Exhibit No. ___ (LHL-1)

DECOMMISSIONING COST STUDY

for the

CONNECTICUT YANKEE NUCLEAR POWER PLANT

Prepared by

NORTHEAST UTILITIES SERVICE COMPANY

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DECOMMISSIONING COST STUDY FOR THE CONNECTICUT YANKEE NUCLEAR POWER PLANT

1. INTRODUCTION

1.1 Purpose of Study

The purpose of this study is to prepare estimates of the cost, schedule, and the waste volume generated in decommissioning the Connecticut Yankee Nuclear Power Plant (CY). The DECON, SAFSTOR, and ENTOMB alternatives were evaluated in this study. In addition, this study will determine the currently most cost-effective decommissioning option for the CY Plant.

1.2 Summary

This study provides cost, schedule, and waste generation/disposition associated with the decommissioning of CY. This estimate is different from previous estimates as a result of the decision to permanently cease operations as of December 4, 1996 instead of operating until the expiration of the CY license on June 29, 2007. Estimates are provided for the DECON (Prompt Removal/Dismantling), SAFSTOR/ DECON (Mothballing with Delayed Dismantling) and ENTOMB (Entombment with Delayed Dismantling) decommissioning alternatives. Each alternative reflects the long-term storage of spent fuel on the CY site following the cessation of plant operations. Definitions of each of the alternatives evaluated in this study are as follows:

> **DECON** of a power reactor consists of removing from the site all fuel assemblies and source material, radioactive fission and corrosion products, and all other radioactive materials having activities above release limits. The facility operator may then have unrestricted use of the site with no requirement for a license. This scenario is equivalent to the DECON mode described in decommissioning regulations issued by the Nuclear Regulatory Commission (NRC), "General Requirements for Decommissioning Nuclear Facilities" (53 Fed. Reg. 24018). This study also assumes that the balance of plant systems and structures are also removed. The site can then be restored and made available for alternative use.
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> The **SAFSTOR** alternative, as considered for Connecticut Yankee, initially consists of placing and maintaining the facility in protective storage. Immediately after shutdown, the plant staff conducts general plant decontamination activities, radiation surveys, and removal (including processing) of radioactive waste materials remaining from operations. Security, surveillance and maintenance plans for the delay period are implemented. Delayed DECON (decontamination) activities are initiated

such that license termination is accomplished within the 60-year time period set by the NRC. As with the DECON alternative, this study further assumes that the remainder of the reactor facility is dismantled and the site is restored to its original landscape.

ENTOMB initially places the facility into protective storage. Contaminated components and structural materials that are located outside the designated entombment boundary are removed from the site or relocated within the boundary. The remaining radioactivity is sealed within an entombment structure (includes the massive, concrete central portion of the Reactor Building). This structure provides for isolation of the residual radioactive inventory on the site during the dormancy period. Delayed DECON (decontamination) activities are initiated such that license termination is accomplished within the 60 year time period set by the NRC. As with the DECON alternative, this study further assumes that the remainder of the reactor facility is dismantled and that the site is restored.

After conducting a thorough review of the estimated costs and other factors involved in the decommissioning methods currently available, the major conclusion of this study is that CY decommissioning can be accomplished technically, as well as in the most cost-effective manner, by the prompt dismantlement (DECON) alternative.

There are definite advantages to this alternative. DECON is less costly than scenarios involving an extended delay in the plant dismantling. (The ultimate cost of any alternative for the CY site will depend upon future economic factors such as inflation, changes in NRC regulations and long term waste policy decisions and actions.) DECON is favored in most situations because (1) it minimizes long-term security, and radiological/environmental surveillance, (2) operating personnel familiar with the nuclear facility will still be available to support the dismantling effort, (3) it reduces the risk to the environment from the continued presence of radioactive material at CY, (4) there is no lengthy period of property taxes and insurance on a non-productive facility, (5) reduces uncertainties of new regulatory requirements by avoiding the lengthy delays that are inherent with the mothballing/delayed dismantlement and entombment options, and (6) DECON reduces the long term obligation and liability for maintenance of the property.

The cost of delaying plant decommissioning (either through the SAFSTOR or ENTOMB alternatives) is significantly increased by the expense of maintaining the station in protective storage, i.e., the utility continues to incur the cost of manning and maintaining the site. In addition, at the end of the dormancy period, the station must be partially reactivated (those systems necessary to support decommissioning operations) and/or replacement systems and services must be procured. Refurbishment activities involve requalifying the cranes and other lifting devices, and reactivating electrical, lighting, air handling, and other service systems. In addition, the procurement of waste processing/ treatment services will be necessary if plant systems cannot be salvaged. One of the biggest drawbacks to delaying decommissioning is the unavailability, at the time of decommissioning, of station operations personnel, whose knowledge of the station is invaluable in supporting and assisting decommissioning operations. Without personnel familiar with station operations, the decommissioning program may incur additional cost and worker exposure as it compensates for engineering and planning developed from a less than complete data base. The advantages of these alternatives are: costs spread out over a longer period and a reduction in personnel radiation exposure.

While the cost to dispose of the spent fuel assemblies generated during plant operations is not considered a decommissioning expense, the on-site presence of the assemblies can adversely affect the total cost to decommission. This study recognizes that the spent fuel storage facilities at CY may be active for twenty-five (25) years after operations have ceased at the plant. This period is based upon both the spent fuel assembly inventory produced over the operating life of the reactor as well as the U.S. Department of Energy's (DOE) timetables for taking receipt of the fuel. For the purpose of this study, it was assumed that the DOE will begin accepting spent fuel in the year 2006. Based on this assumption, all the spent fuel would be removed by 2022.

This study provides a cost estimate for decommissioning CY under current requirements, based on present day costs and available technology. Cost and schedule estimates presented herein are based on the complete removal of all components and structures within the property lines, as the plant is presently configured, except as noted within the body of this report. The cost estimate for each of the scenarios is shown in Table 1.0. Cost details of the DECON alternative are shown in Appendix B.

This study has been performed in accordance with the latest cost estimating methodologies used in power plant decommissioning. The resultant cost estimate is specific to CY. This approach is consistent with the NRC rule, where a site specific study is recommended for determining accurate funding levels.

TABLE 1.0

SUMMARY OF DECOMMISSIONING COST ESTIMATES AND SCHEDULE
July 1996 Dollars (Millions)

	Cost Estimate*	Schedule (Years)
DECON (Prompt Removal/Dismantling)		
Period 1 (Engineering and Decontamination)	$ 76.2	2.0
Period 2 (Disposal of Plant Systems)	194.8	3.0
Period 3 (Demolition of Site Buildings)	64.2	1.5
Period 4 (Spent Fuel Storage)	91.5	19.5
Total	**$426.7**	**26.0**
SAFSTOR (Mothballing with Delayed Removal/Dismantling)		
Mothball Operations	$ 71.8	2.5
53 year dormancy	244.2	53.0
Delayed dismantling	275.6	4.5
Total	**$591.6**	**60.0**
ENTOMB (Entombment with Delayed Removal/Dismantling)		
Entombment Operations	$180.7	4.5
51 year dormancy	191.5	51.0
Delayed dismantling	212.0	4.5
Total	**$584.2**	**60.0**

1.3 Description of Northeast Utilities and Subsidiaries

Northeast Utilities (NU) is the parent company of the NU System. The four principal NU System operating companies which furnish electric service in regions of Connecticut, western Massachusetts and New Hampshire are: The Connecticut Light and Power Company (CL&P), Western Massachusetts Electric Company (WMECO), Holyoke Water Power Company (HWP) and Public Service Company of New Hampshire (PSNH).

Other subsidiaries of NU include Northeast Utilities Service Company (NUSCO), a service company supplying centralized administrative services to the system operating companies; Northeast Nuclear Energy Company (NNECO), agent for the NU System companies in the operation of the Millstone Nuclear Power Station, and North Atlantic Energy Service Corporation (NAESCO), agent for the NU System companies in the operation of the Seabrook Nuclear Power Station.

In addition to the Millstone units, the NU companies have a controlling interest in the Connecticut Yankee Atomic Power Company (CYAPCO). CYAPCO is owned by ten New England electric utility companies and operates a nuclear generating plant known as Connecticut Yankee (CY). The 582-MWe CY nuclear unit is a Westinghouse pressurized water reactor and is located in the Town of Haddam, Connecticut, on a site of approximately 545 acres.

1.4 CY Site Description

CY is located on the east bank of the Connecticut River in the town of Haddam, Connecticut. The station is approximately 22 miles southeast of the city of Hartford, and 16 miles northwest of Saybrook Point, where the Connecticut River flows into Long Island Sound. Figure 1.0 depicts the major structures considered within the scope of the decommissioning study for the station. The cost estimates associated with the decontamination and dismantling of these structures are provided in Table 3.1.

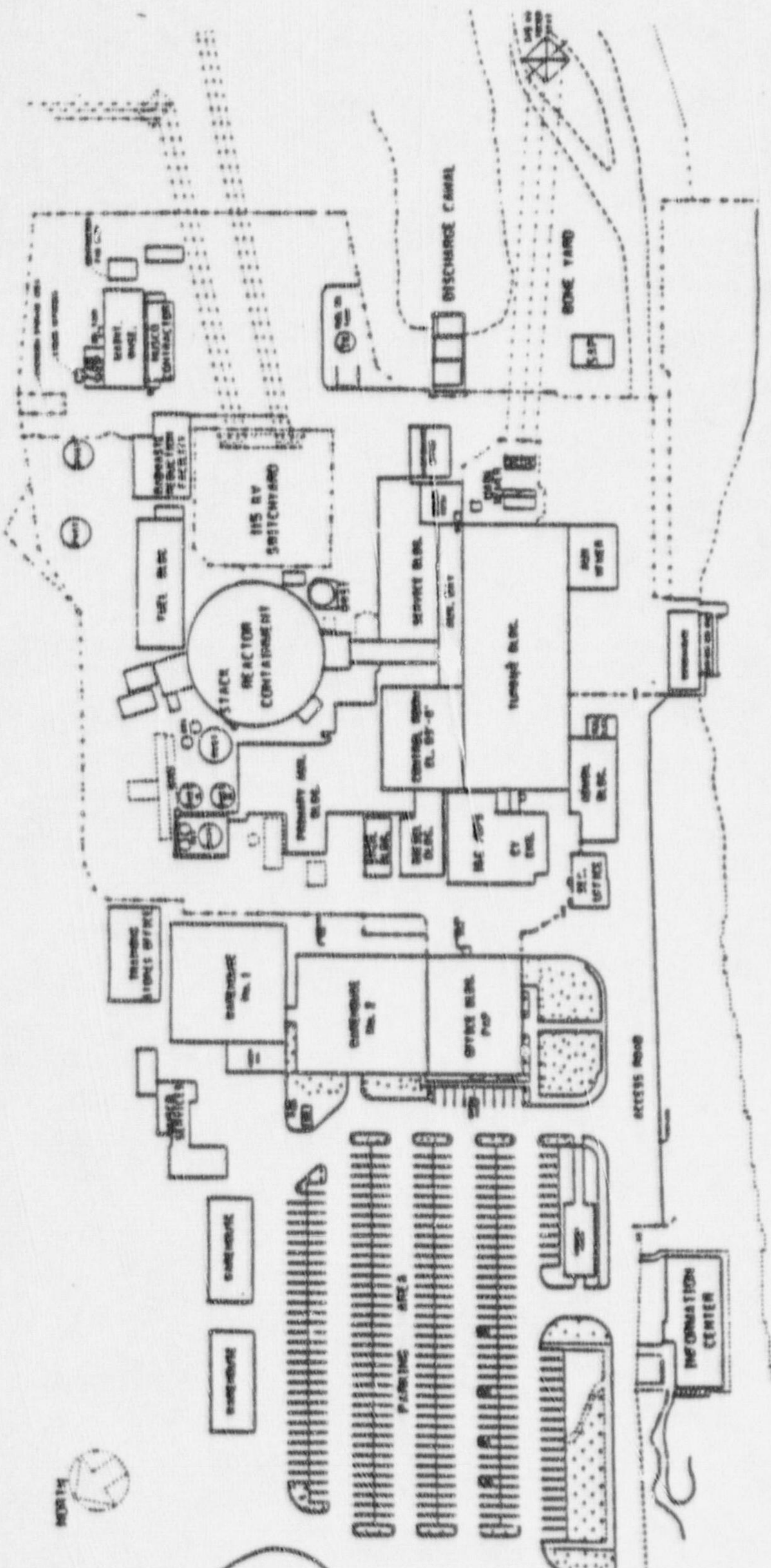
The Nuclear Steam Supply System (NSSS) of CY consists of a pressurized water reactor and a four loop Reactor Coolant System (RCS). The NSSS was supplied by the Westinghouse Electric Corporation. The generating unit has a reference core design of 1825 MWt (thermal) with a corresponding net dependable capacity electric rating of 583 megawatts (electric) with the reactor at rated power.

The RCS is comprised of the reactor vessel and four heat transfer loops, each containing a vertical shell and U-tube steam generator, and a vertical, single speed centrifugal reactor coolant pump. In addition, the system includes an electrically heated pressurizer, a pressurizer relief tank and interconnected piping. The system is housed within a containment structure (a seismic Category I reinforced concrete dry structure) which is designed to function at a slight positive pressure. It consists of a right circular cylinder topped with a hemispherical dome, supported on a seismic bed (base mat) nine feet thick. An epoxy covered welded steel liner plate, anchored to the inside face of the containment, serves a leak-tight membrane. The liner on top of the foundation mat is protected by a two foot thick concrete fill mat which supports the containment internals and forms the floor of the containment structure.

Heat produced in the reactor is converted to electrical energy by the steam and power conversion system. A turbine-generator system converts the thermal energy of the steam produced in the steam generators into mechanical shaft power and then into electrical energy. The unit's turbine generator consists of a tandem compound, quadruple exhaust, condensing turbine. It consists of one high pressure double flow impulse section and two low pressure sections driving a direct-coupled generator at 1800 rpm. The turbine is operated in a closed feedwater cycle which condenses the steam, with the heated feedwater being returned to the steam generators. Heat rejected in the main condenser is removed by the circulating water system (CWS).

The Connecticut River serves as the ultimate heat sink for CY. Cooling of the main condenser system is accomplished by the CWS which takes water from the river and pumps it through the condenser shells in the Turbine Building. The heated water is then returned to the river by means of the discharge canal.

FIGURE 1.0
CONNECTICUT YANKEE SITE PLAN



2. DECOMMISSIONING ALTERNATIVE DESCRIPTIONS

Three specific decommissioning alternatives have been reviewed for CY: DECON (prompt removal/dismantling) SAFSTOR (mothballing with delayed dismantling) and ENTOMB (entombment with delayed dismantling). The SAFSTOR/ENTOMB program duration selected for use in this study was 60 years, the maximum allowed by the NRC (unless it can be shown that a longer duration is necessary to protect public health and safety). Although they differ with respect to technique, process, cost, and schedule, each alternative attains the same result: removal of all radioactive materials from the site and ultimate release of the site for unrestricted and/or alternative use.

2.1 Regulatory Guidance

The NRC provides decommissioning guidance in its "General Requirements for Decommissioning Nuclear Facilities" (Ref. 1) in addition to that previously set forth in Regulatory Guide 1.86 (Ref. 2). This rule defines three decommissioning alternatives acceptable to the NRC, i.e., DECON, (prompt removal/dismantling), SAFSTOR (mothball), and ENTOMB (entombment).

DECON (Prompt Removal/Dismantling) is defined by the NRC as "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations."

SAFSTOR (Mothball) is defined as "the alternative in which the nuclear facility is placed and maintained in a condition that allows the nuclear facility to be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release for unrestricted use." This process is restricted in overall duration to 60 years and therefore limited in application unless it can be shown that a longer duration is necessary to protect the health and safety of the public.

ENTOMB (Entombment) is defined as "the alternative in which radioactive contaminants are encased in a structurally long-lived material, such as concrete; the entombed structure is appropriately maintained and continued surveillance is carried out until the radioactivity decays to a level permitting unrestricted release of the property." This process is restricted in overall duration to 60 years and therefore limited in application unless it can be shown that a longer duration is necessary to protect the health and safety of the public.

