**Supplemental Response to NRC Generic Letter 96-06**
**Potential SW Flashing in FCU Coils During LOCA with Coincident LOOP**

# Summary of Evaluations in Response to Generic Letter 96-06 Waterhammer Effects

NEW YORK POWER AUTHORITY

INDIAN POINT 3 NUCLEAR POWER PLANT

**FOR INFORMATION ONLY**

# SUMMARY OF EVALUATIONS IN RESPONSE TO USNRC GL 96-06 WATERHAMMER EFFECTS

**REPORT NO: IP3-RPT-SWS-02585**

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## SPECIAL NOTICE

This report documents the evaluations performed by NYPA to resolve waterhammer concerns of NRC Generic Letter 96-06, "Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions for Waterhammer Effects".

## GLOSSARY/DEFINITIONS

| | | |
|---|---|---|
| ADLPIPE | - | Static and dynamic pipe stress computer software |
| Appendix F | - | ASME B&PV Code Section III, Appendix F - Faulted Conditions |
| Column Closure | - | Waterhammer where moving fluid surface collides, resulting in pressure rise |
| Condensation Induced (Void Collapse) | - | Collapse of Steam Void by Water resulting in pressure rise. |
| DBA | - | Design Basis Accident |
| FCU | - | Fan Cooler Unit |
| GL | - | Generic Letter |
| GPM | - | Gallons per minute |
| HELB | - | High Energy Line Break |
| LOCA | - | Loss of Coolant Accident |
| LOOP | - | Loss of Offsite Power |
| MSLB | - | Main Steam Line Break |
| NRC | - | Nuclear Regulatory Commission |
| RO9 | - | Refuel Outage Number 9 |
| SI | - | Safety Injection |
| SW | - | Service Water System |
| UFSAR | - | Updated Final Safety Analysis Report |

## 1.0 INTRODUCTION

This report provides the results of the evaluations performed by NYPA to verify equipment operability and containment integrity during design basis accident conditions in response to waterhammer issues outlined in US NRC GL 96-06 (Ref. 8.1), specifically, for containment service water piping to and from the fan cooler units when subjected to postulated waterhammers which could occur during plant LOOP and LOOP with LOCA events. This report summarizes the methodology, results and corrective actions taken to resolve the issues during the RO9 refueling outage.

## 2.0 BACKGROUND

The objective of the evaluation was to determine if during postulated waterhammers of LOOP and LOOP with LOCA events, the service water system would maintain its structural integrity and continue to provide the required heat removal capability in the containment following the events. The evaluations of these scenarios were performed in response to issues raised in Generic Letter 96-06.

The evaluated system consists of five fan cooler units (FCUs) each with 10" service water (SW) supply and return lines (Figures 9.1 and 9.2).. The coolers are normally supplied with SW at a rate of approximately 570 g.p.m. The SW system provides flow to the coolers during a LOCA (with or without a LOOP) at a rate of approximately 1400 g.p.m., based on design basis ultimate heat sink temperature of 95°F. The coolers discharge through 10" lines with throttled butterfly valves that join in an 18" header prior to entering a 24" header. The 24" header discharges into the discharge canal and the service water is returned to the Hudson River (Ref. 8.2).

During a LOOP, the pumps and fans lose power until the diesel generators start. Two SW pumps restart approximately 25 seconds after initiation of a LOOP, with a third pump restarting approximately 5 seconds later (Ref. 8.7).

## 3.0 ENGINEERING EVALUATION

Two types of waterhammer events were determined to occur following a LOOP. These are, column-closure caused by a LOOP only event or a simultaneous LOOP and LOCA events;.and steam condensation induced (void collapse) caused by simultaneous LOOP and LOCA events. Column-closure waterhammer occurs at the time of resumption of flow from pump restart. The moving flow impacts the stationary water resulting in a column-closure waterhammer. Such loading results in a pressure transient wave traveling through the system. Condensation-induced waterhammer occurs when steam bubbles, or voids, condense and collapse. This event is bounded by the column-closure event in the severity of the pressure pulse.

## 3.0 ENGINEERING EVALUATION (Cont'd)

All SW supply and return lines to the five containment fan cooler units were analyzed for the postulated waterhammer loadings. The purpose of the analysis was to determine the ability of each piping system (pipe, supports, equipment nozzles, and penetrations) to withstand such loadings, maintain the integrity of the pressure boundary, and to ensure the function of the system to pass the required flow.

Analyses performed includes hydraulic system response, system monitoring during a simulated SI test, and structural assessments. A summary of these evaluations are described below.

### 3.1 Hydraulic Assessment

A detailed hydraulic model and assessment of the service water system, including the FCUs, and supply and return piping was performed considering LOOP only and simultaneous LOCA and LOOP events. The objectives of the assessment were: 1) to define loads caused by the LOOP, and LOCA with LOOP, and 2) to validate the model using the results of the in-situ safety injection test described in Section 3.2.

The LOCA analyzed was a double ended guillotine break of the reactor coolant loop. The effects of the main steam line break were also reviewed and found to be enveloped by the LOCA. The LOCA fills the containment with saturated steam that results in the peak containment temperature. During this same time, all power is assumed to be lost to the service water pumps and fans in the containment fan cooler units. The water flow and air flow both coast down, resulting in a condition where heat is absorbed out of the containment atmosphere and transferred into the service water remaining in the fan cooler units.

From the hydraulic analysis, two types of waterhammer events were characterized. The **condensation induced waterhammer** which occurs only during the LOOP with LOCA event, is caused during the uncovering of horizontal runs of pipe during the draindown. As a water surface in the horizontal portions of the lines are exposed, steam created in the FCU tubing from the LOCA environment inside containment will enter the space formed at the top of the pipe. The space between the top of the pipe and the exposed water will allow steam to enter followed by the condensation of steam and the trapping of steam bubbles. The rapid creation of trapped steam and the subsequent closing of the void by cooler water causes condensation induced waterhammer pressure pulses. The resulting pressure pulses in the discharge piping were predicted to be as high as 213 psi; the pulses in the supply piping were predicted to be as high as 268 psi. These pulses will occur in the first horizontal line upstream and/or downstream of the cooler for the supply and/or return piping, respectively.

**Column closure waterhammers** are predicted to occur upon pump start in the 10 inch pipe in both the LOOP and LOOP with LOCA events. Pressure pulsations occur in systems where voids form due to elevation differences between the equipment or piping and their suction or discharge reservoir. In the case of the fan coolers, a void will form due to column

## 3.0 ENGINEERING EVALUATION (Cont'd)

separation in the supply and discharge piping any time that the service water pumps are shut down. The void will subsequently collapse when flow is reestablished resulting in a pressure pulse. The closure impact velocity is dependent on the distance of the void from the pumps, fluid velocity, and flow resistance in the lines. The highest system velocity will occur following safety injection initiation or during a safety injection test. Calculations indicated that the largest waterhammer pressure pulse occurs in the return side piping during a LOOP only event, and based on additional input provided during system monitoring of a simulated SI test, the magnitude of a column closure waterhammer has been calculated to be approximately 360 psi.

During refilling, bubble collapse type waterhammers similar to those that occur in the horizontal lines during draining will not occur because the refill velocity exceeds the velocity required to keep the pipe full. A velocity of approximately 5 ft/sec is needed to keep a 10" pipe full. The refilling velocity exceeds this and will preclude the occurrence of condensation induced waterhammer in the horizontal lines during refill.

The results of the hydraulic assessment are presented in Technical Report 97108-TR-01, Rev. 4, (Ref. 8.2).

### 3.2 In-Situ Monitoring of System

During Refueling Outage RO9, the service water system was monitored during the performance of a simulated safety injection test (Ref. 8.8). Service water supply and return lines 11c and 12c (respectively) were selected for monitoring as representative of the other FCU lines. The basis for selection of Lines 11c and 12c was due to this system configuration; i.e., a longest line segment with largest unbalanced forces at pipe ends. The purpose of this test was to obtain actual data and correlate the analytical predictions from the hydraulic assessment calculation with actual data. The monitored results of the SW system are outlined in Technical Report 97140-TR-01, Rev. 0 (Ref. 8.3).

Repeatability of results for each of the individual tests performed was demonstrated. Each test indicated a strong initial event followed by two smaller pressure pulses. For each of the three pulses observed for each test, each consists of multiple reflected waves. The initial supply side pressure pulse magnitude was categorized as a fast acting pressure pulse. It was evident that the resulting supply side waterhammers propagate through the coolers down the return line to the void. Thus, it was appropriate to consider this waterhammer on return piping as well. Considering pressure amplification, the test results showed the column closure waterhammer for both supply and return lines were determined to have peak pressures of approximately 330 psi, with a total time duration of 1.5 ms.

## 3.0 ENGINEERING EVALUATION (Cont'd)

Another factor considered when analyzing the results of the safety-injection test was the oxygen content of the supply water. Water quality data for the Hudson River, from where supply service water is drawn, indicate seasonal variations in oxygen content. Oxygen levels reach a high during the winter months and a low during the summer months. The oxygen content of the supply water will have an effect on resulting waterhammers since the level of noncondensibles released from the water during the draindown (i.e., air released into the void) will vary and the resulting sonic velocities will be higher with less oxygen present.

