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COMMENTS ON COST ESTIMATES IN THE REGULATORY ANALYSIS SUPPORTING THE PROPOSED STATION BLACKOUT RULE

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1. SUMMARY

This report reviews the basis for cost estimates provided in the regulatory analysis supporting the Nuclear Regulatory Commission's (NRC) proposed station blackout rule, "Regulatory Analysis of Unresolved Safety Issue A-44, Station Blackout," NUREG-1109. This review concentrates on the estimates contained in "Cost Analysis for Potential Modifications to Enhance the Ability of a Nuclear Plant to Endure Station Blackout," NUREG/CR-3840, published in July 1984.

Important findings resulting from this review are:

A. The design upon which the regulatory analysis cost estimate was based is not the product of an extensive, detailed coping analysis which the proposed rule and corresponding regulatory guides require. If the design had been so based the regulatory analysis' cost estimate would have been significantly higher.

B. Traditional cost estimating methodologies and nuclear construction cost data were not used in preparing the regulatory analysis. Had they been used, a significant increase in the cost estimate for the given designs would have resulted.

C. Significant deficiencies exist in the NUREG/CR-3840 methodology and calculations which underestimate the costs of implementing individual backfit options by factors of up to twenty. These deficiencies include arithmetic mistakes, use of inappropriate productivity factors, and the absence of certain indirect costs.

D. If the regulatory analysis made use of available and realistic cost data, the total cost impact of the proposed regulation would be over 200% higher than that indicated.

Based on the above findings it can be concluded that the regulatory analysis cost estimates are so understated as to call into question the validity of any conclusions made using these cost estimates.

2. GENERAL COMMENTS ON THE SCOPE, METHODS, AND ACCURACY OF THE REGULATORY ANALYSIS COST ESTIMATE

This review approached the cost analysis from the following perspectives:

(1) the maturity of the design upon which the cost estimate was performed;

(2) the cost estimating methodology and data source for materials and labor costs;

(3) the accuracy of the cost estimate in the regulatory analysis; and,

(4) the application of the cost estimates to the regulatory analysis.

During this review, several general comments were identified and are summarized in this section. These comments are contextual and establish a framework within which the cost analysis should be viewed.

Overall Validity

Historically, regulatory analyses underestimate the final cost of backfits. This review did not encounter evidence that the cost analysis for station blackout significantly departs from this pattern. It was found, for example, that the analysis significantly underestimates both labor and material costs in assessing the impact of station blackout modifications. Further, no contingency is provided for the costs of the inevitable criteria evolution and reinterpretations which occur after backfits are imposed. Correcting the underestimate for identifiable deficiencies and including the contingencies would considerably improve the validity of the estimated backfit costs.

Proposed Modifications Do Not Meet Requirements of the New Design Basis

The proposed station blackout rule contemplates changes to the design basis of nuclear power plants based on a coping analysis which all licensees must perform. The draft regulatory guide accompanying the notice of rulemaking defines the scope of the coping analysis and directs licensees to consider plant conditions which may emerge both during a station blackout and in the subsequent recovery period when AC power is restored. The minimum coping duration will be determined by the NRC following a review of the licensee's coping analysis. Although the draft regulatory guide discusses a 4 and 8-hour minimum required coping duration, it is possible that shorter periods would be acceptable.

A major segment of the new design basis coping requirement affects the instrumentation and control function supporting systems, such as heating, ventilation, and air conditioning (HVAC). These impacts represent a significant portion of the modifications that must be made to satisfy the design basis coping requirement. The problem with the NUREG/CR-3840 analysis is that it does not recognize the potential for modifications to these systems in any of the four basic options for which cost estimates are provided. Consequently, a significant basis for the cost estimate (i.e., the list of backfit modifications from which a cost estimate is derived) is missing.

Major Conclusion Conflicts With Actual Cost Data

The NUREG/CR-3840 methodology conflicts with two reliable sources of nuclear plant construction data: (1) "Handbook for Cost Estimating", NUREG/CR-3971 (Ball[1984]), and (2) the Energy Economic Data Base. NUREG/CR-3971 has a goal "... to provide a consistent methodology and constant set of assumptions to assist the NRC user in preparing absolute as well as comparative cost estimates of generic requirements for light-water-reactor nuclear power." (1) Although available at the time the regulatory analysis was performed, this methodology was not used in preparing NUREG/CR-3840. Moreover, certain productivity and other major assumptions found in NUREG/CR-3840 conflict with the "rules of thumb" found in this handbook and lead to sytematic underestimates. This point is discussed further in Sections 4 and 5 of this review.

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(1) page ix, NUREG/CR-3971

In addition to NUREG/CR-3971, another source of cost information readily available at the time the cost analysis was prepared is the EEDB,published by the Department of Energy. This program has been ongoing for at least 20 years and provides reliable cost data for newly constructed power plants, notes the existence of cost trends, and provides a methodology for use in estimating new nuclear construction costs. Again a key NUREG/CR-3840 finding - that hardware costs tend to dominate the cost estimate for the postulated station blackout backfit - directly conflicts with the established EEDB data. This point will also be discussed at greater length in Section 4.

Estimate Not Based On Engineering Data

Another serious difficulty encountered in this review was the lack of important details in the cost estimate. Specifically, while the backfit options are outlined and a detailed bill of materials is provided in NUREG/CR - 3840, no engineering and construction cost information is provided. This information is essential to developing a complete cost estimate. A partial listing of the necessary information missing from NUREG/CR-3840 includes:

(1) DESIGN STANDARDS USED - needed to determine quality assurance and equipment qualification requirements;

(2) SYSTEM SPECIFICATIONS - needed to determine quality assurance and equipment qualification requirements;

(3) PIPING AND CONDUIT ROUTING DIAGRAMS - needed to identify construction conflicts and task sequencing;

(4) DESCRIPTIONS OF OPERATING FEATURES - provides a means for checking the design adequacy;

(5) SUPPORT SYSTEM REQUIREMENTS - needed to identify other modifications necessary;

(6) SURVEILLANCE FEATURES - provides a means for determining design completeness; and,

(7) PLANT TECHNICAL SPECIFICATION REQUIREMENTS - essential for operability considerations.

The practical impact of this missing information becomes evident in the undue importance placed on equipment costs in the NUREG/CR-3840 analysis. Without a detailed engineering design to consider, it is not possible to accurately estimate the removal or relocation costs for existing plant equipment, a significant portion of a backfit project. The focus on the bill of materials also overlooks modifications required to meet existing regulatory standards, such as qualifying plant equipment to blackout conditions as is discussed in the draft regulatory guide.

Another example of oversights created by not considering detailed engineering design is the cost of additional instrumentation and control capability used during the postulated blackout or to properly restore AC power. Such costs can be extensive. For example, simply automating the initiation of auxiliary feedwater flow at Millstone 2 and providing the necessary indication, a TMI Action Plan item not requiring any new pumps or large valves, cost over $700,000 to install. (Counsil [1981]) This single alteration to existing control circuitry is almost twice the cost estimated in NUREG/CR-3840 for the entire set of blackout modifications.

NUREG/CR-3840 Methodology is Inconsistent and Inaccurate

NUREG/CR-3840 acknowledges that the work necessary to develop the proposed backfits and prepare the cost estimates was performed in a very short period of time (approximately two months). Consequently, it should not be surprising that there are a significant number of problems due to the limited time available to do the cost study. A partial list of the problems identified in this review includes:

(1) use of low unit costs for nuclear construction;

(2) misquotes of cost data from the report's own references;

(3) arithmetic errors;

(4) unrealistically low material costs assumed for nonstandard materials;

(5) inconsistent treatment of labor and material rates without explanation; and;

(6) no inclusion of the cost of capital.

The NUREG/CR-3840 analysis also employs a significant number of productivity assumptions which are either unsubstantiated or are contradicted by actual nuclear plant construction data.

Staff Costs Associated With Implementing a Station Blackout Rule are Low

Certain costs presented in NUREG/CR-3840 analysis which are not attributable to hardware costs appear to have been underestimated. For example, the analysis indicates that the NRC's costs for reviewing a licensee's coping analysis and proposed plant modifications is only $7,000 per plant. This estimate is substantially less than that required to review the design of a Technical Support Center (TSC) and issue a safety evaluation report (SER). For example, an estimate of the TSC NRC Staff review costs provided in NUREG/CR-3971 (functions 35-38) is $93,800 per site. Assuming that the cost per Staff manhour has not changed, then the cost of reviewing plant-wide modifications required to comply with a 4 or 8-hour station blackout design basis coping requirement is only 7.5% of that required to review a TSC design. The apparent differences in Staff workscope require clarification.

Effects of Low Cost Estimate for Performing a Coping Analysis

The proposed station blackout rule may require some licensees to modify their facilities. The total regulatory analysis cost estimate is a function of the number of facilities requiring modifications. However , all plants are required to perform a coping analysis. Hence, any deficiencies in the cost estimate for performing a coping analysis bears a one-to-one correspondence to a deficiency in the total regulatory analysis cost estimate. The draft regulatory guide accompanying the proposed rule provides some guidance as to the scope of the coping analysis. However, it does not provide sufficient detail to be able to provide a cost estimate for performing a coping analysis. NUREG-1109 estimates the cost of performing a "coping analysis" to be in the range of $100,000 to $200,000. In contrast, industry estimates for such an analysis range from $500,000 to $2,000,000. The industry estimates are based on a scope of coping analysis described in ANS-STD-58.12 and on previous experience where station blackout was considered as a part of a license application. The importance of these costs is significant. For example, a six-fold increase in the cost of a coping analysis to $750,000 raises the regulatory analysis cost estimate by over $40 million.

Additional Considerations

The proposed resolution described in the report places heavy reliance on reactor coolant pump (RCP) seal cooling proposal which is based on installing a new AC-independent charging pump. This proposal is directed at mitigating the effects of postulated seal failure due to loss of cooling in a station blackout. Although seal failure is important to station blackout risk resolution, resclution of this concern is in the advanced stage in the Generic Issue (GI) 23 task action plan. However, the GI-23 approach concentrates on improving the seal design and does not involve a new pump. Further, recent tests have shown that RCP seals do not fail in a manner requiring extensive makeup capability. In any event, at the time NUREG/CR-3840 was prepared, a new charging pump was considered "preliminary" within the Generic Issue 23 task action plan. The only conclusion that can be drawn at this point is that the proposed resolutions discussed in NUREG/CR-3840 may no longer be necessary.

3. COMMENTS ON THE UNDERLYING ASSUMPTIONS OF THE PROPOSED DESIGN SOLUTION'S COST ESTIMATE

NUREG/CR-3840 considers four types of modifications designed to mitigate the effects of a station blackout. These modifications seek to enhance the operability of AC-independent equipment in a station blackout. The enhancements include:

(1) increasing battery capacity;

(2) providing an AC-independent RCP seal injection capability;

(3) increasing condensate storage tank (CST) capacity; and,

(4) increasing instrument air system supply.

The NUREG/CR-3840 analysis determines the backfit costs of imposing each of these four modifications on two base case reactors (Arkansas Nuclear One, Unit 1, and Quad Cities, Unit 1). Six explicit assumptions are also used in performing this analysis which are the subject of this section's review. These NUREG/CR-3840 assumptions are summarized below:

(1) Modifications During Shutdown - Modifications will be made during normal plant operation or during scheduled shutdowns such that no replacement power cost will be incurred;

(2) ALARA - Occupational radiological exposure during installation and subsequent operation and maintenance of the added equipment will be minimal or zero and are not included as an increment of cost;

(3) Socio-Economic Costs - Socio-economic impacts are considered as being minimal and, therefore, are not included as an increment of cost;

(4) Seismic Qualification - All new equipment, structures, etc., needed to implement the proposed modifications will not be designed to meet seismic requirements;

(5) Equipment Qualification - All new equipment and components installed outside containment will not require harsh environmental equipment qualification;

(6) Quality Assurance - To ensure reliability, all electrical components and

equipment will be assumed to meet Class 1E requirements (other than seismic) and quality assurance requirements normally afforded safety grade components; and,

(7) No Cost of Capital - No interest for the cost of capital during the period between initiation of design studies and incorporation of the capital improvements in the rate base is included in this estimate.

