SCE&G
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October 30, 1998
RC-98-0202

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

Attention: Mr. L. M. Padovan

Gentlemen:

Gary J. Taylor
Vice President
Nuclear Operations

Subject: VIRGIL C. SUMMER NUCLEAR STATION
DOCKET NO. 50/395
OPERATING LICENSE NO. NPF-12
REQUEST FOR ADDITIONAL INFORMATION
REGARDING RESPONSE FOR GENERIC LETTER 96-06
(TAC No. M96872)
"Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions"

Reference:
1. L. Mark Padovan letter to Gary J. Taylor, dated August 5, 1998
2. Gary J. Taylor letter to Document Control Desk, RC-97-0026, January 28, 1997
3. Gary J. Taylor letter to Document Control Desk, RC-96-0261, October 30, 1996
4. Gary J. Taylor letter to Document Control Desk, RC-96-0032, February 13, 1996

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The NRC letter of August 5, 1998 issued a request for additional information (RAI) regarding the Virgil C. Summer Nuclear Station (VCSNS) Response to Generic Letter 96-06 submitted January 28, 1997 and requested that the additional information be provided by October 31, 1998. The RAI pertains to two-phase flow concerns for the reactor building cooling units (RBCUs) at VCSNS.

South Carolina Electric and Gas Company (SCE&G) has reviewed the RAI and provides response as an attachment to this letter.

I declare that these statements and matters set forth herein are true and correct to the best of my knowledge, information and belief.

A072 1/1

Should you have questions, please call Mr. Jim Turkett at (803) 345-4047 or Mr. Gil Williams at (803) 345-4159.

Very truly yours,

Gary J. Taylor

JT/GJT/dr
Attachment

c: J. L. Skolds
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DMS (RC-98-0202)

STATE OF SOUTH CAROLINA :
: TO WIT :
COUNTY OF FAIRFIELD :

I hereby certify that on the 30th day of October 1998, before me, the subscriber, a Notary Public of the State of South Carolina personally appeared Gary J. Taylor, being duly sworn, and states that he is Vice President, Nuclear Operations of the South Carolina Electric & Gas Company, a corporation of the State of South Carolina, that he provides the foregoing response for the purposes therein set forth, that the statements made are true and correct to the best of his knowledge, information, and belief, and that he was authorized to provide the response on behalf of said Corporation.

WITNESS my Hand and Notarial Seal

Notary Public

My Commission Expires

My Commission Expires July 13, 2005

Date

RESPONSES TO USNRC
REQUEST FOR ADDITIONAL INFORMATION
PERTAINING TO V. C. SUMMER NUCLEAR STATION
RESPONSE TO GENERIC LETTER 96-06

1. **If you used a methodology other than that discussed in NUREG/CR-5220, "Diagnosis of Condensation-Induced Waterhammer", in evaluating water hammer effects, describe this alternate methodology in detail. Also, explain why this methodology is applicable and gives conservative results (typically accomplished through rigorous plant-specific modeling, testing, and analysis).**

RESPONSE:

1. Transient analyses were performed to determine the range of steam generation rates and steam velocities in the 16-inch Reactor Building Cooling Unit (RBCU) return lines. The criteria of Fauske and Associates Report FAI/96-75, "Evaluation of Possible Water-Hammer Loads in the Service Water System for DBA Conditions", October 16, 1996, (presented to the NEI GL 96-06 NRC/Industry meeting 10/29/96), were applied to determine whether a significant potential existed for condensation induced water hammer in the RBCU/SW (Service Water) piping. The analyses concluded that the Froude numbers for flows occurring during the steam generation phase of the transient ranged between 0.89 and 1.97. The Froude number indicates the potential for liquid/vapor separation in a moving fluid. When the Froude number is close to or higher than 1.0, the horizontal legs of the RBCU return lines will be filled with liquid water. Since the onset of steam bubble condensation occurs at or below a Froude number of 0.5, the potential for condensation induced water hammer does not exist in the V. C. Summer Nuclear Station (VCSNS) RBCU piping.

   Had the analysis predicted Froude numbers closer to 0.5, the analysis plan called for a detailed analysis using the methodology of NUREG-5220 to have been conducted to determine the magnitude of the condensation induced water hammer forces.

2. Provide the following information for both the water hammer and two phase flow analyses:

a. Identify any computer codes that were used in the water hammer and two phase flow analyses, and describe the methods used to bench mark the codes for the specific loading conditions involved (see Standard Review Plan Section 3.9.1).

