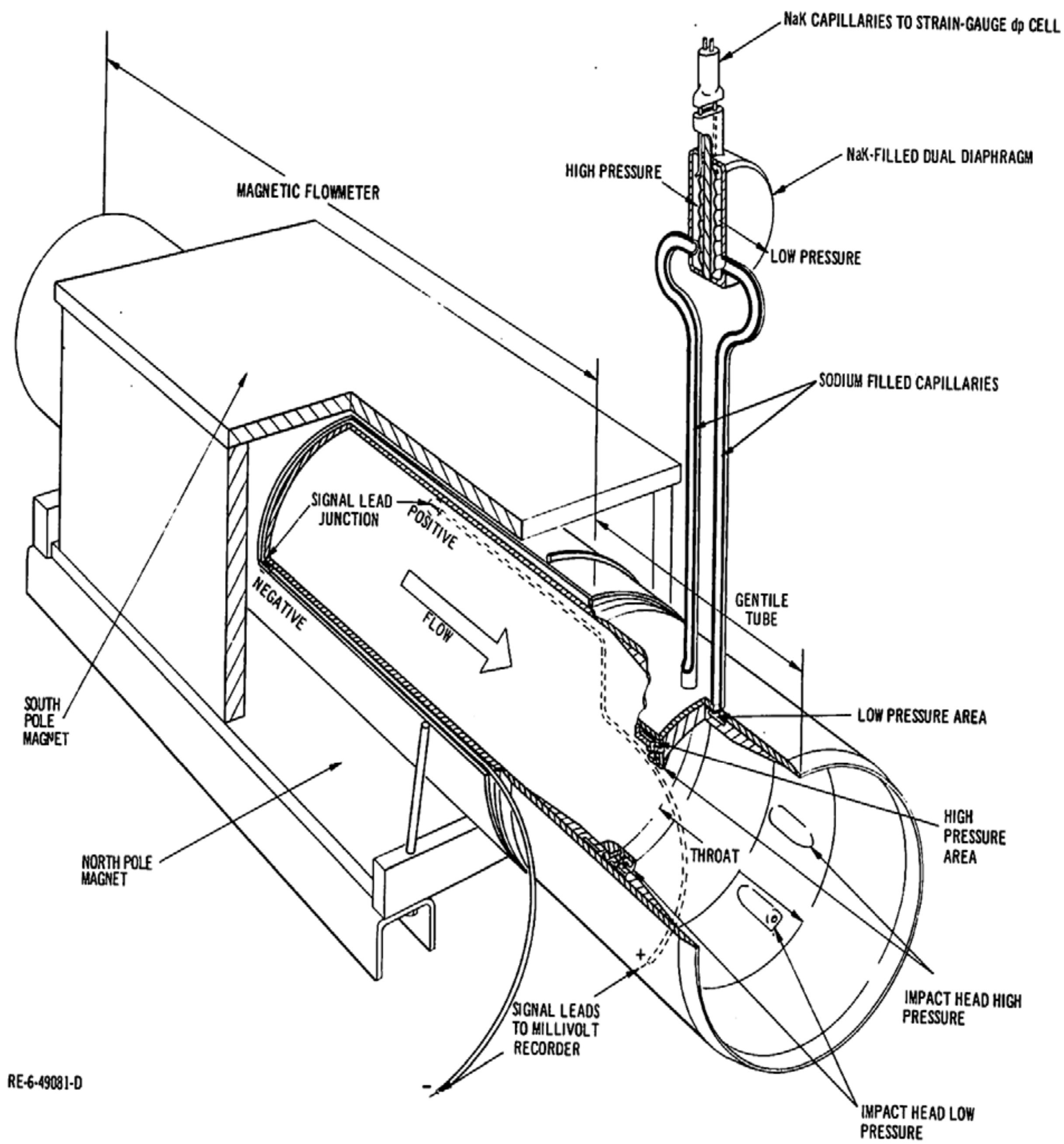

Figure 27 Figure 6.11-1 Magnetic Flowmeter and Flow Tube for Large Sodium Coolant Piping **[Vol. II, Chapter 6, p.6.11-3]**

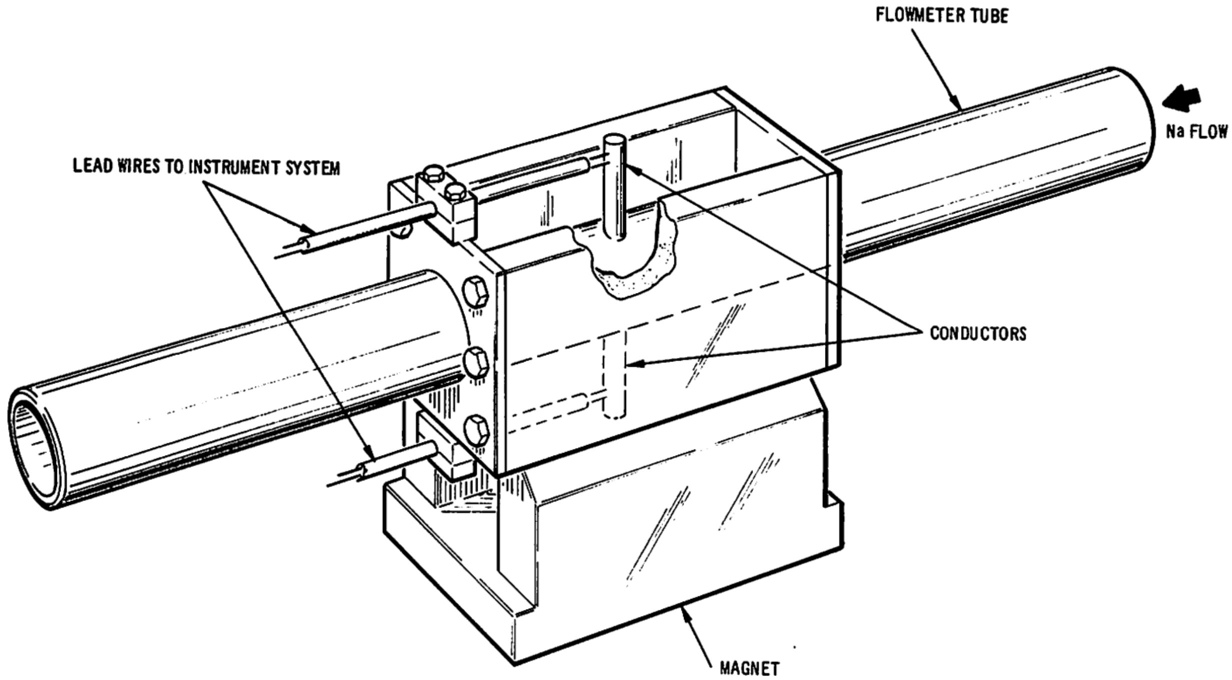

Figure 28 Figure 6.11-8 Small Magnetic Flowmeter Installation – Sodium Purification Flowmeters, R1-FM-515-A and R1-FM-515-B **[Vol. II, Chapter 6, p.6.11-17]**

