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

Subject: Waterford 3 SES
Docket No. 50-382
License No. NPF-38
Engineering Evaluation of Nitrogen Gas Pockets in the LPSI Piping

Gentlemen:

As requested by NRR, a copy of the Low Pressure Safety Injection (LPSI) piping evaluation is attached for review. This evaluation discusses the affect nitrogen gas pocket formation in the LPSI piping would have on system operation. The evaluation is for the LPSI "B" train piping only. Due to the presence of a smaller nitrogen gas pocket and a different piping configuration for "A" train, it is assumed that the effects on the "A" train piping system will be bounded by the "B" train evaluation. An analysis has begun on the LPSI "A" train piping to verify this assumption.

This submittal does not include a copy of the actual calculations due to the large size of the calculation packages. Should it be necessary to review these calculations in the future, special arrangements will be made to have a copy shipped to the appropriate party.

A001/1

Should you have any questions on the LPSI piping evaluation, please contact John Burke at (504) 739-6250 or me at (504) 739-6242.

Very truly yours,

E. C. Ewing
Director
Nuclear Safety & Regulatory Affairs

ECE/DMU/tjs
Attachment

cc: E. W. Merschoff, NRC Region IV
C.P. Patel, NRC-NRR
J.T. Wheelock - INPO Records Center
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Detailed Engineering Evaluation
CR 96-1965

I. Summary Statements

On December 18, 1996, CR-96-1965 was written to identify a gas pocket in the LPSI B-train piping at Penetrations 36 and 37. The gas pockets were located at the LPSI B-train piping high points between the flow control valves and the inside containment isolation check valves.

Inspection of this piping was the result of CR-96-1943 which identified pockets of nitrogen in the high points of the piping upstream of the LPSI A-train flow control valves. The source of this nitrogen was determined to be leakage from the nitrogen laden water contained in the Safety Injection Tanks (SITs). The SITs contain a nitrogen blanket pressurized at approximately 650 psig. The solubility of nitrogen in water is greater at higher pressures. If leakage occurs into a lower pressure system, the nitrogen will come out of solution forming a gas pocket in the local high points in the piping system.

This engineering evaluation has determined that the LPSI B-train can be subjected to the worst case hydraulic transient with up to an 11.3 inch arc length of nitrogen gas pocket and still fulfill its safety function, therefore, Design Engineering recommends that the LPSI B-train be considered operable.

APPROVAL:

Preparer: Jn H. Baung / Rm B. Gilmore Date: 3/26/97

Independent Reviewer: John P Burke Date: 3/26/07

Design Engineering Manager: J. Humphrey for LNR Date: 3-26-97

lpsi-sum.nrc

II. References

1. FSAR Sections 6.3
2. Waterford 3 Condition Reports 96-1831 and 96-1943
3. W3-DBD-001; "Safety Injection System"
4. Waterford 3 Technical Manual 457000272
5. Waterford 3 Flow Diagrams G-167, "Safety Injection System"
6. Waterford 3 Isometric Drawings - 8469-18, 8469-19, 4305-1865, 4305-1893
7. Waterford 3 Calculations EC-M92-038 and EC-M95-011
8. Waterford 3 Station Information Management System
9. Record of Phone Communication from CE to Paul Gropp dated 12/19/96
10. Waterford 3 Letter W3F1-96-0013, GL 95-07 180 Day Response
11. Waterford 3 Stress Calculations SA-1029-1, SA-1029-3, and SA-1029-8
12. ASME Section III, '71 Edition up to Winter '72 Addenda
13. HYTRAN Hydraulic Transient Analysis Program by Sargent and Lundy - Rev. 2
14. Calc. EC M97-002, Rev.0 "Water Hammer analysis-LPSI B train."
15. Calc. EC-P97-001, Rev.0 "Operability Analysis of LPSI B piping-Part 1."
    Calc. EC-P97-002, Rev.0 "Operability Analysis of LPSI B piping-Part 3."
    Calc. EC-P97-003, Rev.0 "Operability Analysis of LPSI B piping-Part 8."
16. EPRI NP-6766, "Water Hammer Prevention, Mitigation, and Accommodation"
17. DEGP-005, Rev. 0, "Design guide for Operability Criteria for Piping"
18. DEAM No. PS-S-002-00, "Pipe Support Operability Standard"

