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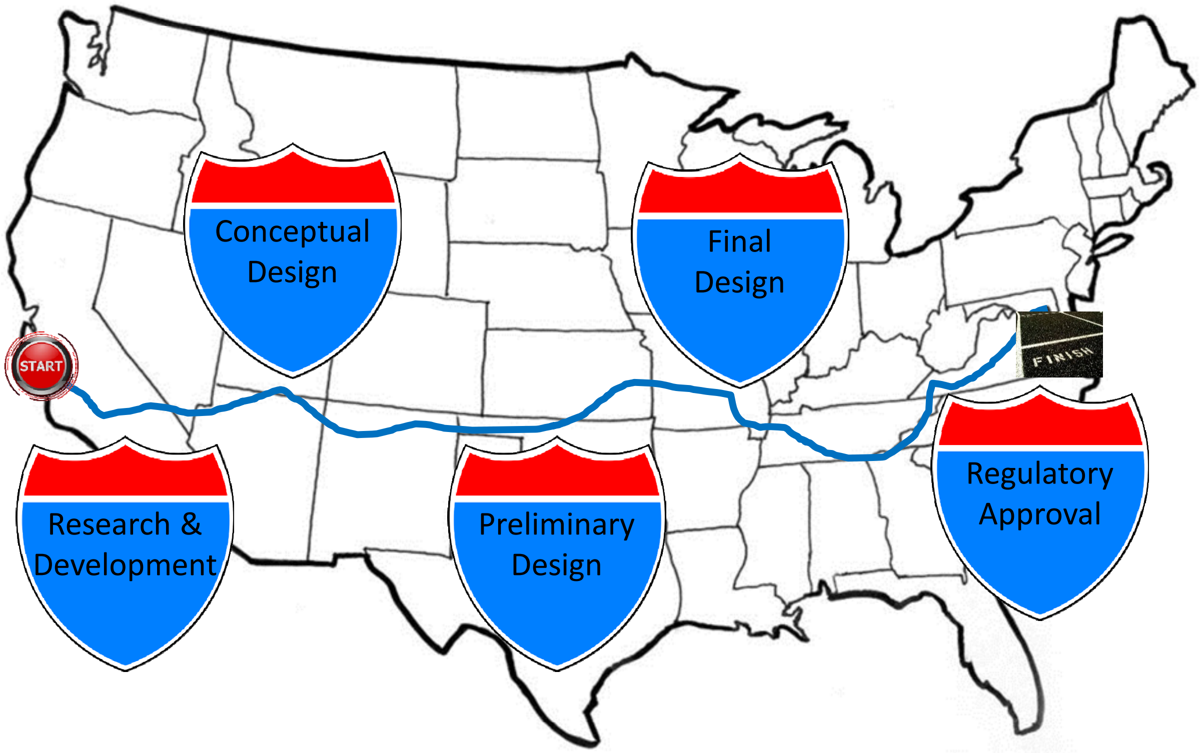
U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

A Regulatory Review Roadmap For Non-Light Water Reactors



Advanced Reactors Policy Branch
Division of Safety Systems, Risk Assessment, and Advanced Reactors
Office of New Reactors
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1) Purpose

The U.S. Nuclear Regulatory Commission (NRC) has a variety of options for performing regulatory reviews of new designs for nuclear power plants. Those options include the more formal reviews of final designs in an application for a permit, license, certification, or approval, as well as the less formal reviews of pre-application information. Understanding what options are available and how to choose the best option may be difficult for a designer, especially one that is less familiar with the NRC's regulatory framework and associated review processes.

This document is intended to provide the reader with a "regulatory review roadmap" of the options available for NRC review of pre-application information and of formal applications. In addition, Enclosure 1 to this document describes testing needs and prototype plants. Testing can be done at various stages of the design process, and is an important part of the regulatory review roadmap that a designer should consider early in the design process.

2) Introduction

The Federal Government and private companies have shown an interest in the development of nuclear reactor designs that are different than the currently operating reactors, which use water for both cooling and supporting the nuclear reactions in the core by moderating or slowing neutrons generated by the fission process. Various reactor technologies being considered include those using coolants such as helium, liquid metal, and molten salt. These reactor technologies are referred to as non-light-water reactor (non-LWR) or Generation IV designs. A desire to maintain U.S. leadership in nuclear technology, provide domestic sources of secure energy, and other energy policy considerations drive the potential interest in non-LWR technologies.

The role of the NRC as an independent regulatory agency is limited to ensuring that the potential design, construction, and operation of non-LWR technologies provide for the safe and secure use of radioactive materials. However, many assessments identify the NRC's licensing processes and readiness to regulate different reactor designs as a potential challenge to the development and deployment of non-LWR designs. The NRC has prepared a vision and strategy document (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16356A670) for improving the agency's readiness to regulate non-LWR technologies, which includes developing implementation action plans (IAPs) in areas of technical readiness, regulatory readiness, and communications. The following is the strategic objective for optimizing regulatory readiness:

> Regulatory review processes are optimized when the resources of the NRC and potential applicants are effectively and efficiently used in a way that meets NRC requirements in a manner commensurate with the risks posed by the technology, that maximizes regulatory certainty, and that considers the business needs of potential non-LWR applicants. Additional options for long-range changes for non-LWR regulatory reviews and oversight that would require rulemaking will also be considered. Regulatory readiness includes the clear identification of NRC requirements and the effective and timely communication of those requirements to potential applicants in a manner that can be understood by stakeholders with a range of regulatory maturity.

The strategies and contributing activities necessary to achieve the strategic objectives include items categorized as near-term (0–5 years), mid-term (5–10 years) and long-term (beyond

10 years) timeframes. In the area of improving the NRC's regulatory readiness for possible non-LWR designs, the staff defines the near-term Strategy 3 as follows:

> Develop guidance for a flexible non-LWR regulatory review process within the bounds of existing regulations, including the use of conceptual design reviews and staged-review processes.

The NRC's IAP (ADAMS Accession No. ML17165A069) includes the following contributing activities under Strategy 3 for improving its regulatory readiness for non-LWR designs:

3.1) Establish and document the criteria necessary to reach a safety, security, or environmental finding for non-LWR applicant submissions. The criteria and associated regulatory guidance are available to all internal and external stakeholders.

3.2) Determine and document appropriate non-LWR licensing bases and accident sets for highly prioritized non-LWR technologies.

3.3) Identify, document and resolve (or develop plan to resolve) current regulatory framework gaps for non-LWRs.

3.4) Develop and document a regulatory review "roadmap" that reflects the design development lifecycle and appropriate points of interaction with the NRC, and references appropriate guidance to staff reviewers and applicants.

3.5) Prepare and document updated guidance for prototype testing, research and test reactors.

3.6) Engage reactor designers and other stakeholders regarding technology- and design-specific regulatory engagement plans and develop regulatory approaches commensurate with the risks posed by the technology.

3.7) Support longer-term efforts to develop, as needed, a new non-LWR regulatory framework that is risk-informed, performance-based, and that features staff review efforts commensurate with the demonstrated safety performance of the non-LWR NPP design being considered.

This document describes a regulatory review "roadmap" reflecting design development activities and appropriate interactions between the NRC staff and stakeholders at various stages of the reactor design process. The NRC made a draft version of the roadmap available to the public (ADAMS Accession No. ML16291A248), and it was the subject of discussions during routine public meetings with stakeholders. The issuance of this roadmap completes Contributing Activity 3.4 within the near-term IAP, but the guidance may be revised or updated as the NRC staff and stakeholders gain additional experience and insights into the development and licensing of non-LWR technologies. Because the subject of testing and prototypes is closely related to regulatory review readiness, an enclosure to this document contains updated guidance for the prototype testing mentioned under Contributing Activity 3.5. This document also addresses the regulatory engagement plans described under Contributing Activity 3.6.

3) Background

Various references define key safety objectives and functions for nuclear reactors, including NRC regulations such as Appendix A, “General Design Criteria for Nuclear Power Plants,” to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, “Domestic Licensing of Production and Utilization Facilities.” Over the years, the NRC based the development of its requirements in 10 CFR Part 50 primarily on experience with light-water-reactor (LWR) technology. The International Atomic Energy Agency (IAEA) Specific Safety Requirements SSR-2/1, “Safety of Nuclear Power Plants: Design,” describes safety in design for any nuclear reactor technology as follows:

> [2.8] To achieve the highest level of safety that can reasonably be achieved in the design of a nuclear power plant, measures are required to be taken to do the following, consistent with national acceptance criteria and safety objectives:
>
> (a) To prevent accidents with harmful consequences resulting from a loss of control over the reactor core or over other sources of radiation, and to mitigate the consequences of any accidents that do occur;
> (b) To ensure that for all accidents taken into account in the design of the installation, any radiological consequences would be below the relevant limits and would be kept as low as reasonably achievable;
> (c) To ensure that the likelihood of occurrence of an accident with serious radiological consequences is extremely low and that the radiological consequences of such an accident would be mitigated to the fullest extent practicable.

IAEA SSR-2/1 goes on to define fundamental safety functions for nuclear reactors as follows:

> Fulfilment of the following **fundamental safety functions** for a nuclear power plant shall be ensured for all plant states:
>
> (i) **control of reactivity**;
> (ii) **removal of heat** from the reactor and from the fuel store; and
> (iii) **confinement of radioactive material**, shielding against radiation and control of planned radioactive releases, as well as limitation of accidental radioactive releases.

The history of LWRs includes an evolution in the designs and related regulatory requirements associated with fulfilling the fundamental safety functions. Examples of regulatory improvements reflecting the importance of the fundamental safety functions include the NRC’s issuance of the General Design Criteria and the acceptance criteria in 10 CFR 50.46, “Acceptance Criteria for Emergency Core Colling Systems for Light-Water Nuclear Power Reactors.” Plant designs and operating practices have been improved based on operating experience, analytical studies, and technological advancements. Regulatory requirements and associated approaches taken by reactor vendors have likewise evolved and increasingly reflect the NRC’s adoption of a risk-informed, performance-based regulatory framework.

The current efforts to define regulatory approaches for non-LWRs provide an opportunity to develop a technology-inclusive framework to ensure the fundamental safety functions are fulfilled in a manner commensurate with the risks associated with specific technologies or designs. The NRC has had some experience in the regulation of non-LWR plants and has previously had preapplication interactions with reactor designers and DOE. The NRC staff has developed potential approaches to the licensing and regulation of non-LWR technologies in studies such as NUREG-1860, "Feasibility Study for a Risk-Informed and Performance-Based Regulatory Structure for Future Plant Licensing," issued December 2007, and NUREG-2150, "A Proposed Risk Management Regulatory Framework," issued April 2012. Relevant to that effort is a DOE report entitled, "Guidance for Developing Principal Design Criteria for Advanced (Non-Light Water) Reactors," submitted to the NRC in December 2014. The NRC reviewed the information in the report and solicited public comment on Draft Regulatory Guide 1330, "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors," issued February 2017 (ADAMS Accession No. ML16301A307).

The non-LWR technologies and designs currently being discussed incorporate features and characteristics consistent with expectations set forth in the NRC's "Policy Statement on the Regulation of Advanced Reactors," (73 FR 60612; October 14, 2008) which states:

> Regarding advanced reactors, the Commission expects, as a minimum, at least the same degree of protection of the environment and public health and safety and the common defense and security that is required for current generation light-water reactors (LWRs). Furthermore, the Commission expects that advanced reactors will provide enhanced margins of safety and/or use simplified, inherent, passive, or other innovative means to accomplish their safety and security functions.

Consistent with these expectations, interactions between the NRC staff and non-LWR designers indicate that many of the potential non-LWR designs include less radioactive inventory, more stable fuel forms, higher system thermal capacities, and longer thermal constants, as well as passive safety features that rely on natural phenomena. Inclusion of such attributes could facilitate the NRC's safety review of these designs. However, the non-LWR technologies also bring less operating experience and incorporate innovative or novel design features that could complicate the regulatory review. The potential benefits, as well as potential challenges for non-LWR designs, highlight the importance of early interactions between the NRC staff and designers to help develop regulatory approaches commensurate with risks from the technologies. The development of appropriate regulatory approaches for non-LWR designs will likely occur in parallel with the development of the designs and performance of related research and testing.

4) Design Stages

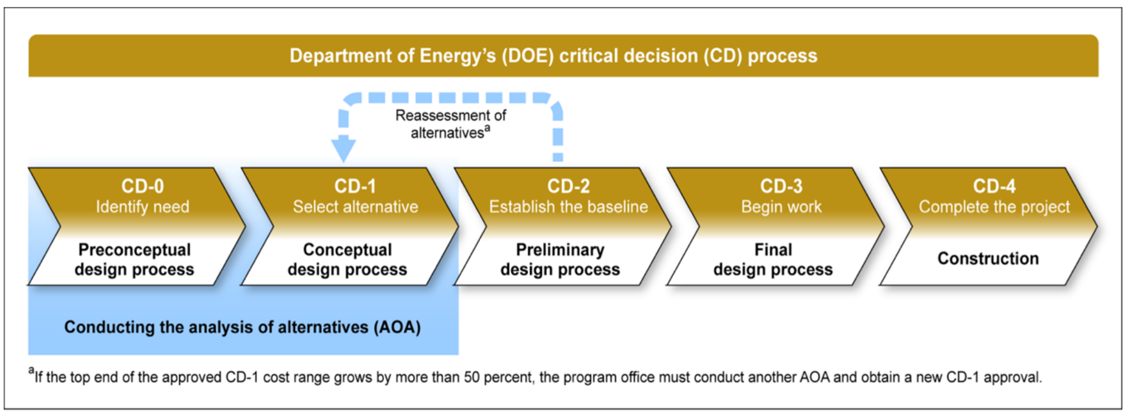
The NRC encourages early preapplication interactions with reactor designers. The Advanced Reactor Policy Statement states:

> To provide for more timely and effective regulation of advanced reactors, the Commission encourages the earliest possible interaction of applicants, vendors, other government agencies, and the NRC to provide for early identification of regulatory requirements for advanced reactors and to provide all interested parties, including the public, with a timely, independent assessment of the safety and security characteristics of advanced reactor designs. Such licensing

interaction and guidance early in the design process will contribute towards minimizing complexity and adding stability and predictability in the licensing and regulation of advanced reactors.

In accordance with the policy statement, the NRC has worked with designers and DOE on several non-LWR designs and provided varying degrees of feedback on designs and testing programs related to the development of non-LWR designs. Examples include the NRC staff's review and issuance of preapplication safety evaluation reports for liquid-metal and gas-cooled reactor technologies.[1] There are also numerous examples of less-formal interactions with specific reactor designers.

Various non-LWR technologies and specific designs based on similar technologies are at different points in the development process. Figure 1[2] is a representation of the design processes from the DOE Order 413.3B, "Program and Project Management for the Acquisition of Capital Assets." This figure provides a useful distinction between different phases of project development and critical decisions, and is relevant to the associated interactions between the NRC staff and designers.



Source: GAO analysis of DOE's Order 413.3B. | GAO-15-37

Figure 1: DOE critical decision process

Plans for the overall deployment of non-LWR designs might include multiple projects involving critical decisions for related research and test reactors, first-of-a-kind (FOAK) large scale plants, and subsequent commercial plants. The NRC's existing processes and practices are flexible and support interactions related to this wide variation in design development, recognizing that

1 See NUREG-1368, "Preapplication Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid-Metal Reactor," issued February 1994 (ADAMS Accession No. ML063410561); NUREG-1369, "Preapplication Safety Evaluation Report for the Sodium Advanced Fast Reactor (SAFR) Liquid-Metal Reactor," issued December 1991 (ADAMS Accession No. ML063410547); and NUREG 1338, "Draft Preapplication Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor," issued March 1989 (ADAMS Accession No. ML052780497)

2 See U.S. Government Accountability Office (GAO) Report GAO-15-37, "Analysis of Alternatives Could Be Improved by Incorporating Best Practices," issued December 2014.

the NRC staff may in some cases be providing feedback and developing regulatory positions[3] in parallel with designers assessing various alternatives during the conceptual design process. The regulatory interactions are intended to align with other related plans for developing non-LWR technologies. These related plans include plant design, research and development (R&D), finance, public policy, and fuel cycle.

The NRC staff prepared this regulatory roadmap to help define processes and interactions for various stages of the design and licensing processes and to standardize terminology and expectations. Technology- or design-specific regulatory engagement plans[4] can then be developed in cooperation with groups or individual designers to align the regulatory review plan with other plans, including R&D. A key aspect of aligning the design, research, and regulatory processes will be including characterization of design or technology status (e.g., technology readiness level, phenomena identification and ranking table (PIRT)). Figures 2 and 3 show examples of these relationships from DOE Guide 413.3-4A, "Technology Readiness Assessment Guide."