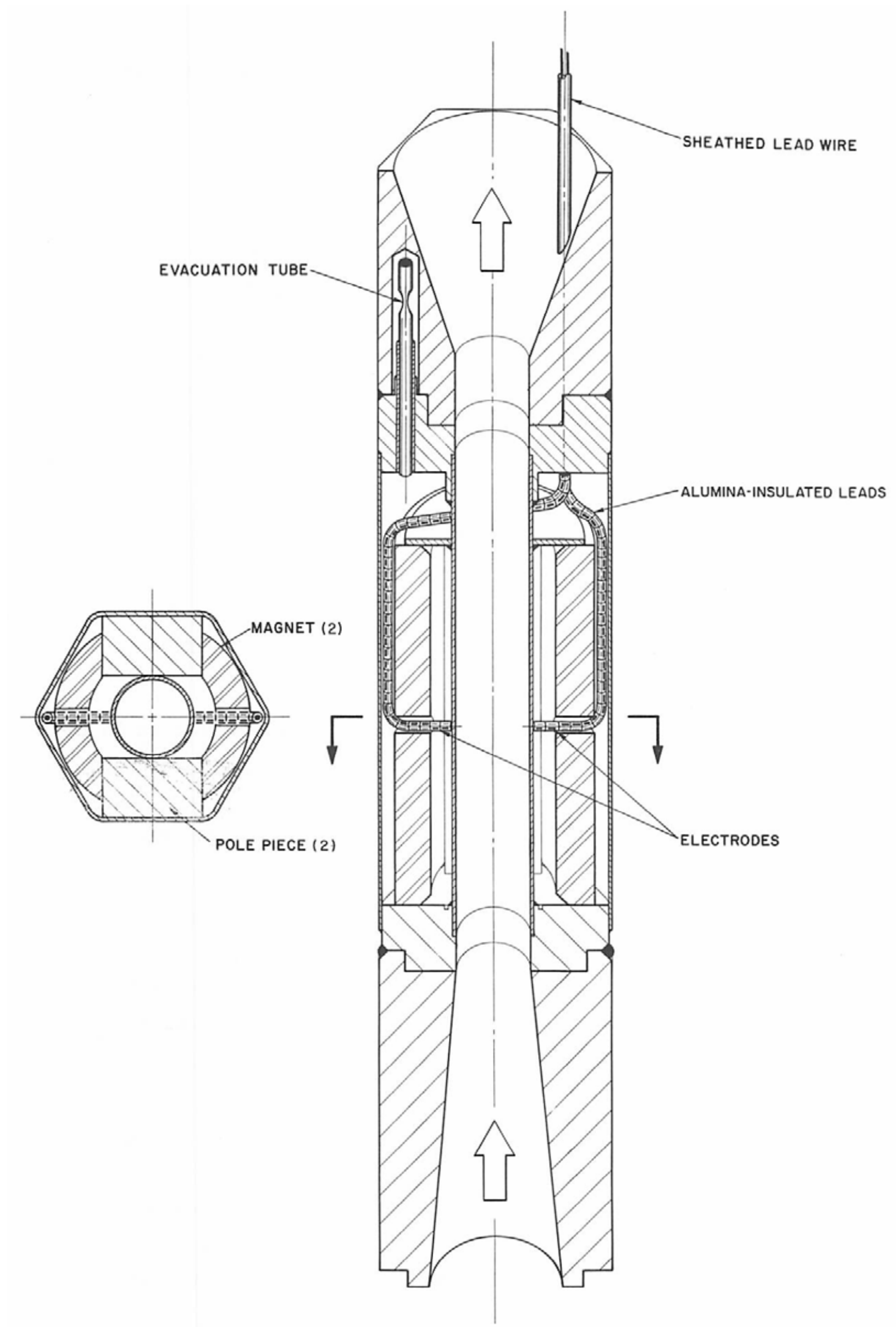

Figure 29 Figure 6.15-27 Magnetic Flowmeter **[Vol. II, Chapter 6, p.6.15-77]**

5.4 Level Sensors

Figure 30 shows the installation of resistance probes to measure the sodium level in the primary tank. Two kinds of level sensing elements were employed to measure the sodium level in primary tank: a differential pressure type level transmitter and a float type level transmitter. Figure 30 and Figure 31 show the differential pressure type and float type level transmitters, respectively.

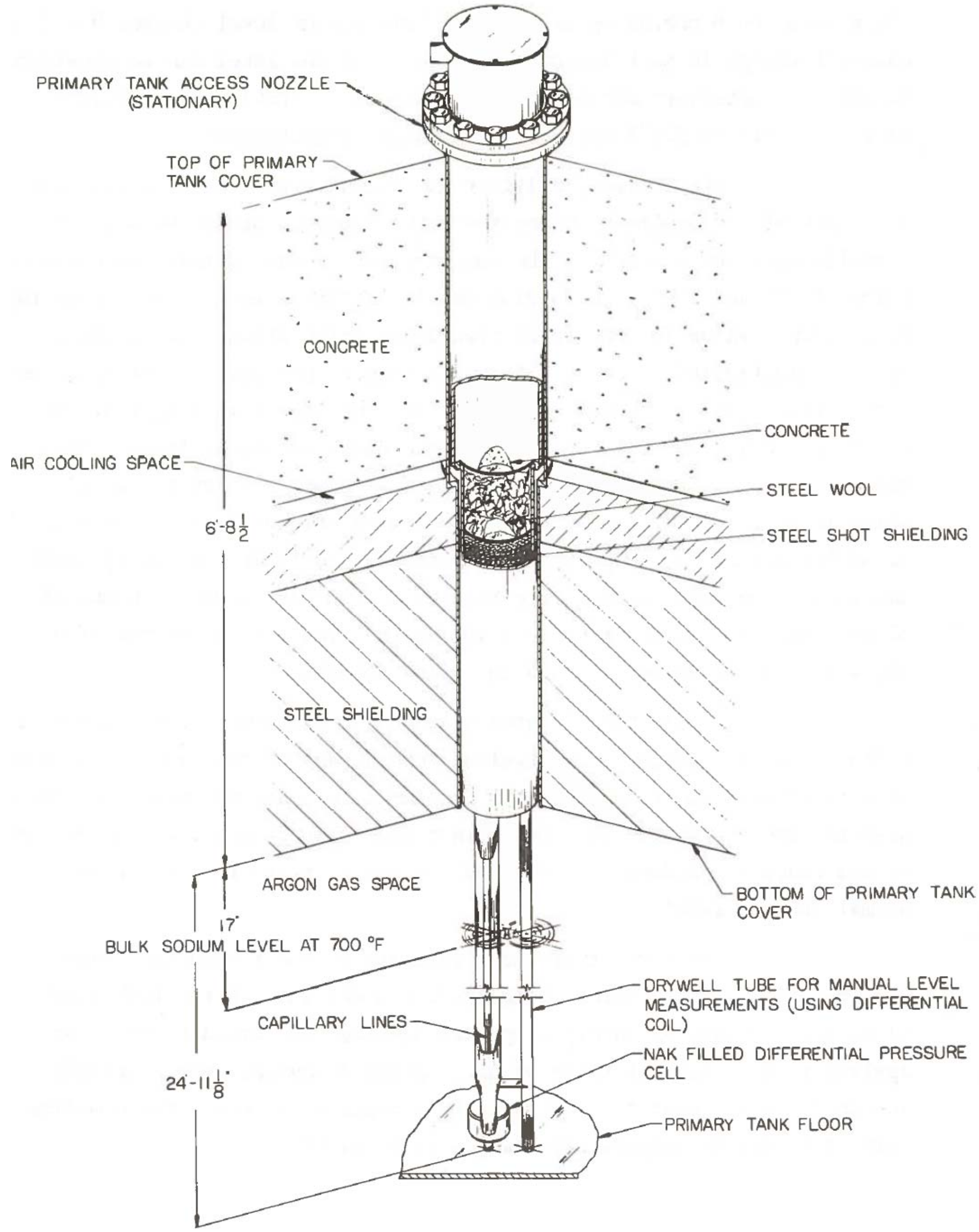

Figure 30 Figure 6.12-3 Differential Pressure Type Level Transmitter **[Vol. II, Chapter 6, p.6.12-7]**

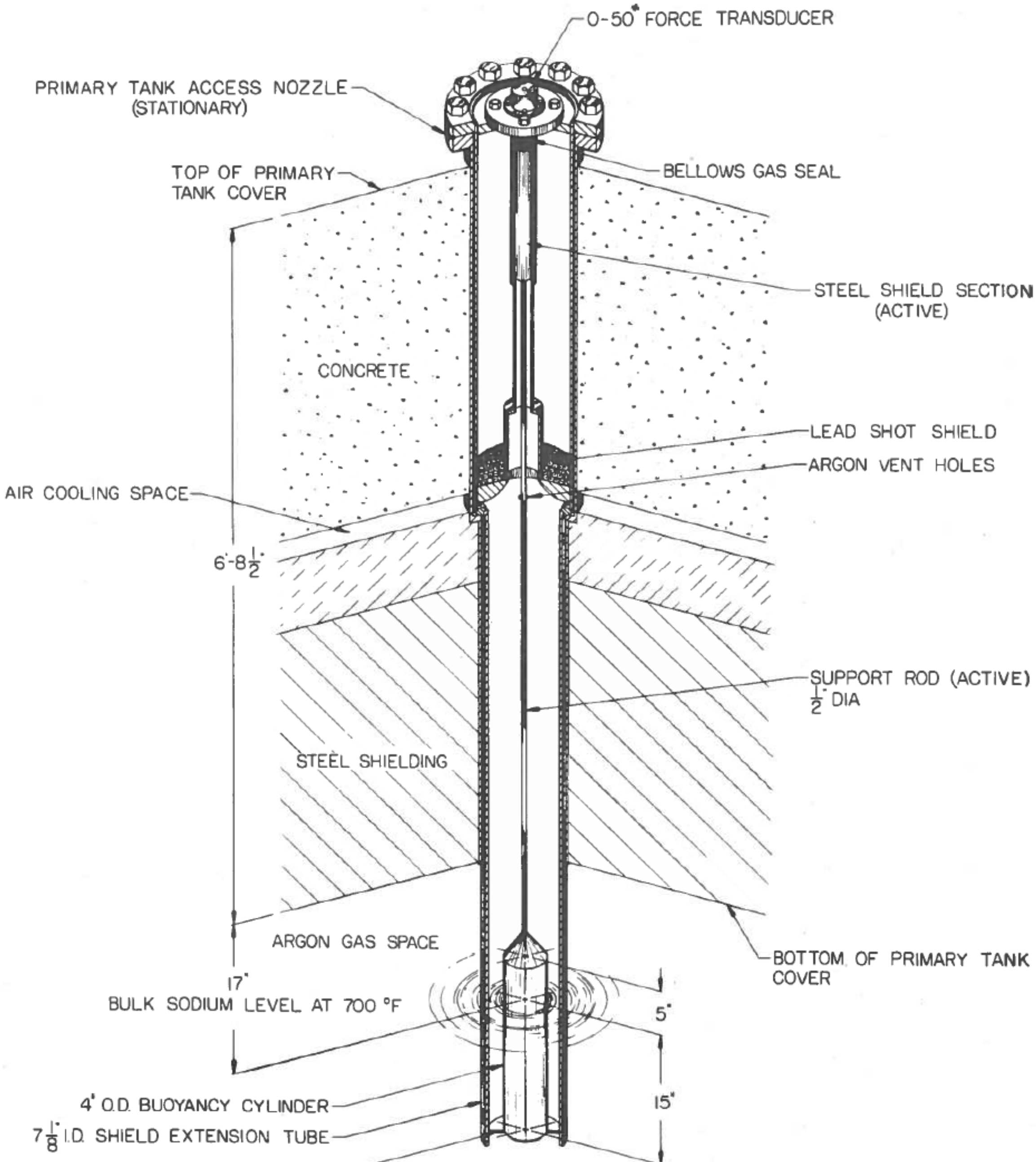

Figure 31 Figure 6.12-4 Float Type Level Transmitter **[Vol. II, Chapter 6, p.6.12-9]**