III. Detailed Problem Statements

On December 18, 1996, CR-96-1965 was written to identify a gas pocket in the LPSI B-train piping at Penetrations 36 and 37. The gas pockets were located at the LPSI B-train piping high points between the flow control valves, SI-139B & SI-138B, and the inside containment isolation check valves, SI-143B & SI-142B (See Attachment 1). The arc length of the gas pocket at Penetration 36 was 11.3 inches over a length of 19.38 feet which equates to a volume of 1.802 ft^3. The arc length of the gas pocket at Penetration 37 was 10 inches over a length of 17.66 feet which equates to a volume of 1.229 ft^3.

Inspection of this piping was the result of CR-96-1943 which identified pockets of nitrogen in the high points of the piping upstream of the LPSI A-train flow control valves. The source of this nitrogen was determined to be leakage from the nitrogen laden water contained in the Safety Injection Tanks (SITs). The SITs contain a nitrogen blanket pressurized at approximately 650 psig. The solubility of nitrogen in water is greater at higher pressures. If leakage occurs into a lower pressure system, the nitrogen will come out of solution forming a gas pocket in the local high points in the piping system. For CR 96-1943, the inside containment LPSI A-train isolation check valves have a higher leak rate than the upstream flow control valves. Therefore, the pressure

differential occurs across the flow control valve allowing the nitrogen to come out of solution upstream of the flow control valves.

For CR 96-1965, the LPSI B-train flow control valves have a higher leak rate than the inside containment isolation check valves. Therefore, the pressure differential occurs at the inside containment check valves, and the nitrogen comes out of solution downstream of the flow control valves. Based on the piping elevation changes in the LPSI system, this is not a column separation phenomenon such as ACCW system (CR 95-1300).

The principal concern is that this entrapped gas may cause a pressure transient that may exceed the design pressure of the system or create dynamic forces that may fail piping supports. The result may prevent the LPSI system from fulfilling its safety function which is to provide emergency core cooling in the event of a LOCA.

IV. Assumptions

None

V. Design Evaluation

LPSI Operation

On a SIAS, for both Offsite and Loss of Offsite Power, the safety loads are sequenced onto the safety bus according to their designated load block. The motor operated flow control valves are actuated at the 0 second load block. The valves then open to the preset position in approximately 6 seconds. The LPSI pump is started on the 17 second load block. Therefore, the flow control valve is in its open position when the pump starts, and the gas pocket downstream of the flow control valve will be compressed by the moving fluid when the LPSI pump starts. The momentum of the moving fluid will eventually collapse against the compressed gas pocket which will cause a pressure surge that can vary in magnitude depending on the time rate of change of momentum. Since the flow control valve is in its safety position when the pump starts, the transient will not affect the operation of the valve.

Actual Pressure Surge Evaluation

On November 20, 1996, CR 96-1831 was written to identify a pressure transient in the LPSI B-train which occurred at the start of LPSI Pump B. Air voiding in the pipe/ pump/ instrument line was suspected. The system and instrumentation was vented in accordance with I&C procedures and OP-903-026. The pump was started afterwards with a strip chart recorder installed to measure any pressure transients. A pressure transient of 660 psig was recorded on the strip chart recorder (See Attachment 2). System Engineering walked down the piping outside containment and no pipe or support damage was found. It was subsequently found that the LPSI flow control valve,

SI-139B, was open. After closing SI-139B, the pump was started and no transient was experienced. On December 18, 1996, after nitrogen gas pockets were found in the piping at the containment penetrations, Design Engineering walked down the piping and supports for LPSI 'B' system inside and outside containment to confirm there was no damage due to the November 20 condition. No damage was found.

