UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

SUPPLEMENTAL RESPONSE TO NRC BULLETIN 88-08 "THERMAL STRESSES IN PIPING CONNECTED TO REACTOR COOLANT LOOP SYSTEMS"

FACILITY OPERATING LICENSE NOS. NPF-76 AND NPF-80

HOUSTON LIGHTING & POWER COMPANY

CITY PUBLIC SERVICE BOARD OF SAN ANTONIO

CENTRAL POWER AND LIGHT COMPANY

CITY OF AUSTIN, TEXAS

DOCKET NOS. 50-498 AND 50-499

SOUTH TEXAS PROJECT, UNITS 1 AND 2

1.0 BACKGROUND

Action 3 of Bulletin 88-08 (Reference 1) requested licensees to "plan and implement a program to provide continuing assurance that unisolable sections of piping connected to the RCS [reactor coolant system] will not be subjected to combined cyclic and static thermal and other stresses that could cause fatigue failure during the remaining life of the unit." Licensees can provide the required assurance by reanalysis or by instrument monitoring.

By letter dated November 20, 1989, Houston Lighting and Power Company (HL&P) stated that it had installed instrumentation at South Texas Project Unit 1 (STP) to monitor temperatures in unisolable sections of piping connected to the RCS, in accordance with Action 3 of the Bulletin.

By letter dated September 21, 1990, HL&P reported that an engineering evaluation performed by Westinghouse (W) (Reference 2) determined that the measured thermal time histories in the normal charging, alternate charging and auxiliary spray lines indicated that thermal stratification was occurring in these lines, but not thermal cycling. On this basis, W also concluded that the ASME Section III Class 1 design fatigue limit would be satisfied for these lines, for the life of the plant, and recommended that thermal monitoring be discontinued. This letter, therefore, informed the staff that HL&P had decided, on this basis, to remove the temperature monitoring instrumentation it had previously installed.

The staff reviewed the W evaluation and identified a number of significant technical issues. In Reference 3 the staff summarized these issues, and concluded that the W evaluation may not have been based on fully-supported assumptions, and that the decision to remove the temperature monitoring instrumentation may have been premature. The staff also requested that HL&P submit a plan of action to provide the requested assurance per Action 3 of the Bulletin, or submit additional information in support of the W analysis.

On November 8 and 9, 1993, the staff and its consultant, the Brookhaven National Laboratory, (BNL), met in Monroeville, PA, with representatives of HL&P, W and the Electric Power Research Institute (EPRI), for the purpose of discussing and resolving the technical issues identified by the staff. At this meeting, W provided information regarding the revised response, and indicated that it was based on aspects of an analytical methodology developed by W under an EPRI sponsored program. HL&P indicated that the objective of this program was to investigate the effects of Thermal Stratification, Cycling, and Striping (TASCS) phenomena on nuclear piping, and to develop applicable analytical tools to prevent failure of branch piping connected to the reactor coolant loop (RCL) if subjected to these phenomena, as requested by Bulletins 88-08 and 88-11. A summary of this meeting was reported in Reference 4.

By letter dated November 30, 1993, (Reference 5), HL&P submitted Supplement 1 to WCAP-12598 (Reference 6). It consisted essentially of the presentation made by W and EPRI at the Monroeville meeting, and also contained chapters of a handbook which EPRI intended to publish, summarizing the methodology and its basis of the TASCS research effort.

In Reference 7, BNL provided a technical evaluation of the W analysis, and concluded that "HL&P had adequately demonstrated the piping integrity of the normal charging, alternate charging and auxiliary spray piping to justify short term operation (not to exceed 10 years) considering the effects of potential thermal stratification and cycling..." At the time of this letter, the TASCS report had as yet not been finalized. BNL therefore concluded that it was not appropriate to reach a final conclusion on the acceptability of the TASCS analysis methodology for long term resolution of the Bulletin 88-08 issues at STP, and recommended that "In order to justify long term operation, the licensee will have to provide additional detailed information on the TASCS program methodology for staff review and approval."

In Reference 8, the staff accepted the interim response by HP&L to NRC Bulletin 88-08 regarding the provision to provide continuing assurance for the life of the plant. This letter stated that the staff would continue to review this issue on a generic basis, and that upon completion, it would provide a plant-specific safety evaluation regarding long term operation.

In March 1994, EPRI published a proprietary, confidential report prepared by W on the TASCS program and methodology (Reference 9). This report was provided to the NRC on October 1994 as supplementary information to WCAP-12598, Supplement 1. A paper based on this report was also presented in 1994 (Reference 10).