RESPONSE

2.a. Both the two phase flow analysis and the (slug impact) water hammer analysis were performed with FORTRAN coded algorithms which directly solve the governing heat transfer and fluid motion equations for the affected piping network. The water hammer analysis algorithm was found to compare favorably against V. C. Summer plant specific diagnostic test data for the RBCU and SW system.

The results of these analyses showed that the bounding water hammer transient is a loss-of-power and subsequent SW pump restart. The effects of this transient were confirmed by in-plant tests which showed that the pressure stresses of the transient were within design limits when coupled with the respective design loads. These transients were mild in nature. Detailed system walkdowns revealed no indication of any structural damage. Thus, no design basis structural or seismic structural reanalysis (per SRP 3.9.1) was required.

b. Describe and justify all assumptions and input parameters (including those used in any computer codes) such as amplifications due to fluid structure interaction, cushioning, speed of sound, force reductions, and mesh sizes, and explain why the values selected give conservative results. Also, provide justification for omitting any effects that may be relevant to the analysis (e.g., fluid structure interaction, flow-induced vibration, erosion). Confirm that all assumptions and input parameters are consistent with the design and licensing basis of the plant. Please explain and justify any exceptions.

RESPONSE

2.b. For the transient analyses, the significant analysis assumptions and input parameters are included in the following table:

ANALYSIS ASSUMPTIONS AND INPUT PARAMETERS		
	ASSUMPTION/INPUT PARAMETER	**BASIS/VALUE**
1	10 second SW pump coast-down time.	• Representative of measured coast down times for service water system pumps; • The sensitivity of the analysis results to coast-down time was examined by the investigation of two identical cases with different assumed coast down times, Case #1 assumed 10 sec. coast-down, Case #5 assumed a 5 sec. coast-down. • The net effect of a coast-down time change is to shift the time at which boiling in the RBCU is initiated for the Loss of Coolant Accident (LOCA) cases. For comparison, a 5 second shift in coast-down time resulted in a 4.3 second shift in the time to boiling. The calculated steady state system pressures, temperatures and flow velocities are not significantly different for the two cases. For Case 5. the net steam generation is slightly lower (-8%). This is attributed to the fact that the initial steam production begins at lower temperatures and pressures which tend to reduce the volume of the steam. Since the Froude number is directly dependent on the fluid velocity and the fluid properties, which are in turn functions of temperature and pressure, it was judged by this comparison that the differences in the results due to coast down time are insignificant.

ANALYSIS ASSUMPTIONS AND INPUT PARAMETERS		
	ASSUMPTION/INPUT PARAMETER	**BASIS/VALUE**
2	The steam void analyses are based upon the containment post LOCA temperatures and structural heat transfer coefficients provided in VCSNS Final Safety Analysis Report (FSAR), and on clean RBCU tubes.	• The FSAR LOCA temperatures provide the bounding high temperature conditions for RBCU heatup. • The effect of tube fouling is to reduce heat transfer, and accordingly the temperature and flow velocity of the vapor, which subsequently reduces the estimated water hammer pressure.
3	The heat transfer mechanism from containment to the RBCU tubes is 100% condensation.	Considerably more heat can be transferred by condensation than by convection from a given quantity of steam. The heat transfer on the outside surface of the RBCU tubes is normally dominated by condensation. During the initial phases of a LOCA, the RBCU fans primarily function to bring additional moist air/steam onto the coils. It is therefore conservative to consider condensation heat transfer only for the transient duration.
4	SW system back-pressure	• Minimum back pressure results in greater steam/water slug acceleration. • 0.815 psia for the two phase cases (at the 12-inch return line to the industrial cooling system). • Zero back pressure (0 psia) is assumed for the cold pump start cases.
5	SW inlet temperature	95°F for two phase cases, approximately 60°F (density = 62.4 lb/ft^3) for cold pump start cases.
6	SW Booster Pump (SWBP) start time	41.5 seconds after initiating event (LOCA coincident with Loss of Offsite Power [LOOP]), consistent with the timing of re-energizing the SWBP Emergency Safeguards (ES) electrical buses.

Also, provide justification for omitting any effects that may be relevant to the analysis (e.g., fluid structure interaction, flow-induced vibration, erosion).

RESPONSE

The analysis results show that the transient effects are well within the design limits of the SW system. Thus additional rigorous structural and/or fluid dynamic computations are unnecessary.

Confirm that all assumptions and input parameters are consistent with the design and licensing basis of the plant. Please explain and justify any exceptions.