Prior to adoption of an NRC rulemaking in 1988, no endpoint was identified for either the SAFSTOR or ENTOMB process (i.e., a facility could remain in either state indefinitely). This is no longer the case, as the rule places upper limits on the completion of the decommissioning process. Consequently, with these restrictions, the SAFSTOR and ENTOMB options are no longer decommissioning alternatives in themselves, as neither terminates the license for the site. At the end of the dormancy periods, both alternatives would still require site decontamination/decommissioning.

In most situations the DECON alternative is the preferred mode of decommissioning. This decommissioning alternative is favored because (1) it minimizes long-term security, and radiological surveillance, (2) operating personnel familiar with the nuclear facility will still be available to support the dismantling effort, (3) minimizes risk to public safety by reducing the presence of radioactive material at CY, (4) there is no lengthy period of insurance costs and property taxes on a nonproductive facility, (5) reduces uncertainties of new regulatory requirements by avoiding the lengthy delays that are inherent with the mothballing/delayed dismantlement and entombment options, and (6) DECON reduces the long term obligation and liability for maintenance of the property. In addition, both the mothball and entombment alternatives still require eventual decontamination/decommissioning after the maximum allowed dormancy durations. This results in higher overall costs for the mothball and entombment alternatives, as ongoing dormancy expense and reactivation costs offset the potential savings gained from the delay.

The following sections describe the basic activities necessary for each alternative. Although detailed procedures for each activity required are not provided, and actual sequences of work may vary, these activity descriptions should provide a basis for detailed engineering planning and scheduling at the time of decommissioning.

2.2 DECON (Prompt Removal/Dismantling)

This alternative deals with the immediate removal of all radioactivity with the exception of spent fuel from the site, upon cessation of operations at the expiration of the operating license. This study does not address the cost of the removal of spent fuel from the site because such costs are assumed to be covered by the 1 mil/kWhr DOE surcharge. However, the study does consider the on-site presence of spent fuel and its potential constraint on decommissioning activities. In addition to the removal of radioactivity, this study also assumes the removal of the non-essential structures from the site, thereby permitting return of the CY site for other use.

2.2.1 Period 1: Preparations

Prior to the commencement of decommissioning operations, detailed preparations are undertaken to provide a smooth transition from plant operations to site decommissioning activities. These preparations include engineering planning, surveys of plant areas to determine contamination levels, activation analyses of the vessel and vessel internals, as well as the assembly of a decommissioning management organization. Final planning for activities and writing of activity specifications and detailed procedures are also initiated at this time. Under normal circumstances, preparations for decommissioning begin five years prior to the projected end of plant operations with the submittal of a preliminary decommissioning plan to the NRC. However, with the early shutdown of Connecticut Yankee, the planning and engineering required for dismantlement will take about two (2) years. Period 1 is considered to begin on December 4, 1996, which was the date of the official announcement by the CY Board of Directors that the plant has ceased operations.

2.2.1.1 Engineering and Planning

According to the Decommissioning Final Rule (Reference 13) that become effective on August 28, 1996, licensees will no longer be required to obtain NRC approval of a Decommissioning Plan before undertaking decommissioning, but rather will be allowed to undertake decommissioning activities pursuant to 10CFR50.59, and to undertake—subject to the possible need to obtain prior NRC approval based on Section 50.59 review—"major" decommissioning activities 90 days after submitting a Post-Shutdown Decommissioning Activities Report ("PSDAR") to the NRC. After this time, licensees may undertake any decommissioning activities that do not (1) foreclose release of the site for possible unrestricted use; (2) result in there no longer being reasonable assurance that adequate funds will be available for decommissioning; or (3) cause any significant environmental impacts not previously reviewed.

The PSDAR must be submitted within two years following permanent cessation of operations. The PSDAR will include a description and preliminary schedule of planned decommissioning activities, an estimate of expected costs as well as a statement as to whether environmental impacts of decommissioning have been covered in previous environmental impact statements or reports. If not, a license amendment is required to address environmental concerns. A 90 day hold is required on the PSDAR to allow NRC review. Afterwards, if the NRC has no objections, the licensee may begin major decommissioning activities. These may include removal of the reactor vessel, steam generators, pumps, valves and piping systems, without specific NRC approval. The PSDAR will be made available for public comment, and then presented in a public meeting to be held near the plant. Licensees may not use decommissioning funds (other than 3% of required funds which may be used for planning purposes) prior to the expiration of the 90-day post-PSDAR-submittal period.

The development of a decommissioning organization by the Licensee is essential to the successful planning and execution of the decontamination and dismantling of the nuclear unit. This activity not only includes identifying the staff requirements, but securing the commitment of key personnel.

Much of the work in the development of the PSDAR is also relevant to the development of the detailed decommissioning engineering plans and procedures. This work includes:

* Site preparation plans for decommissioning activities;

* Identification of the detailed procedures needed and sequence intended for removal of systems and components;

* Scoping of procedures for disassembling and removing the reactor vessel, internal packages and other NSSS components;

* Plans for decontamination of structures and systems, including the removal of all activated and contaminated material;

* Identification of long-lead specialty components and equipment including design, procurement and testing requirements;

* Identification/selection of specialty contractor(s);

* Identification of procedures for processing and treating radioactive materials from the decommissioning waste streams; and

* Sequential planning of activities to minimize conflicts with concurrent activities.

2.2.1.2 Site Preparations

Following final plant shutdown, and in preparation for actual decommissioning activities, the following activities are initiated:

* Prepare site support services, as required.

* Defuel the reactor and transfer the spent fuel assemblies to the Fuel Building. Once completed, the Fuel Building will be isolated and will serve as an ISFSI until such time that the DOE can take receipt of the assemblies. This will allow decommissioning operations to commence once the PSDAR has been reviewed by the NRC. Fuel transfer will be carried

out by existing plant personnel in accordance with standard operating technical specifications.

* Clean all plant areas of loose contamination and process all liquid and solid wastes.

* Conduct radiation surveys of work area contamination and general dose levels; major component, piping, and structure dose levels (including the reactor vessel and its internals); internal piping contamination levels; and activation profiles from primary shield core samples.

* Calculate residual byproduct material inventory for plant components, structures and systems, for development of packaging and shipping requirements and decommissioning safety requirements.

* Determine shipping container requirements for radioactive materials and fabricate such containers.

* Develop procedures for occupational exposure control, control and release of liquid and gaseous effluent, control of solid radwaste, site security and emergency programs, and industrial safety.

2.2.2 Period 2: Decommissioning Operations and License Termination

The following listing indicates the Period 2 dismantlement activities:

* Perform primary system decontamination to lower overall dose to workers.

* Perform asbestos abatement program.

* In preparation for fuel storage, separate fuel building from the rest of the site's mechanical and electrical systems. This involves modifications to electrical, security, spent-fuel pool cooling and ventilation systems.

* Construct temporary enclosures in existing facilities and modify existing storage facilities to support the dismantling activities. These may include: changing rooms and "hot" laundry for the increased work force, protected and open laydown areas to facilitate equipment removal and shipping operations, additional roads to facilitate hauling and transportation, and additional airlocked access portals to control movement to and from contaminated areas.

- Design, procure, and install water cleanup system for removal of cutting residues and crud deposits from the reactor vessel and piping systems.

- Design and fabricate special shielding and contamination control envelopes, special tooling and remotely operated equipment. Modify the refueling canal to support segmentation activities and prepare rigging for segmentation and removal of piping sections and components, including the reactor vessel and its internals.

- Procure required shipping casks, liners, and waste containers from suppliers.

- Prepare and submit a license application for a 10CFR Part 72 license to operate the Fuel Building as an ISFSI following termination of the existing 10CFR Part 50 license.

- Conduct decontamination of components and piping systems as required. Remove, package and dispose of piping and components as they are no longer required to support the decommissioning process.

- Remove reactor vessel closure head and prepare for intact disposition.

- Remove control rod drive housings and instrumentation tubes from reactor vessel closure head and cut housings and tubes into sections for disposal in shielding containers.

- Remove reactor vessel internal components and transfer them to the staging area for disassembly. Segment upper and lower core support structures including the control rod guide tubes upper and lower grid plates, core baffle and in-core instrumentation for packaging and disposition by shielded container. Cutting operations are performed underwater with remote equipment.

- Isolate reactor well/cavity and lower water level to below reactor vessel flange. Sever reactor vessel flange from vessel shell. Flange can be shipped intact with the reactor vessel closure head.

- Complete reactor vessel closure head/flange package with steel plate for disposition as its own container. Decontaminate exterior surfaces for transport and disposal.

- Remove reactor coolant piping and pumps once the inlet and outlet nozzles have been isolated. Piping is placed in standard Low Specific Activity (LSA) containers; the reactor coolant pumps are sealed and decontaminated for intact transport and disposal.

- Segment the reactor vessel shell as the water level is dropped. In-air cutting will use a shielded platform and contamination control envelope placed over the reactor well/cavity. Segments are removed from the cavity and placed in the refueling cavity for packaging. Shielded containers are used for transport to the disposal facility.

- Remove systems and associated components as they become nonessential to the support of vessel disposition, other decommissioning operations or worker health (e.g., decommissioning waste processing systems, electrical systems, HVAC systems, water systems).

- Remove reactor vessel lower head and prepare for intact disposition.

- Remove concrete biological shield and all accessible activated and contaminated concrete.

- Remove steam generators and pressurizer for intact shipment and disposal. Decontaminate exterior surfaces, as required, and seal-weld all openings in steam generators and pressurizer. These components can serve as their own shipping and burial packages provided that all penetrations are properly sealed. Decontaminate all remaining containment structure areas, including steam generator and pressurizer cubicles.

- Perform radiation survey to assure that the remaining portions of the containment structure are free of surface contamination and that containment integrity is no longer required.

- Ship and dispose of all remaining radioactive materials.

- Conduct final radiation survey to assure that all radioactive materials have been removed. This survey may coincide with final NRC site inspection.

- Following notification by CYAPCO of completion of the decontamination and disposal of components and materials from the facility, the NRC regional staff conducts an on-site survey to verify that the acceptable activity and contamination levels are satisfied. When these requirements are satisfied, the NRC can terminate the 10 CFR Part 50 license for the facility. (Termination of all site license(s) is predicated upon DOE's ability to ultimately take possession of the spent fuel assemblies. A 10 CFR Part 72 license will be in effect until this occurs.)

2.2.3 Period 3: Site Restoration

Following completion of the decommissioning operations, site restoration activities may begin. These activities will (once all spent fuel has been transferred to DOE) assure compliance with applicable codes and permit unrestricted access by the public, therefore limiting liability of the owners with regard to intentional or unintentional intrusion by the public on the site. Building foundations are backfilled, using non-contaminated concrete rubble with a structural fill to the grade elevation. Site areas affected by the dismantling activities are cleaned up and the plant area graded and landscaped as required. These activities are listed below.

* Demolition of the remaining portions of the primary containment structure and interior portions of the Reactor Building. Internal floors (and walls if above grade) are removed from the lower levels upward, using controlled blasting techniques. Concrete rubble and other suitable materials can be utilized on site for fill.

* Ancillary buildings are then removed using conventional demolition techniques for above ground structures, including the Turbine, Primary Auxiliary, Intake, Administration, Engineering and Waste Disposal Buildings, as well as other non-essential site structures. In addition, outside storage tanks are drained and removed.

* Prepare the final dismantling program report.

* In the DECON scenario outlined in this report, CYAPCO will be operating the Fuel Building for many years after the plant has been decommissioned and dismantled. Once the turnover of the spent fuel to DOE is complete, CYAPCO will be able to decontaminate and dismantle the Fuel Building and surrender any associated licenses.

2.3 SAFSTOR (Mothball with Delayed Dismantling)

The SAFSTOR decommissioning alternative provides a condition that ensures public health and safety from residual radioactivity remaining at the site without the need for extensive modifications to the facility. While "mothball" is used to describe this alternative (Ref. 2), it is a misnomer since under SAFSTOR reactivation of the plant is not intended. During the SAFSTOR period the facility is left intact and all structures are maintained in a sound condition. Systems not required to be operational for maintenance and surveillance purposes during the dormancy period are drained, de-energized, and secured. Minimal cleaning/removal of loose contamination and/or fixation and sealing of remaining contamination is performed. Access points to contaminated areas are sealed and/or secured to provide controlled entry for inspection and maintenance.

The engineering and planning requirements are similar to those for the DECON alternative although a shorter time period is expected for these activities. Site preparations are also similar to those for the DECON alternative. However, with the exception of required radiation surveys, the mobilization and preparation of site facilities is less extensive.

2.3.1 Period 1: SAFSTOR Operations

Prior to the start of the decommissioning process, CYAPCO will file a PSDAR with the NRC describing how it will remove all radioactivity from the CY site. The PSDAR addresses the eventual dismantling of the reactor and termination of the facility operating license and also includes a description of the organization and program that will be used during the decommissioning of the facility. The report will describe how the major activities will be accomplished with personnel radiation exposure controlled to reasonably achievable levels.

The PSDAR will describe spent fuel disposition, partial decontamination and a delay period before the remaining radioactive components are removed.

The submission of the PSDAR will permit ownership and possession of spent fuel, by-product material and reactor components, but does not permit operation of the reactor. This license status, though permitting significant relief from the technical specifications, still requires adequate surveillance, monitoring and reporting.

After plant shutdown, modified technical specifications are implemented. Spent fuel and in-core source materials are isolated in the spent fuel storage facilities awaiting ultimate disposal or until they can be transferred to another facility. These steps may be carried out by plant personnel in accordance with standard operating procedures. Liquid and solid wastes are processed and removed and plant radiation surveys initiated.

The decommissioning activities for the SAFSTOR alternative are as follows:

- Drain/de-energize/secure non-contaminated systems not required to support decommissioning operations.
- Dispose of contaminated filter elements and resin beds not required for processing wastes from decontamination activities.
- Drain reactor vessel; internals will remain in place.

* Drain/de-energize/secure all contaminated systems. Decontaminate as required.

* Prepare lighting and alarm systems whose continued use is required. De-energize and/or secure portions of fire protection, electric power, and HVAC systems whose continued use is not required.

* Clean loose surface contamination from building access pathways.

* Perform radiation survey of plant; post warning signs as appropriate.

* Erect physical barriers and/or secure all access to radioactive or contaminated areas, except as required for controlled entry for inspection and maintenance.

* Install security and surveillance monitoring equipment and relocate security fence around secured structures as required.

* Sections of the site outside the controlled area may be graded and landscaped as required. Part of this site area may be released for unrestricted use or for restricted use.

2.3.2 Period 2: SAFSTOR Dormancy

For the SAFSTOR alternative, activities required during the planned dormancy period include a 24 hour guard force, preventive and corrective maintenance on security systems, area lighting, general building maintenance, heating and ventilation of buildings, routine radiological inspections of contaminated buildings, maintenance of structural integrity, and an environmental and radiation monitoring program.

Maintenance and equipment inspection activities are provided by the utility maintenance staff. Their duty is to maintain the structures in a safe condition, provide adequate lighting, ventilation, and heating, and perform periodic preventative maintenance on essential equipment.

An environmental surveillance program is carried out during the dormancy period to ensure that releases of radioactivity to the environment are controlled (i.e., they are identified, quantified and maintained within prescribed limits). Appropriate emergency procedures are established and initiated to provide a high degree of assurance that unplanned releases will not exceed prescribed limits. The environmental surveillance program will generally be a modified/abbreviated version of that carried out during normal plant operations.

Security during the dormancy period is conducted primarily to prevent unauthorized entry and to protect the public from the consequences of such entry. Security detection and notification systems used during plant operations are augmented by installation of audible alarms. Since contaminated areas and equipment can conceivably be reached by the breach of a door or window, a full-time security force is maintained on site throughout the SAFSTOR dormancy. Additionally, silent alarms may be installed to alert off-site security personnel to trespass or fire. Liaison with local law enforcement agencies is maintained and their assistance requested as necessary.

Primary physical security is provided by the security fence which must be maintained in good condition for the duration of this period. The facility will also be secured by high security locks on exterior doors and intrusion alarms. Fire and radiation alarms will be monitored continuously by security personnel.

