Public Service
Electric and Gas
Company

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Senior Vice President - Nuclear Engineering

DEC 1 1 1996
LR-N96401
LCR S96-13

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

**REQUEST FOR ADDITIONAL INFORMATION
CONTAINMENT FAN COOLING UNIT RESPONSE TIME
SALEM GENERATING STATION UNIT NOS. 1 AND 2
DOCKET NOS. 50-272 AND 50-311**

Gentlemen;

Public Service Electric & Gas Company (PSE&G) submits Attachment 1 to this letter in response to questions associated with License Change Request (LCR) S96-13. This LCR was originally transmitted on October 25, 1996 LR-N96278).

The information contained in Attachment 1 addresses the concerns outlined in NRC Generic Letter 96-06, "Assurance of Operability and Containment Integrity During Design-Basis Accident Conditions," as they relate to the Containment Fan Coil Unit (CFCU) Response Time and the associated accident analyses. The enclosed information does not impact on the previous "No Significant Hazards Determination" provided by PSE&G in support of this LCR.

Should you have any questions regarding this information, please feel free to contact us.

Sincerely;

E C Simpson

A001/,

ADD: NRR/DRPW 1/1

Attachment

C Mr. H. Miller, Administrator - Region I
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STATE OF NEW JERSEY)
) SS.
COUNTY OF SALEM)

E. C. Simpson, being duly sworn according to law deposes and says:

I am Senior Vice President - Nuclear Engineering of Public Service Electric and Gas Company, and as such, I find the matters set forth in the above referenced letter, concerning Salem Generating Station, Units 1 and 2, are true to the best of my knowledge, information and belief.

E C Simpson

Subscribed and Sworn to before me
this 11 day of December 1996

Ann L Shimp
Notary Public of New Jersey

My Commission expires on October 13, 1997

ANN L. SHIMP
NOTARY PUBLIC OF NEW JERSEY
My Commission Expires Oct. 13, 1997

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1.0 BACKGROUND

The design of the Salem plants includes five safety related Containment Fan Coil Units (CFCUs) per plant, each cooled by the service water (SW) system. There are three vital power buses and six service water (SW) pumps per plant. Under worst case single failure conditions (failure of a vital bus), a minimum of three CFCUs and 2 SW pumps are available for accident mitigation. The CFCUs are located at elevation 130'(30' above grade) inside containment. Each CFCU has separate supply and return piping that branches off two main SW supply headers. The CFCU loops are the highest elevation point in the SW system, with the outlet piping reaching as high as elevation 152'. A schematic of the CFCU loop piping is shown in Attachment 2.

During normal operation, the CFCUs operate (as required) to remove heat from containment to keep the containment average temperature below 120°F. For this normal condition, the SW flow through each CFCU is about 700 - 900 gpm and the CFCU fan speed is 1200 rpm. Following a LOCA or MSLB, the CFCUs are automatically placed in accident mode. For this accident condition, the SW flow through each CFCU is a minimum of 2500 gpm and the CFCU fan speed is 600 rpm. If a loss of offsite power (LOOP) occurs concurrent with the LOCA or MSLB, the CFCU fans begin to coast down and the SW pumps stop. When power is restored to the vital busses (from the EDGs), the CFCUs and SW pumps are sequenced back on. The time required to restore full SW flow to each CFCU after a LOCA and/or LOOP is dependent on the number of CFCUs and SW pumps operating and several time delays associated with the opening and closing of valves in the SW system. Details of this sequencing, including a time line, are provided below.

2.0 CFCU WATERHAMMER

Westinghouse NSAL 96-03 (and NRC GL 96-06) identified the potential for waterhammer in the CFCU cooling water piping following a LOCA (or MSLB)/LOOP due to continued heating in the CFCU coils while the power is off. This heating occurs because the CFCU fans continue to coast down throughout the entire period of loss of power.

For the Salem design, there is also the potential for column separation waterhammer in the SW piping. The CFCUs are relatively high in containment and the CFCU control valves are located on the discharge piping at a low point. When the LOOP occurs, the control valves close over about nine seconds while the SW pumps stop in about two seconds. The delay in closing the control valves allows the downcomer legs from the CFCUs to drain

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and form a void. When the SW pumps are restarted, the void collapses and the impact of the two columns of water creates a waterhammer overpressure. This sequence of events was identified previously and evaluated in calculation S-C-SW-MDC-1373. The results of this calculation were presented to the Service Water operational Performance Inspection (SWSOPI) Audit Team in 1994.

