Backup Power for PWRs with Ice Condenser Containments and for BWRs with Mark III Containments under SBO Conditions: Impact Assessment

Revision 2

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Executive Summary

In support of resolution of Generic Safety Issue 189 (GSI-189), a cost (impact) assessment for providing backup power to hydrogen igniters for PWRs with ice condenser (IC) containments and for BWRs with Mark III containments under station blackout (SBO) conditions has been performed. The methodology used is consistent with the Value-Impact (cost-benefit) portions of a regulatory analysis as defined and described in NUREG/BR-0058, Rev. 3 and NUREG/BR-0184.

Under SBO conditions, these containment types are vulnerable to failures from hydrogen deflagrations, failures what would otherwise be prevented if the existing hydrogen igniter systems were energized.

The costs for implementing and maintaining backup power for these systems for the life of the plants are estimated by considering three cases: 1) a pre-staged diesel generator powering only the hydrogen igniters (base case), 2) a portable diesel generator powering only the hydrogen igniters, and 3) a pre-staged diesel generator powering both hydrogen igniters and air return fans for ice condenser plants. For each candidate regulatory action, estimates are made for implementation and operational (recurring) costs for both the licensee and the NRC. Licensee implementation costs included allowance for materials and equipment, installation, engineering, worker dose, emergency procedures, and licensing costs. Licensee operational costs considered routine periodic surveillance, maintenance and testing of the independent power supply. For the NRC, implementation costs covered rulemaking and reviews of licensee documentation, and operational costs allowed for periodic inspection.

In addition, uncertainties associated with these three cases and sensitivity cases reflecting various requirement and procedural options are assessed. The base case is a fixed, permanent installation that is energized locally and manually. The portable diesel must be transported from its storage area to a dedicated panel and manually hooked up with proper sequencing for powering the igniters.

Because of power requirements and dual-unit versus single-unit differences among the 13 reactors potentially affected by this issue, no “generic” plant would be representative. Instead, the study considered four classes of plants, namely (1) the 3 dual-unit PWR stations at McGuire, Catawba, and D.C. Cook; (2) the dual-unit PWR Sequoyah station, (3) the single-unit PWR Watts Bar plant, and (4) the four Mark III BWR plants.

The “best estimate” total cost results for the base case (pre-staged) range from about $265,000 to $320,000 per reactor for the different classes of plants. Similar estimates for Case 2 approximate $195,000 to $240,000 per reactor, and for Case 3, $570,000 to $670,000 per reactor.

An uncertainty assessment was performed for the above cases using the Monte Carlo simulation software, @RISK. This assessment was based on adopting high, most likely, and low estimates for each of the cost elements underlying the total cost estimate. High, most likely, and low values were based on industry input and engineering judgement. Using Monte Carlo sampling, @Risk propagates uncertainties in the cost elements to a probability distribution of the total cost. Estimates at the 5th percentile and 95th percentile confidence levels indicate that the uncertainties are skewed toward the higher costs.

An important consideration in the assessment of backup power options is the functional reliability of the options and the relationship between this reliability and the associated costs. System costs tend to increase as the system's reliability increases.

Since the values (benefits) of backup power are calculated assuming a perfect backup system, the benefits would need to be multiplied by the functional reliability of the backup system to obtain a realistic value for the benefits. If the functional reliability of an option is greater than 0.9, then the benefits would be reduced by, at most, ten percent. This would have a negligible effect on the overall value-impact assessment in light of the other large uncertainties.

A recent independent study at San Onofre Nuclear Generating Station, "A PRA-Based Design Change at SONGs Units 2 & 3: Add Portable Gasoline-Powered Generators for Risk Reduction," addresses similar "reliability" issues and estimated functional reliability values in the range of 97 to 98%. Since a portable generator system would probably have a lower functional reliability than a pre-staged generator system, and since a portable system can have high reliability, meaningful differences in the reliability between these systems is unlikely. Thus, for the purposes of this assessment, it is concluded that a backup system (either portable or pre-staged) can be designed which has sufficiently high functional reliability to not make it a factor in the cost-benefit assessment.

In addition to the uncertainty assessment, four sensitivity studies were performed. Three of the studies (rulemaking separate from the current 10 CFR 50.44 rulemaking; implementation requiring extended outage; and 3% real discount rate compared to standard 7%) were determined to have little impact on the costs.

The fourth study, which considered qualifying the backup power equipment for external events, does have a major cost impact. However, since the external event contributors and magnitudes vary from site to site and much of the external event information is qualitative, no detailed cost assessment was performed. Based on past experience, it is estimated that costs would double to accommodate seismic events. This additional cost, of course, would vary from site to site depending on the external risk profile and on what external event accommodation would best maximize the benefits versus the costs.

In conclusion, the "best estimate" costs vary from about $195,000 to $670,000 depending on the nature of the modifications and plant-specific variabilities and expands to approximately $185,000 to $830,000 when accounting for uncertainties.

In addition to addressing the powering of hydrogen igniters under SBO conditions, the study also considered the costs of a hydrogen control capability completely independent of igniter systems, namely passive autocatalytic recombiners. The cost of these recombiners would be considerably higher than the igniter power alternatives assessed in this study.

Backup Power for PWRs with Ice Condenser Containments and for BWRs with Mark III Containments under SBO Conditions: Impact Assessment

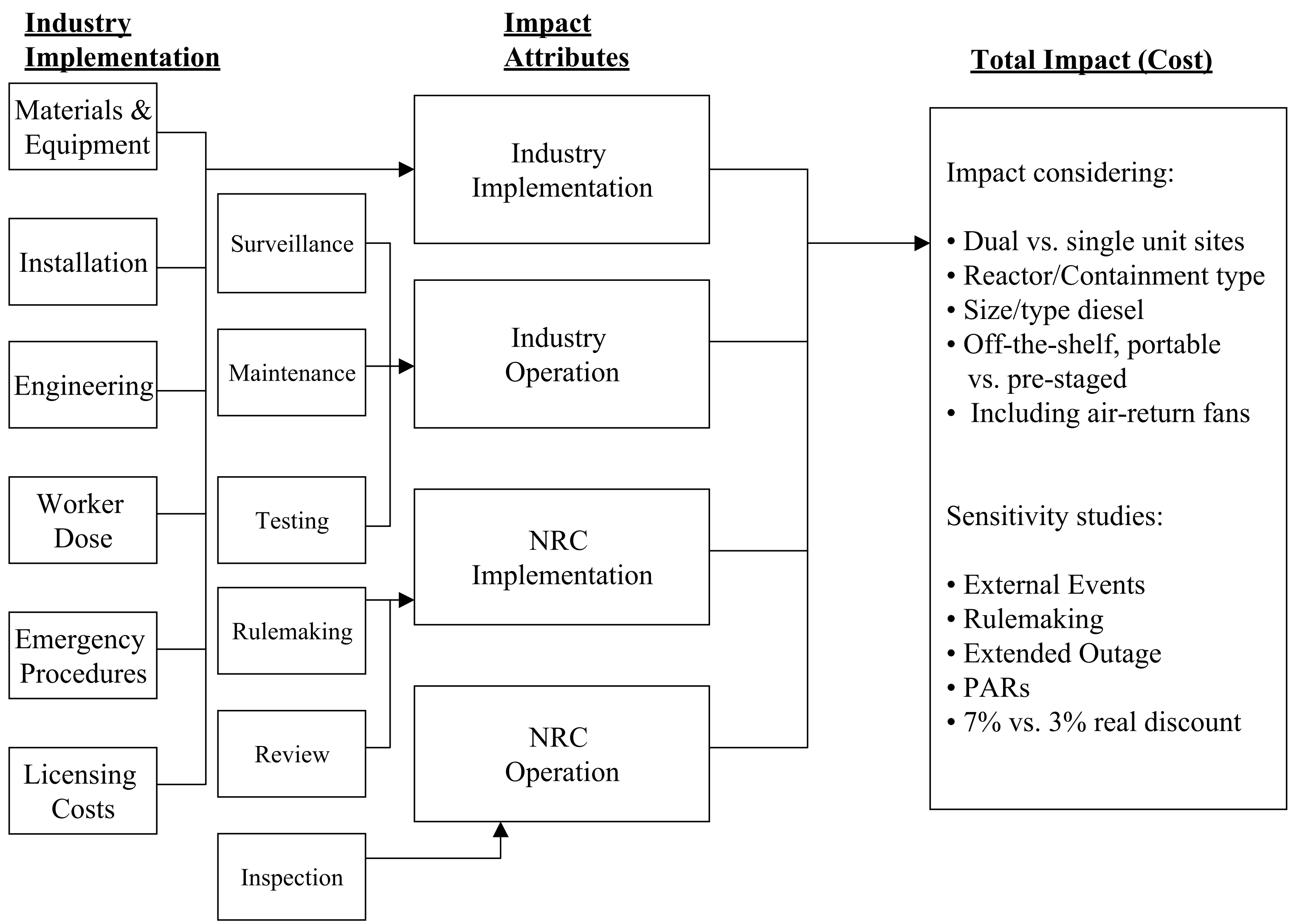
1. Introduction

The costs analyzed here together with the benefits (averted risks) analyzed in a separate document provide the data for a cost-benefit or Value-Impact assessment that can, in turn, be used as part of a regulatory analysis that assesses the pros and cons of a candidate regulatory action, including application of backfit requirements. These costs are developed consistent with the guidelines described in the Regulatory Analysis documents NUREG/BR-0058, Rev. 3 [Reference 1] and NUREG/BR-0184 [Reference 2]. They cover the full spectrum of industry and NRC costs from implementation to maintenance and inspection over the life of the plant. For each candidate regulatory action, estimates are made for implementation and operational (recurring) costs for both the licensee and the NRC. Licensee implementation costs included allowance for materials and equipment, installation, engineering, worker dose, emergency procedures, and licensing costs. Licensee operational costs considered routine periodic surveillance, maintenance and testing of the independent power supply. For the NRC, implementation costs covered rulemaking and reviews of licensee documentation, and operational costs allowed for periodic inspection. The elements of this cost (or “Impact”) assessment are displayed in Figure 1-1. The cost assessment in this study follows the structure displayed in this figure and analyzes the options and sensitivities listed. The costs for a given case or sensitivity are normalized to 2002 dollars and summed to give a dollar value to the candidate regulatory action. This cost is then compared to the 2002 dollar equivalent of the benefit (or Value) from averting the risk otherwise imposed on the public from containment failure. (Note that here, the term “Cost Benefit” is analogous to the term “Value-Impact.”)

The staff considered a range of potential modifications to address GSI-189 safety concerns. These included reliance on: (1) a pre-staged diesel generator to power the hydrogen igniters; (2) an “off-the-shelf” portable diesel generator to power the hydrogen igniters; (3) and a pre-staged diesel generator to power the hydrogen igniters and air return fans (ARF).

This cost analysis includes an uncertainty assessment, using the software @RISK, a Monte Carlo computer code. This assessment was based on adopting high, most likely, and low estimates for each of the cost elements underlying the total cost estimate. High, most likely, and low values were based on industry input and engineering judgement. (Note that in this report, the term “most likely” is equivalent to the term “best estimate.”) Using Monte Carlo sampling, @Risk propagates uncertainties in the cost elements to a probability distribution of the total cost. Another important methodology consideration is how to “adjust,” if necessary, the averted risks (benefits), which are developed under the assumption that the candidate regulatory action is 100% effective, to reflect the actual reliability of the system under study. The systems that are considered as candidates in this cost study are judged to have a “functional reliability” [1 - (hardware unreliability + hardware unavailability + human unreliability)] that is sufficiently close to 1 such that it is not an important consideration in the estimation of benefits either in an absolute or comparative sense. This aspect is also assessed in the study.

Figure 1-1 Impact (Cost) Assessment Process: GSI-189



Since, for some of the 13 units, external events are relatively important contributors to core damage from station blackout (SBO), it is important to assess the cost implications of qualifying systems for external events. For example, there will be additional costs for seismically qualifying a pre-staged diesel generator. This added cost will only be worthwhile if the added (averted risk) benefits exceed the added costs associated with seismic qualification. This is a highly complex determination. Not only do the external event contributors and associated magnitudes vary from site to site, but much of the external event information is qualitative (e.g., through the use of the seismic margins approach for evaluating seismic events) and is not conducive to estimating costs for equipment to accommodate the external events. Thus, only a general guideline on the added costs for accommodating external events is provided.

2. Objective and Scope

The objective is to support RES/DSARE in the development of a cost (impact) analysis in order to determine whether the candidate safety modifications being considered under GSI-189 are cost justified.

Costs (Impacts) are determined for the following cases.

1. Costs for a pre-staged diesel generator as backup power to the hydrogen igniters for ice condenser (IC) and Mark III plants under SBO conditions: Base Case

2. Costs for off-the-shelf portable diesel generator as backup power to the hydrogen igniters for ice condenser and Mark III plants under SBO conditions: Low Cost Case

3. Costs for pre-staged diesel generator backup power to the hydrogen igniters and air return fans (ARF) for ice condenser plants under SBO conditions

4. Costs for passive autocatalytic recombiners (PARs) for ice condenser plants and Mark III plants under SBO conditions

For these four cases, costs (impacts) are estimated for the following four attributes:

- Industry Implementation
- Industry Operation
- NRC Implementation
- NRC Operation

In addition, an uncertainty assessment is performed and other sensitivity studies are addressed, as noted below.

Except where noted, the guidance described in the Regulatory Analysis documents, NUREG/BR-0058, Rev. 3 and NUREG/BR-0184 (1997), will be used.

The following assumptions apply to all 4 cases:

- All costs are expressed in 2002 dollars.
- The remaining life of the average plant is assumed to be 40 years. This value was determined by adding 20 years (term of license renewal) to typically 20 years remaining on the plant's current license.

