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A Handbook for Cost Estimating

A Method for Developing Estimates of Cost for Generic Actions for Nuclear Power Plants

Prepared by J. R. Ball, S. Cohen, E. J. Ziegler

Argonne National Laboratory

S. Cohen and Associates, Inc.

United Engineers and Constructors, Inc.

Prepared for
U.S. Nuclear Regulatory
Commission

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Prepared by
J. R. Ball, S. Cohen*, E. Z. Ziegler**

Argonne National Laboratory
9700 South Class Avenue
Argonne, IL 60439

Subcontractors:
*S. Cohen and Associates, Inc.
8200 Riding Ridge Place
McLean, VA 22102

and

**United Engineers and Constructors, Inc.
30 South 17th Street
Philadelphia, PA 19101

Prepared for
Division of Safety Technology
Office of Nuclear Reactor Regulation
and
Cost Analysis Group
Office of Resource Management
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
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CONTRIBUTORS

This report was prepared by Argonne National Laboratory (ANL) for the U.S. Nuclear Regulatory Commission. The work was performed by the ANL Energy and Environmental Systems Division, Special Projects and Industrial Applications Group, S. Cohen and Associates, Inc., and United Engineers and Constructors, Inc.

The following individuals were the principal contributors to this project from their respective organizations:

John R. Ball, Argonne National Laboratory
Sanford Cohen, S. Cohen and Associates, Inc.
E.J. Ziegler, United Engineers and Constructors, Inc.

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SUMMARY

INTRODUCTION AND BACKGROUND

The NRC Office of Nuclear Reactor Regulation (NRR) has established a practice of performing regulatory analyses, including analyses of the cost as well as the benefits, of generic safety issues and of new or revised generic requirements. Generic safety issues are evaluated to assist the NRC in establishing regulatory priorities as part of its internal decision-making process. This handbook has been developed to assist the NRC in: (a) preparing the types of cost estimates required by the Regulatory Analysis Guidelines and internal NRC policy, and (b) estimating cost for the assignment of priorities in the resolution of generic safety issues. This handbook is intended as a roadmap through the complex process of structuring such a cost estimate, identifying the major cost contributors, and identifying sources of cost data for estimating the magnitude of the major cost contributors. The specific goals of the handbook are:

- To provide a consistent methodology and consistent 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 plants.

- To identify all potentially significant cost elements associated with generic requirements and characterize their significance.

- To provide an annotated bibliography of available cost data and economic assumptions.

- To provide a step-by-step example estimate demonstrating the use of the methodology and cost information.

For the purposes of this handbook, and consistent with the Regulatory Analysis Guidelines, the monetary cost of generic requirements is defined as the net cost, expressed in terms of the present value of total lifetime cost, incurred by the public, industry, and government in implementing the requirement for all of the affected plants. It should be stressed, however, that all potentially relevant cost considerations are not addressed. For example, the handbook does not address societal costs such as the effects on unemployment, industry viability, population exposure, and environmental costs, nor the various other secondary costs that may result from implementing the proposed requirement. Furthermore, the types of cost considerations addressed here will be subject to modification based on actual NRC user experience with this handbook. Thus, although on balance this handbook should be viewed as an important tool in supporting the development of NRC cost analyses, it should not be considered the sole or final source of such guidance.

APPROACH

The overall approach used in developing this handbook was to establish a series of sequential steps needed to prepare a total lifetime cost estimate, to provide the NRC analysts with guidance in carrying out each step. The major steps involved in the cost estimating process are:

1. Identify all potentially significant work packages (functional responses) required to implement the requirement.

2. Identify all potentially significant cost elements associated with each work package.

3. Obtain estimates for the cost of each cost element.

4. Organize and aggregate individual costs to obtain total plant cost.

5. Aggregate individual plant costs and other indirect costs to obtain national lifetime cost of implementing the requirement.

The several chapters of the handbook deal with these steps and provide the NRC cost analyst with methods, tools, guidance, and references to carry out the steps.

Chapter 2 of the handbook presents a generic graphical model of the chronological activities required to implement an NRC requirement. The model distinguishes between changes required for a future plant, a plant under construction, and an operating plant.

Chapter 3 consists of a detailed discussion of each of the 49 functional responses (work packages) in the model. The significance of each response is discussed. The cost elements associated with each functional response are provided and discussed. Guidance is provided, where possible, as to when certain cost elements are likely to be of major or lesser significance. Guidelines on dealing with such important costs as backfitting, rework, and labor cost for work in a radiation or congested environment are provided where possible. For each cost element or group of elements, references are provided, where possible, on sources of cost data available to the user. Also, where possible, rules-of-thumb and cost factors are provided to assist the user in assigning realistic cost values to each element.

Having identified and estimated the cost of the major cost elements for a particular requirement, Chapter 4 instructs the user in how to organize and account for all of the capital cost items. Capital costs are separated into direct and indirect costs.

Direct capital costs are organized using an existing nuclear plant cost data base (the Energy Economic Data Base, or EEDB). The EEDB is described in detail, and typical nuclear plant accounts, with cost values, are presented to show organization and to illustrate for the user the relative magnitude of the costs in each of the various accounts in a reference commercial PWR power plant. Guidance is provided on choosing the appropriate level of aggregation of costs to meet the particular need of the case in hand. Where possible, guidance is also provided on how to select the appropriate level of detail for a particular estimate, so as to restrict the level of effort to that necessary for the particular case under study.

A methodology for dealing with indirect capital costs is presented in the form of cost models for engineering and design, nuclear supplier analysis, and construction management activities. The methodology includes organization of cost data and aggregation of detailed cost data for each of the models.

Chapter 5 instructs the user in the methods used to calculate the total, constant-dollar, capital (one-time) cost; the total, constant-dollar, periodic cost; and finally the total, constant-dollar, lifetime cost for the requirement being evaluated.

The total capital cost is simply the sum of the constant-dollar capital costs of each of the major cost sectors evaluated in the previous chapters. The total periodic cost is evaluated on a constant-dollar basis over the remaining life of the plant. This chapter concludes with instructions on evaluating the total lifetime cost of the requirements, either in terms of constant dollars, or preferably as an equivalent present-worth value.

The final chapter of the handbook provides a step-by-step working example of estimating the cost of providing a Technical Support Center for all commercial LWR plants using the methods, references, and other information included in the handbook. The requirement for providing a Technical Support Center is included in NUREG-0578, "TMI-2 Lessons Learned Task Force Status Report and Short-Term Recommendations," dated July, 1979.

A HANDBOOK FOR COST ESTIMATING

A Method for Developing Estimates of Costs for Generic Actions for Nuclear Power Plants

ABSTRACT

This document provides overall guidance to assist the NRC in preparing the types of cost estimates required by the Regulatory Analysis Guidelines and to assist in the assignment of priorities in resolving generic safety issues. The Handbook presents an overall cost model that allows the cost analyst to develop a chronological series of activities needed to implement a specific regulatory requirement throughout all applicable commercial LWR power plants and to identify the significant cost elements for each activity. References to available cost data are provided along with rules of thumb and cost factors to assist in evaluating each cost element. A suitable code-of-accounts data base is presented to assist in organizing and aggregating costs. Rudimentary cost analysis methods are described to allow the analyst to produce a constant-dollar, lifetime cost for the requirement. A step-by-step example cost estimate is included to demonstrate the overall use of the Handbook.

1 INTRODUCTION

1.1 BACKGROUND

For the past 3-4 years, the NRC has been performing regulatory analyses on generic nuclear safety issues, including analyses of the cost of implementing any requirement resulting from the resolution of such issues. The NRC Office of Nuclear Reactor Regulation (NRR) has established a practice of performing regulatory analyses, including analyses of the cost as well as the benefits of generic safety issues and of proposed new or revised generic requirements.* In addition, cost and benefits are evaluated to assist the NRC in establishing regulatory priorities as part of its internal decision-making process concerning generic safety issues. In evaluating these priorities, a method is used that gives each safety issue a priority ranking based on estimates of net safety benefit and total cost to achieve that benefit (Ref: A Prioritization of Generic

*The term "generic requirement" used in the context of this handbook is any requirement that is applied to a class of nuclear plants. The class could encompass all LWRs, PWRs or BWRs; plants of one or more specific nuclear steam supply vendors (Westinghouse, GE, CE, B&W); or as few as two plants having certain design features or other characteristics in common.

Safety Issues, NUREG-0933, Dec. 1983). Regulatory impact analyses (also called value/impact analyses) are performed on proposed requirements to help determine whether the safety enhancement or other public benefit sought is sufficient to justify the estimated cost of implementing the requirement (Ref: Charter of the Committee to Review Generic Requirements and NUREG/BR-0058). Analyses are performed regardless of the form of the requirement; i.e., whether the requirement is a new regulation, an order, a regulatory guide, etc.

General methods and assumptions for performing regulatory impact analyses are described in NUREG/BR-0058. Further guidance relevant to the Office of Nuclear Reactor Regulation is available in the periodically updated NRR Office Letter No. 16. "A Handbook for Value-Impact Assessment" (NUREG/CR-3568) has been recently completed and is available for reference in performing regulatory analyses to which this Cost Analysis Handbook contributes.

1.2 PURPOSE

The purpose of this handbook is to assist the NRC in: (a) preparing the types of cost estimates required by the Regulatory Analysis Guidelines and internal NRC policy, and (b) estimating cost for the assignment of priorities in the resolution of generic safety issues. This handbook is intended as a road-map through the complex process of structuring such a cost estimate, identifying the major cost contributors, and identifying sources of cost data for estimating the magnitude of the major cost contributors. The specific goals of the handbook are:

- To provide a consistent methodology and a consistent set of assumptions to assist the user in preparing absolute as well as comparative cost estimates of generic requirements for light-water-reactor nuclear power plants.

- To identify all potentially significant cost elements associated with generic requirements and characterize their significance.

- To provide an annotated bibliography of available cost data and economic assumptions.

- To provide a step-by-step example estimate demonstrating the use of the methodology and cost information.

1.3 PROBLEMS WITH ESTIMATING GENERIC REQUIREMENTS

The process of estimating the cost of designing, building, and operating nuclear power plants has been going on within the nuclear industry since the first commercial plants were ordered. Although there are various twists to the basic methods used in estimating these costs, depending on who is doing the estimating, the methods are reasonably well defined, and sources of cost data are maintained and tracked by architect-engineers, suppliers, and the utilities. Several data bases exist in both the private and public sectors to assist those involved in new-plant cost estimating.

The task of estimating the cost of implementing a generic regulatory requirement throughout all of the affected sectors of the commercial nuclear community poses a unique set of problems to the user of this handbook. The extent to which these problems are addressed and overcome will determine in large part the success of the user in estimating the true cost of the requirement. These major problem areas are summarized as follows:

- By definition, a generic requirement is a multiplant requirement affecting one or more classes of plants. The manner in which the requirement is implemented and the significant cost areas may vary--perhaps greatly--among the affected plants.

- Generic requirements cover the full spectrum of regulatory authority and therefore can affect such diverse areas of the plant as hardware and structures, procedures, personnel, operating status, etc.

- Generic requirements can be applied to plants covering the full range of plant status, from plants that exist only on paper to plants under construction to operating plants. The status of the plant will likely play a large role in determining the overall cost of implementing the requirement for that plant.

- The user must be directed to focus his efforts on the areas of greatest cost impact for each of the plants involved. At the same time, he must be warned against overlooking potentially significant costs in areas where these costs may not be readily evident.

- The user will find a lack of specific information on the costs associated with plant changes. This is somewhat true in the redesign costs for changes in new plants, largely true for rework costs in plants under construction, and true without question when dealing with the retrofitting costs incurred for plants in operation. Because of this lack of cost data, estimating the cost of plant changes often involves the use of rules of thumb and cost factors in arriving at a cost figure for a particular activity. The lack of information can also result in a major cost area being overlooked altogether.

This handbook has been developed with at least a recognition of the above problem areas. A primary goal is to assist the user wherever possible in overcoming these problems.

To keep the information and data in this handbook reasonably current and to reflect the lessons of user experience, it is intended that the handbook will be periodically updated and revised.

1.4 SCOPE OF THE HANDBOOK

This handbook has been prepared to address the task of estimating the total lifetime cost of generic requirements for commercial light-water-reactor power plants. For these purposes, and consistent with the Regulatory Analysis Guidelines, the monetary cost of generic requirements is defined as the net cost, expressed in terms of the present value of total lifetime cost, incurred by the public, industry, and government in implementing the requirement for all of the affected plants. This includes all costs that are directly caused by the requirement as well as any indirect costs that are clearly and readily traceable to the requirement. This guide does not address societal costs such as the effects on unemployment, industry viability, population exposure, and environmental costs nor the various other secondary costs that may result from implementing the proposed requirement. Although the guide focuses on industry and government costs, the user should be alerted to the possibility of other significant costs not specifically dealt with in this guide. The total cost is considered to be net of all transfer payments such as tax credits, depreciation, and tax payments. Where possible, the handbook provides guidance in dealing with some of the more subtle but important cost effects such as labor productivity in areas of significant radiation and other limiting environments, quality assurance costs, and replacement power costs.

Plant costs considered in the handbook are those costs that are related to and/or support the facilities, personnel and equipment located within the boundary of the plant site. Off-site costs such as shipping and disposal costs that may be affected by a requirement and may be significant are not dealt with specifically in the Handbook. The user should be aware in cases involving such costs that their magnitude should be estimated.

It is appropriate to emphasize at the outset that it is not within the scope of this handbook to provide actual cost data or to carry out any cost estimating or cost analysis. The financial resources available for this project precluded these activities from this effort. The handbook does provide, where inclusion was possible, rules of thumb and other cost factors that may be of benefit to the user in preparing cost estimates.

1.5 ASSUMPTIONS ABOUT USERS

In order to limit the amount of technical information on the design, construction, and operation of nuclear power plants included in the handbook, it has been assumed that the user has as a minimum the professional capabilities generally associated with the following academic credentials and experience:

- B.S. degree in one of the major engineering disciplines associated with commercial nuclear plants, i.e., nuclear, electrical, mechanical, chemical, or structural.

- Several years of experience in the design, engineering, construction, or operation of commercial PWR or BWR power plants.

1.6 LOGIC OF MODEL DEVELOPMENT

One of the major tasks in preparing this handbook was the development of a model that would describe the interaction and identify the significant areas of cost of the major cost sectors that make up the commercial nuclear power community. The following five cost sectors were chosen:

Regulatory Sector

Utility Sector

Engineering and Design Sector

Nuclear Supplier Sector, including the NSS supplier

Constructor Sector

In addition, the public-sector costs, not addressed in detail in this handbook, may be important in certain specific cases.

Outside of the regulatory sector, the role of the other sectors on any given project may be quite different. One utility may carry out much of the engineering and design, procurement, and construction activities as well as the operations itself, while another utility may utilize architect-engineers (A-E) and construction contractors to perform all of the design and construction activities. A survey of several utilities was conducted in order to find a common structure around which to build a model to ensure that all of the major cost functions, regardless of who carried them out, were identified. The survey investigated each utility's response to a set of previously implemented requirements. The common reaction to these requirements was found in a set of generic functional responses carried out by the nuclear industry implementing a regulatory requirement.

For the purposes of evaluating costs, it is not important to identify who actually performs a certain function, but to identify the function being performed. A reliable cost model must include all of the significant activities carried out in response to a generic requirement and the associated costs of these activities. The model presented in Sec. 2 of this handbook is centered around this concept of generic functional responses that are common throughout the industry.

Another major consideration in the development of a cost model for generic requirements is the recognition of the increasing complexity associated with changes involving new plants, plants under construction, and operating plants. Each of these classes of plants contains some unique features that can greatly affect the cost of changes to a plant in a given status. Any successful cost model must capture the significant differences actually encountered in implementing changes to plants of different status.

1.7 ORGANIZATION OF GUIDE

The remainder of this handbook provides a description of a cost estimating method suited for the stated purpose. It also provides guidance for the method's use, annotated references of available cost data, and a step-by-step example cost estimate demonstrating its application.

The process of carrying out a cost estimate for generic requirements involves several sequential steps. It is around these sequential activities that this handbook is organized. The first step is to define the chronology of activities that must be carried out to implement the requirement fully. This chronology can be developed using the general model presented in Chapter 2. Next the work packages associated with each of the major activities must be defined, and the individual elements of cost for each work package must be identified. Guidance in defining the work packages (response functions) and their associated cost elements is provided in Chapter 3. Having identified the cost elements, the magnitude of each cost element must be estimated. Cost data references, cost factors, rules of thumb, and other cost information is provided in Chapters 3 and 4. The large amounts of cost data needed to estimate the total cost of typical generic requirements should be organized in some accounting fashion to insure that all significant costs have been accounted for and to assist in aggregating them to arrive at total cost. Chapter 4 of the handbook is intended to assist the user in this complex task. Finally, the various types of cost, i.e., one-time and periodic, need to be evaluated in a consistent manner to produce a total lifetime cost of the requirement so that consistent comparisons can be made. Chapter 5 of the handbook provides guidance in cost analysis.

1.7.1 Methodology Overview (Chapter 2)

This chapter provides the user with an overview description of the methodology. The chapter begins with a discussion of the utility survey conducted at the outset of the project and the importance of the results of the survey in providing the basis for the model.

Next, a summary of the overall cost model is presented with emphasis on the major activities addressed in the model. Three plant status categories--new plants, plants under construction, and operating plants--are introduced and the significance of each is discussed in relation to cost factors.

Finally, the detailed graphical models for each of the plant categories are presented and discussed in an overview fashion. This discussion highlights the logical flow of information throughout the model and describes in detail the various decision nodes within the model. This section also provides guidance on how the detailed model can be simplified and collapsed to focus the estimating effort on the areas of greatest cost, depending on the nature of the requirement. This allows less detailed, "quickie" estimates to be performed when appropriate.

1.7.2 Functional Responses and Cost Elements (Chapter 3)

This chapter gets to the heart of the handbook with a detailed discussion of the individual functional responses and their associated cost elements. Each of these terms is defined and described. Two major categories of cost, one-time (capital) cost and periodic costs, are introduced and defined.

The bulk of Chapter 3 consists of a detailed discussion of each of the 49 functional responses in the model. The significance of each response is discussed. The cost elements associated with each functional response are provided and discussed. Guidance is provided, where possible, as to when certain cost elements are likely to be of major or lesser significance. Guidelines on dealing with such important costs as backfitting, rework, and labor cost for work in a radiation or congested environment are provided where possible. For each cost element or group of elements, references are provided, where possible, on sources of cost data available to the user. Also, where possible, rules of thumb and cost factors are provided to assist the user in assigning realistic cost values to each element.

1.7.3 Capital Cost Accounting Methodology (Chapter 4)

Having identified and organized the major cost elements for a particular requirement, this chapter instructs the user in how to organize and account for all of the capital cost items. Capital costs are separated into direct and indirect costs.

Direct capital costs are organized using an existing nuclear plant cost data base (the Energy Economic Data Base, or EEDB). The EEDB is described in detail and typical nuclear plant accounts, with cost values, are presented to show organization and to illustrate to the user the relative magnitude of the costs in each of the various accounts. Guidance is provided on choosing the appropriate level of aggregation of costs to meet the particular need of the case in hand. Where possible, guidance is also provided on how to select the appropriate level of detail for a particular estimate so as to restrict the level of effort to that necessary for the particular case under study.

A methodology for dealing with the indirect capital costs is presented in the form of cost models for engineering and design, nuclear supplier analysis, and construction management activities. The methodology includes organization of cost data and aggregating detailed cost data for each of the models.

Although the EEDB has been compiled to provide cost information for new plant construction, much information is included in the data base on the cost of backfitting plants under construction. Chapter 4 of this guide also addresses some of the special problems when dealing with modifications to operating plants and provides cost factors and rules of thumb for these cases where possible.

1.7.4 Cost Analysis Methodology (Chapter 5)

This chapter instructs the user in the methods used to calculate the total, present value of capital (one-time) cost; the total, present value of periodic cost; and finally the total, present value lifetime cost for the requirement being evaluated.

The total capital cost is simply the sum of the present value of capital costs of each of the major cost sectors evaluated in the previous chapters. The total periodic cost is evaluated on the basis of the total constant dollar annual costs summed over the remaining life of the plant and discounted back to the present. This chapter concludes with instructions on evaluating the total present value lifetime cost of the requirements.

1.7.5 Example Cost Estimates (Chapter 6)

Chapter 6 presents an example cost estimate that has been selected to demonstrate as many of the facets of the overall handbook as possible. The format of this chapter is a step-by-step walk through the estimating process for the example. Explanation is provided as appropriate to help the user understand the overall use of the methodology.

This chapter also summarizes recommendations and lessons learned from the application of the model and methods in this handbook to an actual example cost estimate.

2 PRESENTATION OF THE MODEL

This section presents the graphical model developed to identify costs resulting from the implementation of NRC multiplant requirements. The section is divided into four parts. The first part (Sec. 2.1) summarizes the results of case studies that were conducted to assess typical industry response to NRC requirements. The case studies pointed to a consistent framework for disaggregating costs, which has been used in the development of the graphical model, and which is presented in summary form in Sec. 2.2. The detailed model is presented and discussed in Sec. 2.3. Section 2.4 provides guidance in simplifying the model for certain specific applications.

2.1 CASE STUDY RESULTS

Case studies were conducted to assess typical industry response to NRC multiplant requirements. Two recent multiplant requirements were traced through the implementation process at three utilities to uncover patterns of response. The case studies were accomplished by conducting on-site interviews with project managers at nuclear utilities. The nuclear units included in the survey are four operating BWRs, three operating Westinghouse PWRs, two operating Combustion Engineering PWRs, and two Westinghouse PWRs under construction.

The case studies were designed to identify a consistent framework for disaggregating costs. Additionally, the case studies were used to determine the relative magnitudes of the various costs, and which industry sectors typically incur the costs. The contribution of the case studies in guiding the development of the framework of the model is summarized below; the detailed results are presented in Appendix A.

Each of the three utilities surveyed is organized differently. One utility has a project management department under the vice president for engineering, which interfaces with an internal engineering group, an outside architect-engineer, an internal production maintenance group (which in turn interfaces with an outside constructor), and an internal plant operating group. A second utility is split into design/construction and operations, each with nearly complete autonomy. The third utility is partly project-oriented (a nuclear station is considered a project) and partly centrally organized, with engineering, construction, and operations under a single manager of nuclear generation. Some design and construction is performed in-house and some under contract. Purchasing departments are independent of engineering and operations in two of the three utilities. Although it would be possible to identify costs by organizational element at any one utility, it is not possible to generalize on the basis of organization because of the variability between utilities.

Accounting systems also vary substantially from utility to utility. Moreover, the use of accounting elements as the building blocks for this model is impractical because it is difficult to correlate specific accounting elements with regulatory requirements.

Therefore, the case studies dissuaded us from attempting to construct a model using organizational or accounting elements as building blocks. However, a common thread was apparent in tracing the implementation of NRC requirements through the diverse organizations of several utilities. This was the "functional response" to each aspect of the requirement. A functional response is defined as an action or "work package" adopted in response to a regulatory requirement. For example, if a requirement involves new or modified hardware, each utility responds with a design function, whether the function is actually carried out by an internal design department at headquarters or at the plant, or by an outside contractor (architect-engineer). Similarly, if the requirement involves an interaction with the NRC, a licensing function, whether resident within a design group or an operations group, is involved. Similar considerations apply to procurement, equipment installation, training, and other functions.

Similar or identical functional responses were obtained at each utility corresponding to a specific regulatory requirement, even though the organizational structures differed. Moreover, the costs associated with a few of the major functional responses (i.e., detailed design, procurement, and installation) were tracked to some extent by each of the utilities. It is possible to disaggregate the functional responses into their component cost elements (i.e., specific categories of labor, materials, reproduction, etc.) However, quantitative cost data that can be related to specific regulatory requirements are seldom available at this level.

2.2 OVERVIEW OF THE MODEL

The functional responses to regulatory requirements comprise the framework or building blocks of the graphical cost model. The first step in the development of the model was to compose a list of functional responses*, which is given in Table 2.1. The identifiers in parenthesis following each functional response refer to the sector that incurs the cost.** The identifiers are defined as follows:

U = Utility

A-E = Architect-Engineer

C = Constructor

V = Nuclear steam supply system vendor, other equipment vendor, or contractor to the utility or the NRC

N = NRC

G = Federal (other than the NRC), state, or local government

*This initial list is most assuredly incomplete; comprehensiveness can only be approached through review and update.

**In the final analysis, all costs are ultimately borne by the utility and reimbursed by the ratepayers (NRC costs through license fees).

TABLE 2.1 List of Functional Responses

1. Develop a new regulation (N)
2. Develop/change regulatory guide (N)
3. Change/write section of Standard Review Plan (N)
4. Notify project managers, notify licensees, prepare Technical Assignment Control (N)
5. Analyze the requirement (U)
6. Meet with licensee and/or owners' group (N)
7. Meet with NRC (A-E and/or V and/or U)
8. Request OMB clearance (N)
9. Contractor assists NRC in reviewing responses (V and N)
10. Solicit and review responses from licensees (N)
11. Prepare responses for NRC (A-E and/or V and/or U)
12. Solicit and review answers to questions (N)
13. Answer questions from NRC (A-E and/or V and/or U)
14. Perform conceptual design, including unresolved safety question determination, resource estimate, and preliminary schedule (A-E and/or U)
15. Evaluate budget requirements (A-E and/or U)
16. Perform detailed design and/or design review, including specifications for outside procurement (A-E and/or U)
17. Perform safety/risk/reliability analysis (A-E and/or V and/or U)
18. Procure materials and equipment, including preparation of the bid package, evaluation of proposals, and preparation of purchase order (U and/or A-E and V)
19. Plan installation, including detailed procedures, labor requirements, and schedule (C and/or U)
20. Modify structures (V and/or C and/or U)
21. Install, test and maintain hardware (V and/or C and/or U)
22. Inspect hardware (V and/or C and/or U)
23. Develop software (A-E and/or V and/or U)
24. Add to or change record keeping (U)
25. Add to or change reporting (U)
26. Increase nonoperating staff (U)
27. Federal, state, local government participation (G)
28. Impact on international trade (A-E and/or V and/or C)
29. Write/rewrite procedures (V and/or U)
30. Conduct test of system/subsystem (V and/or C and/or U)
31. Write/rewrite training manuals (V and/or U)
32. Train/retrain staff (V and/or U)
33. Write/rewrite Technical Specifications (U)
34. Review Technical Specifications (N)
35. Contractor assists NRC in reviewing design (V and N)
36. Review of design (N)
37. Contractor prepares Technical Evaluation Report (V and N)
38. Prepare Safety Evaluation Report (N)
39. Replacement energy penalty (U)
40. Modify structures in a radiation environment (V and/or C and/or U)[a]
41. Install, test and maintain hardware in a radiation environment (V and/or C and/or U)[a]
42. Draft license amendment (U)

TABLE 2.1 (Cont'd)

43. Review license amendment (N)
44. Contractor assists NRC in inspecting hardware (V and N)
45. Inspect hardware (N)
46. Conduct monitoring/sampling (V and/or U)
47. Change number of operating staff. (U)
48. Change number of maintenance staff (V and/or U)
49. Change in accident cost (U).

[a]There are additional costs for performing these activities in an operating plant.

In many cases, one or another of the cost sectors, or more than one, may be involved. Also, note that the identifier, V, refers to any contractor, other than the architect-engineer or constructor, hired by the utility (or the NRC). This could include, for example, a maintenance contractor hired by the utility to supply craft labor for the installation of equipment.

The structure of the model is based on a chronological presentation of activities, beginning with the establishment of a new requirement and proceeding through the appropriate activities necessary to implement the requirement throughout the industry. The proper flow path through the model for a specific requirement is determined by a series of decision nodes where the analyst is queried about the nature of the requirement and the status of the plant(s) affected. Based on the answers to these questions, the user is directed through the proper logic of the model.

For example, the analyst is queried whether the requirement involves the installation or modification of hardware or structures. If the answer to this question is "yes," the branch of the graphical model leads the analyst to a number of functional responses associated with the installation/modification of hardware/structures. These include the performance of design, procurement of equipment, and installation of hardware, among other functional responses. If the answer to this question is "no," none of these functional responses pertain and the analyst is directed to the next decision node.

This process is repeated until all appropriate activities for implementing the requirement for a plant or group of plants have been addressed. For each functional response identified, an appropriate set of cost elements needed to carry out the response and sources of cost information, where available, are identified. (See Sec. 3).

To emphasize the importance of plant status in the evaluation of regulatory costs, the model is presented in three parts. The first part is intended to represent a planned unit or one under construction that has major structures in place, but few or none of the major systems installed. Thus little or no backfit would be entailed in the event of a hardware modification, unless the structures already in place are affected or long lead-time equipment is involved. Modifications to structures for plants, even at this early stage of construction, could incur significant cost and should be evaluated on a case-by-case basis. Also, this plant typically would not have procedures written, nor personnel trained, nor Technical Specifications written. Typically, such a plant is less than 70% complete.

The second part represents a plant well along in construction, having many or most of the major systems in place. A hardware modification in such a plant would entail substantial backfit. Also, the procedures are assumed to have been written, the training conducted, and Technical Specifications drafted. Typically this plant can be anywhere from about 70% complete to the point of loading fuel.

Finally, an operating plant is depicted in the third part. This part of the model encompasses all of the complexities of the plant in the final stages of construction. In addition, however, hardware modifications may entail backfit in a radiation environment. Modifications to operating plants also often require the purchase of replacement power as a result of plant downtime, reduction in plant electrical output, or reduction in plant availability or capacity factor. Similar plant unavailability costs can result from modifications made during construction, if they cause startup delay.

Figure 2.1 illustrates how the three parts of the model fit together. For ease of presentation, the part of the model that depicts the new plant or the plant in early stages of construction also contains functional responses appropriate to all plants. The part of the model that depicts plants well under construction emphasizes modifications to existing hardware, and also contains activities that are not performed until the latter stages of construction, such as writing procedures and training operating personnel. Finally, the part of the model that depicts operating plants emphasizes hardware modifications carried out in a radiation environment, and also contains activities specific to operating plants, such as the possible purchase of replacement energy. To avoid duplication, the part of the model for plants well under construction is added to the portion of the part of the model for new plants, and the part of the model for operating plants is added to the portion of the part of the model for plants well under construction. In other words, for an operating plant, all three parts of the model must be considered.

The model is subdivided into three parts in order to sensitize the user to the potentially significant impact on costs of making modifications in an operating plant or one under construction, in which many or most of the major systems are already installed. It is not only more costly to design a new piece of hardware around existing systems, but it may be necessary to modify existing systems or structures to accommodate the new equipment. Compounding the complexity and cost of a backfit, the presence of a radiation environment, as in the case of an operating plant, may increase the costs by an order of magnitude or more.

2.3 DETAILED MODEL

The detailed models are presented in Figures 2.2, 2.3, and 2.4 for the new unit or one under construction with few or no major systems installed, the plant under construction with many or most of the major systems installed, and the operating plant, Meetings on New Requirement

Questions and Responses on New Requirement

Regulations, Reg. Guides, and Standard Review Plans

ALL PLANTS

Design for New Plant

Procure Equipment

Install in New Plant

Add Non-Operating Staff

NEW AND EARLY PLANTS

Inspect Hardware

Write Software

Change Reporting

Change Recordkeeping

ALL PLANTS

Redesign

Reinstall

Write Procedures

Train Staff

PLANTS WELL UNDER CONSTRUCTION

Reinstall in Radiation Environment

Purchase Replacement Energy

Add Operating Staff

License Amendment

OPERATING PLANTS

FIGURE 2.1 Illustration of the Three Parts of the Graphical Model

Figure 2.2 GRAPHICAL MODEL FOR A NEW PLANT UNDER CONSTRUCTION WITH NONE OR FEW OF THE MAJOR SYSTEMS INSTALLED

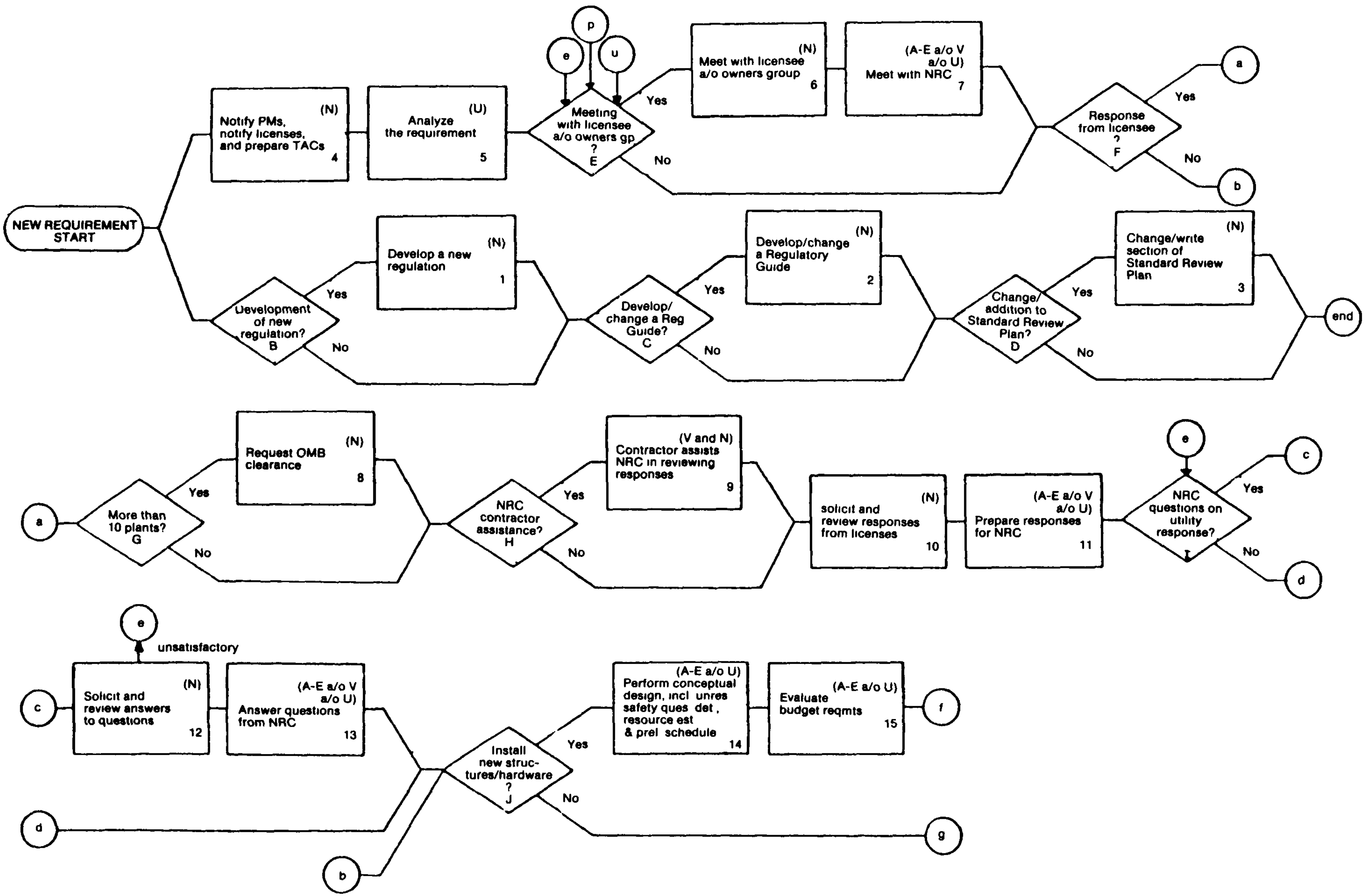

Figure 2.2 GRAPHICAL MODEL FOR A NEW PLANT OR A PLANT UNDER CONSTRUCTION WITH NONE OR FEW OF THE MAJOR SYSTEMS INSTALLED (Cont.)

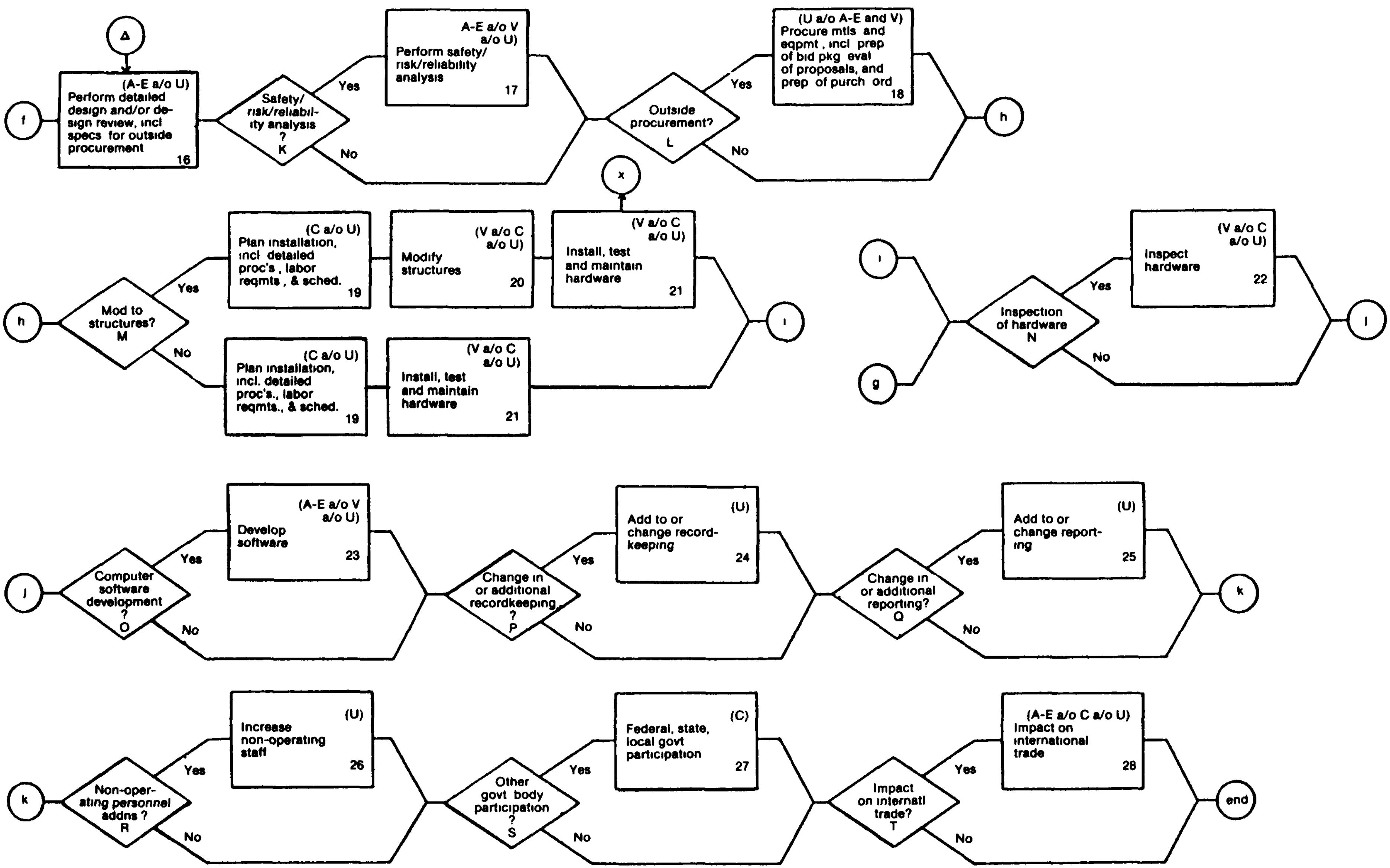

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Figure 2.3 GRAPHICAL MODEL FOR PLANT UNDER CONSTRUCTION WITH MANY OR MOST OF THE MAJOR SYSTEMS INSTALLED

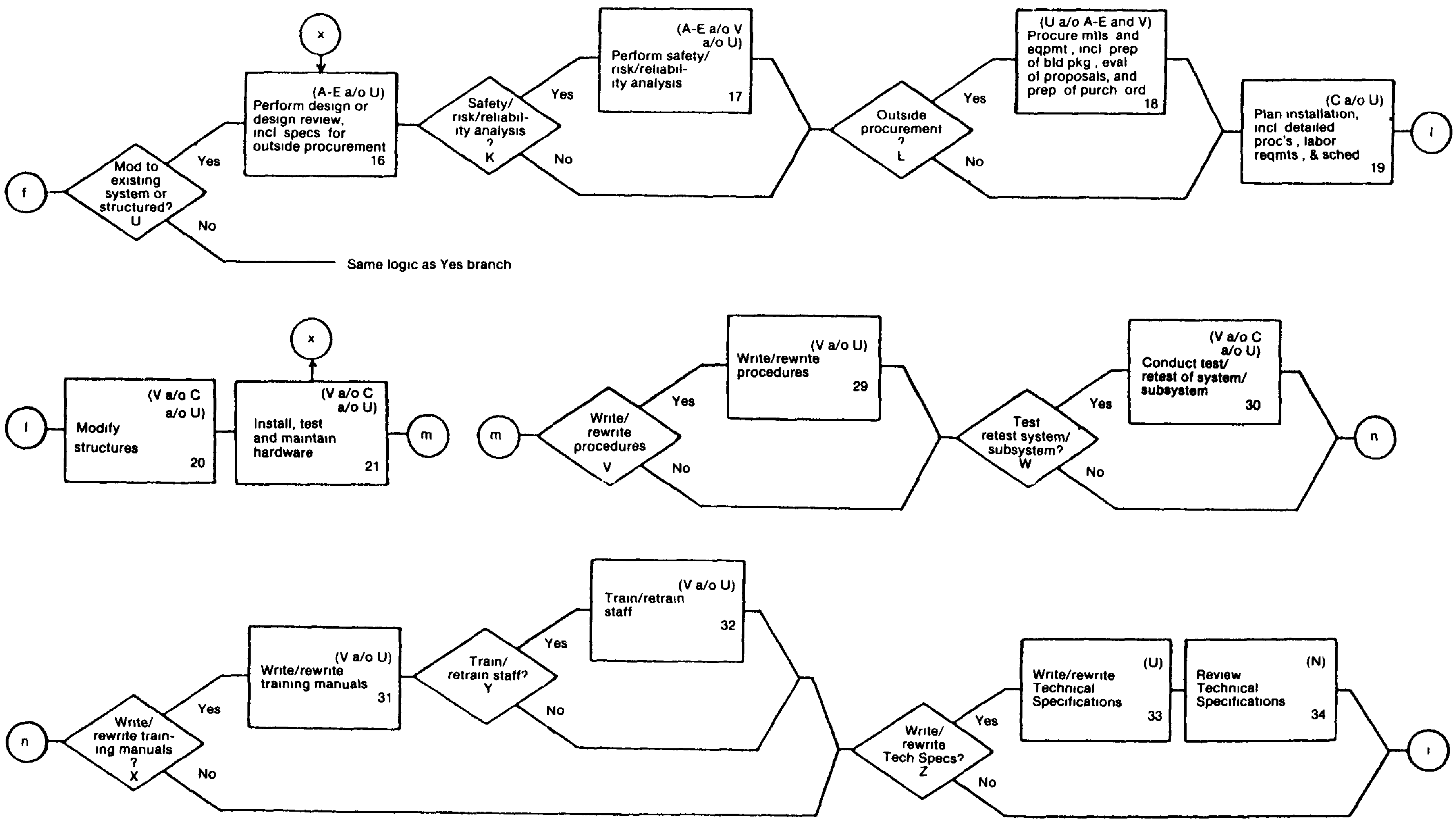

Figure 2.4 GRAPHICAL MODEL FOR OPERATING PLANT

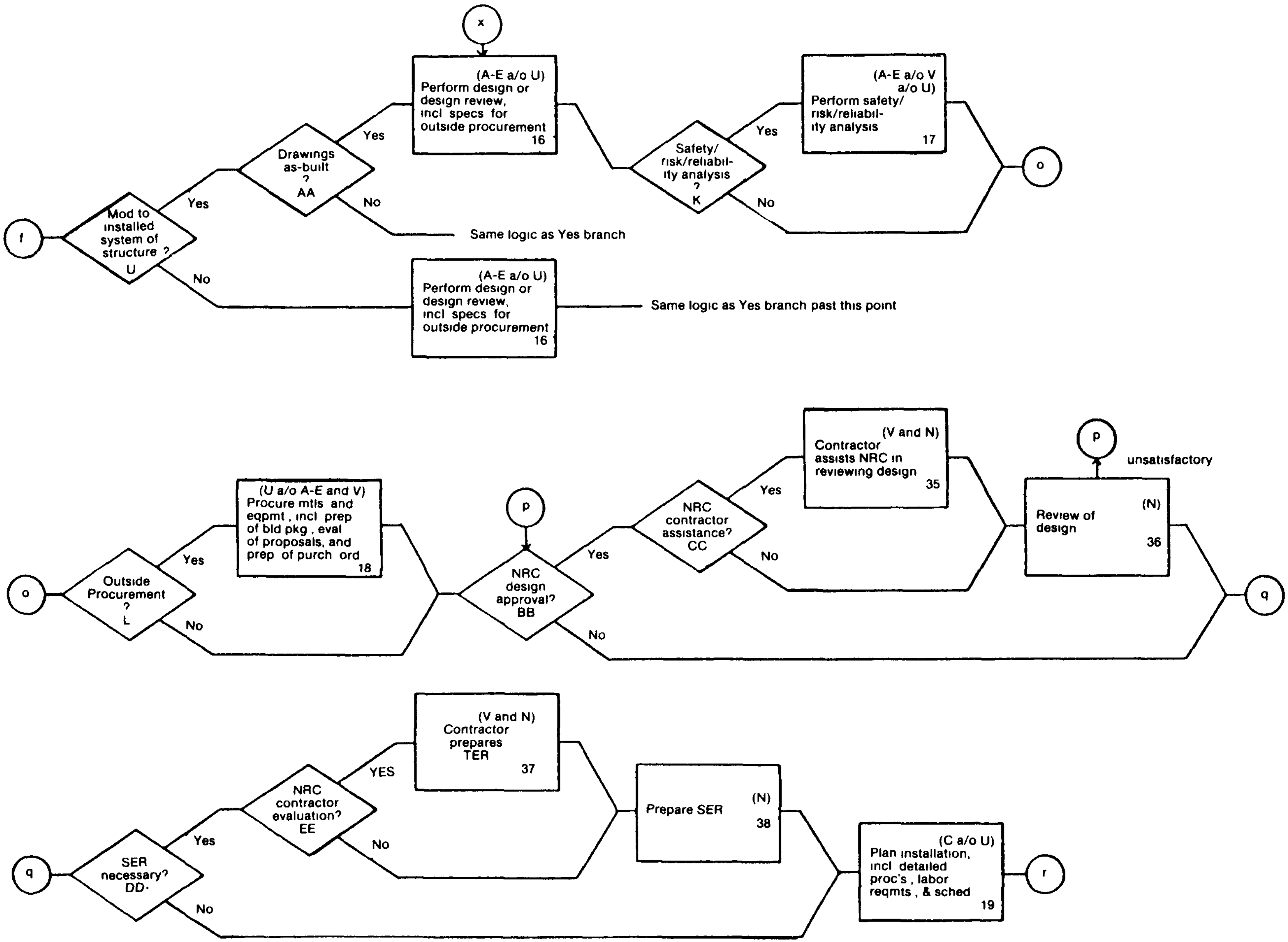

Figure 2.4 GRAPHICAL MODEL FOR OPERATING PLANT (Cont.)

