March 5, 1997

See Reports

LICENSEE: Commonwealth Edison Company (ComEd)

FACILITIES: Dresden Station, Units 2 and 3

SUBJECT: SUMMARY OF THE MEETING CONCERNING THE EMERGENCY TECHNICAL SPECIFICATION CHANGE REQUESTING THE USE OF CONTAINMENT OVER PRESSURE TO COMPENSATE FOR A NET POSITIVE SUCTION HEAD DEFICIENCY FOR THE EMERGENCY CORE COOLING PUMPS

On January 16, 1997, the staff met with ComEd to discuss an emergency Technical Specification (TS) change involving the use of containment over pressure to make up for a deficiency in net positive suction head (NPSH) of the Emergency Core Cooling Pumps (ECCS). A list of attendees is provided as Enclosure 1.

The objective of the meeting was to discuss the licensee's response to the staff's January 15, 1997, request for additional information (RAI). The major topics discussed were the NPSH calculations, containment over pressure analysis and ECCS pump cavitation issues. A copy of the licensee's presentation is included as Enclosure 2.

Original signed by:
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Office of Nuclear Reactor Regulation

Docket Nos. 50-237 and 50-249

Enclosures: 1. List of Attendees
2. Licensee's Presentation

cc w/encls: see next page

<u>DISTRIBUTION</u> w/encl 1 & 2: Docket PUBLIC PD3-2 r/f OGC 015-B18 ACRS T2-E26

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Enclosure 1

50-237 CEC DRESDEN 2

LICENSEE'S PRESENTATION

REC'D W/LTR DTD 03/05/97....9703070103

The Use of Containment Overpressure in NPSH Calculations for Dresden/Quad Cities Stations

Introduction

Recent engineering efforts involved in the support of containment strainer replacement modifications, as well as inquiries received during the Dresden ISI have resulted in new information as well as new concerns regarding NPSH calculations for ECCS pumps during LOCA events. Specifically, the following items have become concerns:

1) Review of Mark I strainer modification documents for QC and Dresden have revealed that the differential pressure that would be expected at design flow rates is approximately 5.8 feet, vs the 1 foot value shown on the original containment drawings and used in support of ECCS pump NPSH predictions.

2) ISI questions raised concern regarding the NPSH performance of ECCS pumps during the initial phase of a LOCA, since the pumps would be expected to be operating at or near runout conditions following vessel depressurization, and would not be throttled by operator actions until 10 minutes into the event.

There are a number of issues specifically regarding Dresden LPCI/CCSW pump and heat exchanger performance that require reconstitution of the containment analysis to resolve. This effort has been in progress for several months, with a significant analytical basis nearing completion. Licensing amendments are in preparation to document the new analysis and benchmarks to allow replacement of the existing analysis.

The purpose of this submittal is to document the justification for the use of containment overpressure in current NPSH evaluations. 10CFR50.59 evaluations of the above concerns have determined that an unresolved safety question (USQ) exists specifically regarding the use of overpressure in these evaluations at Dresden. For Dresden, the question is whether any overpressure can be applied. Quad Cities is still performing a 10CFR50.59 evaluation and has not concluded whether or not an USQ exists at this time.

Description of Post-LOCA Plant Response

Both Dresden 2/3 and Quad Cities 1/2 are BWR 3/4 designs with Mark I containment systems. The limiting design basis accident with respect to containment thermal response is the DBA LOCA, which is a double ended break of a recirculation system suction pipe. This event yields a rapid vessel depressurization, fuel uncovery and places maximum demands on the ECCS systems. Following the blowdown, the vessel is reflooded to approximately two thirds core height due to injection by the Low pressure coolant injection (LPCI/RHR) and Core Spray (CS) pumps. At the 10 minute time frame, the operators are trained to initiate suppression pool cooling. For the limiting case of LOOP plus failure of a D/G, this would lead to one CS pump maintaining vessel level, one LPCI/RHR pump in the pool cooling mode, and 2 containment cooling service water pumps (CCSW) supplying the LPCI HX. For Quad Cities, only one service water pump would be started in this condition due to the higher horsepower requirements of their RHRSW pumps and limitations imposed by diesel loading capacity. The ECCS system performance, containment parameters, core power, and containment heat exchanger performance are essentially identical between the plants. Key parameters are shown in Table 1.

Containment Pressure Response

This event yields a rapid containment pressure rise initially due to the transport of non-condensibles from the drywell to the wetwell, and achieves a peak drywell pressure early in the event due to the differential pressure developed across the vent header system. The initial suppression pool heatup is approximately 50 F due to the effects of the blowdown and pool temperatures of approximately 150F are expected at 10 minutes into the event. The suppression pool temperature would continue to rise until the heat load of the containment cooling heat exchanger matched the heat input to the containment due to decay heat, latent heat from the vessel, feedwater addition, and pump heat. This occurs between 3 to 6 hours, depending on the availability of pumps for containment cooling. Maximum temperatures reached range from 163 F for a "complete" pool cooling complement (2 LPCI/2 CCSW) to 179 F for a "minimum" case of 1 LPCI/1 CCSW. Dresden's current design basis peak suppression pool temperature is 170 F for a 1 LPCI/2 CCSW pump configuration.

The pressure response of the drywell and wetwell are coupled over the long term, and are dependent on a number of factors. The key factors determining this response are:

1. Mixing fraction of fluid spilling from the break with drywell atmosphere. This affects the short term pressure response since the break fluid rapidly becomes subcooled following reflood, and would act to reduce pressure drywell pressure by condensing steam.

2. Manual Initiation of Containment Spray. This has a dominant effect on the pressure response of the coupled system. Initiation of containment spray in the 10 minute time frame would lead to rapid quench of steam in the drywell and return of non-condensibles to the drywell via the vacuum breakers. This reduces the system pressure and effectively sets the temperature of both the drywell and the wetwell airspace. In the long term, the spray temperature in the wetwell airspace effectively determines the containment pressure response.

3. Heat transfer to containment liner. This affects the short term pressure by condensing more steam in the drywell. It tends to have minor effect on the long term response, being overwhelmed by the action of containment spray. (Containment heat sinks have historically been ignored in BWR containment calculations).

4. Initial conditions in containment. The initial conditions of temperature and particularly relative humidity set the total non-condensible inventory. High initial temperatures and humidity lead to the lowest non-condensible inventory, and have a dramatic effect on the long term pressure response of the system.

5. Containment Cooling flow rates. The flow rates of LPCI/RHR and CCSW determine the effectiveness of the heat exchanger, which determines the peak pool temeperature achieved. In addition, the flow rates determine the spray temperature, which has a direct impact on the containment pressure.

Description of New Calculations

As indicated above, a series of new containment calculations has been performed for Dresden to address a number of design basis issues. These calculations were performed by General Electric, using the SHEX computer code. A number of cases were performed to identify the limiting scenario, relative to ECCS NPSH calculations, selected based on reaching the maximum pool temperature with lowest containment pressure. The new calculations are based on ANS 5.1-1979 decay heat standards and include all appropriate heat sources including FW mass energy and ECCS pump heat. In addition, the new analyses employed assumptions consistent with NRC Information Notice 96-55, specifically addressing the addition of heat sinks. The new containment calculations employ a methodology that is intended to provide the lowest pressure in the long term. These include:

1. Minimizing the non-condensibles present at initiation of event.

2. Initiating containment spray at 10 minutes and continuing for duration of event.

3. Including the effects of heat conduction to containment surfaces, based on Branch Technical position CSB 6-1.

4. Use of bounding values for drywell mixing ratio, to predict the lowest pressures both in the short term as well as the long term.

5. Calculation of variety of ECCS flow rates and pump combinations to ensure that the potential range of ECCS flows has been bounded.

Results of New Calculations

When combined with previous analyses performed for both Dresden and Quad Cities, a clear picture of the most limiting NPSH scenarios results. Some of the key results identified are:

1. The scenarios that employ a single LPCI in conjunction with two CCSW pumps yield the highest suppression pool temperatures with the lowest containment pressures. Previous studies were based on 2/2 or 1/1 combinations, and achieved higher pressures, even with lower suppression pool temperatures.

2. The coupled analyses demonstrate that at suppression pool temperatures of 171 F or greater, at least 2.9 psig overpressure is available.

3. The containment pressure during the short term, (eg. first 10 minutes) has been demonstrated to be at least 5.5 psig, even with worst case assumptions applied.

4. While different decay heat standards and heat exchanger performance predictions are applied in the new calculations, the peak containment temperatures being predicted are consistent with and fall near the original design basis temperature predictions. The pressure response is not a function of decay heat models, but is primarily only effected by the pool temperature and heat exchanger performance.

A comparison calculation of containment long term pressure based on ideal gas law models was also generated to confirm that the trend and overall results predicted by the new containment analyses is appropriate. This calculation supports the conclusions that the 1/2 cases will provide bounding pressure response as well as demonstrating that the GE calculations are yielding conservatively low values of containment pressure, relative to the suppression pool temperature predicted. This calculation is attached as an appendix to this document. These analyses were required to be performed in order to minimize pressure in the suppression pool. The data required to support the existing design basis of Dresden and Quad Cities is not available and therefore, the new data must be utilized. The existing containment responses for Dresden and Quad Cities will remain until they are further amended. Dresden is preparing a submittal that will change its Design Basis Containment Response. This submittal should be prepared by January 24, 1996.

Conclusions

Based on the results of new calculations, it is clear that significant containment overpressure conditions would exist, both in the short term (<10 minutes) as well as the long term post-LOCA period. The new calculations have been performed to minimize the extent of overpressure that would exist in both periods, and support the conclusion that overpressure would be available and can be employed to demonstrate adequate ECCS NPSH performance.

While the new containment calculations have not been reviewed and approved by NRC to date, they are more appropriate with respect to the prediction of minimum containment pressure both in the long and short term post-LOCA periods, than are the original design basis calculations. They result in peak pool temperatures near to but slightly above the original calculated values, and predict containment overpressures of several psi, even with the incorporation of currently recommended analysis assumptions to minimize overpressure. Therefore, the conceptual use of containment overpressures in the ranges indicated in the new analyses appears warranted in the performance of ECCS NPSH calculations.

Table 1. **Comparison of Key Containment Parameters for Dresden and Quad Cities**

Equipment/Parameter	**Dresden 2/3**	**Quad Cities 1/2**
Core Licensed Power	2527 MWT	2511 MWT
LPCI/RHR pump flow rate	4500 gpm rated	4500 gpm rated
CS pump flow rate	4500 gpm rated	4500 gpm rated
CCSW/RHRSW pump flow	3500 gpm/pump	3500 gpm/pump
LPCI/RHR HX original design condition	105 MBTU at 10700 gpm LPCI/ 7000 gpm CCSW 165F pool 95 F service water side	105 MBTU at 10700 gpm RHR/ 7000 gpm RHRSW 165F pool 95 F service water side
Drywell Free Volume	158236 cuft	158236 cuft
Wetwell Free Volume	120097 cuft	119963 cuft
Wetwell Water Volume	112000 cuft	111500 cuft

Calculation Title Page

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☒ Safety Related ☐ Regulatory Related ☐ Non-Safety Related

Calculation Title:

Dresden LPCI/Core Spray NPSH Analysis
Post-DBA LOCA: GE SIL 151 Case Short-Term

Station/Unit: Dresden Units 2 and 3 System Abbreviation: LPCI/CS

Equipment No.: 2(3)-1502A/B/C/D
2(3)-1401A/B
Project No.:

Rev: 0 Status: QA Serial # or CHRON # NA Date:

Prepared by: HARRY PALAS Date: 1/8/97

Revision Summary:

Electronic Calculation Data Files Revised:

RING.PLL
RING.PLU

4L512C58.PLU
4L512C55.PLU
4L512C50.PLU

Do any assumptions in this calculation require later verification? ☐ Yes ☒ No

Reviewed by: J. W. Dromley Date: 1/8/97

Review Method: DETAILED REVIEW Comments (C, NC or CI): NC

Approved by: Date: 1/9/97

Calculation Revision Page

Calculation No.: **DRE96-0002** Page 2 of 11

Rev: **0** Status: QA Serial # or CHRON # **NA** Date:_________

Prepared by:____ Date:_________

Revision Summary:

Electronic Calculation Data Files Revised:

Do any assumptions in this calculation require later verification? ☐ Yes ☐ No

Reviewed by:____ Date:_________

Review Method: Comments (C, NC or CI): ______

Approved by:____ Date:_________

Table of Contents

1.0 PURPOSE/OBJECTIVE

This calculation examines the Net Positive Suction Head (NPSH) available to the Dresden LPCI and Core Spray (CS) pumps in the first 600 seconds following a DBA-LOCA. Specifically, the GE SIL 151 case will be evaluated, which postulates a failure of the LPCI Loop Select logic. This case is bounding since it results in all 4 LPCI and 2 CS pumps operating at above rated flows (maximizing pump suction losses), with the LPCI pumps injecting into a broken reactor recirculation loop (minimizing flow to reactor for Peak Clad Temperature considerations). Due to the high flows anticipated, the Core Spray pumps may cavitate, resulting in reduced system flow. This reduced flow will be calculated and compared to the minimum flow required of the CS system. This calculation will be performed using a reduced initial torus temperature of 75°F and a torus pressure of 2 psig. The results of this calculation will be used to support a Dresden Exigent License Amendment.

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

The minimum suppression pool pressure required to satisfy LPCI and CS pump NPSH requirements will be determined under short-term post-LOCA conditions. If the pool pressure required is greater than the pressure available, then the potential exists for the pumps to cavitate, resulting in reduced flows. A minimum Core Spray system flow of 10,552 gpm (5276 gpm per pump) is required for the first 200 seconds post-accident to ensure the Peak Clad Temperature (PCT) remains below 2200°F, while a nominal Core Spray flow of 4500 gpm per pump is acceptable beyond 200 seconds (Ref. 19).

NPSH Required (NPSHR) curves for the LPCI/CS pumps are provided on the original vendor pump curves (Refs. 12, 13). These NPSHR curves represent the point at which a 3% reduction in pump developed head has occurred. Cavitation tests were performed on this pump model by the vendor at various flow rates (Ref. 16). The test data indicates that the pump remains stable for several feet below the NPSHR value, which is expected, before the pump head collapses (full cavitation). Based on the flow rates at which the pumps were tested, it is possible to develop a reduced NPSHR curve that represents the point at which full cavitation has been achieved, as shown in Figure 1 (Refs. 17, 18). Thus, given a known set of conditions (temperature, pressure, level), the reduced flows at which the pumps will operate can be determined as follows:

1. Assume initial operating pump flow rate (maximum pump flow).
2. Determine the suppression pool pressure required to satisfy the pump's reduced NPSH requirements (Fig. 1) using the assumed pump flow and the expected torus temperature at 200 seconds post-LOCA (Ref. 1).
3. Reduce pump flow estimate until the pool pressure required equals the minimum pool pressure available (Assumption 5). It is at this flow that the pump will be in full cavitation and the total developed head (TDH) will drop off. Since this drop-off is essentially vertical, the pump curve will intersect the system curve at this flow, i.e., this is the flow at which the system will operate.

3.0 ASSUMPTIONS

1. LPCI/CS pump friction losses (excluding strainer losses) were developed for a single flow case using a FLO-SERIES model of the Dresden ECCS ring header and pump suction piping (Ref. 5). This model was then run at the various LPCI/CS pump combinations and flows as required to support the cases evaluated in this calculation (Attachment A). The model that was developed uses clean, commercial steel pipe. In order to compensate for the increased loss due to the effects of aging, the resulting friction losses from the model were increased by 15%. This is consistent with discussions provided in References 14 and 15.

2. To account for strainer plugging, one of the four torus strainers is assumed 100% blocked, while the remaining three strainers are assumed clean. While the torus strainers are not included in the FLO-SERIES model discussed in Assumption 1, blocking a strainer translates to blocking a torus-to-ring header entrance leg. This is accomplished in the model by closing one of the torus legs (Torus 1-4). Based on previous sensitivity analyses, Torus-4 is chosen for maximum effect on LPCI and Core Spray suction losses.

3. Reference 3 developed LPCI system resistance curves and expected maximum operating flows for Unit 2. It is assumed that the Unit 3 results are similar based on identical pumps and elevations, and similar discharge piping layouts.

4. Reference 2 developed Core Spray system resistance curves and expected maximum operating flows utilizing actual Core Spray pump performance. For the Core Spray loop with the least system resistance, the original vendor pump curve was plotted with the system curve developed in Reference 2. The operating point was determined to be the same as that developed in the calculation. Therefore, the maximum Core Spray system flow of 5800 gpm used in Design Input 1 is appropriate.

5. For the purposes of this calculation, a suppression pool pressure of 2 psig will be assumed. This is consistent with the discussion provided in Dresden UFSAR Section 6.3.3.4.3, in which the presence of 2 psig in the drywell is expected since this is one of the signals which initiates the ECCS. This assumption is conservative based on the following.

   - The Dresden post-LOCA containment pressure response (Dresden UFSAR Figure 6.2-19) indicates an expected suppression pool pressure of >15 psig at 200 seconds, and >10 psig at 600 seconds.
   - The Quad Cities post-LOCA expected suppression pool pressure is >20 psig at 200 seconds and 600 seconds (Quad Cities UFSAR Figure 6.2-16).
   - Reference 1 indicates a minimum expected pool pressure of approximately 20 psig at 200 seconds, and 5.5 psig at 600 seconds.

6. While no Dresden-specific short-term containment temperature response exists, a reasonable estimate can be made using the following existing analyses:

   - In Reference 1, the Dresden post-LOCA suppression pool temperature at 200 seconds is <u>138°F</u>, and at 600 seconds is <u>150°F</u>, based on a 95°F initial pool temperature. These values were developed using modern analysis techniques, including ANS 5.1 decay heat model, feedwater flow and addition of pump heat.
   - The temperature profiles for Quad Cities are available and are considered representative for use at Dresden, based on plant similarities with respect to containment size, core power, and reactor operating parameters. The Quad Cities containment response (Quad Cities UFSAR Figure 6.2-18) indicates the pool temperature at 200 seconds is 144°F, and at 600 seconds is 147°F, based on a 90°F initial pool temperature. These values were developed using original analysis techniques, including the May-Witt decay heat model, no feedwater flow and no pump heat added. If corrected to a 95°F initial pool temperature (assuming a one-to-one short-term temperature relationship), these values conservatively bound the Reference 1 values listed above.

   Therefore, for the purposes of this calculation, the more conservative Quad Cities temperatures will be used.

