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September 15, 1998

Re: Indian Point Unit No. 2
Docket No. 50-247

Document Control Desk
US Nuclear Regulatory Commission
Mail Station P1-137
Washington, DC 20555-0001

Subject: Response to Request for Additional Information - Generic Letter 96-06, "Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions," for Indian Point Unit No. 2. (TAC No. M96822)

Pursuant to 10CFR50.54(f), this letter and attachment provide the response of Consolidated Edison Company of New York, Inc. (Con Edison) to NRC's May 20, 1998 request for additional information on Generic Letter 96-06.

Generic Letter 96-06, "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions," dated September 30, 1996, requested nuclear utilities to address the susceptibility of 1) containment air cooler cooling water systems to either waterhammer or two-phase flow conditions during postulated accident conditions and 2) piping systems that penetrate containment to thermal expansion of fluid such that overpressurization of piping could occur.

Pursuant to 10CFR50.54(f), Con Edison provided written responses to Generic Letter 96-06 on October 30, 1996, November 18, 1996, January 28, 1997, April 30, 1997, August 29, 1997, and November 21, 1997.

The attachment to this letter responds to your specific requests for additional information.

Should you or your staff have any concerns regarding this matter, please contact Mr. Charles W. Jackson, Manager, Nuclear Safety & Licensing.

Very truly yours,

Subscribed and sworn to
before me this 15th day
of September 1998

Karen L. Lancaster
Notary Public

KAREN L. LANCASTER
Notary Public, State of New York
No. 60-4643659
Qualified In Westchester County
Term Expires 9/30/99

Attachment

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ATTACHMENT

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING RESPONSE TO GENERIC LETTER 96-06

Consolidated Edison Company of New York, Inc.
Indian Point Unit No. 2
Docket No. 50-247
September 1998

Response to Request for Additional Information
Regarding Response to Generic Letter 96-06

Request Item 1:

If a methodology other than that discussed in NUREG/CR-5220, "Diagnosis of Condensation Induced Waterhammer," was used in evaluating the effects of waterhammer, describe this alternate methodology in detail. Also, explain why this methodology is applicable and gives conservative results for Indian Point Unit 2 (typically accomplished through rigorous plant-specific modeling, testing, and analysis).

Response:

The methodology used to predict the type and magnitude of waterhammer pressure pulses was consistent with NUREG/CR-5220 and with the assumptions and input parameters described in the response to Item 2b below. Plant specific modeling was performed to determine fan cooler behavior, void sizes, driving pressures, and impact velocities. Supplemental guidance from EPRI NP-6766 (Reference 3) was used for pump restart column closure waterhammer predictions and from NUREG/CR-6519 (Reference 2).

Although the referenced NUREG-5220 does not specifically address the process that would initiate the draining type condensation induced waterhammer considered during the loss of power, the methodologies contained within the above-mentioned references were applied to conservatively predict condensation induced waterhammer magnitudes prior to restart of the pumps.

Request Item 2a:

For both the waterhammer and two phase flow analyses, provide the following information:

Identify any computer codes that were used in the waterhammer and two-phase flow analyses and describe the methods used to benchmark the codes for the specific loading conditions involved (see Standard Review Plan Section 3.9.1).

Response:

For the waterhammer portion of the analysis, hand calculations and spreadsheets were used to evaluate the piping drain down following the loss of pump pressure and the potential for waterhammer and two-phase flow occurrences.

ADLPIPE is a piping software package and was used to analyze piping stress. All waterhammer loads were evaluated against the design criteria contained in the Indian Point

Unit 2 UFSAR. ADLPIPE is approved for use in accordance with our vendor's QA program, which has been accepted by Con Edison.

Request Item 2b:

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).

Response:

The waterhammers that could occur in the Loss of Offsite Power (LOOP) / Loss of Coolant Accident (LOCA) scenario include condensation induced and column rejoin waterhammers. Column rejoin waterhammers occur when an advancing column of water impacts the stationary water at the other end of a collapsing steam void. Condensation induced waterhammers occur when a steam void becomes trapped along the top surface of a pipe and collapses. Both types of waterhammers were evaluated as part of this analysis.

