American Nuclear Society

nuclear safety design process for modular helium-cooled reactor plants

an American National Standard

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This standard does not necessarily reflect recent industry initiatives for risk informed decision-making or a graded approach to quality assurance. Users should consider the use of these industry initiatives in the application of this standard.

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American National Standard
Nuclear Safety Design Process
for Modular Helium-Cooled Reactor Plants

Secretariat
American Nuclear Society

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American National Standard

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Foreword

(This Foreword is not a part of American National Standard "Nuclear Safety Design Process for Modular Helium-Cooled Reactor Plants," ANSI/ANS-53.1-2011.)

The purpose of this standard is to provide nuclear safety criteria applicable to the design of modular helium-cooled reactor (MHR) nuclear power plants (hereinafter referred to as "plants"). To achieve this purpose, this standard provides a process that can be used to

- develop MHR top-level nuclear regulatory safety criteria;
- identify safety functions, top-level design criteria, licensing-basis events, design-basis accidents, and methods for performing safety analyses;
- determine safety classification of systems, structures, and components (SSCs);
- identify safety-related SSC special treatment requirements and defense-in-depth (DID) provisions;
- demonstrate the adequacy of DID by applying a risk-informed approach.

This standard does not address plant security design requirements or criteria. MHR security design requirements, including design-basis threats, are design elements that may be brought into the plant design process to address licensing requirements of the national nuclear regulator. In general, both deterministic and risk-based approaches may be considered in the plant security design process. It is anticipated that MHR passive safety features and inherent safety characteristics together with the use of the risk-informed nuclear safety process herein will effectively support plant security design.

This risk-informed process standard represents a new design approach for professional communities familiar with traditional, deterministic light water reactor (LWR) design processes. These include plant architect/engineers, nuclear licensing, and risk assessment professionals. This process presents an opportunity to extend traditional use of probabilistic risk assessment as applied to LWRs to MHRs and to incorporate risk insights early in the design process. Two examples are (a) modeling long-duration nonequilibrium plant conditions and (b) extensive quantification of event frequency and consequence, including uncertainty. Nuclear professional communities should develop other complementary risk-informed, performance-based consensus processes that continue to address the challenges presented with this standard.

In addition to designers, regulators, and the risk community, this standard provides a tool for plant operators who use design processes to maintain licensed plant designs. Some uses of this standard, such as SSC classification, apply beyond initial plant design, procurement, and construction into operations. Use of this standard for SSC classification also allows plant owner/operators to specify special treatments over the life of the plant for procurement, application, testing, and maintenance commensurate with risk. This standard documents an established process that nuclear design organizations can use to develop nuclear safety designs. It is anticipated that sponsors and communities of MHR-based designs will develop further specific designs with dependent standards that integrate these risk-informed characteristics. In any event, the fundamental objective of this standard is to provide clear design process guidance subordinate to the MHR's fundamental design technology. Because the traditional LWR design community is unfamiliar with MHR technology, it is expected that this standard will present the first non-LWR design process challenge.

Consider the question of secondary containment in LWRs. For high-temperature gas-cooled reactors (HTGRs), fundamentally different approaches to retention of radionuclides lead to differences in the design of the reactor building.

To specify "containment" directly, as commonly used and interpreted for LWRs, would supersede the design development process of this standard. Therefore, that is not done. The design process provided in this standard is adequate alone to assure that the containment of radionuclide safety functions is accomplished. For that reason, this standard does not specify discrete design applications that those familiar with other reactor types, like LWRs, might expect. Rather, only the fundamental attributes that distinguish an MHR are provided. Those are the minimum set of design characteristics, agreed upon by this working group, which must be met for the use of this standard.

This standard could reference documents or other standards that have been superseded or withdrawn when the standard is applied. In that case, references in the section(s) include statements that provide guidance on their use. The format of the standard provides a table at the end of each body of text that summarizes and provides succinct actionable content required. The "Summary of Requirements" tables at the end of each body of text provide that body of text's explicit requirements. Users should evaluate the requirements with the tables at the end of each body of text. In the event of a compliance question with the standard's requirements, evaluation should include the explicit body of text in the standard. The tables should be used to evaluate compliance, in the event of a question of compliance with the standard's requirements.

This standard was initiated in 1971 and released as N213, January 1974 Draft, "Nuclear Safety Criteria for the Design of Stationary Gas Cooled Reactor Plants," for comment. Waning interest in gas reactors left that early deterministic standard incomplete. Two LWR counterparts, ANSI N18.2-1973, "Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants" (redesignated ANS-51.1), and ANSI/ANS-52.1-1978, "Nuclear Safety Criteria for the Design of Stationary Boiling Water Reactor Plants," were completed and approved. Revisions of both these standards were approved in 1983 adding a form of risk-based classification; however, all these documents remained essentially deterministic compilations of the state-of-the-art design from that era.

The American Nuclear Society Gas-Cooled Reactor Design and Operation Subcommittee, ANS-28, was inaugurated in November 2003 and tasked with developing ANS-53.1. The working group was quickly formed and began development on this standard in 2004. Use of this standard does not supersede the responsibility to review and apply the top-level safety criteria (TLSC) of the authorities in the country where the user plans to license, build, and operate MHR(s). The users of this standard are responsible to review and apply the TLSC set by the authorities in whichever country the user plans to license, build, and operate MHR(s). This standard may also be used to support the preparation of an MHR safety analysis report for the purpose of MHR licensing. When used for MHR licensing, the standard does not provide the only basis for establishing the MHR safety and design criteria. The designer also assesses the applicability of the existing body of technical licensing requirements and guidance for nuclear plant licensing in the particular country of application. In this regard, the designer determines the applicability, partial applicability, or nonapplicability of these licensing requirements. The designer may also use this standard and other supporting standards to determine what additional MHR licensing technical requirements are required for important technical design and safety aspects that are not addressed by the existing body of technical licensing requirements and guidance.

In light of the 2011 disaster in Japan at Fukushima Daiichi Units 1 through 4, the ANS-28 Subcommittee stresses that those events have been considered for this standard as well as they are known at this time. Furthermore, while those issues are being developed, as a process standard, we do not anticipate that the process that this standard identifies will be changed at all. This standard does not exclude the use of any additional guidance or requirements to supplement that information.

The ANS-53.1 Working Group consisted of the entire ANS-28 Subcommittee of the American Nuclear Society. Members of ANS-28 who participated directly in the development of this standard are as follows:

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The Nuclear Facility Standards Committee (NFSC) had the following membership at the time of its approval of this standard:

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