Additional Costs of Implementation (Modification During Shutdown)

The assumption of no replacement power costs due to these backfits does not have substantial basis and is not accurate. The apparent motivation for neglecting these costs is that it simplifies the economic analysis. However, this assumption cannot be justified if replacement power costs are both significant and likely to occur in the course of installing station blackout equipment.

As further evidence of the magnitude of replacement power costs it can be readily shown from experience that power plant outage frequency durations have grown significantly in recent years due to regulatory change. While some of the growth is certainly attributable to equipment refurbishment and replacement, activities not directly caused by regulatory interventions (e.g., recirculation pipe replacements in BWRs and steam generator overhauls in PWRs), it is also clear that a significant portion of this growth is the result of plant backfits. Komanoff[1981] makes the argument that this phenomenon is likely to continue, given the Commission's policy of backfitting new requirements in response to the identification of new licensing issues. Using the TMI Action Plan as a model, Komanoff's argument is as follows:

> Most reactors have sustained only brief (one to four week) shutdowns or outage extensions since TMI for minor equipment modifications, but NRC has committed itself in its post-TMI Action Plan to weigh major plant changes involving instrumentation, containment, and heat-removal systems... . TMI also takes some credit for NRC's recent establishment of compliance schedules for equipment installation (with attendant outages) to address long standing safety issues such as environmental qualification of electrical equipment and fire protection. In addition, the accident has directed NRC's attention away from reactor *licensing* toward reactor *operations* ... , making it less likely that licensees will be able to operate plants with equipment problems or shorten maintenance and repair outages (Komanoff [1981], page 252).

These replacement impacts can be translated into significant replacement power costs as analysis performed by W.A. Buehring and J.P. Peerenboom [1982] at Argonne National Laboratory demonstrates. Buehring and Peerenboom argue that three types of consequences are likely to result from unplanned outages or scheduled outage extensions caused by regulatory interventions:

(1) increased costs of system generation;

(2) increased demand for fossil fuels; and,

(3) reduced electrical system reliability.

To illustrate this point, six cases were examined involving shutdowns of various reactor types and geographical locations(3). The results show that undiscounted production costs increase significantly with reactor shutdown, yielding normalized increases ranging from $0.125 million/Mwe - yr to $0.33 million/Mwe-yr in the first year of outage(4). By way of example, for a nominal 700 Mwe unit in shutdown for 4 months to implement a backfit, these costs translate to between $29 million and $77 million in additional undisclosed production costs.

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(3) The plants examined were Zion, Oconee, Prairie Island, Browns Ferry, Indian Point, and Three Mile Island. The latter two analyses were based on work independently performed by the General Accounting Office.

(4) In this context, production costs conform with the accounting requirements of the Fuel, Operation and Maintenance Accounts of the Federal Energy Regulatory Commission Uniform System of Accounts.

Buehring and Peerenboom also noted sensitivities to fuel mix, load growth, and seasonal variations. In worst case situations affecting grid reliability, economic losses due to unserved energy were comparable to or greater than anticipated production cost increases. At the bottom line, their conclusions directly contradict the assumptions of NUREG/CR-3840:

> The loss of benefits that result from nuclear plant shutdowns, whether temporary or permanent, are potentially significant and warrant consideration in the regulatory decision making process. (Buehring and Peerenboom [1981], page 133.) (Emphasis added)

The magnitude of these costs can be easily estimated. Van Kuiken, *et al*, reviewed FERC data to determine the time for planned outages to cover refueling, maintenance, and repair. Their analysis concluded 76 days per year was the typical planned outage duration. Since straight refueling outage time (i.e., the time to cool down, shuffle fuel and heat up) is typically eight weeks (56 days), then the typical plant is spending an additional 20 days per year on maintenance and modification. A significant fraction of these 20 days are clearly associated with changing regulatory requirements.

The above studies all point to the conclusion that any backfit will contribute some amount of time to the annual outage duration. This contribution is due to resource, craft density and operational constraints which require the work to be performed during the planned outage or as a result of work displaced into the outage from when the plant was in normal power operation. Any amount of time yields significant costs which are excluded from the NUREG/CR-3840 analysis.

ALARA Considerations

The NUREG/CR-3840 assumption that radiological exposure need not be considered in estimating backfit costs conflicts with normal regulatory practice and ignores plant experience. In fact, guidelines provided several years ago by the NRC's Executive Director of Operations specify radiological safety consequences as a cost to be considered in backfit decision making (Dircks [1982]). This guidance also directs the Staff to include occupational exposure during plant installation, operation, and maintenance as part of the estimated consequences of the proposed backfit. The NUREG/CR-3840 assumptions violate these guidelines.

Until recently, the industry experienced a significant growth in worker exposure contemporaneous with the increasing rate of change in regulatory requirements. This growth has peaked and declined somewhat in recent years. The trends are significant to support a correlation between radiological exposure and the imposition of new regulatory requirements. Power plant experience further indicates that contractor personnel dominated the upward trend in occupational doses, constituting approximately 70% of the total dose received in the past (Silver and Mays [1983]). These workers are generally employed in support of refueling, special maintenance, and modification installation. In particular, Brooks [1983] notes a consistent pattern from 1975 to 1982 in the allocation of dose to maintenance and inspection, constituting approximately 75-80% of the total dose received. In 1982 alone, the total annual collective dose represented 52,190 man-rem for 74 reactors. The maintenance and surveillance portion in that year was 81.2% of the total or over 42,000 man-rem. This data underscores the magnitude of the ALARA concerns and its importance in the regulatory analysis. NUREG/CR-3840 should reflect this consideration in its analysis.

Seismic Qualification

The NUREG/CR-3840 analysis excludes station blackout mitigation equipment from seismic qualification requirements. While designed to reduce the impact of station blackout modifications, the problem with this assumption is that it also conflicts with the apparent direction being pursued by the Staff within the seismic qualification task action plan (USI A-46). The resolution of USI A-46 is expected to result in new qualification guidelines affecting equipment required for safe shutdown as well as equipment whose failure could result in adverse conditions which might impair shutdown functions. At the time NUREG/CR-3840 was prepared, this new guidance was under consideration by CRGR and should have been factored into the cost estimate.

Presently, it is not clear how station blackout can be made a design basis accident without also imposing seismic qualification requirements on coping equipment. Even if station blackout mitigation equipment can be excluded from qualification requirements, existing regulations may require that some portions of the blackout backfit be qualified simply to ensure that seismic failure of this new equipment does not threaten existing safety systems. Examples of blackout mitigation structures, systems and components possibly requiring seismic qualification include the proposed new building housing the blackout systems discussed in Subtasks 1 and 2, steam piping required for the turbine-driven charging pump, and new DC switchgear. Qualifying such structures, systems, and components is an extremely expensive activity and missing from the NUREG/CR-3840 analysis.

Environmental Qualification of Blackout Mitigation Equipment

The NUREG/CR-3840 analysis assumes that new blackout mitigation equipment installed outside containment will be Class 1E and conform with quality assurance standards without necessarily being qualified for harsh environments. This assumption conflicts with the requirements of 10 CFR 50.49 (Environmental Qualification Rule) if station blackout becomes a design basis event. Specifically, Section 2(b) of 10 CFR 50.49 defines safety related equipment affected by the rule as "... that relied upon to remain functional during and following design basis events." If 10 CFR 50.49 requirements are imposed on station blackout, licensees would have to embark on a comprehensive analytical program to determine environmental profiles (i.e., temperature, pressure and humidity) during a station blackout. Should these profiles qualify as mild environments, then no further action would be necessary under 10 CFR 50.49. However, if thermal or humidity conditions exceed the severity associated with a mild environment, then utilities would be required to take the next step and qualify blackout mitigation equipment by further testing or analysis.

In addition to questions concerning the applicability of 10 CFR 50.49, the "no EQ" assumption also conflicts with Section 3.1.4 of the draft station blackout regulatory guide which states:

> All AC-independent decay heat removal systems and associated equipment needed to function during a station blackout should meet design and performance standards that ensure adequate reliability and operability in extreme environments, including hazards due to severe weather, that may be associated with a station blackout.

Reconciling these conflicts between NUREG/CR-3840 and the proposed new requirements may not be easy. The cost of analysis and subsequent qualifications are extremely significant. Indeed, typical qualification costs for Class 1E equipment are often as much as if not more than the costs of the equipment itself.

Any savings offered by "exempting" this equipment from the full documentation requirements of 10 CFR 50.49 may not be meaningful since the station blackout regulation still establishes the need for an analysis to demonstrate equipment operability during blackouts for 4 or 8 hours under the loss of both HVAC and most equipment cooling systems.

No Cost of Capital

In establishing utility revenue requirements, economic regulatory practice defines the rate base as the net book value of the plant considered used or useful in dispensing service plus some reasonable allowance for working capital. Improvements to existing commercial facilities increase the net book value of the plant. The capital improvement cost includes engineering, craft and white collar labor and materials. There is a substantial amount of time between start of design, procurement of materials, installation, and declaration of operation. It is not until after these costs have been expended and the resulting modifications have been put in service that the assets are considered useful in dispensing service. In addition to this consideration, there is another period between the declaration of operation and the inclusion of the capital improvement in the rate base upon which consumer rates are set. During this time, the utility must finance the capital improvement at rates established by the market for alternative investments of comparable risk. The period of time involved before the modifications can be credited to the plant's book value would realistically be on the order of three years. This cost of capital represents a substantial sum which should be included in the cost analysis.

4. COMMENTS ON THE METHODOLOGY AND CALCULATIONS OF THE NUREG/CR-3840 PROPOSED DESIGN SOLUTION'S COST ESTIMATE

This section provides detailed comments on methodology and calculations found in the cost analysis of NUREG/CR-3840. Particular attention is provided to errors which affect the overall estimated costs and generally involve costing problems in unit rates and productivity. The problems manifest themselves in the data sources, a series of procedural errors, a general lack of data substantiation, and exclusion of additional costs normally incurred in plant backfits.

Data Sources

The NUREG/CR-3840 cost analysis attempts to reflect standard engineering practice for estimating costs. Material, engineering, and labor costs are developed based on data provided by a standard cost manual for commercial construction, the Dodge Manual [1983], supplemented by telephone surveys where necessary. Adjustments to productivity and labor costs are then made to account for factors which may alter these numbers, such as geographical differences, the impact on productivity of work inside containment, engineering, quality assurance, and management overhead.

To begin with, many of the more serious problems with the NUREG/CR-3840 cost estimate can be traced to the decision to use commercial construction cost data in estimating the magnitude of nuclear power plant backfit costs. While useful to its own purpose, the Dodge Manual simply does not reflect the unique attributes of nuclear construction experience, ie. it systematically underestimates the material costs, and overestimates the productivity of nuclear crafts.

For example, since material costs are likely to be relatively independent of industry application, it might seem reasonable to use the Dodge Manual as a basic source of data. However, unit costs for safety-related equipment consist of both the actual material costs <u>and</u> the documentation costs necessary to demonstrate the component's ability to perform the intended function. The documentation costs for safety-related equipment can be as much as or more than the base material costs alone, due to the cost of qualifying equipment to requisite standards and the anticipated environment.