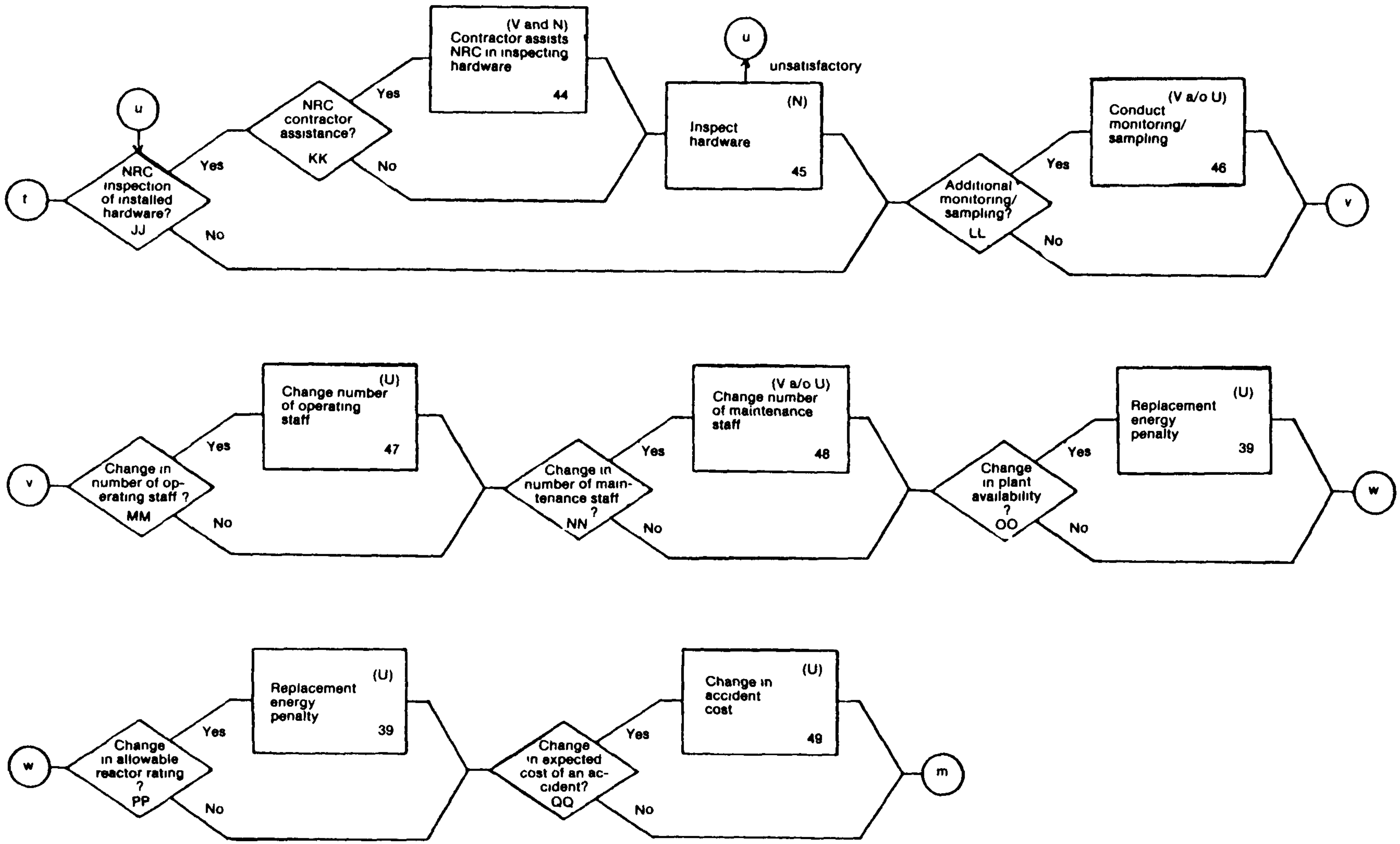

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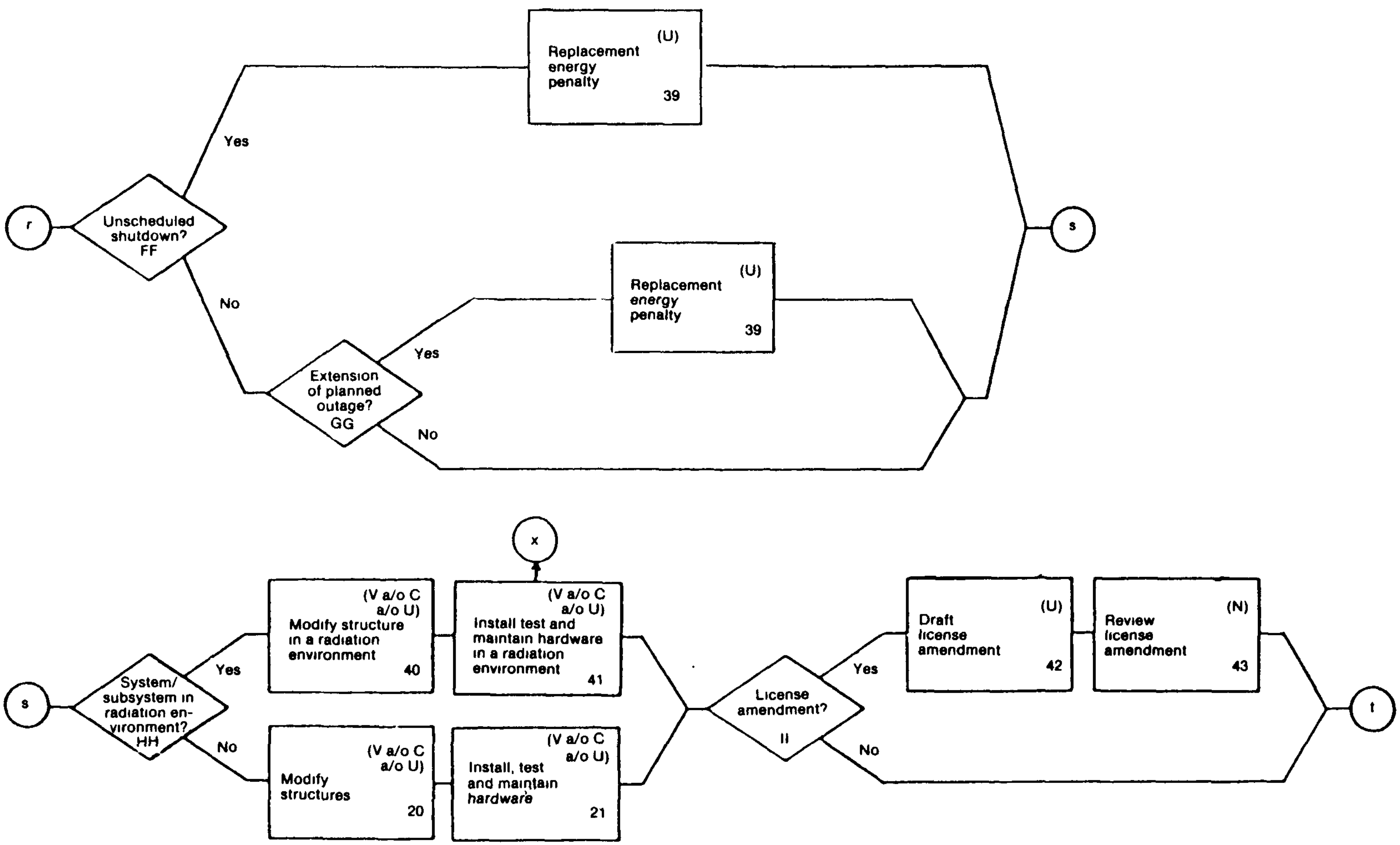
Figure 2.4 GRAPHICAL MODEL FOR OPERATING PLANT (Cont.)



respectively. In each diagram, the decision nodes, or yes-no questions, are denoted by diamonds and identified sequentially by capital letters. The functional responses are denoted by rectangles and identified by the number shown with each response in Table 2.1. The cost sectors defined for Table 2.1, "U" through "6," are identified in the upper right-hand corner of each functional response rectangle. The symbol "a/o" refers to "and/or," suggesting that one or another or more than one cost sector may be involved in a specific response.

The branches in the diagrams are connected by circles containing lower-case letters. Lower-case letters are also used to indicate feedback loops in the models. For example, an unsatisfactory response by the licensee to questions from the NRC may elicit more questions or it may call for another meeting with the licensee (connection e).

Insofar as possible, the functional responses are ordered chronologically. For example, the potential development of a new regulation by the NRC (functional response 1) is shown to be going on simultaneously with the analysis of a new requirement by the licensee (functional response 5). This is a simplification, in that the development of regulations may not be undertaken until considerable dialogue has taken place between the NRC and the licensees. Similarly, some of the functional responses shown in series, such as the design (functional response 16) and safety analysis (functional response 17), may be going on in parallel.

The assumed initial point in time for the analysis is the beginning of the implementation of a new requirement. At this point, the requirement is assumed to be fairly well defined, the approval has been obtained from the Committee to Review Generic Requirements (CRGR), and an implementation plan has been adopted. This omits a number of steps (and costs) prior to the actual implementation of a new requirement, such as research, office approvals, preparation of the regulatory package, and presentations to the CRGR and other review bodies.* This approach assumes that the costs associated with these early steps are incurred in the course of normal NRC business, and are not, therefore, marginal costs attributable to the new requirement. If, however, some of these costs can be directly attributed to a new requirement, the analyst should be aware that such costs could be significant. Also such costs must be included in estimating the costs of resolving an issue, in connection with prioritization of generic-issue resolution efforts.

As discussed in the previous section, the model is presented in three parts to emphasize the importance of plant status in the evaluation of regulatory costs. Comparison with the top branch in Figure 2.3 (f through n) with the corresponding branch of Figure 2.2 (f through i) demonstrates that the separation is more a matter of emphasis than one of substance. Although the contents of the branches are nearly identical, they are displayed separately to alert the user to the potentially higher costs encountered in backfit situations. Similarly the two branches after the decision node U, although identical in structure, are included to emphasize the additional costs of modifying systems and/or structures when these systems or structures are in place.

*In fact, a considerable effort could be expended on the development of a new regulation (functional response #1) prior to CRGR approval. The extent is left open to the user.

As discussed in the previous section, all three parts of the model must be considered in the analysis of an operating plant. Although not as obvious, the inverse is also true. That is, when evaluating a requirement on a new plant, consideration must be given to the eventual impact of the requirement on the same plant when it is further along in construction and when it is ultimately generating electricity. For example, a requirement on a plant in the early stages of construction (Figure 2.2) might affect the training of operating staff (decision nodes X and Y in Figure 2.3). It might also ultimately affect the availability of the plant (decision node OO in Figure 2.4), the allowable reactor rating or the net electrical generating capacity (decision node PP in Figure 2.4), resulting in replacement energy costs (functional response 39). Therefore, all parts of the model must be consulted in a comprehensive analysis.

2.4 SIMPLIFICATION OF THE MODEL

The detailed model presented in Figures 2.2, 2.3, and 2.4 incorporates functional responses that span the full range, in magnitude and complexity, of responses to generic NRC requirements. In particular, many of the NRC functional responses constitute relatively small tasks in comparison with the utility outlays required for a hardware modification. However, these smaller tasks are retained in the detailed model in order to provide the capability to analyze a complete range of possible administrative requirements. Some of these administrative requirements might result in relatively small costs that cannot be neglected because the benefit of the requirement, namely the risk reduction, might also be small. In prioritizing issues, it is the ratio of the risk reduction to the costs that is evaluated.

2.4.1 Collapse of the Model for a Hardware Modification

In the event that a requirement entails a hardware modification, a number of the administrative functional responses identified in the detailed model can be consolidated without jeopardizing the accuracy of the analysis.* A collapsed model is presented for a hardware modification, again in three parts, in Figures 2.5, 2.6, and 2.7. In these diagrams, the identity and numbering of the original detailed functional responses shown in Table 2.1 are retained.

The most significant change in the model is the consolidation of eight early NRC functional responses into the following two (the parenthetical numbers are keyed to Table 2.1):

- Staff administrative actions, including meetings, questions, and review (4,6,8,10,12),

- Develop regulation, regulatory guide, and/or Standard Review Plan modification (1-3),

*Some caution should be exercised by the analyst in accepting this approximation, as it may not be appropriate for all hardware requirements.

Figure 2.5 COLLAPSED MODEL FOR A HARDWARE MODIFICATION IN A NEW PLANT OR A PLANT UNDER CONSTRUCTION WITH NONE OR FEW OF THE MAJOR SYSTEMS INSTALLED

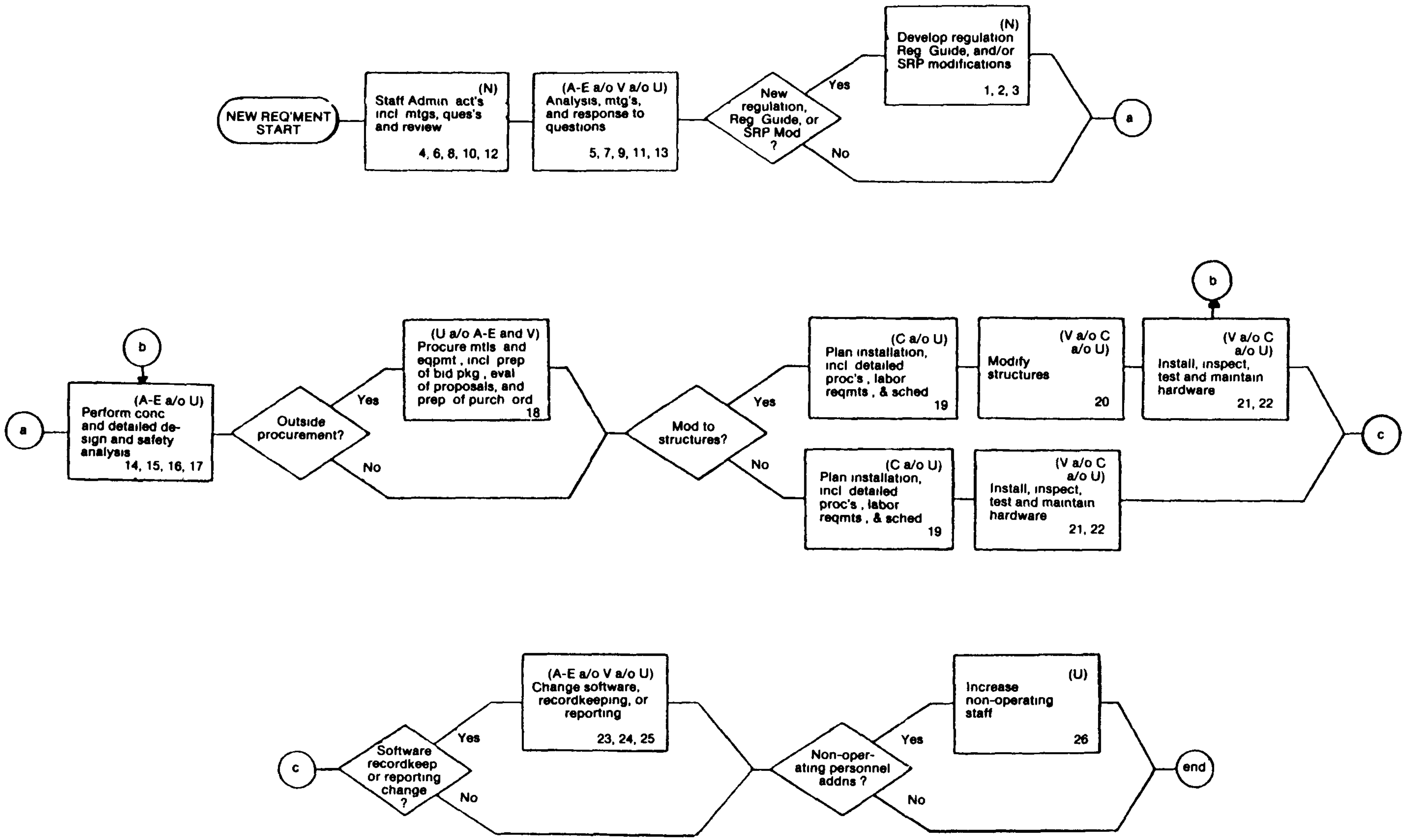


Figure 2.6 COLLAPSED MODEL FOR A HARDWARE MODIFICATION IN A PLANT UNDER CONSTRUCTION WITH MANY OR MOST OF THE MAJOR SYSTEMS INSTALLED

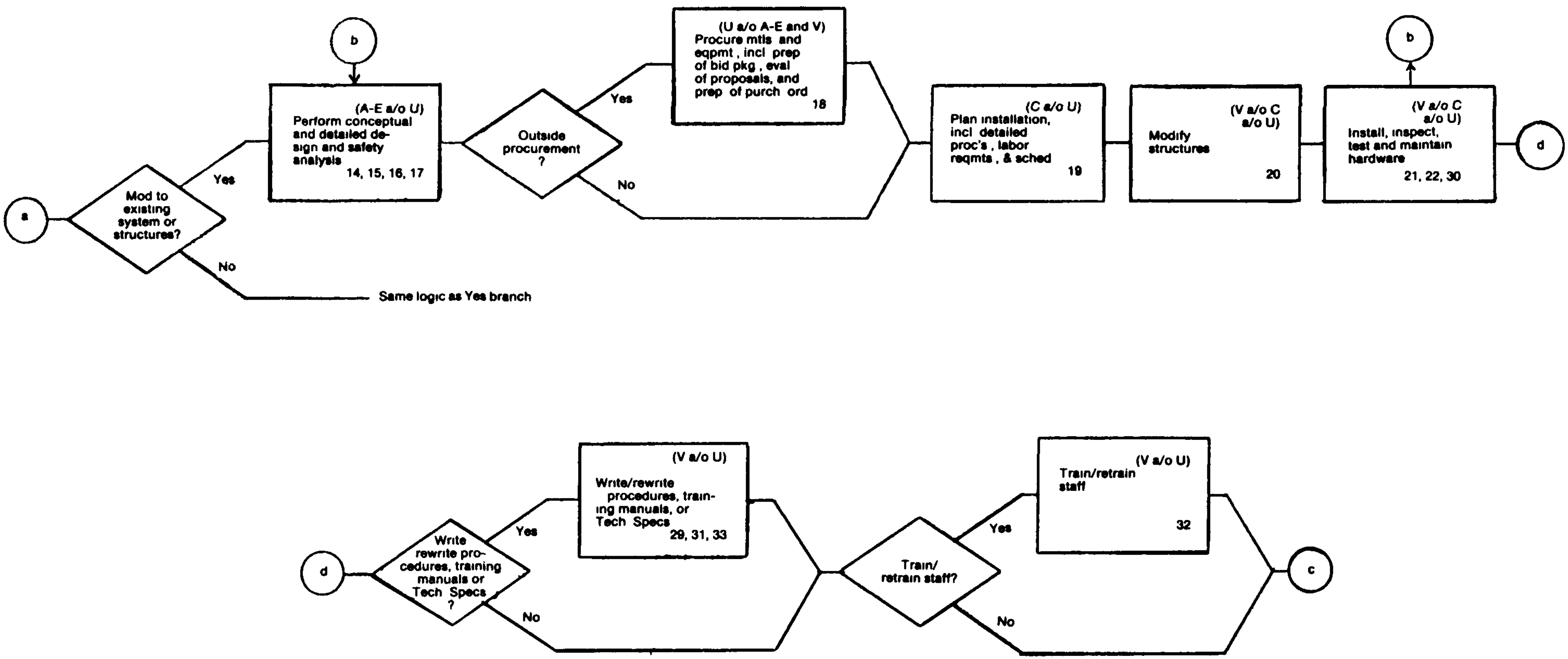


Figure 2.7 COLLAPSED MODEL FOR A HARDWARE MODIFICATION IN AN OPERATING PLANT

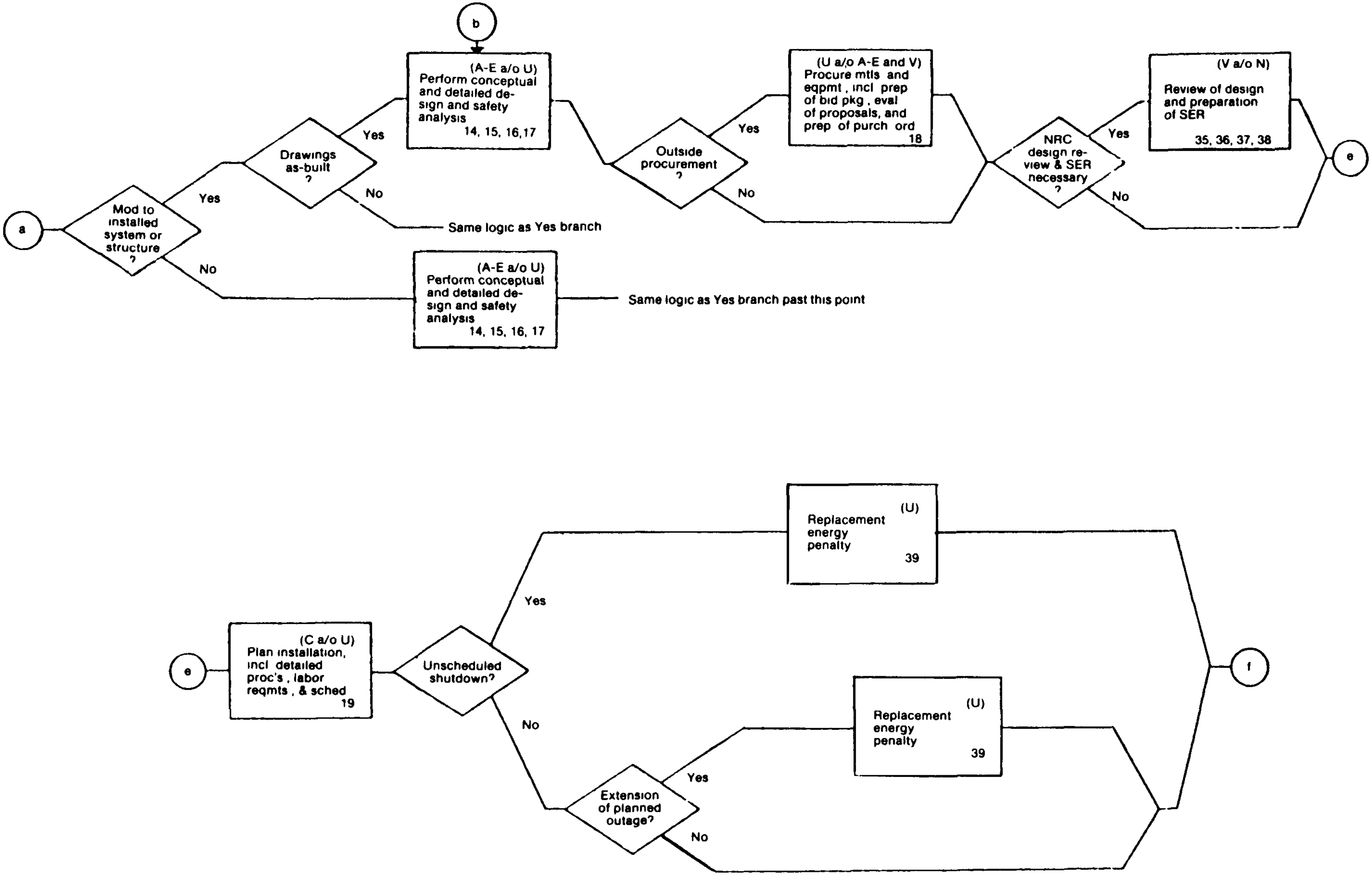
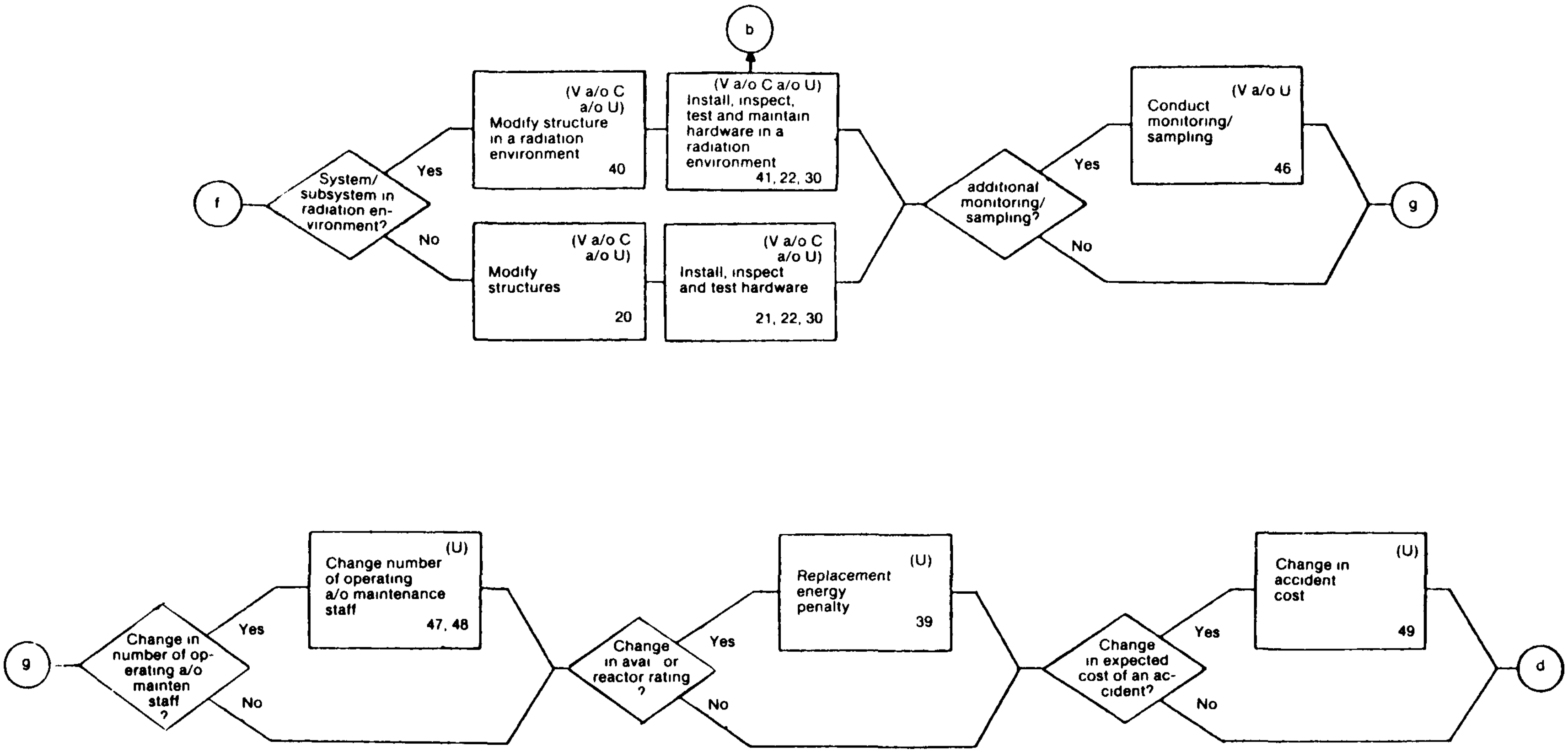


Figure 2 7 COLLAPSED MODEL FOR A HARDWARE MODIFICATION IN AN OPERATING PLANT (Cont.)



and the consolidation of five early industry functional responses into the following one:

- Analysis, meetings, and responses to questions (5,7,9,11,13).

Later administrative tasks are also consolidated, such as the following utility functional response:

- Write/rewrite procedures, training manuals, or Technical Specifications (29-31),

and the following NRC functional response:

- Review of design and preparation of SER (35-38).

Design and safety analysis functions are also consolidated, as in the following:

- Perform conceptual and detailed design and safety analysis (14-17),

and installation, inspection, and testing functions are also consolidated:

- Install, inspect, test, and maintain (21,22,30).

The following functional responses, considered to be either irrelevant or negligible for a hardware modification requirement, were eliminated from this simplified model:

- Federal, state, local government participation (27)
- Impact on international trade (8)
- Write/rewrite Technical Specifications (33)
- Review Technical Specifications (34)
- Draft license amendment (42)
- Review license amendment (43)
- Contractor assists NRC in inspecting hardware (44)
- Inspect hardware (45)

For most hardware modifications, other functional responses could also be eliminated. For example, additions of staff (26,47,48), additional training (32), and additional monitoring (46) do not result from most hardware modifications. However, these functional responses are retained for purposes of generality, and because of the continuing nature of the costs associated with these functional responses, they could be significant for certain hardware modifications.

2.4.2 Collapse of the Model for a Shutdown without Hardware Modifications

In the event of a plant shutdown without a hardware modification, such as an inspection or test, the part of the model that deals with an operating plant can be considerably simplified, as illustrated in Figure 2.8. The functional responses relating to design, procurement, and installation of hardware have been eliminated. Additionally, potential changes in staff, plant availability, and accident costs are not relevant. Only the outage planning, potential purchase of replacement power, hardware inspection, and system testing activities are retained.

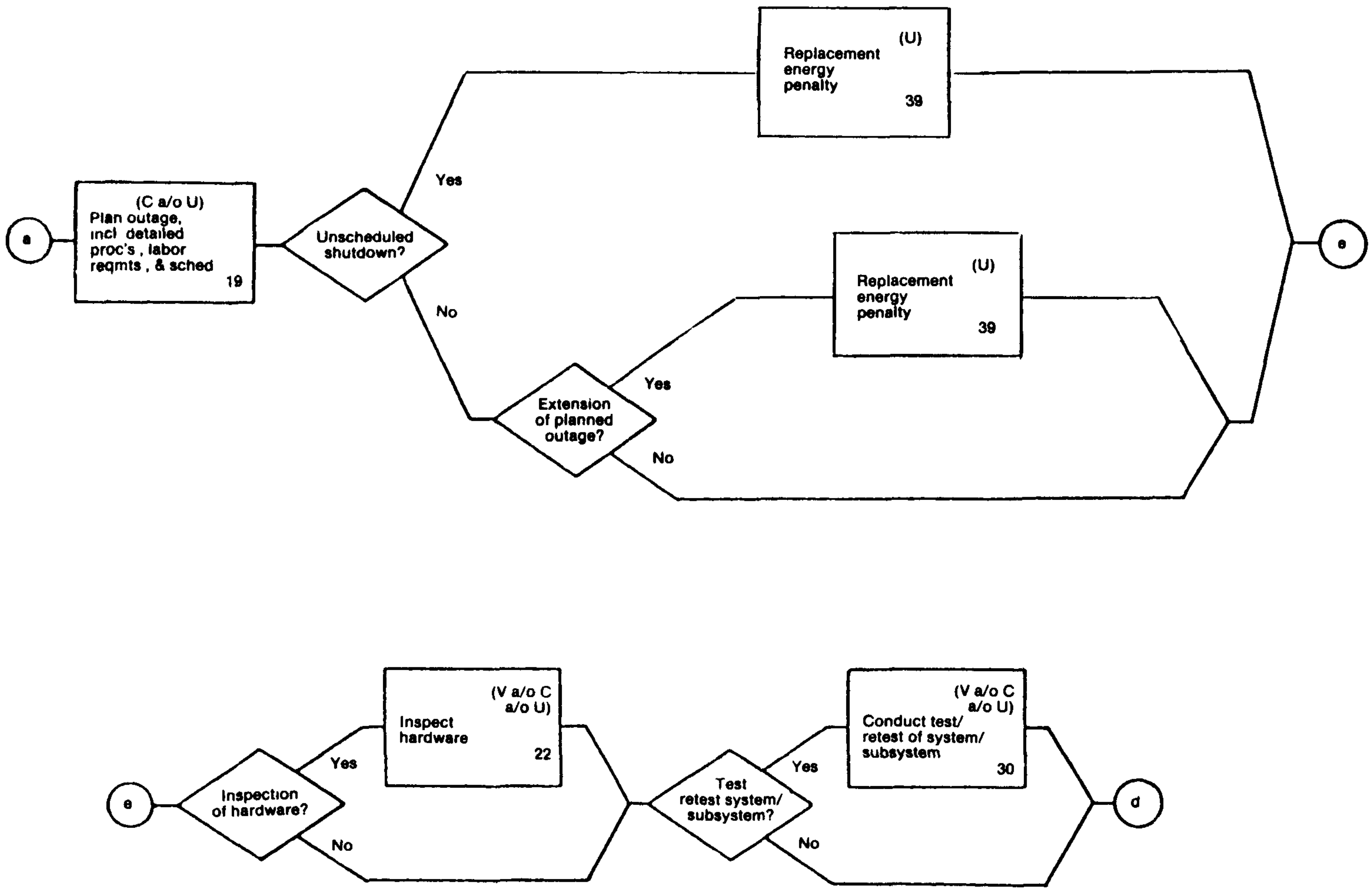
2.5 APPLYING THE MODEL

The cost estimating model presented in this chapter provides a general road map through the process of identifying significant costs for the full range of potential generic requirements and for all possible categories of plants. In practice, the user will be evaluating the cost of a specific requirement affecting a specific number of plants. Section 2.4 provided guidance on simplifying the model to emphasize the likely areas of dominant cost for a particular requirement. This section will assist the user in applying the model so as to minimize the number and scope of the individual activities to be estimated in order to evaluate the overall national cost of implementing the requirement.

The first task in this process is to identify, from the simplified model, which functional responses need be performed only once regardless of the number of plants affected. These activities, which typically involve the regulatory responses, can be estimated independent of any plant specific considerations. The cost of these generic activities can be spread over all of the affected plants.

The remaining functional responses will be carried out on a plant-by-plant basis. Therefore, it is necessary to determine what specific plants are affected by the requirement and how the requirement will be implemented for each plant. To assist the user in this task, Appendix B of this handbook presents a current list of all U.S. commercial nuclear power plants with information on plant status, ownership, type of reactor, etc. for each. Having identified the individual plants to which the requirement applies, the user should attempt to group these plants according to plant type: PWR or BWR; plant status: operating or under construction; or any other grouping that would represent a common method of implementing the requirement. In some cases all affected plants will require a similar type of response and the estimate can be carried out on one representative plant and that cost multiplied by the total number of plants affected. Other cases could involve more than one category of plants, i.e., PWRs and BWRs, with different types of modifications for each. In this case a reference plant could be selected for each category with an associated cost estimate. Plant status could also be important in categorizing how plants respond to a requirement. Operating plants may have no choice but to build new facilities, whereas new plants or plants still under construction could incorporate required changes into existing structures. In some cases, it may be necessary to do a plant-by-plant estimate for each of the affected plants. Such a task would be very time-consuming and costly. Therefore the user is encouraged

Figure 2.8 COLLAPSED MODEL FOR A SHUTDOWN WITH NO HARDWARE MODIFICATIONS IN AN OPERATING PLANT



to take sufficient time initially to identify the smallest number of plant groups to be evaluated so as to minimize the number of estimates to be prepared.

Once the affected plants have been identified and grouped according to common types of response to the requirement, specific changes required for each group need to be identified and developed. These changes may involve structural and hardware modifications, procedural changes, changes in personnel or training, etc. The model presented in this chapter will assist the user in identifying what changes are required, but the user must also develop the specifications for these changes for each group of plants so that their costs can be reasonably estimated. Input from the utilities, A-Es, and/or nuclear suppliers could be valuable in developing these specifications. The more detailed the specifications, the more accurate the cost estimate that can be prepared. Also, the user must be alert to the possibility that a functional response not considered in developing the existing model may be necessary in evaluating the costs associated with a specific requirement. Only through review and update can the model approach comprehensiveness.

Based on the specifications, which spell out the specific changes required, the cost estimate for implementing these changes for each group of plants can be prepared. Chapters 3, 4, and 6 of this guide will assist the user in preparing these estimates.

Finally, the results of the cost estimating process have to be allocated to all affected plants and the individual plant costs aggregated to arrive at the total national lifetime cost of implementing the requirement. Chapters 5 and 6 of this guide will assist the user in this final task.

3 FUNCTIONAL RESPONSES AND COST ELEMENTS

Chapter 2 of this guide presented a graphical model that was developed to assist the NRC analyst in identifying the significant costs associated with the implementation of generic regulatory requirements. The building blocks of this model are functional responses, which are defined as actions or "work packages" performed in response to regulatory requirements. This chapter describes these functional responses in some detail, identifies cost elements associated with each functional response given in the detailed model, and further provides guidance and sources of information potentially useful in evaluating costs. The final section of this chapter discusses the use of simplifying approximations in evaluating costs using the model.

3.1 FUNCTIONAL RESPONSES

The model presented in Chapter 2 is intended to permit the analyst to identify the significant activities that must be carried out in response to the promulgation of an NRC requirement. These activities -- functional responses -- form the basis for evaluating the costs associated with the requirement. A functional response is defined as a well-defined activity in a series of such activities that ultimately results in the implementation of a requirement for a specific plant or group of plants. As an example, a requirement that calls for the installation of a new type of containment radiation monitor at a plant will involve a functional response that deals with the engineering and design of the monitor and associated hardware.

In theory, the cost of each functional response can be evaluated directly, with no further analysis, if the data are available. However, this is rarely the case, and it is usually more convenient to break down the functional response into its constituent cost elements and evaluate the costs of these entities. Cost elements are discussed in the next section.

3.2 COST ELEMENTS

Each functional response can be broken into one or more specific areas of cost that would be incurred in performing the activity. These cost elements address the specific categories of equipment, materials, labor and professional effort to which estimated dollar values are conventionally assigned. The cost elements are the building blocks with which the total lifetime cost estimate can be constructed. Continuing with the example in Section 3.1, the functional response calling for the engineering and design of a containment monitor could involve any or all of the following cost elements:

Project Management Labor	QA or QC Labor
Engineering Labor	Computer Charges
Clerical Labor	Programming Labor
Drafting Labor	

Tables 3.1 and 3.2 provide lists of potentially significant cost elements. For convenience in associating cost elements with specific functional responses, NRC cost elements are listed separately. In the discussion of functional responses given in Sec. 3.4, the cost elements associated with each functional response are identified according to their roman numerals in Table 3.1 and the lower-case letters used in Table 3.2.

3.3 ONE-TIME VS. PERIODIC COSTS

Compiling the cost information for a particular functional response requires knowledge not only of the estimated costs involved, but also of the time behavior of the costs. This is important because in developing a total lifetime cost estimate, one-time and periodic costs are evaluated differently. One-time (capital-cost) items are defined as those costs which are incurred only once in implementing a requirement. Periodic (operating) costs are those costs which continue to be incurred on a periodic basis over the life of the plant.

All one-time costs are estimated on a current dollar basis and reflect the cost of the equipment, material, labor, and effort as if all costs were incurred in the current year. If the overall cost estimate is to be expressed in a year other than the current year, these costs must be inflated or deflated to the year of interest. The method by which this is done is described in Chapter 5.

Periodic costs are not necessarily all annual costs. These costs can be incurred either on a continuing basis or for periods ranging from semiannually to every 5 or 10 years. For example, a requirement that calls for an increase in the plant operating staff would result in an increase in the plant annual operating costs, whereas a requirement for performing an in-service inspection every 10 years would lead to costs being incurred only on that 10-year cycle. In order to account for the periodic costs in a lifetime cost

TABLE 3.1 List of NRC Cost Elements[a]

i.	Office of Nuclear Reactor Regulation Labor
ii.	Office of Research Labor
iii.	Office of Inspection & Enforcement Labor
iv.	Regional Office Labor
v.	Office of the Executive Legal Director Labor
vi.	Technical Support Contract

[a]It is assumed that travel, computer, communications, clerical support, and support from other offices, such as Administration, Resource Management, etc., are applied as overhead burdens to the direct labor cost elements listed in this table.

TABLE 3.2 List of Non-NRC Cost Elements

a. Project Management Labor
b. Engineering Labor
c. Clerical Labor
d. Drafting Labor
e. Programming Labor
f. Administrative Labor
g. Accounting Labor
h. Quality Assurance/Quality Control Labor
i. Executive Labor
j. Craft Supervisory Labor
k. Craft Labor
l. Radiation Protection Labor
m. Security Labor
n. Replacement Power
o. Technician Labor
p. State Official Labor
q. Local Official Labor
r. Federal Official Labor
s. Computer
t. Equipment
u. Materials
v. Simulator
w. Reproduction
x. Storage
y. State Contract/Grant

estimate, these costs need to be expressed in terms of an equivalent, one-time cost in the year of the estimate (constant dollars). The method by which this can be done is also described in Chapter 5.

In the description of the functional responses given in the following section, a distinction is made between those cost elements which are typically one-time costs and those which are periodic costs.

3.4 DESCRIPTIONS OF THE FUNCTIONAL RESPONSES

This section of the handbook describes each of the 49 functional responses identified in Table 2.1 for the model presented in Figs. 2.2-2.4. The cost elements associated with each functional response are identified, and guidance is provided for estimating the value of the cost element and the nature (one-time or periodic) of the cost. The last digit of each of the following subsection numbers corresponds to the numerical designation of each functional response number given in Table 2.1 and the graphical model, and the user is referred to Figs. 2.2-2.4 for an understanding of the linkages between individual functional responses.

3.4.1 Develop a New Regulation (N)

Some requirements involve the development of a new regulation, others do not, and in many cases the need for a new regulation is ambiguous at the time that the cost assessment for the requirement is performed. In any case, the analyst should make an assumption regarding the need to develop a new regulation, because the costs to the NRC may be substantial.

