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ULTIMATE HEAT SINK FOR NUCLEAR POWER PLANTS

A. INTRODUCTION

General Design Criterion 44, "Cooling Water," of Appendix A, "General Design Criteria," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires, in part, that suitable redundancy in features be provided for the cooling water system to ensure that its safety function can be accomplished. General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena," requires, in part, that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena without loss of capability to perform their safety functions. This guide describes a basis acceptable to the NRC staff that may be used to implement General Design Criteria 44 and 2 with regard to a particular feature of the cooling water system, namely, the ultimate heat sink.* This guide applies to all types of nuclear power plants that use water primarily as the ultimate heat sink. Air heat exchangers or other heat-dissipation methods used as ultimate heat sinks will be discussed in future revisions or appendices.

B. DISCUSSION

The ultimate heat sink (hereinafter "sink") for the cooling water system is that complex of water sources, including necessary retaining structures (e.g., a pond with its dam or a river with its dam), and the canals or conduits connecting the sources with, but not including, the cooling water system intake structures for a nuclear power unit. The sink constitutes the source of service or "house" water supply necessary to safely operate, shut down, and cool down a plant. This safety-related water supply may be shared by nonsafety systems (e.g., circulating water supply). If cooling towers or portions thereof are required to accomplish the sink safety functions, they should satisfy the same requirements as the sink. The sink performs two principal safety functions: (1) dissipation of residual heat after reactor shutdown and (2) dissipation of residual heat after an accident. For a single nuclear power unit, the sink should be capable of providing sufficient cooling water to accomplish each of these safety functions.

In considering a multiple-unit station, it is recognized that the design of each nuclear reactor unit includes sufficient safety in depth that it is highly unlikely that more than one reactor unit will be in an accident condition at any particular time. On this basis, the ultimate heat sink complex serving multiple units should be capable of providing sufficient cooling water to permit simultaneous safe shutdown and cooldown of all units it serves and to maintain them in a safe shutdown condition. Also, in the event of an accident in one unit, the sink should be able to dissipate the heat for that accident safely, to permit the concurrent safe shutdown and cooldown of the remaining units, and to maintain all of them in a safe shutdown condition.

The capacity of the sink should be sufficient to provide cooling both for the period of time needed to evaluate the situation and for the period of time needed to take corrective action. A period of 30 days is considered to be adequate for these purposes. In addition, procedures should be available for ensuring the continued capability of the sink beyond 30 days.

Sufficient conservatism should be provided to ensure that a 30-day supply of water is available and that the design basis temperatures of safety-related equipment are not exceeded. For heat sinks where the supply may be limited and/or the temperature of plant intake water from the sink may become critical (e.g., ponds, lakes, cooling towers, or other sinks where recirculation between plant cooling water discharge and intake can occur), transient analyses of supply and/or temperature should be performed. A capacity of less than 30 days may be acceptable if it can be demonstrated that

*Lines indicate substantive changes from Revision 1, March 1974.

replenishment can be effected to ensure the continuous capability of the sink to perform its safety functions, taking into account the availability of replenishment equipment and limitations that may be imposed on "freedom of movement" following an accident.

The meteorological conditions considered in the design of the sink should be selected with respect to the controlling parameters and critical time periods unique to the specific-design of the sink. For example, consider a dry cooling tower as the sink. The controlling parameter would be a dry bulb temperature, and the critical time period may be on the order of one hour. Therefore, an acceptable design basis meteorological condition for this sink would be the maximum observed (based on regional climatological information) one-hour dry bulb temperature. As another example, consider a cooling pond as the sink where the pond temperature may reach a maximum in 5 days following a shutdown This maximum temperature should coincide with the most severe combination of controlling meteorological parameters for a 1-day period. Therefore, three critical time periods should be considered: 5 days, 1 day, and 30 days (to ensure the availability of a 30-day cooling supply). These three periods need not occur contiguously. They may be combined, however, in the indicated order to produce a synthetic 36-day period which may be used as the design basis for the pond. Alternatively, the worst 36-consecutive-day period from historical climatological data may be used as the design basis. This period may or may not include the worst 5-day, 1-day or 30-day period.