The fact that no damage was found in either walkdown demonstrates that the LPSI 'B' train will fulfill its safety function in the event of an SIAS. The hydraulic transient documented in CR 96-1831 envelopes the worst case hydraulic transient that will occur with less than 11.3" arc length of nitrogen gas post-accident since SI-139B was in its open position and the system was completely depressurized, by static venting, when the LPSI pump was started. After closing SI-139B, the pump was started and no transient was experienced. Since valve SI-139B closure in November there had been no IST valve stroking until the gas pocket measurement in December. Also the SIT level had been monitored and was stable. Therefore, it is a reasonable assumption that the gas pocket size measured on December 18, was the same as on November 20.

A detailed HYTRAN[1] fluid transient analysis was performed simulating (See Attachment 3) the strip chart recorder pressure plot and generated unbalanced fluid dynamic forcing functions to be applied to ME-101 stress analysis. It was shown from the results of the stress analysis that the maximum stress of 51,918 psi appeared on the 1/2" sampling line connected to 10" ϕ flange. This exceeded Faulted design allowable and required use of Operability Criteria (Ref. 17). Using Operability Criteria, the 51,918 psi is 86.5 % of the capacity.. The maximum stress of the 10" ϕ main line, however, was only 13,758 psi or 35.4 % of the Faulted design allowable. There were 11 supports exceeding Faulted design allowables and required use of Operability criteria (Ref. 18). The controlling pipe support was SIRR-715 which was at 89.5 % of the capacity. A thorough walkdown inspection on these 1/2" ϕ sampling line and 11 supports that exceeded design allowables was performed and no sign of damage was found except support SIRR-400 which was rotated and slightly shifted. The piping, piping components, equipment nozzles, pipe supports, and support structures have met the operability criteria. Calculations are documented in References 14 & 15.

To clarify lingering questions on "How much gas is too much for operability?", a parametric study varying the initial pressure and size of the gas pocket was performed using HYTRAN computer program:

- Initial studies have shown that the pressure surge and the resulting segment forces are greatly influenced by the initial pressure of gas pocket, i.e., the lower the initial pressure of the gas pocket, the higher the surge pressure and the forces. When the surge pressure was recorded by CR 96-1831, the pressure of gas pocket at the penetration header(EL.+15.0') was at the lowest expected pressure, i.e., RWSP

[1] HYTRAN is a program for water hammer analysis that can handle liquid filled piping networks.

static head. The pressure surge of 660 psig measured on strip chart recorder was for the system condition that was completely depressurized, by static venting, prior to the LPSI pump start and the flow control valve SI-139B was in its open position. The initial engineering evaluation completed on December 19, 1996 required that RWSP level be maintained at > 93 % to assure the minimum pressure in gas pocket remains consistent with the analysis..

- The study also showed that increasing the gas pocket size up to a certain limit would increase the surge pressure and the forces, although it was not as influential as the initial pressure of the gas pocket. Increasing the gas pocket size beyond this limit would decrease the surge pressure and the forces. In this case, the threshold of the gas pocket size for the maximum surge pressure was around 3.0 ft^3, or approximately 56 % of the total header volume, which is equivalent to 14.4 inches of arc length. The summary of these parametric study results are as shown in Attachment 5.

On a SIAS, both flow control valves, SI-138B and SI-139B, will open to inject LPSI into RCS Loops 1A and 1B, however, the LPSI B configuration recorded by CR 96-1831 had SI-138B closed which is not its post-accident alignment. However, the fluid transient analysis of the latter (Analysis No. 1) enveloped the former case (Analysis No. 2) as shown in Reference 14 because of the higher flow rate through the flow control valve if only one is open (See Attachment 4).

