Regulatory Analysis for Proposed Rulemaking 10 CFR 50.46c:
“Emergency Core Cooling System Performance During Loss-of-Coolant Accidents”

This document presents a regulatory analysis of a proposed rule (and implementing regulatory guidance) which that would amend Title 10 of the *Code of Federal Regulations* (10 CFR) by establishing new, performance-based requirements for emergency core cooling systems (ECCS) for light water nuclear power reactors.

Background

In SECY-98-300, “Options for Risk-Informed Revisions to 10 CFR Part 50-‘Domestic Licensing of Production and Utilization Facilities,’” dated December 23, 1998, (NRC’s Agencywide Document Access and Management Systems (ADAMS) Accession No. ML992870048), the U.S. Nuclear Regulatory Commission (NRC or the Commission) began to explore approaches to risk-informing its regulations for nuclear power reactors. One alternative (termed “Option 3”) involved making risk-informed changes to the specific requirements in the body of 10 CFR Part 50. As the NRC began to develop its approach to risk-informing these requirements, it sought stakeholder input in public meetings. Two of the regulations identified by industry as potentially benefitting from risk-informed changes were §§ 50.44 and 50.46. Section 50.44 specifies the requirements for combustible gas control inside reactor containment structures, and § 50.46 specifies the requirements for light-water power reactor emergency core cooling systems. For § 50.46, the potential was identified for making risk-informed changes to requirements for both ECCS cooling performance and ECCS analysis acceptance criteria in § 50.46(b).

On March 14, 2000, as amended on April 12, 2000, the Nuclear Energy Institute (NEI) submitted a petition for rulemaking (PRM) requesting that the NRC amend its regulations in §§ 50.44 and 50.46 (PRM-50-71). The NEI petition noted that these two regulations apply to only two specific zirconium-alloy fuel cladding materials (zircaloy and ZIRLO^{TM}). The NEI stated that reactor fuel vendors[1] had subsequently developed new cladding materials other than zircaloy and ZIRLO^{TM} and that, in order for licensees to use these new materials under the regulations, licensees had to request NRC approval of exemptions from §§ 50.44 and 50.46.

On May 31, 2000, the NRC published a notice of receipt (65 FR 34599) and requested public comment. The public comment period ended on August 14, 2000, and the NRC received 11 public comment letters from public citizens and the nuclear industry. Although the majority of the comments generally supported the requests of the PRM, one commenter suggested that the enhanced efficiency of the proposal would be at the expense of public health and safety. The NRC disagrees with that commenter and notes that, while the petition's proposal would remove specific zirconium-alloy names from the regulation, the NRC review and approval of specific zirconium-alloys for use as reactor fuel cladding would be required prior to their use in reactors (with the exception of lead test assemblies permitted in technical specifications). A detailed discussion of the public comments submitted on PRM-50-71 is contained in a separate document (*see* Section IX of the Statement of Considerations (SOC), "Availability of Documents.")

After evaluating the petition and public comments received, the NRC decided that PRM-50-71 should be considered in the rulemaking process. The NRC's determination was published in the *Federal Register* (FR) on November 6, 2008, (73 FR 66000). Because most of the issues raised in this PRM pertain to § 50.46, the PRM is addressed in this proposed rule.

---

[1] For the purpose of this analysis, the term "vendor" refers to manufacturers of NRC approved fuel assembly designs. To support implementation of the proposed requirements on individual plant dockets, fuel vendors would submit for NRC review alloy-specific hydrogen uptake models and LOCA model updates.

The PRM also requested changes to § 50.44. Those changes were addressed in a rulemaking which revised that section (68 FR 54123; September 16, 2003), to include risk-informed requirements for combustible gas control. The regulation was also modified to be applicable to all boiling or pressurized water reactors regardless of the type of fuel cladding material used.

On March 31, 2003, in response to SECY-02-0057, "Update to SECY-01-0133, 'Fourth Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.46 (ECCS Acceptance Criteria),'" the Commission issued a staff requirements memorandum (SRM) (ADAMS Accession No. ML030910476) directing the NRC staff to move forward to risk-inform its regulations in a number of specific areas. Among other things, this SRM directed the staff to modify the ECCS acceptance criteria to provide a more performance-based approach to the ECCS requirements in § 50.46.

Separate from the effort to modify the regulations to provide a more risk-informed, performance-based regulatory approach, the NRC had also undertaken a fuel cladding research program to investigate the behavior of high exposure fuel cladding under accident conditions. This research program included an extensive LOCA research and testing program at Argonne National Laboratory (ANL), as well as jointly-funded programs at the Kurchatov Institute (supported by the French Institute for Radiological Protection and Nuclear Safety and the NRC) and the Halden Reactor project (a jointly-funded program under the auspices of the Organization for Economic Cooperative Development – Nuclear Energy Agency, sponsored by national organizations in 18 countries), to develop the body of technical information needed to support the new regulations.

The effects of both alloy composition and fuel burnup (the extent to which fuel is used in a reactor) on cladding embrittlement (i.e., loss of ductility) under accident conditions were studied in these research programs. The research programs identified new cladding embrittlement mechanisms and expanded the NRC's knowledge of previously identified mechanisms. The research results revealed that alloy composition has a minor effect on embrittlement, but that the cladding corrosion that occurs as fuel burnup increases has a substantial effect on embrittlement. One of the major findings of the NRC's research program was that hydrogen, which is absorbed in the cladding as a result of zirconium oxidation (i.e., corrosion) under normal operation, has a significant influence on embrittlement during a postulated LOCA. Increased hydrogen content increases both the solubility of oxygen in zirconium and the rate at which it is diffused within the metal, thus increasing the amount of oxygen in the metal during high temperature oxidation in LOCA conditions. Further, the NRC's research program found that oxygen from the oxide fuel pellets enters the cladding from the inner surface if a bonding layer exists between the fuel pellet and the cladding, in addition to the oxygen that enters from the oxide layer on the outside of the cladding. Moreover, under some small-break LOCA conditions (such as extended time-at-temperature around 1,000 degrees Celsius (°C) (1832 degrees Fahrenheit (°F))), the accumulating oxide on the surface of the cladding can break up, allowing large amounts of hydrogen to diffuse into the cladding, exacerbating the embrittlement process.

The research results also confirmed a previous finding that if cladding rupture occurs during a LOCA, large amounts of hydrogen from the steam-cladding reaction can enter the cladding inside surface near the rupture location. These research findings have been summarized in Research Information Letter (RIL) 0801, "Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46," (ADAMS Accession No. ML081350225) and the detailed experimental results from the program at ANL are contained in NUREG/CR-6967, "Cladding Embrittlement during Postulated Loss-of-Coolant Accidents" (ADAMS Accession No. ML082130389). Since the publication of NUREG/CR 6967 and RIL-0801, additional testing was conducted related to the embrittlement phenomenon, which has been documented in supplemental reports. Where the additional testing relates to conclusions and recommendations in RIL-0801, RIL-0801 has been supplemented to reference the additional reports and incorporate findings (ADAMS Accession No. ML113050484).

The NRC publicly released the technical basis information in RIL 0801 on May 30, 2008, and NUREG/CR-6967 on July 31, 2008. When the NRC publicly released NUREG/CR-6967, the NRC published in the FR a notice of availability of the RIL and NUREG/CR-6967, together with a request for comments (73 FR 44778). In that notice, the NRC stated that these documents and comments on the documents would be discussed at a public workshop to be scheduled in September 2008. The public workshop was held on September 24, 2008, and included presentations and open discussion between representatives of the NRC, international regulatory and research agencies, domestic and international commercial power firms, fuel vendors, and the general public. A summary of the workshop, including a list of attendees and presentations, is available at ADAMS Accession No. ML083010496. The NRC has not prepared responses to comments received on the technical basis information as a result of the July 31, 2008, *Federal Register* Notice (FRN) (including comments received in the 2008 public workshop), because: i) the public workshop was held, in part, to discuss public comments on the technical basis information, and ii) further opportunity to comment is available during the proposed rule's formal public comment period.

Based upon a preliminary safety assessment in response to the research findings in RIL-0801, the NRC determined that immediate regulatory action was not required, and that changes to the ECCS acceptance criteria to account for these new findings could reasonably be addressed through the rulemaking process. Recognizing that finalization and implementation of the new ECCS requirements would take several years, the NRC completed a more detailed safety assessment which confirmed current plant safety for every operating reactor. See Section V.F of the SOC for further information.

On March 15, 2007, Mark Leyse submitted a PRM to the NRC (ADAMS Accession No. ML070871368). In the petition, which was docketed as PRM 50-84, the petitioner requests that all holders of operating licenses for nuclear power plants be required to operate such plants at operating conditions (e.g., levels of power production, and light-water coolant chemistries) necessary to effectively limit the thickness of crud[2] and/or oxide layers on fuel rod cladding surfaces. The petitioner requests the NRC to conduct rulemaking in the following three specific areas:

1) Establish regulations that require licensees to operate light-water power reactors under conditions that are effective in limiting the thickness of crud and/or oxide layers on zirconium-clad fuel in order to ensure compliance with § 50.46(b) ECCS acceptance criteria;

2) Amend Appendix K to Part 50 to explicitly require that steady-state temperature distribution and stored energy in the reactor fuel at the onset of a postulated LOCA be calculated by factoring in the role that the thermal resistance of crud deposits and/or oxide layers plays in increasing the stored energy in the fuel (these requirements also need to apply to any NRC-approved, best-estimate ECCS evaluation models used in lieu of Appendix K to Part 50 calculations); and

3) Amend § 50.46 to specify a maximum allowable percentage of hydrogen content in (fuel rod) cladding.

On May 23, 2007, the NRC published a notice of receipt for this petition in the FR (72 FR 28902) and requested public comment. The public comment period ended on August 6, 2007. After evaluating the public comments, the NRC resolved PRM-50-84 by deciding that each of the petitioner's issues should be considered in the rulemaking process. The NRC's determination, including the NRC's response to public comments received on the petition, was published in the FR on November 25, 2008 (73 FR 71564). Because the issues

---

[2] For the purpose of this discussion, the NRC defines "crud" as any foreign substance deposited on the surface of the fuel cladding prior to the initiation of a LOCA. It is known that this layer can impede the transfer of heat.

raised in the petition pertain to ECCS analysis and acceptance criteria, the need for rulemaking to address each of the petitioner's concerns will be addressed in this proposed rule.

I. Statement of the Problem and Objective

Statement of the Problem

The proposed action is needed in response to recent research by the Argonne National Laboratory, the Kurchatov Institute, and the Halden Reactor project into the behavior of fuel cladding under accident conditions, mainly a loss of coolant accident. This research indicated that the current combination of peak cladding temperature (2200 °F (1204 °C)) and local cladding oxidation criteria (17 percent) do not always ensure post quench ductility (PQD) following a postulated LOCA. The proposed action would replace the limits on peak cladding temperature and local oxidation with specific cladding performance requirements and acceptance criteria which ensure that an adequate level of cladding ductility is maintained throughout the postulated LOCA. The NRC developed three draft regulatory guides which provide acceptable means of meeting the proposed performance requirements.