Actual labor costs are also greater than the Dodge Manual projects for commercial construction. The NUREG/CR-3840 analysis recognizes this potential. To compensate for this situation, the analysis develops a composite work crew for cost estimation and introduces adjustments for nuclear-related work and geographical costs. Additional multipliers are also provided to account for overhead (25%) and quality control (25%). However, the combined effect of these multipliers does not accurately reflect the actual productivity experienced in installing safety-related materials. This point is best illustrated in Figure 4-1 which compares labor rates for selected items taken from the Dodge Manual against actual nuclear construction experience reported in the NRC/ERDA PWR Capital Cost Report, NUREG-0242 (UEC [1977]). The three civil/structural related items presented in the figure were selected as representative. The materials are typically used in normal construction applications and do not appear to have unique features which might affect the cost of their installation. Yet, the average labor hours required to install these items in a new PWR is almost five times greater than reported by Dodge. Further, these rates are based on constructing a new PWR and do not involve work in radiation areas. In addition, the NUREG-0242 data in the Capital Cost Report is based on 1977 construction data while the Dodge Manual is more current. The growth rate for structural craft costs is substantial, as shown by Figure 4-2, suggesting that more current costs should be even greater.

The inappropriateness of the Dodge Manual is also evident in comparing material costs (Figure 4-3). This figure illustrates recent material costs for the three items discussed. Costs are shown for the Dodge Manual, NUREG-0242 costs, and NUREG-0242 costs based on an average cost escalation of 30% since the 1977 NUREG-0242 study (see UEC [1984], page 3-3). The differences between these costs and those projected by the Dodge Manual are striking. In fact, some of the material costs estimated by NUREG/CR-3840 in 1984 for station blackout modifications are less than previously reported in 1977 for new PWR construction. Adjusting for the 30% average cost escalation experienced in commodity/equipment costs since 1977 only widens this gap.

While this discussion has concentrated on unit labor and material costs, there are also problems with the use of adjustment terms to account for overheads, as is done in the NUREG/CR-3840 analysis. This is best illustrated in Figure 4-4 which presents two overhead ratios for data presented in each of three reports: NUREG/CR-3840, NUREG/CR-3971, and the EEDB (DOE/NE 0051/2). The first ratio presents engineering, quality assurance, and project management costs to total equipment and material costs. The second is the ratio of craft labor costs to total equipment and material costs. These comparisons clearly demonstrate the systematic underestimates of these overheads by factors of 4-5 or more.

These comparisons are important because a key conclusion of the Dodge Manual analysis is that material costs dominate the overall cost estimate for the proposed backfits. The EEDB and NUREG/CR-3971 studies arrive at the opposite conclusion: labor costs dominate the overall cost estimate. This point is underscored by the Figure 4-4 comparisons. In addition to placing undue emphasis on materials in the cost estimates, an important implication of this result is that the Dodge Manual is inaccurate in estimating the cost of nuclear construction. Clearly, it is an inappropriate data source for estimating current backfit costs. A preferable approach to the cost analysis would have been to use the more traditional nuclear construction data sources cited in the previous comparisons. Had these sources been used, it is more likely that the cost estimate would have been more accurate as well as yielding significantly greater backfit costs.

Procedural Errors in the NUREG/CR-3840 Analysis

In addition to underestimating unit costs, a number of errors also plague the NUREG/CR-3840 analysis. While of somewhat lesser importance than the unit rate problems previously discussed, the mistakes distort the results and tend to further underestimate the backfit costs beyond that previously noted. These errors include arithmetic mistakes, misquotations from the Dodge Manual, and inappropriate data extrapolations. The errors were identified by independent verification of spreadsheet analysis provided in the appendices to the NUREG.

The importance of these procedural errors should not be overlooked because they compound the systematic errors arising out of the Dodge Manual methodology. For example, on the bottom of page A-4 of NUREG/CR-3840, 4 hours of resistance measurements, priced at $40/hour, are shown to cost $120 instead of $160. This error adds another 25% to the unit rate errors previously discussed. Since other costs are based on adjustments to this value, the 25% error is propagated throughout the overhead and geographical costs.

In other cases, the Dodge Manual is simply misquoted. Case in point, the unit cost for a 3/0 bare wire is given in the NUREG/CR-3840 analysis as $1.10/ft. (pages A-14, 18, 34, and 39, NUREG/CR-3840). In contrast, the Dodge Manual quotes this wire at $1.703/ft (page 235).

Other problems arise from an inconsistent cost treatment for the same item. Backfill, for example, has a unit labor value of 0.25 hr./YD^3 (page A-13, NUREG/CR-3840) and 1.00 hr./YD^3 (page B-16, NUREG/CR-3840).

In other locations, the inconsistencies affect the interpolation and extrapolation procedures applied to non-standard items. For example, NUREG/CR-3840 reports the cost of an enclosed 250 Vac circuit breaker rated at 1,000 amps to be $1,875, an almost linear extrapolation of costs based solely on the electrical current rating of a standard 70-100 amp, 250 Vac breaker. Contrary to this assumption, though, the cost of non-standard items increases non-linearly due to special design costs, setup charges, and additional material requirements.

Other difficulties are simply the result of using the wrong adjustment productivity factors. For example, normalized productivity and labor cost adjustment terms are used for implementing the backfits at ANO and Quad Cities despite the fact that the Dodge Manual provides adjustment rates for Arkansas and Illinois of 0.73 and 0.94, respectively.

Lack of Substantiation

One of the problems encountered in reviewing this analysis is that NUREG/CR-3840 provides only the first and last steps of the cost estimation process. In the first step, general assumptions are made (e.g., pump capacity, incremental battery size, etc.), and one-line diagrams illustrate where the major components are located. In the last step, a bill of materials is created which forms a basis for the material cost estimates. The missing elements are the detailed engineering and construction details used in preparing the labor cost and schedule. This information must exist since a bill of materials was created. It would have been beneficial if it was provided with the report.

Another problem area concerns the lack of substantiation for the labor productivity and cost assumptions used. Many of these assumptions do not compare well with actual experience, as previously discussed. Of particular interest are the considerations which led to the use of composite construction teams and multipliers to account for work inside containment, geographical variations, and non-construction costs (e.g., engineering, overhead, etc.). Although experience has shown that these costs are more significant than craft-related costs alone, there may be some foundation for the values used which would permit their use in spite of the experience.

Additional Costs Not Considered In NUREG/CR-3840

In addition to the problems identified in the costs estimated in NUREG/CR-3840, there appear to be other costs which should have been considered in the estimate and were not. These costs are in addition to that provided by using more realistic unit costs discussed and include:

- Equipment Removal Costs

  Plant modifications often require the removal of existing equipment. These tasks affect both the cost and schedule of a backfit project and have not been considered in the NUREG/CR-3840 analysis.

- Delay and Disruption Costs

  Backfits generally introduce delay and disruption effects ("ripple effects") on work planning. These effects translate into lower labor productivity within crafts and engineering disciplines on other projects.

- Engineering Costs

  As discussed previously, engineering costs can represent a significant fraction of backfit costs, especially in backfit issues subject to evolving requirements. Using new plant construction costs as an example, DOE/NE-0051/2 (UEC [1984]) suggests 50% more engineering costs for a more recent PWR than used in the NUREG/CR-3840 analysis.

- Field Supervision and Indirect Labor Costs

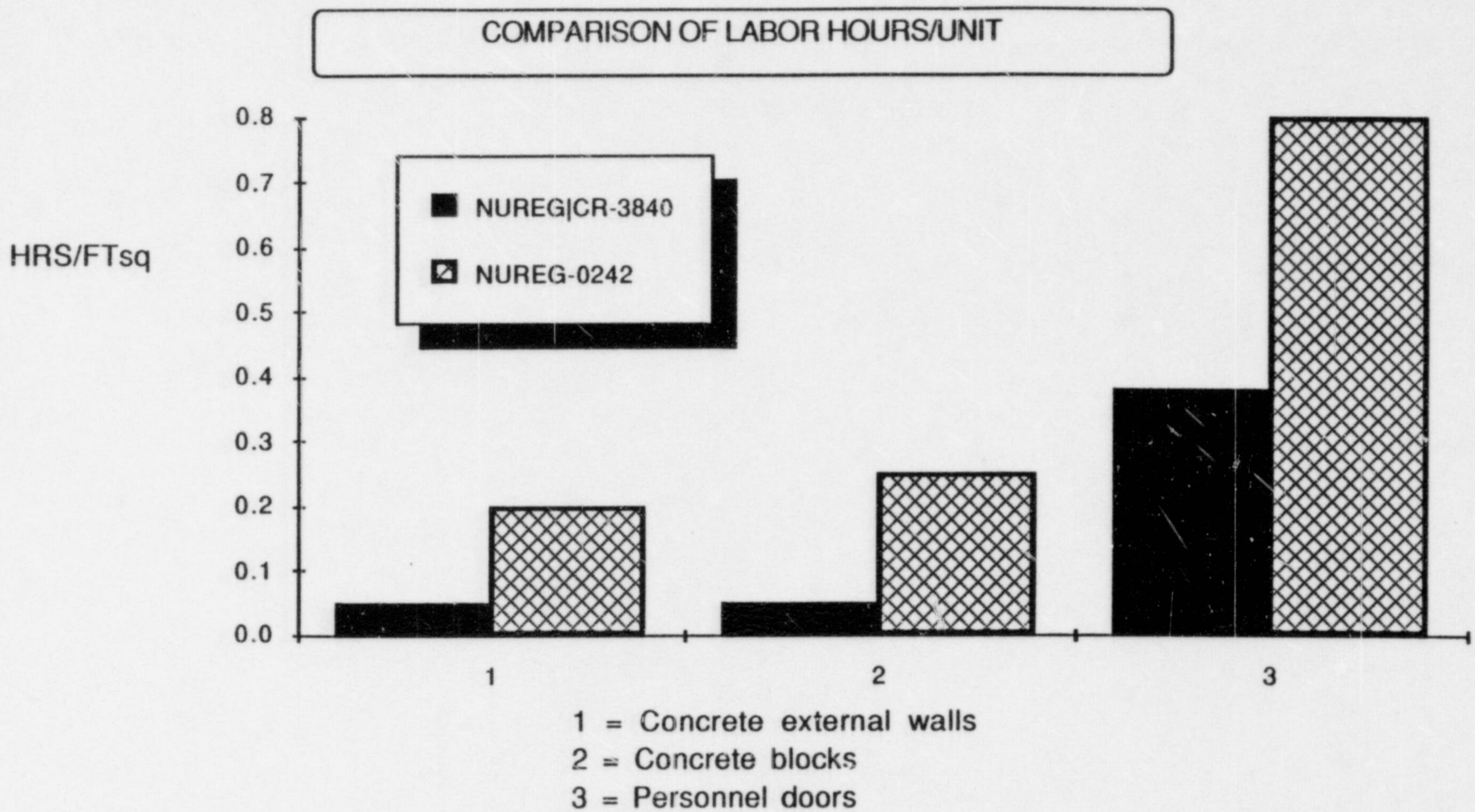
  DOE/NE-0051/2 (UEC [1984]) suggests almost four times more field supervision, administrative, and overhead costs than assumed by the NUREG/CR-3840 analysis.

- Equipment Conformance to Codes and Standards

  Material costs for materials meeting requisite codes and standards are likely to be twice those assumed by the NUREG/CR-3840 analysis based on DOE/NE-0021/2 (UEC [1984]), Counsil [1983], and common experience.

These costs should have been included in the NUREG/CR-3840 cost estimate. Failure to do so may result in a substantial underestimation of the costs.

The last section of this report discusses the impact of these additional costs on the proposed backfits using the Department of Energy (DOE) database (UEC [1983], [1984]) and more accurate productivity data. The revised cost estimate is then compared with previous backfit experience to provide a picture of what the impact of the staff's proposals might ultimately be.