The measured sonic velocities were under 2,000 ft/sec. The hydraulic analysis and structural assessments had conservatively assumed sonic velocities of 2,300 ft/sec. Due to the variability in oxygen content, the higher sonic velocity of 2,300 ft/sec was conservatively maintained in the analysis. To address any air content variability to that present during the test measured pressure response, an additional 10% factor was applied to the measured pressure pulse. The maximum analytical pressure pulse of approximately 360 psi was in good agreement with the results of the in-situ monitoring results, and thus the analytical models were validated.

### 3.3 Structural Assessment

A structural analysis was performed to assess the capability of the piping supply and return lines to withstand the resulting waterhammers which occur either from condensate void collapse or column closure following restart of the pumps. The definition of the resulting waterhammer loading to the piping system were based on a previous report, IP3-RPT-UNSPEC-02395, Rev. 0 (Ref. 8.4), which considers the LOOP loading as an Upset condition and the LOOP with LOCA loading as an Emergency condition.

Seismic loading was also considered since it is reasonable to assume that the seismic event may cause a LOOP but, its effect would be separated in time with waterhammer loading. This position is consistent with ANSI/ANS 51.1 position, which allows "smart timing" to be appropriately considered in determining the method of load combinations (Ref. 8.7).

A computer model of the ten (10) SW supply and return lines were generated using the ADLPIPE program, and the resulting Upset (column closure) and Emergency (column closure and condensate void collapse) waterhammers were evaluated in a dynamic force/time history assessment. The piping stresses were evaluated in accordance with the requirements of the IP3 UFSAR, and the resulting piping stresses meet appropriate Upset and Emergency Load Category limits. The pipe support system was also evaluated in accordance with appropriate IP3 Upset and Emergency Load Category limits. Although the pipe support system met stress allowable operability limits, a total of ten (10) supports required structural modification to meet design basis allowable stresses, per IP3 UFSAR (Ref. 8.9).

## 3.0 ENGINEERING EVALUATION (Cont'd)

### 3.3 Structural Assessment (Cont'd)

The results of the structural assessments are presented in Technical Report 97124-TR-01, Vol. 1, Rev. 3, and Vol. 2, Rev. 1 (Ref. 8.5).

## 4.0 CORRECTIVE ACTIONS

Several options had been considered in an attempt to attenuate or mitigate the effects of potential waterhammer loading. These included connecting an air injector bottle system to each supply and return pipe line, or by installing air supply tanks outside containment with connections to inside containment supply and return pipes; or by providing a continuous source of air from existing plant instrument air lines or from a new compressor. Although, these options would have yielded better results, that is, the mitigation or attenuation of waterhammer loading on the SW system, the activation of such a system might further challenge the systems capability to provide necessary containment cooling; i.e., potential for air entrapment in FCU tubes. Therefore, corrective actions were limited to modifications of pipe supports.

A total of ten pipe supports were modified during refueling outage RO9. A listing of these supports, including function and upgrade, is included MMP 97-3-193 SWS (Ref. 8.6).

## 5.0 CONCLUSIONS

NYPA has performed an evaluation of the service water supply and return piping to the containment fan cooler units (FCUs) to assess the effects of postulated waterhammer loading as outlined in NRC GL 96-06. Evaluations and assessments have been performed in regards to system response when subjected to LOOP and LOOP with LOCA events. This work has encompassed hydraulic system response, system monitoring during a simulated SI test, system walkdowns to visually observe the structural condition of the piping and pipe support system (part of ISI program), and structural assessments.

In support of this work, NYPA has upgraded a number (ten) of service water pipe supports to enhance loading capability. Based on the analytical work performed, the consideration of actual measured data during a simulated SI, present system condition, and support enhancements, NYPA has concluded that the containment service water piping and FCUs are capable of withstanding the postulated waterhammers which can occur either during LOOP or LOOP with LOCA events within the design-basis acceptance criteria stated in the UFSAR.

## 6.0 SUMMARY

Based on evaluations performed for the service water supply and return piping system for postulated waterhammer loading as outlined in NRC GL 96-06, a total of ten (10) supports were modified during RO9 to provide additional support capabilities and minor function change. With these modifications performed, the system now complies with the requirements of NRC Generic Letter 96-06 for waterhammer loading.

Minor modification package MMP 97-3-193SWS and corresponding Nuclear Safety Evaluation 97-3-248SWS were plant approved documents used for these system modifications (Ref. 8.6 and 8.7).

## 7.0 RECOMMENDATIONS

A feasibility study has been recommended to seek a procedural change to the present safety injection test procedure 3PT-R003D, Rev. 12, to attenuate or mitigate potential waterhammers which can occur in the supply and return lines to the FCUs during the performance of the SI test (ACTS 26957).

## 8.0 REFERENCES

8.1 USNRC Generic Letter No. 96-06, "Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions", September 30, 1996

8.2 Technical Report No. 97108-TR-01, Rev. 4, "IP3 Service Water Containment Fan Cooler Waterhammer Analysis", by Altran Corp., July 1997

8.3 Technical Report No. 97140-TR-01, Rev. 0, "Monitoring of a Service Water FCU Supply and Return Line During a Simulated Safety Injection Test", by Altran Corp., June 1997

8.4 Report No. IP3-RPT-UNSPEC-02395, Rev. 0, "White Paper for Plant Conditions, Load Combinations, Stress Allowable for Evaluating Service Water System GL 96-06 Transients", by Raytheon Engineers and Constructors, April 11, 1997

8.5 Technical Report No. 97124-TR-01, Vol. 1, Rev. 3, and Vol. 2, Rev. 1, "Structural Analysis of Containment Fan Cooler Supply and Return Lines Subject to Waterhammer Loading", by Altran Corp., June 1997.

8.6 MMP 97-3-193 SWS, Rev. 0, "Upgrade of Service Water FCU Pipe Supports for Waterhammer Event", 6/21/97

8.7 NSE 97-3-248SWS, Rev. 0, "Upgrade of Service Water FCU Pipe Supports for Waterhammer Event", 6/17/97

## 8.0 REFERENCES (Cont'd)

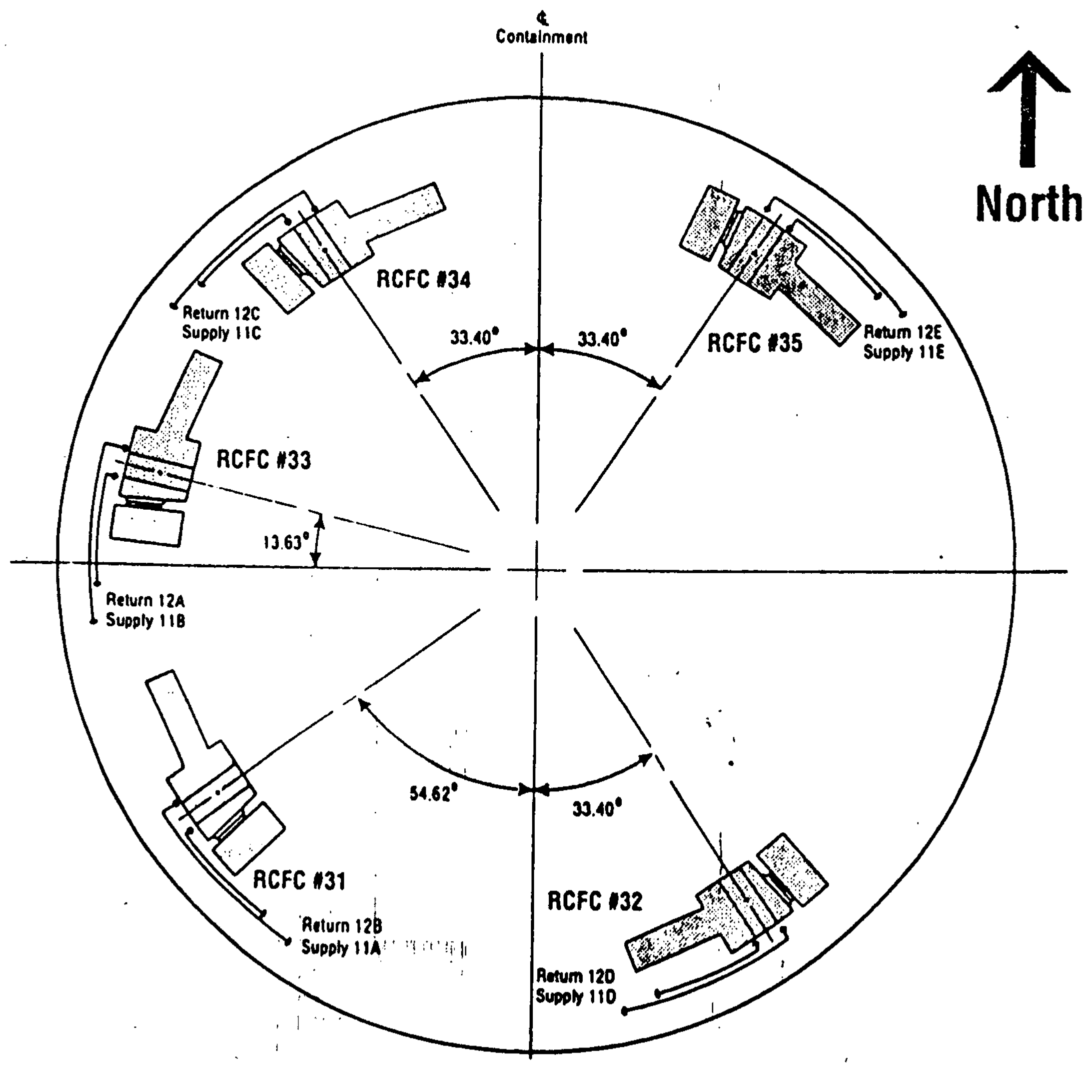
8.8 ENG -612, Rev. 1, "Waterhammer Test-Service Water Piping for Containment Fan Cooler Unit Number 34", 5/21/97; with additional TPCs.

