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Technical Lead
G. Purciarello

# REGULATORY GUIDE

## REGULATORY GUIDE 1.27

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# ULTIMATE HEAT SINK FOR NUCLEAR POWER PLANTS

## A. INTRODUCTION

**Purpose**

This regulatory guide (RG) describes methods and procedures acceptable to the staff of the U.S. Nuclear Regulatory Commission (NRC) that nuclear power plant facility licensees and applicants can use to establish ultimate heat sink (UHS) features of plant systems required by NRC rules and regulations.

Note: Passive light-water reactors have significantly different design bases for the UHS than traditional plants that use active systems. For passive plants, the passive containment cooling system (PCCS) may be used as the UHS. The guidance provided in this regulatory guide does not apply to passive plants that utilize a PCCS as their UHS.

**Applicable Rules and Regulations**

- General Design Criterion (GDC) 1, "Quality Standards and Records," in Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10 of the *Code of Federal Regulations,* Part 50, "Domestic Licensing of Production and Utilization Facilities (10 CFR Part 50) (Ref. 1) requires in part, that structures, systems, and components (SSCs) important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function. A quality assurance program shall be established and implemented in order to provide adequate assurance that these SSCs will satisfactorily perform their safety functions.

- GDC 2, "Design Bases for Protection Against Natural Phenomena," requires that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these SSCs shall reflect: (1) appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of

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normal and accident conditions with the effects of the natural phenomena, and (3) the importance of the safety functions to be performed.

- GDC 4, "Environmental and Dynamic Effects Design Bases," requires, in part, that SSCs important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. These SSCs shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.

- GDC 5, "Sharing of Structures, Systems, and Components," requires that SSCs important to safety shall not be shared among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units.

- GDC 44, "Cooling Water," requires, in part, that a system to transfer heat from SSCs important to safety, to an ultimate heat sink shall be provided. The system safety function shall be to transfer the combined heat load of these SSCs under normal operating and accident conditions. Suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities shall be provided to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished, assuming a single failure.

- GDC 45, "Inspection of Cooling Water System," requires that the cooling water system shall be designed to permit appropriate periodic inspection of important components, such as heat exchangers and piping, to assure the integrity and capability of the system.

- GDC 46, "Testing of Cooling Water System," requires that the cooling water system shall be designed to permit appropriate periodic pressure and functional testing to assure: (1) the structural and leak-tight integrity of its components, (2) the operability and the performance of the active components of the system, and (3) the operability of the system as a whole and, under conditions as close to design as practical, the performance of the full operational sequence that brings the system into operation for reactor shutdown and for loss-of-coolant accidents, including operation of applicable portions of the protection system and the transfer between normal and emergency power sources.

- 10 CFR 50.65 "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants", also known as the Maintenance Rule, requires in part that SSCs that are relied upon to remain functional during and following design basis events be subjected to performance monitoring in a manner sufficient to provide assurance that they will perform their safety functions, as designed.

- In addition, nuclear power plant facility licensees and applicants must meet the minimum requirements for quality assurance (QA) in Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50.

- These regulatory criteria apply to an application for a construction permit or operating license under 10 CFR Part 50, or an application for a standard design certification, combined license, or standard design approval under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants" (Ref. 2).

Note: The requirements for physical protection of plants are outside the scope of the RG and can be found in 10 CFR 73, "Physical Protection of Plants and Materials".

**Purpose of Regulatory Guides**

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required.

**Paperwork Reduction Act**

This regulatory guide contains information collection requirements covered by 10 CFR Part 50 and 10 CFR Part 52 that the Office of Management and Budget (OMB) approved under OMB control number 3150-0011 and 3150-0151, respectively. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

# B. DISCUSSION

**Reason for Revision**

This revision (Revision 3) of this guide addresses revisions in regulations and lessons learned from operating experience since the guide was last revised in January 1976, including system design considerations, natural phenomena and site hazards design criteria, and periodic inspection and maintenance considerations. This revised guide contains information applicable to both current operating plants and new plants being licensed under both 10 CFR Parts 50 and 52.

**Background**

The UHS is the system of structures and components and associated assured water supply and atmospheric condition(s) credited for functioning as a heat sink to absorb reactor residual heat and essential station heat loads after a normal reactor shutdown or a shutdown following an accident or transient including a loss-of-coolant accident (LOCA). This includes those necessary water-retaining structures (e.g., a pond, a reservoir with its dam) and the canals, aqueducts, or piping systems connecting those cooling water sources with the essential or safety-related cooling water intake structure of the nuclear power units. Non-safety systems (e.g., circulating water supply) may share this safety-related water supply. If cooling towers or portions of cooling towers are required to accomplish the UHS safety functions, they should satisfy the same requirements as the UHS.