RESPONSE

The scenarios considered and analyzed for GL 96-06 used bounding initial conditions from the VCSNS Technical Specifications where applicable. For key inputs not directly addressed by the Technical Specifications, bounding values were applied.

The analyses considered the effects of abnormal system alignments and conditions within the bounds of the single active failure criterion (including system test configurations and procedural failures such as mis-alignments).

c. **Provide a detailed description of the worst case scenarios for water hammer and two phase flow, taking into consideration the complete range of event possibilities, system configurations, and parameters, and confirm that all applicable situations have been considered. For example, all water hammer types and water slug scenarios should be considered, as well as temperatures, pressures, flow rates, load combinations, and potential component failures.**

RESPONSE

2.c. The following water hammer scenarios were investigated:

1. <u>Column separation due to gravity head</u>

This scenario creates the initial condition for the cold start transients (cases 4 and 5 following). Column separation occurs whenever the Service Water Booster Pumps (SWBPs) are secured. On the RBCU inlet side (SWBP discharge side), the SWBP discharge check valve (XVC-3135A,B-SW) is closed and maintains a full column. Also, Service Water pressure at the suction of the SWBPs (bottom of the column) is sufficient to maintain a full column. On the RBCU discharge side, a void is created from the closed XVG-3107A,B-SW valve (el. 465'6") down to approximately elevation 450'.

2. <u>Two phase/stratified flow</u>

Large break LOCA is the bounding heat transfer condition for the two phase flow scenarios. The transient begins when the non-safety related electric loads (Industrial Cooling, fast speed RBCU fans, etc.) lose power following a design basis LOCA and ends when Service Water flow is established in the RBCUs (SWBP start). The critical time for heat transfer from containment to the RBCUs occurs between 11.5 and 46.5 seconds after the accident. Steam generation in the RBCU tubes induces flow in the RBCU discharge piping.

This scenario was specifically analyzed for the case of steam generation in the RBCUs due to containment air flow with no SW pumps running. Flow was able to occur because the analysis conservatively assumed that SW was lined up to supply the RBCUs prior to the accident.

If the Froude number for a given fluid flow is near or above unity, then the pipe may be assumed to be running full (no phase separation). At the time of the accident the RB supply (XVB-3106A,B-SW) and discharge (XVG-3107A,B-SW) isolation valves, being MOVs, would remain in the open position. Thus the flow would occur down the SW return line towards the SW Pond. All scenarios produced high enough velocities such that stratified flow does not occur.

3. Steam void generation in the RBCUs

As noted previously, large break LOCA is the bounding heat transfer condition for the two phase flow scenarios. The transient begins when the non-safety related electric loads lose power following a LOCA and ends when Service Water flow is established in the RBCUs (SWBP start). The critical time for heat transfer from containment to the RBCUs occurs between 11.5 and 46.5 seconds after the accident. Steam generation in the RBCU tubes induces flow in the RBCU discharge piping.

This case is assumed to occur with the SW Pumps not running. Hot air and steam from Containment is pulled across the RBCUs by coast down of the RBCU fans and convection from the LOCA blowdown. Condensation heat transfer to the RBCU tubes causes boiling and thus a steam void is created in the RBCUs. Boiling occurs rapidly such that the RBCUs pressurize and induce flow in the discharge piping. This scenario has the highest potential to produce two phase stratified flow. Similar to Case 2 (Two phase/stratified flow), the bounding operating conditions occur when SW is lined up to supply the RBCUs prior to the accident. For this scenario, the analysis shows that the calculated Froude number is near or above unity. Therefore, the return line runs full and stratified flow does not occur. A review of fluid velocity results shows that the other analyses produce higher velocities than this scenario. Thus the Froude numbers for the other analyses would be higher than unity.

4. Column rejoining/slug collision

This scenario occurs when a SWBP is started and the RBCU discharge line fills, collapsing the previously created void (see Case #1). When the void collapses, the incident water column impacts the stationary column. The abrupt deceleration increases the local fluid pressure and causes water hammer shock waves to be distributed through the piping network. Calculated peak pressures for this scenario are 666 psig in the 10-inch return line, 265 psig for the 8-inch lines, and 274 psig for the 16-inch line. This is for the limiting case scenario of all flow from a SWBP going to a single RBCU. The results show that the calculated fluid pressures and forces from this case bound all other scenarios, including the two phase/stratified flow scenarios.