The work involved in the development of the regulation may be quite protracted, possibly extending over a period as long as several years, and involving at least two offices of the NRC. Labor cost elements will involve staff in both offices; thus the cost elements are:

i. Office of Nuclear Reactor Regulation Labor

ii. Office of Research Labor

Labor expenditures for the development of some regulations are tracked in the Regulatory Activities Manpower System (RSAMS). This system is maintained by the Program & Administrative Services Branch, Administration & Resource Control Staff, Office of Nuclear Regulatory Research. The RSAMS System is described in a memorandum to RES personnel from R.M. Scroggins, Director, ARCS, RES, entitled, "Immediate Implementation of Changes in the Manpower System for the Office of Nuclear Regulatory Research," September 17, 1981. The RSAMS System is RES's management information system, formed by a merger of the original Research and Standards systems. The system is similar to the RAMS system maintained by NRR (see functional response #4). Manpower expenditures are tracked according to task numbers from the "Green Book" (NUREG-0566, Standards Development Status Summary Report). Task numbers in the "Green Book" cover regulatory guides, regulations, and standard review plans under development by the Office of Nuclear Regulatory Research.

Although the RSAMS system contains raw data on resource expenditures for the development of some regulations, only limited analyses have been conducted on these data to determine, for example, typical resource expenditures for these efforts.

Salary levels for NRC employees are available in "Budget Estimates Fiscal Year ______," published annually in January for the following fiscal year by the Budget Operations & System Development Branch, Division of Budget and Analysis, Office of Resource Management. This document contains salary levels and benefits for each NRC office and for the NRC as a whole. Data are also available for administrative support, which may be treated as an overhead item for direct labor from the relevant offices (NRR, I&E, and RES). Input data are supplied by the appropriate organs within the NRC offices, i.e., the Planning Resource and Analysis Branch within NRR. From these input sources, branch-specific data may be obtained.

3.4.2 Develop/Change Regulatory Guides (N)

Many requirements entail the development of one or more Regulatory Guides. The development of a Regulatory Guide is the responsibility of the NRC Office of Research (RES). The work involved may be quite protracted, and the resource expenditures substantial. Input may be required from the NRC Office of Nuclear Reactor Regulation as well as the Office of Research. Thus the cost elements are:

i. Office of Nuclear Reactor Regulation Labor

ii. Office of Research Labor

RES expenditures for the development of some Regulatory Guides are tracked in the RSAMS System. The RSAMS System is described in the discussion of functional response #1. Only limited analyses have been conducted on the data contained in this system to determine, for example, typical resource expenditures in the development of a Regulatory Guide. The evaluation of NRR costs is addressed under functional response #4.

3.4.3 Change/Write Section of Standard Review Plan (N)

Many requirements entail rewriting sections of the Standard Review Plan (NUREG-0800), or even adding new sections to that document. The Standard Review Plan is an NRC document that describes what the reviewers look for in their evaluation of a Safety Analysis Report. Input may be required from both the NRC Office of Research and the Office of Nuclear Reactor Regulation. Thus the cost elements are:

i. Office of Nuclear Reactor Regulation Labor

ii. Office of Research Labor

RES labor expenditures for the preparation of the Standard Review Plan are tracked in the RSAMS System, which is described above in the discussion of functional response #1. NRR labor expenditures in connection with the preparation of the Standard Review Plan are tracked in NRR's RAMS System, which is described below in the discussion of functional response #4. Only limited analyses have been conducted on the data contained in either system to determine, for example, typical resource expenditures for the revisions to the Standard Review Plan. The evaluation of NRR costs is addressed under functional response #4.

3.4.4 Notify Project Managers, Notify Licensees, Prepare TACs (N)

After the assignment by the NRC of a lead project manager and a lead engineer to the generic requirement, the lead project manager notifies the relevant plant project managers about the nature of the requirement. Then the licensees are notified. The lead project manager also prepares the paperwork required to track the multiplant requirement in the NRR management information system, known as the RAMS System. This paperwork results in the assignment of a TACs (Technical Assignment Controls) number. The magnitude of the costs associated with this NRC administrative functional response is usually negligible in comparison with industry costs. The relevant cost element is:

i. Office of Nuclear Reactor Regulation Labor

The NRR RAMS System is a management information system that tracks the man-hours spent by NRR personnel in accomplishing various tasks. The system is described in NRR Office Letter No. 27, Rev. 4, "User's Guide to the NRR RAMS System, NRR Planning and Program Analysis Staff, May 12, 1982. Tasks are defined by entering work assignments into the system on TAC Forms (NRC Form 197). TAC Forms contain the titles and brief descriptions of new work assignments, activity codes, relevant facilities and docket numbers, and names of personnel authorized to work on the assignment. NRC staff reference the relevant TAC numbers when they fill out so-called Reviewer Report Forms every week. These forms contain spaces for the number of hours worked and permit the addition or deletion of new case assignments.

The Program and Program Analysis Staff performs periodic assessments of the data contained in the RAMS System. Typical levels of effort for various NRR activities, including multiplant requirements, are evaluated and converted to dollars (using the time and attendance system). Most of this analysis has been performed in support of budget preparation. Although the data have not been analyzed to the level of this functional response, there is a general administrative category that includes these costs.

3.4.5 Analyze the Requirement (U)

Assuming that there is time (this step is frequently bypassed in the interest of expediency), the first action by the utility after receipt of the requirement is to analyze its impact. This may be performed within a licensing group or a project management organization, depending on the organization of the utility. This relatively small effort may involve the following cost elements:

a. Project Management Labor

b. Engineering Labor

i. Executive Labor

Project Management is intended here and in all subsequent functional response to include all professional management and supervisory personnel directly working on the response, not only the overall project manager. Executive labor is normally included in overhead as an indirect cost. However, during the analysis and initial response to NRC regulatory requirements, a disproportionate amount of executive time may be required. Accordingly, it is shown here as a direct cost.

Project management and executive salaries and benefits can be obtained, by subscription, from the annual Edison Electric Institution (EEI) survey, "Annual Wage and Salary Surveys." This survey tabulates executive compensation and benefits for the top ten executive positions, and management, administrative, and professional salaries for 75 jobs. Fringe and overhead rates and the compensation of engineers are also addressed under functional response #26.

Additionally, a recent Electrical World article, "Utility Executive Salaries: How High? How Low?" (Electrical World, pp. 31-35, January 1983), provides estimates of compensation for utility Chief Executive Officers, Chief Operating Officers, and Chief Financial Officers as functions of revenues, kWhr sales, and numbers of employees.

Compensation for utility project managers is also addressed under functional response #7.

3.4.6 Meet with Licensee and/or Owners' Group (N)

For some requirements, a meeting with the licensee is necessary to clarify the requirement or to discuss the utility response. For a requirement specific to a particular type of reactor, the utilities may choose to be represented by an owners' group. The magnitude of the costs associated with this NRC administrative functional response is usually negligible in comparison with industry costs. The relevant cost element is:

i. Office of Nuclear Reactor Regulation Labor

The evaluation of NRR costs is addressed under functional response #4. Although the data in the RAMS system have not been analyzed to the level of this functional response, there is a general administrative category that includes these costs.

3.4.7 Meet with NRC (A-E and/or V and/or U)

For some requirements, a meeting with the NRC is necessary to clarify the requirement or to discuss the utility response. The utility may elect to include in these discussions representatives from its architect-engineer or NSSS vendor. Or, for a requirement specific to a particular type of reactor, the utilities themselves may be represented by an owners' group. Cost elements for this functional response are:

a. Project Management Labor

b. Engineering Labor

Compensation and fringe benefits for project managers and engineers may be obtained from the Edison Electric Institute survey, discussed under functional response #5. Fringe and overhead rates and the compensation of engineers are additionally addressed under functional response #26.

Recent articles in the periodical, Electrical World, also quantify engineers' compensation. One of these, which also includes technicians' salaries, is "The Engineer's Pay: Fatter Than Ever?", Electrical World, pp. 45-48, March 1982. This article gives ranges of utility engineers' salaries as a function of number of years since bachelor's degree, for both supervisors and nonsupervisors, for the year 1981.

A more recent article is "Survey Shows Engineering Salaries Rise 6%," Electrical World, pp. 29-32, July 1983. This report gives average engineering salaries by level of responsibility, branch of engineering, job function, and supervisory/managerial responsibility.

3.4.8 Request Office of Management and Budget Clearance (N)

Any time a government agency formally surveys more than 10 private-sector organizations, a clearance is required from the Office of Management and the Budget. The procedures for obtaining an OMB clearance are described in NRR Office Letter No. 32, Revision 2, "Procedures for Obtaining OMB Clearance," memorandum for all NRR Personnel from Jesse L. Funches, Acting Director, Planning and Program Analysis Branch, August 4, 1982. This memorandum describes the steps necessary to process an OMB Clearance Package, including the completion of Standard Form SF-83.

The NRC cost element for this relatively small administrative functional response is:

i. Office of Nuclear Reactor Regulation

The evaluation of NRR costs is addressed under functional response #4. There are also costs to the Office of Management and Budget in reviewing the request, which are not explicitly identified here.

3.4.9 Contractor Assists NRC in Reviewing Responses (V and N)

The NRC frequently uses contractors to assist the staff in reviewing documentation. It is assumed that the lead engineer monitors the contractor. Therefore, the cost elements are:

i. Office of Nuclear Reactor Regulation Labor

vi. Technical Support Contract

The evaluation of NRR costs is addressed under functional response #4. The costs incurred in the procurement of contractual support, which may be substantial, are assumed to be reflected by the overhead burden on NRR labor. The NRR RAMS system contains a cost category for contractual support, but these data have not been analyzed to provide typical expenditures for this item.

3.4.10 Solicit and Review Responses from Licensees (N)

The NRC may solicit formal responses from affected licensees on proposed methods for compliance. A package describing the information desired must be prepared, and the responses must be reviewed (frequently with help from contractors -- see functional response #9). The information solicited may consist of preliminary or final hardware designs, procedures, or plans. The following NRC cost element is involved:

i. Office of Nuclear Reactor Regulation Labor

The evaluation of NRR costs is addressed under functional response #4. The data contained in the RAMS system have not been analyzed to the level of this functional response; however, there is a general administrative category that includes these costs.

3.4.11 Prepare Responses for NRC (A-E and/or V and/or U)

In responding to a new NRC requirement, a preliminary evaluation is performed to determine whether the new requirement affects the utility's nuclear project, and if so, to prepare a recommendation to the utility. The chain of events for accomplishing this is initiated by a request from the utility to the A-E to review the document, or upon direct receipt of the document by the A-E. Typically, the new NRC requirement is reviewed by a licensing engineer assigned to the nuclear project, who determines its applicability to the project. His recommendation is forwarded to the project's engineering manager, who determines which engineering disciplines are affected. If necessary, speciality technical analysis groups outside of the project are called in, as well as the NSSS vendor. For those projects under construction or in operation, input is also solicited from site engineering and home office construction management. An acceptable engineering response is formulated by the appropriate parties. A recommendation is made to the utility advising what general design changes are necessary, if any, and the estimated cost of such changes. This recommendation in turn is forwarded to the NRC if acceptable by the utility.

The costs of implementing changes generally increase with the percent completion of the plant. Costs are limited to A-E, V, and U manhours and expenses, and vary considerably with the nature of the requirement. Using the Energy Economic Data Base (EEDB) code of accounts, as described in Chapter 4 of this handbook, as a guide for the distribution of costs, they are as follows:

Cost Element	EEDB Code of Accounts
a. Project Management Labor	921 - Primarily -- Home Office Services 923 - Home Office Construction Management
b. Engineering Labor	921 - Primarily -- Home Office Services 922 - Home Office QA 220B - NSSS Vendor Engineering
c. Clerical Labor	

Cost Element	EEDB Code of Accounts
e. Programming Labor	921 - Primarily -- Home Office Services
w. Reproduction	

Cost References: Accounts 921, 922, and 923

1. National Survey of Professional, Administrative, and Clerical Pay, March, 1983 published by the U.S. Department of Labor, Bureau of Labor Statistics (Bulletin 2181).

2. Consultants, Constructors, and Designers to the Power Industry, published by Power Engineering, 1301 S. Grove Ave., Barrington, Illinois 60010.

3. Management Consulting Firms

Cost reference (1) summarizes the results of the Bureau of Labor Statistics annual salary survey of selected white-collar occupations in private industry. This information can be used to develop rough estimates of cost.

References (2) and (3) are provided as possible sources of more specific professional, administrative, technical, and clerical pay scales for the power-generation field. This type of data is generally proprietary information, not available to the public. It may therefore require the retention of an independent consultant to assist in obtaining such data, usually for a fee.

Reference (2) is a listing of representative consulting firms associated with the power industry.

Reference (3) is a general reference to management consulting firms that perform surveys of salary structures of selected occupations in private industry.

Account 220B: NSSS Options - NSSS Vendor Engineering

The costs of NSSS vendor engineering are included in the cost of NSSS equipment, which appears in cost element (t), factory equipment, in functional response #18.

3.4.12 Solicit and Review Answers to Questions (N)

The NRC may have questions on the responses from the licensees. If so, the staff would prepare a list of questions to be answered by the licensees. This work, as well as the review of the answers to the questions, may involve the NRC contractor (see functional response #9) as well as the staff. Also, if the answers are unsatisfactory, or bring up additional questions, there may be another round of questions. The relevant NRC cost element is:

i. Office of Nuclear Reactor Regulation Labor

The evaluation of NRR costs is addressed under functional response #4. The data contained in the RAMS system have not been analyzed to the level of this functional response; however, there is a general administrative category that includes these costs.

3.4.13 Answer Questions from NRC (A-E and/or V and/or U)

All responses to questions from the NRC follow a procedure similar to that described in the discussion of functional response #11. Responses are prepared by the A-E, V, or U or any combination thereof, and require, where necessary, their approval.

Costs are limited to the A-E, V, or U manhours and expenses, and vary considerably with the nature and extent of the questions. The cost elements are the same as and are distributed among the EEDB code of accounts as described in functional response #11.

Cost References: Same as those for functional response #11.

3.4.14 Perform Conceptual Design, Including Unresolved Safety Question Determination, Resource Estimate, and Preliminary Schedule (A-E and/or U)

As part of the preliminary evaluation of a new NRC requirement, as discussed in functional response #11, the affected engineering disciplines perform engineering changes, analyses, and redesign as required. This is accomplished first at the conceptual level to meet the intent of the new NRC requirement. At this level, safety questions and preliminary schedules are addressed to determine the extent of the modifications and changes, if any, that are required. All proposed changes are subject to approval by the utility.

Costs are primarily the A-E home office and utility manhours and/or expenses, and vary considerably depending upon the magnitude of the proposed changes. The cost elements are:

a. Project Management Labor

b. Engineering Labor

c. Clerical Labor

d. Drafting Labor

These cost elements are primarily included in the EEDB code of accounts 921, Home Office Services.

Cost References: Same as those for Account 921 of functional response #11.

3.4.15 Evaluate Budget Requirements (A-E and/or U)

An evaluation of the budget is undertaken if it is determined by the affected engineering disciplines that significant changes and associated costs are required to meet the intent of the new NRC requirement. This evaluation includes estimating the cost of design changes, analyses, procurement, construction, testing, and scheduled changes. This is subject to negotiations with and approval of the utility. Costs are primarily A-E home office and utility manhours and/or expenses, and are relatively insensitive to the complexity of the requirement. The cost elements are:

e. Clerical Labor

f. Administrative Labor

g. Accounting Labor

These cost elements are primarily included in the EEDB code of accounts 921, Home Office Services.

Cost References: Same as those for Account 921 of functional response #11.

3.4.16 Perform Detailed Design and/or Design Review, Including Specifications for Outside Procurement (A-E and/or U)

If it is determined in the preliminary evaluation that design changes are necessary to meet the new NRC requirements, as discussed in functional response #11, and utility approval is received, the detailed design phase of the process is performed. The affected engineering disciplines, as well as the NSSS vendor -- if necessary -- perform the design changes, which may entail new and/or revised drawings, specifications, and system design descriptions along with any needed supporting stress and safety analyses. For projects under construction or in operation, input is also solicited from site engineering and home office construction management. The work is done in considerably more detail than required during the preliminary stage, and is reviewed by all affected parties prior to submission to the utility for approval.

Costs are limited primarily to A-E home office and/or U manhours and expenses. For new construction (no backfit), design costs typically account for about 17% of the total project costs. Backfit design costs are higher, typically 30%. Design costs for modifications to older plants could be higher yet due to the possible unavailability of drawings or questions as to their accuracy. The costs elements are distributed among the following EEDB code of accounts:

Cost Element	EEDB Code of Accounts
a. Project Management Labor	921 - Primarily - Home Office Services 923 - Home Office Construction Management
b. Engineering Labor	921 - Primarily - Home Office Services 220B - NSSS Vendor Engineering
c. Clerical Labor d. Drafting Labor e. Programming Labor h. QA/QC Labor s. Computer	921 - Primarily - Home Office Services 922 - Home Office QA

Cost References: Same as those for functional response #11.

3.4.17 Perform Safety/Risk/Reliability Analysis (A-E and/or V and/or U)

In conjunction with required design changes, analyses of safety, risk, and reliability are performed as required. These analyses are required to assure the credibility of the redesign, and can be highly complex and sophisticated, requiring interfacing of the organizational participants. The greater the number of the analytical groups required and the more complex the changes, the greater the cost. The performance of these analyses is subject to the approval of the utility.

Costs are incurred by the home office operations of the participants, and are distributed as follows:

Cost Element	EEDB Code-of-Accounts
a. Project Management Labor	921 - Home Office Services
b. Engineering Labor	921 - Home Office Services 220B - NSSS Vendor Engineering
c. Clerical Labor e. Programming Labor s. Computer w. Reproduction	921 - Primarily - Home Office Services

Cost References: Same as those for Accounts 921 and 220B of functional response #11.

3.4.18 Procure Materials and Equipment, Including Preparation of the Bid Package Evaluation of Proposals, and Preparation of Purchase Order (A-E and/or V and/or U)

At the same time that the detailed drawings are being revised by the A-E to meet the new NRC requirement, the appropriate engineering disciplines revise the existing procurement specifications or write new specifications for factory-built equipment or hardware. These are transmitted to procurement personnel to purchase the factory-built equipment. Additional costs can be incurred at this time due to vendor construction changes, or changes in equipment that is being fabricated.

Because of the long lead times required to procure and receive nuclear-grade equipment and materials, the timing and expediting of this procurement process can have a large impact on the cost of implementing the requirement at a specific plant. This lead time has a direct affect on the timing and scheduling of construction activities at the plant site. This will usually be of minor importance to new plants or plants in the very early stages of construction, but can be of major importance at plants greater than 70% complete, and for operating plants. After the construction plan has been set, the site equipment and material required to perform the modifications are procured. This stage includes preparation of the bid packages, evaluation of proposals, preparation of the purchase orders, and the actual costs of site equipment and materials. This also involves the services of the construction managers (923 EEDB code of accounts) in conjunction with the utility and A-E sectors. Site equipment costs are indirect costs and include temporary construction facilities and construction tools and equipment (911 and 912 EEDB code of accounts). Site materials are primarily direct costs and include such items as pipe, wire and cable, concrete, steel, etc. (21-26 EEDB code of accounts).

Costs for these activities consist of the home office manhours and expenses of the procuring organizations, and also the cost of the purchase of factory equipment and site materials and equipment.

The costs components are distributed as follows:

	Cost Element	EEDB Code of Accounts	
a.	Project Management Labor	923	- Home Office Construction Management
b.	Engineering Labor	921	- Home Office Services
c.	Clerical Labor	921	- Home Office Services
f.	Administrative Labor	921	- Home Office Services
h.	QA/QC Labor	922	- Home Office Q/A
t.	Equipment - Factory	21-26	- Direct Cost Accounts
	- Site	911 & 912	- Temporary Construction Facilities and Construction Tools and Equipment
u.	Materials	21-26	- Direct Cost Accounts

Cost References: Accounts 921, 922, and 923

Same as those for functional response #11.

Accounts 21-26 (Materials)

1. R. S. Means Co., Inc., Construction Consultants and Publishers, Kingston, MA 02364

   a. Building Construction Cost Data, 1983

   b. Mechanical & Electrical Cost Data, 1983

   c. Means Square Foot Costs, 1983

Cost reference (1a) contains unit prices for building construction items broken down into material, labor, and total costs, as well as total costs including subcontractors' overhead and profit.

Cost reference (1b) contains highly detailed treatment of all mechanical and electrical unit and systems costs.

Cost reference (1c) contains reliable total costs of construction for typical building structures.

2. Energy Economic Data Base, Phase VI, 1983, by United Engineers and Constructors, published periodically by the U.S. Department of Energy

Cost reference (2) presents factory equipment, site labor, and site material costs for nuclear plants sited in the Northeast United States. The data base can be used to ascertain relative costs for factory equipment, site labor, and material for conventional structures and systems and those related to safety. Generalized costs can be obtained from the data base and can be made specific by use of other cost references. The data base can be used as a reference for new construction and therefore used as a gauge for estimating other structure and system costs.

Accounts 25-26 (Factory Equipment)

1. Factory equipment costs (for capital equipment) are best obtained directly from the respective equipment vendors through quotations.

2. Same as for Accounts 21-26, 911, and 912 (Materials) of functional response #18, reference 2.

Accounts 911 and 912 (Site Equipment)

1. Same as that for Accounts 21-26, 911 and 912 (Materials) of functional response #18, reference 1a - fire equipment rental

2. Same as that for Accounts 21-26, 911 and 912 (Materials) of functional response #18, reference 2 - for equipment rental and purchase

3. The purchase of site equipment is best obtained directly from the respective equipment vendors through quotations.

3.4.19 Plan Installation, Including Detailed Procedures, Labor Requirements, and Schedule (C and/or U)

This segment of the process is accomplished in conjunction with the utility, A-E and nuclear supplier sectors, and involves specifying the work to be done to install the equipment in the plant. This includes developing the detailed procedures for accomplishing the work and the construction work schedule, defining the equipment and materials required for construction purposes and specifying the labor required. The costs of these activities are assigned to the construction management and engineers who are responsible for detailing the work procedure (EEDB code of accounts 923).

This stage of the construction planning is significant because it defines the scope of the work to be performed. This effort can be accomplished in a straightforward manner for a plant in the early stages of construction. Plants well along in construction require planning around existing construction activities and may involve planning for work on existing structures and systems. For operating plants, planning may be done within the context of a normal plant outage or a special plant outage, both of which call for precise scheduling and scope definition.

Costs for this effort are limited to organization office manhours and expenses, and could involve assistance from the A-E design organization. The cost elements are as follows:

	Cost Element	EEDB Code-of-Accounts
a.	Project Management Labor	923 - Home Office Construction Management
b.	Engineering Labor	923 - Home Office Construction Management 923 - Home Office Services
c.	Clerical Labor	923 - Home Office Construction Management

Cost References: Same as those for Accounts 921 and 923 of functional response #11.

3.4.20 Modify Structure (V and/or C and/or U)

Modifying structures can be very costly and time consuming. In most cases, construction of new structures requires less time and money than modifying existing structures. Modification of structures becomes more difficult and complex in proportion to the percentage of the plant that is complete. If modifications are to be done to a Seismic Category I structure, the work will be more complex and require more time and materials than a similar modification on a nonseismic Category I structure. This is due to the fact that Seismic Category I structures are designed to more stringent requirements (seismic, aircraft impact, etc.) than nonseismic Category I structures. Modifications may involve adding to or removing portions of existing concrete structures, during which special procedures may be necessary such as the hand chipping of concrete to ensure that no rebar or embedments that are to remain are damaged. Modifications may also require the removal of piping, wiring, and components previously installed. Consideration must also be given to protecting existing equipment, e.g., by the use of equipment coverings, semipermanent shielding walls, and high-powered vacuums to eliminate concrete dust. These modifications may also involve access to and work in confined and hazardous spaces, which may significantly reduce labor productivity. As a result, the cost of modifying existing structures can vary from two to five times the cost of constructing those portions of new structures.

Costs will include all normal field personnel manhours, home office support manhours, and expenses, and may require consultation, assistance, and design changes by the A-E. The cost elements can be detailed as:

Cost Element	EEDB Code of Accounts
a. Project Management Labor	923 - Home Office Construction Management
b. Engineering Labor	932 - Field Job Supervision
h. QA/QC Labor	933 - Field QA/QC
j. Craft Supervisory Labor	
k. Craft Labor	21-26 - Direct Cost Accounts
	913 - Payroll Insurance and Taxes

Cost References: Account 923, 932, and 933

Same as those for Account 923 of functional response #11.

Accounts 21-26 and 913

1. Labor refer to the Construction Industry, 1983, published annually by R. S. Means Co., Inc., Kingston, MA 02364.

2. Same as those for Accounts 21-26, (Materials) of functional response #18, references (1a), (1b) and (2).

Cost reference (1) provides an accurate listing of current hourly union wages for building construction trades in all major U.S. and Canadian cities.

Most of these costs will be from the craft labor and field supervision. For new structures, typical labor, QA/QC, and field support costs are on the order of 30% of the total cost of the new structure. As construction percent increases, these costs will comprise an even larger percentage.

3.4.21 Install, Test and Maintain Hardware (V and/or C and/or U)

Costs for installing hardware vary considerably, depending on the systems involved, the physical location of the components, and the presence of interferences with existing hardware. For example, installation of safety-grade equipment requires a more stringent quality control program than nonsafety-grade equipment, including more inspection and verification, thus affecting labor productivity. Installation within some buildings results in greater costs due to congestion, making work more difficult, e.g., the containment building versus the turbine building. Installation is a one-time cost. However, testing and maintenance may be continuing costs.

The task can involve the removal of portions of other system and their reinstallation to provide access for the new hardware installation. The costs are greater the more complete the plant is prior to the installation of the new hardware. As a result, the cost of installing hardware in an existing plant -- 50% to 100% complete -- can vary from one to five times the cost of such installation at a new plant.

Costs for installation will include all the usual site craft labor costs, supervision, and field support, and may require consultation, assistance, and design changes by the A-E. Cost elements can be detailed as:

	Cost Element	EEDB Code of Accounts	
a.	Project Management Labor	923	- Home Office Construction Management
b.	Engineering Labor	932	- Field Job Supervision
h.	QA/QC Labor	933	- Field QA/QC
j.	Craft Supervisory Labor		
k.	Craft Labor	21-26	- Direct Cost Accounts
		913	- Payroll Insurance and Taxes

Most of this cost will result from the craft labor and field supervision. For plants in early stages of construction, typical labor, QA/QC, and field support costs are on the order of 30% of the cost of the work. As the construction percentage increases, these costs will comprise a larger percentage.

Cost References: Same as those for functional response #20.

3.4.22 Inspect Hardware (V and/or C and/or U)

This task involves inspecting and verifying the quality of the construction work to ensure that installation complies with design and QA programs.

The regulatory requirement may include inspecting existing hardware, in addition to inspecting the modification work performed. In fact, a requirement might also involve periodic inspections, in which case continuing costs as well as initial costs may be entailed. The cost components involved are Field Job Supervision (932), Field Quality Assurance/Quality Control (933), Craft Labor (21-26), and Payroll, Insurance, and Taxes (913). This segment of work is typically performed jointly by the utility and the A-E, and the costs can increase considerably if the inspection is performed in a radiation environment. Much of the work by the construction sector may involve removing equipment, and then replacing the same equipment after the inspection has been performed.

The cost elements are as follows:

	Cost Element	EEDB Code of Accounts
b.	Engineering Labor	932 - Field Job Supervision 933 - Field QA/QC
k.	Craft Labor	21-26 - Direct Cost Accounts
o.	Technician Labor	932 and 933 Accounts

Cost References: Accounts 932 and 933

Same as those for Account 923 of functional response #11.

Accounts 23-16 and 913

Same as those for Accounts 21-26 and 913 of functional response #20, references (1) and (2).

3.4.23 Develop Software (A-E and/or V and/or U)

New requirements may require the development of new computer programs or modifications to existing programs to evaluate parameters such as fuel temperatures, occupational radiation exposures, mechanical stresses, and many other technical factors. This work may involve off-line analysis software or plant operations software. Development of and/or revisions to programs require the modeling of the engineered systems as well as interpretation and application of physical laws, thus requiring engineering personnel, scientists, and computer programmers working as a team.

Costs are primarily centered at the performing organization's home office, and include manhours, expenses, and computer charges. It will include checkout and certification of the software, documentation of the program, and preparation of a user's manual. Costs can range widely, from minor modifications of a few lines of program to the development of new computer codes, which may require tens of thousands of manhours. These costs are relatively independent of the percentage of the plant that is complete. The cost elements are:

	Cost Element	EEDB Code of Accounts
b.	Engineering Labor	921 - A-E Home Office Services
c.	Clerical Labor	220B - NSSS Vendor Engineering
e.	Programming Labor	21-26 - Other Vendor Engineering Equipment
s.	Computer	

Cost References: Account 921

Same as those for Account 921 of functional response #11, plus computer time sharing costs, which can be obtained from the various computer companies.

Accounts 21-26 (including 220B)

Same as that for Account 220B of functional response #11.

3.4.24 Add To or Change Record Keeping (U)

A new NRC requirement might entail the addition of or changes to a record keeping system. The system might be manual or automated. If it is automated, or if the requirement entails conversion to an automated system, hardware procurement and/or software development might be involved. Also, there may be continuing costs as well as initial costs. One type of continuing cost incurred might be the labor associated with an increase in staff to maintain the new or enhanced record-keeping system. Potential utility cost elements are:

Cost Element

a. Project Management Labor
c. Clerical Labor
e. Programming Labor
f. Administrative Labor
s. Computer
w. Reproduction
x. Storage

Compensation and benefits for several categories of utility employees are compiled in the annual EEI survey, which is discussed under functional response #5. Fringe and overhead rates are also addressed under functional response #26.

3.4.25 Add To or Change Reporting (U)

A new NRC requirement might entail additional reporting or changes in the existing reporting system. The system might be manual or automated. If it is automated, or if the requirement entails conversion to an automated system, hardware procurement and/or software development might be involved. Also, there may be continuing costs as well as initial costs. One type of continuing cost incurred might be the labor associated with an increase in staff to compile the data associated with the new or changed reporting requirement. Potential utility cost elements are:

Cost Element

a. Project Management Labor
c. Clerical Labor
f. Administrative Labor
s. Computer
w. Reproduction

Compensation and fringe benefits for several categories of utility employees are compiled in the annual EEI survey, which is discussed under functional response #5. Fringe and overhead rates are also addressed under functional response #26.

3.4.26 Increase Nonoperating Staff (U)

A new NRC requirement might entail the addition of nonoperating utility staff (functional response #47 deals with operating staff). An increase in staff is a continuing cost. Cost elements are:

Cost Element

a. Project Management Labor
b. Engineering Labor
c. Clerical Labor
d. Drafting Labor
e. Programming Labor
f. Administrative Labor
g. Accounting Labor
h. QA/QC Labor
i. Executive Labor
j. Craft Supervisory Labor
k. Craft Labor

Compensation and benefits for several categories of utility employees are compiled in the annual EEI survey, which is discussed under functional response #5. Compensation for utility engineers is addressed under functional response #7. Fringe and overhead rates are also addressed under functional response #26.

Additionally, the International Brotherhood of Electrical Workers publishes annually the "Utility Department Nuclear Guide," which gives current wage schedules for classifications of union worker by individual power station. The data are based on an annual survey. This source would be useful in estimating unit costs of craft supervisory and craft labor.

The Bureau of Labor Statistics publishes monthly data (in BLS Bulletin 1312-5) on employment and earnings throughout the U.S. These monthly data on payroll reports of employers are based on the 1957 Standard Industrial Classification Manual. The data may be useful for some of the categories of utility labor.

It should be noted that this functional response may be redundant with functional responses 11, 13, 14, 15, 16, 17, 18, 19, 22, 24, and/or 25.

3.4.27 Federal, State, Local Government Participation (G)

Federal agencies other than the NRC that are most likely to be involved include the Environmental Protection Agency (radiation standards), the Federal Emergency Management Agency (emergency response), the Department of Justice (anti-trust), the Department of State (export licenses), the Department of Energy (nuclear research), the Health and Human Services Food and Drug Administration (emergency response), and the Department of Transportation (shipments of radioactive materials). State and local agencies may be affected by NRC requirements that relate to siting and emergency preparedness. The involvement of government agencies may entail both continuing and initial costs. The cost elements are:

Cost Element

p. State Official Labor
q. Local Official Labor
r. Federal Official Labor
y. State Contract/Grant

3.4.28 Impact on International Trade (A-E and/or V and/or C)

Foreign sales by architect-engineers, constructors, or vendors might be affected by changes of NRC requirements under their export license responsibilities. Utilities are not likely to be directly affected. Any cost impact under this category is likely to be a continuing cost.

3.4.29 Write/Rewrite Procedures (V and/or U)

A new NRC requirement might entail new or revised procedures for plant operation. The procedures may be written in-house by the utility, by a vendor under contract, or by a combination of the two. The cost elements of this one-time cost are:

Cost Element

a. Project Management Labor
b. Engineering Labor
c. Clerical Labor
h. QA/QC Labor
w. Reproduction

Compensation and benefits of utility engineers and project managers are addressed under functional responses #5 and #7. Fringe and overhead rates and compensation of engineers are additionally addressed under functional response #26.

3.4.30 Conduct Test of System/Subsystem (V and/or C and/or U)

This effort may be a repeat test of a modified system, or the first test if the system was modified during plant construction prior to testing. It may also involve the testing of an additional system. Also, it may entail continuing as well as initial costs.

Costs include the test personnel manhours and expenses of the team involved in the testing. Care must be taken to include only additional testing not costed in the new plant testing program.

The costs elements are as follows:

Cost Element	EEDB Code of Accounts
b. Engineering Labor	932 - Field Job Supervision
h. QA/QC Labor	933 - Field QA/QC
o. Technician Labor	934 - Plant Startup and Test

Accounts 932, 933, and 934

Same as those for Accounts 921, 922 and 923 of functional response #11.

3.4.31 Write/Rewrite Training Manuals (V and/or U)

A new NRC requirement might entail new or revised training manuals for plant operating personnel. The training manuals may be written in-house by the utility, by a vendor under contract, or by a combination of the two. The cost elements for this one-time cost are:

Cost Element

b. Engineering Labor
c. Clerical Labor
h. QA/QC Labor
w. Reproduction

Compensation and benefits of utility engineers are addressed under functional responses #5 and #7. Fringe and overhead rates and compensation of engineers are additionally addressed under functional response #26.

3.4.32 Train/Retrain Staff (V and/or U)

A new NRC requirement might entail training of operating personnel or additional training of already trained personnel. (The development of training manuals to support the training efforts is addressed by functional response #31.) Training may be conducted in-house by the utility, by a vendor under contract, or by a combination of the two. Training may be a one-time or a continuing cost, depending on the nature of the requirement. The cost elements are:

Cost Element

b. Engineering Labor
o. Technician Labor

Compensation and benefits of utility engineers and technicians are addressed under functional responses #5 and #7. Fringe and overhead rates and compensation of engineers are additionally addressed under functional response #26.

3.4.33 Write/Rewrite Technical Specifications (U)

A new NRC requirement could involve the drafting of a new plant operating Technical Specification or the revision of an existing one. This would be a one-time cost incurred directly by the utility and is usually negligible in comparison with other costs. Cost elements are:

Cost Element

a. Project Management Labor
b. Engineering Labor
c. Clerical Labor
i. Executive Labor

Compensation and benefits for utility engineers, project managers, executives, and clerical personnel are addressed under functional response #5. Compensation for utility engineers and project managers is additionally addressed under functional responses #7 and #26. Fringe and overhead rates are additionally addressed under functional response #26.

3.4.34 Review Technical Specifications (N)

The Technical Specifications drafted by the utility must be reviewed for technical and legal content by the NRC staff. The magnitude of the costs associated with this NRC administrative functional response is usually negligible in comparison with industry costs. The relevant cost elements are:

Cost Element
i. Office of Nuclear Reactor Regulation Labor
ii. Office of the Executive Legal Director Labor

The evaluation of NRR costs is addressed under functional response #4. Labor costs by the Office of the Executive Legal Director (ELD) may be included in the overhead costs of NRR staff.

3.4.35 Contractor Assists NRC in Reviewing Design (V and N)

This response provides assistance to the NRC in understanding the design and interpreting the drawings and analyses submitted by an applicant for the purposes of demonstrating that the additions or modifications meet NRC requirements. Costs are dependent upon NRC requests for assistance and include the contractor's home office manhours and expenses, and may require the interaction of many engineering disciplines. Travel to the NRC or other locations may be necessary. Costs are not expected to be significantly affected by the percentage of construction that is complete. The relevant cost element is:

Cost Element	EEDB Code of Accounts
i. Office of Nuclear Regulation Labor	921 - Home Office Services
	220B - NSSS Vendor Engineering

Cost References: Accounts 921 and 220B

Same as those for Accounts 921 and 220B of functional response #11.

3.4.36 Review of Design (N)

For operating plants, the NRC may require the affected licensees to submit for NRC review plans and designs prior to the implementation of modifications. (Review of modification plans for plants under construction would be conducted during the operating license review, and costs incurred would be indistinguishable from that overall review.) This one-time cost would require the following NRC cost element:

Cost Element

i. Office of Nuclear Reactor Regulation Labor

The evaluation of NRR costs is addressed under functional response #4.

3.4.37 Contractor Prepares TER (V and N)

The NRC frequently uses contractors to assist the staff in preparing its Safety Evaluation Report (SER). When a contractor is used in this capacity, a stand-alone document known as a TER, or "Technical Evaluation Report," is prepared. The NRR lead engineer monitors the work of the contractor. The relevant cost elements are:

Cost Element

i. Office of Nuclear Reactor Regulation Labor
vi. Technical Support Contract

The evaluation of NRR costs is addressed under functional response #4. The costs incurred in the procurement of contractual support are assumed to be reflected by the overhead burden on NRR labor. The NRR RAMS system contains a cost category for contractual support, but these data have not been analyzed to provide typical expenditures for this item.

3.4.38 Prepare SER (N)

SER stands for the NRC's "Safety Evaluation Report." This step is shown only in the plant operating phase because it is assumed that during the construction phase, the safety evaluation of a design modification would be reviewed during the operating license proceedings, and would thus be indistinguishable from that overall review. The SER is prepared by the NRR staff (with possible help from a contractor -- see functional response #37). The relevant cost elements are:

Cost Element

i. Office of Nuclear Reactor Regulation Labor

The evaluation of NRR costs is addressed under functional response #4. The NRR RAMS system tracks SER preparation, and some of the data have been analyzed for purposes of budget preparation.

3.4.39 Replacement Energy Penalty (U)

If replacement energy costs result from a regulatory requirement, these costs are likely to predominate. In addition, the considerations leading up to the accrual of a cost for replacement energy are quite complex. First, it must be determined if the requirement would lead to a forced shutdown of the plant at a time other than a planned outage. Then, depending on the season and the status of other units in the system, a determination must still be made regarding the source of replacement energy. Replacement energy may be supplied by the same utility with sufficient excess capacity, or by purchase from another utility or power grid. In either case, as long as the marginal energy source commands a higher cost than the disabled nuclear unit, there will be a replacement energy cost penalty.

Even if it appears possible to accomplish a modification during a planned outage, there still exists a possibility that the work would extend the outage, resulting in the need for replacement energy. Also, it is not possible to evaluate regulatory requirements individually when evaluating the potential for outage extension, since it is the totality of all of the modifications that affects the outage duration. Although it may not be possible for the analyst to take all of these factors into account in determining the need for a replacement energy cost penalty, there should be an awareness of the complexity of the problem.

The most comprehensive and timely compilation of replacement energy costs is contained in the following report:

> "Replacement Energy Costs for Nuclear Generating Units in the U.S.," NUREG/CR-XXXX to be published in October 1984.
>
> This report will provide estimates of replacement energy costs for each of the nuclear units expected to be in operation by early 1986. Replacement energy costs will be provided in units of mills/kWhr and average daily production cost increases. A consistent methodology will be used to estimate the costs, taking into account the regional power pools, and assuming a nominal utility maintenance schedule.

Three earlier reports may contain useful information for the evaluation of replacement energy costs:

1. "Loss of Benefits Resulting from Nuclear Power Plant Outages," NUREG/CR-3045, March 1982.

   This source estimates costs of replacement power in mills/kWhr from case studies on six utility systems, taking into account the regional power pools. The estimates were based on utility simulations, with an attempt to make the estimates consistent.

However, the focus is on the long-term costs of losing a reactor due to an accident. The six plants examined were Zion, Oconee, Prairie Island, Browns Ferry, Indian Point, and Three Mile Island.

2. "A Guide for Reviewing Estimates of Production Cost Increases Resulting from Nuclear Plant Outages," NUREG/CR-XXXX draft September 1982, to be published.

   This report uses information from NUREG/CR-3045 (above) to develop rough rules of thumb for estimating replacement power costs. The percentage of oil-fired capacity in the system, for example, is a first-order parameter.

3. "An Efficient Simulation Approach for Evaluating the Potential Effects of Nuclear Power Plant Shutdowns on Electric Utility Generating Systems," NUREG/CR-3553, June 1983.

   This report describes the computer methodology developed to perform replacement power cost estimates for power pools in a consistent manner.

The actual cost of purchased power for each utility is compiled annually by the Federal Energy Regulatory Commission, using data from FERC-1 (formerly FPC-L) for private utilities, and from FERC-1-F, for publicly-owned utilities. The data are collected and published by the Energy Information Administration (EIA). The relevant EIA publication for private utilities is "Statistics of Privately Owned Electric Utilities, ____ Annual (Classes A and B Companies)," DOE/EIA-0044(__). For publicly-owned utilities, the EIA publication is "Statistics of Publicly Owned Electric Utilities, ___ Annual," published annually by the DOE Energy Information Administration DOE/EIA-0172(_).

3.4.40 Modify Structures in a Radiation Environment (V and/or C and/or U)

In addition to the costs associated with structure modifications on new plants and plants under construction as described under response function #20, the presence of radiation from operating plants poses additional problems and cost. Where work on structures or systems involving a radiation environment are encountered, temporary shielding, personnel radiation protection, training, and additional personnel (to reduce individual exposure time) may all be required. This will result in increased costs as well as lengthened schedules, due to greatly reduced labor productivity as compared to work in a nonradioactive area. In the absence of specific cost data of previous similar work performed in a similar environment, a useful rule of thumb in estimating labor requirements for work in a radiation environment involving all of the special activities identified above is to assume a labor productivity factor of 0.1 when compared with similar activities involving new construction. Except for replacement energy costs, this factor may be the single greatest cost in modifying structures in a plant that is in operation.

Costs will include all normal field personnel manhours, home office support manhours and expenses, may require consultation, assistance, and design changes by the A-E, and can be detailed as:

Cost Element	EEDB Code of Accounts
a. Project Management Labor	923 - Home Office Construction Management
b. Engineering Labor	932 - Field Job Supervision
h. QA/QC Labor j. Craft Supervisory Labor	933 - Field QA/QC
k. Craft Labor	21-26 - Direct Cost Accounts 913 - Payroll Insurance and Taxes
l. Radiation Protection Labor	Operating Costs
m. Security Labor	91 - Construction Services

Cost References: Accounts 911, 923, 932, 933 and Radiation Protection Labor

Same as those for Accounts 921, 922 and 923 of functional response #11.

Accounts 21-26 and 913

Same as those for Accounts 21-26 and 913 of functional response #20, references (1) and (2).

3.4.41 Install, Test and Maintain Hardware in a Radiation Environment (V and/or C and/or U)

In addition to the costs associated with installing hardware in a new plant or plant under construction as described in response function #21, additional costs are incurred for operating plants due to the presence of a radiation environment. Where hardware must be installed in structures or systems that contain radiation, temporary shielding, personnel radiation protection, training, and additional personnel (to reduce individual exposure time) will be required. This will result in increased costs as well as lengthened schedules as compared to work in a nonradioactive area. The use of a labor productivity factor of 0.1, as discussed in Sec. 3.4.40 is applicable to hardware installation in a radiation environment. As stated previously, this may be the single greatest factor in the costs in installing hardware in a plant that is in operation.

Costs will include all the usual site craft labor costs, supervision, and field support, and may require consultation, assistance, and design changes by the A-E costs can be detailed as:

Cost Element	EEDB Code of Accounts
a. Project Management Labor	923 - Home Office Construction Management
b. Engineering Labor	932 - Field Job Supervision
h. QA/QC Labor j. Craft Supervisory Labor	933 - Field QA/QC
k. Craft Labor	21-26 - Direct Cost Accounts 913 - Payroll Insurance and Taxes
l. Radiation Protection Labor	Operating Cost
m. Security Labor	91 - Construction Services

Most of this cost will be from the craft labor and field supervision. For plants in early stages of construction, typical labor, QA/QC and field support costs are on the order of 30% of the cost of the work. As construction percent increases, these costs will comprise a larger percentage.