7. It is assumed that a reduction in initial suppression pool temperature will result in a corresponding linear reduction in the short-term pool temperature response, since pool cooling is not active. Given this assumption, therefore, for a reduced initial pool temperature of 75°F (15°F reduction from Quad Cities values based on 90°F initial torus temperature), the pool temperature at 200 seconds post-LOCA is 129°F, and at 600 seconds is 132°F.

8. GE SIL 151 includes a case of all 4 LPCI pumps injecting into both reactor recirculation loops simultaneously, with one loop broken. While it is expected that this case may result in slightly higher LPCI pump flow rates, a significant amount of water will be injected into the reactor through the intact loop. Therefore, any reduction in Core Spray system flow due to cavitation below the minimum required flow will be made up by the LPCI flow injecting into the reactor. Therefore, it is expected that the PCT will not be challenged in this case.

4.0 DESIGN INPUTS

1. Maximum LPCI and Core Spray pump flows used are as follows:

Core Spray 1-Pump Maximum Injection Flow	5800 gpm	(Ref. 2)
LPCI 4-Pump Maximum Injection Flow to broken loop	20,600 gpm	(Ref. 3, Att. S)

2. The maximum allowable suppression pool temperature under normal operating conditions is 95°F (Ref. 4). For the purposes of this calculation, the effects of an initial pool temperature of 75°F on LPCI/CS pumps NPSH margin will be examined.

3. The NPSH Required for the LPCI and Core Spray pumps is 31.5 ft. at 5150 gpm, 38.5 ft. at 5800 gpm (Refs. 12, 13).

4. LPCI/CS pump suction piping friction losses (excluding strainer losses) were developed for a single flow case using a FLO-SERIES Version 4.11 model of the Dresden ECCS ring header and pump suction piping (Ref. 5). This model was then run at the various LPCI/CS pump combinations and flows as required to support the cases evaluated in this calculation (Attachment A).

5. The minimum suppression pool level elevation using a maximum drawdown of 2.1 ft. is 491' 5", or 491.4 ft. (Ref. 6).

6. The suppression pool strainers have a 100% clean head loss of 5.8 ft. @10,000 gpm (Ref. 7).

7. LPCI and Core Spray pump centerline elevation is 478.1 ft. (Refs. 8, 9).

8. NPSH Available (NPSHA) is calculated using the following equation:

$$NPSHA = 144 \times V \times (P_t - P_v) + Z - h_L - h_{strain}$$ (based on Ref. 10, p. 2.216)

where: P_t = suppression pool pressure in psia
P_v = saturation pressure in psia
V = specific volume in ft^3/lb
h_L = suction friction losses in feet
h_{strain} = head loss across strainer in feet
Z = static head of water above pump inlet in feet

9. Saturation pressure of water at 129°F is 2.164 psia, at 132°F is 2.345 psia (Ref. 11).

10. Specific volume of water at 129°F is 0.016243 ft^3/lb, at 132°F is 0.016256 ft^3/lb (Ref. 11).

5.0 REFERENCES

1. "Dresden Containment Analysis for Limiting DBA-LOCA", GE letter from S. Mintz to J. Nash dated November 18, 1996, Project No. DRF T23-00740
2. "Evaluation of Core Spray Capabilities and Surveillance Basis", Dresden Calculation No. DRE96-0207, dated December 17, 1996
3. "LPCI System Derivation of System Resistance Curves, Pump Curves, and Comparison to LOCA Analysis - Unit 2", Dresden Calculation No. DRE96-0211, Rev. 1, December 17, 1996
4. Dresden Unit 2 Technical Specifications, DPR-19, Section 3.7.A.1.c.1
5. "ECCS Suction Hydraulic Analysis without the Strainers", Duke Engineering & Services Calculation Number DRE96-0241 dated December 20, 1996
6. "Submergence of LPCI Discharge Line Post LOCA - Dresden Units 2 & 3", letter from S. Eldridge to C. Schroeder dated September 29, 1992, CHRON# 0115532
7. "Supporting Calculations for the ECCS Suction Strainer Modification", Nutech File No. 64.313.3119 Rev. 1, dated June 22, 1983
8. Sargent & Lundy Drawing M-547, LPCI pump suction
9. Sargent & Lundy Drawing M-549, Core Spray pump suction
10. "Pump Handbook", 2nd Edition, Karassik, Igor et. al., 1986
11. ASME Steam Tables, 1967
12. Bingham Pump Curve Nos. 25355-7, 27367-8, 27383, 25384-5 for Model 12x14x14.5 CVDS, Dresden Station LPCI pumps
13. Bingham Pump Curve Nos. 25213 (2A), 25243 (2B), 25231 (3A) and 25242 (3B) for Model 12x16x14.5 CVDS, Dresden Station Core Spray pumps
14. Hydraulic Institute Engineering Data Book, Second Edition, 1990
15. Cameron Hydraulic Data, 17th Edition, Ingersoll-Rand Company, 1988
16. "Cavitation Test Report - 12x14x14-1/2 CVDS Pump", Bingham Pump Co., May 22, 1969
17. "S/B Pumps 12x14x14.5 (LPCI) and 12x16x14.5 (CS) CVDS - Flow Delivery Under Full Cavitation Conditions", letter from H. Palas to D. Spencer dated November 1, 1996
18. "Comments to Quad Cities LPCS/CS Pump NPSH Position", letter from D. Spencer to H. Palas dated November 1, 1996
19. "Dresden LOCA PCT Impact of NPSH Limiting ECCS Flow", letter NFS:BSA:96-165 from R. Tsai to R. Freeman dated December 20, 1996

6.0 CALCULATIONS

The equation presented in Design Input 8 can be rewritten to solve for the minimum suppression pool pressure required for pump protection by setting NPSHA equal to NPSHR as follows:

$$P_{t,\,min} = \frac{(NPSHR - Z + h_{total})}{144 \times V} + P_v \qquad (1)$$

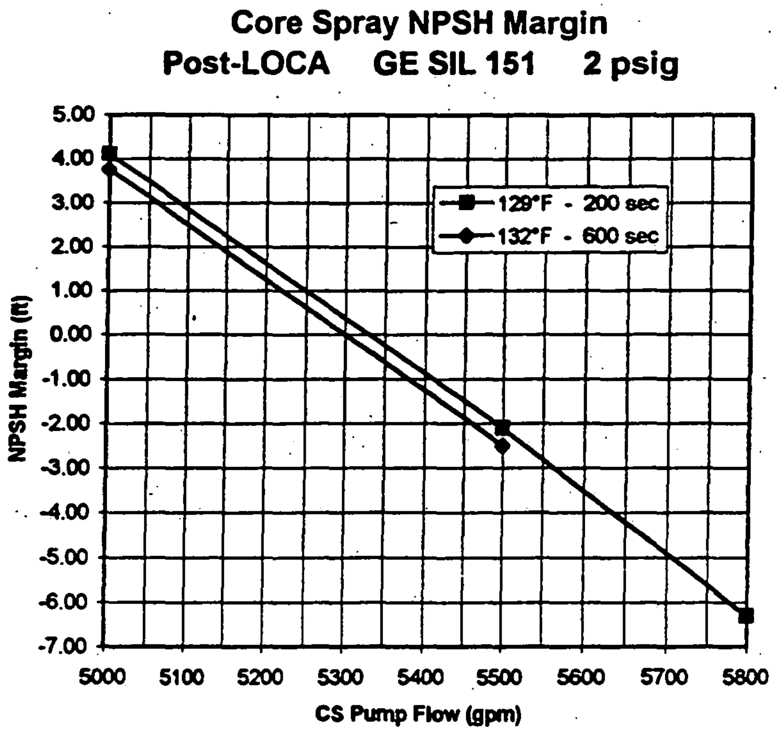
where P_v	=	2.164 psia @129°F	(Design Input 9)
		2.345 psia @132°F	(Design Input 9)
V	=	0.016243 ft^3/lb @129°F	(Design Input 10)
		0.016256 ft^3/lb @132°F	(Design Input 10)
h_{total}	=	friction (h_L) + strainer (h_{strain}) loss	(Attachment A)
h_{strain}	=	5.8 ft. @ 10,000 gpm clean	(Design Input 6)
Z	=	491.4 ft. - 478.1 ft. = 13.3 ft.	(Design Inputs 5, 7)
NPSHR	=	31.5 ft. @ 5150 gpm	(Design Input 3)
		38.5 ft. @ 5800 gpm	(Design Input 3)

Solving Equation 1, the minimum suppression pool pressure required to satisfy LPCI and Core Spray pump NPSH requirements is determined to be:

LPCI/CS Pumps	LPCI/CS Flow per Pump (gpm)	Torus Temp (°F)	Total LPCI Suction Loss, h_{total} (ft)	Total CS Suction Loss, h_{total} (ft)	Minimum Required Torus Pressure for LPCI (psia)	Minimum Required Torus Pressure for CS (psia)	Minimum Available Torus Pressure (psia)	LPCI NPSH Margin (ft)	CS NPSH Margin (ft)
4/2	5150/5800	129	18.7	17.9	17.9	20.6	16.7	-2.9	-9.1
4/2	5150/5800	132	18.7	17.9	18.1	20.8	16.7	-3.3	-9.5

As shown above, when all six ECCS pumps are running the potential exists for both the LPCI and Core Spray pumps to cavitate. The LPCI pumps NPSH deficit is relatively small and will result in a negligible reduction in flow due to cavitation (< 100 gpm per pump). The reduced flow at which the CS pumps will operate can be determined using the methodology presented in Section 2.0. Note: Reduction in LPCI flow is conservatively ignored for CS pump reduced flow determination.

CS Flow Per Pump (gpm)	Temp (°F)	Total CS Suction Losses (ft)	LPCI Flow Per Pump (gpm)	Static Head (ft)	Vapor Pressure (psia)	Specific Volume (ft^3/lb)	[Fig. 1] Reduced NPSHR (ft)	Required Torus Pressure (psia)	Available Torus Pressure (psia)	CS NPSH Margin (ft)
5800	129	17.9	5150	13.3	2.164	0.016243	35.7	19.4	16.7	-6.3
5500	129	16.9	5150	13.3	2.164	0.016243	32.5	17.6	16.7	-2.1
5000	129	15.3	5150	13.3	2.164	0.016243	27.9	14.9	16.7	4.1
5500	132	16.9	5150	13.3	2.345	0.016256	32.5	17.8	16.7	-2.5
5000	132	15.3	5150	13.3	2.345	0.016256	27.9	15.1	16.7	3.8



As shown above, it is expected that the Core Spray pump reduced flow due to cavitation would be greater than 5300 gpm per pump within the first 200 seconds post-LOCA. This is greater than the 5276 gpm per pump required in the first 200 seconds post-LOCA to ensure the PCT remains below 2200°F. The Core Spray pump reduced flow beyond 200 seconds would be at least 5300 gpm per pump, greater than the nominal 4500 gpm per pump that is required.

7.0 SUMMARY AND CONCLUSIONS

An NPSH analysis was performed for the LPCI/CS pumps bounding the first 600 seconds following a DBA-LOCA. Specifically, the GE SIL 151 case was evaluated postulating a failure of the LPCI Loop Select logic. The calculation was performed using a reduced initial torus temperature of 75°F and a torus pressure of 2 psig. It was determined that when all six ECCS pumps are running, the potential exists for the LPCI and Core Spray pumps to cavitate. The LPCI pump NPSH deficit is relatively small and will result in a negligible reduction in flow due to cavitation (< 100 gpm per pump). The reduced flow at which the Core Spray pumps will operate in the first 200 seconds was estimated to be greater than 5300 gpm per pump, which is adequate to ensure the PCT remains below 2200°F. The Core Spray pump reduced flow beyond 200 seconds would be at least 5300 gpm per pump, which is greater than the nominal 4500 gpm per pump required. Therefore, it is concluded that adequate NPSH exists to ensure the LPCI/CS pumps can perform their safety function using a reduced initial torus temperature of 75°F and a torus pressure of 2 psig.

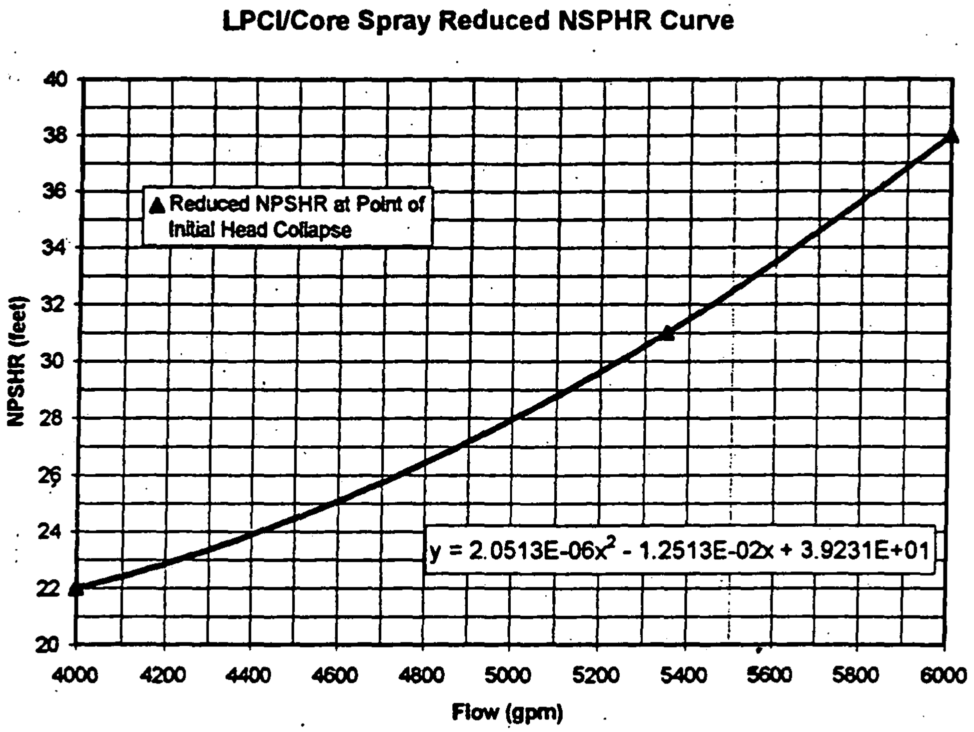


Figure 1 (Refs. 17, 18)

ATTACHMENT A

LPCI/Core Spray Suction Friction Losses
FLO-SERIES Model

LPCI/Core Spray pump suction friction losses were developed using a FLO-SERIES model of the Dresden ECCS ring header and pump suction piping (Ref. 5). The model was run at the various LPCI and Core Spray pump flows listed below as required to support the cases evaluated in this calculation. The input and output of the FLO-SERIES runs are included in this Attachment.

LPCI Pumps	Flow Per LPCI (gpm)	CS Pumps	Flow Per CS (gpm)	Strainer Loss# h_{strain} (ft)	LPCI Friction Loss (ft)	LPCI Loss +15% h_L (ft)	Total LPCI Suction Loss* h_{total} (ft)	CS Friction Loss (ft)	CS Loss +15% h_L (ft)	Total CS Suction Loss* h_{total} (ft)	FLO-SERIES Line-up Filename
4	5150	2	5800	6.7	10.4	12.0	**18.7**	9.8	11.2	**17.9**	4L512C58.PLU
4	5150	2	5500	6.4	10.3	11.8	**18.2**	9.1	10.4	**16.9**	4L512C55.PLU
4	5150	2	5000	6.0	10.0	11.5	**17.6**	8.0	9.2	**15.3**	4L512C50.PLU

 # Strainer Loss = (Flow per strainer/10,000 gpm)^2 x 5.8 ft.

*** Total Loss = (Loss +15%) + Strainer Loss**

Table A-1

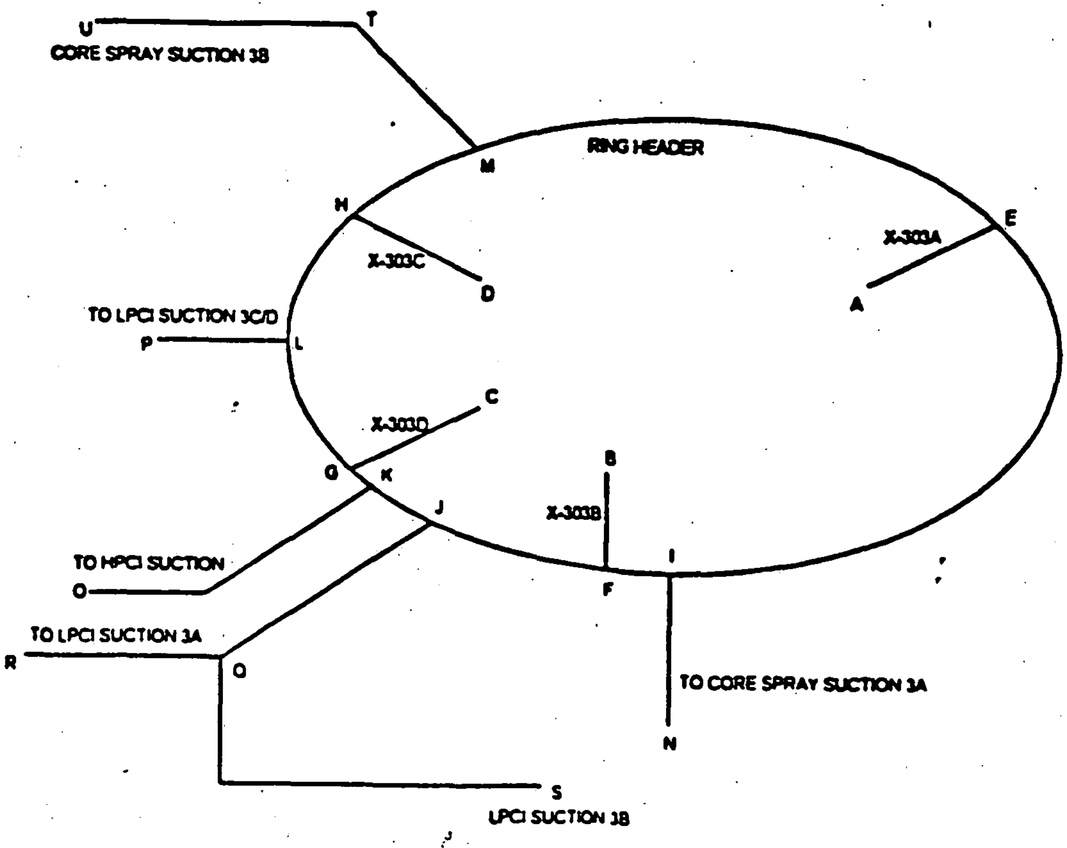


Figure A1: ECCS Suction Nodal Diagram including the Ring Header

```
Project: Dresden GE SIL 151 Case
    by: palas

                    LINEUP REPORT   rev: 01/03/97

LINELIST: RING                                   DEVIATION: 0.00898 %
   dated: 12/18/96                                   after: 5 iterations

     4 LPCI @5150 and 2 CS @5800 Injecting. Nearest torus leg blocked
Volumetric flow rates require constant fluid properties in all pipelines.
         Fluid properties in the first specification were used.

    NODE                DEMAND          NODE                DEMAND
                        gpm                                 gpm

    N           >>>     5800            O           >>>     0.0001
    P           >>>     10300           R           >>>     5150
    S           >>>     5150            U           >>>     5800

                                           FLOWS   IN: 0 gpm
                                           FLOWS  OUT: 32200    gpm
                                       NET FLOWS  OUT: 32200    gpm


    PIPELINE                FLOW            PRESSURE       SET
                            gpm             SOURCE         psig

    Torus-1         <<<     10501     <<<   A              0
    Torus-2         <<<     10632     <<<   B              0
    Torus-3         <<<     11068     <<<   C              0

                                          FLOWS   IN: 32201    gpm
                                          FLOWS  OUT: 0 gpm
                                      NET FLOWS   IN: 32201    gpm
```

