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OFFICE OF STANDARDS DEVELOPMENT

REGULATORY GUIDE 1.102

FLOOD PROTECTION FOR NUCLEAR POWER PLANTS

A. INTRODUCTION

General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires that structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as floods, tsunami, and seiches without loss of capability to perform their safety functions. Criterion 2 also requires that the design bases for these structures, systems, and components reflect:

1. Appropriate consideration of the most severe natural phenomena that have been historically reported for the site and surrounding region, with sufficient margin for the limited accuracy and quantity of the historical data and the period of time in which the data have been accumulated;

2. Appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena; and

3. The importance of the safety functions to be performed.

Paragraph 100.10(c) of 10 CFR Part 100, "Reactor Site Criteria," requires that physical characteristics of the site, including seismology, meteorology, geology, and hydrology, be taken into account in determining the acceptability of a site for a nuclear power reactor.

Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to 10 CFR Part 100 identifies the investigations necessary for a detailed study of seismically induced floods and water waves. The appendix requires that design bases for seismically induced floods and water waves take into consideration the results of geologic and seismic investigations and that these design bases be taken into account in the design of the nuclear power plant.

Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants," describes acceptable methods of determining the design basis flood conditions that nuclear power plants located on sites along streams must withstand without loss of safety-related functions. It also discusses the phenomena producing comparable design basis floods for coastal, estuary, and Great Lakes sites. The guide states that examples of the type of flood protection to be provided for nuclear power plants will be the subject of a separate regulatory guide.

This guide describes types of flood protection acceptable to the NRC staff for the safety-related structures, systems, and components identified in Regulatory Guide 1.29.* In addition, this guide describes acceptable

*Regulatory Guide 1.29, "Seismic Design Classification," identifies structures, systems, and components of light-water-cooled nuclear power plants that should be designed to withstand the effects of the Safe Shutdown Earthquake and remain functional. These structures, systems, and components are those necessary to ensure (1) the integrity of the reactor coolant pressure boundary, (2) the capability to shut down the reactor and maintain it in a safe shutdown condition, or (3) the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the guideline exposures of 10 CFR Part 100. These structures, systems, and components should also be designed to withstand conditions resulting from the design basis flood and remain functional.

It is expected that safety-related structures, systems, and components of other types of nuclear power plants will be identified in future regulatory guides. In the interim, Regulatory Guide 1.29 should be used as guidance when identifying safety-related structures, systems, and components of other types of nuclear power plants that need to be protected from floods by methods such as those suggested in this guide.

methods of protecting nuclear power plants from the effects of Probable Maximum Precipitation (PMP) falling directly on the site.*

B. DISCUSSION

Nuclear power plant structures, systems, and components important to safety should be designed to withstand, without loss of capability to perform their safety functions, the most severe flood conditions that can reasonably be postulated to occur at a site as a result of severe hydrometeorological conditions, seismic activity, or both. The flood protection features necessary to protect the safety-related structures, systems, and components should be designed for the range of precipitation, wind, and seismically induced flood conditions identified in Regulatory Guide 1.59. The water-induced effects, both static and dynamic, on the flood protection features are considered to constitute normal environmental forces for use in the design of such features. The forces are developed from the hydrologic engineering analysis of the flood conditions.

For purposes of this guide, the Design Basis Flooding Level (DBFL) is defined as the maximum water elevation attained by the controlling flood, including coincident wind-generated wave effects. The wind-generated wave component of elevation is generally controlled by fetch and water depth and may differ at locations around the plant. Further distinction must be made between estimates of "structural" effects (i.e., static and dynamic forces) and flooding or inundation effects. Additionally, the controlling flood event may be different for evaluating structural effects than for evaluating inundation effects. For example, the Probable Maximum Flood (PMF) may produce the highest water level and static forces on a given structure, but the total static and dynamic forces on the structure may be greater during a smaller (in elevation) flood wave from the seismically induced failure of an upstream dam.

For structural purposes, the significant wave height is used; for inundation considerations, the one-percent wave height is used. *Significant wave height* (H_s) is the average of the highest one-third of wind-generated waves in a representative spectrum. *One-percent wave height* (H_1), sometimes erroneously called the *maximum wave height*, is the average of the highest 1 percent of wind-generated waves in a representative spectrum. Use of the relation $H_1 = 1.67H_s$ is acceptable for determining the one-percent wave height.**

*Suggested criteria for the consideration of localized severe precipitation are contained in Section 2.4.2.3 of Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants." The definition of Probable Maximum Precipitation is contained in Regulatory Guide 1.59.