Cost References: Same as those for functional response #40.

3.4.42 Draft License Amendment (U)

A new requirement may entail a license amendment. Although the contribution of this functional response to the overall utility costs should be negligible, the cost elements involved in drafting the amendment are:

Cost Element

a. Project Management Labor
b. Engineering Labor
i. Executive Labor

Compensation and benefits for utility engineers, project managers, executives, and clerical personnel are addressed under functional response #5. Compensation for utility engineers and project managers is additionally addressed under functional responses #7 and #26. Fringe and overhead rates are additionally addressed under functional response #26.

3.4.43 Review License Amendment (N)

The license amendment drafted by the utility must be reviewed for technical and legal content by the NRC staff. The magnitude of the costs associated with this NRC administrative functional response is usually negligible in comparison with other costs. The relevant NRC cost elements are:

Cost Element

i. Office of Nuclear Reactor Regulation Labor
v. Office of the Executive Legal Director Labor

Plant project managers and technical reviewers are in the Office of Nuclear Reactor Regulation. The evaluation of NRR costs is addressed under functional response #4. Labor costs by the Office of the Executive Legal Director (ELD) may be included in the overhead costs of NRR staff.

3.4.44 Contractor Assists NRC in Inspecting Hardware (V and N)

The NRC Office of Inspection & Enforcement (I&E) occasionally uses contractors to assist in inspection of hardware. The cost elements for this functional response are:

Cost Element

iv. Regional Office Labor
vi. Technical Support Contract

I&E costs are addressed under functional response #45. The I&E management information system ("766" system) presumably contains a cost category for contracts, but the data have not been analyzed to provide typical expenditures for this item.

3.4.45 Inspect Hardware (N)

Once a hardware modification has been made, it may be subject to inspection by the NRC Office of Inspection & Enforcement (I&E). A contractor may assist in the inspection (see functional response #44). The cost elements are:

Cost Element

iii. Office of Inspection and Enforcement Labor
iv. Regional Office Labor

I&E costs are tracked on the I&E "766" system, maintained by the I&E Program Support Branch. The I&E "766" system is so-named because the input to the system (containing approximately 100 data entry items) is entered on NRC Form 766. The system contains the statistics associated with each of the roughly 4000 annual NRC inspections, including the dates, the resulting report(s), the inspection procedures followed, the time devoted to each procedure, and the resulting citations. If a procedure is identified with a generic or multiplant requirement through a "Temporary Instruction," it is included in the system.

Only the very largest effort among the generic or multiplant requirements are assigned "Temporary Instructions" (TIs). Most of the inspections related to generic requirements are conducted during the regularly scheduled inspections (for example, the monthly maintenance inspections) and are not accounted for separately. Thus the costs are hidden within the costs of regular inspection procedures. It would be possible to analyze the existing TIs to determine the resource expenditures for larger inspection efforts associated with generic requirements, but this has not as yet been accomplished.

3.4.46 Conduct Monitoring/Sampling (V and/or U)

A new NRC requirement may entail new or increased monitoring/sampling. The monitoring/sampling may be conducted by utility personnel, by a vendor under contract to the utility, or by a combination of the two. The monitoring/sampling may be performed once, in which case these are only one-time costs, or it may impose a continuing cost. The cost elements are:

Cost Element

b. Engineering Labor
h. QA/QC Labor
l. Radiation Protection Labor
o. Technician Labor

Compensation and fringe benefits for several categories of utility personnel may be obtained from the EEI survey, discussed under functional response #5. Compensation of engineers and technicians is additionally addressed under functional response #7. Fringe and overhead rates and the compensation of engineers are addressed under functional response #26.

3.4.47 Change Number of Operating Staff (U)

A new NRC requirement might entail the addition of operating utility staff (functional response #26 deals with nonoperating staff). An increase in staff is a continuing cost. Cost elements are:

Cost Element

b. Engineering Labor
c. Clerical Labor
f. Administrative Labor
h. QA/QC Labor
l. Radiation Protection Labor
m. Security Labor
o. Technician Labor

Compensation and benefits for several categories of utility employees are compiled in the annual EEI survey, which is discussed under functional response #5. Compensation for utility engineers and technicians is addressed under functional response

#7. Fringe and overhead rates and compensation for engineers, are addressed under functional response #26.

It should be noted that this functional response may be redundant with functional responses #22, 24, 25, 29, 30, 31, 32, and 46.

3.4.48 Change Number of Maintenance Staff (V and/or U)

A new NRC requirement might entail the addition of maintenance personnel, either on a one-time basis, or on a continuous basis. The maintenance personnel may be employees of the utility, or they may be contracted for from a vendor. If the requirement can be accomplished on a one-time basis, or during periodic refueling outages, the increase in staff is more likely to be provided by a contractor. Cost elements are:

Cost Element

b. Engineering Labor
c. Clerical Labor
f. Administrative Labor
h. QA/QC Labor
j. Craft Supervisory Labor
k. Craft Labor
l. Radiation Protection Labor
m. Security Labor
o. Technician Labor

Compensation and benefits for several categories of utility employees are compiled in the annual EEI survey, which is discussed under functional response #5. Compensation for utility engineers and technicians is addressed under functional response #7. Fringe and overhead rates, as well as compensation for engineers and craft personnel, are addressed under functional response #26.

It should be noted that this functional response may be redundant with functional response #47.

3.4.49 Change in Accident Cost (U)

Theoretically, an NRC requirement should reduce either the probability or the consequences of a major accident. If a major accident were to occur, the utility would be liable for very large costs for plant rehabilitation (e.g., Three Mile Island). (We do not include here the concomitant environmental, off-site property, and public health costs.) Thus, a new NRC requirement has a negative cost (or a benefit) relating to a potential accident. Although difficult to evaluate, this includes essentially all of the cost elements considered in other functional responses.

Several reports have been written providing estimates of the cleanup costs for Three Mile Island, Unit 2. (See, for example, "TMI-2 Recovery Program Estimate," General Public Utilities Corp., July 1981.) On a more generic basis, Sandia National Laboratories estimated the financial consequences of accidents to the involved utilities ("Estimates of the Financial Consequences of Nuclear Reactor Accidents," Sandia National Laboratories, NUREG/CR-2723).

3.5 SIMPLIFYING APPROXIMATIONS

The costs associated with a number of the functional responses, particularly those attributed to the NRC, are small in comparison with others. These response functions with relatively small associated costs are retained in the detailed model in order to provide the capability to analyze a complete range of possible administrative requirements. However, even for those requirements that do not entail hardware modifications at the plants, some of the NRC functional responses can be consolidated and others neglected. For example, NRC functional responses #4, 6, 8, 10, and 12 can be consolidated into a single NRC administrative task that includes initial organization, meetings, questions, and review. The NRR RAMS system tracks these activities in a single administrative category. However, even this consolidated administrative activity can probably be neglected in comparison with the development of a new regulation (functional response #1) or regulatory guides (functional response #2). These activities may extend over several years and consume several man-years of effort. Typical resource expenditures are available from the NRR RAMS system and the RES RSAMS system.

Several NRC functional responses performed during the latter stages of response to a regulatory requirement also entail relatively small costs and can probably be neglected. These are the review of technical specifications (functional response #33), review of license amendment (functional response #36), and inspection of hardware (functional response #45). Indeed, these activities are rarely tracked in any of the NRC management information systems. The preparation of the Safety Evaluation Report (SER) (functional response #38) may entail a substantial effort, and can probably be combined with the design review (functional response #36). Resource expenditures for SER preparation are tracked by the NRR RAMS system. Some of the data have been analyzed for budget preparation purposes, so that generic estimates of levels of effort in SER preparation are available.

3.5.1 Collapse of the Model for a Hardware Modification

Section 2.4.1 presents a collapsed version of the detailed model for the case in which a regulatory requirement involves a hardware modification. This simplification incorporates the approximations to the NRC functional responses contained in the previous section. It additionally collapses several of the early stage industry actions (functional responses #5, 7, 9, 11, and 13) into a consolidated administrative task that includes initial analysis, meetings, and response to questions. The cost evaluation of these activities would be difficult under any circumstance, because the tasks are generally performed by senior utility personnel as part of their overall licensing functions.

Industry administrative tasks, such as the development of technical specifications (functional response #34) and license amendments (functional response #42), are neglected, as are functional responses #27 (federal, state, and local government participation) and functional response #28 (impact on international trade), not considered relevant to a hardware modification. Also, some of the activities are collapsed into a single functional response. For example, the design and design-related tasks, encompassing functional responses #14, 15, 16, and 17, are consolidated into a single activity entitled, "perform conceptual and detailed design and safety analysis." This is convenient from a cost analysis perspective, because most of the cost data that encompass design include all of these tasks. Similarly, installation (functional response #21), inspection (functional response #22), and testing of hardware (functional response #30) are consolidated. These tasks are also likely to be consolidated in cost data that encompass installation.

For purposes of generality, the collapsed model retains additions of staff (functional response #26, 47, and 48), training (functional response #32), and monitoring (functional response #46), but these activities do not result from most hardware modifications and can thus be neglected. Similarly, most hardware modifications do not result in changes to software (functional response #23), record keeping (functional response #24), or reporting (functional response #25), but these activities are retained as a consolidated activity for purposes of generality. Drafting of revised procedures (functional response #29), training manuals (functional response #30), and technical specifications (functional response #31) generally do result from hardware modifications, but these are collapsed into a single activity for purposes of simplicity.

For most hardware modifications, the costs of design, procurement, and installation of hardware predominate, and the administrative activities can usually be neglected. These activities are presented as five collapsed functional responses in Figures 2-6, 2-7, and 2-8, encompassing the detailed functional responses #14 through 22, 30 (for a plant well under construction and an operating plant), and 40 and 41 (for an operating plant). The costs of the design function can be approximated generically without evaluating the associated cost elements, using rules of thumb presented elsewhere in this report or estimates in the open literature. Equipment procurement costs must be evaluated on a case-by-case basis using, for example, the EEDB data base. As discussed in Chapter 4, studies of nuclear plant capital costs have shown that 85% of the direct costs are tied up in structural commodities, the nuclear steam supply system, the turbine generator unit, piping and duct work, electric plant and instrumentation and controls, cooling towers and condensers. Considerable care must be exercised, however, in evaluating the costs of equipment destined for a nuclear power plant because, as discussed elsewhere in this report, the quality assurance requirements on safety-grade equipment can elevate the cost substantially. Installation costs can also vary substantially, depending on the extent of the job, whether it is a new installation or a backfit, and whether the job must be performed in a radiation environment. Although it is not possible to derive generic installation costs, the effects of the complications can be factored into new installation cost estimates, and these rules of thumb are discussed elsewhere in this report.

The foregoing is premised on the assumption that the hardware modification is carried out during a scheduled outage. If the requirement necessitates an unscheduled shutdown, the cost of replacement power could well dominate the costs associated with the hardware modification itself, depending on the length of the shutdown, the need for replacement power, the availability of excess capacity from the utility, and the marginal cost of the replacement power. The evaluation of the cost of replacement power is not a trivial analysis, but for those cases in which this cost element predominates, there is a consolation in the absence of other cost elements to consider.

3.5.2 Collapse of the Model for a Shutdown without Hardware Modifications

Section 2.4.4 presents a collapsed version of the detailed model for the case in which a regulatory requirement leads to a shutdown of an operating plant without a hardware modification. Thus the functional responses relating to design, procurement, and installation of hardware have been eliminated. Moreover, the functional responses relating to potential changes in staff, plant availability, and accident costs are not relevant. A very simple model results, in which only hardware inspection (functional response #22) and system testing (functional response #30) remain for the cases in which replacement power is unnecessary. If replacement energy is necessary, the cost of the replacement energy is the only cost element requiring evaluation.

4 CAPITAL COST ACCOUNTING METHODOLOGY

This chapter of the handbook presents a methodology that can be used in estimating the capital (one-time) costs associated with implementing an NRC requirement when such a requirement calls for changes to plant hardware or structures. Chapter 2 of this handbook identified certain functional responses that deal with the design, engineering, procurement, installation and modification of components and structures as a result of an NRC requirement -- functional responses #16, 17, 18, 19, 20, and 21. Chapter 3 identified the general cost elements associated with these functional responses. When a regulatory requirement leads to significant modification of a plant's hardware or structures, estimating the cost of these plant modifications will likely require a higher level of detail of cost breakdown than that represented by the cost element breakdown. Because of the complexity involved in identifying, costing, and aggregating all of the individual costs encountered when a physical plant change is necessary, a detailed accounting system to identify and track these costs is a valuable tool. This chapter describes just such an existing accounting system and explains how it can be fully utilized.

As stated in Chapter 2, the first task that the analyst faces in evaluating the plant-specific costs associated with the requirement is to determine what specific plants are affected by the requirement and how the requirement will be implemented for each plant. To assist the user in this task, Appendix B of this handbook presents a current list of all U.S. commercial nuclear power plants with information on plant status, ownership, type of reactor, etc., for each. Next the user should attempt to group these plants into the smallest number of categories that represent similar types, and therefore costs, of plant modifications. For each plant category, specifications need to be developed to define the specific changes to be made. These specifications will provide the basis for the required changes and will therefore determine the costs for such changes.

Having identified and grouped all of the plants affected by the requirement, and having specified the nature of the changes resulting from the requirement, the user is faced with the task of estimating the capital cost of the requirement for each plant or groups of plants. It is this task that will be dealt with in this chapter.

The principles of power plant capital cost accounting are illustrated here through a description of the Energy Economic Data Base (EEDB). The methodology presented is based on an "engineering approach" to cost estimating that defines the equipment, material quantities, and labor content required to build or modify a specific plant. The capital cost estimate is developed by summing those costs. Costs are delineated as direct costs and indirect costs, discussed in Secs. 4.2 and 4.3, respectively.

4.1 DESCRIPTION OF EEDB

The EEDB is a consistent, readily available and flexible data base that contains annually updated, comparable-baseline capital, fuel cycle, and operating and maintenance costs for different types of nuclear and coal-fired electricity generating plants.

Each plant in the data base consists of a technical model and a directly related cost estimate for that model. The cost estimates included in the data base are unencumbered by controversial factors such as the effects of future inflation, and by non-uniform factors such as costs arising from owners' options or utility system configurations. All assumptions and ground rules are clearly identified in the data base report and are applied uniformly to all cost estimates.

The conceptual designs of technical models in the EEDB are based upon a common hypothetical "Middletown" site. Middletown is a hard-rock site on a navigable river in the northeastern U.S., having specifically identified environmental, geological, and labor-cost characteristics.

Each cost estimate in the EEDB is developed in accordance with an expanded AEC code of accounts (USAEC Report NUS-531) and is based on a detailed technical model -- described in the EEDB report -- that includes system design descriptions for over 400 plant systems; a detailed equipment list containing over 1250 mini-specifications; and up to 10.000 subdivisions of commodity, materials, and equipment quantities, labor hours, and costs. The technical models are based on actual power plant designs and over 50 years of power plant design and construction experience. Site-related factors are normalized by locating each technical model on the common hypothetical "Middletown" site, for which there is a detailed, written geological and environmental description.

For each plant design the EEDB provides base capital costs composed of direct and indirect costs, reported in terms of factory equipment, site labor, and site materials costs. The results are internally consistent across each plant and are sufficiently detailed to identify why costs differ and whether they are credible.

The use of the EEDB will provide the user with several tools that will be useful in estimating the cost of changes to nuclear plants. These include:

1. Providing a structured code of accounts around which to organize and sum the various costs for the changes.

2. Identifying, at varying levels of detail, specific elements of cost that make up the overall cost of the change.

3. Providing up-to-date cost data on plant components, materials, and labor prepared by professional cost estimators in the nuclear field.

4. Providing a source of cost information for major structures, systems, and components that can be used to estimate analogous costs dealing with plant changes.

The user is advised to take some time at the outset of the project at hand to become familiar with the structure and content of the EEDB so as to take full advantage of all the data base has to offer.

4.2 DIRECT PLANT COSTS

Direct costs are defined as all costs associated with factory equipment and site material used and installed in the power plant, and the labor required for that installation. The total direct plant cost includes the cost for land (20)*, expenditures for structures and improvements (21), reactor and/or steam generating plant equipment (22), turbine plant equipment (23), electric plant equipment (24), miscellaneous plant equipment (25), and main condenser heat rejection systems (26). More detailed written descriptions of what constitutes those major categories of direct costs are provided in Appendix C.

4.2.1 EEDB Code of Accounts

The structure of the expanded code of accounts used in the EEDB equipment list permits the degree of detail entered in the model to vary according to the amount of information that is available and the level of precision desired in the estimate. Consequently, mature estimates where considerable information is available, can be detailed down to the "nine-digit" level, whereas less mature estimates can be detailed to a lesser level of detail. Table 4.1 shows the significance of the various levels of detail, as related to the information provided.

Studies of nuclear plant capital costs have shown that about 85% of a plant's direct cost is tied up in six areas of plant cost. These are structural commodities, the nuclear steam supply system, turbine generator unit, piping and duct work, electric plant and instrumentation and controls, and cooling towers and condensers. Therefore the cost of making major plant changes can be estimated to an acceptable level of accuracy if the cost impact can be estimated for these six major areas of cost. The EEDB code of accounts can assist in organizing the individual accounts that make up these major cost areas and in aggregating these accounts to produce an estimated cost effect on each of these areas.

Table 4.2 illustrates a typical aggregation of current capital costs for a pressurized water reactor plant model at the "two-digit" account levels. Each account in turn is disaggregated into factory equipment costs, site labor hours, site material costs, and total costs. Each account can be detailed down to a nine-digit level, as mentioned above and illustrated in Table 4.1 for a particular account. Figures 4.1 and 4.2 present typical cost elements for a structure (waste processing building) and system (residual heat removal system) within the accounting system.

4.2.2 Application to Regulatory Costs Estimating

Although the EEDB code of accounts system is set up to deal with new construction costs, this system is readily adaptable to estimating the costs for modifying plants

*The numbers in parentheses refer to the EEDB account numbers, as illustrated in Table 4.2.

TABLE 4.1 Cost of Accounts, Example of Levels of Detail

No. of Digits	No. of Account	Name of Account	Function/Level
2	26	Main Condenser Heat Rejection System	Name/Account
3	262	Mechanical Equipment	Name/Sub-Account
4	262.1	Heat Rejection System	Name/System
5	262.15	Main Cooling Tower Make-up and Blowdown System	Name/Sub-System
6	262.151	Make-up Water System	Name/Sub-Sub-System
7	262.1511	Rotating Machinery	Class/Equipment Category
8	262.15111	Make-up Pump and Motor	Class/Equipment Sub-Category
9	262.151111	Make-up Pump	Class/Component

Note: The final account, in this case the 9th digit, is the line item where specific equipment and material technical and/or cost information is recorded. At levels above the 9th digit, cost information is collected from lower level accounts and recorded as the summation of the lower level accounts. Depending on the complexity of the system, or the level of detail available, the final account may appear at any digit level from the 5th digit to the 9th digit.

TABLE 4.2 UE&C, Inc. Energy Economic Data Base (EEDB) Phase VI, 1139 MWe Pressurized Water Reactor

PLANT CODE 148 | COST BASIS 01/83 | 09/30/83

ACCT NO	ACCOUNT DESCRIPTION	FACTORY EQUIP. COSTS	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL COST	TOTAL COSTS
21 .	STRUCTURES + IMPROVEMENTS	10,943,477	9063311 MH	167,658,008	86,931,496	265,532,981
22 .	REACTOR PLANT EQUIPMENT	199,412,349	4059370 MH	82,058,379	17,889,132	299,359,860
23 .	TURBINE PLANT EQUIPMENT	161,221,837	3089762 MH	62,061,719	10,818,296	234,101,852
24 .	ELECTRIC PLANT EQUIPMENT	28,876,413	2619599 MH	51,825,535	17,067,562	97,769,510
25 .	MISCELLANEOUS PLANT EQUIPT	17,303,003	1562223 MH	31,458,700	5,966,012	54,727,715
26 .	MAIN COND HEAT REJECT SYS	21,966,074	981040 MH	18,861,678	3,652,860	44,480,612
	TOTAL DIRECT COSTS	439,723,153	21375305 MH	413,924,019	142,325,358	995,972,530
91 .	CONSTRUCTION SERVICES	96,000,000	7415000 MH	143,400,000	93,700,000	333,100,000
92 .	HOME OFFICE ENGRG.&SERVICE	325,250,000				325,250,000
93 .	FIELD OFFICE ENGRG&SERVICE	328,300,000	1012000 MH	17,680,000	15,700,000	361,680,000
	TOTAL INDIRECT COSTS	749,550,000	8427000 MH	161,080,000	109,400,000	1,020,030,000
	TOTAL BASE COST	1,189,273,153	29802305 MH	575,004,019	251,725,358	2,016,002,530

TABLE 4.2 (Cont'd)

PLANT CODE 148   COST BASIS 01/83   09/30/83

ACCT NO	ACCOUNT DESCRIPTION	FACTORY EQUIP. COSTS	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL COST	TOTAL COSTS
211.	YARDWORK	358,366	1008092 MH	17,001,262	10,561,463	27,921,091
212.	REACTOR CONTAINMENT BLDG	2,841,174	3106289 MH	57,948,001	28,702,534	89,491,709
213.	TURBINE ROOM + HEATER BAY	536,285	887696 MH	16,875,251	14,595,715	32,007,251
214.	SECURITY BUILDING	75,000	52788 MH	1,002,638	487,912	1,565,550
215.	PRIM AUX BLDG + TUNNELS	2,952,069	789050 MH	14,692,969	5,714,807	23,359,845
216.	WASTE PROCESS BUILDING	580,642	717526 MH	13,230,414	5,822,999	19,634,055
217.	FUEL STORAGE BLDG	934,564	304592 MH	5,697,378	3,650,043	10,281,985
218A.	CONTROL RM/D-G BUILDING	1,574,364	928204 MH	17,654,329	7,115,391	26,344,084
218B.	ADMINISTRATION+SERVICE BLG	869,514	261379 MH	4,938,553	2,718,606	8,526,673
218D.	FIRE PUMP HOUSE,INC FNDTNS	36,966	15469 MH	292,225	146,939	476,130
218E.	EMERGENCY FEED PUMP BLDG	21,409	126083 MH	2,336,550	883,904	3,241,863
218F.	MANWAY TUNNELS (RCA TUNLS)		47736 MH	851,286	277,528	1,128,814
218G.	ELEC. TUNNELS	5,465	1828 MH	36,592	14,919	56,976
218H.	NON-ESSEN. SWGR BLDG.	20,904	20581 MH	385,157	261,720	667,781
218J.	MN STEAM + FW PIPE ENC.	31,560	394802 MH	7,425,639	3,119,683	10,576,882
218K.	PIPE TUNNELS		17653 MH	313,248	110,616	423,864
218L.	TECHNICAL SUPPORT CENTER	60,000	19729 MH	364,145	203,615	627,760
218M.	HYDROGEN RECOMBINER STRUCT	4,102	7579 MH	138,215	65,162	207,479
218P.	CONTAIN EQ HATCH MSLE SHLD		10277 MH	187,707	51,400	239,107
218S.	HOLDING POND		9640 MH	173,763	64,435	238,198
218T.	ULTIMATE HEAT SINK STRUCT	41,093	308284 MH	5,603,492	2,076,756	7,721,341
218V.	CONTR RM EMG AIR INTK STR		11034 MH	186,194	75,349	261,543
218Z.	WASTE WATER TREATMENT BLDG		17000 MH	323,000	210,000	533,000
21 .	STRUCTURES + IMPROVEMENTS	10,943,477	9063311 MH	167,658,008	86,931,496	265,532,981

TABLE 4.2 (Cont'd)

PLANT CODE 148   COST BASIS 01/83   09/30/83

ACCT NO	ACCOUNT DESCRIPTION	FACTORY EQUIP. COSTS	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL COST	TOTAL COSTS
220A.	NUCLEAR STEAM SUPPLY(NSSS)	139,050,000				139,050,000
220B.	NSSS OPTIONS					
221.	REACTOR EQUIPMENT	770,964	184500 MH	3,700,034	3,295,381	7,766,379
222.	MAIN HEAT XFER XPORT SYS.	3,053,817	461736 MH	9,376,459	1,161,581	13,591,857
223.	SAFEGUARDS SYSTEM	7,857,712	619001 MH	12,545,725	1,733,934	22,137,371
224.	RADWASTE PROCESSING	11,077,652	468739 MH	9,486,393	1,250,645	21,814,690
225.	FUEL HANDLING + STORAGE	4,273,034	78962 MH	1,598,398	170,136	6,041,568
226.	OTHER REACTOR PLANT EQUIP	18,619,531	1628012 MH	32,986,102	6,615,452	58,221,085
227.	RX INSTRUMENTATION+CONTROL	12,377,046	377700 MH	7,472,968	565,178	20,415,192
228.	REACTOR PLANT MISC ITEMS	2,332,593	240720 MH	4,892,300	3,096,825	10,321,718
22 .	REACTOR PLANT EQUIPMENT	199,412,349	4059370 MH	82,058,379	17,889,132	299,359,860
231.	TURBINE GENERATOR	110,132,487	454270 MH	9,000,548	1,657,983	120,791,018
233.	CONDENSING SYSTEMS	20,549,964	621181 MH	12,529,748	2,033,281	35,112,993
234.	FEED HEATING SYSTEM	15,794,659	579940 MH	11,755,730	1,172,108	28,722,497
235.	OTHER TURBINE PLANT EQUIP.	13,011,569	949971 MH	19,245,437	2,233,243	34,490,249
236.	INSTRUMENTATION + CONTROL	1,733,158	230900 MH	4,565,102	389,881	6,688,141
237.	TURBINE PLANT MISC ITEMS		253500 MH	4,965,154	3,331,800	8,296,954
23 .	TURBINE PLANT EQUIPMENT	161,221,837	3089762 MH	62,061,719	10,818,296	234,101,852

TABLE 4.2 (Cont'd)

PLANT CODE 148 COST BASIS 01/83 09/30/83

ACCT NO	ACCOUNT DESCRIPTION	FACTORY EQUIP. COSTS	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL COST	TOTAL COSTS
241.	SWITCHGEAR	10,033,856	25880 MH	510,894	78,326	10,623,076
242.	STATION SERVICE EQUIPMENT	15,786,132	128036 MH	2,525,725	347,067	18,658,924
243.	SWITCHBOARDS	1,382,728	16340 MH	322,860	123,632	1,829,220
244.	PROTECTIVE EQUIPMENT		132050 MH	2,625,100	1,648,138	4,273,238
245.	ELECT.STRUC +WIRING CONTNR		1435863 MH	28,318,482	4,936,615	33,255,097
246.	POWER & CONTROL WIRING	1,673,697	881430 MH	17,522,474	9,933,784	29,129,955
24 .	ELECTRIC PLANT EQUIPMENT	28,876,413	2619599 MH	51,825,535	17,067,562	97,769,510
251.	TRANSPORTATION & LIFT EQPT	3,003,980	58550 MH	1,187,324	475,539	4,666,843
252.	AIR,WATER+STEAM SERVICE SY	8,658,335	1202063 MH	24,353,632	4,843,273	37,855,240
253.	COMMUNICATIONS EQUIPMENT	1,948,800	192200 MH	3,820,858	585,348	6,355,006
254.	FURNISHINGS + FIXTURES	2,081,888	27410 MH	538,886	61,852	2,682,626
255.	WASTE WATER TREATMENT EQ	1,610,000	82000 MH	1,558,000		3,168,000
25 .	MISCELLANEOUS PLANT EQUIPT	17,303,003	1562223 MH	31,458,700	5,966,012	54,727,715
261.	STRUCTURES	258,105	144576 MH	2,650,503	1,372,577	4,281,185
262.	MECHANICAL EQUIPMENT	21,707,969	836464 MH	16,211,175	2,280,283	40,199,427
26 .	MAIN COND HEAT REJECT SYS	21,966,074	981040 MH	18,861,678	3,652,860	44,480,612
	TOTAL DIRECT COSTS	439,723,153	21375305 MH	413,924,019	142,325,358	995,972,530

TABLE 4.2 (Cont'd)

PLANT CODE 148 — COST BASIS 01/83 — 09/30/83

ACCT NO	ACCOUNT DESCRIPTION	FACTORY EQUIP. COSTS	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL COST	TOTAL COSTS
911.	TEMPORARY CONSTRUCTION FAC		6990000 MH	135,200,000	28,800,000	164,000,000
912.	CONSTRUCTION TOOLS & EQUIP		425000 MH	8,200,000	62,900,000	71,100,000
913.	PAYROLL INSURANCE & TAXES	96,000,000				96,000,000
914.	PERMITS,INS. & LOCAL TAXES				2,000,000	2,000,000
915.	TRANSPORTATION					
91 .	CONSTRUCTION SERVICES	96,000,000	7415000 MH	143,400,000	93,700,000	333,100,000
921.	HOME OFFICE SERVICES	310,000,000				310,000,000
922.	HOME OFFICE Q/A	10,400,000				10,400,000
923.	HOME OFFICE CONSTRCTN MGMT	4,850,000				4,850,000
92 .	HOME OFFICE ENGRG.&SERVICE	325,250,000				325,250,000
931.	FIELD OFFICE EXPENSES		62000 MH	1,180,000	15,700,000	16,880,000
932.	FIELD JOB SUPERVISION	293,550,000	600000 MH	10,600,000		304,150,000
933.	FIELD QA/QC	19,250,000	350000 MH	5,900,000		25,150,000
934.	PLANT STARTUP & TEST	15,500,000				15,500,000
93 .	FIELD OFFICE ENGRG&SERVICE	328,300,000	1012000 MH	17,680,000	15,700,000	361,680,000
	TOTAL INDIRECT COSTS	749,550,000	8427000 MH	161,080,000	109,400,000	1,020,030,000
	TOTAL BASE COST	1,189,273,153	29802305 MH	575,004,019	251,725,358	2,016,002,530

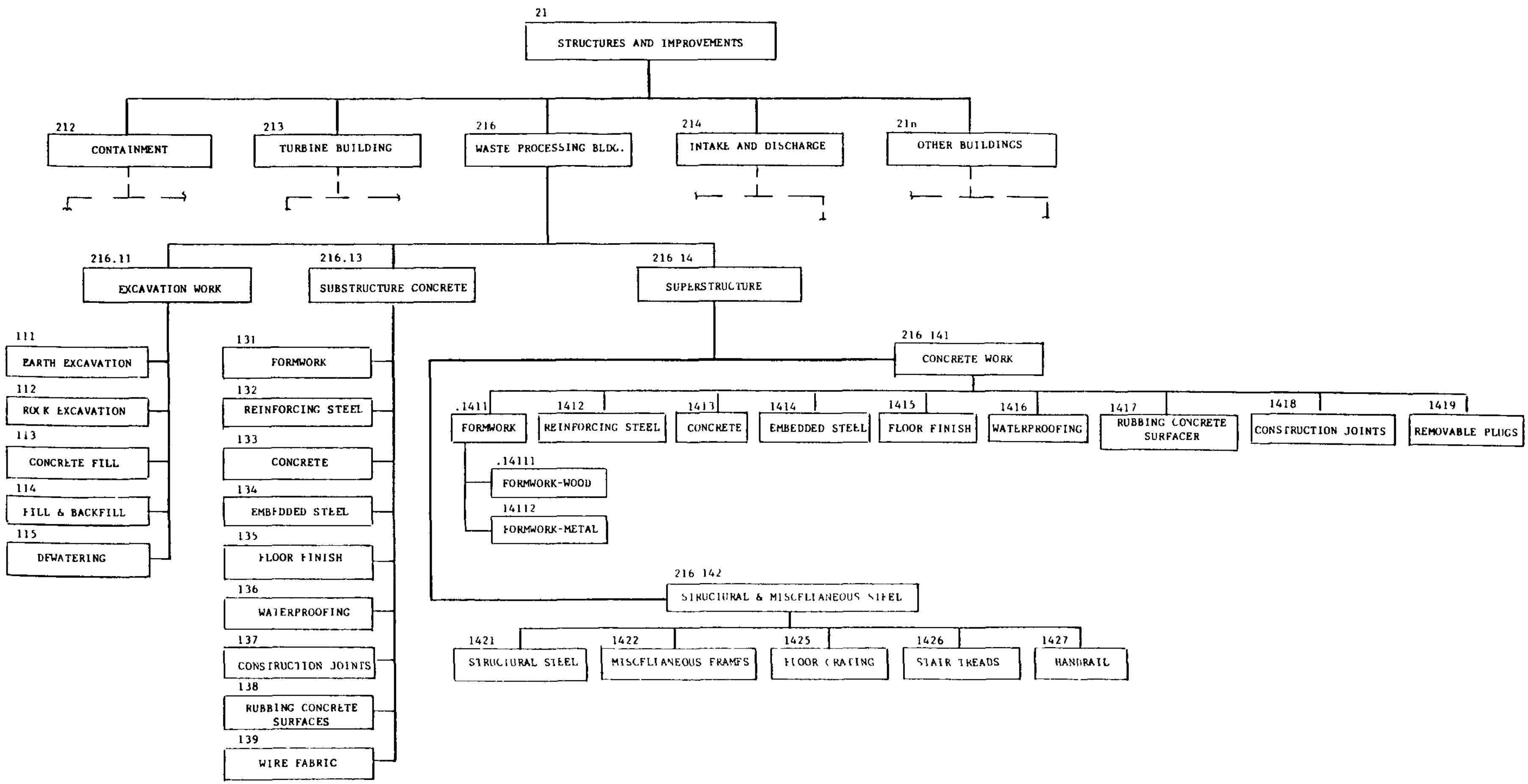


FIGURE 4.1 Typical Structural Cost Elements

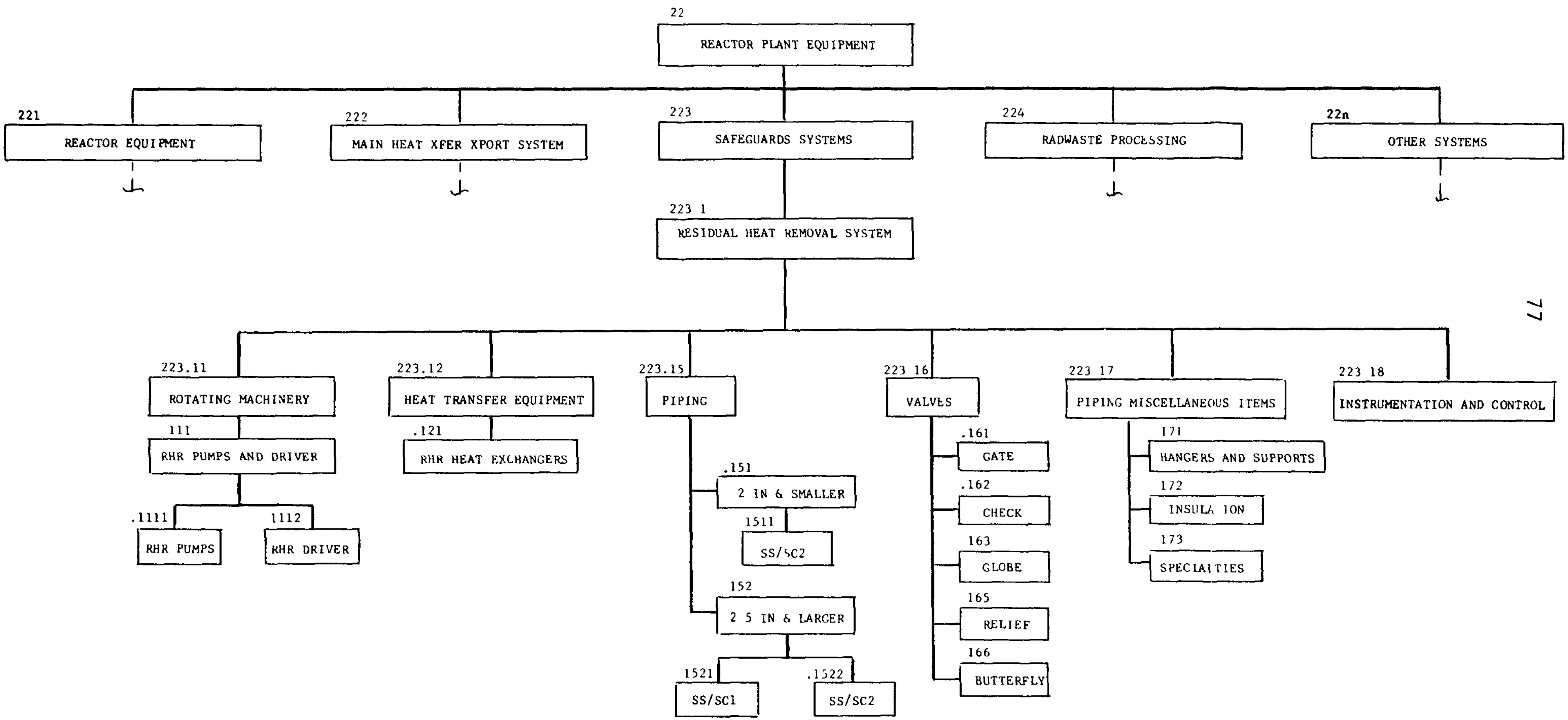


FIGURE 4.2 Typical System Cost Elements

under construction and operating plants. The accounts system contains all features of the plant and thus can be used to identify the needed materials, equipment, etc., to satisfy the design changes resulting from the requirement. The use of the EEDB code of accounts to locate specific cost elements in the EEDB and to apply the EEDB cost figures to a regulatory cost estimate is demonstrated in Chapter 6 of this handbook, where a specific example cost estimate is carried out.

Special attention is required in the application of the EEDB cost information when dealing with the quantity of field craft labor needed to perform a task. The time and difficulty involved in backfitting an existing plant is different from that involved in building a plant from scratch, so the labor hours and costs assumed in the new construction process will need to be scaled to reflect this difference. The labor hours specified in the EEDB for a certain activity already takes into account some amount of rework hours that typically occurs during construction up to about the 70% construction-completion stage. Therefore, when dealing with plants at or before this stage, the labor hours requirements need not be adjusted for rework of hardware or systems. If, however, the requirement involves a major structural modification even at or before the 70% complete stage, the cost for reworking the structure should be estimated separately. Beyond the 70% stage, rework labor should be estimated on a case-by-case basis. The use of a labor-cost value for an analogous activity found in the EEDB would be appropriate. However, if a change occurs during the middle stages of construction, the change may require rework of existing structures or systems at the site, refabrication of equipment, reduced labor productivity due to congested work areas, etc. All of these activities will drive up the cost of implementing the changes beyond that identified in the EEDB. For example, a requirement may call for existing piping to be removed and replaced. To accomplish this, other materials such as cables and cable trays may have to be removed, thus causing rework in these other areas as well. Reports have shown that rework can add 10-35% to the labor cost of a modification at a plant that is more than 70% complete. At a national average rate of $19/hr, this could result in additional labor costs of $70,000 for a task that would normally require 10,000 labor hours.

Equipment cost will not be greatly affected if changes occur to designs of equipment where fabrication has not yet started. However, if equipment fabrication has started, and the equipment has to be modified, the results are higher costs and delays in delivery. Even worse, if the fabricated equipment has been installed, then modification will cause on-site rework, and the equipment may have to be replaced, which will lead to further cost and delays.

Rework in an area of the plant that is near completion must be performed under congested conditions, sometimes where only one or two workers can fit. Reports have shown that overcrowding can result in an estimated 10% reduction in labor productivity. Because walls, supports, and large pieces of equipment may already be installed, the installation of a new large component may require that the component be brought in unassembled and fabricated in place.

The type of structures and equipment to be modified also affects the costs. For seismic Category I structures, the work will likely be more complex and require more time and materials than similar modifications on a nonseismic Category I structure.

Typical costs for both seismic and nonseismic Category I structures can be found in the EEDB.

The type of equipment under modification also determines the difficulty and extent of the construction work needed. The difficulty of the work, the equipment and materials needed, the type of labor required, and the time required all depend on whether the modification involves the reactor plant or the turbine plant or the electric plant, etc. For example, safety-grade equipment requires a more stringent quality control program with more inspection than nonsafety-grade equipment. Changes to some buildings result in greater costs than others. Some buildings are more congested than others, thus making changes more difficult, e.g., the containment building versus the turbine building. Safety-related structures, such as the containment building, require more stringent quality control programs, thus adding to the costs. Moreover, seismic Category I structures require more materials than nonseismic Category I structures (thicker walls, more rebar, deeper foundations).

An understanding of the cost effects of design changes is best gained when costs can be presented at a high level of detail. This level of detail, however, varies with the scope of the design change as well as the plant construction status. For example, if plant changes are comprehensive and occur early in the plant construction schedule, then costing guidance may be found in the fact that the six costing items discussed earlier comprise about 85% of a plant's direct costs. Any major redesign would likely affect most or all of these six items. Estimating the costs for changes in these six areas could form the basis for a first order cost estimate. If the overall change involves several small changes, then the above approach would not be detailed enough to identify these changes and cost them. Thus, a more detailed breakdown of costs, such as the EEDB, is required.

As construction progresses, changes in design become more capital intensive. That is, labor is needed not only to install the new equipment but to remove the old equipment. Thus, a cost accounting system such as the EEDB, which disaggregates the capital costs of an item into its labor, materials, and equipment components, can provide more useful guidance. As construction nears completion, the cost of a design change is very dependent on the equipment already installed in an area, its configuration and congestion, and construction completion date. Guidance on costing this complex situation may, in addition to the above, require the use of detailed drawings, PERT/CPM documents, and the systems turnover schedule.

One particularly valuable application of the EEDB technical and cost information is in estimating the cost of a complete structure or system when an analogous structure or system can be found in the EEDB. The EEDB includes technical descriptions of all structures and systems in the data base, which will allow the user to match systems or structures as a whole and to identify the total cost without detailed costing of the components. The user is cautioned, when using this technique, to match or prorate all important aspects of the EEDB system or structure to the user's system or structure. This includes such aspects as seismic category, safety class, need for rework, building volumes or surface areas, system capacities, redundancy requirements, etc.

4.3 INDIRECT PLANT COSTS

Indirect costs are defined as all costs associated with the engineering and design of the power plant, as well as tools, equipment, temporary structures, and services required to construct the plant. The total indirect costs include expenditures for construction support activities, home office and field office engineering services, and construction management. Stated another way, indirect costs may be viewed as costs for materials, equipment, and labor needed to support construction of the power plant, but which are no longer needed once the plant is operational.

The indirect cost accounting method presented here is based upon the EEDB code of accounts as a guide for the distribution of indirect costs. These costs are contained in Account 91, Construction Services; Account 92, Home Office Engineering Services; and Account 93, Field Office Engineering and Services. NSSS vendor engineering is addressed in account 220B, NSSS Options are accounted for, as are all vendor engineering costs, as direct costs. Appendix D provides more detailed descriptions of accounts 91, 92, and 93. To aid the user in understanding the complex process of design and construction, models for the Architect Engineering A-E*, Nuclear Supplier Engineering (NSSS), and Construction Management sectors have been developed and are presented in the following sections.

4.3.1 A-E Sector

The process by which the A-E sector carries out its design and engineering functions is an iterative decision-making process depicted graphically in Fig. 4.3. This process is centered around two phases:

1) Preliminary Assessment Phase

   Determining whether the new requirement affects the client's nuclear project, and if so, preparing a recommendation to the client (utility).

2) Detailed Design and Procurement Phase

   Enacting engineering changes and procuring necessary equipment to accomplish the changes.

The following discussion explains this process.

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*As stated previously, the breakdown of responsibility for design and construction in an A-E sector, NSSS sector and a construction management sector is done for bookkeeping purposes only. Some utilities perform their own engineering and design as well as construction.