CALCULATION NO. DRE97-0002 REVISION 0

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NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -1.739	-4.037
F	0		* -1.783	-4.138
G	0		* -1.932	-4.484
H	0		* -2.052	-4.763
I	0		* -1.792	-4.16
J	0		* -1.948	-4.521
K	0		* -1.942	-4.507
L	0		* -2.06	-4.782
M	0		* -2.049	-4.755
N	0	> 5800	* -2.209	-5.127
O	0	> 0.0001	* -1.942	-4.507
P	0	> 10300	* -2.341	-5.433
Q	0		* -2.596	-6.026
R	0	> 5150	* -3.172	-7.362
S	0	> 5150	* -4.493	-10.43
T	0		* -2.473	-5.74
U	0	> 5800	* -4.203	-9.756

CALCULATION NO. DRE97-0062 REV. 0
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PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	Hl ft
CS-3A	I	N	5800	8.086	0.417	0.967
CS3B-16	T	U	5800	10.2	1.73	4.016
CS3B-18	M	T	5800	8.086	0.424	0.984
HPCI	K	O	0	0	0	0
LPCI3A	Q	R	5150	11.99	0.576	1.336
LPCI3A/B	J	Q	10300	7.79	0.649	1.506
LPCI3B	Q	S	5150	11.99	1.897	4.404
LPCI3C/D	L	P	10300	7.79	0.281	0.651
Ring-1	E	I	3020	2.284	0.053	0.124
Ring-2	F	I	2780	2.103	0.010	0.022
Ring-3	F	J	7852	5.938	0.165	0.383
Ring-4	K	J	2448	1.852	0.006	0.013
Ring-5	G	K	2448	1.852	0.010	0.023
Ring-6	G	L	8619	6.519	0.128	0.298
Ring-7	H	L	1681	1.271	0.008	0.019
Ring-8	M	<-> H	1681	1.271	0.004	0.008
Ring-9	E	M	7481	5.658	0.310	0.719
Torus-1	A	E	10501	12.71	1.739	4.037
Torus-2	B	F	10632	12.87	1.783	4.138
Torus-3	C	G	11068	13.4	1.932	4.484
Torus-4	D	H	closed	0	0	0

CALCULATION NO. DRE 97-0002 REV. 0
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```
Project: Dresden GL SIB [illegible]
     by: palas

                         LINEUP REPORT   rev: 01/03/97

LINELIST: RING                                        DEVIATION: 0.01 %
   dated: 12/18/96                                        after: 5 iterations

     4 LPCI @5150 and 2 CS @5500 Injecting. Nearest torus leg blocked
Volumetric flow rates require constant fluid properties in all pipelines.
       Fluid properties in the first specification were used.

    NODE              DEMAND          NODE              DEMAND
                      gpm                               gpm

    N          >>>  5500              O          >>>  0.0001
    P          >>>  10300             R          >>>  5150
    S          >>>  5150              U          >>>  5500

                                         FLOWS  IN: 0 gpm
                                         FLOWS OUT: 31600   gpm

                                      NET FLOWS OUT: 31600   gpm


    PIPELINE                  FLOW          PRESSURE        SET
                              gpm           SOURCE          psig

    Torus-1           <<<   10299     <<<   A               0
    Torus-2           <<<   10428     <<<   B               0
    Torus-3           <<<   10873     <<<   C               0

                                         FLOWS  IN: 31600   gpm
                                         FLOWS OUT: 0 gpm

                                     NET FLOWS  IN: 31600   gpm
```

CALCULATION NO. DRE97-0002 REV.0
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NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -1.673	-3.883
F	0		* -1.715	-3.981
G	0		* -1.865	-4.328
H	0		* -1.978	-4.591
I	0		* -1.723	-4
J	0		* -1.88	-4.364
K	0		* -1.875	-4.351
L	0		* -1.988	-4.614
M	0		* -1.973	-4.58
N	0	> 5500	* -2.098	-4.87
O	0	> 0.0001	* -1.875	-4.351
P	0	> 10300	* -2.268	-5.265
Q	0		* -2.529	-5.87
R	0	> 5150	* -3.104	-7.206
S	0	> 5150	* -4.426	-10.27
T	0		* -2.355	-5.466
U	0	> 5500	* -3.911	-9.079

CALCULATION NO. DRE 97-0002 REV.0
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PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	Hl ft
CS-3A	I	N	5500	7.668	0.375	0.870
CS3B-16	T	U	5500	9.669	1.557	3.613
CS3B-18	M	T	5500	7.668	0.381	0.885
HPCI	K	O	0	0	0	0
LPCI3A	Q	R	5150	11.99	0.576	1.336
LPCI3A/B	J	Q	10300	7.79	0.649	1.506
LPCI3B	Q	S	5150	11.99	1.897	4.404
LPCI3C/D	L	P	10300	7.79	0.281	0.651
Ring-1	E	I	2932	2.217	0.050	0.117
Ring-2	F	I	2568	1.942	0.008	0.019
Ring-3	F	J	7860	5.945	0.165	0.383
Ring-4	K	J	2440	1.845	0.006	0.013
Ring-5	G	K	2440	1.845	0.010	0.023
Ring-6	G	L	8433	6.378	0.123	0.286
Ring-7	H	L	1867	1.412	0.010	0.023
Ring-8	M	<-> H	1867	1.412	0.004	0.010
Ring-9	E	M	7367	5.572	0.300	0.697
Torus-1	A	E	10299	12.47	1.673	3.883
Torus-2	B	F	10428	12.63	1.715	3.981
Torus-3	C	G	10873	13.16	1.865	4.328
Torus-4	D	H	closed	0	0	0

CALCULATION No. DRE97-0002 REV. 0
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```
Project: Dresden CS SIZ
    by: palas

                            LINEUP REPORT   rev: 01/03/97

LINELIST: RING                                           DEVIATION: 0.0121 %
   dated: 12/18/96                                           after: 5 iterations

        4 LPCI @5150 and 2 CS @5000 Injecting. Nearest torus leg blocked
 Volumetric flow rates require constant fluid properties in all pipelines.
         Fluid properties in the first specification were used.

     NODE            DEMAND            NODE            DEMAND
                     gpm                               gpm

     N         >>>   5000              O         >>>   0.0001
     P         >>>   10300             R         >>>   5150
     S         >>>   5150              U         >>>   5000

                                           FLOWS  IN: 0 gpm
                                           FLOWS OUT: 30600   gpm
                                       NET FLOWS OUT: 30600   gpm


     PIPELINE              FLOW            PRESSURE        SET
                           gpm             SOURCE          psig

     Torus-1         <<<   9962      <<<   A               0
     Torus-2         <<<   10088     <<<   B               0
     Torus-3         <<<   10550     <<<   C               0

                                          FLOWS  IN: 30600   gpm
                                          FLOWS OUT: 0 gpm
                                      NET FLOWS  IN: 30600   gpm
```

CALCULATION NO. DRE97-0002 REV.0
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```
NODE        ELEVATION    DEMAND          PRESSURE        H GRADE
            ft           gpm             psi g           ft