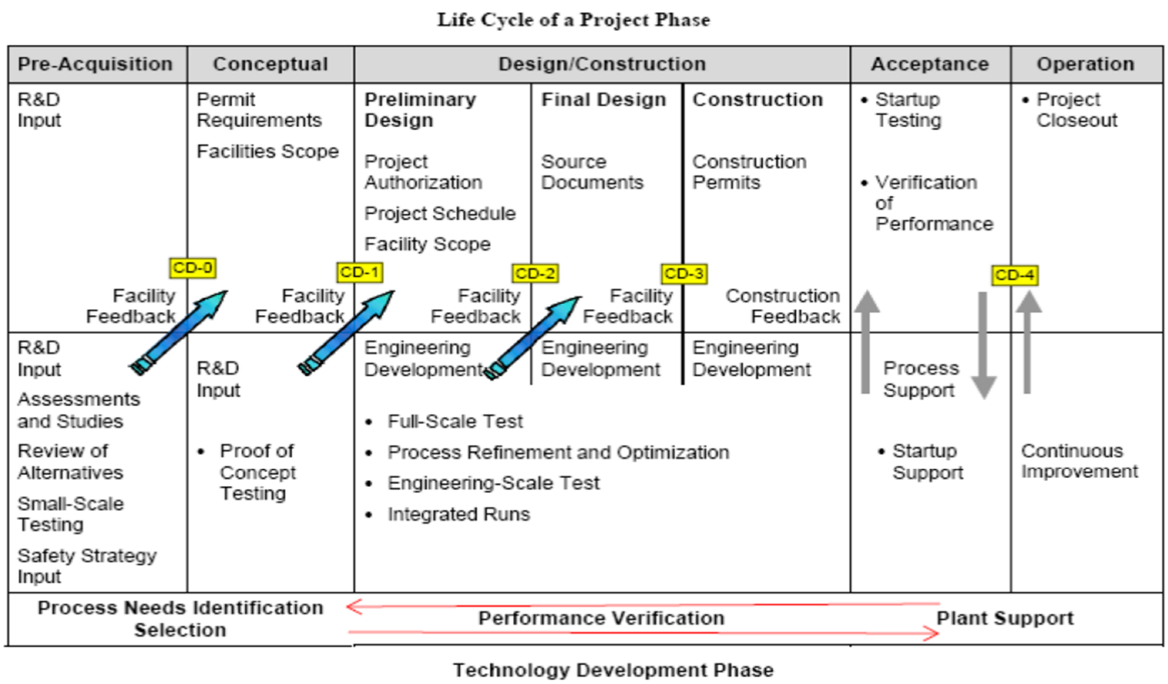


Figure 2: Technology development integration with project management

3 In this context, "regulatory positions" may range from preliminary discussions with designers without the creation of documentation to be cited in future applications to Commission decisions (e.g., staff requirements memorandum or policy statement) or other published regulatory positions (e.g., interim staff guidance, regulatory guides, or safety evaluations). See Section 4 of this document. While NRC processes can provide needed flexibility, the interactive and iterative nature of some interactions, especially in the conceptual design phase, is not the standard operating procedure familiar to many NRC staff members.

4 A regulatory engagement plan describes a potential applicant's plan to engage with the NRC during the development and review of an application for a license, certification, or approval of an advanced reactor design. See Section 5 of this document for further discussion of regulatory engagement plans.

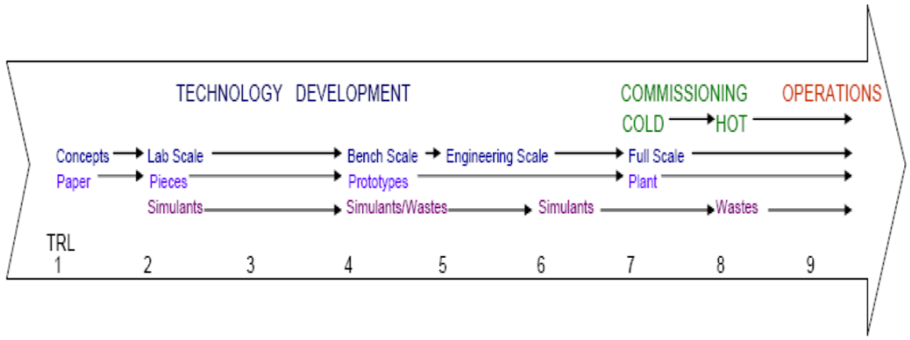


Figure 3: Schematic of DOE Office of Environmental Management Technology Readiness Levels (TRLs)

The critical decision process shown in Figure 1 and reflected in Figures 2 and 3 are useful starting points in the development of a non-LWR design. However, the detailed discussions within the associated DOE orders and guidance support DOE projects, and some aspects of those discussions may not be relevant to the development of non-LWR technologies and the related regulatory engagement plans. This roadmap moves beyond the design process described in the DOE documents, and describes the regulatory review options that are available within the NRC's regulatory framework.

The roadmap described in the following sections aligns NRC licensing-related processes (e.g., construction permit (CP), operating license (OL), standard design approval (SDA), design certification (DC), combined license (COL)) and preapplication interactions (e.g., meetings, topical reports, white papers, conceptual design reviews) with different stages of the design process. Figure 4 provides a general summary of the various regulatory processes.

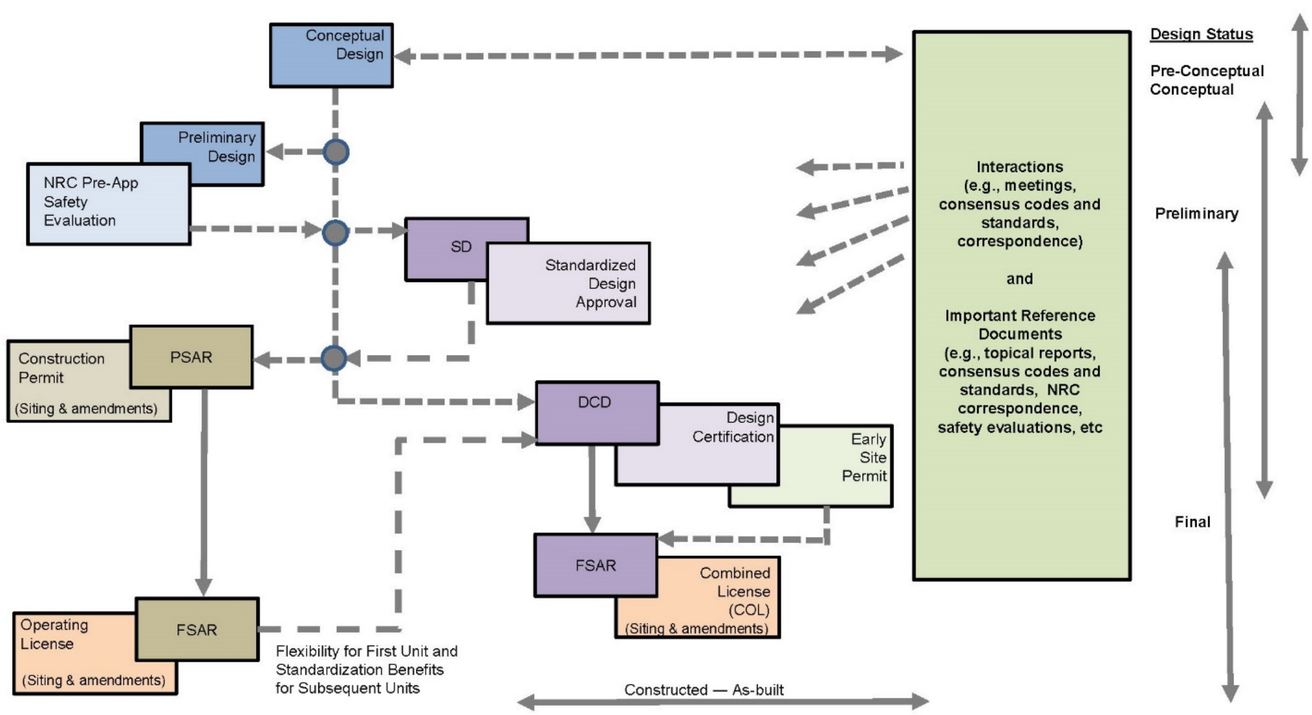


Figure 4: NRC licensing-related processes

Previous preapplication interactions highlight the importance of regulatory feedback in areas such as fundamental safety approaches, research, qualification of materials and fuels, and plans for integral and systems tests. The NRC staff included an introductory section[5] in the standard review plans for LWRs specifically related to preapplication activities for light-water small modular reactors (SMRs). Consistent with this guidance, the NRC staff has been engaged in significant preapplication interactions with SMR vendors on a variety of topics. Building on recent experiece with LWRs and past experience with non-LWRs, the NRC staff has developed this roadmap to help developers prepare regulatory engagement plans and is working on other contributing activities to ensure regulatory requirements are commensurate with risks from non-LWR technologies. As discussed further in Sections 5 and 6 of this document, the roadmap describes flexible non-LWR regulatory review processes, including interactions during the conceptual design phase, preliminary design reviews, and SDAs, to define possible staged reviews for designs or parts of designs at various levels of completion or maturity (i.e., across a spectrum of technology readiness levels).

The alignment of regulatory interactions with the stages of development of non-LWR designs requires a technology- or design-specific regulatory engagement plan that reflects the results of technology- or design-specific assessments, such as PIRTs or technnology readiness level evaluations (at the technology, plant and/or structure, system, or component level); the status of supporting research and testing; and the prioritization of desired feedback from the NRC. The NRC staff and the requester will need to agree on the appropriate levels of review and possible forms of feedback (e.g., verbal exchange, written correspondence, safety evaluation), considering available resources within the NRC and from the requester, the schedule, and the importance of the issue. Aspects of the overall project plan dealing with the designer's business model, as well as some public policy issues, may influence the priorities and schedules proposed by a designer but are not directly related to the NRC's regulatory review and licensing processes. The NRC's ability to support the non-LWR program will be determined based on broader agency budgets and priorities.

This roadmap will support the development of the technology- or design-specific regulatory engagement plans as described in Section 6, "Regulatory Engagement Plans To Obtain NRC Licenses, Certifications, and Approvals," on interactions and processes and the relationships between various stages of design, R&D, and licensing. The regulatory engagement plan and interactions with the NRC should also address the appropriate time for establishing and obtaining NRC approval of quality assurance plans. Designers will need to request access to safeguards information at the appropriate time, to enable them to address regulatory requirements such as 10 CFR 50.150, "Aircraft Impact Assessment," and to appropriately integrate security into the plant design, consistent with the NRC's Advanced Reactor Policy Statement.

5) Interactions, Reference Documents, and Applications

There are a variety of regulatory processes and tools that can support the design, construction, and operation of one or more nuclear power plants. Figure 4 shows the processes and tools that provide flexibility to address a range of possible circumstances associated with the development and deployment of non-LWR technologies. This section describes the individual interactions and applications from Figure 4. Section 6 discusses how the processes and tools can support various stages of the design process within a regulatory engagement plan,

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5 NUREG-0800, Introduction - Part 2: Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: Small Modular Reactor Edition, January 2014.

including examples of scenarios for different combinations of processes and tools for different development and deployment models.

Interactions between the NRC staff and a designer involve exchanges of information that ultimately support a regulatory decision. Some interactions warrant preparing and archiving records of decisions for reference in formal applications for permits, licenses, or other agency actions. Other interactions may help manage resources and schedules, resolve process or policy issues, or otherwise support the decisionmaking process, but do not result in a record that will be referenced in a formal application. Given that the results of interactions can range from simple exchanges to legally binding regulatory decisions, an important part of navigating the regulatory process is to ensure that all parties have the same understanding of the desired outcome for each interaction. The ability of the NRC staff to provide definitive responses and decisions is dependent on the availability of supporting information from research and analysis. Nevertheless, early interactions can be useful to both NRC staff and designers, and can help define appropriate activities that will ultimately be included or referenced in formal applications.

Possible outcomes from regulatory interactions (from the preapplication stage through the eventual licensing application stage) include the following:

- Information exchange: Some interactions between designers and the staff simply involve exchanges of information on reactor design concepts, technical information, regulatory requirements, or guidance.

- Initial feedback: Initial feedback from the NRC is usually provided as the result of staff-level interactions in meetings or correspondence. The feedback can range from the views of individual NRC staff members provided during meetings to more formal exchanges that might result from written documents. The feedback often involves insights from previous regulatory actions, operating experience, or cursory assessments of proposals or issues by the NRC staff. Interactions resulting in initial feedback may be valuable to both the requester and staff but do not result in documents for referencing in subsequent applications or binding regulatory positions, even if provided in written correspondence.

- Conditional staff findings: The NRC staff may make findings and document them in correspondence, “preapplication” or “preliminary” safety evaluation reports, topical report safety evaluations, or other records that a proposed design feature, analysis method, or operational program conforms to regulatory requirements or is otherwise acceptable, provided that testing, analyses, or other activities are completed and provide the expected results. Conditional findings are intended to improve the efficiency of the staff’s review process and supporting activities such as testing and analyses performed by applicants. Applicants can reference the conditional findings in subsequent submittals — with the requested information to satisfy the condition or in support of other proposals with the potential of creating a cascading dependency on the supporting testing or analyses. Conditional findings are developed and documented using established agency processes (e.g., correspondence, safety evaluations for topical reports) and include the appropriate reviews by management, the Office of the General Counsel (OGC), and the Advisory Committee on Reactor Safeguards (ACRS). These findings would be technically conclusive and would not be revisited, assuming any conditions of approval are met and that the design has not changed in such a way as to invalidate the staff’s findings. These findings do not, however, have finality with respect to future Commission decisionmaking and could be subject to a hearing opportunity as part of a future licensing proceeding.

- Conclusive NRC staff finding: The NRC staff may make findings and document them in correspondence, safety evaluations, or other records that an applicant has provided sufficient justification to conclude that a proposed design feature or operational program conforms to regulatory requirements or is otherwise acceptable. The NRC staff provides conclusive findings in safety evaluation reports for licenses, certifications, SDAs, and topical reports. Correspondence or other reference documents prepared by the NRC staff may also contain conclusive findings in support of future or ongoing reviews of applications for licenses, certifications, or SDAs. Applicants can reference the conclusive findings in subsequent submittals, provided the information remains applicable to the associated design feature or operational program. The NRC develops and documents its conclusive findings using established agency processes, including the appropriate reviews by management, OGC, and ACRS. These findings do not, however, have finality with respect to future Commission decisionmaking and could be subject to a hearing opportunity as part of a future licensing proceeding.

- Final agency position: Final agency positions are those established in regulations, issued licenses or certifications, Commission decisions and orders, and other documents issued following the review and approval by the Commission or delegated official. The NRC usually documents final agency positions after providing opportunities for public participation (e.g., licensing hearings or rulemakings). Applicants can reference final agency positions in subsequent submittals, provided the information remains applicable to the associated design feature or operational program. The NRC processes for changing final agency positions are defined by regulations such as 10 CFR 50.109, "Backfitting," and 10 CFR 52.63, "Finality of Standard Design Certifications."

In addition to the above outcomes from some interactions with stakeholders, the NRC staff will prepare for non-LWR reviews by developing internal guidance documents (e.g., design-specific review standards developed for SMRs), performing independent research and analyses, and completing other activities as described in the various IAPs. These activities will involve interactions with designers and other stakeholders and will ultimately support making the findings or developing positions described above. NRC's technical and regulatory readiness, combined with technology and design maturity, will need to be considered to realistically assess the expected outcome of specific interactions. To the degree that a particular outcome (e.g., conditional staff finding) is needed to support the development of design, research, or business plans, the regulatory engagement plan and associated staff review plan should be developed with that outcome in mind. The plans will also need to reflect the resource and schedule limitations facing all parties and appropriately prioritize, and in some cases adjust, the expected outcomes from interactions on a variety of topics.

The potential regulatory outcomes can be associated with various levels of available design information throughout the development of a non-LWR technology or design. Figure 4 reflects this flexibility by showing the spectrum of regulatory interactions available from the conceptual through the final design processes. Interaction between the NRC and a designer as early and often in the design process as possible can have a positive effect on the regulatory readiness of the design at later stages in the design process. For example, a final agency position such as rulemaking to establish requirements for risk-informed, performance-based approaches to emergency planning may be conducted, in part, to resolve questions arising in the conceptual design process for non-LWRs. On the other hand, a designer may request informal feedback on a specific detail of a system or component before submitting a supplement to an application for a DC.

The primary interactions between the NRC staff and reactor designers, industry organizations, and other stakeholders include the following:

- Meetings: Meetings with the NRC staff can provide initial feedback on design options and support ongoing reviews of submitted material. The NRC staff can hold meetings with individual designers, technology or design-centered groups, industry organizations (e.g., Nuclear Energy Institute, Nuclear Infrastructure Council, Nuclear Innovation Alliance), DOE, and other stakeholders. The feedback a designer receives from the NRC during meetings can include preliminary questions from the NRC staff on the design, sharing regulatory perspectives with the designer, or NRC staff describing needed information to complete a more formal review supporting a higher-level outcome. Unless they involve discussion of sensitive information (e.g., proprietary or security-related information), meetings with the NRC staff are open to the public. The NRC prepares meeting summaries to document these interactions but rarely uses these summaries to document staff findings or regulatory positions.

- Correspondence, white papers, and technical reports: Letters and reports outlining policy or technical positions can be used to provide information to the NRC staff and to solicit feedback in the form of initial, conditional, or conclusive regulatory positions. Although the NRC has no formal guidelines or naming conventions for these interactions, the following describes the agency's general practices:

    - Correspondence without an attached report is usually used for project management issues (e.g., costs and schedules), to clarify processes and procedures, and to address technical issues not needing detailed supporting information. Stakeholders may also request the NRC to provide information on regulations, including conclusive or binding interpretations in accordance with 10 CFR 50.3, "Interpretations," and 10 CFR 52.2, "Interpretations."

    - Documents often referred to as white papers can be used to request general feedback, to obtain preliminary regulatory responses (e.g., a template could be submitted to propose a reasonable format and content for a submittal), or a more formal regulatory decision (e.g., applicability of a regulatory requirement to the design). Note that staff responses for these types of documents are generally less specific and provide less regulatory certainty than responses for topical reports and formal applications.

    - Documents often referred to as technical reports can be used to provide results of research, testing, or analyses that help verify or validate computer models, expected performance of components or systems, or other supporting information of an application. The NRC's assessment of the relevance and adequacy of technical reports is usually documented in safety evaluations related to specific topical reports or applications. For example, technical reports for the AP1000 design were referenced in the NRC staff's FSER (see section 1.10 of NUREG-1793, Supplement 2).

- Topical reports: A topical report is a standalone report containing technical information about a reactor, SSC, or safety topic that can be submitted to the NRC for its review and approval. Topical reports improve the efficiency of the licensing process by allowing the staff to review proposed methodologies, designs, operational requirements, or other subjects for subsequent referencing in licensing applications. An NRC-approved topical report can provide a technical basis for a licensing action. Topical reports have traditionally been used to obtain NRC approval for the design of key SSCs, methodologies, and computer codes and models. Topical reports have been used extensively in the review of LWR designs and are expected to be an important vehicle for obtaining NRC staff findings (conditional or conclusive) on proposed design features and analysis methodologies for non-LWR designs.