The proposal to expand applicability to all light-water nuclear power reactors, regardless of fuel design or cladding material used, is necessary to account for the development of new fuel designs and cladding materials other than zircaloy and ZIRLO™. Under the current rule, licensees that use different types of cladding material are required to request NRC approval for an exemption from the rule.

Lastly, the proposal would require licensees to evaluate thermal effects of crud and oxide layers that accumulate on fuel cladding. This proposed amendment would address one of the requests of PRM 50-84.

Objectives

The principal objectives of the proposed revision to the requirements for ECCS performance for light-water nuclear power reactors are to provide more performance-based criteria and also account for the new research information. Further, the NRC intends to expand the applicability of the rule to all fuel design and fuel cladding materials. In addition, this proposed rule would address the issues raised in PRM-50-71 and PRM-50-84.

As noted in Section V of the SOC, and expanded upon in Section XVII of the SOC, "Backfitting and Issue Finality," this rulemaking is proposed because of the NRC's position that it is necessary to ensure adequate protection to the public health and safety by restoring that level of protection (i.e., reasonable assurance of adequate protection) which the NRC thought would be achieved (throughout the entire term of licensed operation) by the current rule. Regulatory guidance, in the form of three regulatory guides, were developed in order to: (1) provide a clear, acceptable methodology for supporting and establishing the performance-based regulatory limits called for in 50.46c (2) simplify the staff's review process; and (3) reduce regulatory uncertainty and thereby help to minimize the costs associated with the implementation of the regulatory requirements proposed for 50.46c. The three regulatory guides are: DG-1261, "Conducting Periodic Testing for Breakaway Oxidation Behavior," (ADAMS Accession No. ML110840089), DG-1262, "Testing for Post Quench Ductility," (ADAMS Accession No. ML110840283), and DG-1263, "Establishing Analytical Limits for Zirconium-Based Alloy Cladding" (ADAMS Accession No. ML110871607).

This regulatory analysis was developed following the "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission"[3] (Guidelines). In particular, with regard to adequate protection, the Guidelines state that "The level of protection constituting 'adequate protection' is that level which must be assured *without regard to cost"* (emphasis added). The Guidelines

[3] NUREG/BR-0058, Revision 4, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," Office of Nuclear Regulatory Research, September 2004.

also state that " . . . a proposed backfit to one or more of the facilities regulated under 10 CFR Part 50 does not require a regulatory analysis if the resulting safety benefit is required for purposes of compliance or adequate protection under 10 CFR 50.109(a)(4)." However, the Guidelines note that if there is more than one way to achieve compliance or reach a level of adequate protection, costs may be a factor in that decision. The NRC believes that a rulemaking is the only credible regulatory action that can provide the necessary adequate protection in this case. With respect to the regulatory guides, the NRC believes that the development of such guidance is desirable in § 50.46c, in order to ensure a consistent means of generating and using experimental data to establish regulatory limits.

Disaggregation

In order to comply with the guidance provided in Section 4.3.2 ("Criteria for the Treatment of Individual Requirements") of the Regulatory Analysis Guidelines, the NRC conducted a screening review to determine if any of the individual requirements (or set of integrated requirements) of the proposed rule are unnecessary to achieving the objectives of the rulemaking. The NRC determined the objectives of the rulemaking are to: 1) incorporate recent research findings; 2) establish performance-based requirements for ECCS in the event of a LOCA; 3) expand the regulation's applicability; and (4) incorporate the requests of two PRMs. Furthermore, the NRC concluded that each of the proposed rule's requirements is necessary to achieve one or more objectives of the rulemaking. The results of this determination are set forth in the following table.

Table 1 – Disaggregation

Regulatory Goals for 10 CFR 50.46c	1) Revise the ECCS acceptance criteria to reflect recent research findings	2) Establish performance-based requirements	3) Expand applicability of the 10 CFR 50.46 to all fuel types and cladding materials	4) Incorporate requests of 2 PRMs
Paragraph (a) Applicability.			X	X
Paragraph (b) Definitions.	X			
Paragraph (d) Emergency core cooling system design.		X		
Paragraph (g) Fuel system designs: uranium oxide or mixed uranium-plutonium oxide pellets within cylindrical zirconium-alloy cladding.	X			
Paragraph (k) Use of NRC approved fuel in reactor.			X	X
Paragraph (m) Reporting.	X			
Appendix K to 10 CFR Part 50, Paragraph (I)(B)				X

II. Identification and Preliminary Analysis of Alternative Approaches

Given the existing data and information, this proposed rule is considered by the NRC to be the only credible regulatory action to attain adequate protection. Consequently, a rulemaking is the only regulatory action alternative considered. The no-action option is used only as a basis against which to measure the costs and benefits of the proposed rule.

In light of recent research findings which indicate that the current regulations do not always ensure post quench ductility (PQD) following a LOCA, this proposed rule is necessary to ensure adequate protection to the public health and safety by restoring that level of protection (i.e, reasonable assurance of adequate protection) which the NRC thought would be achieved (throughout the entire term of licensed operation). However, based upon a preliminary safety assessment in response to the research findings in RIL-0801, the NRC determined that immediate regulatory action was not required, and that changes to the ECCS acceptance criteria to account for these new findings could reasonably be addressed through the rulemaking process. Recognizing that finalization and implementation of the new ECCS requirements would take several years, the NRC completed a more detailed safety assessment which confirmed current plant safety for every operating reactor. See Section V.F of the SOC for further information.

Proposed Rule

The proposed rule would amend the current regulations for ECCS acceptance criteria, found in § 50.46(b), by establishing performance-based requirements. The proposed rule would expand applicability to all light water reactors, regardless of fuel design or cladding materials. It should be noted that this amendment would satisfy a request of a PRM (docketed as PRM-50-71). The proposed rulemaking would also incorporate recent research findings which identified previously unknown cladding embrittlement mechanisms and expanded the NRC's knowledge of previously identified mechanisms. Specifically, the research identified that hydrogen, which is absorbed in the cladding during normal operation, has a significant influence on embrittlement during a postulated accident. Finally, the proposed rule would require licensees to evaluate the thermal effects of crud and oxide layers which may have developed on the fuel cladding. It should be noted that this amendment would satisfy a request of a PRM (docketed as PRM-50-84).

Regulatory Guidance

Because this proposed rule would be performance-based, three companion draft regulatory guides (DGs) were developed. The proposed rule calls for measurement of the onset of breakaway oxidation for a zirconium cladding alloy based on an acceptable experimental technique. The proposed rule also calls for the evaluation of the measurement relative to emergency core cooling system performance, and periodic testing and reporting of the values measured. Draft Guide 1261 describes an experimental technique acceptable to the NRC staff to measure the onset of breakaway oxidation in order to support a specified and acceptable limit on the total accumulated time that a cladding may remain at high temperature, as well as a method acceptable to the NRC to implement the periodic testing and reporting requirements in the proposed rule.

The proposed rule also calls for the establishment of analytical limits on peak cladding temperature and time at elevated temperature that correspond to the measured ductile-to-brittle transition for the zirconium-alloy cladding material. Draft Guide 1262 describes an experimental technique that is acceptable to the NRC for measuring the ductile-to-brittle transition for a zirconium-based cladding alloy. Draft Guide 1263 provides a method of using experimental data to establish regulatory limits. These DGs will be published for comment along with the proposed rule.

III. Estimation and Evaluation of Values and Impacts

This section identifies the components of the public and private sectors, commonly referred to as attributes, that are expected to be affected by this rulemaking. An inventory of the impacted attributes was developed using the list provided in Chapter 5 of the NRC's "Regulatory Analysis Technical Evaluation Handbook"[4] (Handbook). The identified impacts are quantified where

[4] NUREG/BR-0184, "Regulatory Analysis Technical Evaluation Handbook," U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, 1997.

possible. However, impacts to accident-related attributes are qualified because new research has determined that existing estimates of probabilities of accidents were found to be too low. This proposed rule attempts to retain the level of safety that NRC previously determined to have been acceptable.

Assumptions

All 104 currently operating light-water nuclear power reactors will be affected by this proposed rule. The quantifiable impacts, (i.e., those which are able to be monetized) are the implementation and operation costs for both industry and the NRC. All monetized costs are expressed in 2014 dollars, the year the rule is assumed to be implemented. Other than for operating reactors which have indicated they would not seek a license renewal, this analysis assumes that remaining operating reactors' life expectancy will include a 20-year license extension. As a result, the average license will expire in 2039. Given the rule is assumed to be implemented in 2014, the average remaining life will be 25 years from implementation and any recurring costs will be discounted over that time period. Any costs incurred over future years are discounted back to 2014 values. Based on the most recent NRC labor rates, an NRC staff-year is valued at $173,000, while an annual industry staff labor rate of $200,000 is assumed.

There are currently two design certifications that are expected to be renewed. For the regulatory analysis, the NRC assumes that these are the only design certifications that will be submitted.

The NRC assumes that there are six future operating light-water nuclear power reactors that would be affected by this rule. The nuclear power reactors are: Watts Bar Nuclear Power Plant, Unit 2, with an assumed beginning of operations date in 2013; Vogtle, Units 3 and 4, with an assumed beginning of operations date of 2017; Virgil C. Summer Nuclear Station, Units 2 and 3, with an assumed beginning of operations dates of 2017 and 2019, respectively; and Bellefonte Nuclear Station Unit 1, with an assumed beginning of operations date of 2020.[5]

The NRC assumes that other new design certifications could be submitted to the NRC for approval and have developed a hypothetical design certification to analyze the costs and benefits of the proposed rule on a design certifications.

The NRC also assumes that other new light-water nuclear power reactors could begin to operate in the future and have developed a hypothetical light-water nuclear power reactor to analyze the costs and benefits of the proposed rule on a new light-water nuclear power reactor. The NRC assumes that no other types of reactors will be built and that there will be no significant differences between the future operating reactors and the hypothetical reactor.

Another assumed difference in this analysis is that Industry Implementation costs are separated into so-called direct and indirect costs. This difference is explained further in the Industry Implementation paragraph.

This regulatory analysis assumes that the final rule is published on January 1, 2014. It would then take vendors approximately one year to submit their revised models. This regulatory analysis assumes that nine alloy-specific cladding hydrogen uptake models would need to be developed and twelve existing LOCA models would need to be revised in order to implement the proposed rule. (To facilitate this analysis, and the assumptions within, the LOCA models are distinguished between PQD/Breakaway and Long Term Cooling.) Next, we assume 1 year for the NRC review and comment of the nine vendor cladding hydrogen uptake models, and 2 years for the NRC review and comment of the twelve vendor LOCA models. Next, the 65 plants in Track 1 would demonstrate compliance within 24 months by providing a letter report to the NRC. No NRC review of these letters is necessary. Finally, the remaining 39 plants in Tracks 2

[5] Bellefonte Nuclear Station, Unit 2, as well as all other combined operating licenses submitted to the NRC are too speculative in nature to be included in the regulatory analysis.

and 3 would demonstrate compliance within 48 months and 60 months, respectively, by submitting a new LOCA analysis of record.

