GE Nuclear Energy

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Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Jerry N. Wilson, Acting Director
Standardization Project Directorate

Subject: **NRC Requests for Additional Information (RAIs) on the Simplified Boiling Water Reactor (SBWR) Design**

Reference: Transmittal of Requests for Additional Information (RAIs) for the SBWR Design, Letter from M. Malloy to P. W. Marriott Dated August 20, 1993

The reference requested additional information on the SBWR Design. In partial fulfillment of this request, GE is submitting responses to RAIs 950.1 - 950.16 and RAIs 950.21 - 950.26.

Sincerely,

J. F. Quirk
Project Manager
ABWR Certification Program
M/C 782, (408)925-6219

210018

Note: Enclosure can be processed per conversation between David Foreman (GE) and M. Malloy (NRC) and made PDR available

D040
1/1

RAI Number: 950.1

Question:

What are the system set points that activate (all) the squib valves?

GE Response:

Squib valves in the Standby Liquid Control System (SLCS). The analytic limits of the set points will be determined when the technical specifications are finalized.

Squib valves in the GDCS. The squib valves shall be signaled to open following a specified time delay after a confirmed low-low water level (RPV Level-1) condition is detected and sealed-in to GDCS logic.

Squib valves in the Depressurization Valves (DPV). The DPV are large squib valves used to depressure the Reactor Pressure Vessel (RPV) as part of the Automatic Depressurization Subsystem, ADS of the Nuclear Boiler System (NBS). The RPV Low Water Level 1 trip set point is the automatic initiation setpoint for the ADS. This is identified in 1 is Figure 21.7.3-1 in the SBWR Standard Safety Analysis Report

RAI Number: RAI Number: 950.2

Question:

What is the delay time associated with activation of the squib valves?

GE Response:

Squib valves in the Standby Liquid Control System (SLCS). The primary delays in actuation are most likely in the system logic and not due to the squib valves operation delays, which are negligible. The configuration of timers are shown in SSAR Figure 7.3-4a. The 3 minute timer shall ensure that the injection of the boron solution is initiated only after the other preventative measures are not successful.

Squib valves in the Gravity Driven Cooling System (GDCS). The squib-actuated valves in the GDCS branch secondary lines connecting to the GDCS pools open at 150 seconds +/-2 seconds after the receipt of confirmed Reactor Pressure Vessel (RPV) Level-1 signal. The squib actuated valves in the equalizing lines connecting to the suppression pool open at 30 minutes +/-2 minutes after receipt of a confirmed RPV Level-1 condition signal and when RPV is reduced to 1 meter above Top of the Active Fuel (TAF). The valve is opened in less than or equal to 0.5 seconds after receiving an actuation signal.

Squib valves in the Depressurization Valves (DPVs). Once the Automatic Depressurization System (ADS) logic confirms that ADS initiation is required, the opening of the DPVs is staggered by time delays in the ADS logic to control the depressurization rate of the RPV. The ADS logic opens the DPVs in all three groups, with two DPVs per group.

To determine if ADS initiation is required, the ADS logic requires the RPV Low Water Level 1 signal to exist for 10 seconds. Once the ADS logic determines that ADS initiation is required the first DPV group is initiated after a 55 second time delay, the second DPV group is initiated after a 100 second time delay, and the third DPV group is initiated after a 145 second time delay. The time delays for the ADS timers will be set such that logic response times and inacuracies associated with the timers will not result in these times being exceeded. The logic is shown in SSAR Figure No. 21.7.3-1 Nuclear Boiler System (NBS) Logic Diagram.

RAI Number: RAI Number: 950.3

Question:

What are the pressure losses and the area associated with the squib valves?

GE Response:

Part 1–SLCS Squib Valve:

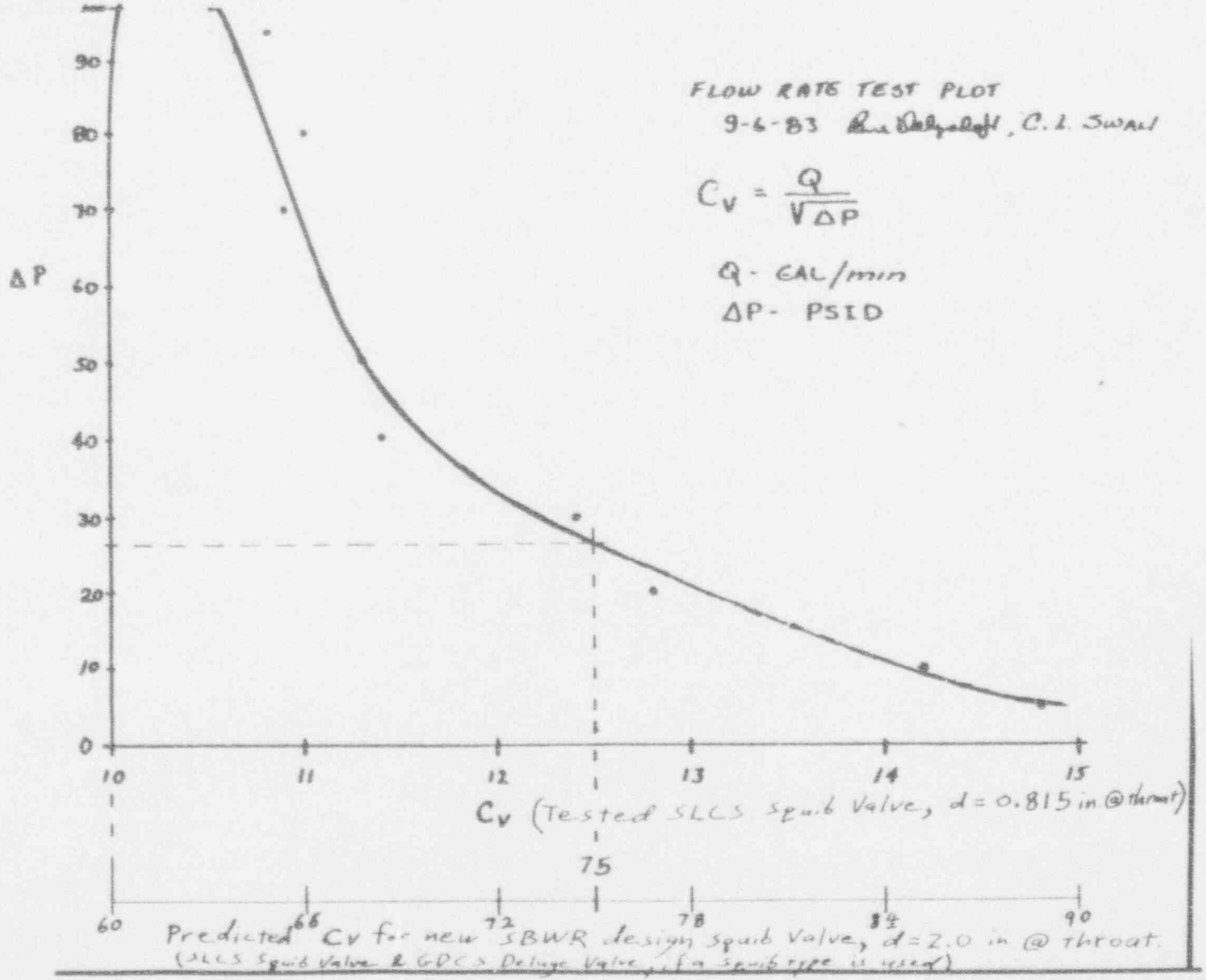
The SLCS Squib Valve opens to permit injection of sodium pentaborate into the reactor for mitigation of ATWS. There are two SLCS Squib Valves mounted in parallel on the line between the SLCS Accumulator and the reactor vessel. Current SLC design for SBWR employs a squib valve with nominal 3-inch inlet and outlet and a 2-inch throat diameter ($A=3.1416\ in^2$) at the location where the cap is sheared during actuation. The current minimum requirement for flow coefficient ($Cv = Q/\sqrt{\Delta P}$)is 40, where Q is given in gal/min and ΔP in psid). Nitrogen gas over a sodium pentaborate solution in an accumulator (2500 psi system design) is used to pump the pentaborate solution through the open valve into the reactor vessel. The valve must remain closed and contain this pressure until actuated. This design feature means that a pressure differential of up to 1500 psi may exist across the system when the valve is opened, dropping quickly as the nitrogen volume in the accumulator decreases. At the instant of valve actuation, this pressure may be almost entirely across the valve.

A smaller squib valve model with similar internal geometry (proportionally smaller throat, ram, and capture space for the sheared cap) is used in existing domestic GE BWRs. Actual testing was performed on that smaller model to establish Cv for pressures of ΔP up to 100 psid. That valve model had a nominal 1 1/2-inch inlet/outlet and a throat diameter of 0.815 inch ($A=0.5217\ in^2$) at the shear section. Test results revealed that the value of Cv for this (smaller) valve model varied with the value of ΔP, and suggested a relatively smooth curve from almost 15 at ΔP near zero to about 10.6 at 100 psi.

At pressures above 100 psi, theory predicts that Cv should asymptotically approach a minimum value. The shape of the curve suggests a value of abour 10 for the tested valve.

Theory further predicts, for similar geometries, that Cv is proportional to throat area; hence, the current SBWR squib valve design would expect to provide a Cv of 6.022 times (or conservatively, about six times) the Cv of the tested valve.

The current valve design meets the specification minimum Cv requirement of 40. This prediction method also estimates that the specification nominal value of 75 is exceeded for values of ΔP up to 25 psid. This is important from a practical viewpoint, as it indicates that the current design has considerable margin at low values of differential pressure, where adequate flow rate might otherwise become a concern. A graphical illustration of



Resp. to RAI 950.03, Part 1, Att. 1A

the predicted C_V values (→flow rates), superimposed over the curve for the tested (smaller) valve, is provided as Attachment 1A.

As long as the internal geometry of the SBWR SLCS squib valve design remains proportionally the same, flow characteristics for a revised SIZE can be predicted in the same manner as that described above, using the new ratio of areas to adjust the Cv from the tested valve to a new size of valve.

Information for Responses to the NRC's RAI no. 950.03, Concerning SBWR Squib Valves:

Part 2–GDCS Valves:

(A) GDCS Deluge Valve–

The deluge valve opens to permit water to drain from the GDCS pool into the lower drywell to cover the core in a severe accident. Current system design provides for three divisions (i.e., separate lines), each of which contains three valves in parallel. The specifiv valve design has not been finalized at this time. Use of a squib valve is one possibility being considered. If a squib valve is used, it will have 2-inch (nominal) inlet and outlet connections and a 2-inch throat diameter. This valve may be required to remain closed against a short-lived pressure transient. Design is for up to 1437 psid, resulting in a 1500 psig design pressure. Therefore, it will have thinner body sections and lower flange ratings than the SLCS Squib Valve described in Part 1. Notwithstanding the different design pressure, the internal geometry of this valve (if a squib type) will be virtually identical to the SLCS Squib Valve. The required (target) value of Cv for this valve is 73. The supplier conservatively predicts a Cv of 65; however, direct application of the prediction methods used in Part 1 permits the conclusion that the flow coefficient of this valve will exceed 73 for differential pressures up to slightly over 25 psid. This valve is expected to open (remaining open) at approximately 7 psid, decreasing with time, as the initial water head to the top of the GDCS pool is about five meters.

It can, therefore, be concluded that the squib type valve, if used, will meet the system requirements. Flow rate will be determined by water head and lower drywell pressure (both functions of time) and by system piping configuration. Also since Cv varies with ΔP across the valve, the most accurate calculation of flow rate will be iterative, using the prediction curve of Attachment 1A.