1. The inside containment isolation check valves, SI-143B & SI-142B, may gradually open as the pressure of gas pocket at the penetration header rises and exceeds the pressure of downstream side of the check valves after the LPSI pump start-up. In this case, the gas pocket will be compressed in between two water columns and the fluid momentum collapsed to turn into pressure surge. The surge pressure will propagate toward both upstream and downstream generating wave forces. Subsequently, the moving fluid with gas pocket will generate unbalanced momentum force which is insignificant and bounded by the wave force. Or,

2. The inside containment isolation check valves, SI-143B & SI-142B, may be stuck and does not open quickly. In this case, the gas pocket will be compressed against dead end (or closed check valves) and the fluid momentum collapsed to turn into pressure surge. The surge pressure will propagate toward upstream generating wave forces.

It is known to the industry that the second case is more severe than the first (Ref. 16).

It is concluded that LPSI "B" train will fulfill its safety function in the event of an SIAS by the fact that no pipe and support damage was found during walkdown noted above, which is also supported by the results of detailed engineering evaluation that envelopes the worst case hydraulic transient that will occur in LPSI "B" train during Safety Injection mode of operation with up to 11.3 inch arc length of nitrogen gas pocket.

Growth of Nitrogen gas pocket

On a SIAS for both Offsite and Loss of Offsite Power, the safety loads are sequenced onto the safety bus according to their designated load block. The motor operated flow control valves are actuated at the 0 second load block, and the LPSI pumps are started on the 17 second load block. Therefore, It must be determined whether the size of an existing nitrogen gas pocket would increase significantly over this 17 second period.

The following evaluation estimates the rate at which the volume of nitrogen will increase in 17 seconds. This evaluation is based upon recent data obtained when LPSI 'A' flow control valve, SI-138A, was opened periodically during a 14 hour period for maintenance/testing. Following the test, a nitrogen gas pocket was found to exist in the LPSI train A piping at penetration 39. This gas pocket completely filled the horizontal run and 80 inches of the vertical run of piping between flow control valve SI-138A and check valve SI-142A. It was determined that the enlarged gas pocket formed over a known period of time during stroke testing of SI-138A. Prior to testing, a gas pocket arc length of 4" was measured. Since the initial and final gas pocket volume are known, the increase in nitrogen volume can be determined:

Initial nitrogen gas pocket volume = 0.107 ft^3 (initial arc length was 4")
Final nitrogen gas pocket volume = 7.58 ft^3
Increase in nitrogen gas pocket volume = 7.47 ft^3

The 7.47 ft^3 increase in nitrogen volume displaces approximately 56 gallons of water. This water must leak through either LPSI pump discharge check valve, SI-122A and/or RCS Loop 2 Shutdown Cooling Warm-up valve SI-135A for the nitrogen volume to increase. Since the nitrogen volume increase must be coupled with valve leakage, the increase in gas pocket size will occur gradually rather than suddenly. Although the stroke testing occurred over a 14 hour period, it is most conservative to assume the nitrogen volume increased only when the flow control valve, SI-138A was opened. This assumption reduces the time that the 7.47 ft^3 increase in nitrogen volume occurred, and therefore, maximizes the rate at which the nitrogen gas pocket is expected to increase. Data from the Plant Monitoring Computer indicate that SI-138A was not fully closed for 62 minutes out of the 14 hour period.

Using this data, the rate at which the nitrogen gas pocket volume increased when the flow control valve was open can be calculated:

$$\frac{\Delta V}{\Delta t} = \frac{7.47}{62 * 60} = 2.01 * E - 3 \quad ft^3/sec$$

where,

ΔV = Change in nitrogen gas pocket volume, ft^3

Δt = Amount of time SI-138A was open, sec.

Since an increase in gas pocket volume must be coupled with valve leakage, a nitrogen gas pocket formation rate of 2.01E-3 ft^3/sec can be characterized as very conservative because this formation rate requires 0.90 gpm of water to be concurrently leaking back through SI-122A and SI-135A to the Reactor Water Storage Pool (RWSP). SI-122A is a class 2 check valve, and the manufacturer seat leakage test report showed no significant seat leakage. Also, MSS-SP-61, the required testing standard in the valve specs, indicates maximum allowable seat leakage rates of 320 cc/hr and 80 cc/hr for SI-122A and SI-135A, respectively. Although it is recognized that some degradation may occur, the leakage assumed for this evaluation (0.90 gpm) is more than 500 times the specified leak rates. This fact further illustrates that the calculated gas pocket formation rate of 2.01E-3 ft^3/sec is a conservative result.

