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January 28, 1997

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

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

SUBJECT: 10 CFR 50.54 (f) Notification in Response to NRC Generic Letter 96-06: Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions

Pursuant to 10 CFR 50.54 (f), this letter is Consolidated Edison's (Con Edison) 120 day written response to the subject generic letter.

Generic Letter 96-06, "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions," dated September 30, 1996, requests 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.

As required within 120 days from the date of this generic letter, Con Edison hereby submits two summary reports (see attached) describing the actions taken to address the concerns of this generic letter, the conclusions that were reached, the bases for continued operability of affected systems and components, and the corrective actions that are planned to be implemented.

Con Edison has obtained the services of an outside consultant to determine the susceptibility of the Indian Point Unit 2 (IP-2) containment fan cooler unit service water system to waterhammer and two-phase flow. These evaluations conclude that waterhammer can occur but that the calculated waterhammer loads during a design basis accident concurrent with a loss of offsite power are less severe than those loads experienced during a loss of offsite power event without accident. Required testing conducted at every refueling outage subjects the containment fan cooler service water piping to acceleration forces greater than the calculated waterhammer loads during an accident. Past operating and test history indicates no piping failures associated with these lines. Based upon

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our evaluations it is concluded that the IP-2 containment fan cooler service water system will not be subject to failure as a result of waterhammer and/or two-phase flow conditions during postulated accident conditions. See Attachment 1 for summary report.

To address the Generic Letter's question of the susceptibility to thermal overpressurization of piping that penetrates containment, Con Edison initiated an extensive review of all containment penetrations. Our reviews found UFSAR design basis stress limits were exceeded on six of the 107 lines that penetrate containment. These lines have been evaluated in accordance with the guidance contained in NRC Generic Letter 91-18 and have been determined to be operable. Scoping evaluations are underway to determine the most effective method of meeting design basis requirements for these lines. They will be restored to their design basis criteria prior to startup from the 1997 refueling outage, currently scheduled to commence on April 5, 1997.

For those lines with installed relief valves, additional reviews are underway to evaluate relief actuation effects under accident conditions. The results of these additional reviews will be provided in a supplemental report by April 30, 1997.

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

Very truly yours,

[signature]

Subscribed and sworn to
before me this 28 day
of January 1997

GERALD O. CULLEN
Notary Public, State of New York
No. 4959345
Qualified in Westchester County
Commission Expires November 27, 1997

[signature]
Notary Public

Attachment

cc: Mr. Hubert J. Miller
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ATTACHMENT 1

Summary Report

Evaluation of Containment Fan Cooler Waterhammer and Two-Phase Flow

SUMMARY

This evaluation concluded that the waterhammer loads postulated to occur during a design basis loss of coolant accident (LOCA) with loss of offsite power (LOOP) event are less severe and are thus enveloped by the LOOP without a LOCA event. A simulated LOOP without a LOCA occurs as part of the IP2 testing program performed prior to restart from each refueling outage. Past operating and test history indicates no failures associated with these lines. Based on the evaluation and operating experience it is concluded that the waterhammer loads postulated to occur during a design basis accident will not adversely affect the ability of the containment fan coolers to perform their required safety function.

These evaluations also indicate that during a design basis accident, the discharge piping exiting the containment fan cooler units are susceptible to two-phase flow conditions. Further analyses determined that although the flow would be reduced by as much as 50%, the containment fan cooler units would still meet their required UFSAR design heat removal rates.

INTRODUCTION

The purpose of this evaluation was to determine whether the IP-2 containment fan cooler units and their associated service water piping systems were susceptible to either waterhammer or two-phase flow conditions during a postulated accident. The results of this evaluation concluded that two types of waterhammer could occur during design basis accident conditions. The calculated waterhammer loads occurring during a design basis accident concurrent with a loss of offsite power were found to be within FSAR acceptance.

SYSTEM DESCRIPTION

The Indian Point Unit No. 2 containment fan cooling system consists of a total of five fan cooler units (FCU). Each FCU is comprised of two banks of five cooling coils. Four cooling coils in each bank contain 24 U tubes each, while the remaining two coils contain 20 U tubes each. Each U-shaped stainless steel tube is 5/8 inch diameter and 17.5 feet long. All FCUs are located at the 68 ft. elevation.

All FCUs are supplied with cooling water from a common Service Water system header. This water is pumped from the Hudson River by a total of three essential service water pumps. Only two pumps are required to be operable during a design basis accident event.

SEQUENCE OF EVENTS

LOOP WITHOUT A LOCA

If power is lost during normal operation, column separation will occur in the supply and discharge sides of the fan coolers. This column separation occurs because the pressure in the region of the fan coolers will drop to subatmospheric and a vapor pocket will form. Upon the restart of the Service Water pumps, the water columns will close. The corresponding magnitude of waterhammer that would occur from this velocity of impact is approximately 394 psig.

LOOP WITH A LOCA

The postulated event is initiated by the simultaneous occurrence of a LOCA and a LOOP. Both the service water pumps and the containment fan cooler unit fans coastdown. The temperature in the containment will rise quickly. The pump coastdown is assumed to occur within two seconds.

