ENCLOSURE

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Director of Nuclear Reactor Regulation
Attention: Mr. C.L. Miller, Project Director
Project Directorate I-2
Division of Reactor Projects
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

SUSQUEHANNA STEAM ELECTRIC STATION
FUEL POOL COOLING HYDRODYNAMIC LOADS
PLA-4076 FILES R41-2/SO35

Docket Nos. 50-387
and 50-388

Reference: ***PLA-4057, R.G. Byram to C.L. Miller, "Transmittal of Piping Stress Evaluation for Fuel Pool Cooling Hydrodynamic Loads," dated December 8, 1993.***

Dear Mr. Miller:

In response to a request from the NRR staff, attached please find further information to supplement the referenced summary evaluation of the impact of LOCA induced hydrodynamic loads on Fuel Pool Cooling and Service Water Piping. Any questions should be directed to Mr. R. Sgarro at (215) 774-7914.

Very truly yours,

R.G. Byram

Attachment

cc: NRC Document Control Desk (original)
NRC Region I
Mr. G. S. Barber, NRC Sr. Resident Inspector - SSES
Mr. R. J. Clark, NRC Sr. Project Manager - Rockville
Mr. J. W. Shea, NRC PD I-2 - Rockville

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SUMMARY OF ANALYSIS

Impact of LOCA Hydrodynamic Loads on Fuel Pool Cooling and Service Water Piping in the Reactor Building.

I. Background

As a result of EDR G20020 a preliminary assessment of the ability of Fuel Pool Cooling piping to withstand seismic and hydrodynamic loads was performed in October 1992. The conclusions reached at that time were that there was a low to moderate risk to the system during hydrodynamic events (LOCA) and a high risk to system function during a seismic event. These conclusions were reached based on reviews of piping isometrics, pipe support drawings, response spectra and existing piping calculation results. In order to further address concerns raised by the EDR originators regarding the adequacy of the FPC system during LOCA loadings, a more quantitative evaluation of FPC piping was requested. Service Water piping was also included in the evaluation since it provides cooling flow to the fuel pool heat exchangers. The condensate transfer supply to the fuel pool pumps was not included in the evaluation since it has been determined that the operation of the fuel pool cooling pumps would not be affected by a loss of these condensate lines. Representative portions of the FPC and Service Water systems were subsequently analyzed for hydrodynamic loadings. The purpose of this document is to provide a more detailed summary of the evaluations performed including evaluation scope, design basis, analytical methodology and analytical results; (Reference PLA-4057 dated December 8, 1993).

II. Evaluation Purpose

The purpose of the evaluation was to provide a quantitative assessment of representative portions of the Fuel Pool Cooling system and the Service Water system for their ability to withstand hydrodynamic (LOCA) loadings. The results of this evaluation could then be used to check the validity of the conclusions reached in the preliminary assessment, i.e. that hydrodynamic loads pose a low to moderate risk to the FPC system.

III. Evaluation Scope

A. Fuel Pool Cooling

The FPC P&ID's and piping isometrics were reviewed to identify a representative portion of the system for analysis. Portions of the FPC system were originally dynamically analyzed due to a safety related classification or interface with safety related systems/components such as the pool liner. Other pipe runs are partially embedded in the structural concrete and as such were not considered representative of the system. Small bore pipe, two inches in diameter or less, was also not considered representative since the majority of the FPC system consists of large bore lines. In addition, small bore pipe hangers typically have relatively larger design margins than do large bore pipe hangers due to minimum design loads. The majority of large bore FPC piping which was not originally analyzed for hydrodynamic loads is located adjacent to the Fuel Pool heat exchangers and pumps. Two of these lines were considered to be acceptable representative samples of

FPC piping. The selected lines included the inlet piping to the FPC heat exchangers and the discharge lines from the FPC pumps in Unit 2. The selection criteria included the following considerations:

- The selected lines encompass typical FPC pipe sizes, from 3" to 10" in diameter.
- The selected lines include equipment terminations, i.e. heat exchangers and pumps.
- The selected lines contain concentrated masses, i.e. valves.
- The selected lines span various reactor building elevations, i.e. from elevation 719′-0" to 779′-0".
- The selected lines are supported using typical pipe spans (B31.1) and pipe hanger types. The pipe support designs include spring can hangers, rigid struts, rod hangers, stanchions, structural steel members and in-line anchors.

Based upon the considerations described above, the following lines were judged to be good analytical examples of the FPC system and subsequently analyzed for hydrodynamic loadings. The analytical boundaries are described below.

Analysis # 1 - Original Bechtel Calculation # 2968
Piping Isometric FCI-P51-2968
Analysis extends from in-line anchors HBC-214-H6 and HBC-214-H10 to the inlet of the fuel pool heat exchangers 2E202A, B & C.