2.3.3 Periods 3-5: SAFSTOR Delayed Removal/Dismantling

At the end of the dormancy period for the SAFSTOR alternative, the remaining structures are completely dismantled. Basically, the same dismantling operations as those described for the DECON alternative will be performed. SAFSTOR Period 3 activities would correspond to the DECON Period 1 Planning Phase, Period 4 to the Period 2 Decommissioning Operations Phase, and Period 5 to the Period 3 Site Restoration Phase. Section 2.2 of this report delineates the activities associated with each phase of the dismantling process. Because the SAFSTOR alternative permits a period of decay of the residual radioactivity, lower personnel radiation exposures are incurred than with the DECON alternative. Many of the dismantling activities may therefore, employ manual techniques rather than remote procedures, and dismantling operations can be simplified.

Although the initial radiation levels due to Cobalt-60 (Co60) will decrease during the dormancy period, the internal components of the reactor vessel will still have sufficiently high radiation dose rates to require remote sectioning under water, due to the presence of long-lived radionuclides such as Niobium-94 (Nb94), Nickel-59 (Ni59) and Nickel-63 (Ni63). Therefore, the dismantling procedures described for the DECON alternative would be employed. Portions of the concrete shield will still be radioactive because of the presence of activated trace elements with long half-lives and will require controlled removal, packaging, and waste disposal procedures. It is unlikely that radioactive corrosion products on inner surfaces of piping and components will have decayed to levels that will permit unrestricted use or allow conventional removal. These systems and components are surveyed as they are removed, with disposition dependent upon the existing release criteria. No systems in this study designated as contaminated in the DECON alternative are assumed to be releasable after the dormancy; these are removed and disposed of as contaminated material.

Following notification by CYAPCO of completion of the decontamination and disposal of components and materials from the facility, the NRC regional staff conducts an on-site survey to verify that the acceptable activity and contamination level requirements are satisfied. When these requirements are satisfied, NRC can terminate the license and any further NRC jurisdiction over the facility.

Site restoration activities may then be performed, similar to those for DECON, for structures still remaining on site. The site is graded and landscaped as required.

2.4 ENTOMB (Entombment with Delayed Dismantling)

This alternative requires creation of an entombment structure within the Reactor Building. An entombment structure serves as an additional barrier in preventing contact with the reactor vessel and internals, steam generators, reactor coolant pumps, piping, pressurizer, and the refueling area. This structure uses the existing biological shield concrete where possible; new concrete is added, as necessary, to provide a sealed reinforced concrete barrier around the primary system, preventing personnel access. Feedwater and steam piping to and from the steam generators is also isolated. Radioactive material exterior to this structure is either moved within the entombment structure, or removed and packaged for off-site disposal. The decontaminated structures and systems and all other non-essential site structures and systems external to the entombment barrier will be decontaminated and removed at the end of the dormancy period. At the end of the dormancy period, the remaining contaminated materials on site within the entombment structure are removed and shipped for controlled disposal and the Reactor Building dismantled.

2.4.1 Period 1: Entombment Operations

Prior to the start of the decommissioning process, detailed preparations are undertaken for the site and the personnel involved in decommissioning in order to provide a smooth transition from operations to decommissioning. These preparations include engineering planning, surveys of plant areas to determine contamination levels, and activation analyses of the vessel and vessel internals, as well as the assembly of a decommissioning management organization. Upon final shutdown, more detailed surveys and benchmarking of calculated estimates are performed to validate results. Final planning for activities and writing of activity specifications and detailed procedures are also initiated at this time.

2.4.1.1 Engineering and Planning

CY will file a Post Shutdown Decommissioning Activities Report (PSDAR) with the NRC describing how it will remove all radioactive components and essentially all radioactivity from the CY site. The PSDAR includes eventual dismantling of the reactor and termination of the facility operating license and will include a detailed plan describing the organization and program that will be used during the decommissioning of the facility. The PSDAR will describe how the major activities will be accomplished with the least possible personnel exposure to radioactive and other hazardous contaminants. It will also clearly describe how CYAPCO will continue to protect the health and safety of the public and the environment during the dismantling activities.

The PSDAR will describe spent fuel disposition, partial decontamination of plant facilities that are outside of the entombment boundary and a delay period before the remaining radioactive components within the entombment are removed.

After submission of the certificates that the plant has ceased operations and that fuel is out of the reactor, the amended license would permit ownership and possession of spent fuel, by-product material and reactor components, but not permit operation of the reactor. This license status, though permitting significant relief from the technical specifications, still requires adequate surveillance, monitoring and reporting.

The goal in the ENTOMB method of decommissioning is to confine the highly radioactive or contaminated components (e.g., the reactor vessel and its internals) within a concrete structure integral with the primary containment and other designated portions of the reactor building. This method includes the removal and disposal of solid and liquid wastes, and any remaining radioactive materials, components, and structural materials exterior to the entombment structure. The spent fuel assemblies will continue to be stored within the Fuel Building. The engineering and planning requirements for this alternative are similar to those described for the DECON method. However, the PSDAR will include descriptions for monitoring the structures/ facility and the environment, with associated reports, security requirements, and any other activities necessary during the dormancy period.

2.4.1.2 Site Preparations

Site preparations for ENTOMB include most of the activities previously described for the DECON alternative. Radioactive components and structures will be removed or decontaminated. The decontaminated facilities will not be dismantled until the end of the dormancy period.

The Fuel Building will remain operational until all of the spent fuel has been transferred to the DOE. Once the storage pool within the Fuel Building has been emptied, the building will be decontaminated and then dismantled at the end of the dormancy period. The Reactor Building and the remaining decontaminated structures will also occupy the site for the entire 60 year duration of dormancy.

After final plant shutdown, modified technical specifications are implemented. Spent fuel and in-core source materials are isolated in the fuel building awaiting ultimate disposal or transfer to another facility. These steps may be carried out by plant personnel in accordance with standard operating procedures.

An entombment structure is constructed within the containment structure to serve as an additional barrier in preventing contact with the reactor vessel and internals, steam generators and pressurizer, reactor coolant pumps, piping, and the refueling area. This structure uses the existing concrete where possible; new concrete is added as necessary to provide a sealed reinforced concrete barrier around the Nuclear Steam Supply System, preventing access. Except for draining and drying the reactor coolant system, only minimal work is performed on any component(s) within the entombment boundary prior to the dormancy period, thereby significantly reducing the occupational radiation exposure. By the time deferred dismantlement commences, plant radiation fields are reduced due to natural decay of the radionuclides during the dormancy period.

Following review of the PSDAR by the NRC, CYAPCO can begin major decommissioning activities.

2.4.2 Period 2: Decommissioning Operations

The activities necessary to accomplish the entombment requirements are as follows:

- Drain/de-energize/secure non-contaminated systems not required to support decommissioning operations.
- Isolate the Fuel Building from the other structures on site such that decommissioning operations can commence. This activity may be carried out by existing plant personnel in accordance with standard operating technical specifications.
- Dispose of contaminated filter elements and resin beds not required for processing wastes from decontamination activities.
- Drain reactor vessel, steam generators and pressurizer. Cut, cap, and seal weld all piping at the entombment boundary interface.
- Drain/de-energize/secure contaminated systems. Decontaminate, as required, and remove portions of these systems located outside the entombment boundary. Package, ship, and dispose of removed systems; isolate remaining systems, if required, at entombment boundary. Certain components can be moved or stored within the entombment structure.
- Prepare lighting and security alarm systems required for continued use. De-energize and/or secure sections of the fire protection, electric power, and HVAC systems not required for continued use.
- Remove all large contaminated components external to the entombment boundary. Where feasible, these components are decontaminated and then removed; otherwise the components are boxed/packaged and shipped for additional treatment or disposal.
- Complete the entombment barrier by capping and sealing all openings and penetrations with concrete.
- Structural surfaces exterior to the entombment barrier are cleaned/decontaminated to unrestricted levels. Equipment and normal personnel access hatches located outside the entombment barrier boundary remain operational, with controlled access.
- Dismantle all other radioactive structures and remove all radioactive materials for shipping and disposal. Alternatively, selected contaminated material and non-combustible wastes may be transferred to storage within the entombment structure.

Decontaminated structures other than the Reactor Building and Fuel Building will not be dismantled at this time.

* Install security and surveillance monitoring equipment and relocate security fence around structures containing radioactive material, if required.

* Perform radiation survey of plant and post warning signs, as appropriate.

2.4.3 Period 3: ENTOMB Dormancy

For the ENTOMB alternative, activities required during the planned dormancy period include routine inspection, preventive and corrective maintenance on safety systems, maintenance of structural integrity, and an environmental and radiation monitoring program. Maintenance and equipment inspection activities may also be performed over a quarterly period in such a manner that all portions of the plant are inspected and maintained within that period.

Until such time as the DOE completes the transfer of spent fuel for ultimate disposition, CYAPCO will maintain an operational Fuel Building. Once the transfer has been achieved, the building will be decontaminated and dismantled.

An environmental surveillance program is carried out during the dormancy period to ensure that releases of radioactivity to the environment are controlled (i.e., they are identified, quantified and maintained within prescribed limits). Appropriate emergency procedures will be established and initiated to provide a high degree of assurance that unplanned releases will not exceed prescribed limits. The environmental surveillance program is generally a modified/abbreviated version of that carried out during normal plant operations.

Security during the dormancy period is primarily conducted to prevent unauthorized entry and to protect the public from the consequences of such entry. Security detection and notification systems, used during plant operations, are augmented by installation of audible alarms. Additionally, silent alarms may be installed to alert off-site security personnel to trespass or fire. It is assumed that CYAPCO will maintain a minimal site security presence during the dormancy period. These personnel can provide periodic site checks and prompt response to alarms. Liaison with local law enforcement agencies is maintained and their assistance requested as necessary.

Primary physical security is provided by the security fence which must be maintained in good condition for the duration of this period. The facility is secured; exterior doors locked and alarmed for intrusion. Fire and radiation alarms are monitored continuously by security personnel.

CYAPCO will designate a representative who will be responsible for controlling authorized entry into, and movement within, the facility. Interior access doors are also under this person's control. In addition, this representative is responsible for plant maintenance, surveillance programs and for providing notification and administrative reports for security breaches and taking appropriate actions.

2.4.4 Periods 4-6: ENTOMB Delayed Removal/Dismantling

At the end of the dormancy period for the ENTOMB alternative, the Reactor Building will be decontaminated and dismantled. Basically, the same dismantling operations as those described for the DECON alternative are performed. Because the ENTOMB alternative permits a period of decay for the residual radioactivity, lower personnel radiation exposures will be incurred than in the DECON alternative. Many of the dismantling activities may employ manual techniques rather than remote procedures, and dismantling operations can be simplified.

Although the initial contact dose levels due to Co60 would decay significantly during the dormancy period, the internal components of the reactor vessel will still have sufficiently high radiation dose rates to require remote sectioning under water, due to the presence of long-lived radionuclides such as Nb94, Ni59, and Ni63. Therefore, the same procedures described for the DECON alternative are employed during the deferred phase. Portions of the concrete biological shield will still be radioactive because of the presence of activated trace elements with long half-lives and will require controlled removal, packaging, and burial procedures. It is unlikely that radioactive corrosion products on inner surfaces of piping and components will have decayed to levels that will permit unrestricted release or allow conventional removal. These systems and components will have to be removed under controlled conditions and their interiors surveyed to determine their disposition as either radioactive waste or releasable as unrestricted scrap material.

The Fuel Building and all other decontaminated structues left standing outside the entombment will also be dismantled. Following notification of completion of the decontamination and disposal of components and materials from CY, the NRC regional staff will conduct an on-site survey to verify that the acceptable activity and contamination levels are satisfied. When these requirements are satisfied, the NRC can terminate the license and any further NRC jurisdiction over the facility.

Site restoration activities may then be performed. A final radiation survey is prepared for the NRC and the site released for alternative use.

3. COST ESTIMATE

A site-specific cost estimate was prepared for CY to account for the unique features of the nuclear steam supply systems, electric power generation systems, site buildings and structures. The basis for the estimate, including the source of information, methodology, assumptions and total costs, is described in this section.

3.1 Basis Of Estimate

CY developed site-specific cost estimates using the proprietary computer code "DECCER" purchased from TLG Services. The DECCER program utilizes site, system and structure databases that contain the unit and site-specific inventory acquired from CY plant drawings and inventory documents. The program computes the decommissioning cost estimate by accumulating the costs associated with decontamination, removal, packaging, shipping and disposal for each activity. The program output defines many aspects of the decommissioning effort including activity and period-dependent costs, schedule, and waste generated.

The decommissioning effort is labor-intensive. Representative labor rates for hourly craft and salaried administrative workers in the geographical region, are essential for the development of a meaningful site-specific decommissioning cost estimate. Recent salary data for NU craft personnel was used for the positions identified as being necessary to perform labor intensive decommissioning activities at the site. NU salary data was also used for the supervisory, engineering and administrative positions necessary to accomplish the decommissioning.

Disposition of radioactive wastes is a significant contributor to the cost of decommissioning. The availability of disposal sites is of national concern, with regional compacts formed to provide adequate disposal space for operating and planned reactors if and when existing disposal sites close. Currently, there are no regional compact burial sites available for the disposal of CY radioactive waste.

In this study, estimates for disposal of decommissioning LLRW were provided by Envirocare of Utah, Inc. and Barnwell South Carolina facility. The combination of these rates resulted in an average low level radioactive waste disposal cost of $168.70 per cubic foot.

Listed below are the major factors considered as the basis of the cost estimates.

1. CY plant drawings, equipment and structural specifications, including construction details.

2. Current employee salaries for site administration, operations, construction and maintenance personnel were used for the identified positions.

3. Engineering services for such items as preparation of activity specifications, detailed procedures, detailed activation analyses, structural modifications, etc. are assumed to be provided by Northeast Utilities engineering personnel and supplementary specialty contractors.

4. Material and equipment costs for conventional demolition and/or construction activities are taken from R.S. Means Construction Cost Data (Ref. 3).

5. Rates for shipping radioactive wastes by truck were provided by Tri-State Motor Transit in published tariffs for this type of cargo (Ref. 4). Barge shipping costs were provided by Chem-Nuclear Systems, Inc.

6. The costing basis for the estimate for low-level radioactive waste disposal were based on estimates for the disposal of decommissioning waste as provided by Envirocare of Utah, Inc. and Chem-Nuclear Systems, Inc. Package surcharges, such as total shipment curies, package weight, special handling requirements, etc., were derived from information provided by Chem-Nuclear Systems, Inc., for the Barnwell facility (Ref. 5).

7. Costs in this estimate reflect July 1996 dollars. This estimate excludes interest and escalation, during the decommissioning period.

8. This study does not address the costs for removal or disposal of spent fuel from the site. The costs for such activities are assumed to be covered under the 1 mil/kWhr surcharge the Licensee is paying to the DOE during plant operations. However, this study does consider the constraints that the presence of spent fuel on site will impose on other decommissioning activities.

9. Ultimate license termination for the CY site is based upon DOE's current acceptance schedule for the spent fuel assemblies generated during plant operation, with an initial start date for acceptance of January 2006. Based upon this start date, NUSCO determined that the final fuel shipment would occur in 2022.

10. The Licensee staffing requirements during decommissioning vary with the level of activity on-site.

11. This study follows the principles of ALARA through the use of work duration adjustment factors which incorporate such items as radiological protection instruction, mock-up training, the use of respiratory protection and personnel protective clothing. These items lengthen a task's duration, which increases the costs and lengthens the schedule. Costs

shown for engineering and planning reflect ALARA planning considerations.

12. This study has been performed in accordance with the published study from the Atomic Industrial Forum/National Environmental Studies Project report AIF/NESP-036, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates" (Ref. 6). The contents of these guidelines were prepared under the review of a task force consisting of representatives from utilities, state regulatory commissions, architect/engineering firms, the Federal Energy Regulatory Commission, the NRC, and the National Association of Regulatory Utility Commissioners.

3.2 Methodology

The methodology used to develop CY's cost estimates follows the basic approach presented in the AIF/NESP-036 study (Ref. 6) and the U.S. DOE "Decommissioning Handbook" (Ref. 7). These references utilize a unit cost factor method for estimating decommissioning activity costs to simplify the estimating calculations. Unit cost factors for concrete removal ($/cubic yard), steel removal ($/ton), and cutting costs ($/in) were developed from current labor and material cost information. With the item quantity (cubic yards, tons, inches, etc.) developed from plant drawings and inventory documents, these activity-dependent costs are estimated.

The unit cost factor method provides a demonstrable basis for establishing reliable cost estimates. The detail of activities provided in the unit cost factors for activity time labor costs (by craft), and equipment and consumable costs, provide assurance that cost elements have not been omitted. These detailed unit cost factors, coupled with the plant-specific inventory of piping, components and structures, provide a high degree of confidence in the reliability of the cost estimates.