The UHS performs three principal safety functions: (1) dissipation of residual heat after reactor shutdown, (2) dissipation of residual heat after an accident such as a LOCA and (3) dissipation of maximum expected decay heat from the spent fuel pool to ensure the pool temperature remains within the design bounds for the structure. For a single nuclear power unit, the UHS should be capable of providing sufficient cooling water to accomplish these safety functions.

A UHS complex serving multiple units should be able to provide sufficient cooling water to SSCs important to safety to permit the simultaneous safe shutdown and cooldown of all units and maintain them in a safe-shutdown condition. In the event of an accident in one unit, the UHS should be able to dissipate the heat for that accident safely, permit the concurrent safe shutdown and cooldown of the remaining units, maintain them in a safe-shutdown condition, and dissipate maximum expected decay heat of the spent fuel pools.

The capacity of the UHS should be sufficient to provide cooling for the time necessary to evaluate the situation and take corrective action. A period of 30 days is considered adequate for these purposes. In addition, procedures should be available for ensuring the continued capability of the UHS beyond 30 days. A capacity of less than 30 days may be acceptable if it can be demonstrated that replenishment can be effected to ensure the continuous capability of the UHS to perform its safety functions, taking into account the availability of replenishment equipment and limitations that may be imposed following an accident or severe natural event.

Sufficient conservatism should be provided to ensure that a safety-related water supply for a 30-day cooling capacity is available (e.g., there is a 30-day supply of water available for those UHSs relying on evaporation) and that the design-basis temperatures of equipment that is important to safety are not exceeded. For UHSs where the water supply may be limited or the temperature of plant intake water from the UHS may become critical (e.g., ponds, lakes, cooling towers, or other UHSs where recirculation between plant cooling water discharge and intake can occur), transient analyses of supply and/or temperature should be performed. Techniques for selecting the meteorological conditions for minimum heat transfer and examples for performing the transient analysis for cooling ponds, spray ponds and wet cooling towers are provided in NUREG-0693, "Analysis of Ultimate Heat Sink Cooling Ponds" (Ref. 3), NUREG-0733, "Analysis of Ultimate Heat Sink Spray Ponds" (Ref. 4), and a technical report titled "Method for Analysis of Ultimate Heat Sink Cooling Tower Performance" (Ref. 5), respectively. Design inputs for wind functions and wind gradients and UHS modeling are unique to each facility and should be justified for cooling ponds and spray ponds. In addition, UHS cooling towers should be designed for the potential effects of recirculation (defined as some portion of the saturated air leaving a tower being induced back into the same tower's air inlets) and interference (defined as a portion of the saturated effluent of an upwind tower contaminating the ambient intake air of a downwind tower). The design, location, and orientation of the towers can influence the entering wet-bulb temperature, which can require additional wet-bulb temperature margins ranging from 0.5 °F to 4 °F (typical value) or in some adverse siting cases 10 °F wet-bulb or higher. These additional wet-bulb temperature margins should be determined on a case-by-case basis.

The meteorological conditions considered in the design of the UHS to ensure sufficient cooling for at least 30 days should be selected with respect to the controlling parameter(s) and critical time periods unique to the specific design of the UHS. Critical time periods are associated with UHSs that recycle water and/or rely on evaporation for cooling and are not relevant to oceans, large lakes or rivers where water is not recycled or where evaporation is not a factor in UHS performance. One critical time period is associated with ensuring that the design basis temperatures of equipment that is important to safety are not exceeded. This critical time period would be the time interval after a DBA to when the intake water to the plant from the UHS reaches its maximum value. The meteorological conditions resulting in the maximum intake water temperature to the plant from the UHS should be the worst combination of controlling parameters, including diurnal variations, where appropriate, for the critical time periods unique to the specific design of the UHS. Determining the maximum intake water temperature to the plant from the UHS after a DBA and the associated critical time period can be an iterative process since the maximum intake water temperature to the plant from the UHS can be a function of meteorological conditions, plant heat input, and recirculation time. Another critical time period is associated with ensuring the availability of a 30-day cooling supply. The meteorological conditions resulting in maximum evaporation should be the worst 30-day combination of controlling parameters specific to the design of the UHS.