A           0                            p  0            0
B           0                            p  0            0
C           0                            p  0            0
E           0                            * -1.565        -3.633
F           0                            * -1.605        -3.725
G           0                            * -1.755        -4.075
H           0                            * -1.856        -4.309
I           0                            * -1.611        -3.74
J           0                            * -1.771        -4.111
K           0                            * -1.765        -4.097
L           0                            * -1.87         -4.34
M           0                            * -1.851        -4.296
N           0            > 5000          * -1.921        -4.458
O           0            > 0.0001        * -1.765        -4.097
P           0            > 10300         * -2.15         -4.991
Q           0                            * -2.42         -5.616
R           0            > 5150          * -2.995        -6.952
S           0            > 5150          * -4.317        -10.02
T           0                            * -2.166        -5.027
U           0            > 5000          * -3.453        -8.016
```

CALCULATION DRE97-0002 REV.0
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PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	Hl ft
CS-3A	I	N	5000	6.971	0.310	0.719
CS3B-16	T	U	5000	8.79	1.287	2.988
CS3B-18	M	T	5000	6.971	0.315	0.732
HPCI	K	O	0	0	0	0
LPCI3A	Q	R	5150	11.99	0.576	1.336
LPCI3A/B	J	Q	10300	7.79	0.649	1.506
LPCI3B	Q	S	5150	11.99	1.897	4.404
LPCI3C/D	L	P	10300	7.79	0.281	0.651
Ring-1	E	I	2789	2.109	0.046	0.106
Ring-2	F	I	2211	1.672	0.006	0.014
Ring-3	F	J	7877	5.957	0.166	0.385
Ring-4	K	J	2423	1.833	0.006	0.013
Ring-5	G	K	2423	1.833	0.010	0.023
Ring-6	G	L	8127	6.146	0.114	0.265
Ring-7	H	L	2173	1.644	0.013	0.031
Ring-8	M	<-> H	2173	1.644	0.006	0.014
Ring-9	E	M	7173	5.425	0.285	0.662
Torus-1	A	E	9962	12.06	1.565	3.633
Torus-2	B	F	10088	12.21	1.605	3.725
Torus-3	C	G	10550	12.77	1.755	4.075
Torus-4	D	H	closed	0	0	0

CALCULATION NO. DRE97-0002 REV. 0
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Calculation Title Page

Calculation No.: **DRE97-0003** Page 1 of 10

☒ Safety Related ☐ Regulatory Related ☐ Non-Safety Related

Calculation Title:

Dresden LPCI/Core Spray NPSH Analysis
Post-DBA LOCA: Reduced Torus Temperature
Long-Term

Station/Unit: Dresden Units 2 and 3 System Abbreviation: LPCI/CS

Equipment No.: 2(3)-1502A/B/C/D
2(3)-1401A/B
Project No.:

Rev: 0 Status: QA Serial # or CHRON # NA Date:

Prepared by: HARRY PALAS Date: 1/7/97

Revision Summary:

Electronic Calculation Data Files:

RING.PLL
RING.PLU
4L502C45.PLU
4L372C45.PLU
4L252C45.PLU
3L502C45.PLU
3L_50_25.PLU
3L_25_50.PLU
2L502C45.PLU
2L372C45.PLU
1L502C45.PLU

Do any assumptions in this calculation require later verification? ☐ Yes ☒ No

Reviewed by: J.W. Drowley Date: 1/7/97

Review Method: DETAILED REVIEW Comments (C, NC or CI): NC

Approved by: Date: 1/8/97

Calculation Revision Page

Calculation No.: **DRE97-0003** Page 2 of 10

Rev: **0** Status: QA Serial # or CHRON # **NA** Date:__________

Prepared by:____ Date:__________

Revision Summary:

Electronic Calculation Data Files Revised:

Do any assumptions in this calculation require later verification? ☐ Yes ☐ No

Reviewed by:____ Date:__________

Review Method: Comments (C, NC or CI): ______

Approved by:____ Date:__________

Table of Contents

1.0 PURPOSE

The purpose of this calculation is to determine if sufficient Net Positive Suction Head (NPSH) is available to the Dresden LPCI and Core Spray (CS) pumps following a DBA-LOCA with atmospheric pressure in the torus. This calculation examines NPSH conditions at the bounding, long-term (> 600 seconds) condition following the accident, which occurs at the time of peak suppression pool temperature. The effects of throttled LPCI pumps and reduced peak suppression pool temperature will also be examined. The results of this calculation will be used to support a Dresden Exigent License Amendment.

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

The minimum suppression pool pressure required to ensure LPCI and CS pump protection will be determined under long-term post-LOCA conditions at the bounding NPSH condition. Since the suppression pool pressure remains constant after 600 seconds (14.7 psia), the bounding NPSH condition occurs at the time of peak suppression pool temperature. If the pressure required is less than 14.7 psia, then the pump NPSH requirements have been met. If the required pressure is greater than 14.7 psia, then the potential exists for the pumps to cavitate. In these situations, LPCI pump flows will be reduced to below-nominal values and new cases will be run to establish the ability of the operator to throttle the pumps to an acceptable condition. This acceptable condition is defined by the following criteria:

1) Adequate NPSH to the pumps - minimum pressure available is greater than minimum pressure required for the LPCI and CS pumps.

2) Adequate containment cooling - the minimum containment cooling flow analyzed is 5000 gpm (LPCI) through a single LPCI heat exchanger.

If an acceptable condition cannot be achieved by throttling, then cases involving reduced suppression pool temperatures will be explored.

Various pump combinations will be explored to determine the bounding NPSH case for the LPCI and Core Spray pumps. It will be shown that NPSH for the LPCI/CS pumps with 4 LPCI/2 CS pumps running is the bounding NPSH case. This calculation is bounding for NPSH due to use of the following conservative inputs:

- maximum long-term suppression pool temperature post-LOCA, thus maximizing the vapor pressure and minimizing NPSH margin
- torus pressure at time of peak temperature is atmospheric, thus minimizing NPSH margin
- Technical Specifications minimum suppression pool level including drawdown, minimizing elevation head and minimizing NPSH margin
- increased clean, commercial steel pipe friction losses by 15% to account for aging effects

3.0 ASSUMPTIONS

1. It is assumed that at 10 minutes into the accident, operator action will be taken to ensure that the LPCI/CS pumps have been throttled to their rated flows (5000 and 4500 gpm respectively). Therefore, the pumps are at their rated flows at the time of peak suppression pool temperature.
2. LPCI/CS pump suction piping friction losses (excluding strainer losses) were developed for a single flow case using a FLO-SERIES model of the Dresden ECCS ring header and pump suction piping (Ref. 3). This piping model was then run at the various LPCI/CS pump combinations and flows as required to support the cases evaluated in this calculation (Attachment A). The model that was developed uses clean, commercial steel pipe. In order to compensate for the increased loss due to the potential effects of aging, the resulting friction losses from the model were increased by 15%. This is consistent with discussions provided in References 13 and 14.
3. To account for strainer plugging, one of the four torus strainers is assumed 100% blocked, while the remaining three strainers are assumed clean. While the torus strainers are not included in the FLO-SERIES model discussed in Assumption 2, blocking a strainer translates to blocking a torus-to-ring header entrance leg. This is accomplished in the model by closing one of the torus legs (Torus 1-4). Based on previous sensitivity analyses, Torus-4 was chosen for maximum effect on both LPCI and Core Spray suction losses for all pump combinations.
4. The peak suppression pool temperature post-LOCA is not provided in the original Dresden FSAR for any LPCI/CCSW pump combinations. A value of 170°F is estimated for the Dresden 1 LPCI / 2 CCSW case based on the following:
    - Quad Cities has similar ECCS flows, heat exchanger capacities and heat loads to Dresden; therefore, Quad Cities post-LOCA results can be employed to provide a reasonable estimate of Dresden's peak pool temperature (Ref. 1). Table 5.2.5 of the Quad Cities FSAR provides a Case (d), which yields a suppression pool maximum temperature of 168°F for a 1 RHR/2 RHRSW pump scenario based on an initial pool temperature of 90°F. For a Dresden initial pool temperature of 95°F, an adder of 2°F is used, resulting in a Dresden peak suppression pool temperature estimate of 170°F. The 2°F adder is supported by subsequent GE calculations which show a sensitivity of 1°F for a 5°F change in initial pool temperature (Ref. 2).
    - Reference 15, page 2-5 states the following: "The maximum torus temperature for a design basis accident would reach about 170°F."
    - The Dresden FSAR, page 6.2-17 includes a discussion regarding LPCI/CCSW heat exchanger sizing. It states "that in the event of the loss of coolant accident the terminal suppression pool temperature would not exceed 170°F."
5. Suppression pool pressure is assumed atmospheric (14.7 psia). This is conservative since pressure above atmospheric is expected in the suppression pool as a result of the elevated temperatures and blowdown of the non-condensables post-LOCA.

4.0 DESIGN INPUTS

1. LPCI and CS pump suction piping friction losses (excluding strainer losses) from the torus strainers to the pumps were developed in Reference 3 using a FLO-SERIES model of the ECCS ring header and suction piping. This piping model was then utilized for the various LPCI/CS pump combinations and flows as required to support the cases evaluated in this calculation (Attachment A).

2. The minimum torus level elevation with a maximum drawdown of 2.1 ft. is 491'5", or 491.4 ft. (Ref. 4). At the time of peak suppression pool temperature, a recovery of 1.1 ft. occurs, resulting in a net drawdown of 1 ft (Ref. 5). This represents a torus level elevation of 492.5'.

3. The torus strainers have a head loss of 5.8 ft. @ 10,000 gpm clean (Ref. 6).

4. LPCI and Core Spray pump centerline elevation is 478.1 ft. (Refs. 7, 8).

5. NPSH Available (NPSHA) is calculated using the following equation:

$$NPSHA = 144 \times V \times (P_t - P_v) + Z - h_L - h_{strain}$$ (based on Ref. 9, p. 2.216)

where: P_t = suppression pool pressure in psia
P_v = saturation pressure in psia
V = specific volume in ft^3/lb
h_L = suction friction losses in feet
h_{strain} = head loss across strainer in feet
Z = static head of water above pump inlet (feet)

6. Saturation pressure of water at 170°F is 5.99 psia, and at 160°F is 4.74 psia (Ref. 10)

7. Specific volume of water at 170°F is 0.016451 ft^3/lb, and at 160°F is 0.016395 (Ref. 10)

8. The NPSH Required (NPSHR) for the LPCI pump is 30 ft. at 5000 gpm, 25.5 ft. at 3750 gpm, and 25 ft. at 2500 gpm (Ref. 11).

9. The NPSHR for the Core Spray pump is 27 ft. at 4500 gpm (Ref. 12).

5.0 REFERENCES

1. "An Estimated Suppression Pool Temperature for Dresden NPSH Evaluation", Nuclear Fuel Services Memo from K. Ramsden dated August 22, 1996
2. General Electric report GENE-637-042-1193 dated February, 1994
3. "ECCS Suction Hydraulic Analysis without the Strainers", Duke Engineering & Services Calculation Number DRE96-0241 dated December 20, 1996
4. "Submergence of LPCI Discharge Line Post LOCA - Dresden Units 2 & 3", letter from S. Eldridge to C. Schroeder dated September 29, 1992, CHRON# 0115532
5. "Dresden LPCI/Containment Cooling System," GE Nuclear Energy letter from S. Mintz to T. L. Chapman dated January 25, 1993
6. "Supporting Calculations for the ECCS Suction Strainer Modification", Nutech File No. 64.313.3119 Rev. 1, dated June 22, 1983
7. Sargent & Lundy Drawing M-547, LPCI pump suction
8. Sargent & Lundy Drawing M-549, Core Spray pump suction
9. "Pump Handbook", 2nd Edition, Karassik, Igor et. al., 1986
10. ASME Steam Tables, 1967
11. Bingham Pump Curve Nos. 25355-7, 27367-8, 27383, 25384-5 for Model 12x14x14.5 CVDS, Dresden Station LPCI pumps
12. Bingham Pump Curve Nos. 25213 (2A), 25243 (2B), 25231 (3A) and 25242 (3B) for Model 12x16x14.5 CVDS, Dresden Station Core Spray pumps.
13. Hydraulic Institute Engineering Data Book, Second Edition, 1990
14. Cameron Hydraulic Data, 17th Edition, Ingersoll-Rand Company, 1988
15. Dresden FSAR, Amendment 22, May 7, 1970

6.0 CALCULATIONS

The NPSHA equation presented in Design Input 5 can be rewritten to solve for the minimum suppression pool pressure required for pump protection by setting the NPSHA equal to the NPSH Required (NPSHR) as follows:

$$P_{t,\,min} = \frac{(NPSHR - Z + h_{total})}{144 \times V} + P_v \qquad (1)$$

where P_v = 5.99 psia @170°F (Design Input 6)

V = 0.016451 ft^3/lb @170°F (Design Input 7)

h_{total} = friction (h_L) + strainer (h_{strain}) loss (Attachment A)

h_{strain} = 5.8 ft. @ 10,000 gpm clean (Design Input 3)

Z = 492.5 ft. - 478.1 ft. = 14.4 ft. (Design Inputs 2, 4)

NPSHR = 30 ft. @ 5000 gpm for LPCI (Design Input 8)
27 ft. @ 4500 gpm for CS (Design Input 9)

Solving Equation 1, the minimum suppression pool pressure required to satisfy LPCI and Core Spray pump NPSH requirements under a spectrum of pump combinations is determined to be:

LPCI/CS Pumps	Total LPCI Suction Loss h_{total} (ft)	Total CS Suction Loss h_{total} (ft)	Minimum Required Torus Pressure for LPCI (psia)	Minimum Required Torus Pressure for CS (psia)	Minimum Available Torus Pressure (psia)	**LPCI Margin (ft)**	**CS Margin (ft)**
4/2	16.1	13.3	19.4	16.9	14.7	**-11.1**	**-5.3**
3/2	13.0	10.1	18.1	15.6	14.7	**-8.0**	**-2.1**
2/2	10.6	7.5	17.1	14.5	14.7	**-5.6**	**0.5**
1/2	7.5	5.8	15.7	13.7	14.7	**-2.5**	**2.3**

All the combinations evaluated above involve 2 CS pumps. These cases bound the respective 1 CS pump scenarios due to the higher ring header/strainer losses of the 2-pump cases combined with no pool temperature benefit (cooling) from the added Core Spray pump (second pump actually adds heat to the pool). As shown above, the potential exists for the LPCI and CS pumps to cavitate in most of the pump scenarios. For these cases, throttling of the LPCI pumps may be required to ensure NPSH requirements are met. The following cases are provided to establish the ability of the operator to throttle the pumps to an acceptable condition as defined in Section 2.0.

Pump	NPSHR (ft)	Suction Loss h_L (ft)	Strainer Loss h_{strain} (ft)	Static Head (ft)	Vapor Pressure (psia)	Req'd Torus Pressure (psia)	Available Torus Pressure (psia)	Margin (ft)	LPCI/CS Pumps Running	LPCI/CS Total System Flows (gpm)	Status of Pumps
LPCI	30.0	10.7	5.4	14.4	5.99	19.4	14.7	**-11.1**	**4/2**	20000/9000	4 LPCI pumps throttled to 5000 gpm per pump
LPCI	25.5	6.5	3.7	14.4	5.99	15.0	14.7	**-0.7**	**4/2**	15000/9000	4 LPCI pumps throttled to 3750 gpm per pump
LPCI	25.0	3.4	2.3	14.4	5.99	12.9	14.7	**4.3**	**4/2**	10000/9000	4 LPCI pumps throttled to 2500 gpm per pump
LPCI	30.0	9.3	3.7	14.4	5.99	18.1	14.7	**-8.0**	**3/2**	15000/9000	3 LPCI pumps throttled to 5000 gpm per pump
LPCI 1-pp loop	30.0	7.0	2.3	14.4	5.99	16.5	14.7	**-4.3**	**3/2**	10000/9000	2 LPCI pumps throttled to 2500 gpm per pump; single LPCI throttled to 5000 gpm
LPCI 2-pp loop	25.0	3.4	2.3	14.4	5.99	12.9	14.7	**4.3**	**3/2**	10000/9000	2 LPCI pumps throttled to 2500 gpm per pump; single LPCI throttled to 5000 gpm
LPCI	30.0	8.3	2.3	14.4	5.99	17.1	14.7	**-5.6**	**2/2**	10000/9000	2 LPCI pumps throttled to 5000 gpm per pump
LPCI	25.5	5.0	1.8	14.4	5.99	13.5	14.7	**2.8**	**2/2**	7500/9000	2 LPCI pumps throttled to 3750 gpm per pump
LPCI	30.0	6.2	1.3	14.4	5.99	15.7	14.7	**-2.4**	**1/2**	5000/9000	1 LPCI pump throttled to 5000 gpm
CS	27.0	7.9	5.4	14.4	5.99	16.9	14.7	**-5.3**	**4/2**	20000/9000	4 LPCI pumps throttled to 5000 gpm per pump
CS	27.0	6.5	3.7	14.4	5.99	15.6	14.7	**-2.2**	**4/2**	15000/9000	4 LPCI pumps throttled to 3750 gpm per pump
CS	27.0	5.4	2.3	14.4	5.99	14.6	14.7	**0.3**	**4/2**	10000/9000	4 LPCI pumps throttled to 2500 gpm per pump
CS	27.0	6.4	3.7	14.4	5.99	15.6	14.7	**-2.1**	**3/2**	15000/9000	3 LPCI pumps throttled to 5000 gpm per pump
CS	27.0	5.4	2.3	14.4	5.99	14.6	14.7	**0.3**	**3/2**	10000/9000	2 LPCI pumps throttled to 2500 gpm per pump; single LPCI throttled to 5000 gpm
CS	27.0	5.2	2.3	14.4	5.99	14.5	14.7	**0.5**	**2/2**	10000/9000	2 LPCI pumps throttled to 5000 gpm per pump
CS	27.0	4.5	1.3	14.4	5.99	13.7	14.7	**2.3**	**1/2**	5000/9000	1 LPCI pump throttled to 5000 gpm

As shown above, the LPCI and Core Spray pumps can be throttled to ensure NPSH requirements are met and that adequate containment cooling exists for all ECCS pump combinations except the 1/2 case. In this case, the LPCI NPSH deficit is approximately 1 psi. Reducing the pool temperature by 10°F would result in a reduction in vapor pressure of slightly more than 1 psi. Therefore, at a suppression pool temperature of 160°F, the 1/2 case is as follows:

Pump	NPSHR (ft)	Suction Loss h_L (ft)	Strainer Loss h_{strain} (ft)	Static Head (ft)	Vapor Pressure (psia)	Req'd Torus Pressure (psia)	Available Torus Pressure (psia)	Margin (ft)	LPCI/CS Pumps Running	LPCI/CS Total System Flows (gpm)	Status of Pumps
LPCI	30.0	6.2	1.3	14.4	4.74	14.5	14.7	**0.4**	**1/2**	5000/9000	1 LPCI pump throttled to 5000 gpm

7.0 SUMMARY AND CONCLUSIONS

An NPSH analysis was performed for the LPCI/CS pumps under bounding, long-term post-accident conditions with atmospheric pressure in the torus. Selecting inputs to minimize NPSH margin, it was determined that the potential exists for the LPCI and CS pumps to cavitate in most of the pump scenarios. For these cases, throttling of the LPCI pumps may be required to ensure NPSH requirements are met. Specific cases involving throttled LPCI pumps were evaluated to establish the ability of the operator to throttle the pumps to an acceptable condition. The results of these cases were as follows:

- In the 3/2 case, the single pump LPCI loop may need to be throttled to below 5000 gpm, and containment heat removed with the 2-pump loop. This will ensure the LPCI heat exchanger receives its rated LPCI flow. Alternatively, a LPCI pump can be dropped to gain the required NPSH margin.

- In the 1/2 case, an NPSH deficit still exists after maximum throttling of the LPCI pump to 5000 gpm. It was determined that a reduction in the peak suppression pool temperature to 160°F would result in positive NPSH margin.

Therefore, at a reduced suppression pool peak temperature of 160°F, it is concluded that under all post-LOCA pump combinations, positive NPSH margin for the LPCI and Core Spray pumps can be achieved by throttling the available LPCI pumps.

ATTACHMENT A

LPCI/Core Spray Suction Friction Losses
FLO-SERIES Model

Dresden LPCI/Core Spray pump suction friction losses were developed using a FLO-SERIES model of the Dresden ECCS ring header and pump suction piping (Ref. 3). The nodal diagram of the piping model is included as Figure A1. This model was run at the various LPCI and Core Spray pump combinations and flows listed below as required to support the cases evaluated in this calculation. The FLO-SERIES runs are included in this Attachment.

LPCI Pumps	CS Pumps	LPCI/CS Flow per Pump (gpm)	Strainer Loss# h_{strain} (ft)	LPCI Friction Loss (ft)	LPCI Loss +15% h_L (ft)	**Total LPCI Loss* h_{total} (ft)**	CS Friction Loss (ft)	CS Loss +15% h_L (ft)	**Total CS Loss* h_{total} (ft)**	FLO-SERIES Line-up Filename
4	2	5000/4500	5.4	9.3	10.7	**16.1**	6.9	7.9	**13.3**	4L502C45.PLU
4	2	3750/4500	3.7	5.6	6.5	**10.2**	5.7	6.5	**10.2**	4L372C45.PLU
4	2	2500/4500	2.3	2.9	3.4	**5.7**	4.7	5.4	**7.7**	4L252C45.PLU
3	2	5000/4500	3.7	8.1	9.3	**13.0**	5.6	6.4	**10.1**	3L502C45.PLU
3	2	5000/4500	2.3	6.1	7.0	**9.3**	4.7	5.4	**7.7**	3L_50_25.PLU
3	2	2500/4500	2.3	2.9	3.4	**5.7**	4.7	5.4	**7.7**	3L_25_50.PLU
2	2	5000/4500	2.3	7.2	8.3	**10.6**	4.5	5.2	**7.6**	2L502C45.PLU
2	2	3750/4500	1.8	4.4	5.0	**6.8**	4.2	4.8	**6.6**	2L372C45.PLU
1	2	5000/4500	1.3	5.4	6.2	**7.4**	3.9	4.5	**5.7**	1L502C45.PLU

 # Strainer Loss = (Flow per strainer/10,000 gpm)^2 x 5.8 ft.

*** Total Loss = (Loss +15%) + Strainer Loss**

Table A-1

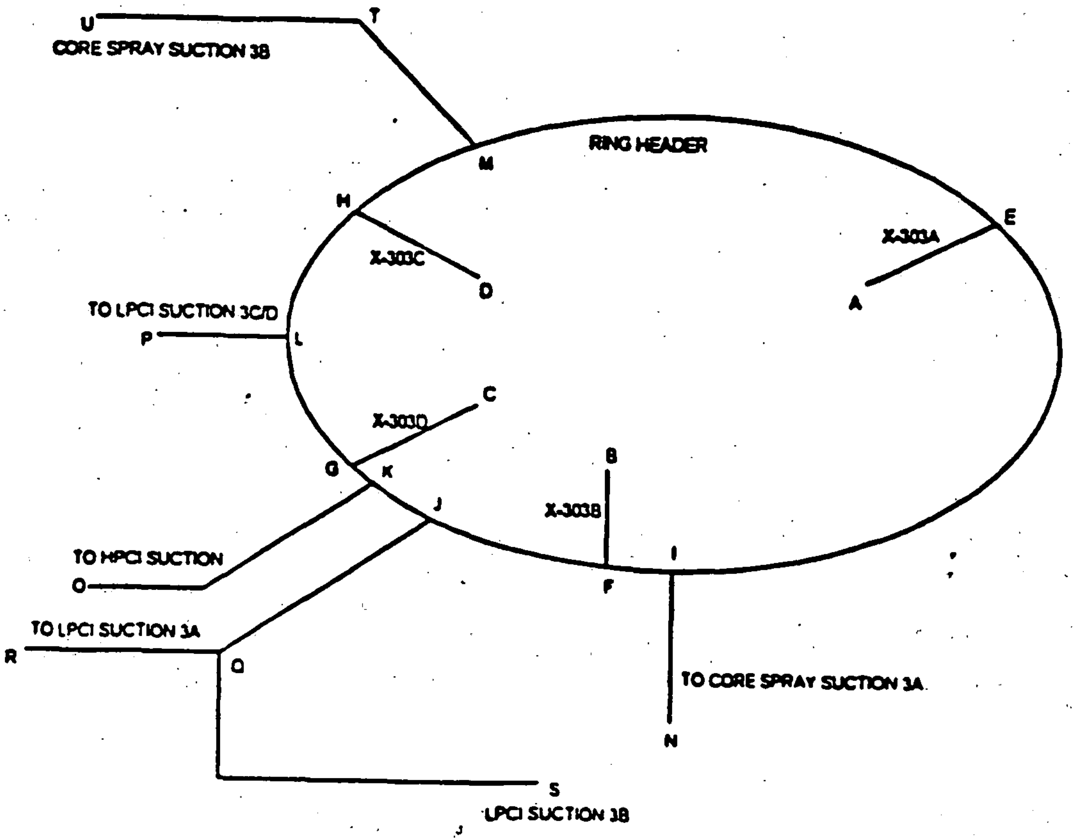

Figure A1: ECCS Suction Nodal Diagram including the Ring Header

```
Company:
Project:                                                        12/21/96
    by: Palas

                        LINEUP REPORT   rev: 12/21/96

LINELIST: RING                                       DEVIATION: 0.0157 %
   dated: 12/18/96                                       after: 5 iterations

    4 LPCI @5000 and 2 CS @4500 Injecting. Nearest torus leg blocked.
Volumetric flow rates require constant fluid properties in all pipelines.
        Fluid properties in the first specification were used.

    NODE            DEMAND          NODE            DEMAND
                    gpm                             gpm

    N         >>>   4500            O         >>>   0.0001
    P         >>>   10000           R         >>>   5000
    S         >>>   5000            U         >>>   4500

                                        FLOWS  IN: 0 gpm
                                        FLOWS OUT: 29000   gpm

                                    NET FLOWS OUT: 29000   gpm


    PIPELINE              FLOW          PRESSURE       SET
                          gpm           SOURCE         psig

    Torus-1         <<<   9433      <<< A              0
    Torus-2         <<<   9552      <<< B              0
    Torus-3         <<<   10015     <<< C              0

                                        FLOWS  IN: 29000   gpm
                                        FLOWS OUT: 0 gpm

                                    NET FLOWS  IN: 29000   gpm
```

CALCULATION NO. DRE97-0003

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NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -1.403	-3.258
F	0		* -1.439	-3.341
G	0		* -1.582	-3.672
H	0		* -1.669	-3.874
I	0		* -1.444	-3.351
J	0		* -1.596	-3.705
K	0		* -1.591	-3.693
L	0		* -1.684	-3.909
M	0		* -1.662	-3.858
N	0	> 4500	* -1.694	-3.933
O	0	> 0.0001	* -1.591	-3.693
P	0	> 10000	* -1.948	-4.523
Q	0		* -2.208	-5.125
R	0	> 5000	* -2.75	-6.384
S	0	> 5000	* -3.996	-9.276
T	0		* -1.918	-4.451
U	0	> 4500	* -2.961	-6.874

CALCULATION No. DRE97-0003

REV. 0 PAGE A4

PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	H1 ft
CS-3A	I	N	4500	6.274	0.251	0.582
CS3B-16	T	U	4500	7.911	1.044	2.423
CS3B-18	M	T	4500	6.274	0.255	0.593
HPCI	K	O	0	0	0	0
LPCI3A	Q	R	5000	11.64	0.543	1.259
LPCI3A/B	J	Q	10000	7.563	0.612	1.42
LPCI3B	Q	S	5000	11.64	1.789	4.152
LPCI3C/D	L	P	10000	7.563	0.264	0.614
Ring-1	E	I	2609	1.973	0.040	0.093
Ring-2	F	I	1891	1.43	0.004	0.010
Ring-3	F	J	7661	5.794	0.157	0.365
Ring-4	K	J	2339	1.769	0.005	0.012
Ring-5	G	K	2339	1.769	0.009	0.021
Ring-6	G	L	7676	5.805	0.102	0.237
Ring-7	H	L	2324	1.758	0.015	0.035
Ring-8	M	<-> H	2324	1.758	0.007	0.015
Ring-9	E	M	6824	5.161	0.259	0.601
Torus-1	A	E	9433	11.42	1.403	3.258
Torus-2	B	F	9552	11.57	1.439	3.341
Torus-3	C	G	10015	12.12	1.582	3.672
Torus-4	D	H	closed	0	0	0

CALCULATION NO. DRE97-0003

REV. 0 PAGE A5

```
Project:                                                          12/21/96
    by: Palas

                    LINEUP REPORT   rev: 12/21/96

LINELIST: RING                                     DEVIATION: 0.031 %
   dated: 12/18/96                                     after: 5 iterations

      4 LPCI @3750 and 2 CS @4500 Injecting. Nearest torus leg blocked.
  Volumetric flow rates require constant fluid properties in all pipelines.
          Fluid properties in the first specification were used.

