Ultimate Heat Sink Test Interim Report

1.0 Purpose

PP&L has tested the Susquehanna SES Ultimate Heat Sink (Spray Pond) as committed to in FSAR Section 9.2. The purpose of the test was to demonstrate that measured performance for two unit operation equals or exceeds that which is predicted by analysis. This report provides the Commission with preliminary test results. As post test calibration of instruments is not complete, these results are not final. However, post test calibration is not expected to cause changes in the data or impact our findings.

2.0 Data Acquisition

The Spray Pond Test procedures, test plans and analytical techniques were submitted to the commission by letter dated June 16, 1982 (PLA-1138). Two tests were performed between July 23, 1983 and July 25, 1983. Both the High Heat Rate Test and the Low Heat Rate Test were run for periods of approximately 27 hours each. Both tests were performed according to the procedures previously submitted with the exception of the following:

A. The Steam Condensing Mode of Residual Heat Removal (RHR) did not allow as much heat transfer to the Pond as originally anticipated. This resulted in the use of lower heat rates to the pond than originally planned. For the High Heat Rate Test, a heat load of approximately 193 million Btu/hr was supplied to the pond. The original test plans were to supply a heat rate of 214 million Btu/hr. For the Lower Heat Rate Test, a heat load of approximately 115 million Btu/hr was supplied to the pond. The original plans were to use a heat rate of 155 million Btu/hr.

   The use of lower heat rates during the test does not affect the validity of the test results. The actual heat rates used are still near the midrange of heat loads expected on the pond during a Design Basis Accident (DBA) for the Spray Pond. As stated in FSAR Table 9.2-30, heat loads on the pond range from 79.8 to 388.1 million Btu/hr.

B. The original test plans called for the use of the two large spray networks to dissipate the Spray Pond heat load during the test. However, the Spray Pond is designed to provide cooling by the use of one loop (one large array and one small array). One RHRSW pump and one ESW pump are not intended to supply a large spray array with the flow necessary to produce 7 psid at the spray nozzles. Consequently, the pressure drop across the spray nozzles was found to be below the design value of 7 psid with two large arrays in operation.

This forced the use of one large spray array (A1) and one small spray array (B2) for the test. When this arrangement was used, it was found that the pressure drop across the nozzles in the A1 array was approximately 6.2-6.4 psid. The pressure drop across the nozzles in the B2 array was approximately 7.2-7.4 psid. The pressure drop for both arrays calculated together is less than 7 psid. This will cause drop sizes to be larger than those accounted for in the model and the height of the sprays to be lower than design. Therefore, less heat transfer can be expected during the test than predicted by model. Hence the lower pressure drops experienced during the test will cause the measured efficiencies to change in the conservative direction.

3.0 Data Analysis

The Spray Pond Minimum Heat Transfer analysis utilizes two wind speed models to predict thermal efficiency. The low wind speed model is used for wind speeds up to 3 mph and accounts for natural convection only. This model does not consider forced convection and neglects all cooling effects due to wind. Air is assumed to be drawn in through all sides of the spray array and exit vertically upward.

The high wind speed model is used for wind speeds upwards of 3 mph and neglects natural convection for conservatism. Air is assumed to flow through the length of the spray array. The sprayed water temperature, air temperature, and moisture content of the air are predicted for points throughout the array.

Thermal efficiencies were calculated from the data collected and compared to those predicted by the appropriate wind speed model. The comparison reveals that measured efficiencies were greater than those predicted by the model for wind speeds of approximately 4.5 mph and less. This demonstrates the conservatism of the low wind speed model.

Conservatism in the high wind speed model could not be consistently demonstrated using the data collected. This is attributed to a lack of wind data in the immediate spray array area and the complexity of the wind patterns at the arrays. Although wind speed and direction were recorded at either end of the Pond, data at the two ends differed significantly. Wind speed differed by a factor as great as 2 while directions differed by as much as 180 degrees. The difference in the wind data at the two ends of the pond does not allow the wind speed and direction through the arrays to be determined. The lack of this wind data and the simplifying assumptions used in the model present difficulties in predicting accurate efficiencies using the high wind speed model.

4.0 Revision of FSAR Minimum Heat Transfer Case Analysis

Since the high wind speed model could not be verified as being conservative by test, the FSAR minimum heat transfer case was run using only the low wind speed model. These calculations do not use wind as input for the prediction of Pond performance. By using this approach, the Spray Pond analysis can be considered fully verified by test. PP&L

proposes to change the operating limits of the Spray Pond to reflect this analysis.

Calculations for the Minimum Heat Transfer case, utilizing only the low wind speed model, reveal that the Spray Pond can provide sufficient cooling for a 2 unit DBA (LOCA in one unit, safe shutdown of the other) if the Pond temperature at the start of the DBA is 81°F and the starting inventory is 23 million gallons. A discussion of the different parameters of the analysis is given below. Also discussed are the ways in which the analysis differs from that in the FSAR.

Spray Pond Temperatures

The FSAR analysis is based on a starting Pond temperature of 88°F for a two unit DBA. For the revised analysis, a starting temperature of 81°F is used. An operating temperature limit of 81°F is not expected to impact the operation of the plant until the summer of 1984. A Technical Specification change will be requested to reflect a maximum operating temperature of 81°F for two unit operation.

