Implementation Report
Reactor Vessel Level Monitoring System
Ginna Station

Rochester Gas and Electric Corporation
89 East Avenue
Rochester, New York 14649

EWR 2799

Revision 3

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RVLMS Implementation Report

1.0 Summary Description of the RVLMS System

1.1 General

The Reactor Vessel Level Monitoring System (RVLMS) is designed to trend coolant inventory within the reactor vessel during all phases of plant operation, including post accident conditions with quasi-steady-state conditions, and during relatively slow developing transients. The system consists of two redundant differential pressure trending channels, each consisting of one transmitter per channel. The signals are processed to compensate for reference leg temperature differences, primary coolant flow and temperature, safety injection, and residual heat removal operation. In addition to local indication at each RVLMS instrument rack, each channel drives a remote indicator on the main control board which displays reactor vessel level and vessel fluid fraction. The RVLMS differential pressure sensing lines are obtained from tubing connections to the Reactor Vessel Head Vent System (EWR 2447) and one of the Reactor Incore Instrumentation Guide Tubes.

1.2 Functions

The RVLMS system is designed to provide redundant trending of reactor vessel coolant inventory to the plant operators for the purpose of assuring adequate core cooling under all plant conditions.

1.3 Modes of Operation

The RVLMS system is designed to function during shutdown, refueling, and all normal and post accident operating conditions.

2.0 Referenced Documents

2.1 Design Criteria, EWR 2799, Revision 3, 10/2/85.

2.2 Safety Analysis, EWR 2799, Revision 2, 10/15/85.

3.0 RVLMS System Description of Components

Refer to Attachment I, RVLMS Block Diagram and Attachment II, RVLMS System Elevations.

3.1 General

The RVLMS system is a Class IE system, therefore, all components of the RVLMS system are designated Seismic Category I. All RVLMS electrical hardware is seismically qualified per IEEE 344-1974, and all conduit, tubing, piping, and electrical hardware is seismically supported to withstand the effects of a safe shutdown earthquake. All electrical components, cable, and splices located in potential harsh environment areas are environmentally qualified per IEEE 323-1974.

3.2 Reactor Vessel Upper Tap, Seal Pot and Reference Leg Sensing Line

A single RVLMS differential pressure transmitter upper tap is made at the reactor head vent piping in parallel with the head vent valves. A single run of stainless steel tubing (3/8" O.D. x .065" wall) with Swagelok fittings is run from the upper tap through the refueling cavity wall to the reference leg seal pot. The tubing inside the reactor cavity is designed to be removable to permit lifting the reactor head for refueling. The tubing is welded to the stainless steel liner as it penetrates the cavity wall to maintain the integrity of the refueling cavity. The differential pressure (DP) reference leg runs from the seal pot on the wall of the containment intermediate level to the DP transmitters on the basement level. The seal pot is designed to maintain sufficient inventory to fill the reference leg twice in the event of flashing of the reference leg due to rapid low pressure transients.

3.3 Reactor Vessel Lower Tap and Sensing Line

One RVLMS differential pressure transmitter lower tap is made in the containment Sump A below the reactor vessel by teeing off one of the neutron flux mapping guide tubes. A single run of stainless steel tubing (3/8" x .065" wall) with Swagelok fittings is run from the lower tap up through the basement floor to the DP transmitters on the basement level.

3.4 Differential Pressure Level Transmitters

Two Foxboro N-E11DM differential pressure transmitters are connected in parallel to the upper and lower tap sensing lines to provide redundant measurement of differential pressure over the height of the reactor vessel. The transmitters are sensitive to the static differential pressure due to the level of fluid in the reactor vessel plus the dynamic differential pressure due to reactor coolant flow while one or two reactor coolant pumps are running. The transmitters are located at elevation 247'11", which insures that they will remain above the worst case containment flood level.

3.5 Tcold RTDs

A Conax dual element 100 ohm RTD is installed in each reactor coolant loop cold leg to provide a redundant, isolated, independently routed Tcold output to each RVLMS channel. During natural circulation, it is assumed that the temperature of fluid below the core in the reactor vessel is represented by the Tcold temperature. The Tcold RTDs are also used to calculate reactor vessel fluid fraction when one or both RCPs are running. The Tcold signal from each loop is also input directly to an indicator on the main control board.

3.6 RVLMS Signal Processing Racks

Two Foxboro Spec 200 analog signal processing racks, one for each RVLMS channel (RVLMS1 and RVLMS2), are installed in the relay room to process signals from the DP transmitter, Tcold, sensing line RTDs and other inputs and convert them to a reactor vessel level or vessel fluid fraction. The RVLMS racks each contain a local reactor vessel inventory indicator and four status lights to indicate specific modes of operation. In addition, the RVLMS racks generate isolated analog outputs to the Plant Process Computer System (PPCS) to enable an independent calculation of reactor vessel inventory to be performed.

3.7 RVLMS Main Control Board Indicator

3.7.1 A Sigma International Instruments 203 segment LED vertical scale indicator is installed on the main control board center section for each RVLMS channel (see Attachment III). The LED indicator eliminates problems common to conventional meter movement indicators such as parallax and static charge buildup, and has a full scale accuracy of ± 1%.

3.7.2 The RVLMS indicator displays two types of reactor vessel inventory measurements. When no reactor coolant pumps are running, a discrete reactor vessel level with separated vapor and liquid phases is assumed to exist. The RVLMS indicator is scaled on its left hand side for 0 to 100% reactor vessel level and has an additional upper graduation labeled "seal pot". Normally, the seal pot is physically located at the 100% level elevation and is not required to appear on the indicator, however, due to interferences in the upper tap region and sloping of horizontal tubing runs, the seal pot is located 33.64 inches above the 100% vessel level, and, therefore must appear on the indicator. The reactor coolant system is normally initially filled to the seal pot and therefore vessel level is indicated at the seal pot elevation. If vessel level decreases, the small quantity of water in the seal pot and tubing to the upper tap will drain quickly to the reactor and the indicator will then read 100% and continue trending normally from that point.