- Consensus codes and standards: The NRC encourages the development and use of consensus codes and standards as part of its regulatory programs and can incorporate the codes and standards into regulations and guidance documents.

- Rulemaking and regulatory guidance development: Stakeholder input can be provided and is encouraged when the NRC is considering new or revised regulations or regulatory guidance documents (e.g., interim staff guidance, standard review plans, design-specific review standards, and regulatory guides). Industry groups have also developed guidance documents to address technical or policy issues, which the NRC staff can reference in interim staff guidance and regulatory guides.

- Research and development plans: Entities may submit R&D plans supporting reactor technologies or designs. An applicant's R&D plan is an important part of the overall testing plan described in Appendix A to this document. This information is useful for the NRC to be aware of what data may become available for verification and validation of computer models, what test facilities may need to be inspected for quality assurance, and which tests the NRC may wish to observe; it may also help determine what related independent research the NRC may wish to conduct. The results from the R&D programs can be provided in technical reports or within applications, including topical reports.

- Other supporting documents/programs: The design and licensing of non-LWRs are expected to introduce topics such as the use of historical Atomic Energy Commission (AEC) or DOE research programs, operating experience outside the United States, and increased use of advanced computer simulation tools. Designers may identify other available supporting documents that may be submitted to the NRC within their regulatory engagement plan and discuss the desired outcomes with the NRC staff.

The above interactions can be used to exchange information between designers and the NRC and can result in the NRC providing varying degrees of feedback for use in the design process and application development for licenses, certifications, or design approvals. A discussion of how the design process and regulatory engagement plan for non-LWRs can use these interactions and the formal application processes defined in NRC regulation follows.

Conceptual Design

Recent discussions regarding non-LWR technology development have stressed the importance of better coordinating the licensing process with other aspects of project plans, including design, funding, research, and public policy considerations. Some stakeholders have suggested that the NRC should consider conceptual design approvals as a possible way to provide early feedback to reactor designers to help better coordinate the licensing and design processes.[6] The Advanced Reactor Policy Statement acknowledges the importance of early interactions between the NRC staff and reactor designers, including what is referred to as the conceptual design process, as depicted in Figure 1. Although all parties have a general agreement on the need for regulatory interactions during the design process, defining terms and establishing common expectations is important to ensure mutual understanding of the purpose and conduct of such interactions and associated outcomes.

This roadmap uses the term "conceptual design process" to refer to early consideration and selection of various key alternatives that will define the fundamental design features and general principles of operation. These decisions involve matters such as basic approaches to the safety functions of controlling reactivity, removing heat from the reactor and waste stores, and limiting the release of radioactive material. The selection of these design features helps define research and testing programs (see also Enclosure 1 to this document), appropriate safety analyses, associated fuel cycle and public policy issues, and other matters to be resolved in later phases of the design. The conceptual design phase supports the development of a regulatory engagement plan, including identifying those matters needing early regulatory interactions to support coordination with other aspects of the overall project. The regulatory engagement plan and the associated NRC review plan should define the expected outcomes from early interactions (e.g., initial, conditional, conclusive, or final) and related matters such as costs, schedules, and research plans.

The NRC has previously interacted with non-LWR designers during the conceptual design process and provided initial feedback on possible design approaches to fulfill fundamental safety functions. During these interactions, the NRC has also identified technical and policy issues and worked to develop and issue final agency positions providing non-LWR designers with additional confidence in selecting design alternatives. The NRC's ongoing assessment of possible changes to emergency planning requirements for light-water SMRs and other nuclear technologies, including non-LWRs, is an example of such activities. The NRC staff has typically not provided conditional or conclusive findings related to an overall design during the conceptual design process because of the level of design detail available at the conceptual design phase and changing nature of the design during this phase of a project would not support such regulatory decisionmaking. However, the NRC staff has provided conditional findings and conclusive findings on more specific issues in response to submittals of white papers and topical reports. The NRC staff foresees maintaining this approach for future interactions with non-LWR designers such that the NRC review plans will identify key topics, associated interactions, and outcome goals. These interactions support the designers' abilities to assess alternatives and progress to the preliminary design process. As previously discussed, available resources may limit the ability of designers and the NRC staff to develop and execute plans during the conceptual design process. These limitations may, therefore, require prioritization of key topics and could affect expected regulatory outcomes.

Preliminary Design (Preapplication Submittals)

Research, analyses, and other activities performed during the preliminary design process support more detailed design decisions and verification of the design performance in terms of commercial targets and safety requirements. Preliminary or preapplication design documents

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[6] This roadmap does not use the phrases "conceptual design approval" or "preliminary design approval" to avoid confusion with the formal processes for licensing, certifications, and approvals defined in NRC regulations.

can be provided to the NRC for information or to solicit feedback on testing programs, safety analysis approaches, or the overall feasibility of licensing a design. The preliminary design documents and related NRC reviews in the late 1980s and early 1990s involved essentially complete plant designs with regard to the scope of the design and the level of design detail. Some previous non-LWR preapplication submittals have focused more on specific design features or portions of the design (e.g., fuel design).

The preapplication safety evaluation reports prepared in the 1990s for liquid-metal and gas-cooled reactor designs helped the NRC identify and develop the regulatory framework to review non-LWR designs as well as provided confidence to designers in the feasibility of licensing the specific designs. Although circumstances led to those projects being deferred, the NRC's interactions with DOE and the designers identified valuable insights on safety features, R&D programs, and proposed testing needs (see also Enclosure 1 to this document). The NRC reviews did not result in an approval of the designs because of project termination; however, it was expected that the preapplication efforts would help inform future licensing submittals. The NRC staff was able to conclude, at that time, that its reviews had identified no obvious impediments to licensing the designs. The appropriate use of the various interactions and tools described above can support a long-term program for the design and deployment of a non-LWR reactor while potentially minimizing the additional review efforts needed to reach conclusive findings or final agency positions during different parts of the subsequent review and approval process.

Preliminary design reviews and other tools may help designers, DOE, and other stakeholders determine whether or not design and testing programs for a non-LWR will support the eventual approval, certification, or licensing of a plant. The scope of the NRC's review findings will be dependent on the design maturity and the completeness of the submittals. NUREG-1226, "Development and Utilization of the NRC Policy Statement on the Regulation of Advanced Nuclear Power Plants," issued June 1988, identifies various potential benefits of preapplication interactions during the preliminary design process. These include sharing design information; assessing licensing feasibility; gaining insights on key design features; refining regulatory engagement plans, including defining scope, cost, and schedules; advancing principal design criteria and other acceptance criteria; reporting on research and testing programs; assessing technology readiness levels and phenomenological issues; and identifying possible prototype testing for FOAK non-LWR plants. Note that business case considerations, such as operation economics and investment factors, must be evaluated by the applicants and are outside the NRC's responsibilities.

Frequently asked questions about the preapplication review process relate to the costs of NRC reviews and the agency's ability to provide timely regulatory feedback for consideration within a broader project plan. The range of potential applicants, designs, and degrees of design completeness limits the ability to define a single product cost and schedule for the review of a preliminary design. Instead, the NRC will work with a designer to establish a mutually agreeable review plan for a specific preliminary design that includes a defined scope and level of review, desired outcome in terms of regulatory observations, particular areas of focus, review costs, and review schedules. The NRC staff will arrange meetings during the process to support the review, ensure the goals of the review plan are being met, and monitor costs and schedules. The scope and level of detail of preapplication submittals that will be necessary to achieve the desired regulatory outcomes should be determined as part of a regulatory engagement plan.

For preapplication design interactions where there is a high degree of design completeness, such as the preapplication safety analysis reports previously reviewed by the NRC (as described in Section 4 of this document), a preliminary design review could result in a statement from the NRC similar to that in the preapplication safety evaluation reports prepared in the 1990s — that is, that the NRC has identified no obvious impediments to the licensing of the subject non-LWR design or major parts of the design provided for review. For preliminary designs with a lesser degree of maturity, the staff evaluation of the design would have a commensurate, and likely lesser degree of regulatory certainty. If the NRC does identify impediments to licensing during the preliminary design review, that feedback will also be valuable to the potential applicant.

Before submitting the preapplication design documents, the NRC expects that the designer will have held meetings with the NRC staff to describe the design and the licensing strategy being pursued. The regulatory engagement plan and preliminary design information should describe the design; relationships to previously submitted or planned white papers, topical reports, consensus standards, and other activities supporting the design; R&D and confirmatory testing programs (see also Enclosure 1 to this document); historical and foreign operating experience; and other relevant information. The preliminary design can describe the principal design criteria being proposed and the acceptance criteria being established for the plant SSCs for normal and abnormal operation, and for a range of possible transients and accidents. Past NRC interactions with non-LWR vendors have included the early submittal of white papers on key licensing matters such as licensing-basis event selection and classification of SSCs. The use of such white papers or adoption of related consensus codes and standards can allow the preliminary design review to be focused on the technical issues related to the safety of the design.

During the preliminary design process, as shown in Figure 4, preapplication reports can be submitted in support of applications for an SDA, DC, or CP. The regulatory engagement plan can reflect the use of preapplication submittals to support these subsequent applications. A preapplication submittal early in the preliminary design process may help the applicant and the NRC staff resolve possible licensing issues and prepare for the formal application. A preliminary design sufficiently developed to support preparing a preliminary safety analysis report can support an application for a CP when combined with the submittal of required siting evaluations. A preapplication submittal might also support an SDA when focused only on a major portion or portions of a design versus an essentially complete design (in scope), as required for a license or DC application. Submittal of preapplication reports while research and testing are still underway will likely result in conditional findings, but such interactions can provide additional confidence to proceed with other parts of a project and regulatory engagement plan.

Licenses, Certifications, and Approvals

The above discussions on preapplication interactions and preparation of supporting reference documents are intended to help ensure that potential applications for licenses, certifications, and approvals are in accordance with NRC's regulations. In addition to the flexibility provided to potential applicants during preapplication interactions, the NRC's regulations for licenses, certifications, and approvals, as described in the licensing processes in 10 CFR Part 50 and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," and as shown in Figure 4, provide several options for licensing non-LWR technologies. Plans for the overall deployment of non-LWR designs might include multiple projects involving critical decisions and different licensing approaches for related research and test reactors, FOAK large-scale plants, and subsequent commercial plants.

Various regulations and guidance documents describe the regulatory processes associated with issuing licenses, certifications, and approvals. NUREG/BR-0298, "Nuclear Power Plant Licensing Process," issued July 2009, contains a summary, and Figure 4 shows the major elements.

Construction Permit

Under 10 CFR Part 50, a CP from the NRC authorizes construction of a nuclear power plant. The NRC focuses on the preliminary design and the suitability of the site before authorizing construction of the nuclear power plant. The NRC reviews the application and documents its findings on site safety characteristics and emergency planning in a safety evaluation report. The NRC also conducts an environmental review, in accordance with the National Environmental Policy Act (NEPA), to evaluate the potential environmental impacts and benefits of the proposed plant. The ACRS reviews each CP application and the NRC's related safety evaluation and reports its findings and recommendations to the Commission. The Atomic Safety and Licensing Board (ASLB) conducts a mandatory public hearing.

The NRC may authorize an applicant to do some work at a site before a CP is issued. The agency can grant a "limited work authorization" after issuing a final environmental impact statement and other conditions in accordance with 10 CFR 50.10(e).

The development of advanced reactor applications could include using the 10 CFR Part 50 licensing process to apply for a CP instead of using the processes in 10 CFR Part 52. An advantage of the 10 CFR Part 50 process is that it supports beginning the licensing process and, if the applicant wishes, starting construction earlier in the design process (at the preliminary design stage) than would be required by 10 CFR Part 52. While offering some advantages, the "design-as-you-build" approach introduces some project risks in the regulatory arena if the NRC imposes additional requirements as a condition of receiving an OL. This approach also provides less finality before making a significant financial investment in plant construction.

An overall licensing plan for non-LWR technology might include multiple reactors (e.g., test reactors, FOAK large-scale reactors, and subsequent commercial units) and include a CP application within the regulatory engagement plan for the test or FOAK reactors. As shown in Figure 4, a CP application may benefit from preapplication interactions during the conceptual and preliminary design processes. Interactions, NRC staff findings and final agency positions, and preapplication submittals can help prepare the NRC for receipt and review of the CP application. The CP application may reference an SDA or cite staff reports that document existing conclusive staff findings associated with the application. The application may also reference an early site permit (ESP), which represents a final agency position, provided the proposed plant remains bounded by the parameters defined in the ESP.

Operating License

Under the 10 CFR Part 50 licensing process, an applicant develops final design information and plans for operation during the construction of the nuclear plant and then submits an application to the NRC for an OL. The application contains a final safety analysis report and an updated environmental report in accordance with NEPA requirements. The safety analysis report describes the plant's final design, operational limits, anticipated response of the plant to postulated accidents, and plans for coping with emergencies. The ACRS reviews each OL application and the NRC's related final safety evaluation report and offers findings and recommendations to the Commission. The NRC provides an opportunity for any person whose interests might be affected by the proceeding to petition the NRC for a hearing. If a public hearing is held, the ASLB conducts it as described in NUREG/BR-0249, "The Atomic Safety and Licensing Board Panel," Revision 4, issued December 2013.

Design Certification

The NRC can certify a reactor design for 15 years through the rulemaking process, independent of a specific site. A certified design, as defined by 10 CFR 52.41, "Scope of Subpart," consists of an essentially complete nuclear power plant design. The application must also contain a level of design information sufficient to enable the Commission to reach a final conclusion on all safety questions associated with the design before the certification is granted. The ACRS reviews each application for a DC, together with the NRC staff's safety evaluation report. If the design is found to be acceptable, the NRC certifies it through a rulemaking. Under this process, the NRC issues a public notice of the proposed rule in the *Federal Register* seeking public comments. The NRC resolves the comments in the final rule, and then publishes it in the *Federal Register*. The design is certified as an appendix to 10 CFR Part 52. The NRC has previously certified five designs as Appendices A through E to 10 CFR Part 52. The rulemaking process and related Commission decisions establish final agency positions on the certified design, which can then be referenced in future COL applications.

Early Site Permits

Under the regulations in 10 CFR Part 52 and NEPA, the NRC can issue an ESP for approval of one or more sites separate from an application for a CP or COL. Issuance of an ESP includes ACRS reviews and a mandatory ASLB hearing and results in a final agency position suitable for referencing in subsequent applications for a CP or COL. Such permits are good for 10 to 20 years and can be renewed for an additional 10 to 20 years. They address site safety and environmental protection issues, and can address complete plans for coping with emergencies or major features of such plans, independent of the review of a specific nuclear plant design.

Combined License

Under the regulations in 10 CFR Part 52 and NEPA, the NRC may issue a COL to authorize construction and conditional operation of a nuclear power plant. The application for a COL must contain essentially the same information required in an application for an OL issued under 10 CFR Part 50. An application for a COL may reference a DC or an SDA; an ESP; both; or neither. The ACRS reviews each application for a COL. A hearing opportunity also provides the public an opportunity to participate in the licensing process. The ASLB conducts hearings on any contested matters, while the Commission conducts a mandatory hearing before issuance of every COL. After issuing a COL, the NRC verifies that the licensee has completed the required inspections, tests, and analyses, and that the acceptance criteria have been met before the plant can operate. The NRC publishes a notice providing an opportunity for members of the public to participate in a hearing conducted by the ASLB related to satisfaction of the inspections, tests, analyses and acceptance criteria before plant operation.

Standard Design Approval

A designer may submit a proposed final[7] standard design for the entire nuclear power plant or major portions of it to the NRC for review. Unlike a DC, the SDA documents the NRC staff's conclusive findings but does not prevent issues resolved by the design review process from being reconsidered during a rulemaking for a DC or during hearings associated with a CP or COL application. An SDA can nevertheless be a useful tool within a regulatory engagement plan, in combination with preapplication interactions held during the conceptual and preliminary design processes. The SDA and the related safety evaluation report document NRC staff findings, involve ACRS reviews, and provide a reference for subsequent applications. As such, the SDA can provide incremental progress towards the licensing or certification of a non-LWR design in what can be referred to as a staged-licensing process.

A potentially useful feature of an SDA is that its scope is defined in 10 CFR 52.131, "Scope of Subpart," to include the design of a nuclear power plant or major portions thereof. This differs from the scope of a DC, which is defined by 10 CFR 52.41, "Scope of Subpart," to consist of an essentially complete nuclear power plant design. The ability to limit the scope of an SDA to major portions of a design provides an opportunity for regulatory interactions to focus on those plant features most related to controlling the risks to public health and safety or those plant features whose design has been finalized under a staged design and licensing strategy. Power conversion systems or other plant features may either remain in a conceptual or preliminary design process or not be included in information provided for NRC staff review. Defining a major portion of a design for the purpose of an SDA may be challenging given the relationships between various plant systems and the contributions of safety and nonsafety systems to plant risk. Regulatory engagement plans and other interactions between a designer and the staff will need to include a rationale for which portion(s) of a plant will be included in the application and which can be excluded from the review or addressed though concepts similar to the "conceptual design information" or "design acceptance criteria" used for some DCs.

Non-LWR developers considering seeking an SDA may find additional insights in the Nuclear Innovation Alliance report "Clarifying 'Major Portions' of a Reactor Design in Support of a Standard Design Approval" (ADAMS Accession No. ML17128A507). The NRC staff provided feedback on this report on July 20, 2017 (ADAMS Accession No. ML17201Q109).[8]

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7 The regulation at 10 CFR 52.135 states, "The submittal may consist of either the *final* design for the entire facility or the *final* design of major portions thereof" (emphasis added). The level of detail in an SDA application and use of the term "final" are based on the potential referencing of an SDA within a COL application. The level of detail in an SDA application for the subject major portions of the design might, therefore, be greater than the "preliminary" design and analysis information required to support an application for a CP. Nevertheless, the potential use of an SDA within the critical decision process (Figure 1) to reduce regulatory uncertainties before completing the design could be useful for a reactor developer in terms of the broader project plan. As discussed in the Nuclear Innovation Alliance report, "Clarifying 'Major Portions' of a Reactor Design in Support of a Standard Design Approval," the applicant bears all programmatic risk associated with changes in the design between an SDA and subsequent applications for a CP, DC, or COL.