For example, if a wet cooling tower is used as the UHS, the controlling parameter would be a wet-bulb temperature. Therefore, a transient analysis for the maximum cooling tower water basin temperature should be conducted using the maximum observed (based on representative regional climatological information) wet-bulb temperature in the 30-year weather period coincident with the highest plant heat ejection rates. As another example, the transient analysis for the maximum UHS temperature to the plant from a cooling pond should consider the most severe combination of controlling meteorological parameters (e.g., dew point temperature, dry bulb temperature, solar radiation, wind speed and direction, etc.), and recirculation of plant heat load occurring coincidently with the highest heat rejection and flow rates to the pond. The transient analysis can be performed by either: a) first determining the applicable most severe combination of meteorological parameters for the critical time period associated with peak UHS intake temperature for the particular UHS design, then calculating the peak UHS intake temperature to the plant and finding the most severe combination of meteorological parameters for inventory loss and then verifying a 30 day supply, or b) performing the transient analysis numerous times throughout the entire 30 year weather period to find the same peak UHS intake temperature to the plant and corresponding assurance of a 30 day supply for throughout the 30 years of meteorological data.

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

For instances where the UHS structure is partially embedded in the ground or in contact with ground water, the structural design should include the buoyancy forces of ground water on the foundation. If ground water is used for makeup of UHS water supply, the potential effects of settlement or land subsidence should be evaluated. Sedimentation buildup of sand and/or silt over time should be considered in the design of the UHS.

There should be a high level of assurance that the UHS's water sources will be available when needed. For natural sources, historical experience indicates that river blockage (e.g., ice dams or flood debris) or diversion may be possible, as well as potential changes in ocean, river, or lake levels as a result of severe natural events, or possible changes in climatological conditions in the site region resulting from human or natural causes that may occur during the plant lifetime. For manmade portions, particularly structures above ground, failures are not uncommon. Because of these factors, a UHS comprising at least two water sources should be considered; each source should be capable of performing the UHS safety functions, unless it can be demonstrated that there is an extremely low probability of losing the capability of a single source.

Examples of UHSs that the staff has found acceptable are as follows:

- a large river,
- a large lake,
- an ocean,
- two spray ponds,[1]
- a spray pond[1] and a reservoir,
- a spray pond[1] and a river,
- two mechanical draft towers with basins,[1]
- a mechanical draft tower with a basin[1] and a river,
- a mechanical draft tower with a basin[1] and a lake,
- a cooling lake with a submerged pond,[1] and
- two wet/dry forced draft towers.[1]

The UHS complex, whether supplied by single or multiple water sources, should be capable of withstanding, without loss of the UHS safety functions, all of the following events:

1. the most severe natural phenomena expected at the site in accordance with GDC 2,

2. the site-related events (e.g., river blockage, river diversions, reservoir depletion, ship collisions, airplane crashes, oil spills, fires) that have occurred or may occur during the lifetime of the plant,

3. appropriate combinations of less severe natural phenomena and/or site-related events,

4. failure of reservoirs, dams, and other manmade water retaining structures both upstream and downstream of the site including the potential for resultant debris to block water flow, and

5. potential changes in ocean, river, or lake levels as a result of severe natural events, or possible changes in climatological conditions in the site region resulting from human or natural causes, that may occur during the plant lifetime.

In applying this approach, various mechanistic failure modes should be postulated. A licensee or applicant 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. As another example, the consequences of a postulated slide of earthen canal walls should be assumed; however, it is not necessarily required to assume that waterflow ceases completely. Realistic assumptions about potential flow blockage from resultant debris should also be made.

In cases where canals (aqueducts) or piping systems are required as part of the UHS, at least two should be provided, even if only one source of water can be demonstrated to be adequate. However, a single canal (aqueduct) may be acceptable if it satisfies the five conditions above. In the event the UHS 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 (aqueducts) and piping systems, should be separated and protected so that failure of either one will not induce failure in any other that would preclude accomplishing the safety functions of the UHS. The UHS complex (whether it comprises an acceptable single source or multiple sources of water), but not necessarily its individual features, must be capable of withstanding each of the most severe natural phenomena expected, other site-related events, appropriate combinations of natural phenomena or site-related events, and a single failure of manmade structural features without loss of capability of the UHS to

[1] These are designated as Seismic Category I design.

accomplish its safety functions. The most severe phenomena may be considered to occur independently and not simultaneously (e.g., a tornado and an earthquake). In addition, the single failure of manmade structural features need not be considered to occur simultaneously with severe natural phenomena or site-related events unless the severe natural phenomena can cause failure of a manmade structural feature.