When one or both reactor coolant pumps are running and voiding occurs, the primary coolant is assumed to be a homogeneous mixture of steam and water phases flowing through the reactor vessel. If the reactor coolant inventory decreases during a loss of coolant accident, there will continue to be a homogeneous mixture of water and steam, but the ratio of the water volume to the entrained steam volume, or fluid fraction, will decrease. The right side of the RVLMS indicator is scaled 0 to 100% vessel fluid fraction for use when RCPs are running. The 0 to 100% scales on each side of the indicator are designed to coincide for human factors considerations. A simplified derivation of the "variable gain" compensation equation is given in Attachment VI.

4.0 RVLMS System Inputs

Refer to Attachment I, RVLMS Block Diagram and Attachment IV, RVLMS Analog Block Diagram for description of inputs to the RVLMS racks.

4.1 Core Exit Thermocouples (0-700°F)

The average of three selected core exit thermocouples (CETs) is input to each RVLMS rack. The CET signals are read directly from each thermocouple in parallel with the CET display existing in Incore Rack #4. The CETs are used to calculate the specific gravity of reactor coolant above the core (sgt) as a function of temperature during natural circulation or RCP operation.

4.2 Tcold (0-700°F)

The Tcold RTD in each cold leg supplies one RVLMS channel and is used to calculate the specific gravity of the reactor coolant below the core (sgb) as a function of temperature during natural circulation. The Tcold RTDs are also input to two function generators used to calculate reactor vessel fluid fraction when one or both RCPs are running. The Tcold RTDs are input directly to the RVLMS racks.

4.3 RCS Wide Range Pressure (0-3000 psig)

One RCS wide range pressure channel is input to each RVLMS rack from existing instrument loops for PT-420 and PT-420A in the relay room. The specific gravities of saturated vapor (sgv) and saturated liquid (sgtp) are calculated as a function of RCS pressure. The saturation temperature of liquid (Tsat) is also calculated as a function of RCS pressure.

4.4 Differential Pressure Level Transmitter

The RVLMS DP transmitters input directly to their respective RVLMS racks and measure differential pressure due to reactor coolant level (static DP) and RCP operation (dynamic DP).

4.5 Reactor Coolant Pump (RCP) Status

On/off status for each RCP is input to both RVLMS racks to actuate the RVLMS fluid fraction calculation mode when one or two RCPs are running. RCP on/off status is obtained from existing RCP circuit breaker contact output relays in racks RB1, RB2, RY1, and RY2 in the relay room.

4.6 Safety Injection (SI) Status

Safety injection status is input to both RVLMS racks from existing instrument loops for FT-924 and FT-925 in the relay room. Safety injection on/off status is used to select the mode of operation of the RVLMS system.

4.7 Residual Heat Removal (RHR) Status

RHR status is input to both RVLMS racks from existing instrument loop FT-626 in the relay room. RHR on/off status is used to select the mode of operation of the RVLMS system when RCPs are off.

4.8 Sensing Line RTDs

The RVLMS upper tap (reference leg) sensing line has one Conax dual element 100 ohm platinum RTD installed on the intermediate level to monitor the temperature of the sensing line fluid in that region. The RTD is in direct contact with the sensing line fluid via a Swagelok tee and provides a redundant, isolated, independently routed input to each RVLMS channel to compensate for changing specific gravity of sensing line fluid as a function of temperature. The lower tap sensing line has two RTDs as described above, one on the basement level and one at the Sump A level. The RVLMS system was designed to accept inputs from as many as six sensing line RTDs, but only three are actually used.

5.0 RVLMS System Function Generators

Refer to Attachment IV, RVLMS Analog Block Diagram for description of function generators. The inputs described in sections 4.1, 4.2, 4.3 and 4.8 are used to drive Foxboro signal characterizers (function generators) in the RVLMS racks which calculate the following parameters:

5.1 $f_1(x)$ - specific gravity of saturated vapor as a function of RCS pressure (sgv)

5.2 $f_2(x)$ - saturation temperature of liquid as a function of RCS pressure (Tsat)

5.3 $f_3(x)$ - specific gravity of saturated liquid as a function of RCS pressure (sgtp)

5.4 $f_4(x)$ - specific gravity of subcooled liquid in reactor vessel as a function of temperature (sgt, sgc, sgb)

5.5 $f_5(x)$ - specific gravity of subcooled liquid in sensing lines as a function of temperature (sg1, sg2, sg3)

5.6 $f_6(x)$ - DP solid as a function of Tcold for 1 RCP running.

5.7 $f_7(x)$ - DP solid as a function of Tcold for 2 RCPS running

6.0 RVLMS System Outputs

Each RVLMS rack provides one output to its respective reactor vessel inventory indicator on the main control board in addition to several computer outputs which allow the PPCS to perform an independent calculation of reactor vessel inventory. Refer to Attachments I, III, and IV.

6.1 RVLMS Inventory Output

Reactor vessel inventory is output to the main control board indicator as an isolated 4-20ma signal for each channel. Since the MCB indicator output is isolated, vessel inventory can still be read locally at the RVLMS rack in the event of failure of the MCB indicator or its signal cable.

6.2 Computer Output - Sensing Line RTDs

An isolated analog 1-5 vdc output for each sensing line RTD is provided to the PPCS for independent calculation of vessel level.

6.3 Computer Output - Differential Pressure Transmitter

An isolated analog 1-5 vdc output for each DP transmitter is provided to the PPCS for independent calculation of vessel inventory.

6.4 Computer Output - Safety Injection Flow

Prior to installation of the RVLMS system, Safety Injection (SI) flow was not an existing computer parameter, therefore, it was input as part of the RVLMS system and is used to select the RVLMS calculation mode used by the PPCS for its independent RVLMS calculation. The SI computer outputs are electrically isolated from the rest of the RVLMS system.

6.5 Computer Output - RVLMS Level Output

An isolated 1-5 vdc analog RVLMS Level output is provided to the PPCS for display and for comparison with the PPCS independently calculated value of vessel inventory.

7.0 <u>RVLMS Modes of Operation</u>

7.1 RCPs Off - Natural Circulation Mode

During natural circulation, reactor coolant inside the vessel is assumed to be partitioned into three temperature layers. The specific gravity of the top layer (sgt) is computed using the average of three core exit thermocouples. The specific gravity of the bottom layer (sgb) is computed using the Tcold input. The specific gravity of the central core layer (sgc) is computed using the average of the core exit and Tcold temperatures.