8 Subsequent to the development of the Nuclear Innovation Alliance white paper, the NRC identified an omission in 10 CFR 50.43(e) and is in the process of issuing a correction to include an SDA within the scope of that regulation. The requirement for an SDA application to meet the requirements of 10 CFR 50.43(e) is defined in 10 CFR 52.137(b). The use of an SDA within a staged process might include the need for the NRC staff to include in the safety evaluation report "conditional findings" versus "conclusive findings" if the associated testing, operating experience, or operational programs are not completed or available at the time of the application.

An applicant for a construction permit or combined license may reference an SDA for those portions of the plant included in the scope of the SDA.

As in preapplication interactions, the regulatory engagement plan and associated NRC review plans should establish expectations in terms of outcomes, resources, and schedules. Periodic project management meetings will be conducted during the SDA review process to monitor project progress and costs.

Research and Test Reactors and Prototype Plants

An overall or integrated plan for developing non-LWR technologies and specific designs may include the construction and operation of research and test reactors or prototype plants. The development of such reactors and potential NRC licensing of these facilities are major activities in and of themselves. The importance of such facilities warrants a mention and emphasis early in the development of this roadmap and any technology- or design-specific regulatory engagement plan.

Enclosure 1 to this paper provides background information and guidance on the potential use of a FOAK unit for prototype testing or other validations, considerations in the use of research and test reactors as part of the design development, and additional information on planning for performing testing (including prototypes) to support the design.

Other Activities

This roadmap is part of a larger NRC effort to improve its readiness for possible applications related to non-LWR reactors. IAPs are being developed or pursued on a variety of topics, such as supporting activities related to IAP Strategy 3 for developing technical acceptance criteria for non-LWR designs in parallel with this roadmap. Longer-term activities could include revising NRC regulations to facilitate licensing, certifying, and approving non-LWR designs. While the current focus of the longer-term activities and possible rulemaking is related to technical requirements, process changes could also be explored as part of the assessment and development of new or revised regulations.[9]

6) Regulatory Engagement Plans To Obtain NRC Licenses, Certifications, and Approvals

The various interactions and processes discussed in the previous sections provide general directions for engaging the NRC about licensing non-LWR designs. The appropriate use of these tools is dependent on various factors and interrelationships. Interaction with the NRC staff on licensing questions is but one of a number of plans and strategies that face a reactor designer. As depicted in Figure 5, the challenges include funding, public policy, R&D, and infrastructure issues (e.g., fuel cycle). The project and its related regulatory engagement plan would be even more complex than shown when siting and construction considerations are included.

[9] Subpart F, "Manufacturing Licenses," to 10 CFR Part 52 defines processes for manufacturing licenses but is not discussed within this roadmap. Adjusting the current requirements for manufacturing licenses to reflect possible approaches for SMRs or non-LWR technologies could be included in the longer-term activities if the NRC develops new or revised regulations.

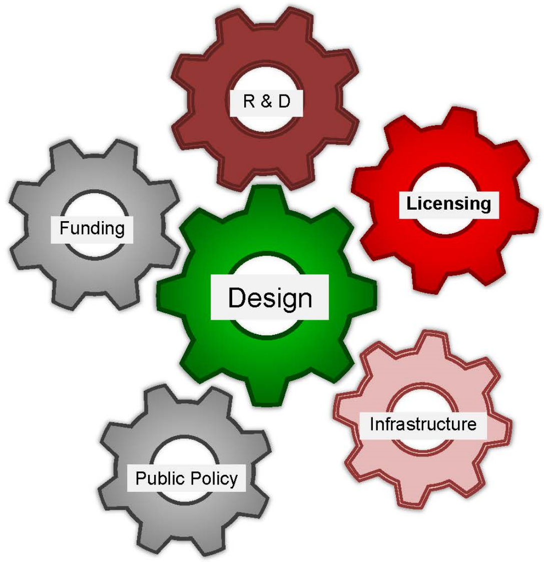

Figure 5: Interrelated technology development plans

Reactor designers need to consider the various factors as they develop a technology- or design-specific regulatory engagement plan. While public policy matters such as whether or not nuclear power plants benefit from taxes on carbon are outside the NRC's responsibility, such questions would likely influence the pace of design efforts, the availability of funding for research and testing, and other topics included in a regulatory engagement plan. The purpose of this roadmap is to prepare the NRC for interactions related to non-LWR designs and to provide sufficient clarity of requirements for non-LWR designers to support other aspects of the product development process (e.g., design process, R&D, financial plan).

A key factor in developing the regulatory engagement plan and other design-related plans and strategies is the current maturity or level of technological readiness of the proposed reactor concept and related SSCs. The roadmap includes optional steps for interactions, such as preapplication reviews and SDAs. The various paths provide flexibility to address non-LWR designs in various stages of development. As mentioned in previous sections, designers should address any planned research or test reactors within the regulatory engagement plan and would likely develop a separate regulatory engagement plan for such reactors. Figure 6 shows the added complexity of the longer-term plans that are likely to include a test reactor as a key part of R&D.

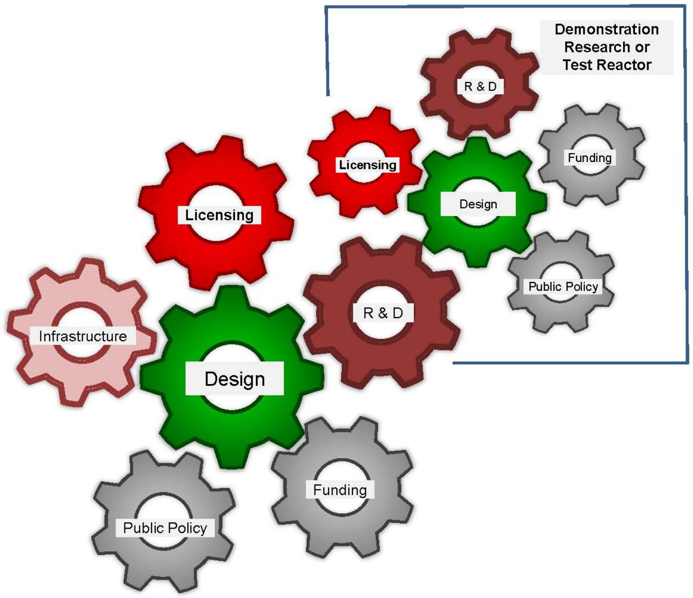

Figure 6: Interrelated plans with a test reactor

Other plans or subplans could be shown for developing the design and licensing of associated fuel cycle facilities, FOAK reactors, and other areas needed to introduce a new technology. The regulatory engagement plan should reflect the interplay and dependencies among the various activities through realistic schedules, resource estimates, capabilities, and outcomes from specific interactions.

A regulatory engagement plan could include numerous possible plans and combinations of interactions and submittals during the conceptual or preliminary design processes. Interactions with the NRC staff on proposed regulatory engagement plans would include consideration of the agency's capabilities and resource availability, recognizing the allocations for supporting non-LWR activities and the potential need to support multiple non-LWR technologies. The development of a regulatory engagement plan allows the designer and the NRC staff to prioritize issues and optimize interactions to address design alternatives or those issues most important to the overall project plan.

A brief discussion of regulatory engagement plans and possible combinations of interactions and applications to support the development and licensing of non-LWRs is provided below. The development of regulatory engagement plans will be discussed in more detail under the documentation for Contributing Activity 6 within the IAP for improving regulatory readiness.

As discussed in previous sections, those parties designing non-LWRs or wishing to construct and operate a non-LWR should prepare a regulatory engagement plan as an early step in the overall program to develop and deploy a new reactor technology. The regulatory engagement plan will reflect the technology readiness level of the reactor design, including innovative features, and the related R&D activities. The development of the regulatory engagement plan will include interactions with the NRC staff to reach mutual agreement on the desired outcomes of defined interactions and estimated costs and schedules for defined reviews. The regulatory engagement plan should pay particular attention to near-term activities needed to support the critical decision process (see Figure 1) and the development of submittals and NRC review plans. Longer-term licensing and construction strategies for commercial units can be useful to include in the regulatory engagement plan to align the licensing processes with R&D activities, business models, and the resolution of associated public policy matters. Uncertainties in these areas need not prevent interactions and progress on near-term activities related to the selection of key design alternatives and the development of a preliminary design.

The first interactions between a designer and the NRC staff are usually intended to familiarize the staff with the design concepts or preliminary design and familiarize the designer with NRC's regulatory processes. At initial meetings the designer may give presentations and provide available design documents. The NRC staff may identify available guidance documents or other references to support future discussions. These initial familiarization interactions will be followed by more specific discussions leading to the development of a regulatory engagement plan and a related NRC review plan. The plans and related discussions should identify the expected meetings, correspondence, and submittal of documents for review and issuance of NRC staff findings or final agency positions. The discussions between the designer and the NRC staff and the development of coupled licensing and review plans should address expected outcomes, priorities, resources, and schedules. Where available resources or other constraints on the NRC staff or designer limit the scope or possible outcomes related to submittals and reviews, the designer should determine which topics are most important to making critical project decisions. Routine interactions between the designer and the NRC staff should ensure the goals of the licensing and review plans are being met, monitor the costs and schedules, and identify and implement appropriate changes to the plans.

The regulatory engagement plan will identify the important reference documents that are expected to be submitted and reviewed to support future applications. As discussed in the previous section, these reference documents can include correspondence (including white papers), topical reports, consensus codes and standards, industry guidance documents, research plans, and other supporting material. The submittal and review of these reference documents not only support potential future applications but are also expected to play a role in critical project decisions and influence plans and strategies related to R&D, funding, infrastructure development, and possibly even the overall direction of the program. The topical reports or other submittals will provide a starting point for the design of the overall plant and specific SSCs; possible future research and testing (including potential prototype plant testing); operating limits; and surveillance, testing, and monitoring requirements during construction and operations. The assessments performed during the conceptual design process are expected to support the evaluation and selection of design alternatives and will likely deal with general approaches to key safety functions or specific topics related to critical project decisions. The NRC staff review of reference documents during the preliminary design process is expected to include more detailed topics related to overall plant design, system interactions, accident analyses, and other topics needed to support future applications for licenses, certifications, or approvals. Designers, potential licensees, and industry groups may find it useful to submit additional reference documents during the final design process and even following plant operation, if needed, to address issues related to plant design, construction, or operation.

Regulatory engagement plans for non-LWRs progressing into the preliminary design process have a number of options for applying for licenses, certifications, or approvals to support the design processes and potential commercial deployment of a non-LWR design. In addition to the submittal of important reference documents for future applications, designers may submit information on the preliminary design of a plant or key systems before a formal application. The DOE used this type of preliminary design review by the staff and issuance of preapplication safety evaluation reports for the design documents it submitted following the issuance of the NRC's Advanced Reactor Policy Statement. Designers may also elect to submit an application for standard design approval as a means of progressing in the regulatory area as design decisions are made and the overall program advances. An SDA, in combination with other reference documents, can be used to support a license or certification under either 10 CFR Part 50 or 10 CFR Part 52. The use of the available combinations of preapplication interactions, creation of reference documents, and SDA is sometimes referred to as a staged licensing process. The use of a staged licensing process can reduce the degree to which applicants fail to address regulatory risks until late in the preliminary or final design processes.

A Regulatory Review Roadmap for Non-Light Water Reactors Date 12/26/2017.

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<u>Enclosure</u>

Nuclear Power Reactor Testing Needs and Prototype Plants for Advanced Reactor Designs

What Is the Purpose of This Enclosure?

The purpose of this enclosure is to do the following:

- Describe the regulations governing the testing requirements for the licensing, approval, or certification of a proposed standard plant design for advanced reactors.
- Describe the process for determining testing needs to meet the U.S. Nuclear Regulatory Commission's (NRC's) regulatory requirements.
- Clarify when a prototype plant might be needed and how it might differ from the proposed standard plant design.
- Describe licensing strategies and options that include the use of a prototype plant to meet the NRC's testing requirements.

What Types of Facility Licenses Does the NRC Issue?

The NRC is authorized under the Atomic Energy Act of 1954, as amended (AEA), to grant licenses to two types of production and utilization facilities:

(1) a commercial or industrial facility licensed under AEA Section 103, "Commercial Licenses"

(2) a research and development (R&D) facility licensed under AEA Section 104, "Medical Therapy and Research and Development"

All future NRC-licensed commercial nuclear power reactors are to be licensed as utilization facilities under AEA Section 103. This enclosure is directed specifically at nuclear power plants (including prototype plants) that would also be licensed as commercial utilization facilities under AEA Section 103. Pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) 50.22, "Class 103 Licenses; for Commercial and Industrial Facilities," a facility is deemed commercial if more than 50 percent of the annual cost of owning and operating it is devoted to the production of materials, products, or energy for sale or commercial distribution, or to the sale of services other than R&D, education or training.

The NRC will license all future research and test reactors under AEA Section 104(c). Some designers' plans for advanced reactors may include obtaining data from an R&D facility that will be licensed under AEA Section 104(c) before licensing a commercial plant under AEA Section 103. NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," issued February 1996, contains additional information and guidance on the licensing process for research and test reactors. Data obtained from the operation of a research or test reactor could be used to fulfill the testing requirements of 10 CFR 50.43(e) during a subsequent application for a license, approval, or certification for a prototype or commercial reactor under AEA Section 103. An applicant should also be aware that any data obtained using a research and test reactor for this purpose and subsequently used to support a commercial nuclear power plant design would be required to meet the quality assurance requirements set forth in Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” to 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities.”

What Unique Terminology Is Used in this Enclosure?

The terms “prototype plant” and “demonstration reactor” have been used seemingly interchangeably throughout the nuclear industry and have thus confused stakeholders at times. Additionally, the terms “research reactor” and “testing facility” or “test reactor” are sometimes used interchangeably. Each of these terms has a different regulatory or practical meaning, and the definitions below are intended to clarify them. This section also describes several different categories of testing to be performed.

Advanced Reactor

The NRC’s “Policy Statement on the Regulation of Advanced Reactors,” published in the *Federal Register* (73 FR 60612; October 14, 2008), does not specifically define an “advanced” reactor. However, it does establish a set of expectations for advanced reactor designs, including providing at least the same degree of protection of the environment and public health and safety and the common defense and security that is required for current generation light-water reactors (those licensed before 1997); providing enhanced margins of safety; or using simplified, inherent, passive, or other innovative means to accomplish their safety and security functions. It also describes several attributes that could assist in establishing the acceptability of a proposed advanced reactor design, and therefore should be considered in advanced designs.

The NRC created its regulations for prototype plants specifically to license new or innovative design or safety features that are fundamental to advanced reactor designs.

NRC Regulatory Terminology Related to Facility Type

Prototype Plant

The NRC’s regulations at 10 CFR 50.2, “Definitions,” and 10 CFR 52.1, “Definitions,” define a “prototype plant” as a nuclear reactor or power plant that is used to test design features or new safety features, such as the testing required under 10 CFR 50.43(e). The prototype plant is similar to, and can be, a first-of-a-kind (FOAK) or standard plant design in all features and size, but may include additional safety features to protect the public and the plant staff from the possible consequences of accidents during the testing period. The purpose of the prototype plant is to test new or innovative design or safety features and to validate integral system computer models.

The NRC addressed the need for prototype testing in its 2007 rulemaking amending its licensing processes under 10 CFR Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants” (72 FR 49352; August 28, 2007). In responding to public comments on imposing prototype testing on combined license (COL) applicants (see 72 FR 49370), the NRC stated the following:

> Although the Commission stated that it favors the use of prototypical demonstration facilities and that prototype testing is likely to be required for certification of advanced non-light-water designs (see Advanced Reactor Policy

Statement at 51 FR 24646; July 8, 1986, and the statement of consideration for 10 CFR part 52, 54 FR 15372; April 18, 1989), this rule does not require the use of a prototype plant for qualification testing. Rather, this rule provides that if a prototype plant is used to qualify an advanced reactor design, then additional conditions may be required for the licensed prototype plant to compensate for any uncertainties with the unproven safety features. Also, the prototype plant could be used for commercial operation.

While the definition of a prototype plant (e.g., under 10 CFR 50.2) does not preclude the NRC from licensing a prototype plant under a Class 104(c) license as a research or test reactor, this reactor would not need to be licensed as a prototype. As discussed in the 2007 rulemaking amending 10 CFR Part 52 (72 FR 49437), "the purpose of the prototype plant is to perform testing of new or innovative safety features for the first-of-a-kind nuclear plant design, *as well as being used as a commercial nuclear power facility*" (emphasis added). Accordingly, the NRC anticipates that any prototype plant licensed and built would eventually be intended for commercial operation because of the substantial investment in licensing, construction, and operation of such a facility. Therefore, for the purpose of this paper, a prototype plant will be considered to be licensed under AEA Section 103 with a Class 103 license as a commercial power facility.

First-of-a-Kind Reactor

A FOAK reactor refers to the first reactor representing a standard reactor design that has been licensed, constructed, and operated. The FOAK reactor may or may not be licensed as a prototype plant. The standard reactor design could be approved or certified as a standard design approval (SDA) or design certification (DC). A standard reactor design need not have subsequent units licensed, constructed, or operated for the first unit to be considered FOAK.

Demonstration Reactor

The NRC does not have regulations specific to "demonstration reactors," nor does it use this term in its licensing processes. Accordingly, such a facility could be licensed under NRC regulations as a research or test reactor under AEA Section 104 or as a commercial facility under AEA Section 103, depending on the purpose and attributes of the facility. The NRC does not use the term "demonstration reactor" elsewhere in this enclosure because it does not have any specific meaning within the agency's licensing and regulatory processes.

