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SUBJECT: Forwards final rept for UHS (spray pond) performance test to justify operation w/operating limits of spray pond changed to reflect max temp of 81 F & min inventory of 23 million gallons.

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DEC 21 1983

Director of Nuclear Reactor Regulation
Attention: Mr. A. Schwencer, Chief
Licensing Branch No. 2
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUSQUEHANNA STEAM ELECTRIC STATION
FINAL SPRAY POND REPORT
ER 100508 FILE 841-2
PLA-2007

Docket No. 50-388

Dear Mr. Schwencer:

Enclosed is the Final Report for the Ultimate Heat Sink (Spray Pond) Performance Test. This report justifies operation of two units with the operating limits of the spray pond changed to reflect a maximum operating temperature of 81°F and a minimum inventory of 23 million gallons.

If you have any questions, please contact us.

Very truly yours,

N. W. Curtis
Vice President-Engineering & Construction-Nuclear

Enclosure
cc: R. L. Perch NRC

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Ultimate Heat Sink Test
Final 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 final test results.

2.0 SUMMARY

In PLA-1896 dated October 12, 1983, the Commission was provided with a report of the preliminary Spray Pond test results. These test results were not considered final as post test calibration of instruments was not complete.

The Interim Test Report indicated that measured Spray Pond performance equaled or exceeded that predicted by analysis for low wind speeds (4.5 mph or lower). The analysis done to that point did not consistently demonstrate conservatism at higher wind speeds. The Spray Pond analysis was revised to reflect these findings. The revised analysis assumed that no wind would be present over the 30 day Design Basis Accident (DBA) for the Spray Pond. This approach is conservative since the added cooling effects due to wind are neglected. The revised analysis indicated that the Spray Pond will provide sufficient cooling for a two unit DBA if the pond operating temperature is limited to 81°F and the inventory is maintained at a minimum of 23 million gallons.

Post test calibration of instruments is now complete. No significant changes were made to the test data due to this calibration. PP&L therefore concludes, based on final test data, that the Spray Pond will perform its intended safety function if the above operating limits are imposed.

3.0 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 by use of the Steam Condensing and Suppression Pool Cooling modes of RHR. 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 through the Steam Condensing and Suppression Pool Cooling modes. 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 Spray Pond DBA. 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 specified the use of two large spray array 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). The spray nozzle design pressure drop of 7 psid is not achievable when two large spray arrays are used simultaneously.

This forced the use of one large spray array (A1) and one small spray array (B2) for the test. When this arrangement was used, the pressure drop across the nozzles in the A1 array was 6.2-6.4 psid and 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.

4.0 DATA ANALYSIS

There are four models used to predict UHS thermal and water loss performance:

1. The Thermal Performance Models (low and high wind speed models).

2. The Drift Loss Model

3. The Natural Evaporation Model

4. The UHS System Model

Based on these models, Spray Pond performance is predicted for two sets of assumed meteorological data. In one case, meteorology is assumed such that the ability to dissipate heat to the atmosphere is minimized (Minimum Heat Transfer Case). In the other case, meteorology is assumed such that the potential for water loss is maximized (Maximum Water Loss Case).

Performance predicted by each of the models was compared to performance as measured. Overall response of the Spray Pond was then evaluated in light of the measured results.

Thermal Performance Models

The thermal performance model is used to predict thermal efficiency. Thermal efficiency is defined as follows:

$$E_{TH} = \frac{T_H - T_C}{T_H - T_{WB}}$$

where E_{TH} = Thermal efficiency

T_H = Temperature of water before being sprayed

T_C = Temperature of water as it lands on the pool surface

T_{WB} = Wet bulb temperature

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 above 3 mph. In this model, air is assumed to flow horizontally through the length of the spray array. Cooling effects due to natural convection are neglected for conservatism.

Thermal efficiencies were calculated from the test 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 model for wind speeds of approximately 4.5 mph and less. This demonstrates the conservatism of the low wind speed model.

Conservatism in the existing high wind speed model has not been consistently demonstrated by the data analysis done to this point. Additional work will be performed with the high wind speed model in an effort to show conservatism with the test data.

Drift Loss Model

Drift loss as a function of windspeed (among other less dominant parameters) is calculated according to the analytical technique described in FSAR Section 9.2.7. Once this relationship is determined, drift is subtracted from the pond inventory based on the windspeeds used in the assumed meteorology.

Drift losses were measured using a sensitive paper technique. In this technique, a paper is used that discolors when exposed to water droplets. The exposed paper is used to determine the concentration of drops leaving the periphery of the pond. The loss concentration is used to determine the drift loss rate at the windspeed measured for that instant in time. In the calculation of drift loss, water droplets were assumed to leave the pond in all directions simultaneously. This feature of the drift loss calculation is conservative.