8.9 UFSAR, Chapter 16, "Design Criteria for Structures and Equipment", 9/16/96

## 9.0 APPENDICES (FIGURES)

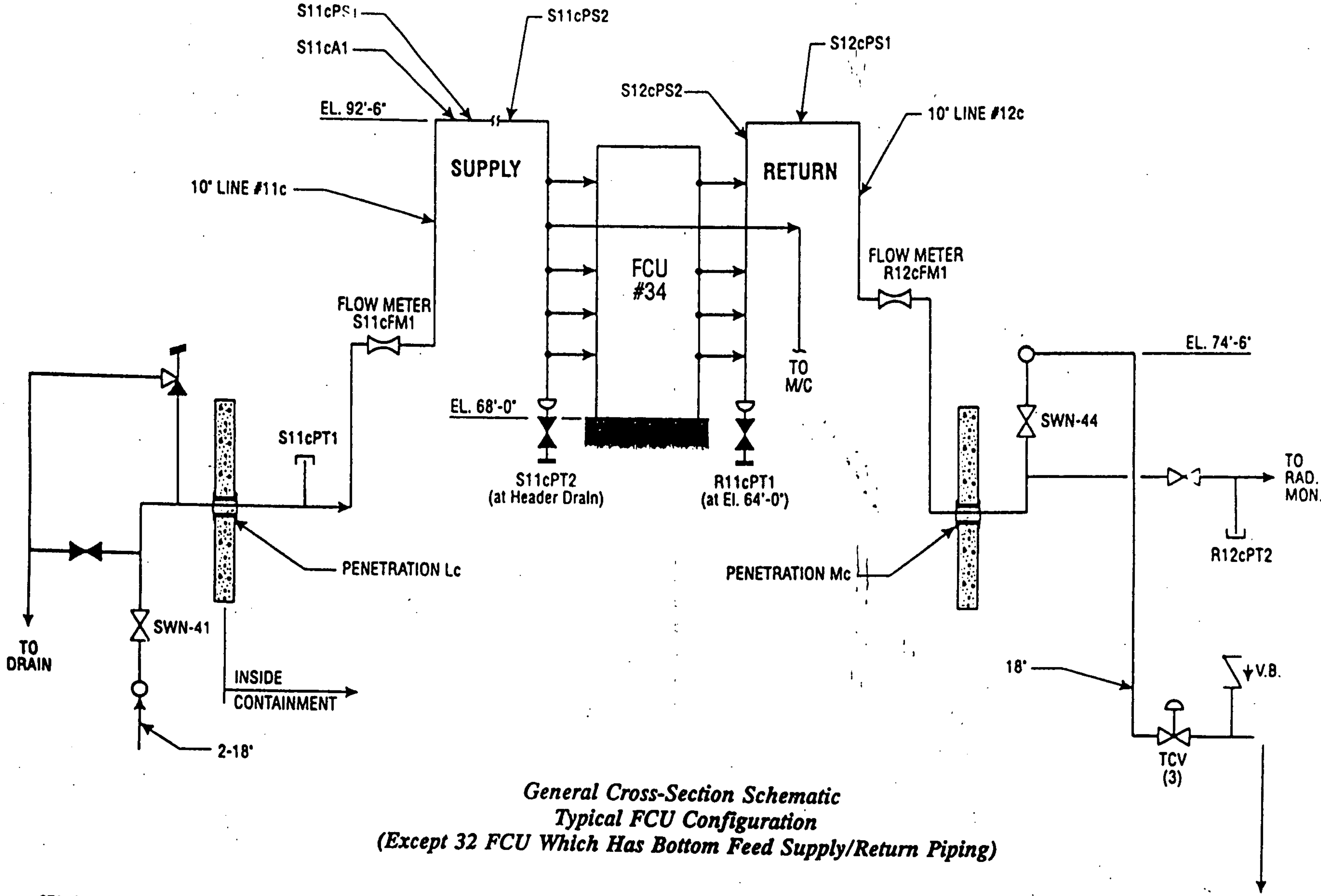
9.1 General Plan Configuration - FCU layout & Supply/Return Line Designation

9.2 General Cross-Section Schematic/Typical FCU configuration




*General Plan Configuration*
*FCU Layout & Supply/Return Line Designation*

97140.22A-LAL




*General Cross-Section Schematic*
*Typical FCU Configuration*
*(Except 32 FCU Which Has Bottom Feed Supply/Return Piping)*

97140.22A-LAL

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**Evaluation of Thermal Overpressurization of Isolated Piping Sections**

## PURPOSE

The susceptibility and potential for thermally induced overpressurization of isolated piping sections at Indian Point 3 has been evaluated in response to NRC Generic Letter 96-06, reference 1. This report summarizes the results of the evaluations and updates the information provided in attachment III to reference 2. Also included is the additional information requested in reference 4.

## BACKGROUND

In attachment III to reference 2, NYPA identified 16 containment penetration lines containing piping/valve configurations that could be potentially susceptible to thermally induced pressurization resulting from either or both Containment LOCA and Primary Auxiliary Building (PAB) HELB temperature conditions. Further evaluations have been conducted which has resulted in a reduction of penetration lines considered potentially susceptible. The following section discusses the foregoing actions and summarizes the results. A summary description of the analytical methodology utilized for the evaluations including assumptions, acceptance criteria, and detailed results is provided for those lines justified by analysis.

## SUMMARY/CONCLUSION

The following summarizes what is considered to be the final status of the evaluations conducted to determine the susceptibility of containment piping penetrations to thermally induced overpressurization as a result of high post-accident ambient temperature conditions.

Out of a total evaluation population of 137 containment penetration configurations, thirteen (13) lines have been determined to be potentially susceptible to thermal pressurization resulting from either or both Containment LOCA and PAB HELB conditions. Three (3) lines previously identified as being susceptible have been eliminated as a result of further evaluation (Table 1, Items 1 and 11) or corrective action (Table 1, Item 15). Note, drilling the hole in one of the disks of AC-MOV-730 eliminated the susceptibility of that line (Item 5) for LOCA conditions, but the susceptibility of valve AC-732 in the line to PAB HELB thermal pressurization remains. The long-term acceptability of the 13 lines determined to be susceptible has been demonstrated by analyses as follows:

- Three (3) lines (Table 1, Items 2, 12 and 13) contain air-operated diaphragm valves that would self-relieve pressure prior to exceeding design code or UFSAR faulted condition stress limits.

- Six (6) lines (Table 1, Items 3, 4, 5, 9, 14 and 16) meet design code normal condition stress acceptance criteria.

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- Four (4) lines (Table 1, Items 4, 6, 8 and 10) meet faulted condition stress limits allowed by the UFSAR.

The following eight of the sixteen have been determined based on analysis to not be susceptible to PAB temperature conditions in the pipe penetration area due to a closure of containment isolation valves from a phase A containment isolation signal. A Steam Generator Blowdown Line Break (SGBLB) was previously considered to have the potential for generating a Phase A containment isolation in the pipe penetration area, however, further analysis has determined that isolation of a SGBLB would occur before enough steam generator inventory could be lost to result in a Phase A signal.

| | |
|---|---|
| Line #22 | (Table 1, Item 1) |
| Line #25 | (Table 1, Item 6) |
| Line #26 | (Table 1, Item 7) |
| Line #59 | (Table 1, Item 8) |
| Line #69 | (Table 1, Item 10) |
| Line #18 | (Table 1, Item 11) |
| Line #338 | (Table 1, Item 12) |
| Line #40 | (Table 1, Item 13) |

Early isolation limits the mass energy release which in turn will limit the maximum temperature profile for the piping penetration area. Revised thermal pressurization and stress analyses were conducted using the piping penetration area temperature profile consistent with the Environmental Qualification Program requirements, which include the effect of early isolation. The results of the revised analyses show that for PAB HELB conditions, the piping and valves for Lines #DW-2", #10, #31, #60, and #294 (Table 1 Items 3, 5, 9, 14, and 16 respectively) now meet original design code normal condition stress limits.

The 120-day response evaluation indicated the higher limits of ASME III, Appendix F were required to qualify those lines. It should also be noted that for Line #711 (Table 1, Item 4), the administrative controls that have been implemented to ensure the line is drained are not necessary, since, with the lower PAB HELB temperature profile, the piping and valves meet original design code normal condition limits.

a) Six (6) of the 10 lines (Table 1, Items 3, 5, 9, 14, 15, and 16) have been dispositioned under the actions discussed above, and use of stress acceptance limits above design code normal condition limits is not required.

b) Four (4) of the 10 lines (Table 1, Items 6, 7, 8 and 10) postulated LOCA conditions may result in thermally induced pressure stresses above original design code limits. However, the results of the detailed thermal and pressure stress analyses for those lines and associated valves have been determined to be within the faulted condition acceptance limits specified in the UFSAR; therefore,

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no further actions are deemed necessary. For faulted conditions, UFSAR Table 16.1-2, Loading Combinations And Stress Limits, permits the use of plastic analyses for piping, and a maximum average membrane stress of 2.4 times the code allowable for valves.