However, Section 202 of the Energy Reorganization Act of 1974, as amended (ERA) does use the term "demonstration nuclear reactor." Sections 202(1) and (2) describe it as being "operated as part of the power generation facilities of an electric utility system, or when operated in any other manner for the purpose of demonstrating the suitability for commercial application of such a reactor." Further, the Atomic Energy Commission (AEC), the predecessor agency to the NRC and the U.S. Department of Energy (DOE), did recognize "demonstration reactors" through its Cooperative Power Reactor Demonstration Program of 1955. Through this program, the AEC assisted in the development of commercial nuclear power in the United States by providing limited funding, R&D, and fee waivers.

Although the NRC does not define or use the term "demonstration reactor" in its regulations, the nuclear industry, DOE and its national laboratories, and other stakeholders use this term in various documents and media to refer to a facility that could be used to demonstrate a new technology, safety feature, or design. The term has been used in conjunction with a wide range of reactors, including testing facilities and FOAK commercial reactors that could collect data and demonstrate that a particular technology can be constructed and operated safely.

For example, in 2014, DOE's Nuclear Energy Advisory Committee's Nuclear Reactor Technology Subcommittee considered focusing on "a demonstration reactor that would be used to evaluate several aspects of a selected advanced reactor technology, e.g., licensing process, safety case, operating characteristics, etc." DOE also refers to demonstration reactors in its "Vision and Strategy for the Development and Deployment of Advanced Reactors," dated January 2017, in which it describes a planning study completed in 2016 to identify "test/demonstration reactor options that would be needed to satisfy…testing and demonstration needs…including NRC licensing requirements." It also explains that this "test/demonstration" reactor "should provide further options for supporting future reactor commercialization with the expectation that a potential new test or demonstration reactor would be operational by the late 2020s if needed."

Non-Power Reactor

The NRC's regulations at 10 CFR 50.2 define a "non-power reactor" as a research or test reactor licensed under 10 CFR 50.21(c) or 10 CFR 50.22. Non-power reactors are primarily used for R&D or training. Most non-power reactors in the United States are located at universities or colleges.

A non-power reactor can also be licensed as a commercial facility. For example, the NRC issued a construction permit (CP) on February 29, 2016, for a medical radioisotope production facility (81 FR 11600; March 4, 2016).

Testing Facility or Test Reactor

The NRC's regulations at 10 CFR 50.2 define a "testing facility" as a production or utilization facility which is useful in the conduct of R&D, and licensed for operation at—

1) a thermal power level in excess of 10 megawatts, or

2) a thermal power level in excess of 1 megawatt, if the reactor is to contain:

    i) A circulating loop through the core for fuel experiments; or

    ii) A liquid fuel loading; or

    iii) An experimental facility in the core in excess of 16 square inches in cross-section.

A test reactor could be licensed as a smaller scale version of an advanced reactor design. It could be used for several purposes, including (but not limited to) providing data for compliance with the NRC's testing requirements for the full-scale design; or proof of concept for new or innovative designs, systems, materials, structures, or components. While a test reactor could theoretically replace or supplement the use of a prototype reactor, there may be challenges with using a test reactor for these purposes, including (but not limited to) scalability of the acquired test data and ensuring compliance with the NRC's quality assurance requirements when the test data is applied to the full-scale design.

Research Reactor

In 10 CFR 170.3, "Definitions," the NRC's regulations define a "research reactor" as a nuclear reactor licensed under AEA Section 104(c) and 10 CFR 50.21(c) for operation at a thermal power level of 10 megawatts or less, and that is not a testing facility. A research reactor's key output is the production of neutron and gamma radiation for experiments. While DOE operates some research reactors, the NRC does not regulate them.

As discussed above with respect to test reactors, research reactors could also be used for gathering test data or for proof of concept for a full scale reactor design. Research reactors also have the same challenges as test reactors when used in this way, including scalability and quality assurance.

Production Facility

A "production facility" is defined in 10 CFR 50.2 as follows:

> (1) Any nuclear reactor designed or used primarily for the formation of plutonium or uranium-233; or
>
> (2) Any facility designed or used for the separation of the isotopes of plutonium, except laboratory scale facilities designed or used for experimental or analytical purposes only; or
>
> (3) Any facility designed or used for the processing of irradiated materials containing special nuclear material, except (i) laboratory scale facilities designed or used for experimental or analytical purposes, (ii) facilities in which the only special nuclear materials contained in the irradiated material to be processed are uranium enriched in the isotope U-235 and plutonium produced by the irradiation, if the material processed contains not more than 10^{-6} grams of plutonium per gram of U-235 and has fission product activity not in excess of 0.25 millicuries of fission products per gram of U-235, and (iii) facilities in which processing is conducted pursuant to a license issued under parts 30 and 70 of this chapter, or equivalent regulations of an Agreement State, for the receipt, possession, use, and transfer of irradiated special nuclear material, which authorizes the processing of the irradiated material on a batch basis for the separation of selected fission products and limits the process batch to not more than 100 grams of uranium enriched in the isotope 235 and not more than 15 grams of any other special nuclear material.

An NRC-licensed production facility could be needed for certain advanced reactor designs; for example, where a molten salt and radioisotope mixture is being produced and delivered to the reactor as fuel. The definition of production facilities is included here for context only, as production facilities are considered beyond the scope of this paper.

Utilization Facility

A "utilization facility" is defined in 10 CFR 50.2 as follows:

(1) Any nuclear reactor other than one designed or used primarily for the formation of plutonium or U-233; or

(2) An accelerator-driven subcritical operating assembly used for the irradiation of materials containing special nuclear material and described in the application assigned docket number 50-608.

Categories of Tests To Be Performed by Licensees

Preoperational Tests

Preoperational tests are those tests conducted following completion of construction and construction-related inspections and tests but before fuel loading. Such tests demonstrate, to the extent practicable, the capability of structures, systems, and components (SSCs) to meet performance requirements and design criteria. An initial test plan addresses an applicant's plan for preoperational and initial startup testing as described in Regulatory Guide (RG) 1.68, "Initial Test Program for Water-Cooled Nuclear Power Plants."

Initial Startup Tests

Initial startup tests include those test activities scheduled to be performed during and following fuel loading activities. Testing activities include precritical tests, initial criticality tests, low-power tests, and power ascension tests that confirm the design bases and demonstrate, to the extent practicable, that the plant will operate in accordance with its design and is capable of responding as designed to anticipated transients and postulated accidents. An initial test plan addresses an applicant's plan for preoperational and initial startup testing as described in RG 1.68.

Inspections, Tests, Analyses, and Acceptance Criteria

Inspections, tests, analyses, and acceptance criteria (ITAAC) provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant is built and will operate in accordance with the DC (for a COL referencing a DC), the provisions of the AEA, and the NRC's regulations. A DC application must contain the proposed ITAAC that are necessary and sufficient to provide such reasonable assurance. Certain preoperational tests under the initial test plan for a COL include ITAAC testing.

Integral Effects Test

An integral effects test, as described in Chapter 15.0.2, "Review of Transient and Accident Analysis Method," of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," is an experiment in which the primary focus is on the global system behavior and the interactions between parameters and processes. It involves the examination of a large-scale system to determine the performance of various components and the interaction of subsystems. Integral effects testing is performed to demonstrate that the interactions between different physical phenomena and system components and subsystems are identified and predicted correctly. Step 10 of Appendix A to this enclosure describes integral effects testing.

Separate Effects Test

A separate effects test, as described in Chapter 15.0.2 of NUREG-0800, is an experiment in which the primary focus is on a specific parameter or process. Data from separate effects tests provide localized information on the behavior of a specific part of a system. Separate effects testing is performed to demonstrate the adequacy of the physical models to predict physical phenomena that the accident scenario identification process determined to be important. Separate effects testing is also used to determine the uncertainty bounds of individual physical models. Step 3 of Appendix A to this enclosure describes separate effects testing.

Prototype Test

A prototype test is defined in this enclosure as a test that is intended to satisfy the requirements of 10 CFR 50.43(e)(2). The requirements of 10 CFR 50.43(e) allow an advanced reactor applicant's design to comply with either of two alternatives in 10 CFR 50.43(e)(1) and (e)(2). Under 10 CFR 50.43(e)(1), the NRC requires a demonstration of the performance of each safety feature, consideration of interdependent effects among the safety features, and evidence that sufficient data exist on the safety features. The alternative in 10 CFR 50.43(e)(2) requires an applicant to comply through a demonstration of acceptable testing of a prototype plant, on which the NRC could impose additional requirements to protect the public and the plant staff. Therefore, a prototype plant (as defined above) would need to have prototype testing performed to comply with 10 CFR 50.43(e). Appendix A to this enclosure describes the process for determining testing needs. Step 16 of Appendix A to this enclosure specifically describes prototype testing.

What Are the Testing Requirements for Commercial Power Facilities?

In 10 CFR 50.43(e), the NRC lists additional testing requirements specific to licensing advanced reactors intended as commercial power facilities under 10 CFR Part 50 and 10 CFR Part 52. The regulation in 10 CFR 50.43(e)(1) states that the NRC will approve applications for an advanced reactor design only if (i) the performance of each safety feature of the design has been demonstrated through either analysis, appropriate test programs, experience, or a combination thereof; (ii) interdependent effects among the safety features of the design are acceptable, as demonstrated by analysis, appropriate test programs, experience, or a combination thereof; and (iii) sufficient data exist on the safety features of the design to assess the analytical tools used for safety analyses over a sufficient range of normal operating conditions, transient conditions, and specified accident sequences (including equilibrium core conditions). Alternatively, 10 CFR 50.43(e)(2) allows the use of a prototype plant to fulfill the testing requirements. The regulation permits an applicant to choose either alternative. The NRC recognizes that licensing, constructing, and operating a prototype plant would require significant time and resources to plan, license, construct, and operate before the plant is authorized to remove any operational restrictions necessitated by the need for prototype testing. If information is available to an applicant that would support compliance with the demonstration, analysis, and data requirement in paragraph (e)(1) and thus would not necessitate such operational restrictions, the applicant would likely choose to comply using this alternative. Appendix A to this enclosure describes the process for determining testing needs, including whether a prototype plant is needed.

For many years, the U.S. nuclear industry has contemplated the use of a prototype plant to test safety features of proposed advanced reactor designs, but has never done so. Discussions of prototype plants and their envisioned use to support the approval and certification of advanced reactor designs appear in the Statements of Consideration for the 10 CFR Part 52 rulemaking in 1989 (54 FR 15372; April 18, 1989). The NRC later amended the testing requirements and moved them to their present location in 10 CFR 50.43(e). NUREG-1226, "Development and Utilization of the NRC Policy Statement on the Regulation of Advanced Nuclear Power Plants," issued June 1988, and SECY-91-074, “Prototype Decisions for Advanced Reactor Designs,” dated March 19, 1991, discuss related background information. In SECY-91-074, the staff stated that advanced reactor designs may need testing ranging from basic R&D up to a full-size prototype plant to demonstrate that these designs are sufficiently mature to be certified. The NRC staff anticipated that testing and evaluation of an advanced reactor design would continue through the conceptual, preliminary, and final design stages. SECY-91-074 also describes a process to determine the various types of testing for a prototype plant that may be needed to determine that advanced reactor designs are sufficiently mature to be certified. The NRC expects that this process will be an integral part of the design and licensing process for advanced reactor designs. For convenience, Appendix A to this enclosure provides the process described in SECY-91-074.

Prototype testing will generally not suffice by itself to meet the full scope of testing requirements specified in 10 CFR 50.43(e). Instead, the testing requirements should be met by using data from system and component tests conducted at other nuclear and non-nuclear facilities in combination with operational and test data from the prototype plant. Such test data from other sources may be essential to the advanced reactor licensing basis and may play a significant role in supporting the safety case for an SDA or DC, if pursued.

For cases in which a FOAK plant is constructed and operated abroad or is otherwise not originally licensed by the NRC (e.g., a prototype plant funded by the U.S. Department of Defense), a prospective applicant would need to ensure that the scope and quality of all necessary test data will meet NRC requirements for allowing commercial deployment of the standard plant design. In particular, the capabilities and reliability of SSCs will need to be demonstrated using appropriate combinations of testing, operating experience, and operational programs. Test data used to support the qualification of safety-related SSCs for a commercial nuclear power plant must be shown to meet quality assurance criteria commensurate with those in Appendix B to 10 CFR Part 50.

How Do I Determine My Testing Needs?

Enclosure 2 to SECY-91-074 describes the process for determining testing needs for a commercial nuclear power plant. Appendix A to this enclosure includes that process in full for the reader’s convenience, with changes (e.g., updates, clarifications) annotated in brackets.

To summarize the process described in Appendix A, the process for determining testing needs involves a series of questions that enable the applicant to consider the testing objectives, evaluate those objectives in ascending order of testing complexity and value, combine tests where possible, analyze the results against the regulatory requirements, and determine the acceptability or deficiency of the testing or the new reactor design. Testing could include tests of components, systems, simulators, non-nuclear or nuclear test loops, and comprehensive prototypes for determining proof of principle.

The applicant would ask the following questions:

- What are the testing objectives?
- Is testing required for component performance, reliability, feasibility, or availability?
- Is testing required for human-machine interface, instrumentation information transfer, plant automation, or operator actions?

- Is testing required to determine the performance, reliability, availability, or feasibility of systems?
- Is testing required to determine nuclear performance, physics coefficients, reactivity control, or stability?
- Is testing required for systems interactions, interdependencies, overall feasibility, integrated system performance, or reliability?
- Is testing required for other objectives?
- Is combined testing possible?
- Can the test(s) objective(s) be demonstrated with a scale test(s)?
- Did the testing successfully justify the safety claims, or should the applicant redefine the testing objective(s) or redesign the plant?

How Do I Determine Whether a Prototype Plant Is Needed?

An applicant should first complete the process for determining testing needs as described above and in Appendix A to this enclosure. The necessary testing may encompass component tests, separate effects tests, and integral effects tests up to and including prototype testing. If an applicant determines that sufficient data are not available from component, integral, and separate effects testing to demonstrate safety features to satisfy the requirements of 10 CFR 50.43(e) before licensing, the applicant may propose that the planned FOAK reactor or standard plant design be licensed and tested as a prototype plant. The applicant may find, for example, that testing in a prototype plant can be used to reduce licensing basis analysis uncertainties (i.e., validate system design models) in relation to those derived solely from code assessment against scaled integral effects and separate effects tests from other facilities. (The potential for using a research or test reactor licensed under AEA Section 104 in lieu of a full-scale prototype for this purpose is discussed later in this enclosure.) The resulting uncertainty reductions could then be used to allow higher operating powers, higher operating temperatures, longer operating cycles, and less restrictive reactor protection system parameters, for example, for that plant or subsequent plants of the same design. The prototype plant can be considered as a transitional step between the development of a particular reactor technology and full commercial deployment. The prospective applicant should, as early as possible, decide whether and how any prototype testing would support the R&D and licensing of the design.

Is a Prototype Plant Needed To Perform Fuel and Materials Qualification Testing?

If sufficient testing data and analyses are available for the NRC to reach its safety conclusions regarding fuel and material qualification testing, a prototype would not be necessary for this purpose. However, the scope of prototype testing may, in some cases, include irradiation testing to extend or supplement other sources of test data. Conversely, qualification test data from the prototype plant would not be expected to replace or eliminate the need for qualification data from other sources. For example, test reactors may be better able to provide safety margin data by performing fuel irradiations at well-controlled, long-term operating temperatures higher than those expected in the prototype plant. Moreover, post-irradiation testing of fuel irradiated in either a test reactor or a prototype plant would typically be performed in separate facilities designed for conducting fuel tests under controlled accident heat-up or oxidation conditions and for measuring fuel integrity parameters and related fuel fission product retention and transport phenomena.

Can the NRC Determine that an Application Must Be Submitted for a Prototype Plant?

During its review of an application for a new advanced reactor design, the NRC may determine that sufficient data are not available from integral effects and separate effects testing or other sources to demonstrate safety features to satisfy the requirements of 10 CFR 50.43(e). In such cases, the NRC may determine that the FOAK power reactor facility needs to be licensed as a prototype plant to develop the needed test data during prototype testing. Further, 10 CFR 50.43(e)(2) requires, in part, that, "if a prototype plant is used to comply with the testing requirements, then the NRC may impose additional requirements on siting, safety features, or operational conditions for the prototype plant to protect the public and the plant staff from the possible consequences of accidents during the testing period."

When Would the NRC Impose Additional Requirements on a Prototype Plant?

Applicants are expected to propose sufficient measures to compensate for potential consequences based on uncertainties in the design for which the testing is needed. Under 10 CFR 50.43(e)(2), the NRC may impose additional requirements on a prototype plant to protect the public and plant staff from possible consequences of accidents during the testing period. These requirements would compensate for, among other things, technical uncertainties that exist before the testing program is complete and acceptable operation has been demonstrated. Additional requirements would be design-specific and only in areas where further verification is needed. Examples of potential preventive and mitigative compensatory measures for a prototype plant include remote siting, supplemental robust systems, supplemental emergency preparedness measures, an incrementally staged startup process, limits on operating parameters imposed by technical specifications or license conditions, or a limited duration of the license.

In determining needs for compensatory measures, an applicant should (1) conservatively estimate the relevant safety analysis uncertainties that exist before and during prototype testing, (2) predict how those uncertainties will be reduced by the testing results, and (3) evaluate the sensitivity of safety and compliance margins to the estimated uncertainties before testing. The applicant should then apply targeted compensatory measures where necessary to ensure acceptable margins of safety and compliance before and during testing in the prototype plant.

Safety feature performance and overall risk factors during the initial phases of prototype operation and testing may differ from those evaluated over the full operating lifetime of the plant. For example, calculated radionuclide releases will generally be smaller for analyzed transients and accidents that occur during the initial weeks and months of plant operation when the available core inventories of radiologically important long-lived fission products like cesium-137 and strontium-90 remain relatively small. Certain design safety functions (e.g., fuel radionuclide retention, passive shutdown, conductive cooling) may perform either more or less favorably during early plant operations than later. Safety margins during prototype plant testing could also be increased by lowering the total decay heat loads. This could be accomplished, for example, by testing from lower pre-test levels of fission power or with the lower decay heating that follows shorter periods (e.g., 1 day) of power operation.