Assumptions for the waterhammer analysis included:

1. During the period when power is lost, steam is formed at the fan coolers due to boiling in the tubes. The resulting steam pressure was assumed to rise during the transient due to heat input from the containment LOCA environment. This pressure was allowed to rise until the saturation pressure at the containment maximum temperature (260 F) was reached or until pumps were restarted. Since the magnitude of the calculated condensation induced waterhammer is greater as the steam pressure rises, this assumption conservatively increased the magnitude of the calculated pressure pulse. Other assumptions to conservatively increase the heat transfer into the FCUs and increase the steam pressure included:

   - Containment temperature was assumed to be a constant (maximum) value of 260 F.
   - Heat exchanger fouling factors were assumed to be zero.
   - No credit was taken for the coastdown of the fans. Maintaining a higher fan speed increases air flow past the FCU and conservatively increases heat transfer.

2. Fluid/structural interaction was conservatively not credited as a method for reducing waterhammer pulse magnitude as it travels through the system. Additionally, the fluid structural interaction phenomenon was reviewed relative to the possibility of amplifying

piping loads. It was determined that experimental fluid structural interaction results which showed potential amplification were not applicable to the piping at Indian Point Unit 2.

3. Cushioning as a result of air in the collapsing steam environment was conservatively not credited in calculating the magnitude of the waterhammer pressure pulse.

4. The driving pressure for condensation induced waterhammers during the draining transient was assumed to be the maximum steam pressure generated during the transient. This assumption is conservative because the steam pressure would be reduced if condensation on the piping and water interfaces were credited. This assumption conservatively increased the magnitude of the calculated waterhammer pressure pulse.

5. A fluid sonic velocity of 2300 feet per second was used to calculate the condensation induced waterhammer pressures during the draining stage of the transient and the column closure waterhammer. This sonic velocity is approximately half the sonic velocity calculated for water with no bubbles or entrained non-condensibles. This assumption, as outlined in NUREG/CR-5220, Reference 1, after describing the classical equations for determining waterhammer loads, states, "While an upper bound to the resulting loads is easily estimated by the methods described above, actual loads are usually lower by a factor from 2 to 10." Several reasons are provided for this load reduction including non-condensable gas, compliance of piping and hangars, and others. A sonic velocity adjustment was used to account for this reduction. NUREG/CR-6519, Reference 2, also recommends using half the sonic velocity value typically determined for water with no air or non-condensibles when calculating the magnitude of the waterhammer pressure pulse. This assumption is justified considering the fluid. The water in the open loop system at Indian Point Unit 2 is drawn from the Hudson River and has a high air (non-condensable) content. These non-condensibles are released during the boiling process in the fan coolers and will be in the steam void during waterhammer.

6. A steam to water volume ratio of 0.35 in the horizontal pipes during the draining was used in the condensation induced waterhammer calculations. As the steam to water ratio grows larger (the pipe drains more), the likelihood of trapping a steam bubble on the top of the pipe becomes much smaller. This is because the distance between the free surface of the water and the pipe is larger and because the steam velocity is lower. The steam velocity will go down because the cross-sectional area available for steam flow will grow more rapidly than the water and pipe surface area available to condense the steam and because the pipe surface and the water surface will heat up due to rapid condensation and will condense less steam. The heating of the water on the surface as the steam volume increases also reduces the capability of the water to rapidly condense a trapped bubble. Subcooled water is required for a waterhammer, and the water on the surface will heat up. If the subcooling in the water in contact with the steam drops below 36 F, no waterhammer would be expected. Based on the reasons described above, steam to water volume ratio of 0.35 was selected for use in the calculations.

As the steam enters the horizontal pipes, it will quickly reach a point where its condensation rate can exceed the generation rate. At this point, the steam pressure will be moderated (i.e., remain relatively constant). There are a number of horizontal piping segments where this will occur prior to restart of the pumps. This will significantly reduce the pressure below the maximum used in the calculation and will reduce the probability of reaching a volume ratio of 0.35 in the last horizontal header.

Additionally, the reduction in waterhammer is justified due to the limited potential to develop waves and trap steam bubbles above a volume ratio of 0.35. The horizontal pipes of concern are draining from the top down and will develop a warm water layer at the water/steam interface. Approximately 40° F subcooling is required in order to initiate a condensation-induced waterhammer (Reference 2). As the water surface heats, the amount of subcooling will decrease substantially. As the void grows, the steam velocity is reduced because its flow area is reduced. The condensing rate is reduced as the water temperature increases. The net effect is to reduce the potential for waves being trapped and voids collapsing at volume ratios above 0.35.