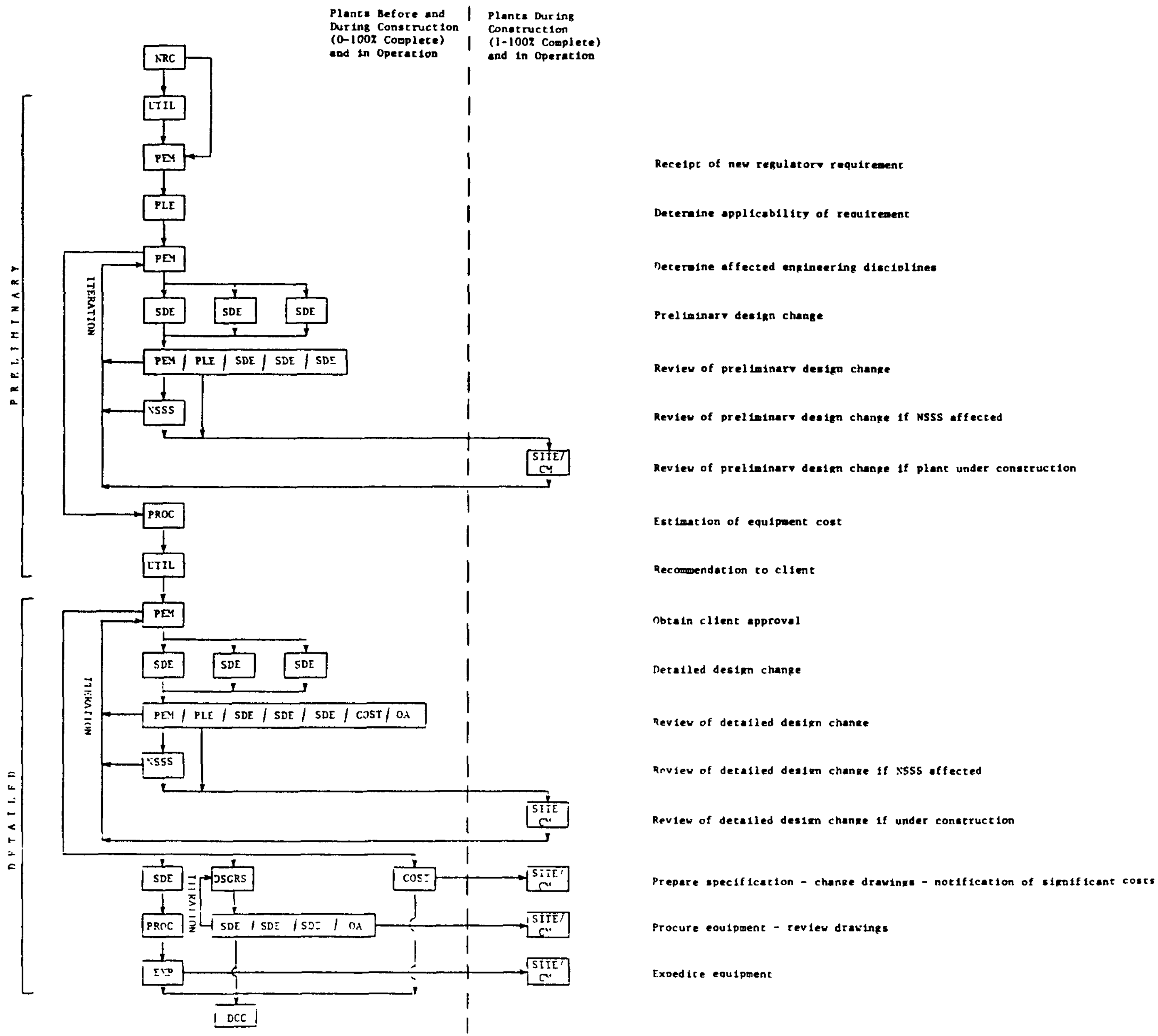

FIGURE 4.3 A-E Engineering Logic Flow

LIST OF ABBREVIATIONS FOR FIGURE 4.3

NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System Vendor
UTIL	Utility
COST	A-E Cost Engineering
CM	Home Office Construction Management
DCC	Document Control Center
DSGRS	Designers/Draftsmen
EXP	Expediting Personnel
PEM	Project Engineering Manager
PLE	Project Licensing Engineer
PROC	Procurement Personnel
SDE	Senior Discipline Engineer
SITE	Site Engineering
QA	Quality Assurance Engineering

4.3.1.1 Preliminary Phase

For new plants, plants under construction, and operating plants, the flow of preliminary activities is generally similar, the primary differences being:

1) a review of the preliminary design changes by site engineering and construction management is required only when construction is underway; review by the operations management is required only when the plant is in operation, and

2) the A-E's chain of activities must be initiated by the utility for operating plants.

It must be noted, however, that although the activities are the same, the costs to carry out these activities may not be the same. The costs increase with percentage of plant completion because acceptable design solutions become more difficult to find once other equipment is installed in and around the area of a design change.

The chain of events is initiated either by a request from the utility to the A-E to review a new NRC document for all of the utility's plants, or upon direct receipt of the document by the A-E (plants 0-100% complete), (see area marked Preliminary on Fig. 4.3). Typically, the new NRC requirement is reviewed by the project licensing engineer assigned to the nuclear project, who determines its applicability to the project. His recommendation is forwarded to the project's engineering manager, who determines which engineering disciplines are affected. If necessary, specialty technical groups (groups that typically perform such activities as seismic, radiological, and blowdown analyses) outside of the project group will be called in, as well as the NSSS vendor. A key factor in estimating the cost of the new requirement occurs at this stage. That is, the greater the number of engineering disciplines and specialty groups affected, the greater the cost, as more man-hours are expended. For example, a requirement involving the determination of seismic response spectra will affect the design of every structure, piping run, cable run, etc. On the other hand, a requirement affecting the placement of alarms and annunciators in the control room may affect only I&C and electrical engineering disciplines.

For those projects under construction or in operation, input will also be solicited from site engineering and home office construction management. As noted previously, the further along construction is, the greater the number of man-hours required in finding acceptable solutions. This is because of physical space requirements and construction sequence requirements. For example, installation of new equipment may involve removing and reinstalling equipment that blocks access to the location of the new equipment. For plants in operation, design consideration must also be given to minimizing radiation exposure to site laborers during installation and to minimizing plant downtime.

Once an engineering response is formulated it is reviewed by all affected parties. The review process is iterated by these parties until an acceptable solution is formulated. A recommendation is made to the client advising what general design changes need to be made, if any, and at what approximate cost.

Two examples will illustrate the range of man-hours expended during the preliminary phase as a result of new or revised regulatory actions.

Revision 3 of Reg. Guide 1.70 (SAR Format Guide) asks for the design that will be used to meet the criticality accident monitoring requirements of 10 CFR Part 70 Section 70.24 for the storage of new fuel. Providing guidance to Section 70.24 is Reg. Guide 8.12, which basically adopts ANSI N16.2 with minor upgradings. The above regulatory material was reviewed according to the flow path of activities shown in Fig. 4.3 for the preliminary stage. After approximately 200 man-hours, a recommendation was made to the client that no new monitors were required.

By comparison, when Reg. Guide 1.120 "Fire Protection Guidelines for Nuclear Power Plants" was put forth, approximately 20,000 man-hours were expended in the preliminary stage. When Appendix R to 10 CFR 50, "Fire Protection Program for Nuclear Plants" was issued, a roughly equal number of man-hours was expended in the preparation of specific recommendations for plant design changes.

4.3.1.2 Detailed Design and Procurement Phase

The flow of activities for this phase is similar for all plants, except for a review of the detailed design changes by site engineering and construction management for plants under construction, and by operations management for plants in operation. As with the preliminary phase, the flow of activities may be similar, but costs increase with the percentage of construction that is complete.

Once client approval of the preliminary design changes is received by the project's engineering manager, the affected engineering disciplines perform the detailed engineering changes via analyses and re-design (see area marked Detailed in Fig. 4.3). These design changes are reviewed by all affected parties, including site engineering, home office construction management, quality assurance engineering, and the NSSS vendor, where necessary. As in the preliminary stage, costs increase with the number of engineering disciplines and specialty groups affected.

Detailed design is an iterative process with review sessions, comments, revised designs, and more reviews being held until a satisfactory design is achieved. For plants under construction, any satisfactory design must minimize construction schedule delays. The further complete a plant is, the more complicated this task becomes due to the consideration of equipment and materials already installed in and around the area of the change. For plants in operation, design consideration must also be given to minimize radiation exposure to craft laborers during installation of equipment and materials and to minimize plant downtime.

The approved changes are then incorporated into the engineering drawings by draftsmen, and these drawings are then reviewed by the appropriate engineering disciplines as well as by quality assurance engineering. Review is iterated until any problems are resolved. The approved design changes are then sent to cost engineering, which evaluates the cost of the change for the site construction management.

The examples of criticality accident monitors and the fire protection program considered earlier illustrate possible ranges of A-E manhours expended in the detailed phase. Because the recommendation of no additional criticality monitors was accepted by the client, no man-hours were expended by the A-E during the detailed stage. On the other hand, client concurrence that design changes were needed for fire protection to meet 10 CFR 50 - Appendix R resulted in approximately 40,000 man-hours being expended for detailed design changes.

At the same time that the design drawings are being revised, the affected engineering disciplines revise the procurement specifications for the affected equipment or write new ones. These are transmitted to procurement personnel to purchase the equipment. Additional costs may be incurred at this time due to vendor construction changes, or costs may be encountered to change equipment that is already in fabrication. Next, expediting personnel track the equipment and advise construction management of delivery dates.

Examples of the costs incurred at the procurement stage are typified by the Control Room Human Factors Review and the Fuel Cask Handling Crane. One of the requirements of NUREG-0700 was that control room panel arrangements be reviewed from a human factors standpoint. Although this requirement was put forth before the control panels of one plant were completely fabricated (they had been completely designed, however), the review resulted in changes to many of the major control room panels. The total cost for this review and subsequent changes was approximately $2.5 million, of which $1.5 million was due to additional procurement costs. Moreover, schedule delays resulted from the extended delivery dates for the revised panels.

On the other hand, when NUREG-0554 was issued, the fuel cask handling crane for one plant had been completely fabricated and delivered. The new requirements necessitated a complete redesign of the crane. Because of the extensive changes, little hardware from the original crane could be salvaged. The modification cost essentially amounted to the cost of a new crane, approximately $1.5 million. Additionally, changes were required to the structural steel due to higher crane loadings, and construction delays were experienced.

4.3.2 NSSS Sector

The flow of the NSSS sector engineering activities is similarly to that of the A-E sector for all stages of plant completion with the exception that the NSSS vendor actually manufactures part of the nuclear steam supply system in addition to procuring equipment from other vendors. (See Fig. 4.4, "NSSS Engineering Logic Flow.") Therefore, the earlier discussion of the A-E sector is applicable to the NSSS engineering with the following exceptions:

1) During the preliminary and detailed phases, input from the NSSS manufacturing facilities is requested on problems dealing with retooling, production delays, manufacturing limitations (both technical and material supply), and make/buy decisions.

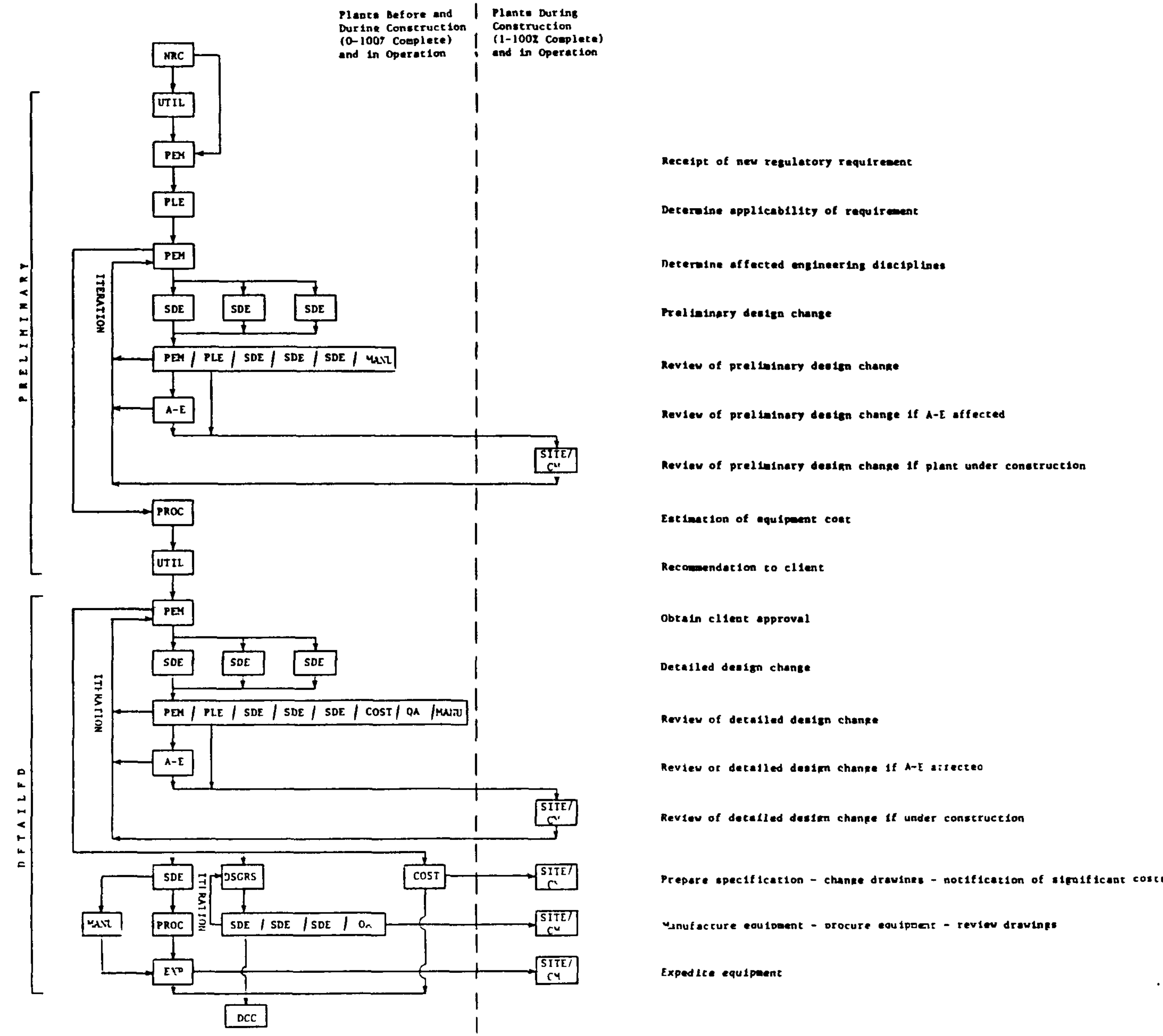

FIGURE 4.4 NSSS Engineering Logic Flow

LIST OF ABBREVIATIONS OF FIGURE 4.4

A-E	Architect-Engineer
NRC	Nuclear Regulatory Commission
UTIL	Utility
COST	NSSS Cost Engineering
CM	Home Office Construction Management
DCC	Document Control Center
DSGRS	Designers/Draftsmen
EXP	Expediting Personnel
MANU	Manufacturing Personnel
PEM	Project Engineering Manager
PLE	Project Licensing Engineer
PROC	Procurement Personnel
SDE	Senior Discipline Engineer
SITE	Site Engineering
QA	Quality Assurance Engineering

2) Input is obtained from the A-E during the preliminary and detailed phases of NSSS equipment. (In the A-E Sector, input was obtained from the NSSS vendor.)

3) After changes are agreed to, specifications are sent to the NSSS procurement group to send out to vendors, and/or to the NSSS manufacturing facilities.

As with the A-E sector, costs are a function of the number of engineering disciplines involved. For example, changes due to revised asymmetrical loads require analysis and redesign of many NSSS and A-E systems, supports, and pieces of equipment both mechanical and electronic. These analyses would involve engineers and scientists from numerous disciplines, the manufacturing facilities, and the A-E. It should be noted that when input is required from the A-E it may involve several of the A-E's engineering disciplines, and thus many A-E man-hours may be required. On the other hand, a change in the location of a control room annunciator within the NSSS scope of supply may affect only the NSSS engineering disciplines.

As with the A-E sector, costs also increase significantly with the project completion status even though the flow of activities remains essentially the same. However, large costs can be incurred earlier by the NSSS sector as manufacturing of major NSSS components usually begins immediately after award of the NSSS contract. Therefore, a regulatory change that may require the redesign of a major nuclear component after fabrication has started could be a very costly change. It bears noting that the redesign of a component after fabrication has started may require a redesign of the whole manufacturing process including retooling (such as redesign and remanufacturing of stamps, dies, and castings), retraining of shop personnel, and loss of materials already utilized. There is also the cost of the labor required for the above as well as the resulting rescheduling of the manufacturing equipment usage so as to attempt to meet all contractual obligations.

Once components are delivered to the site (or worse, installed in the plant), changes to NSSS components can be extremely costly and difficult to redesign due to the massive size and weight of the components. Thus, changes may have to be "add-ons" in an area (such as the NSSS cavity) that is already crowded. For example, the addition of a pipe whip restraint in the NSSS cavity after major components were installed required the hand chipping of several cubic yards of concrete (so as to not disturb embedded reinforcing steel), the use of special air vacuums and filters to minimize concrete dust, additional labor and materials, and the rescheduling of other construction work planned in that area. This type of activity could affect the entire plant construction schedule.

4.3.3 Construction Management Sector

4.3.3.1 Discussion of Model

The construction management sector consists of all the construction management activities normally controlled by the construction manager. These include management of direct costs in the form of site labor and site material as explained in Sec. 4.2, and the indirect costs as explained in this section.

The major activities involving the construction management costs include (at the two digit level):

91 Construction Services (temporary facilities, equipment)

92 Home Office Engineering and Services (construction management)

93 Field Office Engineering and Services (Supervision, QA/QC).

The two- and three-digit code of accounts for these costs are presented in Sec. 4.2, Table 4.2, sheets 1 and 5.

Five major activities are typically performed by the construction management sector. The first four of these apply to all stages of plant completion, while the final action (Plant/Subsystem Testing) is only applicable to plants in operation or nearly complete. The five major activities, in chronological order, are:

1) Plan Installation Procedures

2) Procure Equipment

3) Perform Modification/Installation

4) Inspect Hardware

5) Test Systems and Subsystems

Figure 4.5 provides a graphical representation of the construction management activities and their associated cost elements. Costs for each of the activities (action nodes) depends on various factors that define the scope of the work to be done. These include:

1) At what stage is the plant construction:?

2) Will work be done on Structures (Account 21) or Equipment (22-26) or both?

3) Will the work require modification or installation (or both)?

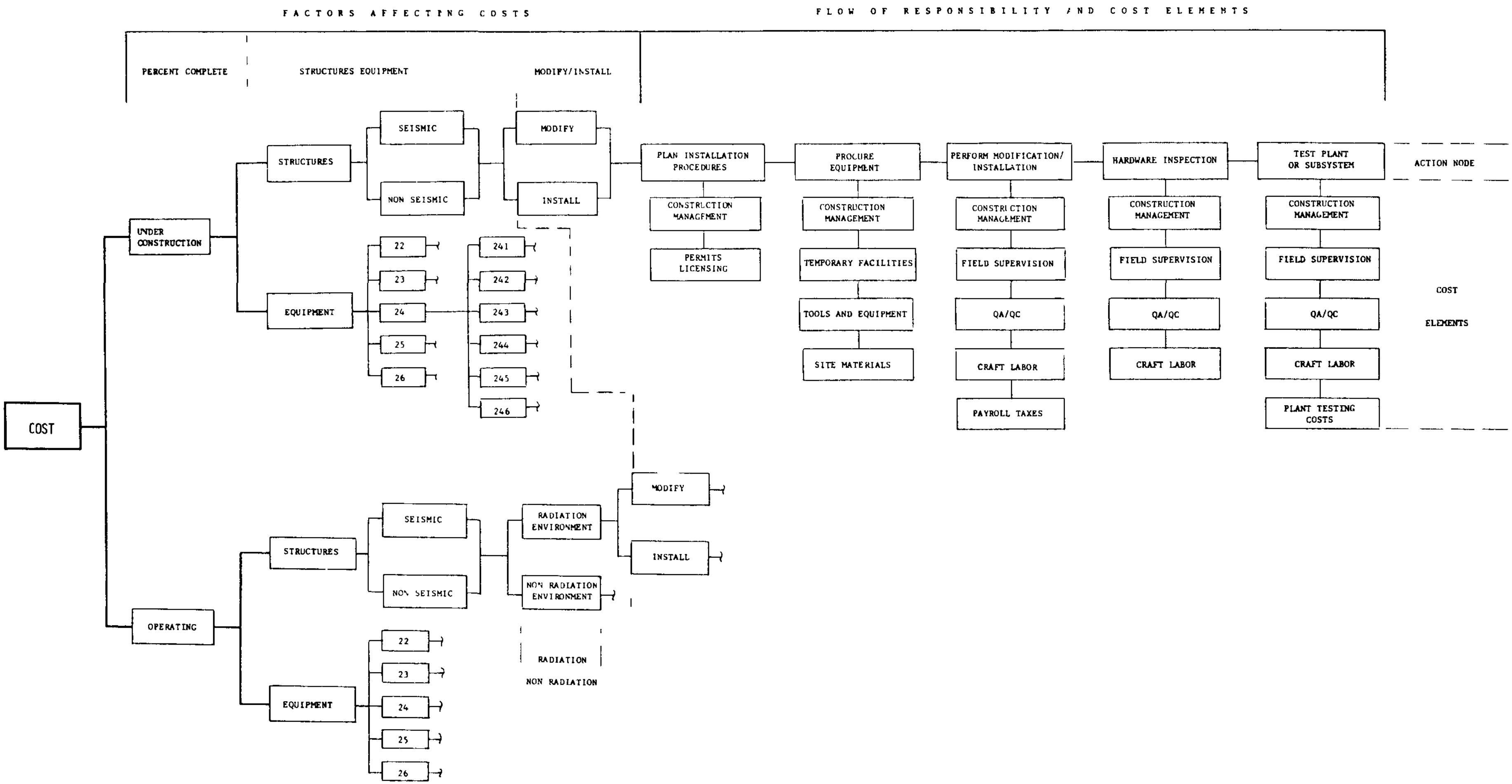

FIGURE 4.5 Construction Management Sector: Factor Affecting Costs, Flow of Responbility, and Cost Elements

4) If the work is required on structures, are the affected structures in a seismic or nonseismic category?

5) If the work is on equipment, is it Account 22, 23...or 26?

6) Does it require work in a radiation environment?

7) What is the scope of the work to be done?

Each of the cost elements under the action nodes can be determined by the answers to these seven questions. Once these cost elements are defined, the cost estimates can then be obtained.

The following sections explain the action nodes and their respective cost elements, and how the factors presented above affect the costs.

Plan Installation Procedures

This activity is done in conjunction with the utility, A-E, and nuclear supplier sectors and involves specifying the work to be done at the plant site. This includes developing the construction work schedule, detailing procedures defining equipment and materials needed for construction purposes, and specifying the labor required. The costs in this segment are assigned to the construction management and engineers who are responsible for detailing the work procedures (Account 923).

This activity is especially significant because it defines the scope of the entire construction effort. The actual construction costs that will be faced are determined by the decisions made at this stage of the operation, because all of the cost elements are defined here.

Procure Equipment

After the construction plan has been worked out, the construction equipment and site materials needed to perform the modifications are procured (this does not include factory equipment that is incorporated in the A-E and NSSS sectors). This stage includes the actual costs of equipment and materials, preparation of the bid packages, evaluation of proposals, and preparation of the purchase orders. This also involves the services of the construction managers (923) in conjunction with the utility and A-E sectors.

The construction equipment includes temporary construction facilities and construction tools and equipment from the 911 and 912 accounts. The site materials costs are primarily from the 200 accounts, and are those direct costs described in Chapter 4.2.

The equipment may be bought or leased, and some of the necessary equipment and materials may already be on the site (especially if the plant is still under construction).

Perform Modification/Installation

This action node is where the costs of construction management and labor supervision directly associated with the construction process are assigned. For the construction sector these are:

Construction Manager (923)

Field Job Supervisor (932)

Field Quality Assurance/Quality Control (933)

Payroll Insurance, Taxes (913)

Most of the cost from this action results from the field supervision. These costs are greatly affected by the scope of the work, mostly because the costs of this sector depend on the length of the construction schedules and where the work is to be done. Management costs vary considerably depending on what type of work is to be done, whether it is on structures or equipment, and the types of structures and equipment.

Inspect Hardware

The NRC requirement may include inspecting existing hardware, or inspecting the modification(s) just completed. This involves essentially the same cost elements as the previous action. If this is a necessary action, it adds to the cost of those elements (construction manager, field job supervisor, QA/QC) an appropriate amount of man-hours and increases the construction schedule length. This activity is done jointly with the utility and the A-E, and is heavily affected if the inspection needs to be done in a radiation environment. Much of the work may involve removing equipment to be inspected and then replacing the same equipment.

Plant/Subsystem Testing

This activity involves the testing of components, systems, or the entire plant following modifications to plant hardware. The scope of the testing requirements is determined at the construction planning stage and can include the full spectrum of testing possibilities from testing only individual components to testing subsystems, systems, or even the entire plant if the modifications were extensive and involved an operating plant.

4.3.3.2 Cost Accounting in the Construction Management Sector Model

Costs are primarily incurred in the following accounts:

- Account 911 - Temporary Construction Facilities

- Account 912 - Construction Tools and Equipment
- Account 913 - Payroll Insurance, and Taxes
- Account 923 - Home Office Construction Management
- Account 931 - Field Office Expenses
- Account 932 - Field Job Supervisor
- Account 933 - Field QA/QC
- Account 934 - Plant Startup and Testing

4.3.3.3 How Scope of Work Effects Cost Elements

The scope of construction work is affected by the factors shown in Fig. 4.5. These factors define the extent of the construction work to be performed, and directly affect the magnitude of the cost elements of the construction sector.

Percent Completion

Three phases of plant status have been described for this guide. The construction status affects the procurement of equipment and materials and the difficulty of modifying or installing the necessary structure and equipment. If a plant is still in the construction phase, the temporary facilities (911), the tools and equipment (912), and much of the materials may already be at the site, so this cost may be minimal.

The cost of modifying a plant changes with the percentage of the plant that is completed. During the early stage of construction, much of the equipment and structures are not installed and the modification costs are the difference between the original construction and the new construction costs. If the structures and equipment are already in place, as is likely later in construction, the modification or installation may be more difficult, and may require different operations and more complex cost estimating, especially in calculating the craft labor.

Structures/Equipment

Whether the modifications or installations are performed on structures or equipment or both affects the type of work required. The equipment needs, material requirements, time span, and type of labor necessary to work on structures is different than those for equipment. These are affected by whether the modification is prefabricated or needs to be built on site.

Not only must the equipment or structure being changed/reworked be considered, so must other equipment already installed. Often equipment coverings, semi-permanent shielding walls, and high powered vacuums to eliminate concrete dust are required.

Modification/Installation

Whether the job requires modification of existing structures/equipment or installation of new structures/equipment will determine both the materials needed for construction and the craft labor types. In many cases, construction of new structures requires less time and costs than modifying existing structures. Modifying or installing equipment may be the most difficult when a plant is complete or nearly so, because working in a confined area may require removing and replacing equipment other than that directly affected by the requirement. Modification of installed equipment/ structures may cause increases in commodities as well, due to the rework made necessary.

Radiation/Non-Radiation

This is only applicable to operating plants. If the work is done in a radiation environment, the type of materials needed (radiation shielding and measurement equipment), the quality of labor, and the level of supervision needed increases the costs of the modification. For work in a radiation environment, time lost in the preparation of workers will be increased, up to two hours before and two hours after the work is done. Because of dose limits, more workers may be needed and each must be instructed and briefed for the task. Except for replacement energy costs, this factor may have the greatest single impact on the increase in costs of modifying a plant that is in operation.

4.3.4 Aggregating Indirect Costs

The aggregation of indirect costs using the EEDB codes of account as a guide for the three sector models is as follows:

A-E Sector Model - Cost are predominately centered in Account 921-Home Office Services, with four exceptions. NSSS Vendor Engineering is account 220B, Quality Assurance Engineering is account 922, Home Office Construction Management is account 923, and Site Engineering is part of account 932 - Field Job Supervision.

NSSS Sector Model - Costs incurred are considered in Account 220B, NSSS Options, with the exception of A-E Engineering, for which costs would be distributed as above.

5 COST ACCOUNTING METHODOLOGY

Preceding chapters of this handbook have dealt with the methods that are used to: 1) identify the activities that incur costs in implementing generic requirements, 2) identify the specific cost elements that are necessary to carry out the action and which must be estimated, 3) characterize the costs as one-time or periodic (including continuing) costs, and 4) organize these costs into a consistent accounting structure so that costs can be aggregated. This chapter provides guidance on how the one-time and periodic costs can be combined to arrive at a present value, total lifetime cost estimate for the requirement. It is on the basis of the present value of the total lifetime cost that regulatory alternatives can be compared and cost/benefit comparisons can be made.

Figure 5.1 illustrates that the present value of the total lifetime cost is the sum of two cost components: 1) total capital cost and 2) total lifetime periodic cost. Each of these two components is expressed as a present year total dollar cost, i.e., in constant dollars wherein all future costs are discounted to arrive at a present value estimate. It is preferred that all costs be expressed in constant dollars as it permits the user to choose appropriate future inflation rates and discount rates in order to arrive at a present-value cost estimate. A present-value cost estimate is required when regulating alternatives are to be compared and cost benefit comparisons are to be made.

As a general proposition, all costs must be expressed in the same year's dollars, and brought to the same point in time. Typically the year in which the analysis is being performed is adopted as the year of interest since this is when the regulatory decision will be made. Thus, if the regulatory analysis is being prepared in 1985, all costs should be expressed in 1985 constant dollars. All future costs should be discounted back to 1985 and all estimates of cost obtained prior to 1985 should be escalated to 1985.

To perform these adjustments in cost, the analyst must know three parameters:

- the discount or escalation rate
- the time period over which the adjustment is to be performed
- the amount of money or value that is to be adjusted.

5.1 AGGREGATING CAPITAL (ONE-TIME) COSTS

As stated previously and as illustrated in Fig. 5.1, the total capital cost is the sum of the direct and indirect costs. Having identified and costed all of the one-time costs for each of the plants affected by the requirement plus all of the nonplant-specific costs, the total capital cost can be evaluated simply as the sum of these individual plant costs plus the generic costs, provided all of these costs are expressed in terms of the same year dollar. This is typically the case, since estimates of labor rates, equipment, materials, etc., are easiest to obtain for the present-year market conditions.

If however, the cost estimates are not expressed in dollars representative of the year of interest, than the capital costs must be adjusted. This is done through the formula:

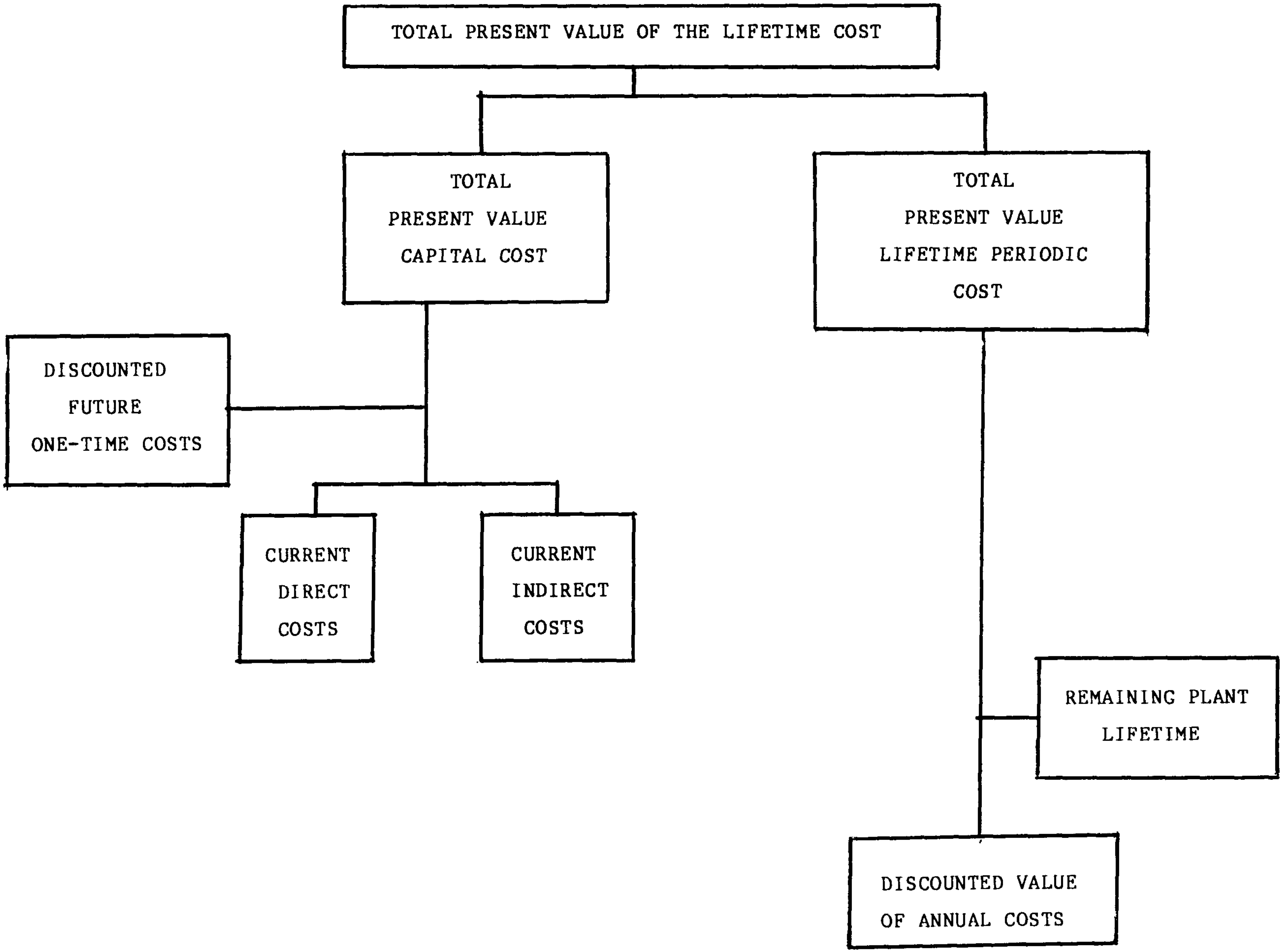

FIGURE 5.1 Total Present Value Lifetime Cost Components

$$FC = C (1 + i)^n$$

where:

- C = capital cost expressed in present year's dollars
- FC = equivalent future value (year of interest)
- i = inflation rate as a decimal
- n = number of years between the current year and the future year of interest

For example, if it is desired to express the cost of implementing a requirement in 1988 dollars but the costs have been estimated on the basis of present (1984) costs and have a total value of $10 million, and the inflation rate is assumed to be 5%, the 1988 cost estimate would be:

$$Cost_{1988} = \$10 \times 10^6 (1 + 0.05)^4$$

$$Cost_{1988} = \$12.2 \times 10^6$$

Note, the inflation rate of 5% in this example corresponds to one's perception of general inflation. If one expects these particular capital costs to increase faster than the rate of general inflation, than the capital cost must also increase by that rate of growth. Thus, for example if general inflation is 5% and real escalation is assumed to be 3%, than the capital cost must be adjusted by an 8% rate of growth.

The same formula is used to estimate the present cost of an item whose cost was previously estimated. An important rule to remember is that expressing a total cost in terms of a single year's dollar requires that all of the components of the total cost also be expressed in terms of that year's dollar.

5.2 AGGREGATING PERIODIC COSTS

The evaluation of the total lifetime cost of a requirement that contains periodic, or continuing, costs as part of the cost estimate requires that these periodic costs be summed over the plant lifetime. This summation cannot be done directly since the costs are incurred at different points in time and may be subject to escalation. First, all costs should be expressed in constant dollars commensurate with the year of interest. If each year's costs are given in current dollars, the costs can be converted to constant dollars using the formula in Sec. 5.1. Then the future cost stream must be discounted back to the year of interest by applying a real discount rate. Note, that since all costs are already expressed in constant dollars, the discount rate does not have to include a factor for nominal changes in the value of the dollar due to general inflation. This is what is meant by a real discount rate.

The real discount rate is the real rate of return on investment after adjustments for inflation have been taken into account. Because future rates of inflation are difficult to predict and are subject to much speculation; cost calculations are often done in constant (inflation-free) dollars. In such calculations, it is appropriate to use a real discount rate. The analyst should be aware that the real rate of return on investment and therefore the real discount rate is determined by many factors related to financial risk and competing need for capital.

For the purposes of calculating the estimated total lifetime present value of a requirement, NUREG/BR-0058 stipulates that a discount rate of 10% be used. Other discount rates may also be used to test the sensitivity of the analysis, and therefore it is recommended that a value of 5% also be included in the sensitivity assessment.

When discounting a stream of periodic costs, the lump sum, present value can be calculated using the following annuity formula:

$$PV = C_A \left[\frac{(1 + d)^n - 1}{d(1 + d)^n}\right]$$

where

C_A = constant dollar periodic cost

d = the real discount rate

n = the number of periods over which the costs recur.

Alternatively, if future costs are more irradic (e.g., vary in magnitude from period to period), it is necessary to calculate the present value of each future cost period separately.

The following basic formula can be used to determine the present value (PV) of an amount (F_t) at the end of a future time period:

$$PV = \frac{F_t}{(1 + d)^n}$$

where

d = the real annual discount rate (expressed as a decimal)

n = the number of years in the future in which the costs occur.

Two rule-of-thumb approximations that the user may find helpful in evaluating the present value of a future cost are the rules of 72 and 35. These rules state that the discount factor -- $(1 + d)^n$ -- is 2 when the product of rate, expressed in percent, and number of years is 72 and is 1.4 when the product is 35.

5.3 TOTAL PRESENT VALUE LIFETIME COST

The present value of total capital cost from a requirement plus the present value of all non plant-specific costs and the present value of all periodic costs summates to the Total Present Value of the Lifetime Cost.

6 COST ESTIMATE EXAMPLE: TECHNICAL SUPPORT CENTER

6.1 INTRODUCTION

This final chapter of the handbook presents, as an example, the procedure for estimating the cost of implementing a recent NRC requirement throughout the nuclear industry. The purpose of including this example estimate is to illustrate to the analyst, in a step-by-step fashion, the use of the models, methods, and cost references presented in the previous chapters. The NRC requirement selected to illustrate the estimating process is the Technical Support Center (TSC) requirement, an outgrowth of the TMI-2 accident evaluation. The basic NRC requirement and schedule for its implementation is included in NUREG-0578, entitled "TMI-2 Lessons Learned Task Force Status Report and Short-Term Recommendation," published July, 1979. The detailed requirement is promulgated in NUREG-0696, entitled "Functional Criteria for Emergency Response Facilities", published in February, 1981.

A graphical display that portrays the implementation of the TSC for a typical plant was developed from the general model presented in Chapter 2, and is included as Fig. 6.1. The display consists of the appropriate flow path through the decision nodes leading to the series of appropriate "functional responses," needed to implement this requirement, based on the assumptions discussed below.

6.2 ASSUMPTIONS

To develop the graphical model for the implementation of the TSC requirement, the following assumptions were used:

1. The reference plant to be analyzed is an operating plant responding to the requirement.

2. Since the plant is already built, a separate structure was built to house the TSC, which could also be utilized for other purposes.

3. All construction would take place in a nonradiation environment.

4. Construction of the facility would not interfere with the normal operation of the plant, therefore no replacement power would be necessary.