The activity duration critical path was used to determine the total decommissioning program schedule. The program schedule is used to determine such period-dependent costs as program management, administration, field engineering, equipment rental, quality assurance and security. Typical NU salary and hourly rates for personnel associated with period-dependent costs are used. The costs for conventional demolition of nonradioactive structures, materials, backfill, landscaping and equipment rental were obtained from the "Building Construction Cost Data" published by R. S. Means (Ref. 3). Examples of unit cost factor development are presented in the AIF "Guidelines" study (Ref. 6), one of which is reproduced in Appendix C. Appendix D lists the specific factors developed for the CY estimates.

The activity-dependent and period-dependent costs are summed to develop the total decommissioning costs. Contingency is applied to each element of cost, as described below. "Contingencies" are defined in the American Association of Cost Engineers' Cost Engineers' Notebook (Ref. 8) as "specific provision for unforeseeable elements of cost within the defined project scope; particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events which will increase costs are likely to occur." As with any major project, items which could occur that have not been explicitly accounted for in this estimate are changes in the regulatory requirements, the effects of craft labor strikes, bad weather halting or slowing down dismantling activities or waste shipments to the disposal facility, equipment/tool breakage, changes in the anticipated plant shutdown conditions, etc. In the AIF/NESP-036 study, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates" (Ref. 6), the types of unforeseeable events that are likely to occur in decommissioning are discussed and guidelines are provided for percentage contingency in each category. Application of these types of contingencies, on a line item basis, yielded a weighted average contingency of 14.04% for the DECON cost estimate.

3.3 Site-Specific Considerations

There are a number of site-specific considerations that affect the method chosen for dismantling and removal of equipment from the site and the degree of restoration required. The cost impact of these considerations is included in this cost study.

3.3.1 Major Component Removal

The reactor pressure vessel (shell and nozzle zone) and reactor internal components will be segmented for disposal and shipped in shielded casks. Segmentation and packaging of the internals packages will be performed underwater in the refueling cavity where a turntable and remote cutter will be installed. The vessel will be segmented in-place using a mast-mounted cutter supported off the lower head of the reactor pressure vessel and directed from a shielded work platform installed overhead in the reactor cavity. Shipping cask specifications and U.S. Department of Transportation (DOT) regulations will dictate segmentation and packaging methodology. All designated packages must meet current physical and radiological limitations and regulations. Shielded shipments will be made in DOT approved, currently available, truck casks. Large components such as the pressurizer and the four steam generators, may be modified for barge shipment as their own containers. An existing barge docking facility in the CY discharge canal will be refurbished for this purpose.

Reactor coolant piping will be cut from the reactor vessel once the inlet and outlet nozzles have been isolated. The piping will be boxed and shipped by shielded van. The reactor coolant pumps and motors will be lifted out intact, and packaged for barge transport with the pressurizer.

The steam generators will be extracted from the Reactor Building and moved to a temporary on-site staging area. The generators are then moved off-site by barge.

The main turbine will be dismantled, using conventional maintenance procedures. The turbine rotors and shafts are transported to a clean laydown area for disposal. The lower turbine casings will be removed from their anchors by controlled demolition. The main condensers will be segmented and transported to the laydown area for disposal, together with the lower turbine casings.

3.3.2 Transportation Methods

For the purposes of this cost study, it was assumed that the NSSS components will be transported by a combination of barge and overland transporter. These payloads include the reactor coolant pumps, steam generators and the pressurizer unit. At the disposal facility, the NSSS components will be off-loaded to an overland transporter for the remaining distance to the disposal site.

3.3.3 Site Conditions at Facility Closeout

It is assumed that the site will be restored by regrading to conform to the adjacent landscape. Sufficient topsoil is to be placed to permit new growth of native vegetation. The intake and discharge structures on-site will be demolished and removed, with the circulating water piping sealed and backfilled.

3.4 Assumptions

The following are the major assumptions made in the development of the cost estimates for CY:

1. CYAPCO will act as the Decommissioning Operations Contractor (DOC). In this role, CYAPCO will provide sufficient staff to perform the preparatory decommissioning planning and scheduling, and manage the demolition efforts. Site security during demolition will be provided by the Licensee or its subcontractor. The demolition work will be performed by the subcontractors, who will provide adequate staff, labor, equipment and materials to complete the demolition.

2. Existing site structures and alternations necessary to support long term wet storage of spent fuel were considered in the dismantling cost. The alterations considered include provision of a closed cooling system in the fuel building, establishment of a control room and primary access point in

the radwaste reduction facility, establishment of a dedicated spent fuel cooling electric supply and provision of construction power.

3. Disposal fees based upon estimates for the disposition of decommissioning waste provided by Envirocare of Utah, Inc. and Barnwell.

   Disposal costs were calculated using actual component dimensions for those components not requiring additional packaging, e.g., the NSSS components.

4. The decommissioning activities are performed in accordance with the following regulations:

10 CFR 20	Standards for Protection Against Radiation
10 CFR 30	Rules of General Applicability to Licensing of Byproduct Materials
10 CFR 40	Licensing of Source Material
10 CFR 50	Domestic Licensing of Production and Utilization Facilities
10 CFR 51	Licensing and Regulatory Policy and Procedures for Environmental Protection
10 CFR 61	Licensing Requirements for Land Disposal of Radioactive Wastes
10 CFR 72	Licensing Requirement for the Independent Storage of Spent Nuclear Fuel and High Level Radioactive Waste
10 CFR 170	Fees for Facilities and Material Licenses and Other Regulatory Services
29 CFR 1910	Occupational Safety and Health Standards
49 CFR 170-178	Department of Transportation Regulations Governing the Transport of Hazardous Materials

   The cost estimate reflects the environmental regulations currently in effect.

5. Nuclear liability insurance provides coverage for damages or injuries due to radiation exposure from equipment, material, etc. used during decommissioning. Nuclear liability insurance is phased out upon final decontamination of the site.

6. The NSSS will be chemically decontaminated using one chemical flush and two water rinses prior to segmentation in the DECON scenario.

7. Reactor vessel and internals packages conditions:

Any cladding failure that has or may occur during the lifetime of the plant is assumed:

(i) to have released fission products at sufficiently low levels that the buildup of quantities of long-lived isotopes (e.g. cesium-137 or strontium-90) has not reached levels that would prevent the major NSSS components to be shipped as Low Specific Activity (LSA) waste and disposal within the requirements of 10 CFR 61 or the regional disposal facility; or

(ii) to have necessitated systematic decontamination during the operating life of the plant and because of such decontamination the levels again are at acceptable levels for transport as LSA waste and disposal within the requirements of 10 CFR 61.

Control element assemblies will be packaged with the spent fuel for disposition by DOE. No additional cost is included for their disposal.

The curie contents of the vessel and internals at final shutdown are estimated from those radionuclides listed in NUREG/CR-3474 (Ref. 10). Actual estimates are derived from the Ci/gram values in NUREG/CR-3474 and adjusted for the different mass of CY components, as well as for different periods of decay. Additional short-lived isotopes were derived using NUREG/CR-0130 (Ref. 9) and NUREG/CR-0672 (Ref. 11), benchmarked to the long-lived values from NUREG/CR-3474.

8. The disposal costs for the reactor vessel (beltline and nozzle regions) and the internals packages are based on remote segmentation, packaging in shielded casks and transported by truck to the disposal facility. A maximum normal road weight limit of 80,000 pounds is assumed for all truck shipments including cask shipments. This weight includes vessel segment(s), supplementary shielding, cask tie-downs and tractor trailer. The maximum curies per shipment are based on the license limits of available shielded shipping casks and Barnwell site limits on maximum curie content per shipment. The number and curie content of vessel segments are selected to meet these limits.

9. Barge and overland transport costs for the steam generators are based on an estimate provided by Chem-Nuclear Systems, Inc.

10. Steam generators are removed sequentially and stored on site until ready to be moved. This scenario will consolidate shipping and reduce mobilization costs for the heavy haul vehicles. The steam generators will be transported to the CY barge docking facility (in the discharge canal). Here they will be loaded on to barges for transport to the Chem-Nuclear Savanah River site. At the Chem-Nuclear barge site, the steam

generators will be reloaded on to an overland transport vehicle for movement to the actual burial location.

11. Because of the new Barnwell weight based burial cost schedule, only a small percentage of the contaminated metallic inventory is assumed to be routed through a waste recovery vendor. This is because the cost of decontamination yields no benefit under the weight based disposal cost schedule unless it eliminates all burial cost by reaching a contamination level that permits unrestricted release.

12. Materials containing asbestos insulation are assumed to be removed under a decommissioning asbestos abatement program. Radioactivity contaminated asbestos is assumed to be disposed of at Envirocare. Clean asbestos will be disposed of at an approved landfill in accordance with applicable state and local regulations.

    It is assumed that all PCBs have been removed from the power transformers and capacitors. Therefore, no additional remediation is included in decommissioning.

13. CY will be isolated electrically from the rest of the transmission system and completely decommissioned (i.e., the station will be out of service prior to commencing the demolition effort).

14. CY will provide for the availability of the electrical power required to decommission and dismantle the station.

15. Scrap generated during decommissioning is not included as a salvage credit line item in this study for two reasons: (1) the scrap value is offset by the associated site removal and scrap reprocessing costs, and (2) a relatively low value of scrap exists in the market. Scrap processing and site removal costs are not included in the estimate.

16. CY will act as project manager and will remove all items of furniture, tools, mobile equipment (such as forklifts, trucks, bulldozers, other similar mobile equipment) and other such items of personal property owned by CY that is easily removed without the use of special equipment. The cost for removal of such non-affixed items is not included in this decommissioning cost estimate.

17. All contaminated piping, components and structures (other than the reactor vessel and internals) are assumed to meet DOT limits for LSA material.

18. Fuel oil tanks will be emptied. Tanks will be cleaned by flushing or steam cleaning, as required, prior to disposal. Acid and caustic tanks are

emptied through normal usage. Lubricating and transformer oils will be drained and removed from site by a waste disposal vendor.

19. All above-grade structures will be removed to a minimum of 3 feet below grade level. Structures will be backfilled to grade level. Water drain holes will be drilled in the bottom of all below grade structures to be abandoned. Piping and electrical manholes will be backfilled with a suitable earthen material and abandoned. Vertical pump structures and sumps will be backfilled with a suitable earthen material and abandoned.

20. Non-contaminated underground piping (except the intake, discharge tunnel, and circulating water piping) will be abandoned without special considerations. The plant intake and discharge circulating water piping and tunnel will be sealed/backfilled or partially collapsed and backfilled to eliminate the potential for collapse after the site is released for unrestricted access.

21. The station grounds will be landscaped to match the environs for erosion control and will have a final contour consistent with adjacent surroundings. Culverts, head walls and rip-rap will remain in place to allow natural drainage. The discharge canal will be left in its existing condition.

22. The switchyard that exists in the woods above the plant will be left intact for use by CL&P's electrical distribution system.

23. The perimeter fence will be moved to conform with the technical specifications in force at the various stages in the project. Plant roadways and parking areas with asphalt or concrete surfacing will be broken up and the areas covered with fill. Site access roads will remain intact. Contaminated asphalt and soil discovered during the process of decommissioning will be disposed of as low level waste.

24. This study estimates that there will be some radioactive waste generated which is greater than 10 CFR 61 Class C quantities, as the result of disposal of the highly activated sections of the reactor vessel internals. "Currently, this material exceeds the limits on the type of waste that can be buried as low level waste. This estimate assumes that this material can be disposed of in the same manner as spent fuel at a DOE deep geological repository. Since greater than class C waste disposal cost is not covered by the accrual of funds under the DOE's 1 mil/kWhr fuel surcharge, a separate cost has been estimated for the deep repository disposal of this material. This estimate for deep repository disposal of greater than class C waste is based on a model that simulates this material as spent fuel (i.e., the 1 mil/kWhr surcharge is the basis for calculating greater than class C disposal costs)."

25. Segments of the reactor vessel internals that exceed 10 CFR 61 Class C burial limits will be stored with the spent fuel in the Fuel Building. For the purposes of this study, it is assumed that this material will be removed from the site by shielded cask shipments at some point in the 19 year fuel storage period.

26. Spent fuel will remain on-site for approximately 25 years following final plant shutdown. CY will provide staffing throughout this time period to safeguard the fuel, and to process spent fuel shipments to DOE's facility.

3.5 Cost Estimate Summary

A summary of the decommissioning alternative costs, with annual expenditures, is provided in Table 3.1. Appendix B provides the detailed listings and costs of major activities for the DECON decommissioning scenario.

As used in the headings of Appendix B, "DECON" refers to decontamination, and "Total" is the sum of Decon, Remove, Pack, Ship and Disposal as well as other miscellaneous items not listed (such as engineering, taxes and insurance). "Other" cost, as shown in the disposition for plant systems and structures reflect the costs associated with asbestos abatement, primary system decontamination and spent fuel storage. Costs are reported in July 1996 dollars.

TABLE 3.1a

SUMMARY OF DECON DECOMMISSIONING COST ESTIMATES (Thousands of Dollars)

	Period	Calendar Years	*Cost
Preparations	1	1997	$ 10,800
		1998	$ 55,506
		1999	$ 9,942
Subtotal Period 1			$76,248
Decommissioning Activities	2	1999	$64,810
		2000	$65,123
		2001	$64,849
Subtotal Period 2			$194,782
Structure Demolition/ Site Restoration	3	2002	$46,289
		2003	$17,931
Subtotal Period 3			$64,220
Post Period 3 Fuel Storage		2003-2022	$82,345
Fuel Building Decont/Demolition		2022	$ 9,132
Subtotal Post Period 3			$91,477
TOTAL COST			**$426,727**

*Costs reported in July 1996 dollars; may not add due to rounding.

TABLE 3.1b

SUMMARY OF SAFSTOR
DECOMMISSIONING COST ESTIMATE
(Thousands of Dollars)

	Period	Calendar Years	*Cost
SAFSTOR Operations	1	1997	$10,800
		1998	$37,561
		1999	$23,458
Subtotal Period 1			$71,819
Dormancy (including fuel storage)	2	1999-2052	$244,167
Decommissioning Preparations	3	2052	$15,713
		2053	$36,299
		2054	$ 2,387
Subtotal Period 3			$54,399
Decommissioning Activities	4	2054	$60,507
		2055	$64,765
		2056	$60,152
Subtotal Period 4			$185,424
Site Restoration	5	2056	$2,484
		2057	$33,304
Subtotal Period 5			$35,788
TOTAL COST			**$591,596**

*Costs reported in July 1996 dollars; may not add due to rounding.

TABLE 3.1c

SUMMARY OF ENTOMBMENT DECOMMISSIONING COST ESTIMATE (Thousands of Dollars)

	Period	Calendar Years	*Cost
ENTOMB Preparations	1	1997	$10,800
		1998	$39,787
		1999	$10,684
Subtotal Period 1			$61,271
ENTOMB Operations	2	1999	$50,499
		2000	$51,198
		2001	$17,765
Subtotal Period 2			$119,462
Dormancy (including fuel storage)	3	2001-2053	$191,501
Decommissioning Preparations	4	2053	$28,745
		2054	$25,213
Subtotal Period 4			$53,958
Decommissioning Activities	5	2054	$16,338
		2055	$55,216
		2056	$50,601
Subtotal Period 5			$122,155
Site Restoration	6	2056	$ 2,476
		2057	$33,377
Subtotal Period 6			$35,853
TOTAL COST			**$584,200**

*Costs reported in July 1996 dollars; may not add due to rounding.

3.6 Spent Fuel Storage

Post-operation spent fuel storage can represent a significant expense. Therefore, the assumptions used to construct the current scenario need periodic evaluation as DOE moves closer to developing a repository for high-level waste and finalizes its acceptance schedule.

Spent fuel storage costs entail initial expenditures to isolate the fuel building and long-term expenses related to staffing, pool maintenance, and fuel shipments. Accordingly, long-term storage costs are directly related to the length of the spent-fuel storage period in the pool. The storage period, in turn, is a direct function of when the United States Department of Energy (DOE) begins to remove fuel and the rate at which fuel is taken. The revised study assumes that the DOE will begin taking CY fuel in 2006, and will finish by January 1, 2022.