7.2 RCPs Off - Safety Injection or Residual Heat Removal Mode

During safety injection (SI) or residual heat removal (RHR) phases of operation, Tcold is not considered representative of the reactor coolant bottom layer temperature, therefore, the reactor coolant is assumed to have a uniform specific gravity equal to sgt throughout the reactor vessel. When SI or RHR flow is sensed by the RVLMS system, relays automatically cut out the

Tcold RTD input and the system computes vessel level using only the core exit thermocouples for reactor coolant temperature input. SI, RHR, and Tcold disabled conditions are all annunciated on the test panel in the rear of each RVLMS instrument rack.

7.3 RCPs Off - Vessel Level Below Top of Core or Refueling

It is assumed that vessel level has dropped below the top of the core when the average core exit thermocouple (CET) temperature is greater than the saturation temperature (Tsat) computed from RCS wide range pressure. The RVLMS system continuously computes Tsat and compares it to the CET temperature. If reactor vessel level drops below the top of the core, the core exit thermocouples will be uncovered and no longer reliably measure reactor coolant temperature. When the CET temperature exceeds Tsat, the core exit thermocouple inputs are disabled and an annunciator on the RVLMS local test panel is actuated. In this situation, the remaining reactor coolant is assumed to be a uniform saturated fluid and its specific gravity (sgtp) is computed from RCS wide range pressure. During refueling, the CET connectors are necessarily disconnected to permit lifting the reactor head and are, therefore, disabled. The output of each CET input module in the RVLMS racks is set to automatically fail high when the CET circuit is broken. This simulates a high temperature exceeding Tsat and actuates the CET disabling feature as described above.

7.4 Reactor Coolant Pumps Running

When one or both RCPs are running, the vessel level calculating instrumentation described in Sections 7.1, 7.2, and 7.3 is disabled, and reactor vessel fluid fraction is calculated. The fluid fraction is computed by taking the ratio of the reactor vessel differential pressure as measured by the transmitter (DPxmtr) to the differential pressure known to exist if the reactor vessel were free of voids, or "solid" (DPsolid) (see Attachment VI). Since the fluid in the transmitter reference leg remains "solid" regardless of the state of reactor coolant within the vessel, the static head due to fluid in the transmitter reference leg must be compensated out of DPxmtr and DPsolid prior to calculating the fluid fraction. The fluid fraction will then represent the ratio of DPxmtr and DPsolid over the height of the reactor vessel only, excluding the static head due to the transmitter reference leg. Compensation of DPxmtr is performed by the S8 summer, and compensation of DPsolid is incorporated into the $f_6(x)$ and $f_7(x)$ function generator curves. DPsolid is continuously calculated as a function of Tcold for both one and two RCPs running.

8.0 Differential Pressure Equations

Refer to Attachment V, Reactor Vessel Level Differential Pressure Equations.

8.1 The primary level sensing element of the RVLMS system is the differential pressure transmitter (ref. sections 3.4 and 4.4). When connected to the reactor vessel via instrument tubing as shown in Attachments I, II, and V, a change in reactor vessel level will produce a change in the differential pressure (DP) measured at the transmitter. Reactor coolant system static pressure can be neglected because it is present on either side of the DP transmitter diaphragm and, therefore, cancels itself out of the measurement. Since level measurements usually involve relatively low differential pressures, and it is a water level which is being measured, it is convenient to express DP and head in inches of water at standard temperature and pressure. At standard temperature and pressure, the density of water is .03612 lb/cu. in. therefore, a one inch square column of water $(.03612)^{-1} = 27.684$ inches high will weigh one pound and exert a pressure of 1 pound/sq. in. at its base. When temperature and pressure deviate from standard conditions (which is the majority of the time) the density of water and, therefore, the pressure or head resulting at the base of a column of water changes. This change is proportional to the ratio of the density of water at existing conditions to the density of water at standard conditions or:

Eq. 1 $$\text{Head (in. H2O)} = \text{Height of water column} \times \frac{\text{density H2O at existing conditions}}{\text{density H2O at STP}}$$

The density ratio is simply the specific gravity of water at the existing temperature and pressure, therefore, the head or pressure exerted by a column of any type of fluid can be expressed in terms of inches of water at standard conditions by:

Eq. 2 $$\text{Head (in. H2O)} = \text{Height of fluid column (inches)} \times \text{fluid specific gravity (sg)}$$

8.2 The RVLMS differential pressure (DP) transmitter, in effect, measures the head existing on either side of the DP diaphragm and produces an output proportional to the difference. A head is produced on side a of the DP diaphragm due to the column of water in the instrument sensing line reference leg. Likewise, a head is produced on side b of the DP diaphragm due to the height of water in the reactor vessel. The heights and lengths of the sections of the reactor vessel and sensing lines are known constants and the various fluid specific gravities are continuously calculated as described in sections 4.0 and 5.0.

8.3 RCPs Off - Natural Circulation

Using Eq. 2:

Head at a = h3sg3 + h2asg2

Likewise:

Head at b = (hr-hf)sgv + (hf-hb-hc)sgt + hcsgc + hbsgb + h1asg1 - h1bsg1 - h2bsg2

The last two terms in the latter expression are negative since the head produced by those sections is directed away from the transmitter. The transmitter actually measures DP which is:

DP = head at a - head at b

Therefore:

DP = h3sg3 + h2asg2 + h2bsg2 + h1bsg1-h1asg1-(hr-hf)sgv - (hf-hb-hc)sgt - hbsgb - hcsgc

The only quantity which is not known in the above expression is hf, which is the actual reactor vessel water level, therefore, by solving for hf:

Eq. 3 $$hf = \frac{h1sg1 + h2sg2 + h3sg3 + (hb+hc)sgt-hrsgv-hbsgb-hcsgc-DP}{sgt-sgv}$$

The RVLMS system calculates vessel level, hf, in accordance with Eq. 3 during natural circulation.