5. No increase in nonoperating or operating and maintenance staffs would be required.

6. Plant availability and reactor rating would not be significantly affected by the construction of the TSC.

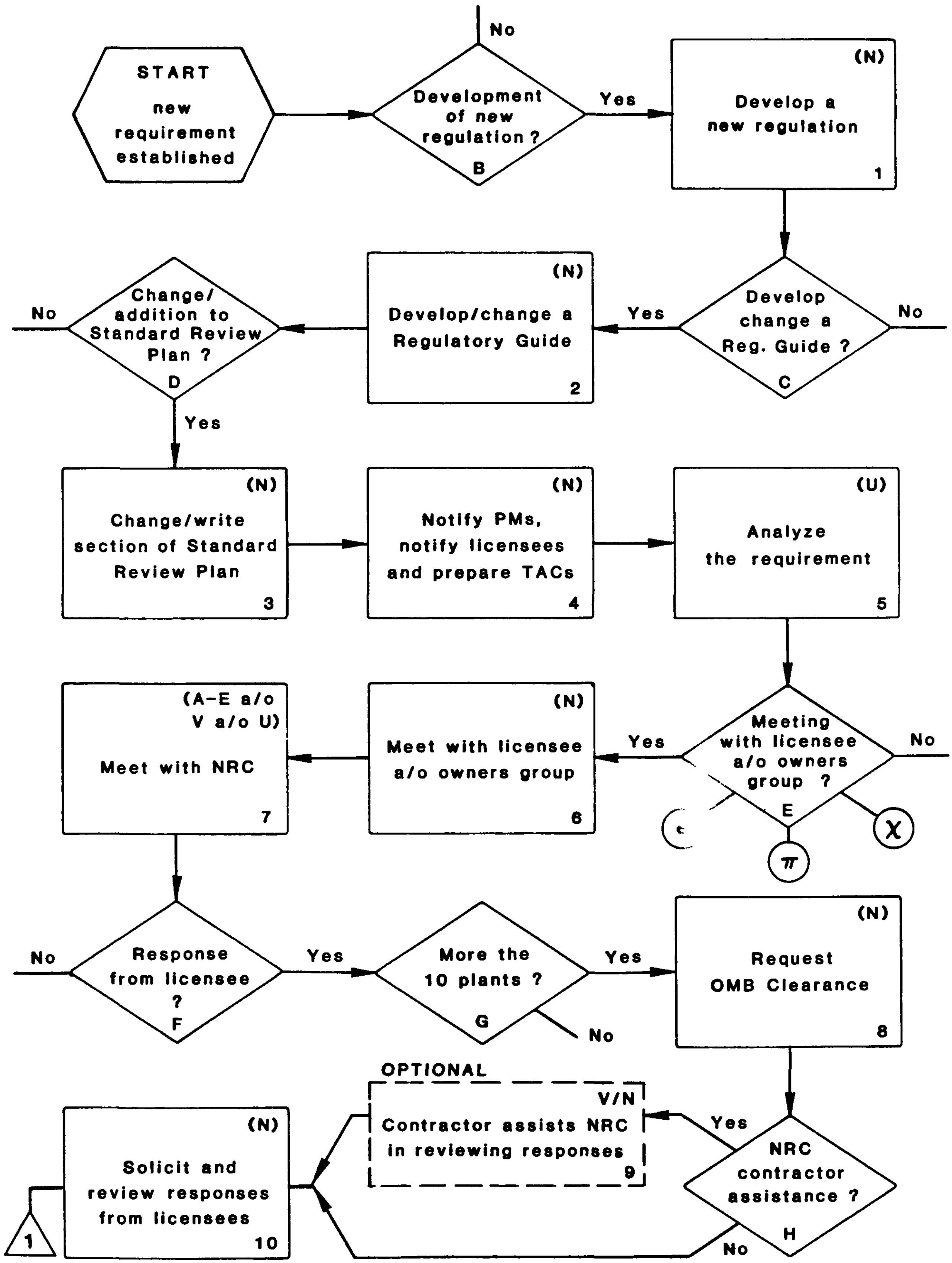

FIGURE 6.1 Technical Support Center Logic Flow Diagram

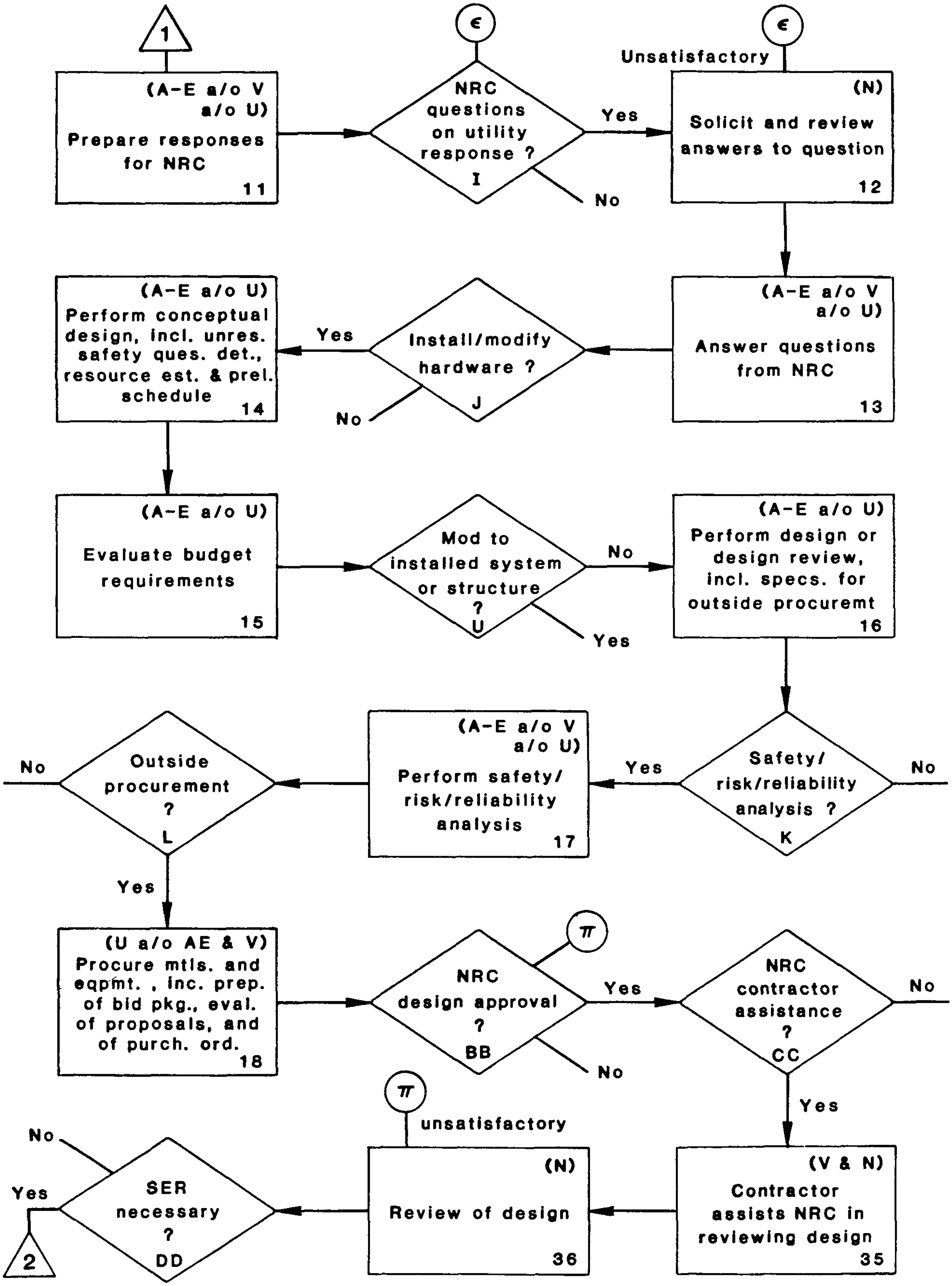

FIGURE 6.1 (Cont'd)

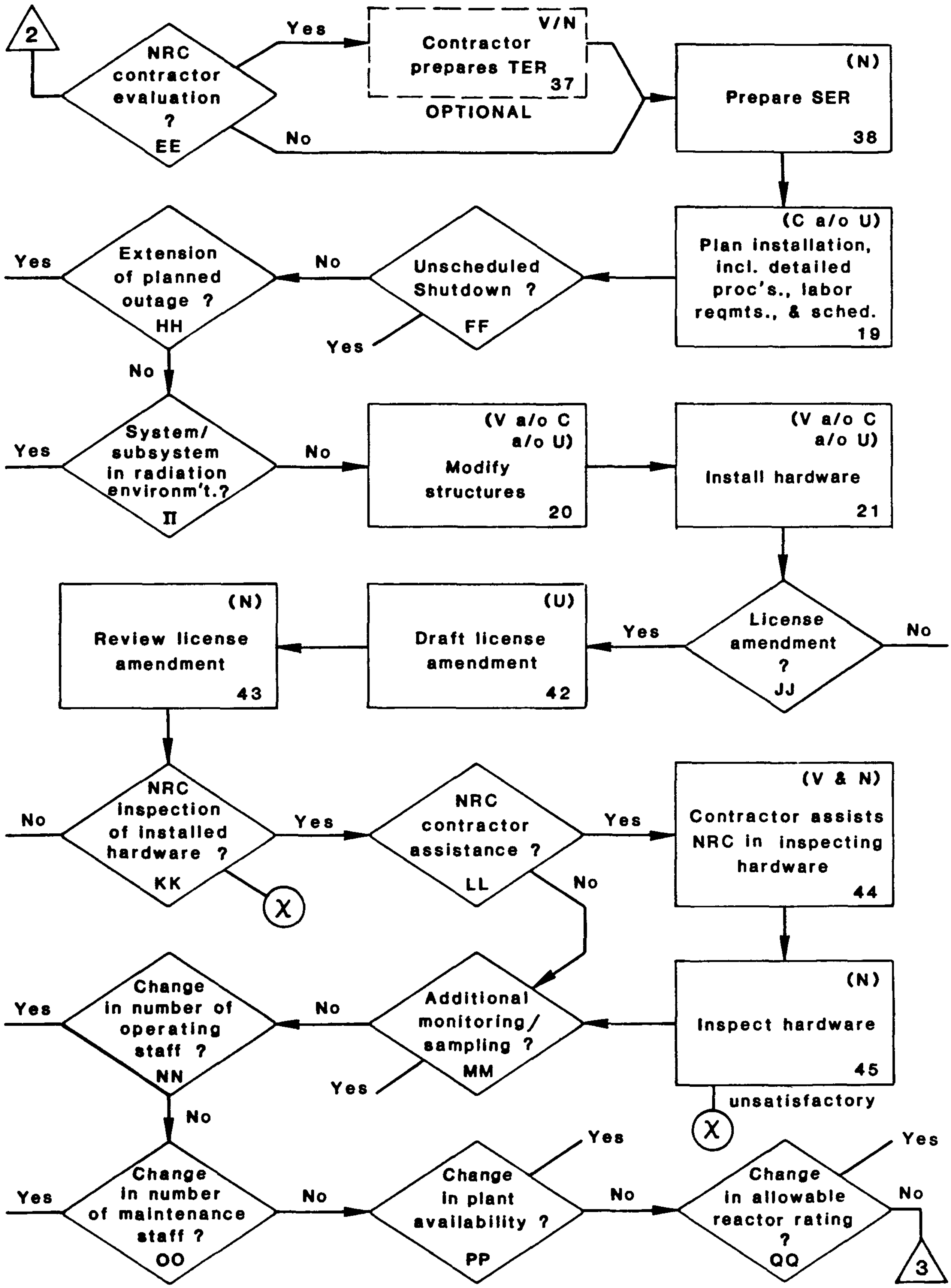

FIGURE 6.1 (Cont'd)

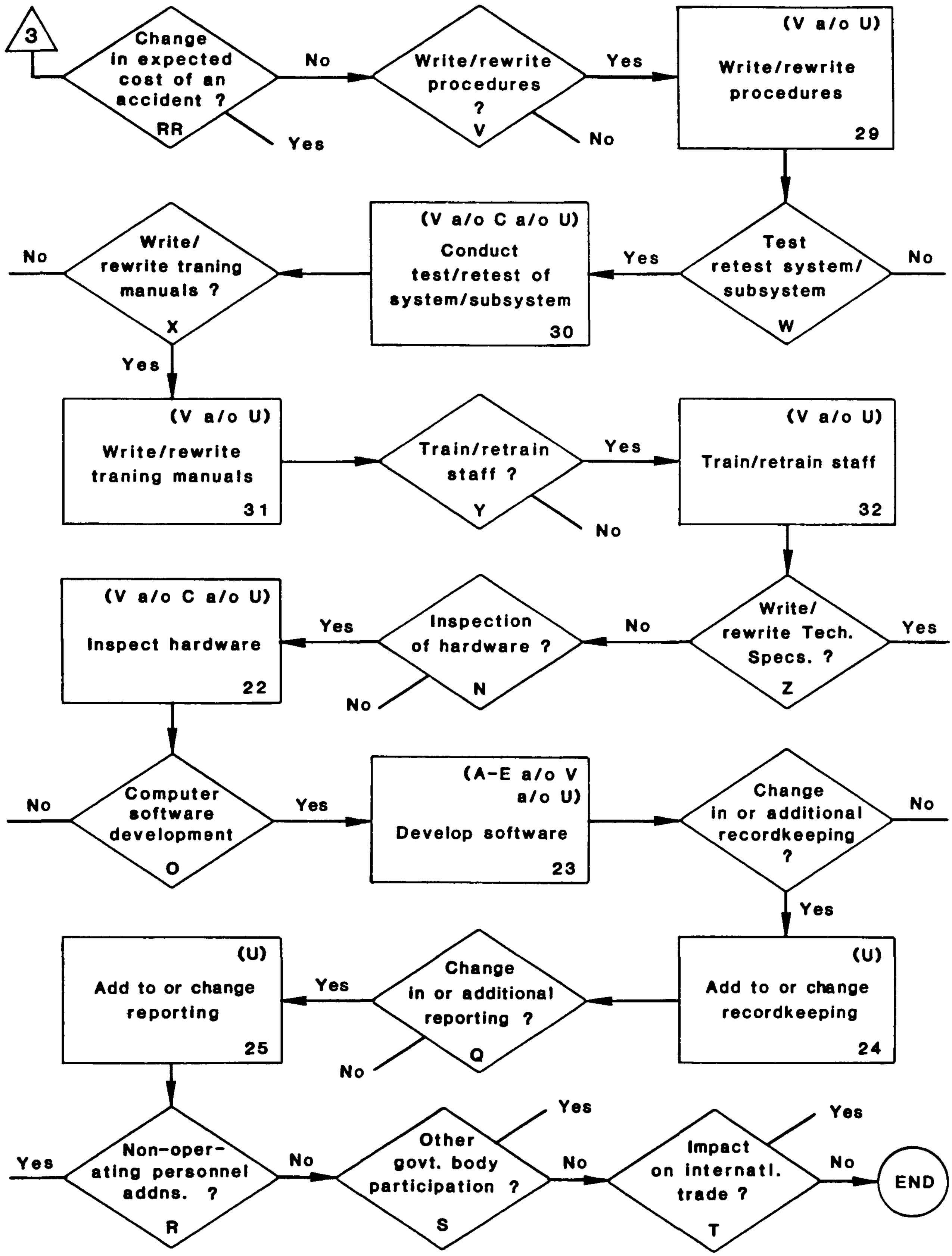

FIGURE 6.1 (Cont'd)

6.3 FUNCTIONAL RESPONSE FLOW PATH

For the purpose of this example, it is assumed that at least initial preparation of draft regulations and NUREG-0696 have occurred, so the implementation of the requirement starts with functional responses (FR) 1, 2, and 3, and then proceeds to notification of licensees, FR 4 and 5 (for FR 1-3, the costs have been prorated or estimated on a per-plant basis).

In the case of TSC requirements, the NRC held several meetings at various locations throughout the United States to explain the details of the requirements. The logic flow through FR 6 and 7 represents this process, and the cost of FR 6 has been prorated for an individual plant.

Inasmuch as all U.S. plants were involved, a request for OMB clearance is required (FR 8). Here again, the cost was prorated for an individual plant. The logic flow then progresses through solicitation of responses, FR 9 (optional) and FR 10, and then to preparation of responses, FR 11, and a question and answer phase, FR 12 and 13. The cost of FR 10 has been prorated for an individual plant.

For this example, the TSC requirement necessitates new design and construction, so that the logic flow moves to conceptual design and budget estimation, FR 14 and 15, then to the detailed design phase, FR 16, and to reliability analysis, FR 17, which results from the data system availability requirements. The next step is FR 18, for the procurement of materials and equipment.

The flow then proceeds through the NRC design review and SER preparation phases, FR 35, 36, 37 (optional), and 38, and through the construction planning and nonradiation-environment construction phases FR 19, 20, and 21.

Since the TSC is required by 10 CFR 50, a license amendment may be required, which leads next to FR 42 and 43, and then to the NRC inspection of the utility's hardware, FR 44 and 45.

To support the requirement for readiness testing, the logic flow then proceeds to procedures preparation, testing of systems, revision of training manuals, and staff training, FR 29 through 32, and initial and periodic inspection, FR 22.

The flow then proceeds to the development of software for the data system, FR 23, and finally to record keeping and reporting, FR 24 and 25.

6.4 TSC EXAMPLE SCHEDULE

Following development of the logic flow diagram, a schedule is prepared to assist in developing the cost estimates of the associated functional responses. The schedule is essential to permit a determination of the magnitude and distribution of the hours of the various personnel categories required to perform the project.

Figure 6.2 is a schedule of the design, engineering, and construction phases of the project. As indicated in the figure, the overall design, engineering, and construction

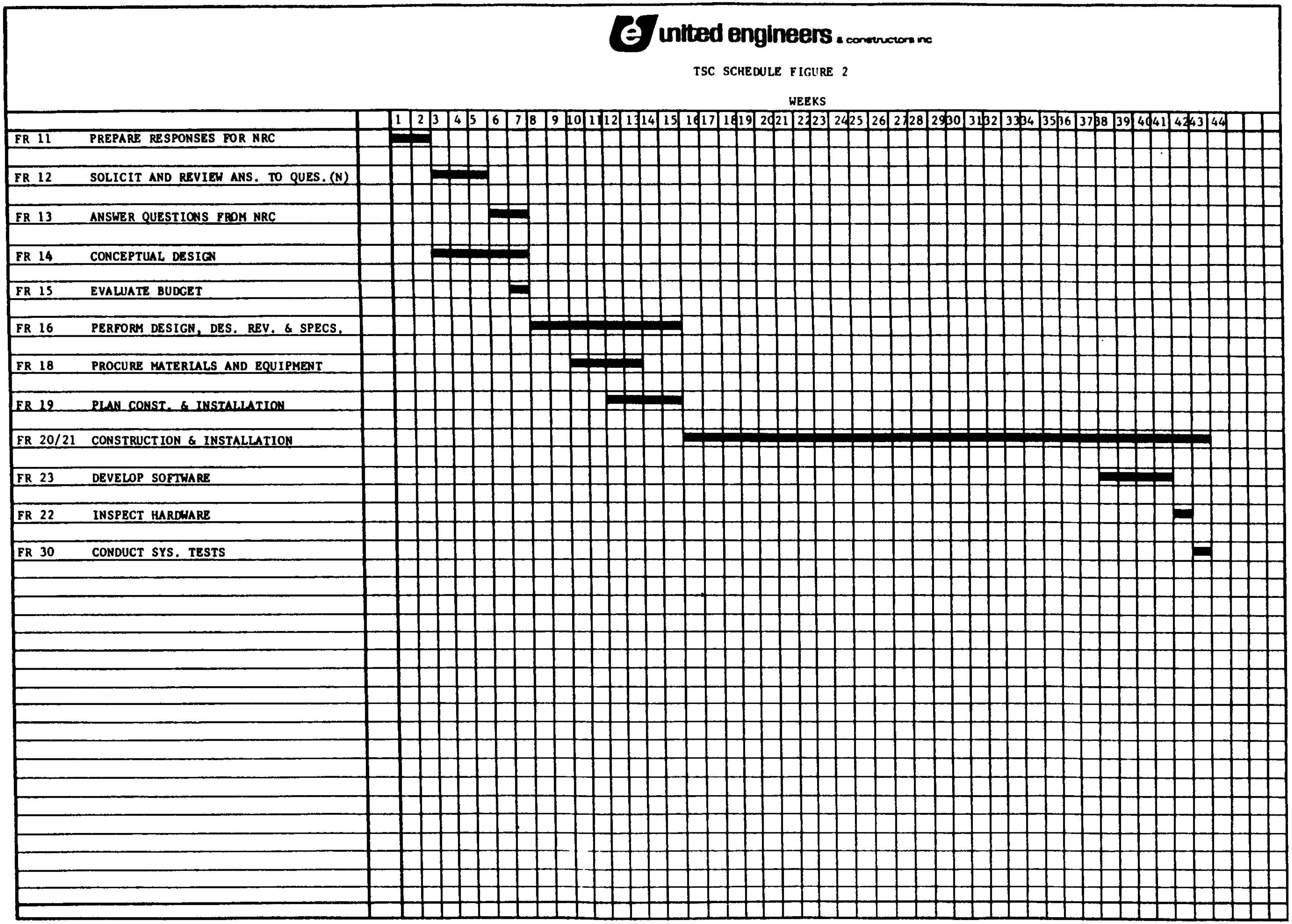

FIGURE 6.2 TSC Schedule

schedule for the TSC example consists of an overall estimated duration of 43 weeks, which starts with FR 11 (preparation of responses to the NRC) and ends with systems tests, FR 30. It includes a 15-week preconstruction phase and a 26-week construction phase, followed by two weeks of inspection and testing.

The following tabulation provides a summary of the schedule:

Functional Response	Start - Beginning of Week	Complete - End of Week
FR 11	1	2
FR 12*	3	5
FR 13	6	7
FR 14	3	7
FR 15	7	7
FR 16	8	15
FR 18	10	13
FR 19	12	15
FR 20/21	16	43
FR 23	38	41
FR 22	42	42
FR 30	43	43

6.5 TSC EXAMPLE COST ESTIMATE

To develop a cost estimate for any NRC requirement, the following steps have been identified:

1. Develop a specific logic flow diagram from the generic model of Chapter 2.

   a. Identify functional responses required.

   b. Identify cost elements required.

2. Determine costs and/or rates for each of the required cost elements.

   a. From various references identified in Chapter 3.

   b. Labor rates must include allowances for fringe benefits, payroll taxes, insurances, overhead, profit and expenses. Some craft labor rates and allowances may be obtained from the references in Chapter 3.

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*FR 12 is an NRC response and is shown since it influences the design schedule. For this example it has been assumed that no iterative resolution is required.

White collar salaries and allowances are generally proprietary, and may require the services of a consultant to obtain them.

3. Prepare a schedule identifying the period of performance for each of the major functional responses.

4. Using the schedule as a basis, estimate the hours required for each labor cost element of each functional response. This is usually accomplished through the use of engineering judgment, based upon experience, and may require the services of a consultant.

5. Develop the costs associated with the hours and labor rates determined above for the project.

On the basis of the assumptions that appear in this chapter, and with a step-by-step approach, the costs associated with the implementation of the TSC were developed as described below.

6.5.1 Estimating the Cost of Individual Functional Responses

FR 1 (Develop a New Regulation (N))

The cost shown for FR 1 represents the cost of developing changes to 10CFR50. Since the TSC requirement is a generic requirement, the overall cost for the regulatory changes was prorated among all of the plants operating and under construction. For this exercise a total of 140 plants was assumed (circa 1980) to be affected. Cost per plant should be distributed between the cost elements i. NRR labor and ii. RES labor.

The total estimated cost for this activity is: 4 engineers x 1 year x 2080 hr/yr x $50/hr ÷ 140 plants = $2970* per plant. The hourly rate includes a multiplier to cover overhead costs.

The analyst is urged to use the RSAMS management information system as a means of establishing benchmarks for manpower requirements of NRC personnel. Raw data on resource expenditures should be analyzed to ascertain manpower levels required, and the salary levels can be determined from annual budgets. NRC personnel can estimate the cost of FR 1 using the resources listed below:

- Regulatory Activities Manpower System (RSAMS).
- "Green Book" (NUREG-0566, Standards Development Status Summary Report).

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*Details for costs are assumed and the analyst is directed to the references that follow.

- RAMS System.
- "Budget Estimates Fiscal Year ___." Published Annually.

These resources are discussed in Chapter 3, Secs. 3.4.1 and 3.4.4.

FR 2 (Develop/Change Regulatory Guide (N))

The cost shown for FR 2 represents the cost of preparing a NUREG that was issued for the TMI requirements, including the TSC. The cost estimated for these documents has been spread among the plants operating and under construction, and also among the several requirements (4 were assumed) included in the NUREG. As in FR 1, the cost should be distributed between cost elements ix and x.

The total estimate for this example is: 4 Engineers x 24 wks x 40 hr/wk x \$50/hr ÷ 140 plants ÷ 4 requirements = \$343* per plant per requirement. The analyst is urged to use the RSAMS and "Green Book" to establish manpower requirements and salary levels for similar types of NRC activities.

NRC personnel can estimate costs for FR 2 using the resources listed below:

- Regulatory Activities Manpower System (RSAMS)
- "Green Book" (NUREG-0566, Standards Development Status Summary Report)
- RAMS System
- "Budget Estimates Fiscal Year ___."

These resources are discussed in Chapter 3, Secs. 3.4.1. and 3.4.4.

FR 3 (Change/Write Section of Standard Review Plan (N))

The cost for FR 3 is the cost of incorporating the TSC requirements into the standard review plans and, as in FR 1 and 2, should be distributed between ix. NRR labor, and x. RES labor. The costs have been prorated over the plants under construction and in operation, as in FR 1.

The total estimated cost for this example is: 2 Engineers x 4 wks x 40 hr/wk x \$50/hr ÷ 140 plants = \$114* per plant

*Details for costs are assumed and the analyst is directed to the resources listed in FR1.

FR 4 (Notify PMs, Notify Licensees, Prepare TACs (N))

The cost of FR 4 is the cost of notifying the PMs and the licensees, and of preparing the Technical Assignment Controls (TACs). The costs of this functional response should be distributed between the following cost elements:

i. Lead PM labor

ii. Plant PMs labor

iii. Clerical Labor

iv. Lead Engineer Labor

The cost for this example is: 3 Engineers x 1/2 wk x 40 hr/wk x $50/hr = $3000* per plant. The analyst is directed to the NRR RAM System to establish a typical level of effort for FR 4. Analysis of administrative costs will provide benchmarks for manpower and salary.

FR 5 (Analyze the Requirement (U))

The cost of FR 5 represents the initial analysis of the TSC requirement by the utility and is distributed between upper level management and engineering personnel (per plant).

a.	Project Manager	20 hr x $55/hr	=	$1100
b.	Engineering Labor	80 hr x $45/hr	=	$3600
c.	Executive Labor	10 hr x $65/hr	=	$ 650
			TOTAL	$5350

The analyst is directed to industry resources cited below, and should consult with utilities directly. Executive manpower levels required are included in internal utility budgets, which are not normally published.

- "Annual Wage and Salary Surveys", EEI
- "Utility Executive Salaries: How High? How Low?" Electrical World, pp 31-35, January 1983
- "The Engineer's Pay: Fatter Than Ever?", Electrical World pp. 45-48, March 1982.

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*Details of costs are assumed, and the analyst is directed to the NRR RAM System discussed in Chapter 3, Section 3.4.4, and FR 1.

- BLS Bulletin 1312-5, Bureau of Labor Statistics.
- "Cost Estimating Guide" Tennessee Valley Authority, Division of Engineering
- "Survey Shows Engineering Salaries Rise 6%", Electric World, pp. 29-32, July 1983

These resources are discussed in Chapter 3, Secs. 3.4.5 and 3.4.7.

FR 6 (Meet With Licensee and/or Owners' Group (N))

The costs shown for FR 6 represent the cost of the meetings with the licensees. It is not presently known whether each licensee required a separate meeting at this stage; however, it is known that the NRC held four general meetings throughout the country. A cost estimate for these meetings is made here and prorated among the plants under construction and operating, as in FR 1. Costs per plant should be distributed between the cost elements i. Head PM Labor and iv. Lead Engineer Labor.

The total estimated cost for these meetings is:

Transportation:	4 engineers x $1200 x 4 meetings	=	$19,200
Travel Time:	4 engineers x $50/hr x 8 hr x 4 meetings	=	6,400
Preparation:	4 engineers x $50/hr x 40 hr	=	8,000
Meeting:	4 engineers x $50/hr x 12 hr x 4 meetings	=	9,600
	TOTAL = $43,200 ÷ 140 = $310* per plant		

FR 7 (Meet With NRC (A-E and/or V and/or U))

The costs shown for FR 7 represents the costs for the utility or its representatives to attend the meeting discussed in FR 6. It is assumed that two high-level representatives attend the meeting, and the hours include any preparation and debriefing before and after the meeting. The effort is distributed between a project manager and engineer. The total estimated costs are:

a.	Project Manager: 30 hr x $65/hr + $1200 (travel)	=	3150
b.	Engineering Labor: 40 hr x $45/hr + $1200 (travel)	=	3000
			$6150*

*Details of costs are assumed and the analyst is directed to the NRR RAM system discussed in Chapter 3, Section 3.4.4.

The following references are useful in estimating these rates:

- "Annual Wage and Salary Surveys", EEI
- "Utility Executive Salaries, How High? How Low?", Electrical World, pp 31-35, January 1983
- "The Engineer's Pay: Fatter Than Ever?", Electrical World pp 45-48, March 1982
- BLS Bulletin 1312-5, Bureau of Labor Statistics
- "Cost Estimating Guide" Tennessee Valley Authority, Division of Engineering
- "Survey Shows Engineering Salaries Rise 6%", Electrical World, pp 29-32, July 1983

These resources are discussed in Chapter 3, Secs. 3.4.5 and 3.4.7.

FR 8 (Request OMB Clearance (N))

The cost shown for FR 8 is required, since the TSC requirement applied to all plants. The cost has been prorated among all the plants as in FR 1 and others, and should be distributed between i. Lead PM Labor and iii. Clerical Labor.

The total estimated cost for this effort is 3 Engineers x 40 hrs x \$50/hr ÷ 140 = \$40.

- "Procedures for obtaining OMB Clearance" memorandum for all NRR Personnel, Jesse L. Funches, Acting Director, Planning and Program Analysis Branch, August 4, 1982
- NRR RAMS System

These resources are discussed in Chapter 3, Secs. 3.4.4 and 3.4.8.

These administrative costs can be determined using the RAMS system and the OMB procedures cited.

FR 9 (Contractor Assists NRC in Reviewing Responses (V and N))

This cost (FR 9) is based on the assumption that the NRC used an outside contractor to assist in the review of licensee responses. The costs are estimated on a per-plant basis, and represent the NRC cost of monitoring the contractor and the cost of contracting the consulting service.

The cost estimate is:

iv. Lead Engineer: 1 engineer x 20 hr x $50/hr = $1000

xi. Labor Hour Contract: 1 engineer x 40 hr x $45/hr = $1800

$2800*

The RAMS system also has a cost category for contractual support that should be used by the analyst to establish benchmarks for FR 9.

FR 10 (Solicit and Review Responses From Licensees (N))

The cost of FR 10 is dependent upon whether FR 9 is used or not. Therefore three costs are given, below, for FR 10. The first cost is the cost of developing the request for responses and then formally requesting the responses. This cost is prorated over the total number of plants as in FR 1. The second cost is the cost of reviewing the contractor's work performed in FR 9. The third cost is the cost of reviewing a single plant response. Therefore, the total cost of FR 10 is either cost 1 + 2 if FR 9 is used, or cost 1 + 3 if FR 9 is not used. All costs should be distributed among:

i. Lead PM Labor

ii. Plant PMs Labor

iii. Clerical Labor

iv. Lead Engineer Labor

v. Technical Input Labor

The three estimated costs are:

1. 4 engineers x 4 wk x 40 hr x $50/hr ÷ 140 = $ 230

2. 1 engineer x 1 wk x 40 hr x $50/hr = $2000

3. 1.5 engineer x 1 wk x 40 hr x $50/hr = $3000

Therefore FR 10 with the use of FR 9 cost $2230, and FR 10 without the use of FR 9 cost $3230.*

*Details for costs are assumed and the analyst is directed to the RAMS system discussed in Chapter 3, Section 3.4.4.

FR 11 (Prepare Responses For NRC (A-E and/or V and/or U))

FR 11 represents the effort required to perform a preliminary evaluation to determine whether the new TSC requirement affects the utility's nuclear project, and if so, the preparation of a recommendation to the utility. The chain of events for accomplishing this is initiated by a request from the utility to the A-E to review the document, or upon direct receipt of the document by the A-E.

Typically, the new NRC requirement is reviewed by a licensing engineer assigned to the nuclear project, who determines its applicability to the project. His recommendation is forwarded to the project's engineering manager, who determines which engineering disciplines are affected. If necessary, speciality technical analysis groups outside the project are called in, as is the NSSS vendor. For those projects under construction or in operation, input is also solicited from site engineering and home office construction management. An acceptable engineering response is formulated by the appropriate parties. A recommendation is made to the utility advising what general design changes are necessary, if any, and the estimated cost of such changes. This recommendation in turn is forwarded to the NRC, if it is acceptable to the utility.

The cost elements and associated costs are as follows:

Cost Element	Hours	Rate ($/hr)	Cost
a. Project Management Labor	20	69	$ 1,400
b. Engineering Labor	560	45	25,200
c.,f.,x. Clerical, Administrative & Reproduction Labor	80	19	1,500
e. Programming Labor-Not Req'd	___		_______
TOTAL	720		$28,100

On the basis of the schedule shown in Fig. 6.2, hours were determined for the various white-collar cost elements. Rates per hour for white-collar cost elements were obtained from "National Survey of Professional, Administrative and Clerical Pay," March 1983, published by the U.S. Department of Labor, Bureau of Labor Statistics (Bulletin 2181). The rates were marked up by a factor of 2.5 to account for direct payroll charges, overhead, expenses, and profit. This factor was obtained from the detailed data base that supports the Energy Economic Data Base.

Engineering judgment was used to estimate the hours for each of the cost elements required to complete each functional response as scheduled. There is a rather formal, detailed approach for estimating engineering and supporting white-collar labor hours needed to comply with NRC requirements. This approach is beyond the scope of this handbook to describe in detail, but it is widely used to support proposals for engineering projects. Briefly, the procedure is as follows:

- Review the NRC requirements, which will permit definition of the type of equipment, type of structure, and size of structure needed to comply.

- From the above, determine the number and types of drawings and specifications that must be prepared to meet the requirements.

- Estimate the engineering, drafting, and other white-collar support labor hours required to prepare the drawings and specifications.

These hours and associated costs were correlated with the TSC portion of the detailed data base that supports the Energy Economic Data Base, Phase VI-1983, by United Engineers and Constructors, published periodically by the U.S. Department of Energy. Following are the total white-collar labor hours for FRs 11-16, 18-23, and 30 estimated for the TSC example.

Cost Element	Total Hours
a. Project Management Labor	1,040
b. Engineering Labor	17,920
c.,f.,x. Clerical, Administrative, and Reproduction Labor	6,366
d. Drafting Labor	16,720
e. Programming Labor	160
g. Accounting Labor-Included in Overhead Costs	
h. QA/QC Labor	1,200
j. Craft Supervisory Labor	5,680
o. Technician Labor	160
TOTAL	49,246

Note that in the present example, costs c., f., and x. (Clerical, Administrative, and Reproduction labor) were combined to simplify the costing task.

FR 12 (Solicit and Review Answers to Questions (N))

The cost shown for FR 12 represents the development of plant-specific questions, the transmittal of the questions, and review of the answers provided by the utility. The cost for this FR should be distributed between:

i. Lead PM Labor

ii. Plant PM Labor

iii. Clerical Labor

iv. Lead Engineer Labor

v. Technical Input Labor

The cost is estimated to be

3 engineers x 4 wk x 40 hr/wk x $50/hr = $24,000*

The RAMS system should be used to develop benchmark activity levels for NRC personnel. Comparison to other similar activities will aid the analysts in establishing manpower levels and salaries.

FR 13 (Answer Questions From NRC (A-E and/or V and/or U))

The costs for FR 13 represent the effort required to respond to questions from the NRC. This follows a procedure which is similar to that described in the discussion of FR 11.

The cost elements and associated costs are as follows:

Cost Element	Hours	Rate ($/Hr.)	Cost
a. Project Engineering Management	40	69	$ 2,800
b. Engineering Labor	560	45	25,200
c.,f.,x. Clerical, Administrative & Reproduction Labor	120	19	2,300
e. Programming Labor-Not Req'd			
TOTAL COST	720		$30,300

The procedure for estimating the above hours and rates is the same as that explained in connection with FR 11.

FR 14 (Perform Conceptual Design, Including Unresolved Safety Question Determination, Resource Estimate, and Preliminary Schedule (A-E and/or U))

The costs for FR 14 represent the effort required to perform engineering changes, analyses, and redesign as required. This is part of the preliminary evaluation of a new NRC requirement, as discussed in FR 11. This is accomplished first at the conceptual level to meet the intent of the new NRC requirement. At this level, safety questions and preliminary schedules are addressed to determine the extent of the modifications and changes, if any, that are required. All proposed changes are subject to approval by the utility.

*Details for costs are assumed and the analyst is directed to the RAMS system, which is discussed in Chapter 3, Section 3.4.4.

The cost elements and associated costs are as follows:

Cost Element	Hours	Rate ($/Hr.)	Cost
a. Project Engineering Management	100	69	$ 6,900
b. Engineering Labor	1540	45	69,300
c.,f.,x. Clerical, Administrative & Reproduction Labor	547	19	10,400
d. Drafting labor	3060	24	73,400
TOTAL COST	5,247		$160,000

The procedure for estimating the above hours and rates is the same as that explained in connection with FR 11.

FR 15 (Evaluate Budget Requirements (A-E and/or U))

These costs represent the effort required to evaluate the budget, as required, to determine the impact of changes and associated costs to meet the intent of the new NRC requirement. This evaluation includes estimating the cost of design changes, analyses, procurement, construction, testing, and scheduled changes. This is subject to negotiations with, and approval by, the utility.

Costs are primarily A-E home office and utility manhours and/or expenses, and are relatively insensitive to the complexity of the requirement.

The cost elements and associated costs are as follows:

Cost Element	Hours	Rate ($/Hr.)	Cost
a. Project Management Labor	40	69	$ 2,800
c.,f., x. Clerical, Administrative & Reproduction Labor	120	19	2,300
g. Accounting Labor-Included overhead costs	3060	24	73,400
TOTAL COST	3220		$78,500

The procedure for estimating the above hours and rates is the same as that explained in connection with FR 11.

FR 16 (Perform Detailed Design and/or Design Review, Including Specifications For Outside Procurement (A-E and/or U))

These costs represent the effort required to perform design changes, as required, to meet the new NRC requirements, as discussed in FR 11. With utility approval, the detailed design phase of the process is performed. The affected engineering disciplines, as well as the NSSS vendor if necessary, perform the design changes, which may entail new and/or revised drawings, specifications, and system design descriptions.

The cost elements and associated costs are as follows:

Cost Element	Hours	Rate ($/Hr.)	Cost
a. Project Management Labor	296	69	$ 20,400
b. Engineering Labor	4620	45	207,900
c.,f., x. Clerical, Administrative & Reproduction Labor	1639	19	31,100
d. Drafting Labor	9180	24	220,300
e. Programming Labor-Not Req'd			
f. Computer-Not Required			
h. QA/QC	107	45	4,800
TOTAL COST	15,842		$484,500

The procedure for estimating the above hours and rates is the same as that explained in connection with FR 11.

FR 17 (Perform Safety/Risk/Reliability Analysis (A-E and/or V and/or U))

For the TSC example, these are vendor costs, and are included in the factory equipment costs, cost element (E), of FR 18.

FR 18 (Procure Materials and Equipment, Including Preparation of the Bid Package, Evaluation of Proposals, and Preparation of Purchase Order (U and/or A-E and V))

These costs represent the effort required to revise existing procurement specifications or to write new specifications for factory-built equipment or hardware, and to procure this equipment. It also represents the procurement of site equipment and material. After the construction plan has been set, the site equipment and material required to perform the modifications are procured. This stage involves the services of the construction managers (923 EEDB code of accounts) in conjunction with the utility and A-E sectors. Site equipment costs are indirect costs, and include temporary construction facilities and construction tools and equipment (911 and 912 EEDB code of accounts). Site materials are primarily direct costs, and include such items as pipe, wire and cable, concrete, steel, etc. (21-26 EEDB code of accounts).

Costs for these activities consist of the home office manhours and expenses of the procuring organizations, and also the cost of the purchase of factory equipment and site materials and equipment.

The cost elements and associated costs are as follows:

Cost Element	Hours	Rate ($/Hr.)	Cost ($)
a. Project Management Labor	12	69	800
b. Engineering Labor	1120	45	50,400
c.,f.,x. Clerical, Administrative & Reproduction Labor	377	19	7,200
h. QA/QC	53	45	2,400
m. Materials and Site Equipment			390,000
t. Factory Equipment			1,080,000
TOTAL COST	1562		$1,530,800

The white-collar hours and hourly rates above were estimated by the same procedure described in connection with FR 11. The other costs of FR 18, for this example, were extracted from a draft of the EEDB-PWR cost model for Phase VI.(4) Factory equipment, site equipment, and site material costs were obtained from the detailed data base that supports the Energy Economic Data Base, Phase VI-1983, by United Engineers and Constructors, published periodically by the U.S. Department of Energy. For the structure, direct factory equipment and site materials were extracted from EEDB account 218L, "Technical Support Center." For the data system, direct factory equipment cost was based on EEDB account 227.9, "TMI Instrumentation." Since account 227.9 costs are for a data system that supplies data to three locations (one of which is the TSC), the costs were prorated as 1/3 for each location. Therefore the costs for this example are 1/3 of account 227.9. For the costs of control/display panels, direct factory equipment cost was based on EEDB account 243.15, "TSC + OSC System Control Panels". Since account 243.15 costs are for two locations, the costs for the TSC were prorated as 1/2 for each location. The indirect material costs were estimated by multiplying the TSC total direct material costs, as determined above, times the ratio of total PWR indirect material costs to total PWR direct material costs. EEDB accounts 218L, 227.9, and 243.15 are presented in Table 6.1.

More detailed considerations for determining material and equipment costs follow.

Materials

Materials needed for construction are based on a structural design that is interpreted as fulfilling the requirement of the NRC or as having the enclosure capacity to house the equipment required by the NRC. For this example, NUREG-0696 specified the housing requirements of the structure, the habitability requirements, and the adverse conditions such as earthquake, winds, and floods that the structure must withstand. With this information and the costs in EEDB (in this example), a structure was sketched and material take-offs made to develop the structural commodities.

By using references such as "Means Construction Cost Data" (Robert Snow Means Company, Inc.), or "Richardson Rapid System - Process Plant Construction Estimating

TABLE 6.1 UE&C, Inc. Energy Economic Data Base (EEDB) Phase VI, 1139 MWe Pressurized Water Reactor

ACCT NO.	ACCOUNT DESCRIPTION	FACTORY QUANTITY	FACTORY COSTS	SITE QUANTITY	SITE LABOR HRS	SITE LABOR COST	SITE MATERIAL COST	TOTAL COSTS
218L.	TECHNICAL SUPPORT CENTER							
218L.1	BUILDING STRUCTURE							
218L.11	EXCAVATION WORK							
218L.111	EARTH EXCAVATION							
218L.112	ROCK EXCAVATION							
218L.113	CONCRETE FILL							
218L.114	FILL + BACKFILL							
218L.115	DEWATERING							
	218L.11 EXCAVATION WORK							
218L.13	SUBSTRUCTURE CONCRETE							
218L.131	FORMWORK			500 SF	400 MH	7,297	1,500	
218L.132	REINFORCING STEEL			23 TN	920 MH	18,202	13,915	
218L.133	CONCRETE			250 CY	1050 MH	16,930	9,750	
218L.134	EMBEDDED STEEL							
218L.135	FLOOR FINISH			3308 SF	165 MH	2,666	198	
218L.136	WATERPROOFING							
218L.137	CONSTRUCTION JOINTS			230 SF	230 MH	4,196	426	
218L.138	RUBBING CONCRETE SURFACE							
218L.139	WIRE FABRIC			6620 SF	132 MH	2,620	1,456	

TABLE 6.1 (Cont'd)

PLANT CODE 148	COST BASIS 01/83	UNITED ENGINEERS & CONSTRUCTORS INC. ENERGY ECONOMIC DATA BASE (EEDB) PHASE VI 1139 MWE PRESSURIZED WATER REACTOR	PAGE 95 09/28/83

		******* FACTORY ********		********************* SITE *********************				TOTAL
ACCT NO.	ACCOUNT DESCRIPTION	QUANTITY	COSTS	QUANTITY	LABOR HRS	LABOR COST	MATERIAL COST	COSTS
	218L.13 SUBSTRUCTURE CONCRETE				2897 MH	51,911	27,245	79,156
218L.14	SUPERSTRUCTURE							
218L.141	CONCRETE WORK							
218L.1411	FORMWORK							
218L.14111	FORMWORK-WOOD			6468 SF	5821 MH	106,204	16,170	
218L.14112	FORMWORK-METAL			3308 SF	496 MH	9,839	9,924	
	218L.1411 FORMWORK				6317 MH	116,043	26,094	142,137
218L.1412	REINFORCING STEEL			31 TN	1705 MH	33,735	18,755	
218L.1413	CONCRETE			243 CY	1130 MH	18,219	9,477	
218L.1417	CONSTRUCTION JOINTS			500 SF	500 MH	9,122	925	
218L.1418	RUBBING CONCRETE SURFACES			3234 SF	582 MH	9,385	809	
	218L.141 CONCRETE WORK				10234 MH	186,504	56,060	242,564
218L.142	STRUCT. + MISC. STEEL			53 TN	2385 MH	47,292	75,260	
218L.143	EXTERIOR WALLS							
218L.144	ROOF DECK							
218L.145	ROOFING + FLASHING							
218L.1452	B.U.ROOF.+FLASH(NO INSUL.)			3300 SF	264 MH	5,166	5,610	
	218L.145 ROOFING + FLASHING				264 MH	5,166	5,610	10,776
218L.147	DOORS			180 SF	144 MH	2,794	3,600	
218L.148	WALL,FLOOR,+CEILING FINISH							

TABLE 6.1 (Cont'd)

PLANT CODE	COST BASIS	UNITED ENGINEERS & CONSTRUCTORS INC.	PAGE 96
148	01/83	ENERGY ECONOMIC DATA BASE (EEDB) PHASE VI	
		1139 MWE PRESSURIZED WATER REACTOR	09/28/83

ACCT NO.	ACCOUNT DESCRIPTION	******* FACTORY ******** QUANTITY	COSTS	********************* SITE ********************* QUANTITY	LABOR HRS	LABOR COST	MATERIAL COST	TOTAL COSTS
218L.1481	VINYL TILE FLOOR			3080 SF	246 MH	4,772	4,158	
218L.1482	SUSPENDED CEILING			3080 SF	308 MH	5,975	3,234	
218L.1483	SANDWICH PANELS			1600 SF	240 MH	4,656	14,389	
218L.1486	RAISED FLOOR(DISPLAY AREA)			1000 SF	450 MH	8,730	2,450	
	218L.148 WALL,FLOOR,+CEILING FINISH				1244 MH	24,133	24,231	48,364
218L.149	PAINTING							
218L.1491	CONCRETE			3000 SF	570 MH	8,556	630	
218L.1492	STEELWORK (PAINTING)			53 TN	392 MH	5,884	1,328	
218L.1493	METAL DECK			3300 SF	99 MH	1,486	528	
	218L.149 PAINTING				1061 MH	15,926	2,483	18,409
	218L.14 SUPERSTRUCTURE				15332 MH	281,815	167,244	449,059
	218L.1 BUILDING STRUCTURE				18229 MH	333,726	194,489	528,215
218L.2	BUILDING SERVICES	1 LT	60,000	1 LT	1500 MH	30,419	9,126	
218L.21	PLUMBING + DRAINS							
218L.22	HEATING,VENTILATION + AC							
218L.24	LIGHTING + SERVICE POWER							
	218L.2 BUILDING SERVICES		60,000		1500 MH	30,419	9,126	99,545
	218L. TECHNICAL SUPPORT CENTER		60,000		19729 MH	364,145	203,615	627,760
218M.	HYDROGEN RECOMBINER STRUCT							
218M.1	BLDG. STRUCTURES							

TABLE 6.1 (Cont'd)

PLANT CODE 148	COST BASIS 01/83	UNITED ENGINEERS & CONSTRUCTORS INC. ENERGY ECONOMIC DATA BASE (EEDB) PHASE VI 1139 MWE PRESSURIZED WATER REACTOR						PAGE 164 09/28/83
		******* FACTORY ********		********************* SITE **********************				TOTAL
ACCT NO.	ACCOUNT DESCRIPTION	QUANTITY	COSTS	QUANTITY	LABOR HRS	LABOR COST	MATERIAL COST	COSTS
227.9	TMI INSTRUMENTATION	1 LT	2,160,060	1 LT	57900 MH	1,144,736	24,686	
	227. RX INSTRUMENTATION+CONTROL		12,377,046		377700 MH	7,472,968	565,178	20,416,192
243.18	TSC + OSC SYS CONTROL PNLS	1 LT	695,474	1 LT	1850 MH	36,521	12,943	

Standards" (Richardson Engineering Services, Inc.), the cost of these materials can be estimated. In some accounts, material costs represent tangible materials such as cost of concrete, rebar, etc. In other accounts, intangible materials such as fuel or rental of excavation equipment, etc., are required; these costs can be found in the publications mentioned.