COMPARISON OF LABOR HOURS/UNIT
NUREG|CR-3840
NUREG-0242
HRS/FTsq
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
1 = Concrete external walls
2 = Concrete blocks
3 = Personnel doors

FIGURE 4-1

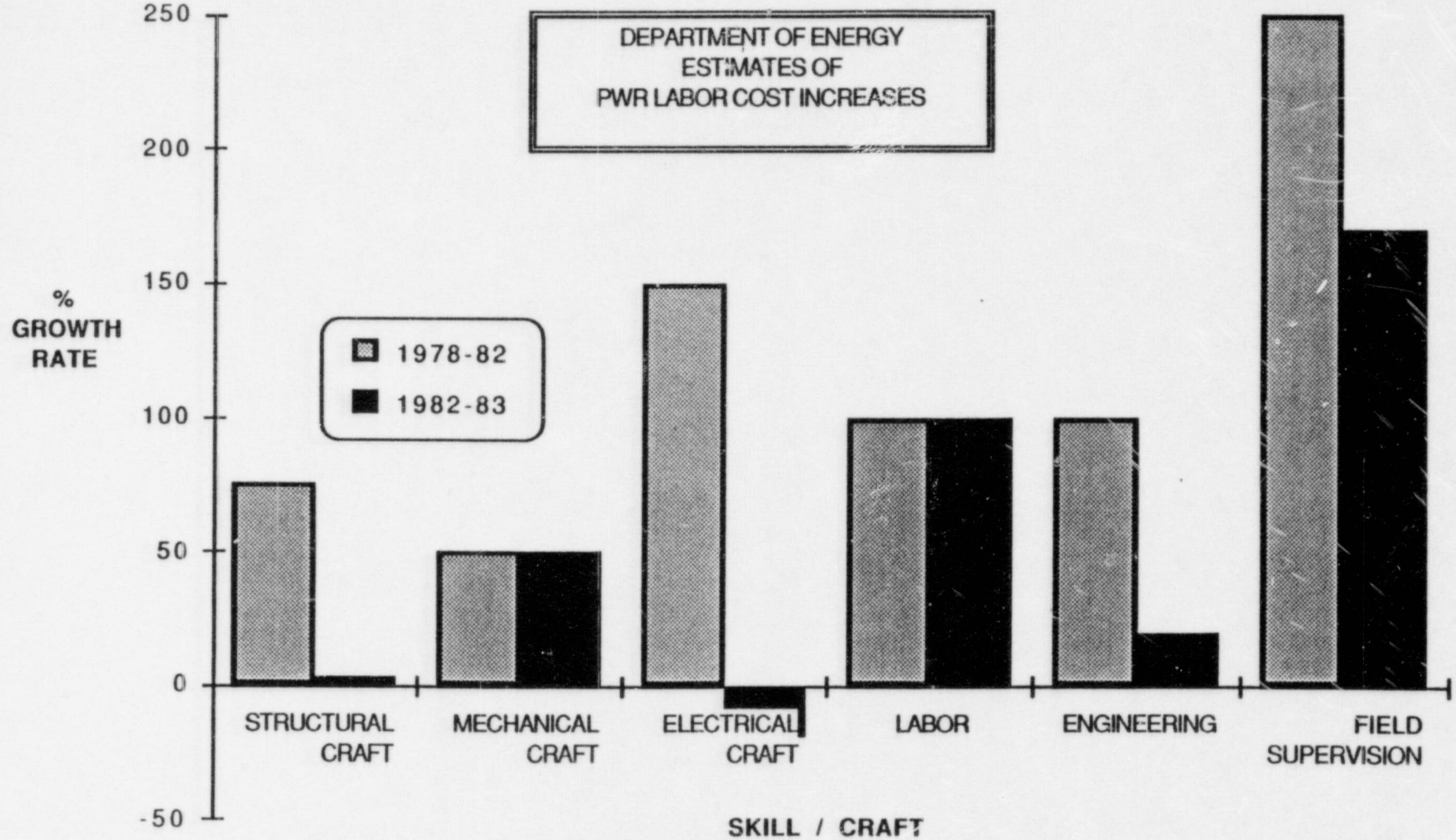

DEPARTMENT OF ENERGY
ESTIMATES OF
PWR LABOR COST INCREASES
250
200
150
100
50
0
-50
% GROWTH RATE
1978-82
1982-83
STRUCTURAL CRAFT
MECHANICAL CRAFT
ELECTRICAL CRAFT
LABOR
ENGINEERING
FIELD SUPERVISION
SKILL / CRAFT

FIGURE 4 - 2

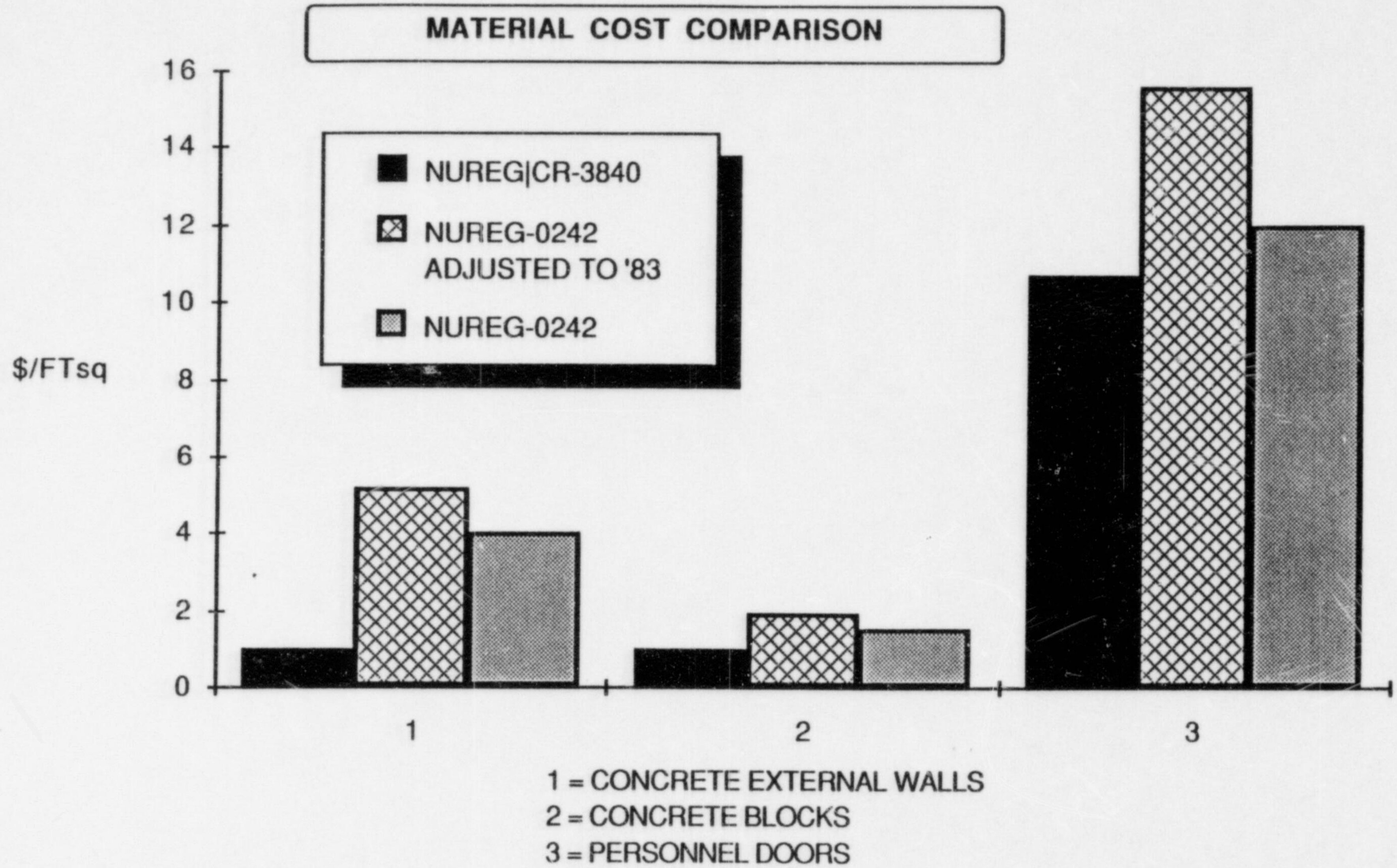

MATERIAL COST COMPARISON
NUREG|CR-3840
NUREG-0242 ADJUSTED TO '83
NUREG-0242
$/FTsq
0
2
4
6
8
10
12
14
16
1
2
3
1 = CONCRETE EXTERNAL WALLS
2 = CONCRETE BLOCKS
3 = PERSONNEL DOORS

FIGURE 4-3

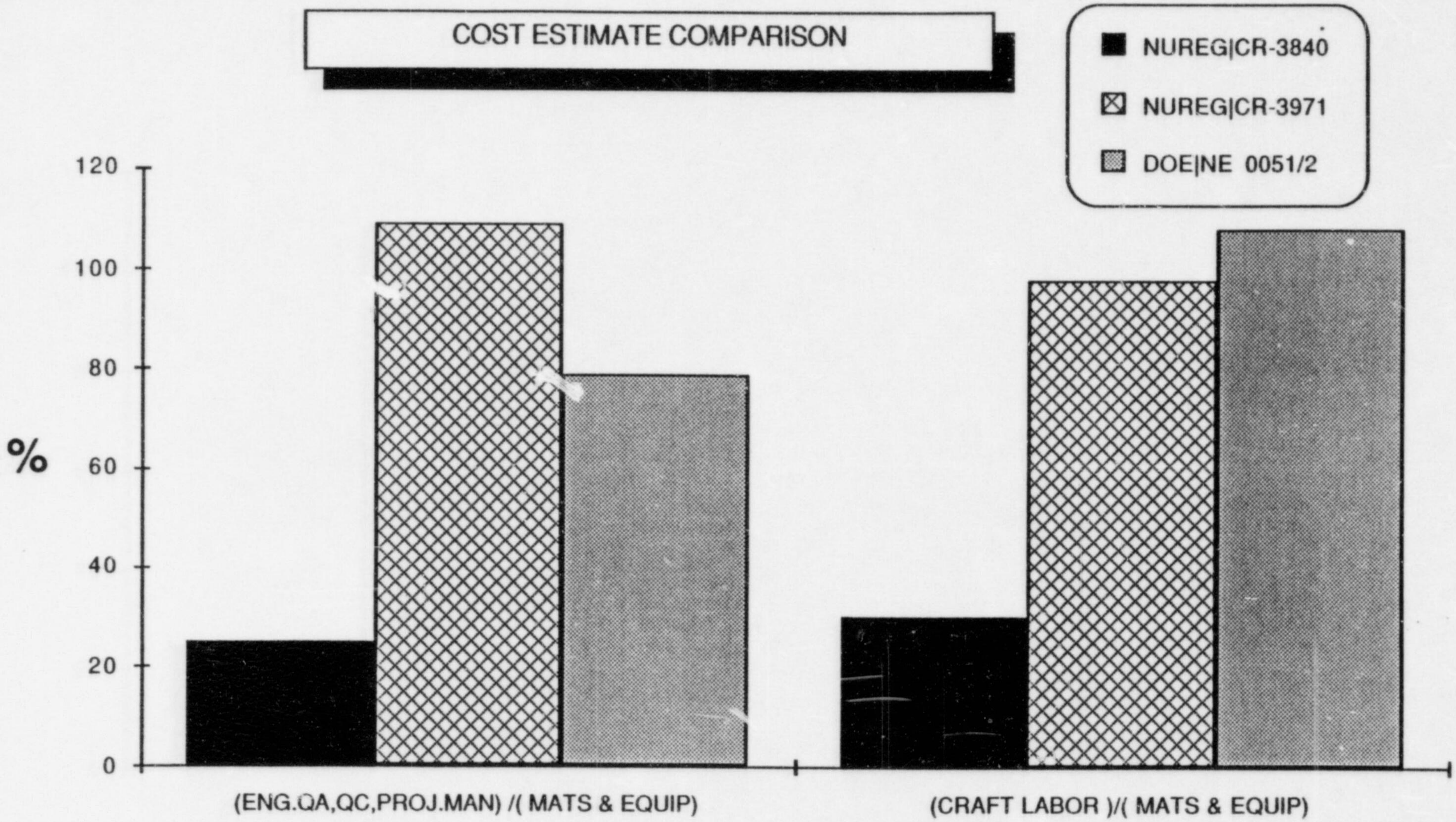

COST ESTIMATE COMPARISON
NUREG|CR-3840
NUREG|CR-3971
DOE|NE 0051/2
%
120
100
80
60
40
20
0
(ENG.QA,QC,PROJ.MAN) /(MATS & EQUIP)
(CRAFT LABOR)/(MATS & EQUIP)