(B) GDCS Injection Valve–

The injection valve opens to permit water to drain from the GDCS pool into the reactor vessel to keep the core covered. Current system design provides for three divisions (i.e., separate lines), each of which contains two valves in parallel. This valve is mounted on a nominal 6-inch Sch. 80 line (inlet and outlet) and has a 5.76 inch throat. The required Cv for this valve is 876. The supplier indicates that the value of Cv for this valve is 1095, which provides acceptable margin. The valve must remain closed at (design) pressure up to 1500 psid. It operates (opening and remaining open) at pressure differentials of <20 psid–somewhat higher than the

deluge valve since the injection valve is at a considerably lower elevation. In a similar manner as that of the deluge valve, flow rate of the injection valve will depend on GDCS pool height and reactor pressure, as well as system configuration.

Information for Responses to the NRC's RAI no. 950.03, Concerning SBWR Squib Valves:

Part 3—Depressurization Valve (DPV):

The Depressurization Valve opens on low reactor water level signal to depressurize the reactor to the point at which GDCS flow can be initiated. There are six DPVs in the nuclear boiler system. The valves are horizontally mounted to 12-inch flanges. Two of these mountings are connected to 12-inch sweepolets welded to the (28-inch) main steam lines (one per line). The other four are connected from the vessel through 18-inch stub tubes which are reduced to 12 inches at the flange connecting to the valve.

The flow-related feature of greatest interest in connection with the DPV is "flow capacity" (i.e., similar to relief capacity) rather than flow coefficient. Minimum flow capacities are 1.5 million lb/hr at 1085 psig (inlet) and 1.75 million lb/hr at 1240 (inlet). The upper limits on individual DPV and total (system) depressurization flow rate are configuration-dependent.

The flow associated with this valve is steam, initially near saturation, which flows out the open valve at choked flow conditions until the reactor pressure has been significantly reduced from that at which the valve was initially actuated. For inlet pressures up to the design pressure of 1500 psig, the DPV must remain closed until signaled to open. It may be required to open at inlet pressures up to 1460 psig.

The steam flow rate of a prototype DPV has been tested for blowdown to atmospheric conditions at a large test facility of known steam volume. Initial inlet pressures were 1450 psig (3 tests) and 1050 psig (1 test), with the steam conditions initially near saturation. A very interesting feature of these tests was that observed flow rates at any given pressure vary somwhat, depending upon the initial pressure at which the valve was opened. These tests were pressure decay tests.

Observed flow rates decreased with pressure, as expected. For initial pressures at 1450 psig, initial flow rates varied from 3 to 4 million lb/hr (initial flow rates as observed)–nominally 3.5 million lb/hr ±15%. For the test run which started at 1050 psig, initial flow rate was approximately 2.4 million lb/hr. By interpolation, a flow rate of about 3 million lb/hr (±15%) would be expected at 1240 psig. By a wide margin, these observed and interpolated flow rates exceed the minimum values required by the equipment and system specifications.

The tested prototype was constructed with an 8-inch inlet. The test configuration had piping from the test volume to a header, then additional piping through an 8-inch pipe to the test valve. Both of the mounting configurations of the actual SBWR production units will have a much more direct flow path from the steam volume to the valve–therefore, less total restriction to flow. Test unit results can

therefore be considered to conservatively predict minimum flow rates and can, therefore, be used for conservative estimation of reactor depressurization rates. The throat size of the DPV is not expected to change. Discharge lines, if used, will be designed to keep the outlet pressure at or below 40% of the inlet pressure, assuring that critical flow is maintained; therefore, the flow characteristics of valves in service will be similar to those demonstrated in tests of the prototype.

RAI Number: 950.4

Question:

Provide the decay heat curves associated with SBWR fuel at several state points in the fuel cycle, if different from the standard ANS curves.

GE Response:

The SBWR decay heat curves are based on the ANSI/ANS-5.1-1979 standard for decay heat power in light water reactors.

RAI Number: 950.5

Question:

For the TRACG input deck that was used in the Chapter 15 analysis of the SBWR Standard Safety Analysis Report (SSAR), provide a noding diagram, input deck of TRACG, and an input description to decipher the information.

GE Response:

All the SBWR TRACG inputs for Chapter 15 analyses are currently being updated and verified. They will be transmitted as a response to this RAI before the end of 1993.

RAI Number: 950.6

Question:

Provide the point kinetics parameters for the equilibrium fuel cycle of the SBWR at several state points.

GE Response:

Point kinetics reactivity data is provided in the SSAR in Chapter 4, Appendix D. This data is at the limiting conditions for stability calculations. GE is separately providing reactivity data on computer tape in response to RAI 440.1 through 440.5 which provide sufficient information to determine reactivity at various state points.

RAI Number: 950.7

Question:

What is the flow area for the fully opened check valve in the condensate return line of the isolation condenser? What are the flow characteristics of this check valve, i.e., pressure losses, area function of gate, and activation set points?

GE Response:

A check valve is not included in the condensate return line of the isolation condenser for the SBWR. The valving arrangement is shown on the ICS P&ID, Figure 21.5.4-1 of the SBWR SSAR.