It should be noted that following an accident signal, SW flow to the turbine generator area (TGA) non-essential loads is automatically isolated after a 30 second delay using redundant motor operated valves. Field experience with waterhammer in the CFCU flow path led to the installation of the TGA isolation delay during plant startup testing. When the TGA valves are open at the time of waterhammer, the incoming fluid into the CFCU piping is moving at a lower velocity, which decreases the waterhammer overpressure, and the larger system tends to dampen the pressure wave.

The 1994 evaluation of the column separation waterhammer (i.e., without heat input), was performed using a computer model based on the method of characteristics (the LIQT-386 program maintained by Stoner Associates, Inc.). An inherent conservatism in the method of characteristics analysis method is the inability to model the air entrained in the fluid. For all of the scenarios evaluated, this “air” will leave solution and form a bubble in the system when the pumps stop. Significant testing and operational experience in the industry shows that this air will have a large damping effect on the resulting waterhammer overpressures. This is because the air must be compressed prior to the column impact.

The analysis described in calculation S-C-SW-MDC-1373 used a model of essentially the entire Salem SW system. The calculated overpressures are dependent on the assumed water temperature, but were generally between about 710 and 780 psig at the CFCU SW control valves. Using hoop stress allowables derived from ANSI B31.1 and the associated AL-6XN material yield strengths, the piping can withstand steady state pressures of 2500 psi (using an allowable of 0.9Sy). It should be noted that INCO 25-6MO, which is also used in the Salem SW system, would have a slightly lower value of 2350 psi. The calculated waterhammer pressures are well within either of these allowable values.

This result is supported by plant operating experience. There have been several loss of power events at Salem. There have also been several instances in which the CFCU downcomer legs were allowed to completely drain. The waterhammer pressures for those conditions are greater than the nominal LOOP waterhammer where

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void size is limited by the automatic closure of the outlet control valve.

Following these events, the CFCU SW piping was inspected. Damage was limited to small mechanical joint leakage and isolated degradation and leakage at two identical two inch connections. These connections were found to be degraded bi-metallic welds. These bi-metallic welds were eliminated during subsequent piping upgrades.

It should be noted that the Salem CFCU SW piping and CFCU cooling coils have been replaced with 6% molybdenum austenitic steel, which has a greater corrosion resistance and greater strength than the original lined carbon steel pipe and 90/10 Copper-Nickel coils. While the piping and cooling coils were replaced with a stronger material, the wall thickness was not changed. This provides superior strength and corrosion resistance.

The key difference for waterhammer events following LOCA/MSLB events is the addition of substantial heat to the system in the CFCU coils. For LOCA/MSLB events with coincident LOOP, vapor pockets (e.g., voids) will form in the CFCU piping as the system pressure drops below the vapor pressure of the fluid. Continued heat input in the coils causes the water in the coils to increase in temperature and expand. This expansion reduces the volume of the void in the downcomer. Since the void is smaller, the resulting waterhammer will be less severe. However, if the heat input is sufficient to fully close the void in the downcomer and create a new void in the coils (flashing in the coils), there can still be a waterhammer when the pumps are restarted and the void collapses.

A thermal/hydraulic computer model was used to predict the system time history response following the LOCA/LOOP (Engineering Evaluation S-C-SW-MEE-1138). The computer program (SYSFLO maintained by MPR Associates) is based on the basic conservation of momentum, energy, and mass equations for the fluid (i.e., the SW water) and conservation of heat for the metal (the coils). The model included the various heat transfer mechanisms (boiling, forced convection, free convection, condensation, etc.) between the coils, the SW water and the containment atmosphere. It also included the potential for steam to travel to other sections of the system, and a correlation for "slip" between the steam and water.

The purpose of the thermal/hydraulic model analysis was to compare the results without heat input to those with heat input. This comparison was then used with the results from the method of characteristics analysis to evaluate the heat input case. The

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analysis determined that boiling would occur in some of the CFCU coils (but not all) and that a steam void would be present in the upper coils when the pumps restarted.