Based on the foregoing it is concluded that all piping segments penetrating containment, and identified as potentially susceptible to accident-induced thermal pressurization, are currently operable and also acceptable for the long-term, relative to GL 96-06 thermal overpressure concerns. The above discussions are reflected in Table 1.

## ANALYSIS METHODOLOGY/ACCEPTANCE CRITERIA/RESULTS

Analyses of the isolated piping segments utilized thermodynamic and heat transfer principles to determine the transient temperature and pressure responses. Utilizing fluid and pipe properties, the change in water temperature due to the heat loading as a result of the Containment LOCA or PAB HELB was established and then used to determine the pressure response. The resulting pressures were utilized in the structural qualification of the piping segments and boundary valves.

### Heat Transfer Analysis and Line Temperature and Pressure Response

The line temperature and pressure responses were based on transient heat transfer analyses considering heat flux from the ambient air to the pipe and heat flux from the pipe to the trapped fluid assumed to be water solid. The heat transfer processes considered include:

1. Convective heat transfer from the ambient environment to the outside surface of the pipe or insulation(if insulated).

2. Conduction across the pipe.

3. Convection from pipe to contained fluid.

These processes and resulting heat transfer coefficients are summarized in Table 2.

Since the heat loading is transient, the fluid and pipe properties also change with time. The time varying parameters and heat transfer coefficients were utilized with classical two-dimensional thermal analysis methods to determine the resulting fluid and pipe temperatures.

The increase in contained fluid pressure resulting from the increased fluid and pipe temperatures were then determined utilizing an iterative process which included the effect of the changes in pipe volume resulting from thermal expansion and internal pressure. The changes in fluid volume with temperature were derived from steam tables, and pipe volume increases resulting

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from internal pressure conservatively considered only elastic response.

For those isolated line segments spanning a containment penetration, the thermal analyses treated the line as two segments; the segment exposed to the containment environment and the segment outside. The dividing point was considered to be the middle of the containment wall and the length inside was conservatively taken from that point. This was considered conservative since temperature degradation occurs at the inner penetration plate and, as shown by a separate thermal attenuation analysis, decays well within the penetration wall. Since the lines are isolated, the fluid inside the pipe was assumed to be stagnant with minimal mixing due to the temperature change. As such, the two segments were conservatively assumed to be isolated thermally but to communicate barometrically. Where there were instances of smaller pipe legs connected to the main isolated leg, the smaller leg was assumed to be isolated from the main leg thermally but connected barometrically. That approach was considered to be conservative since the smaller leg would heat up faster and thus its pressure contribution to the main leg would be larger.

The maximum calculated temperatures and pressures for each of the lines analyzed are summarized in Table 3.

**Structural Qualification Acceptance Criteria**

Structural evaluation of the potentially susceptible isolated piping segments and end valves was performed utilizing the maximum temperature and pressure responses as determined above for Containment LOCA and/or PAB HELB heat loading conditions, whichever was limiting. Structural qualification of the piping and end valves was based on acceptance criteria derived either from original component design codes for normal conditions, or the UFSAR criteria for faulted conditions. Although the accidents for which the thermal overpressure evaluations were conducted are faulted conditions, and thus qualification to the original design code acceptance criteria for normal conditions is not required, it was done for conservatism.

**Normal Condition Design Code Criteria**

For normal conditions, the subject piping systems were originally designed and evaluated in accordance with the USAS B31.1 Code for Power Piping-1967. Stress limits and load combinations are outlined in the UFSAR, Table 16.1-2. Re-evaluation of piping systems are typically performed in accordance with the requirements of the ANSI B31.1-1973 Code, and is the case for this GL 96-06 evaluation. Although the original design code for valves was typically USAS B16.5, ANSI B16.34 was utilized for the evaluations(except for the air operated diaphragm valves as explained later). A reconciliation of those codes for the evaluation parameters utilized pressure temperature ratings, hydrostatic test requirements and minimum wall thickness has demonstrated that the valves will also qualify under USAS B 16.5.

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The applicable criteria and load combinations utilized to qualify the piping for normal conditions is presented in Table 4. That Table addresses two basic equations. The first equation, based on B31.1 minimum wall requirements, ensures acceptability of induced hoop stress. The B31.1 allowable has been increased by the k term which is permitted for occasional loading which occurs less than 1% of operational life. Also as permitted, the corrosion allowance term is taken to be zero. In the second equation, for the calculation of sustained longitudinal stresses due to dead weight effects, a conservative stress intensification factor (denoted as i) of 2.1 was selected.

Qualification of the valves, other than the air operated diaphragm valves, isolating the piping segments to design code requirements for normal conditions was based on comparing the maximum line pressure developed to the valves B16.34 rated pressure at the appropriate temperature, or to a value 1.5 times its rated pressure based on its hydro-test requirement. Although the bodies and bonnets for the diaphragm valves in the lines of Items 2, 12 and 13 (see Tables) were designed in accordance with USAS B16.5 , they are not in accordance with the standard pressure class ratings of USAS B16.5 or ANSI B16.34. Their design pressure and temperature is 200 psi and 200°F respectively, and they were hydrostatically tested at 300psi. The qualification of these valves was based on the 300 psi hydro-test pressure.

**Faulted Condition Criteria**

The UFSAR (Table 16.1-2) permits the use of plastic analysis methodology for piping under faulted conditions and provides two acceptable alternate methods; one is based on design limit curves, and the second uses a plastic instability method. The design limit curves were developed using the approach presented in WCAP 5890 Rev.1. That report recommends using 50% of the ultimate strain as the allowable membrane strain; however the UFSAR conservatively uses only 20% of the uniform strain as the allowable for membrane strain. For stainless steel, limiting the membrane strain to 20% of uniform strain corresponds to a membrane stress limit of 1.8 times the material yield stress, Sy, at the appropriate temperature. This value was used as the stress limit for those lines not able to be qualified to the above normal condition design code criteria. The load combinations and stress equations utilized for the faulted condition qualification of piping is presented in Table 5.

For valves, the UFSAR faulted condition criteria specifies a maximum average membrane stress allowable of 2.4S, where S is defined as the allowable value specified in design codes. This value was utilized in a component stress evaluation performed for those valves not able to be qualified as above. The valve component stress evaluation considered minimum wall thickness requirements and body/bonnet leak tightness.

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## Results

The detailed results of the evaluations summarized above are presented in Tables 6 and 7 for the isolated piping segments. Table 6 and 7 summarizes the hoop stresses , in the form of minimum wall thickness (tm), and the longitudinal sustained stresses for both the normal condition design code criteria and the faulted condition criteria. The sustained stress, determined in accordance with B31.1 requirements, represents the sum of the longitudinal pressure stress and the deadweight stress. The deadweight stress was assumed to be 1500 psi as typically permitted by USAS B31.1-1967 Paragraph 121.1.4 based on standard B31.1 hanger criteria. Note that the normal condition design code acceptance criteria has been increased by 20% in accordance with ANSI B31.1-1973 Par. 102.24 for abnormal operation. The results show that only the piping for lines of Items 6, 7, 8 and 10 are not qualified under the design code normal condition criteria but are qualified under the UFSAR faulted condition criteria.

The evaluation results for the valves isolating the piping segments are presented in Tables 8 and 9. Those results show that the valves for Items 2, 6, 7, 8, and 10 do not qualify under the design code normal condition criteria, but are qualified under the UFSAR faulted condition criteria.

It is noted that for the Item 2 segment between the diaphragm valves RC-AOV-552 & 519 exposed to PAB HELB conditions, the evaluation determined that the pressure could reach the maximum lift pressure of 435 psig for RC-AOV-552 & 519. This evaluation conservatively assumed the line pressure outboard of either side of the isolated segment to be atmospheric. Any coincident line pressure outboard of the isolated segment would reduce by a corresponding amount the pressure in the isolated segment required to lift the diaphragm. The 435 psig pressure is above the 300 psig hydrostatic test pressure for the affected diaphragm valves. Consequently, seepage type leakage through the body/bonnet joint at a pressure less than that required to lift the diaphragm cannot be ruled out. However, this is not considered to be of significant consequence for the following reasons:

1. The volume of fluid that could leak by the body/bonnet joint (or by the diaphragm if it lifted) is limited to the thermally induced fluid volume increase. That amount has been calculated to be 0.000185 $ft^3$ or 0.32 $in^3$ which is considered insignificant.

2. Containment integrity would not be affected since body/bonnet leakage would only occur either on the outboard (relative to containment) side of the first CIV (552) or the inboard side of the second CIV (519). This is due to the design characteristic of these valves in which the diaphragm is sandwiched between the body and bonnet flanges. When in the closed position, any seepage would occur between the diaphragm and body flange on the pressurized side of the valve, and the diaphragm would maintain separation from the low pressure side.

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**Evaluation of Thermal Overpressurization of Isolated Piping Sections**

## CORRECTIVE ACTIONS

1. The initial evaluation also indicated that as a result of SI-MOV-1835A & B, the CIVs isolating Line #16 (Table 1, Item 15), being normally closed , the valves could be subject to thermal pressurization under PAB HELB conditions. As a corrective action, procedural revisions have been implemented to keep SI-MOV-1835A & B normally open.

2. Previously it had been determined that in Line #10 (Table 1, Item 5), the RHR suction isolation valve, AC-MOV-730, could be susceptible to thermal pressurization resulting from LOCA conditions inside containment. As a corrective action, a hole has been drilled in the upstream disk of AC-MOV-730 thereby eliminating its susceptibility.