Industry Implementation – This attribute is composed of indirect and direct licensee implementation costs for operating reactors, design certifications and future operating reactors. The proposed rule would require licensees of operating reactors, design certifications, and future operating reactors to make use of revised ECCS analysis models based upon the new required acceptance criteria. The revised ECCS models and alloy-specific cladding hydrogen uptake models would be developed by vendors, at the request and expense of the licensees. Because the vendors are not licensed by the NRC and are developing the revised ECCS models because of the new requirements being imposed upon licensees, these costs are considered to be *indirect industry implementation costs*. The vendors would also produce licensing topical reviews describing the new models for NRC review and approval. The vendors would also produce test data to characterize alloy performance and develop analytical limits based on this test data include within each alloy's topical review.

After NRC approval in relation to operating reactors, the models would be run to perform plant-specific analyses, demonstrate compliance with the proposed acceptance criteria, and to employ the post quench ductility (PQD) analytical limits. Costs incurred by licensees under these three tracks are considered *direct industry implementation costs*.

Sixty-five operating plants under Track 1 and 5 future operating plants with similar implementation steps as Track 1 would complete any necessary engineering calculations, update their plant updated final safety analysis report UFSAR, and provide a letter report to the NRC documenting compliance to § 50.46c. The plants in Track 1 meet the new requirements without new analysis or model revisions (beyond use of Cathcart-Pawel – Equalivalent Cladding Reacted (CP-ECR) to integrate time-at-temperature and hydrogen uptake models to establish PQD analytical limits), and thus would meet the new requirements with a low level of effort. The

16 operating plants in Track 2 are PWR plants using realistic evaluation models, as well as BWR/2 plants, which will require new analyses or model revisions to demonstrate compliance. The NRC anticipates that Track 2 plants will exert a medium level of effort to comply with the proposed regulation. The 23 operating plants in Track 3 are PWR plants using Appendix K evaluation models, as well as BWR/3 plants, which will require new analyses or model revisions to demonstrate compliance. The NRC anticipates that Track 3 plants will exert a medium – high level of effort to comply with the proposed regulation. Track 2 and Track 3 plants would be required to conduct a new ECCS evaluation, and submit a new LOCA analysis of record. The vendors would also conduct initial breakaway testing on all cladding alloys. Again, because the vendors are not licensed by the NRC, and conducting initial breakaway tests because of the new requirements imposed on the licensee, these costs are considered indirect costs.

The proposed rule would require licensees to evaluate the thermal effects of crud and oxide layers that accumulate on the fuel cladding during plant operation. Because licensees are required to account for various thermal parameters under the current regulation, the NRC's position is that the proposed requirement to evaluate crud is a clarification of the current requirement. As such, there is no additional cost incurred as a result of the rule.

Although multiple designs for new reactors have been certified by the NRC, only one type of design is currently in the construction phase in the United States, the Westinghouse Electric Company's AP1000. The AP1000 uses the same fuel design as the current fleet and, thus, will have no effect in relation to the attributes. As no other construction has begun, all other reactor designs would be too speculative to provide within the Regulatory Analysis.

The current ECCS performance regulation applies to "each boiling or pressurized light-water nuclear power reactor fueled with uranium oxide pellets within cylindrical zircaloy or ZIRLO cladding." As such, licensees must request an exemption to use fuel designs consisting of materials other than those stated. The proposed rule would extend applicability to all LWRs, regardless of fuel design. This eliminates the need for exemption requests, and represents a benefit.

NRC Implementation – The NRC would incur several implementation costs. The first set of costs is for the development of the regulatory guides and final rule. Once the rule is implemented, the NRC would review and approve the approximately 21 vendor licensing topical reviews which provide the revised ECCS analysis model. Next, the NRC would need to review the approximately 27 revised ECCS Analyses of Record (AOR) in Track 2 and 3 (due to multiple units sites which share common analyses, total number of AORs reduced from 39 plants). Lastly, the proposed rule would eliminate the need for licensees to submit an exemption request to use materials other than "uranium oxide pellets within cylindrical zircaloy or ZIRLO cladding." The NRC would no longer be required to review such exemption requests, which results in a benefit

Industry Operation – Industry would incur annual costs in performing the Periodic Breakaway Tests. These tests involve the performance of the required breakaway oxidation tests as performed by vendors and, as a result, are considered indirect costs. These costs would be incurred for plants that are both currently operating or operating in the future (does not apply for design certifications). The NRC notes that the proposed rule would require licensees to report errors in calculated equivalent cladding reacted (ECR) in concert with reported changes in PCT. For the purposes of this analysis, the NRC assumes that the cost of reporting ECR is negligible since licensees calculate ECR under the current regulation and are already required to report changes to or errors in ECCS evaluation models with respect to calculated PCT.

The NRC notes that the proposed reporting criteria is restructured and rewritten to provide clarification on which items need to be reported, and the timeframe for reporting. The proposed additional language clarifies the intent of the current regulation. As such, the proposed revision does not constitute a change in burden to the NRC or the industry.

NRC Operation – NRC would experience recurring costs as a result of the industry's periodic breakaway tests by analyzing the test results. The NRC would also incur annual costs as a result of reviewing reported errors in calculated ECR. However, the current regulation requires licensees to report errors in calculated PCT, and the actions the NRC would take for an error in ECR are the same as those actions for errors in calculated PCT. Additionally, errors in calculated ECR would have an associated error in calculated PCT. For all of these reasons, the NRC assumes that the change in annual cost between the current and proposed rule, with respect to reporting ECR, are negligible.

Improvements in Knowledge – The proposed rule incorporates research findings which identified new cladding embrittlement mechanisms. As a result, future LOCA analysis will improve their predictions of cladding embrittlement.

Regulatory Efficiency – Expanding the applicability of this rule to different fuel designs and additional cladding materials would contribute to the regulatory efficiency by eliminating the need for licensees to submit exemption requests for different fuel designs or cladding material.

Public Health (Accident) – As noted above, the NRC is initiating these new requirements so that the risk of accidental radiation exposure to the public remains at the previously assumed level. This corresponds to a decrease in the value of this attribute from the existing actual value.

Occupational Health (Accident) – Similarly, the NRC assumes that the risk of an accidental radiation exposure is now at the level it was assumed to have been prior to the proposed rule. Again, this corresponds to a decrease in the value of this attribute.

Onsite Property – Likewise, the NRC assumes that the risk of damage to onsite property is now at the level it was assumed to have been prior to the proposed rule. As seen above, this corresponds to a decrease in the value of this attribute and represents a cost savings.

Offsite Property – The NRC also assumes that the risk of damage to offsite property is now at the level it was assumed to have been prior to the proposed rule. As seen above, this corresponds to a decrease in the value of this attribute and represents a cost savings.

Attributes that are *not* expected to be affected under the proposed rulemaking include the following: public health (routine); occupational health (routine); other government; general public; antitrust considerations; safeguards and security considerations; and environmental considerations.

IV. Presentation of Results

This section presents the quantitative results by attribute. Values are shown in 2014 dollars.

Industry Implementation Costs

The industry implementation costs are spread among operating reactors, design certifications and future operating reactors. As noted above, the proposed rule would require licensees to make use of revised ECCS analysis models based upon the new required acceptance criteria. The revised ECCS models would be developed by vendors, at the request and expense of the licensees. These models are the Cladding Hydrogen Uptake Models and the LOCA Model Updates. The vendors would also produce test data to characterize alloy performance and develop analytical limits based on this test data. The vendors would produce licensing topical reviews regarding the new models, which would require NRC review and approval. After NRC approval, vendors would run the models under contract to licensees to perform plant-specific analyses and demonstrate compliance with the proposed acceptance criteria. The costs associated with implementation assume the use of the Regulatory Guides developed for this proposed rule and include the costs of the testing as outlined in the Regulatory Guides.

As shown in Table 2, Industry Implementation Costs for Operating Reactors, on pages 34 – 35, the first component is the indirect costs resulting from vendor implementation. As noted above, because the vendors are not licensed by the NRC and are developing the revised ECCS models because of the new requirements being imposed upon licensees, these are considered to be *indirect industry implementation costs*. The Cladding Hydrogen Uptake Models are assumed to be performed in a one-year period in 2014 and the LOCA Models are assumed to be performed in a 2-year period between 2013 and 2014. The Initial Breakaway Tests are assumed to be performed in 2014. The nine hydrogen uptake models are assumed to require 0.75 full-time equivalent (FTE)/year/alloy. (For this analysis, the NRC assumes an industry labor rate of $200,000/year.) The 12 LOCA models (PQD and breakaway) are assumed to require 0.75 FTE/year/alloy. The 12 LOCA models (long term cooling) are assumed to require 0.5 FTE/year/alloy. There are also assumed to be nine Initial Breakaway Test Models requiring a third of an FTE each and that the tests would be performed in 2014. The 9 models of Cladding Alloys cost an estimated $1,350,000. Further, all 12 of the LOCA models (which include estimates for the completion of the topical reports) area estimated to cost $3,000,000.[6] The Initial Breakaway Test is expected to occur in 2014 and has an estimated cost of $600,000.

Adding to the Licensee Implementation Costs for Operating Reactors are the Track 1, Track 2, and Track 3 activities. The NRC assumes that there would be 50, 13, and 14 revised AORs in the three tracks, respectively. Due to multiple unit sites which share common analyses, the number of AORs is less than the 104 plants. Track 1 actions would require 0.5 FTE over a two year period (0.25 FTE/year); Track 2 actions would require 1.5 FTE over a 3 year period (0.5 FTE/year); Track 3 actions would require 2.25 FTE over a 3 year period (0.75 FTE/year). The NRC estimates the total costs for these tracks range from $13,397,000 (7 percent real discount rate) to $14,371,000 (3 percent rate). Track 1 has values ranging from $4,836,000 (7 percent) to $4,927,000 (3 percent). Track 2 ranges from $3,411,000 (7 percent)

[6] In this analysis, where activities occur in 2014, no discounted values are provided.

to $3,667,000 (3 percent). Similarly, for Track 3, the cost estimate ranges from $5,150,000 (7 percent) to $5,767,000 (3 percent).

Another potential indirect licensee cost for operating reactors would be the development of new PQD analytical limits in place of utilizing the acceptable PQD analytical limits provided in the regulatory guide. For the purpose of this regulatory analysis, the NRC assumes that the industry elects to establish new PQD analytical limits for two cladding alloys requiring a quarter of an FTE per year. It is also assumed that this test will be accomplished in 2014, and the estimated cost is $100,000. The remaining seven cladding alloys will utilize the PQD analytical limits in the regulatory guide (RG). The NRC assumes that, due to the high cost of establishing a new experimental technique (outside the acceptable experimental technique in the RG), no vendor will choose that method.