The waterhammer pressures predicted in the CFCU piping for the heat input case are bounded by the case without heat input. The pressures in the piping are about 250 psia with heat input and over 700 psia without heat input. The waterhammer pressures in the coils for the heat input case are greater than those in the piping. The maximum estimated pressure in the coils is about 1125 psia. However, using the same hoop stress limits as described above for the piping, the allowable pressure for the coils is 4800 psi. Thus, the ratio of calculated pressure to allowable pressure in the coils for the heat input case is less than the equivalent ratio for the piping for the case without heat input. The primary reason for the difference in pressure between the coils and piping is the attenuation of the pressure wave in the CFCU water box.

The model did not predict significant steam migration to other locations for the case considered. However, if steam migration did occur, it most likely would result in a steam bubble at the top of the downcomer, essentially reproducing the case without heat input. The potential for steam to travel from the coils or top of the downcomer is further avoided by the large elevation drop from the steam source (the coils) and the fact that the pumps restart and collapse the void a few seconds prior to reopening the CFCU control valve.

In conclusion, for the case with heat input the waterhammer pressures in the piping are less than those obtained for the non-heat input case. Operating experience supports the conclusion that non-heat input case waterhammer loads will not challenge the integrity of the SW piping. Waterhammer pressures are higher in the cooling coils for the heat input case, however; a greater margin to the allowable pressure also exists for this area. As such, the current design is acceptable without further evaluation, testing, or modification.

3.0 CFCU TWO PHASE FLOW

The actual conditions in the SW piping supplying the CFCUs and in the CFCU coils depends on the number of CFCUs in operation, the number of SW pumps operating and the valve lineup in the SW system (i.e., which flow paths are open and which are closed). If the SW pressure is low enough, or the heat input in the CFCUs is high enough, there is the possibility for flashing to occur in the CFCU coils or outlet piping. This could result in two phase flow in the SW system piping downstream of the CFCUs. However,

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calculations for the Salem SW/CFCU design show that two-phase flow will not occur after the initial LOOP/LOCA transient as discussed below.

Following the accident signal, the SW system and CFCUs are placed in accident mode. The key changes for this switch are:

- the CFCU fans switch from 1200 rpm to 600 rpm,
- the CFCU loop control valves in the SW piping open from 700 to 900 gpm to >2500 gpm, and
- the SW valves controlling flow to the Turbine Generator Area (TGA) nonessential loads close, directing all SW flow to the safety related loads (CFCUs and EDGs, etc.).

As noted previously, there is a 30 second delay in the signal to close the TGA piping control valves. This delay was installed early in plant life (1976) to mitigate waterhammer events in the CFCU SW loops. The time delay reduced the SW system pressure, which in turn reduced the effects of waterhammer events.

If there is a LOOP concurrent with accident, the same basic system changes occur, however, there are additional delays due to the loss of power. The key delays are:

- the SW pumps stop quickly (less than about two seconds) but the CFCU loop SW control valves require about nine seconds to close, allowing the CFCU downcomer piping to drain and void,
- the SW pumps are repowered 24-28 seconds after the accident,
- the CFCU fans are repowered 33-37 seconds after the accident signal, and
- the CFCU SW control valves do not receive an open signal until 5 seconds after the fans are repowered.

There is additional delay in closing the TGA SW control valves. The valves are not fully closed until about 56 seconds after the accident. A timeline for the system response following LOCA/MSLB with coincident LOOP is provided as Attachment 3.

The evaluation for possible two-phase flow in the CFCU SW piping is included in calculation S-C-SW-MDC-1656. It should be noted that this calculation is applicable to Salem units 1 and 2 and supersedes calculation S-2-SW-MDC-1653 which was referenced in our original submittal of LCR S96-13. This calculation uses results from S-C-CBV-MDC-1637 and the Salem SW system hydraulic model.

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- In calculation S-C-CBV-MDC-1637, the maximum outlet temperatures from the CFCUs are determined using conservative assumptions such as zero fouling and maximum service water inlet temperature (90°F). The calculated maximum CFCU outlet temperature was about 191°F. As an additional conservatism, the outlet temperature was assumed to be 195°F. The water vapor pressure for this outlet temperature is 10.5 psia. As a final conservatism, the effects of the actual Salem SW chemistry (i.e. brackish water) to lower the vapor pressure were also neglected.