The UHS complex should be shown to be highly reliable by demonstrating that certain site characteristics are satisfied. Such site characteristics might include: (1) the river cannot be diverted or blocked sufficiently to affect the availability of water at the connecting piping systems, (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) is expected to function properly for the lifetime of the nuclear power unit(s). However, compliance with these site characteristics would not 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. To ensure that the UHS has sufficient water available for its safety functions if a dam or other water-controlling structure is required, the dam or other water-controlling structure, within the jurisdiction of the licensee/applicant, and connecting piping systems should be included in the Structures Monitoring Program in accordance with Regulatory Guide 1.160 (Ref. 6) and the Maintenance Rule at 10 CFR 50.65. Inspection and monitoring of dams or other water control structures should be conducted to ensure that changes in structural, hydraulic and foundation conditions can be detected. Regulatory Guide 1.127, "Inspection of Water-Control Structures Associated with Nuclear Power Plants" (Ref. 7) provides more details on inspection and performance monitoring of water-controlling structures.

Structural components not required to be designed to withstand the most severe natural phenomena in accordance with GDC 2 should at least be designed and constructed to withstand the effects of the operating-basis earthquake, as defined in Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to 10 CFR Part 100, "Reactor Site Criteria" (Ref. 8), or Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to 10 CFR Part 50, as applicable.

The importance of the UHS to nuclear safety is such that, if during plant operation the capability of the UHS is threatened (e.g., to permit necessary maintenance or as a result of damage), restrictions should be placed on plant operation. The technical specifications should specify a limiting condition for operation and state the actions to be taken if the UHS limiting condition for operation is temporarily unavailable during the operating modes.

**Harmonization with International and Industry Standards**

The International Atomic Energy Agency (IAEA) has established a series of safety guides and standards constituting a high level of safety for protecting people and the environment. IAEA safety guides present international good practices and increasingly reflect best practices to help users striving to achieve high levels of safety. Relative to this regulatory guide, IAEA Safety Guide No. NS-G-1.9, "Design of the Reactor Coolant System and Associated Systems in Nuclear Power Plants" (Ref. 9), issued in 2004, addresses UHS design considerations. The NRC has an interest in facilitating the harmonization of standards used domestically and internationally. In this case, there are many similar elements between this RG and the corresponding sections of the safety guide. This RG consistently implements and details the principles and basic safety aspects presented in IAEA Safety Guide No. NS-G-1.9.

American National Standards Institute/American Nuclear Society (ANSI/ANS) Standard 2.21-2012, "Criteria for Assessing Atmospheric Effects on the Ultimate Heat Sink," (Ref. 10) has been reviewed for applicability to this guide. This ANSI/ANS standard describes atmospheric effects for consideration when designing ultimate heat sinks for safety-related systems at nuclear power plants. Guidance from the ANSI/ANS standard has been incorporated in this guide where appropriate.

**Documents Discussed in Staff Regulatory Guidance**

This regulatory guide endorses the use of one or more codes or standards developed by external organizations, and other third party guidance documents. These codes, standards and third party guidance documents may contain references to other codes, standards or third party guidance documents ("secondary references"). If a secondary reference has itself been incorporated by reference into NRC regulations as a requirement, then licensees and applicants must comply with that standard as set forth in the regulation. If the secondary reference has been endorsed in a regulatory guide as an acceptable approach for meeting an NRC requirement, then the standard constitutes a method acceptable to the NRC staff for meeting that regulatory requirement as described in the specific regulatory guide. If the secondary reference has neither been incorporated by reference into NRC regulations nor endorsed in a regulatory guide, then the secondary reference is neither a legally-binding requirement nor a "generic" NRC approval as an acceptable approach for meeting an NRC requirement. However, licensees and applicants may consider and use the information in the secondary reference, if appropriately justified and consistent with current regulatory practice, consistent with applicable NRC requirements such as 10 CFR 50.59, "Changes, tests and experiments."

# C. STAFF REGULATORY GUIDANCE

## 1. System Design Considerations for the Ultimate Heat Sink

a. The UHS should be capable of providing sufficient cooling for at least 30 days to: (1) permit simultaneous safe shutdown and cooldown of all nuclear reactor units that it serves and to maintain them in a safe-shutdown condition, and (2) in the event of an accident in one unit, to limit the effects of that accident safely, to permit simultaneous and safe shutdown and cooldown of any remaining units, and to maintain them in a safe-shutdown condition. Procedures should be available for ensuring a continued capability of the UHS to provide sufficient cooling after 30 days.