The last Licensee Implementation Test is the long term cooling test. The NRC assumes that nine cladding alloys will need to be tested, requiring 0.15 FTE per year. It is also assumed that this test will be accomplished in 2014. The total cost for the long term cooling testing is estimated to be $270,000.

The proposed rule reduces licensee implementation cost by eliminating the need for exemption requests to use materials other than uranium-oxide fuel pellets within cylindrical zircaloy or ZIRLO cladding. The NRC assumes that 50 plants (five per year over a 10 year period, beginning in 2014) would request an exemption if the proposed rule did not extend applicability. It is also assumed that the exemption requests would require 0.2 FTE per exemption request. This results in a total savings ranging from $1.5 million (7 percent) to $1.76 million (3 percent). The estimated implementation cost for operating reactors ranges from $22,531,000 (7 percent) to $26,323,000 (3 percent).

As shown in Table 3, Industry Implementation Costs for Design Certifications, on page 35, the costs come from an analysis of the design certifications. The Track 2[7] cost is an indirect cost that would occur for both design certifications in 2017. The NRC assumes that the design certifications would require 1.5 FTE per design certification. Track 2 has an estimated cost range from $490,000 (7 percent) to $549,000 (3 percent). The estimated implementation costs for design certification ranges from $490,000 (7 percent) to $549,000 (3 percent).

Table 4, Industry Implementation Costs for Future Operating Reactors, on page 36, provides costs for the Initial Breakaway Test, the track designation which most closely matches implementation required for the reactors, and the LTC test that each reactor would use. The Initial Breakaway Test, which occurs for Watts Bar in 2014, the Summer and Vogtle future operating reactors in 2017 and the Bellefonte 1 in 2020, has an estimated cost range from $36,000 (7 percent) to $43,000 (3 percent).

The Track 1[8] costs, which occur for Watts Bar in the years 2014 and 2015, requiring 0.25 FTE for each year and for all other reactors in years 2018 and 2019, each AOR requiring 0.25 FTE. The Watts Bar Track 1 estimated cost ranges from $97,000 (7 percent) to $99,000 (3 percent). The Summer and Vogtle future operating reactors Track 1 estimated cost ranges from $296,000 (7 percent) to $351,000 (3 percent). The Bellefonte 1 Track 1 estimated cost ranges from $64,000 (7 percent) to $83,000 (3 percent). The total cost estimate for Track 1 ranges from $457,000 (7 percent) to $533,000 (3 percent).

The LTC Test cost is incurred in years 2014, for Watts Bar, 2019, for the Summer and Vogtle future operating reactors, and 2020 for Bellefonte 1. The LTC requires 0.04 FTE per reactor and has an estimated total cost range from $36,000 (7 percent) to $43,000 (3 percent).

[7] Although labeled "Track 2," the NRC assumes that design certifications will not be a part of Track 2, but will have characteristics similar to Track 2 and are, thus, labeled as "Track 2."

[8] Although labeled "Track 1," the NRC assumes that future operating reactors will not be a part of Track 1, but will have characteristics similar to Track 1 and are, thus, labeled as "Track 1."

The total estimated industry implementation cost for future operating reactors ranges from $529,000 (7 percent) to $619,000 (3 percent).

The total estimated industry implementation cost for operating reactors, design certifications and future operating reactors ranges from $18,232,000 (7 percent) to $19,101,000 (3 percent).

Industry Operation Costs

The NRC assumes that, once all licensees of operating reactors have implemented the proposed rule, 60 periodic breakaway tests will be submitted to the NRC each year (based on distribution between 18 month and 24 month operating cycles). However, between publication and full implementation, the NRC estimates the number of periodic breakaway tests will be as indicated for operating reactors:

2017	Periodic Breakaway Tests	60
2018	Periodic Breakaway Tests	0
2019	Periodic Breakaway Tests	55
2020	Periodic Breakaway Tests	44
2021	Periodic Breakaway Tests	60

Table 5, Industry Operating Costs for Operating Reactors, on page 37, shows that in 2017, the majority of Track 1 plants will have conducted periodic breakaway tests. As such, in 2018 those plants will not have to re-test for breakaway oxidation, and neither Track 2 nor Track 3 plants have implemented the rule. By 2019, a portion of Track 1 plants will re-test for breakaway oxidation, as well as a portion of Track 2 plants. The 2020 value also reflects the total resulting from a portion of Track 1 and Track 2 plants. In 2021, Track 3 plants will begin their periodic breakaway tests, and a portion of Track 1 and Track 2 plants will conduct testing. Starting 2022, and annually thereafter through the average remaining life, the NRC assumes that a total of 60 breakaway oxidation tests will be submitted per year. The total discounted costs of the periodic breakaway testing for operating reactors is $5,318,000 (7 percent) and $8,390,000 (3 percent).

Table 6, Industry Operation Costs for Future Operating Reactors, on page 37, shows the industry operation costs for future operating reactors. The NRC assumes that Watts Bar will perform a periodic breakaway test in 2015, 2017 and 2019 during reloading fuel. After 2020, all six reactors will be online and the number of reloads per year will be, on average, 4 for the 57 years of remaining life, with an average FTE requirement of 0.05 FTE per reload. The estimated total cost for the industry operation costs for future operating reactors ranges from $372,000 (7 percent) to $911,000 (3 percent).

The total estimated industry operation cost for operating reactors, design certifications and future operating reactors ranges from $5,690,000 (7 percent) to $9,301,000 (3 percent).

Total Industry Costs

Table 7, Total Industry Costs, on page 37, shows the total industry costs broken down between direct and indirect costs as well as by implementation and operation costs. The total industry costs range from $23,922,000 (7 percent) to $28,402,000 (3 percent).

Industry Average Implementation Costs per Designated Unit

Table 8, Industry Average Implementation Cost per Designated Unit, on pages 38 – 41, provides the estimates of the various average costs per designated unit, by type of cost for operating reactors, design certifications and future operating reactors. As shown, the largest average designated unit cost contributors for operating reactors and future operating reactors are the 3 Track Activities. Almost all of the average designated unit cost contributors for design certifications are from the initial breakaway test. The total industry operating reactor implementation cost per AOR estimate ranges from $225,000 (7 percent) to $235,000 (3 percent). The total industry design certification implementation estimated cost per reactor/DC ranges from $245,000 (7 percent) to $275,000 (3 percent). The total industry future operating reactor implementation cost per reactor/AOR estimate ranges from $273,000 (7 percent) to $314,000 (3 percent).

NRC Implementation Costs

Table 9, NRC Implementation Costs Affecting Operating Reactors, Design Certifications and Future Operating Reactors, on page 42, shows the NRC implementation costs that affect operating reactors, design certifications and future operating reactors. Three regulatory guides would be published as a result of this rule. The first relates to analytical limits and the second and third to test procedures. As shown in Table 9, the NRC estimates the costs to be approximately $865,000. This is based upon the assumptions of 5 NRC staff-years to complete the regulatory guides, with an NRC yearly rate of $173,000. The NRC also assumes that it will take approximately 2 calendar years to complete the guides.

The NRC would also need to develop and issue a revision to NUREG-0800 Standard Review Plan. The cost estimates for this action would require one FTE and is estimated to be $173,000.

The NRC would also incur costs reviewing and commenting on the hydrogen uptake models and the LOCA models. For the hydrogen uptake models, the NRC estimates that it would take 2 FTE at $173,000 annually, be implemented in 2015, and, therefore, ranging from $323,000 (7 percent) to $336,000 (3 percent). The NRC review of the LOCA models (PQD, Breakaway) is estimated to take 2 FTE/year over a two year period, beginning in 2015. The cost for this activity is estimated to be from $625,000 (7 percent) to $662,000 (3 percent). The NRC review of the LOCA models (long term cooling) is estimated to take 1 FTE/year over a two year period, beginning in 2015. The cost for this activity is estimated to be from $313,000 (7 percent) to $331,000 (3 percent). Next, the NRC estimates that this final rule development would take approximately 6 FTE over 1.5 years, beginning in 2012, and have a cost of approximately $1,038,000.

Table 10, NRC Implementation Costs for Operating Reactors, on pages 43 – 44, shows the NRC implementation costs for operating reactors. The NRC's break away test review is assumed to require 1 FTE in the year 2015. The resulting cost estimate ranges from $162,000 (7 percent) to $168,000 (3 percent).

Table 10 also provides estimated implementation costs for operating reactors for analysis of record reviews for Tracks 2 and 3. (Track 1 compliance for operating reactors is demonstrated through a letter report – no NRC review is necessary.) These efforts would take place over a 2 year period and begin in the years 2016, 2018, and 2019 for the Tracks 1, 2, and 3, respectively. Because Track 1 requires no NRC review, there is no cost associated with this track. For Track 2, the range is $511,000(7 percent) to $605,000 (3 percent). Lastly, for Track 3, the values range from $478,000 (7 percent) to $588,000 (3 percent). Therefore, the total estimated NRC implementation cost for the amendment reviews ranges from $989,000 (7 percent) to $1,193,000 (3 percent). The next NRC implementation costs for operating reactors are a result of PQD Tests. As mentioned, the assumption is that only two cladding alloys would need to be done under the so-called "redone NRC Version." Per cladding alloy is assumed to require 0.25 FTE, beginning in 2015. The resulting estimates are calculated to be $81,000 (7 percent) to $84,000 (3 percent).

The last NRC implementation costs are a result of long term cooling (LTC) tests. The assumption is that the NRC review would require 0.15 FTE for each of the 9 cladding alloys, beginning in 2015. The resulting estimates are calculated to be $219,000 (7 percent) to 227,000 (3 percent).

The proposed rule eliminates the need for the NRC to review licensee exemption requests to use materials other than uranium-oxide fuel pellets within cylindrical zircaloy or ZIRLO cladding; this represents a cost savings. The NRC assumes that 50 plants (five per year over a 10 year period, beginning in 2014) would request an exemption if the proposed rule did not extend applicability. It is also assumed that NRC review of the exemption requests would require 0.1 FTE per exemption request. This results in a total savings ranging from $750,000 (7 percent) to $879,000 (3 percent).

Therefore, the total NRC Implementation costs for operating reactors are estimated to range from $798,000, using a 7 percent real discount rate, and $907,000 using a 3 percent rate.

Table 11, NRC Implementation Costs for Design Certifications, on page 44, shows the NRC implementation costs for design certifications. In 2018, a review of the license amendment analysis for both design certifications, requiring 0.27 FTE each, and providing an estimated cost range from $70,000 (7 percent) to $82,000 (3 percent). The total NRC implementation costs for design certifications ranges from $70,000 (7 percent) to $82,000 (3 percent).

