ADVANCED REACTOR

RESEARCH PROGRAM

Office of Nuclear Regulatory Research

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INTRODUCTION

The Office of Nuclear Regulatory Research (RES) has updated the U.S. Nuclear Regulatory Commission (NRC) Advanced Reactor Research Program. This update revises the original program plan, which was forwarded to the Commission on April 18, 2003 as Attachments 1 and 2 to SECY-03-0059, "NRC's Advanced Reactor Research Program. The update provides the NRC staff's detailed assessment of the HTGR technical infrastructure development and safety research that would be needed to support the review of High Temperature Gas Cooled Reactors (HTGRs) and Very High Temperature Gas Cooled Reactors (VHTRs) that are currently being designed and developed for potential NRC application. The update also provides the proposed safety R&D that the NRC would need to conduct in order to establish NRC's independent technical reveiw capabilities for potential HTGR and VHTR applications. The current version of the program plan reflects the changes and accomplishments associated with external HTGR R&D organizations as well progress made im implementing selected higher priority NRC R&D activities that had been planned and implemented in connection with Enclosure 1 to SECY -03-0059.

Although applicants and designers are responsible for developing the methods, tools, and data sufficient to demonstrate the safety of proposed reactor designs and technologies, the NRC conducts research to independently assess applicant submittals and to provide the technical bases needed to develop the regulatory requirements that these designs must meet. Independent research programs provide a sound technical basis for regulatory decisions and reduce the need for the excessive conservatism that normally results from a lack of knowledge. In general, the staff will determine not only the information that the applicant must furnish as part of its license application, but also the additional NRC research necessary to support the licensing offices.

BACKGROUND

Since the staff issued SECY-03-0059, significant changes have occurred in the potential advanced reactor design applications that may be submitted for NRC review and approval. These include (1) a potential license application for a very high temperature reactor (VHTR), which may be constructed at the Idaho National Laboratory in connection with the Next Generation Nuclear Plant (NGNP) project, as directed by the Energy Policy Act of 2005, (2) a potential license application for a Super Safe, Small and Secure (4S) fast liquid metal-cooled reactor, which may be sited near Galena, Alaska, (3) a potential design certification application for the Pebble Bed Modular Reactor (PBMR), (4) a potential license application for a commercial advanced burner reactor (ABR), which would be used for nuclear fuel recycling as part of the Global Nuclear Energy Partnership (GNEP) initiative, and (5) a potential license application for the High Temperature Teaching and Test Reactor (HTTTR), which may be sited near the University of Texas of the Permian Basin.

In addition, several of the technical issues and the related proposed NRC safety research that had been identified in Enclosure 1 to SECY-03-0059 were subsequently incorporated into the research and development (R&D) program plans of either foreign or domestic organizations involved in HTGR design, development or research. The RES staff also implemented several of the higher priority safety R&D activities, identified in Enclosure 1 to SECY 03-0059, and documented the results achieved.

In view of the potential for new non-LWR applications, the Commission issued "Staff Requirements - COMSECY-05-0024 - FY 2007 Budget Proposal," dated August 19, 2005. COMSECY-05-0024 directed the staff to begin development of the technical and licensing infrastructure for non-light-water reactors (non-LWRs), specifically for HTGRs, and, to a reasonable extent, for small secure reactors (i.e., fast liquid metal reactors (LMRs)), as appropriate. This update of the Advanced Reactor Research Program Plan is consistent with and responsive to that direction.

DISCUSSION

The updated Advanced Reactor Research Program focuses on advanced non-LWR designs involving high (and very high) temperature, graphite-moderated, gas-cooled thermal reactor technology and liquid metal-cooled fast reactor technology. The NRC staff updated, as appropriate, the previous technical infrastructure needs assessment to identify the methods, tools, data, and expertise necessary to support the certification and/or licensing of advanced (i.e., modular) HTGRs. The update also includes generic technical infrastructure needs assessment for what are considered generic (i.e., human performance, advanced instrumentation and controls) and applicable to HTGRs, LMRs as well as to LWRs. Enclosure 1 to this document includes a summary of the proposed NRC safety R&D activities for each of the highest priority technical areas for advanced HTGRs. The highest priority was given to those activities that support potential schedules for potential HTGR design certifications applications or license applications and are intended to provide the basis for regulatory and licensing decisions. For LMR designs, the staff conducted an initial limited-scope technical infrastructure needs survey. The LMR survey (which was conducted at a higher level than the HTGR infrastructure assessment) provides: (1) an initial examination of the technical issues and safety R&D needs for LMRs and (2) a starting point for a followup in-depth LMR technology infrastructure needs assessment comparable to the completed HTGR infrastructure needs assessment. Enclosure 2 documents the detailed infrastructure needs assessment for HTGRs and the initial infrastructure needs survey for LMRs. The HTGR (and generic) infrastructure needs assessment documented in Enclosure 2 provides the bases for the proposed NRC HTGR (and generic) safety R&D documented in Enclosure 1.

The update of the NRC Advanced Reactor Research Program Plan does not include potential technical infrastructure development and safety research that would be needed to support the review of new or advanced LWR applications (e.g., evolutionary power reactor [EPR], economic simplified boiling water reactor [ESBWR], international reactor innovative and secure reactor [IRIS]). Such LWR safety R&D needs either have or will be documented separately, on an LWR-specific basis.

The HTGR infrastructure assessment and initial LMR infrastructure survey identify the gaps in the NRC's independent technical capabilities and its reactor safety research and development. The HTGR infrastructure assessment and LMR infrastructure survey do not delineate the safety R&D that will be conducted solely by the NRC. Rather, they note gaps in NRC information and capabilities in terms of required expertise, analytic tools, methods, data and facilities.