b. Sufficient conservatism should be provided to ensure that a 30-day cooling supply is available and that design-basis temperatures of equipment that is important to safety are not exceeded. For UHSs where the water supply may be limited or the temperature of plant intake water from the UHS eventually may become critical (e.g., ponds, lakes, cooling towers, or other UHSs where recirculation between plant cooling water discharge and intake can occur), transient analyses of supply and/or temperature, as appropriate, should be performed. The transient analysis for the effluent from one unit affecting the performance of an adjacent unit should also be considered, for both normal operation and accident conditions. The analysis should account for all variations of design parameters and the full range of operating conditions that may exist at the time of the postulated event. This type of analysis is commonly accomplished when the most severe set of operating parameters and/or operational conditions is assumed to occur simultaneously and is commonly referred to as a bounding analysis. Alternatives to this approach should be communicated to the NRC staff for review. UHS cooling towers should be designed for the potential effects of recirculation and interference.

c. For UHSs that rely on evaporation or where loss of inventory can affect UHS functions, the meteorological conditions resulting in maximum cooling water loss should be the worst 30-day combination of controlling parameters.

d. The meteorological conditions resulting in the maximum intake water temperature to the plant from the UHS should be the worst combination of controlling parameters, including diurnal variations for the critical time period(s) unique to the specific design of the UHS.

e. The bases and procedures used to select and develop bounding meteorological conditions should be provided and justified. The following are acceptable methods for selecting these conditions:

   (1) Transient analyses used to predict the maximum intake water temperature to the plant and the maximum 30-day water usage should be based on regional climatological data, with substantiation of the conservatism of the data for site use. The climatological measurements used for this analysis should be based on a recent period of record at least 30 years in length and should be demonstrated to be representative of conditions that may occur at the site. If significantly less than 30 years of representative data are available, other historical regional data (including, if available, quality assured onsite meteorological data) should be examined to determine the controlling meteorological conditions for the critical time period(s). If an 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, these conditions should be correlated with the available representative data and appropriate adjustments should be

made for site conditions. Current literature on possible changes in the climatological conditions in the site region should also be reviewed to be confident that the methods used to predict weather extremes are reasonable.

(2) In rare cases, design-basis meteorological conditions less severe than those suggested in Regulatory Position C.1.e (1) may be assumed when it can be demonstrated that the consequences of actual meteorological conditions exceeding the assumed design-basis conditions for short time periods can be accommodated by the applicable design (for example, short-term excursions of ambient wet-bulb temperatures exceeding a cooling tower's design-basis wet-bulb). Information on magnitude, persistence, and frequency of occurrence of controlling meteorological parameters that exceed the design-basis conditions, based on representative climatological data as discussed above, should be presented.

f. The above analyses related to the 30-day cooling supply and peak UHS intake water temperature to the plant 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, drift loss (if applicable), and heat transfer values have been used.

g. 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 ensure the continuous capability of the UHS to perform its safety functions. The availability of replenishment equipment and limitations that may be imposed following a DBA or the occurrence of severe natural phenomena should be considered.

h. Construction materials should be fire resistant. However, buried piping and spray pond piping may be constructed of fiberglass-reinforced thermosetting resin as long as the use of such material is within the limitations of RG 1.72, "Spray Pond Piping Made from Fiberglass-Reinforced Thermosetting Resin" (Ref. 11), and Table 2 of RG 1.84, "Design, Fabrication, and Materials Code Case Acceptability, ASME Section III" (Ref. 12).

i. Heat loads that are important to safety or must be cooled during the 30-day period by the UHS should be included in determining the UHS thermal performance, such as the heat loads from the spent fuel pool and operating pumps.

j. UHS mechanical components, such as pumps, valves, and cooling tower fans, should automatically start and open/close as appropriate to support DBA heat loads. If the UHS mechanical component does not incorporate design features that automatically start and open/close, operator actions are required to support its intended safety function. For example, placing UHS safety-related makeup water in service to the UHS cooling tower may require operator actions to start makeup pumps to satisfy the 30 days UHS water inventory. RG 1.62, "Manual Initiation of Protective Actions" (Ref. 13) provides guidance for manual initiation of protective actions.

k. UHS inventory to support the 30 day period for UHSs where the water supply may be limited, (e.g., ponds, lakes, cooling towers) should account for potential water losses such as evaporation, cooling tower drift, boundary leakage to include valve seat leakage and seepage, etc.