- For the “Operation” costs (impacts), a 7% real discount rate is used, as recommended in NUREG/BR-0184. (For the assumed 40-year remaining life of the plant, this translates into a multiplier for the year 2002 annual rate for operation costs of about 13.)
- Outage replacement power costs are zero (when considering “Industry Implementation”) since it is assumed that installation of these backup power supplies can be accomplished while on-line and/or during normal outage time. A sensitivity study will consider the cost (impact) of extended outage costs.
- Rulemaking costs will be considered as minimal. This would be appropriate if the GSI-189 effort is subsumed by the current 10 CFR 50.44 rulemaking rebaselining effort. A sensitivity study will be included that assumes a major rulemaking effort.
- Costs will be determined on a “per unit” basis, with consideration of reduced per-unit costs for sites with dual units.
- It is assumed that any rulemaking associated with the resolution of GSI-189 will not affect the Station Blackout Rule or the License Renewal Rule.
- Consistent with the purpose of these options, namely to mitigate the consequences of severe accidents, the focus of equipment qualification will be the survivability of equipment, in contrast to meeting stringent design-basis requirements.
- This assessment assumes that only one backup power source will be needed during the remaining life of the plant.

Certain other assumptions are relevant only to Cases 1, 2, and 3:

- The backup power supplies will not be external event qualified. External event qualification costs will be considered as a variation of the Base Case (Sensitivity Study 1).
- One train of igniters is considered necessary and sufficient for accommodating hydrogen burns and preventing containment failure. Only train A will be powered.
- For Case 3, one air return fan is considered sufficient. Only the train A ARF will be powered.
- The hardware (e.g., backup power generators) will meet the Category 3 standards and requirements of Regulatory Guide 1.97, Revision 3 [Reference 3], unless, for certain components, a higher category will be required. Category 3 hardware needs to meet basic engineering standards but does not have to meet many of the requirements and standards associated with safety-grade systems, for example, the hardware does not have to be seismically qualified, nor does it have to meet any redundancy standards. It is assumed that all the systems that are considered as candidates in this cost study should have a “functional reliability” [1 - (hardware unreliability + hardware unavailability + human unreliability)] that is sufficiently close to 1 such that it is not an important consideration in the cost benefit analysis. If the functional reliability of an option is greater than 0.9, then the benefits would be reduced by, at most, 10%. This would have a negligible effect on the overall cost-benefit assessment in light of the other large uncertainties. A recent independent study at SONGS, “A PRA-Based Design Change at SONGS Units 2 & 3: Add Portable Gasoline-Powered Generators for Risk Reduction” [Reference 4], addresses similar “reliability” issues and estimated functional reliability values in the range of 97 to 98%. Thus, for the purposes of this study, it is concluded that a backup system can be designed which has sufficiently high functional reliability to not make it a factor in the cost-benefit assessment.

3. Estimation and Evaluation of Impacts for the GSI-189 Action

3.1 Case 1 – Costs for Backup Power to the Hydrogen Igniters for Ice Condenser and Mark III Plants During SBO Conditions: Base Case

The Base Case (Case 1) is a modest but permanent modification that can provide alternate backup power to igniters under SBO conditions. For the resolution of GSI-189, the Base Case modification will include a pre-staged diesel generator (DG) sized to power one train of igniters. Due to ventilation, radiation and fire protection concerns as well as space limitations in the auxiliary building, it is more reasonable to locate the DG outside, in an area that can be accessed by an operator. Because the alternate power supply is assumed not to be safety-related nor qualified for external events, the DG will not be housed in a separate structure. However, it is assumed that it will be designed for normal outdoor conditions, i.e., will be protected by a weather enclosure. Since the DG will be pre-staged, the cost of the modification includes installation on a concrete slab. The powering of a train of igniters from the backup power supply is assumed to be remote and local, that is, not powered from the control room. During a SBO, an operator, following appropriate procedures, would start the DG, isolate the hydrogen igniters from the existing Class 1E system, and provide power to the igniters.

For the four dual-unit IC plants, the previous assessment assumed that one pre-staged DG, centrally located between the two units, could provide backup power to the unit experiencing a SBO event. Re-analysis has shown that it would be more cost-effective to have two pre-staged DGs, one for each unit. These DGs would be located as close as practical to their respective units, close to the auxiliary building where the motor control centers that distribute normal power to the hydrogen igniters are located. The main reason why one DG would be less cost-effective is that this diesel would have to be centrally located between the two units, thereby requiring a larger amount of cable. Cable installation costs are sufficiently large to make this single diesel option more costly. This position is supported by recent comments from Duke regarding the Catawba and McGuire stations [Reference 5]. Further supporting the use of two DGs in the cost analysis are the implications of the cross-tie capability at the Sequoyah site. At sites like Sequoyah, the cross-tie capability allows for equipment from the SBO-affected unit to be powered by the existing Class 1E DG from the non SBO-affected unit. Therefore, one would expect either no SBO core damage at the site or a SBO core damage event at both units. Thus, both units would need backup power at the same time, making the use of two alternate DGs more plausible.

The existing power supply to the hydrogen igniters is Class 1E, and typically rated at 120 V. The exact tie-in to the existing power supply would be plant-specific, but for this case it is assumed to occur at a juncture just prior to the hydrogen igniters.

The table below provides the total number of igniters per unit and the total power needed for one train of igniters.

Table 3-1 Igniter Data

Plant	Total Number of Igniters per unit	Number of Igniters per Train	Power Needed for One Train of Igniters
Catawba 1 and 2	70	35	4,400 watts[1]
McGuire 1 and 2	70	35	4,400 watts[1]
D.C. Cook 1 and 2	70	35	4,400 watts[1]
Sequoyah 1 and 2	68	34	20,400 watts[2]
Watts Bar 1	68	34	20,400 watts[2]
Grand Gulf	90	45	6,000 watts[3]
River Bend	104	52	6,500 watts[1]
Clinton	115	58	7,300 watts[1]
Perry	102	51	6,400 watts[1]

[1]Assumes wattage of igniter is 125 watts
[2]Each igniter requires approximately 600 watts
[3]Grand Gulf UFSAR states one train of igniters requires 6,000 watts

Industry Implementation

This attribute accounts for the projected incremental cost on the affected licensees to install or implement mandated changes. Cost elements such as engineering, materials and equipment, structures, installation, occupational exposure, procedures and training are considered. Other costs elements such as planning, scheduling, and procurement are included with the engineering costs.

Based on the information obtained from the Individual Plant Examinations (IPEs) and updated final safety analysis reports (UFSARs), the approximate size of the generator needed to power one train of igniters ranges from 4.3 to 20.4 kW. Based on information obtained from different manufacturers/distributors, diesel generators (with weather enclosures) for the size needed range in cost from $6,000 to $20,000.

Duke recently supplied a cost estimate for this type of modification in response to an RAI [Reference 6] on a severe accident mitigation alternative (SAMA) for McGuire and Catawba. The cost for equipment and materials for a small diesel generator (~5 kW), cables, circuit breakers, concrete pad, and related items was estimated to be $50,000. This cost is adopted as representative of adding one independent power supply per unit at a dual unit ice condenser plant. The cost for the TVA plants is increased by $10,000, and by $5,000 for the Mark III's to account for the larger diesel generators required.

Installation was estimated by Duke to cost $110,000/unit [Reference 6]. The installation cost is assumed to include installation of conduit or cable raceways, pulling and terminating the cable, installation of electrical panels, circuit breakers, switches, etc., pouring of a concrete pad, and anchoring of the diesel generator. The majority of this cost is attributed to the installation of conduit and cable. At the time Duke provided the estimate, the understanding was that there would be one pre-staged diesel generator with the capability of supplying power to either unit. Since that time, it has been shown that the use of two diesel generators (one per unit) is more cost-effective than the use of one centrally located diesel generator due to the expense of installing conduit and cable [Reference 5]. Accordingly, the installation cost previously provided is adjusted by 25% to account for the reduced amount of conduit and cable that will be needed outside of the auxiliary building. An estimate for installation of conduit and cable by another utility [Reference 7] is on par with the estimate provided by Duke. Therefore, $82,500 for installation will be used in this analysis as the cost for installation.

Engineering was estimated by Duke to be $5,000 which appears to be a low figure [Reference 6]. Other SAMA evaluations, past and recent, estimate engineering costs for similar modifications to be between $50,000 and $175,000 [References 7 and 8]. A cost of $50,000 will be used for this analysis; this is applicable to single unit IC's as well as the Mark III plants. For dual unit IC's an engineering cost of $60,000 is used, or $30,000/unit.

For the generators of interest, the fuel consumption rate is between 1 and 2 gallons per hour. Based on the assumption that the diesel will be required to operate for 24 hours, 50 to 100 gallons of diesel fuel will be required. Since the diesel does not have this fuel capacity, an additional tank, or means of supplying the fuel will be necessary. The cost associated with this is expected to be minimal, about $1,000, and is included in the equipment and materials cost.

A connection/tie-in to the existing power supply to the hydrogen igniters will be necessary. The power distribution panels and motor control centers are typically located in the auxiliary building. The exposure rate for this specific location is not known; however, a dose rate of 5 mrem/hour is not unreasonable, considering the auxiliary building dose rates described in Reference 9. It is assumed that 60% of the "installation" labor occurs outside of the auxiliary building while the remainder of the labor occurs inside the auxiliary building. It is further assumed that the time spent in the auxiliary building would be about 1,120 person hours. At a cost of $2,000/person-rem, the cost for occupational exposure due to installation is approximately $11,200/unit. Dose rates outside the auxiliary building are assumed to be negligible.

According to several SAMA evaluations, the minimum cost for a procedure change and training is $30,000 [Reference 10]. This modification will require the development or modification of emergency procedures as well as training. Therefore, an estimate of $50,000 is used for this analysis. Because of possible differences between the units at a dual-unit site, the dual-unit site costs are estimated to be $60,000, or $30,000/unit.

For this case, it is assumed that the resolution of GSI-189 will be subsumed by the 10 CFR 50.44 rulemaking. Therefore, it is likely that a change to the UFSAR would be appropriate. In order to make a change to the UFSAR without prior NRC approval (which is assumed by this analysis), the licensee would need to perform a 10 CFR 50.59 evaluation. Licensee costs associated with a 50.59 evaluation and modification to the UFSAR are estimated to be $10,000. Again, as with procedure changes, the units at a dual-unit site may be sufficiently different that costs will be higher for those sites. Thus, the dual-unit costs are assumed at $12,500, or $6,250/unit. Since the proposed modification does not involve any safety-related equipment, i.e., the equipment will be Category 3, no changes to the technical specifications are expected.

The table below contains a summary of the costs for Industry Implementation.

Table 3-2 Industry Implementation - Base Case (Case 1)

Cost Element	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
Materials and Equipment	$50,000	$60,000	$60,000	$55,000
Installation	$82,500	$82,500	$82,500	$82,500
Engineering	$30,000	$30,000	$50,000	$50,000
Worker Dose	$11,200	$11,200	$11,200	$11,200
Emergency Procedures	$30,000	$30,000	$50,000	$50,000
Licensing Costs	$6,250	$6,250	$10,000	$10,000
Total for Industry Implementation	$209,950	$219,950	$263,700	$258,700

Industry Operation

This attribute accounts for the projected incremental cost due to routine and recurring activities required by the proposed action on all affected licensees. The most notable costs considered are routine surveillance, maintenance and testing. Since the diesel generator will only be used in the event of SBO, periodic surveillance, testing and maintenance to ensure its operability will be necessary. Duke estimated operations and maintenance (O&M) costs for the remaining life including the license renewal period to be $40,000 [Reference 6]. Another utility estimated O&M costs for a larger generator (50 kW) and more complex system to be $100,000 [Reference 7]. This estimate was based on periodic testing requiring 3 operators for ½ shift (annually) and periodic maintenance requiring 3 mechanics for 1 shift and 2 electricians for 1 shift (annually) over a 30-year remaining life. For the purposes of this analysis, Duke's estimate of $40,000/unit will be used. As previously stated, dose rates in the test area are assumed to be negligible. Therefore, there is no occupational exposure associated with surveillance and maintenance.

NRC Implementation

This attribute measures NRC's incremental cost in implementing this regulatory change. Costs associated with a rulemaking and any review of licensee documentation are considered here. For the Base Case (Case 1), it is assumed that the resolution of GSI-189 will be included with the rulemaking effort for 10 CFR 50.44. In Reference 11, the cost estimated for a rulemaking of this type is $500,000. We assume that an additional incremental cost of $150,000 will be added to the rulemaking cost by adding the GSI-189 action. This cost will be equally shared among the 13 units involved in the GSI-189 action, thus yielding a per-unit cost of approximately $12,000.

Since the equipment is not safety-related, no changes to the technical specifications will be necessary. However, changes to the UFSAR and PRA models are expected. NRC review of the UFSAR occurs every two years. Since the change will likely be submitted with the required update, the additional NRC cost should be minimal. Furthermore, since licensees do not typically submit their PRA models to the NRC for review, no additional NRC costs are assumed.

NRC Operation

This attribute measures NRC's incremental costs after the proposed action is implemented. As a result of the proposed action, there will be an increased effort during inspections. Assuming that an additional two-hour of inspection time is required annually, the total cost for NRC operation over 40 years is estimated to be $2,000 [based on an NRR labor rate of $80/hour].

Summary of Impacts for the Base Case (Case 1)

The table below contains a summary of the impacts for the Case 1, which is considered to be the Base Case.

Table 3-3 Summary of Impacts for the Base Case (Case 1)

Attribute	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
Industry Implementation	$209,950	$219,950	$263,700	$258,700
Industry Operation	$40,000	$40,000	$40,000	$40,000
NRC Implementation	$12,000	$12,000	$12,000	$12,000
NRC Operation	$2,000	$2,000	$2,000	$2,000
Total for Case 1 (Base Case)	$263,950	$273,950	$317,700	$312,700

The values in Table 3-3 are "best estimate" point values. An uncertainty assessment was also performed that considered possible variations in costs across all the cost element and cost attribute variables. The uncertainties are discussed in Section 4.