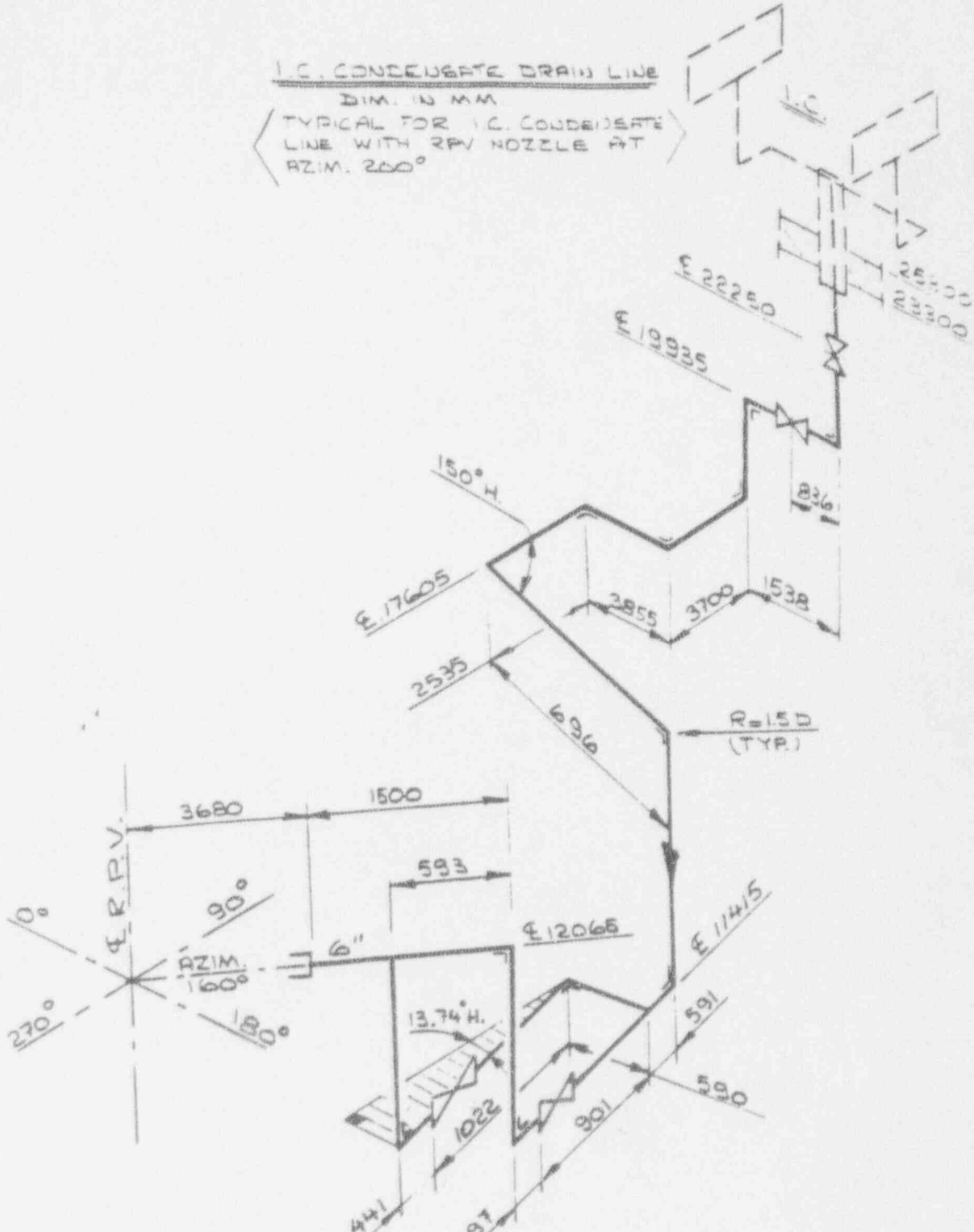
RAI Number: 950.8

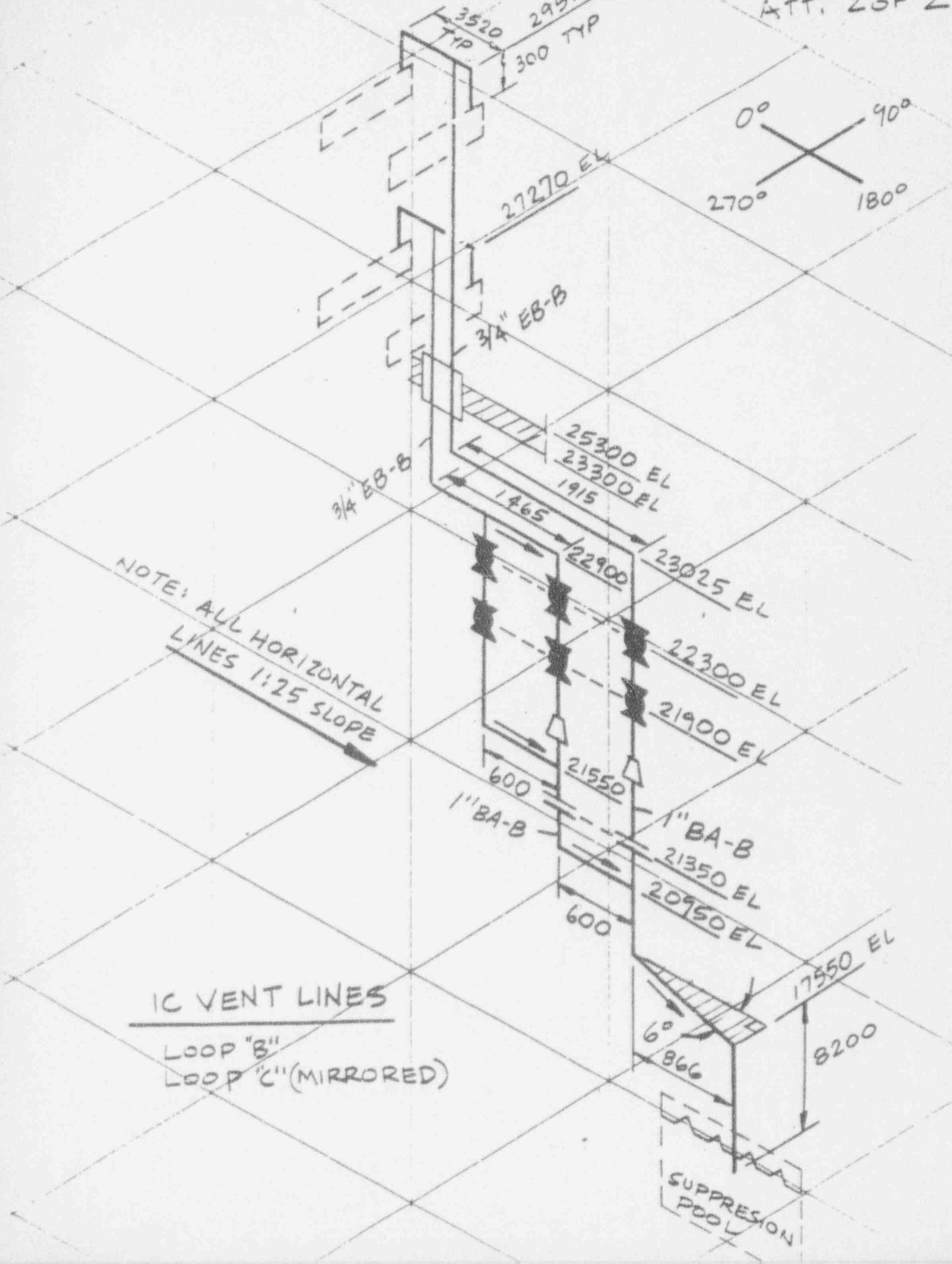
Question:

Provide a drawing showing the total pipe length and elevation difference between the isolation condenser exit and entrance to the reactor pressure vessel for the condensate return line and the non condensable vent line.