5.5 Flux-monitor Tube

Figure 32 shows the installation of flux-monitor tube. This sealed tube is build to allow the insertion of a small diameter flux monitor where the self-powered neutron detector (Reuter Stokes Model RSN-202-MI) is inserted.

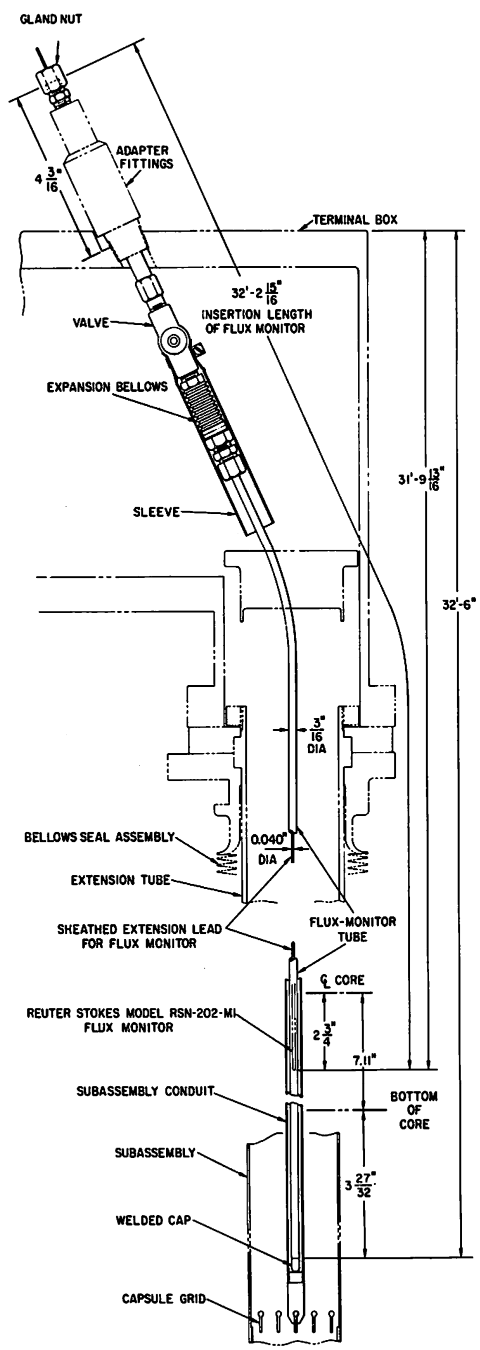

Figure 32 Figure 2.11-11 Installation of Flux-monitor Tube **[Vol. II, Chapter 2, p.2.11-28]**

6. Descriptions of the Sensors

In Chapter 2, Chapter3 and Chapter 6 of Volume II, it is described the detailed information of the sensors in the primary system. In this section, the descriptions for each sensor are summarized chapter by chapter.

6.1 Volume II, Chapter 2

6.1.1 Thermocouple

Volume II, Pages: 2.11-23) Thermocouples are available to measure fuel-centerline, coolant, and structural-material temperatures. Two-types of thermocouples are used: chromel/alumel thermocouples to measure coolant and structural-material temperatures, and tungsten-3% rhenium/tungsten-25% rhenium thermocouples to measure fuel-centerline temperatures.

The tungsten/rhenium fuel-centerline thermocouples have tantalum sheaths and thoria insulation. Reactor experience with this type of thermocouple is limited; however, this thermocouple provides useful temperature data below 2400°F. The components of the tungsten/rhenium thermocouples are manufactured by Engelhard Industries Incorporated. These materials are guaranteed to ±1% accuracy at the anticipated fuel-centerline temperatures. Fuel enrichment was selected to produce temperatures in the 1700~2000°F range.

The chromel/alumel coolant and structural thermocouples have Type 304 stainless steel sheaths and alumina insulation. The chromel and alumel materials are a special close-tolerance grade of Chromel-P and Alumel developed for precision applicants. These materials are guaranteed to register voltage values accurate to within ±3/8% from 530° to 2300°F. This material is "Specification 3G-178," manufactured by Hoskins Manufacturing Company. The chromel/alumel thermocouples have either 0.062-in. or 0.040-in. diameters. Thermocouples used to sense coolant inlet and outlet temperature are 0.062 in. in diameter. The 0.040-in.-ida thermocouples replace the normal spacer wires on some capsules. The spacer-wire thermocouples measure capsule-cladding temperature.

Volume II, Pages: 2.12-20) Two types of thermocouples are included in the FPTF: the regular type, and the fast-response type. The fast-response thermocouples have a time constant of 25 ms or less. The regular thermocouples have a response time of 250 ms. The signals from all thermocouples are read out on the DAS. The fast-response thermocouples have a grounded junction, so their operability cannot be checked by checking insulation resistances. These thermocouples are connected to differential-input amplifier in the TIR. The primary output from the amplifiers is routed to the DAS expansion room patch panel, and the auxiliary output from the amplifiers is connected to the DAS in the TIR. Figure 2.12-7 shows a block diagram of the fast-response-thermocouple system. The regular thermocouples and the cable for the fast-response thermocouples were procured according to RDT Standard C7-6T; the junction of the fast-response thermocouple is not covered by this standard.

6.1.2 Fission-gas Pressure Transducer

Volume II, Pages 2.11-25) The fission-gas pressure transducer is a pressure-balancing type device used to measure buildup of fission-gas pressure in fueled capsules. This instrument contains two bellows joined by a coupling disk and an electrical contact probe. The inside of the lower bellows is directly connected to the fuel-element gas space. The inside of the upper bellows is connected to a reference-gas supply. Reference-gas pressure is read directly from a gauge and from a millivolt recorder via a strain-gauge transducer. The transducer controls the reference-gas pressure to the point where it equals the fission-gas pressure. Figure 2.11-9 is a block diagram of the pressure transducer; a typical capsule with a pressure transducer was shown in Figure 2.11-8. Reference-gas pressure is controlled by a solenoid valve.

This valve admits the gas (argon) from a high-pressure source (a separate bottle supply regulated to 100 psig) into the pressure transducer. The solenoid valve (Hoke, model 590A320C, with a 1/32-in. body orifice) is controlled by the resistance between the transducer electrical probe and the bellows coupling disk. The transducer has a resolution of ±1/4 psig and an overall accuracy of±8 psig over the full 0-350-psig range of the instrument.

6.1.3 Flowmeter

Volume II, Pages 2.11-27) The flowmeter is a sealed unit that fits into the subassembly hexagonal can between the lower adapter and the capsule bundle. The magnetic field is provided by two Alnico 5 magnets operating in parallel with a total flux of 740 gauss at room temperature. The electrical leads for the flowmeter are routed through alumina-insulated, stainless-steel-sheathed cable. This cable passes through the capsule bundle via a conduit tube that replaces one capsule. The sheathed cable is welded into the top of the flowmeter. The sheathed leads are connected to Type 304 stainless steel conductors that are welded to the flowmeter electrodes. The Type 304 stainless steel wire and electrodes are used to minimize thermoelectric and thermal-expansion effects that could be encountered if dissimilar metals were used. The flowmeter has a sensitivity of 0.325 mV/gpm at 800°F, or about 10.5 mV output at a flow rate of 32 gpm. The unit is flow-tested in sodium before installation in the subassembly.

Volume II, Pages 2.12-17: The total sodium flow from the subassembly through the FPTF is measured by eddy-current flowmeters. Two flowmeters are provided to ensure continued monitoring of subassembly flow if one flowmeter fails. The flowmeters and flowmeter electronics for the FPTF are essentially identical to the flowmeters and electronics used for the BFTF (Breached Fuel Test Facility). The flowmeters and electronic package were obtained from Kaman Science Corp. The flowmeter were calibrated in an existing sodium loop at ANL-East. Some modification of the loop and a special test section were required before the calibration runs were made. This test loop provided a wider range of flow and a greater degree of calibration accuracy than the test loop used for BFTF calibration. A weigh tank was used to calibrate the flowmeter.