3.1.1 Sensitivity Studies

In addition to considering a low-cost version of the Base Case (Case 1), assessed as Case 2, a number of sensitivities are considered. All of these sensitivity studies are relative to the Base Case. The following evaluations were performed:

- cost if the backup power supplies are qualified for external events
- cost if GSI-189 evolves into a separate and extensive rulemaking
- cost if the industry implementation requires an extension of an outage

- cost if a 3% real discount rate is used instead of a 7% real discount rate.

3.1.1.1 Sensitivity Study 1: Alternate Power Supply and Equipment is Qualified for External Events

Since, for some of the 13 units, external events are relatively important contributors to core damage from station blackout, it is important to understand the cost implications of qualifying systems for external events. As discussed in Section 1, it is beyond the scope of this assessment to make these determinations in any detail. Not only do the external event contributors and associated magnitudes vary from site to site, but much of the external event information is qualitative (e.g., through the use of the seismic margins approach for evaluating seismic events) and not conducive to estimating costs for equipment to accommodate the external events. Thus, only a general guideline on the added costs for accommodating external events is provided.

If the alternate power supply and associated equipment (if located outdoors) are required to be qualified for external events, several of the cost elements are expected to increase significantly. Specifically, it is estimated that the cost of the materials and equipment would increase by a factor of three, the cost for installation would at least double, and the cost for engineering would double. These estimated increases are for seismic qualifications and are based on information obtained from a distributor of Class 1E electrical equipment, a national engineering laboratory that performs seismic qualifications, as well as cost estimates for severe accident mitigation alternatives submitted by license renewal applicants. All other costs are assumed to remain the same. These cost differentials are consistent with general cost trends experienced when a physical modification at a nuclear power plant is qualified for external events.

The adjusted numbers are given below. These numbers were extracted from the "Industry Implementation" table (Table 3-2) in the Base Case (Case 1) above and adjusted accordingly.

Table 3-4 Industry Implementation - Sensitivity Study: External Event Qualification

Cost Element	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
Materials and Equipment	$150,000	$180,000	$180,000	$165,000
Installation	$165,000	$165,000	$165,000	$165,000
Engineering	$60,000	$60,000	$100,000	$100,000
Worker Dose	$11,200	$11,200	$11,200	$11,200

Table 3-4 (Continued)

Cost Element	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
Emergency Procedures	$30,000	$30,000	$50,000	$50,000
Licensing Costs	$6,250	$6,250	$10,000	$10,000
Total for Industry Implementation	$422,450	$452,450	$516,200	$501,200

All other attributes are assumed to remain the same as in the Base Case (Case 1). The summary of attributes for external event qualification is provided in Table 3-5.

Table 3-5 Summary of Impacts for Sensitivity Study: External Event Qualification

Attribute	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
Industry Implementation	$422,450	$452,450	$516,200	$501,200
Industry Operation	$40,000	$40,000	$40,000	$40,000
NRC Implementation	$12,000	$12,000	$12,000	$12,000
NRC Operation	$2,000	$2,000	$2,000	$2,000
Total for External Event Qualification	$476,450	$506,450	$570,200	$555,200

3.1.1.2 Sensitivity Study 2: If Separate Rulemaking is Required

The Base Case (Case 1) assumes that the resolution of GSI-189 will be subsumed by the 10 CFR 50.44 rulemaking. However, it is conceivable that a separate rulemaking could be pursued. For this reason, a sensitivity study is performed to assess the impact of the separate rulemaking. The cost for a simple rulemaking is estimated to be $300,000. More complex rulemakings can cost upwards of $1,000,000. It is likely that a rulemaking to resolve GSI-189, although it affects only 13 units, would likely face opposition by the industry. Therefore, a cost of $400,000 is estimated for the rulemaking. On a per unit basis, this equates to approximately $30,800. The attribute that changes is “NRC Implementation”; all other attributes are assumed to remain the same as the Base Case (Case 1).

Table 3-6 Summary of Impacts for Sensitivity Study: Rulemaking Required

Attribute	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
Industry Implementation	$209,950	$219,950	$263,700	$258,700
Industry Operation	$40,000	$40,000	$40,000	$40,000
NRC Implementation	$30,800	$30,800	$30,800	$30,800
NRC Operation	$2,000	$2,000	$2,000	$2,000
Total for Rulemaking	$282,750	$292,750	$336,500	$331,500

3.1.1.3 Sensitivity Study 3: If Extended Outage is Required

Although it is not anticipated that an extended outage would be necessary to accommodate the modification(s), it is possible that limited incremental downtime during a scheduled outage might occur. For the purpose of this sensitivity analysis, an incremental downtime of 8 hours is assumed. For outages greater than or less than 8 hours, the costs stated below can be adjusted to assess the impact of a longer or shorter outage. A typical cost for an outage is $300,000 per day per unit [Reference 12], each day the unit is down. Therefore, it is expected that, for 8 hours of an extended outage, it would cost $100,000 per unit. The numbers below are extracted from the Base Case (Case 1) above, and industry implementation is adjusted to account for a one-day extended outage.

Table 3-7 Summary of Impacts for Sensitivity Study: Extended Outage

Attribute	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
Industry Implementation	$309,950	$319,950	$363,700	$358,700
Industry Operation	$40,000	$40,000	$40,000	$40,000

Table 3-7 (Continued)

Attribute	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
NRC Implementation	$12,000	$12,000	$12,000	$12,000
NRC Operation	$2,000	$2,000	$2,000	$2,000
Total for Sensitivity: Extended Outage	$363,950	$373,950	$417,700	$412,700

3.1.1.4 Sensitivity Study 4: If a 3% Real Discount Rate is Used

For sensitivity analysis purposes, a 3% real discount rate is recommended [Reference 2] to assess the uncertainty in the time value of money. For 40 years the present-worth multiplier is 13.42, assuming 7%. Assuming a 3% real discount rate, the multiplier becomes 23.29. Thus, for the “Operation” attributes, the Base Case (Case 1) numbers are multiplied by the ratio of these numbers (23.29/13.42), which is 1.735, to obtain the values for a 3% real discount rate. However, because the costs associated with the operation attributes are relatively small, this adjustment has a minimal effect on the total costs.

3.2 Case 2: Costs for Off-the-Shelf Backup Power to the Hydrogen Igniters for Ice Condenser and Mark III Plants During SBO Conditions

This case represents a lower bound to establish the least expensive, yet feasible modification. The Base Case assumes that an alternate ac power source to power one train of hydrogen igniters is pre-staged or permanently placed. Because of the relatively small amount of power needed to power one train of igniters, it is believed that the objective can be accomplished with a portable alternate ac power source, i.e., can be stored in a location then hooked up to the igniters via a patch panel on an as-needed basis. Some of the cost elements will remain the same (as the Base Case) such as emergency procedures and licensing. Other costs such as materials and equipment, installation and engineering will be less.

As is the case with the Base Case (Case 1), permanent modifications to the plant are necessary to accommodate the hook up of the alternate power supply.

Although this alternative to the Base Case (Case 1) is assessed here for accommodating internal events, it is important to note that portable diesel generators are designed for use at construction sites, outdoors, and the like; therefore they tend to be durable, and as such, could possibly survive external events, depending upon where and how they are stored. In the study described in Reference 4, generators are stored in a seismically bolted down storage locker in the vicinity of the connection panel. The costs for this type of storage locker are not included in this assessment.

Industry Implementation

This attribute accounts for the projected incremental cost on the affected licensees to install or implement mandated changes. Cost elements such as engineering, materials and equipment, structures, installation, occupational exposure, procedures and training are considered. Other costs elements such as planning, scheduling, and procurement are included with the engineering costs.

The general design considered which serves as the basis for this portion of the cost analysis includes an emergency patch panel. The patch panel accommodates the hook up of the portable diesel generator. For the purposes of this analysis, it is assumed that the patch panel will be installed at the exterior of the auxiliary building or within a short distance of the auxiliary building. Therefore, the amount of conduit and cable needed outside of the building is minimal, thereby reducing the cost of installation, relative to that assumed in the Base Case, which is mainly driven by the cost associated with installing conduit and cable. The remainder of the design, that which is inside the auxiliary building, is assumed to be the same as that considered for the Base Case (Case 1). Therefore, the installation costs used in the Base Case are reduced by 40 percent, which results in a per-unit installation cost of $49,500.

The materials and equipment costs associated with the portable diesel generator option are less than those used in the Base Case – $50,000 to $60,000 – (Case 1). The diesel generators considered in the Base Case are “industrial grade,” and therefore, are more expensive. Based on information obtained from different manufacturers/distributors of portable diesel generators, for the sizes needed, the costs range from $2,000 to $12,000.

The cost of $12,000 is estimated for a diesel generator for the TVA plants. Because a larger diesel generator is needed for these plants (~20 kW), in order for the generator to be “portable,” it would be mounted on a trailer.

Less conduit and cable will be required due to the use of the portable diesel generator as well as the proximity of the patch panel to the auxiliary building. The use of the patch panel is an additional cost; however the cost for a patch panel is $1,000 or less. As is the case with Base Case (Case 1), the portable diesel generator does not have a sufficient fuel capacity; therefore, an additional tank, or means of supplying the fuel will be necessary. The cost associated with this is expected to be minimal, about $1,000. This cost is included in the equipment and materials cost. Thus, for this analysis, the cost for equipment and material is estimated to be $25,000/unit for the dual-unit ice condenser sites (excluding TVA plants), $35,000/unit for the TVA plants, and $30,000 for the Mark III plants.

Engineering costs are expected to be less than those used in the Base Case. Since the modification inside the auxiliary building is similar for both the Base Case and this case, and since there is not expected to be a large amount of cable installed outside the auxiliary building, the engineering costs are reduced to $40,000 for dual-unit sites, and $30,000 for single-unit sites.

A connection/tie-in to the existing power supply to the hydrogen igniters will be necessary. The power distribution panels and motor control centers are typically located in the auxiliary building. This installation activity inside the auxiliary building will be similar to the Base Case however, not as extensive. The cost for occupational exposure due to installation is estimated at $8,400/unit. Dose rates outside the auxiliary building are assumed to be negligible.

According to several SAMA evaluations, the minimum cost for a procedure change and training is $30,000 [Reference 10]. This modification will require the development or modification of emergency procedures as well as training. Therefore, an estimate of $50,000 is used for this analysis for single-unit sites. Because of possible differences between the units at a dual-unit site, the dual-unit site costs are estimated to be $60,000, or $30,000/unit.

The licensing costs are assumed to be similar to those for the Base Case.

Table 3-8 Industry Implementation - Case 2

Cost Element	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
Materials and Equipment	$25,000	$35,000	$35,000	$30,000
Installation	$49,500	$49,500	$49,500	$49,500
Engineering	$20,000	$20,000	$30,000	$30,000
Worker Dose	$8,400	$8,400	$8,400	$8,400
Emergency Procedures	$30,000	$30,000	$50,000	$50,000
Licensing Costs	$6,250	$6,250	$10,000	$10,000
Total for Industry Implementation	$139,150	$149,150	$182,900	$177,900

Industry Operation

This attribute accounts for the projected incremental cost due to routine and recurring activities required by the proposed action on all affected licensees. The most notable costs considered is routine surveillance, testing and maintenance. Since the diesel generator will only be used in the event of SBO, periodic surveillance, testing and maintenance to ensure its operability is likely. Duke estimated operations and maintenance (O&M) costs to be $40,000 [Reference 6]. This value is used for the purposes of this analysis. As previously stated, dose rates outside are assumed to be negligible. Therefore, there is no occupational exposure associated with surveillance and maintenance.

NRC Implementation

This attribute measures NRC's incremental cost in implementing this regulatory change. Costs associated with a rulemaking and any review of licensee documentation are considered here. It is assumed that the resolution of GSI-189 will be included with the rulemaking effort for 10 CFR 50.44. In Reference 11, the cost estimated for a rulemaking of this type is $500,000. We assume that an additional incremental cost of $150,000 will be added to the rulemaking cost by subsuming the GSI-189 action. This cost will be equally shared among the 13 units involved in the GSI-189 action, thus yielding a per-unit cost of approximately $12,000.

Since the equipment is not safety-related, no changes to the technical specifications will be necessary. However, changes to the UFSAR and PRA models are expected. NRC review of the UFSAR occurs every two years. Since the change will likely be submitted with the required update, the additional NRC cost should be minimal. Furthermore, since licensees do not typically submit their PRA models to the NRC for review, no additional NRC costs are assumed.

NRC Operation

This attribute measures NRC's incremental costs after the proposed action is implemented. As a result of the proposed action, there will be an increased effort during inspections. Assuming that an additional two hours of inspection time is required annually, the total cost for NRC operation over 40 years is estimated to be $2,000 (based on an NRR labor rate of $80/hour).

Table 3-9 Summary of Impacts for Case 2

Attribute	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
Industry Implementation	$139,150	$149,150	$182,900	$177,900
Industry Operation	$40,000	$40,000	$40,000	$40,000
NRC Implementation	$12,000	$12,000	$12,000	$12,000
NRC Operation	$2,000	$2,000	$2,000	$2,000
Total for Case 2	$193,150	$203,150	$236,900	$231,900

3.3 Case 3: Costs for Backup Power to the Hydrogen Igniters and Air Return Fans for Ice Condenser Plants Under SBO Conditions

This case is similar to the Base Case (Case 1) with the exception of the size of the diesel generator required, and it only applies to plants with ice condenser containments. Other information pertinent to powering an air return fan (ARF) in addition to one train of igniters is discussed below. As is considered for the Base Case, each unit will be supplied with a diesel generator.

The existing power supply to the ARFs is Class 1E, and typically rated at 480 V. The exact tie-in to the existing power supply would be plant specific, but for this case is assumed to occur at the 480 V motor control center or comparable power panel. Therefore, the rating of the generator would be 480 V. The typical power needed for one train of igniters at McGuire, Catawba and Cook plants is 4,400 watts and 20.4 kW for the TVA plants as indicated in Table 3-1. Air return fans require between 20 and 30 kW of power. Therefore, the size of the generator needed to power one train of igniters and one ARF is between 25 and 50 kW. It is anticipated that the ARF will be energized before the igniters are energized. This sequencing allows for the containment atmosphere to mix before activating the igniters. Further, it allows for more generator power to be available to the ARF during startup, when the ARF motor will draw more current.