7. Column closure waterhammers have occurred during SI/LOOP testing at Indian Point Unit 2. Pressures that occurred during these tests were measured, post-test inspections were performed, and the piping was analytically evaluated and shown to be acceptable. This test experience provides less uncertainty when evaluating LOOP with LOCA waterhammer consequences than performing time history load calculations or fluid/structure interaction calculations alone. NUREG/CR-5220, Reference 1, provides guidance for use of inspection results when evaluating waterhammers.

Analyses were performed to compare the predicted column closure waterhammer pressure pulses to the values obtained from the testing. These analyses concluded that the measured pressure pulses were very conservatively bounded by the analyzed pressure pulse magnitudes. Another analysis was performed to determine the expected increase in column closure waterhammer magnitude for various alternate valve line-ups which could occur during testing. This analysis concluded that column closure waterhammer pulses could increase significantly in some valve positions, but these pulse magnitudes were still bounded by the analyzed results.

A testing program was initiated by Consolidated Edison to help establish the conservatism inherent in the modeling of waterhammer pressure pulses and the resulting loading of the piping system. Traditional waterhammer analysis methods that utilize idealized pressure waves and structural responses produce pipe and support stresses that are more severe than is realistic. Failure criteria for static, sustained loads are used for single-impact dynamic loading of extremely short duration (milliseconds). The objective of the testing project was to produce measured waterhammer data under controlled laboratory conditions and to correlate the results to expected response. This testing program helped to remove uncertainty and provide an understanding of the level of conservatism in the analysis.

Assumptions for the Two-Phase Flow Evaluation included:

- A flashing condition was calculated to occur downstream of the 10" butterfly control valves SWN-44- (1 - 5). During a LOOP/LOCA event, the system pressure will be determined by the relative elevation of the control valves to the vacuum breaker. Pressure downstream of the 8 inch throttling valve was conservatively assumed to be 14.7 psia. In reality, the header will pressurize above this as the pumps push the two-phase flow out. This is conservative for two phase flow predictions since it allows greater than actual steam generation.

- The assumed flashing across the 10 inch butterfly control valves was conservative since the increase in system pressure as a result of the two phase flow may cause more flashing to occur further downstream.

- Two cases for heat exchanger capability were analyzed: A fouled heat exchanger, and a perfectly clean heat exchanger. The fouling factors used were 0.001, and 0.0, respectively.

Request Item 2c:

Provide a detailed description of the "worst case" scenarios for waterhammer and two-phase flow, taking into consideration the complete range of event possibilities, system configurations, and parameters. For example, all waterhammer types and water slug scenarios should be considered, as well as temperatures, pressures, flow rates, load combinations, and potential component failures. Additional examples 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.

While the last three items (listed above) are important considerations for assuring that system integrity will be maintained during two-phase flow conditions, they were not discussed in the licensee's response. Also, NUREG/CR-6031, "Cavitation Guide for Control Valves," may be helpful in addressing some aspects of the two-phase flow analyses.

Response:

1. System lineups and component failures were evaluated against the limiting parameters for waterhammers and two phase flow conditions. The occurrence of a Loss of Offsite Power (LOOP) only with no Loss of Coolant Accident (LOCA) was determined by analysis to result in a more significant column closure waterhammer than a LOOP with LOCA waterhammer. Restart of three SW pumps upon restoration of power was determined to result in a more significant waterhammer than one pump restarting. In this scenario, the following factors contribute to make it the conservative configuration:

- The least potential for air cushioning results since there is no heating of the water.

- The highest potential for a clean water front (no bubbles or cushioning) upon closure of the steam results since there is no heating of the water.

2. A LOCA with a concurrent LOOP was determined to potentially result in condensation induced waterhammers in long horizontal lines that are draining during the transient. Clean heat exchangers with zero fouling results in the worst case scenario for condensation induced waterhammers. In this scenario, the heat transfer to the SW is the greatest. Subsequent steam pressures will be higher than other configurations/breaks and as a result the driving pressure for condensation induced waterhammers will be limiting. The loads as a result of the worst case condensation induced waterhammer were bounded by the worst case column closure waterhammer event.

3. The worst case scenario for the heat exchanger fouling condition with respect to two phase flow is described in response to question 2.b above. The zero (0) fouling case was found to be the worst case.

4. Erosion, cavitation, and fatigue/vibration issues during the event are not a concern since the two-phase flow period is limited to a short period of time during the transient. The flashing will be eliminated by the return to operating system pressure and/or temperatures. No damage is expected to occur.