8.4 RCPs Off - Safety Injection or RHR

During SI or RHR, Tcold is not considered representative of the reactor coolant bottom layer temperature, therefore, the reactor coolant in the vessel is assumed to have a uniform specific gravity equal to sgt throughout the reactor vessel or:

sgt = sgc = sgb

Inserting sgt for sgc and sgb in Eq. 3 yields:

Eq. 4 $hf = \dfrac{h1sg1 + h2sg2 + h3sg3 - hrsgv\text{-}DP}{sgt - sgv}$

The RVLMS system calculates vessel level, hf, in accordance with Eq. 4 during SI or RHR operation.

8.5 RCPs Off - Vessel Level Below Top of Core or Refueling

As described in Section 7.3, when either of the above conditions exist, the core exit thermocouples are disabled and the reactor coolant in the vessel is assumed to be a uniform fluid whose specific gravity sgtp is calculated from wide range RCS pressure. Substituting sgtp for sgt, sgc, and sgb in Eq. 3 yields:

Eq. 5 $hf = \dfrac{h1sg1 + h2sg2 + h3sg3 - hrsgv\text{-}DP}{sgtp - sgv}$

The RVLMS system calculates vessel level, hf, in accordance with Eq. 5 when vessel level is below the top of the core or during refueling.

8.6 RCPs Running

As mentioned previously in Section 7.4, starting the reactor coolant pumps will automatically switch the RVLMS system from the vessel level mode to the fluid fraction mode. The reactor vessel fluid fraction (ff) is:

Eq. 6 $ff = \dfrac{DPxmtr}{DPsolid}$

where:

DPxmtr is the DP due to reactor vessel static head and dynamic flow conditions as measured by the DP transmitter. Static head due to the transmitter reference leg is compensated out of the measurement by the S8 summer.

DPsolid is the DP known to exist over the height of the reactor vessel at a given temperature if the reactor vessel were free of voids (solid), excluding the reference leg static DP.

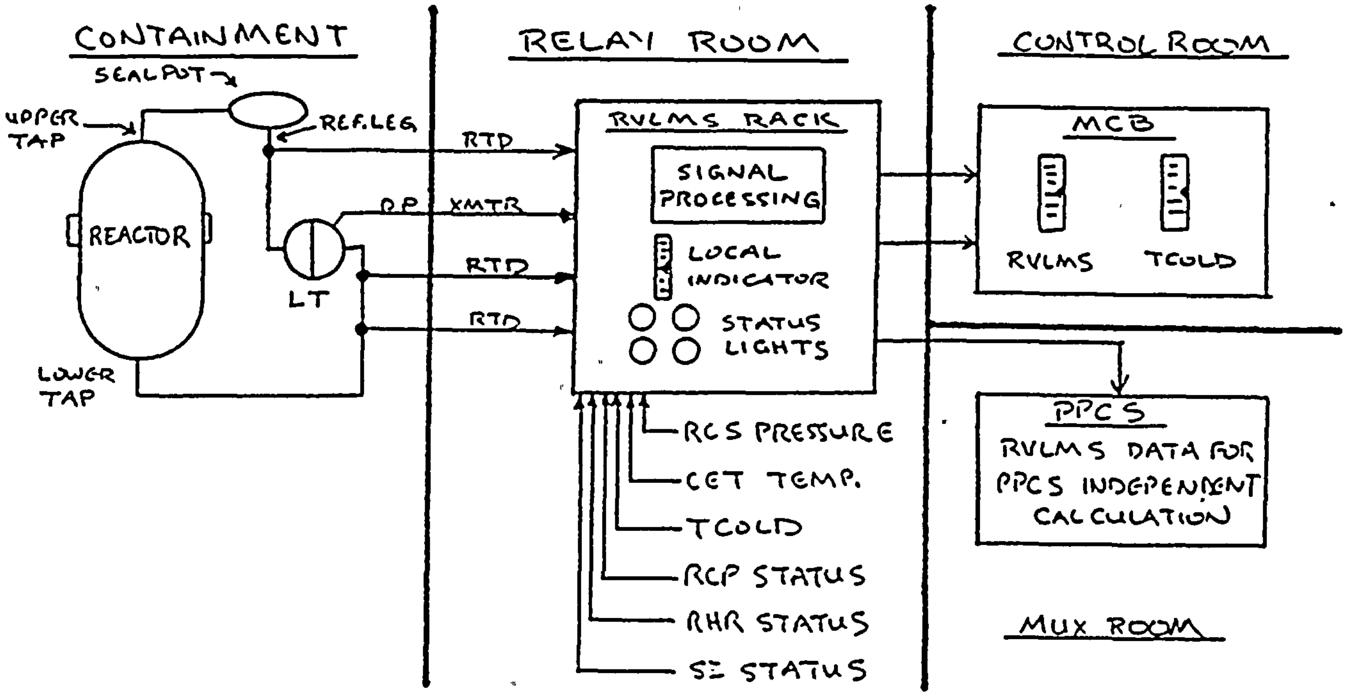
As described in section 7.4, the static head due to the transmitter reference leg is compensated out of the fluid fraction calculation by the S8 summer and the $f_6(x)$ and $f_7(x)$ function generators:

Eq. 7 $ff = \dfrac{DPxmtr - h1sg1 - h2sg2 - h3sg3}{DPsolid}$

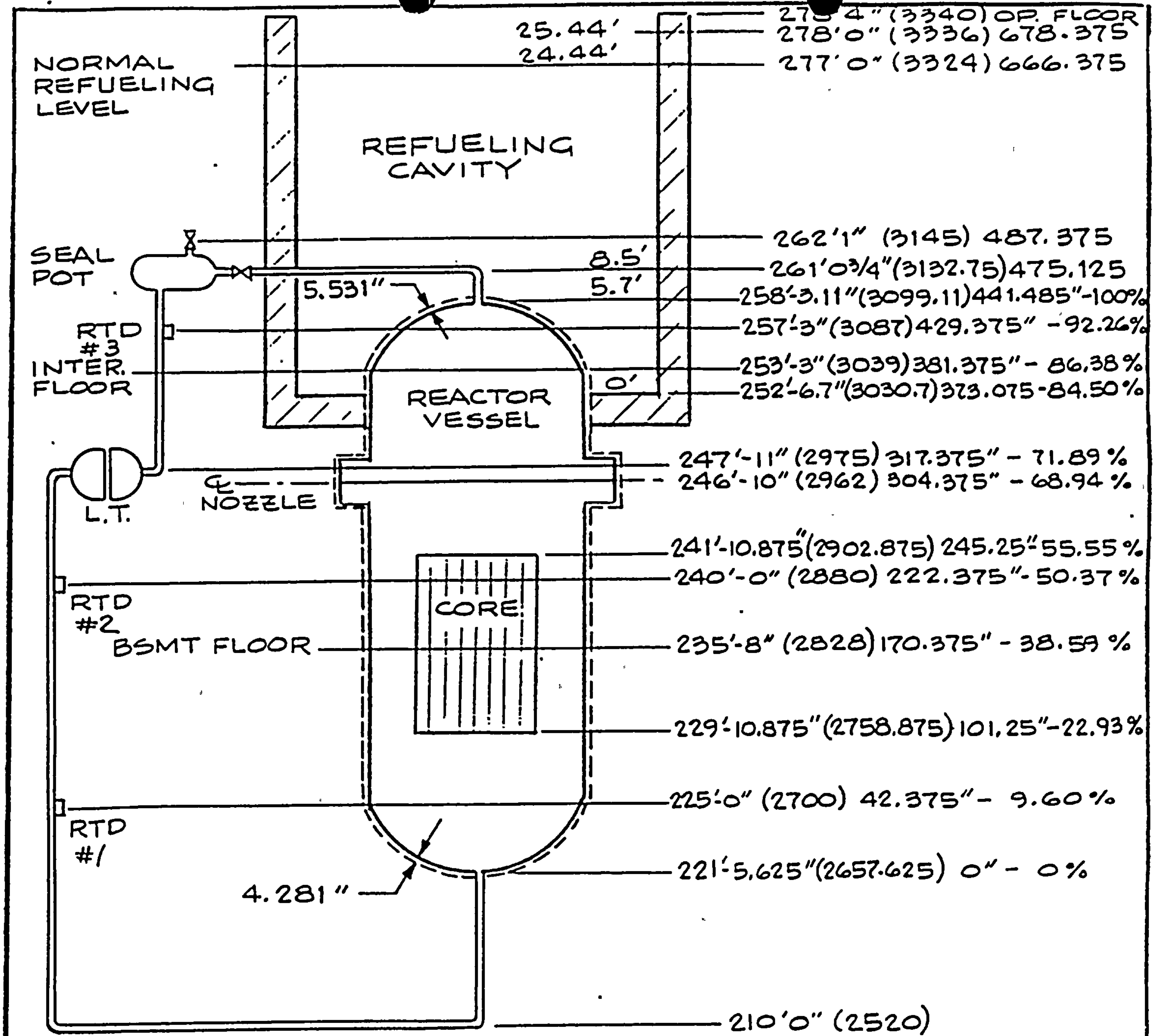
ATTACHMENT I

ENG. DEPT.	STATION: GINNA	DATE: 10/13/86	PAGE 01
JOB: EWR 2799- RVLMS		MADE BY: RAB	CK:

RVLMS BLOCK DIAGRAM



ATTACHMENT II



RVLMS SYSTEM ELEVATIONS

"This drawing includes equipment or structures subject to Section C.2 of Regulatory Guide 1.29. Refer to notes and specifications to determine specific QA program applicability."

	CONSTRUCTION	
	LIMITED CONSTRUCTION: AS NOTED	
	PRELIMINARY NOT FOR CONSTRUCTION	
	BIDDING PURPOSES	
DATE	RELEASED FOR	ENGR

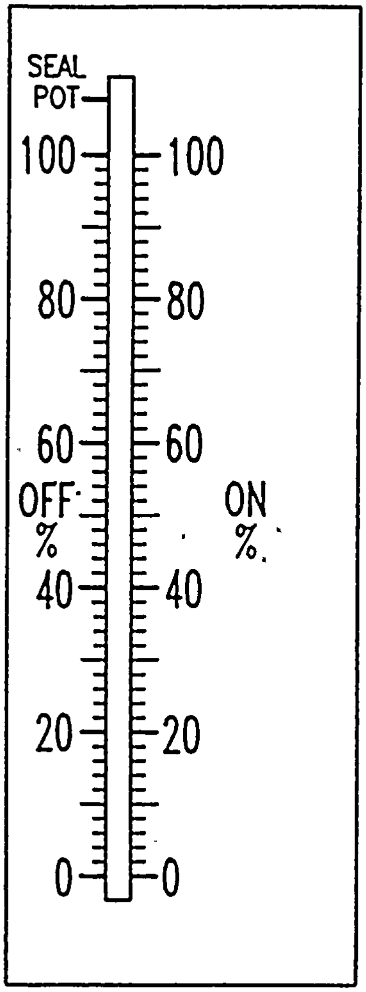
NUMBER	REVISION	INITIAL DATE	DRAWN BY	CHECKED BY	RESP. ENG.	ENG. MANG'R.
1	ALL LEVELS		EJD/1-23-87			
0	ORIGINAL		EJD/6-9-86	RAB 7/10/86	RAB 7/10/86	FWA 7/10/86