Table 12, NRC Implementation Costs for Future Operating Reactors, on page 45, shows the NRC implementation costs for future operating reactors. A breakaway test review would be performed in 2015 by the NRC for Watts Bar and would require 0.01 FTE for an estimated cost of $2,000. The NRC breakaway test reviews for the Summer and Vogtle reactors would be conducted in 2020, requiring 0.05 FTE and has an estimated cost range from $5,000 (7 percent) to $9,000 (3 percent). The NRC breakaway test review for Bellefonte 1 would be conducted in 2021, requiring 0.01 FTE and has an estimated cost range from $1,000 (7 percent) to $2,000 (3 percent). Also, as all future operating reactors are assumed to be submitting LARs following the Track 1 methodology, no NRC review is required. The last implementation cost is the LTC review costs. The NRC would review the Watts Bar LTC test in 2015, requiring 0.04 FTE for an estimated cost of $7,000. The NRC would perform the Summer and Vogtle units LTC test reviews in 2020, requiring 0.04 FTE per reactor for an estimated cost range from $19,000 (7 percent) to $23,000 (3 percent). The NRC would perform the Bellefonte 1 LTC test review in 2021, requiring 0.04 FTE for an estimated cost range from $4,000 (7 percent) to $6,000 (3 percent). The NRC implementation costs for future operating reactors ranges from $38,000 (7 percent) to $47,000 (3 percent).

The total NRC implementation costs range from $4,243,000 (7 percent) to $4,441,000 (3 percent).

NRC Operation Costs

As noted above, the NRC would experience recurring costs for operating reactors and future operating reactors as a result of the industry's periodic breakaway tests. As shown in Table 13, NRC Operation Costs for Operating Reactors, on page 46, for operating reactors, the assumption is that the analysis of the tests by NRC would require about 0.15 FTE per year (once all licensees are fully implemented and conducting periodic breakaway tests) and would run for 23 years, the assumed average remaining years of life for operating reactors after implementation of the rule.

The estimated discounted flow of funds runs from $211,000 (7 percent) to $340,000 (3 percent).

Table 14, NRC Operating Costs for Future Operating Reactors, on page 46, outlines the NRC operating costs for future operating reactors. The periodic breakaway test reviews will be performed for Watts Bar (requiring 0.01 FTE per review) until 2022 where all future operating reactor reviews will be conducted (requiring 0.04 FTE per year). The estimated NRC operating costs for future operating reactors ranges from $65,000 (7 percent) to $160,000 (3 percent).

The total NRC operating costs ranges from $276,000 (7 percent) to $500,000 (3 percent).

Total NRC Costs

Table 15, Total NRC Costs, on page 46, shows the total NRC costs broken down by implementation and operation costs. As stated above, the estimated NRC implementation costs range from $4,243,000 (7 percent) to $4,441,000 (3 percent) and the NRC operating costs range from $276,000 (7 percent) to $500,000 (3 percent). The total NRC cost estimate ranges from $4,519,000 (7 percent) to $4,941,000 (3 percent).

Total Rule Costs

Total cost estimates including both industry and the NRC range from $28.8 million (7 percent) to $34.3 million (3 percent). As shown in Table 16, Total Costs, on page 47, they are composed of implementation costs of $22.8 million (7 percent) to $24.5 million (3 percent) and operating costs of $6.0 million (7 percent) to $9.8 million (3 percent).

Lastly, the average implementation costs per AOR are estimated to range from $159,000 (7 percent) to $207,000 (3 percent).

Future Design Certifications

As there are potential design certifications that may come into the NRC for review, but are too uncertain regarding likelihood and timing to be properly added into the regulatory analysis, the NRC assumes a hypothetical design certification (beginning) in a hypothetical year (year X), based on 2014 dollars, to determine the cost to the industry and the NRC for the future design certifications..

As shown in Table 17, Industry Costs for Hypothetical Design Certification, on page 48, the Industry would incur costs in relation to implementation costs. One industry cost would be the initial breakaway test in year X that would require 0.04 FTE and provide an estimated cost of $8,000. The other industry cost would come from the PQD test, which is assumed to be a redone NRC version. This cost would occur in year X, would require 0.01 FTE of effort and provide an estimated cost of $2,000.

The total estimated industry cost for a hypothetical design certification is $10,000.

As shown in Table 18, NRC costs for hypothetical design certification, on page 48, the NRC would incur costs in relation to the review of the initial breakaway test and the PQD test. The breakaway test review, which would occur in year X+1, would require 0.01 FTE of effort and have an estimated cost of $2,000. The PQD test review, which would also occur in year X+1, would require 0.005 FTE of effort and have an estimated cost of $1,000.

The total estimated NRC cost for a hypothetical design certification is $3,000.

Hypothetical Future Operating Reactors

As there are future operating reactors that are also too uncertain regarding likelihood and timing to be properly added into the regulatory analysis, the NRC assumes a hypothetical future operating reactor (a single reactor at a new site) beginning operation in a hypothetical year (year X), based on 2014 dollars, to determine the cost to the industry and the NRC for the future operating reactor.

As shown in Table 19, Industry Costs for Hypothetical Future Operating Reactor, on page 49, the Industry would incur both implementation and operating costs in relation to a hypothetical reactor. One industry implementation cost would be a breakaway test in year X that would require 0.04 FTE and provide an estimated cost of $8,000. Another implementation cost would be for Track 1, which would be over 2 years (X and X+1) and would require a total FTE of 0.5, spread between the 2 years and having a total estimated cost of $100,000. The final implementation cost would be for the LTC test, which would occur in year X and would require 0.04 FTE and provide a total cost of $8,000. The total industry hypothetical future operating implementation cost is estimated at $116,000. The industry operating costs for the hypothetical operating reactor, the periodic breakaway test, would occur during the first reload, would occur during each reload and would require 0.05 FTE for the expected life of the reactor. The total industry estimated cost for the periodic breakaway test is $390,000.

The total cost for the industry hypothetical future operating reactor is estimated at $506,000.

As shown in Table 20, NRC Hypothetical Future Operating Reactor Cost, on page 50, the NRC incurs both implementation and operating costs due to this rulemaking for a hypothetical future operating reactor. The implementation costs are divided into breakaway test review, Track 1 review and LTC test review. The breakaway test review would occur in year X+1 and would require 0.08 FTE for an estimated cost of $14,000. For the Track 1 review, the NRC would not incur any costs as no FTE would be required. For the LTC review, the review would occur in year X+1 and would require 0.04 FTE for the unit for an estimated cost of $7,000. The total NRC hypothetical future operating reactor implementation cost is estimated at $21,000. The NRC would incur an operation cost starting in year X+2.5 for the periodic breakaway test review. The FTE requirement per year would be 0.002 and would occur for through the expected life of the reactor, providing a total estimated cost of $20,000.

The total NRC hypothetical future operating reactor cost is estimated at $41,000.

V. Decision Rationale

As noted above, this rulemaking is predicated upon the belief that this proposed action falls under the adequate protection justification. The Regulatory Analysis Guidelines state that, "The level of protection constituting 'adequate protection' is that level which must be assured *without regard to cost"* (emphasis added). The Guidelines also state that, ". . . a proposed backfit to one or more of the facilities regulated under 10 CFR Part 50 does not require a regulatory analysis if the resulting safety benefit is required for purposes of compliance or adequate protection under 10 CFR 50.109(a)(4)." The NRC believes that rulemaking is the only credible regulatory action that can provide the necessary adequate protection in this case.

VI. Implementation

Proposed Rule

It is assumed that the rule would initially take effect 30 days after its publication in the FR. The rule would establish a staged implementation approach to improve the efficiency and effectiveness of the migration to the new ECCS requirements. The staged implementation plan will have a duration of 5 years. As the first step, vendors will develop, and submit to the NRC for review via topical reports, hydrogen pick up models and LOCA model updates. This is expected to occur during the first year. Also, during the first year, the vendors will obtain PQD analytical methods by either: 1) using the analytical limits provided in an NRC regulatory guide, or 2) using an NRC approved experimental method provide in a regulatory guide. (A third option, which involves the vendors developing their own experimental method for NRC approval, is available but, due to the high cost and burden of this option, the NRC assumes that no vendors will develop their own experimental method.) The PQD analytical limits which are obtained via the approved experimental method will be submitted for NRC review in the form of a topical report. Also, the vendors would perform long term cooling tests to determine the long term cooling limit for each of the nine cladding alloys. Finally, during the first year after the rule becomes effective, the vendors will perform initial breakaway testing. The results of the initial breakaway tests will be submitted by the licensee via their license amendment request (LAR) which is necessary to demonstrate compliance with the proposed rule.

As part of this implementation plan, licensees will be divided among three implementation tracks based upon existing margin to the revised requirements and anticipated level of effort to demonstrate compliance. The purpose of the staged implementation approach is to bring licensees into compliance as quickly as possible, while accounting for: 1) more effort and longer schedules are necessary for plants which require new LOCA analyses with revised LOCA models; and 2) differences between realistic and Appendix K LOCA models.

Lastly, the tracks will begin to conduct periodic breakaway test one year after they are in full compliance. (Track 1 to being periodic breakaway testing in Year 3, Track 2 in year 5 and Track 3 in Year 6.) The results of these tests will be included in the annual ECCS submittal.

Regulatory Guidance

There are three draft regulatory guides developed along with the proposed rule. These regulatory guides would be available for use as guidance immediately upon their issuance in final form; issuance in final form may pre-date the necessary date for compliance with the rule as specified in paragraph (o) of § 50.46c.

Table 2 – Industry Implementation Costs for Operating Reactors

Industry Implementation Costs (Indirect - Vendor Implementation Costs)

Year	Activity	Number of Models/Cladding Alloys	Per Model/Cladding Alloy		Cost per year		
			FTE Required	Yearly Rate	Undiscounted	3% NPV	7% NPV
2014	Cladding Hydrogen Uptake Models (Including Topic Rpts)	9	0.75	$200,000	$1,350,000	$1,350,000	$1,350,000
2013	LOCA Models (PQD, Breakaway)	6	0.75	$200,000	$900,000	$900,000	$900,000
2014		6	0.75	$200,000	$900,000	$900,000	$900,000
2013	LOCA Models (LTC)	6	0.50	$200,000	$600,000	$600,000	$600,000
2014		6	0.50	$200,000	$600,000	$600,000	$600,000
2014	Initial Breakaway Test	9	0.33	$200,000	$600,000	$600,000	$600,000
				Total:	**$4,950,000**	**$4,950,000**	**$4,950,000**

Industry Implementation Costs

Year	Activity (Includes PQD, Breakaway, LTC)	Number of AOR (approx. 77 AORs for 104 reactors)	Per AOR		Cost per year		
			FTE Required	Yearly Rate	Undiscounted	3% NPV	7% NPV
2014	Track #1	50	0.25	$200,000	$2,500,000	$2,500,000	$2,500,000
2015			0.25		$2,500,000	$2,427,000	$2,336,000
2015	Track #2	13	0.50	$200,000	$1,300,000	$1,262,000	$1,215,000
2016			0.50		$1,300,000	$1,225,000	$1,135,000
2017			0.50		$1,300,000	$1,190,000	$1,061,000
2016	Track #3	14	0.75	$200,000	$2,100,000	$1,979,000	$1,834,000
2017			0.75		$2,100,000	$1,922,000	$1,714,000
2018			0.75		$2,100,000	$1,866,000	$1,602,000
				Total:	**$15,200,000**	**$14,371,000**	**$13,397,000**