Therefore, the increase in nitrogen volume during the 17 second pump start delay can be determined:

= 17 seconds x 2.01E-3 ft^3/sec
= 3.41E-2 ft^3 gas pocket volume increase

Assuming an initial gas pocket arc length of 8" (the maximum allowed for LPSI 'A') exists upon initiation of an SIAS, this represents an increase of 4.5% in gas pocket volume. Based on the similarity between the 'A' train and 'B' train headers, and interpolation of the HYTRAN sensitivity studies of the LPSI 'B' train, an increase of this volume will result in an insignificant increase on the pressure transient. Note that the results of this evaluation are expected to be bounded by the final hydraulic analysis. Since, the LPSI 'B' headers have been evaluated for larger arc lengths, the estimated volume increase would have an even lesser impact on the pressure transient in the 'B' headers.

As stated above, there were no vents at the high points at Penetrations 36 & 37 and its not possible for the gas to leak out due to the existing boundary condition (See Attachment 1 Flow Diagram).

The analysis is based on the lowest gas pocket pressure that the head of the RWSP can provide. It is found from a parametric study that the lower the initial pressure of the gas pocket, the higher the surge pressure and the forces.

VI. Impact on Nuclear Safety

The LPSI B-train piping and supports are capable of being subjected to the system pressure and dynamic loading resulting from a transient caused from the nitrogen entrapment in the LPSI B flow. Therefore there is no adverse impact on Nuclear Safety.

VII. Immediate Actions

1. System Engineering to continue to periodically verify and trend that the arc length of the gas pocket does not exceed the following. These arc lengths should also be verified after valve stroke or pump surveillances.

Penetration 36	2SI8-113RL1A	11.3 inches
Penetration 37	2SI8-122RL1B	10.0 inches

   These arc lengths are based on as-found gas pocket condition.

2. Operations to maintain the RWSP level at or above 93%.

VIII. Long Term Actions

1. Install vent lines on the high points between the inside and outside containment isolation valves at Penetrations 36, 37, 38 and 39 as detailed in WA Repair package CI 306751, and comply with Tech. Spec. Change request to ensure piping is full every 30 days.

2. Maintain system RWSP level > 93 % until action 1 is completed for all LPSI penetrations.

3. When the system is placed in service in Shutdown Cooling Mode, sweep gas pocket out of line by slowly opening the flow control valves. This requirement remains in effect until action 1 is complete for respective LPSI penetrations.