FIGURE 4 - 4

5. COMPARATIVE COST ESTIMATES USING ALTERNATIVE NUCLEAR POWER PLANT SOURCE DATA AND ASSUMPTIONS

This section examines the effects of individual assumptions on the cost estimate and provides a comparative analysis of the NUREG/CR-3840 analysis by correcting arithmetic errors and modifying several basic assumptions to reflect actual plant experience. These revisions are provided in order to identify the principal sensitivities inherent in the NUREG/CR-3840 analysis. The basic design solutions are the same as in NUREG/CR-3840 as well as are the equipment costs. The results of this analysis highlight the variation in the NUREG/CR-3840 analysis to data provided by the EEDB and NUREG/CR-3971. The results also demonstrate that the cost estimate supporting the regulatory analysis increases by a factor of 2-3 simply by applying industry cost data to the NUREG/CR-3840 methodology. Three factors that are considered in the analysis are: (1) correcting the arithmetic errors, (2) updating labor productivity assumptions, and (3) considering the cost of capital and replacement power.

Arithmetic Errors

The first modification to the NUREG/CR-3840 analysis corrects the arithmetic errors and data misquotations from the Dodge report. The details of each option are set forth in the appendix. Table 5-1 provides the cost for each option estimated, without the arithmetic errors. The combined effect of these errors underestimates the cost of individual NUREG/CR-3840 modifications by up to 69%.

Labor Productivity Assumptions

The NUREG/CR-3840 analysis was also corrected to reflect the labor hours/unit cited in the EEDB (UEC,"Phase VI Update" [1984]). Table 5-2 provides the results of this calculation for each option estimated. In this case, the cost underestimation for the various options provided in the NUREG/CR-3840 analysis is up to 115%.

Labor Productivity (NUREG/CR-3971 Rule of Thumb)

An important "real-life" consideration in estimating nuclear construction costs is the sensitivity of productivity to rework, overcrowding, and work in radiation areas. Guidance provided in NUREG/CR-3971, "A Handbook for Cost Estimation," includes several rules of thumb concerning productivity factors for use in preparing such estimates. These rules suggest that a correction factor be applied to the labor productivity rate when estimating work to be performed in a radiation environment. This correction factor only affects the RCP seal cooling modifications. Even this singular case decreases overall labor productivity (i.e., weighted productivity) to as low as 34%, thereby increasing all labor costs by 33%.

For all areas outside radiation areas, a loss in productivity results from rework and overcrowded work quarters. For example, to install piping or conduit cable trays, other piping which is in the way of newly added piping or conduit may have to be removed and replaced. NUREG/CR-3971 estimates that rework can add 10-35% to the labor cost of a modification, and overcrowding can result in an estimated 10% reduction in labor productivity. In contrast, the NUREG/CR-3840 analysis assumes no labor for rework and overcrowding. A nominal 17% increase in labor costs may be used to account for the combined effect of rework and overcrowding. Using this value results in a productivity loss of 10% and can be shown to lead to additional labor costs of up to 190% of the NUREG/CR-3840 baseline estimate (See Table 5-3).

Engineering and QA/QC (NUREG/CR-3971 Rule of Thumb)

Engineering, project management, QA/QC and other clerical costs are estimated by the NUREG/CR-3840 analysis to be 25% of the total craft labor and material costs. In the NUREG/CR-3971 sample estimate provided for a Technical Support Center, the ratio of noncraft labor costs (i.e., engineering, project management, QA/QC drafting and clerical) to craft labor and materials cost exceeds 54%. This cost variance translates into a significant increase in noncraft labor costs by multiples up to 250%. Table 5-3A presents the underestimate percentage for all modifications.

Cost of Capital

The NUREG/CR-3840 analysis assumes no interest or other cost of capital charges for money from the start of the work until the inclusion of the capital improvement in the rate base. While such an assumption simplifies the analysis, it is also unrealistic. Approximately two years is normally required from the initial engineering through inclusion in the rate base. Throughout this period capital charges accrue to the expenditures. The cost of capital varies but even if a conservative rate of 7% is assumed, the total dollar amount of the backfit would be sufficiently large to be considered. Thus the cost of capital, if included in the cost estimate, would increase the cost estimate by 14% or more.

Replacement Power Costs

In addition to other costs discussed above, replacement power costs can be a significant increment to the overall impact of a backfit. The NUREG/CR-3840 analysis assumes zero replacement power costs for all modifications reflecting the assumption that all work can be done while the plant is operating. However, due to resource constraints, site craft density restrictions, and operating conditions at the location of installation, the suggested modifications may not all be completed in a non-outage situation. Experience supports that backfits and regulatory requirements contribute to plant outage time. For example, in NUREG/CR-4012, Van Kuiken, *et al*, calculate that the typical planned operation and maintenance outages are 72-76 days in duration. Since the "shell outage" which includes cooldown, fuel movement, and heatup is normally on the order of eight weeks (56 days) there exists ~20 days of scheduled operations and maintenance outage attributable to other work (e.g., modifications, maintenance, surveillance,plant betterment, etc.). To determine an upper bound on the costs that could be attributed to the associated replacement power costs, a calculation was performed assuming the crew labor hours are consumed in two shifts per day, six days per week for each option analyzed in NUREG/CR-3840. This calculation yields the number of crew days required to complete the task. The number of crew days can then be multiplied by $500,000 per day to obtain approximate replacement power costs. These results are summarized in Table 5-4.

The replacement power costs associated with the proposed modifications are significant. Typically these costs amount to 5-10 times the estimated capital costs of the backfit. Yet, they are not normally considered in the value-impact analysis.

Comparative Analysis

While each of the factors previously discussed will increase the size of the backfit cost estimates, it is not feasible to readily present all possible combinations of factors in a sensitivity analysis. Consequently, the factors which could easily be corrected or otherwise substantiated in the existing cost database (e.g., the use of actual cost data from EEDB or NUREG/CR-3971) were isolated for analysis. These factors were limited to:

(a) correcting arithmetic errors;
(b) EEDB craft labor costs and productivities;
(c) substituting a ratio of Engineering, QA, QC, and Project Management costs to materials and equipment costs of 50%;
(d) NUREG/CR-3971 productivity factors for rework and overcrowding; and,
(e) considering the cost of capital of 7% for two years on the total cost.

The assumptions used in the comparative analysis are summarized in Table 5 - 5. It should be noted that replacement power costs were not considered in keeping with the basic structure of the NUREG/CR-3840 study.

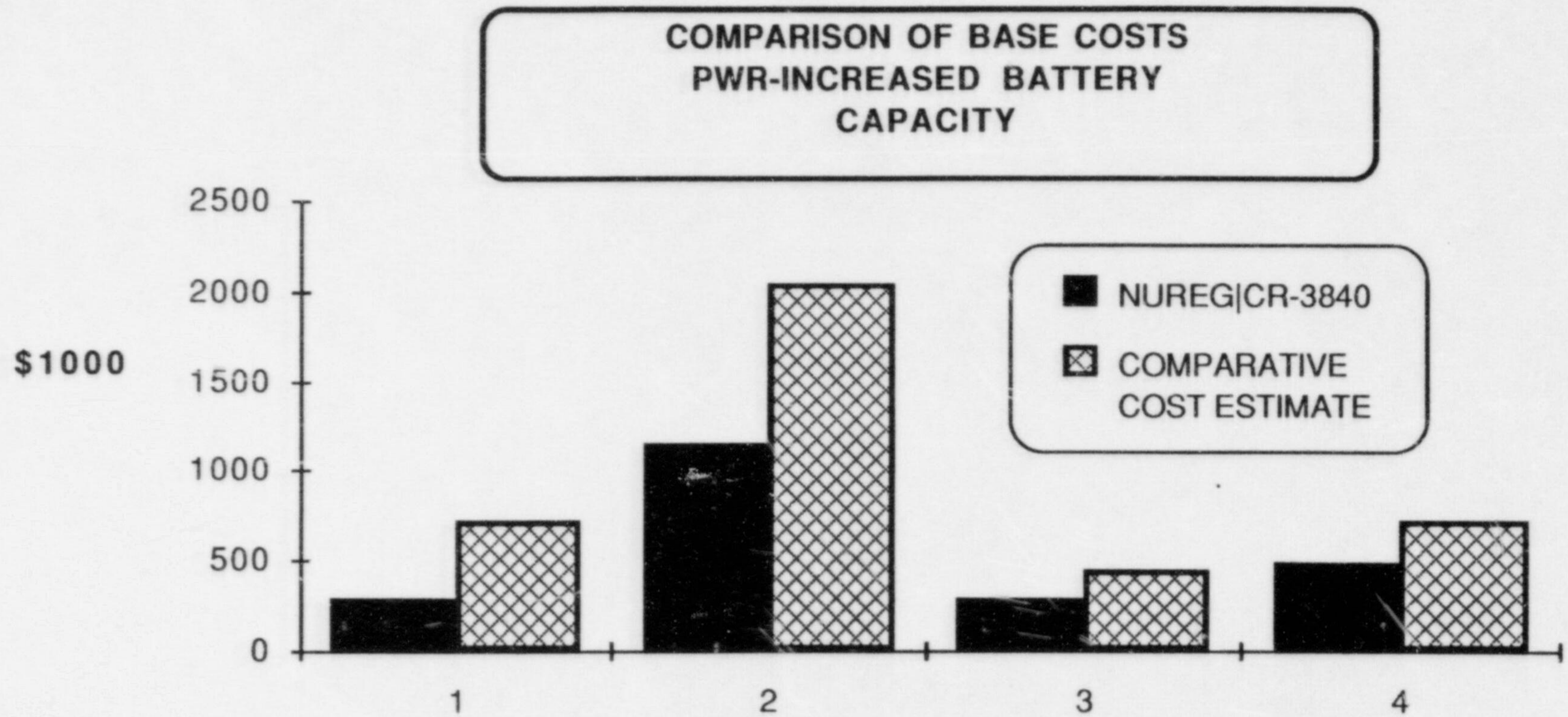
The results of the sensitivity analysis are provided in Figures 5-1 and 5-2 for the representative "base case" examples listed in NUREG/CR-3840. Figure 5-3 provides a category comparison for Option 2 in Figure 5-1. As is clearly evident, the modified analysis results are, for the most part, two or more times larger than the NUREG/CR-3840 base case estimates. These results are significant in themselves. Further, when replacement power is also added, the modified case estimate could exceed the base case by up to a factor of 500.

Extending these results to the regulatory analysis supporting the proposed station blackout rule (i.e., NUREG-1109) demonstrates the inefficiency of the proposed rule's requirements. For example, a factor of two difference between the NUREG/CR-3840 cost estimate and the modified analysis estimate applied to the number of affected plants listed in Table 6 of NUREG-1109 doubles the costs for these hardware modifications. Doubling the total cost of the backfit without a comparable improvement in safety reduces the value-impact ratio for the proposed rule by 1/2.