- The pressure conditions at the CFCU outlet were determined using the Salem SW system hydraulic model. This model, which has been validated with extensive in-situ testing of the Salem SW system piping (calculation S-C-SW-MDC-1317), provides the steady state pressures and flows in the SW system for a given set of operating conditions (number of pumps, valves open/closed etc.). The minimum pressures at the CFCU outlet with the TGA still open are for the case of minimum SW pumps operating (2) and either four ("A" vital bus failure) or five (SW pump failure) CFCU loops.

When the switch to accident mode has been completed (TGA valves closed), the minimum CFCU outlet pressure at the top of the CFCU downcomer in a limiting alignment is 43 psia as identified in the SW MODE OP Calculation S-C-SW-MDC-1350. This pressure is significantly greater than the maximum temperature vapor pressure of 10.5 psia, so two-phase flow will not occur in the CFCU SW piping for that configuration. However, the minimum pressure at the CFCU outlet prior to the TGA valves closing could be as low as 8.4 psia for the case with 2 pumps and four CFCU's and even lower for the case with 2 pumps / 5 CFCU's. For these cases, two-phase flow in the CFCU SW piping is possible for a short period of time until the TGA valves close. The comparison to conditions prior to the TGA valves closing was first performed in 1996 after the TGA valve time delay was identified. Prior to this year, all evaluations had considered only the accident configuration.

PSE&G reported this potential for short periods of two-phase flow in LER 272/96-020, dated September 18, 1996 (LR-N96286). This LER was submitted primarily to address the effects of the delay in restoring the CFCUs to full operational status (the delay in isolating the TGA SW loads), however, this potential for periods of two-phase flow under certain, specific single failure assumptions was also included. As stated above, after the TGA valves close, there is sufficient SW capacity to prevent two-phase flow.

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As a corrective measure, a reanalysis of the affected accidents was conducted with no credit taken for CFCU cooling until 60 seconds after an accident. This direction was selected by PSE&G to avoid disturbing the existing TGA time delay since it was installed to mitigate actual waterhammer observed in the CFCU loop during initial plant startup. At 60 seconds the TGA valves will be closed and the CFCU SW piping will only see single phase flow. The results of these analyses are summarized in PSE&G's original submittal on LCR S96-13, dated October 25, 1996 (LR-N96278).

4.0 THERMALLY INDUCED OVERPRESSURIZATION

Westinghouse NSAL 96-003 (and NRC GL 96-06) also addressed the heat input to the CFCUs during coastdown following LOCA or MSLB concurrent with a LOOP. The combination of issues with heat input during fan coastdown and the TGA isolation delay initiated a 1996 re-assessment of the full time response sequence for restoration of the CFCUs following these events. This assessment identified two other CFCU sequencing issues in addition to the TGA isolation delay (for the LOOP case):

- The Technical Specification time response surveillance requirement had only considered the CFCU start time and not delays associated with SW valve sequencing. There are also delays in the automatic sequencing associated with reopening of the CFCU outlet (control) valves.

- There is a short period of time during the initial CFCU restoration sequence when both the CFCU loop inlet check valves and the outlet control valves are closed. Large amounts of heat transfer into the SW in the CFCU coils during this period cause thermal expansion of the trapped fluid, possibly challenging the pressure retaining integrity of the system.

Both of these issues were also included in LER 272/96-020. The valve sequencing time delays are addressed implicitly in the revised LOCA and MSLB analyses which do not credit the CFCUs for the first 60 seconds following the accident. The potential for thermally induced overpressure is included in Engineering Evaluation S-C-SW-MEE-1138.

Following restart of the SW pumps (for the LOOP), there is a nine second delay until the CFCU fans are powered. During this time, any voids which had existed in the system would be collapsed by the incoming SW flow. There is an additional five seconds after the CFCU fans are powered until the CFCU SW control valves begin

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to open. Thus, there is a total of about 14 seconds during which heat transfer will continue in the coils, but the CFCU SW loop is isolated. As the fluid in the coils continues to expand, the pressure in the CFCU loop piping will continue to increase. For the MSLB, the fluid in the coil could heatup by 72°F during this time. Unless pressure relieving capability is installed, the system would likely fail or leak at the weakest location.