**Containment Piping and Valving Screening Analysis Summary**
**Table 1**

| ITEM NO. | PEN/LINE DESCRIPTION | EVALUATION SUMMARY (1) | | ACCEPTANCE CRITERIA/ REMARKS |
|---|---|---|---|---|
| | | PAB TEMP EFFECT | VC TEMP EFFECT | |
| 1. | PEN U, LINE # 22-3"-AC-152N: EXCESS LETDOWN HEAT HX CCWs SUPPLY | YES STRUCTURAL EVALUATION OF PIPING BETWEEN CIVs | NO LINE IS NOT SUSCEPTIBLE TO THERMALLY INDUCED OVERPRESSURIZATION. LINE IS PROTECTED BY RELIEF VALVE. | CIVs ARE AIR OPERATED DIAPHRAGM VALVES (SELF RELIEVING) INTERCONNECTING PIPING MEETS DESIGN BASIS REQUIREMENTS |
| 2. | PEN Y LINE # 33-3"-RC-151R: PRIMARY MAKE-UP WATER SUPPLY TO PRT AND RCP SEAL STANDPIPES | YES STRUCTURAL EVALUATION OF PIPING BETWEEN CIVs | YES STRUCTURAL EVALUATION OF LINE INSIDE CONTAINMENT UP TO THE FIRST CIV | LINE CONTAINS AIR OPERATED DIAPHRAGM VALVES (SELF RELIEVING) PIPING MEETS DESIGN BASIS REQUIREMENTS |
| 3. | PEN Y, LINE DW-2"-DW-151: DEMINERALIZED WATER INTO CONTAINMENT | YES THERMAL/STRUCTURAL EVALUATION FOR CIVs AND INTERCONNECTING PIPING | NO LINE IS NOT SUSCEPTIBLE TO THERMALLY INDUCED OVERPRESSURIZATION. LINE IS PROTECTED BY RELIEF VALVE | MEETS ASME SECTION III APPENDIX F CRITERIA |
| 4. | PEN TT, LINE # 711-3/8"-SL-2505R: RECIRCULATION PUMP DISCHARGE SAMPLE LINE | YES THERMAL/STRUCTURAL EVALUATION OF CIVs AND INTERCONNECTING PIPING | NO LINE IS NOT SUSCEPTIBLE TO THERMALLY INDUCED OVERPRESSURIZATION. LINE UPSTREAM OF CIVs IS OPEN TO THE RECIRCULATION SYSTEM | PIPING MEETS ASME SECTION III APPENDIX F CRITERIA. FOR CIVs, BODY TO BONNET JOINT VULNERABLE TO LEAKAGE (SEE NOTE 2) |
| 5. | PEN K, LINE # 10-14"-AC-601R: RESIDUAL HEAT REMOVAL LOOP OUT | YES THERMAL/STRUCTURAL EVALUATION OF THE CIV (DOUBLE DISC GATE VALVE). LINE IS NOT SUSCEPTIBLE TO THERMALLY INDUCED OVERPRESSURIZATION. LINE IS PROTECTED BY RELIEF VALVE. | YES THERMAL/STRUCTURAL EVALUATION OF RHR SUCTION ISOLATION VALVE. LINE IS NOT SUSCEPTIBLE TO THERMALLY INDUCED OVERPRESSURIZATION. LINE IS PROTECTED BY RELIEF VALVE. | VALVES MEET ASME SECTION III, APPENDIX F CRITERIA |
| 6. | PEN W, LINE # 25-3/8"-SL-2505R: PRESSURIZER STEAM SPACE SAMPLE LINE | YES THERMAL/STRUCTURAL EVALUATION TO ACCOUNT FOR THE POSSIBILITY OF INLEAKAGE BETWEEN CIVs | YES THERMAL/STRUCTURAL EVALUATION OF LINE INSIDE CONTAINMENT UP TO THE FIRST CIV | MEETS ASME SECTION III, APPENDIX F CRITERIA |
| 7. | PEN W, LINE # 26-3/8"-SL-2505R: PRESSURIZER LIQUID SPACE SAMPLE LINE | YES THERMAL/STRUCTURAL EVALUATION TO ACCOUNT FOR THE POSSIBILITY OF INLEAKAGE BETWEEN CIVs | YES THERMAL/STRUCTURAL EVALUATION OF LINE INSIDE CONTAINMENT UP TO THE FIRST CIV | MEETS ASME SECTION III, APPENDIX F CRITERIA |

## Containment Piping and Valving Screening Analysis Summary
## Table 1

| ITEM NO. | PEN/LINE DESCRIPTION | EVALUATION SUMMARY (1) | | ACCEPTANCE CRITERIA/ REMARKS |
|---|---|---|---|---|
| | | PAB TEMP EFFECT | VC TEMP EFFECT | |
| 8. | PEN W, LINE # 59-3/8"-SL-2505R: REACTOR COOLANT SYSTEM SAMPLE | YES THERMAL/STRUCTURAL EVALUATION TO ACCOUNT FOR THE POSSIBILITY OF INLEAKAGE BETWEEN CIVs | YES THERMAL/STRUCTURAL EVALUATION OF LINE INSIDE CONTAINMENT UP TO THE FIRST CIV | MEETS ASME SECTION III, APPENDIX F CRITERIA |
| 9. | PEN Y, LINE # 31-3/4"-SL-1501R: SAFETY INJECTION TEST LINE FROM ACCUMULATOR TANKS # 31 THRU 34 TO RWST | YES THERMAL/STRUCTURAL EVALUATION OF CIVs AND INTERCONNECTING PIPING | NO LINE AND ITS ASSOCIATED CIVs IS NOT SUSCEPTIBLE TO THERMALLY INDUCED OVERPRESSURIZATION. LINE INSIDE CONTAINMENT UP TO THE FIRST CIV IS PROTECTED BY RELIEF VALVE | MEETS ASME SECTION III APPENDIX F CRITERIA |
| 10. | PEN RR, LINE # 69-3/8"-SL-2505R: ACCUMULATORS SAMPLE LINE | YES THERMAL/STRUCTURAL EVALUATION TO ACCOUNT FOR THE POSSIBILITY OF INLEAKAGE BETWEEN CIVs. | YES THERMAL/STRUCTURAL EVALUATION OF LINE INSIDE CONTAINMENT UP TO THE FIRST CIV | MEETS ASME SECTION III, APPENDIX F CRITERIA |
| 11. | PEN R, LINE # 18-3"-AC-152N: EXCESS LETDOWN HEAT HX CCWS RETURN LINE | YES STRUCTURAL EVALUATION OF PIPING BETWEEN CIVs. | NO LINE IS NOT SUSCEPTIBLE TO THERMALLY INDUCED OVERPRESSURIZATION. LINE IS PROTECTED BY RELIEF VALVE. | ONE CIV IS AIR OPERATED DIAPHRAGM VALVE (SELF RELIEVING). INTERCONNECTING PIPING MEETS DESIGN REQUIREMENTS |
| 12. | PEN Y, LINE #338-2"-WD-151R: CONTAINMENT SUMP PUMP DISCHARGE LINE | YES STRUCTURAL EVALUATION OF PIPING BETWEEN CIVs. | YES, STRUCTURAL EVALUATION OF LINE INSIDE CONTAINMENT UP TO THE FIRST CIV | LINE CONTAINS AIR OPERATED DIAPHRAGM VALVES (SELF RELIEVING) PIPING MEETS DESIGN BASIS REQUIREMENTS |
| 13. | PEN Z, LINE #40-3"-WD-151R: RCDT PUMP DISCHARGE LINE | YES STRUCTURAL EVALUATION OF PIPING BETWEEN CIVs. | YES, STRUCTURAL EVALUATION OF LINE INSIDE CONTAINMENT UP TO THE FIRST CIV | LINE CONTAINS AIR OPERATED DIAPHRAGM VALVES (SELF RELIEVING) PIPING MEETS DESIGN BASIS REQUIREMENTS |
| 14. | PEN QQ, LINE #60-8"-SI-601R: RESIDUAL HEAT REMOVAL LOOP TO SI PUMPS LINE | YES THERMAL/STRUCTURAL EVALUATION OF THE CIVs (DOUBLE DISC GATE VALVE) LINE IS NOT SUSCEPTIBLE TO THERMALLY INDUCED OVERPRESSURIZATION. LINE IS PROTECTED BY RELIEF VALVES. | NO LINE INSIDE CONTAINMENT IS PROTECTED BY RELIEF VALVES | MEETS ASME SECTION III, APPENDIX F CRITERIA |

## Containment Piping and Valving Screening Analysis Summary
## Table 1

| ITEM NO. | PEN/LINE DESCRIPTION | EVALUATION SUMMARY (1) | | REMARKS |
|---|---|---|---|---|
| | | PAB TEMP EFFECT | VC TEMP EFFECT | |
| 15. | PEN Q, LINE #16-4"-SI-1501R: SAFETY INJECTION HEADERS | YES THERMAL/STRUCTURAL EVALUATION OF THE CIVs (DOUBLE DISC GATE VALVE) LINE IS NOT SUSCEPTIBLE TO THERMALLY INDUCED OVERPRESSURIZATION. LINE IS PROTECTED BY RELIEF VALVE. | NO LINE INSIDE CONTAINMENT IS PROTECTED BY RELIEF VALVE | MEETS ASME SECTION III, APPENDIX F CRITERIA |
| 16 | PEN QQ, LINE #294-3/8"-SI-2505R: RESIDUAL HEAT REMOVAL SAMPLING LINE | YES THERMAL/STRUCTURAL EVALUATION OF CIVs AND INTERCONNECTING PIPING. | NO LINE INSIDE CONTAINMENT UPSTREAM OF THE CIVs IS NOT SUSCEPTIBLE TO THERMALLY INDUCED OVERPRESSURIZATION. LINE IS PROTECTED BY RELIEF VALVES | MEETS ASME SECTION III APPENDIX F CRITERIA |

NOTES:

1. Containment temperature effect on CIVs and their interconnecting piping located outside containment following a LOCA is negligible, since the temperature along the pipe will decay sufficiently prior to reaching the first containment isolation valve.