5. Waterhammers as a result of the rapidly changing fluid velocity during the single phase to two phase flow transition periods were determined to be an order of magnitude less than calculated column closure and condensation induced waterhammers. Two phase flow transition waterhammers occur when flow flashes to steam. The rapid increase in volume downstream of a valve or orifice locations "backs up" flow on the upstream side of the valve. This decrease in velocity is similar to (but approximately an order of magnitude less than) a column closure waterhammer in which refill flow is suddenly stopped. In the worst flashing flow case, flow still passes through each FCU at approximately 780 gpm. This decrease in velocity from normal flow is much less than the column closure case. The column closure calculation used a velocity change from pump run-out to full stop to determine waterhammer magnitude. Since the velocity change is significantly less, these waterhammers are also much less severe.

Request Item 2d:

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 and confirm that the FMEA is documented and available for review, or explain why a complete and fully documented FMEA was not performed.

Response:

Although a complete FMEA was not performed, the analyses included a review of all components that would be active during the course of the combined LOOP/LOCA event. Of all the components, the potentially active equipment included the following:

1. Pumps
2. Fans
3. Valves

The analysis conservatively assumed a single failure for one diesel generator, powering one set of pumps, and delaying the time until pumps could restart. This longer time duration for the event increases drain down time, heat input into the coolers and the resulting magnitude of both the column closure and condensation induced waterhammers.

The analysis also conservatively assumed a failed breaker allowing the fans to stay on during the event. This further increases the heat input into the coolers and the magnitude of the resulting waterhammers.

Three valves in parallel (TCV-1103, TCV-1104, and TCV-1105) control the outlet flow from the coolers. One 8-inch valve (TCV-1103) is normally open and throttled to control temperature. The other two 18 inch valves (TCV-1104 and TCV-1105) are normally closed. Upon receiving a SI signal, the two 18 inch valves move to an open position. Each 18-inch valve is sized to allow full flow, and the failure of any one valve will not affect the potential waterhammer magnitude.

No other failure modes and effects were determined to be important to the event. Therefore, the review of operating components was appropriate and conservative.

Request Item 2e:

Explain and justify all uses of "engineering judgement."

Response:

Applications of "engineering judgement" that were of significance to the evaluation were identified as assumptions and discussed in response to questions 2.b and 2.c above.

Request Item 3:

Determine the uncertainty in the waterhammer and two-phase flow analyses, explain how the uncertainty was determined, and how it was accounted for in the analyses to assure conservative results for the Indian Point Unit 2.

Response:

Uncertainty in the waterhammer and two-phase flow analyses were addressed by using conservative assumptions in the analyses. Column closure waterhammer data from previous SI/LOOP testing corroborates the analysis and provides assurance that the system is sufficiently robust to appropriately function under the waterhammer conditions analyzed.

Two phase flow evaluations were appropriately performed using a Martinelli, one-dimensional, two-phase flow model using conservative assumptions for all input parameters.

Request Item 4:

Confirm that the waterhammer 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; and confirm that the system will continue to perform its design basis functions as assumed in the safety analysis report for the facility.

Response:

A structural analysis of the fan cooler unit (FCU) pressure retaining components, FCU supply, and return piping and associated support system was performed. The piping system supply and return piping to each FCU was computer modeled using the ADLPIPE program and loaded with the imbalanced forces resulting from the predicted waterhammers. The pipe was evaluated per the requirements of the IP2 UFSAR, and the stresses were found to be acceptable per the Upset Load Category limits for LOOP and SI test induced waterhammers. Included in this analysis was an evaluation of the FCU tubes for hoop stress and imbalanced loads. Transient pressure waves attenuate due to area increases in the FCUs' inlet regions, and the resulting loads on the FCUs were not great. The FCUs were acceptable per the normal design limits. The pipe support system was evaluated in accordance with equivalent IP2 Faulted Load Category Limits. All supports were found to be acceptable to this criteria. As such it is concluded that the FCU piping and supports are operable and capable of performing their function in the event of the postulated LOOP/LOCA condition and meet the requirements of the IP2 UFSAR.