5. <u>Cold transient SW Booster Pump start (operational transient results)</u>

This is an in-plant post-modification test of the SWBP cold start scenario (Case #4 preceding). Prior to pump start, there is a substantial vapor void in the RBCU discharge line due to gravity drain and liquid fallback. A water hammer is postulated to occur following pump start as the vapor void collapses and the water columns impact. Parameters such as free and dissolved non-condensables, pipe friction and form losses, and/or incremental fluid/structure interactions are known to reduce water hammer severity. However, these parameters are not easily quantified under field test conditions.

Post-modification testing of MRF 22362 included the SWBP cold start transient scenario. Using MOVATS equipment, pressure vs time traces were made during SWBP starting and stopping for the pressures upstream and downstream of the Reactor Building (RB) supply (XVB-3106A,B-SW) and discharge (XVG-3107A,B-SW) isolation valves. These traces showed that while pressure spikes were evident, they were limited in number, magnitude, and duration. The maximum pressure achieved was 200 psig. This is substantially less than the maximum pressure (404.54 psig most limiting) allowed under ASME B&PV Code, Section III, 71 edition, W'73 addenda, subsection NC-3612.3 "Allowance for Variations from Design Conditions." A subsequent comprehensive walkdown inspection confirmed no evidence of damage to or displacement of the piping, components or supports.

Additional operational transients and single failure scenarios were also considered and evaluated. See response to item 2.d below.

Additional considerations for two phase flow include:

- **the effects of void fraction on flow balance and heat transfer;**
- **the consequences of steam formation, transport, and accumulation;**
- **cavitation, resonance, and fatigue effects; and**
- **erosion considerations.**

RESPONSE

1. The effects of fluid void fraction on RBCU heat transfer rates were included as follows: The RBCU tube heat transfer rate was calculated based upon the RBCU outside surface area and temperature, the fin efficiency, and the post LOCA temperature and condensation heat transfer coefficient profiles provided in the VCSNS FSAR. The rate of heat addition to the water/steam inside the RBCUs was determined based upon the RBCU inside surface area and temperature, the water/steam temperature and pressure, and the forced convection/boiling heat transfer coefficient at the inside surface of the RBCU tubes, depending upon the surface and saturation temperatures. The difference between the above values was the rate of heat addition to the copper tubes and fins throughout the transient.

   In regards to flow balance, flows were considered in terms of mass flow rates. Any errors in density due to increased void fraction would yield lower calculated velocities and thus lower calculated Froude numbers than the actual velocities and Froude numbers. Since the calculated Froude numbers are greater than 0.5, they already indicate full flow. Therefore, the results remain conservative.

2. The consequences of steam formation, transport, and accumulation were included by calculating the transient steam generation conditions within the RBCU tubes. The increased pressure accelerated the water column in the return line. Conservatively, no credit was taken for steam condensation at the downstream steam/water interface during this phase.

3. Cavitation, resonance, fatigue effects and erosion considerations are not a concern because of the brevity of the two phase conditions, the absence of flow control valves or components (in the affected piping) which could be adversely affected by cavitation, and the fact that the scenario occurs only coincident with a category IV Design Basis Accident (DBA) LOCA or Main Steam Line Break (MSLB).

It is important for you to realize that in addition to heat transfer considerations, two phase flow also involves structural and system integrity concerns that must be addressed. You might find NUREG/CR-6031, Cavitation Guide for Control Valves, helpful in addressing some aspects of the two phase flow analyses.

RESPONSE

Cavitation is not a concern because there are no control valves or similar components (other than flow orifices) in the affected RBCU/SW piping. Since the relatively brief two phase transient conditions are bounded by the fluid forces associated with the SWBP "cold start" scenario, and the cold start transient is well within system design limits, structural integrity is also maintained for the two phase scenarios.

d. Confirm that the analyses included a complete Failure Modes and Effects Analysis (FMEA) for all components (including electrical and pneumatic failures) that could impact performance of the cooling water system. Also, please confirm that the FMEA is documented and available for review, or explain why you did not perform a complete and fully documented FMEA.