In some instances the above information can be approximated by comparison of a required facility with a similar facility that has been previously designed, thereby eliminating a considerable amount of the effort described above.

Equipment

Equipment costs include all mechanical services for the structure, such as plumbing, HVAC, drainpipe, and lighting, and also any process equipment, instrumentation, displays, computers and the like that are either required by the NRC or needed to support the NRC requirements.

For this example, the EEDB equipment costs for the structures (account 21 L EL - building services) were based on like equipment utilized in other similar structures in the data base. The instrumentation costs in account 227.9 and the control/display panels in account 243.15 were based on vendor quotation.

For structural-account cost estimates, an alternative approach in the absence of a comparable structure would be to prepare a detailed sizing of equipment, and to obtain costs from quotation or estimate them from references such as the Means or Richardson publications mentioned.

FR 35 (Contractor Assists NRC in Reviewing Design (V and N))

The cost shown for FR 35 includes the cost of A-E assistance to the NRC in reviewing the designs: it includes A-E costs, travel to NRC, and the cost of NRC lead engineers.

The total costs for this review are:

iv. Lead engineer: 2 days x 8 hr/day x $50/hr	=	$ 800
A-E (EEDB Code of Accounts 921-Home Office Engineering):		
4 engineers x 4 days x 8 hr/day x $45/hr	=	$5,800
4 engineers x $1200 (travel expenses)	=	$4,800
TOTAL	=	$11,400*

*Details of costs are assumed and the analyst is directed to the RAMS system, which is discussed in Chapter 3, Section 3.4.4. A-E costs depend on NRC request, and salaries of engineering personnel may be obtained from: "National Survey of Professional, Administrative, Technical and Clerical Pay" - U.S. Dept. of Labor, Bureau of Labor Statistics, September 1983: Bulletin 2181.

The salaries for the above must be multiplied by a factor to account for company expenses, payroll costs, overhead, and fee.

FR 36 (Review of Design (N))

The costs shown for FR 36 covers the design review by NRC of a specific plant change prior to construction of the structures and manufacture of the equipment. The cost should be distributed between:

i. Lead PM

iv. Lead Engineer

v. Technical Input

The total estimated cost for the review is:

3 engineers x 2 wks x 40 hr/wk x $50/hr = $12,000.*

FR 37 (Contractor Prepares TER (V and N))

This cost (FR 37) assumes that the NRC used an outside contractor to prepare a Technical Evaluation Report.

The cost estimate is:

iv. Lead engineer: 1 engineer x 80 hr x $50/hr = $ 4,000

xi. Labor Hour Contract:

3 engineers x 4 wk x 40 hr/wk x $55/hr = $26,400

TOTAL = $30,400*

The RAMS system also has a cost category for contractual support. The raw data of the RAMS system must be analyzed to establish benchmarks for contractual support activities.

FR 38 (Prepare SER (N))

The cost for FR 38 depends on whether FR 37 is used or not. Therefore two costs are given for FR 38. The first cost is the cost of preparing the Safety Evaluation Report (SER) using the input Technical Evaluation Report (TER) from FR 37; the second

*Details of the costs are assumed and the analyst is directed to the RAMS system which is discussed in Chapter 3, Section 3.4.4, and FR 1.

cost is the cost of preparing the SER without the benefit of a TER (including developing the information that would have been supplied in a TER). The costs should be distributed between:

i. Lead PM Labor

iii. Clerical Labor

iv. Lead Engineer Labor

v. Technical Input Labor

The total estimated cost if FR 37 is used is:

2 engineers x 2 wks x 40 hr/wk x \$50/hr = \$8,000*

The total estimated cost if FR 37 is not utilized is :

2 engineers x 2 wks x 40 hr/wk x \$50/hr = \$ 8,000

4 engineers x 4 wks x 40 hr/wk x \$50/hr = \$32,000

\$40,000*

The analyst is cautioned that the contractual support category of NRR RAMS system should be analyzed to establish benchmarks.

FR 19 (Plan Installation, Including Detailed Procedures, Labor Requirements, and Schedule (C and/or U))

These costs represent the effort required in specifying the work to be done to install the equipment in the plant. This includes developing the detailed procedures for accomplishing the work and the construction work schedule, defining the equipment and materials required for construction purposes, and specifying the labor required. The costs of these activities are primarily assigned to the construction management and engineers, who are responsible for detailing the work procedure (EEDB code of accounts 923).

*Details of the costs are assumed and the analyst is directed to the RAMS system, which is discussed in Chapter 3, Section 3.4.4 and FR 1.

The cost elements and associated costs are as follows:

Cost Element	Hours	Rate ($/Hr.)	Cost
a. Project Management Labor	12	69	$ 800
b. Engineering Labor	1600	45	72,000
c.,f.,x. Clerical, Administrative, & Reproduction Labor	537	19	10,200
TOTAL COST	2149		$83,000

The procedure for estimating the above hours and rates is the same as that described in connection with FR 11.

FR 20 (Modify Structures (V and/or C and/or U))

These costs represent the effort required to build a new structure for the TSC. It should be noted that the modification of existing structures to accommodate a design backfit can range from two to five times the cost of constructing new structures, as discussed in Chapter 3.

The cost elements and associated costs are as follows:

Cost Element	Hours	Rate ($/Hr.)	Cost
a. Project Management Labor	260	69	$ 17,900
b. Engineering Labor	3,640	45	163,800
c.,f.,x. Clerical, Administrative and Reproduction Labor	1,300	19	24,700
d. Drafting Labor	2,240	24	53,800
j. Craft Supervisory Labor	3,500	42.50	148,700
k. Craft Labor	34,500	22	759,000
h. QA/QC Labor	630	45	28,400
TOTAL COST	46,070		$1,196,300

The procedure for estimating the above hours and rates (except for cost element k, craft labor) is the same as that described in connection with FR 11. Craft labor hours and rate were obtained from the detailed data base that supports the Energy Economic Data Base, Phase VI-1983; the analyst should consult FR 18 and the detailed data base for similar craft labor content and labor rates.

Craft labor productivity for structures is obtained from the data base by dividing quantities of material installed by the manhours shown for each individual account. This can be simplified by combining types of accounts under a given category, e.g., substructure, superstructure, and excavation work. For the TSC, the subtask for substructure is 218L.13, and for superstructure it is 218L.14.

FR 21 (Install, Test and Maintain Hardware (V and/or C and/or U))

These costs represent the effort required to install the hardware in the new TSC structure. It should be noted that the cost of installing hardware varies considerably depending on the systems involved, the physical location of the components, the presence of interferences with existing hardware, and the percent completion of the plant/housing structure.

The cost elements and associated costs are as follows:

Cost Element	Hours	Rate ($/Hr.)	Cost
a. Project Management Labor	260	69	$ 17,900
b. Engineering Labor	3,640	45	163,800
c.,f.,x. Clerical, Administrative and Reproduction Labor	1,300	19	24,700
d. Drafting Labor	2,240	24	53,800
j. Craft Supervisory Labor	2,180	24	52,300
k. Craft Labor	22,300	22	490,600
h. QA/QC Labor	410	45	18,500
TOTAL COST	32,330		$821,600

The procedures for estimating the above hours and rates are the same as those discussed in connection with FR 11 and FR 20.

The analyst is urged to review the different types of craft labor associated with material and equipment installation for the TSC example. The data base provides a variety of craft labor benchmarks for use by the NRC analyst. These benchmarks may be understood and utilized by dividing the craft labor hours for a particular account by the items being installed to determine hardware installation productivity. These benchmarks will increase by a multiplier of from 2 to 10 when the work is performed in radiation environments, depending on the radiation level present and the need for special support activities such as those described in Sec. 3.4.40. Consultants may provide additional insight.

FR 42 (Draft License Amendment (U))

The costs shown for FR 42 represents the costs to the utility for drafting a licensee amendment. The total estimated costs are:

a. Project Management Labor 40 hr x $65/hr = $2,600

b. Engineering Labor 80 hr x $45/hr = $3,600

c. Executive Labor 20 hr x $100/hr= $2,000

TOTAL = $8,200*

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*Details of costs are assumed and the analyst is referred to the resources provided for FR 5 and 7.

For this exercise it has been assumed that the first draft is acceptable to the NRC and no iteration is required.

FR 43 (Review License Amendment (N))

The cost of FR 43 represents the NRC review of the license amendment prepared by the utility. For this example it is assumed that the draft is acceptable and no iteration is required. The costs should be distributed among:

ii. Plant PMs Labor

v. Technical Input Labor

viii. ELD Labor

The total cost is estimated as:

5 engineers x 40 hr x $50/hr = $10,000*

Labor costs by the office of the Executive Legal Director (ELD) may be included in the overhead costs of NRR staff.

FR 44 (Contractor Assists NRC in Inspecting Hardware (V and N))

The cost of FR 44 includes the cost of NRC labor associated with using the assistance of a contractor in the inspection of the modifications. The costs should be distributed between the following cost elements:

vii. I&E Region Labor

xi. Labor Hour Contract

The total estimated cost for this effort is estimated to be:

4 engineers x 40 hr x $55/hr = $8,800**

The I&E management system ("766" system) presumably contains a cost category for contracts. The analyst is cautioned that raw data needs to be analyzed to establish benchmarks for contracts.

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*Details of costs are assumed and the analyst is referred to the resources provided for FR 5 and 7.

**Details of costs are assumed and the analyst is directed to the I&C "766" system which is discussed in Chapter 3, Section 3.4.45.

FR 45 (Inspect Hardware (N))

Since a contractor is assumed to assist in the inspection of the modifications (FR 44), the cost shown for FR 45 includes the additional effort to complete the inspection. The costs for FR 45 should be distributed between:

vi. I&E Headquarters Labor

vii. I&E Region Labor

The total estimated cost is:

4 engineers x 40 hr x $50/hr = $8,000*

FR 29 (Write/Rewrite Procedures (V and/or U))

The cost shown for FR 29 represents the utility's expenses in revising operating procedures as a result of the added structure, hardware, and testing requirements.

For this example the costs for clerical labor and reproduction are assumed to be included in the overhead markups for the other labor cost categories.

The total costs are estimated to be:

a.	Project Management Labor: 1 person x 20 hr x $65/hr	= $ 1,300
b.	Engineering Labor: 3 engineers x 160 hr x $45/hr	= $21,600
c.	QA/QC Labor: 1 engineer x 80 hr x $45/hr	= $ 3,600
	TOTAL	= $26,500*

FR 30 (Conduct Test of System/Subsystem (V and/or C and/or U))

These costs represent the effort required for testing a modified system, or the first test if the system was modified during plant construction prior to testing. It may also involve testing an additional system that was added during construction or after the plant went into operation.

Care must be taken to include only the additional testing resulting from the new requirements. For the TSC, the costs are for a new system added after the plant went operational. The cost elements and associated costs are as follows:

*Details of costs are assumed and the analyst is directed to the I&C "766" system which is discussed in Chapter 3, Section 3.4.45.

The cost for initial testing is:

	Cost Element	Hours	Rate ($/Hr.)	Cost
b.,h.	Engineering Labor (includes QA/QC	280	45	$12,600
o.	Technician Labor	80	25	2,000
c.,f.,x.	Clerical, Administrative and Reproduction Labor	93	19	1,700
	TOTAL COST	453		$16,300

The cost for periodic testing is:

	Cost Element	Hours	Rate ($/Hr.)	Cost
b.,h.	Engineering Labor (includes QA/QC	80	45	$3,600
o.	Technician Labor	80	25	2,000
c.,f.,x.	Clerical, Administrative and Reproduction Labor	40	19	760
	TOTAL COST	200		$6,360/yr*

The procedure for estimating the above hours and rates is the same as that described in connection with FR 11.

FR 31 (Write/Rewrite Training Manuals (V and/or U))

The cost shown for FR 31 represents the expense incurred by the utility to prepare training manuals to address the added structures and equipment. For this example clerical and reproduction costs are assumed to be included in the overhead markups for professional labor rates, and the total costs are estimated as:

b.	Engineering Labor: 2 engineers x 80 hr x $45/hr	= $ 7,200
h.	QA/QC Labor: 1 engineer x 80 hr x $45/hr	= $ 3,600
	TOTAL	= $10,800*

FR 32 (Train/Retrain Staff (V and/or U))

The cost for this FR represents the training required by the utility personnel due to the added structure and hardware systems. For purposes of this example, two

*Details of the costs are assumed and the analyst is directed to the resources provided in FR 5 and 7.

separate sets of costs are shown. The first set is for the initial training, the second set is for annual retraining and the training of new personnel in future years.

The cost for initial training is:

b.	Engineering Labor to prepare and give training course:	
	2 engineers x 80 hr x $45/hr	= $ 7,200
	To receive training: 10 engineers x 20 hr x $25/hr	= $ 5,000
o.	Technician Labor to receive training:	
	20 technicians x 20 hr x $45/hr	= $18,000
	TOTAL	= $30,200*

The cost of annual training and retraining is:

b.	Engineering Labor to provide retraining:	
	2 engineers x 10 hr x $45/hr	= $ 900
	To receive retraining: 10 engineers x 8 hr x $45/hr	= $3,600
o.	Technician Labor to receive retraining:	
	20 technicians x 8 hr x $30/hr	= $4,800
	TOTAL	$9,300/Yr*

FR 22 (Inspect Hardware (V and/or C and/or U))

These costs represent the effort required to inspect and verify the quality of the construction work, to insure that the installation complies with the design and QA programs. It should be noted that costs can increase considerably if the inspection is performed in a radiation environment; however, this consideration does not apply to the TSC.

The cost elements and associated costs are as follows:

Cost Element	Hours	Rate ($/Hr.)	Cost
b. Engineering Labor	280	45	$12,600
c.,f.,x. Clerical, Administrative and Reproduction Labor	93	19	1,700
o. Technician Labor	80	25	2,000
k. Craft Labor (not required for the TSC)	-	-	-
TOTAL COST	453		$16,300

The procedure for estimating the above hours and rates is the same as that described in connection with FR 11.

*Details of the costs are assumed and the analyst is directed to the resources provided in FR 5 and 7.

FR 23 (Develop Software (A-E and/or V and/or U))

These costs represent the effort required for the development of new computer programs or modifications of existing programs, to evaluate such areas as energy releases, dose dispersions, mechanical stresses, and many others. This work may involve off-line analysis software or plant operations computer software. Development or revisions of programs requires the modeling of the engineered systems as well as interpretation and application of physical laws, thus requiring engineering personnel, scientists, and computer programmers working as a team.

Costs are primarily centered at the performing organization's home office and include manhours, expenses, and computer charges. It includes check out and certification of the software, documentation of the program, and preparation of a user manual. Costs can range widely, from minor modification of a few lines of program to the development of new computer codes that may require tens of thousands of manhours. These costs are pretty much independent of the percentage of completion of the plant.

The cost elements and associated costs are as follows:

Cost Element	Hours	Rate ($/Hr.)	Cost
b. Engineering Labor	80	45	$ 3,600
c.,f.,x. Clerical, Administrative & Reproduction Labor	160	19	3,000
e. Programming Labor	160	31	5,000
s. Computer - Included with other expenses in white-collar discipline costs	-	-	-
TOTAL COST	400		$11,600

The procedure for estimating the above hours and rates is the same as that described in connection with FR 11.

FR 24 (Add to or Change Record Keeping (U))

Since periodic testing is required, FR 24 represents the cost of modifying the plant record keeping. Here the clerical and administrative labor and computer, reproduction, and storage costs are assumed to be included as overhead markup in the professional labor rates.

The cost is estimated to be:

a. Project Management Labor:	1 man x 40 hr x $65/hr	= $2,600
b. Programming Labor:	2 pgr. x 80 hr x $40/hr	= $6,400
	TOTAL	= $9,000*

FR 25 (Add to or Change Reporting (U))

FR 25 represents the cost incurred by the utility to make additions to the required reporting system. The costs of clerical and administrative labor and the costs of computer and reproduction are assumed to be included in the professional labor overhead mark-up.

The cost is estimated as:

a. Project Management Labor: 1 man x 40 hr x $65/hr = $2,600*

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*Details of cost are assumed and the analyst is directed to the resources provided for FR 5 and 7.

6.5.2 Present Value of the Total Lifetime Cost

The total capital cost of the TSC for the reference plant evaluated is estimated to be $4,712,500, and the annual cost is estimated to be $15,700. These costs, which were evaluated for each functional response, are summarized below.

Single Plant Capital Costs

Single plant capital costs are aggregated as follows. All costs have been rounded to the nearest $100.

FR	COST
1	$ 3,000
2	300
3	100
4	3,000
5	5,400
6	300
7	6,200
8	-
9	2,800
10	2,200
11	28,100
12	24,000
13	30,300
14	160,000
15	78,500
16	484,500
18	1,530,800
35	11,400
36	12,000
37	30,400
38	40,000
19	83,000
20	1,196,300
21	821,600
42	8,200
43	10,000
44	8,800
45	8,000
29	26,500
30	16,300
31	10,800
32	30,200
22	16,300
23	11,600
24	9,000
25	2,600
Total	$4,712,500

Single Plant Annual Costs

FR	COST
30	6,400
32	9,300
Total	$15,700

For this example, the total estimated capital cost of the TSC to the total nuclear industry is not simply the cost to this reference plant multiplied by the 140 plants in the nation. Approximately half of the nuclear units in the country were able to accommodate the TSC within existing structures, while the remaining units required construction of separate structures. Therefore the overall cost for units using existing structures to accommodate the TSC are reduced for Functional Responses 18 and 20. These involve the structural costs and the labor to install new structures. The cost reduction for these plants for FR 18 is $194,000 per plant for material; for FR 20 the reduction is $334,000 per plant for labor, a total of $528,000. For the total of 140 plants in the country, the overall cost of the TSC is therefore estimated as described below.

Total National Capital Costs

70 plants x $4,712,500	=	$329,875,000
70 plants x ($4,712,500 - 528,000)	=	292,915,000
Capital Costs	=	$622,790,000

Assuming these one-time capital costs are in 1984 constant dollars, the 1984 P.V. of the total national capital costs also equals $622,790,000.

Total National Annual Costs

140 plants x $15,700	=	$2,198,000/yr

Present Value of Total National Lifetime Periodic Costs

For the purposes of this example, it is assumed that the 140 plants affected by this requirement have an average remaining operating lifetime of 20 years. It is also assumed that the total national annual cost of $2,198,000 is in 1984 constant dollars. Therefore, the 1984 P.V. of the Total National Lifetime Periodic Costs, assuming a 10% real discount rate, is:

$$PV = C_A \frac{((1 + d)^n - 1)}{d(1 + d)^n}$$

$$PV = \$2,198,000 \frac{(1 + .10)^{20} - 1}{(.10)\ (1 + .10)^{20}} = \$2,198,000(8.51) = \$18,705,000$$

Present Value of Total National Lifetime Cost

$622,790,000 + 18,705,000 = $641,495,000

6.6 LESSONS LEARNED FROM THE EXAMPLE PROBLEM

1. When dealing with a generic requirement that will require structures and equipment to be modified or installed, the groups of FRs in descending order of cost significance are likely to be:

   A. Design, Review, Procure, Construct, and Install: FRs 14, 16, 18, 20, 21

   These functional responses will tend to dominate the cost of the graphical model when structures and equipment changes are required.

   B. Licensing, Inspection, Testing, Manuals, Records, Specification: FRs 22, 23, 24, 25, 29, 30, 31, 32, 35, 36, 37, 38, 42, 43, 44, 45.

   The supporting services and follow-up work to implement a requirement for structures and equipment will be the second largest category of cost in the graphical model.

   C. NRC costs will be minimal for this type of requirement.

2. For this particular example, the number of cost elements could have been reduced without sacrificing the accuracy of the overall estimate. For the example problem the cost elements could have been reduced in the following manner:

   A. Combine all white-collar engineering cost elements for the A-E Functional Responses, i.e.:

   - Project Management Labor
   - Home Office and Field Engineering Labor
   - QA/QC Engineering Labor

B. Combine all white-collar nonengineering cost elements for the A-E Functional Responses, i.e.:

- Programming Labor
- Technician Labor
- Craft Supervisory Labor
- Drafting Labor

C. Combine all white-collar clerical/administrative cost elements for the A-E Functional Responses, i.e.:

- Clerical Labor
- Administrative Labor
- Reproduction Labor

D. Include expenses such as computer costs, reproduction costs, etc. in white-collar labor overhead costs.

Therefore, the number of cost elements for A-E Functional Responses could conceivably be reduced as follows:

a., b., h	-	Engineering Labor
e., d., o., j.	-	Nonengineering Labor
c., f., x.	-	Clerical/Administrative Labor
u.	-	Materials and Site Equipment
t.	-	Factory Equipment
k.	-	Craft Labor

Average labor rates can be developed for each of the above categories, and white-collar overhead mark-up factors determined, which include expenses. However, it may require the assistance of a consultant.

The above approach can also be to reduce the number of cost elements to be considered for the utility, constructor, vendor, and NRC Functional Responses.

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APPENDIX A

INDUSTRY COST ELEMENTS RESULTING FROM THE IMPLEMENTATION OF MULTI-PLANT NRC REQUIREMENTS

TASK 1 REPORT

Submitted to:
Mr. John Ball
Energy & Environmental Systems Division
Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

Under Contract No. 31-109-38-7163

Submitted by:
SC&A, Inc.
8200 Riding Ridge Place
McLean, Virginia 22102
(703) 893-6592

September 30, 1983

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INDUSTRY COST ELEMENTS RESULTING FROM THE IMPLEMENTATION OF MULTI-PLANT NRC REQUIREMENTS

1.0 INTRODUCTION

Argonne National Laboratory is developing for the Nuclear Regulatory Commission (NRC) a methodology guide for cost analysis associated with NRC requirements. The guide will assist the NRC staff in assigning costs for establishing priorities and resolving generic issues relating to LWRs. The guide will consist of three sections. The first section will summarize the underlying principles of cost estimation. The second section will identify the significant cost elements incurred by the industry, NRC, and others when NRC requirements are implemented. The third section will consist of an annotated bibliography of cost estimating data sources. The guide will be written for a competent engineer who has little or no experience in performing cost estimations.

SC&A is supporting Argonne in this effort by undertaking the following three tasks:

1. Trace through a "typical" nuclear utility two recent example NRC requirements, identifying all significant cost elements encountered in the implementation of each requirement. Where possible, estimate the magnitude of the actual cost associated with each cost element, and the estimated cost prior to the implementation of the requirement.

2. Describe (model) a "typical" nuclear utility organizationally and functionally, with the objective of tracing NRC requirements through the organization, and in so doing, identifying each potential cost element associated with the implementation of NRC requirements in each part of the organization. Develop a comparable model for the NRC in its implementation of a requirement.

3. Determine sources of information/data used by nuclear utilities for estimating costs associated with each cost element identified in Task 2.

This report presents the results of Task 1. We selected for analysis two multi-plant requirements--Accident Monitoring Instrumentation and Emergency Planning & Revisions. These requirements were selected by reviewing the 198 multi-plant requirements listed in a recent issue of NUREG-0748 (Operating Reactors Licensing Actions Summary, Vol. 3, No. 6) against the following criteria:

The requirement should be generic to several, if not all, Nuclear Steam Supply System vendors.

The requirement should be fully, or nearly fully implemented.

The requirement should have been recently implemented.

The requirement should apply to operating plants, as well as plants under construction.

At least one of the requirements should involve a physical modification to the plants.

The requirement should involve multi-dimensional cost impacts.

Using the first four of the above criteria, the list was winnowed to 31 requirements. This list was further compressed to 12 requirements by invoking the last criterion, involvement of multi-dimensional cost impacts. Finally, the selected requirements were chosen based on complexity, namely the ability to illustrate a large number of diverse cost elements.

The Accident Monitoring Instrumentation requirement consists of six parts, listed as code numbers F-20 through F-25 in NUREG-0748. It is also a Three Mile Island Action Plan requirement, listed in NUREG-0737 (Clarification of TMI Action Plan Requirements, November 1980) as item II.F.1, Attachments 1 through 6. The first three of the parts are essentially complete at all plants. These are the noble gas effluent monitor (F-20, TMI item II.F.1, Attachment 1), iodine/particulate sampling (F-21, TMI item II.F.1, Attachment 2), and containment high-range monitor (F-22, TMI item II.F.1, Attachment 3). The last three of the parts are only approximately 60% implemented. They are the containment pressure monitor (F-23, TMI item II.F.1, Attachment 4), containment water level monitor (F-24, TMI item II.F.1, Attachment 5), and containment hydrogen monitor (F-25, TMI item II.F.1, Attachment 6).

Noble gas effluent monitors with an extended range (ALARA to $10^5 \mu Ci/cc$) were required to operate for all plants during accident conditions. All plants were additionally required to have the capability to sample radioiodines and particulates for accident conditions, followed by laboratory analysis. Two containment radiation-level monitors with a maximum range of 10^8 rad/hr were to have been installed in all plants. Containment pressure instruments, capable of providing measurements in the control room up to four times the design pressure (for steel containments), were required for all plants. A continuous indication of containment water level was also required in the control room of all plants. For PWRs this was to cover the range from the bottom to the top of the containment sump with a narrow range instrument, and from the bottom of the containment to the 600,000 gallon level with a wide range instrument. For BWRs, a wide range instrument was required to cover the range from the bottom to 5 feet above the normal water level of the suppression pool. Finally, a continuous indication of hydrogen concentration in the containment atmosphere was to be provided over the range of 0 to 10% hydrogen concentration under accident conditions at all plants. All of these accident monitoring instruments required changes to technical specifications and reviews by the NRC of design details.

The Emergency Planning and Revisions requirement incorporates code numbers B-16 and F-67 of NUREG-0748. F-67 is also TMI Action Plan requirement III.A.2.1, entitled "Improving Licensee Emergency Preparedness." These are the "software" requirements of emergency planning, as given in 10 CFR Part 50, Appendix E.* An emergency plan, as outlined in NUREG-0654, is required, which includes the roles of the utility, the state, and the local government. This plan is to be supported by detailed emergency procedures, which are to be implemented annually by exercises conducted at each station. The plan is to be maintained and updated, as appropriate, training of on-site and off-site

* Facilities' requirements are given in item III.A.1.2, entitled "Upgrade Emergency Support Facilities," and clarified in NUREG-0737 Supplement No. 1. Additionally, a meteorological data upgrade is required under TMI item III.A.2.2.

personnel is to be carried out on a continuous basis, and the public is to be informed of its role. All of the documentation was to be reviewed and approved by the NRC, and the exercises are observed by the NRC and the Federal Emergency Management Agency.

Discussions were held with representatives of three nuclear utilities to identify cost elements encountered by their organizations in the implementation of the two multi-plant requirements. Additionally, actual cost data were obtained where available, as well as estimated cost prior to the implementation of the requirement. The nuclear units owned and operated by these utilities include four BWRs, three Westinghouse PWRs, and two Combustion Engineering PWRs. Additionally, data were obtained for two Westinghouse PWRs under construction. (These utilities are building several additional nuclear units for which data were not obtained.)

The results are presented in Sections 2,3, and 4 of this report. Section 2 describes the approach taken in the identification of cost elements for a "typical" utility, followed by a presentation of the functional responses and corresponding cost elements for each of the two multi-plant requirements. Section 3 compares actual costs, where available, for each of the stations owned by the three utilities surveyed. Section 4 presents a comparison of estimated (by the utility) costs with actual costs, for those few cases in which estimated costs were made available.

2.0 IDENTIFICATION OF COST ELEMENTS

2.1 Approach

Each of the three utilities surveyed is organized differently. One utility had recently formed a project management department under the vice-president for engineering, which interfaces with an internal engineering group, an outside architect-engineer, an internal production maintenance group (which in turn interfaces with an outside constructor), and an internal plant operating group. A second utility is split into design/construction and operations, each with nearly complete autonomy. Architect-engineering and construction services are rarely purchased by this utility from the outside. The third utility is a mixed bag, partly project oriented (a nuclear station being a project) and partly centrally organized, with engineering, construction, and operations under a single manager of nuclear generation. Some design and construction are performed in-house and some under contract. Purchasing departments were independent of engineering and operations in two of the three utilities.

It is expected that other forms of organization would be uncovered at other utilities. Although it would be possible to identify cost elements according to organizational elements at any one utility, the marked differences between utilities renders this approach unproductive from a generic point of view. Basically, there is no such thing as a "typical" utility organization.

Identifying cost elements from an accounting perspective is equally fruitless. There are virtually as many accounting systems as there are utilities. Accounting systems are primarily driven by rate regulatory requirements.

There is, however, a common thread between utilities from the functional point-of-view. Each utility exhibits a design function, whether it is resident with an internal headquarters design department, a plant design group, or an external architect-engineer. A licensing function may reside in design or operations. Similar considerations apply to construction, QA, procurement, project management, etc. Therefore, we will identify cost elements by examining regulatory requirements in terms of related functional responses. To each functional response we will assign corresponding cost elements. Our "typical" utility, therefore, exhibits typical functional responses to regulatory requirements.

Functional responses are listed together with the "organization affected" -- namely, utility (U),architect-engineer (A-E), constructor (C), or other vendor/contractor (V). Where more than one organization may be affected, an attempt is made to indicate this. Both the functional responses and corresponding cost elements are liberally annotated to provide the reader with insights obtained in the course of the discussions with utility representatives.

2.2 Accident Monitoring Instrumentation

The six parts of the Accident Monitoring Instrumentation requirement were not necessary for all plants surveyed, nor were all of the items which were necessary completed at all plants. The six parts were sufficiently similar in terms of functional response, however, to address the requirement as a single entity. Table I.a. presents the functional response elements corresponding to the consolidated regulatory requirement. Although the functional responses are presented roughly in chronological order, some of the elements may have been undertaken simultaneously or even in a different order by some utilities.

The cost elements corresponding to each functional response are given after each functional response in Table I.a. An alphabetized list of cost elements is contained in Table I.b.

Table I.a.
Functional Responses to the Accident Monitoring Instrumentation Requirement

1. Analyze the requirement[1] (U)
   Involved (a) project management, (b) engineering, and (c) clerical labor

2. Perform conceptual design of the modification, including unresolved safety question determination, estimates of detailed design and installation efforts, outside procurement requirement, preliminary schedule[1] (A-E and/or U)
   Involved (a) project management, (b) engineering, (c) clerical, and (d) drafting labor

3. Evaluate budget requirement[1] (U)
   Involved (e) administrative, (f) accounting, and (c) clerical labor

4. Perform detailed design, including specifications for outside procurement, and safety analysis, as necessary[2,3] (A-E and/or U)
   Involved (a) project management, (b) engineering, (c) clerical (d) drafting, and (g) QA labor, and possibly (h) computer analysis

5. Procure materials and equipment, including preparation of the bid package, evaluation of proposals, and preparation of purchase order[4] (U and V)
   Involved (a) project management, (b) engineering, (c) clerical, (e) administrative, and (g) QA labor, as well as purchased (i) equipment and (j) materials

6. Plan installation, including detailed procedures, labor requirements, and schedule[5,6] (C and/or U)
   Involved (a) project management, (b) engineering, and (c) clerical labor

7. Install equipment[7,8] (V[9] and/or C and/or U)

Involved (a) project management, (b) engineering, (g) QA, (k) craft supervisory, (l) craft, (m) radiation protection,[10] and (n) security labor, and possibly (o) replacement power[10,11]

8. Write procedures for testing, operation, and maintenance of the new equipment (U)

   Involved (a) project management, (b) engineering, and (c) clerical labor

9. Test installed equipment[8] (U)

   Involved (a) project management, (b) engineering, and (p) technician labor

10. Train operating personnel in the operation and maintenance of the new equipment (U)

    Involved (a) project management, (b) engineering, (c) clerical, and (p) technician labor

11. Obtain NRC approval for design, safe operation, and revised technical specifications (U)

    Involved (a) project management and (c) clerical labor

12. Operate and maintain new equipment (U)

    Involves (l) craft and (p) technician labor, and possibly (q) change in plant efficiency

Notes:

[1]This step was frequently bypassed in the interest of expediency.

[2]According to TVA statistics, this step generally consumes only 6-7% of the total project costs (for new plants).

[3]Design costs for modifications to other plants are generally higher than those for newer plants because it may be time consuming to locate drawings, and once they are located, they may not be accurate. Also, visits to the plant by the design team may be necessary to accurately locate existing equipment.

[4] Vendors must be pre-qualified, an indirect cost.

[5] This involves a considerably lesser effort for a plant under construction than an operating plant.

[6] The installation is planned for a scheduled outage, although the procedure is iterative, since the length of the outage is dependent on the work to be performed, amongst other considerations.

[7] This response element, which includes the unloading, handling, inspection, erection, and installation of equipment, generally dominates the costs, particularly for an operating plant. The productivity of labor is very inefficient in a radiation environment.

[8] At this step, it is frequently discovered that it is necessary to change the design, in which case we go back to Step 4. This occurred at least once for one of the surveyed utilities, resulting in an increment of work which was at least 50% of the original effort.

[9] Several utilities use outside contractors to supplement in-house radiation protection and security during an outage.

[10] This cost component does not apply to a plant under construction.

[11] Even if the modification is scheduled during a planned outage, there is potential to extend the outage, resulting in the need for replacement power. It is not possible to examine regulatory requirements individually when evaluating the potential for outage extension, since it is the combination of all of the modifications that affects outage schedule.

Table I.b.

Cost Elements Relating to the
Accident Monitoring Instrumentation Requirement

a. Project Management Labor[1,2]
b. Engineering Labor[1]
c. Clerical Labor[1]
d. Drafting Labor[1]
e. Administrative Labor[1]
f. Accounting Labor[1]
g. Quality Assurance/Quality Control Labor[1,3]
h. Computer
i. Equipment[4,5,6]
j. Materials[6,7]
k. Craft Supervisory Labor[1]
l. Craft Labor[1]
m. Radiation Protection Labor[1,8]
n. Security Labor[1]
o. Replacement Power[9]
p. Technician Labor[1,10]
q. Change in Plant Efficiency

Notes:

[1]Direct labor includes base wages, fringe benefits, employee benefits, and overhead. Items to be included in overhead vary by the worker category and by individual accounting practices. Indirect costs applicable to this regulatory requirement include company management and administration, expendable materials (such as concrete, fittings, cable, etc.), construction equipment, document storage, reproduction, and buildings.

[2]Project management is intended to include all professional management and supervision directly related to the project, not only that of the overall project manager.

[3]Includes Non-Destructive Testing.

[4]Includes cost of freight and spare parts included with the procurement of the original equipment.

[5]Evaluation of the cost of safety-grade equipment is tricky. A factor of 10 may need to be applied to the off-the-shelf cost to account for QA, seismic qualification, environmental qualification, etc.

[6]If equipment or materials are capitalized, it may be necessary to consider financing costs.

[7]Some materials, such as concrete fittings, cable, etc., may be included in overhead.

[8]Includes professional health physicists and H.P. technicians.

[9]At one of the plants surveyed, installation of the hydrogen monitor extended the planned outage by 15 days, or approximately 20%.

[10]Includes supervisory level non-professionals.

2.3 Emergency Planning and Revisions

Functional response elements relating to the Emergency Planning Requirement are presented in Table II.a., followed by the corresponding cost elements in Table II.b. An additional organizational identifier, "S-L," which denotes state and local government, follows some of the functional response elements in Table II.a.

The Emergency Planning requirement that was selected for this study, as described in the Introduction to this report, does not include the extensive emergency response facilities' capability nor the meteorology upgrade additionally required by the Commission. The costs of these additional requirements are likely to swamp the costs of the requirements examined here. However, our focus is on the "software" aspects of the emergency preparedness upgrade following Three Mile Island. Accordingly, we are also ignoring the costs of notification systems, communications systems, survey instruments, and computers, each of which is significant.

One of the interesting aspects of the emergency planning requirement is the significant continuing costs related to maintenance of the plan and procedures, training of personnel, conducting exercises and drills, and informing the public. Most of the utilities have established discrete units within their organizations to conduct these activities, staffed by several professionals and support personnel. These units may be located within the operating organ or within a central service organization, in which case emergency preparedness coordinators are appointed at the plants. In general, however, these emergency preparedness units did not exist during the early response to the NRC requirement. Therefore, functional response elements 1 through 4 in Table II.a. were typically coordinated by an ad-hoc organization.

Table II.a.
Functional Responses to the
Emergency Planning Requirement

1. Analyze the requirement (U)

   Involved (a) project management, (b) engineering, (c) clerical, and (d) executive labor

2. Rewrite[1] Emergency Plan consistent with the format of NUREG-0654 (V, and/or U, and S-L)

   Involved (a) project management, (b) engineering, (c) clerical, and (e) radiation protection labor, and possibly (f) labor-hour contract(s) with private consultant(s)[2] and (g) contract(s)/grant(s) to the state(s). (h) State official and (i) local official labor at various levels were also required.

3. Write Emergency Procedures in Support of the Emergency Plan (V, and/or U, and S-L)

   Involved (a) project management, (b) engineering, (c) clerical, (e) radiation protection, and (j) technician labor, and possibly (f) labor-hour contract(s) with private consultant(s) and (g) contract(s)/grant(s) to the state(s). (h) State official and (i) local official labor at various levels were also required.

4. Obtain NRC approval of plan and procedures, and revised technical specifications (U)

   Involved (a) project management and (c) clerical labor.

5. Continuously maintain Emergency Plan and Procedures, train personnel, and inform the public (U)

   Involves (a) project management, (b) engineering, (c) clerical, (e) radiation protection, (j) technician, and (k) public relations labor.

During training, plant operating labor is involved.[3] Also may involve (g) contract(s)/grant(s) to the state(s).

6. Annually conduct exercises and drills (V and/or U and S-L)

Involves (a) project management, (b) engineering, (c) clerical, (d) executive, (e) radiation protection, (k) public relations, and (l) administrative labor, (m) simulator time, and possibly an (f) outside contract.[4] (h) State and (i) local official labor at various levels are also involved. Additional plant personnel labor is tied up.[5]

Notes:

[1]Emergency plans already existed for all sites; the requirements of NUREG-0654 were so extensive, however, that existing documentation was of little help.

[2]These include contracts for evacuation studies.

[3]Typically, approximately 50 plant operating personnel may be trained for one week annually. Assume that these personnel are technicians.

[4]For scenario development.

[5]Exercises involve significant disruptions in plant operations, the costs of which are difficult to quantify.

Table II.b.

Cost Elements Relating to the Emergency Planning Requirement

a. Project Management Labor[1,2]
b. Engineering Labor[1]
c. Clerical Labor[1]
d. Executive Labor[1,3]
e. Radiation Protection Labor[1,4]
f. Labor-Hour Contract (private)
g. State Contract(s)/Grant(s)[5]
h. State Official Labor
i. Local Official Labor
j. Technician Labor[1,6]
k. Public Relations Labor[1]
l. Administrative Labor[1]
m. Simulator

Notes:

[1]Direct labor includes base wages, fringe benefits, employee benefits, and overhead. Items to be included in overhead vary by the worker category and by individual accounting practices. Indirect costs applicable to this regulatory requirement include company management and administration, document storage, reproduction, and buildings.

[2]Project management is intended to include all professional management and supervision directly related to the project, not only that of the overall project manager.

[3]Executive labor is normally included in overhead as an indirect cost. However, executive involvement was so extensive in implementing this requirement that explicit recognition of this cost element was deemed to be desirable.

[4]Includes professional health physicists and H.P. technicians

[5]The extent of state funding for emergency preparedness varies from utility to utility, depending on local political considerations, amongst other factors.

[6]Includes supervisory level non-professionals

3.0 MAGNITUDE OF THE COSTS

This section contains quantitative cost data which were available for the two regulatory requirements we examined. The data were not comprehensive, and detailed breakdowns were largely unavailable.

3.1 Accident Monitoring Instrumentation

The total costs for each of the six parts of the accident monitoring instrumentation requirement are given in Table III. For some of the plants, totally disaggregated costs are not available. Also, parts of the requirement were not necessary to implement at a couple of the plants. There are some comforting consistencies in the magnitude of the costs for several of the parts of the requirement from plant to plant, and some striking anomalies. Some of the anomalies may be explainable; for example, the high cost of iodine-particulate sampling for the 2 unit PWR under construction may be due to the fact that this is only a budgeted, not an actual cost. On the other hand, we are unable to explain the difference in containment water level instrumentation costs between the two BWRs.

It is important to realize that there may be large real differences in costs for any specific requirement between seemingly comparable plants. Costs are influenced by the availability of accurate design drawings (a function of the plant age), the accessibility of components in high radiation fields, the tightness of planning and management control, and, to a certain extent, good old fashioned luck. At one of the surveyed plants, an Engineering Change Notice had to be issued because of inadequate cooling to an instrumentation cabinet, resulting in an additional effort of approximately 50% of the initial effort.

TABLE III

Magnitude of the Costs for Accident Monitoring Instrumentation

	Utility #1	Utility #2			Utility #3	
	2 unit op. CE PWR	3 unit op. BWR	2 unit op. W PWR[1]	2 unit W PWR (const.)[2]	2 unit op. BWR	1 unit op. W PWR
Noble Gas Monitor	$1500K	N/A	N/A	$533K	N/A	N/A
Iodine-Part. Sampling	N/A	N/A	N/A	3065K	N/A	N/A
Both of Above	--	--	$513K	--	--	--
Contain. High Range Monitor	425K	$350K	493K	840K	N/A	N/A
All 3 of Above	--	--	--	--	$5800K	$700K
Containment Pressure	370K	200K	407K	120K	175K	102K
Containment Water Level	302K	350K	Not required	N/A	2500K	217K
Containment Hydrogen	1300K	1000K	Not required	N/A	9300K[3]	260K

Notes:

[1]Does not include materials cost, estimated to comprise approx. 30% of the total

[2]Budgeted, not actual costs

[3]Includes replacement of other monitors in containment in addition to hydrogen monitor

We were successful in obtaining only limited data on materials (including equipment) costs, shown in Table IV. These data illustrate the relatively small contribution that materials make to the total costs of these modifications. Clearly, an initial cost estimate based only on materials costs would be grossly in error.

The contribution of design costs to total costs is illustrated in Table V, based on slightly more data. Table V points out that, on the average, engineering design may well contribute more to total costs than materials.

Finally, Table VI illustrates the contribution of radiation protection and security to total installation costs at one of the plants. These costs are not negligible.

Table IV

Materials Costs As A Percentage of Total Costs for Accident Monitoring Instrumentation

	Utility #1 2 unit op. CE PWR	Utility #3 2 unit op. BWR
Noble Gas Monitor	10%	N/A
Iodine-Particulate Sampling	Not required	N/A
Contain. High Range Monitor	21%	N/A
All 3 of Above	---	21%
Containment Pressure	18%	N/A
Containment Water Level	6%	5%
Containment Hydrogen	10%	4%

TABLE V

Engineering Design Costs As a Percentage of Total Costs for Accident Monitoring Instrumentation

	Utility #1 2 unit op. CE PWR[1]	Utility #2 2 unit op. W PWR[2]	Utility #3 2 unit op. BWR
Noble Gas Monitor	22%	N/A	N/A
Iodine-Particulate Sampling	Not required	N/A	N/A
Both of Above	---	30%	---
Contain. High Range Monitor	N/A	5%	N/A
All 3 of above	---	---	22%
Containment Pressure	N/A	5%	N/A
Containment Water Level	17%	Not required	30%
Containment Hydrogen	N/A	Not required	6%

Notes:

[1]Includes costs of Project Management

[2]Total does not include materials cost; thus this percentage reflects the ratio of design labor to design plus installation labor

TABLE VI

Radiation Protection and Security Costs As a Percentage of Installation Costs for Accident Monitoring Instrumentation

	Utility #3 2 unit op. BWR[1]	
	Radiation Protection	Security
Noble Gas Monitor	N/A	N/A
Iodine-Particulate Sampling	N/A	N/A
Contain. High Range Monitor	N/A	N/A
All 3 of Above	5%	0.4%
Containment Pressure	N/A	N/A
Containment Water Level	7%	1%
Containment Hydrogen	4%	0.6%

Note:
[1] Based on 1983 project costs only

3.2 Emergency Planning and Revisions

There was no formal tracking of costs at any of the three utilities surveyed during the development of the emergency plans or procedures. Continuing costs for maintaining the plan and training are fairly well known, but the costs for conducting an exercise are so diffuse that it is difficult to get a handle on them. One of the utilities substantially funded the states during the development of the off-site plans, and continues to provide them funding for the maintenance of the off-site plans.