The meteorological conditions resulting in maximum evaporation and drift losses should be the worst 30-day average combination of controlling parameters (e.g., dewpoint, depression, windspeed,, solar radiation). The meteorological conditions resulting in minimum water cooling should be the worst combination of controlling parameters, including diurnal variations where appropriate, for the critical time period(s) unique to the specific design of the sink.

The sink safety functions may be provided by natural or manmade features. More than one water source may be involved in the sink complex in performing these functions under different conditions. Because of the importance of the sink to safety, these functions should be ensured during and following the most severe natural phenomena postulated for the site (e.g., the Safe Shutdown Earthquake, design basis tornado, hurricane, flood, or drought). In addition, the sink safety functions should be ensured during other applicable site-related events that may be caused by natural phenomena such as river blockage, river diversion, or reservoir depletion or, if applicable, accidents such as ship collisions, airplane crashes, or oil spills and fires. Reasonable combinations of less severe natural and accidental phenomena or conditions should also be considered to the extent needed for a consistent level of conservatism; for example, such combinations should be evaluated in cases where the probability of their existing at the same time and having significant consequences is comparable to that associated with the most severe phenomena.

There should be a high level of assurance that the water sources of the sink will be available when needed. For natural sources, historical experience indicates that river blockage or diversion may be possible, as well as changes in ocean or lake levels as a result of severe natural events. For manmade portions, particularly structures above ground, failures are not uncommon. Because of these factors, consideration should be given to the sink comprising at least two water sources, each capable of performing the sink safety functions, unless it can be demonstrated that there is an extremely low probability of losing the capability of a single source.

Examples of sinks that have been found acceptable by the staff are as follows:

1. A large river
2. A large lake
3. An ocean
4. Two spray ponds*
5. A spray pond* and a reservoir
6. A spray pond* and a river
7. Two mechanical draft towers with basins*
8. A mechanical draft tower with basin* and a river
9. A mechanical draft tower with basin* and a lake
10. A cooling lake with a submerged pond*
11. Two wet/dry forced draft towers*
12. Two dry forced draft towers*

For those cases in which an applicant believes a single water source may be acceptable, it should be demonstrated that the source can withstand, individually without loss of the sink safety function, each of the following events: (1) the most severe natural phenomena expected at the site with appropriate ambient conditions, but with no two or more such phenomena occurring simultaneously, (2) the site-related events that have occurred or that may occur during the plant lifetime, (3) reasonable probable combinations of less severe natural phenomena and/or site-related events, and (4) a single failure of manmade structural features. In applying this "single failure," various mechanistic failure modes should be postulated. One may choose to assume a complete functional loss, but this is not necessarily required. For example, the consequences of a postulated major rupture of a dam (including the time-related effects of forces imposed at the time of rupture) should

*Seismic Category I design.

be assumed; however, it is not necessarily required that one assume that the dam disintegrates instantaneously with total loss of function. As another example, the consequences of a postulated slide of earthen canal walls should be assumed; however, it is not necessarily required that one assume that waterflow ceases completely.

Where canals or conduits are required as part of the sink, at least two should be provided, even if only one source of water has been demonstrated to be adequate. However, a single canal may be acceptable if it satisfies the four conditions above. Where the sink includes more than one source of water, the individual water sources may have different design requirements. Multiple water sources, including their associated retaining structures and required canals and conduits, should be separated and protected so that failure of any one will not induce failure in any other that would preclude accomplishing the safety functions of the sink. The complex (but not necessarily its individual features) must be capable of withstanding each of the most severe natural phenomena expected, other site-related events, reasonable combinations of natural phenomena and/or site-related events, and a single failure of manmade structural features without loss of capability of the sink to accomplish its safety functions. The most severe phenomena may be considered to occur independently and not simultaneously. In addition, the single failure of manmade structural features need not be considered to occur simultaneously with severe natural phenomena or site-related events.