4. Include snubbers SISR-707 (CI# 308754) & SISR-711 (CI# 306741) to be inspected and tested during RF-08.

5. Rework SIRR-400 during RF-8.

IX. Signatures

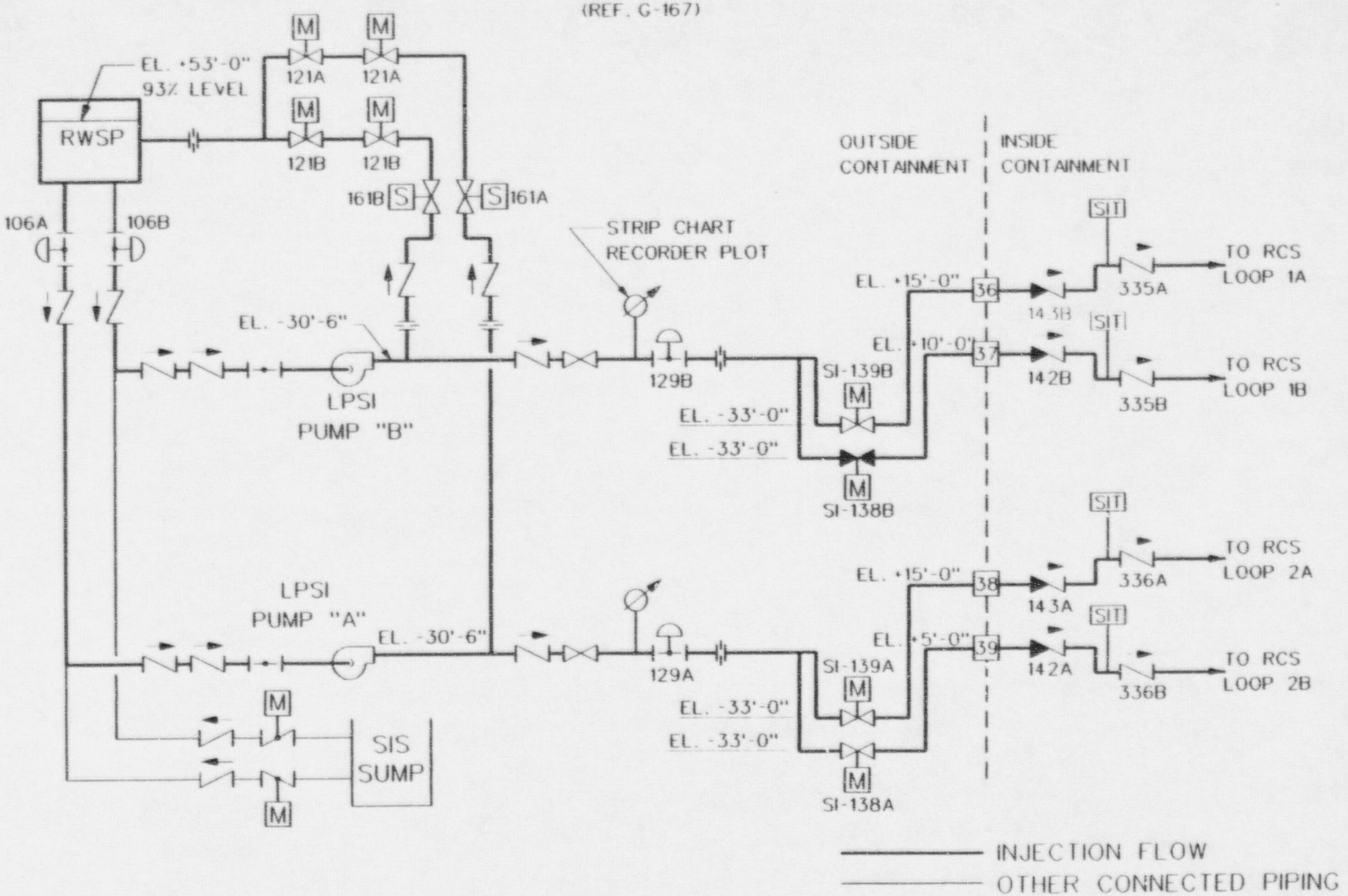
See page 1.