The 2006 assumption is based on the possibility that DOE will have access to a centralized interim storage facility by 2006 and reflects CY's priority ranking to have fuel taken away in the first year that centralized interim storage is available to the nation.

The rate at which fuel will continue to be taken away from CY (thereafter) is based upon:

(a) The annual national spent fuel acceptance rates that were specified in the legislation which was recently passed by the U.S. Senate (S. 1936), and

(b) CY's Acceptance Priority Ranking (relative to other contract-holders), as established by DOE.

Both initial and long-term costs for fuel storage have been included in this estimate. Capital costs for the isolation of the Fuel Building and (initial) licensing costs are included within the estimates. Period-dependent (longer-term) costs, i.e., staffing, security, licensing, and insurance, have also been included in support of operations in the Fuel Building over the 25 years (1997-2022).

One advantage of isolating the fuel assemblies from the remainder of the site is that decommissioning can commence unimpeded by the presence of the fuel, providing a substantial cost saving. After the remainder of the site has been cleared, the Fuel Building would continue to function until all fuel has been removed from the site.

4. SCHEDULE ESTIMATE

The schedule for the DECON decommissioning alternative considered in this study follows the sequence presented in the AIF/NESP-036 study, with minor changes to reflect recent experience and revised estimates. The assumptions for the schedule are listed in Section 4.1. Figure 4.1 presents the schedule of key activities for the DECON scenario. Note that the activities listed in the schedule do not reflect a one to one correspondence with the activities in Appendix B, but reflect splitting some activities for clarity and combining others for convenience. The schedule was prepared using the computer software "Microsoft Project 4.0 for Windows." A project time line is shown in Figure 4.2 for the DECON, ENTOMB and SAFSTOR scenarios.

4.1 Schedule Estimate Assumptions

The schedule in Figure 4.1 reflects the results of a precedence network developed for CY decommissioning activities. The durations used in the precedence network reflect the actual man-hour estimates from Appendix B. The schedule output is then adjusted by stretching certain activities over their slack range; other activities were pushed to the end of their slack period. The following assumptions were made in the development of the schedule for CY:

1. All work except vessel and internals removal activities will be performed during an 8-hour workday, 5 days per week with no overtime.

2. The Fuel Building will be isolated, maintained, and operational until the time when all spent fuel has been transferred from the spent fuel pool to a DOE facility, approximately 25 years after shutdown.

3. Vessel and internals removal activities will be performed by using separate crews for different activities working on different shifts, with a corresponding backshift charge for the second shift.

4. Multiple crews will work parallel activities to the maximum extent possible consistent with optimum efficiency, adequate access for cutting, removal and laydown space, and compliance with the stringent safety measures necessary during demolition of heavy components and structures.

FIGURE 4.1
CY DECON SCHEDULE DETAILS

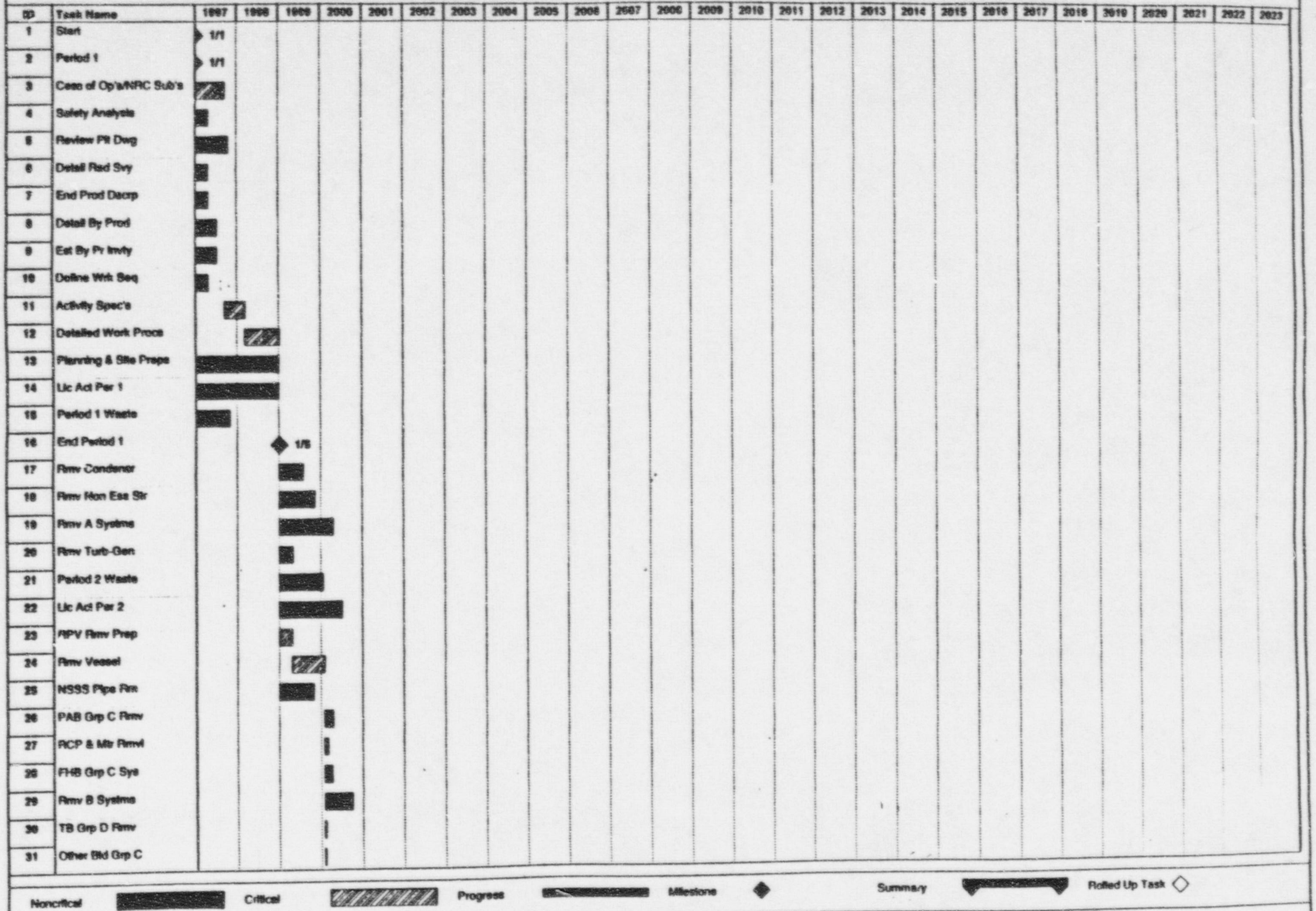
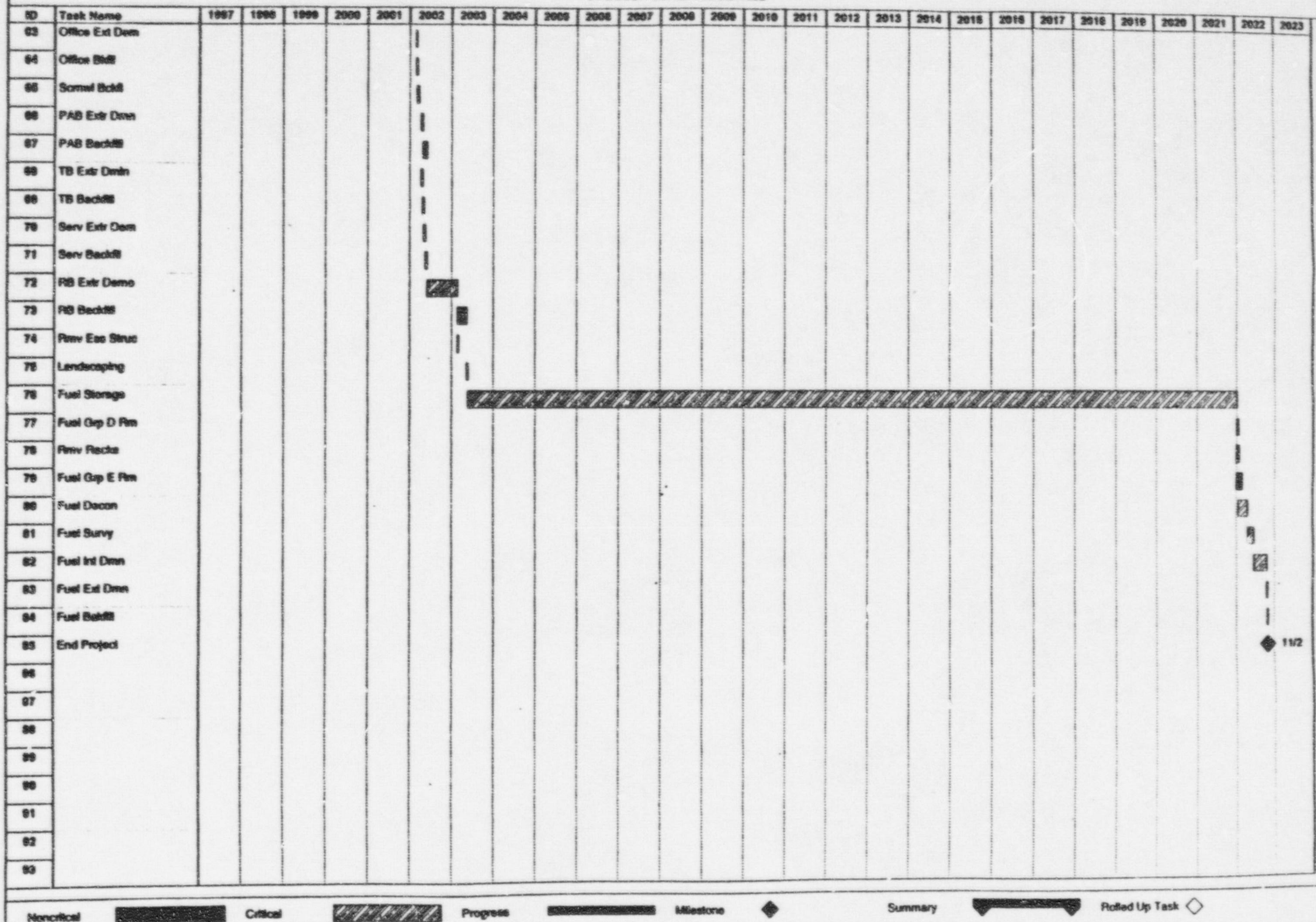
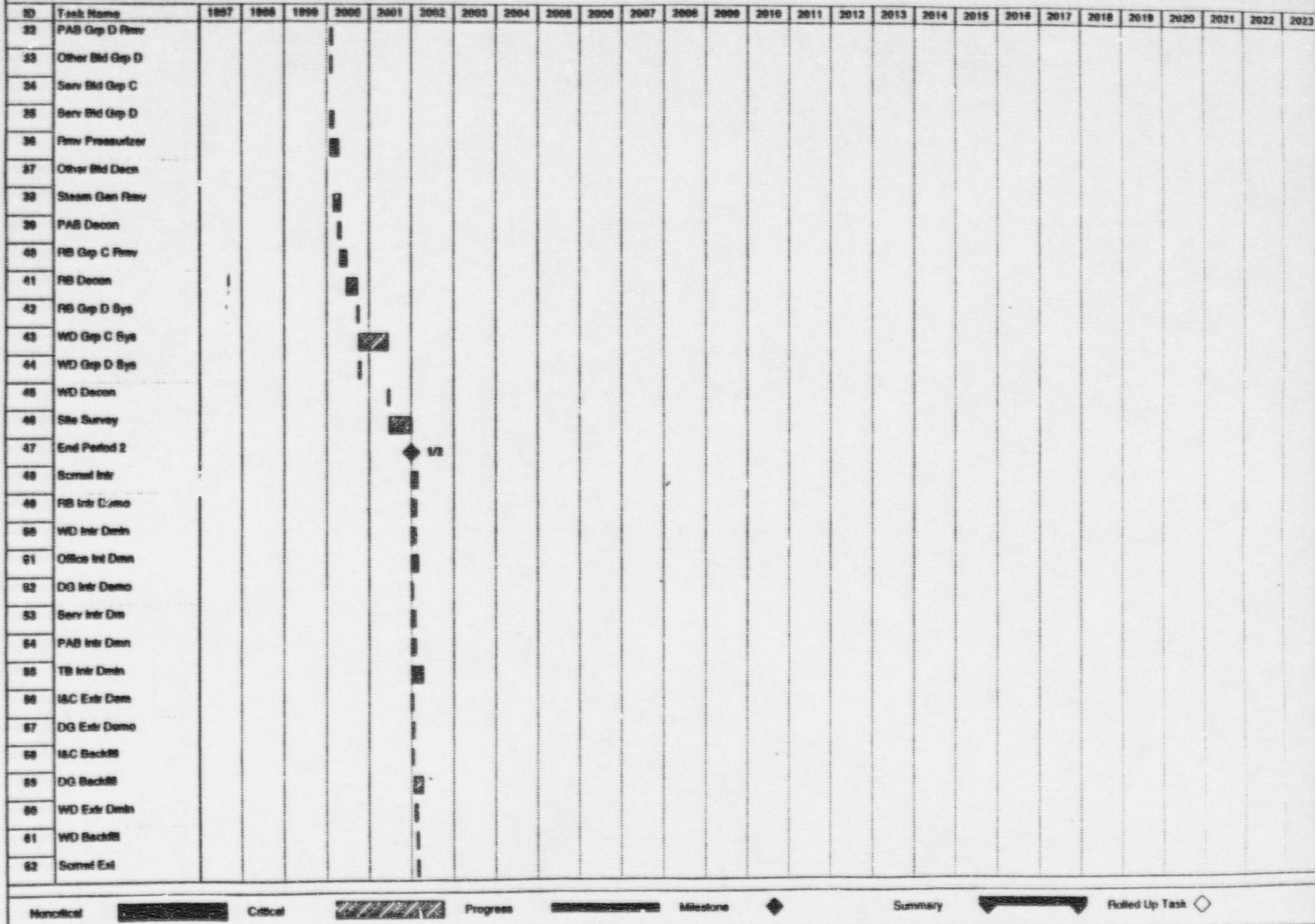


FIGURE 4.1
CY DECON SCHEDULE DETAILS



URE 4.1
CY DECON SCHEDULE DETAILS

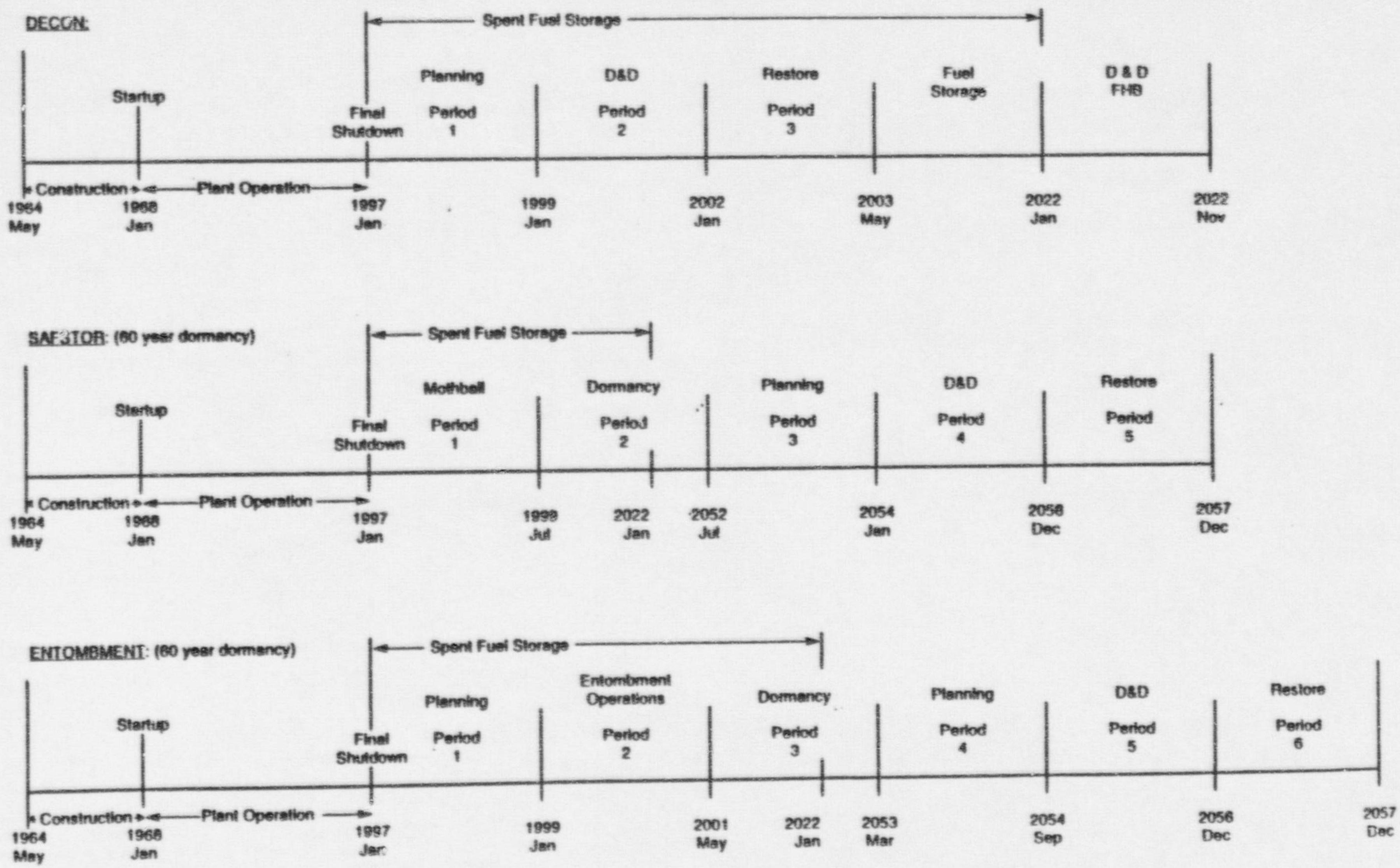


4.2 Project Schedule

Period-dependent costs are based upon critical path durations developed in the schedules for the DECON, SAFSTOR and ENTOMBMENT alternatives. Each of the decommissioning schedules is composed of periods (or milestones) that mark the beginning and/or completion of major phases to the decommissioning project. The schedules combine the sequence in which activities are to be performed within a period with activity durations obtained from DECCER output to determine critical path and critical path duration.