Analysis # 2 - Original Bechtel Calculation # 2970
Piping Isometric FCI-P51-2970
Analysis extends from in-line anchor HBC-216-H10 to the discharge nozzle of the fuel pool cooling pumps 2P-211A, B & C.

B. Service Water

The Service Water P&ID′s and piping isometrics were reviewed to identify a representative portion of the system for analysis. The bulk of the Service Water piping located in the reactor building is associated with the fuel pool heat exchangers, the reactor building chillers, the pipe tunnel coolers and the RBCCW heat exchangers. The piping supplying the RBCCW heat exchangers was not selected because much of this piping was seismically analyzed due to its interface with the ESW system. The pipe tunnel cooler lines are 4 inch and smaller in diameter and were not considered representative of Service Water piping which is mainly larger in size. Also, as was stated earlier, small bore pipe supports typically have larger design margins since they very often contain components designed to minimum vendor loads which are significantly larger than actual developed loads. The inlet and outlet lines associated with the fuel pool heat exchangers were considered good analytical candidates. Since the inlet and outlet lines are similar in size, layout and support configuration, the

Unit 1 outlet lines were selected as representative. The selection criteria also included the following considerations:

- The selected lines include typical Service Water pipe sizes, from 8" to 24" in diameter.
- The selected lines include equipment terminations, i.e. heat exchangers.
- The selected lines contain concentrated masses, i.e. valves and radiation detector lead blankets.
- The selected lines span various reactor building elevations, i.e. from elevation 719'-0" to 779'-0".
- The selected lines are supported using typical pipe spans (B31.1) and pipe hanger types. The pipe support designs include spring can hangers, rigid rod hangers, stanchions, riser clamps and structural steel members.

Based upon the considerations described above, the following lines were judged to be good analytical examples of the Service Water System and were subsequently analyzed for hydrodynamic loadings. The analytical boundaries are described below.

<u>Analysis # 3</u> - No original Bechtel calculation found.
Piping Isometrics JRD-130-1
JRD-132-1, -2, -3
JRD-133-1
Analysis extends from the outlet nozzles of the fuel pool heat exchangers 1E-202A, B & C to the Reactor Building/Turbine Building penetration. (Note that in order to limit the size of the service water model, two 12" diameter branch lines, JRD-127 and JRD-129, were not included in the analysis).

IV. <u>Analytical Methodology</u>

A. <u>Original Design Basis</u>

- <u>Fuel Pool Cooling & Clean-Up</u>
  - Piping Design Code: ASME Section III, 1971 Edition with Addenda thru Winter 1972, Nuclear Class 3.
  - Piping Design: Line Numbers - HBC-214, 215, 216
    Design Temperature - 212°F
    Design Pressure - 30 PSI (HBC-214, 215)
    135 PSI (HBC-216)
    Size/Thickness - 3" 0.216"
    - 6" 0.280"
    - 10" 0.365"
    Material - SA-106, Gr. B seamless
    Design Loading - Deadweight, Thermal Expansion

Analysis Method - Linear Elastic Analysis (Computer)

- Pipe Support Design: ANSI B31.1, 1973
  AISC
  Vendor Load Capacities

- Equipment Interface Evaluations:
  1) Fuel Pool Heat Exchangers 2E202A, B & C Bechtel Design Guide P-2.6.1.11; "Calculation of Allowable Forces and Moments in Equipment Nozzles".
  2) Fuel Pool Cooling Pumps 2P211A, B & C Vendor Criteria; "Allowable Nozzle Loads of ANSI Pumps".

• <u>Service Water</u>
  - Piping Design Code: ANSI B31.1, 1973 Edition

  - Piping Design:
    Line Numbers - JRD-132, 133
    Design Temperature - 115°F
    Design Pressure - 150 PSI
    Size/Thickness - 8" 0.322"
    12" 0.375"
    14" 0.375"
    20" 0.375"
    24" 0.500"
    Material - ASTM A-53, Gr. A or B Seamless
    Design Loading - Deadweight, Thermal Expansion
    Analysis Method - Hand Calculations and Limited Computer Analysis

  - Pipe Support Design: ANSI B31.1, 1973
    AISC
    Vendor Load Capacities

  - Equipment Interface Evaluations: Fuel Pool Heat Exchangers 1E202A, B & C Bechtel Design Guide P-2.6.1.11; "Calculation of Allowable Forces and Moments on Equipment Nozzles".