     NODE             DEMAND           NODE             DEMAND
                      gpm                               gpm

     N        >>>     4500             O        >>>     0.0001
     P        >>>     7500             R        >>>     3750
     S        >>>     3750             U        >>>     4500

                                           FLOWS   IN: 0 gpm
                                           FLOWS OUT: 24000    gpm

                                       NET FLOWS OUT: 24000    gpm


     PIPELINE                  FLOW            PRESSURE        SET
                               gpm             SOURCE          psig

     Torus-1        <<<        7829     <<<    A               0
     Torus-2        <<<        7929     <<<    B               0
     Torus-3        <<<        8242     <<<    C               0

                                           FLOWS   IN: 24000    gpm
                                           FLOWS OUT: 0 gpm

                                       NET FLOWS   IN: 24000    gpm
```

CALCULATION NO. DRE97-0003

REV. 0   PAGE A6

NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -0.967	-2.244
F	0		* -0.992	-2.302
G	0		* -1.072	-2.487
H	0		* -1.141	-2.648
I	0		* -0.998	-2.316
J	0		* -1.08	-2.507
K	0		* -1.077	-2.5
L	0		* -1.144	-2.656
M	0		* -1.14	-2.645
N	0	> 4500	* -1.249	-2.899
O	0	> 0.0001	* -1.077	-2.5
P	0	> 7500	* -1.293	-3.001
Q	0		* -1.425	-3.307
R	0	> 3750	* -1.73	-4.016
S	0	> 3750	* -2.432	-5.645
T	0		* -1.395	-3.238
U	0	> 4500	* -2.439	-5.661

CALCULATION No. DRE97-0003

REV. 0 PAGE A7

PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	H1 ft
CS-3A	I	N	4500	6.274	0.251	0.582
CS3B-16	T	U	4500	7.911	1.044	2.423
CS3B-18	M	T	4500	6.274	0.255	0.593
HPCI	K	O	0	0	0	0
LPCI3A	Q	R	3750	8.732	0.305	0.709
LPCI3A/B	J	Q	7500	5.672	0.345	0.800
LPCI3B	Q	S	3750	8.732	1.007	2.338
LPCI3C/D	L	P	7500	5.672	0.149	0.345
Ring-1	E	I	2283	1.726	0.031	0.072
Ring-2	F	I	2217	1.677	0.006	0.014
Ring-3	F	J	5712	4.32	0.088	0.205
Ring-4	K	J	1788	1.352	0.003	0.007
Ring-5	G	K	1788	1.352	0.005	0.013
Ring-6	G	L	6454	4.881	0.073	0.169
Ring-7	H	L	1046	0.791	0.003	0.008
Ring-8	M	<-> H	1046	0.791	0.001	0.003
Ring-9	E	M	5546	4.194	0.173	0.401
Torus-1	A	E	7829	9.478	0.967	2.244
Torus-2	B	F	7929	9.6	0.992	2.302
Torus-3	C	G	8242	9.979	1.072	2.487
Torus-4	D	H	closed	0	0	0

CALCULATION NO. DRE97-0003

REV. 0 PAGE A8

```
                         LINEUP REPORT   rev: 12/21/96

LINELIST: RING                                     DEVIATION: 0.0111 %
   dated: 12/18/96                                     after: 6 iterations

      4 LPCI @2500 and 2 CS @4500 Injecting. Nearest torus leg blocked.
Volumetric flow rates require constant fluid properties in all pipelines.
          Fluid properties in the first specification were used.

     NODE               DEMAND          NODE              DEMAND
                        gpm                               gpm

     N        >>>       4500            O        >>>      0.0001
     P        >>>       5000            R        >>>      2500
     S        >>>       2500            U        >>>      4500

                                           FLOWS  IN: 0 gpm
                                           FLOWS OUT: 19000    gpm

                                        NET FLOWS OUT: 19000    gpm


     PIPELINE                  FLOW            PRESSURE        SET
                               gpm             SOURCE          psig

     Torus-1           <<<     6218     <<<    A               0
     Torus-2           <<<     6302     <<<    B               0
     Torus-3           <<<     6480     <<<    C               0

                                           FLOWS  IN: 19000    gpm
                                           FLOWS OUT: 0 gpm

                                        NET FLOWS  IN: 19000    gpm
```

CALCULATION No. DRE97-0003

REV. 0   PAGE A9

NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -0.610	-1.416
F	0		* -0.626	-1.454
G	0		* -0.662	-1.538
H	0		* -0.712	-1.652
I	0		* -0.634	-1.472
J	0		* -0.666	-1.547
K	0		* -0.665	-1.544
L	0		* -0.711	-1.651
M	0		* -0.712	-1.652
N	0	> 4500	* -0.885	-2.054
O	0	> 0.0001	* -0.665	-1.544
P	0	> 5000	* -0.778	-1.805
Q	0		* -0.820	-1.903
R	0	> 2500	* -0.956	-2.219
S	0	> 2500	* -1.269	-2.945
T	0		* -0.967	-2.245
U	0	> 4500	* -2.011	-4.668

CALCULATION NO. DRE97-0003

REV. 0 PAGE A10

PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	H1 ft
CS-3A	I	N	4500	6.274	0.251	0.582
CS3B-16	T	U	4500	7.911	1.044	2.423
CS3B-18	M	T	4500	6.274	0.255	0.593
HPCI	K	O	0	0	0	0
LPCI3A	Q	R	2500	5.822	0.136	0.315
LPCI3A/B	J	Q	5000	3.781	0.154	0.357
LPCI3B	Q	S	2500	5.822	0.449	1.041
LPCI3C/D	L	P	5000	3.781	0.066	0.154
Ring-1	E	I	1999	1.512	0.024	0.056
Ring-2	F	I	2501	1.892	0.008	0.018
Ring-3	F	J	3800	2.874	0.040	0.093
Ring-4	K	J	1200	0.907	0.001	0.003
Ring-5	G	K	1200	0.907	0.002	0.006
Ring-6	G	L	5280	3.993	0.049	0.113
Ring-7	L	<-> H	280.3	0.212	0	0
Ring-8	H	M	280.3	0.212	0	0
Ring-9	E	M	4220	3.191	0.102	0.236
Torus-1	A	E	6218	7.529	0.610	1.416
Torus-2	B	F	6302	7.629	0.626	1.454
Torus-3	C	G	6480	7.845	0.662	1.538
Torus-4	D	H	closed	0	0	0

CALCULATION NO. DRE97-0003

REV. 0 PAGE A11

```
   by: Palas

                     LINEUP REPORT   rev: 12/21/96

LINELIST: RING                                    DEVIATION: 1.37 %
   dated: 12/18/96                                    after: 3 iterations

      3 LPCI @5000 and 2 CS @4500 Injecting. Nearest torus blocked.
Volumetric flow rates require constant fluid properties in all pipelines.
          Fluid properties in the first specification were used.

     NODE            DEMAND           NODE            DEMAND
                     gpm                              gpm

     N         >>>   4500             P         >>>   5000
     R         >>>   5000             S         >>>   5000
     U         >>>   4500

                                         FLOWS  IN: 0 gpm
                                         FLOWS OUT: 24000    gpm
                                     NET FLOWS OUT: 24000    gpm


     PIPELINE              FLOW            PRESSURE        SET
                           gpm             SOURCE          psig

     Torus-1         <<<   7825      <<<   A               0
     Torus-2         <<<   7891      <<<   B               0
     Torus-3         <<<   8284      <<<   C               0

                                         FLOWS  IN: 24000    gpm
                                         FLOWS OUT: 0 gpm
                                     NET FLOWS  IN: 24000    gpm
```

CALCULATION NO. DRE97-0003

REV. 0   PAGE A12

NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -0.966	-2.242
F	0		* -0.982	-2.28
G	0		* -1.082	-2.513
H	0		* -1.109	-2.574
I	0		* -1.012	-2.349
J	0		* -1.086	-2.52
K	0		* -1.106	-2.568
L	0		* -1.118	-2.595
M	0		* -1.108	-2.573
N	0	> 4500	* -1.263	-2.931
P	0	> 5000	* -1.184	-2.748
Q	0		* -1.697	-3.939
R	0	> 5000	* -2.24	-5.199
S	0	> 5000	* -3.486	-8.091
T	0		* -1.364	-3.166
U	0	> 4500	* -2.408	-5.589

CALCULATION No. DRE97-0003

REV. 0 PAGE A13

PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	Hl ft
CS-3A	I	N	4500	6.274	0.251	0.582
CS3B-16	T	U	4500	7.911	1.044	2.423
CS3B-18	M	T	4500	6.274	0.255	0.593
HPCI	K	O	closed	0	0	0
LPCI3A	Q	R	5000	11.64	0.543	1.259
LPCI3A/B	J	Q	10000	7.563	0.612	1.42
LPCI3B	Q	S	5000	11.64	1.789	4.152
LPCI3C/D	L	P	5000	3.781	0.066	0.154
Ring-1	E	I	2801	2.119	0.046	0.107
Ring-2	F	I	1699	1.285	0.004	0.008
Ring-3	F	J	6192	4.683	0.103	0.240
Ring-4	K	J	3808	2.88	0.014	0.032
Ring-5	G	K	3808	2.88	0.024	0.056
Ring-6	G	L	4476	3.385	0.035	0.082
Ring-7	H	L	523.9	0.396	0	0.002
Ring-8	M	<-> H	523.9	0.396	0	0
Ring-9	E	M	5024	3.8	0.143	0.331
Torus-1	A	E	7825	9.474	0.966	2.242
Torus-2	B	F	7891	9.553	0.982	2.28
Torus-3	C	G	8284	10.03	1.082	2.513
Torus-4	D	H	closed	0	0	0

CALCULATION No. DRE97-0003

REV. 0 PAGE A14

```
Project:
    by: Palas

                    LINEUP REPORT   rev: 12/21/96

LINELIST: RING                                    DEVIATION: 0.0106 %
   dated: 12/18/96                                    after: 6 iterations

   2 LPCI @2500, 1 LPCI @5000 and 2 CS @4500 Injecting. Nearest torus
                              blocked.

Volumetric flow rates require constant fluid properties in all pipelines.
         Fluid properties in the first specification were used.

    NODE            DEMAND             NODE            DEMAND
                    gpm                                gpm

    N       >>>     4500               P       >>>     5000
    S       >>>     5000               U       >>>     4500

                                          FLOWS   IN: 0 gpm
                                          FLOWS  OUT: 19000    gpm

                                       NET FLOWS OUT: 19000    gpm


    PIPELINE                 FLOW          PRESSURE        SET
                             gpm           SOURCE          psig

    Torus-1          <<<     6218    <<<   A               0
    Torus-2          <<<     6302    <<<   B               0
    Torus-3          <<<     6480    <<<   C               0

                                          FLOWS   IN: 19000    gpm
                                          FLOWS  OUT: 0 gpm

                                       NET FLOWS  IN: 19000    gpm
```

CALCULATION NO. DRE97-0003

REV. 0 PAGE A15

NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -0.610	-1.416
F	0		* -0.626	-1.454
G	0		* -0.662	-1.538
H	0		* -0.712	-1.652
I	0		* -0.634	-1.472
J	0		* -0.666	-1.547
K	0		* -0.665	-1.544
L	0		* -0.711	-1.651
M	0		* -0.712	-1.652
N	0	> 4500	* -0.885	-2.054
P	0	> 5000	* -0.778	-1.805
Q	0		* -0.820	-1.903
R	0		* -0.820	-1.903
S	0	> 5000	* -2.609	-6.055
T	0		* -0.967	-2.245
U	0	> 4500	* -2.011	-4.668

CALCULATION No. DRE97-0003

REV. 0 PAGE A16

PIPELINE	FROM		TO	FLOW gpm	VEL ft/sec	dP psi g	H1 ft
CS-3A	I		N	4500	6.274	0.251	0.582
CS3B-16	T		U	4500	7.911	1.044	2.423
CS3B-18	M		T	4500	6.274	0.255	0.593
HPCI	K		O	closed	0	0	0
LPCI3A	Q		R	0	0	0	0
LPCI3A/B	J		Q	5000	3.781	0.154	0.357
LPCI3B	Q		S	5000	11.64	1.789	4.152
LPCI3C/D	L		P	5000	3.781	0.066	0.154
Ring-1	E		I	1999	1.512	0.024	0.056
Ring-2	F		I	2501	1.892	0.008	0.018
Ring-3	F		J	3800	2.874	0.040	0.093
Ring-4	K		J	1200	0.907	0.001	0.003
Ring-5	G		K	1200	0.907	0.002	0.006
Ring-6	G		L	5280	3.993	0.049	0.113
Ring-7	L	<->	H	280.3	0.212	0	0
Ring-8	H		M	280.3	0.212	0	0
Ring-9	E		M	4220	3.191	0.102	0.236
Torus-1	A		E	6218	7.529	0.610	1.416
Torus-2	B		F	6302	7.629	0.626	1.454
Torus-3	C		G	6480	7.845	0.662	1.538
Torus-4	D		H	closed	0	0	0

CALCULATION NO. DRE97-0003
REV. 0 PAGE A17

```
                    LINEUP REPORT   rev: 01/03/97

LINELIST: RING                                      DEVIATION: 0.0106 %
   dated: 12/18/96                                      after: 6 iterations

     2 LPCI @2500, 1 LPCI @5000 and 2 CS @4500 Injecting. Nearest torus
                                 blocked.

Volumetric flow rates require constant fluid properties in all pipelines.
          Fluid properties in the first specification were used.

    NODE             DEMAND           NODE             DEMAND
                     gpm                               gpm

    N          >>>   4500             P          >>>   5000
    R          >>>   2500             S          >>>   2500
    U          >>>   4500

                                          FLOWS   IN: 0 gpm
                                          FLOWS  OUT: 19000    gpm
                                      NET FLOWS  OUT: 19000    gpm


    PIPELINE                 FLOW           PRESSURE        SET
                             gpm            SOURCE          psig

    Torus-1             <<<  6218      <<<  A               0
    Torus-2             <<<  6302      <<<  B               0
    Torus-3             <<<  6480      <<<  C               0
                                          FLOWS   IN: 19000    gpm
                                          FLOWS  OUT: 0 gpm
                                      NET FLOWS   IN: 19000    gpm
```

CALCULATION No. DRE97-0003
REV. 0   PAGE A18

NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -0.610	-1.416
F	0		* -0.626	-1.454
G	0		* -0.662	-1.538
H	0		* -0.712	-1.652
I	0		* -0.634	-1.472
J	0		* -0.666	-1.547
K	0		* -0.665	-1.544
L	0		* -0.711	-1.651
M	0		* -0.712	-1.652
N	0	> 4500	* -0.885	-2.054
P	0	> 5000	* -0.778	-1.805
Q	0		* -0.820	-1.903
R	0	> 2500	* -0.956	-2.219
S	0	> 2500	* -1.269	-2.945
T	0		* -0.967	-2.245
U	0	> 4500	* -2.011	-4.668

CALCULATION NO. DRE97-0003

REV. 0 PAGE A19

PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	Hl ft
CS-3A	I	N	4500	6.274	0.251	0.582
CS3B-16	T	U	4500	7.911	1.044	2.423
CS3B-18	M	T	4500	6.274	0.255	0.593
HPCI	K	O	closed	0	0	0
LPCI3A	Q	R	2500	5.822	0.136	0.315
LPCI3A/B	J	Q	5000	3.781	0.154	0.357
LPCI3B	Q	S	2500	5.822	0.449	1.041
LPCI3C/D	L	P	5000	3.781	0.066	0.154
Ring-1	E	I	1999	1.512	0.024	0.056
Ring-2	F	I	2501	1.892	0.008	0.018
Ring-3	F	J	3800	2.874	0.040	0.093
Ring-4	K	J	1200	0.907	0.001	0.003
Ring-5	G	K	1200	0.907	0.002	0.006
Ring-6	G	L	5280	3.993	0.049	0.113
Ring-7	L	<-> H	280.3	0.212	0	0
Ring-8	H	M	280.3	0.212	0	0
Ring-9	E	M	4220	3.191	0.102	0.236
Torus-1	A	E	6218	7.529	0.610	1.416
Torus-2	B	F	6302	7.629	0.626	1.454
Torus-3	C	G	6480	7.845	0.662	1.538
Torus-4	D	H	closed	0	0	0

CALCULATION NO. DRE97-0003

REV. 0 PAGE A20

```
Project:
    by: Palas

                    LINEUP REPORT   rev: 12/21/96

LINELIST: ring                                      DEVIATION: 1.47 %
  dated: 12/18/96                                       after: 4 iterations

   2 LPCI @5000 and 2 CS @4500 Injecting. Nearest torus leg blocked.
Volumetric flow rates require constant fluid properties in all pipelines.
     Fluid properties in the first pipe specification were used.

    NODE            DEMAND          NODE            DEMAND
                    gpm                             gpm

    N       >>>     4500            R       >>>     5000

    S       >>>     5000            U       >>>     4500

                                    NET FLOWS OUT:  19000   gpm


    PRESSURE CONNECTIONS            FLOW            PRESSURE
    Node            Pipeline        gpm             psi g

    A       >>>     Torus-1         6169    >>>     0

    B       >>>     Torus-2         6419    >>>     0

    C       >>>     Torus-3         6412    >>>     0

                                    NET FLOWS  IN:  19000   gpm
```

CALCULATION NO. DRE97-0003
REV. 0   PAGE A21

NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
[illegible]	0		p 0	0
C	0		p 0	0
E	0		* -0.600	-1.394
F	0		* -0.650	-1.509
G	0		* -0.649	-1.506
H	0		* -0.657	-1.525
I	0		* -0.653	-1.515
J	0		* -0.716	-1.662
K	0		* -0.691	-1.604
L	0		* -0.652	-1.513
M	0		* -0.659	-1.53
N	0	> 4500	* -0.904	-2.097
Q	0		* -1.327	-3.081
R	0	> 5000	* -1.87	-4.34
S	0	> 5000	* -3.116	-7.233
T	0		* -0.915	-2.123
U	0	> 4500	* -1.958	-4.546

CALCULATION NO. DRE97-0003

REV. 0 PAGE A22

PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	Hl ft
CS-3A	I	N	4500	6.274	0.251	0.582
[illegible]-16	T	U	4500	7.911	1.044	2.423
[illegible]-18	M	T	4500	6.274	0.255	0.593
HPCI			closed	0	0	0
LPCI3A	Q	R	5000	11.64	0.543	1.259
LPCI3A/B	J	Q	10000	7.563	0.612	1.42
LPCI3B	Q	S	5000	11.64	1.789	4.152
LPCI3C/D	D	L	closed	0	0	0
Ring-1	E	I	2991	2.262	0.052	0.121
Ring-2	F	I	1509	1.141	0.003	0.007
Ring-3	F	J	4910	3.714	0.066	0.153
Ring-4	K	J	5090	3.849	0.025	0.057
Ring-5	G	K	5090	3.849	0.042	0.098
Ring-6	G	L	1322	1.000	0.003	0.008
Ring-7	L	<-> H	1322	1.000	0.005	0.012
Ring-8	H	M	1322	1.000	0.002	0.005
Ring-9	E	M	3178	2.403	0.059	0.136
Torus-1	A	E	6169	7.469	0.600	1.394
Torus-2	B	F	6419	7.772	0.650	1.509
Torus-3	C	G	6412	7.763	0.649	1.506
Torus-4	D	H	closed	0	0	0

CALCULATION NO. DRE97-0003
REV. 0 PAGE A23

```
     by: Palas

                        LINEUP REPORT   rev: 12/21/96

   LINELIST: RING                                    DEVIATION: 0.29 %
     dated: 12/18/96                                    after: 4 iterations

       2 LPCI @3750 and 2 CS @4500 Injecting. Nearest torus leg blocked.
   Volumetric flow rates require constant fluid properties in all pipelines.
          Fluid properties in the first specification were used.