2. Configuration of CIVs associated with line # 711, recirculation pump discharge sample line will be administratively controlled. Draining of the sampling line between CIVs is an easily obtainable procedural corrective action.

**TABLE 2**
**HEAT TRANSFER PROCESS**

| Heat Transfer Process | Assumptions/ Considerations | Heat Transfer Coefficient |
|---|---|---|
| 1. Convection with condensation, containment to pipe environment | Assume all-steam environment | $h_o = C\left[\frac{g\rho_1(\rho_1-\rho_v)k^3h_{fg}}{\mu_1(T_{sat}-T_s)D}\right]^{1/4}$ Note 1 |
| 2. Conduction across pipe | Small resistance relative to convection coefficients, assume negligible. | $k_{pipe}$ = infinite |
| 3. Convection, pipe to inside fluid | Assume laminar (slow moving) fluid | $N_u = hD/k = 4.364$ $\therefore h_i = 4.364 \cdot k/D$ Note 2 |

Notes:
1. Incropera/Dewitt, *Fundamentals of Heat and Mass Transfer*, 2nd Edition. John Wiley and Sons, 1985. Equation 10.40.
2. Todd, P. J., and Ellis, B. H., *Applied Heat Transfer*, Harper and Row Publishers, New York, 1982. Equation 4-22.

## TABLE 3
## MAXIMUM PRESSURE AND TEMPERATURE RESPONSE

| DESCRIPTION | | PIPE PROPERTIES | | | DESIGN | | LINE OP. COND. | | Condition | MAX. RESPONSE | | RELIEF PRESSURE (psig) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ITEM NO. | PEN NO. | LINE NO. | O.D. (in.) | nom. wall thick (in.) | press. (psig) | temp. (°F) | press. (psig) | temp. (°F) | | P3 (psig) | temp. (°F) | |
| 1 | Pen. U | # 22 3-AC-152N | REMOVED FROM POTENTIAL SUSCEPTIBILITY AC-AOV-791 AND 798 ARE NORMALLY OPEN; PAB-HELB WILL NOT CAUSE THESE VALVES TO CLOSE | | | | | | | | | |
| 2 | Pen. Y | # 33 3-RC-151R | 3.5 | 0.216 | 150 | 500 | 130 | 100 | Cont. LOCA | 271 | 219 | 271 (Self Relief) |
| | | | | | | | | | PAB-HELB | 435 | 108 | 435 (Self Relief) |
| 3 | Pen. Y | # 2-DW-151R | 2.375 | 0.154 | 150 | 500 | 80 | 90 | PAB-HELB | 621 | 110 | N/A |
| 4 | Pen. TT | # 711 3/8-SL-2505R | 0.375 | 0.065 | 2500 | 650 | 150 | amb. | PAB-HELB | 3,295 | 149 | N/A |
| 5 | Pen. K | # 10 14-AC-601R | N/A AC-732 | | 600 | 600 | 400 | 140 | PAB-HELB | 440 | 101 | N/A |
| 6 | Pen W | # 25 3/8-SL-2505R | 0.375 | 0.065 | 2500 | 650 | 2235 | 650 | Cont. LOCA | 17,051 | 262 | N/A |
| 7 | Pen. W | # 26 3/8-SL-2505R | 0.375 | 0.065 | 2500 | 650 | 2235 | 650 | Cont. LOCA | 17,050 | 262 | N/A |
| 8 | Pen. W | # 59 3/8-SL-2505R | 0.375 | 0.065 | 2500 | 650 | 2235 | 605 | Cont. LOCA | 17,220 | 262 | N/A |
| 9 | Pen. Y | # 31 3/4-SL-1501R | 1.05 | 0.154 | 1400 | 650 | 100 | amb. | PAB-HELB | 1,354 | 121 | N/A |
| 10 | Pen. RR | # 69 3/8-SL-2505R | 0.375 | 0.065 | 2500 | 650 | 650 | 120 | Cont. LOCA | 13,229 | 262 | N/A |
| 11 | Pen. R | # 18 3-AC-152N | REMOVED FROM POTENTIAL SUSCEPTIBILITY AC-AOV-796 AND 793 ARE NORMALLY OPEN; PAB-HELB WILL NOT CAUSE THESE VALVES TO CLOSE | | | | | | | | | |
| 12 | Pen. Y | # 338 2-WD-151R | 2.375 | 0.154 | 150 | 500 | 40 | 120 | Cont. LOCA | 298 | 237 | 298 (Self Relief) |
| 13 | Pen. Z | # 40 3-WD-151R | 3.5 | 0.216 | 150 | 500 | 70 | 120 | Cont. LOCA | 228 | 219 | 228 (Self Relief) |
| 14 | Pen. QQ | # 60 8-SI-601R | N/A MOV-888A&B | | 600 | 600 | 600 | 140 | PAB-HELB | 746 | 103 | N/A |
| 15 | Pen. Q | # 16 4-SI-1501R | REMOVED FROM POTENTIAL SUSCEPTIBILITY PROCEDURAL CHG IMPLEMENTED TO KEEP VALVES SI-MOV-1835A & B OPEN DURING NORMAL OPERATION | | | | | | | | | |
| 16 | Pen. QQ | # 294 3/8-SL-2505R | 0.375 | 0.065 | 2500 | 650 | 450 | 140 | PAB-HELB | 3,595 | 149 | N/A |

**TABLE 4**
**DESIGN CODE LOAD COMBINATIONS AND ACCEPTANCE CRITERIA**

| LOAD COMBINATION | STRESS EQUATION | References B31.1-1973 Code |
|---|---|---|
| Design - Hoop Stress by Min. Wall Thickness [$t_m$] | $t_m = \frac{PD_o}{2\cdot(k\cdot S_h\cdot E + Py)} + A$ | Par. 104 |
| Sustained; P + DW | $\frac{PD}{4t} + \frac{0.75iM_A}{Z} \le k\cdot S_h$ | EQ 11 |

Where for these equations:

- $D_o$ =Pipe outside diameter [in.]
- $t_m$ = Minimum Pipe Wall (in.)
- t = Nominal pipe wall thickness [in.]
- y = Coefficient = 0.4
- P = Max. Internal pressure [psig]
- $S_h$ = Material Allowable, hot [psi]
- A = Corrosion allowance = 0
- k = 1.2; Allow. Stress increase per [8, par. 102.2.4]
- E = joint efficiency [8 Appendix A]
- DW = Dead Weight
- $M_A$ = Moment term due to sustained (DW) loads
- i = Stress intensification factor = 2.1 (considered bounding for butt & Socket Welded fittings & Swagelock

**TABLE 5**
**FAULTED CONDITION LOAD COMBINATIONS AND ACCEPTANCE CRITERIA**

| LOAD COMBINATION | STRESS EQUATION | References B31.1-1973 Code |
|---|---|---|
| Design - Hoop Stress by Min. Wall Thickness [$t_m$] | $t_m = \frac{PD_o}{2\cdot(S_a\cdot E + Py)} + A$ | Par. 104 |
| Sustained; P + DW | $\frac{PD}{4t} + \frac{0.75iM_A}{Z} \le S_a$ | EQ 11 |

Where for these equations:

$S_a = 1.8\cdot S_y$
All other terms per Table 4-1

# TABLE 6
## PIPING RESULTS SUMMARY - HOOP STRESS

| DESCRIPTION | | PIPE PROPERTIES | | | | | MAX. RESPONSE | | B31.1 -1973 | MIN WALL THICK: tm | | Interaction Ratio | | RESULT | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ITEM NO. | PEN NO. | LINE NO./ VALVE NO. | O.D. (in.) | nom. wall thick (in.) | man. min. thick (in.) | material spec. | P3/RP (psi) | temp. (F) | Allow Stress [Sh] (psi) | Design [Sa = 1.2Sh] | Faulted [Sa = 2.4Sh] | Design [Sa = 1.2Sh] | Faulted [Sa = 2.4Sh] | Design | Faulted |
| 1 | Pen. U | # 22 3-AC-152N | REMOVED FROM SUSCEPTIBILITY | | | | | | | | | | | | |
| 2 | Pen. Y | # 33 3-RC-151R | 3.5 | 0.216 | 0.189 | SA 312 TP 304 | 435 Relief Press. | 219 | 15,299 | 0.041 | 0.021 | 0.217 | 0.109 | OK | OK |
| 3 | Pen. Y | # 2-DW-151R | 2.375 | 0.154 | 0.135 | SA 312 TP 304 | 621 PAB-HELB | 110 | 18,376 | 0.033 | 0.017 | 0.245 | 0.123 | OK | OK |
| 4 | Pen. TT | # 711 3/8-SL-2505R | 0.375 | 0.065 | 0.057 | A213/A249 TP 316 | 3,295 PAB-HELB | 149 | 14,830 | 0.032 | 0.017 | 0.568 | 0.294 | OK | OK |
| 5 | Pen. K | N/A AC-732 | Valve AC-732 modeled as 18" SCH 40 pipe | | | | 440 PAB-HELB | 101 | See Tables 8 and 9 for Qualification of AC-732 | | | | | | |
| 6 | Pen W | # 25 3/8-SL-2505R | 0.375 | 0.065 | 0.065 | A213/A249 TP 316 | 17,051 Cont. LOCA | 262 | 24,250 [Sy] | 0.089 | 0.063 | 1.369 | 0.975 | NG | OK |
| 7 | Pen. W | # 26 3/8-SL-2505R | 0.375 | 0.065 | 0.065 | A213/A249 TP 316 | 17,050 Cont. LOCA | 262 | 24,250 [Sy] | 0.089 | 0.063 | 1.369 | 0.975 | NG | OK |
| 8 | Pen. W | # 59 3/8-SL-2505R | 0.375 | 0.065 | 0.065 | A213/A249 TP 316 | 17,220 Cont. LOCA | 262 | 24,250 [Sy] | 0.090 | 0.064 | 1.380 | 0.983 | NG | OK |
| 9 | Pen. Y | # 31 3/4-SL-1501R | 1.05 | 0.154 | 0.135 | SA 312 TP 316 | 1,354 PAB-HELB | 121 | 18,153 | 0.032 | 0.016 | 0.236 | 0.120 | OK | OK |
| 10 | Pen. RR | # 69 3/8-SL-2505R | 0.375 | 0.065 | 0.065 | A213/A249 TP 316 | 13,229 Cont. LOCA | 262 | 24,250 [Sy] | 0.072 | 0.051 | 1.110 | 0.780 | NG | OK |
| 11 | Pen. R | # 18 3-AC-152N | REMOVED FROM SUSCEPTIBILITY | | | | | | | | | | | | |
| 12 | Pen. Y | # 338 2-WD-151R | 2.375 | 0.154 | 0.135 | SA 312 TP 304 | 298 Relief Press. | 237 | 15,014 | 0.020 | 0.010 | 0.145 | 0.073 | OK | OK |
| 13 | Pen. Z | # 40 3-WD-151R | 3.5 | 0.216 | 0.189 | SA 312 TP 304 | 228 Relief Press. | 219 | 15,299 | 0.022 | 0.011 | 0.114 | 0.057 | OK | OK |
| 14 | Pen. QQ | N/A MOV-888A&B | Valves SI-MOV-888A & B modeled as 8" SCH 40S pipe | | | | 746 PAB-HELB | 103 | See Tables 8 and 9 for Qualification of SI-MOV-888A & B | | | | | | |
| 15 | Pen. Q | N/A MOV-1835A&B | REMOVED FROM SUSCEPTIBILITY | | | | | | | | | | | | |
| 16 | Pen. QQ | # 294 3/8-SL-2505R | 0.375 | 0.065 | 0.065 | A213/A249 TP316 | 3,595 PAB-HELB | 149 | 14,830 | 0.035 | 0.018 | 0.539 | 0.280 | OK | OK |

## TABLE 7
## PIPING RESULTS SUMMARY - SUSTAINED STRESS

| DESCRIPTION | | PIPE PROPERTIES | | | MAX. RESPONSE | | LOAD COMBINATION | | | B31.1 -1973 | Interaction Ratio | | RESULT | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ITEM NO. | PEN NO. | LINE NO./ VALVE NO. | O.D. (in.) | nom. wall thick (in.) | P3 (psig) | temp. (°F) | Long. Stress (psi) | D.W. Stress (psi) | Total Stress (psi) | Allow. Stress [Sh] (psi) | Design [Sa = 1.2Sh] | Faulted [Sa = 2.4Sh] | Design | Faulted |
| 1 | Pen. U | # 22 3-AC-152N | REMOVED FROM SUSCEPTIBILITY | | | | | | | | | | | |
| 2 | Pen. Y | # 33 3-RC-151R | 3.5 | 0.216 | 435 Relief Press. | 219 | 1,762 | 2,363 | 4,125 | 15,299 | 0.225 | 0.112 | OK | OK |
| 3 | Pen. Y | # 2-DW-151R | 2.375 | 0.154 | 621 PAB-HELB | 110 | 2,392 | 2,363 | 4,755 | 18,376 | 0.216 | 0.108 | OK | OK |
| 4 | Pen. TT | # 711 3/8-SL-2505R | 0.375 | 0.065 | 3,295 PAB-HELB | 149 | 4,752 | 2,363 | 7,114 | 14,830 | 0.400 | 0.200 | OK | OK |
| 5 | Pen. K | # 10 14-AC-601R | N/A AC-732 | | 440 PAB-HELB | 101 | See Tables 8 and 9 for Qualification of AC-732 | | | | | | | |
| 6 | Pen W | # 25 3/8-SL-2505R | 0.375 | 0.065 | 17,051 Cont. LOCA | 262 | 24,592 | 2,363 | 26,955 | 24,250 [Sy] | 1.742 | 0.618 [Sa = 1.8Sy] | NG | OK |
| [illegible] | Pen. W | # 26 3/8-SL-2505R | 0.375 | 0.065 | 17,050 Cont. LOCA | 262 | 24,592 | 2,363 | 26,954 | 24,250 [Sy] | 1.742 | 0.618 [Sa = 1.8Sy] | NG | OK |
| 8 | Pen. W | # 59 3/8-SL-2505R | 0.375 | 0.065 | 17,220 Cont. LOCA | 262 | 24,837 | 2,363 | 27,199 | 24,250 [Sy] | 1.758 | 0.623 [Sa = 1.8Sy] | NG | OK |
| 9 | Pen. Y | # 31 3/4-SL-1501R | 1.05 | 0.154 | 1,354 PAB-HELB | 121 | 2,308 | 2,363 | 4,671 | 18,153 | 0.214 | 0.107 | OK | OK |
| 10 | Pen. RR | # 69 3/8-SL-2505R | 0.375 | 0.065 | 13,229 Cont. LOCA | 262 | 19,081 | 2,363 | 21,443 | 24,250 [Sy] | 1.386 | 0.491 [Sa = 1.8Sy] | NG | OK |
| 11 | Pen. R | # 18 3-AC-152N | REMOVED FROM SUSCEPTIBILITY | | | | | | | | | | | |
| 12 | Pen. Y | # 338 2-WD-151R | 2.375 | 0.154 | 298 Relief Press. | 237 | 1,149 | 2,363 | 3,511 | 15,014 | 0.195 | 0.097 | OK | OK |
| 13 | Pen. Z | # 40 3-WD-151R | 3.5 | 0.216 | 228 Relief Press. | 219 | 924 | 2,363 | 3,286 | 15,299 | 0.179 | 0.089 | OK | OK |
| 14 | Pen. QQ | # 60 8-SI-601R | N/A MOV-888A&B | | 746 PAB-HELB | 103 | See Tables 8 and 9 for Qualification of SI-MOV-888A & B | | | | | | | |
| 15 | Pen. Q | N/A MOV-1835A&B | REMOVED FROM SUSCEPTIBILITY | | | | | | | | | | | |
| 16 | Pen. QQ | # 294 3/8-SL-2505R | 0.375 | 0.065 | 3,595 PAB-HELB | 149 | 5,184 | 2,363 | 7,547 | 14,830 | 0.424 | 0.212 | OK | OK |