X. Attachments

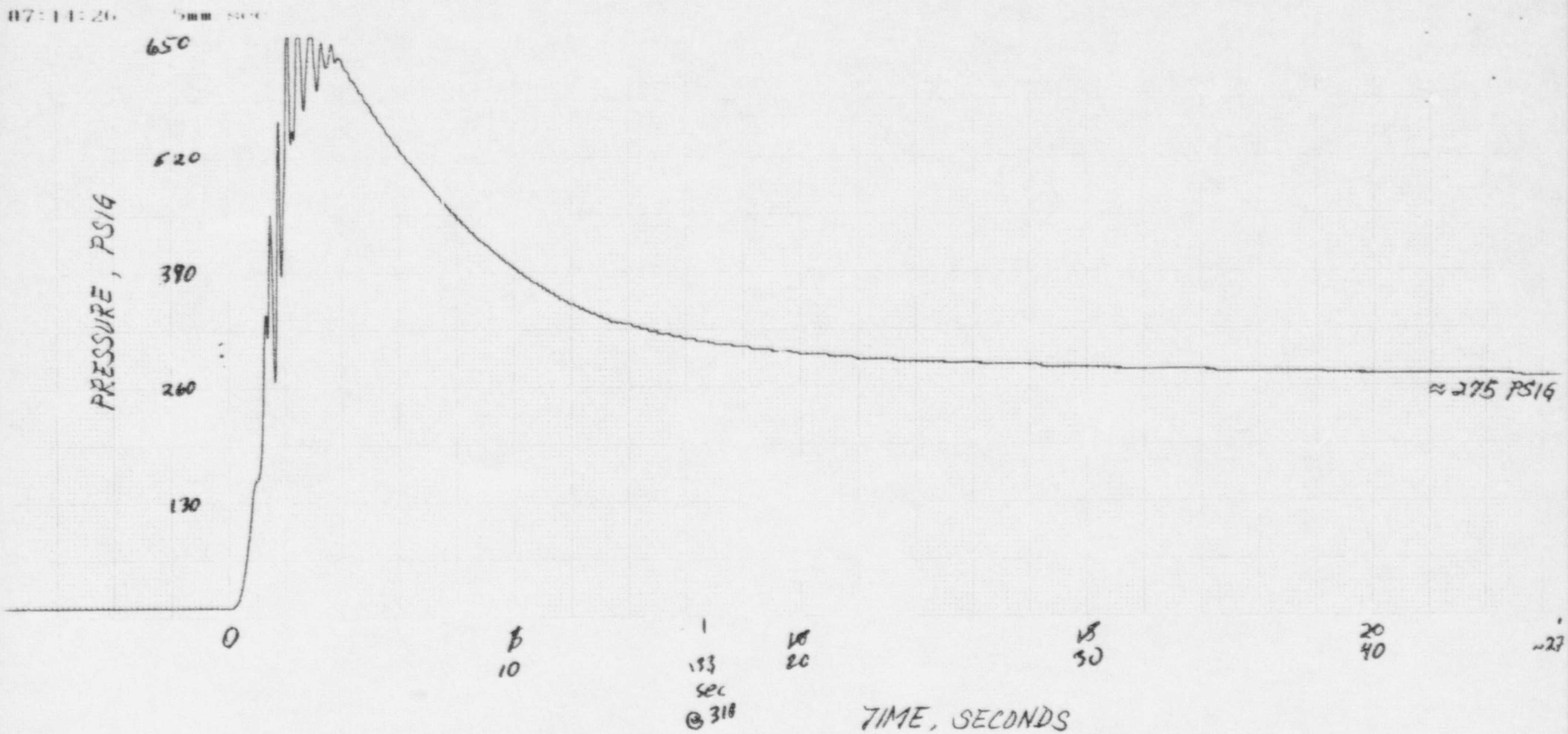
1. Flow diagram
2. Strip chart recorder plot for CR-96-1831
3. Simulated pressure plot-One flow control valve open
4. Maximum calculated vs. Strip chart recorder plot pressure
5. Summary of Parametric Study Results

LPSI SYSTEM - INJECTION MODE

(REF. G-167)