ROCHESTER GAS & ELECTRIC CORP. ROCHESTER, NEW YORK	RVLMS SYSTEM ELEVATIONS	SCALE — NO. 03021-687

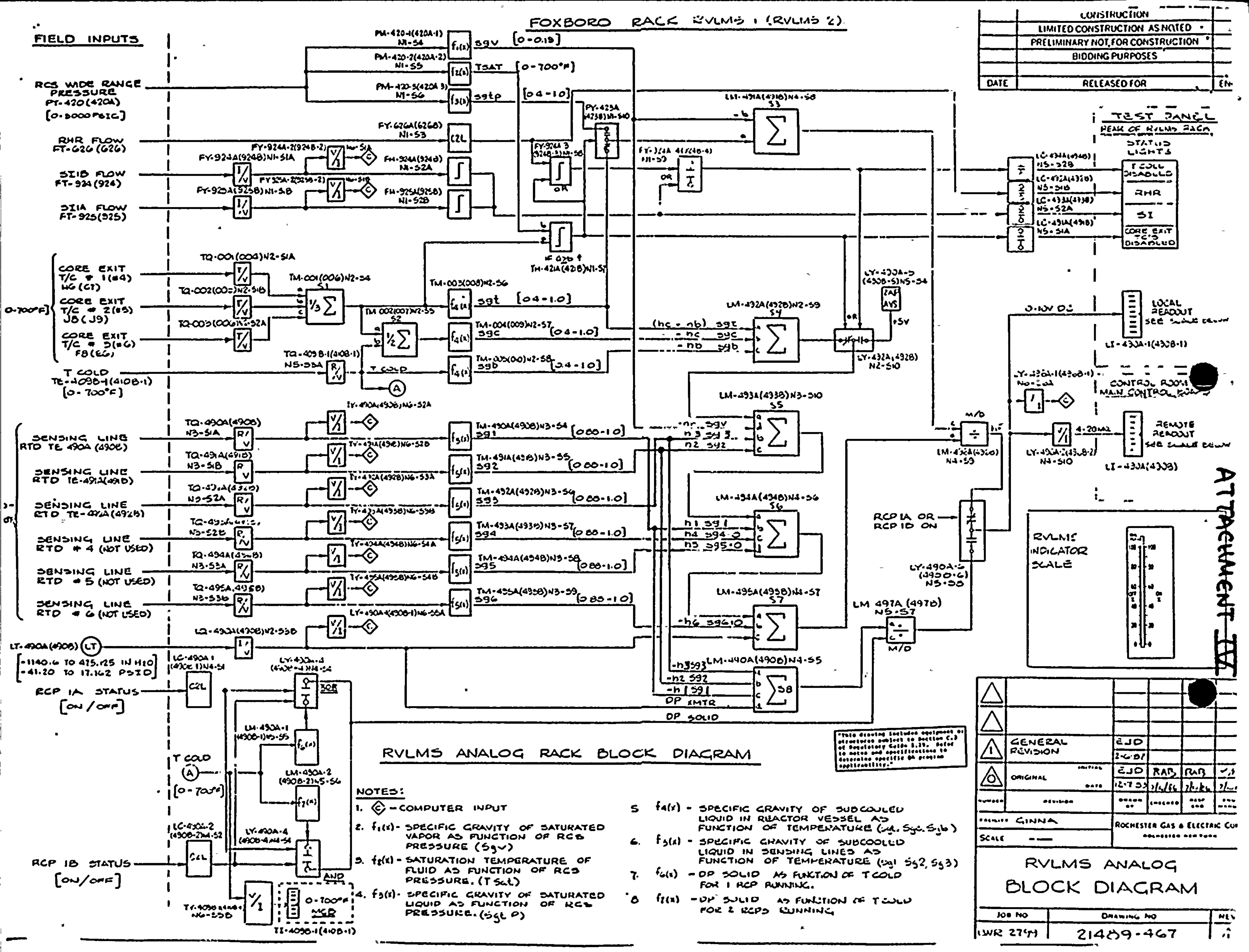
58009

HKS-191153

ATTACHMENT III

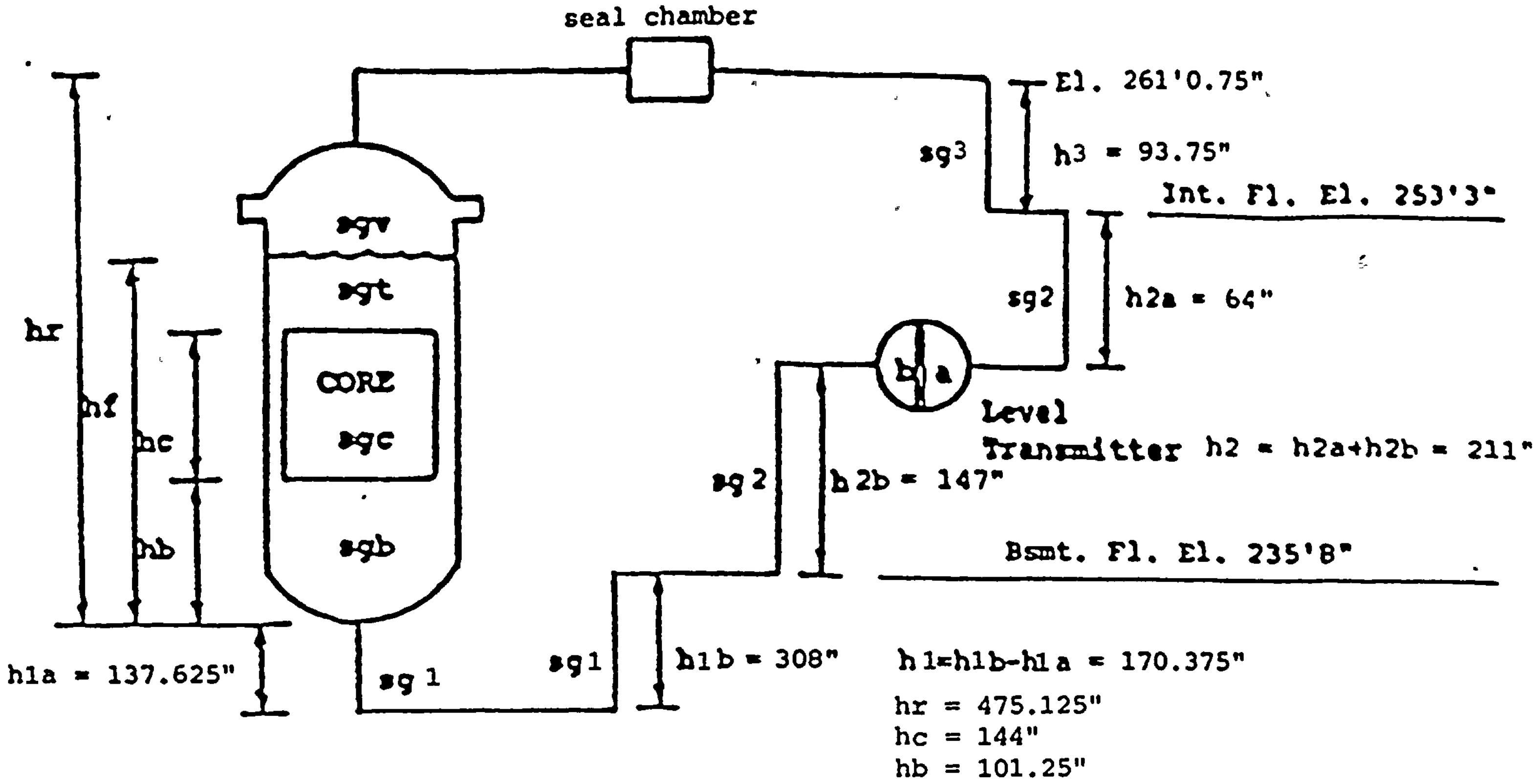


RVLMS INDICATOR SCALE


FOXBORO RACK RVLMS 1 (RVLMS 2)
FIELD INPUTS
RCS WIDE RANGE PRESSURE PT-420 (420A) [0-3000 PSIG]
RHR FLOW FT-626 (626)
SIB FLOW FT-924 (924)
SIA FLOW FT-925 (925)
CORE EXIT T/C # 1 (#4)
CORE EXIT T/C # 2 (#5)
CORE EXIT T/C # 3 (#6)
T COLD TE-409B-1 (410B-1) [0-700°F]
SENSING LINE RTD TE 490A (490B)
SENSING LINE RTD TE-491A (491B)
SENSING LINE RTD TE-492A (492B)
SENSING LINE RTD # 4 (NOT USED)
SENSING LINE RTD # 5 (NOT USED)
SENSING LINE RTD # 6 (NOT USED)
LT-490A (490B)
[-1140.6 TO 415.125 IN H2O]
[-41.20 TO 17.162 PSID]
RCP 1A STATUS [ON/OFF]
RCP 1B STATUS [ON/OFF]
T COLD
[0-700°F]
sgv [0-0.19]
TSAT [0-700°F]
sgtp [0.4-1.0]
sgt [0.4-1.0]
sgc [0.4-1.0]
sgb [0.4-1.0]
sg1 [0.80-1.0]
sg2 [0.80-1.0]
sg3 [0.80-1.0]
sg4 [0.80-1.0]
sg5 [0.80-1.0]
sg6 [0.80-1.0]
DP XMTR
DP SOLID
TEST PANEL
REAR OF RVLMS RACK
STATUS LIGHTS
T COLD DISABLED
RHR
SI
CORE EXIT T/C'S DISABLED
LOCAL READOUT
0-10V DC
REMOTE READOUT
4-20mA
CONTROL ROOM MAIN CONTROL BOARD
RCP 1A OR RCP 1B ON
RVLMS INDICATOR SCALE
RVLMS ANALOG RACK BLOCK DIAGRAM
NOTES:
1. (C) - COMPUTER INPUT
2. f1(x) - SPECIFIC GRAVITY OF SATURATED VAPOR AS FUNCTION OF RCS PRESSURE (Sgv)
3. f2(x) - SATURATION TEMPERATURE OF FLUID AS FUNCTION OF RCS PRESSURE. (T Sat)
4. f3(x) - SPECIFIC GRAVITY OF SATURATED LIQUID AS FUNCTION OF RCS PRESSURE. (Sgt P)