Industry Implementation Costs: Exemption Request Savings

Year	Activity	Number of Exemption Requests	Per Exemption Request		Cost per year		
			FTE Required	Yearly Rate	Undiscounted	3% NPV	7% NPV
2014	Exemption Requests (ER) Preparation and Submission	5	0.2	$200,000	($200,000)	($200,000)	($200,000)
2015	Exemption Requests (ER) Preparation and Submission	5	0.2	$200,000	($200,000)	($194,000)	($187,000)
2016	Exemption Requests (ER) Preparation and Submission	5	0.2	$200,000	($200,000)	($189,000)	($175,000)
2017	Exemption Requests (ER) Preparation and Submission	5	0.2	$200,000	($200,000)	($183,000)	($163,000)
2018	Exemption Requests (ER) Preparation and Submission	5	0.2	$200,000	($200,000)	($178,000)	($153,000)
2019	Exemption Requests (ER) Preparation and Submission	5	0.2	$200,000	($200,000)	($173,000)	($143,000)
2020	Exemption Requests (ER) Preparation and Submission	5	0.2	$200,000	($200,000)	($167,000)	($133,000)
2021	Exemption Requests (ER) Preparation and Submission	5	0.2	$200,000	($200,000)	($163,000)	($125,000)
2022	Exemption Requests (ER) Preparation and Submission	5	0.2	$200,000	($200,000)	($158,000)	($116,000)
2023	Exemption Requests (ER) Preparation and Submission	5	0.2	$200,000	($200,000)	($153,000)	($109,000)
				Total:	**($2,000,000)**	**($1,758,000)**	**($1,504,000)**

Industry Implementation Option Costs: PQD Tests

Year	Activity	Number of Cladding Alloys	Per Cladding Alloy		Undiscounted	3% NPV	7% NPV
			FTE Required	Yearly Rate			
2014	PQD Test - Accepted NRC Reg Guide	7	0	$200,000	$0	$0	$0
2014	PQD Test - Redone NRC Version	2	0.25	$200,000	$100,000	$100,000	$100,000
2014	PQD Test - Industry Version	0	0.5 - 2.5	$200,000	$0	$0	$0
				Total:	**$100,000**	**$100,000**	**$100,000**

Industry Implementation Option Costs: LTC Tests

Year	Activity	Number of Cladding Alloys	Per Cladding Alloy		Undiscounted	3% NPV	7% NPV
			FTE Required	Yearly Rate			
2014	LTC Tests	9	0.15	$200,000	$270,000	$270,000	$270,000
				Total:	**$270,000**	**$270,000**	**$270,000**

Total Industry Operating Reactor Cost (Direct):	**$13,570,000**	**$12,983,000**	**$12,263,000**
Total Industry Operating Reactor Cost (Indirect):	**$4,950,000**	**$4,950,000**	**$4,950,000**
Total Industry Operating Reactor Implementation Cost:	**$18,520,000**	**$17,933,000**	**$17,213,000**

Table 3 – Industry Implementation Costs for Design Certifications

Industry Implementation Costs: Design Certification

Year	Activity	Number of Design Certifications	Per Design Certification		Cost per year		
			FTE Required	Yearly Rate	Undiscounted	3% NPV	7% NPV
2017	Track #2	2	1.50	$200,000	$600,000	$549,000	$490,000
				Total:	**$600,000**	**$549,000**	**$490,000**

Total Industry Design Certification Cost:	**$600,000**	**$549,000**	**$490,000**

Table 4 – Industry Implementation Costs for Future Operating Reactors

Industry Implementation Costs (Indirect - Vendor Implementation Costs): Future Operating Reactors

Year	Activity	Number of Reactor	Per Reactor		Cost per year		
			FTE Required	Yearly Rate	Undiscounted	3% NPV	7% NPV
2014	Initial Breakaway Test (Watts Bar)	1	0.04	$200,000	$8,000	$8,000	$8,000
2019	Initial Breakaway Test (Vogtle and Summer Units)	4	0.04	$200,000	$32,000	$28,000	$23,000
2020	Initial Breakaway Test (Bellefonte)	1	0.04	$200,000	$8,000	$7,000	$5,000
				Total:	**$48,000**	**$43,000**	**$36,000**

Industry Implementation Costs: Future Operating Reactors

Year	Activity (Includes PQD, Breakaway, LTC)	Number of AOR	Per AOR		Cost per year		
			FTE Required	Yearly Rate	Undiscounted	3% NPV	7% NPV
2014	Track #1 (Watts Bar)	1	0.25	$200,000	$50,000	$50,000	$50,000
2015			0.25		$50,000	$49,000	$47,000
2018	Track #1 (Vogtle and Summer Units)	4	0.25	$200,000	$200,000	$178,000	$153,000
2019			0.25		$200,000	$173,000	$143,000
2020	Track #1 (Bellefonte)	1	0.25	$200,000	$50,000	$42,000	$33,000
2021			0.25		$50,000	$41,000	$31,000
				Total:	**$600,000**	**$533,000**	**$457,000**

Industry Implementation Option Costs: LTC Tests: Future Operating Reactors

Year	Activity	Number of Reactor	Per Reactor		Undiscounted	3% NPV	7% NPV
			FTE Required	Yearly Rate			
2014	LTC Test (Watts Bar)	1	0.04	$200,000	$8,000	$8,000	$8,000
2019	LTC Tests (Vogtle and Summer Units)	4	0.04	$200,000	$32,000	$28,000	$23,000
2020	LTC Tests (Bellefonte)	1	0.04	$200,000	$8,000	$7,000	$5,000
				Total:	**$48,000**	**$43,000**	**$36,000**

	Undiscounted	3% NPV	7% NPV
Total Industry Future Operating Reactor Implementation Cost (Indirect):	**$48,000**	**$43,000**	**$36,000**
Total Industry Future Operating Reactor Implementation Cost (Direct):	**$648,000**	**$576,000**	**$493,000**
Total Industry Future Operating Reactor Implementation Cost:	**$696,000**	**$619,000**	**$529,000**

Table 5 – Industry Operating Costs for Operating Reactors

Industry Operation Costs (Indirect - Vendor Operation Costs)

Start Year	Activity	Per Year				Number of Years	Indirect Operation Cost		
		Number of Reloads	Per Reload		Total Cost		Total	3% NPV	7% NPV
			FTE Required	Yearly Rate					
2016	Periodic Breakaway Tests	60	0.05	$200,000	$600,000	1	$600,000	$566,000	$524,000
2017	Periodic Breakaway Tests	0	0.05	$200,000	$0	1	$0	$0	$0
2018	Periodic Breakaway Tests	60	0.05	$200,000	$600,000	1	$600,000	$533,000	$458,000
2019	Periodic Breakaway Tests	44	0.05	$200,000	$440,000	1	$440,000	$380,000	$314,000
2020	Periodic Breakaway Tests	60	0.05	$200,000	$600,000	18	$10,800,000	$6,911,000	$4,022,000
						Total:	**$12,440,000**	**$8,390,000**	**$5,318,000**
						Total Industry Operating Reactor Operation Cost (Indirect):	**$12,440,000**	**$8,390,000**	**$5,318,000**

Table 6 – Industry Operation Costs for Future Operating Reactors

Industry Operation Costs (Indirect - Vendor Operation Costs): Future Operating Reactors

Start Year	Activity	Per Year				Number of Years	Indirect Operation Cost		
		Number of Reloads	Per Reload		Total Cost		Total	3% NPV	7% NPV
			FTE Required	Yearly Rate					
2015	Periodic Breakaway Tests	1	0.05	$200,000	$10,000	1	$10,000	$10,000	$9,000
2016	Periodic Breakaway Tests	0	0.05	$200,000	$0	1	$0	$0	$0
2017	Periodic Breakaway Tests	1	0.05	$200,000	$10,000	1	$10,000	$9,000	$8,000
2018	Periodic Breakaway Tests	0	0.05	$200,000	$0	1	$0	$0	$0
2019	Periodic Breakaway Tests	1	0.05	$200,000	$10,000	1	$10,000	$9,000	$7,000
2020	Periodic Breakaway Tests	0	0.05	$200,000	$0	1	$0	$0	$0
2021	Periodic Breakaway Tests	4.0	0.05	$200,000	$40,000	57	$2,280,000	$883,000	$348,000
						Total:	**$2,310,000**	**$911,000**	**$372,000**
						Total Industry Future Operating Reactor Operation Cost (Indirect):	**$2,310,000**	**$911,000**	**$372,000**

Table 7 – Total Industry Costs

	Industry Costs		
	Total:	3% NPV	7% NPV
Total Industry Cost (Indirect):	**$22,658,000**	**$14,843,000**	**$11,166,000**
Total Industry Cost (Direct):	**$14,218,000**	**$13,559,000**	**$12,756,000**
Total Industry Implementation Cost:	**$19,816,000**	**$19,101,000**	**$18,232,000**
Total Industry Operation Cost:	**$14,750,000**	**$9,301,000**	**$5,690,000**
Total Industry Cost:	**$36,876,000**	**$28,402,000**	**$23,922,000**

Table 8 – Industry Average Implementation Cost per Designated Unit

Industry Implementation Costs (Indirect - Vendor Implementation Costs): Operating Reactors

Year	Activity	Total Cost	3% NPV	7% NPV	Average Cost Per AOR (77 AORs)	
					3% NPV	7% NPV
2014	Cladding Hydrogen Update Models (Including Topic Rpts)	$1,350,000	$1,350,000	$1,350,000	$18,000	$18,000
2013	LOCA Models (PQD, Breakaway)	$900,000	$900,000	$900,000	$12,000	$12,000
2014		$900,000	$900,000	$900,000	$12,000	$12,000
2013	LOCA Models (LTC)	$600,000	$600,000	$600,000	$8,000	$8,000
2014		$600,000	$600,000	$600,000	$8,000	$8,000
2014	Initial Breakaway Test	$600,000	$600,000	$600,000	$8,000	$8,000
	Total:	**$4,950,000**	**$4,950,000**	**$4,950,000**	**$66,000**	**$66,000**

Industry Implementation Costs: Operating Reactors

Year	Activity (Includes PQD, Breakaway, LTC)	Total Cost	3% NPV	7% NPV	Average Cost Per AOR (77 AORs)	
					3% NPV	7% NPV
2014	Track #1 (50 AORs)	$2,500,000	$2,500,000	$2,500,000	$32,000	$32,000
2015		$2,500,000	$2,427,000	$2,336,000	$32,000	$30,000
2015	Track # 2 (13 AORs)	$1,300,000	$1,262,000	$1,215,000	$16,000	$16,000
2016		$1,300,000	$1,225,000	$1,135,000	$16,000	$15,000
2017		$1,300,000	$1,190,000	$1,061,000	$15,000	$14,000
2016	Track # 3 (14 AORs)	$2,100,000	$1,979,000	$1,834,000	$26,000	$24,000
2017		$2,100,000	$1,922,000	$1,714,000	$25,000	$22,000
2018		$2,100,000	$1,866,000	$1,602,000	$24,000	$21,000
	Total:	**$15,200,000**	**$14,371,000**	**$13,397,000**	**$186,000**	**$174,000**