6.1.4 Flux-monitor Tube

Volume II, Pages 2.11-27) A sealed tube is provided to allow the insertion of a small diameter flux monitor (see Figure 2.11-11). This tube extends from the terminal box, through the extension tube, and into the subassembly, where it terminates at the capsule support gird. The tube has a 3/16-in. OD and a 0.016-in. wall thickness. The bottom of the tube is sealed by a plug, and the top is connected to a ball valve in the terminal box. The valve extends through the terminal-box wall and is capped. It is operated by a sealed stem that passes through the terminal-box wall. The flux-monitor tube is filled with argon. A subminiature, 0.063-in.-OD, sodium-wire, self-powered neutron detector (Reuter Stokes Model RSN-202-MI) is inserted in the tube. The flux-monitor leads are sealed to the top of the monitor-tube valve by a packing gland that replaces the cap.

6.2 Volume II, Chapter 3

6.2.1 Flowmeter

Volume II, Pages 3.2-2) Three methods of flow measurement are used in the EBR-II primary system. The first method uses Gentile tubes, manufactured by the Hammel Dahl/Foster Engineering Division of General Controls Company; the second method uses permanent-magnet flowmeters, manufactured by the Mine Safety Appliance Company. The third method uses microprocessor-controlled ultrasonic flowmeters built by the EBR-II and Electronics Division of ANL. Additional information on Flow

Measurement System may be found in Volume II, Chapter 6, (Instrumentation). The Gentile tubes are a shortened variation of a venturi flow tube, with fluid impact heads positioned around the inside diameter of the venturi. Half of the impact heads face upstream; the order half face downstream. The differential pressure between the two sets of impact heads is used to measure fluid flow rate. The fluid flow is measured by applying the pressure from the impact heads to a NaK-filled differential-pressure transducer.

Volume II, Pages 3.2-4) The operation of magnetic flowmeters is based on the fact that an electrical current is produced when an electrical conductor is moved within a magnetic field. The EBR-II flowmeters use the liquid sodium itself as a conductor; the magnetic field is provided by a permanent magnet that is positioned around the pipe containing the sodium. Flowing through the pipe, the sodium cuts the magnetic lines of force; as a result, a D.C voltage appears on the pipe walls at right to the magnetic poles. This voltage is directly proportional to the velocity of the sodium. A pair of electrodes is welded to the pipe walls at right angles to the magnetic field.

Volume II, Pages 3.2-5a: Ultrasonic-flowmeter operation is based on the fact that the velocity of an ultrasonic wave is related to the media in which it travels. Therefore, if two ultrasonic transducers are fixed in a flowing fluid, the apparent velocity of an ultrasonic pulse between them is the vector sum of the ultrasonic velocity relative to the fluid, and the fluid velocity relative to the transducers. Because the shape and size of the piping system is known, this information can easily be converted to system flow. These flowmeters have been used commercially in many forms.

6.2.2 Pressure Transducer

Volume II, Pages 3.2-1: NaK-filled pressure transducers are used to measure the various pressures in the primary system. This type of pressure sensing device consists of a stainless steel diaphragm unit that has one side of the diaphragm exposed to the pressure that is to be measured. The other side of the diaphragm has a capillary tube completely filled with NaK connected to it. The opposite end of the capillary tube is connected to a small bellows. The bellows has one end solidly anchored, with the movable end connected to an electrical strain-gauge transducer. As sodium pressure is applied to the sodium-side of the diaphragm unit, the diaphragm flexes slightly. As the diaphragm flexes, a small amount of NaK is forced through the capillary tube into the bellows. The bellows applies the force from the NaK flow to the electrical strain gauge, which changes resistance in proportion to the original sodium pressure. This electrical resistance is translated into a pressure reading on the Control-Panel instruments. Additional information on the Pressure Transducer Systems can be found in Volume II, Chapter 6, (Instrumentation).

6.2.3 Level Indicator

Volume II, Pages: 3.2-6) Sodium level in the primary tank is measured by two methods. The first method uses a NaK-filled differential-pressure indicator at the bottom of the tank. The high-pressure side of the indicator is open to the sodium the low-pressure side is piped to the blanket gas space above the sodium surface. Sodium pressure at the tank bottom is directly proportional to the depth of sodium above the differential pressure cell. This system has proven reliable, but has a major disadvantage; the system cannot be zeroed for recalibration after the primary tank has been filled. Additional information on Level Measurement System may be found in Volume II, Chapter 6, (Instrumentation).

Volume II, Pages: 3.2-6: The second method of level indication uses electrical probes of various lengths that extend through the primary tank cover into the tank. Each probe is a stainless steel tube with a heavy copper conductor inside. The conductor is insulated from the tube except at the tip, where the tube and conductor are connected (the copper conductor is completely enclosed and is not exposed to sodium). The probes are of different lengths with each probe connected to an individual Wheatstone bridge circuit.

The bridge circuits are balanced while the probes are not in equals the sum of the resistances of the stainless tube and copper conductor. As the sodium level rises in the tank and strikes a probe the resistance of the stainless tube (which is considerably higher than the copper conductor) decreases and unbalances the bridge circuit that closes a relay and lights an indicator.

6.3 Volume II, Chapter 6

6.3.1 Fission Counter

Volume II, Pages: 6.4-1: The nuclear instrumentation system monitors the EBR-II reactor power by measuring the intensity of neutron flux during all modes of reactor operation including shutdown maintenance, fuel handling, reactor startup, approach to power, and full power operation. It converts the detected neutron flux into informational displays, and, is an emergency or unsafe flux condition, opens trip contacts in the plant protection system for the safe shutdown of the reactor.

Originally eleven nuclear instrument channels were provided to monitor the large range of neutron flux. Channels 1, 2 and 3, startup channels, monitored neutron source flux levels; channel 4, 5, and 6, monitored intermediate power range; channels 9, 10, and 11, power level channels, monitored high neutron flux levels; and channels 7 and 7a, linear level channels, monitored neutron flux in approximately the same rages as the intermediate and high power level channels. Detectors for the eleven channels were housed in the eight air cooled thimbles located around the cylindrical portion of the reactor within the neutron shield at the approximate centerline of the reactor core.

Under Plant Modification No. 753, startup channels 1, 2 and 3, intermediate channel 4, 5, and 6, and power level channels 9, 10, and 11 were replaced with a wide-range nuclear instrumentation system consisting of three identical, redundant, and independent wide-range channels, each of which covers the 10 decades of neutron flux range of the EBR-II. Each wide range channel has three circuits that measure a different neutron flux range. The three measuring circuits are: log count rage (LCR) which covers a range of 1 count per second (cps) to 2×10^5 cps; average magnitude squared (AMS) which covers a range of 2×10^4 nv to 2×10^{10} nv; and linear power level (dc current range) which covers a range of 0 to 125% power. Also, the LCR and AMS signals are summed to provide a signal that covers 10 decades of neutron flux from 2 nv to 2×10^{10} nv.

Volume II, Pages: 6.4-2) Channels 7 and 7a have not been changed. These linear level channels cover a range of about 50 w to 110 Mw. Figure 6.4-1 shows the range of all nuclear instrumentation circuits.

P.6.4-2: Detectors for the three wide-range channels and for channels 7 and 7a are located in three "J" thimbles (J-1, J-3 and J-4). Design of the thimbles and thimble cooling is discussed in Volume II, Chapter 7.

Volume II, Pages: 6.4-2) The three wide-range channel guarded fission chamber detector assemblies, which have an overall length less than 20 in. and an O.D. of less than 4 in., are located in the "J" thimbles: Channel A in J-1, B in J-3, and C in J-4. The fission chambers are mounted at an elevation that provides ~1×1010 nv of detected neutrons at 62.5 MW(t). The detector output signal and the high voltage input are routed through separate shielded 35 ft. long coaxial cable in a ½ in. conduit to the respective preamplifier.

Volume II, Pages: 6.4-2) Figure 6.4-3 is a graph of normalized neutron flux and gamma flux in the J-2 thimble at 62.5 MW(t). The other "J" thimbles have similar characteristics.

6.3.2 Thermocouples

Volume II, Pages: 6.9-1) Temperature conditions in the EBR-II primary system are monitored by an extensive network of thermocouples and resistance thermometers. The majority of these temperature sensors are thermocouples because of the lower cost and ease of installation of these units, compared to resistance thermometers. Resistance thermometers are installed in areas where greater accuracy in temperature measurement is desired, and it exceed the one than can be obtained using thermocouples.

In addition to the thermocouples and resistance thermometers, a small number of locally indicating temperature gages are installed on some primary sodium auxiliary systems.