In this regard, applicants and designers have the primary responsibility to demonstrate safety and to conduct the research needed to support both the plant design and the technical basis for the safety analysis. Applicants and designers are responsible for conducting R&D to (1) demonstrate safe performance of their proposed plant design and applied technology, (2)

provide the technical basis for the application, including the safety analysis, (3) demonstrate sufficient margins to safety-significant structure, system, and component (SSC) design and safety limits, (4) search for and identify, as well as assess and resolve, significant reactor and plant safety issues involving large uncertainties, (5) develop, verify, and validate the proposed safety analysis evaluation methods, (6) provide the technical basis for requirements, criteria, codes, or standards that are proposed for the design basis for plant licensing, (7) understand and quantify the failure thresholds for safety-significant SSCs, (8) examine and analyze what-if scenarios that are needed to establish requirements and analyze plant safety performance for events and conditions beyond the design basis, and (9) support NRC regulatory and licensing decisions.

To a large extent, the research that the applicant submits and the designer conducts will significantly reduce the research that the NRC will need to conduct. Consequently, information can and will be obtained through R&D conducted by the designers and developers of these new plant designs as well as through domestic and international cooperative research projects. Accordingly, prioritization and budgeted resources for NRC safety R&D activities will consider information that can be obtained from others, giving due consideration to NRC's role and responsibilities as a regulator.

The HTGR infrastructure assessment technical arenas and activities are linked to 10 key research arenas. These involve: (1) development of risk-informed and performance-based regulatory review infrastructure such as draft regulatory guides and draft review plans for the first non-LWR applications to propose increased use of probabilistic information for establishing in-plant licensing basis, (2) accident analysis, including probabilistic risk assessment (PRA) methods and assessments, human factors, and I&C, (3) reactor/plant systems analysis, including thermal fluid analysis, nuclear analysis, and accident source term analysis, (4) fuel performance analysis, (5) materials analysis, including nuclear graphite and metallic component performance, (6) structural analysis, including the performance of civil structures and reactor core internals, (7) consequence analysis, including dose calculations and environmental impact studies, (8) analysis of the potential hazards to reactor plant safety posed by a nearby hydrogen production facility, (9) nuclear materials safety, including enrichment, fabrication, and transport, and (10) waste safety (including storage, transport, and disposal) and nuclear safeguards and security. Human factors and I&C are basically technology-neutral arenas applicable to both advanced non-LWRs and advanced LWRs. The LMR infrastructure survey addressed reactor/plant systems analysis, including thermal fluid analysis, nuclear analysis, and severe accident and source term analysis; fuels analysis; materials analysis; and structural analysis.

The role of and acceptable approach for increasing the application of probabilistic information and insights for establishing the licensing basis for advanced reactors is a potential policy matter that has not been fully reflected in this revision to the Advanced Reactor Research Program Plan. In this regard, the applicant and designer responsibilities (7) and (8) described above are not viewed as requirements. However, these may become requirements in the future for applications that propose to significantly increase the use of probabilistic information in establishing the licensing basis.

In general, the NRC will conduct or support safety R&D if it falls in one or more of the following four categories:

(1) Develop adequate staff technical knowledge, expertise, and capabilities to

independently review and effectively evaluate the acceptability of the application, including the safety analysis and the technical basis for the safety analysis

(2) Independently confirm the technical basis for the requirements and criteria needed for plant licensing as well as the regulatory guides and Standard Review Plans needed for developing an acceptable application and an effective and efficient staff review.

(3) Develop an independent analytical capability to confirm both safety analysis evaluation methods and safety analysis results as well as the adequacy of proposed resolutions of safety issues and/or the development of the technical basis for staff-proposed reactor safety enhancements.

(4) Adequately confirm or interpret existing technical information for which there is significant uncertainty or adequately validate and scope out technical issues involving significant safety or risk implications to justify the need for followup resolution by the applicant

The staff has organized, or "binned," all proposed NRC safety research and development activities documented in Enclosure 1 into one or more of the above four categories.

Experience with the review of previous non-LWR applications and pre-applications indicates that the scope, schedule, and resource demands for NRC safety research and development can be large and that the staff could benefit from worldwide research and experience. Accordingly, the NRC will seek opportunities to interact with and, where appropriate, initiate cooperative research activities with other agencies as well as national and international organizations. These groups may include domestic universities, DOE national laboratories, international organizations, and nuclear plant designer-developer organizations.

Priorities will also consider near-term needs, the lead times necessary to develop the required data or information, and opportunities to join national or international programs that can result in substantial savings of NRC resources. Routine peer reviews of progress and research products will be conducted to ensure the quality of the research, and these reviews will include frequent interactions with the Advisory Committee on Reactor Safeguards and the Advisory Committee on Nuclear Waste.

The NRC staff has also begun to invest agency resources to plan and implement an advanced HTGR knowledge management (KM) project. The HTGR KM project focuses on collecting, storing (electronically), and enabling the staff to access key historical and current HTGR technical information that is organized and searchable. In addition, as part of the HTGR KM project, the RES staff has conducted several HTGR technical workshops and seminars for the NRC technical staff. The staff is also now beginning to plan and implement a parallel KM project for LMR technology. The U.S. Department of Energy (DOE) laboratories have agreed to assist the NRC in planning and conducting a series of LMR technical seminars, with the support of subject matter experts from the national laboratories.

RESOURCES

All proposed activities will be prioritized through the planning, budget, and program management process. Some HTGR research activities will require long-term resource commitments. For example, existing NRC computer codes that were developed for LWR

applications will require modifications to accommodate HTGR accident analysis calculations, and some new codes will need to be developed. The NRC will seek opportunities to collaborate with other agencies and organizations to ensure efficient use of resources.