Because general experience with system reliability shows that failure frequencies tend to be high when a FOAK facility is new, higher failure rates should be conservatively considered in evaluating how plant risk factors and safety performance characteristics may vary with operating time during the prototype testing period.

The safety analysis of the prototype plant should address all tests included in the planned test program. Analysis uncertainties and safety margins for each kind of test should be conservatively estimated and characterized in terms of their sensitivities to when the test is first conducted during the prototype testing period. As discussed above, a given kind of test may be found to have larger safety margins, smaller uncertainties, or both, if the first test is conducted within the initial weeks or months of power operation as opposed to during later operation of the plant. Updating the assessment of analysis methods against early test results may then help reduce the estimated uncertainties for similar tests performed later.

In accordance with 10 CFR 50.43(e)(1), analysis, testing, experience, or a combination thereof is required to demonstrate that new safety systems function satisfactorily in accordance with the safety analysis. In addition to testing, FOAK reactors are likely to have additional operational programs typical of a lead plant. These FOAK requirements and practices may include monitoring and surveillance requirements, evaluations of operating experience, and other operational programs to support the deployment of subsequent units. The goal is to ensure the design provides needed confidence for key safety functions through combinations of analysis, testing, and experience. The FOAK reactor license will include conditions or other means to define an appropriate combination of methods, possibly including acceptable testing of a prototype plant, to ensure operation of safety systems during a range of operating and accident conditions.

If the NRC or the applicant identifies compensatory requirements on operational conditions, siting, or safety features of a prototype plant, the applicant should propose approaches to delineate when each additional requirement is no longer applicable and effective or delineate the criteria for revoking each additional requirement on the prototype plant and other subsequent plants that are designed and licensed based on the prototype plant. In particular, the applicant should describe all necessary prototype testing and surveillance programs and the results therefrom that would provide an adequate basis for making each additional requirement unnecessary for subsequent plants.

As described above, the additional requirements placed on a prototype plant could involve additional safety features. However, prototype plants may also warrant special design features and programmatic measures to facilitate detailed inspections and sampling and to accommodate the placement and use of extra sensors and test equipment during the testing period. If the testing is successful, subsequent plants based on this design would not need to include provisions for these design features and programmatic measures.

How Would a Prototype Plant Fit into a Regulatory Engagement Plan?

A regulatory engagement plan describes a potential applicant's plan to engage with the NRC during the development and review of an application for a license, certification, or approval of an advanced reactor design. Such a plan is intended to identify the desired interactions with the NRC staff, the applicant's submittals and related NRC evaluations, dependencies on research and testing, cost and schedule, and other relevant information to facilitate the review. The plan could also include periodic meetings and discussions between the NRC staff and the potential applicant. These periodic meetings provide opportunities to ensure that the scope, schedule, and costs of activities remain consistent with the potential applicant's plans or to inform the potential applicant to adjust the plans, as appropriate.

Prospective developers and applicants are encouraged to work as early as possible with the NRC to clearly define the testing to be performed in a prototype plant, including expected results and associated criteria, and to determine how to address the licensing of a prototype plant and prototype testing in the regulatory engagement plan. Further, these interactions can be used to ensure the applicant understands what regulatory requirements it would need to satisfy in order to rely on test data used in the power plant design application (e.g., ensuring that the test program is developed and implemented under the appropriate quality controls). Prototype testing may include special surveillance and inspection programs, as well as safety testing of system performance under controlled conditions of normal and off-normal operations, transients, and accidents.

This enclosure describes several approaches for approval, licensing, or certification of reactor designs using a prototype plant. Licensing of a prototype plant can be accomplished through the processes in 10 CFR Part 50 (construction permit (CP) followed by an operating license (OL)), or through 10 CFR Part 52 (COL). Appendix B to this enclosure outlines several possible approaches for licensing a prototype plant under the 10 CFR Part 50 and 10 CFR Part 52 licensing processes. Figure 1 below gives a notional depiction of the prototype licensing process. These approaches include the potential for use of the testing conducted in a prototype plant to subsequently support an SDA under Subpart E, “Standard Design Approvals,” of 10 CFR Part 52 or a DC under Subpart B, “Standard Design Certifications,” of 10 CFR Part 52. While either licensing process in 10 CFR Part 50 or 10 CFR Part 52 could be used to license that prototype plant as a standalone plant with no further standardization actions (e.g., obtaining a subsequent DC or SDA), this enclosure assumes that a potential applicant’s regulatory engagement plan would include both the licensing of a prototype plant and subsequent pursuit of a DC or SDA. The process shown in Figure 1 and the approaches described in Appendix B to this enclosure are a few of the many possible approaches to licensing a prototype plant — there are many other approaches that could be taken to successfully license a prototype plant that are not described here.

Because of the variety of approval, licensing, and certification options presented in 10 CFR Part 52 and the combinations within that part and with those of 10 CFR Part 50, numerous possible approaches are available. As part of their regulatory engagement plans, applicants are encouraged to engage the NRC as early as possible with their intended approaches for the licensing and use of a prototype plant.

It is important to note that any option selected would require an environmental review under the National Environmental Policy Act of 1969 and the NRC’s regulations at 10 CFR Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.” This includes an evaluation of severe accident mitigation alternatives for CPs, OLs and COLs, or severe accident mitigation design alternatives for DCs and SDAs. The NRC would conduct mandatory public hearings before a prototype plant could be licensed and constructed. Contested hearings before the NRC’s Atomic Safety and Licensing Board could also occur in connection with CPs and OLs under 10 CFR Part 50 and COLs under 10 CFR Part 52.

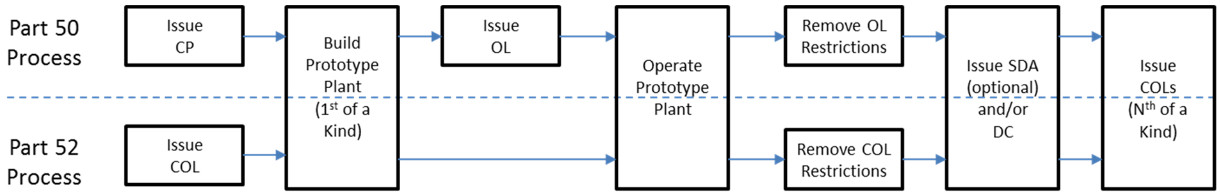

Figure 1: Simplified prototype plant licensing process

How Would an Application Differ for a Reactor Design with a Prototype?

For a reactor design without a prototype, all testing and analysis relied upon for compliance with 10 CFR 50.43(e)(1) must be completed before the NRC can arrive at its safety conclusion and issue a license. For a reactor design that proposes to use a prototype, choosing to comply with 10 CFR 50.43(e)(2), some testing could be planned and accomplished using the prototype plant, in lieu of additional testing at a separate facility such as a research or test reactor. The prototype plant application would contain information specifically related to prototype testing, including but not limited to describing the specific SSCs that rely on the test results, SSCs involved in the test, temporary test devices required, operational conditions or restrictions, and success criteria for the test. Further, the designer could propose additional safety features during the prototype testing to compensate for uncertainties in the safety analysis.

How Would the License Issued, or the NRC's Safety Conclusions in Its Safety Evaluation, Differ for a Prototype Plant?

The NRC must be able to reach safety conclusions on any application it reviews, including standard reactor design and license applications. The standard design or license application and the NRC's safety evaluation must address the performance criteria and expected outcomes of the prototype testing that is relied upon for the safety finding in lieu of other data or analysis. Placing license conditions on a license or restrictions on a standard design could be one way to identify the necessary prototype testing outcomes. The license condition or restriction could be removed upon successful completion of prototype testing.

How Is the Prototype Testing Period Determined?

The prototype testing period is the period during which prototype testing is being performed, the plant is operating under related license conditions, and additional safety features have been installed as necessary. There is no predefined prototype testing period. The prototype testing period will be selected by the applicant based on the testing purpose. Further, although certain prototype tests may be conducted as part of the initial startup testing program, the overall duration of the prototype testing period will vary depending on the purpose and type of the testing. The testing period must be sufficient to provide assessment data to demonstrate the performance of the intended safety feature(s). For this reason, for the purpose of certain tests, the prototype plant testing period may need to continue through equilibrium core conditions. Equilibrium core conditions may be necessary to demonstrate important fuel and core safety characteristics, such as nuclear reactivity feedback effects and the performance of fuel fission product barriers, and their variation over the reactor's operating lifetime.

The time needed to attain an equilibrium core configuration depends on the reactor technology. For example, in currently operating light-water reactors, it may take four or five refueling cycles to transition from an initial core configuration starting with 100 percent fresh fuel to an essentially equilibrium core configuration. During refueling of these reactors, about one-third of the fuel is removed and replaced with fresh fuel, and the remaining fuel that has been used for one or two refueling cycles is relocated within the core. As another example, in the case of the Next Generation Nuclear Plant licensing strategy for a modular high-temperature gas-cooled reactor, DOE proposed a prototype demonstration period lasting at least 5 years with a 12-month refueling cycle. For designs with lifetime cores, the term "equilibrium core" would have no meaning or possibly a different meaning from that described here. Such designs may warrant additional or alternative considerations for testing that adequately address the variation of fuel and core safety characteristics over the operating lifetime.

The NRC encourages applicants to propose performance-based approaches and criteria for determining the necessary prototype testing period. For example, an applicant may propose a design-specific testing period that can provide an adequate basis for assessing, with acceptable uncertainty, the licensing-basis calculations of core physics and fuel performance behavior. Related considerations could include the degree to which safety-significant phenomena over the plant's lifetime are represented over the proposed duration of the prototype testing program and the sensitivity of predicted safety and compliance margins to remaining code assessment uncertainties.

Is It Possible To License a Smaller Scale Reactor Instead of a Prototype Plant?

As previously described, "a prototype plant is *similar to* a FOAK or standard plant design *in all features and size*, but may include additional safety features to protect the public and the plant staff from the possible consequences of accidents during the testing period" (emphasis added). When the NRC defined this term, it envisioned that the prototype would resemble, to the extent possible, the standard plant design with additional safety features, as needed. However, the NRC understands that, for some advanced reactor designs and technologies, an applicant may seek to license, build, and operate a reactor that is smaller in scale than the standard plant design but would be used, in part, for the same kinds of testing as would be performed using a full-scale prototype plant. The smaller reactor could be licensed as a commercial facility under AEA Section 103 or a research or test reactor under AEA Section 104. There could be many reasons for choosing a smaller reactor, including cost, safety, time, and manufacturing issues.

The NRC could review an application for a commercial reactor that is smaller in scale than the standard plant design but is intended to function as a prototype plant in some respects. If a subsequent application for a larger plant was submitted, the NRC staff would support using as much data and analysis from the smaller reactor as applicable. However, the applicant would need to evaluate scaling considerations to ensure that the data obtained from a smaller reactor would be adequate to satisfy the 10 CFR 50.43(e) testing requirements in a subsequent application for a full-scale plant.

How Would Prototype Testing Be Done for a Multi-module Facility?

A multi-module facility is a nuclear power plant with multiple reactor modules of a standard plant design. For proposed multi-module facilities, an applicant could propose to perform prototype testing on only the first one or few reactor modules. This testing could be performed on a facility in which the modules are sufficiently independent so that multi-module effects of the entire facility do not need to be tested. The conduct of prototype testing in any reactor module of a multi-module facility could make the entire plant meet the regulatory definition of a prototype plant. For example, test results from the first reactor module could be used to support the eventual approval or certification of the reactor module design while also satisfying related technical specifications or license conditions on subsequent modules in the prototype plant whose operations are subsequent to those of the first module. In principle, the applicant could use more than one reactor module in the prototype plant to address different testing and surveillance needs. For example, one module could address surveillance testing needs for normal power operating conditions while another undergoes safety testing under controlled or simulated transient or accident conditions (e.g., passive shutdown testing, passive decay heat removal testing). Moreover, concurrent testing on multiple prototype reactor modules could reduce schedules.

For multi-module facilities that share systems between reactors (e.g., shared control rooms, heat exchangers, power conversion units, feedwater systems, heat sinks), it may be necessary to conduct prototype tests that address interactions between modules. The necessity of conducting such multiple reactor tests in a multi-modular prototype plant would depend on the potential safety significance of the effects of these interactions and whether the analysis of such effects can be adequately verified by other means.

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APPENDIX A

PROCESS FOR DETERMINING TESTING NEEDS

Reprint of: SECY-91-074, “Prototype Decisions for Advanced Reactor Designs,” dated March 19, 1991, Enclosure 2, as annotated

Note: This appendix is included for the reader’s convenience. Several annotations [in brackets] have been added for clarity.

Introduction

The staff proposes the following process for determining the type of demonstration facilities that may be needed for the certification-by-test approach under Part 52 of Title 10 of the *Code of Federal Regulations* (10 CFR [Part] 52). These facilities will enable the applicant to perform tests in order to justify the performance characteristics and safety claims regarding a new reactor design or design feature not previously licensed by the [NRC] staff. The process enables the applicant to consider the testing objectives, evaluate those objectives in ascending order of testing complexity and value, combine tests where possible, analyze the results against the regulatory requirements, and determine the acceptability or deficiency of the testing or the new reactor design. The process begins whenever the staff challenges the applicant’s bases for the safety claims or performance characteristics of a new reactor design.

The types of possible testing include tests of components, systems, simulators, non-nuclear or nuclear test loops, and comprehensive prototypes for determining proof of principle. The applicant may consider the least burdensome type of testing that provides the safety-related insights required to substantiate the applicant’s bases. For instance, the applicant may consider component testing first and only consider the most burdensome type of testing (the testing of a full-scale prototype) as a last resort. The actual item being tested may be prototypical of the item under consideration (e.g., component or system), it may be scaled in size, or it may be limited in the features modeled. For each type of test, the objectives of the test will determine the appropriate degree of test similarity to the matter under consideration. Table 1 briefly relates the types of tests to the item under consideration. “Full-scale prototype” is defined as a full-size plant representing the first-of-a-kind (FOAK) facility in all features and size [refer to the definitions of the term “prototype” in 10 CFR 50.2 and 10 CFR 52.1]. The prototype need not include the power production systems, similar to the fast flux test facility (FFTF) [a 400 megawatt-thermal liquid sodium-cooled test reactor owned by the U.S. Department of Energy and located at the Hanford site in southeastern Washington]. The prototype could include additional safety features to protect the public, the plant staff, and the plant itself from the possible consequences of failures during the testing period. An alternative to the construction of a prototype could be the testing of a special feature or system combined with a rigorous and robust start-up testing program at the FOAK plant.

When this process is applied to a component, system, or sub-system and testing requirements are identified, it is important that the testing requirements be evaluated at the overall plant design level. Combinations of tests could provide more representative safety insights and reduce the burden of the overall testing program. More importantly, combining tests may increase assurance that a particular departure from existing technology does not result in unidentified interdependent effects among the safety systems.

The following describes the individual steps of the process. The step numbers in front of paragraphs correspond to the numbers in the lower part of the symbols (boxes, diamonds, and circles) in the simplified process diagram shown in Figure 1.

Process Description

[The following paragraph discusses the need for prototype testing in terms of the NRC's review of an application and its finding of an insufficient safety basis. However, the process for determining testing needs should actually begin during the design phase and well before the submission of an application to the NRC. Potential applicants are strongly encouraged to interact with the NRC staff through preapplication interactions, with a focus on new and unique design features and the safety rationale supporting their performance. Potential applicants should pursue a structured approach for each SSC and for each safety function to be performed and document their rationale for deciding whether analysis, existing data, or new testing is needed to demonstrate safety performance. Furthermore, potential applicants may consider submitting technical reports during the pre-application phase discussing the analytical tools, experimental results, operating experience, and expert judgement that will be used to demonstrate the safety performance of the design. During preapplication interactions, potential applicants should discuss with the NRC the structured approach they pursued to determine the sufficiency of analysis, data, and testing needed. Ideally, there would never be a situation where the NRC makes an insufficient basis finding during the review of an application, and preapplication interactions would ideally result in a lower likelihood of such a finding. This would, in turn, result in a more efficient and effective review of the application.]

The process is applied to each performance or safety claim made for the new design. Different claims may indicate the need for different levels of testing. The process for determining the appropriate testing option begins when the staff finds the applicant's bases to be insufficient for substantiating the performance or safety claims made by the designer or implied in the design. This finding would indicate that attempts to use analytical tools, experimental results, operating experience, and expert judgement have failed to provide adequate justification of the design. The staff may determine the justification to be insufficient because of the size of the uncertainties associated with the design or because of the magnitude of the consequences that could result if a safety feature fails to perform its function. To apply the process, the applicant would begin in box 1 and then identify the type(s) of test(s) for each safety claim (circles 3, 5, 7, or 9, as appropriate) for all of the safety claims before proceeding to box 12.

1. Identify and define testing objectives.

To select the appropriate type of test(s) or prototype, the applicant must clearly define the objectives. The applicant should select objectives and subordinate objectives to define the results desired from the testing process. The objectives will determine the type of testing to be conducted. Therefore, the applicant should carefully consider the objectives for completeness and clarity. The applicant should identify testing objectives separately for each performance or safety claim. In Figure 1, the applicant would combine tests in decision box 12 of the process diagram, after identifying all testing requirements that may be necessary.

Next, the applicant would evaluate the test objectives identified for each claim to select the appropriate level of testing that is needed. The applicant would begin the process by considering the simpler testing options before considering the more extensive options.

2. Is testing required for component performance, reliability, feasibility, or availability?

In this step, the applicant would identify those testing objectives for determining the acceptability of component performance, the reliability of component functions, the feasibility of using a component in the proposed way, the availability of the component to perform its function, the ability of the component to perform in adverse environments (i.e., environmental qualification), and other attributes of the component.

