Building a Safety Case for Advanced Reactor Designs

Charles E. Ader and N. Prasad Kadambi
US Nuclear Regulatory Commission, USA

Abstract:

The U.S. Nuclear Regulatory Commission (USNRC) is currently engaged in pre-application reviews for two advanced reactor designs: the AP1000, an advanced light water reactor; and the Pebble Bed Modular Reactor, a high temperature gas-cooled reactor. Two other pre-application reviews are planned for the GT-MHR, a high temperature gas-cooled reactor, and the IRIS, advanced light water reactor. These pre-application reviews provide for early interaction between the USNRC and the reactor designers to identify key safety and policy issues, propose paths for their resolution and establish a regulatory framework providing guidance on applicable requirements that are different from current requirements. The USNRC is also developing an advanced reactor research plan to identify research necessary to provide the data and analytical tools to support an independent assessment of the safety of these designs.

Discussion:

The U.S. Nuclear Regulatory Commission (USNRC) is currently conducting two pre-application reviews for advanced reactor designs: the AP1000, an advanced light water reactor; and the Pebble Bed Modular Reactor (PBMR), a high temperature gas-cooled reactor (HTGR). Two other pre-applications reviews are planned for the Gas Turbine-Modular Helium Reactor (GT-MHR), also an HTGR, and the International Reactor Innovative and Secure (IRIS), an advanced light water reactor. These reviews are being conducted under the framework of the USNRC's Advanced Reactor Policy Statement[1], which was first issued in 1986 and reissued in 1994. This statement sets forth the Commission's policy regarding the review of, and desired characteristics associated with, advanced reactors. For purposes of this policy statement, advanced reactors are considered those reactors that are significantly different from current generation light water reactors and includes reactors that provide enhanced margins of safety or use simplified or other innovative means to accomplish their safety function. The Commission expects that as a minimum, these advanced reactors will provide the same degree of protection of the public and the environment required for the current generation light water reactors, but also expects that they "will provide enhanced margins of safety and/or utilize simplified, inherent, passive or other innovative means to accomplish their safety function." Among the specific attributes that the Commission believes should be considered in advanced designs are: highly reliable and less complex shutdown and decay heat removal systems; longer time constants to allow more time before reaching adverse conditions; simplified safety systems; designs that incorporate defense-in-depth; and designs based on existing technology or a suitable technology development program. It is believed that incorporation of some or all of these attributes may assist in establishing acceptability or licensability of a proposed design with minimum regulatory burden and help in the understanding by the public.

Because advanced reactors are likely to have characteristics and features that are different from the existing generation of light water reactors, it is recognized that new or modified regulatory guidance may be needed and that new design features may require a commitment to a suitable technology development program to support their safety case. Accordingly, the Advanced Reactor Policy Statement encourages early interactions between the regulator and the applicant and/or designers to facilitate the early identification of safety and regulatory issues and to identify possible paths for their resolution. It is this early interaction that the USNRC is currently engaged in for the AP1000 and PBMR advanced reactor designs.

The Westinghouse AP1000 design is based on the AP600 advanced light water design that the USNRC previously reviewed and certified under 10 CFR Part 52, "Early Site Permits, Standard Design Certifications, and Combined Licenses for Nuclear Power Plants."[2] As part of the pre-application review of the AP1000, the USNRC is assessing the applicability of the AP600 test program and analysis codes to the AP1000 design. This early identification of technical and safety issues, along with any necessary technology development programs, will support a decision by Westinghouse regarding the feasibility of seeking a design certification for the AP1000. Because it is estimated that about 80% of the AP1000 design is similar to the AP600 design, the safety review efforts are expected to be less challenging than for other advanced reactors such as the PBMR.

The PBMR is a modular HTGR under development in the Republic of South Africa and is being considered for licensing in the United States by Exelon Generation, USA. The proposed design includes certain innovative aspects of design, technology, and operating characteristics that are unique to the PBMR. As such, because many of the current USNRC reactor regulations are specific to light water reactors, they may not be applicable to the PBMR. Likewise, due to the different technology and approach to safety employed by the PBMR, new requirements will likely be necessary in some areas. Because of the more limited operating experience with HTGR technology, the pre-application activities for the PBMR include a preliminary assessment of both HTGR technology and PBMR specific technology to identify key safety and policy issues. HTGRs, such as the PBMR, involve characteristics that make their approach to protecting public health and safety very different from reactor designs currently licensed in the United States. For example, when considering the traditional layers of defense-in-depth, modular HTGRs typically shift the emphasis from mitigation features to highly reliable prevention features. Specifically, the PBMR proposes to shift much of the containment function to fuel capable of withstanding high temperatures and to rely on simpler and more passive decay heat removal processes that also rely on high temperature material behavior (e.g, graphite). These and other differences from current light water reactors are expected to lead to a number of safety, technology and policy issues. Fuel performance, high temperature material performance and containment vs. confinement are examples of issues will need to be addressed.