Schedule critical path durations were also used to develop the decommissioning timelines in Figure 4.2

FIGURE 4.2
CONNECTICUT YANKEE
1996 DECOMMISSIONING TIMELINE
(not to scale)



5. RADIOACTIVE WASTE VOLUME

The radioactive waste volume generated during the various decommissioning programs at CY are shown by line activity in the cost tables. Approximately 283,117 cubic feet of radioactive material are buried during the DECON program as shown in Table 5.1. Waste volumes are quantified consistent with 10 CFR 61 classifications and are based on the gross container volume and weight to be shipped to controlled disposal facilities.

Most of the materials for controlled disposal are categorized as Low Specific Activity (LSA) material containing less than Type A quantities, as defined in 49 CFR 173-178 (Ref. 13). The containers are strong, tight packages. For this study, commercially available steel containers are used for packaging piping, small components and concrete.

The reactor vessel and internals are categorized as large quantity shipments and, accordingly, must be shipped in reusable shielded casks with disposable liners. In this case, the liner volume is taken as the waste volume.

Because of the high charge for waste disposal, a percentage of the contaminated metallic inventory is assumed to be routed through a waste recovery vendor. It is expected that a percentage of this material can be recovered, i.e., decontaminated to levels permitting unrestricted use, at a significant savings. The waste volumes reported in Table 5.1 represent what could not be reclaimed, as well as the inventory that was not identified as being suitable for recovery.

TABLE 5.1

PROJECTED RADIOACTIVE WASTE DISPOSAL VOLUMES

		Waste Class[1]	Volume[2] (cubic feet)
DECON			
		A	272,641
		B	9,753
		C	115
		>C	608
	Total		**283,117**
SAFSTOR			
		A	276,637
		B	5,754
		C	631
		>C	191
	Total		**283,213**
ENTOMB			
		A	278,284
		B	5,392
		C	631
		>C	191
	Total		**284,498**

1 Waste is classified according to the requirements delineated in 10 CFR 61.55.

Class A and B wastes contain types and quantities of radioisotopes that will decay within 100 or 300 years respectively, with Class B waste having more rigorous requirements on waste form to ensure stability. Class C wastes require additional measures at the disposal facility to protect against inadvertent intrusion for up to 500 years. Waste in which the radionuclide concentrations identified for Class C are exceeded is generally not suitable for near-surface disposal; such waste is classified as greater than Class C.

2 No estimate has been made of the LSA waste that will be generated by spent fuel shipping.

6. CONCLUSIONS

In the selection of decommissioning alternatives, several factors must be considered; mainly the post-decommissioning use of the site and facilities, public and occupational safety aspects, the environmental impact of dismantling operations, the decommissioning cost, and the cost of post decommissioning surveillance, security and other activities. The evaluation of alternatives for decommissioning must be based on an evaluation and balancing of these factors.

6.1 Connecticut Yankee's Decommissioning Recommendation

Decommissioning technology is well established and the tools and equipment necessary to completely dismantle CY are available and have been demonstrated through normal plant maintenance and past reactor decommissioning. This study provides an estimate for decommissioning the site under current requirements, based on present costs and available technology. The cost to decommission the CY nuclear unit using the DECON (Prompt Removal/Dismantling) alternative is $426,727,000, including shipment of all wastes and dismantled materials to a disposal site and demolition of the remaining site structures. The decommissioning costs using the SAFSTOR and ENTOMB alternatives are $591,596,000 and $584,200,000, respectively. The estimate reflects the site-specific features of CY and the estimated cost of radioactive waste shipping and disposal costs. An analysis of the major activities contributing to the total cost is shown in Table 6.1.

The decommissioning and CY staff costs and removal costs are the largest percentages of the total cost, reflecting the labor intensive nature of decommissioning programs. Radioactive waste disposal is the next most costly activity in the program. Shipping costs will be most sensitive to changes in fuel costs and distance to waste disposal facilities. Removal costs are dependent on the degree of remotely operated equipment available in the future and the associated higher cost of that equipment versus the savings in labor costs. These results point to the need for periodic reviews of these estimates.

In summary, on the basis of this study, Connecticut Yankee believes that prompt dismantling is the decommissioning method which, at this time, provides its customers with the safest and most cost-effective alternative for Connecticut Yankee, and the decommissioning alternative which is planned to be used for this plant.

TABLE 6.1

SUMMARY OF DECOMMISSIONING COSTS

Work Category	Costs*** (Thousands)	Percent of Total Costs
DECON		
Decontamination	$ 3,638	1.0
Removal	35,147	9.4
Packaging	1,845	0.5
Shipping	7,644	2.0
Radioactive waste disposal	61,265	16.4
Decommissioning Staff	169,726	45.4
Other *	94,920	25.4
Total	$374,185	100.0
Contingency	52,542	14.0
GRAND TOTAL**	**$426,727**	
SAFSTOR		
Decontamination	$ 5,118	1.0
Removal	34,964	6.6
Packaging	1,334	0.3
Shipping	7,556	1.4
Radioactive waste disposal	53,004	10.0
Decommissioning Staff	284,845	53.9
Other *	141,919	26.8
Total	$528,739	100.0
Contingency	62,857	11.9
GRAND TOTAL**	**$591,596**	
ENTOMBMENT		
Decontamination	$ 3,526	0.7
Removal	35,248	6.8
Packaging	1,387	0.3
Shipping	7,507	1.4
Radioactive waste disposal	61,133	11.8
Decommissioning Staff	213,233	41.2
Other *	195,713	37.8
Total	$517,747	100.0
Contingency	66,453	12.8
GRAND TOTAL**	**$584,200**	

* "Other" includes items such as engineering & preparations, insurance, and spent fuel storage expenditures.

** Costs are shown in July 1996 dollars. Numbers may not add due to rounding.

7. REFERENCES

1. Federal Register Volume 53, Number 123 (p 24018+), June 27, 1988, Nuclear Regulatory Commission, Code of Federal Regulations, Title 10, Parts 30, 40, 50, 51, 70 and 72 "General Requirements for Decommissioning Nuclear Facilities."

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3. "Building Construction Cost Data 1996", Robert Snow Means Company, Inc., Kingston, Massachusetts.

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5. Chem-Nuclear Services, Inc., Low-Level Radioactive Waste Management Facility, Barnwell, S.C., Rate Schedule.

6. T.S. LaGuardia et al., "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates", AIF/NESP-036, May 1986.

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8. Cost Engineers Notebook: American Association of Cost Engineers, AA-4.000, pg 3 of 22, Rev. 2 (January, 1978) (Updated periodically).

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11. H.D. Oak, et al., "Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station," NUREG/CR-0672 and addenda, Pacific Northwest Laboratory for the Nuclear Regulatory Commission. June 1980.

12. U.S. Department of Transportation, Section 49 of the Code of Federal Regulations, "Transportation", Parts 173 through 178.4

13. Federal Register Volume 61, Number 146 (page 39278), July 29, 1996, NRC, Code of Federal Regulations, Title 10, Parts 2, 50 and 51 "Decommissioning of Nuclear Power Reactors.

APPENDIX A

DEFINITION OF ACRONYMS

APPENDIX A

DEFINITION OF ACRONYMS

AE	Architect/Engineer
ALARA	As Low As Reasonably Achievable
CWS	Circulating Water System
CYAPCO	Connecticut Yankee Atomic Power Company
D&D	Decontamination and Decommissioning
DOC	Decommissioning Operations Contractor
DOE	United States Department of Energy
ISFSI	Independent Spent Fuel Storage Installation
LSA	Low Specific Activity
NNECO	Northeast Nuclear Energy Company
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
NUSCO	Northeast Utilities Service Company
PSDAR	Post Shutdown Decommissioning Activities Report
RCS	Reactor Coolant System
MWt	Megawatts thermal
MWe	Megawatts electrical

APPENDIX B

DECON COST ESTIMATE

PROMPT REMOVAL/DISMANTLING

PLANT NAME: Connecticut Yankee Atomic Power Station
UTILITY NAME: Northeast Utilities
DATE/VERSION: Monday, December 2, 1996 / DECCER Version CY 96.11.13
TIME OF RUN: 13:09:39

Costs stated in thousands of 1996 dollars.
Columns may not total due to rounding errors.

PERIOD 1

Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
1. Site characterization survey						228	34	263	263									
2. Prepare preliminary decom. cost estimate								n/a										
3. Notification of cessation of operations								n/a										
4. Remove fuel & source material								n/a										
5. Notification of permanent defueling								n/a										
6. Deactivate plant systems & process waste								n/a										
7. Review plant dwgs & specs.						153	23	176	176									
8. Perform detailed rad survey								n/a										
9. Prepare and submit PSDAR						67	10	77	77									
10. End product description						33	5	38	38									
11. Detailed by-product inventory						77	12	89	89									
12. Define major work sequence						250	38	288	288									
13. Perform SER and EA						103	16	119	119									
14. Perform site-specific cost study						167	25	192	192									

Activity Specifications

Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
15.1 Plant & temporary facilities						164	25	189	169	19								
15.2 Plant systems						139	21	160	160	18								
15.3 Reactor internals						237	36	272	272									
15.4 Reactor vessel						217	33	249	249									
15.5 Biological shield						17	3	19	19									
15.6 Steam generators						104	16	120	120									
15.7 Reinforced concrete						53	8	61	61	31								
15.8 Turbine & condenser						27	4	31	31	31								
15.9 Plant structures & buildings						104	16	120	120	60								
15.10 Waste management						153	23	176	176									
15.11 Facility & site closeout						30	5	35	35	17								
15. Total						1244	187	1431	1431	173								

Planning & Site Preparations

Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
16. Prepare dismantling sequence						240	36	276	276									
17. Plant prep, temp. svcs. & dis. canal dredge						2734	410	3144	3144									
18. Design water clean-up system						140	21	161	161									
19. Rigging/CCEs/tooling/etc.						1455	218	1674	1674									
20. Procure casks/liners & containers						123	18	141	141									

Detailed Work Procedures

Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
21.1 Plant systems						158	24	181	163	18								
21.2 Vessel head						83	13	96	96									
21.3 Reactor internals						83	13	96	96									
21.4 Remaining buildings						45	7	52	13	39								
21.5 CRD cooling assembly						33	5	38	38									
21.6 CRD housings & ICI tubes						33	5	38	38									
21.7 Incore instrumentation						33	5	38	38									
21.8 Reactor vessel						121	18	139	139									
21.9 Facility closeout						40	6	46	23	23								
21.10 Missile shields						15	2	17	17									
21.11 Biological shield						40	6	46	46									
21.12 Steam generators						153	23	176	176									
21.13 Reinforced concrete						33	5	38	19	19								
21.14 Turbine & condensers						104	16	120		120								
21.15 Auxiliary building						91	14	105	94	10								
21.16 Reactor building						91	14	105	94	10								
21. Total						1158	174	1332	1092	240								

	Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	Bl-Hrs
Subtotal Period 1 Activity Costs							8173	1226	[illegible]399	9186	413								
Period 1 Undistributed Costs																			
	1. Decon equipment						218	33	251	251									
	2. Decon supplies						205	51	256	256									
	3. DOC staff relocation expenses								n/a										
	4. Process liquid waste	41		19	33	118		87	269	269			282			282			74
	5. Insurance						899	90	989	989									
	6. Property taxes						3658	[illegible]66	4024	4024									
	7. Health physics supplies						1415	354	1769	1769									
	8. Heavy equipment rental						292	44	336	336									
	9. Disposal of stored contaminated tools			107	48	640		164	958	958				10000	10000				5440
	10. Disposal of DAW generated			56	25	333		88	502	502				5207	5207				7082
	11. Plant energy budget						1483	222	1705	1705									
	12. ISFSI capital expenditures						1000		1000	1000									
	13. ISFSI site alterations						1248		1248	1248									
	14. ISFSI licensing and permits						1125		1125	1125									
	15. NRC Fees						419	42	461	461									
	16. Emergency Planning Fees						44	4	48	48									
	17. Primary System Decontamination Program						8000	900	8900	8900			1000			1000			
	18. Asbestos Abatement Program						5000	750	5750	5750				21266	21266				
	19. Administrative & General						3212	161	3372	3372									
	20. Materials & Supplies						1040	156	1196	1196									
Subtotal Undistributed Costs Period 1		41		182	106	1092	27258	3481	32159	32159			1282	36473	36473	1282			12596
Staff Costs	Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	Bl-Hrs
	DOC Staff Cost						14128	706	14835	14835									
	Utility Staff Cost						18909	945	19855	19855									
TOTAL PERIOD 1 COST		41		182	106	1092	68468	8359	76248	76006	413		1282	36473	36473	1282			12596

PERIOD 2

Nuclear Steam Supply System Removal	Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
	1.1 Reactor Coolant Piping	90	129	9	67	1411		794	2499	2499			4800		4800				8214
	1.2 Pressurizer Relief Tank	12	65	0	4	132		89	302	302			449		449				2109
	1.3 Reactor Coolant Pumps & Motors	65	57	37	100	1844		872	2775	2775			3592		3592				3849
	1.4 Pressurizer	21	37	5	800	510		173	1546	1546			2063		2063				1597
	1.5 Steam Generators	113	3119	148	4000	4752		3249	15381	15381			20772		20772				67850
	1.6 CRDMs/ ICIs/Service Structure Removal	67	31	2	14	350		131	595	595			1192		1192				2820
	1.7 Reactor Vessel Internals	37	2555	309	412	2326		2058	7699	7699			1836		1377	344	115		7851
	1.8 Reactor Vessel	153	4223	386	515	6471		4026	15754	15754			7892		5889	2003			24585
	1. Totals	558	10217	877	5912	17597		11391	46550	46550			44817		42154	2348	116		138335