## 2. Natural Phenomena and Site Hazards Design for the Ultimate Heat Sink

a. The UHS complex, whether supplied by single or multiple water sources, should be capable of withstanding, without loss of the UHS safety functions, all of the following events:

(1) the most severe natural phenomena expected at the site in accordance with GDC 2;

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

(3) appropriate combinations of less severe natural phenomena and/or site-related events;

(4) failure of reservoirs, dams, and other manmade water retaining structures both upstream and downstream of the site including the potential for resultant debris to block water flow; and

(5) potential changes in ocean, river, or lake levels as a result of severe natural events, or possible changes in climatological conditions in the site region resulting from human or natural causes, that may occur during the plant lifetime.

b. UHS features constructed specifically for normal operation and shutdown of the nuclear power unit(s) that do not provide a post-accident safety function and are not required to be designed to withstand the most severe natural phenomena in accordance with GDC 2, should at least be designed and constructed to withstand the effects of the operating-basis earthquake as defined in Appendix A to 10 CFR Part 100 or Appendix S to 10 CFR Part 50, as applicable.

c. The potential for adverse environmental conditions, such as icing, should be considered in determining UHS performance. If applicable, the potential for water freezing in the UHS water storage facility should also be analyzed.

d. The UHS complex should be designed to accommodate the effects of missiles inside and outside of containment, effects of pipe whip, jets, environmental conditions from high and moderate energy line breaks, and dynamic effects of flow instabilities and attendant loads (i.e., water hammer) during normal plant operation as well as upset or accident conditions in accordance with GDC 4.

e. Operating experience from other similarly designed and sited power plants should be used as appropriate. For example, if the UHS relies on cooling water from a reservoir, lake, or ocean, etc., the design should accommodate potential clogging of suction flow paths from silt, aquatic fauna such as fish, and biological growth such as seaweed (see Information Notice (IN) 2004-07 "Plugging of Safety Injection Pump Lubrication Oil Cooler with Lakeweed" dated April 7, 2004 (Ref. 14) and IN 2006-17 "Recent Operating Experience of Service Water Systems Due to External Conditions" dated July 31, 2006 (Ref. 15)).

## 3. Defense-in-Depth Considerations

a. The UHS 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.a, unless it can be demonstrated that there is an extremely low probability of losing the capability of a single source. For closed-loop cooling systems, at least two canals (aqueducts) or piping systems should connect the source(s) with the intake structures of the nuclear power unit(s), and at least two canals (aqueducts) or piping systems should return the cooling water to the source(s), unless it can be demonstrated that there is extremely low probability that a single canal (aqueduct) or piping system can functionally fail entirely as a result of natural or site-related phenomena. For once-through cooling systems, at least two canals (aqueducts) or piping systems should connect the source(s) with the intake structures of the nuclear power units, and at least two canals (aqueducts) or piping systems should 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 canal (aqueduct) or piping system can functionally fail as a result of natural or site-related phenomena.

b. All water sources and their associated canals (aqueducts) or piping systems should be highly reliable and separated and protected so that failure of any one will not induce failure of any other.

**4. Technical Specifications**

The technical specifications for the plant should include provisions for actions to be taken if conditions threaten partial loss of the capability of the UHS or the plant temporarily does not satisfy Regulatory Positions 1 through 3 during operation (e.g., UHS water temperature, UHS water volume).

**5. Inspection, Maintenance, and Performance Testing**

a. A routine inspection and maintenance program should be established for the UHS system piping, structures, and components. This program should be able to detect corrosion, erosion, protective coating failure, silting, and bio-fouling so that degradation can be identified and corrective action can be taken before the performance of the safety-related systems is negatively impacted.

b. Both the initial pre-service test program and the periodic test program should encompass those safety-related heat exchangers that are connected to the UHS and required for the UHS to perform its nuclear safety-related functions.

c. Performance testing of the UHS heat exchangers should be in accordance with ASME-OM-2012 "Operation and Maintenance of Nuclear Power Plants," Division 2 "OM Standards," Part 21, "In-service Performance Testing of Heat Exchangers in Light Water Reactor Power Plants" (Ref. 16), or an equivalent test method.

d. Where a dam or other water-controlling structure is required to ensure that the UHS has sufficient water available for its safety functions, the dam or other water-controlling structure and connecting piping systems within the jurisdiction of the licensee should be included in the Structures Monitoring Program in accordance with Regulatory Guide 1.160 and the Maintenance Rule at 10 CFR 50.65. Inspection and monitoring of dams or other water control structures should be conducted to ensure that changes in structural, hydraulic and foundation conditions can be detected. RG 1.127 provides more details on inspection and performance monitoring of water-controlling structures.