Analysis of the drift data collected indicates that the drift losses predicted by model are considerably more (by a factor of approximately 27) than measured losses. From this, it is concluded that the drift model is conservative. In addition to the sensitive paper technique, funnels with collection bottles were placed on the edge of the pond (downwind of the sprays) in order to measure drift losses. However, the drift rate was not high enough to measure drift using this method and no measurable drift was collected by the funnels.

Natural Evaporation Model

The natural evaporation rate, M_c, is calculated using the following relation:

$$M_e = A_p \, F(w) (P_{SAT}(T_p) - P_a) / h_{fg}(T_p)$$

where

A_p = Total pond surface area

T_p = Pond surface temperature

P_a = Vapor pressure in ambient air

$P_{SAT} (T_p)$ = Saturation vapor pressure of water at the pond surface temperature

$h_{fg} (T_p)$ = Heat of vaporization of water at pond surface temperature

The wind function, F(w), is given by

$F(w) = 70 + .7w^2$, where

w = wind speed

Natural evaporation is calculated over the 30 day DBA based on the assumed design meteorology.

During the test, natural evaporation was measured using three evaporation pans located at the east end of the pond. The temperature of the water

in each pan was monitored using an RTD. The pans were located such that neither drift nor splashing waves added to the water in the evaporation pans.

Measured evaporation rates were reasonably close to those calculated. For the data collected, 87.5% of all the calculated evaporation rates are within one standard deviation of the average measured evaporation rates.

From this it is concluded that the natural evaporation model adequately predicts evaporative losses.

System Model

The system model describes the heat and mass flows to and from the spray pond. It is used to predict pond performance using input from the thermal, natural evaporation and drift loss models. Also considered in the system model are spray evaporation losses, seepage, siphoning allowances (as described below) and insolation.

Pond temperature and inventory are predicted for two 30 day periods, one each for the Minimum Heat Transfer and Maximum Water Loss cases. In each case, the assumed plant heat loads on the pond reflect a LOCA in one unit and a safe shutdown in the other with no off site power supplied to either unit.

As stated in the FSAR, the system model had predicted that the Spray Pond would perform its safety function for two units if the pond inventory was 25 million gallons and the pond temperature was a maximum of 88°F at the start of the DBA. The system model predicted that the Spray Pond provided sufficient cooling under both Minimum Heat Transfer and Maximum Water Loss conditions if these operating limits were applied.

However, these predictions assumed that thermal performance, drift and natural evaporation were accurately predicted by their respective models. As described below, the system model runs for the Minimum Heat Transfer and Maximum Water Loss cases have been re-evaluated in light of the Spray Pond test results and the appropriate revisions to these analyses have been made.

5.0 DISCUSSION OF THE REVISED SPRAY POND ANALYSIS

The revised Minimum Heat Transfer and Maximum Water Loss analyses are discussed below along with departures from the FSAR analyses.

Revised Minimum Heat Transfer Case

As the high wind speed model was not verified as being conservative by test, the design meteorology for the Minimum Heat Transfer case was revised to exclude all wind. The revised meteorology was then used as input for the system model. The system model for the Minimum Heat Transfer case can then be considered verified by test. Using the revised meteorology (no wind), the system model indicates that the Spray Pond will perform its intended safety function for a two unit DBA if the initial pond temperature is a maximum of 81°F and the starting inventory is 23 million gallons. The maximum pond temperature during the 30 day transient is expected to be 95.26°F. It is concluded that the maximum

Emergency Safeguards Service Water temperature of 95°F is supported in light of the many conservatisms and modeling assumptions used in the analysis. In addition, 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.

The following items are departures from the FSAR analysis:

Spray Drop Sizes

A spray drop of 2800 microns was used in the analysis reflected in the FSAR. 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 those predicted despite the use of the smaller drop size in the model. This demonstrates conservatism in the low wind speed model using the smaller drop size and its use is therefore justified.

Siphoning Allowances

A possibility exists that the Spray Pond can be siphoned through 4" makeup/deicing line HCD-3041 (refer to a Report on the subject dated November, 1983; PLA-1925). 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.

Revised Maximum Water Loss Case

Water losses were calculated using a starting inventory of 23 million gallons and a starting temperature of 81°F. These calculations reveal that a water loss of 21.87 million gallons can be expected over the 30 day maximum water loss transient. This value includes losses for spray evaporation, drift, percolation, natural evaporation, siphoning, sedimentation, fuel pool makeup and allowances for water quality considerations. The maximum expected pond temperature during the transient is 83°F. From this it is concluded that a starting inventory of 23 million gallons and a starting temperature of 81°F is adequate for Maximum Water Loss Case conditions.

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 for both the Minimum Heat Transfer and Maximum Water Loss cases. Accordingly, PP&L has submitted a request to change the Technical Specifications to reflect these operating limits in PLA-1909, dated October 24, 1983.

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 and analytical changes that will result in increasing the Pond temperature limit. 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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