Along with the assumptions above, the following is assumed:

- the igniters and air return fan will be required to run for 24 hours, and
- all modifications can be made on-line or during a planned outage.

Industry Implementation

This attribute accounts for the projected incremental cost on the affected licensees to install or implement mandated changes.

Based on information obtained from different manufacturers/distributors, diesel generators (with weather enclosures) for the size needed at a 480 V rating are estimated to be between $15,000 and $50,000.

Duke recently supplied a cost estimate for this type of modification in response to an RAI [Reference 6] on a severe accident mitigation alternative (SAMA) for McGuire and Catawba. The cost for equipment and materials for a larger diesel generator (~30 kW), cables, circuit breakers, concrete pad, and other was estimated to be $210,000.

Installation was estimated by Duke to cost $240,000. The additional $100,000 for installation (compared with the Base Case (Case 1)) is assumed to be for routing of cable, installation of switches and other components for the ARF. As explained in Case 1, it has been shown that the use of two diesel generators (one per unit) is more cost-effective than the use of one centrally located diesel generator due to the expense of installing conduit and cable. Therefore, to account for the reduction in the amount of conduit and cable needed outside of the auxiliary building, the installation cost previously provided is reduced by 25%, to $180,000/unit.

Engineering was estimated by Duke to be $50,000/unit, or $100,000 per station. For a single-unit site (Watts Bar), this estimate is reduced to $75,000.

For the generators of interest, the fuel consumption rate is between 5 and 7 gallons per hour. Based on the assumption that the diesel will be required to operate for 24 hours, 120 to 168 gallons of diesel fuel will be required. Since the diesel generator does not have this fuel capacity, an additional tank, or means of supplying the fuel will be necessary. The cost associated with this is expected to be minimal (approximately $2,000). This estimate is double the estimate used in the Base Case (Case 1). The cost is added to the Materials and Equipment costs discussed above.

A connection/tie-in to the existing power supply to the igniters and ARF will be necessary. The power distribution panels and motor control centers are typically located in the auxiliary building. The exposure rate for this specific location is not known; however, a dose rate of 5 mrem/hour is not unreasonable, considering the auxiliary building dose rates described in Reference 9. Dose rates outside the auxiliary building are assumed to be negligible. At a cost of $2,000/person-rem, the cost for occupational exposure due to installation is estimated to be $24,500/unit. The increase in dose relative to the Base Case (Case 1) is primarily due to the fact that there will be an increase in time in the auxiliary building in order to install conduit, cable, switches, and circuit breakers for the ARF.

According to several SAMA evaluations, the minimum cost for a procedure change and training is $30,000 [Reference 10]. This modification will require the development or modification of emergency procedures as well as training. Therefore, an estimate of $50,000 is used for this analysis for a single-unit site. Because of possible differences between the units at a dual-unit site, the dual-unit site costs are estimated to be $60,000, or $30,000/unit.

For this case, it is assumed that the resolution of GSI-189 will be subsumed by the 10 CFR 50.44 rulemaking. Therefore, it is likely that a change to the UFSAR would be appropriate. Licensee costs associated with a modification of this nature to the UFSAR are typically between $10,000 and $15,000. For the purposes of this analysis, an estimate of $12,500 for the dual-unit sites, and $10,000 for the single-unit site is used. Since the proposed modification does not involve any safety-related equipment, i.e., the equipment will be Category 3, no changes to the Technical Specifications are expected.

Table 3-10 Industry Implementation - Case 3

Cost Element	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)
Materials and Equipment	$212,000	$262,000	$262,000
Installation	$180,000	$180,000	$180,000
Engineering	$50,000	$50,000	$75,000
Worker Dose	$24,500	$24,500	$24,500
Emergency Procedures	$30,000	$30,000	$50,000
Licensing Costs	$6,250	$6,250	$10,000
Total for Industry Implementation	$502,750	$552,750	$601,500

Industry Operation

This attribute accounts for the projected incremental cost due to routine and recurring activities required by the proposed action on all affected licensees. The costs for industry operation at IC plants are increased (from the Base Case) to account for additional time needed to test the ARF and sequencing.

NRC Implementation

This attribute measures NRC's incremental cost for the rulemaking effort associated with implementing this regulatory change. The costs for NRC implementation are assumed to be the same as for the Base Case (Case 1), except that only the nine ice condenser units are considered. Thus, the cost of NRC implementation, namely $150,000, is divided by 9 units, yielding approximately $17,000 per unit.

NRC Operation

This attribute measures NRC's incremental costs after the proposed action is implemented. As a result of the proposed action, there will be an increased effort during inspections. The costs for NRC operation are assumed to be the same as for the Base Case (Case 1).

Table 3-11 Summary of Impacts for Case 3

Attribute	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)
Industry Implementation	$502,750	$552,750	$601,500
Industry Operation	$50,000	$50,000	$50,000
NRC Implementation	$17,000	$17,000	$17,000
NRC Operation	$2,000	$2,000	$2,000
Total for Case 3	$571,750	$621,750	$670,500

3.4 Case 4: Costs for Passive Autocatalytic Recombiners (PARs) for Ice Condenser and Mark III Plants Under SBO Conditions

This case considers installation of PARs in containment. Much of the information provided below is taken from Reference 11 and adjusted to reflect the containment designs of consideration.

Industry Implementation

This attribute accounts for the projected incremental cost on the affected licensees to install or implement mandated changes. It is estimated that an average of 40 half-sized PARs would be installed in each ice condenser and Mark III containment. The average purchase price per half-sized PAR is estimated to be $24,000 [Reference 13]. Although the ability exists to produce PARs domestically, currently, PARs are imported from Europe. The amount above is based on the cost of an imported PAR. Thus, the purchase cost equates to $960,000. Should a catalyst bed need to be replaced (due to test failure), a replacement bed would cost approximately $350 [Reference 13]. A few beds are likely to be purchased at the time the PARs are purchased. Therefore, an additional cost of $1,000/unit is likely. The catalyst beds need to be tested in a testing enclosure complete with sensing instrumentation and a computer. The current cost for such a testing apparatus is $10,000. Each plant would require a testing apparatus. Thus, the total estimated Materials and Equipment element for a single-unit site is $960,000 + $1,000 + $10,000 = $971,000. The corresponding total for the dual-unit sites is 2x($960,000) + 2x($1,000) + $10,000 = $1,932,000.

Installation costs will also vary depending on the area of the country (differing labor rates) in which the plant is located. At Indian Point 2, it cost approximately $100,000 to install two full-sized PARs [Reference 13]. Although the cost for installing 40 PARs is not expected to increase by 20 times, it is expected to increase by a factor of five (based on economies of scale). Thus, total labor costs are expected to be $500,000 per unit.

The engineering associated with installation of the PARs will vary depending on the intended location of the PARs and whether extensive modifications will be necessary to accommodate the PARs. Based on information provided in past SAMA evaluations, a recent response to a Request for Additional Information related to SAMA evaluations, and information obtained from Indian Point 2, engineering costs ranged from $35,000 to $400,000 [References 8, 13]. Assuming units at dual-unit sites are similar in design and layout, our estimate for engineering of the PARS is $150,000 which is independent of whether it is a single or dual unit site. This estimate is largely driven by the fact that the PARs will have to be seismically installed.

During installation, workers are expected to receive occupational doses. The dose rates assumed are based on those given for recombiners in Reference 9, which are 10 mrem/hour for PWRs and 20 mrem/hour for BWRs. For this assessment, an average of 15 mrem/hour will be used. Since many, if not all, of the PARs will be seismically installed, it is estimated that it will take two men 24 hours per PAR. At the dose rate assumed for 40 PARs, this equates to 28.8 person-rem. The total cost for occupational exposure is estimated to be $57,600 per unit.

The PARs, most probably, will be maintained as Category 3 components (as defined in Reference 3). Testing and surveillance, although not required, would be recommended. A testing/surveillance procedure would need to be developed. Industry estimates for development of a procedure and its implementation (i.e., training) are a minimum of $30,000 [Reference 10]. However, the procedure for testing the PARs is not as complex as other procedures (such as emergency operating procedures), and has already been developed for Indian Point 2. The effort at Indian Point 2 cost approximately $2,000 [Reference 13]. However, this included the training of only two individuals. Since for the purposes of this analysis 40 PARs are going to be installed, it is likely that more than two individuals would be trained. Therefore, the estimated cost for developing and implementing the testing procedure at a typical plant is estimated to cost $3,000.

For this case, it is assumed that the resolution of GSI-189 will be subsumed by the 10 CFR 50.44 rulemaking. Therefore, it is likely that a change to the UFSAR would be appropriate. Licensee costs associated with a modification of this nature to the UFSAR are typically between $10,000 and $15,000. Here $12,500 for dual-unit sites and $10,000 for single-unit sites is assumed. Since the proposed modification does not involve any safety-related equipment, i.e., the equipment will be Category 3, no changes to the Technical Specifications are expected.

Table 3-12 Industry Implementation - Case 4

Cost Element	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
Materials and Equipment	$966,000*	$966,000*	$971,000	$971,000
Installation	$500,000	$500,000	$500,000	$500,000
Engineering	$75,000**	$75,000**	$150,000	$150,000
Worker Dose	$57,600	$57,600	$57,600	$57,600

Table 3-12 (Continued)

Attribute	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
Emergency Procedures	$1,500	$1,500	$3,000	$3,000
Licensing Costs	$6,250	$6,250	$10,000	$10,000
Total for Industry Implementation	$1,606,350	$1,606,350	$1,691,600	$1,691,600

*Assumes testing apparatus is shared by both units
**Assumes units are similar in design and layout

Industry Operation

This attribute accounts for the projected incremental cost due to routine and recurring activities required by the proposed action on all affected licensees.

The only expected operation costs associated with the PARs after installation will be due to testing. One catalyst bed per PAR should be tested periodically. It is estimated that it will take a technician 0.5 hour to remove a catalyst bed, observe the PAR for any fouling (accumulation of dirt, debris, dust), then reinstall it after testing [Reference 13]. The total time estimated for performing the test, including transportation time, paper work, etc., is one hour per PAR [Reference 13]. This process involves two persons. Therefore, the total labor cost involved with testing a PAR is estimated to be $200/PAR, assuming a labor rate of $100/hour [Reference 13]. Since it is recommended that 1/4th of the PARs be tested every refueling outage [Reference 13], this equates to approximately $1,333 per year per plant based on an 18-month refueling cycle. Using the multiplier of 13.42 to determine the year 2002 cost equivalent, the cost is $18,000.

Testing also involves the passing of a known concentration of hydrogen gas across the catalyst bed. A cylinder of hydrogen would be required to perform the testing. At Indian Point 2, it cost approximately $100/PAR for the hydrogen [Reference 13]. Therefore, at a PWR considered by this analysis, the cost for hydrogen per year is estimated to be $700 ($100/PAR x 10 x 12/18 = $667). Again, using the multiplier of 13.42 to determine the year 2002 cost equivalent, the cost is $9,400.

The last expected cost associated with testing of the PARs is a calibration of the testing unit once every six years. Assuming 7 tests over the 40 year remaining life of the plant and a cost per test of $3,000, the approximate cost for calibration will be approximately $10,000.

NRC Implementation

This attribute measures NRC's incremental cost in implementing this regulatory change. Costs associated with a rulemaking and any review of licensee documentation are considered here. For Case 4, it is assumed that the resolution of GSI-189 will be included with the rulemaking effort for 10 CFR 50.44. In Reference 11, the cost estimated for a rulemaking of this type is $500,000. We assume that an additional incremental cost of $150,000 will be added to the rulemaking cost by adding the GSI-189 action. This cost will be equally shared among the 13 units involved in the GSI-189 action, thus yielding a per-unit cost of approximately $12,000.

Since the equipment is not safety-related, no changes to the technical specifications will be necessary. However, changes to the UFSAR and PRA models are expected. NRC review of the UFSAR occurs every two years. Since the change will likely be submitted with the required update, the additional NRC cost should be minimal. Furthermore, since licensees do not typically submit their PRA models to the NRC for review, no additional NRC costs are assumed.

NRC Operation

This attribute measures NRC's incremental costs after the proposed action is implemented. As a result of the proposed action, there will be an increased effort during inspections. This Increase is expected to be small, and not quantified in detail for the purposes of this analysis. An additional inspection cost of about $1,000/year is not unreasonable. Thus, the 2002 cost equivalent is $13,400.

Table 3-13 Summary of Impacts for Case 4

Attribute	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)
Industry Implementation	$1,606,350	$1,606,350	$1,691,600	$1,691,600
Industry Operation	$37,400	$37,400	$37,400	$37,400
NRC Implementation	$12,000	$12,000	$12,000	$12,000
NRC Operation	$13,400	$13,400	$13,400	$13,400
Total for Case 4	$1,669,150	$1,669,150	$1,754,400	$1,754,400

4. Uncertainty

The uncertainty analysis was performed using simulation technique supported by @RISK software [Reference 14]. This software operates in Microsoft Excel environment. The uncertainty in the value of the parameters of the cost model was characterized using a triangular distribution with three points -- minimum, most likely value (the values in Tables 3-2, 3-3 and 3-8 through 3-11) and maximum. The uncertainty analysis accounted for the correlation among the parameters of the cost model.

A summary of the uncertainty assessment is provided in Table 4-1.

Table 4-1 Summary of Uncertainty Assessment

Uncertainties		McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III BWRs (Single-Unit)
Base Case (Case 1)	95th%	$375,000	$387,000	$464,000	$459,000
	mean	$316,000	$329,000	$387,000	$380,000
	5th%	$262,000	$274,000	$315,000	$308,000
Portable Diesel (Case 2)	95th%	$271,000	$282,000	$331,000	$326,000
	mean	$225,000	$237,000	$278,000	$272,000
	5th%	$185,000	$196,000	$230,000	$222,000
Igniters + ARFs (Case 3)	95th%	$715,000	$785,000	$830,000	N/A
	mean	$611,000	$689,000	$738,000	N/A
	5th%	$506,000	$602,000	$652,000	N/A

It is noted that the best-estimate values provided in Tables 3-3, 3-9, and 3-11 are consistently less than the mean values provided in the uncertainty analysis. This is due to the triangular distributions being skewed to higher costs.