5. f4(x) - SPECIFIC GRAVITY OF SUBCOOLED LIQUID IN REACTOR VESSEL AS FUNCTION OF TEMPERATURE (Sgt, Sgc, Sgb)
6. f5(x) - SPECIFIC GRAVITY OF SUBCOOLED LIQUID IN SENSING LINES AS FUNCTION OF TEMPERATURE (Sg1 Sg2, Sg3)
7. f6(x) - DP SOLID AS FUNCTION OF T COLD FOR 1 RCP RUNNING.
8. f7(x) - DP SOLID AS FUNCTION OF T COLD FOR 2 RCPS RUNNING
CONSTRUCTION
LIMITED CONSTRUCTION AS NOTED
PRELIMINARY NOT FOR CONSTRUCTION
BIDDING PURPOSES
DATE
RELEASED FOR
GENERAL REVISION
EJO
2-6-87
ORIGINAL
GINNA
ROCHESTER GAS & ELECTRIC CORP
RVLMS ANALOG BLOCK DIAGRAM
JOB NO
DRAWING NO
LWR 2754
21489-467
ATTACHMENT IV

REACTOR VESSEL LEVEL
ATTACHMENT V

DIFFERENTIAL PRESSURE EQUATIONS



1. Natural Circulation

Head at a: $h3sg3 + h2asg2$

Head at b: $(hr - hf)sgv + (hf - hb - hc)sgt + hcsgc + hbsgb + h1asg1 - h1bsg1 - h2bsg$

$$DP = a-b = h3sg3 + h2asg2 + h2bsg2 + h1bsg1 - h1asg1 - (hr - hf)sgv - (hf - hb - hc)sgt - hbsgb - hcsgc$$

$$DP = h3sg3 + (h2a + h2b)sg2 + (h1b - h1a)sg1 - hrsgv + hfsgv - hfsgt + hbsgt + hcsgt - hbsgb - hcsgc$$

$$DP = h3sg3 + h2sg2 + h1sg1 + hf(sgv - sgt) + (hb + hc)sgt - hrsgv - hbsgb - hcsgc$$

$$hf = \frac{h1sg1 + h2sg2 + h3sg3 + (hb + hc)sgt - hrsgv - hbsgb - hcsgc - DP}{sgt - sgv}$$

2. Safety Injection or RHR

$$hf = \frac{h1sg1 + h2sg2 + h3sg3 - hrsgv - DP}{sgt - sgv}$$

3. Reactor Vessel Level Below Top of Core or Refueling

$$hf = \frac{h1sg1 + h2sg2 + h3sg3 - hrsgv - DP}{sgtp - sgv}$$

ATTACHMENT VI

$$\Delta P_{TOT} = P_A - P_B = \underbrace{\rho'' g L_o - \rho' g L - \rho''' g L}_{\text{STATIC TERM}} \; \underbrace{- \rho' f A'_{eff} V^2}_{\text{DYNAMIC TERM}}$$