       NODE            DEMAND          NODE            DEMAND
                       gpm                             gpm

       N        >>>    4500            R        >>>    3750
       S        >>>    3750            U        >>>    4500
                                          FLOWS  IN: 0 gpm
                                          FLOWS OUT: 16500    gpm
                                      NET FLOWS OUT: 16500    gpm


       PIPELINE             FLOW          PRESSURE       SET
                            gpm           SOURCE         psig

       Torus-1        <<<   5376     <<<  A              0
       Torus-2        <<<   5571     <<<  B              0
       Torus-3        <<<   5553     <<<  C              0
                                          FLOWS  IN: 16500    gpm
                                          FLOWS OUT: 0 gpm
                                      NET FLOWS  IN: 16500    gpm
```

CALCULATION No. DRE97-0003

REV. 0 PAGE A24

NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -0.456	-1.059
F	0		* -0.490	-1.137
G	0		* -0.487	-1.129
H	0		* -0.500	-1.16
I	0		* -0.494	-1.148
J	0		* -0.526	-1.221
K	0		* -0.511	-1.187
L	0		* -0.492	-1.141
M	0		* -0.503	-1.168
N	0	> 4500	* -0.745	-1.73
Q	0		* -0.870	-2.021
R	0	> 3750	* -1.176	-2.729
S	0	> 3750	* -1.878	-4.359
T	0		* -0.759	-1.761
U	0	> 4500	* -1.802	-4.184

CALCULATION No. DRE97-0003
REV. 0 PAGE A25

PIPELINE	FROM	TO	FLOW gpm	VEL ft/sec	dP psi g	Hl ft
CS-3A	I	N	4500	6.274	0.251	0.582
CS3B-16	T	U	4500	7.911	1.044	2.423
CS3B-18	M	T	4500	6.274	0.255	0.593
HPCI	K	O	closed	0	0	0
LPCI3A	Q	R	3750	8.732	0.305	0.709
LPCI3A/B	J	Q	7500	5.672	0.345	0.800
LPCI3B	Q	S	3750	8.732	1.007	2.338
LPCI3C/D	L	P	closed	0	0	0
Ring-1	E	I	2545	1.924	0.038	0.089
Ring-2	F	I	1955	1.479	0.005	0.011
Ring-3	F	J	3615	2.734	0.036	0.084
Ring-4	K	J	3885	2.938	0.014	0.033
Ring-5	G	K	3885	2.938	0.025	0.058
Ring-6	G	L	1668	1.262	0.005	0.012
Ring-7	L	<-> H	1668	1.262	0.008	0.019
Ring-8	H	M	1668	1.262	0.003	0.008
Ring-9	E	M	2832	2.142	0.047	0.109
Torus-1	A	E	5376	6.509	0.456	1.059
Torus-2	B	F	5571	6.744	0.490	1.137
Torus-3	C	G	5553	6.723	0.487	1.129
Torus-4	D	H	closed	0	0	0

CALCULATION NO. DRE97-0003

REV. 0 PAGE A26

```
Project:                                                      12/21/96
    by: Palas

                      LINEUP REPORT   rev: 12/21/96

LINELIST: RING                                   DEVIATION: 0.0179 %
   dated: 12/18/96                                   after: 5 iterations

    1 LPCI @5000 and 2 CS @4500 Injecting. Nearest torus leg blocked.
Volumetric flow rates require constant fluid properties in all pipelines.
        Fluid properties in the first specification were used.

    NODE            DEMAND           NODE            DEMAND
                    gpm                              gpm

    N       >>>     4500             S       >>>     5000
    U       >>>     4500

                                        FLOWS   IN: 0 gpm
                                        FLOWS  OUT: 14000    gpm
                                     NET FLOWS OUT: 14000    gpm