Rough estimates were made by each of the utilities for the costs of some of the functional response elements given in Table II.a. We have taken the liberty of converting estimates given in man-years to dollars. No attempt was made to disaggregate costs by individual plant. The composite of these various estimates are given in Table VII.

Despite the tenuous basis for most of the estimates given in Table VII, there is surprising consistency between the two available estimates for the development of emergency plans and procedures, and between the two available estimates of the in-house costs of maintaining the plan. The funding by one of the utilities of the state governments is anomalous, although other utilities have provided direct grants to the states for off-site emergency planning. Also, little can be surmised from the estimates of the costs of annual exercises, since these were all very rough estimates.

Table VII

Magnitude of the Costs for Emergency Planning

	Utility #1 (1 station)	Utility #2 (3 stations)	Utility #3 (2 stations)
Develop Emergency Plan and Procedures			
In-house effort	$300K[1]	N/A	$75K
Private contract	N/A	None	300K
State contract	None	$3300K	None
Annual Maintenance of the Plan			
In-house effort	N/A	650K[4]	500-600K
State contract	None	915K	None
Annual Exercise			
In-house effort	30K[2]	100K[5]	175K[5]
State effort	30K[3]	N/A	N/A

Notes:

[1] Based on utility estimate of 6 man-yrs at 50K/man-yr

[2] Based on utility estimate of 310 man-days at $150/man-day

[3] Based on utility estimate of 200 man-days at $150/man-day

[4] $300K/yr for unit at headquarters plus $150K/yr for team performing radiological monitoring and meteorology plus $165K/yr for time of plant personnel undergoing training plus $12K/yr/plant for plant coordinators

[5] Rough estimate

4.0 COMPARISON BETWEEN COST ESTIMATES AND COSTS INCURRED

The three utilities surveyed differ in the methods used to perform an initial cost estimate of a plant modification. At one of the utilities, time permitting (and it frequently doesn't), the esimate is based on the results of an interdisciplinary conceptual design of the modification. At another it is based on a "rap session" attended by a few engineers. A small sample of comparisons indicates that the accuracy of the original estimate is independent of the sophistication of the methods used.

There were no original cost estimates available for the Emergency Planning and Revisions Requirement. Only one utility had some data relating to the Accident Monitoring Instrumentation Requirement, and a comparison of these original cost estimates with actual costs are given in Table VIII. In general, the original estimates are lower than the actual costs by roughly one order of magnitude.

One other utility, with the two-unit operating CE PWR, had some comparative data for an aggregate of several TMI items. For this aggregate, the original cost estimate was $10 million and the actual cost was $17 million. For this same utility, the fire barriers under the fire protection requirement (10 CFR 50, Appendix R) cost $1.8 million, whereas the original cost estimate was $8 million. The comparison between the estimated and actual costs for the alternate safe shutdown mechanism under the same regulatory requirement was much closer -- $6.5 million (original estimate) versus $8 million (actual).

Table VIII

Comparison Between Cost Estimates and Costs Actually Incurred

	Utility #3 2 unit op. BWR Original Cost Est.	 Actual Cost
Noble Gas Monitor	N/A	N/A
Iodine/Part. Sampling	N/A	N/A
Contain. High Range Monitor	N/A	N/A
All Three of Above	$650K	$5800K
Containment Pressure	165K	175K
Containment Water Level	208K	2500K
Containment Hydrogen	564K	>9300K[1]

Notes:

[1]Contains work in addition to the installation of containment hydrogen monitors. Also work is not complete.

APPENDIX B

COMMERCIAL NUCLEAR POWER ELECTRIC GLNERATING PLANTS IN THE UNITED STATES*

United States

NORTHEAST	Net MWe	Type	Reactor Supplier	Generator Supplier	Architect Engineer	Constructor	Construction stage (%)	Commercial Operation: orig schedule†	Commercial Operation: actual or expected
Baltimore Gas & Electric Co									
• Calvert Cliffs 1 (Lusby, Md)	850	PWR	C-E	GE	Bechtel	Bechtel	100	1/73	5/75
• Calvert Cliffs 2 (Lusby, Md)	850	PWR	C-E	W	Bechtel	Bechtel	100	1/74	4/77
Boston Edison Co.									
• Pilgrim 1 (Plymouth, Mass)	670	BWR	GE	GE	Bechtel	Bechtel	100	10/71	12/72
Connecticut Yankee Atomic Power Co									
• Haddam Neck (Haddam Neck, Conn)	582	PWR	W	W	S&W	S&W	100	11/67	1/68
Consolidated Edison Co.									
• Indian Point 2 (Indian Point, N Y)	873	PWR	W	W	UE&C	Wedco	100	6/69	7/74
Duquesne Light Co.									
• Beaver Valley 1 (Shippingport, Pa)	833	PWR	W	W	S&W	S&W/DLC	100	6/73	4/77
Beaver Valley 2 (Shippingport, Pa)	833	PWR	W	W	S&W	DLC	78 1	10/78	5/86
GPU Nuclear Corporation									
• Oyster Creek 1 (Forked River, N J)	620	BWR	GE	GE	B&R/GE	B&R	100	2/68	12/69
• Three Mile Island 1 (Londonderry Twp , Pa)	792	PWR	B&W	GE	Gilbert	UE&C	100	9/71	9/74
• Three Mile Island 2 (Londonderry Twp , Pa)	880	PWR	B&W	W	B&R	UE&C	100	5/73	12/78
Long Island Lighting Co.									
Shoreham (Brookhaven, N Y)	820	BWR	GE	GE	S&W	Utility	99	/75	early 85
Maine Yankee Atomic Power Co.									
• Maine Yankee (Wiscasset, Me)	825	PWR	C-E	W	S&W	S&W	100		12/72
New York Power Authority									
• Indian Point 3 (Indian Point, N Y)	965	PWR	W	W	UE&C	Wedco	100	7/71	8/76
• James A FitzPatrick (Scriba, N Y)	821	BWR	GE	GE	S&W	J P. Bell	100	1/73	7/75
Niagara Mohawk Power Corp									
• Nine Mile Point 1 (Scriba, N Y)	610	BWR	GE	GE	Utility	S&W	100	11/68	12/69
Nine Mile Point 2 (Scriba, N Y)	1080	BWR	GE	GE	S&W	S&W	78	7/78	10/86
Northeast Utilities									
• Millstone 1 (Waterford, Conn)	660	BWR	GE	GE	Ebasco	Ebasco	100	6/69	12/70
• Millstone 2 (Waterford, Conn)	870	PWR	C-E	GE	Bechtel	Bechtel	100	4/74	12/75
Millstone 3 (Waterford, Conn)	1150	PWR	W	GE	S&W	S&W	81	3/78	5/86
Pennsylvania Power & Light Co.									
• Susquehanna 1 (Berwick, Pa)	1050	BWR	GE	GE	Bechtel	Bechtel	100	5/79	6/83
Susquehanna 2 (Berwick, Pa)	1050	BWR	GE	GE	Bechtel	Bechtel	99	5/81	11/84
Philadelphia Electric Co									
• Peach Bottom 2 (Peach Bottom, Pa)	1065	BWR	GE	GE	Bechtel	Bechtel	100	/71	7/74
• Peach Bottom 3 (Peach Bottom, Pa)	1065	BWR	GE	GE	Bechtel	Bechtel	100	/73	12/74
Limerick 1 (Pottstown, Pa)	1055	BWR	GE	GE	Bechtel	Bechtel	90	8/78	4/85
Limerick 2 (Pottstown, Pa)	1055	BWR	GE	GE	Bechtel	Bechtel	30	1/80	10/88
Public Service Co. of New Hampshire									
Seabrook 1 (Seabrook, N H)	1150	PWR	W	GE	UE&C	UE&C	89	11/79	12/84
Seabrook 2 (Seabrook, N H)	1150	PWR	W	GE	UE&C	UE&C	29	8/81	7/87
Public Service Electric & Gas Co.									
• Salem 1 (Salem, N J)	1079	PWR	W	W	Utility	UE&C	100	/71	6/77
• Salem 2 (Salem, N J)	1106	PWR	W	W	Utility	UE&C	100	/73	10/81
Hope Creek 1 (Salem N J)	1070	BWR	GE	GE	Bechtel	Bechtel	81	3/75	12/86
Rochester Gas & Electric Corp									
• Robert E Ginna (Ontario N Y)	490	PWR	W	W	Gilbert	Bechtel	100	11/69	3/70
Vermont Yankee Nuclear Power Corp.									
• Vermont Yankee (Vernon, Vt)	514	BWR	GE	GE	Ebasco	Ebasco	100	10/70	11/72
Yankee Atomic Electric Co									
• Yankee (Rowe, Mass)	175	PWR	W	W	S&W	S&W	100	1/61	6/61

CONTINUED

NOTE Deleted from this list are Clinton 2, Shearon Harris-2, River Bend-2, the Clinch River breeder reactor, and Skagit Hanford 1 and -2 These projects have been canceled in recent months Marble Hill 1 and -2 are retained in the list at our deadline there was discussion of canceling the station

*Extracted from Nuclear News, February 1984/Vol. 27/No. 2. This list is updated semiannually (February and August). Reprinted with the permission of Nuclear News.

MIDWEST

	Net MWe	Type	Reactor Supplier	Generator Supplier	Architect Engineer	Constructor	Construction stage (%)	Commercial Operation orig. schedule	Commercial Operation actual or expected
Cincinnati Gas & Electric Co.									
Zimmer 1 (Moscow, Ohio)	810	BWR	GE	W	S&L	Kaiser	98	/75	indef
The Cleveland Electric Illuminating Co.									
Perry 1 (North Perry, Ohio)	1205	BWR	GE	GE	Gilbert	Utility	90	7/79	5/85
Perry 2 (North Perry, Ohio)	1205	BWR	GE	GE	Gilbert	Utility	42	7/80	5/88
Commonwealth Edison Company									
• Dresden 1 (Morris, Ill.)	207	BWR	GE	GE	Bechtel	Bechtel	100	7/60	8/60
• Dresden 2 (Morris, Ill.)	794	BWR	GE	GE	S&L	UE&C	100	2/69	8/70
• Dresden 3 (Morris, Ill.)	794	BWR	GE	GE	S&L	UE&C	100	2/70	10/71
• LaSalle County 1 (Seneca, Ill.)	1078	BWR	GE	GE	S&L	Utility	100	2/76	10/82
LaSalle County 2 (Seneca, Ill.)	1078	BWR	GE	GE	S&L	Utility	99	2/77	4/84
• Zion 1 (Zion, Ill.)	1040	PWR	W	W	S&L	Utility	100	4/72	12/73
• Zion 2 (Zion, Ill.)	1040	PWR	W	W	S&L	Utility	100	5/73	9/74
Byron 1 (Byron, Ill.)	1120	PWR	W	W	S&L	Utility	93	5/79	6/84
Byron 2 (Byron, Ill.)	1120	PWR	W	W	S&L	Utility	67	3/80	11/85
Braidwood 1 (Braidwood, Ill.)	1120	PWR	W	W	S&L	Utility	70	10/79	10/85
Braidwood 2 (Braidwood, Ill.)	1120	PWR	W	W	S&L	Utility	54	10/80	10/86
Commonwealth Edison Company, Interstate Power Company, and Iowa-Illinois Gas and Electric Company									
Carroll County 1 (Savanna, Ill.)	1120	PWR	W		S&L		0	10/87	/2001
Carroll County 2 (Savanna, Ill.)	1120	PWR	W		S&L		0	10/88	/2002
Commonwealth Edison Co. and Iowa-Illinois Gas & Electric Co.									
• Quad-Cities 1 (Cordova, Ill.)	789	BWR	GE	GE	S&L	UE&C	100	3/70	8/72
• Quad-Cities 2 (Cordova, Ill.)	789	BWR	GE	GE	S&L	UE&C	100	3/71	10/72
Consumers Power Co.									
• Big Rock Point (Charlevoix, Mich.)	63	BWR	GE	GE	Bechtel	Bechtel	100	12/62	12/62
• Palisades (South Haven, Mich.)	740	PWR	C-E	W	Bechtel	Bechtel	100	7/70	12/71
Midland 1 (Midland, Mich.)	425[a]	PWR	B&W	GE	Bechtel	Bechtel	85	5/78	indef
Midland 2 (Midland, Mich.)	808	PWR	B&W	GE	Bechtel	Bechtel	85	5/79	/86
Dairyland Power Cooperative									
• La Crosse BWR (Genoa, Wis.)	50	BWR	Allis	Allis	S&L	Maxon	100	10/66	11/69
Detroit Edison Co.									
Fermi 2 (Newport, Mich.)	1100	BWR	GE	GEC	Utility	Daniel	98	/74	12/84
Illinois Power Co.									
Clinton 1 (Clinton, Ill.)	933	BWR	GE	GE	S&L	Baldwin	82.4	6/80	11/86
Indiana & Michigan Electric Co.									
• Donald C. Cook 1 (Bridgman, Mich.)	1050	PWR	W	GE	AEPSC	AEPSC	100	4/72	8/75
• Donald C. Cook 2 (Bridgman, Mich.)	1100	PWR	W	BBC	AEPSC	AEPSC	100	4/73	7/78
Iowa Electric Light & Power Co.									
• Duane Arnold (Palo, Iowa)	545	BWR	GE	GE	Bechtel	Bechtel	100	12/73	5/74
Kansas Gas & Electric Co., Kansas City Power & Light Co. and Kansas Electric Power Cooperative, Inc.									
Wolf Creek (Burlington, Kans.)	1150	PWR	W	GE	Bech/S&L	Daniel	90	4/81	2/85
Nebraska Public Power District									
• Cooper (Brownsville, Neb.)	778	BWR	GE	W	B&R	B&R	100	4/71	7/74
Northern States Power Co.									
• Monticello (Monticello, Minn.)	536	BWR	GE	GE	Bechtel	Bechtel	100	5/70	7/71
• Prairie Island 1 (Red Wing, Minn.)	520	PWR	W	W	FPS	Utility	100	5/72	12/73
• Prairie Island 2 (Red Wing, Minn.)	520	PWR	W	W	FPS	Utility	100	5/74	12/74
Omaha Public Power District									
• Fort Calhoun 1 (Fort Calhoun, Neb.)	486	PWR	C-E	GE	G&H	G&H	100	6/71	9/73
Public Service Indiana									
Marble Hill 1 (Jefferson County, Ind.)	1130	PWR	W	W	S&L	Utility	60	/82	12/88
Marble Hill 2 (Jefferson County, Ind.)	1130	PWR	W	W	S&L	Utility	37	/84	6/90
Toledo Edison Co.									
• Davis-Besse 1 (Oak Harbor, Ohio)	906	PWR	B&W	GE	Bechtel	Bechtel	100	12/74	11/77
Union Electric Co.									
Callaway 1 (Fulton, Mo.)	1150	PWR	W	GE	Bechtel	Daniel	98	10/81	4/84
Wisconsin Electric Power Co.									
• Point Beach 1 (Two Creeks, Wis.)	497	PWR	W	W	Bechtel	Bechtel	100	4/70	12/70
• Point Beach 2 (Two Creeks, Wis.)	497	PWR	W	W	Bechtel	Bechtel	100	4/71	10/72

[a] Midland-1 and 2 have the same size reactors. Unit 1, however, was designed to deliver part of its steam to a nearby chemical facility.

	Net MWe	Type	Reactor Supplier	Generator Supplier	Architect Engineer	Constructor	Construction stage (%)	Commercial Operation orig schedule†	Commercial Operation actual or expected
U S —MIDWEST, cont'd									
Wisconsin Public Service Corporation									
• Kewaunee (Carlton, Wis)	535	PWR	W	W	FPS	FPS	100	6/72	6/74
SOUTH									
Alabama Power Company									
• Joseph M Farley 1 (Dothan, Ala)	829	PWR	W	W	SCSI/Bechtel	Daniel	100	4/75	12/77
• Joseph M Farley 2 (Dothan, Ala)	829	PWR	W	W	SCSI/Bechtel	Daniel	100	4/76	7/81
Arkansas Power & Light Co.									
• Nuclear One 1 (Russellville, Ark)	836	PWR	B&W	W	Bechtel	Bechtel	100	7/72	12/74
• Nuclear One 2 (Russellville, Ark)	858	PWR	C-E	GE	Bechtel	Bechtel	100	12/75	3/80
Carolina Power & Light Co.									
• Robinson 2 (Hartsville, S C)	665	PWR	W	W	Ebasco	Ebasco	100	5/70	3/71
• Brunswick 1 (Southport, N C)	790	BWR	GE	GE	UE&C	Brown	100	3/75	3/77
• Brunswick 2 (Southport, N C)	790	BWR	GE	GE	UE&C	Brown	100	3/74	11/75
Shearon Harris 1 (Newhill, N C)	900	PWR	W	W	Ebasco	Daniel	85	3/77	3/86
Duke Power Co.									
• Oconee 1 (Seneca, S C)	860	PWR	B&W	GE	Utility/Bech	Utility	100	5/71	7/73
• Oconee 2 (Seneca, S C)	860	PWR	B&W	GE	Utility/Bech	Utility	100	5/72	9/74
• Oconee 3 (Seneca, S C)	860	PWR	B&W	GE	Utility/Bech	Utility	100	6/73	12/74
• McGuire 1 (Cornelius, N C)	1180	PWR	W	W	Utility	Utility	100	3/76	12/81
McGuire 2 (Cornelius, N C)	1180	PWR	W	W	Utility	Utility	99 4	3/77	3/84
Catawba 1 (Clover, S C)	1145	PWR	W	GE	Utility	Utility	97 8	3/79	6/85
Catawba 2 (Clover, S C)	1145	PWR	W	GE	Utility	Utility	61 9	3/80	6/87
Florida Power & Light Co.									
• Turkey Point 3 (Florida City, Fla)	666	PWR	W	W	Bechtel	Bechtel	100	8/70	12/72
• Turkey Point 4 (Florida City, Fla)	666	PWR	W	W	Bechtel	Bechtel	100	8/71	9/73
• St Lucie 1 (Hutchinson Island, Fla)	777	PWR	C-E	W	Ebasco	Ebasco	100	1/73	12/76
• St Lucie 2 (Hutchinson Island, Fla)	777	PWR	C-E	W	Ebasco	Ebasco	100	9/79	8/83
Florida Power Corporation									
• Crystal River 3 (Red Level, Fla)	875	PWR	B&W	W	Gilbert	Jones	100	9/72	3/77
Georgia Power Co.									
• Edwin I Hatch 1 (Baxley, Ga)	810	BWR	GE	GE	SS/Bechtel	Utility	100	4/73	12/75
• Edwin I Hatch 2 (Baxley, Ga)	820	BWR	GE	GE	Bechtel	Utility	100	4/76	8/79
Vogtle 1 (Waynesboro, Ga)	1100	PWR	W	GE	SS/Bechtel	Utility	61	2/78	3/87
Vogtle 2 (Waynesboro, Ga)	1100	PWR	W	GE	SS/Bechtel	Utility	19 9	2/79	9/88
Gulf States Utilities Co.									
River Bend 1 (St Francisville, La)	940	BWR	GE	GE	S&W	S&W	82	10/79	12/85
Louisiana Power & Light Co.									
Waterford 3 (Taft, La)	1104	PWR	C-E	W	Ebasco	Ebasco	99	1/77	12/84
Mississippi Power & Light Co.									
Grand Gulf 1 (Port Gibson, Miss)	1250	BWR	GE	Allis	Bechtel	Bechtel	100	9/79	9/84
Grand Gulf 2 (Port Gibson, Miss)	1250	BWR	GE	Allis	Bechtel	Bechtel	33 1	9/81	indef
South Carolina Electric & Gas Co.									
Virgil C Summer 1 (Parr, S C)	900	PWR	W	GE	Gilbert	Daniel	100	10/77	1/84
Tennessee Valley Authority									
• Browns Ferry 1 (Decatur, Ala)	1067	BWR	GE	GE	Utility	Utility	100	10/70	8/74
• Browns Ferry 2 (Decatur, Ala)	1067	BWR	GE	GE	Utility	Utility	100	10/71	3/75
• Browns Ferry 3 (Decatur, Ala)	1067	BWR	GE	GE	Utility	Utility	100	10/72	3/77
• Sequoyah 1 (Daisy, Tenn)	1148	PWR	W	W	Utility	Utility	100	10/73	7/81
• Sequoyah 2 (Daisy, Tenn)	1148	PWR	W	W	Utility	Utility	100	4/74	6/82
Watts Bar 1 (Spring City, Tenn)	1177	PWR	W	W	Utility	Utility	96	10/76	11/84
Watts Bar 2 (Spring City, Tenn)	1177	PWR	W	W	Utility	Utility	61	4/77	10/86
Bellefonte 1 (Scottsboro, Ala)	1213	PWR	B&W	BBC	Utility	Utility	76	7/77	4/89
Bellefonte 2 (Scottsboro, Ala)	1213	PWR	B&W	BBC	Utility	Utility	57	4/78	4/91
Hartsville A1 (Hartsville, Tenn)	1233	BWR	GE	BB	Utility	Utility	44	4/79	indef
Hartsville A2 (Hartsville, Tenn)	1233	BWR	GE	BB	Utility	Utility	34	4/80	indef
Yellow Creek 1 (Iuka, Miss)	1285	PWR	C-E	GE	Utility	Utility	35	4/83	indef
Yellow Creek 2 (Iuka, Miss)	1285	PWR	C-E	GE	Utility	Utility	3	4/85	indef
Virginia Electric & Power Co.									
• Surry 1 (Gravel Neck, Va)	775	PWR	W	W	S&W	S&W	100	3/71	12/72
• Surry 2 (Gravel Neck, Va)	775	PWR	W	W	S&W	S&W	100	3/72	5/73

CONTINUED

• Units in commercial operation

† Estimated date of startup, announced at time reactor was ordered

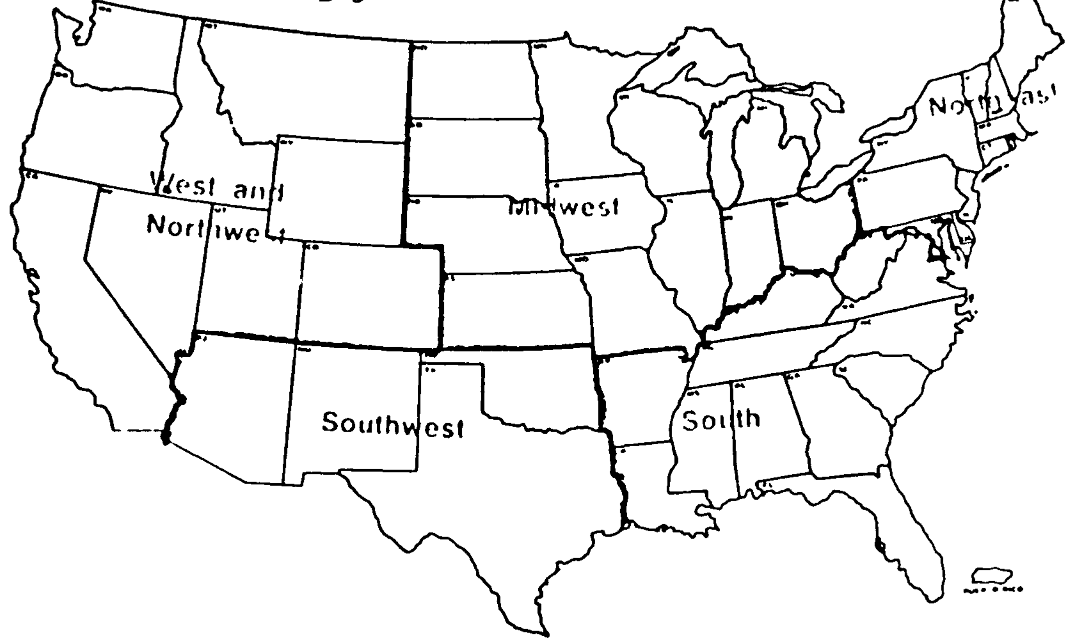
cp — construction permit issued

lwa — limited work authorization issued

	Net MWe	Type	Reactor Supplier	Generator Supplier	Architect Engineer	Constructor	Construction stage (%)	Commercial Operation orig. schedule†	Commercial Operation actual or expected
U.S.—SOUTH, cont'd									
Virginia Electric & Power Co., cont'd									
• North Anna 1 (Mineral, Va.)	877	PWR	W	W	S&W	S&W	100	3/74	6/78
• North Anna 2 (Mineral, Va.)	890	PWR	W	W	S&W	S&W	100	7/75	12/80
SOUTHWEST									
Arizona Public Service Co.									
Palo Verde 1 (Wintersburg, Ariz.)	1270	PWR	C-E	GE	Bechtel	Bechtel	99.5	5/81	12/84
Palo Verde 2 (Wintersburg, Ariz.)	1270	PWR	C-E	GE	Bechtel	Bechtel	98.7	11/82	9/85
Palo Verde 3 (Wintersburg, Ariz.)	1270	PWR	C-E	GE	Bechtel	Bechtel	83.2	5/84	12/86
Houston Lighting & Power Company									
South Texas Project 1 (Palacios, Tex.)	1250	PWR	W	W	Bechtel	Ebasco	50	10/80	6/87
South Texas Project 2 (Palacios, Tex.)	1250	PWR	W	W	Bechtel	Ebasco	25	3/82	6/89
Texas Utilities Generating Company									
Comanche Peak 1 (Glen Rose, Tex.)	1150	PWR	W	Allis	G&H	B&R	97	1/80	/84
Comanche Peak 2 (Glen Rose, Tex.)	1150	PWR	W	Allis	G&H	B&R	65	1/82	/86
WEST AND NORTHWEST									
Pacific Gas & Electric Co.									
Diablo Canyon 1 (Avila Beach, Calif.)	1084	PWR	W	W	Utility	Utility	100	5/72	6/84
Diablo Canyon 2 (Avila Beach, Calif.)	1106	PWR	W	W	Utility	Utility	95	7/74	2/85
Portland General Electric Co.									
• Trojan (Prescott, Ore.)	1130	PWR	W	GE	Bechtel	Indep	100	9/74	5/76
Public Service Company of Colorado									
• Fort St. Vrain (Platteville, Colo.)	330	HTGR	GA	GE	S&L	GA	100	4/72	1/79
Sacramento Municipal Utility District									
• Rancho Seco (Clay Station, Calif.)	913	PWR	B&W	W	Bechtel	Bechtel	100	5/73	4/75
Southern California Edison and San Diego Gas & Electric Co.									
• San Onofre 1 (San Clemente, Calif.)	436	PWR	W	W	Bechtel	Bechtel	100		1/68
• San Onofre 2 (San Clemente, Calif.)	1100	PWR	C-E	GEC	Bechtel	Bechtel	100	6/75	8/83
San Onofre 3 (San Clemente, Calif.)	1100	PWR	C-E	GEC	Bechtel	Bechtel	100	6/75	1/84
United States Department of Energy[b]									
• Hanford-N (Richland, Wash.)	860	LGR	GE	GE	B&R	B&R	100		7/66
Washington Public Power Supply System									
WNP-2 (Richland, Wash.)	1100	BWR	GE	W	B&R	Bechtel	99	9/77	7/84
WNP-1 (Richland, Wash.)	1250	PWR	B&W	W	UE&C	Bechtel	62.5	9/80	indef
WNP-3 (Satsop, Wash.)	1240	PWR	C-E	W	Ebasco	Ebasco	75	3/82	indef
U.S. Total (139 units)	**128 507**								

[b] Power is extracted by WPPSS through the Hanford Generating Project; the reactor is owned by the DOE.

NORTHEAST Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont
SOUTH: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia
MIDWEST: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin
SOUTHWEST: Arizona, New Mexico, Oklahoma, Texas
WEST AND NORTHWEST: California, Colorado, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming



Abbreviations used in this table

A-A ASEA Atom (Sweden)
AC Acres Canatom (Canada)
ACEC Ateliers de Constructions Electriques de Charleroi S A (Belgium)
ACECO ACEC with COP (Belgium)
ACECOWEN ACECO with Westinghouse (Belgium)
ACLF group ACECO/Creusot Loire/Framatome/Westinghouse Electric Energy Systems Europe (France)
ADF Auxeltra Delens Francois
AECL Atomic Energy of Canada Ltd
AEE Atomenergoexport (USSR) (formerly TPE Technopromexport)
AEG Allgemeine Elektricitaets Gesellschaft Aeg Telefunken (W Germany)
AEI Associated Electric Industries Ltd (U K)
AEPSC American Electric Power Service Corp (U S)
AETEA Agroman EyT EA (Spain)
AGR advanced gas-cooled reactor
Allis Allis-Chalmers (U S)
Alsthom Ste Generale de Constructions Electriques et Mechaniques (France)
AMN Ansaldo Meccanico Nucleare SpA (Italy)
APC Atomic Power Construction Ltd (U K)
Arge KKU Dyckerhoff & Widmann AG Wayss & Freitag AG Hegdkamp (FGR)
ASGEN Ansaldo San Giorgio Compagnia Generale (Italy)
Aux Auxini Ingenieria Espanola SA (Spain)
Bal Balfour Beatty & Co (U K)
BAM Balaatsche Aanneming Maatschappij NV (The Netherlands)
BBC Brown Boveri et Cie (Switzerland)
BBR Babcock Brown Boveri Reaktor GmbH (W Germany)
Bech Bechtel Corporation (U S)
BHEL Bharat Heavy Electrical (India)
BLWR same as BWR
BN Belgonucleaire (Belgium)
BNDC British Nuclear Design & Construction Ltd (U K)
B&R Burns & Roe Inc (U S)
B&V Black & Veatch (U S)
B&W Babcock & Wilcox Co (U S)
BRAUN C F Braun & Co (U S)
Brown Brown & Root Inc (U S)
BWR boiling water reactor
C-B Campenon Bernard (France)
CdA Condotte d Acqua (Italy)
C-E Combustion Engineering Inc (U S)
CEA Commissariat a l'Energie Atomique (France)
CEM Compagnie Electro Mechanique (France)
CFE Cie d'Enterprises CFE S A (Belgium)
CGE Canadian General Electric
Chag Chagnaud (France)
Cie GE Cie Generale d'Electricite (France)
CITRA Compagnie Industrielle de Travaux (France)
CL Creusot Loire (France)
CM Chantiers Modernes (France)
CNO Construtora Noberto Oldebrecht (Brazil)
COP/TOSI/ACEC Cockerill Ougree Providence/Franco Tosi SpA/Ateliers de Constructions Electriques de Charleroi SA (Belgium)
CTAFMC CFE Traveaux Astrobel General Contractors Francois et Fils Maurice Delens Campenon Bernard (Belgium)
CTL Canatom Ltd (Canada)
DAE Department of Atomic Energy (India)
Daniel Daniel Construction Co (U S)
D-L Delattre Levivier (France)
DOE Department of Energy (U S)
EA Empresarios Agrupados (Spain)
E&B Emch & Berger (Switzerland)
Ebasco Ebasco Services Inc (U S)
ECC Engineering Construction Corp (India)
EE English Electric Co Ltd (U K)
EEC English Electric Co Ltd (Canada)
EEW English Electric and G Wimpey Group (U K)
EI Elettronucleare Italiana (Italy)
Elin Elin Union AG (W Germany)
ENB Empresa Nacional Bazan (Spain)
ENSA Equipos Nucleares SA (Spain)
EPDC Electric Power Development Co Ltd (Japan)
EROTERV Power Plant Design Bureau (Hungary)
ETOCEA Entrecanales y Ocisa (Spain)
EWI ElectroWatt Ltd (Switzerland)
EyT Entrecanales y Tavora SA (Spain)
Fou Fougerolle (France)
FPS Fluor Power Services (U S)
Fra Framatome Societe Franco-Americaine de Constructions Atomiques SA (France)
FRAMACECO Framatome with ACECO (Belgium)
Fuji Fuji Electric Co Ltd (Japan)
GA General Atomic Company (U S)
GAAA Groupement pour les Activites Atomiques et Avancees (France)
GC Groupement Constructeurs Francais (France)
GCHWR gas-cooled heavy water moderated reactor
GCR gas-cooled reactor
GE General Electric Co (U S)
GEC General Electric Co (U K)
GETSCO General Electric Technical Services Co
G&H Gibbs & Hill Inc (U S)
G&HE Gibbs & Hill Espanola SA (Spain)
Gilbert Gilbert Associates Inc (U S)
GilCom Gilbert/Commonwealth (U S)
GKW Gemeinschaftkraftwerk Weser GmbH (FRG)
GTM Grands Travaux de Marseille (France)
Haz Hazama Gumi Co (Japan)
HCC Hindustan Construction Co (India)
Hoch Hochtief AG (W Germany)
H-P Howden-Parsons (Canada)
HQ Hydro-Quebec (Canada)
HRB Hochtemperatur Reaktorbau GmbH (W Germany)
HTGR high temperature gas-cooled reactor
HWLWR heavy water moderated boiling light water-cooled reactor
Iber Iberduero SA (Spain)
Imp Impresit
INB Internationale Natrium Brutreaktorbau GmbH (W Germany)
INITEC Empresa Nacional de Ingeneria y Tecnologia SA (Spain)
Int Interatom (W Germany)
IyP Informes y Projectas SA (Spain)
JL John Laing Construction Ltd (U K)
Jones J A Jones Construction Co (U S)
J-S Jeumont Schneider (France)
Kaiser Kaiser Engineers (U S)
KHIC Korea Heavy Industries and Construction Company
KTHTR Konsortium THTR—Brown Boveri & Cie AG Hochtemperatur Reaktorbau GmbH Nukem GmbH (W Germany)
Kum Kumagaya Gumi Co (Japan)
KWU Kraftwerk Union AG (W Germany)
L&T Larsen & Toubro (India)
LGR light water cooled graphite-moderated reactor
LMFBR liquid metal fast breeder reactor
LWBR light water breeder reactor
LWCHW light-water-cooled heavy water-moderated reactor
MAPI Mitsubishi Atomic Power Industries Inc (Japan)
Maxon Maxon Construction Company (U S)
McAlp Sir Robert McAlpine & Sons Ltd (U K)
MCING Motor Columbus Consulting Engineers Inc (Switzerland)
MECO Montreal Engineering Co (Canada)
MEL Mitsubishi Electric Corporation (Japan)
MHI Mitsubishi Heavy Industries Ltd (Japan)
MNI Ministry of Nuclear Industry (PRC)
NCC Nuclear Civil Constructors (U K)
NEI Northern Engineering Industries (U K)
Nera Neratoom NV (The Netherlands)
Nersa Centrale Nucleaire Europeenne A Neutrons Rapides (France)
NIRA Nucleare Italiana Reattori Avanzati (Italy)
NNC National Nuclear Corporation (U K)
NPC Nuclear Power Co Ltd (U K)
Nuclebras Empresas Nucleares Brasieiras SA
Nuclen Nuclebras Engenaria SA (Brazil)
Nuclep Nuclebras Equipamentos Pesados SA
NWK Nordwestdeutsche Kraftwerke AG (FRG)
Obay Obayashi Gumi Co (Japan)
OH Ontario Hydro (Canada)
OPS Offshore Power Systems (U S)
Par (U.K.) C A Parsons and Co Ltd (U K)
Parsons Ralph M Parsons Co (U S)
PE Promon Engenharia SA (Brazil)
PH Philip Holzman (W Germany)
PHWR pressurized heavy water moderated and -cooled reactor
PWR pressurized water reactor
Rateau Rateau Ste (France)
R & C Richardson & Cruddas (I) (India)
RDM Rotterdamse Droogdok Madtschappij (The Netherlands)
RPL Reyrolle Parsons Ltd (U K)
RW Richardsons Westgarth Ltd (U K)
SACM Societe Alsacienne de Constructions Mechaniques (France)
SB Spie Batignolles SA (France)
SCG Skanska Cementgjuteriet
SCSI Southern Company Services Inc
SeB Sainrapt et Brice (France)
SEN Sener SA (Spain)
SGE Societe Generale d Enterprises (France)
SHI Sumitomo Heavy Industries Ltd (Japan)
SK Sydvenska Kraft AB (Sweden)
S&L Sargent & Lundy Engineers (U S)
S-L Stal Laval Turbin AB (Sweden)
SNC Surveyer Nenniger & Chenevert Inc (Canada)
SO Siemens Osterreich (Austria)
SOCIA Societe pour l'Industrie Atomique (France)
SOGENE Societa Generale per Lavore e Pubbliche Utilita (Italy)
SR Stearns Roger Corp (U S)
SS Southern Services Inc (U S)
SSPB Swedish State Power Board
Stork Koninklijke Machinefabriek Stork (The Netherlands)
S&W Stone & Webster Engineering Corp (U S)
T&B Townsend & Bottum Inc
TE Traction Electricite
THTR thorium high temperature reactor
TNPG The Nuclear Power Group (U K)
TPC Taiwan Power Company
TR Tecnicas Reunidas SA (Spain)
TW Taylor Woodrow Construction Ltd (U K)
UE&C United Engineers & Constructors (U S)
VANEA Vandellos Empresarios Agrupados (Spain)
VBB AB Vattenbyggnadsbyran
VMF Verenigde Machinefabrieken NV (The Netherlands)
W Westinghouse Electric Corporation (U S)
Wedco a subsidiary of Westinghouse Electric Corporation (U S)
WIL Walchandnagar Industries Ltd (India)
Zachry H B Zachry Company (U S)

APPENDIX C

EEDB DIRECT COST ACCOUNTS — 2 DIGIT DESCRIPTION

Structures and Improvements (Account 21)

This account includes the on-site surface buildings and structures and subsurface foundations and tunnels that house and support all equipment, components, piping, ducting, and wiring. Also included in this account are site improvements such as excavation, grading, roadways, and railroads. The subaccounts for each structure include equipment for the heating, ventilating, and air conditioning systems and the lighting and service power systems for that structure.

Nuclear power plants have two basic classes of on-site structures. Certain structures support and protect safety-related equipment and assist in the prevention of significant release of radioactivity to the environment. These critical structures are designed to withstand a Design Basis Earthquake (as opposed to the earthquake requirements in the Uniform Building Code) at the Middletown site. They are given the designation of Seismic Category I. The other class of structures is designated as Non-Seismic Category I. These structures house and support equipment not essential to the prevention of significant release of radiation.

The account does not include the foundations for individual plant machinery or the buildings and foundations for the heat rejection systems. The foundations are described in the appropriate equipment account and in the Main Condenser Heat Rejection System Structures (Account 261) accounts.

The primary structure in the plant is the Reactor Containment Building. The other major Seismic Category I structures include the Primary Auxiliary Building, the Waste Process Building, the Fuel Storage Building, the Control and Diesel-Generator Building, the Emergency Feedwater Pump Building, the Main Steam and Feedwater Pipe Enclosures, the Hydrogen Recombiner Structure and the Ultimate Heat Sink Structure.

The major Nonseismic Category I structures include the Turbine Room and Heater Bay, the Technical Support Center, the Administration and Service Building, the Security Building, the Fire Pump House, the Nonessential Switchgear Building and the Holding Pond.

Reactor Plant Equipment (Account 22)

This account includes the equipment that liberates thermal energy from fuel and uses the resulting heat to generate steam. For each reactor, support equipment is included to control the plant output, store an inventory of fuel, and store and treat the residue or waste products. For a nuclear power plant, this equipment includes the reactor safety systems, the fuel storage systems, and the radioactive waste handling systems.

The NSSS scope includes the reactor pressure vessel and internals, the control rod system, the reactor core cooling system, the residual heat removal system, the safety injection system, the containment spray system, the combustible gas control system, the fuel handling system, and associated instrumentation and controls for these systems.

The balance of reactor plant systems includes the inert gas system, the reactor water make-up system, the coolant treatment and recycle system, the fluid leak detection system, and the auxiliary cooling system.

Turbine Plant Equipment (Account 23)

The turbine plant includes the power conversion equipment that produces electric power from the steam generated by the reactor plant. All of the EEDB technical models use a conventional steam-turbine generator unit, although the configuration will vary from plant to plant. An elevated foundation pedestal supports the steam turbine and generator. This account includes the turbine generator unit, the condenser, the systems to purify and return the condensate to the reactor plant, the elevated turbine generator pedestal, and the turbine generator unit control system. The turbine plant equipment includes the steam handling, power conversion, and condensate/feedwater machinery of the steam cycle.

Electric Plant Equipment (Account 24)

The electric plant equipment conveys the electric power generated in the plant to the low voltage bushings of the generator step-up (GSU) transformers, controls and meters the electric energy, and protects the components through which the power flows. It is the source of power for the plant auxiliaries and the plant control, protection, and surveillance systems, during normal operation, and for the plant protection system and engineered safety features, during normal operation, abnormal conditions, and accident conditions.

Miscellaneous Plant Equipment (Account 25)

This account includes the auxiliary mechanical and electric equipment required for normal power plant startup, operation, and maintenance. This includes the equipment in the air, water and steam service system, the auxiliary boiler, the fire protection system, and the communication system.

Miscellaneous plant equipment includes systems for maintenance, plant startup, or general supply of plant equipment requirements. Included are the cranes and hoists, the air, water and steam services, the auxiliary boiler and associated services, the plant fuel oil system, the fire protection system, the communications systems, and various on-site and off-site environmental monitoring systems.

Main Condenser Heat Rejection System (Account 26)

This system includes the equipment and associated structures that dispose of the heat rejected by the power plant. The system is a closed-loop circulating water system. It consists of the buildings, structures, and mechanical equipment that serve the main condensers and the service water system to reject the excess plant heat through two mechanical-draft, wet cooling towers. The structures included in this account are the Make-Up Water Intake and Discharge Structure, the Circulating Water Pump House, the Make-Up Water Pretreatment Building, and the Chlorination Building.

APPENDIX D

EEDB INDIRECT COST ACCOUNTS — 2 DIGIT DESCRIPTION

Construction Services (Account 91)

Temporary construction facilities include temporary structures and facilities, janitorial services, maintenance of temporary facilities, guards and security, roads, parking lots, laydown areas, temporary electrical and piping, temporary heat, air, steam, and water systems, general cleanup, etc.

Construction tools and equipment include rental and/or purchase of construction equipment, small tools, consumables (fuel, lubricants, etc.), and maintenance of construction equipment. Payroll insurance and taxes are related to craft labor, such as social security taxes and state unemployment taxes, workmen's compensation insurance and public liability and property damage insurance. Permits insurance and local taxes include builders' all-risk insurance, local fees and permits, state and local taxes and nuclear liability insurance.

Home Office Engineering and Services (Account 92)

Home office services include home office engineering and design, procurement and expediting activities, estimating and cost control, engineering planning and scheduling, home office reproduction services, and expenses associated with performance of the above functions (i.e., telephone, postage, computer use, travel, etc.). The costs for these services include salaries of personnel, direct payroll-related costs (DPC), overhead, loading expenses, and fees for these services consistent with contractual terms.

Home office quality assurance includes the services of home office quality assurance engineering and staff personnel engaged in work on the project. Services include reviews, audits, vendor surveillance, etc. as required for design and construction of the nuclear safety-related portion of the facility. Costs for these services include salaries, DPC, overhead loading, and expenses (i.e., travel) of these individuals.

Home office construction management costs include those of the construction manager and his assistants. Services of construction planning and scheduling, construction methods, labor relations, safety, and security personnel are utilized as required. Costs for these services include salaries, DPC, overhead loading, and expenses.

Field Office Engineering and Services (Account 93)

Field office expenses include costs associated with purchase and/or rental of furniture and equipment (including reproduction), communication charges, postage, stationery, other office supplies, first aid, and medical expenses. Field job supervision includes the resident construction superintendent and his assistants, craft labor supervisors, field accounting, payroll and administrative personnel, field construction schedulers, field purchasing personnel, warehousemen, survey parties, stenographers and clerical personnel. Costs of these services include salaries, DPC, overhead loading, relocation costs of key personnel, and fee.

Field quality assurance/quality control includes services of personnel located at the job site engaged in equipment inspection, required documentation of nuclear safety-related equipment, and inspection of construction activities. Costs included are salaries, DPC, and overhead loading.

Test and startup engineering is associated with preparation of startup and plant operation manuals and test procedures, direction and supervision of all testing of equipment and systems as the plant nears completion, and direction of startup of the facility. Costs of these services include salaries, DPC, overhead loading, and miscellaneous related expenses. Costs of any craft labor required for startup and testing activities are included in the appropriate direct-cost line items.

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