Temperature sensors are installed on all of the important components in the primary system, with the exception of the reactor core and blanket subassemblies. It was not possible to install thermocouples on these subassemblies because of the design of the fuel handling system. Some indication of temperature conditions within these subassemblies is obtained by monitoring coolant outlet temperatures from certain subassemblies in the reactor. This is accomplished by mounting thermocouples on some of the subassembly holddown rods that extend downward from the underside of the reactor vessel cover. These temperature sensors are directly in the path of the outlet coolant stream from the selected subassemblies. All other components in the primary system contain temperature sensors. Considerable redundancy is employed in areas that become permanently radioactive after the start of reactor power operation. This redundancy assures the continued availability of temperature monitoring for all components even in the event of the loss of a few temperature sensors.

Volume II, Pages: 6.9-2) All of the thermocouples in the primary system and its auxiliary systems, are of the chromel-alumel type with K calibration, with the exception of those in the rotating plug freeze seals. These are iron-constantan thermocouples. Several types of thermocouple assemblies and assembly mountings are provided to satisfy the differing requirements of the various systems. A large number of thermocouples are required to operate in a high temperature and an intensely radioactive environment. Other thermocouples are installed in areas of low temperature and in non-radioactive environments. Both standard and special thermocouple assembly designs are provided to meet these requirements.

Volume II, Pages: 6.9-4) A standard type of thermocouple assembly is provided for monitoring temperatures on the outside surfaces of pipes and vessels in the primary and auxiliary systems. These thermocouples are supplied by Leeds & Northrup and are shown in drawing No. B-875-452. A sketch of this type of assembly is shown in Figure 6.9-2. The unit is a spring loaded type with 20 gauge chromel alumel wires electrically insulated with fiberglass. The assembly is a Conax type, catalog no. SL-360-CA. The leads and fiberglass insulation, from the thermocouple assembly to the terminal head, is protected by a polyethylene sleeve.

Volume II, Pages: 6.9-4) The thermocouple assembly mounting consists of a 4-1/2 inch long, ¼ inch diameter schedule 80 pipe nipple which is welded to the surface of a pipe or vessel. The thermocouple assembly is inserted into this pipe and screwed into the top of the mounting. The bottom tip, or hot junction, of the thermocouple is held in close contact with the surface of the sodium pipe by means of the spring in the assembly.

Volume II, Pages: 6.9-4) A number of thermocouples are mounted in thermowells, which extend into the fluid inside a pipe or vessel. The configuration of a thermocouple assembly of this type is shown in Figure 6.9-4, and is Leeds & Northrup drawing No. B-8750456. A thermowell used in this type of application is shown in Figure 6.9-5.

Volume II, Pages: 6.9-4) The thermocouple assembly consists of 2 chromel and 2 alumel, 20 gage wires passing through Mgo electrical insulation, from the hot junctions to the terminal head. These 4 wires form two separate thermocouples which provide redundancy in a single thermocouple assembly.

Volume II, Pages: 6.9-8) Two special thermocouples, which are designed for use in high temperatures and in high radiation environments, are shown in Figure 6.9-8. They are supplied by Leeds & Northrup Co. and are shown in their drawing A-875-457. These thermocouples consists of 22 gage chromel, alumel wires which are either twisted and welded at the hot junction, or are butt welded.

Volume II, Pages: 6.9-8) The electrical insulation consists of a double wrap of fiberglass over each individual conductor and a single wrap of fiberglass over the pair of conductors. This insulation is covered by a 304 stainless steel braid wrapping.

Volume II, Pages: 6.9-8) These thermocouples are used on several components inside the primary tank. They are used to measure temperatures of the bulk sodium, of the nuclear instrument thimbles, of the coolant out of certain core and blanket subassemblies, and in several other applications.

Volume II, Pages: 6.9-25) Thermocouples in six of the eight instrument thimbles monitor air and structure temperatures in the J-1, J-3, J-4, 0-2, 0-3, and 0-4 thimbles. The thermocouples were removed from the J-2 and 0-1 thimbles when they were modified to become the Nuclear Instrument Test Facility. (Refer to Volume II, Chapter 7, for information concerning the NITF.) The thermocouples, located near the neutron detectors, are of the radiation- and temperature-resistant type.

Volume II, Pages: 6.9-25) Three thermocouples in each of the six thimbles provide outputs to the DAS, alarm, and a recorder. Four additional thermocouples monitor outlet air temperatures in the thimble exhaust ducts. All of thermocouples within the instrument thimbles are Type K (chromel-alumel) and pass out of the primary tank through disconnect plugs at the top of each thimble. All the thermocouple leads from the hot junction to the cold junction are chromel-alumel. However, all leads from the cold junction to the recorders, annunciator functions, etc., are copper.

Volume II, Pages: 6.9-29) The locations of the various thermocouples on the reactor vessel, and at the outlets of selected reactor subassemblies are shown in Figure 6.3-5.

Volume II, Pages: 6.9-29) All these thermocouples are of the high temperature and radiation resistant type, shown in Figure 6.9-8, since they are located in the immediate vicinity of the reactor.

Volume II, Pages: 6.9-29) Three different thermocouple systems are shown in Figure 6.3-5. They are the 503, the 1534 and the 540 series thermocouples. The 503 series thermocouples measure coolant temperatures at the outlet of a number of subassemblies in the reactor. The 1534 series measure coolant outlet temperatures from the reactor upper plenum. The 540 series monitor coolant temperatures in the high and low-pressure reactor plenum. The 503 series thermocouples are installed on the underside of the reactor vessel cover and are contained in 304 stainless steel sleeves. These thermocouples are fastened to the subassembly holddown “fingers” which extend downward from the bottom of the cover. The sleeves are located as close as possible to the outlets from certain core and blanket subassemblies. The chromel-alumel leads from the hot junction pass upward through the reactor cover, through the two cover lifting columns to junction boxes at the top of each lifting column. The outputs from these thermocouples are distributed to a recorder, and to the reactor scram circuit.

Volume II, Pages: 6.9-31) Two thermocouples are located on the outlet coolant pipe from the reactor vessel. These are shown as items 1 and 2 in Figure 6.3-5 and are identified in the legend as numbers R1-TC-1534-CG and R1-TC-1534-CF.

Volume II, Pages: 6.9-31) Thermocouple R1-TC-1534-CF is part of a circuit that measures the reactor coolant temperature difference. It provides the reactor coolant outlet temperature data to this circuit, which is described later in paragraph 6.9.3.6. Line diagrams for this circuit are shown in H. K. Ferguson drawing P-461-M.

Volume II, Pages: 6.9-31A) Thermocouple R1-TC-507BK is used to sense the outlet coolant temperature from the reactor. It is mounted on the coolant inlet plenum to the intermediate heat exchanger. At position 3 of Figure 6.3-11 this thermocouples is connected to a cold junction. Output from the cold junction is transmitted via a rotary switch to a Leeds & Northrup, M Line, millivolt-to-current converter. This type of circuit is described in paragraph 6.9.2.3.1. A block diagram of the circuit is shown in Figure 6.11-4 and a line diagram is given on H. K. Ferguson drawing P-461-S.

Volume II, Pages: 6.9-32) The 540 series thermocouples, shown in Figure 6.3-5, monitor coolant temperature in the high and low pressure plenum chambers beneath the reactor. They are used to monitor bulk sodium temperatures for input to the reactor safety shutdown circuit. The four thermocouples in this circuit are listed in Table 6.9-4.

Volume II, Pages: 6.9-32) The locations of some additional thermocouples on the reactor vessel and on the neutron shield are shown in Figure 6.3-6. All these sensors are of the temperature and radiation resistant type as shown in Figure 6.9-8. None of these thermocouples provide a scram or alarm function. Two thermocouples series are represented in Figure 6.3-6. The 507 series and the 540 series. The 507 series are read out on instrument No. P1-TIA-507, which is a Leeds & Northrup, Speedomax G, Model D, 60,000 series recorder. It is located on the Primary Section Panel in the Control Room.

Volume II, Pages: 6.9-34) A number of thermocouples are installed on the primary coolant pump M-1 and M-2. The locations of these are shown in the instrument sensor drawing, Figures 6.3-7 and 6.3-8. A total of five thermocouples are installed on the drive motor of each pump to monitor temperatures. These thermocouples have no identifiable numbers and are read out on the control panel for each pump, in the power plant corridor panels.

Volume II, Pages: 6.9-34) The remaining thermocouples are located below the bulk sodium in the primary tank.

Volume II, Pages: 6.9-35) All of the other thermocouples in the figure have the 540 series designation and are read out on instrument No. R1-T1-540, which is located in Instrument Center No. 1 in the Reactor Containment Building. This instrument is a Leeds & Northrup Speedomax G, Model D, 60,000 Series indicator.

Volume II, Pages: 6.9-36) Thermocouples R1-TC-540-H, K, M, N, and P, listed in Tables 6.9-7 and 6.9-8 are used to determine average bulk sodium temperature. Thermocouples R1-TC-1534-CF, which is described in paragraph 6.9.3.4.2, is used to determine the coolant outlet temperature form the reactor upper plenum. Figure 6.9-13 is a block diagram of these circuits showing the various components and readouts. In this diagram, signals from the bulk sodium average temperature circuit are combined with signals from thermocouple R1-TC-1534-CF, to produce a reactor coolant temperature rise signal.