Plots of the uncertainty distribution for the four classes of plants for the Base Case and for the two option cases are provided in the Appendix. In addition, the input assumptions are also provided.

5. Results

The best-estimate results are presented in table format below. Note that the "sensitivity" cases reflect changes to the Base Case (Case 1).

Table 5-1 Summary of Results

Case	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)	Industry*
Case 1: Base Case	$263,950	$273,950	$317,700	$312,700	$3,700,100
Sensitivity 1: External Event	$476,450	$506,450	$570,200	$555,200	$6,662,600
Sensitivity 2: Rulemaking	$282,750	$292,750	$336,500	$331,500	$3,944,500

Table 5-1 (Continued)

Case	McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III Plants (Single-Unit)	Industry*
Sensitivity 3: Extended Outage	$363,950	$373,950	$417,700	$412,700	$5,000,100
Case 2: Low Cost Fix	$193,150	$203,150	$236,900	$231,900	$2,729,700
Case 3: Igniters + ARF	$571,750	$621,750	$670,500	NA	$5,344,500
Case 4: PARs	$1,669,150	$1,669,150	$1,754,400	$1,754,400	$22,125,200

* 8 IC units at dual-unit sites, 1 IC unit at single-unit site, and 4 Mark III units at single-unit sites, except for Case 3, where the 4 Mark III units are not included.

It should be noted that the significant figures indicated in the results are retained only to allow for cross-checking and independent verification. When considering uncertainties, one significant figure would be more appropriate. For example, the "Industry" cost for the Base Case (Case 1) is about $4M and the cost approximately doubles to $7M when including external event capability.

- The total industry cost (cost for 13 units) for the Base Case (Case 1) is about $4M
- The cost about doubles to $7M when the backup power supply is qualified for external events
- Including a separate rulemaking only increases the cost (relative to the Base Case) by 8%
- If 8 hours of incremental outage time is assumed, the costs increase by about 35% (again, relative to the Base Case)
- There is virtually no additional cost when changing the real discount rate from 7% to 3%
- The "portable generator" option yields a cost that is about 75% of the Base Case cost.
- The cost for the ice condenser PWRs increases by more than 40% when the powering of an air-return fan is required.
- The cost for PARS is about 6 times higher than backup power under Base Case assumptions.
- The differences in the functional reliability between the pre-staged and the portable generators is not significant for cost benefit applications.
- The mean values for the costs are typically 8% to 25% higher than the corresponding best-estimate (most likely) costs.

6. References

1. "Regulatory Analysis Guidelines of the U.S. NRC," NUREG/BR-0058, Rev. 3, U.S. NRC, July 2000.

2. “Regulatory Analysis Technical Evaluation Handbook,” NUREG/BR-0184, U.S. NRC, January 1997.
3. “Instrumentation for Light-Water-Cooled Nuclear power plants to Assess Plant and Environs Conditions during and following an Accident,” Regulatory Guide 1.97, Revision 3, May 1983.
4. Moieni, P. et al., “A PRA-Based Design Change at SONGs Units 2 & 3: Add Portable Gasoline-Powered Generators for Risk Reduction,” (to be published), International Topical Meeting on Probabilistic Safety Assessment, October 6-9, 2002.
5. Letter from M. S. Tuckman, Duke, to Document Control Desk, USNRC, Subject: Comments on draft plant-specific Supplement 9 to NUREG-1437, “Generic Environmental Impact Statement for License Renewal of Nuclear Power Plants” Catawba Nuclear Station, Docket Nos. 50-413 and 50-414, August 9, 2002. [ML022270455]
6. Note from James H. Wilson, USNRC, to File, Subject: Information Provided by Duke Energy Corporation Related to Severe Accident Mitigation Alternatives in its License Renewal Application for the Catawba Nuclear Station, Units 1 and 2 (TAC Nos. MB2031 and MB2032), March 14, 2002. [ML020740179]
7. Note from Andrew J. Kugler, USNRC, to File, Subject: Information Provided by Virginia Electric and Power Company in Relation to Severe Accident Mitigation Alternatives in its License Renewal Application for the North Anna Power Station, Units 1 and 2 (TAC Nos. MB1994 and MB1995), February 11, 2002. [ML020430372]
8. *Applicant’s Environmental Report - Operating License Renewal Stage, Ft. Calhoun*. Omaha, NE, January 2002.
9. Beal, S.K., et al., “Data Base of System-Average Dose Rates at Nuclear Power Plants,” Final Report, NUREG/CR-5035, October 1987.
10. *Applicant’s Environmental Report - Operating License Renewal Stage, Turkey Point Units 3 & 4*. Florida City, FL, September 2000.
11. “PAR Requirements for PWRs: Value Impact Assessment, Draft,” ISL, Inc. January 2002.
12. VanKuiken, J. C., et al., “Replacement Energy Costs for Nuclear Electricity-Generating Units in the United States: 1997-2001,” NUREG/CR-4012, September 1997.
13. Green, Kim. <kgreen@islinc.com> “Cost Information from Indian Point 2,” 25 January 2002.
14. @Risk 4.5 for PC Excel, Palisade Corporation.

APPENDIX

UNCERTAINTY ANALYSIS

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UNCERTAINTY ANALYSIS

An uncertainty assessment was performed for Case 1 (Base Case); Case 2 (Portable Generator Case) and Case 3 (Igniters plus ARF Case) using Monte Carlo simulation software, @RISK. For each of these three cases, the uncertainty profile was assessed for each of the four classes of plants under study, namely (1) Catawba, McGuire, and D.C. Cook -- six units total; (2) Sequoyah -- two units total; (3) Watts Bar – one single unit; and (4) the four single-unit MARK IIIs. The results are portrayed graphically in Figures A-1 through A-11 and are summarized in Table A-1. In addition, the industry total costs are displayed in Figures A-12 through A-14. The 95th percentile value (95% confidence that the cost is less than the value), the Mean value, and the 5th percentile value (5% confidence that the cost is less than the value) are displayed.

It is noted that the best-estimate values (most likely values) provided in Tables 3-3, 3-9, and 3-11 of the report are consistently less than the mean values provided in the uncertainty analysis. This is due to the triangular distributions, which are employed to characterize uncertainty in cost estimates, being skewed to higher costs.

A summary of the uncertainty assessment is provided in Table A-1.

Table A-1 Summary of Uncertainty Assessment

Uncertainties		McGuire, Catawba, and Cook (per Unit)	Sequoyah (per Unit)	Watts Bar (Single-Unit)	Mark III BWRs (Single-Unit)
Base Case (Case 1)	95th%	$375,000	$387,000	$464,000	$459,000
	mean	$316,000	$329,000	$387,000	$380,000
	5th%	$262,000	$274,000	$315,000	$308,000
Portable Diesel (Case 2)	95th%	$271,000	$282,000	$331,000	$326,000
	mean	$225,000	$237,000	$278,000	$272,000
	5th%	$185,000	$196,000	$230,000	$222,000
Igniters + ARFs (Case 3)	95th%	$715,000	$785,000	$830,000	N/A
	mean	$611,000	$689,000	$738,000	N/A
	5th%	$506,000	$602,000	$652,000	N/A

This software operates in Microsoft Excel environment. The uncertainty in the value of the parameters of the cost model was characterized using a triangular distribution with three points -- minimum, most likely value (the values in Tables 3-2, 3-3, and 3-8 through 3-11 in the report) and maximum. The uncertainty analysis accounted for the dependency among the parameters of the cost model. Tables A-2 through A-4 provide the input data for the analyses.

Table A-2 Input for Uncertainty Analysis: Base Case

Cost Element	Dual Unit ICs (DU)	Sequoyah (SQ)	Watts Bar (WB)	Mark III (M3)
Materials and Equipment				
low	$40,000	$50,000		$45,000
most likely	$50,000	$60,000		$55,000
high	$80,000	$100,000		$90,000
Comments on range (see note below)	range is defined using Duke's data	range is modified for these plants		
Installation				
low	$70,125			
most likely	$82,500			
high	$144,375			
Comments on range	range is defined using Duke's data			
Engineering				
low	$3,000		$5,000	
most likely	$30,000		$50,000	
high	$100,000		$175,000	
Comments on range	range is modified for this type of plants		range is defined using SAMAs data	
Worker Dose (calculated)				
point estimate	$11,220			
Comments on calculation	The above value is calculated using the expression shown below which is defined in terms of four uncertain parameters: (1) Installation cost; (2) dose rate; (3) hourly labor rate; and (4) % exposure			

$$\frac{\text{installation cost}}{\text{hourly rate}} \times \text{dose rate} \times \% \text{ exposure time} \times \$2000$$

Installation cost	Range defined above	hourly labor rate	
		low	$30
		most likely	$40
		high	$50
dose rate (rem)		**% of exposure time**	
low	0.002	low	20%
most likely	0.005	most likely	40%
high	0.01	high	60%

Cost Element	Dual Unit ICs (DU) / Sequoyah (SQ)	Watts Bar (WB) / Mark III (M3)
Emergency Procedures		
low	$20,000	$30,000
most likely	$30,000	$50,000
high	$42,500	$75,000
Comments on range	range is modified for this type of plants	range is defined using SAMAs
Licensing Costs		
low	$3,750	$5,000
most likely	$6,250	$10,000
high	$8,750	$15,000
Comments on range	range is modified for this type of plants	range is defined using staff experience in perfoming 50.59
Industry Operation		
low	$10,000	
most likely	$40,000	
high	$100,000	
Comments on range	range is defined using Duke's data and Dominion SAMA	
NRC Implementation		
low	$10,200	
most likely	$12,000	
high	$21,000	
Comments on range	range is defined based on 50.44 rulemaking	
NRC Operation		
low	$1,700	
most likely	$2,000	
high	$3,500	
Comments on range	range reflects uncertainty in the cost for increase in inspection accounting for 40 years of remaining life	

Note: the uncertainty in the value of the parameters of the cost model was characterized using a triangular distribution with three points -- low, most likely value and high.

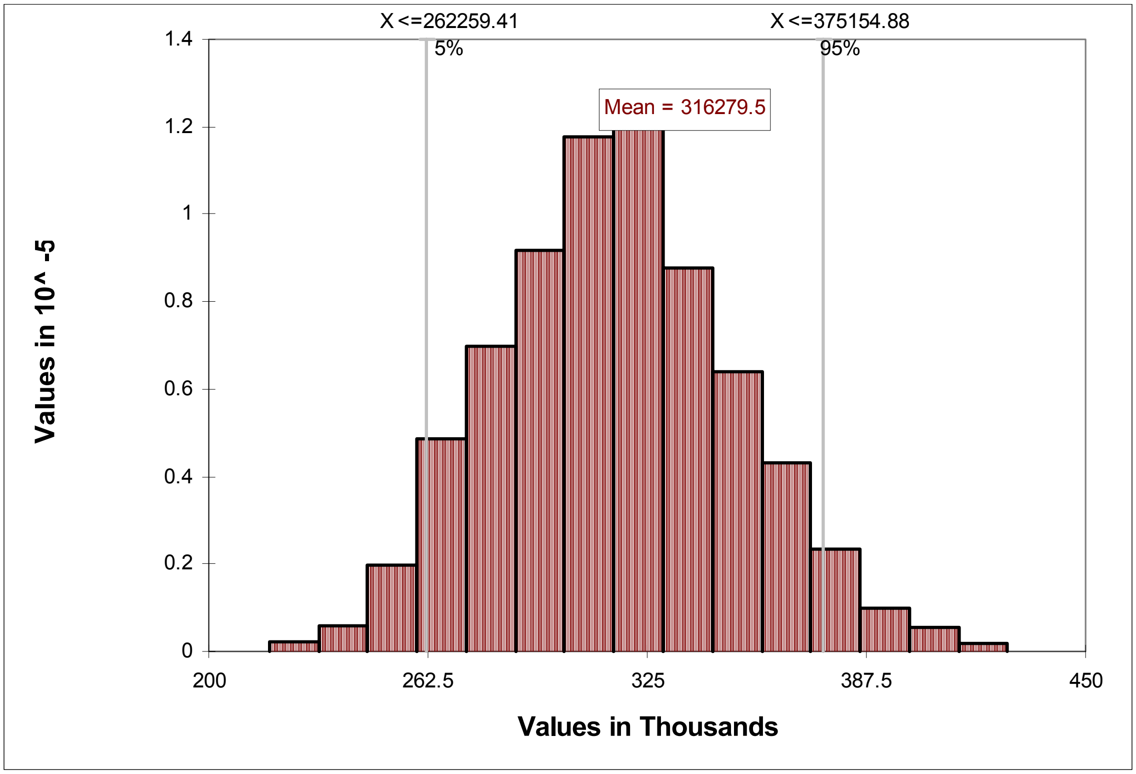

Figure A-1 Distribution for Total Cost for McGuire, Catawba, and Cook (per unit): Base Case (Pre-Staged)