In the advanced reactor designs under development, designers are reducing the redundancy and diversity of components to simplify the new designs. Consequently, the new designs (especially the SBWR and AP-600) [these designs were considered to be new in 1991] rely on the reliability of components to maintain or exceed the safety levels associated with current plants. If the operating history of a component in current nuclear plants or in similar installations does not support the use of the component in new reactor designs that demand high reliability, the applicant may choose testing to demonstrate that the component meets these demands.

Therefore, in determining the need to conduct component tests, the applicant should carefully consider the reliability demands of the component imposed by the new reactor design. The applicant should assess the component's reliability by considering the operating history of the component in current plants. The applicant could do this by considering the similarity of equipment and operating environments, evaluating the redundancy and diversity of the design, and evaluating any modifications or changes incorporated into the new design.

If the purpose of the test is component performance, reliability, etc., then a component test should be adequate to satisfy the test objective and thereby substantiate the safety claim. Refer to the following discussion [in box 3] for this type of test.

3. Component test(s) or separate effects test(s) are required.

The applicant would conduct a component test to verify the performance of a component, such as a valve, a pump, a breaker, or a relay. The test may be required if a component has been significantly redesigned, will be used in a new or innovative way, or has not operated in the past with the reliability needed in the new plant design. The test should generate data to be used to substantiate the performance of the component during both normal and off-normal operating conditions in the plant.

In developing the advanced reactor designs being considered by the industry, designers are increasing the reliance on component reliability and performance, as redundancy and diversity are reduced (simplification). Because many of the components in the new designs are used in current plants (e.g., motor-operated valves, check valves, breakers, and relays), reliability data exists for their performance in nuclear plant conditions. In some cases, the performance of individual components may not be sufficient for the reliability requirements imposed by the new designs. Designers have achieved reliability in current plants by means of redundancy and diversity. In such cases, the designer may need to test these components to demonstrate that the reliability in the new reactor environment is sufficiently improved from their reliability in the existing plants to allow the component to be used in the new design.

With the component testing program, the applicant should demonstrate that the performance of the component fulfills the safety claims directly related to the component's performance. This program could include environmental qualification, seismic qualification, and quality class. Applicants should conduct such tests where high operating cycles can be achieved in short periods of time. To address the issue of age-related degradation in developing the testing plan, the applicant must carefully consider the advantages and disadvantages of conducting accelerated aging tests in relation to testing naturally aged components. The applicant should include in this decision process the results of the NRC's Nuclear Plant Aging Research Program [this program is no longer active, but its work was used in nuclear plant license renewal].

4. Is testing required for man-machine interface, instrumentation information transfer, plant automation, or operator actions?

In this step, the applicant would identify those testing objectives that focus on the human performance element in the design that might be the basis for safety claims about the new reactor design. If, for example, the design depends heavily on operator actions (or inactions) that reactor operating experience has shown to be unreliable, then the applicant may need to perform tests to determine the level of human performance that is needed. In this step, the applicant would also identify the testing required to substantiate safety claims concerning plant automation features that have not been confirmed in existing reactor experience or by testing.

The new reactor designs use much more automation for processing information [compared to that of current operating reactors], displaying the status of systems, and controlling plant operation. In some cases, applicants have proposed major changes in the control room design that involve computer display and manipulation of data for the operators. In such cases, the ability of operators to control the new automated plants cannot be demonstrated from current plant operating history. Therefore, applicants may need to test the manner in which operators interact with automated plant systems for monitoring and control (including related computer systems and software).

The applicant should base the decision to conduct simulator tests, construct mock-ups or otherwise test the interaction of humans with the automated plant on the considerations of design differences between the new and current plants, the current philosophy of procedures and practices, and the consequences of operator inaction and erroneous intervention.

If the objective to be tested meets these qualifications, then the applicant may need a simulator or mock-up in order to satisfy the testing objective. Refer to the following discussion [in box 5] for this type of test.

5. Simulator or mock-up test(s) are required.

A simulator or mock-up test is (1) a computer model of the plant or a part of the plant that is used to test operator performance or (2) a model of a portion of the plant that is used to test the reliability of the operators to perform in that area. The applicant could perform these tests using a full operations simulator, mock-ups and simulations of control panels, or mock-ups of plant areas to test accessibility, maintenance reliability, or other factors.

In developing the new reactor designs, applicants have proposed different control and instrumentation features. These features are not familiar to operators in current light water reactors, and very little performance and reliability data may be available for evaluating the ability of the systems to meet performance specifications and reliability goals.

Applicants should design tests in these areas so as to evaluate both the human and the equipment elements associated with the proposed designs. For such a test, the applicant may need to develop procedures for operators to follow. These procedures might become part of the certified [or licensed] design, depending on the amount of operator action and interaction required. In these types of tests involving human interactions, it is very difficult to completely model all of the factors that affect plant operators in normal and other-than-normal situations. The applicant should evaluate the uncertainties associated with operator performance in these simulated tests to determine the acceptability of the design.

6. <u>Is testing required to determine the performance, reliability, availability, or feasibility of systems</u>?

In this step, the applicant would identify those testing objectives for determining the acceptability of system performance, the reliability of system performance, the feasibility of using a system in the proposed way, the degree of availability of the system to perform its function, or other attributes of the system.

In the simplified reactor designs, passive systems would perform many safety functions that active systems perform in current plants. These passive systems rely on the natural circulation of coolant, gravity-driven flows, and the injection of coolant by pressurized gas. These systems would depart from the design philosophy of current plants by replacing diverse, redundant, active systems with passive designs that need high reliability rather than redundancy and diversity.

In determining to test such systems, the applicant must, therefore, consider the very high demands for reliability placed on these systems and their contribution to overall safety and reliability of the plant. The applicant should provide significant assurance that the passive systems can be initiated from any plant operating condition, including off-normal conditions, and that these passive systems can function as claimed in the new design. The designer should assess the uncertainty associated with the ability to operate the system as designed (system feasibility), system reliability, and system availability.

If the purpose of the test is as discussed, then a system test should be adequate to satisfy the test objective and substantiate the safety claim. Refer to the following discussion [in box 7] for this type of test.

7. <u>Systems test(s) or non-nuclear integral loop test(s) are required</u>.

The applicant would use a system test to verify the performance of a system that includes new, untested features, eliminates levels of diversity and redundancy used in current plants, or claims to have high reliability not substantiated by operating history in existing plants. The test should generate data to be used to substantiate the performance of the system during plant normal and off-normal operating conditions. Depending on the objectives, the test may be a partial scale or a full-size system loop.

The advanced light water reactor (ALWR) designs use systems that operate differently from the technology associated with current LWRs. In many of the systems, after initial actuation of the system (which is mostly an active function), the systems function passively by natural circulation, gravity flow, or pressurized gas. The need for the high reliability of these systems may require testing to demonstrate the reliability or to reduce the uncertainties of performance to acceptable levels.

The applicant should develop these tests to evaluate the performance, the feasibility, and the reliability of the systems. These tests should demonstrate the availability and reliability of the system to function in all operating modes, including off-normal conditions as designed.

8. Is testing required for determining nuclear performance, physics coefficients, reactivity control, or stability?

In this step, the applicant would identify those testing objectives that could validate or substantiate the acceptability of reactor physics performance and could demonstrate the performance of the core in normal and off-normal operating conditions. Such tests could validate the reactor coefficients and their stability over the range of known operating conditions, including off-normal and severe accident conditions, from the conditions at the initial core load up to and including the equilibrium core.

The new reactor core designs differ in varying degrees from the current LWR core designs. The applicant should carefully consider the basic characteristics of the core design, including its stability and control margins for reactivity, and the stability of any neutronic and thermal-hydraulic interactions, as they may affect the stability and control margins of the reactor. The core performance should be predictable and should exhibit favorable (negative) reactivity coefficients (void, temperature, moderator, doppler, pressure, and power) in normal and other-than-normal operating conditions.

Many analytical models are available to evaluate the behavior of existing core designs. However, the applicant should carefully consider the application of a particular model to a specific new core design in terms of applicability of the model, the completeness of the analytical results (have all normal and off-normal operating conditions been considered), and the uncertainties associated with the model. The applicant should consider this type of test if analytic models reveal that the design would diverge from the safety envelope generally associated with current reactor operating philosophy or if the analytical models yield unacceptable uncertainty levels.

If the purpose of the test is as discussed, then the applicant may need to perform a critical facility test in order to satisfy the test objective and thereby substantiate the safety claims associated with the physics and performance characteristics of the reactor core. Refer to the following discussion [in box 9] for this type of test.

9. Critical testing facility is required.

The applicant would construct a critical testing facility [likely a testing facility licensed under Section 104 of the Atomic Energy Act of 1954, as amended (AEA)] to verify the reactor physics and performance characteristics of the reactor core. Using this facility, the applicant would perform tests to verify all reactor coefficients and their stability during all normal and off-normal conditions. Such a test should model the thermal-hydraulics of the core so as to reveal changes that may occur in the reactivity coefficients. These types of tests can range from individual assemblies in test reactors to independent loops designed to model sections of the reactor core.

These tests should be designed to reduce any uncertainties associated with the design and performance of the core. The testing program should model and test all conceivable operating conditions and environments to establish the safety of the core design. This testing program may actually require a series of tests beginning with fuel tests in a test reactor followed by tests of bundles or a partial core in a test facility. Finally, the applicant may test a section of the core for overall performance, reactivity coefficients, and shutdown mechanisms.

10. Is testing required for systems interactions, interdependencies, overall feasibility, integrated system performance, or reliability?

In this step, the applicant would identify those testing objectives for validating or substantiating that interacting and interdependent systems in the plant perform acceptably and for demonstrating the performance of these systems in normal and off-normal operating conditions. The objectives could be directed at assuring that failures of ancillary systems do not cause failures in safety systems, which could result in unacceptable behavior or consequences during operation, including off-normal and severe accident conditions.

In the design of any complex process, particularly in a power generating facility fueled by a nuclear core, the systems are highly interdependent both in their ability to function successfully and to propagate failures. Many systems must operate according to design to ensure the plant produces power safely. The failure of a system may affect the ability of a related system to function properly, which could significantly increase the consequences of the failure.

Therefore, the applicant should base the decision to consider multiple system tests on the degree of interdependency of systems in the proposed design, the redundancy and diversity of the systems that may reduce the consequences of individual system failures, the possibility of synergistic effects from the interactions of various phenomena or systems, and the susceptibility of the design to failures that propagate through one or more systems. As with other testing options, multiple systems test decisions must consider the reliability of the multiple systems compared to the demands placed on the systems by the safety analysis. In addition, the applicant must consider the level of uncertainty associated with the performance and interdependencies of the systems, and the consequences to the plant and the public if one system fails and limits the ability or inhibits the function of other systems to protect the plant and the public.

If the purpose of the test is as discussed, then the applicant should determine whether the testing objectives can be combined with other tests or met with a test of a scale model or a partial plant. Refer to the discussion in boxes 12 and 13 for this decision.

11. Is testing required for other objectives?

In this step, the applicant would identify those testing objectives that have not already been covered in decision boxes 2, 4, 6, 8, and 10. Once the applicant has identified the purpose of the test, the applicant should determine whether the testing objectives can be combined with those of other tests or met with a test of a scale model or partial plant. Refer to the following discussion for this decision.

In this section of the process, the applicant should combine, where appropriate, one or more of the testing options identified in the evaluation of the entire plant design.

12. Is combined testing possible?

In this step, the applicant should consider possible combinations of tests. In evaluating each performance or safety claim against the criteria in the previous decision boxes, the applicant had identified testing requirements. Once all of these tests are identified, the applicant should consider the combinations of tests that can improve the overall confidence of testing results and can achieve economic savings in the testing program. Where tests involve phenomena related to each other, common sense suggests that the combined testing would give higher confidence to the results and may identify synergistic effects. In this step, the applicant would compare the objectives and features of the tests indicated to identify opportunities to combine tests.

Where combinations are possible, the applicant would move to boxes 15 or 16 to develop the integrated test plans. If combinations are not feasible, then the applicant would move to box 14 to consider separate test(s).

13. <u>Can test(s) objective(s) be demonstrated with scale test(s)</u>?

The applicant would use this decision point to determine whether the test objectives can be satisfied by tests of scale models or partial plants. The applicant may perform such tests to demonstrate new phenomenon in the design that have not been justified in currently licensed plants. The applicant may conduct the test to determine seismic responses to input spectrum or other attributes of the design. Testing may range in size and scope from small phenomena tests to larger component or systems interactions tests.

14. <u>Conduct separate test(s)</u>.

If a certain test(s) cannot be combined with other tests and scale testing is not possible, then the designer would conduct the separate tests. The NRC staff may review the testing plan and observe the conduct of the tests.

15. <u>Conduct partial scale test(s)</u>.

The applicant may test scale models to substantiate safety claims associated with limited interactions of systems, structures, and components. This type of test depends significantly on the validity of the scaling factors. Therefore, the applicant should consider the need to carefully and thoroughly analyze these relationships to the full-size design.

When combined testing is possible, the applicant can perform tests of partial-scale systems or loops, where the scaling factors can be justified. With these tests, the applicant can establish performance parameters and basic design proof-of-principle. The applicant must take care in using the results of scale model tests because some phenomena can only be evaluated in full-scale tests.

16. <u>Conduct full-scale integrated test(s) or prototype test</u>.

The designer can now develop the integrated test(s) that satisfies the objectives of each of the contributing test(s). The designer can perform these test(s) to justify claims where the testing objectives cannot be satisfied by scale model tests (from box 13 in Figure 1). The designer or the NRC staff may decide that a test of a full-scale prototype [as defined in 10 CFR 50.2 or 10 CFR 52.1] is required.

A full-scale prototype is defined as a full-size nuclear plant, which represents the FOAK plant, and is prototypical of the new design in all features, size, and performance. Such a prototype would include the reactor core, the nuclear steam supply system (NSSS), the balance-of-plant systems, and the ancillary systems as they would be built in the "production" model plants [i.e., a commercial nuclear power plant]. The prototype may not include the power production systems, similar to the FFTF. The prototype could include additional safety features to protect the public, the plant staff, and the plant itself from the consequences of unanticipated failures during the testing period. The function of each system in the prototype must accurately represent the function specified in the final design in order to justify the design for [licensing or] certification under [10 CFR Part 50 or] 10 CFR Part 52.

In addition to physically constructing the prototype, the applicant must design the testing program to test the full range of design features and safety claims associated with the plant. Some features may not be testable in the prototype without damaging and possibly destroying the plant, resulting in consequences that are unacceptable. For these features and design functions, the prototype test must be performed at partial power levels or be supplemented with other types of tests (e.g., special features tests or component tests) to validate the behavior of the design without the extreme consequences that could result if the feature were tested in the full-size plant. The applicant would need a comprehensive testing program and a program for ensuring safety while the uncertainties of the plant are being tested.

The prototype for an advanced reactor design may need some additional safety features to compensate for the uncertainties in the design that the prototype is intended to test. However, the applicant would have to ensure that the additional safety features would not affect the test program. For example, if a design is proposed without a containment, the ability of such a plant to protect the public would be very uncertain if the safety systems failed and a release occurred. Therefore, the prototype might be built at an isolated site that would minimize the threat of exposure to the public from atmospheric dispersion of accidental releases, or the prototype could be built inside a containment designed to capture any release from the plant under all postulated conditions. New designs with less diversity and redundancy in safety systems or with boundaries that rely on highly reliable equipment may require extra trains or components that can be used if the reliability of the system or component is not as high as expected. The backup system or component, which is only intended for the prototype, could be used to perform the function if the primary equipment were to fail. In such tests, if the backup equipment were used, it would indicate a failure of the plant design, the assumptions, or the reliability of the equipment. Therefore, the safety claim and the design would not be sufficient for the NRC staff to [license or] certify the new design under [10 CFR Part 50 or] 10 CFR Part 52.

The applicant would conduct the tests identified herein and prepare a report of the results to support its request for certification. The NRC staff could review the testing plan and observe the conduct of the tests.

17. Did the testing successfully justify the safety claims?

The designer and ultimately the NRC must determine the acceptability of the test results of both integrated and separate tests. The data must be reviewed to determine whether they support the performance and safety claims.

18. The safety claims are justified.

If the data successfully substantiates the performance and safety claims, then this certification-by-test approach has demonstrated that the advanced reactor design can be [licensed or] certified under [10 CFR Part 50 or] 10 CFR [Part] 52. The process for determining necessary testing is now complete.

If the testing results fail to substantiate the performance and safety claims or fail to reduce the uncertainty levels sufficiently, then either the testing program has failed or the design cannot perform acceptably. The applicant would move to box 19.