RESPONSE

2.d. The licensing design basis of the V. C. Summer Nuclear Station Service Water System does not require a formal FMEA. However, the following comprehensive/bounding set of operational transients and single active failure scenarios were considered, demonstrated acceptable, and documented in the evaluation of GL 96-06:

1. Normal operation - RBCUs supplied by Industrial Cooling Water
2. Abnormal operation - RBCUs supplied by Service Water
3. Emergency operation - RBCUs switchover to Service Water (SW flow through one RBCU)
4. SW Booster Pump testing
5. Emergency Safeguards Features (ESF) Testing
6. Dual train SW operation (current method of operation)
7. Single train SW operation (both trains start during an accident)

8. Failure of one RBCU discharge valve to close (SW flow through two RBCUs)
9. Opening and subsequent failure to close of a RBCU relief valve
10. Failure of the normal/fast speed RBCU fan motor breaker to open during an accident
11. Failure of a SW Booster Pump to start
12. Failure of a SW Pump to start
13. Failure of the SW Booster Pump Discharge Check Valve to close
14. Failure of the SW Supply line valves to open
15. Other Failures (Failure of one of the Industrial Cooling System valves to isolate; Failure of a SW train power bus or emergency diesel generator).

e. Explain and justify all uses of engineering judgment.

RESPONSE

2.e. Instances of "engineering judgment" in this evaluation are as follows:

1. Identification of transients which are clearly not bounding when compared to the limiting cases. Several examples of these non-limiting scenarios appear in the list above (response to item 2.d).

2. The temperature effects of small and intermediate break LOCA conditions are not sufficient to produce significant boiling in the RBCUs prior to SWBP restart/start at 41.5 seconds This is based on observation of the calculations performed for large break LOCA conditions, the relative energy release profiles, and the MSLB containment temperature profiles.

3. Determine the uncertainty in the water hammer and two phase flow analyses. Also, explain how you determined the uncertainty, and how it was accounted for in the analyses to assure conservative results.

RESPONSE

3. A formal uncertainty analysis for the water hammer and two phase flow analyses was deemed unnecessary because:

1. The critical analysis inputs and initial conditions for the analyses were carefully selected to maximize the resultant water hammer fluid forces and pressures. This methodology is consistent with traditional Appendix-K safety analysis methods.

2. The final resulting fluid forces and pressures were well within the existing design limits of the SW system.

4. Confirm that the water hammer and two phase flow loading conditions do not exceed any design specifications or recommended service conditions for the piping system and components, including those stated by equipment vendors. Confirm that the system will continue to perform its design-basis functions as assumed in the safety analysis report for the facility, and that the containment isolation valves will remain operable.

RESPONSE

4. The scenarios considered and analyzed for GL 96-06 used bounding initial conditions from the VCSNS Technical Specifications where applicable. For key inputs not directly addressed by the Technical Specifications (i.e., SWBP maximum flow rates), bounding values were applied.

5. Discuss specific system operating parameters and other operating restrictions that must be maintained to assure that the water hammer and two phase flow analyses remain valid (e.g., head tank level, pressures, temperatures; valve operating sequences). Explain why it would not be appropriate to establish Technical Specification requirements to acknowledge the importance of these parameters and operating restrictions. Also, describe and justify reliance on any non-safety-related instrumentation and controls for maintaining these parameters and operating restrictions.

RESPONSE

5. The analyses considered the effects of abnormal system alignments and conditions within the bounds of the single active failure criterion (including system test configurations and procedural failures such as mis-alignments). No

scenarios were identified which had worse water hammer consequences than the SWBP cold start transient (a normal scenario). Therefore the addition of new procedures or requirements would not necessarily provide any reduction in transient frequency or magnitude.

6. Provide a simplified system diagram showing major components, active components, relative elevations, lengths of piping runs, and the location of any orifices and flow restrictions.

RESPONSE

6. See attached Figure 1 "Schematic of RBCU Connections to Service Water and Industrial Cooling Systems". Representative piping lengths are not readily available in a simplified format. This information is in isometric drawings and our original research documentation for Generic Letter 96-06, which is available for on-site review, if desired.

7. Describe in detail any plant modifications or procedure changes that have been made or are planned to be made to resolve the water hammer and two phase flow issues, including completion schedules.

RESPONSE

7. A potential water hammer concern was identified in 1991 during refueling outage Integrated Safeguards Testing. The maximum pressure seen was just sufficient to lift the RBCU thermal relief valves. The event was only troublesome by the fact that the RBCU relief valves momentarily lifted dumping water into the RB leak detection sumps. This gave a false detection of leakage inside the RB. At that time the Service Water system was deemed to be capable of meeting all design basis requirements (even with the relief valves full open). However, nuisance leakage alarms occurred occasionally during quarterly pump testing requiring RB entry during power operations.