Interaction of RCL fluid with inleakage or outleakage through stagnant branch lines attached to the RCL has the potential for causing thermal cycling of the metal walls, and makes them susceptible to cracking by fatigue and unisolable leakage. This inleakage or outleakage is caused by random inadvertent internal leakage through isolation valve seats, or through the packing of these valves. This apparently was the cause of the eventual fatigue failures in the three plants addressed in the Bulletin and its supplements, Farley, Tihange, and Genkai. However, the exact mechanism of thermal cycling and fatigue failure in these cases does not appear to have been definitively established.

2.0 EVALUATION

The staff has reviewed Supplement 1 to WCAP-12598 and the additional information provided in the EPRI TASCS report, and has identified the following potential weaknesses:

1. The South Texas thermal load calculations for the unisolable portions of the charging and alternate charging lines are based on the temperature difference calculated at the maximum turbulent penetration distance. The South Texas check valve outlets are located at a distance from the RCL greater than the turbulent penetration distance, and will therefore not experience thermal cycling. At other locations where cycling induced by RCL turbulence is possible, the thermal stresses were determined to be below the endurance limit, because the temperature difference decreases as the distance to the RCL is reduced. This does not correspond to the failures at Farley and Tihange. In these plants the check valve and the first elbow were both located within the calculated turbulent penetration length, but the failures occurred at the first elbow welds and in the elbow base metal, i.e., at locations where the temperature difference approaches zero, based on steady state heat transfer calculations of the unisolable segments as described in Section 3.3, "Turbulent Penetration Thermal Cycling," of the TASCS report. The TASCS methodology, based on steady state heat transfer and stress analysis calculations, therefore does not appear to identify the correct location and the time span where a fatigue failure is most likely to occur, and apparently does not account for other thermo-hydraulic phenomena which exist at these locations and may also cause significant thermal cycling.

2. The Low Temperature Turbulent Penetration Test program, described in Section 4.1 of the TASCS report, was conducted with constant inleakage, and therefore assumed this inleakage to be the same as leakage through a swing check valve. No verification has been provided that this assumption is valid under all flow conditions. Furthermore, these tests were performed at atmospheric pressure and room temperature. The velocity component which was measured is unspecified, and the correlation between the velocity and the temperature in the branch line is unclear. In addition, the data in this Section does not correspond to that presented in Reference 11. Cycling was noted to occur between the lower and the upper interaction regions. The nature of this cycling is unclear, and the frequency of this cycling appears not to have been measured or recorded.

3. The W low temperature tests (WLT) in Section 4.2, and the W high temperature tests (WHT) in Section 4.3, both of the TASCS report, do not reflect the thermal operating conditions which led to Bulletin 88-08. These conditions were the inleakage of cold water past a swing check valve into an ultimate source of fluctuating high pressure, high flow turbulent hot fluid, whereas these tests assumed constant inleakage and outleakage into stagnant cold and hot water, respectively.

4. Test 9 of the WHT tests represents intermittent cold inleakage into stagnant hot water. Figure 4.3-57 of the TASCS report shows that the thermal cycling in the fluid at Station II of the test section (shown in Figure 4.3-6) was greater than at Station I, which is where the leakage entered the test section. Likewise, the inside and outside wall temperatures at Station II exhibit much greater cycling than those at Station I. No discussion or explanation of this behavior has been given.

5. The WHT tests also do not reflect the conditions in Supplement 3 of Bulletin 88-08, since no inleakage tests from a hot, turbulent source were performed. They also do not reflect the conditions described in Bulletin 88-11 since no hot water inleakage tests were performed.

6. In Chapter 5.3 of the TASCS report, "Thermal Cycling-Background and Verification", it is stated that the MHI tests were performed under conditions similar to those existing at Farley. (MHI is not identified in the report.) Very little data on this test program has been presented in the reports. Figure 5.3-8 of the TASCS report shows the temperature-time histories measured at various locations along the bottom of the inside surface of a test configuration similar to the safety injection line at Farley. The corresponding temperature-time histories on the outside surface are not shown. Figure 5.3-2 of the TASCS report shows the temperature-time histories measured around the circumference of the outside pipe surface at Farley. No correlation is therefore possible between the MHI and the Farley data.

7. Figure 5.3-2 of the TASCS report represents a small segment of the available data from Farley. Extensive temperature histories were measured on the outside surfaces of two safety injection lines in this plant, both with and without inleakage, and upstream and downstream of the swing check valves. It is not apparent how, or if, these data were used in the development of the TASCS methodology.