Fatigue from prior testing does not require formal analysis per the requirements of B31.1 and ASME Section VIII. However, fatigue issues due to the repeated waterhammer loading from an SI test are being addressed. Stresses in the piping system were reviewed. The number of potential waterhammer cycles, thermal cycles, and potential seismic cycles were estimated (both historically and for future predictions) and compared to the allowable number of cycle per ASME Section III. This comparison indicated that fatigue is not a concern. To attenuate or mitigate the potential waterhammers which can occur during future performance of the SI test, the safety injection test procedure PT-R14, SIS Electrical Load, has been revised to vent the service water supply and discharge lines during restart of the service water piping. This venting allows air to enter and leave the system. This cushions the refill closure and eliminates waterhammer.

Request Item 5:

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

Response:

See attached figures (4).

<u>References:</u>

1. NUREG/CR-5220, "Diagnosis of Condensation Induced Waterhammer," 1988.

2. NUREG/CR-6519, "Screening Reactor Steam/Water Piping Systems for Water Hammer," 1997.

3. EPRI-NP-6766, Volume 5, Part 1, "Water Hammer Prevention, Mitigation, and Accommodation", July 1992.

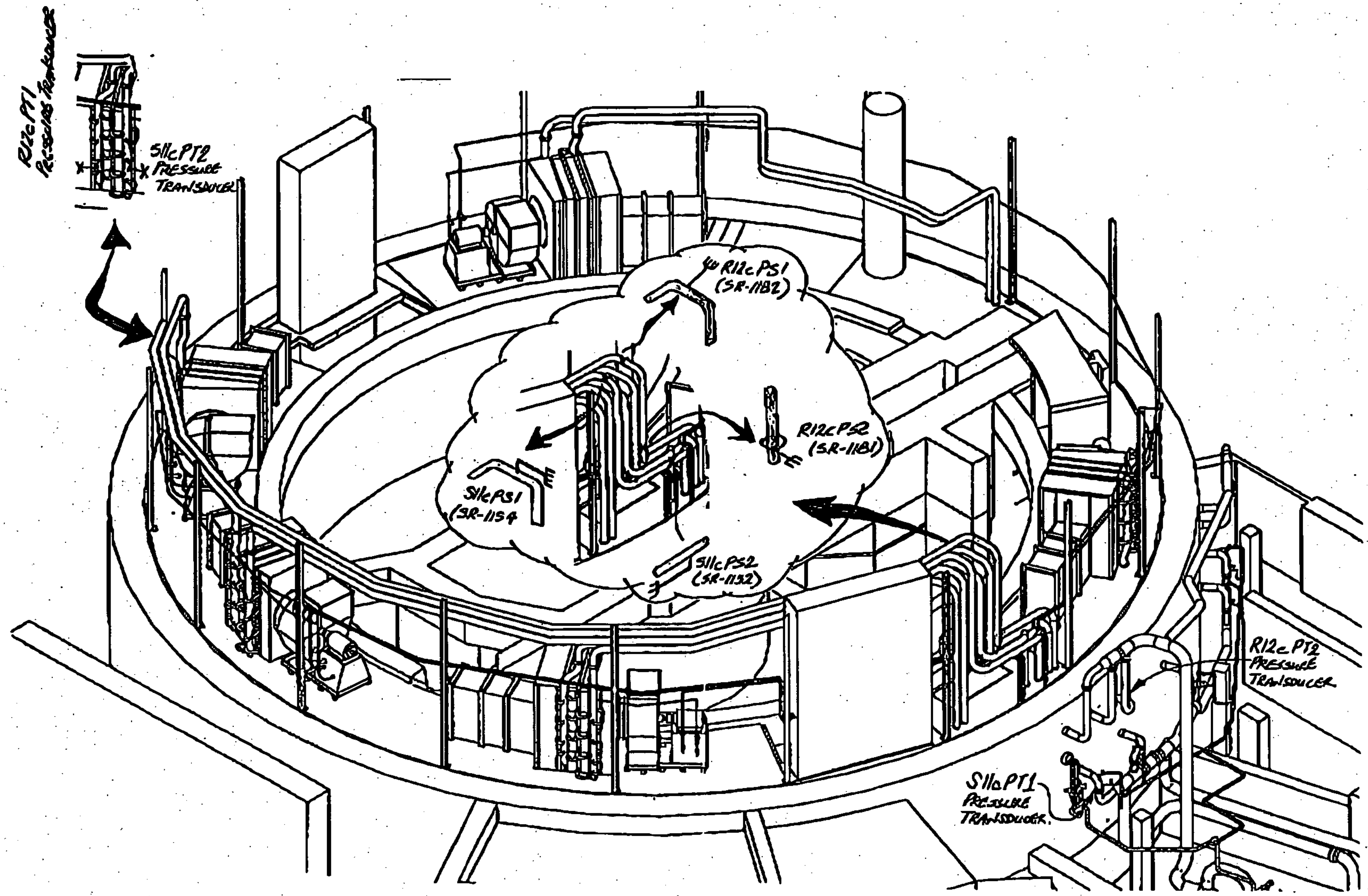
4. Indian Point Unit 2 UFSAR.