Because of elevation differences the service water pressure in the fan coolers is assumed to fall to 0 psia within seconds following the pump stopping. The service water pumps start at 28 seconds after the initiation of the event. The fans in each cooler start at either 33 or 38 seconds. As the flow rate slows, the water in the tubes will be heated. The heat addition soon begins to cause boiling in the tubes. In four of the fan coolers (21, 23, 24 and 25), as steam passes out of the cooler tubes, a trapped volume of water on the supply and discharge side of the fan cooler will condense the steam and will also be heated. Only when that trapped volume of water is heated will the steam pass through the trapped water and begin to cause the service water pressure to rise. The "repressurization" is based on the heat transfer across the tubes and fins and the discharge piping fluid resistance. During the repressurization, the pressure will increase from approximately 0 psia to 6.4 psia in 28 seconds. The repressurization rate is limited by the heat transfer behavior from the containment atmosphere at 259 F and the service water inside the tubes. Since the service water temperature is rising, the temperature difference across the tubes is decreasing. The heat transfer coefficient on the outside of the tubes is also decreasing as the fans continue to coast down. Nevertheless, a constant air-side heat transfer coefficient is assumed, thus conservatively neglecting fan flow degradation. The pressure in the service water will continue to rise until the saturation pressure at 259 F is reached or until the pumps are restarted. The pumps restart at 28 seconds with the pressure at approximately 6.4 psia.

The fifth fan cooler (22) drains fully as steam is generated because the piping configuration allows it. Pressure in the cooler will increase to approximately 13 psia before the cooler is completely drained in approximately 10 seconds. Following draining, the steam will condense in the supply and discharge piping and expand as the piping continues to drain. Final cooler pressure prior to pump restart is approximately 7 psia.

As the "repressurization" occurs, the water column separates in the supply and discharge side of the cooler (column separation also occurs in a LOOP without a LOCA but only because of gravity drainage). The motion of the water is calculated during the entire transient. The void formed by this column separation is filled with steam from the fan cooler. The rate of pressure increase is controlled by the resistance of the advancing water column, the steam condensation that occurs because of steadily increasing pressure, and the need to increase the temperature of the trapped volumes of water on the supply and discharge side of four of the fan coolers.

The uncovering of horizontal runs of pipe during the draindown creates the potential for waterhammer. As horizontal portions of the lines are exposed, steam will enter the space formed at the top of the pipe. The space between the top of the pipe and the exposed water can allow condensation of steam and the trapping of steam bubbles. The rapid condensation of the trapped steam and the subsequent closing of the void by water causes a condensation induced waterhammer pressure pulse [1, 2, 3].

This type of waterhammer has been evaluated by calculating the system pressure that will exist at the time that a horizontal line is exposed. There are several horizontal runs of pipe that will be uncovered on the discharge side of the piping. This system pressure is then used to calculate the pressure pulse that would result from the waterhammer. A volume ratio of the trapped steam bubble to the adjacent water volume in the line of 0.35 is used in the analysis. As recommended in Reference [4], a sonic velocity of approximately one half of the sonic velocity in water with no air or other non-condensables is used in the calculation. This is justified by the amount of non-condensable gas typically found in water and the release of non-condensables during boiling. The condensation induced waterhammers that result will have pressure pulse magnitudes less than 160 psig. This is smaller than the pressure pulse magnitude anticipated at IP2 for the column closure waterhammer. The dynamic response in the piping will be less than that experienced during a LOOP without LOCA.

At 28 seconds when the pumps restart, the ability to generate steam in the fan coolers will rapidly diminish. The fixed volume of steam in the discharge piping can then condense and the pressure in the discharge piping will diminish. The discharge pipe will begin to refill and the advancing column of water will eventually reach the water in the discharge piping and a column closing waterhammer will occur.

The location of the water in the discharge line when the two water columns rejoin is necessary to determine the anticipated magnitude of the column closure waterhammer. Since the column closure occurs either with or without a LOCA in the 10 inch pipe. The velocity at closure will be approximately the same. The pressure pulse that is caused by the column closure further down the pipe will not be larger than the 394 psig pressure anticipated without a LOCA.

During the refilling, the bubble collapse waterhammers that may occur in the horizontal lines during draining will not occur since the refill velocity exceeds the velocity required to keep the pipe full [4]. A velocity of approximately 5 feet per second is required to keep a 10 inch diameter pipe full. The refilling velocity exceeds this and will preclude the occurrence of a condensation induced bubble collapse waterhammer in the horizontal lines.

EFFECT OF NON-CONDENSABLES

A significant contributor to mitigation of waterhammer is the presence of non-condensables. Non-condensables have two effects: One is that they reduce the sonic velocity in water. This a well known effect that is seen clearly in laboratory testing. The sonic velocity has been reduced to approximately one half of the sonic velocity of water with no air. The other effect is the cushioning that will result from the residual non-condensable in a bubble collapse or column rejoining waterhammer. This is caused by the air that is trapped in the space that is being collapsed. The reduction of the pressure pulsations by cushioning has not been taken into account. Given the amount of steam generation and condensation that occurs in the LOOP and LOCA event, the amount of non-condensable gas in the water and in the steam is expected to be significant. The waterhammer calculations are expected to be conservative.