PSE&G addressed this concern in LER 272/96-020 by committing to the installation of appropriate overpressure protection capability prior to restart of the associated unit.

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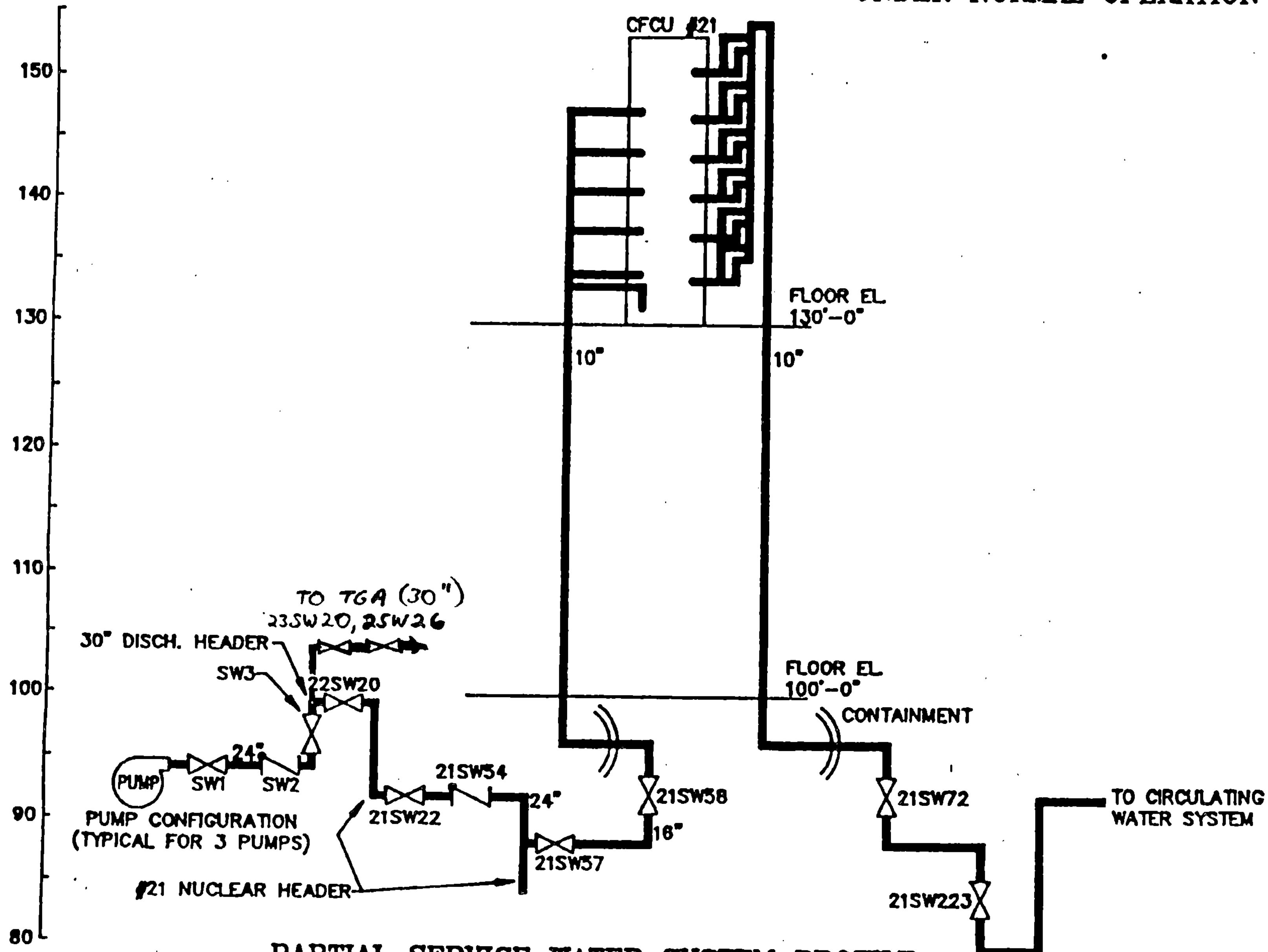
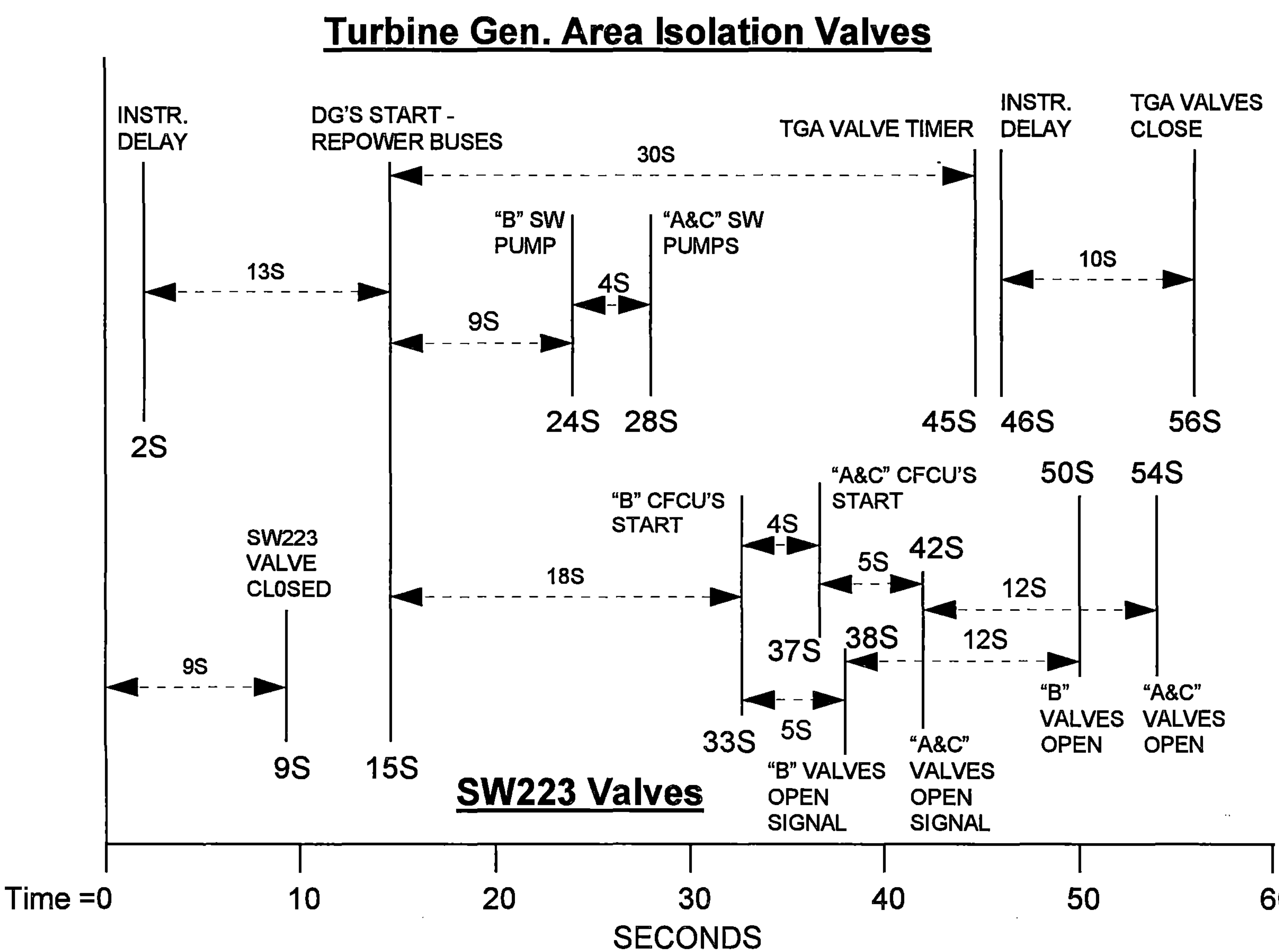
ATTACHMENT 2 TO LR-N96401
SUPPLEMENTAL INFORMATION LCR S96-013
CFCU RESPONSE TIME

FIGURE 3A: SYSTEM FULL
UNDER NORMAL OPERATION



PARTIAL SERVICE WATER SYSTEM PROFILE

ATTACHMENT 3 TO LR-N96401
SUPPLEMENTAL INFORMATION LCR S96-013
CFCU RESPONSE TIME



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