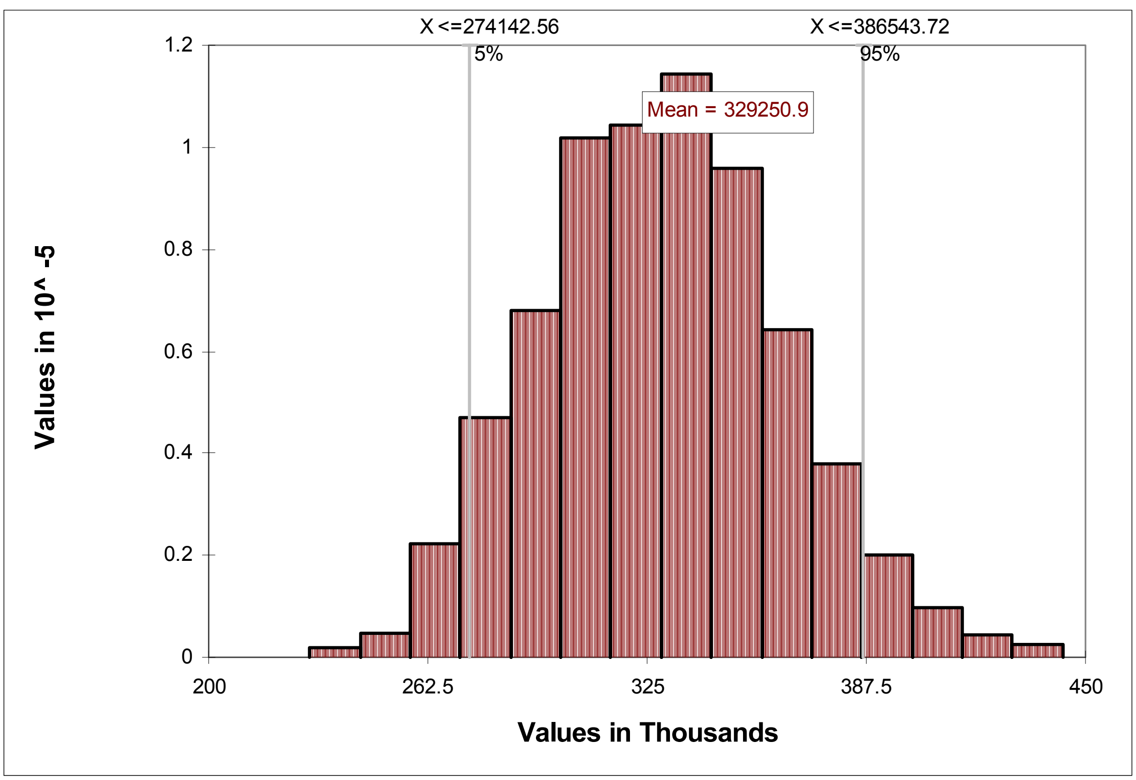

Figure A-2 Distribution for Total Cost for Sequoyah (per unit): Base Case (Pre-Staged)

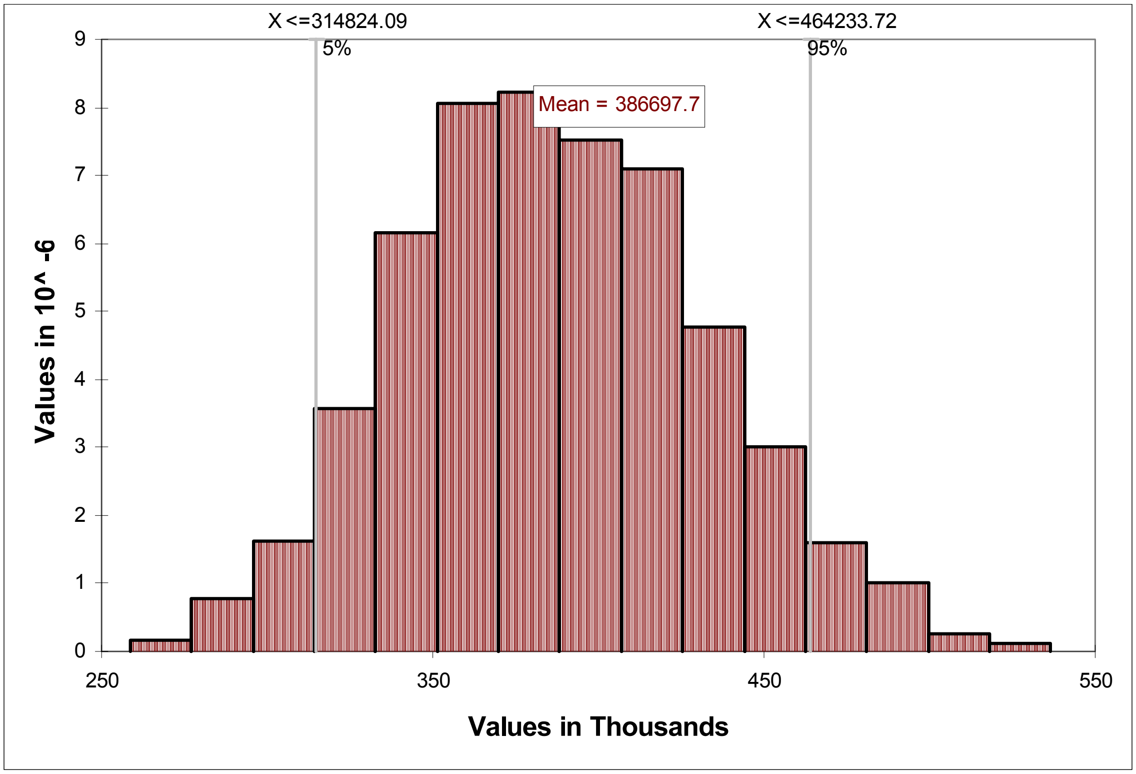

Figure A-3 Distribution for Total Cost for Watts Bar: Base Case (Pre-Staged)

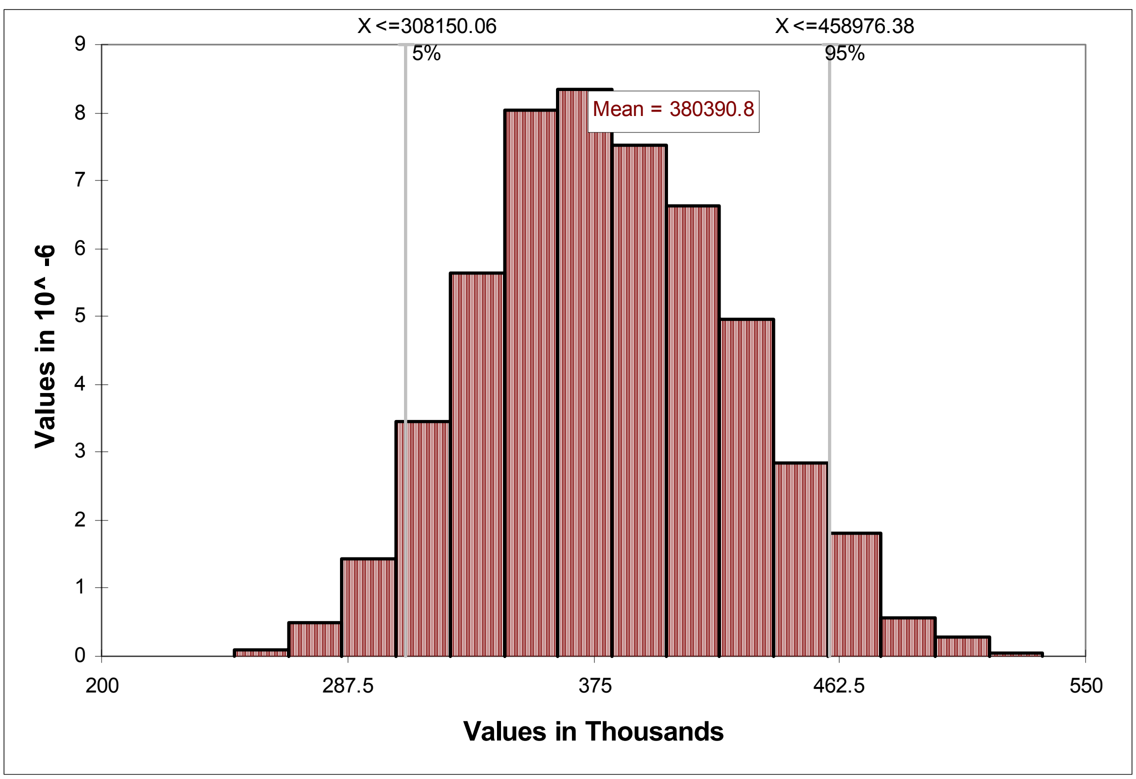

Figure A-4 Distribution for Total Cost for Mark IIIs: Base Case (Pre-Staged)

Table A-3 Input for Uncertainty Analysis: Case 2 (Portable Diesel)

Cost Element	Dual Unit ICs (DU)	Sequoyah (SQ)	Watts Bar (WB)	Mark III (M3)
Materials and Equipment				
low	$10,000	$25,000		$17,500
most likely	$25,000	$35,000		$30,000
high	$40,000	$50,000		$45,000
Comments on range (see note below)	range is defined using Duke's data	range is modified for these plants		
Installation				
low	$42,075			
most likely	$49,500			
high	$86,625			
Comments on range	range is defined using Duke's data			
Engineering				
low	$3,000		$5,000	
most likely	$20,000		$30,000	
high	$62,500		$100,000	
Comments on range	range is modified for this type of plants		range is defined using SAMAs data	
Worker Dose (calculated)				
point estimate	$8,415			
Comments on calculation	The above value is calculated using the expression shown below which is defined in terms of four uncertain parameters: (1) Installation cost; (2) dose rate; (3) hourly labor rate; and (4) % exposure $\frac{\text{installation cost}}{\text{hourly rate}} \times \text{dose rate} \times \%\ \text{exposure time} \times \$2000$			
	Installation cost	Range defined above	**hourly labor rate**	
			low	$30
			most likely	$40
			high	$50
	dose rate (rem)		**% of exposure time**	
	low	0.002	low	30%
	most likely	0.005	most likely	50%
	high	0.01	high	70%
Emergency Procedures				
low	$20,000		$30,000	
most likely	$30,000		$50,000	
high	$42,500		$75,000	
Comments on range	range is modified for this type of plants		range is defined using SAMAs	
Licensing Costs				
low	$3,750		$5,000	
most likely	$6,250		$10,000	
high	$8,750		$15,000	
Comments on range	range is modified for this type of plants		range is defined using staff experience in perfoming 50.59	
Industry Operation				
low	$10,000			
most likely	$40,000			
high	$100,000			
Comments on range	range is defined using Duke's data and Dominion SAMA			
NRC Implementation				
low	$10,200			
most likely	$12,000			
high	$21,000			
Comments on range	range is defined based on 50.44 rulemaking			
NRC Operation				
low	$1,700			
most likely	$2,000			
high	$3,500			
Comments on range	range reflects uncertainty in the cost for increase in inspection accounting for 40 years of remaining life			

Note: the uncertainty in the value of the parameters of the cost model was characterized using a triangular distribution with three points -- low, most likely value and high.

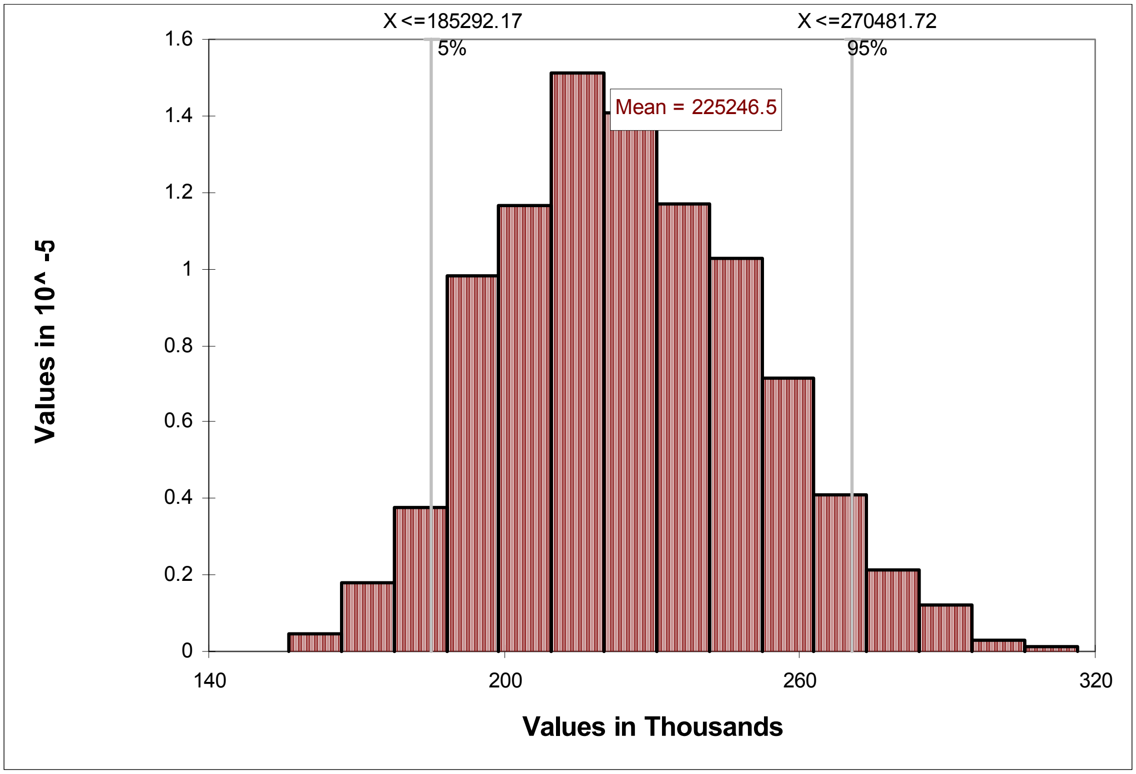

Figure A-5 Distribution for Total Cost for McGuire, Catawba, and Cook (per unit): Case 2 (Portable Diesel)