STRUCTURAL ASSESSMENT

A typical fan cooler return line was selected for structural evaluation to determine the effects of a column closure waterhammer on the integrity of the piping system.

The loading for the piping model consists of pipe, insulation, lining, and content self-weight, thermal expansion loading (under accident temperatures), together with a column closure waterhammer pressure pulse loading. Two potential waterhammer loadings were considered. A void collapse waterhammer and a column closure waterhammer. The location of the column closure waterhammer was simulated and the resulting pressure wave propagates from this location.

The piping system was coded in the ADLPIPE Computer Code [6] and the waterhammer event was evaluated as a time history dynamic analysis. The technique used to evaluate the waterhammer is based on determination of the piping system response to known time dependent forces to calculate resulting stresses and loadings. The response of the piping system is computed by normal mode superposition technique. The coding of the selected piping system was in accordance with the as-built isometrics. Actual support and nozzle stiffness, to more accurately represent the response of the piping system, were included in the model.

The piping was evaluated for the above outlined loadings and qualified in accordance with the stress acceptance criteria of the IP2 UFSAR [7]. The piping stress levels were evaluated in accordance with criteria equivalent to an upset condition.

The pipe supports were qualified for the resulting loading. Qualification was based on load rating to previously qualified loads and ensuring that the resulting support component interaction ratios (i.e., calculated stress/allowable stress) for the weakest component remained within the acceptance criteria outlined in the UFSAR, suitable for a faulted event. The use of faulted condition allowables is appropriate for the evaluation of a LOOP with LOCA event.

The combined stress (i.e., from Dwt + ThA + WH) at the fan cooler nozzles was reviewed. Given the stress level in the nozzle, the fan cooler outlet connections and localized stresses are considered satisfactory.

The combined stress (i.e., from Dwt + ThA + WH) at the containment penetration was determined. The total summation of stress levels at the penetrations in comparison to piping stress acceptance criteria identify the containment penetrations to be lightly loaded and satisfactory.

Based on the evaluation performed for a postulated LOOP/LOCA event on a typical fan cooler return line, it appears the piping system is capable of withstanding the effects of a potential waterhammer occurring in the line.

WATERHAMMER SUMMARY

As described in this summary report, two kinds of waterhammers are anticipated. One is the column closure waterhammer similar to the column closure waterhammer that occurs each time Safety Injection testing is performed. This column closure waterhammer will occur during the refill. The column closure waterhammer that will follow the simultaneous LOOP and LOCA will be less severe. The second waterhammer that may occur is caused by the trapping and condensing of steam during the draining/repressurization phase. These waterhammer pulses are also expected to be below the 394 psig caused by the LOOP without LOCA. The waterhammer loads will be equal to or less than the loads for a LOOP without a LOCA. A LOOP without a LOCA has been simulated during a test and piping integrity was maintained, in addition, a sample structural assessment of one of the return lines also demonstrated the integrity of the pressure boundary.

TWO-PHASE FLOW EVALUATION

The analysis evaluated the potential for two-phase flow conditions and associated flow/heat removal reductions.

Following pump restart, the hot water in FCUs 21, 23, 24, and 25 will be transported into the discharge piping. FCU 22 is completely empty at this time. The water temperature will be approximately 180 F and is not expected to flash since its saturation pressure is below analyzed system pressures for LOCA condition [5].

If it is assumed that there is no fouling of the FCU tubes, the cold water entering the FCUs will be heated to temperatures in excess of 180 F, causing flashing and two-phase flow in the discharge piping. However, analyses show that although the flow will be reduced by as much as 50%, the clean FCUs will still exchange enough heat to meet design bases accident heat removal rates.

REFERENCES

[1] Akselrod, A., Esselman, T., Griffith, P., and Min, E., "Condensation Induced Waterhammer in Steam Distribution Systems," ASME Winter Annual Meeting, 1991, PVP-Vol. 224, FED-Vol. 126.

[2] Griffith, P. and Silva, R., "Steam Bubble Collapse Induced Water Hammer in Draining Pipes," PVP-Vol.231, ASME 1992, pp. 115-119.

[3] Griffith, P., "Screening Reactor Steam/Water Piping Systems for Water Hammer," Unpublished NUREG, August, 1996 Draft.

[4] Griffith, P., Chou, Y., "Admitting Cold Water into Steam Filled Pipes Without Water Hammer Due to Steam Bubble Collapse," PVP-Vol. 156, ASME 1989, pp. 63-71.

[5] Service Water Essential Header Hydraulic Analysis, Raytheon Engineers & Constructors, Calculation No. 9145.002-F-SW-004, 4/27/95.

[6] ADLPIPE, "State & Dynamic Pipe Stress Analysis," Version 4F7, Research Engineers, Yorba Linda, CA.

[7] Con Edison, Indian Point Unit 2, Updated Final Safety Analysis Report.

ATTACHMENT 2

Summary Report

Evaluation of Overpressurization of Isolated Piping Sections