**Lines indicate substantive changes from previous issue.

Methods of flood protection for nuclear power plants fall into one of the following three types (local flooding induced by severe local precipitation will be discussed later):

1. Dry Site

The plant is built above the DBFL, and therefore safety-related structures, systems, and components are not affected by flooding.

2. Exterior Barrier

Safety-related structures, systems, and components are protected from inundation and static and dynamic forces thereof by engineered features external to the immediate plant area. Such features may, when properly designed and maintained, produce the equivalent of a dry site, although care must be taken to ensure that safety-related structures, equipment, and components are not adversely affected by the differential hydraulic head.

3. Incorporated Barrier

Safety-related structures, systems, and components are protected from inundation and static and dynamic effects by engineered features in the structure/environment interface.

Regulatory Position 2 of Regulatory Guide 1.59 provides that those structures, systems, and components necessary for safe shutdown and maintenance thereof should be protected against the DBFL. The position also suggests that, if sufficient warning time is shown to be available to bring the plant to a safe shutdown condition, some of the other safety-related structures, systems, and components identified in Regulatory Guide 1.29 do not require protection against a flood as severe as the DBFL. Use of this method of protection as an acceptable alternative requires development of emergency procedures and technical specifications. Substantiation of the adequacy of the time available will require, in part:

1. Estimating the time required to bring the plant from full-power operation to a safe shutdown mode.

2. Establishing the warning indicators that will initiate shutdown procedures. Flood stage and rate of rise are common and generally acceptable indicators. However, sites along streams downstream from the confluence of major tributaries may require an assessment of flooding potential from floods that are less than the PMF, but could exhibit faster rates of rise than the PMF.

3. Documenting that sufficient time will remain after the warning for the safe shutdown to be accomplished before water can flood any safety-related structures, systems, or components.

The regulatory positions of this guide identify several key items to be considered in developing acceptable flood-related emergency procedures.

Local PMP may produce flooding at sites otherwise considered immune from flooding. The intensity of this rainfall and the usual design of the drainage system may result in ponding in the plant yard that could produce the DBFL. Also, roofs may receive more precipitation than the roof drains are designed to discharge.

Final plant grading is usually designed to cause ponded water to flow away from safety-related buildings. Even so, some temporary ponding is to be expected. Such ponding is generally accommodated by locating penetrations above the level of temporary ponding. Plant structures, systems, and components subject to ponding are also subject to the static and dynamic forces of the ponded water. These forces are usually less, however, than the forces from other design basis events.

C. REGULATORY POSITION

1. The following paragraphs provide working definitions of the various types of flood protection acceptable to the NRC staff.

a. Dry Site

The dry site may be the result of natural terrain or it may be constructed using engineered fill. The latter type refers to the "plant island" concept, rather than the minor fill used to dress plant grade. When fill is required to raise the plant access level above design basis flood conditions, the fill is safety related and must be protected from flood effects in the same manner as safety-related dams, dikes, etc.

b. Exterior Barriers

(1) *Levee.* "A dike or embankment to protect land from inundation."* Levees are generally earthen structures, trapezoidal in cross section, and protected from erosion by armor on the face exposed to waves and current.

(2) *Seawall or Floodwall.* "A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action."* Seawalls are massive structures designed to take the full impact of the design wave. The seawall dissipates wave energy by throwing the water upward and downward. The upward deflection may result in wind-blown overtopping; the downward deflection can cause severe erosion at the toe of the seawall.

(3) *Bulkhead.* Similar to a seawall. The prime purpose is to restrain the land area. A bulkhead should not be used where it may be subject to direct wave attack.

(4) *Revetment.* "A facing of stone, concrete, etc., built to protect a scarp, embankment, or shore structure against erosion by wave action or currents."* Revetments are alternatives to seawalls and bulkheads. They protect the shore from direct wave attack by absorbing the wave energy in their interstices and on the surface of the revetment material. In this regard, riprap is more effective than smoother surfaces. Wave runup on the revetment is a function of incident wave height, revetment slope, and the nature of the revetment material. Rough surfaces reduce runup. When riprap is used, the placement of the material is critical to the effectiveness of the feature. Filling of the interstices with finer material destroys much of the energy-absorbing capabilities of the installation and may result in overtopping a structure that is otherwise adequate to prevent such overtopping.