ATTACHMENT 1 - FLOW DIAGRAM



ATTACHMENT 2

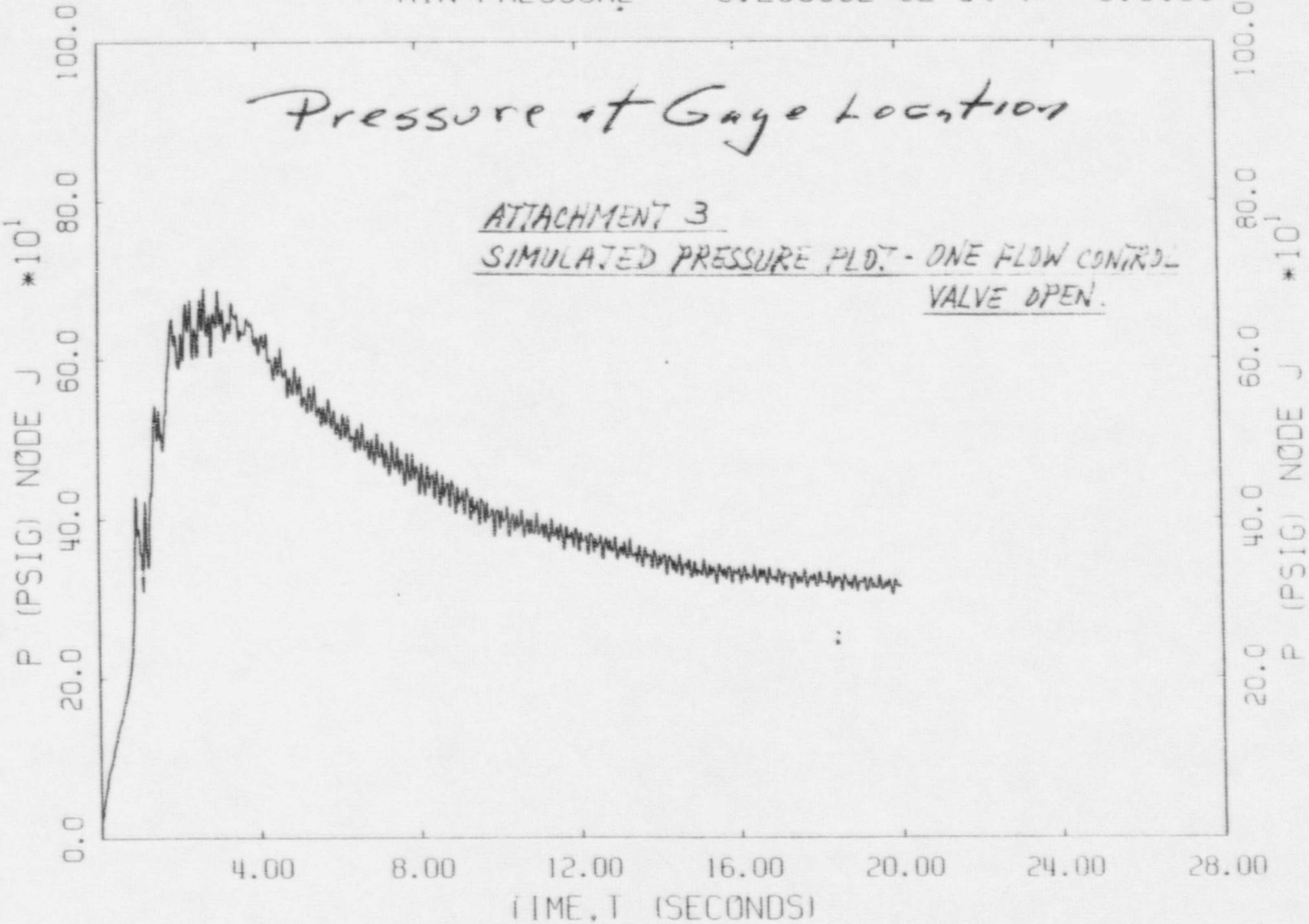
STRIP CHART RECORDER PLOT (LPSI "B")

(6)

02/23/97
09:54:07

LEG NAME 8 LEG NO. 8

MAX PRESSURE = 0.69179E+03 at T= 2.6599
MIN PRESSURE = 0.20999E+02 at T= 0.0100



PUMP START W/TRAPPED GAS @PEN.#36 (Mean Pressure Simulation Method)

Attachment 4

Maximum calculated pressure
vs.
Strip Chart recorder pressure
at the gage location

One flow control valve open maximum	Two flow control valves open maximum	Strip Chart recorder plot maximum (One flow control valve open)
687 psi	666 psi	660 psi