Volume II, Pages: 6.9-38) The reactor outlet coolant temperature is detected by thermocouple R1-TC-1534-CF, which is connected to a solid-state reference junction. The junction is connected to a Leeds & Northrup, M-Line, Model 1990 millivolt-to-current converter located in Instrument Center No. 2 in the reactor building.

Volume II, Pages: 6.9-39) The temperature of the bulk sodium inside the primary tank is monitored by a number of thermocouples installed at various elevations and circumferential positions inside the tank wall. Figure 6.9-8 shows a typical thermocouple of this type.

Volume II, Pages: 6.9-39) Bulk sodium thermocouples are contained inside 5/16 inch diameter 304 stainless steel tubing which is attached to the inside wall of the primary tank. At the hot junction end of the tubing, the tube is bent 90°, and the tip extends approximately six inches into the bulk sodium from the tank wall.

Volume II, Pages: 6.9-40) Thermocouple R1-TC-530 is used as a temperature compensation sensor for the differential pressure type of primary tank bulk sodium level indicator. This thermocouple has no readout or scram function and it is described in the section on liquid level measurement as part of the primary tank bulk sodium level measurement description.

Volume II, Pages: 6.9-41) The location of thermocouples on the walls and cover of the primary tank are shown in Figure 6.3-10. These thermocouples are designed to permit monitoring of the primary tank to detect temperature distributions inside the tank. Even more important is monitoring of temperatures in the primary tank cover. Uneven temperature distributions in the cover could cause distortion in the cover and possible misalignment of sliding or rotating mechanisms passing into the primary tank.

Volume II, Pages: 6.9-41) All of the temperature sensors shown in Figure 6.3-10 are of the temperature and radiation resistant type shown in Figure 6.9-8. None of the thermocouples in the figure have a scram or alarm function and all are read out on recorders. Four readout instruments record data from the thermocouples in Figure 6.3-10. They are P1-TIA-507, which is a Leeds & Northrup Speedomax G, Model D, 60,000 series indicator. It is located in the Primary Section Panel in the Control Room.

Volume II, Pages: 6.9-44) All thermocouples in the primary heat exchanger are of the temperature and radiation resistant type shown in Figure 6.9-8. None of these sensors has an alarm or scram function.

Volume II, Pages: 6.9-44) Table 6.9-14 lists the thermocouples which are read out on indicator P1-TIA-507. The line diagram for these thermocouple systems are given on H. K. Ferguson drawing P-461-W.

6.3.3 Pressure Measurement System

Volume II, Pages: 6.10-1) Pressures in the primary and auxiliary systems are monitored by a number of different types of pressure measuring systems. The fluids being monitored by these systems are liquid sodium, liquid NaK, silicone oil, argon gas, and air. Specially designed sensors are required to monitor sodium and NaK pressures, while more conventional equipment is used in contact with silicone and gases.

Volume II, Pages: 6.10-1) Pressure measurement systems are provided to monitor the following pressure conditions: (1) pressure differential between the inside and outside of the reactor containment building (2) pressures and differential pressures in the reactor vessel (3) primary pump pressures (4) primary sodium purification systems, and (5) pressures within the argon gas supply system. All of the above systems have remote readouts and some provide input to alarm circuits and the reactor scram circuit.

Volume II, Pages: 6.10-1) A differential pressure measuring system is provided to monitor the difference in pressure between the inside and outside of the reactor containment building. The location of these pressure sensors are shown as items 18 and 19 of Figure 6.3-4. Two separate differential pressure transmitters are provided as sensing elements in this system. They are Differential Pressure Transmitters Type 154W, manufactured by the Microsen Electronic Control Division of Manning, Maxwell, & Moore Inc. The specification for the instrument are given in section 6.16 (6.10.2) of the paragraph 6.16.

Volume II, Pages: 6.10-1) Pressure lines for the sensing instruments are attached to each side of the isolation valve shown in Figure 6.3-4. This pressure differential is sensed at the transmitters and electrical signals are distributed to a recorder and annunciators. The two transmitters are numbered R13-dPT641A and … (To P.6.10-2)

Volume II, Pages: 6.10-2) (from P.6.10-1) … R13-dPT641B. They provide signals to the recorder which is located on the Space Heating and Cooling System Panel in the Power Plant Corridor. The recorder is a Taylor Transcope Electronic Recorder, Model 701J. Specifications for this unit are given in section 6.16 (6.9.4.3) of paragraph 6.16.

Volume II, Pages: 6.10-2) A total of ten pressure sensors are installed on the reactor vessel. These sensors provide data on pressure drop across the core and the values of pressure at various positions within the reactor vessel. The locations of these sensors are shown in Figure 6.3-5. Data are provided for a recorder and the Reactor Scram Circuit.

Volume II, Pages: 6.10-3) The sensing element for all theses pressure systems is a NaK filled volumetric pressure unit, manufactured by the Taylor Instrument Co. A sketch of the element is shown in Figure 6.10-2.

Volume II, Pages: 6.10-4) The pressure transmitters used in these systems are Taylor Transet Transducers, Model 750T, manufactured by the Taylor Instrument Co. The specifications of this transmitter and the NaK filled sensing element are given in section 6.16 (6.10.3.1) of paragraph 6.16.

Volume II, Pages: 6.10-8) All these pressure sensors except R1-PT-520A have failed and are no longer read out. This operating sensor is combined with R1-PT-522A to produce a value of pressure difference across the reactor, as described in paragraph 6.10.4. The output from R1-PT-520A is read out on a recorder on the primary-system panel in the control room. It is a 2-pen Leeds & Northrup Speedomax M recorder. Specification of this type of recorder are given in section 6.16 (6.5.3.8) of paragraph 6.16. Line diagrams for these pressure systems are shown on H. K. Ferguson drawing No. P-461-P

Volume II, Pages: 6.10-8) Three pressure sensors are installed on primary-sodium pump No. 1, and four on pump No. 2. Primary pump No. 1 contains sensors R1-PT-522-A, P1-PT-522-B, and R1-PT-522-P. These are items 9, 10, and 11, respectively, of Figure 6.3-7. Only sensor R1-PT-522-A is still operational. Pressure sensors R1-PT-522-H, R1-PT-522-G, R1-PT-522-Q, and R1-PT-522-HX are installed on primary pump No. 2. These are items 31, 32, 33 and 43, respectively, of Figure 6.3-8. (Sensor R1-PT-522-HX was installed under ECN 420 and 422.) Only R1-PT-522-H and R1-PT-522-HX are still operational. Sensor R1-PT-522-A is combined in a special circuit with R1-PT-520-A to measure the pressure drop through the reactor. This circuit is shown in Figure 6.10-4.

Volume II, Pages: 6.10-8) The pressure sensors, transmitters, and power supplies are of the same type as shown in Figures 6.10-2 and 6.10-3, and are described in paragraph 6.10.3. The power supplies for the transmitters are Transpac Model TR10/IT, and are located in Instrument Center No. 2 inside the reactor containment building. The transmitters for all the pressure sensors except R1-PT-522-A, R1-PT-522-H, and R1-PT-522-HX are in cabinet No. 7 of that instrument center. The transmitter for R1-PT-522-A is mounted under the reactor deck plates near primary pump No. 1; the transmitters for the other two sensors are mounted together under the reactor deck plates near primary pump No. 2. Each transmitter is connected to a Leeds & Northrup M-Line millivolt-to-current converter. This converter is described in paragraph 6.9.2.3.1. Output from the converter for R1-PT-520-A is transmitted to a Rochester Model ET-215 electronic trip unit. This unit is described in paragraph 6.4.6.5.1. The trip unit is connected to a relay in the reactor scram circuit.

Volume II, Pages: 6.10-10) Pressure sensors R1-PT-522-H and R1-PT-522-HX are located above the ball joint assembly in the piping of primary pump No. 2. The pressure-sensing heads, the transmitters, and the power supplies are all of the same type as those described in paragraph 6.10.3. The transmitters are connected to Leeds & Northrup M-Line millivolt-to-current converters, described in paragraph 6.9.2.3.1. Output from the converter is transmitted to an indicator on the primary-system panel in the control room. No alarm or reactor scram function is associated with this circuit. The output from both R1-PT-522-A and R1-PT-522-H are read out on a Honeywell Electronic Electronik 17 2-pen recorder on the nuclear panel in the control room. Line diagrams for these pressure systems are presented in H. K. Ferguson drawing No. P-461-Z. The output from R1-PT-522-Hx is displayed by the digital data acquisition system (DAS) only.

Volume II, Pages: 6.10-10) The primary sodium purification system contains a number of direct-pressure and differential-pressure measuring instrument systems. The purification system was recently modified, and additional pressure measuring instrumentation was added to the original instrument systems. The locations of all pressure sensors are shown in Figure 6.3-21.

P. Volume II, Pages: 6.10-12) Two differential pressure measuring sensors, R1-dPT-548-B and G, are installed in the primary sodium purification system. A sketch of a typical sensor is shown in Figure 6.10-5, and a schematic of the differential pressure measuring system is shown in Figure 6.10-6.