Based on the revised analysis, the maximum Pond temperature expected during the 30 day Minimum Heat Transfer event is 95.26°F. It is concluded that the design maximum Emergency Safeguards Service Water design temperature of 95°F is supported in light of the many conservatisms and modeling assumptions used in the analysis. Secondly, the Pond temperature only briefly exceeds 95°F before dropping below 95°F. The impact on plant equipment during this period is expected to be negligible.

A possibility exists that a shutdown can be forced in an operating unit due to high Pond temperatures brought about while the other unit is being shutdown (and uses the Spray Pond to reject heat). To address this, calculations will be performed to determine the maximum safe operating temperature allowable if one unit is being shutdown. This temperature will be dependent on the residual heat removal required in the unit being shutdown and the LOCA loads from the operating unit.

Starting Inventory

The Spray Pond presently has a nominal inventory of approximately 25 million gallons at its normal water level (el 678'6"). The current minimum level allowed by Technical Specifications corresponds to an inventory of 20 million gallons. The revised analysis indicates that a starting inventory of 23 million gallons (coupled with a starting temperature of 81°F) will allow sufficient cooling for a two unit DBA over a 30 day period without makeup. A Technical Specification change will be proposed to reflect a minimum Spray Pond inventory of 23 million gallons. The difference in level between the normal inventory and the Technical Specification limit will provide operating margin.

Wind Speed in Minimum Heat Transfer Case

In the original analysis, high wind speeds (above 3 mph) were present in the Minimum Heat Transfer meteorological conditions 85% of the time. No wind is assumed to exist in the revised analysis. Since there is a high probability that wind will be experienced sometime during a 30 day period, the elimination of wind from the assumed meteorological conditions for the Minimum Heat Transfer Case is a conservative measure.

Sprayed Water Drop Sizes

A drop size of 2800 microns was used in the original analysis. This drop size has the highest volume fraction (20%) as determined by vendor nozzle tests. For the revised analysis, a drop size of 2470 microns was used. This value represents the mass median of the vendor's nozzle drop size test data. The smaller drop size allows for more evaporative cooling and, as such, should predict higher efficiencies. Therefore, the use of the smaller drop size is less conservative. However, the measured efficiencies for low wind speeds were higher than predicted. This demonstrates conservatism in the low wind speed model using the smaller drop size.

Siphoning Allowances

A possibility exists that the Spray Pond can be siphoned through 4" makeup/deicing line HCD-3041 (refer to an Interim Report on the subject dated September 2, 1983; PLA 1816). The maximum anticipated siphoning rate is 35 gpm. For the revised analysis, a water loss rate of 35 gpm was subtracted from the Spray Pond inventory (over the entire 30 day period) for siphoning considerations.

5.0 Maximum Water Loss Case Analysis

In the Maximum Water Loss Case, the use of all spray networks is assumed, thereby maximizing the spray evaporation and drift losses. Meteorological conditions were assumed, per Regulatory Guide 1.27 Rev. 2, to produce maximum losses. The test results demonstrated conservatism of the FSAR Maximum Water Loss Case analysis as discussed below:

Spray Evaporation Losses

As mentioned above, the high wind speed model overpredicts thermal efficiency for wind speeds above 4.5 mph. The cooling capability of the nozzles, therefore, is less than that predicted by analysis. Since spray cooling is directly related to spray evaporation, the high wind speed model predicts more evaporation losses than actually occur. The analysis, therefore, is conservative in terms of spray evaporation water losses.

Drift Losses

The preliminary data for drift loss indicates that the measured loss was a factor of 35 times lower than that predicted in the velocity range measured.

Natural Evaporation

The initial evaluation of natural evaporation data reveals that natural evaporation measured during the test was 26.7% higher than that predicted in the analysis. However, conservatism measured for drift loss more than compensates for the higher natural evaporation rate.

Effect of Revised Starting Temperature and Inventory

The FSAR analysis for the Maximum Water Loss Case required 19.95 million gallons over a 30 day transient. This value includes losses for spray evaporation, drift, percolation, solar evaporation, sedimentation, fuel pool makeup and allowances for water quality considerations. Adding siphoning losses (35 gpm) a volume of 21.46 million gallons would be required.

It is expected that the revised Spray Pond starting temperature and inventory will affect the loss calculations due to different Pond temperatures, spray drop times, etc. Therefore losses were calculated from the revised starting conditions. These calculations reveal that a water loss of 21.87 million gallons can be expected over a 30 day transient (accounting for the losses as listed above). From this it is concluded that a starting inventory of 23 million gallons is adequate for Maximum Water Loss Case conditions.

6.0 Conclusion

PP&L concludes that the Spray Pond will perform its intended safety function for two units if the Pond operating temperature is limited to 81°F and the inventory is maintained at a minimum of 23 million gallons. Using these operating restrictions, the revised Spray Pond analysis as described above is considered verified by test.

Although the above operating restrictions will not impact the operation of either unit for the winter or spring, it is anticipated that the Pond temperature may rise above 81°F on occasion during summer months. PP&L is investigating design changes that will result in increasing the Pond temperature limit. Additionally, we are refining our analysis to remove any excess conservatisms that may exist. Since these efforts may take several months, the conservative limits of 81°F with 23 million gallons of inventory should be applied in order to proceed with Unit 2 start-up.

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