Item B-29: Effectiveness of Ultimate Heat Sinks

DESCRIPTION

This issue was identified in NUREG-0471[1] and addressed the concerns that the validity of the mathematical models used to predict the performance of dedicated ponds, spray ponds, and cooling towers had not been confirmed, and that better guidance was needed regarding the criteria for the selection of weather data to define the design basis meteorology. The vulnerability and need for further improvement to the design and operation of ultimate heat sinks (UHS) are addressed separately in Issues 51, 130, and 153.

The UHS is defined as the complex of sources of service or house water necessary to operate, shut down, and cool down a nuclear plant safely following a design basis accident. Water for the UHS is frequently supplied directly from large-surface water bodies, such as rivers, lakes, or oceans, by which the heat from the service water system can be dissipated safely. The UHS can also be supplied from dedicated ponds, spray ponds, and cooling towers. These devices frequently are small in relation to the heat loads imposed upon them and, thereby, operate at relatively high temperatures. The primary concern of this issue is these dedicated ponds, spray ponds, and cooling towers that are used as the UHS. The following NRC positions on the design of UHS are stated in Regulatory Guide 1.27[2]:

(1) The UHS must be able to dissipate the heat of a design basis accident (e.g., a LOCA) of one unit plus the heat of a safe shutdown and cooldown of all other units it serves.

(2) The heat sink must provide a 30-day supply of cooling water at or below the design basis temperature for all safety-related equipment.

(3) The system must be shown to be capable of performing under the meteorological conditions leading to the worst cooling performance and under the conditions leading to the highest water loss. These must be the worst periods for water loss (30 days) and peak temperatures over the data period (usually at least 30 years) as determined by computer simulation.

The original intent of this issue was to provide: (1) confirmation of currently-used mathematical models for prediction of UHS performance by comparing model performance with field data; and (2) better guidance regarding the criteria for weather record selection to define UHS design basis meteorology. Thus, this issue was expected to provide the basis for a methodology used to validate or predict UHS effectiveness.

The design of small dedicated ponds, spray ponds, and cooling water towers must take into account the meteorological conditions that could reasonably be expected to occur simultaneously with the design basis accident in order to calculate the highest returned-water temperature and water loss. NUREG-0693[3] and NUREG-0733[4] give detailed instructions on computer programs used in analyzing small cooling and spray ponds, respectively. The techniques presented in these reports outline the ways in which long-term, offsite meteorological records can be: (1) scanned to find the most adverse conditions; (2) correlated to onsite data; (3) analyzed statistically; and (4) used to predict the highest temperature and water loss. Heat and mass transfer relationships used in these models were compared, in some cases, with available field data and ranged from "realistic" to "conservative." However, verification of the models was not considered complete on the basis of this comparison. In 1977, the NRC issued a contract to PNL to

[1] NUREG-0471, "Generic Task Problem Descriptions (Categories B, C, and D)," U.S. Nuclear Regulatory Commission, June 1978.
[2] Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, (Rev. 2) January 1976.
[3] NUREG-0693, "Analysis of Ultimate Heat Sink Cooling Ponds," U.S. Nuclear Regulatory Commission, November 1980.
[4] NUREG-0733, "Analysis of Ultimate Heat-Sink Spray Ponds," U.S. Nuclear Regulatory Commission, August 1981.

undertake a comprehensive field-testing program to collect data on the performance of small cooling and spray ponds.

The first series of cooling pond tests were performed at the Raft River geothermal test site in southern Idaho. Hot water, supplied by geothermal wells, was allowed to cool in a small, excavated, lined pond. Extensive water and atmospheric measurements were taken during a series of tests of the pond. Although a spray facility was planned at the same site, further tests were abandoned after accidental destruction of the pond liner.

Another geothermal test site, East Mesa in southern California, was chosen for the spray pond tests. A small, lined pond was filled with hot water and steam provided from a geothermal well. Water in the pond was sprayed from an array of spray nozzles. Extensive water and meteorological measurements were taken during a series

of tests, with and without the sprays in operation. The results of these studies, presented in NUREG-0858,[5] were compared with the predictions made using the UHS models described in NUREG-0693[6] and NUREG-0733.[7] These comparisons generally supported the conclusion that the NRC models were adequate and are useful tools for predicting UHS performance.

Although the resulting comparisons generally supported the NRC models, the comparisons were viewed with a certain amount of caution. The test sites in Idaho and California are generally dry, cloudless deserts and not typical of the climatic conditions at many nuclear power plant sites. The experimental ponds were also somewhat smaller than typical nuclear power plant cooling and spray ponds. Furthermore, the operation of the ponds was not analogous to the operation of cooling and spray ponds used as UHS. This last point is most important in the case of large cooling ponds that could possibly stratify under the influence of external heat load. Hence, a three- dimensional model was developed by ANL and validated using data from two sources, as noted in NUREG/

CR-4120.[8] The results of this comparison revealed that the model exhibited good accuracy in simulating stratified and unstratified conditions in heated ponds. The model was applied to the Catawba UHS pond and indicated that different flow patterns will exist in UHS cooling ponds experiencing high heat loads that differ from ponds used in normal cooling modes. The modeling results indicated that a vertically-mixed pond occurred with no short-circuiting problems encountered between the discharge and intake points.

A paper[9] titled "Performance Model for Ultimate Heat Spray Ponds" details other tests that were used to validate the spray model. The spray model was compared with cooling data on nuclear and industrial spray ponds, as well as data on the temperature and water loss on the East Mesa and Raft River well-instrumented experimental ponds. It was concluded that the model-prototype comparisons generally confirmed that the model accurately or conservatively predicted pond temperature and water loss.

In a report[10] entitled "Method for Analysis of Ultimate Heat Sink Cooling Tower Performance," prepared by the University of Illinois at Urbana-Champaign, a model was proposed that would evaluate UHS mechanical draft cooling towers by using (like the spray pond and cooling pond models) data recorded by the NWS at the site nearest to (and most representative of) the proposed plant. This report states that, unlike cooling ponds and spray ponds, there exists an extensive collection of data on the thermal

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[5] NUREG-0858, "Comparison Between Field Data and Ultimate Heat Sink Cooling Pond and Spray Pond Models," U.S. Nuclear Regulatory Commission, September 1982.
[6] NUREG-0693, "Analysis of Ultimate Heat Sink Cooling Ponds," U.S. Nuclear Regulatory Commission, November 1980.
[7] NUREG-0733, "Analysis of Ultimate Heat-Sink Spray Ponds," U.S. Nuclear Regulatory Commission, August 1981.
[8] NUREG/CR-4120, "Mathematical Modeling of Ultimate Heat Sink Cooling Ponds," U.S. Nuclear Regulatory Commission, March 1985.
[9] "Performance Model for Ultimate Heat Spray Ponds," Journal of Energy Engineering, Vol. 112, No. 2, August 1986.
[10] "Method for Analysis of Ultimate Heat Sink Cooling Tower Performance," University of Illinois at Urbana- Champaign, April 1986. [9704090166]

performance of cooling towers.

However, this work needed only to demonstrate its applicability to an actual example. This was accomplished by comparing the performance predictions of the developed models with data previously collected during an actual cooling tower performance demonstration.

CONCLUSION

The purpose of this issue was to confirm the validity of the NRC models used to make an independent assessment of design safety and, as such, it was classified as a Licensing Issue. Studies completed by the staff in resolving the issue confirmed the capabilities of NRC models and provided assurance that the existing guidance was adequate. However, the adequacy of the models to simulate the performance of a specific UHS must be justified on a case-by-case basis.