GE Response:

Attached is sketch 920828/4 which shows a typical drain line ("condensate return line")for (1) of the (3) isolation condenser loops. Also attached is a sketch ["IC Vent Lines (Loop B)"] that shows a typical non condensable vent line. These sketches show typical line lengths, fittings, elevations and angles.


I.C. CONDENSATE DRAIN LINE
DIM. IN MM.
TYPICAL FOR I.C. CONDENSATE LINE WITH RPV NOZZLE AT AZIM. 200°
I.C.
25300
23300
℄ 22250
℄ 19935
836
150° H.
℄ 17605
2855
3700
1538
2535
6966
R=1.5D (TYP.)
3680
1500
593
℄ R.P.V.
0°
90°
AZIM. 160°
270°
180°
6"
℄ 12066
℄ 11415
13.74° H.
591
590
1022
901
441
497



IC VENT LINES

LOOP "B"
LOOP "C" (MIRRORED)

RAI Number: 950.9

Question:

What is the density (in kg/m_) of the sodium pentaborate solution inside the accumulator of the standby liquid control system?

GE Response:

Due to the range of permissible conditions for the concentration, temperature, and volume of the sodium pentaborate solution, the density can vary somewhat. Based on the maximum specified solution concentration of 13.8 weight percent, a maximum upper bound of specific gravity, equal to 1.07, can conservatively be established. This implies a maximum density of 1.07 g/cm^3; which translates to 1.07 x 10^{-3} kg/m^3.

RAI Number: 950.10

Question:

Provide the exact radial and axial locations of the injection ports of boron from the spargers into the core.

GE Response:

The Standby Liquid Control (SLC) injection ports or nozzles inject into the core region at the following locations:

Radial position	=	2575 mm from the centerline of the core	
Axial positions	=	4000 mm	above vessel 0
		4400 mm	above vessel 0
		4800 mm	above vessel 0
		5200 mm	above vessel 0

There are four sets of injection ports or nozzles located at four azimuthal positions, 90° apart. The azimuthal positions are 45°, 135°, 225° and 315°.

RAI Number: 950.11

Question:

What is the design pressure for the condensate return to the reactor pressure vessel?

GE Response:

The design pressure for the IC condensate return line is 1250 psig.

RAI Number: 950.12

Question:

Provide activation criteria of the vent for noncondensable gas removal from the system isolation condenser to the suppression pool.

GE Response:

The activation criteria of the vent for non-condensable gas removal from the Isolation Condenser (IC) system to the suppression pool is defined on sheets 7 through 12 of the Logic Diagram, Figure 21.7.4-5 in conjunction with ICS P&ID, Figure 21.5.4-1 of SBWR SSAR document 25A5113 Rev. A. As shown on the ICS P&ID, there is one vent line connection to the suppression pool with branch lines to the top and bottom headers of the IC heat exchanger.

The branch line to the top header has two valves in series (F007 & F008) which are remote-manually operable under the conditions shown on sheets 7 and 8 of the Logic Diagram. These conditions allow the operator to open the valve(s) when the reactor is not in the run mode (to aid the initial filling of the IC with condensate during startup) or during operational readiness tests with the series valve closed, or during IC operation when the condensate drain valves(s) are open.

The branch line to the bottom header has two parallel sets of valves in series. Both sets have the same remote-manual control features as described above for valves F007 & F008, as shown on sheets 9 through 12 of the Logic Diagram. In addition, one of the two valve sets in series (F009 & F010) also open automatically following a time delay after the IC is started by opening the condensate drain valves if reactor pressure is also above normal after the time delay. The time delay is to be set so that venting does not occur during the initial reactor pressure transient that may occur during reactor isolation before the IC is fully effective in reducing reactor pressure. The purpose of the automatic venting is to extend the effectiveness of the IC if long term (~ 72 hours) non-condensable gas buildup impairs its ability to limit reactor pressure.

In summary, the activation criteria for IC venting to the suppression pool is as follows:

1) Venting is not needed to limit reactor pressure during IC operation.

2) Remote-manual venting means are provided so the effectiveness of the IC may be improved to lower reactor pressure.

3) Automatic venting is provided to extend long term (~70 hours) IC capacity if non-condensable gas buildup occurs.

RAI Number: 950.13

Question:

Provide the flow-dependent loss coefficients for single-phase flow entrance to the core, two-phase flow across the fuel bundle spacers, and two-phase flow exit losses from the core and riser.

GE Response:

Response to NRC RAI 950.13 and Purdue question 4c.