(5) *Breakwater.* "A structure protecting a shore area, harbor, anchorage, or basin from waves."* Breakwaters may be connected to the shore or may be located entirely offshore. Wave energy is dissipated in the same manner as it is by revetments. Offshore breakwaters are used principally to reduce the wave effects that might otherwise reach safety-related structures, facilities, or components. Shore-connected breakwaters may serve the same purpose and also may be used to train discharge or intake water flow paths to limit recirculation.

c. Incorporated Barriers

Protection is provided by special design of walls and penetration closures. Walls are usually reinforced concrete designed to resist the static and dynamic forces of the DBFL and incorporate special waterstops at construction joints to prevent inleakage. Penetrations include personnel access, equipment access, and through-wall piping. Pipe penetrations are usually sealed with

*Definition from the U.S. Army Coastal Engineering Research Center, "Shore Protection Manual," Kingman Building, Fort Belvoir, Virginia 22060. Copies may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

special rubber boots and flanges. Personnel access closures that have been found acceptable include submarine doors and hatches. The hydraulic and seismic design bases for all types of closures, including waterstops, boots, and flanges, are the same as for the wall (i.e., water tightness and resistance to static and dynamic forces). In addition, the doors should open outward to ensure closure if the door is inadvertently opened during the flood event. Additionally, the plant should be designed and operated to keep doors necessary for flood protection closed during normal operation. Penetrations that are too large to close with a single door (e.g., equipment and fuel loading access) generally require stop logs or flood panels for closure. The design bases for these features are the same as above, as is the need to maintain them normally in a closed position.

Temporary flood barriers, such as sandbags, plastic sheeting, portable panels, etc., which must be installed prior to the advent of the DBFL, are not acceptable for issuance of a construction permit. However, unusual circumstances could arise after construction that would warrant consideration of such barriers. One example of unusual circumstances that might justify use of temporary barriers is a post-construction change in the flood-producing characteristics of the drainage area, as discussed in Regulatory Position 3 of Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants." In such circumstances, and with strong justification, the staff may accept temporary barriers.

2. Past experience suggests the need for guidance in establishing the shutdown technical specifications or emergency operating procedures necessary to utilize Regulatory Position 2 of Regulatory Guide 1.59. The following should be used in establishing the necessary procedures:

a. Stage (elevation)-time relations should be developed using the appropriate flood hydrograph (with coincident wind-generated wave effects) and site characteristics. River sites downstream from the confluence of major tributaries may require assessment of the flood potential from less severe flood events that may exhibit faster rates of rise than the PMF.

b. The flood stage, including design basis wind-generated wave effects and the time of occurrence within the flood event, at which any safety-related structure, system, or component (as defined in Regulatory Guide 1.29) may become degraded or inoperative should establish the completion time for all shutdown procedures.

c. Estimates of the time required for safe shutdown should be based on average rather than best-time operator performance. This time interval should be less than the time for occurrence of the event in Regulatory Position 2.b to establish the limiting values of the selected warning indicators. The procedures should consider the total DBFL; however, the indicators (usually flood stage and rate of rise) should be based on the stillwater level (i.e., DBFL less wind-generated wave effects). This precludes the masking of flood potential by less than design basis wind at the time of observation.

d. A communication system should be established to alert both onsite and offsite company personnel of flood conditions that may require subsequent shutdown of the plant. Such a system may use offsite facilities and services, such as upstream river gages and flood forecasting services, as well as direct communication between onsite and offsite company personnel.

e. The procedures in 2.c should specify that onsite plant personnel will initiate a safe shutdown on their own volition when the limiting values of the indicators are attained. Only those warning systems located at the site and under control of plant personnel should be needed to determine the limiting values of the indicators.

3. Analysis supporting the invulnerability of safety-related structures, systems, and components from the effects of local PMP should be performed using the point rainfall value of the PMP for the site area.

a. Regulatory Guide 1.59 provides guidance on obtaining PMP estimates. An analysis of the estimated depth of ponding in the plant area should also be made.

b. Roofs are usually provided with drains designed to discharge precipitation intensities considerably less than that of the PMP. The following methods of preventing undesirable buildup of standing water on the roofs of safety-related buildings have been found acceptable to the NRC staff:

(1) The parapets (a common architectural feature of nuclear power plant structures) may be deleted on one or more sides of the building. This is the most common method.

(2) The parapet height may be limited to preclude buildup of water in excess of the structural capacity of the roof for design loads.

(3) Scuppers may be installed through the parapets to discharge the standing water over the edge of the building.

(Note that limiting the parapet height or lip of the scupper to, for example, 6 inches above the roof will not necessarily limit the depth of water on the roof to 6 inches. Consideration should be given to the hydraulic head necessary to initiate flow.)

c. The load induced by the maximum depth of standing water on the roofs (including antecedent or coincident snow or ice) during the design basis event should be less than the structural capacity of the roof for design loads, and the discharge capacity of roof drains should be compared with the design basis discharge.

D. IMPLEMENTATION

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

This guide reflects current NRC staff practice. Therefore, except in those cases in which the license applicant or licensee proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein 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.