**6. Water Chemistry and Microbiological Control**

a. The quality of the water used in cooling towers, spray ponds, and heat exchangers should be considered in the design and operation of the UHS because it can greatly affect the thermal performance of the UHS (see Generic Letter 89-13, "Service Water System Problems Affecting Safety-Related Equipment," dated July 18, 1989 (Ref. 17), and IN 2007-28, "Potential Common

Cause Vulnerabilities in Essential Service Water Systems Due to Inadequate Chemistry Controls," dated September 19, 2007 (Ref. 18)). Chemicals or other preventive measures may be needed to treat microbiological growth, macrobiological growth, corrosion, suspended solids fouling and scaling in nuclear power plant water systems that are part of the UHS. However, licensees and applicants are cautioned that the use of specific chemicals may need to be approved by other Federal, State, and local environmental agencies.

b. Redundant and infrequently used cooling loops should be flushed and flow tested periodically at the maximum design flow to ensure that they are not fouled or clogged, and that they are capable of passing the design flow.

# D. IMPLEMENTATION

The purpose of this section is to provide information on how applicants and licensees[2] may use this guide and information regarding the NRC's plans for using this regulatory guide. In addition, it describes how the NRC staff complies with 10 CFR 50.109, "Backfitting" and any applicable finality provisions in 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

**Use by Applicants and Licensees**

Applicants and licensees may voluntarily[3] use the guidance in this document to demonstrate compliance with the underlying NRC regulations. Methods or solutions that differ from those described in this regulatory guide may be deemed acceptable if they provide sufficient basis and information for the NRC staff to verify that the proposed alternative demonstrates compliance with the appropriate NRC regulations. Current licensees may continue to use guidance the NRC found acceptable for complying with the identified regulations as long as their current licensing basis remains unchanged.

Licensees may use the information in this regulatory guide for actions which do not require NRC review and approval such as changes to a facility design under 10 CFR 50.59. Licensees may use the information in this regulatory guide or applicable parts to resolve regulatory or inspection issues.

**Use by NRC Staff**

During regulatory discussions on plant specific operational issues, the staff may discuss with licensees various actions consistent with staff positions in this regulatory guide, as one acceptable means of meeting the underlying NRC regulatory requirement. Such discussions would not ordinarily be considered backfitting even if prior versions of this regulatory guide are part of the licensing basis of the facility. However, unless this regulatory guide is part of the licensing basis for a facility, the staff may not represent to the licensee that the licensee's failure to comply with the positions in this regulatory guide constitutes a violation.

If an existing licensee voluntarily seeks a license amendment or change and (1) the NRC staff's consideration of the request involves a regulatory issue directly relevant to this new or revised regulatory guide and (2) the specific subject matter of this regulatory guide is an essential consideration in the staff's

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2 In this section, "licensees" refers to licensees of nuclear power plants under 10 CFR Parts 50 and 52; and the term "applicants," refers to applicants for licenses and permits for (or relating to) nuclear power plants under 10 CFR Parts 50 and 52, and applicants for standard design approvals and standard design certifications under 10 CFR Part 52.

3 In this section, "voluntary" and "voluntarily" mean that the licensee is seeking the action of its own accord, without the force of a legally binding requirement or an NRC representation of further licensing or enforcement action.

determination of the acceptability of the licensee's request, then the staff may request that the licensee either follow the guidance in this regulatory guide or provide an equivalent alternative process that demonstrates compliance with the underlying NRC regulatory requirements. This is not considered backfitting as defined in 10 CFR 50.109(a)(1) or a violation of any of the issue finality provisions in 10 CFR Part 52.

The NRC staff does not intend or approve any imposition or backfitting of the guidance in this regulatory guide. The NRC staff does not expect any existing licensee to use or commit to using the guidance in this regulatory guide, unless the licensee makes a change to its licensing basis. The NRC staff does not expect or plan to request licensees to voluntarily adopt this regulatory guide to resolve a generic regulatory issue. The NRC staff does not expect or plan to initiate NRC regulatory action which would require the use of this regulatory guide. Examples of such unplanned NRC regulatory actions include issuance of an order requiring the use of the regulatory guide, requests for information under 10 CFR 50.54(f) as to whether a licensee intends to commit to use of this regulatory guide, generic communication, or promulgation of a rule requiring the use of this regulatory guide without further backfit consideration.

Additionally, an existing applicant may be required to adhere to new rules, orders, or guidance if 10 CFR 50.109(a) (3) applies.

If a licensee believes that the NRC is either using this regulatory guide or requesting or requiring the licensee to implement the methods or processes in this regulatory guide in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfit appeal with the NRC in accordance with the guidance in NUREG-1409, "Backfitting Guidelines," (Ref. 19) and the NRC Management Directive 8.4, "Management of Facility-Specific Backfitting and Information Collection" (Ref. 20).

# REFERENCES[4]


1. Code of Federal Regulations (CFR)*, Title 10, Energy,* Part 50, "Domestic Licensing of Production and Utilization Facilities."