Similarly, combining the revised estimate with other compliance costs only reduces the value-impact ratio further. For example, another potential modification to the Table 6 estimate involves increasing the best estimate cost for a coping analysis to a more realistic $750,000. Even this estimate is a number of factors less than the amount spent by some utilities in demonstrating the coping capability for their plants. If this revised cost for a coping analysis is combined with the revised hardware costs, the best estimate cost for the proposed regulation rises by another $46 million, further suppressing the value-impact ratio. Figure 5-4 illustrates this revised cost in comparison with the total backfit cost presented in Table 6 of NUREG-1109.

Conclusion

This reanalysis demonstrates the cost elasticity in the NUREG/CR-3840 estimates for station blackout modifications. Simply using realistic productivity and unit rate data in the NUREG/CR-3840 cost estimate can dramatically shift the value-impact ratio for the proposed rule. The implications highlight the need to reconsider the relevance of the NUREG/CR-3840 analysis to the resolution of the station blackout issue.



1 = Add 4 hour capacity
2 = Add 12 hour capacity
3 = Add battery charger/ DG
4 = Add battery charger/ Gas turbine generator

FIGURE 5 - 1

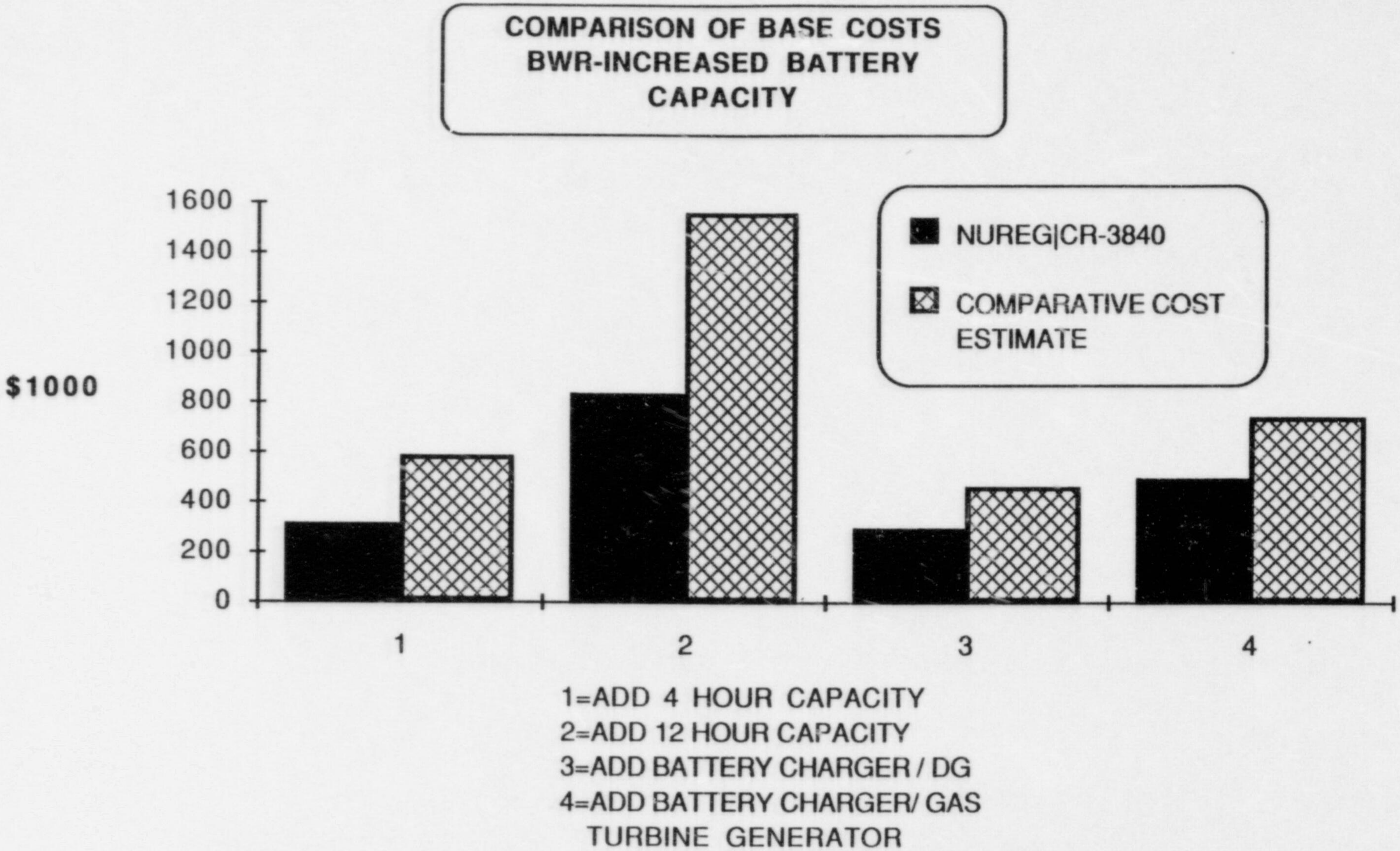

COMPARISON OF BASE COSTS
BWR-INCREASED BATTERY
CAPACITY
$1000
1600
1400
1200
1000
800
600
400
200
0
NUREG|CR-3840
COMPARATIVE COST
ESTIMATE
1
2
3
4
1=ADD 4 HOUR CAPACITY
2=ADD 12 HOUR CAPACITY
3=ADD BATTERY CHARGER / DG
4=ADD BATTERY CHARGER/ GAS
TURBINE GENERATOR

FIGURE 5 - 2

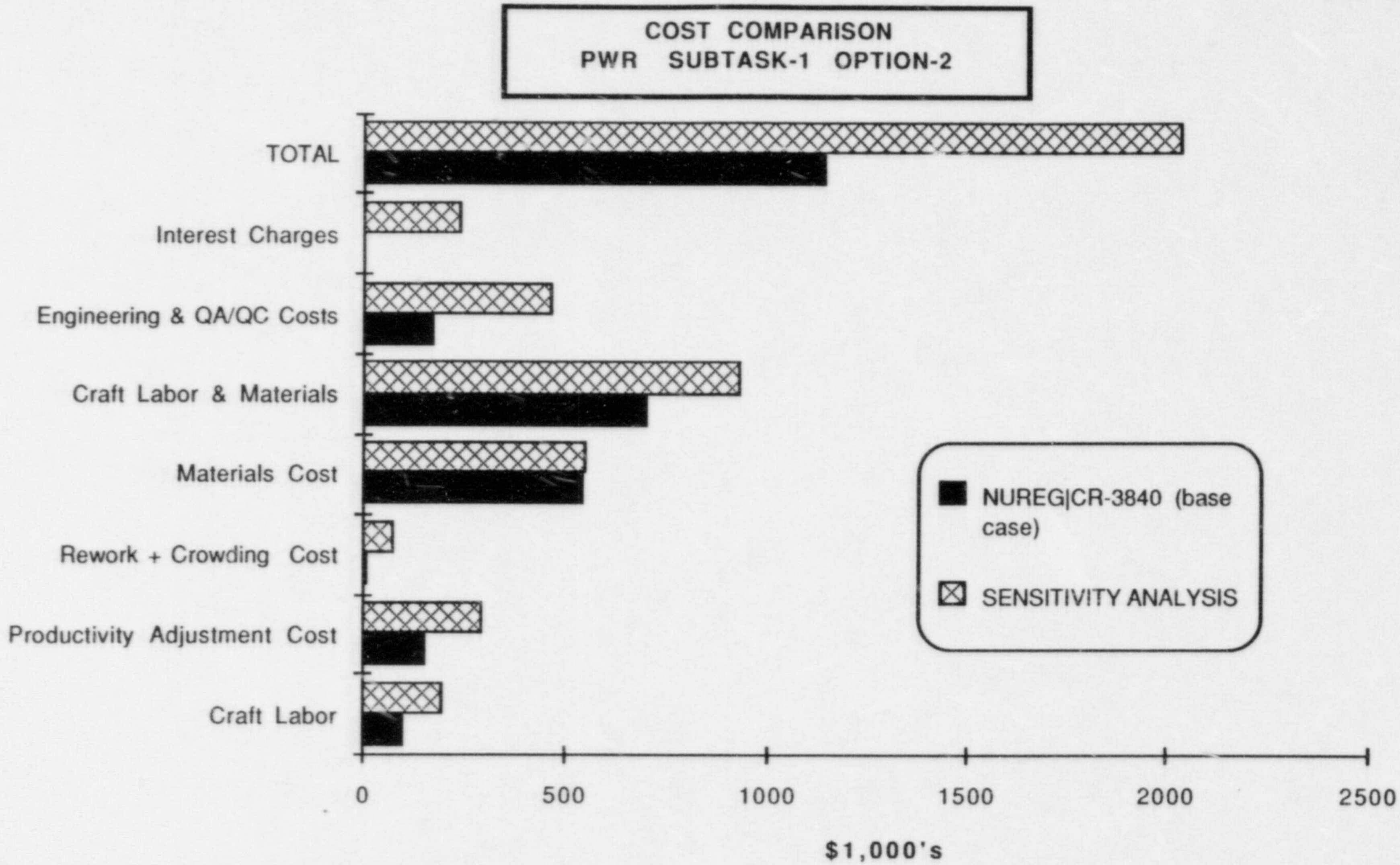
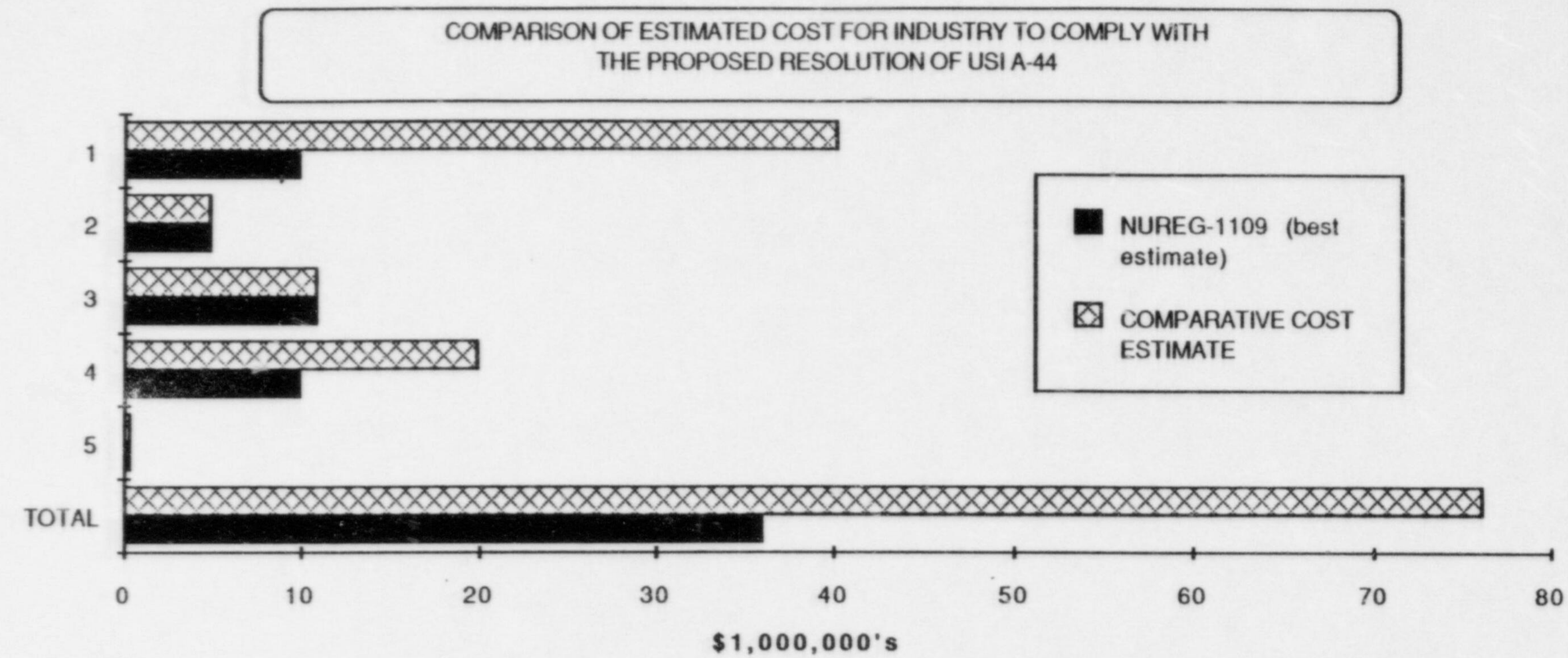