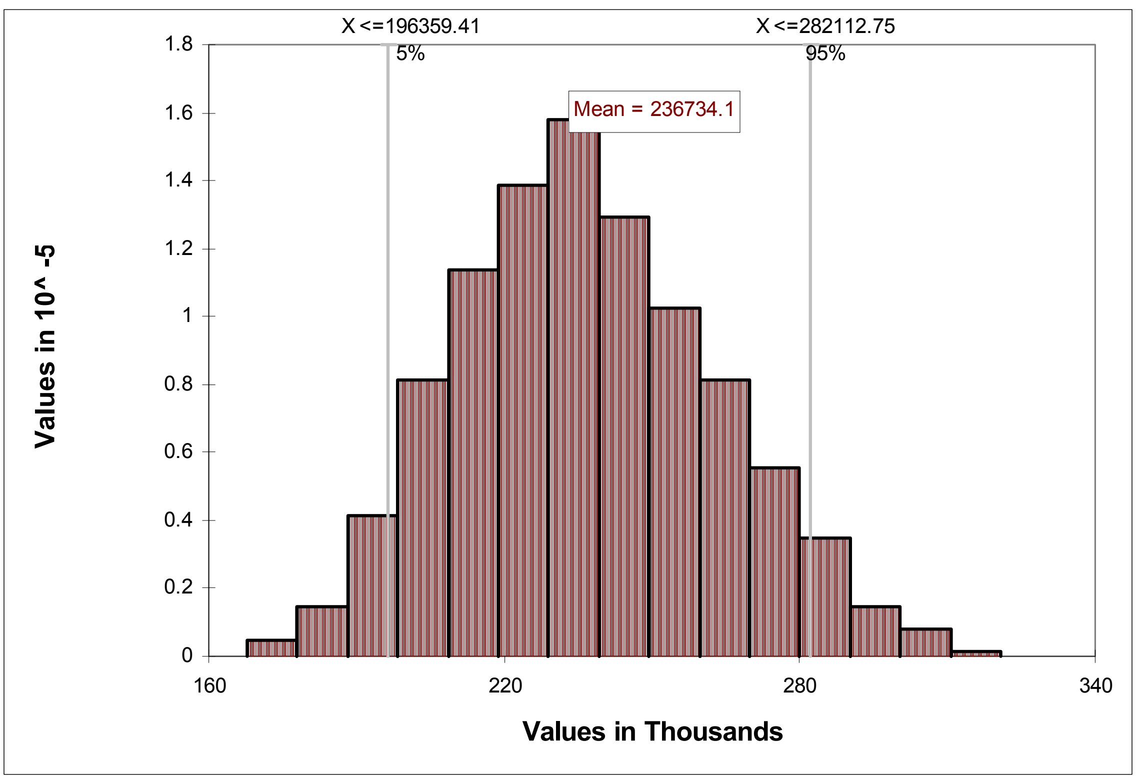

Figure A-6 Distribution for Total Cost for Sequoyah (per unit): Case 2 (Portable Diesel)

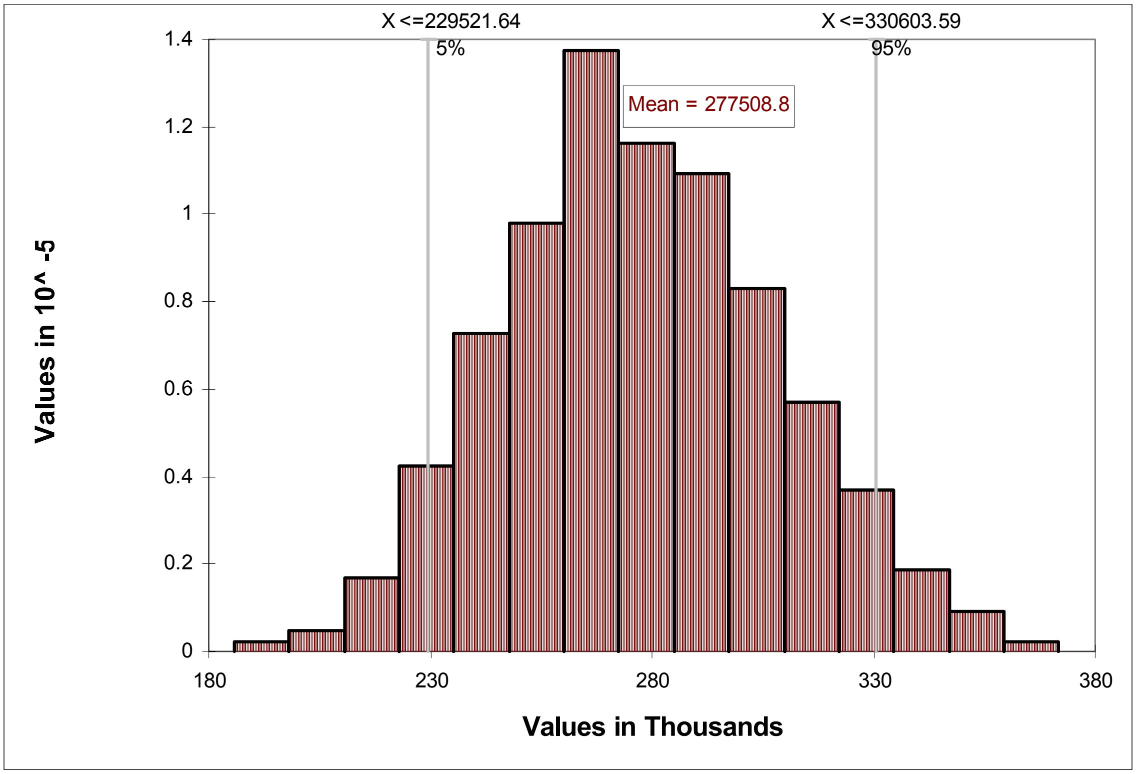

Figure A-7 Distribution for Total Cost for Watts Bar: Case 2 (Portable Diesel)

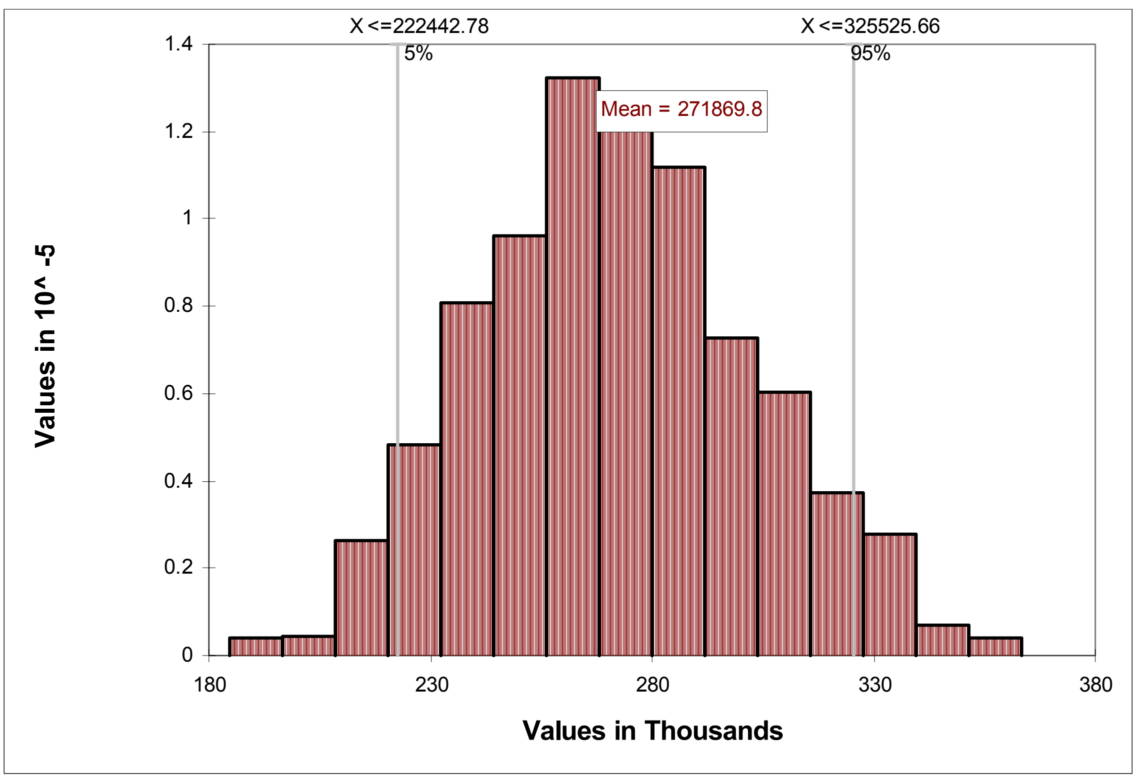

Figure A-8 Distribution for Total Cost for Mark IIIs: Case 2 (Portable Diesel)

Table A-4 Input for Uncertainty Analysis: Case 3 (Igniters plus Air Return Fan)

Cost Element	Dual Unit ICs (DU)	Sequoyah (SQ)	Watts Bar (WB)	Mark III (M3)
Materials and Equipment				
low	$80,000	$212,000		NA
most likely	$212,000	$262,000		NA
high	$300,000	$350,000		NA
Comments on range (see note below)	range is defined using Duke's data	range is modified for these plants		
Installation				
low	$153,000			
most likely	$180,000			
high	$315,000			
Comments on range	range is defined using Duke's data			
Engineering				
low	$20,000		$45,000	
most likely	$50,000		$75,000	
high	$100,000		$125,000	
Comments on range	range is defined using Duke data		range is modified for this type of plants	
Worker Dose (calculated)				
point estimate	$24,480			
Comments on calculation	The above value is calculated using the expression shown below which is defined in terms of four uncertain parameters: (1) Installation cost; (2) dose rate; (3) hourly labor rate; and (4) % exposure			
	$\frac{\text{installation cost}}{\text{hourly rate}} \times \text{dose rate} \times \%\ \text{exposure time} \times \$2000$			
	Installation cost	Range defined above	**hourly labor rate**	
			low	$30
			most likely	$40
			high	$50
	dose rate (rem)		**% of exposure time**	
	low	0.002	low	20%
	most likely	0.005	most likely	40%
	high	0.01	high	60%
Emergency Procedures				
low	$20,000		$30,000	
most likely	$30,000		$50,000	
high	$42,500		$75,000	
Comments on range	range is modified for this type of plants		range is defined using SAMAs	
Licensing Costs				
low	$3,750		$5,000	
most likely	$6,250		$10,000	
high	$8,750		$15,000	
Comments on range	range is modified for this type of plants		range is defined using staff experience in perfoming 50.59	
Industry Operation				
low	$20,000			
most likely	$50,000			
high	$100,000			
Comments on range	range is defined using Duke's data and Dominion SAMA			
NRC Implementation				
low	$14,450			
most likely	$17,000			
high	$29,750			
Comments on range	range is defined based on 50.44 rulemaking			
NRC Operation				
low	$1,700			
most likely	$2,000			
high	$3,500			
Comments on range	range reflects uncertainty in the cost for increase in inspection accounting for 40 years of remaining life			

Note: the uncertainty in the value of the parameters of the cost model was characterized using a triangular distribution with three points -- low, most likely value and high.

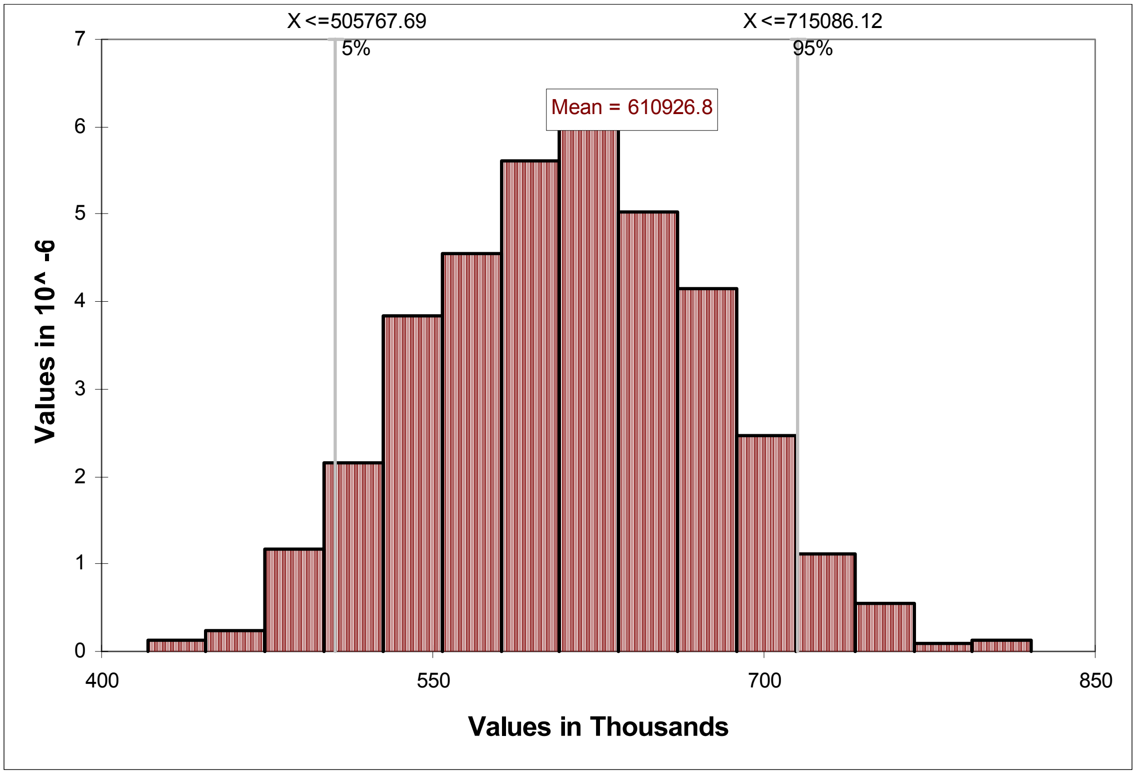

Figure A-9 Distribution for Total Cost for McGuire, Catawba, and Cook (per unit): Case 3 (Igniters and ARF)