    PIPELINE                FLOW          PRESSURE       SET
                            gpm           SOURCE         psig

    Torus-1         <<<     4592     <<<  A              0
    Torus-2         <<<     4719     <<<  B              0
    Torus-3         <<<     4690     <<<  C              0
                                        FLOWS   IN: 14001    gpm
                                        FLOWS  OUT: 0 gpm
                                     NET FLOWS  IN: 14001    gpm
```

NODE	ELEVATION ft	DEMAND gpm	PRESSURE psi g	H GRADE ft
A	0		p 0	0
B	0		p 0	0
C	0		p 0	0
E	0		* -0.333	-0.772
F	0		* -0.351	-0.816
G	0		* -0.347	-0.806
H	0		* -0.365	-0.848
I	0		* -0.359	-0.833
J	0		* -0.366	-0.850
K	0		* -0.359	-0.834
L	0		* -0.354	-0.822
M	0		* -0.370	-0.860
N	0	> 4500	* -0.610	-1.415
Q	0		* -0.520	-1.207
S	0	> 5000	* -2.309	-5.359
T	0		* -0.626	-1.452
U	0	> 4500	* -1.669	-3.875

CALCULATION No. DRE97-0003
REV. 0 PAGE A28

PIPELINE	FROM		TO	FLOW gpm	VEL ft/sec	dP psi g	H1 ft
CS-3A	I		N	4500	6.274	0.251	0.582
CS3B-16	T		U	4500	7.911	1.044	2.423
CS3B-18	M		T	4500	6.274	0.255	0.593
HPCI	K		O	closed	0	0	0
LPCI3A	Q		R	closed	0	0	0
LPCI3A/B	J		Q	5000	3.781	0.154	0.357
LPCI3B	Q		S	5000	11.64	1.789	4.152
LPCI3C/D	L		P	closed	0	0	0
Ring-1	E		I	2074	1.569	0.026	0.060
Ring-2	F		I	2426	1.835	0.007	0.017
Ring-3	F		J	2293	1.734	0.015	0.035
Ring-4	K		J	2707	2.047	0.007	0.016
Ring-5	G		K	2707	2.047	0.012	0.028
Ring-6	G		L	1983	1.499	0.007	0.017
Ring-7	L	<->	H	1983	1.499	0.011	0.026
Ring-8	H		M	1983	1.499	0.005	0.011
Ring-9	E		M	2517	1.904	0.038	0.087
Torus-1	A		E	4592	5.559	0.333	0.772
Torus-2	B		F	4719	5.713	0.351	0.816
Torus-3	C		G	4690	5.678	0.347	0.806
Torus-4	D		H	closed	0	0	0

CALCULATION No. DRE97-0003

REV. 0 PAGE A29

FAX COVER SHEET

Thursday, January, 16, 1997 12:56:25 PM

To: John Stang
At: U.S. NRC Reactor Projects III
Fax #: 1-(301)415-3861

From: Karl Gross
Voice: 815-941-2920 x3710

Fax: 15 pages and a cover page.

Note:
Vibration Data for F. Spangenberg and B. Rybak

Pump EPN	Date	3H	3V
2-1401A	10/19/95	0.1422	0.1198
2-1401A	1/6/96	0.1236	0.2733
2-1401A	2/15/96	0.1255	0.2857
2-1401A	5/8/96	0.1239	0.2025
2-1401A	8/22/96	0.132	0.225
2-1401A	10/26/96	0.1192	0.1941
2-1401A	3/12/95	0.095	0.212
2-1401B	10/26/96	0.1108	0.147
2-1401B	3/12/95	0.138	0.202
2-1401B	1/21/96	0.188	0.2641
2-1401B	2/15/96	0.1308	0.2176
2-1401B	5/8/96	0.1302	0.1713
2-1401B	8/22/96	0.116	0.173
2-1502A	9/25/96	0.057	0.101
2-1502A	12/18/96	0.0548	0.0872
2-1502A	7/3/96	0.0596	0.0816
2-1502A	4/3/96	0.067	0.0767
2-1502B	9/25/96	0.095	0.104
2-1502B	4/3/96	0.0936	0.1117
2-1502B	12/18/96	0.0963	0.0896
2-1502B	7/3/96	0.0963	0.1047
2-1502C	12/18/96	0.1468	0.1459
2-1502C	9/25/96	0.128	0.145
2-1502C	4/3/96	0.11	0.1483
2-1502C	7/3/96	0.1058	0.1306
2-1502D	7/3/96	0.1162	0.1475
2-1502D	4/3/96	0.1352	0.1813
2-1502D	12/18/96	0.1015	0.1264
2-1502D	9/25/96	0.14	0.103
3-1401A	11/26/96	0.0815	0.1012
3-1401A	9/10/96	0.093	0.1019
3-1401B	3/20/96	0.1209	0.1395