COST COMPARISON
PWR SUBTASK-1 OPTION-2
TOTAL
Interest Charges
Engineering & QA/QC Costs
Craft Labor & Materials
Materials Cost
Rework + Crowding Cost
Productivity Adjustment Cost
Craft Labor
NUREG|CR-3840 (base case)
SENSITIVITY ANALYSIS
0
500
1000
1500
2000
2500
$1,000's

FIGURE 5 - 3



1-ASSESS PLANTS ABILITY TO COPE WITH A SBO
2-DEVELOP PROCEDURES AND TRAINING
3-IMPROVE DIESEL GENERATOR RELIABILITY
4-INCREASE CAPABILITY TO COPE WITH A SBO
(i.e., increase capability of station batteries condensate storage tank, and instrament air)

5-ADD AN AC-INDEPENDENT CHARGING PUMP (non-seismatic) CAPABLE OF DELIVERING 50 TO 100 GPM TO REACTOR COOLANT PUMP SEALS

FIGURE 5 - 4

COMPARISON OF NUREG/CR-3840 BASE CASE VERSUS CORRECTED BASE CASE
($1000)

		NUREG/CR-3840	Corrected	Variance
SUBTABLE 1				
Reactor Type	**Option**			
	1	290.8	404.5	39.2%
PWR	2	1145.8	1164.4	1.6%
	3	285.1	288.6	1.2%
	4	486.1	492.9	1.4%
BWR	1	315.1	339.3	1.1%
	2	838.8	850.0	1.3%
	3	295.3	298.3	1.0%
	4	495.8	499.1	0.6%
SUBTABLE 2				
	2A	870	823.2	-5.6%
PWR	2B	829.2	829.5	
	2C	N/A	N/A	
	2D	369.2	375.2	1.6%
BWR	2A	N/A	N/A	
	2B	N/A	N/A	
	2C	180.8	307.2	69.9%
	2D	287.9	292.8	1.7%
SUBTABLE 3				
Reactor Type	**Option**			
PWR		37.4	37.6	0.5%
BWR		72.85	73.1	0.4%
SUBTABLE 4				
PWR	1	25.8	25.8	
	2	56.5	56.4	
BWR	1	20.9	20.9	
	2	39.2	39.2	

TABLE 5 - 1

COMPARISON OF NUREG/CR-3840 CRAFT LABOR HOURS/UNIT TO UE/C DATABASE FOR BASE COST

		NUREG/CR-3840	UEC	Variance
SUBTABLE 1				
Reactor Type	**Option**			
	1	38.1	72.7	90.8%
PWR	2	105.4	200.5	19.0%
	3	12.8	26.8	109.4%
	4	10.9	23.5	115.6%
	1			
BWR	2	90.4	175.2	93.8%
	3	15.1	30.2	100.0%
	4	13.1	26.5	102.3%
SUBTABLE 2				
	2A	60.4	114.9	90.2%
PWR	2B	55.2	116.2	105.0%
	2C			
	2D	18.8	38.0	102.1%
	2A			
BWR	2B			
	2C	18.0	35.7	98.3%
	2D	12.0	23.4	95.0%
SUBTABLE 3				
Reactor Type	**Option**			
PWR				
BWR		3.7	7.4	100.0%
SUBTABLE 4				
	1	2.3	4.6	100.0%
PWR	2	5.1	10.2	100.0%
	1	1.5	3.1	106.6%
BWR	2	3.6	7.2	100.0%

TABLE 5 - 2

COMPARISON OF REWORK/OVERCROWDING LABOR COSTS TO BASE LABOR COSTS

		NUREG/CR-3840	Corrected	Variance
SUBTABLE 1				
Reactor Type	**Option**			
	1	38.1	29.3	76.9%
PWR	2	105.4	80.8	76.6%
	3	12.8	10.8	84.4%
	4	10.9	9.5	87.2%
	1			
BWR	2	90.4	70.6	78.1%
	3	15.1	12.2	80.8%
	4	13.1	26.5	102.3%
SUBTABLE 2				
	2A	60.4	51.7	85.6%
PWR	2B	55.2	71.3	129.2%
	2C			
	2D	18.8	20.2	107.4%
	2A			
BWR	2B			
	2C	18.0	14.4	80.0%
	2D	12.0	35.0	191.6%
SUBTABLE 3				
Reactor Type	**Option**			
PWR				
BWR		3.7	3.0	81.1%
SUBTABLE 4				
PWR	1			
	2	5.1	4.1	80.4%
BWR	1	1.5	1.2	80.0%
	2	3.6	2.9	80.5%

Table 5 - 3

NON-CRAFT HOUR COMPARISON
NUREG/CR-3971 *vs.* NUREG/CR-3840

		NUREG/CR-3840	Corrected	Variance
SUBTABLE 1				
Reactor Type	**Option**			
PWR	1	43.9	164.4	274.5%
	2	176.1	466.6	164.9%
	3	36.7	89.9	144.9%
	4	73.3	161.5	120.3%
BWR	1			
	2	127.0	355.4	179.8%
	3	38.3	94.8	155.4%
	4	74.9	166.0	121.6%
SUBTABLE 2				
PWR	2A	134.7	330.0	144.9%
	2B	128.2	372.0	190.2%
	2C			
	2D	37.1	88.8	139.4%
BWR	2A			
	2B	20.0	61.0	205.0%
	2C			
	2D	37.1	88.8	139.0%
SUBTABLE 3				
Reactor Type	**Option**			
PWR		7.2	18.6	158.3%
BWR				
SUBTABLE 4				
PWR	1	3.1	8.8	183.9%
	2	8.0	21.9	173.8%
BWR	1	3.3	6.1	84.8%
	2	5.2	14.6	180.8%

**includes 50% of craft labor & materials*

TABLE 5 - 3A

UPPER BOUND REPLACEMENT POWER COSTS FOR EACH OPTION

Option	Crew Labor Hours	Crew Days *	Cost ($1,000,000)
PWR S1 01	1380	14.4	7.2
PWR S1 02	3802	39.6	19.8
PWR S1 03	476	4.96	2.5
PWR S1 04	404	4.2	2.1
BWR S1 01	1206	12.6	6.3
BWR S1 02	3304	34.4	17.2
BWR S1 03	561	5.8	2.9
BWR S1 04	481	5.0	2.5
PWR S2 0A	2157	22.5	11.3
PWR S2 0B	2004	20.9	10.4
PWR S2 0C	698	7.3	3.6
BWR S2 0D	659	6.9	3.4
BWR S2 0D	442	4.6	2.3
PWR S3 01	12	0.13	0.06
BWR S3 01	134	1.4	0.7
PWR S4 01	84	0.88	0.44
PWR S4 02	186	1.9	0.97
BWR S4 01	56	0.58	0.3
BWR S4 02	131	1.36	0.68

**assumption:Two eight-hour shifts, six days a week*
+ Replacement Power Costs = 500,000 per day

TABLE 5-4

NUREG|CR-3840 Cost Estimate and Comparative Cost Estimate Assumptions

NUREG|CR-3840 Assumptions	Comparative Cost Estimate Assumptions
-- Uses Materials List Based upon Proposed Design Solutions	-- Same
-- Uses (1)Dodge Manual Labor hrs/Unit (2)Dodge Manual $/Labor hr	-- Uses (1)EEDB 83 Adjusted Labor hrs/Unit (2)1977 UEC Adjusted at 5% per Yr. to '83 (8 Yrs. since '77 Report Based on '76 Wages)
-- Applies Labor Productivity Factor of: LOW 75%, BASE 67%, HIGH 50%	-- Same
-- NO Factors for Rework or Overcrowding	-- Applies Rework & Overcrowding Factor of: Rework LOW 10%, BASE 17%, HIGH 35%; Crowding LOW 5%, BASE 10%, HIGH 15%
-- Adds Material Cost to Labor Cost	-- Same
-- Adjusts Material & Labor Cost for Geographical Differences as Follows: LOW 85%, BASE 0%, HIGH 115%	-- Same
-- Uses an Engineering & QA Factor of 25%	-- Uses an Engineering & QA Factor of 50%
-- Adds Contractor Mark-up of 25% to Materials and Labor	-- Same
-- NO Amount for Interest	-- Adds Interest of 7% of Total for Two Years

TABLE 5-5

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APPENDIX

SUBTASK 1 - INCREASE BATTERY CAPACITY

NUREG/CR-3840 Assumptions

The NUREG/CR-3840 analysis assumes that most station batteries currently have a four-hour capacity and considers three options which are evaluated for increasing that capacity. The options include: (1) shedding loads, (2) adding batteries, and (3) providing an AC-independent charger. Additional batteries are considered in multiples of existing capacity while charger specifications are based on existing equipment.

The PWR battery option consists of two subparts providing 4 and 12 hour expansions:

(1) adding two 125v DC 1350 amp-hr batteries; and,

(2) six 1350 amp-hr battery additions

The BWR battery analysis also provides two options for 8- and 16-hour blackout durations: the first option consisting of one 125v DC 500 amp-hr battery, and a 250v DC 900 amp-hr battery; the second option contains three such batteries at both voltage levels.

The third option, AC-independent chargers, has two alternatives: a turbine-driven charger, and a diesel-driven charger. However, unlike the battery options, both charger options require a new building to house and support the equipment additions.

It should be noted that load shedding was initially considered in the NUREG/CR-3840 analysis and was later discarded because it was "...not within the scope of the analysis" (page 44, NUREG/CR-3840). Yet, Table 1 of NUREG/CR-3840 which lists the loads considered in the analysis and concludes that an 8-hour blackout would require 923 amp-hrs at 125v DC and 190 amp-hrs for each additional hour. The analysis further concludes that, even conservatively assuming a 60% battery derating, most reactors could, nevertheless, maintain DC power for at least 10 hours if load shedding is attempted.

The NUREG/CR-3840 analysis also provides an assessment of the relative merits of the traditional lead-acid battery and a lithium battery. Although largely untested in commercial nuclear power plants, the benefits of the lithium battery appear to reside in its higher density, reducing the requirements for additional space.

Comments on NUREG/CR-3840 Assumptions

The principal comments regarding the NUREG/CR-3840 assumptions affect:

(1) load shedding as an option;
(2) battery qualifications; and,
(3) charger reliability.

The credibility of the options presented is detracted by the failure to consider load-shedding as a viable option for providing DC power to the identified loads. In fact, a good argument is made in the NUREG that for small enough loads (such as those listed in Table 1 in the report), load shedding alone can extend battery availability out to eight-hour station blackouts and longer without the need for additional batteries. For load shedding to work, it would have to occur early in a blackout, which may be accomplished by procedure. In this review, the Table 1 loads are recalculated using peak loads as an indicator of DC power requirements. The total DC power requirements considered are presented below for the loads specified in the NUREG/CR-3840 analysis:

LOAD		PEAK REQUIREMENTS	
Emergency Illumination		12.50	kw
DC MOV Operation		0.75	kw
Instrumentation and Display		31.25	kw
Display Lighting		2.50	kw
EDG Field Flashing and Control		1.50	kw
Switchgear and Breaker Control		32.50	kw
	TOTAL	81.00	kw

Adding power requirements for the emergency lubricating oil and hydrogen seal oil pumps increases the total power requirements to nearly 100 kw.