For example, it would be acceptable if Water Source No. 1 (e.g., a manmade pond with a dam) and connecting conduit were capable of withstanding the Safe Shutdown Earthquake, tornado, and drought and Water Source No. 2 (e.g., a river with an existing dam) and its connecting conduit were capable of withstanding any reasonable probable combination of natural or accidental phenomena without loss of the sink functions.

The ultimate heat sink, as a complex, should be shown to be highly reliable by showing that certain conditions are satisfied. For example, consider Water Source No. 2, above. Such conditions would include: (1) the river cannot be diverted or blocked sufficiently to affect the availability of water at the connecting conduits; (2) no serious transportation accidents have occurred or can be reasonably expected; and (3) the dam was designed to appropriately conservative requirements, has functioned properly over its lifetime, and (based on projection of the best available data) will function properly for the lifetime of the nuclear power units it serves. Compliance with these conditions would not, however, remove the need for another source of cooling water if a single failure of the dam could result in losing the cooling capability of this source of water. Newly constructed features not required to be designed to withstand the Safe Shutdown Earthquake or the Probable Maximum Flood should at least be designed and constructed to withstand the effects of the Operating Basis Earthquake (as defined in 10 CFR Part 100, Appendix A) and waterflow based on severe historical events in the region.

The importance of the sink to safety is such that, if during plant operation the capability of the sink is threatened, as for example to permit necessary maintenance or as a result of damage, restrictions should be placed on plant operation. The technical specifications should state the actions to be taken in the event the required capability of the sink is temporarily unavailable during plant operation. For example, the technical specifications should require that (1) NRC be notified if the sink does not satisfy the limiting condition for operation and (2) if its capability cannot be restored to this condition within a reasonable period of time, all units served by the sink be shut down and remain shut down until this capability is restored.

C. REGULATORY POSITION

1. The ultimate heat sink should be capable of providing sufficient cooling for at least 30 days (a) to permit simultaneous safe shutdown and cooldown of all nuclear reactor units that it serves and to maintain them in a safe shutdown condition, and (b) in the event of an accident in one unit, to limit the effects of that accident safely, to permit simultaneous and safe shutdown of the remaining units, and to maintain them in a safe shutdown condition. Procedures for ensuring a continued capability after 30 days should be available.

Sufficient conservatism should be provided to ensure that a 30-day cooling supply is available and that design basis temperatures of safety-related equipment are not exceeded. For heat sinks where the supply may be limited and/or the temperature of plant intake water from the sink may eventually become critical (e.g., ponds, lakes, cooling towers, or other sinks where recirculation between plant cooling water discharge and intake can occur), transient analyses* of supply and/or temperature should be performed.

The meteorological conditions resulting in maximum evaporation and drift loss should be the worst 30-day

*For transient analysis of small shallow cooling ponds, use may be made of the analytical techniques and computer programs contained in "Generic Emergency Cooling Pond Analysis," COO-2224-1, May 1972–October 1972, prepared for the USAEC by University of Pennsylvania, School of Engineering and Applied Science, Civil Engineering, Philadelphia, Pennsylvania 19104. For sinks other than small shallow cooling ponds, similar transient analyses should be performed to demonstrate acceptable inventory and/or maximum intake water temperature.

average combination of controlling parameters (e.g., dewpoint depression, windspeed, solar radiation).

The meteorological conditions resulting in minimum water cooling should be the worst combination of controlling parameters, including diurnal variations where appropriate, for the critical time period(s) unique to the specific design of the sink.