Volume II, Pages: 6.10-12) This instrument is designed to measure differential pressure on processes having operating temperatures up to 1200°F. The system consists of an electrical output transmitting section which is remote from the process, and diaphragm seal elements which are in contact with the liquid sodium. The diaphragm seals are connected to the transmitting section by means of two capillary tubes. The entire system is solid filled with NaK (78% potassium, 22% sodium eutectic). The diaphragm seals contact the sodium at the high and low pressure taps of the process piping. Pressures developed at the seals are transmitted by means of the NaK fluid to the transmitter section of the unit. Output of the instrument is linearly proportional to the pressure difference existing between the process pressure taps.

Volume II, Pages: 6.10-16) Pressure transmitter R1-PT-523-A is mounted on primary tank nozzle plug “N-1”. It is designed to measure the pressure of the argon gas blanket inside the primary tank. This transmitter is a Leeds & Northrup, Model 1912, Differential Pressure Transmitter, and specifications for the unit are presented in section 6.16 (6.10.6.1) of paragraph 6.16. A block diagram of the circuit is shown in Figure 6.10-1. Output from the transmitter is distributed to two pressure indicators and to the alarm annunciator.

Volume II, Pages: 6.10-16) A pressure transmitter is installed on the outlet gas line from the two argon gas blowers that supply gas to the floating head tank. This transmitter is designated R6-PT-523-B, and is located at position 21 of Figure 6.3-23. It is a Manning, Maxwell, and Moore, Microsen Type 145 pressure transmitter. Specifications for this unit are presented in section 6.16 (6.10.6.2) of paragraph 6.16.

Volume II, Pages: 6.10-17) Two additional pressure measuring systems are installed on the argon gas supply system. The pressure transmitters are designated R6-PT-544-A, and R6-PT-544-B, and they are located at positions 20 and 22, respectively, in Figure 6.3-23. Both of these transmitters are Manning, Maxwell, and Moore, Microsen, Type 145 pressure transmitters. Specifications for these units are presented in section 6.16 (6.10.6.2) of paragraph 6.16.

Volume II, Pages: 6.10-22) Two pressure transmitters which measure pressure in the reactor upper plenum are located in the reactor-vessel instrument probe (refer to Section 6.15.11 for a description of that probe). One of these transmitters, PT-512A, feeds an instrument channel which provides a low-flow trip in the reactor shutdown circuit. Figure 6.10-7 is a block diagram of this instrument channel.

Volume II, Pages: 6.10-22) The pressure sensor, manufactured by Barton Instruments, consists of a sodium-filled line connected to one side of a differential pressure bellows. The bellows transmits the pressure signal (0-10psi) to a NaK-filled line that connects to the differential-pressure bellows in the transmitter case. The transmitter is a Barton Model 368. The Differential pressure bellows is connected to a strain gauge in the transmitter that converts the 0-10 psi pressure signal to an electrical output. The transmitter produces a 4-20 mA output signal proportional to the input pressure. The other side of the differential pressure bellows is open to building pressure and is used for calibration by drawing a vacuum on the line. Having one leg open to the reactor building does not vary the pressure signal, since the pressure of the argon cover gas in the primary tank is held constant with respect to the reactor building by floating-head-tank pressure control.

6.3.4 Flowmeter

Volume II, Pages: 6.11-1) The flow of liquid metals is measured by magnetic flowmeters, flow tubes and ultrasonic flowmeters. The flow tubes were installed on piping in series with magnetic flowmeters in many cases. This was done for the purpose of calibrating the magnetic flowmeters after installation in the coolant system. It is possible for permanent-magnet flowmeters to have a linear output, and they are capable of a range of 100 to 1. However, at the time these units were designed, the state-of-the-art required that they be calibrated in place in the piping system if acceptable accuracy was to be obtained. Differential-head-producing meters, such as flow tubes, have good accuracy but have a range of only about 10 to 1. This is insufficient to cover the desire range of coolant flow in most liquid-metal systems. Therefore, the decision was made to install both types of flow sensors in most liquid metal piping systems where flow measurement is necessary. In this arrangement, the magnetic-flowmeter systems are assigned the main flow measurement task, and the differential-head-producing flow tubes are assigned the task of calibrating the magnetic flowmeters. This combination permitted measurement of sodium flow rate within ±5% of actual values, over the entire range of flow.

Volume II, Pages: 6.11-1) Under Plant Modification No. 5099, one of the differential head flow elements, FE-541E, has been completely instrumented and is in continuous use. This instrument channel (FT-541E) measures total primary reactor flow and is described in paragraph 6.11.3.

Volume II, Pages: 6.11-4) A large magnetic flowmeter is installed in the piping leading from each of the primary sodium pump to the reactor high pressure plenum. These flowmeters are identical and are designated R1-FM-512A and R1-FM-512B. (See item 15, Figure 6.3-7 and item 37, Figure 6.3-8.) Flowmeter R1-FM-512A failed and is no longer read out. The other flowmeter is still operational. Specifications for the flowmeters are given in section 6.16. Some of the details of this type of unit are shown in Figure 6.11.1. These flowmeters were manufactured by the Mine Safety Appliance Research Corporation, their drawing No. 500725.

Volume II, Pages) 6.11-12: A small magnetic flowmeter is installed in the low pressure piping of the No. 2 primary sodium pump. The flowmeter is designated R1-FM-513-B. It is a 4 inch submersible flowmeter manufactured by Mine Safety Appliances (MSA) Research Corporation. Details of the flowmeter are shown on MSA drawing No. 500727, and specifications are given in section 6.16 (6.11.2.3) of paragraph 6.16. Figure 6.11-1 shows a sketch of some of the details of this type of flowmeter. Originally a second flowmeter (FM-513A) was installed in the low pressure plenum of primary pump No. 2 but it failed and was removed from the reactor shutdown system by passing its relay contacts in shutdown strings A and B. This was accomplished under Plant Modification No. 5239.

Volume II, Pages) 6.11-14: A magnetic flowmeter is installed on each of the primary tank shutdown coolers to measure the flow of NaK in these systems. The flowmeters are designated R4-FM-518-A and R4-FM-518-B and are shown as items 27 and 29, respectively, of Figure 6.3-18. They were manufactured by Mine Safety Appliance Research Corporation, and the details of the units are shown in drawing No. 500730. Specifications for the flowmeters are given in section 6.16 (6.11.2.4) of paragraph 6.16.

Volume II, Pages) 6.11-16: Two flowmeters are installed in the primary sodium purification system piping to measure the flow of sodium in the system. They are designated R1-FM-515-A and R1-FM-515-B, and their locations are shown in Figure 6.3-21. A sketch of this type of flowmeter is shown in Figure 6.11-8. These units are manufactured by Mine Safety Appliance Research Corporation and their dimensions are shown in MSA drawing No. 500729. Specifications for these flowmeters are given in section 6.16 (6.11.2.5) of paragraph 6.16.

Volume II, Pages) 6.11-18: Five small magnetic flowmeters are installed on the sampling and plugging loops of the primary sodium purification system. These are designated R1-FM-709, and R1-FM-710 on the plugging loop and three flowmeters, R1-FM-706, R1-FM-707 and R1-FM-708 on the sodium sampling loop.

Volume II, Pages) 6.11-19: Flowmeter R1-FM-710 measures the total flow through the plugging loop. It is read out on an indicator which is also on instrument center No. 3.

Volume II, Pages) 6.11-19: Flowmeters R1-FM-706 and R1-FM-708 measure the inlet and outlet flows from the sodium sampling loop. They are read out on indicators mounted on the sodium sampling and heater control panel in the basement of the reactor containment building. This panel is located at position 10 of Figure 6.2-58.

Volume II, Pages) 6.11-19: Flowmeter R1-FM-707 measures the bypass flow in the sodium sampling system. It is read out on an indicator at position 31 of Figure 6.9-30.

Volume II, Pages) 6.11-19: Magnetic flowmeter R1-FM-551 measures the flow of eutectic NaK in the secondary loop of the primary sodium purification system. The location of this flowmeter is shown on the flow diagram of Figure 6.3-28. This is a pipe mounted flowmeter of the type shown in Figure 6.11-8. It is manufactured by Mine Safety Appliances Research Corporation, and the details of the unit are shown on their drawing No. 500758. Specifications for the flowmeter are given in section 6.16 (6.11.2.7) of paragraph 6.16.

Volume II, Pages) 6.11-20: The primary sodium coolant piping contains five flow tube type flowmeters. These are installed in the high and low pressure piping, and on the reactor coolant outlet piping. Flowmeters R1-FT-541-C, R1-FT-541-A and R1-FT-541-E are shown at positions 14, 17 and 20, respectively, in Figure 6.3-7. Flowmeter R1-FT-541-D and R1-FT-541-B are shown at positions 36 and 39, respectively of Figure 6.3-8. All of the flow tubes are of the "Gentile" design, and are manufactured by the Hammel-Dahl/Foster Engineering Division of the General Controls company.