3-1401B	11/26/96	0.1172	0.118
3-1401B	9/10/96	0.1267	0.0994
3-1502A	9/11/96	0.0889	0.1244
3-1502A	3/21/96	0.0829	0.131
3-1502A	11/27/96	0.0843	0.119
3-1502A	6/12/96	0.0741	0.1109
3-1502B	6/12/96	0.175	0.1226
3-1502B	9/11/96	0.1338	0.0911
3-1502B	11/27/96	0.1162	0.1131
3-1502B	3/21/96	0.1812	0.1039
3-1502C	6/12/96	0.1586	0.1342
3-1502C	9/11/96	0.1706	0.1238
3-1502C	11/27/96	0.1904	0.1332
3-1502C	3/21/96	0.1318	0.1272
3-1502D	6/12/96	0.1155	0.135
3-1502D	9/11/96	0.117	0.1499
3-1502D	3/21/96	0.1086	0.1448
3-1502D	11/27/96	0.12	0.1274

Query1 1/16/97

Pump EPN	Reference 3H	Alert 3H	Req Act 3H	Reference 3V	Alert 3V
2-1401A	0.142	0.325 to 0.700	>0.700	0.120	0.300 to 0.700
2-1401B	0.189	0.325 to 0.700	>0.700	0.203	0.325 to 0.700
3-1401A	0.101	0.253 to 0.606	>0.606	0.091	0.228 to 0.546
3-1401B	0.123	0.308 to 0.700	>0.700	0.153	0.325 to 0.700
2-1502A	0.101	0.253 to 0.606	>0.606	0.111	0.278 to 0.666
2-1502B	0.084	0.210 to 0.504	>0.504	0.089	0.223 to 0.534
2-1502C	0.089	0.223 to 0.534	>0.534	0.170	0.325 to 0.700
2-1502D	0.158	0.325 to 0.700	>0.700	0.135	0.325 to 0.700
3-1502A	0.109	0.273 to 0.654	>0.654	0.109	0.273 to 0.654
3-1502B	0.101	0.253 to 0.606	>0.606	0.101	0.253 to 0.606
3-1502C	0.114	0.285 to 0.684	>0.684	0.114	0.285 to 0.684
3-1502D	0.110	0.275 to 0.660	>0.660	0.142	0.325 to 0.700

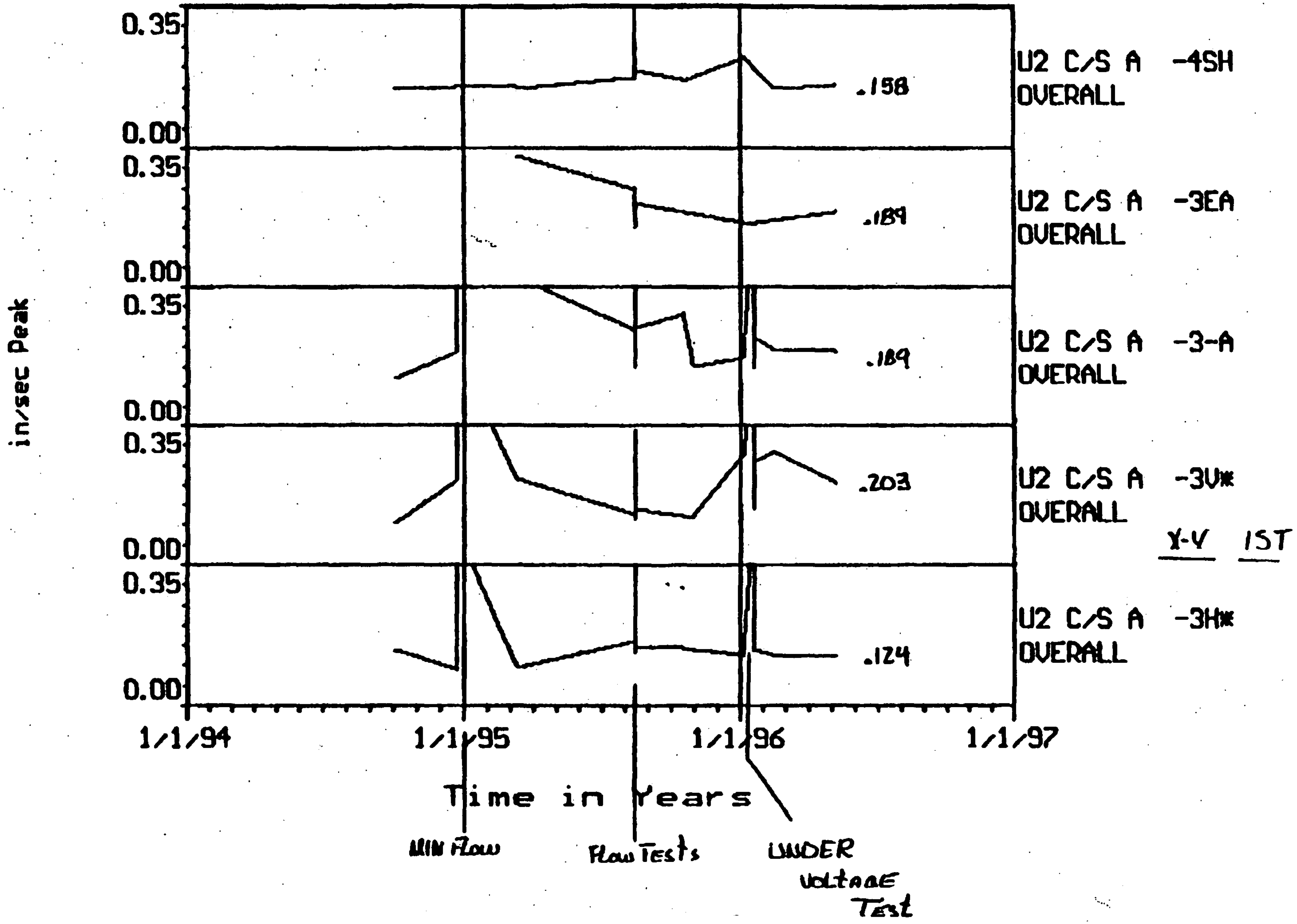
acceptance ranges

Req Act 3V
>0.700
>0.700
>0.546
>0.700
>0.666
>0.534
>0.700
>0.700
>0.654
>0.606
>0.684
>0.700

acceptance ranges

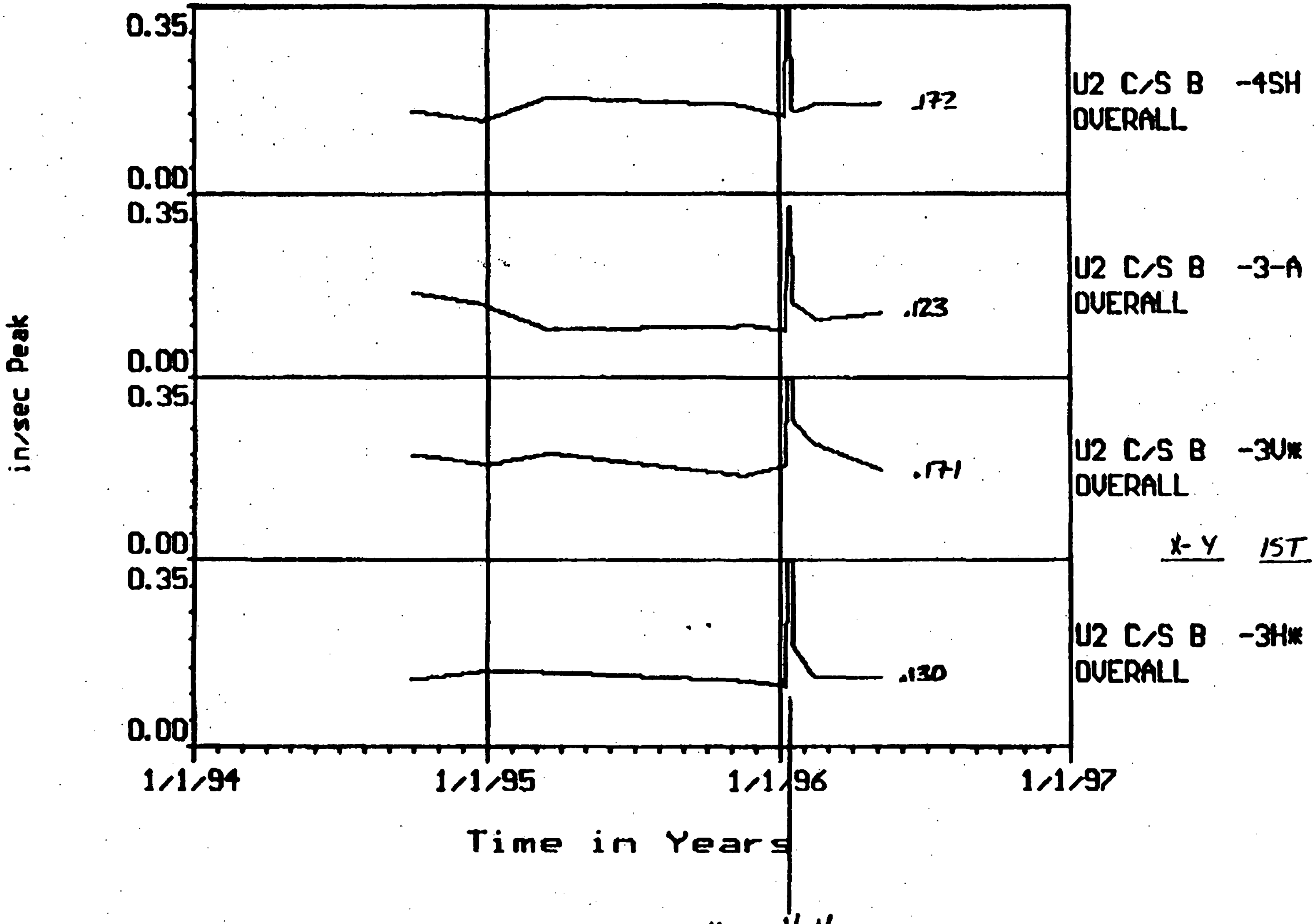
Intelli-Trend(R) Multi-Trend Display

STATION: DRESDEN NUCLEAR STATION UNIT 2



Intelli-Trend(R) Multi-Trend Display

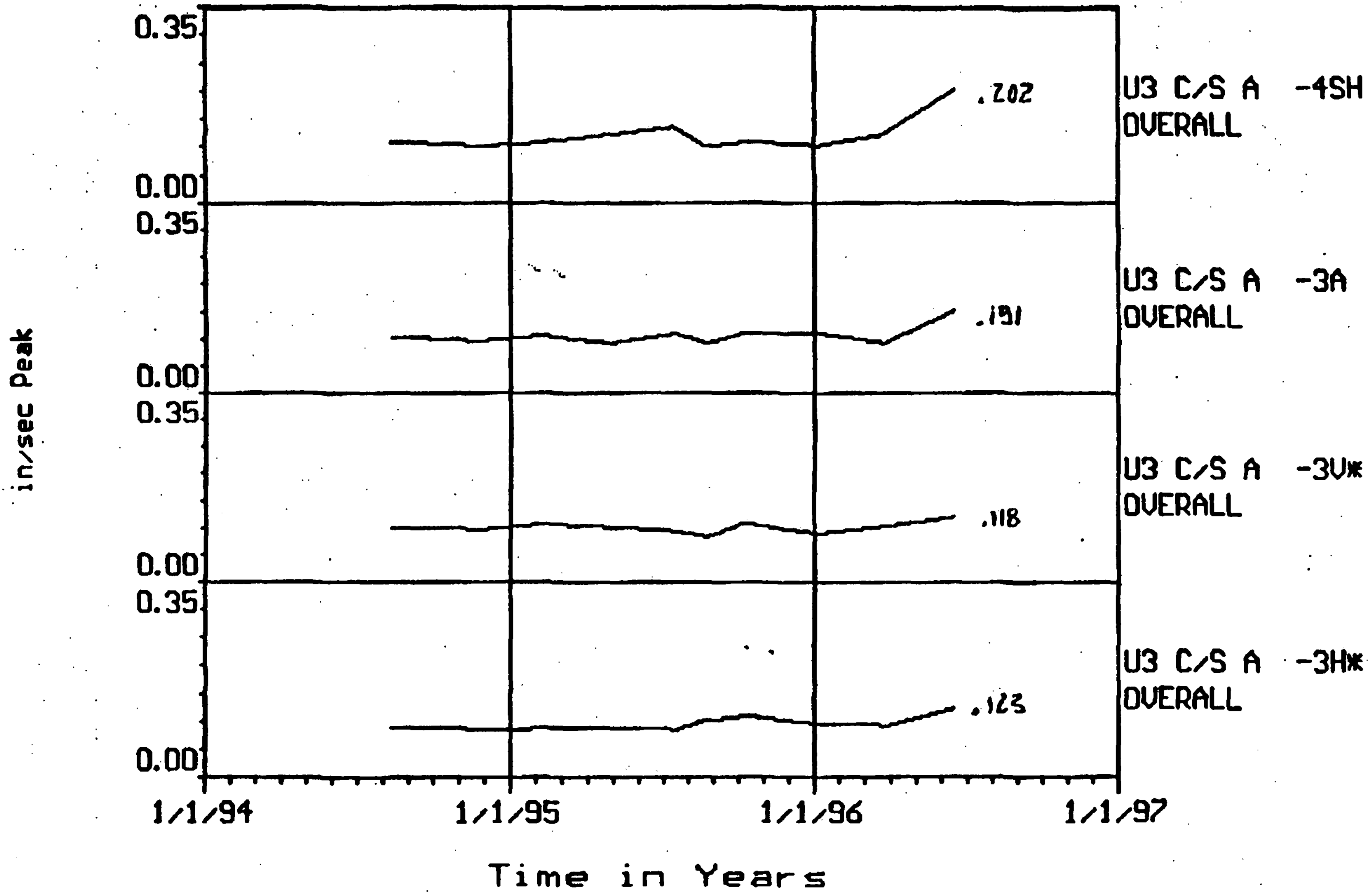
STATION: DRESDEN NUCLEAR   STATION UNIT 2



Under Voltage Test

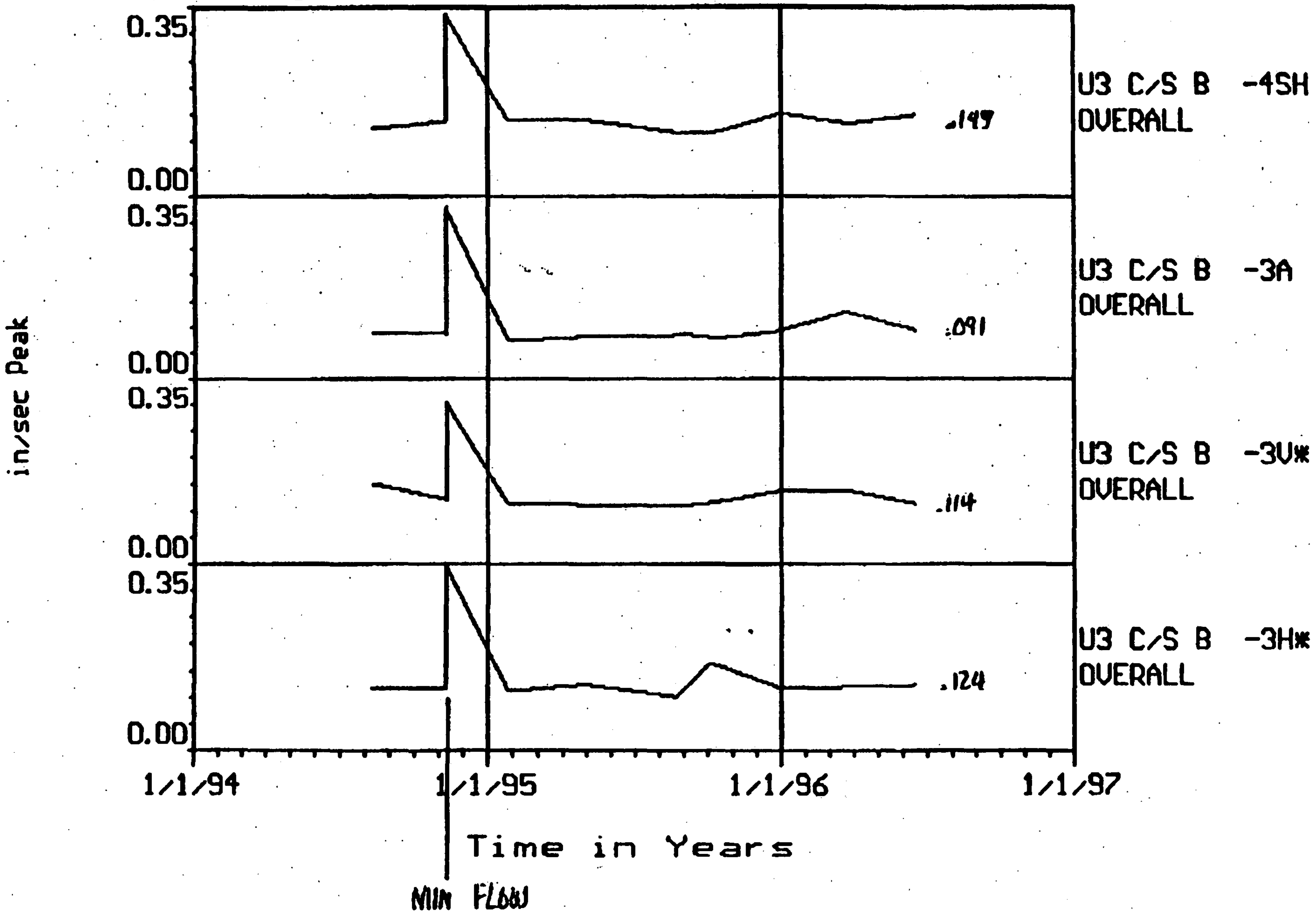
Intelli-Trend(R) Multi-Trend Display

STATION: DRESDEN NUCLEAR STATION UNIT 3



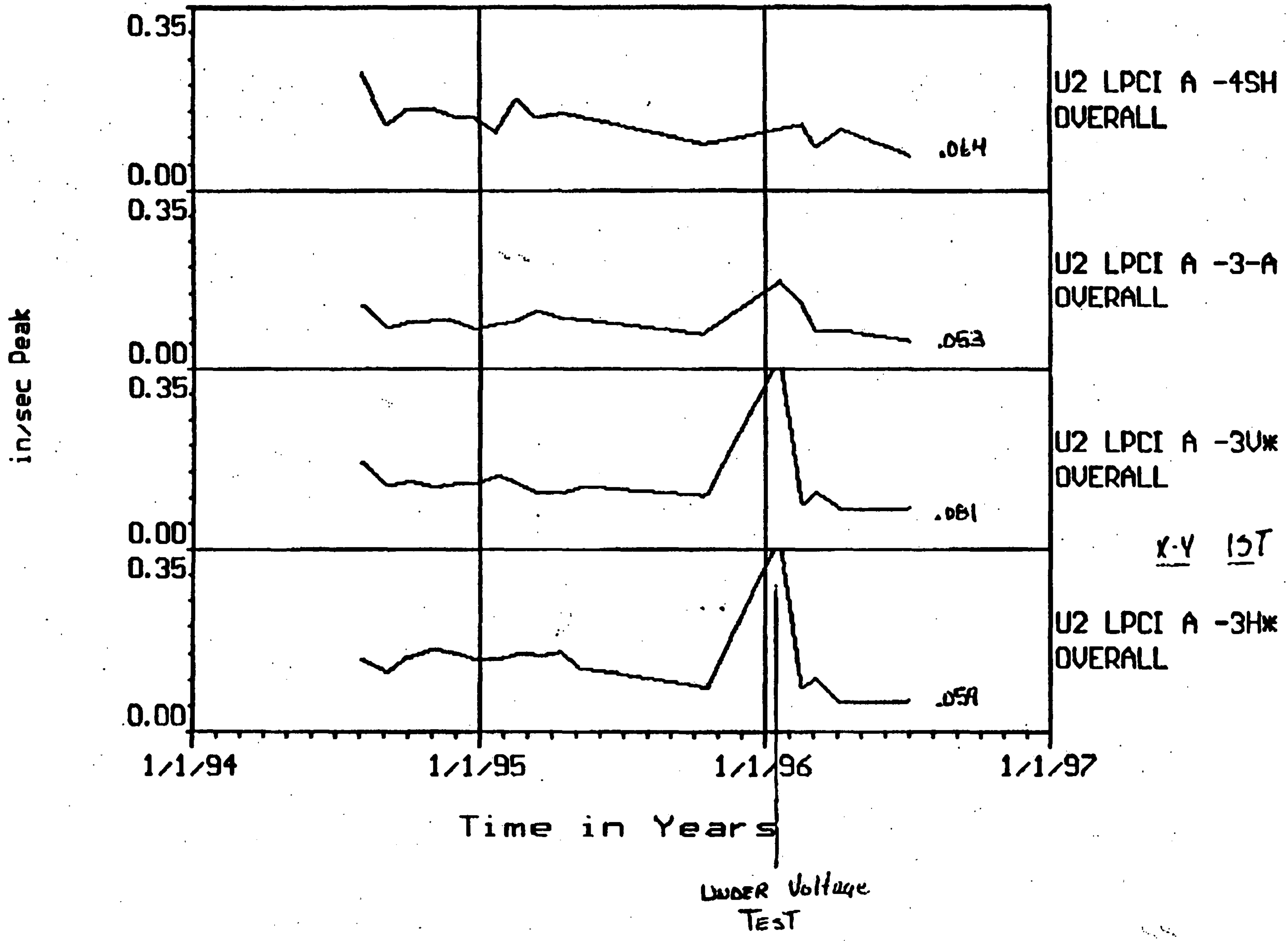
Intelli-Trend(R) Multi-Trend Display

STATION: DRESDEN NUCLEAR STATION UNIT 3



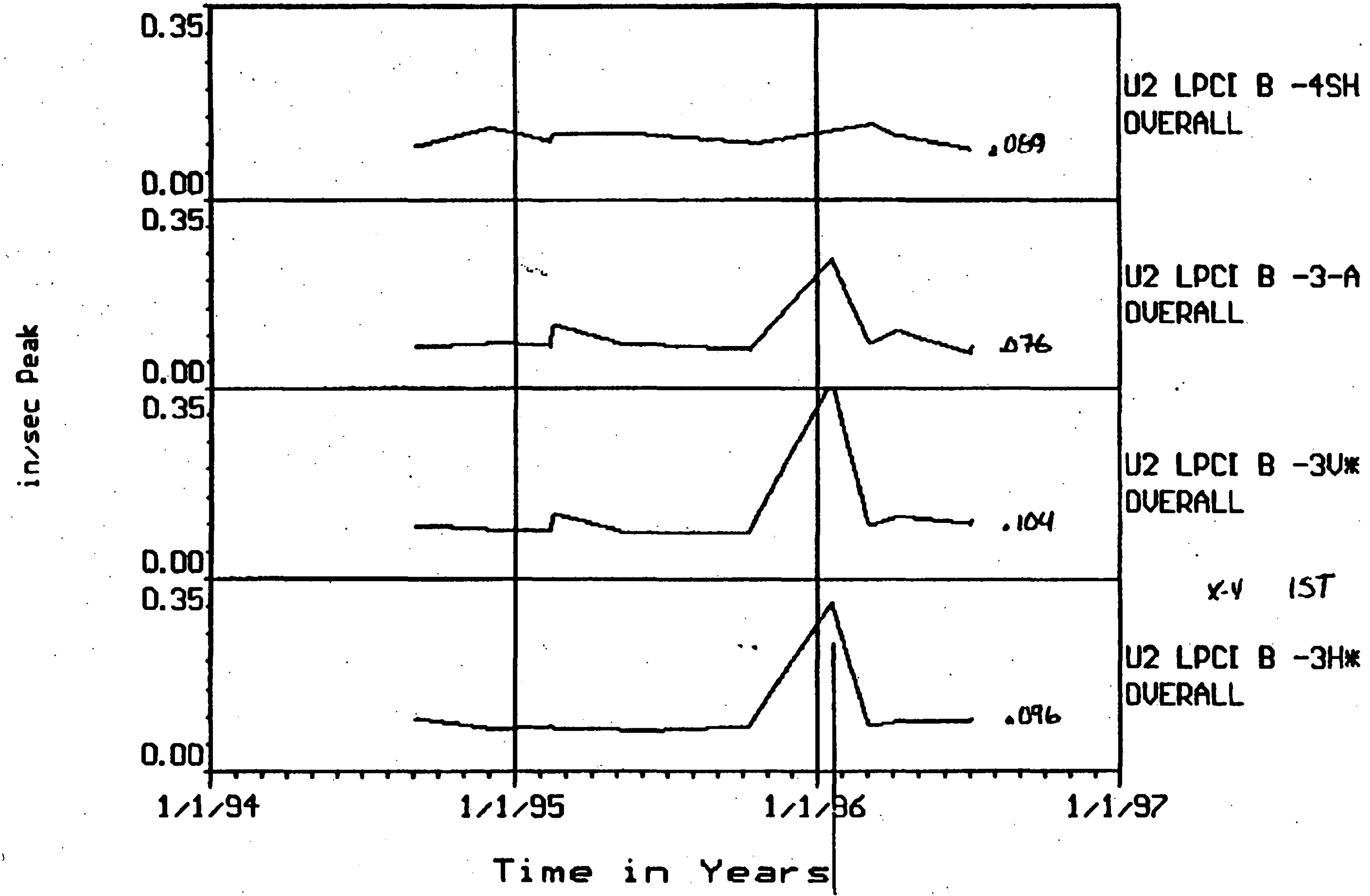
Intelli-Trend(R) Multi-Trend Display

STATION: DRESDEN NUCLEAR STATION UNIT 2



Intelli-Trend(R) Multi-Trend Display

STATION: DRESDEN NUCLEAR STATION UNIT 2



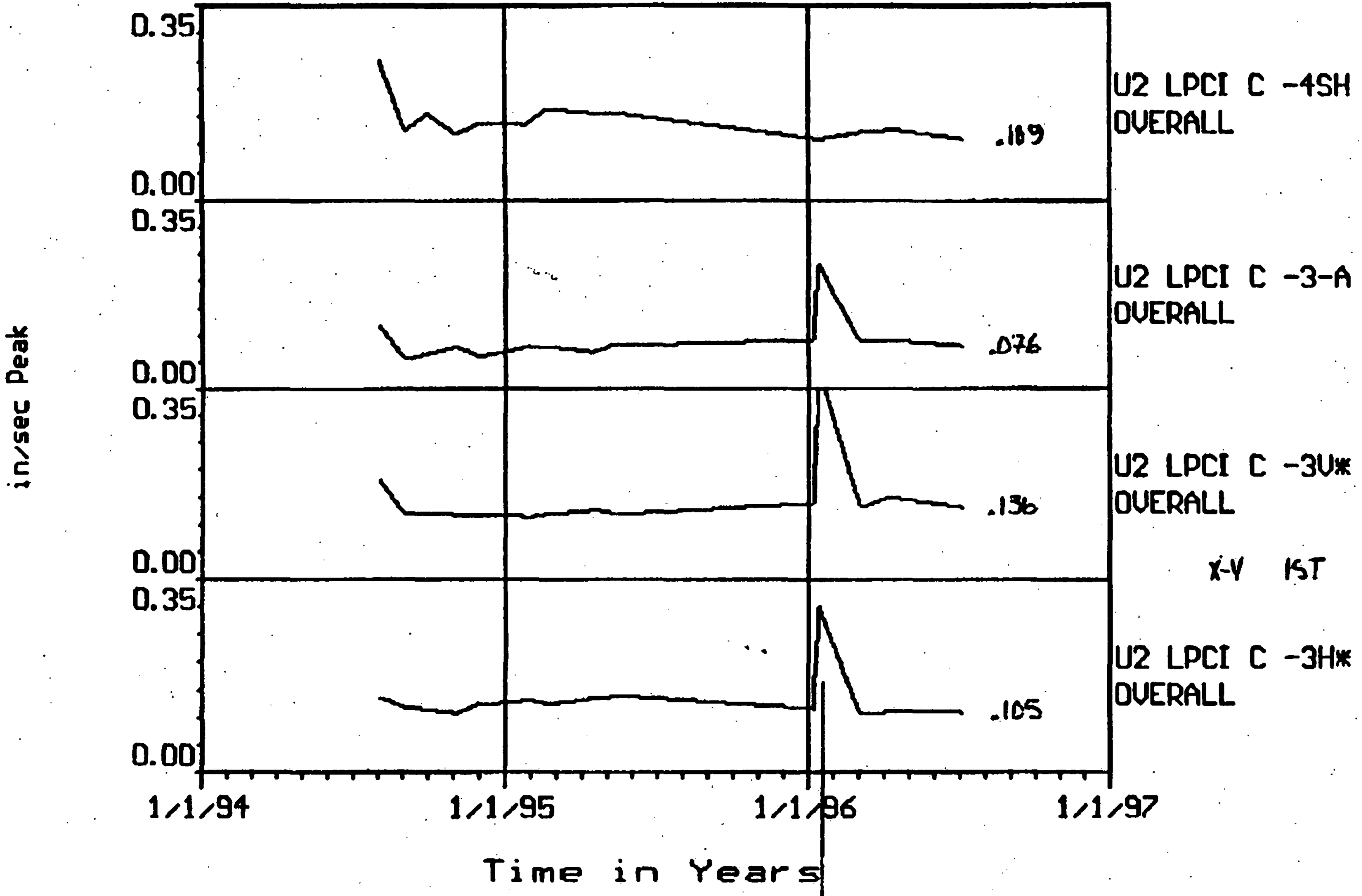
X-Y 1ST

UNDER Voltage

Test

Intelli-Trend(R) Multi-Trend Display

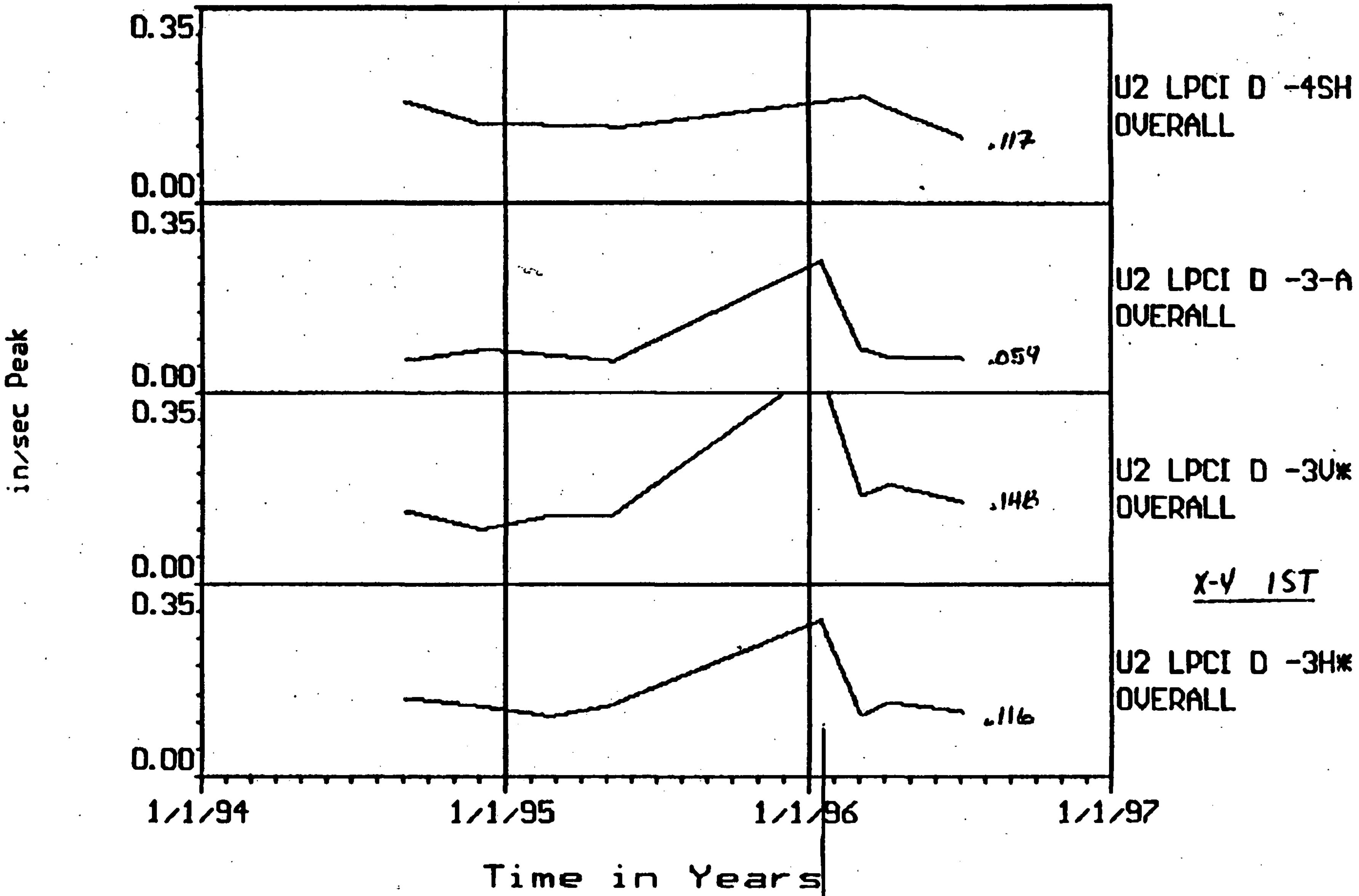
STATION: DRESDEN NUCLEAR STATION UNIT 2



Under Voltage
Test

Intelli-Trend(R) Multi-Trend Display

STATION: DRESDEN NUCLEAR   STATION UNIT 2

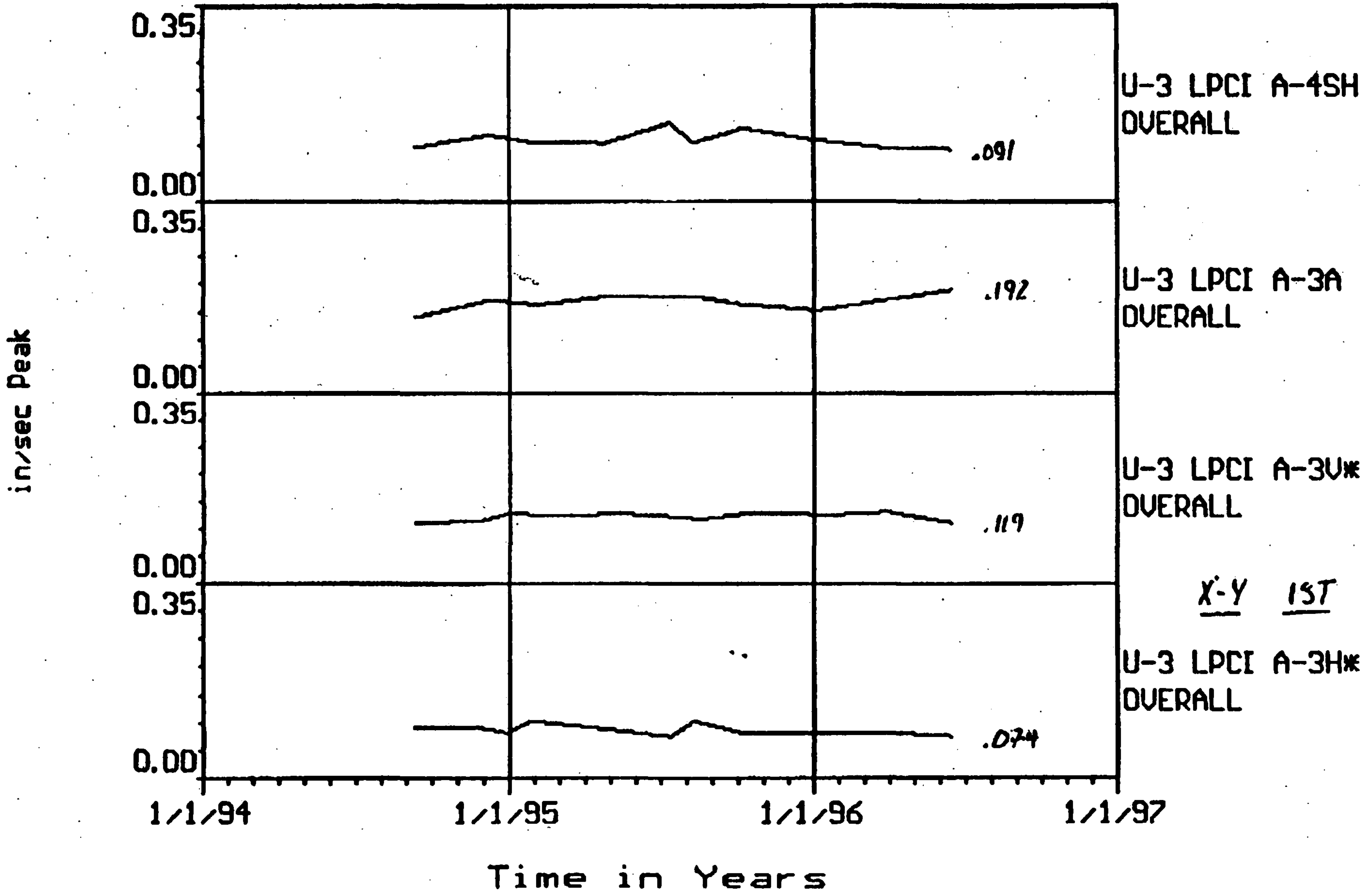


X-Y 1ST

UNDER Voltage test

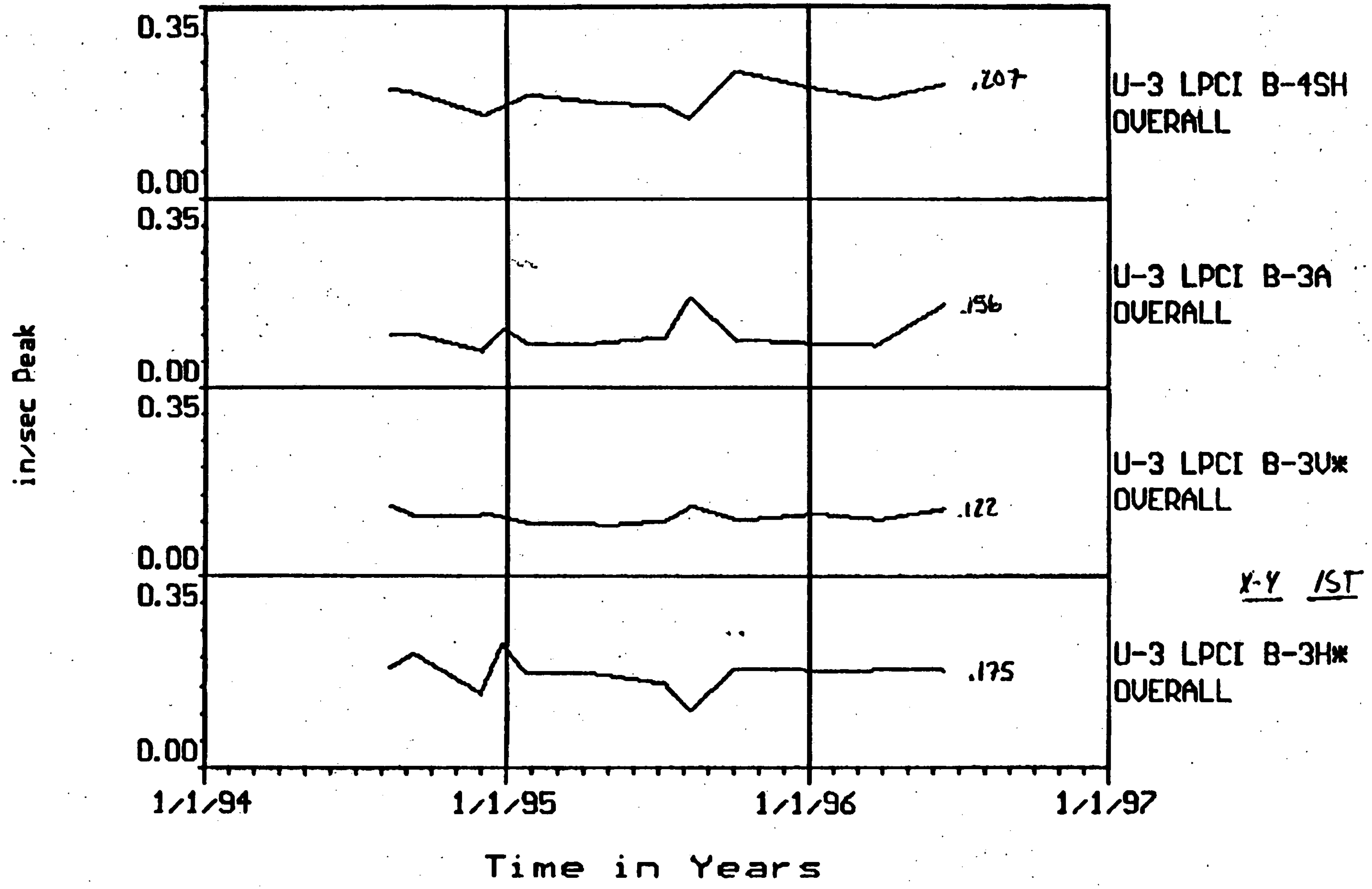
Intelli-Trend(R) Multi-Trend Display

STATION: DRESDEN NUCLEAR   STATION UNIT 3



Intelli-Trend(R) Multi-Trend Display

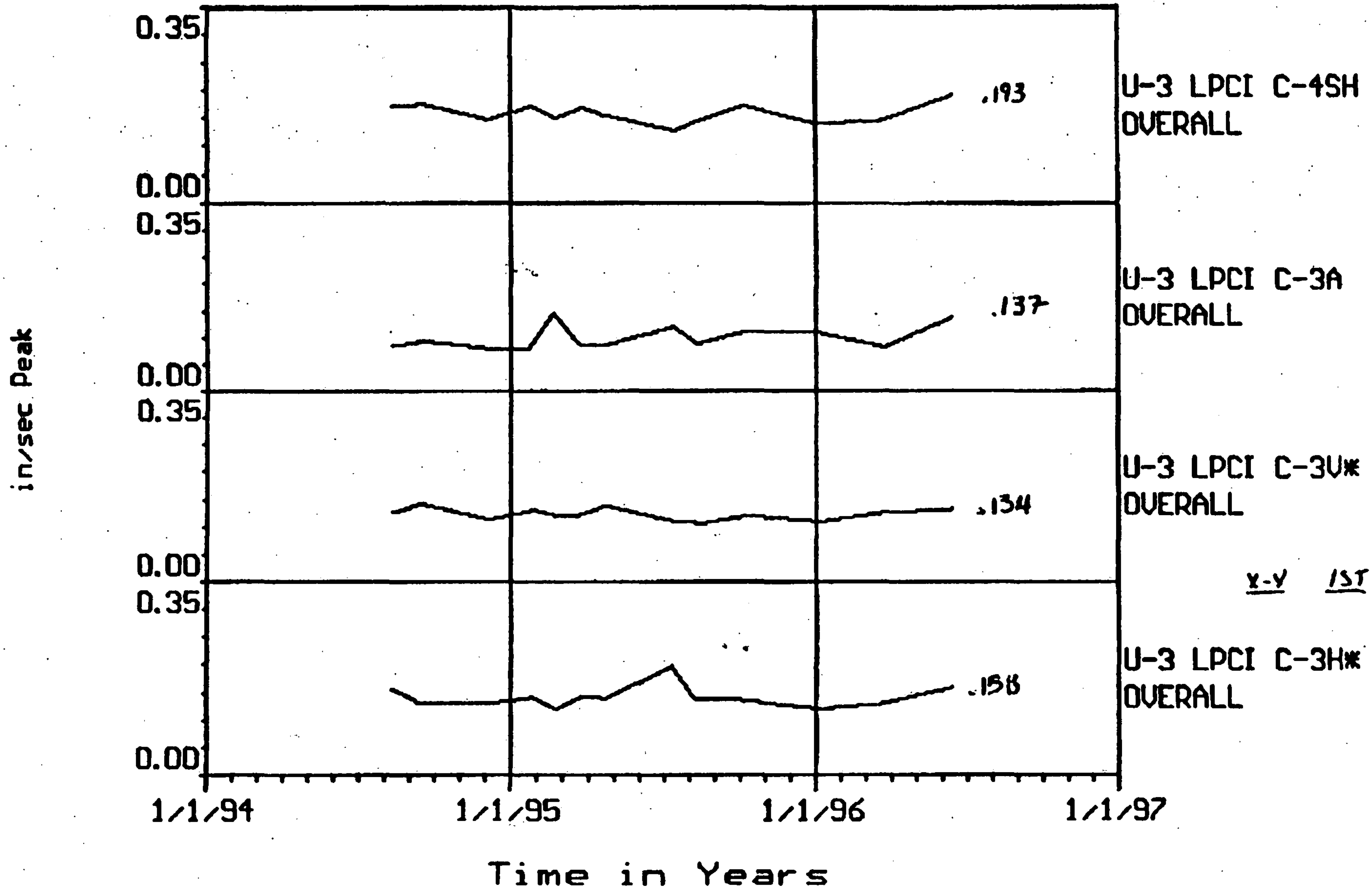
STATION: DRESDEN NUCLEAR STATION UNIT 3



X-Y /ST

Intelli-Trend(R) Multi-Trend Display

STATION: DRESDEN NUCLEAR STATION UNIT 3



Intelli-Trend(R) Multi-Trend Display

STATION: DRESDEN NUCLEAR   STATION UNIT 3