Disposal of Plant Systems	Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
	2.1 Access Control Area Ventilation (ACA)		24					4	28		28								892
	2.2 Aerated Liquid Radwaste (RWS)	68	84	1	5	221		105	483	483		73	858	244	977				3352
	2.3 Auxiliary Feedwater (AFW)		10					2	12		12								312
	2.4 Auxiliary Steam/Heating Steam (ASS)		56					8	64		64								1068
	2.5 Auxiliary/Heating Sys. Condensate (ACN)		40					6	46		46								1195
	2.6 Boric Acid (BAS)		13					2	15		15								390
	2.7 Boron Recovery (BRS)	186	182	3	13	590		286	1263	1263		195	1757	651	2603				8755
	2.8 Cable Vault Air Recirculator (CVA)		24					4	27		27								883
	2.9 Charging (CHG)		212	6	21	941		292	1471	1471		312	2804	1038	4154				5927
	2.10 Chemical Vol. and Control Letdown (RWC)		55	2	8	382		111	558	558		127	1139	422	1687				1576
	2.11 Chlorination (CHL)		2					0	3		3								88
	2.12 Circulating Water (CIR)		39					6	45		45								1159
	2.13 Closed Cooling Water (CCW)		12					2	14		14								357
	2.14 Component Cooling Water (CCR)	55	57					38	147		85								3215
	2.15 Compressed Air (CAS)		68					10	78		78								2030
	2.16 Condensate (CON)		138					21	159		159								4132
	2.17 Condensate Demin Service Water (CDS)		46					7	53		53								1329
	2.18 Condenser Vacuum/Air Removal (CVS)		12					2	13		13								349
	2.19 Condenser Waterbox Priming (CWP)		9					1	10		10								263
	2.20 Containment - Misc. Non-Struct. (CNT)		3	0	0	10		3	17	17		3	31	11	45				87
	2.21 Containment Air Recirculation (CAR)		133	8	22	1045		298	1506	1506		348	3114	1153	4613				3348
	2.22 Containment Instrument Air (CIA)	2	14	1	5	193		54	270	270		64	578	213	854				481
	2.23 Containment Leakage Monitoring (LMS)		17	0	1	41		14	73	73		13	121	45	180				454
	2.24 Containment Purge (CPH)		138	3	10	496		160	808	808		164	1460	548	2192				3324
	2.25 Control Rm AC/Ventilation (ACR)		26					4	30		30								758
	2.26 Control Rod Drive (CRD)	6	19	1	3	118		37	183	183		39	351	130	520				722
	2.27 Diesel Starting (DSA)		9					1	10		10								261
	2.28 Electrical - 115 kV AC (ES3)		36					5	41		41								1085
	2.29 Electrical - 120 V AC (EVI)		38					6	43		43								1122
	2.30 Electrical - 120 V AC Non-Vital (ENV)		38					6	43		43								1114
	2.31 Electrical - 125 V DC (EDC)		43					6	50		50								1279
	2.32 Electrical - 4.16 kV AC (ES4)		40					6	46		46								1188
	2.33 Electrical - 480-600 V AC (ES0)		40					6	45		45								1172
	2.34 Electrical - AC Distribution (ELC)		42					6	48		48								1239
	2.35 Electrical - Contaminated (ECC-1)		1026	22	87	3904		1248	6287	6287		1293	11837	4310	17240				31061
	2.36 Emergency Diesel Generator (DGN)		36					6	42		42								1057
	2.37 Feedwater (FWS)		172					26	197		197								5160
	2.38 Feedwater Control (FWC)		1					0	1		1								37
	2.39 Fill Header (FHD)		0					0	1		1								14
	2.40 Fire Protection (FIR)		49					7	56		56								1465
	2.41 Fire Protection - Deluge (FPD)		2					0	2		2								48
	2.42 Fire Protection - Water (FPW)		61					9	71		71								1843
	2.43 Fuel Handling Area Ventilation (FHV)		115	2	8	343		116	583	583		113	1021	378	1513				2868
	2.44 Fuel Oil and Storage (FO6)		23					3	26		26								658
	2.45 Gaseous Radwaste (GRW)		143	3	12	473		156	786	786		157	1409	522	2087				3995
	2.46 Gland Heating (GHS)		2					0	3		3								68
	2.47 Gland Seal Water (GSW)		3					1	4		4								102
	2.48 Gland Seals and Exhaust (GSE)		12					2	14		14								356
	2.49 HP Safety Injection (HPI)	93	154	8	24	1037		349	1666	1666		343	3081	1145	4580				6179
	2.50 Health Physics Miscellaneous (HPS)		5					1	5		5								137
	2.51 Heat Trace (HTS)		3					0	3		3								83
	2.52 Heating Ventilating and AC (HVA)		44					7	51		51								1295
	2.53 Hot Water Heating (HWH)		9					1	10		10								257
	2.54 Hydrazine (HYZ)		1					0	1		1								25
	2.55 Hydrogen (GH2)		7					1	8		8								204

	2.56 Hydrogen Seal Oil (HSO)		13					2	15		15								396
	2.57 LP Safety Injection (LPI)		86	8	21	987		275	1387	1387		327	2942	1090	4358				2935
	2.58 Liquid Propane (PRO)		1					0	1		1								18
	2.59 Liquid Radwaste (RWS)	209	252	4	17	893		344	1519	1519		229	2065	765	3060				12430
	2.60 Lube Oil (LOS)		51					8	58		58								1493
	2.61 Main Control Board (MCB)		12					2	14		14								352
	2.62 Main Steam Supply System (NSS)		202					30	232		233								6132
	2.63 Misc. Site HVAC Equipment		25					4	28		28								703
	2.64 Miscellaneous (MSC)		50					7	57		57								1470
	2.65 Miscellaneous Reactor Coolant (RCS)		68	4	19	736		205	1033	1033		244	2195	813	3252				2141
	2.66 Nitrogen (GN2)		4					1	4		4								117
	2.67 Nuclear Instrumentation (NIS)		1	0	0	9		3	13	13		3	28	10	41				38
	2.68 Office Building Ventilation (OBV)		29					4	33		33								819
	2.69 Plant Computer System (CMP)		2					0	2		2								52
	2.70 Plant Lighting (LTG)		17					3	20		20								511
	2.71 Primary Water (PWS)		255	5	15	780		261	1316	1316		258	2324	861	3443				7300
	2.72 Radiation Monitoring (RMS)		12	0	2	84		24	123	123		28	250	92	370				382
	2.73 Reactor Coolant Sampling (SSR)		70	2	8	307		96	482	482		102	915	339	1356				1949
	2.74 Reactor Fuel Handling (FHS)		2	0	1	29		8	39	39		9	85	32	127				80
	2.75 Reactor Head Vent System (VRS)		33	1	2	110		38	182	182		37	329	122	488				865
	2.76 Reactor Plant Aerated Drains (RAS)		39	1	5	185		57	286	286		61	552	204	819				1075
	2.77 Reactor Protection (RPS)		85	4	17	646		186	937	937		214	1925	713	2852				2589
	2.78 Recycle Water System (RSS)		104	1	4	187		73	369	369		62	557	206	825				3009
	2.79 Residual Heat Removal (RHR)		223	9	32	1645		473	2381	2381		545	4902	1816	7263				6595
	2.80 Sanitary Sewage Processing (SAN)		10					2	12		12								303
	2.81 Security Equipment (SEC)		15					2	17		17								441
	2.82 Service Air (ASA)		31					5	36		36								836
	2.83 Service Building Ventilation (SBV)		25					4	29		29								713
	2.84 Service Water (SWS)		164					25	189		189								4946
	2.85 Spent Fuel Pool Cooling (SFC)		48	1	5	217		67	339	339		72	647	240	959				1332
	2.86 Steam Dump - HP & HP (ESA)		8					1	9		9								234
	2.87 Steam Generator Blowdown (BDG)		105	4	17	697		204	1027	1027		231	2078	770	3078				3015
	2.88 Tech Support Center Ventilation (TSV)		24					4	27		27								680
	2.89 Transformer Main Service (TRM)		4					1	4		4								109
	2.90 Transformer Normal Station Service (TRN)		22					3	25		25								635
	2.91 Turbine Building Ventilation (TBV)		26					4	29		29								734
	2.92 Waste Water Treatment (WTW)		17					3	19		19								500
	2.93 Water Purification (PUR)		24					4	27		27								708
	2.94 Water Treatment System (WTS)		14					2	16		10								417
	2.95 Well Water (DWS)		20					3	23		23								605
	2.96 Well Water (WWS)		21					3	25		25								635
	2. Totals	616	5785	105	387	17105		6687	29884	27365	2436	6085	60965	18883	78534				183143
	3. Erect scaffolding for systems removal		1192					179	1371	1371									11392
Decontamination of Site Buildings	Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
	4.1 *Reactor Containment	1348	250	4	16	600		889	3107	3107		848	848	1695	3391				43672
	4.2 Ion Exchange Structure & Resin Storage	57		0	0	17		33	108	108		25	25	49	98				1575
	4.3 Primary Auxiliary Bldg. (Balance)	133	3	2	7	259		133	538	538		366	366	731	1463				3480
	4.4 Radwaste Reduction Facility	0		0	0	6		2	9	9		9	9	17	35				10
	4.5 Site Pavement and Soil		19	137	611	8000		3868	12635	12635				93749	93749				4040
	4.6 Waste Disposal Building	40		0	2	66		37	148	148		94	94	188	375				1051
	4. Totals	1579	272	142	637	8949		6963	18542	18542		1340	1340	96430	99111				64028
	5. License termination survey						9000	1350	10350	10350									
	6. Terminate License																		
Subtotal Period 2 Activity Costs		2752	17485	1124	6936	41651	9000	25770	104887	102179	2430	7905	98943	115313	218799	2348	115		384901
Period 2 Undistributed Costs	Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
	1. Decon equipment						218	33	251	251									
	2. Decon supplies						294	74	368	368									
	3. DOC staff relocation expenses								n/a										
	4. Process liquid waste	245		448	512	2572		643	4418	4418			6124			6124			580
	5. Insurance						2169	217	2386	2386									
	6. Property taxes						2972	297	3269	2942	327								
	7. Health physics supplies						2035	509	2544	2290	254								
	8. Heavy equipment rental						7297	1095	8392	7553	839								
	9. Small tool allowance						271	41	311	280	31								

	10. Pipe cutting equipment						880	102	782	782									
	11. Decon rig						884	133	1016	1016									
	12. Disposal of DAW generated			80	36	479		384	959	959				7489	7489				10185
	13. Plant energy budget						5067	760	5827	5244	583								
	14. NRC Fees						755	76	831	831									
	15. Emergency Planning Fees						63	6	69	69									
	16. Administrative & General						3447	172	3619	3619									
	17. Materials & Supplies						1495	224	1719	1719									
Subtotal Undistributed Costs Period 2		245		526	547	3051	27847	4744	38761	34727	2034		6124	7489	7489	6124			10765
Staff Costs	Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
	DOC Staff Cost						24268	1213	25481	25481									
	Utility Staff Cost						26516	1326	27842	27842									
TOTAL PERIOD 2		2997	17485	1850	7483	44702	87431	33053	194782	190229	4471	7005	103086	122803	224286	8471	115		395006

PERIOD 3

ISFSI Remediation	Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
	1. Remove spent fuel racks	279	57	12	48	1514		540	2448	2448			1740	15858	17398				9797
	2. Dispose of Greater-Than-Class C Waste		.			13607		3402	17009	17009								808	
	3. Fuel Building	320	155	2	9	351		268	1126	1126		496	496	991	1982				12929
	4. DOE Spent Fuel Transfer Cost								n/a										

Removal of Major Equipment	Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
	5. Main Turbine/Generator		53					8	61		61								1530
	6. Main Condensers		151					23	173		173								4169

Demolition of Remaining Site Buildings	Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
	7.1 "Reactor Containment		3805					571	4376	219	4157								98365
	7.2 Administration Building		78					12	90		90								1678
	7.3 Diesel Building		339					51	390		390								5734
	7.4 Discharge Tunnel & Piping		496					74	570		570								2127
	7.5 Emergency Operations Facility		352					53	405		405								5877
	7.6 Fuel Building		843					126	969	48	921								18151
	7.7 Information Building		71					11	81		81								1034
	7.8 Ion Exchange Structure & Resin Storage		220					33	253		253								3339
	7.9 Miscellaneous Modular Bldgs & Sheds		174					26	200		200								4707
	7.10 Miscellaneous Yard Foundations		841					126	967		967								18923
	7.11 Office Building #3 and PAP		101					15	116		116								1984
	7.12 Primary Auxiliary Bldg. (Balance)		579					87	666	33	633								7877
	7.13 Primary Auxiliary Building (HP Facility)		77					12	88		88								1307
	7.14 Radwaste Reduction Facility		220					33	253		253								2479
	7.15 Screenhouse		557					84	640		640								9326
	7.16 Security Office and Fitness Center		34					5	39		39								601
	7.17 Service Bldg. (Control, Aux Bay, Boiler)		601					90	692		692								9718
	7.18 Service Building (Maintenance Shop)		14					2	16		16								311
	7.19 Shutdown Aux Feed Pump House		7					1	8		8								135
	7.20 Site Pavement and Soil		12					2	13		13								114
	7.21 Switchgear Building B		224					34	258		258								2855
	7.22 Training Building		29					4	33		33								648
	7.23 Turbine Building		3873					581	4454		4454								77032
	7.24 Warehouse #1		84					13	96		96								1820
	7.25 Warehouse #2		155					23	178		178								3271
	7.26 Warehouses #183, #184, #103, #108, #154		97					15	112		112								2050
	7.27 Waste Disposal Building		181					27	208	10	197								2670
	7. Totals		14061					2109	16170	311	15859								248131

Site Closeout Activities	Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
	8. Remove Rubble		3002					450	3452		3452								6306
	9. Grade & landscape site		202					30	232		232								1020
	10. Final report to NRC						156	23	179	179									
Subtotal Period 3 Activity Costs		539	17882	14	56	15471	156	6874	40852	21074	19778	496	2235	16849	19380			808	283792

Period 3 Undistributed Costs	Activity	Decon	Remove	Pack	Ship	Bury	Other	Contingency	Total	LicTerm	Clean	Recycle	Barnwell	Envirocare	A CF	B CF	C CF	>C CF	M-Hrs
	1. Insurance						6347	635	6982	6982									
	2. Property taxes						5470	547	6018		6018								
	3. Heavy equipment rental						1878	282	2160		2160								
	4. Small tool allowance						164	25	189		189								
	5. Plant energy budget						569	85	654		654								
	6. NRC ISFSI Fees						5219		5219	5219									
	7. Emergency Planning Fees						420	42	462	462									
	8. Administrative & General						8565	428	8993		8993								
	9. Materials & Supplies						2137	321	2458		2458								
Subtotal Undistributed Costs Period 3							30768	2364	33132	12663	20470								

Staff Costs																			
	DCC Staff Cost						23007	1150	24138		24158								
	Utility Staff Cost						54814	2741	57555	51800	5756								
TOTAL PERIOD 3		599	17682	14	58	15471	108746	13129	155897	89536	70181	498	2239	15649	19380			390	283782
TOTAL COST TO DECOMMISSION		3638	35147	1845	7644	81285	264846	52542	424727	351773	75045	7501	108564	175925	298142	9753	115	808	882043

TOTAL COST TO DECOMMISSION WITH CONTINGENCY:	$426,726,587
TOTAL CONTINGENCY PERCENTAGE:	14.04%
TOTAL NRC LICENSE TERMINATION COST:	$351,772,588
TOTAL NRC LICENSE TERMINATION PERCENTAGE:	82.43%
NON-NUCLEAR DEMOLITION & ISFSI OPERATIONS COST:	$75,045,018
NON-NUCLEAR DEMOLITION & ISFSI OPERATIONS PERCENTAGE:	17.59%
TOTAL RADWASTE VOLUME BURIED (CU.FT.):	283,117
TOTAL CRAFT LABOR REQUIREMENTS (MAN-HOURS):	852,043

LABOR COST (W/ CONTINGENCY):	$198,858,148.17
% OF TOTAL COST:	46.60%
EQUIPMENT COST (W/CONTINGENCY):	$46,427,787.80
% OF TOTAL COST:	10.88%
SHIPPING COST (W/CONTINGENCY):	$8,790,885.55
ENERGY COST (W/CONTINGENCY):	$8,185,741.45
% OF TOTAL COST:	3.98%
TOTAL LLRW BURIAL COST (W/CONTINGENCY):	$63,137,180.22
% OF TOTAL COST:	14.80%
TOTAL COST FOR A&G AND M&S (W/CONT.):	$19,637,700.00
% OF TOTAL COST:	4.30%
TOTAL OTHER COST (W/CONTINGENCY):	$81,691,138.29
% OF TOTAL COST:	19.14%

APPENDIX C

UNIT COST FACTOR DEVELOPMENT

APPENDIX C

UNIT COST FACTOR DEVELOPMENT

Example: Unit Cost Factor for Removal of Contaminated Heat Exchanger < 3000 lbs.