(SEE FIG VI - 1)

$f \equiv$ friction factor $\quad A'_{eff} \equiv$ effective flow area in vessel $\quad V \equiv$ fluid velocity

NEGLECT STEAM DENSITY $\Rightarrow \rho''' \equiv 0$

AND ASSUME UNIFORM TEMP $\Rightarrow \rho'' = \rho' = \rho$

$$\Delta P_{TOT} = \rho g L_o - \rho \left(g L + f A'_{eff} V^2 \right)$$

IF VOIDS OCCUR THE VAPOR IS ASSUMED TO BE UNIFORMLY DISTRIBUTED THROUGHOUT THE PRIMARY SYSTEM IF PUMPS ARE ON.

$$f_V \text{ (VOID FRACTION)} \equiv \frac{\text{MASS OF PRIMARY COOLANT DISPLACED BY VOIDS}}{\text{MASS OF PRIMARY COOLANT WITHOUT VOIDS}}$$

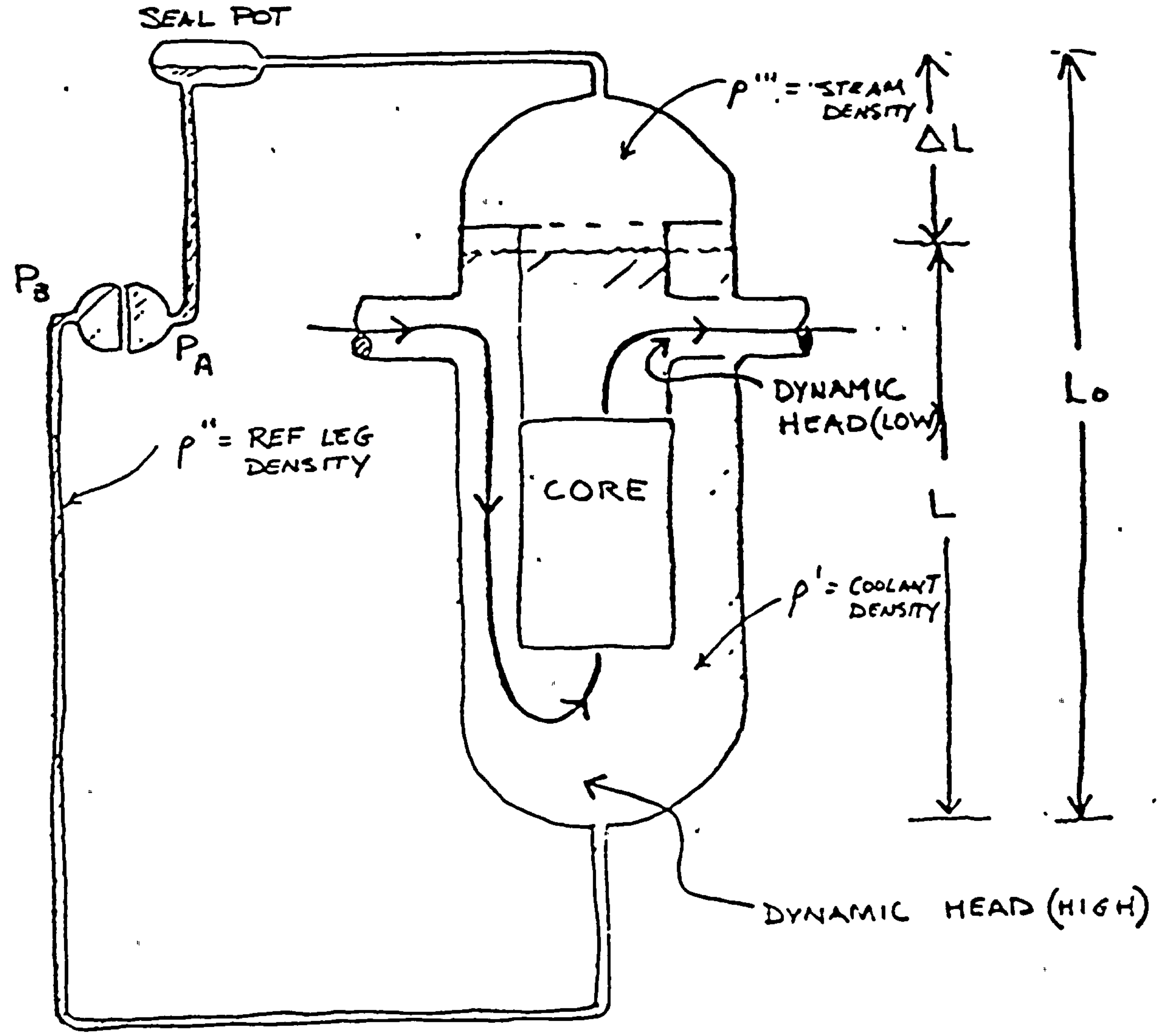
$$\Delta P_{TOT} \text{ (VOIDS PRESENT)} = \rho g L_o - \rho (1 - f_V)\left(g L + f A'_{eff} V^2 \right)$$

THE MEASURED "COMPENSATING" DIFFERENTIAL PRESSURE IS JUST THE UNVOIDED ΔP_{TOT}.

$$\Delta P_{COMP} = \rho g L_o - \rho \left(g L + f A'_{eff} V^2 \right)$$

$$\Delta P_{TOT} - \rho g L_o = (1 - f_V)\left(\Delta P_{COMP} - \rho g L_o \right)$$

$$\boxed{1 - f_V = \frac{\Delta P_{TOT} - \rho g L_o}{\Delta P_{COMP} - \rho g L_o}}$$



SEAL POT
ρ''' = STEAM DENSITY
ΔL
P_B
P_A
DYNAMIC HEAD(LOW)
L_o
ρ'' = REF LEG DENSITY
CORE
L
ρ' = COOLANT DENSITY
DYNAMIC HEAD (HIGH)

FIG VI-1