Analysis was performed to test the impact of these requirements on several power plants. This analysis assumed a 60% battery derating to yield anticipated availability with the load shedding option. The results are summarized below:

STATION	TYPE	VOLTAGE	CAPACITY (UNIT/COMBINED)	CAPACITY (HRS DURATION)
Indian Point	PWR	125	1320/1584	11.3
Comanche Peak	PWR	125	1950/2340	16.7
Ginna	PWR	125	1050/1260	9.0
Peach Bottom	BWR	250/125	1520/1824	13.6
Brunswick	BWR	250/125	1200/1440	10.7

As a brief review of this table suggests, load shedding appears to offer the requisite DC power for the blackout durations under consideration. On the basis of this cursory review, it is not clear why load shedding was not considered in NUREG/CR-3840.

While this brief analysis does present the benefits of load shedding, this option may not be viable in all cases. For example, there may be additional loads necessary to support plant operations during a blackout which were not considered in the NUREG/CR-3840 inventory of DC requirements. HVAC could be one function which might have to be provided by DC power in a blackout, especially for BWR drywells and small rooms containing important plant equipment (e.g., turbine driven auxilliary feedwater pumps or BWR core cooling equipment). Similarly, the NUREG/CR-3840 assumption of only 0.75 kw for all DC MOV operations appears to be low and additional power might also be required. The nature of these loads would depend on the particular shutdown scenario envisioned.

In addition to load shedding, other battery sources already onsite should also be considered. It may be recalled that only Class 1E batteries are acceptable under the draft revisions of the regulatory guide. However, if neither equipment or seismic qualification is necessary, taking credit for capacity present in non-Class 1E batteries offers a significant enhancement to the DC power capabilities assumed to be available.

The new batteries considered by the NUREG/CR-3840 analysis do not credit load shedding and

The new batteries considered by the NUREG/CR-3840 analysis do not credit load shedding and require a significant amount of room. Since this feature may introduce a design constraint, an incentive was created for the lithium battery option. But introducing these batteries may not be as simple as the NUREG suggests. Lithium batteries are highly reactive and have experienced many instances of fires and explosions. Consequently, there is a need to ensure that their introduction into a power plant environment does not pose additional safety and design requirements which are not addressed in the cost analysis. Since no engineering details are available concerning this option, additional comments are reserved on the technical issues of this option.

The NUREG/CR-3840 analysis of the use of AC-chargers without load shedding also lacks sufficient detail for meaningful comment. For example, an argument is presented for selecting a gas-turbine driver over a diesel driver, primarily on the basis of the potential for common cause failure. This goal would be appropriate if the reliability of gas-turbines were very high and comparable to diesels. However, that assumption may not be valid. Further, gas turbines are not readily available in sizes less than 500 kw and may not be a viable option. Finally, while gas turbines may not be susceptible to common cause failures associated with diesel maintenance, fuel and electrical related failures are not excluded simply by using a different driver. In short, the NUREG fails to make a strong case for the gas-turbine charger over the diesel on the basis of the engineering information presented.

SUBTASK 2 - RCP SEAL COOLING

NUREG/CR-3840 Assumptions

An important contribution to station blackout risk is the potential for losing primary coolant inventory due to reactor coolant pump seal failure. To mitigate this event, the NUREG/CR-3840 analysis considers an AC-independent charging pump in one of four configurations:

(a) Steam-driven turbine generator providing power to an existing motor-driven pump;

(b) Steam-driven turbine directly driving a charging pump;

(c) Dedicated diesel coupled directly to a charging pump; and,

(d) Dedicated diesel-generator providing power to an existing motor-driven charging pump.

The charging pump capacity desired is in the range of 50-100 gpm at full system pressure.

Since cooling to the seal injection heat exchanger would also be lost in a station blackout, two additional DC motor-driven valves would be needed to provide the 1 gpm bleedoff from each RCP. This leakage would vent (flash) directly to containment. For steam-driven turbine options, the additional steam line would tap inside the MSIVs with isolation provided by a normally closed DC-powered motor operated valve. Turbine exhaust steam would be vented to the atmosphere. Otherwise, existing seal injection piping would be used.

For the BWR, high pressure makeup capability is substantial with both High Pressure Coolant Injection (HPCI/HPCS) and Reactor Core Isolation Cooling Systems (RCIC) independent of AC power for operation. Therefore, any additional injection deemed necessary would be directed at maintaining seal integrity. For the boiler, seal injection is not considered to be as significant a concern as the PWR. Additional turbines are ruled out for the BWR due to high costs associated with new drywell pipe penetrations. For this reason, diesel driven equipment is proposed along with a new non-seismic building. If a new pump is added, this pump would be in parallel with the

AC-driven control rod drive (CRD) pumps.

Comments on NUREG/CR-3840 Assumptions

The principal comment on the NUREG/CR-3840 assumptions concerns the need for high pressure makeup in the light of the current understanding of RCP seal failure potential. This potential is presently viewed as having an extremely remote likelihood for large-scale leaks. Consequently, the need for a RCP seal makeup system may no longer be necessary. The importance of this issue is underscored by the fact that the seal injection option represents the bulk (i.e., over 70%) of the backfit costs estimated in NUREG/CR-3840. It should be noted,in contrast, that NUREG-1109 assumes that this modification will not be required (see Table 6, NUREG-1109).

An additional problem with the charging pump concept is that which it does not do. A high pressure seal cooling system such as the one proposed does not address the other cooling issues raised by the proposed station blackout rule. These cooling loads include:

(1) PWR containment cooling (fans and spray) to ensure containment integrity and equipment availability;

(2) PWR primary sampling for boron concentration; and,

(3) Auxiliary and Reactor Building cooling to ensure equipment operability.

Normally, charging pump cooling is another support feature required for long-term operability. This cooling is generally provided by component cooling water either directly or indirectly. Moreover, injection may not be the sole means of ensuring seal integrity since, for many plants, injection merely complements cooling provided to the heat exchanger surrounding the seals. The system providing the cooling is, again, component cooling water, a system not available in a station blackout. Thus, the proposed solutions may not be complete.

SUBTASK 3 - INCREASE CONDENSATE STORAGE TANK CAPACITY

NUREG/CR-3840 Assumptions

The NUREG/CR-3840 proposal for expanding CST capacity is directed at maintaining an ultimate heat sink during a station blackout. For PWRs, this would be provided by a portable diesel-driven fire pump making up to the CST. The turbine-driven auxiliary feedwater pump would provide the necessary feedwater for the steam generators. The water chemistry constraints of BWRs apparently preclude this approach from consideration in NUREG/CR-3840 and a more permanent CST makeup arrangement is proposed. For the BWRs, water would be transferred from the condenser hotwell to the CST using an AC-independent pump. Pump capacity would match usage rate at the approximate time (4 hours) when nominal CST level approaches exhaustion (calculated at 5 hours by Cook and Greene [1981]).

Comments on NUREG/CR-3840 Assumptions

As with the previous discussion provided for Subtasks 1 and 2, the particular problems with the NUREG/CR-3840 proposals concern that which is not included but necessary to completely consider decay heat removal in a station blackout. For BWRs, this would include the impact of an eight-hour station blackout on suppression pool stability and drywell thermal limits, and consequential effects on system operation.

Decay heat removal for a BWR in a station blackout is provided through safety relief valves (SRVs) releasing energy to the suppression pool. Initially, makeup is provided by HPCI/HPCS and RCIC. Later, RCIC alone may be used intermittently to control reactor pressure vessel (RPV) water level. Since no AC power is available, the Residual Heat Removal System (RHR) is not available in the torus cooling mode. Hence, the suppression pool serves as the ultimate heat sink and, itself, has no means of being cooled.

To determine suppression pool temperature in a blackout, a pool heatup analysis was performed for a typical BWR 4 with a Mark I containment . The model plant is assumed to have a 400-day operating history and a thermal power rating of 3293-Mwt. Assuming an initial pool temperature of 95°F, it was found that heat rejection to the torus quickly raises the temperature to 124°F within one hour of blackout initiation based on BTP ASB 9.2 assumptions for decay heat generation rates. Due to the loss of normal heat sink, RPV pressure in this scenario was found to hover near the lowest SRV setpoint, which is nominally 1020 psig. Under these conditions of high pool temperature and RPV pressure, General Electric Emergency Procedure Guidelines call for emergency depressurization to cut-in RHR in order to maintain pool stability. (T. Dente [1982]). But, since the RHR system is not available in a station blackout, the success of this depressurization depends on restoring power prior to losing the RCIC turbines on low steam pressure. Analysis performed at Oak Ridge by Cook *et.al.* [1981] confirms the need for RPV depressurization within the first hour but for another reason. In their analysis early depressurization is necessary to maintain drywell air temperatures below the drywell design temperature of 281°F. While early depressurization limits peak drywell temperatures, it does not prevent the rapid temperature rise to 250-300°F early in the blackout nor does it substantially reduce temperatures through the event.

Cook found that high drywell temperature does not threaten containment structural integrity and short-term survivability of some equipment. However, several problems still remain. High drywell temperatures can seriously affect the accuracy of RPV water level instruments by altering the differential pressure sensed between the reference leg and the vessel itself. (Dente [1982]). Should instrument accuracy erode to the point of yielding false high water level indications, it is possible to receive a high level trip of HPCI, precluding the ability to provide makeup. Overall equipment operability in this environment would also be open to question.

This brief review underscores the complexity of designing a station blackout coping capability. Emergency procedures, design limits and potential system malfunctions all need to be carefully considered as part of proposed modification.These key factors are apparently missing from the NUREG/CR-3840 analysis and detract from its validity.

SUBTASK 4 - INCREASE INSTRUMENT AIR SUPPLY

NUREG/CR-3840 Assumptions

The NUREG/CR-3840 analysis assumes that most compressed air systems are capable of providing sufficient air for 4 hours of operation under blackout conditions. This operability is based on the assumption that receivers constitute 10% of system volume and are normally maintained at 100 psig pressure. At 80 psig, air system loads are assumed in the NUREG/CR-3840 analysis to lose their function. These assumptions are used to justify a proposed doubling of present air capacity to achieve 8-hours of operation, and tripling the air capacity for 16 hours operation.

Since the ANO-1 capacity was not available when NUREG/CR-3840 was prepared, the PWR option is based on an average of the Ft. Calhoun and Palisades instrument and service air capacities. These volumes are reported at 3100 scf and 1000 scf, respectively. The average used in the analysis is 200 scf. The proposed option is based on adding a number of standard 2000 psig bottles yielding 250 scf each. At this rate, between 15 and 45 bottles are deemed necessary.

Receiver capacity for the Quad Cities plant is calculated at 1100 scf, thereby requiring between 2200 scf and 6600 scf for 8 and 16 hour blackouts.

Comments on NUREG/CR-3840 Assumptions

With respect to the particular circumstances of this option, compressed air systems are normally used to operate safe shutdown equipment in a blackout. For PWRs, air systems are normally required for many auxiliary feedwater pump controllers and valves, charging and letdown flow control, atmospheric dump valve operation and containment isolation. Under blackout conditions, BWR air systems are not as essential for control of safe shutdown systems.

It is difficult to comment on the generic analysis of air capacity requirements without having a detailed engineering design to review since the need for air would depend on the blackout scenario, design details, and any assumptions concerning equipment failure. A stuck-open valve or break in a line due to seismic event, environment conditions, or random failures could significantly alter air requirements. In addition, the assumption that operability is lost below 80 psig air pressure is very conservative.

The question of whether air is essential depends on the shutdown scenario. As a general rule, if air is not available to operate the valves, manual operation is always possible. Thus, the significance of these options is not clear.