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REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

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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 assure 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 Regulatory 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. The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

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. 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.

* Lines indicate substantive changes from previous issue.

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 assuring the continued capability of the sink beyond 30 days.

Sufficient conservatism should be provided to assure 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 replenishment 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.

The sink safety functions may be provided by natural or man-made features. More than one water source may be involved in the ultimate heat sink complex in performing these functions under different conditions. Because of the importance of the sink to safety, these functions should be assured 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 assured 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, other accidents such as transportation accidents involving 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 man-made 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. For those cases in which an applicant believes a single water source may be acceptable, it should be demonstrated that the source can withstand, without loss of the sink safety functions, the following events: (1) the most severe natural phenomena expected, taken individually, (2) the site-related events that have occurred or that may occur during the plant lifetime, (3) reasonably probable combinations of less severe natural phenomena and/or site-related events, and (4) a single failure of man-made 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 be assumed; however, it is not necessarily required that one assume 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 water flow 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 is 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 man-made 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 man-made 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 (say a man-made pond with a dam) and connecting conduit were capable of withstanding the safe shutdown earthquake, tornado, and drought, and Water Source No. 2 (say a river with an existing dam) and its connecting conduit were capable of withstanding the probable maximum flood. However, the complex as a whole must also be capable of withstanding any reasonably 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 maximum earthquake determined on the basis of historic seismicity at the sink site and water flow 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) the Commission 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 assuring a continued capability after 30 days should be available.

Sufficient conservatism should be provided to assure 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[1] of supply and/or temperature should be performed using the following:

a. Analysis supporting the availability of a 30-day cooling supply should be based on historical regional measurements combining the worst recorded 30-day period (30-day average) of maximum difference between dry bulb temperature and dewpoint temperature, ΔT, and the highest wind speeds recorded during the same 30-day period such that the combination of ΔT and wind speeds occurring simultaneously results in the maximum amount of evaporation and drift loss.

b. Analysis of the temperature problem should use the worst 1-day and worst 30-day periods of meteorological record in the region resulting in minimum heat transfer to the atmosphere and maximum plant intake temperature. Further, the worst 1-day period of record should be assumed to be the *first* day of the worst 30-day period of record. For transient temperature analysis, diurnal variations in temperature should be used for the 1-day and 30-day periods of analysis. These variations are readily estimated from local weather records. Applicants should be assured that either a normal or emergency shutdown during the worst 1-day and 30-day period of record will not result in plant intake water temperatures exceeding design basis temperatures.

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 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 C.1, the following events:

a. The most severe natural phenomena expected taken individually,

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 man-made structural features.

3. The ultimate heat sink should consist of a least two sources of water, including their retaining structures, each with the capability to perform the safety functions specified in regulatory position C.1. above, unless it can

[1] 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.

be demonstrated that there is an extremely low probability of losing the capability of a single source. There should be a least two aqueducts connecting the source(s) with the intake structures of the nuclear power units, unless it can be demonstrated that there is an extremely low probability that a single aqueduct can fail entirely as a result of natural phenomena. All water sources and their associated aqueducts should be highly reliable and 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 C.1 and C.3 above, during operation.