B. Evaluation of Hydrodynamic Loads

The recent analysis of the Fuel Pool Cooling and Clean-Up piping and the Service Water piping performed by PP&L utilized the original design basis data described above with the following changes: 1) All of the piping included in the evaluation scope was analyzed using the linear elastic analysis method (computer program ME101) and 2) Hydrodynamic loads were considered along with the deadweight and thermal expansion loadings. A description of the hydrodynamic analysis performed is provided below:

The load definitions for Mark II hydrodynamic loads are defined in the Susquehanna Design Assessment Report. Hydrodynamic loads are associated with Small Break Accidents (SBA), Intermediate Break Accidents (IBA) and Design Basis Accidents (DBA). They include pool swell loads and steam condensation loads - Condensation Oscillation (CO) and Chugging (CA). Pool swell does not produce inertial loads on structures or components located outside of the pool swell zone. However, the containment structure and the reactor building (including the control structure) will experience steam condensation inertial loads following a LOCA event. These hydrodynamic loads in the reactor building are the result of load transfer from the containment structure via the common basemat. The magnitude of hydrodynamic loads is largest inside containment, therefore, their effects are most significant for systems/components which are located inside containment or are attached to it. The effects on systems/components located in the reactor building is much less due to reduced load magnitudes.

Mathematical (stick) models of the reactor building were used by Bechtel during the original design phase to represent the response of the structure to hydrodynamic loads. The structural response of the reactor building is described by individual response spectra (frequency/acceleration pairs) associated with each node of the stick models. A separate stick model exists for the east-west (X) direction, the vertical (Y) direction and the north-south (Z) direction. These hydrodynamic response spectra were used to analyze the FPC and SW piping as described below.

The physical layout of the FPC and Service Water piping was used to identify the structural nodes which describe or bound the 3-directional boundaries of each piping analysis. Once the nodes are identified, the hydrodynamic response spectra are enveloped for each of the three directions. This results in one enveloped response spectra for each direction and each hydrodynamic load, e.g. X-direction response spectra for condensation oscillation. These enveloped response spectra were then used in the analysis of the FPC and Service Water piping.

The dynamic analysis of the FPC and Service Water piping was performed using the response spectrum method. The Bechtel authored piping analysis computer program, ME101, was used. The piping system is idealized as a mathematical model consisting of

lumped masses connected by massless elastic members. ME101 computes the stiffness matrix, mass matrix, natural frequencies and mode shapes. The response spectra method is then used to find the maximum response of each mode (e.g. displacements, stresses, accelerations, forces, etc.). The analysis is performed for one vertical direction and two horizontal directions of the reactor building. The modal responses and the directional responses are then combined. The internal moments, support reactions and stresses are then combined with system design pressure, deadweight and thermal expansion loadings in accordance with ASME Section III (FPC) or ANSI B31.1 (SW). Reference FSAR Table 3.9-6 and 3.9-14 for design loading combinations.

C. Computer Programs Used:

- ME101 is a finite element computer program which performs linear elastic analysis of piping systems using standard beam theory techniques. ME101 performs static and dynamic load analysis of piping systems and ASME Section III and ANSI B31.1 Code Stress checks. Linear dynamic analysis is based upon standard normal mode superposition techniques and uses response spectra. ME101 is a verified Bechtel piping analysis program which has been validated on PP&L's DEC Microvax 3100-30 computer.

- ME035 is a finite element computer program which is used for analyzing and designing base plates of pipe supports. ME035 is a verified Bechtel pipe support analysis program which has been validated on PP&L's DEC Microvax 3100-30 computer.

- ME150 (or FAPPS) is an interactive computer program for the analysis and design of standard and nonstandard pipe support frames. FAPPS will compute member displacements, forces, reactions, member/baseplate stresses and weld stresses. ME150 is a verified Bechtel pipe support analysis program which has been validated on PP&L's DEC Microvax 3100-30 computer.

- ME153 (or MAPPS) is a miscellaneous applications program for pipe supports that enables the user to perform various pipe support analysis such as local effects on members, clip angle evaluations, non-uniform welds, etc. ME153 is a verified Bechtel pipe support analysis program which has been validated on PP&L's DEC Microvax 3100-30 computer.

V. Analytical Results

The following summarizes the analytical results obtained from the hydrodynamic load analysis performed on the FPC system (2 analysis) and the SW system (1 analysis).

A. Pipe Stress

The maximum pipe stress due to hydrodynamic loads occurred near a

24" diameter elbow on the Service Water line and it's magnitude was less than 1600 psi. This value is less than 10% of the Code pipe stress allowables for occasional loads. The maximum combined pipe stresses due to pressure, deadweight and hydrodynamic loads occurred at the same SW location and were limited to less than 25% of the Code allowables. The maximum hydrodynamic load stresses from the FPC piping analysis were less than 600 psi (or less than 5% of Code allowables) and the maximum combined pipe stresses were limited to less than 15% of the Code allowables.