1. SCOPE

Heat exchangers weighing < 3,000 lb. will be removed in one piece using a crane or small hoist. They will be disconnected from the inlet and outlet piping. The heat exchanger will be sent to the packing area.

2. CALCULATIONS

Act ID	Activity Description	Actual Duration	Critical Duration
a	Mount pipe cutters	45	45
b	Install contamination controls	20	(a)
c	Disconnect inlet and outlet lines	60	60
d	Cap openings	20	(c)
e	Rig for removal	30	30
f	Unbolt from mounts	30	30
g	Remove contamination controls	15	15
h	Remove, wrap in plastic, send to packing area	60	60
	Totals (Activity/Critical)	**280**	**240**

Duration adjustment(s):	
+ Respiratory protection adjustment (50% of critical duration)	120
+ Radiation/ALARA adjustment (33% of critical duration)	79
Adjusted work duration	439
+ Protective clothing adjustment (30% of adjusted duration)	132
Productive work duration	571
+ Work break adjustment (8.33 % of productive duration)	48
Total work duration:	**619 minutes**

***** Total duration = 10.317 hr *****

* Letters refer to the Activity Identifications in the left column of this table; a letter indicates that this activity runs in parallel with the activity corresponding to the Activity identification

APPENDIX C

UNIT COST FACTOR DEVELOPMENT (Cont'd)

3. LABOR REQUIRED

Crew	Number	Duration (hr)	Rate ($/hr)	Cost
Laborers	3.0	10.317	$21.30	$659.26
Craftsmen	2.0	10.317	$27.94	$576.51
Foreman	1.0	10.317	$30.24	$311.99
General Foreman	0.25	10.317	$32.07	$ 82.72
Subtotal labor cost				$1,630.48
Overhead & Profit on labor @ 33.305%				$ 543.03
Total labor cost				$2,173.51

4. EQUIPMENT & CONSUMABLE COSTS

Equipment Costs	none
Consumable/Materials Costs	
- Blotting paper 50 @ $0.67 sq. ft {2}*	$33.50
- Plastic sheets/bags 50 @ $0.07/sq. ft {3}	$3.50
- Gas torch consumables 1 @ $7.85/hr x 1 hr {1}	$7.85
Subtotal cost of equipment and materials	$44.85
Overhead & profit on equipment and materials @ 16.60%	$7.45
Total costs, equipment & material	$52.30

TOTAL COST Removal of contaminated heat exchanger <3000 pound: $2,225.81

Total labor cost	$2,173.51
Total equipment/material costs:	$52.30
Total adjusted exposure man-hours incurred:	42.47
Total craft labor man-hours required per unit:	64.48

* The numbers within the {} brackets indicate the relevant reference on the next page

5. NOTES AND REFERENCES

1. Durations are shown in minutes. The integrated duration accounts for those activities that can be performed in conjunction with other activities, indicated by the alpha designator of the concurrent activity. This results in an overall decrease in the sequenced duration.

2. Work difficulty factors were developed in conjunction with the AIF program to standardize decommissioning cost studies and are delineated in page 64 of the "Guidelines" study (Ref. 6).

3. Costs are adjusted for regional material variations as per R.S. Means; this study used 1.068 above the national average, based upon Hartford, Connecticut.

4. References:

1. R.S. Means (1996) Division 016 Section 420-6360 pg 016-6
2. McMaster-Carr Edition 101, pg 1136
3. R.S. Means (1996) Division 015 Section 602-0200, pg 015-4

APPENDIX D

UNIT COST FACTOR LISTING

APPENDIX D

UNIT COST FACTOR LISTING

Unit Cost Factor	Cost/Unit($)
Removal of clean instrument and sampling tubing, $/linear foot	$ 0.29
Removal of clean pipe 0.25 to 2 inches diameter $/linear foot	5.21
Removal of clean pipe >2 to 4 inches diameter $/linear foot	6.22
Removal of clean pipe >4 to 8 inches diameter $/linear foot	8.43
Removal of clean pipe >8 to 14 inches diameter $/linear foot	11.91
Removal of clean pipe >14 to 20 inches diameter $/linear foot	$ 16.99
Removal of clean pipe >20 to 36 inches diameter $/linear foot	26.68
Removal of clean pipe >36 inches diamater $/linear foot	32.60
Removal of clean valves >2 to 4 inches	62.24
Removal of clean valves >4 to 8 inches	84.30
Removal of clean valves >8 to 14 inches	$ 119.11
Removal of clean valves >14 to 20 inches	169.89
Removal of clean valves >20 to 36 inches	266.80
Removal of clean valves >36 inches	325.96
Removal of clean pipe fittings >2 to 4 inches	62.24
Removal of clean pipe fittings >4 to 8 inches	$ 84.30
Removal of clean pipe fittings >8 to 14 inches	119.11
Removal of clean pipe fittings >14 to 20 inches	169.89
Removal of clean pipe fittings >20 to 36 inches	266.80
Removal of clean pipe fittings >36 inches	325.96
Removal of clean pipe hangers for small bore piping	$ 18.74
Removal of clean pipe hangers for large bore piping	67.14
Removal of clean pumps, <300 pound	155.26
Removal of clean pumps, 300-1000 pound	387.56
Removal of clean pumps, 1000-10,000 pound	1,492.11

APPENDIX D

UNIT COST FACTOR LISTING

Unit Cost Factor	Cost/Unit($)
Removal of clean pumps, >10,000 pound	$ 3,043.95
Removal of clean pump motors, 300-1000 pound	141.10
Removal of clean pump motors, 1000-10,000 pound	658.45
Removal of clean pump motors, >10,000 pound	1,482.96
Removal of clean turbine-driven pumps < 10,000 pounds	1,977.80
Removal of clean turbine-driven pumps > 10,000 pounds	$ 3,848.30
Removal of clean PWR turbine-generator	105,897.90
Removal of clean heat exchanger <3000 pound	809.70
Removal of clean heat exchanger >3000 pound	2,318.82
Removal of clean feedwater heater/deaerator	4,682.92
Removal of clean moisture separator/reheater	$ 10,704.51
Removal of clean PWR main condenser	272,620.90
Removal of clean tanks, <300 gallons	199.78
Removal of clean tanks, 300-3000 gallons	578.96
Removal of clean tanks, >3000 gallons, $/square foot surface area	4.89
Removal of clean electrical equipment, <300 pound	$ 85.69
Removal of clean electrical equipment, 300-1000 pound	297.88
Removal of clean electrical equipment, 1000-10,000 pound	595.75
Removal of clean electrical equipment, >10,000 pound	1,303.30
Removal of clean electrical transformers < 30 tons	987.39
Removal of clean electrical transformers > 30 tons	$ 2,606.57
Removal of clean standby diesel-generator, <100 kW	923.59
Removal of clean standby diesel-generator, 100 kW to 1 MW	2,062.83
Removal of clean standby diesel-generator, >1 MW	4,271.32
Removal of clean electrical cable tray, $/linear foot	7.28

APPENDIX D

UNIT COST FACTOR LISTING

Unit Cost Factor	Cost/Unit($)
Removal of clean electrical conduit, $/linear foot	$ 3.06
Removal of clean mechanical equipment, <300 pound	85.69
Removal of clean mechanical equipment, 300-1000 pound	297.88
Removal of clean mechanical equipment, 1000-10,000 pound	595.25
Removal of clean mechanical equipment, >10,000 pound	1,303.30
Removal of clean HVAC equipment, <300 pound	$ 85.69
Removal of clean HVAC equipment, 300-1000 pound	297.88
Removal of clean HVAC equipment, 1000-10,000 pound	595.75
Removal of clean HVAC equipment, >10,000 pound	1,303.30
Removal of clean HVAC ductwork, $/pound	0.63
Removal/manual flame cut of clean thin metal components, $/linear inch	$ 3.18
Surface decontamination of equipment, $/square foot	4.31
Decontamination of large components, $/square foot	18.37
Decontamination rig hook-up and flush	2,237.28
Removal of contaminated instrument and sampling tubing, $/linear foot	$ 0.49
Removal of contaminated pipe 0.25 to 2 inches diameter $/linear foot	19.91
Removal of contaminated pipe >2 to 4 inches diameter $/linear foot	39.48
Removal of contaminated pipe >4 to 8 inches diameter $/linear foot	50.07
Removal of contaminated pipe >8 to 14 inches diameter $/linear foot	89.64
Removal of contaminated pipe >14 to 20 inches diameter $/linear foot	$ 111.66
Removal of contaminated pipe >20 to 36 inches diameter $/linear foot	164.06
Removal of contaminated pipe >36 inches diameter $/linear foot	196.60
Removal of contaminated valves >2 to 4 inches	179.45
Removal of contaminated valves >4 to 8 inches	237.36
Removal of contaminated valves >8 to 14 inches	$ 448.19
Removal of contaminated valves >14 to 20 inches	634.62
Removal of contaminated valves >20 to 36 inches	881.97
Removal of contaminated valves >36 inches	983.00
Removal of contaminated pipe fittings >2 to 4 inches	179.45

APPENDIX D

UNIT COST FACTOR LISTING

Unit Cost Factor	Cost/Unit($)
Removal of contaminated pipe fittings >4 to 8 inches	$ 237.36
Removal of contaminated pipe fittings >8 to 14 inches	448.19
Removal of contaminated pipe fittings >14 to 20 inches	592.75
Removal of contaminated pipe fittings >20 to 36 inches	820.29
Removal of contaminated pipe fittings >36 inches	983.00
Removal of contaminated pipe hangers for small bore piping	$ 43.90
Removal of contaminated pipe hangers for large bore piping	162.26
Removal of contaminated pumps, <300 pound	483.24
Removal of contaminated pumps, 300-1000 pound	1,171.49
Removal of contaminated pumps, 1000-10,000 pound	4,981.44
Removal of contaminated pumps, >10,000 pound	$ 10,615.60
Removal of contaminated pump motors, 300-1000 pound	520.00
Removal of contaminated pump motors, 1000-10,000 pound	1,711.81
Removal of contaminated pump motors, >10,000 pound	3,569.84
Removal of contaminated turbine-driven pumps < 10,000 pound	5,195.79
Removal of contaminated turbine-driven pumps > 10,000 pound	$ 10,964.04
Removal of contaminated heat exchanger <3000 pound	2,225.81
Removal of contaminated heat exchanger >3000 pound	6,060.95
Removal of contaminated tanks, <300 gallons	859.82
Removal of contaminated tanks, >300 gallons, $/square foot	16.77
Removal of contaminated electrical equipment, <300 pound	300.87
Removal of contaminated electrical equipment, 300-1000 pound	$ 765.87
Removal of contaminated electrical equipment, 1000-10,000 pound	1,437.82
Removal of contaminated electrical equipment, >10,000 pound	2,887.44
Removal of electrical transformers <30 tons	1,087.65
Removal of electrical transformers >30 tons	2,931.59

APPENDIX D

UNIT COST FACTOR LISTING

Unit Cost Factor	Cost/Unit($)
Removal of standby diesel-generator, <100 kW	$ 1,032.97
Removal of standby diesel-generator, 100 kW to 1 MW	2,226.89
Removal of standby diesel-generator, >1 MW	4,815.23
Removal of contaminated electrical cable tray, $/linear foot	27.25
Removal of contaminated electrical conduit, $/linear foot	22.87
Removal of contaminated mechanical equipment, <300 pound	$ 300.87
Removal of contaminated mechanical equipment, 300-1000 pound	765.87
Removal of contaminated mechanical equipment, 1000-10,000 pound	1,437.82
Removal of contaminated mechanical equipment, >10,000 pound	2,887.44
Removal of contaminated HVAC equipment, <300 pound	300.87
Removal of contaminated HVAC equipment, 300-1000 pound	$ 765.87
Removal of contaminated HVAC equipment, 1000-10,000 pound	1,437.82
Removal of contaminated HVAC equipment, >10,000 pound	2,887.44
Removal of contaminated HVAC ductwork, $/pound	1.96
Removal/plasma arc cut of contaminated thin metal components, $/inch cut	1.98
Surface decontamination of equipment, $/square foot	$ 4.31
Decontamination of large components, $/square foot	18.37
Decontamination rig hook-up and flush	2,237.28
Chemical flush of components/systems, $/gallon	8.72
Removal of standard reinforced concrete, $/cubic yard	309.72
Removal of grade slab concrete, $/cubic yard	$ 165.04
Removal of clean concrete floors, $/cubic yard	197.33
Removal of sections of clean concrete floors, $/cubic yard	668.91
Removal of clean heavily rein concrete w/#9 rebar, $/cubic yard	152.97
Removal of contaminated heavily rein concrete w/#9 rebar, $/cubic yard	1,227.37
Removal of clean heavily rein concrete w/#18 rebar, $/cubic yard	$ 194.88
Removal of contaminated heavily rein concrete w/#18 rebar, $/cubic yard	1,626.89
Removal heavily rein concrete w/#18 rebar & steel embedments, $/cubic yard	281.51
Removal of below grade suspended floors, $/square foot	197.33
Removal of clean monolithic concrete structures, $/cubic yard	548.30

APPENDIX D

UNIT COST FACTOR LISTING

Unit Cost Factor	Cost/Unit($)
Removal of contaminated monolithic concrete structures, $/cubic yard	$ 1,223.68
Removal of clean foundation concrete, $/cubic yard	467.78
Removal of contaminated foundation concrete, $/cubic yard	1,140.12
Explosive demolition of bulk concrete, $/cubic yard	22.68
Removal of clean hollow masonry block wall, $/cubic yard	57.40
Removal of contaminated hollow masonry block wall, $/cubic yard	$ 136.44
Removal of clean solid masonry block wall, $/cubic yard	57.40
Removal of contaminated solid masonry block wall, $/cubic yard	136.44
Backfill of below grade voids, $/cubic yard	15.91
Removal of subterranean tunnels/voids, $/linear foot	100.03
Placement of concrete for below grade voids, $/cubic yard	$ 75.33
Excavation of clean material, $/cubic yard	2.82
Excavation of contaminated material, $/cubic yard	6.71
Excavation of submerged concrete rubble, $/cubic yard	9.62
Removal of clean concrete rubble, $/cubic yard	65.22
Removal of contaminated concrete rubble, $/cubic yard	$ 21.98
Romoval of building by volume, $/cubic foot	0.20
Removal of clean building metal siding, $/square foot	1.01
Removal of contaminated building metal siding, $/square foot	2.39
Removal of standard asphalt roofing, $/square foot	1.48
Scarifying contaminated concrete surfaces (drill & spall)	$ 8.28
Scabbling contaminated concrete floors $/square foot	1.16
Scabbling contaminated concrete walls $/square foot	4.30
Scabbling contaminated ceilings $/square foot	43.02
Scabbling structural steel $/square foot	3.04
Removal of clean overhead cranes/monorails < 10 ton capacity	$ 382.97
Removal of contaminated overhead cranes/monorails < 10 ton capacity	870.83
Removal of clean overhead cranes/monorails >10 - 50 ton capacity	917.94
Removal of contaminated overhead cranes/monorails >10 - 50 ton capacity	2,094.83
Removal of polar cranes > 50 ton capacity, each	3,852.33

APPENDIX D

UNIT COST FACTOR LISTING

Unit Cost Factor	Cost/Unit($)
Removal of gantry cranes > 50 ton capacity, each	$ 14,551.97
Removal of clean structural steel, $/pound	0.25
Removal of clean steel floor grating, $/square foot	2.24
Removal of contaminated steel floor grating, $/square foot	5.32
Removal of clean free-standing steel liner, $/square foot	7.34
Removal of contaminated free-standing steel liner, $/square foot	$ 17.77
Removal of clean concrete anchored steel liner, $/square foot	3.67
Removal of contaminated concrete anchored steel liner, $/square foot	20.71
Placement of scaffolding in clean areas, $/square foot	10.58
Placement of scaffolding in contaminated areas, $/square foot	12.69
Landscaping with topsoil, $/acre	$ 16,555.21
Cost of LSA box & preparation for use	136.61
Cost of LSA drum & preparation for use	101.50
Cost of cask liner for CNSI 8-120A cask (resins)	8,184.89
Cost of cask liner for CNSI 8-120A cask (filters)	8,184.89
Decontamination of surfaces with vacuuming, $/square foot	0.86