Volume II, Pages) 6.11-20: A sketch of some of the details of a typical flow tube is shown in Figure 6.11-1. Fluid impact heads are positioned around the inside circumference of the tube on both sides of the venturi throat. Half of the impact heads face upstream and the other half face downstream. When sodium flows through the tube, a pressure difference develops across the throat of the tube. This pressure difference is transmitted by means of two sodium filled capillaries to a differential pressure sensing head. This head is identical to those used to detect differential pressures in primary system components, and is described in paragraph 6.10.5.2. These pressures are transmitted from the differential pressure sensing head to a differential pressure (dp) cell by means of two NaK filled capillaries. The dp cell actuates a Statham, Model G-1 strain gage transducer, which provides a signal to readout equipment. This transducer is described in paragraph 6.10.3.

Volume II, Pages) 6.11-20: These flow tubes were installed in the sodium coolant piping to provide a means of calibrating the magnetic flowmeters after their installation in the piping. A listing of these flow tubes, their location, and General Controls Co. drawing No. which show construction details, is presented in Table 6.11-1.

Volume II, Pages) 6.11-27: Under Plant Modification 5252, ultrasonic flow-measurement systems were added to the two low-pressure-plenum throttle valves (see Figure 6.11-16). The flowmeter systems were installed to partially restore some of the flow-measurement capabilities that were lost by failure of six of the original primary system flowmeters. Three of the Gentile-tube and three magnetic-type flowmeters had failed. These failures left the flow system of primary pump No. 1 without a functioning flowmeter.

6.3.5 Level Measurement System

Volume II, Pages: 6.12-1) Two sodium-level detectors were installed originally in the primary tank before it was filled with sodium. One was a spiral-resistance type probe, which was used for indication only. The other was a device based on measurement of static pressure head, but which incorporated a temperature sensor, or compensator, so that the device would indicate level changes resulting only from temperature changes. (With a constant sodium inventory in the primary tank, the static pressure head remains constant at different temperatures.) The latter device was used for indication and alarm.

Volume II, Pages: 6.12-1) The resistance probe worked only intermittently after it was first installed. Several problems are associated with its operation. Level is displayed in stepwise increments of several inches and is denoted by a series of lights, the number illuminated depending on the level sensed. Each level-indicating light is actuated by a relay that responds to the unbalancing of a bridge circuit, when sodium contacts the lower end of one of a series of probes placed at different levels. Because the resistance involved is small, the current must be relatively high to produce a usable unbalance voltage. Some of the more common problems have been: (1) The power supplies have been high-maintenance units, with filter and transformer failures causing the most frequent breakdowns; (2) the relays are sensitive to variations in supply voltage, are difficult to get, and are subject to drift of the settings with temperature; and (3) the probes are difficult to insulate, and breakdowns of the insulation have been frequent. Electrical problems have hampered the reliability of the unit, which is no longer operable and has not been used for several years.

Volume II, Pages: 6.12-4) The differential pressure type of level measuring sensor is still mounted in the F-2 nozzle of the primary tank cover, but it is no longer read out on any recorder or indicator.

Volume II, Pages: 6.12-4) The level sensor consists of a differential pressure sensor head identical to those described in paragraph 6.10.5.2 “Differential Pressure Measuring Systems”. A sketch of the unit installed in the primary tank is shown in Figure 6.12-3. The sensing head is located at the bottom of the primary tank, beneath the bulk sodium. The high pressure side of the sensing head is open to the bulk sodium at the bottom of the tank. The low pressure side of the head is connected to a tube which is open to the inert gas blanket above the sodium in the primary tank. NaK filled … (To P.6.12-6)

Volume II, Pages: 6.12-6) (from P.6.12-4) … capillaries extend from the sensing head to a differential pressure cell and strain gage transducer which are located above the primary tank cover. These components, and the remainder of the circuit, are similar to those in the differential pressure measuring systems.

Volume II, Pages: 6.12-6) The level sensing unit is designated R1-LT-530 and is located at position 32 of Figure 6.3-9. Thermocouple R1-TC-530 was connected to this circuit to provide compensation for changes in the temperature of the bulk sodium.

Volume II, Pages: 6.12-6) A new bulk sodium level measuring system was recently installed in the primary tank. The level sensor was designated R1-LT-530R, and it was installed in the D-1 plug of the primary tank cover. The location of the plug is shown in Figure 6.3-24, and is item 34 of Figure 6.3-9.

Volume II, Pages: 6.12-6) A sketch of the level sensor installed in the primary tank cover plug is shown in Figure 6.12-4. This plug contains an extension tube which projects below the surface of the sodium to protect the buoyancy cylinder from local movement of sodium, and to limit the exposure of the internals of the transmitter to sodium aerosol that is in the argon-gas space. Just below the shield plug, the extension tube is vented to the argon space to eliminate pressure effects as the sodium level changes in the tube.

Volume II, Pages: 6.12-12) Additional details on this system are described in ANL-7623, “System for Measuring Sodium Level in EBR-II”, By J.B. Waldo and L.J. Christensen, October 1969.

Volume II, Pages: 6.12-12) A contact probe type of level indicator is installed in each of the two shutdown cooler surge tanks. Level indication is obtained by either a shorted or an open circuit condition between a probe and electrical ground. There are also considerably fewer probes on these sensors than on the unit in the primary tank. The locations of these level sensors are shown a position 26 and 28 in Figure 6.3-18, and are designated R5-LT-529-A and R4-LT-529-B.

Volume II, Pages: 6.12-12) There are three probes on each sensor, which consist of 304 stainless steel rods extending downward from their mounting flanges into the surge tank. These rods are 1/8 inch in diameter and have lengths of 2, 6 and 10 inches for each sensor unit. A spark plug, Champion Model no. OB-30X-3, is attached to the top of each rod outside the wall of the surge tank. A sketch of a typical probe installation is shown in Figure 6.12-6. A circuit diagram of the system is also shown in the figure because no H. K Ferguson line diagram of the system was available.

7. Identification of Initial Conditions for the Available Recorded Data

The scope of Task No.3 is the identification of a suitable pattern to identify the core isotopic composition at the moment of the start of the system recording to develop a faithful thermal-hydraulic model of the EBR-II plant. This is to refine the power level measurements to reduce uncertainties in flux levels and therefore burnup. Regarding to the core isotopic composition, it was calculated for each individual assembly, certainly for each of the experiment and for individual driver subassemblies. However, in the EBR-II system design descriptions reports, the information about the core isotopic composition was not found.

A significant amount of work was done to establish thermal power from the secondary sodium system by careful measurements of flow and temperature. This then had to be corrected for heat loss from other systems such as the shutdown coolers, auxiliary systems, etc. Consequently, it was able to reduce uncertainties to somewhere in the order of 3% which was important for calculations of isotopic content. One other aspect of this is that prior to reprocessing, an assay is conducted of isotopic content of the fuel to compare with calculated values.

An important point is that the core isotopic composition had little or no effect on the plant performance and the thermal-hydraulic data that was retrieved. The outlet coolant mixes in the upper plenum and the intermediate heat exchanger so that any differences in power level among individual subassemblies is erased. In conclusion, the detailed core isotopic composition is not necessary for establishing the designated reactor power level from the core-averaged values.

In conclusion the third task was designed as an accessory task in case the isotopic composition would have affected the measure that were collected by the reactor data acquisition system. After careful analysis this seems not relevant information or at least the core loading pattern information and the assembly type information that is present in the run reports is deemed to be sufficient. The run reports have been digitized in most part in particular for the period in consideration is covered by the runs from 1985 to 1994.

8. Summary

In this report, the locations and drawings of the sensors in the EBR-II system and their library IDs such as EDMS ID and Alternate ID were summarized. The temperature, pressure, mass flow rate and fission rate in the EBR-II plant were measured and recorded by totally 931 sensors according to "ANL IFR OPERATIONS DIVISION Run Reports." which are currently available at INL Research Library (https://libhost.inel.gov/). Chromel-Alumel thermocouples and resistance thermometers were used to detect the temperature of the reactor system. Large and small magnetic flowmeters were used to measure the mass flow rate of sodium coolant. NaK filled volumetric pressure sensing element and differential pressure sensing element were used to detect the reactor pressure. Differential pressure type level transmitter and float type level transmitter were used to measure the sodium level in the primary tank. The storing location of the information of the sensors such as library IDs were also reported in the work. The information of core isotopic composition was not found in the EBR-II System Design Descriptions reports which are currently available at INL Research Library. However, it is identified that the previous work has done to establish thermal power from the secondary sodium system and is useful to develop a faithful thermal-hydraulic model of the EBR-II plant. The run reports are available at INL Research Library and the period in consideration is covered by the runs from 1969 to 1994.

9. References

1. EBR-II, 1971, EBR-II System Design Descriptions – Volume I, "General Facilities," Argonne National Laboratory, Argonne, Illinois, June 15.
2. EBR-II, 1971, EBR-II System Design Descriptions – Volume II, "Primary System," Argonne National Laboratory, Argonne, Illinois, June 15.
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