Area (m2)	Irreversible loss coefficient (dimensionless, from TRAC)	Description of loss
FA	FRICP	
2.992000E-03	9.6E-01	(inlet orifice, 3.84 for peripheral channels)
1.011000E-02	8.450000E+00	(lower tie plate)
1.011000E-02	1.244000E+00	(per spacers for 5 spacers)
9.188000E-03	6.290000E-01	(upper tie plate)
5.350000E-04	1.500000E+00	(approximation of channel to bypass flowpath as flow squared loss coefficient)

RAI 950.13 continued: This also is provided in response to a previous NRC question, August 24, 1992:

Response to NRC question 2c			
Location	Inside Channels	Bypass (outside channels) Rod Position:	
		Inserted	Withdrawn
Flow area (m^2)	7.4	5.6	5.0

Response to NRC question 2e		
Flow Path	Pressure Drop (Pascal)	Loss Coefficient (K,dimensionless)
Across Lower Plenum	5240	K=.9 per CRD guide tube row, 83% area obstructed K=.4 per CRD housing row, 65% area obstructed
Core Plate	6400	A/ K=.036 m^2
Core	48200*	Multiple 2 phase losses
Top Guide	600	K=1, associated area=1.7 m^2
Chimney	31700*	K=0.
Steam Separators	26300*	DP=0.083 ~~0.036~~ Q_t^2+8.3 where: Q_t=2 phase volumetric flow, per separator (ft^3/hr divided by 1000) DP=pressure drop, ft of 2 phase mixture
Steam Dryer	2500.	K=165. associated area=28.8 m^2

*Pressure drop includes hydrostatic pressure of 2 phase fluid

RAI Number: 950.14

Question:

Provide the following data on the feedwater pump:

a. pump head and torque characteristic curves

b. feedwater pump head and condensate booster pump head

c. moment of inertia of both pumps

d. feedwater pump speed at rated conditions

e. controllers connected to the electric pumps and their effect on the pump

GE Response:

The maximum feedwater runout capacity with a dome pressure of 7.444 MPa (1065 psig) shall be less than or equal to 180 percent of rated but shall be greater than or equal to 155 percent of rated. The change of flow below the pressure specified above shall be between 29.0% flow/MPa (0 2% flow/psi) and 14.5% flow/MPa (0.1% flow/psi). On loss of power to the pump, the assumed flow coastdown is to 0% flow over five seconds.

RAI Number: 950.15

Question:

Describe the feedwater runback feature of the SBWR, i.e., the related controllers and flow conditions.

GE Response:

The feedwater runback occurs under the following conditions:

1) The Reactor Feedpumps (RFPs) are run back to minimum speed if reactor water level reaches Level 8. This trip is generated by the Feedwater Control System (FWCS) which outputs zero demand upon vessel level reaching Level 8. A zero demand to the RFPs results in feedpump runback at the maximum allowable rate to minimum speed.

2) The RFPs are run back to minimum speed on receipt of an Anticipated Transient Without Scram (ATWS) runback trip signal from the Safety System and Logic Control (SS&LC). This trip is generated by the SS&LC and goes directly to the RFPs thus bypassing the FWCS controllers. The ATWS runback trip signal results in feedpump runback at the maximum allowable rate to minimum speed.

RAI Number: 950.16

Question:

Provide plots of the TRACG predictions for the steam and condensate flow rate from the isolation condensers during the main steam isolation valve closure anticipated transient without scram with fine motion control rod drive (reference SBWR SSAR Figures 15.8-2 and 15.8-3.

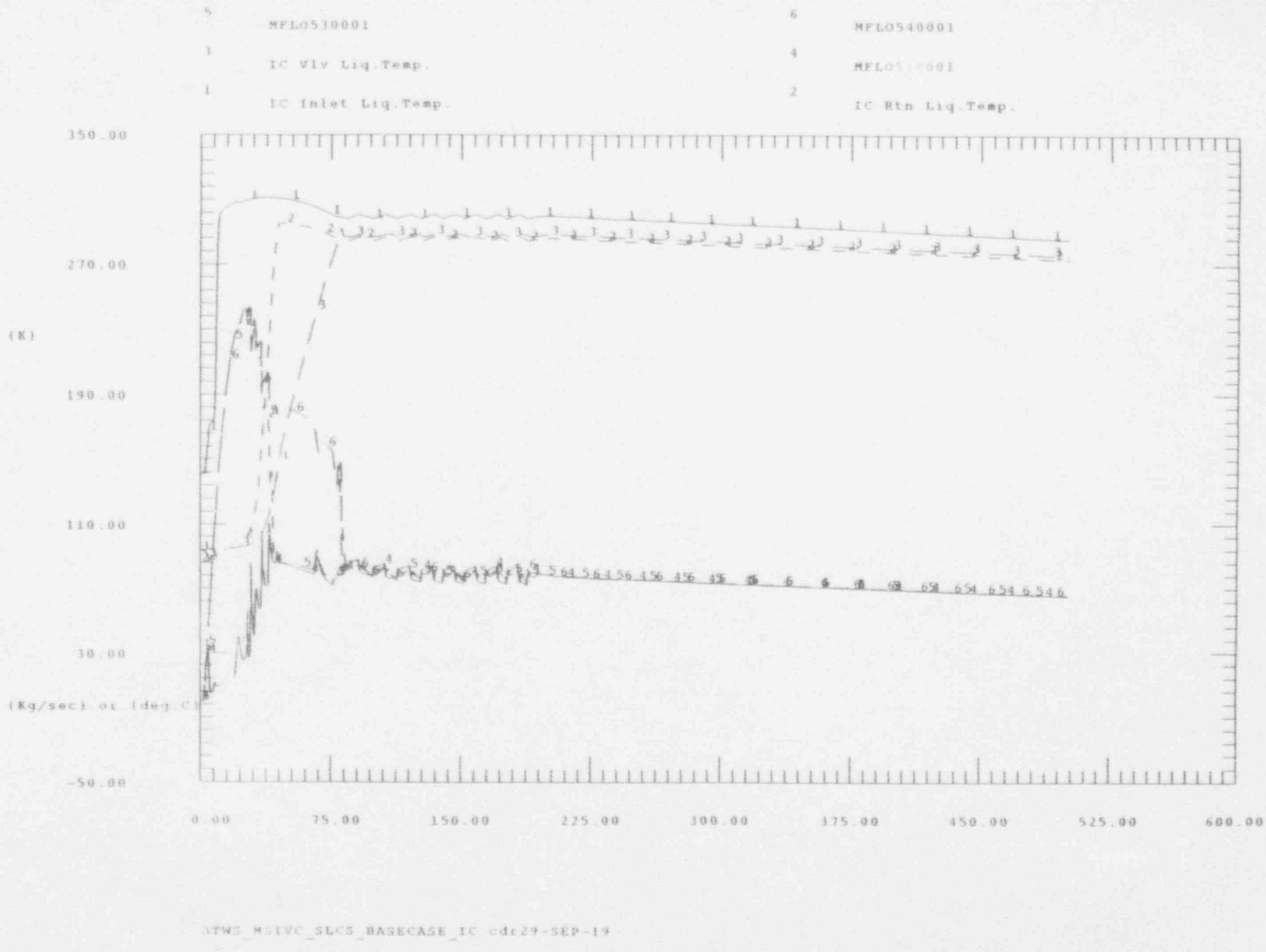
GE Response:

The attached 3 figures show the performance of the IC system during the Main Stream Isolation Valve Closure Anticipated Transient Without Scram (MSIVC ATWS). The figures referenced in the RAI are the case with Fine Motion Control Rod (FMCRD) run-in, and Standby Liquid Control System (SLCS) boron injection, data is provided for both cases. A long term and short term plot is provided for the SLCS case. The plots show the draining transient of the Isolation Condenser (IC). The flowrates all initially increase as the drain valve opens. The mass flow in the upper manifold decreases first, when the the short length of supply line with is initially filled with condensate drains, and the flow changes to steam. Later, when the tube bundle has drained, and steam flow and condensate flow begins, its flow drops off. Later still, the lower manifold drains and it's mass flowrate drops. In the long term the system equilibrates in steady state operation, and the 3 flowrates are equal. The figures also show the fluid temperatures and reflect the change from intially cold condensate to saturated steam or liquid. Note that the IC performance is basically the same between the two cases. The IC initiation during ATWS is similar to the milder transients (load rejection, loss of feedwater and isolation with scram.)The flowrate on the attached figures are encoded:

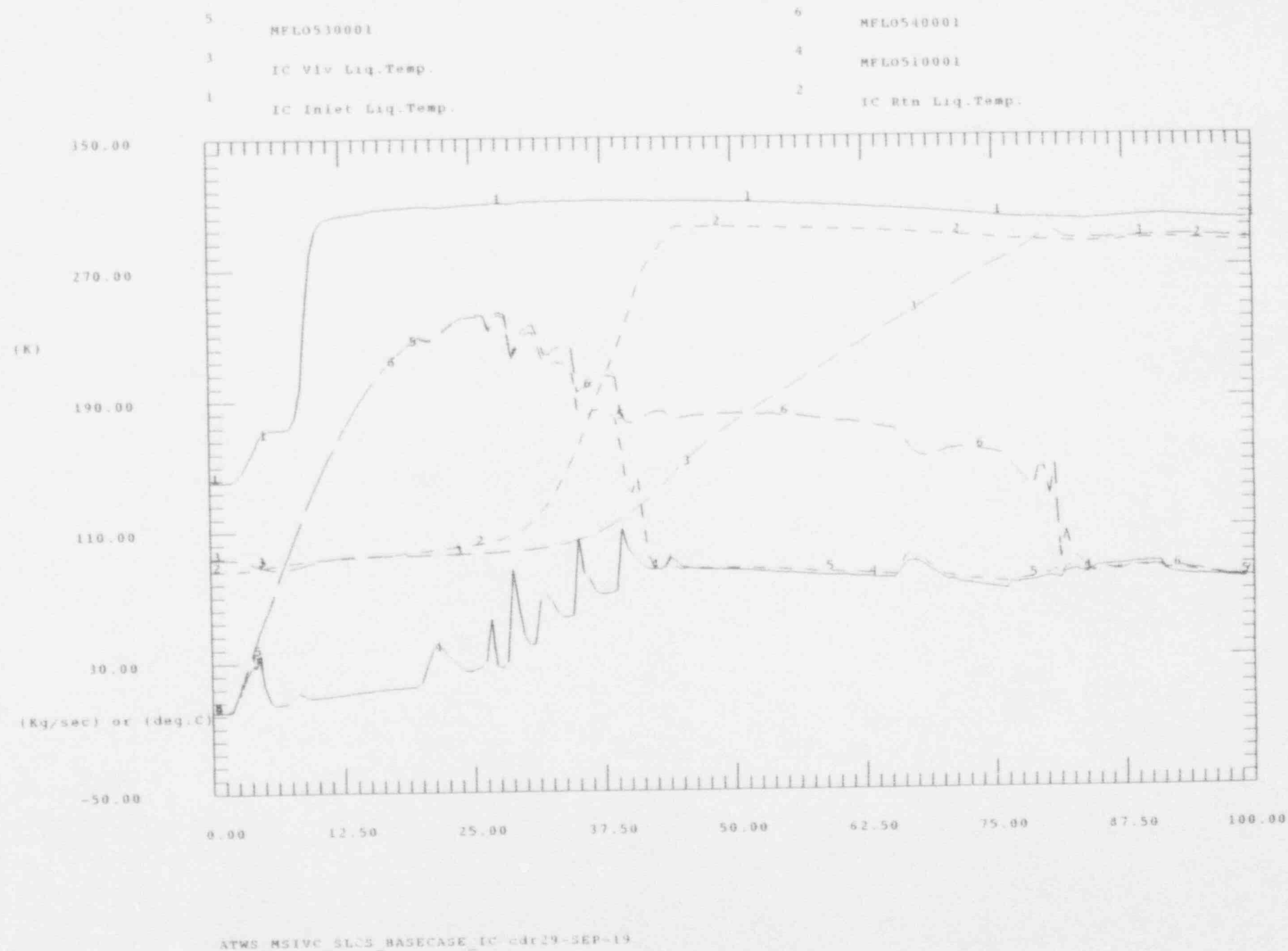
MFL51001 Mass Flow (kg/sec) into the upper manifold from the supply pipe