B. Pipe Support Loads

There is a total of thirty (30) pipe supports located on the FPC and SW piping which were evaluated. Nine (9) of these supports are spring can hangers which do not restrain the pipe during dynamic loadings and are therefore not affected by the hydrodynamic analysis performed here. The remaining pipe supports are rigid type supports or in-line anchors which are comprised of various vendor components such as rigid rods, riser clamps, rigid struts and miscellaneous welded structural members such as tube steel, wide flange shapes, stanchions, plates, etc.

New pipe support design loads were generated for the FPC and SW pipe hangers which included deadweight, thermal expansion and hydrodynamic loadings. These new loads were used in the evaluation of all pipe supports by comparing them to the original design loads as provided in the existing Bechtel calculations (FPC) or as provided on the pipe hanger drawings (SW).

The developed LOCA loads resulted in relatively small increases in overall support loads. The average LOCA load magnitudes associated with the FPC and SW supports were less than 25% of the average design loads originally used in the design of the supports. The original design loads included deadweight and thermal expansion only.

As can be expected, in many instances the addition of LOCA loads to deadweight and thermal expansion loads resulted in new support design loads which exceeded the loads developed for the original support qualification. These new loads were compared to the design margins available for each support component to ensure that the load increase could be accommodated. In instances where direct comparison with existing design margins could not be easily made, additional calculations were made to demonstrate support adequacy. In some cases the new loads were enveloped by the original design loads even though LOCA loadings were now included. This was due to past conservatisms used in computing the original loads (i.e. non-computerized analysis) and the relatively small magnitude of LOCA loads.

The evaluations performed demonstrated that all of the pipe supports contain sufficient design margin to accommodate the addition of LOCA loads and that all can be qualified in accordance with the original design allowables and vendor capacities. In addition, it was found that the vertical LOCA loads will not create an up-lift on vertical direction hangers since in all cases the LOCA loads are not of sufficient magnitude to overcome the múch larger deadweight loads.

C. Equipment Loads

The nozzle loads due to a combination of deadweight, thermal expansion and LOCA loads were evaluated for the three Fuel Pool Cooling pumps and heat exchangers.

The FPC pump nozzles were evaluated based on the original vendor pump allowables provided in Bechtel Calculation ABR-2970. Each of the 3" diameter pump discharge nozzles on 2P-211A, B & C were evaluated. It was demonstrated that all pump nozzle forces and moments are within the original pump nozzle allowable limits.

Each of the 8" diameter Service Water nozzles on fuel pool heat exchangers 1E-202A, B & C were evaluated as were the 6" diameter Fuel Pool Cooling nozzles on fuel pool heat exchangers 2E-202A, B & C. The heat exchanger nozzles were evaluated using the original design criteria used in Bechtel Calculation ABR-2968. The criteria is taken from Bechtel Design Guide P-2.6.1.11 titled "Calculation of Allowable Forces and Moments on Equipment Nozzles". It was demonstrated that all heat exchanger nozzle forces and moments are within the allowable limits identified in the design guide used in the original nozzle assessments.

D. Pipe Displacement (LOCA)

Pipe movement due to LOCA loads is minimal. The maximum LOCA pipe displacement is less than 0.100" on the LOCA analysis performed. Most displacements are less than 1/32". The small pipe displacements will not result in pipe hanger problems such as binding or loss of vertical support, that is, the pipe will not "fall off" it's supporting member. The small pipe movements will also minimize potential problems associated with differential pipe motions such as at small bore branch line connections.

E. Mode Frequencies

A review of the modal results shows that the piping analyzed is very flexible. This is pertinent since no appreciable building response (acceleration) is indicated on the LOCA response spectra curves for frequencies less than 10 Hz. The frequency range for the first 5 piping modes are given below for each analysis.

- Analysis # 1 FPC   6.22 Hz to 26.81 Hz
- Analysis # 2 FPC   3.05 Hz to 9.99 Hz
- Analysis # 3 SW   0.53 Hz to 2.64 Hz

VI. Conclusions

The intent of this evaluation was not to dynamically qualify the entire Fuel Pool Cooling system and Service Water system nor was it the intent to make a definitive statement about the ability of all non-safety related lines in the reactor building to withstand LOCA loads. The purpose, as stated earlier, was to demonstrate quantitively, based on the representative samples chosen here, that LOCA loads do not pose a significant threat to the integrity of these systems.

The analysis performed shows that pipe stresses increased slightly but are a small fraction of Code allowables, that pipe support design margins are large enough to accommodate the additional LOCA loads and that equipment nozzle loads are still within original design basis allowables. Therefore, based on these analytical results it can be concluded that the overall affect of hydrodynamic (LOCA) loads on these systems is not significant. The results support the original assessment conclusions that LOCA loads pose a low to moderate threat to the functionality of the Fuel Pool Cooling and Service Water systems.

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