5. ASME B&PV Code Sections III and VIII.

6. ANSI/ASME Code For Pressure Piping, B31.1, Power Piping.

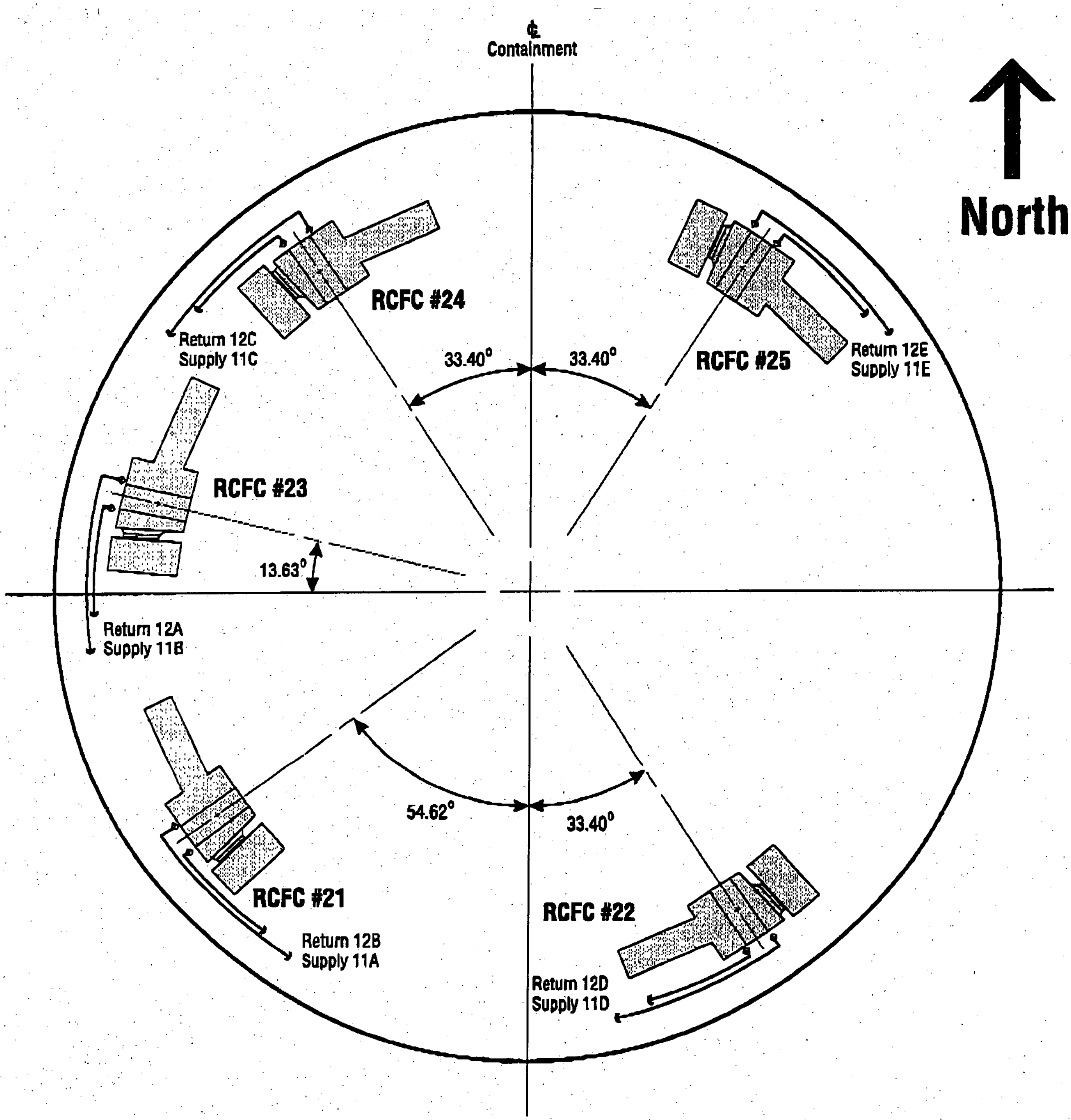
7. Con Edison Performance Test Procedure, PT-R14, SIS Electrical Load.