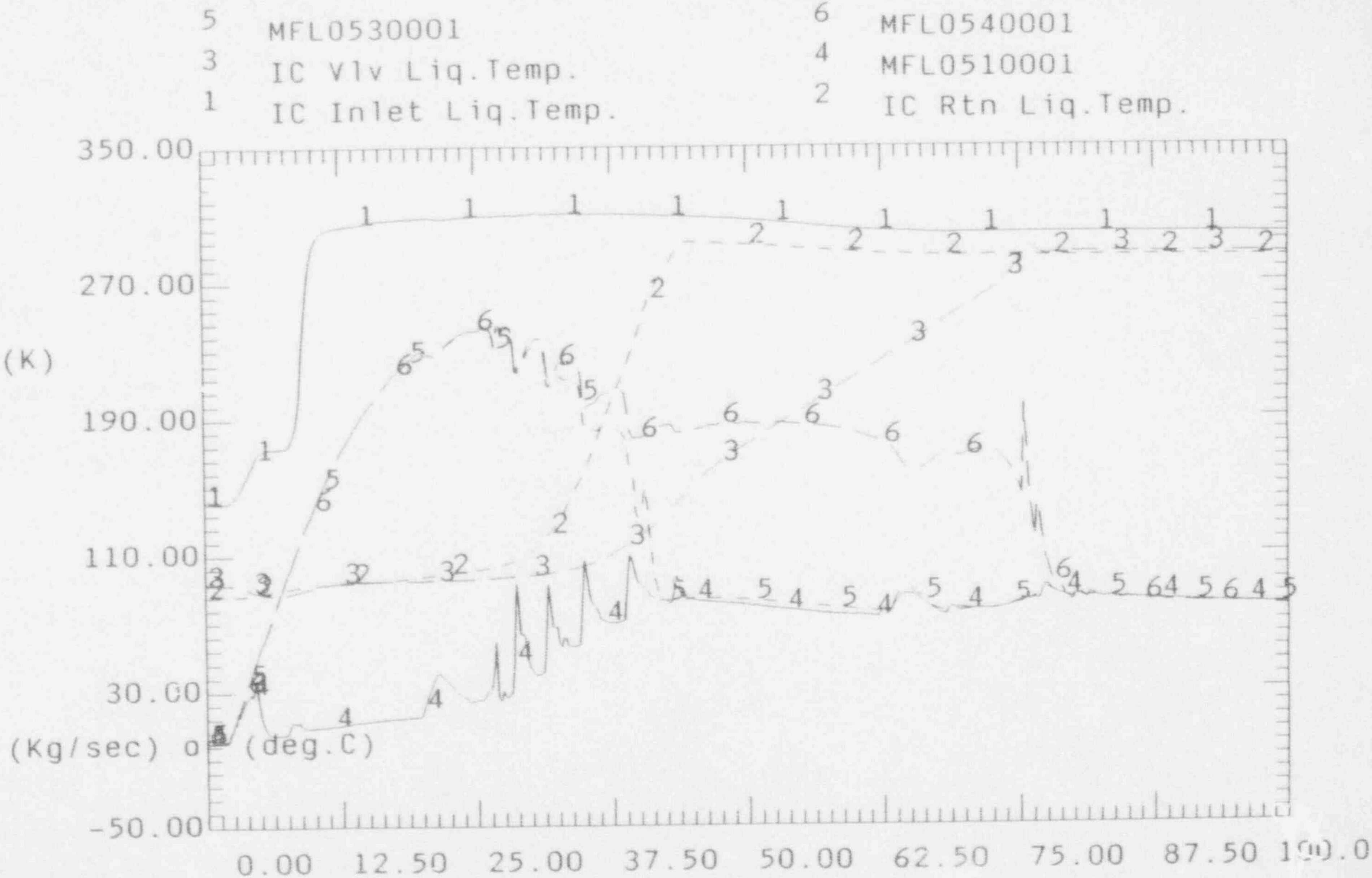
MFL53001 Mass Flow into the lower manifold from the tubes.

MFL54001 Mass Flow from the lower manifold into the return line.



5 MFLO530001
3 IC Vlv Liq.Temp.
1 IC Inlet Liq.Temp.
6 MFLO540001
4 MFLO5
2 IC Rtn Liq.Temp.
350.00
270.00
190.00
110.00
30.00
-50.00
(K)
(Kg/sec) or (deg.C)
0.00
75.00
150.00
225.00
300.00
375.00
450.00
525.00
600.00
ATWS_MSIVC_SLCS_BASECASE_IC cd:29-SEP-19


5 MFLO530001
3 IC Vlv Liq.Temp.
1 IC Inlet Liq.Temp.
6 MFLO540001
4 MFLO510001
2 IC Rtn Liq.Temp.
350.00
270.00
190.00
110.00
30.00
-50.00
(K)
(Kg/sec) or (deg.C)
0.00
12.50
25.00
37.50
50.00
62.50
75.00
87.50
100.00
ATWS_MSIVC_SLCS_BASECASE_IC cdr29-SEP-19



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ATWS_MSIVC_FMCRD_BASECASE_IC cdr30-SEP-1

RAI Number: 950.21

Question:

To facilitate the comparison between the GIRAFFE test data the RELAP5 predictions, provide a digital tape of the GIRAFFE data so that the data can be plotted one-to-one against the RELAP5 predictions.

GE Response:

The GIRAFFE data are provided in the "Test Results" section of Reference 1.

Reference

1. K. M. Vierow, "GIRAFFE Passive Heat Removal Testing Program", NEDC-32215P, Rev. 0, Class 3, GE Nuclear Energy, San Jose. CA, June, 1993.

RAI Number: 950.22

Question:

Provide a description of the May-Witt decay heat curves.

GE Response:

The May-Witt decay heat curve is listed in Table 4.3-1 and described in Ref. 2, a copy of which is attached. The use of the May-Witt curve is justified on sheet no. 2 of this memo, and the calculation method is provided on sheet no.3 and 4.

All figures and page numbers referred to are from Reference 1.

References

1. K. M. Vierow, "GIRAFFE Passive Heat Removal Testing Program", NEDC-32215P, Rev. 0, Class 3, GE Nuclear Energy, San Jose, CA, June, 1993.
2. D. Gibson, "Radioactive Decay Heat Power Data", GE Nuclear Energy Division document 22A5792 Rev. 1, MFL No. A12/A13-6451, July, 1978.