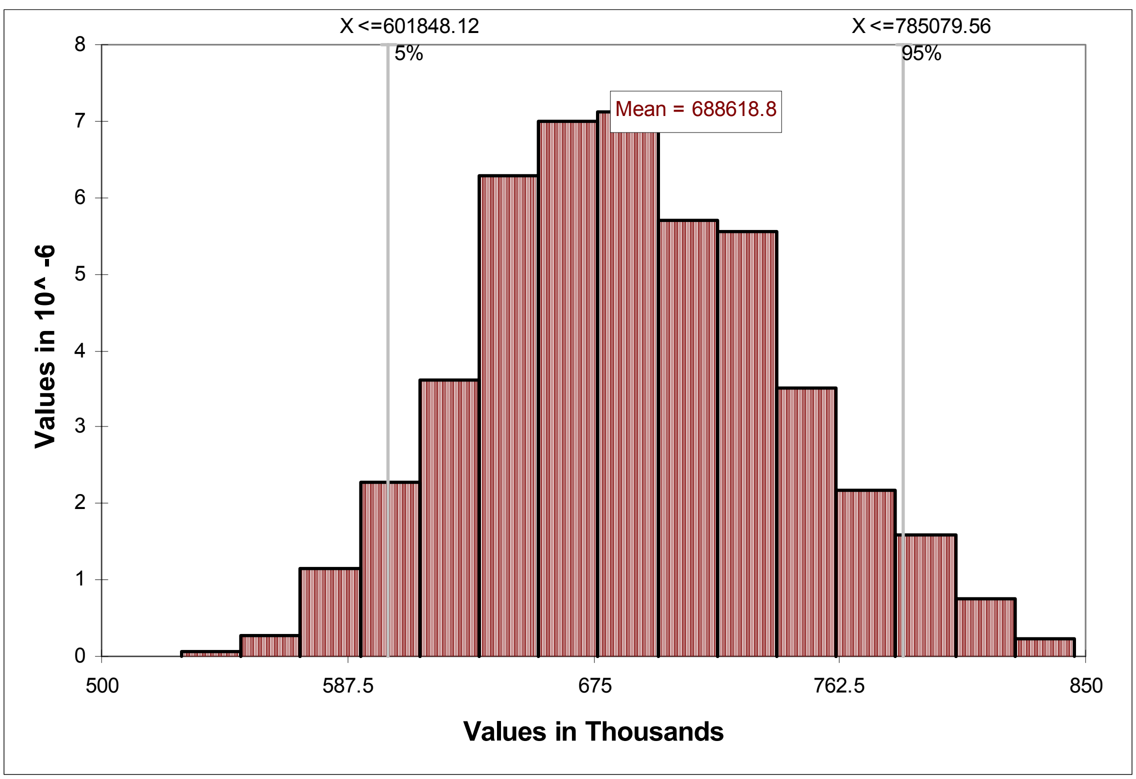

Figure A-10 (Distribution for Total Cost for Sequoyah (per unit): Case 3 (Igniters and ARF)

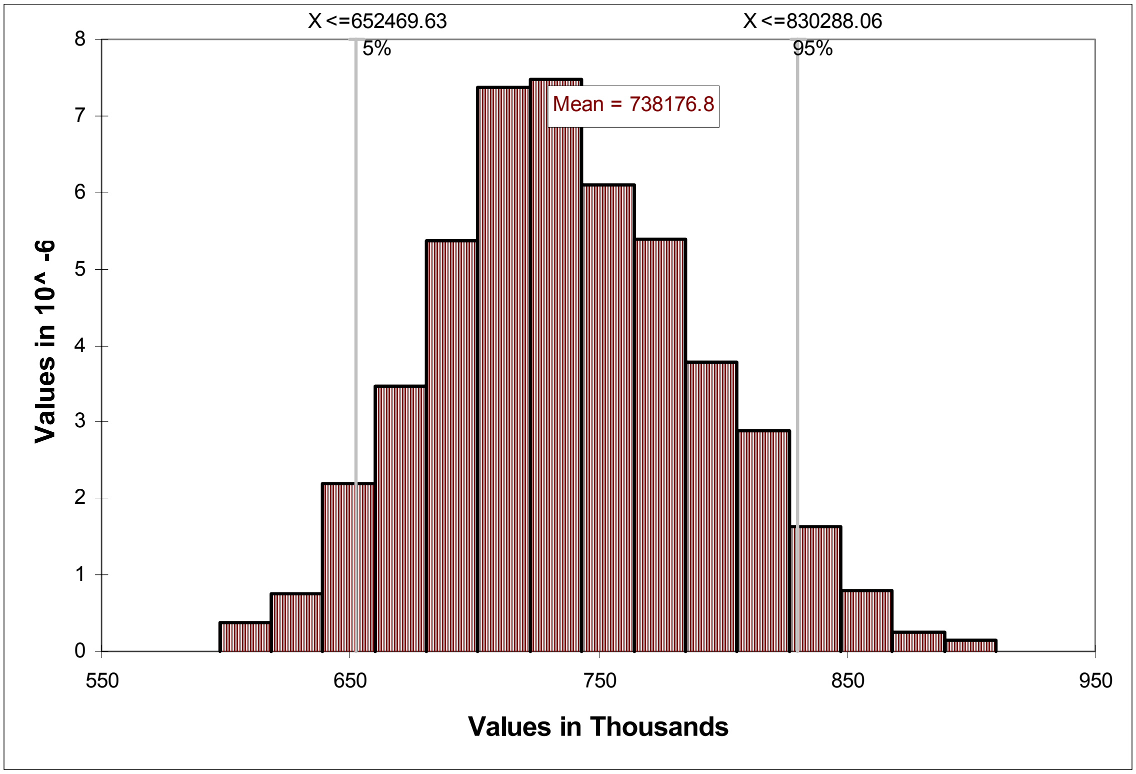

Figure A-11 Distribution for Total Cost for Watts Bar: Case 3 (Igniters and ARF)

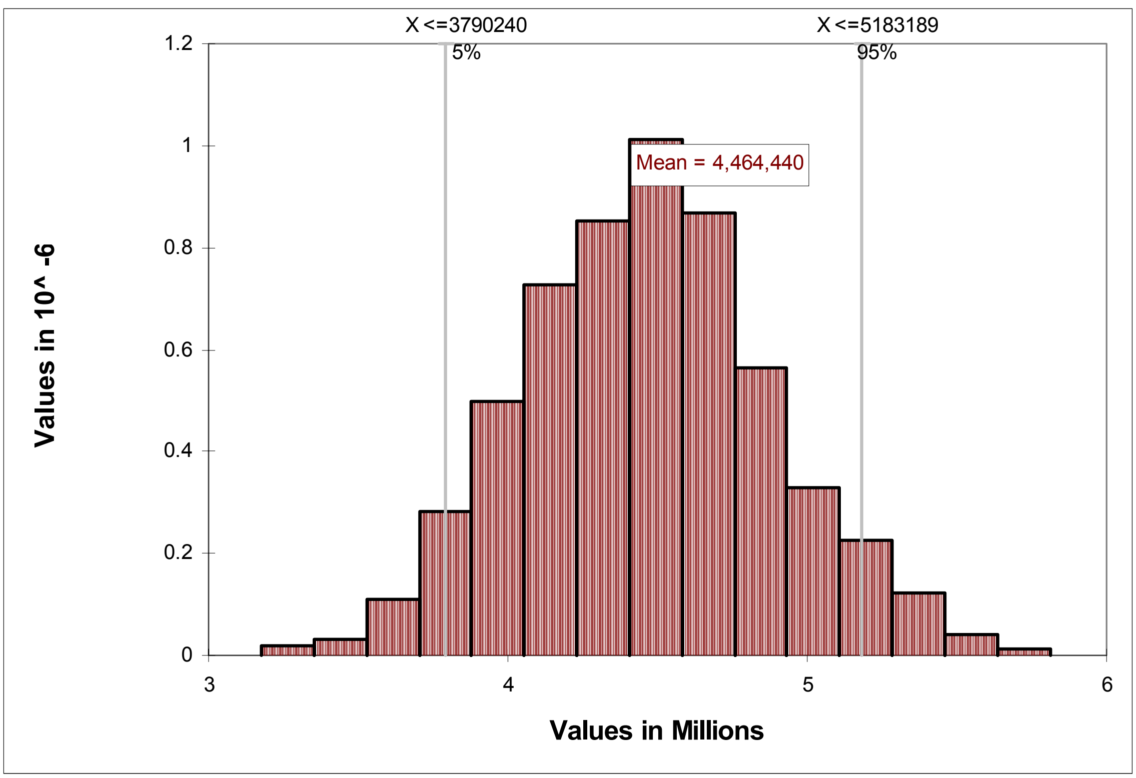

Figure A-12 Distribution for Total Cost for the Industry: Base Case (Pre-Staged)

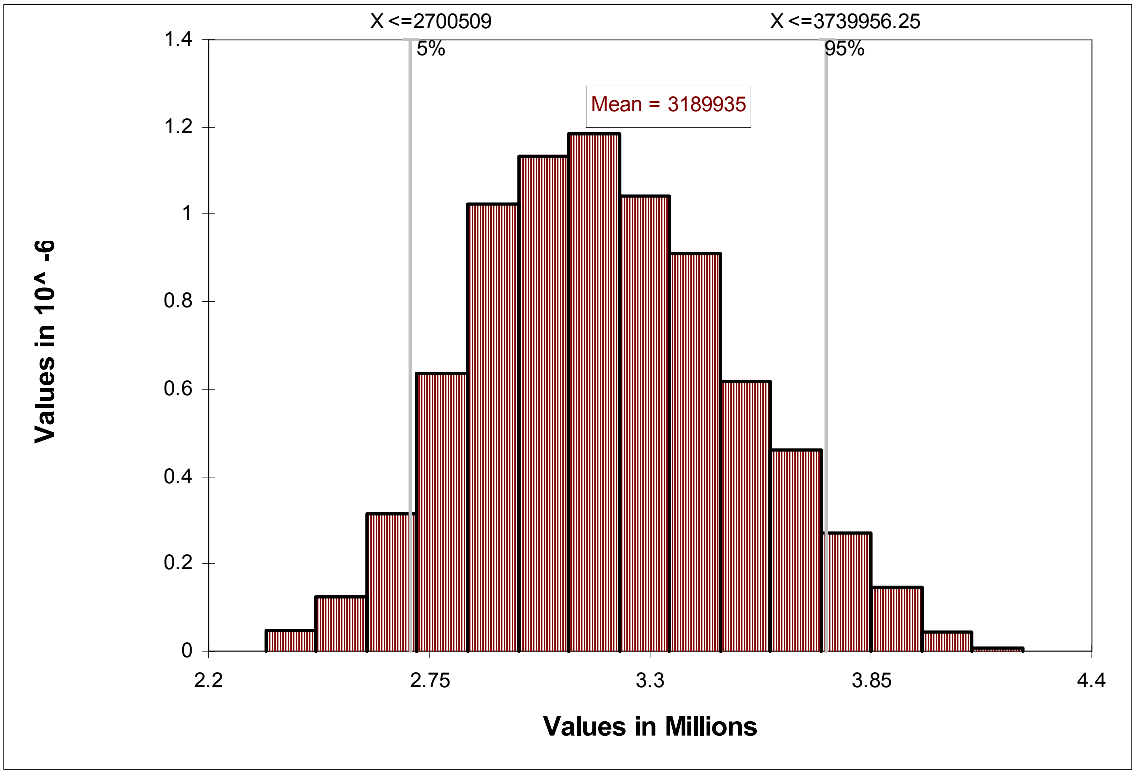

Figure A-13 Distribution for Industry/Total Cost for the Industry: Case 2 (Portable Diesel)

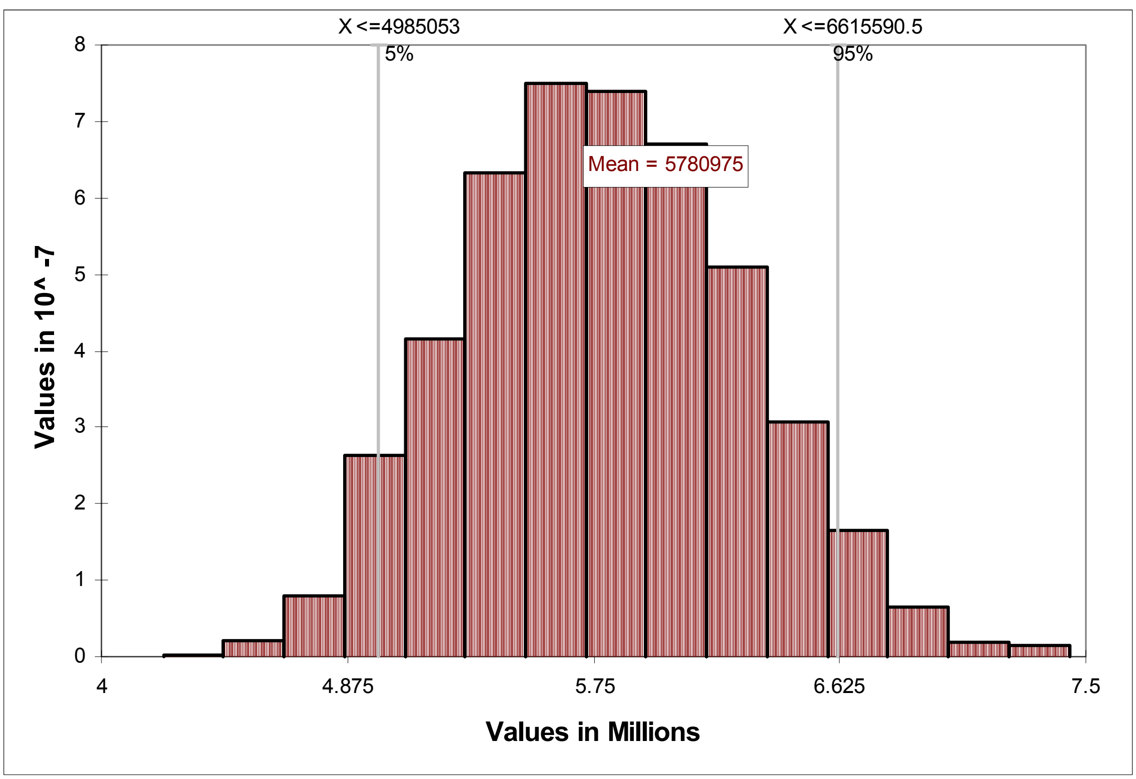

Figure A-14 Distribution for IC Industry/Total Cost for the Industry: Case 3 (Igniters and ARF)