8. Equation 5.2-5 of Chapter 5.2 of the TASCS report, "Stratification Heat Transfer," is based on steady state flow conditions, which do not reflect actual transient temperature conditions in pipes with inleakage. This can be seen from the good correlation of calculated results with the WHT test results, and the poor correlation of the calculated results and the MHI test results.

9. The basis for Bulletin 88-08 was the failure of a safety injection line at Farley Unit 2 due to inadvertent inleakage. Likewise, the basis for Supplement 1 of the Bulletin was the failure of a safety injection line at Tihange. The riser of this line up to the first elbow is inclined at 30° to the horizontal plane. Leaking cracks were found near the welds and in the base metal of this elbow. No detailed analyses of these lines have been performed to predict the thermal histories and the location where the actual failure occurred, or to estimate the time interval it took for a crack to initiate from the start of leakage.

10. The equation for turbulent penetration with leakage under operating conditions appears to be based on an ad-hoc assumption and tangential mean velocity data determined from the Low Temperature Turbulent penetration test program. No justification why this is acceptable for actual operating temperatures and pressures in an environment similar to STP, Units 1 and 2, has been provided. No correlation with turbulent penetration data actually measured in nuclear plants under operating and inleakage or outleakage conditions, similar to those described in Bulletin 88-08, has been shown.

11. The derivation of the equation for turbulent penetration with stratification flow appears to be overly simplified, and should have been based on the rigorous application of transient thermo-hydraulic mechanics principles (e. g., Reference 12), applicable to the operating conditions for nuclear piping attached to the RCL. Effects such as RCL pressure variation, possible gas entrapment in the pipe section between the block and check valves, and check valve chattering under low flow conditions were also not considered.

12. Certain thermo-hydraulic phenomena in stagnant piping attached to the RCL or other high flow rate piping have been described in the literature (References 13-16). These researchers have identified a helicoidal or corkscrew flow pattern, which has not been observed in the <u>W</u> tests. No reason for this has been provided.

3.0 <u>CONCLUSION</u>

Based on a review of the additional material submitted in WCAP-12598, Supplement 1, and the TASCS report, the staff concludes the following:

1. The mechanism of turbulent penetration is as yet not well defined and understood, and has not been fully investigated under the TASCS program. Its significance in the failures at Farley, Tihange and Genkai has not been clearly established. The root cause for the failures described in Bulletin 88-08 remains undetermined.

2. The TASCS methodology does not appear to have the capability to predict the observed fatigue failures described in Bulletin 88-08, since the most likely failure locations appear to be at the closest elbow to the RCL, well within the turbulent penetration region. The TASCS methodology does not predict failure at these locations.

3. HL&P has not adequately justified discontinuing temperature monitoring at STP, Units 1 and 2, nor provided an acceptable alternative to monitoring. On this basis, the staff therefore concludes that HL&P has not provided the requested assurance of Action 3 of the Bulletin against inadvertent leakage in the unisolable segments of the charging lines and auxiliary pressurizer spray systems at South Texas Units 1 and 2. The licensee should be requested to check for potential leakage in these systems, and either reestablish the previous temperature monitoring program at both units, or implement other acceptable monitoring programs that could satisfy the provisions of Action 3 of the Bulletin, for the life of the plant, and provide a description of their actions to the staff.

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Date: February 23, 1996

REFERENCES

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3. Letter of September 23, 1992, from G. F. Dick, Jr., NRC, to D. P. Hall, HL&P.

4. Meeting Summary of December 13, 1993, by L. E. Kokajko, NRC.

5. Letter of November 30, 1993, from T. H. Cloninger, HL&P, to the NRC Document Control Desk.

6. WCAP-12598, Supplement 1, "NRC Bulletin 88-08 Evaluation of Auxiliary Piping for South Texas Project Units 1 and 2," Westinghouse Electric Corporation, November 1993 (proprietary).

7. Letter of April 8, 1994, from G. DeGrassi, BNL, to M. Hartzman, NRC.

8. Letter of April 11, 1994, from L. E. Kokajko, NRC, to W. T. Cottle, HL&P.

9. EPRI TR-103581, "Thermal Stratification, Cycling, and Striping (TASCS)," prepared by Westinghouse Electric Corporation for the Electric Power Research Institute, Palo Alto, California, March 1994. (Licensable material, proprietary and confidential).

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