General Schematic of FCU Service Water Piping

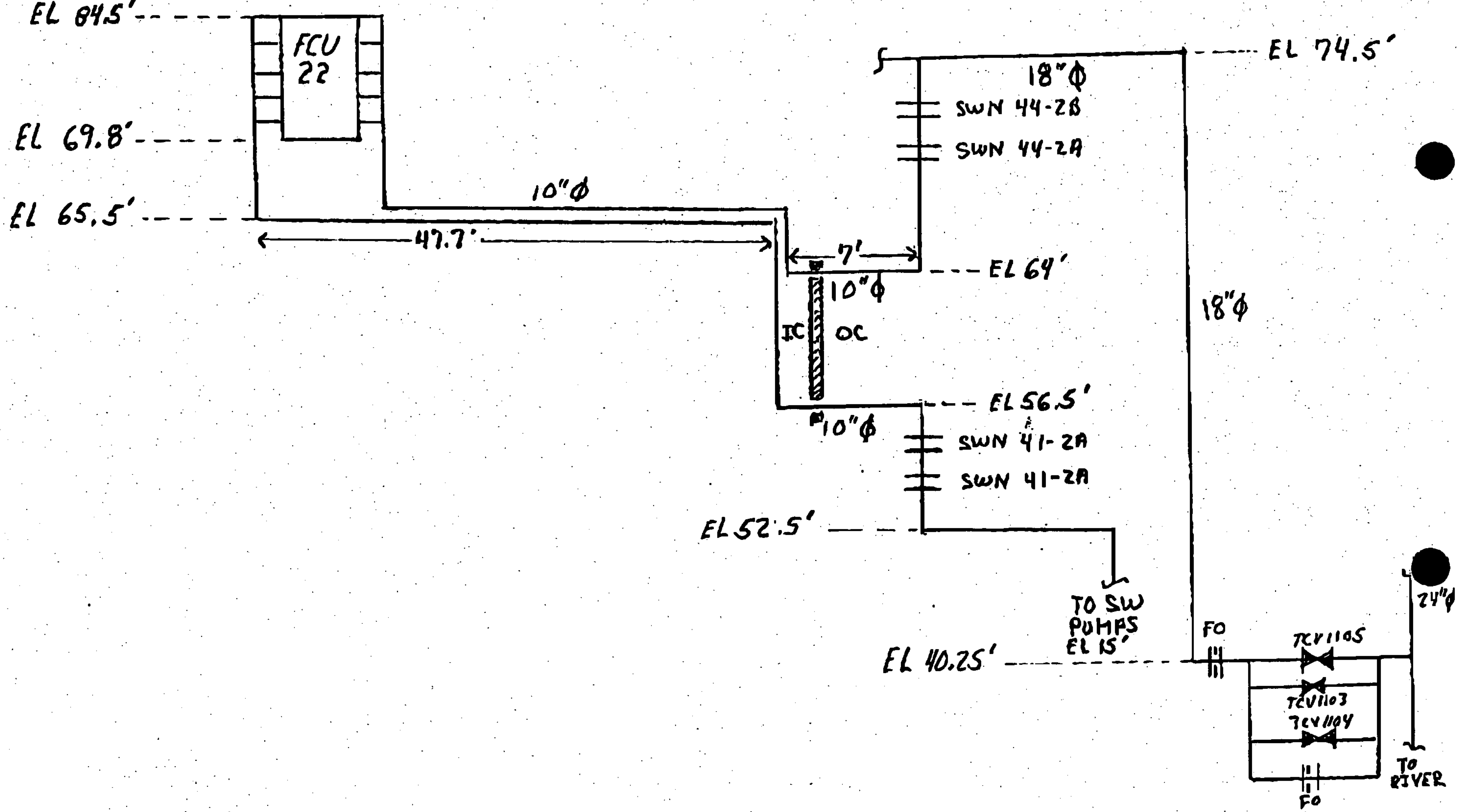


FAN COOLER LAYOUT

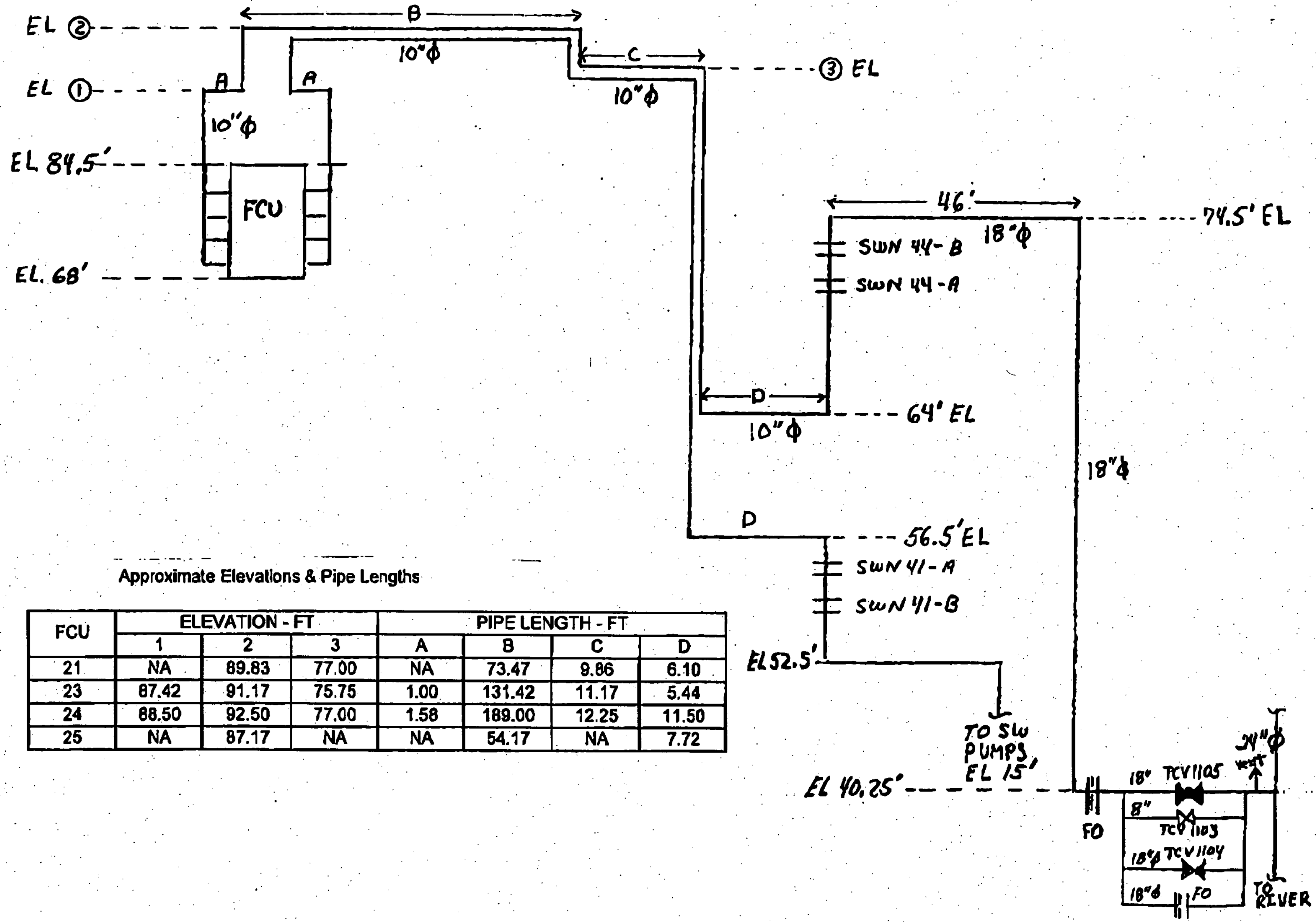
Indian Point Unit 2



Simplified Piping Diagram For FCU 22



Simplified Piping Diagram For FCUs 21, 23, 24 & 25



Approximate Elevations & Pipe Lengths

FCU	ELEVATION - FT			PIPE LENGTH - FT			
	1	2	3	A	B	C	D
21	NA	89.83	77.00	NA	73.47	9.86	6.10
23	87.42	91.17	75.75	1.00	131.42	11.17	5.44
24	88.50	92.50	77.00	1.58	189.00	12.25	11.50
25	NA	87.17	NA	NA	54.17	NA	7.72