Industry Implementation Costs: Exemption Request Savings: Operating Reactors

Year	Activity	Total Cost	3% NPV	7% NPV	Average Cost Per AOR (77 AORs)	
					3% NPV	7% NPV
2014	Exemption Request	($200,000)	($200,000)	($200,000)	($3,000)	($3,000)
2015	Exemption Request	($200,000)	($194,000)	($187,000)	($3,000)	($2,000)
2016	Exemption Request	($200,000)	($189,000)	($175,000)	($2,000)	($2,000)
2017	Exemption Request	($200,000)	($183,000)	($163,000)	($2,000)	($2,000)
2018	Exemption Request	($200,000)	($178,000)	($153,000)	($2,000)	($2,000)
2019	Exemption Request	($200,000)	($173,000)	($143,000)	($2,000)	($2,000)
2020	Exemption Request	($200,000)	($167,000)	($133,000)	($2,000)	($2,000)
2021	Exemption Request	($200,000)	($163,000)	($125,000)	($2,000)	($2,000)
2022	Exemption Request	($200,000)	($158,000)	($116,000)	($2,000)	($2,000)
2023	Exemption Request	($200,000)	($153,000)	($109,000)	($2,000)	($1,000)
	Total:	**($2,000,000)**	**($1,758,000)**	**($1,504,000)**	**($22,000)**	**($20,000)**

Industry Implementation Option Costs: PQD Tests: Operating Reactors

Year	Activity	Total Cost	3% NPV	7% NPV	Average Cost Per AOR (77 AORs)	
					3% NPV	7% NPV
2014	PQD Test - Accepted NRC Reg Guide	$0	$0	$0	$0	$0
2014	PQD Test - Redone NRC Version	$100,000	$100,000	$100,000	$1,000	$1,000
2014	PQD Test - Industry Version	$0	$0	$0	$0	$0
	Total:	**$100,000**	**$100,000**	**$100,000**	**$1,000**	**$1,000**

Industry Implementation Option Costs: LTC Tests: Operating Reactors

Year	Activity	Total Cost	3% NPV	7% NPV	Average Cost Per AOR (77 AORs)	
					3% NPV	7% NPV
2014	LTC Tests	$270,000	$270,000	$270,000	$4,000	$4,000
	Total:	**$270,000**	**$270,000**	**$270,000**	**$4,000**	**$4,000**

Total Industry Operating Reactor Implementation Cost:	**$18,520,000**	**$17,933,000**	**$17,213,000**	**$235,000**	**$225,000**

Industry Implementation Costs (Indirect - Vendor Implementation Costs): Design Certification

Year	Activity	Undiscounted	3% NPV	7% NPV	Average Cost Per Design Certification (2 DCs)	
					3% NPV	7% NPV
2017	Initial Breakaway Test	$600,000	$549,000	$490,000	$275,000	$245,000
	Total:	**$600,000**	**$549,000**	**$490,000**	**$275,000**	**$245,000**
	Total Industry Design Certification Implementation Cost:	**$600,000**	**$549,000**	**$490,000**	**$275,000**	**$245,000**

Industry Implementation Costs (Indirect - Vendor Implementation Costs): Future Operating Reactors

Year	Activity	Undiscounted	3% NPV	7% NPV	Average Cost Per Reactor/AOR	
					3% NPV	7% NPV
2014	Initial Breakaway Test (Watts Bar)	$8,000	$8,000	$8,000	$8,000	$8,000
2019	Initial Breakaway Test (Vogtle and Summer Units)	$32,000	$28,000	$23,000	$7,000	$6,000
2020	Initial Breakaway Test (Bellefonte)	$8,000	$7,000	$5,000	$7,000	$5,000
	Total:	**$48,000**	**$43,000**	**$36,000**	**$22,000**	**$19,000**

Industry Implementation Costs: Future Operating Reactors

Year	Activity (Includes PQD, Breakaway, LTC)	Undiscounted	3% NPV	7% NPV	Average Cost Per Reactor/AOR	
					3% NPV	7% NPV
2014	Track #1 (Watts Bar)	$50,000	$50,000	$50,000	$50,000	$50,000
2015		$50,000	$49,000	$47,000	$49,000	$47,000
2018	Track #1 (Vogtle and Summer Units)	$200,000	$178,000	$153,000	$45,000	$38,000
2019		$200,000	$173,000	$143,000	$43,000	$36,000
2020	Track #1 (Bellefonte)	$50,000	$42,000	$33,000	$42,000	$33,000
2021		$50,000	$41,000	$31,000	$41,000	$31,000
	Total:	**$600,000**	**$533,000**	**$457,000**	**$270,000**	**$235,000**

Industry Implementation Option Costs: LTC Tests: Future Operating Reactors

Year	Activity	Undiscounted	3% NPV	7% NPV	Average Cost Per Reactor/AOR	
					3% NPV	7% NPV
2014	LTC Test (Watts Bar)	$8,000	$8,000	$8,000	$8,000	$8,000
2019	LTC Tests (Vogtle and Summer Units)	$32,000	$28,000	$23,000	$7,000	$6,000
2020	LTC Tests (Bellefonte)	$8,000	$7,000	$5,000	$7,000	$5,000
	Total:	**$48,000**	**$43,000**	**$36,000**	**$22,000**	**$19,000**

Total Industry Future Operating Reactor Implementation Cost:	**$696,000**	**$619,000**	**$529,000**	**$314,000**	**$273,000**

Table 9 – NRC Implementation Costs Affecting Operating Reactors, Design Certifications and Future Operating Reactors

NRC Implementation Costs

Year	Activity	FTE Required	Yearly Rate	Cost per year		
				Undiscounted	3% NPV	7% NPV
2012	Draft Regulatory Guide - Development & Issuance	2	$173,000	$346,000	$346,000	$346,000
2012	Revise Regulatory Guides after Comment Period	2	$173,000	$346,000	$346,000	$346,000
2013	Issue Final Regulatory Guides	1	$173,000	$173,000	$173,000	$173,000
2013	Revise SRP	1	$173,000	$173,000	$173,000	$173,000
2012	Development of Final Rule	3	$173,000	$519,000	$519,000	$519,000
2013		3	$173,000	$519,000	$519,000	$519,000
2015	NRC Review of Cladding Models	2	$173,000	$346,000	$336,000	$323,000
2015	NRC Review of LOCA Models (PQD, Breakaway)	2	$173,000	$346,000	$336,000	$323,000
2016		2	$173,000	$346,000	$326,000	$302,000
2015	NRC Review of LOCA Models (LTC)	1	$173,000	$173,000	$168,000	$162,000
2016		1	$173,000	$173,000	$163,000	$151,000
			Total:	**$3,460,000**	**$3,405,000**	**$3,337,000**

Table 10 – NRC Implementation Costs for Operating Reactors

NRC Implementation Costs: Operating Reactors

2015	Breakaway Test Review	1	$173,000	$173,000	$168,000	$162,000
			Total:	**$173,000**	**$168,000**	**$162,000**

NRC Implementation Costs: License Amendment Reviews: Operating Reactors

Year	Activity	FTE Required	Yearly Rate	Cost Per year		
				Undiscounted	3% NPV	7% NPV
2016	Track #1	0	$173,000	$0	$0	$0
2017		0	$173,000	$0	$0	$0
2018	Track #2	2	$173,000	$346,000	$307,000	$264,000
2019		2	$173,000	$346,000	$298,000	$247,000
2019	Track #3	2	$173,000	$346,000	$298,000	$247,000
2020		2	$173,000	$346,000	$290,000	$231,000
			Total:	**$1,384,000**	**$1,193,000**	**$989,000**

NRC Implementation Costs: Exemption Request Savings: Operating Reactors

Year	Activity	Number of Exemption Requests	Per Exemption Request		Cost per year		
			FTE Required	Yearly Rate	Undiscounted	3% NPV	7% NPV
2014	Exemption Request Review	5	0.1	$173,000	($87,000)	($87,000)	($87,000)
2015	Exemption Request Review	5	0.1	$173,000	($87,000)	($84,000)	($81,000)
2016	Exemption Request Review	5	0.1	$173,000	($87,000)	($82,000)	($76,000)
2017	Exemption Request Review	5	0.1	$173,000	($87,000)	($80,000)	($71,000)
2018	Exemption Request Review	5	0.1	$173,000	($87,000)	($77,000)	($66,000)
2019	Exemption Request Review	5	0.1	$173,000	($87,000)	($75,000)	($62,000)
2020	Exemption Request Review	5	0.1	$173,000	($87,000)	($73,000)	($58,000)
2021	Exemption Request Review	5	0.1	$173,000	($87,000)	($71,000)	($54,000)
2022	Exemption Request Review	5	0.1	$173,000	($87,000)	($69,000)	($51,000)
2023	Exemption Request Review	5	0.1	$173,000	($87,000)	($67,000)	($47,000)
				Total:	**($870,000)**	**($765,000)**	**($653,000)**

NRC Implementation Costs: PQD Tests: Operating Reactors

Year	Activity	Number of Cladding Alloys	Per Cladding Alloy		Cost per year		
			FTE Required	Yearly Rate	Undiscounted	3% NPV	7% NPV
2015	PQD Test - Accepted NRC Reg Guide	7	0	$173,000	$0	$0	$0
2015	PQD Test - Redone NRC Version	2	0.25	$173,000	$87,000	$84,000	$81,000
2015	PQD Test - Licensee Version	0	0.5 - 2.5	$173,000	$0	$0	$0
				Total:	**$87,000**	**$84,000**	**$81,000**

NRC Implementation Costs: LTC Test Reviews: Operating Reactors

Year	Activity	Number of Cladding Alloys	Per Cladding Alloy		Cost per year		
			FTE Required	Yearly Rate	Undiscounted	3% NPV	7% NPV
2015	LTC Test Reviews	9	0.15	$173,000	$234,000	$227,000	$219,000
				Total:	**$234,000**	**$227,000**	**$219,000**

Total NRC Operating Reactor Implementation Cost:	**$1,008,000**	**$907,000**	**$798,000**

Table 11 – NRC Implementation Costs for Design Certifications

NRC Implementation Costs: License Amendment Reviews: Design Certification

Year	Activity	Number of Design Certifications	Per Design Certification		Undiscounted	3% NPV	7% NPV
			FTE Required	Yearly Rate			
2018	Track #2	2	0.27	$173,000	$92,000	$81,741	$70,186
				Total:	**$92,000**	**$82,000**	**$70,000**

Total NRC Design Certification Implementation Cost:	**$92,000**	**$82,000**	**$70,000**