The following are acceptable methods for selecting these conditions:

a. Based on regional climatological* information, select the most severe observation for the critical time period(s) for each controlling parameter or parameter combination, with substantiation of the conservatism of these values for site use. The individual conditions may be combined without regard to historical occurrence.

b. Select the most severe combination of controlling parameters, including diurnal variations where appropriate, for the total of the critical time period(s), based on examination of regional climatological* measurements that are demonstrated to be representative of the site. If significantly less than 30 years of representative data are available, other historical regional data should be examined to determine controlling meteorological conditions for the critical time period(s). If the examination of other historical regional data indicates that the controlling meteorological conditions did not occur within the period of record for the available representative data, then these conditions should be correlated with the available representative data and appropriate adjustments should be made for site conditions.

c. Less severe meteorological conditions may be assumed when it can be demonstrated that the consequences of exceeding lesser design basis conditions for short time periods are acceptable. Information on magnitude, persistence, and frequency of occurrence of controlling meteorological parameters that exceed the design basis conditions, based on acceptable data as discussed above, should be presented.

The above analysis related to the 30-day cooling supply and the excess temperature should include sufficient information to substantiate the assumptions and analytical methods used. This information should include actual performance data for a similar cooling method operating under load near the specified design conditions or justification that conservative evaporation and drift loss and heat transfer values have been used.

A cooling capacity of less than 30 days may be acceptable if it can be demonstrated that replenishment or use of an alternate water supply can be effected to assure the continuous capability of the sink to perform its safety functions, taking into account the availability of replenishment equipment and limitations that may be imposed on "freedom of movement" following an accident or the occurrence of severe natural phenomena.

2. The ultimate heat sink complex, whether composed of single or multiple water sources, should be capable of withstanding, without loss of the sink safety functions specified in regulatory position 1, the following events:

a. The most severe natural phenomena expected at the site, with appropriate ambient conditions, but with no two or more such phenomena occurring simultaneously,

b. The site-related events (e.g., transportation accident, river diversion) that historically have occurred or that may occur during the plant lifetime,

c. Reasonably probable combinations of less severe natural phenomena and/or site-related events,

d. A single failure of manmade structural features.

Ultimate heat sink features, which are constructed specifically for the nuclear power plant and which are not required to be designed to withstand the Safe Shutdown Earthquake or the Probable Maximum Flood, should at least be designed and constructed to withstand the effects of the Operating Basis Earthquake (as defined in 10 CFR Part 100, Appendix A) and waterflow based on severe historical events in the region.

3. The ultimate heat sink should consist of at least two sources of water, including their retaining structures, each with the capability to perform the safety functions specified in regulatory position 1, unless it can be demonstrated that there is an extremely low probability of losing the capability of a single source. For close-loop cooling systems, there should be at least two aqueducts connecting the source(s) with the intake structures of the nuclear power units and at least two aqueducts to return the cooling water to the source, unless it can be demonstrated that there is extremely low probability that a single aqueduct can functionally fail entirely as a result of natural or site-related phenomena. For once-through cooling systems, there should be at least two aqueducts connecting the source(s) with the intake structures of the nuclear power units and at least two aqueducts to discharge the cooling water well away from the nuclear power plant to ensure that there is no potential for plant flooding by the discharged cooling water, unless it can be demonstrated that there is extremely low probability that a single aqueduct can functionally fail as a result of natural or site-related phenomena. All water sources and their associated aqueducts should be highly reliable and

*Climatological in this context pertains to a recent period of record at least 30 years in length.

should be separated and protected such that failure of any one will not induce failure of any other.

4. The technical specifications for the plant should include provisions for actions to be taken in the event that conditions threaten partial loss of the capability of the ultimate heat sink or the plant temporarily does not satisfy regulatory positions 1 and 3 during operation.

D. IMPLEMENTATION

The purpose of this section is to provide information to license applicants and licensees regarding the NRC staff's plans for implementing this regulatory guide.

This guide reflects current Nuclear Regulatory Commission practice. Therefore, except in those cases in which the license applicant or licensee proposes an acceptable alternative method, the method described herein for complying with specified portions of the Commission's regulations is being and will continue to be used in the evaluation of submittals for operating license or construction permit applications until this guide is revised as a result of suggestions from the public or additional staff review.