2. Code of Federal Regulations (CFR)*, Title 10, Energy*, Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

3. NUREG-0693, "Analysis of Ultimate Heat Sink Cooling Ponds," U.S. Nuclear Regulatory Commission, Washington, DC.

4. NUREG-0733, "Analysis of Ultimate Heat Sink Spray Ponds," U.S. Nuclear Regulatory Commission, Washington, DC.

5. Dunn, W. E. and Sullivan, S. M., "Method for Analysis of Ultimate Heat Sink Cooling Tower Performance," University of Illinois at Urbana-Champaign, April 1986 (ADAMS Accession No. ML12146A145).

6. Regulatory Guide 1.160 "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants" U.S. Nuclear Regulatory Commission, Washington, DC.

7. Regulatory Guide 1.127, "Inspection of Water-Control Structures Associated with Nuclear Power Plants" U.S. Nuclear Regulatory Commission, Washington DC.

8. Code of Federal Regulations (CFR)*, Title 10, Energy*, Part 100, "Reactor Site Criteria."

9. IAEA Safety Guide No. NS-G-1.9, "Design of the Reactor Coolant System and Associated Systems in Nuclear Power Plants," International Atomic Energy Agency, Vienna, Austria.[5]

10. ANSI/ANS 2.21-2012, "Criteria for Assessing Atmospheric Effects on the Ultimate Heat Sink," American Nuclear Society, La Grange Park, IL, June 2012.[6]

11. Regulatory Guide 1.72, "Spray Pond Piping Made from Fiberglass-Reinforced Thermosetting Resin," U.S. Nuclear Regulatory Commission, Washington, DC.

12. Regulatory Guide 1.84, "Design, Fabrication, and Materials Code Case Acceptability, ASME Section III," U.S. Nuclear Regulatory Commission, Washington, DC.


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[4] Publicly available NRC published documents are available electronically through the NRC library on the NRC's public Web site at: http://www.nrc.gov/reading-rm/doc-collections/. The documents can also be viewed on-line or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone 301-415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail PDR.Resource@nrc.gov.

[5] Copies of International Atomic Energy Agency (IAEA) documents may be obtained through their Web site: www.IAEA.Org/ or by writing the International Atomic Energy Agency P.O. Box 100 Wagramer Strasse 5, A-1400 Vienna, Austria. Telephone (+431) 2600-0, Fax (+431) 2600-7, or E-Mail at Official.Mail@IAEA.Org

[6] Copies of American Nuclear Society (ANS) standards may be purchased from the ANS Web site (http://www.new.ans.org/store/); or by writing to: American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois 60526, U.S.A., Telephone 800-323-3044

13. Regulatory Guide 1.62, “Manual Initiation of Protective Actions” U.S. Nuclear Regulatory Commission, Washington DC.

14. Information Notice 2004-07 “Plugging of Safety Injection Pump Lubrication Oil Cooler with Lakeweed” U. S. Nuclear Regulatory Commission, Washington, DC, April 7, 2004 (ADAMS Accession No. ML040770145).

15. Information Notice 2006-17 “Recent Operating Experience of Service Water Systems Due to External Conditions,” U.S. Nuclear Regulatory Commission, Washington, DC July 31, 2006 (ADAMS Accession No. ML061510292).

16. ASME OM-2012, “Operation and Maintenance of Nuclear Power Plants,” Division 2 “OM Standards”, Part 21, “In-service Performance Testing of Heat Exchangers in Light Water Reactor Power Plants,” American Society of Mechanical Engineers, New York, NY, 2012.[7]

17. Generic Letter 89-13, “Service Water System Problems Affecting Safety-Related Equipment,” U.S. Nuclear Regulatory Commission, Washington, DC, July 18, 1989 (ADAMS Accession No. ML031150348).

18. Information Notice 2007-28, “Potential Common Cause Vulnerabilities in Essential Service Water Systems Due to Inadequate Chemistry Controls,” U.S. Nuclear Regulatory Commission, Washington, DC, September 19, 2007 (ADAMS Accession No. ML071920514).

19. NUREG-1409, “Backfitting Guidelines,” U.S. Nuclear Regulatory Commission, Washington, DC.

20. Management Directive 8.4, “Management of Facility-specific Backfitting and Information Collection,” U.S. Nuclear Regulatory Commission, Washington, DC.

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[7] Copies of American Society of Mechanical Engineers (ASME) standards may be purchased from ASME, Two Park Avenue, New York, New York 10016-5990; telephone (800) 843-2763. Purchase information is available through the ASME Web based store at http://www.asme.org/Codes/Publications/.