Table 12 – NRC Implementation Costs for Future Operating Reactors

NRC Implementation Costs: Future Operating Reactors

Year	Activity	FTE Required	Yearly Rate	Cost per year		
				Undiscounted	3% NPV	7% NPV
2015	Breakaway Test Review (Watts Bar)	0.01	$173,000	$2,000	$2,000	$2,000
2020	Breakaway Test Review (Vogtle and Summer Units)	0.05	$173,000	$8,000	$7,000	$5,000
2021	Breakaway Test Review (Bellefonte)	0.01	$173,000	$2,000	$2,000	$1,000
			Total:	**$12,000**	**$11,000**	**$8,000**

NRC Implementation Costs: License Amendment Reviews: Future Operating Reactors

Year	Activity (Includes PQD, Breakaway, LTC)	FTE Required	Yearly Rate	Cost per year		
				Undiscounted	3% NPV	7% NPV
2016	Track #1 (Watts Bar)	0	$173,000	$0	$0	$0
2017		0		$0	$0	$0
2020	Track #1 (Vogtle and Summer Units)	0	$173,000	$0	$0	$0
2021		0		$0	$0	$0
2022	Track #1 (Bellefonte)	0	$173,000	$0	$0	$0
2023		0		$0	$0	$0
			Total:	**$0**	**$0**	**$0**

NRC Implementation Costs: LTC Test Reviews: Future Operating Reactors

Year	Activity	Number of Reactor	Per Reactor		Undiscounted	3% NPV	7% NPV
			FTE Required	Yearly Rate			
2015	LTC Test Review (Watts Bar)	1	0.04	$173,000	$7,000	$7,000	$7,000
2020	LTC Test Review (Vogtle and Summer Units)	4	0.04	$173,000	$28,000	$23,000	$19,000
2021	LTC Test Review (Bellefonte)	1	0.04	$173,000	$7,000	$6,000	$4,000
				Total:	**$42,000**	**$36,000**	**$30,000**

Total NRC Future Operating Reactor Implementation Cost:	**$54,000**	**$47,000**	**$38,000**

Table 13 – NRC Operation Costs for Operating Reactors

NRC Operation Costs: Operating Reactors

Start Year	Activity	Per year			Number of Years	Indirect Operation Cost		
		FTE Required	Rate per Person	Total Cost		Total	3% NPV	7% NPV
2017	Periodic Breakaway Test Reviews	0.15	$173,000	$25,950	1	$26,000	$24,000	$21,000
2018	Periodic Breakaway Test Reviews	0	$173,000	$0	1	$0	$0	$0
2019	Periodic Breakaway Test Reviews	0.15	$173,000	$25,950	1	$26,000	$22,000	$19,000
2020	Periodic Breakaway Test Reviews	0.11	$173,000	$19,030	1	$19,000	$16,000	$13,000
2021	Periodic Breakaway Test Reviews	0.15	$173,000	$25,950	17	$441,000	$278,000	$158,000
					Total:	**$512,000**	**$340,000**	**$211,000**
					Total NRC Operating Reactor Operation Cost:	**$512,000**	**$340,000**	**$211,000**

Table 14 – NRC Operating Costs for Future Operating Reactors

NRC Operation Costs: Future Operating Reactors

Start Year	Activity	Per Year			Number of Years	Indirect Operation Cost		
		FTE Required	Yearly Rate	Total Cost		Total	3% NPV	7% NPV
2016	Periodic Breakaway Test Reviews	0.01	$173,000	$1,730	1	$2,000	$2,000	$2,000
2017	Periodic Breakaway Test Reviews	0.01	$173,000	$1,730	1	$2,000	$2,000	$2,000
2018	Periodic Breakaway Test Reviews	0.01	$173,000	$1,730	1	$2,000	$2,000	$2,000
2019	Periodic Breakaway Test Reviews	0.01	$173,000	$1,730	1	$2,000	$2,000	$1,000
2020	Periodic Breakaway Test Reviews	0.01	$173,000	$1,730	1	$2,000	$2,000	$1,000
2021	Periodic Breakaway Test Reviews	0.01	$173,000	$1,730	1	$2,000	$2,000	$1,000
2022	Periodic Breakaway Test Reviews	0.04	$173,000	$6,920	57	$394,000	$148,000	$56,000
					Total:	**$406,000**	**$160,000**	**$65,000**
					Total NRC Future Operating Reactor Operation Cost:	**$406,000**	**$160,000**	**$65,000**

Table 15 – Total NRC Costs

	NRC Costs		
	Total:	3% NPV	7% NPV
Total NRC Operation Cost:	**$918,000**	**$500,000**	**$276,000**
Total NRC Implementation Cost:	**$4,614,000**	**$4,441,000**	**$4,243,000**
Total NRC Cost:	**$5,532,000**	**$4,941,000**	**$4,519,000**

Table 16 – Total Costs

Total Rule Costs

Implementation Costs	Undiscounted	3% NPV	7% NPV
Total NRC Costs	$4,614,000	$4,441,000	$4,243,000
Total Industry Costs (Direct)	$14,218,000	$13,559,000	$12,756,000
Total Industry Costs (Indirect)	$7,908,000	$6,453,000	$5,848,000
Total:	**$26,740,000**	**$24,453,000**	**$22,847,000**

Operation Costs	Undiscounted	3% NPV	7% NPV
Total NRC Costs	$918,000	$500,000	$276,000
Total Industry Costs (Indirect)	$14,750,000	$9,301,000	$5,690,000
Total:	**$15,668,000**	**$9,801,000**	**$5,966,000**

Grand Total 50.46c	Undiscounted	3% NPV	7% NPV
Total NRC Costs	$5,532,000	$4,941,000	$4,519,000
Total Industry Costs	$36,876,000	$29,313,000	$24,294,000
Total:	**$42,408,000**	**$34,254,000**	**$28,813,000**

Average Implementation Costs per AOR	3% NPV	7% NPV
Industry Costs (Direct)	$95,000	$86,000
Industry Costs (Indirect)	$112,000	$73,000
Total:	**$207,000**	**$159,000**

Table 17 - Industry Costs for Future Design Certification

Industry Implementation Costs (Indirect - Vendor Implementation Costs): Future Design Certification

Year	Activity	Number of Design Certifications	Per Design Certification		Undiscounted
			FTE Required	Yearly Rate	
X	Initial Breakaway Test	1	0.04	$200,000	$8,000
				Total:	**$8,000**

Industry Implementation Option Costs: PQD Tests: Future Design Certificaion

Year	Activity	Number of Design Certifications	Per Design Certification		Undiscounted
			FTE Required	Yearly Rate	
X	PQD Test - Accepted NRC Reg Guide	0	0	$200,000	$0
X	PQD Test - Redone NRC Version	1	0.01	$200,000	$2,000
X	PQD Test - Industry Version	0	0.5 - 2.5	$200,000	$0
				Total:	**$2,000**

Total Industry Future Design Certification Cost (Indirect):	**$8,000**
Total Industry Future Design Certification Cost (Direct):	**$2,000**
Total Industry Future Design Certification Cost:	**$10,000**

Table 18 - NRC Costs for Future Design Certification

NRC Implementation Costs: Future Design Certification

Year	Activity	FTE Required	Yearly Rate	Undiscounted
X+1	Breakaway Test Review	0.01	$173,000	$2,000
			Total:	**$2,000**

NRC Implementation Costs: PQD Tests: Future Design Certification

Year	Activity	Number of Design Certifications	Per Design Certification		Undiscounted
			FTE Required	Yearly Rate	
X+1	PQD Test - Accepted NRC Reg Guide	0	0	$173,000	$0
X+1	PQD Test - Redone NRC Version	1	0.005	$173,000	$1,000
X+1	PQD Test - Licensee Version	0	0.5 - 2.5	$173,000	$0
				Total:	**$1,000**

Total NRC Future Design Certification Implementation Cost:	**$3,000**

Table 19 - Industry Costs for Hypothetical Future Operating Reactor

Industry Implementation Costs (Indirect - Vendor Implementation Costs): Hypothetical Future Operating Reactor

Year	Activity	Number of Reactor	Per Reactor		Undiscounted
			FTE Required	Yearly Rate	
X	Initial Breakaway Test	1	0.04	$200,000	$8,000
				Total:	**$8,000**

Industry Implementation Costs: Hypothetical Future Operating Reactor

Year	Activity (Includes PQD, Breakaway, LTC)	Number of AOR	Per AOR		Undiscounted
			FTE Required	Yearly Rate	
X	Track #1	1	0.25	$200,000	$50,000
X+1			0.25		$50,000
				Total:	**$100,000**

Industry Implementation Option Costs: LTC Tests: Hypothetical Future Operating Reactor

Year	Activity	Number of Reactor	Per Reactor		Undiscounted
			FTE Required	Yearly Rate	
X	LTC Test	1	0.04	$200,000	$8,000
				Total:	**$8,000**

Industry Operation Costs (Indirect - Vendor Operation Costs): Hypothetical Future Operating Reactor

Start Year	Activity	Per Year				Number of Years	Undiscounted Total
		Average Number of Reloads	Per Reload		Total Cost		
			FTE Required	Yearly Rate			
X+1.5	Periodic Breakaway Tests	0.67	0.05	$200,000	$6,667	58.5	$390,000
						Total:	**$390,000**

Total Industry Hypothetical Future Operating Reactor Implementation Cost:	**$116,000**
Total Industry Hypothetical Future Operating Reactor Operation Cost:	**$390,000**
Total Industry Hypothetical Future Operating Reactor Cost (Indirect):	**$398,000**

Table 20 - NRC Costs for Hypothetical Future Operating Reactor

NRC Implementation Costs: Hypothetical Future Operating Reactor

Year	Activity	FTE Required	Yearly Rate	Undiscounted
X+1	Breakaway Test Review	0.08	$173,000	$14,000
			Total:	**$14,000**

NRC Implementation Costs: License Amendment Reviews: Hypothetical Future Operating Reactor

Year	Activity (Includes PQD, Breakaway, LTC)	Per AOR		Undiscounted
		FTE Required	Yearly Rate	
X+1	Track #1	0	$173,000	$0
X+2		0		$0
			Total:	**$0**

NRC Implementation Option Costs: LTC Test Reviews: Hypothetical Future Operating Reactor

Year	Activity	Number of Units	Per Unit		Undiscounted
			FTE Required	Yearly Rate	
X+1	LTC Test Review	1	0.04	$173,000	$7,000
				Total:	**$7,000**

NRC Operation Costs: Hypothetical Future Operating Reactor

Start Year	Activity	Per Year			Number of Years	Undiscounted Total
		FTE Required	Yearly Rate	Total Cost		
X+2.5	Periodic Breakaway Test Reviews	0.002	$173,000	$346	57.5	$20,000
					Total:	**$20,000**

Total NRC Hypothetical Future Operating Reactor Implementation Cost:	**$21,000**
Total NRC Hypothetical Future Operating Reactor Operating Cost:	**$20,000**
Total NRC Hypothetical Future Operating Reactor Cost:	**$41,000**