Notes: D. W. Stress = 1500x2.1x0.75 per B31.1-1967 par. 121.1.4

## TABLE 8
## VALVE QUALIFICATION SUMMARY - PRESSURE RATING

| DESCRIPTION | | MAX. RESPONSE | | NYPA-IP3 VALVES | | | | | | ANSI B16.34 PRESSURE QUAL. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ITEM | LINE NO. | P3/R.P. | temp. | TAG NO. | | CLASS | | BODY MATERIAL | | rated (psi) | | tested (psi) | | RESULT | |
| NO. | PEN TAG | (psi) | (°F) | upstream | downstream | upstream | downstream | upstream | downstream | up | down | up | down | up | down |
| 1 | # 22<br>Pen. U | REMOVED FROM SUSCEPTIBILITY | | | | | | | | | | | | | |
| 2 | # 33<br>Pen. Y | 435<br>Relief Press. | 219 | AOV-519 | AOV-552 | 150 # | 150 # | SA351 CF8M | SA351 CF8M | 200 | 200 | 300<br>Note 1 | 300 | NG | NG |
| 3 | # 338<br>Pen. Y | 621<br>PAB-HELB | 110 | AOV-2 | AOV-1 | 600 # | 600# | SA351 CF8M | SA351 CF8M | 1,419 | 1,419 | 2,129 | 2,129 | OK | OK |
| 4 | # 711<br>Pen. TT | 3,295<br>PAB-HELB | 149 | MOV-990A | MOV-990B | 1500 #<br>spec. class | 1500 #<br>spec. Class | SA351 CF8C | SA351 CF8C | 3563 | 3563 | 5344 | 5344 | OK | OK |
| 5 | # 10<br>14-AC-601R | 440 | 101 | AC-MOV-732 | | 300# | | SA182 TP304 | | 719 | | 1,078 | | OK | |
| 6 | # 25<br>Pen W | 17,051<br>Cont. LOCA | 262 | AOV-951 | AOV-956A | 1500 # | 1500 # | SA182 F316 | SA182 F316 | 2,909 | 2,909 | 4,364 | 4,364 | NG | NG |
| 7 | # 26<br>Pen. W | 17,050<br>Cont. LOCA | 262 | AOV-953 | AOV-956C | 1500 # | 1500 # | SA182 F316 | SA182 F316 | 2,909 | 2,909 | 4,364 | 4,364 | NG | NG |
| 8 | # 59<br>Pen. W | 17,220<br>Cont. LOCA | 262 | AOV-955A<br>AOV-955B | AOV-956E | 1500 # | 1500 # | SA182 F316 | SA182 F316 | 2,909 | 2,909 | 4,364 | 4,364 | NG | NG |
| 9 | # 31<br>Pen. Y | 1,354<br>PAB-HELB | 121 | SI-859A | SI-859C | 1500 # | 1500 # | SA351 CF8 | SA351CF8 | 3,474 | 3,474 | 5,211 | 5,211 | OK | OK |
| 10 | # 69<br>Pen. RR | 13,229<br>Cont. LOCA | 262 | AOV-955C/D<br>AOV-955E/F | AOV-956H | 1500 # | 1500 # | SA182 F316 | SA182 F316 | 2,909 | 2,909 | 4,364 | 4,364 | NG | NG |
| 11 | # 18<br>Pen. R | REMOVED FROM SUSCEPTIBILITY | | | | | | | | | | | | | |
| 12 | # 338<br>Pen. Y | 298<br>Relief Press. | 237 | AOV-1723 | AOV-1728 | 150 # | 150 # | SA351 CF8M | SA351 CF8M | 200 | 200 | 300<br>Note 1 | 300 | OK | OK |
| 13 | # 40<br>Pen. Z | 228<br>Relief Press. | 219 | AOV-1702 | AOV-1705 | 150 # | 150 # | SA351 CF8M | SA351 CF8M | 200 | 200 | 300<br>Note 1 | 300 | OK | OK |
| 14 | # 60<br>8-SI-601R | 746<br>PAB-HELB | 103 | valves are<br>parallel | MOV-888A<br>MOV-888B | - -<br>- - | 600 # | - -<br>- - | SA351 CF8M | - -<br>- - | 1,433 | - -<br>- - | 2,150 | - -<br>- - | OK |
| 15 | # 16<br>4-SI-1501R | REMOVED FROM SUSCEPTIBILITY | | | | | | | | | | | | | |
| 16 | # 294<br>Pen. QQ | 3,595<br>PAB-HELB | 149 | AOV-958<br>- - | AOV-959<br>AOV-990C | 1500 #<br>- - | 1500 #<br>2500 # | SA182 F316<br>- - | SA182 F316<br>SA182 TP304 | 3,354<br>- - | 3,354<br>5,514 | 5,032<br>- - | 5,032<br>8,271 | OK<br>- - | OK<br>OK |

Note(s): 1. ITT Grinnell rated at 200 psig in accordance with Westinghouse E-Spec 676281 Rev. 2 and hydro-tested to 300 psig
2. ANSI B16.34 Pressure ratings determined at Max. Response temperature

## TABLE 9
## VALVE QUALIFICATION SUMMARY - MIN VALVE BODY REQUIREMENT

| DESCRIPTION | | MAX. RESPONSE | | NYPA-IP3 - VALVE | | | | Faulted Allow. | | ANSI B16.34 TABLE 3 CRITERIA | | | | | RESULT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ITEM NO. | LINE NO. PEN TAG | P3/RP (psi) | temp. (°F) | TAG NO. upstream | TAG NO. downstream | BODY MATERIAL upstream | BODY MATERIAL downstream | [Sa = 2.4Sh] (psi) inboard | [Sa = 2.4Sh] (psi) outboard | d (in.) | tm (in.) | R/tm < 10? THICK | Press. Stress (psi) | Interaction Ratio | Faulted |
| 1 | # 22 Pen. U | REMOVED FROM SUSCEPTIBILITY | | | | | | | | | | | | | |
| 2 | # 33 Pen. Y | 435 Relief Press. | 219 | AOV-519 | AOV-552 | SA351 CF8M | SA351 CF8M | 31,499 | 31,499 | 2.761 | 0.22 | 6.8 thick | 3,265 | 0.104 | OK |
| 3 | # 338 Pen. Y | 621 PAB-HELB | 110 | AOV-2 | AOV-1 | SA351 CF8M | SA351 CF8M | 35,319 | 35,319 | 1.86 | 0.210 | 4.9 thick | 3,393 | 0.096 | OK |
| 4 | # 711 Pen. TT | 3295 PAB-HELB | 149 | MOV-990A | MOV-990B | SA351 CF8C | SA351 CF8C | 39,899 | 39,899 | 0.221 | 0.143 | 1.3 thick | 5077 | 0.127 | OK |
| 5 | # 10 14-AC-601R | 440 PAB-HELB | 101 | AC-MOV-732 | | SA182 TP304 | | 41,947 | | 15.1884 | 0.69 | 11.5 thin | 5,057 | 0.121 | OK |
| 6 | # 25 Pen W | 17,051 Cont. LOCA | 262 | AOV-951 | AOV-956A | SA182 F316 | SA182 F316 | 36,408 | 36,408 | 0.221 | 0.143 | 1.3 thick | 26,274 | 0.722 | OK |
| 7 | # 26 Pen. W | 17,050 Cont. LOCA | 262 | AOV-953 | AOV-956C | SA182 F316 | SA182 F316 | 36,408 | 36,408 | 0.221 | 0.143 | 1.3 thick | 26,273 | 0.722 | OK |
| 8 | # 59 Pen. W | 17,220 Cont. LOCA | 262 | AOV-955A AOV-955B | AOV-956E | SA182 F316 | SA182 F316 | 36,408 | 36,408 | 0.221 | 0.143 | 1.3 thick | 26,535 | 0.729 | OK |
| 9 | # 31 Pen. Y | 1,354 PAB-HELB | 121 | SI-859A | SI-859C | SA351 CF8 | SA351CF8 | 32,741 | 32,741 | 0.668 | 0.227 | 2.0 thick | 3,049 | 0.093 | OK |
| 10 | # 69 Pen. RR | 13,229 Cont. LOCA | 262 | AOV-955C/D AOV-955E/F | AOV-956H | SA182 F316 | SA182 F316 | 36,408 | 36,408 | 0.221 | 0.143 | 1.3 thick | 20,385 | 0.560 | OK |
| 11 | # 18 Pen. R | REMOVED FROM SUSCEPTIBILITY | | | | | | | | | | | | | |
| 12 | # 338 Pen. Y | 298 Relief Press. | 237 | AOV-1723 | AOV-1728 | SA351 CF8M | SA351 CF8M | 31,328 | 31,328 | 1.86 | 0.210 | 4.9 thick | 1,629 | 0.052 | OK |
| 13 | # 40 Pen. Z | 228 Relief Press. | 219 | AOV-1702 | AOV-1705 | SA351 CF8M | SA351 CF8M | 31,499 | 31,499 | 2.761 | 0.22 | 6.8 thick | 1,711 | 0.054 | OK |
| 14 | # 60 8-SI-601R | 746 PAB-HELB | 103 | valves are parallel | MOV-888A MOV-888B | - - - - | SA351 CF8M | - - | 32,607 | 7.183 | 0.585 | 6.6 thick | 5,487 | 0.168 | OK |
| 15 | # 16 4-SI-1501R | REMOVED FROM SUSCEPTIBILITY | | | | | | | | | | | | | |
| 16 | # 294 Pen. QQ | 3,595 PAB-HELB | 149 | AOV-958 - - | AOV-959 AOV-990C | SA182 F316 - - | SA182 F316 SA182 F304 | 40,366 - - | 40,366 40,833 | 0.221 | 0.143 | 1.3 thick | 5,539 | 0.137 | OK |

Note(s): Press. Stress represents valve body hoop stress for thick or thin wall vessels.

**Drawing List**

| ITEM NO. | LINE NO. | FLOW DIAGRAM 9321-F- | PIPING DESIGN OR PIPING & RESTRAINT 9321-F- |
|---|---|---|---|
| 2 | 33-3'-RC-151R | 27243, 27473, 27383 | 51233, 51223, 54203, 52723, 51933, 54093 |
| 3 | DW-2"-DW-151 | 27243 | 26773 |
| 4 | 711-3/8"-SL-2505R | 27453 | 25973 |
| 5 | 10-14"-AC-601R | 27513 | N/A VALVE ONLY |
| 6 | 25-3/8"-SL-2505R | 27453 | 25973 |
| 7 | 26-3/8"-SL-2505R | 27453 | 25973 |
| 8 | 59-3/8"-SL-2505R | 27453 | 25973 |
| 9 | 31-3/4"-SI-1501R | 27503 | 51203 |
| 10 | 69-3/8"-SL-2505R | 27453 | 25973 |
| 12 | 338-2"-WD-151R | 27193 | 51773 |
| 13 | 40-3"-WD-151R | 27193 | 53353 |
| 14 | 60-8"-SI-601R | 27503 | N/A VALVE ONLY |
| 16 | 294-3/8"-SL-2505R | 27453 | 25973 |