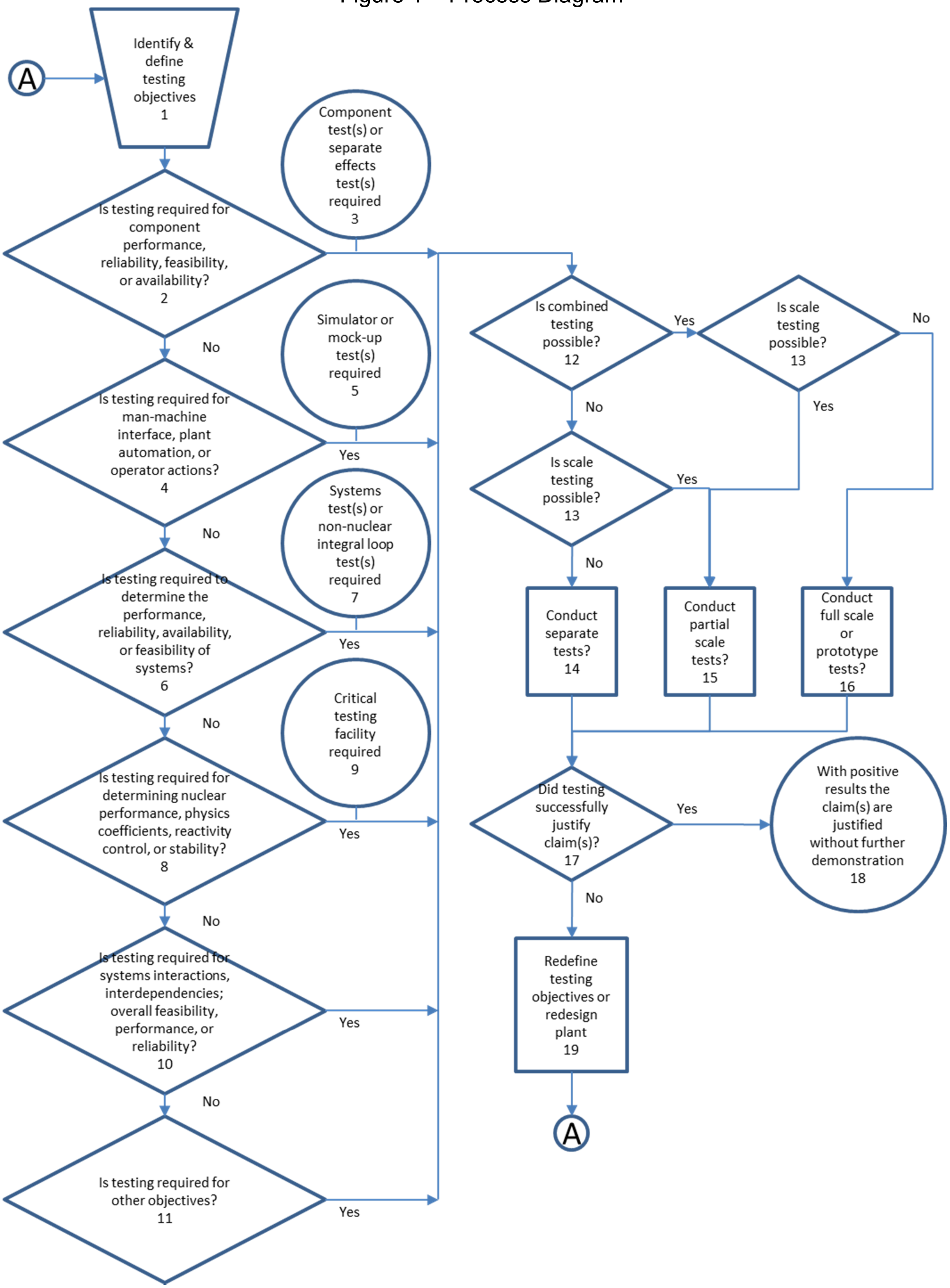
19. <u>Redefine the testing objective(s) or redesign the plant</u>.

In this step, the applicant would revise the testing objectives if the results have failed to substantiate the performance and safety claims. If, during this evaluation, the applicant identifies weaknesses in the testing methods or the objectives, the applicant would return to box 1 to redefine the objectives and redesign or modify the testing program to achieve positive results. If the proposed design cannot meet the performance and safety claims, then the applicant would revise the final design and perform the necessary testing to support certification of the revised final design.

Table 1

Type of Test	Feature to be Tested
special feature(s) test (e.g., control room simulator)	man-machine effects, human error rates
separate effects test (e.g., counter-current flow heat transfer)	heat transfer coefficients
non-nuclear integral loop test (e.g., Semi-scale, FIST, ROSA-4)	thermal-hydraulics, efficacy of ECCS [emergency core cooling system]
critical facility	basic physics characteristics, dynamic reactivity characteristics
partial scale reactor test	engineering feasibility of reactor systems, systems interactions
full-scale reactor test	engineering feasibility of entire reactor plant, extensive systems interactions, synergistic effects

Figure 1 – Process Diagram



APPENDIX B

OPTIONS FOR USING A PROTOTYPE PLANT TO ACHIEVE A DESIGN CERTIFICATION OR STANDARD DESIGN APPROVAL

This appendix describes various options for an applicant to use a prototype plant as part of its regulatory engagement plan to achieve a design certification (DC) or a standard design approval (SDA). One option is to apply for an SDA only after satisfactory completion of all planned prototype testing, or to apply for a restricted SDA before prototype testing and an unrestricted SDA or DC rule after successful completion of prototype testing. Another option for licensing and operating the prototype plant is to use either the construction permit (CP) and operating license (OL) processes under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," or the combined license (COL) process under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." All options would arrive at the same regulatory safety conclusions for the certified design. The sections below describe these options in further detail.

A. <u>10 CFR Part 50 Process for Prototype Licensing and Testing</u>

A 10 CFR Part 50 approach for licensing and testing a prototype plant in support of a CP and OL application could proceed as follows:

(1) The prospective owner of a first-of-a-kind (FOAK) plant submits a CP application to the U.S. Nuclear Regulatory Commission (NRC) under 10 CFR 50.34(a). Under 10 CFR 50.34(a)(8), CP applications are required to identify and provide a schedule for the research and development (R&D) that must be completed before completion of construction to confirm the adequacy of the design. The applicant and designer identify testing requirements not fulfilled before the start of construction for which they propose to perform prototype testing in the FOAK unit. A prototype plant would necessitate the identification and scheduling of any additional supporting R&D that must be completed during the prototype testing period. The prospective owner may conduct such R&D activities outside the prototype plant, but some of these activities may also involve surveillance and testing in the prototype plant. Note that the applicant could also elect to submit more detailed final plant design information at the CP stage.

(2) The NRC issues the CP under 10 CFR 50.35, "Issuance of Construction Permits," after reviewing the preliminary plant design information in the applicant's preliminary safety analysis report and determining the suitability of the prospective site.

(3) During the construction of the plant, the CP holder develops final design and site-specific information and prepares plans for operation and testing.

(4) The CP holder submits an OL application to the NRC under 10 CFR 50.34(b). The OL application describes the systems and components that need prototype testing, provides the plans and timing for performing those tests in the prototype plant, and specifies the criteria for satisfactory test results.

(5) The NRC issues the OL under 10 CFR 50.57, "Issuance of Operating License," and authorizes operation of the facility. The OL has license conditions, including technical specification limits, for plant operation and testing that are met, contingent upon completing the planned tests with satisfactory results. The licensee monitors the

prototype plant's operation and the planned testing in the prototype plant to verify that the results satisfy the relevant license conditions. Upon completion of the planned testing programs for the prototype plant, the licensee reports, and the NRC verifies, that the test results are satisfactory and the relevant license conditions have been met. These license conditions for the prototype plant could then be revised through a license amendment request. These license conditions may or may not be required for subsequent plants licensed under either 10 CFR Part 50 or 10 CFR Part 52, depending on the results of the prototype plant testing.

Using the 10 CFR Part 50 licensing option for constructing and operating the prototype plant, a 10 CFR Part 52 approach in support of an SDA <u>in parallel</u> with the OL could proceed as follows:

(1) The prospective owner of a FOAK plant submits a CP application to the NRC under 10 CFR 50.34(a). Under 10 CFR 50.34(a)(8), CP applications are required to identify and provide a schedule for the R&D that must be completed before completion of construction to confirm the adequacy of the design. The applicant and designer identify testing requirements not fulfilled before the start of construction for which they propose to perform prototype testing in the FOAK unit. A prototype plant would necessitate the identification and scheduling of any additional supporting R&D that must be completed during the prototype testing period. The prospective owner may conduct such R&D activities outside the prototype plant, but some of these activities may also involve surveillance and testing in the prototype plant. Note that the applicant could also elect to submit more detailed final plant design information at the CP stage.

(2) The NRC issues the CP under 10 CFR 50.35 after reviewing the preliminary plant design information in the applicant's preliminary safety analysis report and determining the suitability of the prospective site.

(3) During the construction of the plant, the CP holder and the developer of the standard plant design develop final design and site-specific information and prepare plans for operation and testing.

(4) The developer of the proposed standard plant design applies for an SDA under 10 CFR 52.135, "Filing of Applications," with linkages to the prototype testing program.

(5) In parallel, the CP holder submits an OL application to the NRC under 10 CFR 50.34(b). The OL application incorporates detailed plant design information from the SDA application. The OL application describes the systems and components that need prototype testing, provides the plans and timing for performing those tests in the prototype plant, and specifies the criteria for satisfactory test results.

(6) The NRC issues the SDA under 10 CFR 52.143, "Staff Approval of Design," with restrictions that translate to license conditions and revision criteria for technical specification limits on the prototype facility that can be met contingent upon satisfactory results from testing completed at the prototype facility.

(7) The NRC issues the OL under 10 CFR 50.57 and authorizes operation of the facility. The OL has license conditions, including technical specification limits, for plant operation and testing that are met contingent upon completing the planned tests with satisfactory results. The licensee monitors the prototype plant's operation and the planned testing in the prototype plant to verify that the results satisfy the relevant license conditions. Upon completion of the planned testing programs for the prototype plant, the licensee reports, and the NRC verifies, that the test results are satisfactory and the relevant license

conditions have been met. These license conditions for the prototype plant could then be revised through a license amendment request. These license conditions may or may not be required for subsequent plants licensed under either 10 CFR Part 50 or 10 CFR Part 52, depending on the results of the prototype plant testing. To the extent that prototype testing eliminates the need for restrictions on future COLs, these restrictions on the associated SDA can be removed in a subsequent revision.

(8) Once the SDA restrictions have been removed, the SDA holder can apply for a DC under 10 CFR 52.45, "Filing of Applications."

(9) The NRC issues the DC under 10 CFR 52.54, "Issuance of Standard Design Certification," without restrictions related to the prototype facility.

Using the 10 CFR Part 50 licensing option for constructing and operating the prototype plant, a 10 CFR Part 52 approach in support of an SDA or DC in series with the OL could proceed as follows:

(1) The prospective owner of a FOAK plant submits a CP application to the NRC under 10 CFR 50.34(a). Under 10 CFR 50.34(a)(8), CP applications are required to identify and provide a schedule for the R&D that must be completed before completion of construction to confirm the adequacy of the design. The applicant and designer identify testing requirements not fulfilled before the start of construction for which they propose to perform prototype testing in the FOAK unit. A prototype plant would necessitate the identification and scheduling of any additional supporting R&D that must be completed during the prototype testing period. The prospective owner may conduct such R&D activities outside the prototype plant, but some of these activities may also involve surveillance and testing in the prototype plant. Note that the applicant could also elect to submit more detailed final plant design information at the CP stage.

(2) The NRC issues the CP under 10 CFR 50.35 after reviewing the preliminary plant design information in the applicant's preliminary safety analysis report and determining the suitability of the prospective site.

(3) During the construction of the plant, the CP holder and the developer of the standard plant design develop final design and site-specific information and prepare plans for operation and testing.

(4) The CP holder submits an OL application to the NRC under 10 CFR 50.34(b). The OL application includes detailed plant design information from the standard plant design. The OL application describes the systems and components that need prototype testing, provides the plans and timing for performing those tests in the prototype plant, and specifies the criteria for satisfactory test results.

(5) The NRC issues the OL under 10 CFR 50.57 and authorizes operation of the facility. The OL has license conditions, including technical specification limits, for plant operation and testing that are met, contingent upon completing the planned tests with satisfactory results. The licensee monitors the prototype plant's operation and the planned testing in the prototype plant to verify that the results satisfy the relevant license conditions. Upon completion of the planned testing programs for the prototype plant, the licensee reports, and the NRC verifies, that the test results are satisfactory and the relevant license conditions have been met. These license conditions for the prototype plant could then be revised through a license amendment request. These license conditions may or may

not be required for subsequent plants licensed under either 10 CFR Part 50 or 10 CFR Part 52, depending on the results of the prototype plant testing.

(6) The developer of the proposed standard plant design applies for an SDA under 10 CFR 52.135 or a DC under 10 CFR 52.45. The SDA or the DC application incorporates detailed plant design information from the OL application and ensures the performance of safety functions using analysis, testing, and experience, including the testing and experience from the prototype plant.

(7) The NRC issues the SDA under 10 CFR 52.143 or DC under 10 CFR 52.54 without restrictions related to the prototype facility.

B. 10 CFR Part 52 Process for Prototype Licensing and Testing

A 10 CFR Part 52 approach for licensing and testing a prototype plant in support of a COL application in series with an SDA or a DC application could proceed as follows:

(1) The prospective owner of a FOAK plant submits an application to the NRC under Subpart C, “Combined Licenses,” of 10 CFR Part 52 for a custom COL that includes all necessary standard plant design information. In this instance, the term “custom” refers to a COL application that does not reference a previously reviewed and approved or certified design such as in a DC or an SDA. The custom COL application describes the specific design safety features that need prototype testing, provides the plans and timing for performing those tests, and specifies the criteria for satisfactory test results. The applicant and designer identify testing requirements not fulfilled before the start of construction for which they propose to perform prototype testing in the FOAK unit.

(2) The NRC issues the COL under 10 CFR 52.97, “Issuance of Combined License,” after reviewing the standard plant design information in the applicant’s final safety analysis report and determining the suitability of the prospective site, as well as the specific design safety features that need prototype testing, the plans and timing for performing those tests, and the criteria for satisfactory test results.

(3) Based on the prototype plant’s operation and the planned testing in the prototype plant, the licensee verifies that the results satisfy the affected license conditions.

(4) Upon completion of the planned testing programs for the prototype plant, the licensee reports, and the NRC verifies, that all planned testing achieved satisfactory results. These license conditions for the prototype plant could then be revised through a license amendment request. These license conditions may or may not be required for subsequent plants licensed under either 10 CFR Part 50 or 10 CFR Part 52, depending on the results of the prototype plant testing.

(5) The developer of the proposed standard plant design applies for an SDA under 10 CFR 52.135 or a DC under 10 CFR 52.45 and references the prototype testing performed in the COL.

(6) The NRC issues the SDA under 10 CFR 52.143 or the DC under 10 CFR 52.54 without restrictions related to the prototype facility.

A 10 CFR Part 52 approach for licensing and testing a prototype plant in support of a COL application in parallel with an SDA application could proceed as follows:

(1) The prospective owner of a FOAK plant submits an application to the NRC under Subpart C, "Combined Licenses," of 10 CFR Part 52 for a custom COL that includes all necessary standard plant design information. In this instance, the term "custom" refers to a COL application that does not reference a previously-reviewed and approved or certified design such as in a DC or an SDA. The custom COL application describes the specific design safety features that need prototype testing, provides the plans and timing for performing those tests, and specifies the criteria for satisfactory test results. The applicant and designer identify testing requirements not fulfilled before the start of construction for which they propose to perform prototype testing in the FOAK unit.

(2) In parallel with the custom COL application, the developer of the proposed standard plant design applies for an SDA under 10 CFR 52.135 and references the prototype testing program in the COL application. The SDA application should provide all necessary standard plant design information that the prospective owner included in the custom COL application for the prototype plant.

(3) The NRC issues the COL under 10 CFR 52.97 after reviewing the standard plant design information in the applicant's final safety analysis report and determining the suitability of the prospective site, as well as the specific design safety features that need prototype testing, the plans and timing for performing those tests, and the criteria for satisfactory test results.

(4) The NRC issues the SDA under 10 CFR 52.143 with restrictions on future COLs that translate to license conditions and revision criteria for technical specification limits on the prototype facility that can be met, contingent upon satisfactory results from testing completed at the prototype facility.

(5) Based on the prototype plant's operation and the planned testing in the prototype plant, the licensee verifies that the results satisfy the affected license conditions.

(6) Upon completion of the planned testing programs for the prototype plant, the licensee reports, and the NRC verifies, that all affected license conditions have been met by satisfactory test results. These license conditions for the prototype plant could then be revised through a license amendment request. These license conditions may or may not be required for subsequent plants licensed under either 10 CFR Part 50 or 10 CFR Part 52, depending on the results of the prototype plant testing. To the extent that prototype testing eliminates the need for restrictions on future COLs, these restrictions on the associated SDA can be removed in a subsequent revision.

(7) Once the SDA restrictions have been removed, the SDA holder can apply for a DC under 10 CFR 52.45.

(8) The NRC issues the DC under 10 CFR 52.54 without restrictions related to the prototype facility.

Another 10 CFR Part 52 approach for licensing and testing a prototype plant in support of a COL application <u>in series</u> with a DC application could proceed as follows:

(1) The developer of a proposed standard plant design submits a DC application to the NRC under 10 CFR 52.45. The DC application describes the specific design safety features that need prototype testing, provides the plans and timing for performing those tests, and specifies the criteria for satisfactory test results. The designer identifies testing

requirements not fulfilled before the start of construction for which prototype testing would be required in the FOAK unit.

(2) The NRC issues the DC under 10 CFR 52.54 with restrictions on future COLs, such as license conditions and revision criteria for technical specification limits on the prototype facility that are met, contingent upon satisfactory results from planned testing completed at the prototype facility.

(3) The prospective owner of a FOAK plant submits a COL application to the NRC under Subpart C, “Combined Licenses,” of 10 CFR Part 52 that references the DC.

(4) The NRC issues the COL under 10 CFR 52.97 after reviewing the applicant’s final safety analysis report and determining the suitability of the prospective site, as well as the specific design safety features that need prototype testing, the plans and timing for performing those tests, and the criteria for satisfactory test results.

(5) Based on the prototype plant’s operation and the planned testing in the prototype plant, the licensee should verify that the results satisfy the affected license conditions.

(6) Upon completion of the planned testing programs for the prototype plant, the licensee reports, and the NRC verifies, that all affected license conditions have been met by satisfactory test results. These license conditions for the prototype plant could then be revised through a license amendment request. These license conditions may or may not be required for subsequent plants licensed under either 10 CFR Part 50 or 10 CFR Part 52, depending on the results of the prototype plant testing. To the extent that prototype testing eliminates the need for restrictions on future COLs, these restrictions on the associated DC can be removed in a subsequent amendment.

(7) The DC holder can apply for an amendment to the DC under 10 CFR 52.75, “Filing of Applications.”

(8) The NRC issues the DC under 10 CFR 52.54 without restrictions related to the prototype facility.