In the fall of 1994, a modification (MRF 22363) was implemented to preclude the nuisance leakage alarms. MRF 22363 tied the opening/closing logic to the corresponding SW Booster Pump start and stop and changed the stroke times on XVB-3106A,B-SW and XVG-3107A,B-SW to eliminate the potential for water hammer which was identified in 1991. Additionally, the SWBP recirculation line isolation was locked open thus slowing the RBCU line fill rate. Post Modification Testing and subsequent system walkdowns confirm that any transients are minor and there are no physical indications of water hammer or water hammer damage.

No other modifications have been performed. Additionally, no other modifications are planned as a result of this issue.

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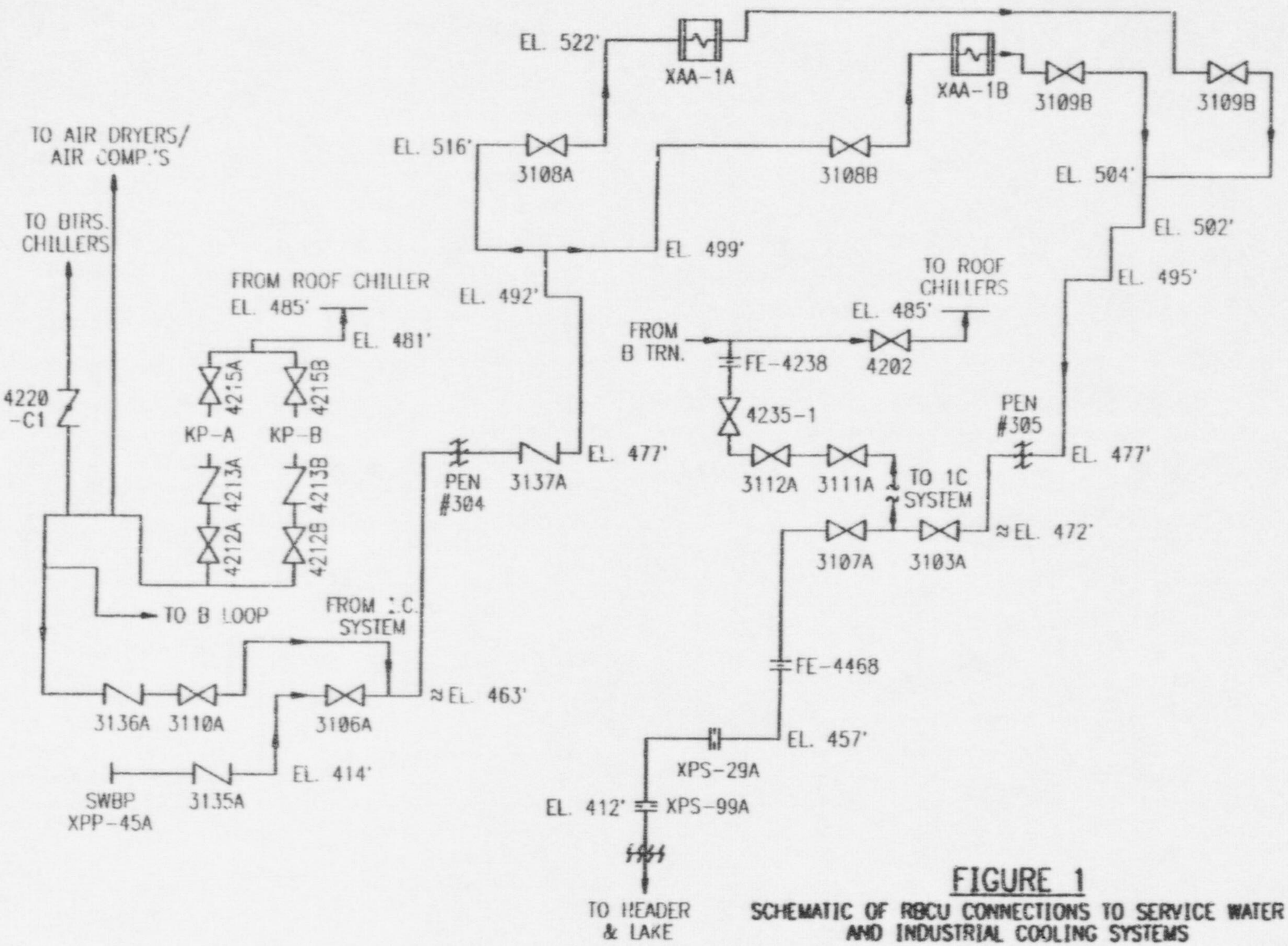

FIGURE 1
SCHEMATIC OF RBCU CONNECTIONS TO SERVICE WATER AND INDUSTRIAL COOLING SYSTEMS