The eventual resolution of these safety and policy issues is only possible if there is a sufficient understanding of the basic technologies involved in the designs. Therefore, a key part of building a safety case for advanced reactor designs is to identify the necessary technology infrastructure needed to review an actual application. While it is the designer/applicants responsibility to conduct the research necessary to support its application, the USNRC also conducts safety research necessary to support its regulatory decisions and to provide an independent confirmation of the key elements of an applicant's safety case. It is important that the USNRC have an independent capability to verify the plant response to accidents, particularly those related to loss of coolant, decay heat removal, and reactivity insertion. Such independent capability is valuable in providing a deeper understanding of plant behavior under a wide range of off-normal conditions, which can result in insights that contribute to the quality and thoroughness of the safety review. It is through this independent research and analysis that there can be greater public confidence in the ultimate safety of these advanced designs.

In an effort to assess the adequacy of the technology supporting these advanced designs and to guide its research program, the USNRC is developing an advanced reactor research plan. This plan will assess key research areas and identify specific research topics and layout a road map for the USNRC's research program over the next several years. A systematic and structured (top-down) approach is being used to identify research needs for the safety review of advanced reactors (Fig. 1.) This effort also is taking into consideration ongoing research initiatives in the international arena, as well as opportunities for future cooperation. In support of this effort, in October 2001, a two-and-a-half day workshop was held at the USNRC that focused on HTGRs. National and international experts discussed a wide range of topical areas and identified research topics that were considered to be high priority. These research topics include: high-temperature material performance; nuclear-grade graphite behavior; fuel performance; containment performance; adequacy of data and analytical tools; and accident scenarios.[3] The priorities given to various research areas will reflect research needs for those designs that the USNRC is currently reviewing or expects to review in the near term. Thus, our current focus is on three general topics, namely, high-temperature gas cooled reactors, advanced light water reactors and regulatory framework developmental activities to assure the needed predictability and versatility in the longer term.

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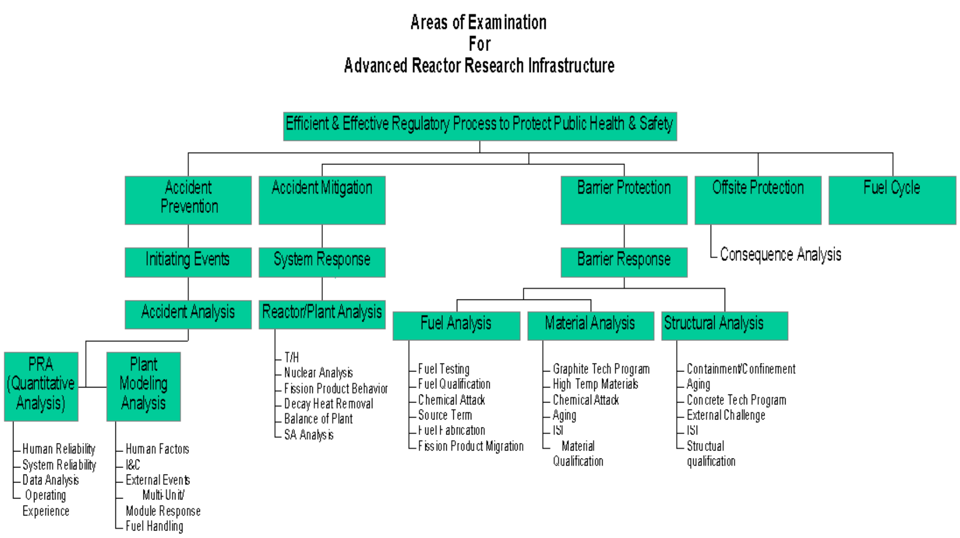

As discussed above, for advanced reactors different from current light water reactors, such as the PBMR, certain reactor regulations may not be applicable to design features of the advanced reactors. Likewise, new requirements may also be needed to address the different approach to safety proposed by these new designs. In the case of the PBMR, Exelon has proposed to use risk-informed approaches to support its safety case at the NRC[4]. They are proposing to use existing regulations, where existing regulations may apply or partially apply, and look to the USNRC to develop new regulatory criteria where existing regulations do not cover the safety review needs. The screening process proposes to use PSA technology to identify such new regulatory criteria. Their proposal is currently under review, but a number of issues will need to be considered to successfully implement this approach, including the role of the defense-in-depth to address uncertainties (including the issue of containment vs. confinement), limited or no operating experience for use in a PSA, identification of or need for appropriate risk metrics (CDF and LERF) and the selection of licensing and design basis events.

In summary, through the pre-application reviews of the AP1000 and PBMR, the USNRC is actively engaged with the reactor designer/applicants to achieve an early identification and resolution of safety issues. At the same time, the USNRC is developing the necessary technical infrastructure to support its regulatory decisions.

References:

1. U.S. Federal Register Notice, "Regulation of Advanced Nuclear Power Plants; Statement of Policy," July 8, 1986, 51 FR 24643 and revised July 12, 1994, 59 FR 35461.

2. U.S. Code of Federal Regulations (CFR), Title 10, Part 52, "Early Site Permits, Standard Design Certifications, and Combined Licenses for Nuclear Power Plants," April 18, 1989.

3. Summary Report, Workshop on High-Temperature Gas-Cooled Reactor Safety and Research Issues, October 10-12, 2001, USNRC, Washington, DC (Adams Accession ML013650004).

4. Letter from K. Borton to US Nuclear Regulatory Commission, "Exelon Generation Company's Proposed Licensing Approach for the Pebble Bed Modular Reactor (PBMR) in the United States," dated August 31, 2001.