A COMPUTER PROGRAM FOR ESTIMATING DECOMMISSIONING COSTS FOR LIGHT WATER REACTORS

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ABSTRACT

A desk-top computer program is being developed for estimating the costs, waste volumes, and occupational radiation exposures associated with decommissioning light-water reactor power stations. Cost categories and cost algorithms used in the program are discussed and a brief description of the user interface is given.

INTRODUCTION

The Cost Estimating Computer Program (CECP), designed for an IBM personal computer or equivalent, is being developed for in-house use by the Nuclear Regulatory Commission (NRC) as a tool for evaluating licensee submittals. The CECP will be used for estimating the cost of decommissioning light-water reactor power stations to the point of license termination. Such costs include component, piping, and equipment removal costs; packaging costs; decontamination costs; transportation costs; burial volumes and costs; and staffing costs. Using equipment and consumables costs and inventory data supplied by the user, the CECP will calculate unit cost factors and then combine these factors with transportation and burial cost algorithms to produce a complete report of decommissioning costs. In addition to costs, the CECP will also calculate man-hours, crew-hours, and exposure man-hours associated with decommissioning. In its present form, the CECP will be used to analyze PWR reactors. BWR capability will be developed later.

The CECP uses and maintains its own data files. CECP data files are not compatible with any commercially available database product, but the output files are in text format and may be viewed, formatted, and printed using any standard word processing package.

Some data used in the calculation of decommissioning costs may not be readily available to the user. Such data consists of duration times for typical decommissioning tasks, labor rates, contract fees for specialized operations, burial container costs, and so on. Data of this type is made available to the user in several default data files. The user may use any or all default values, or his or her own values.

DECOMMISSIONING COST CATEGORIES

The CECP calculates decommissioning costs using several types of data: plant equipment and building inventories, work difficulty factors, disposal charges, work durations for typical decommissioning activities, regional cost data, and salary and labor rates. Most of this information is entered by the user using specially designed entry screens.

Using the data supplied by the user, the CECP calculates the following categories of decommissioning costs:

a. pre-decommissioning engineering and planning costs
b. active decommissioning costs
c. decommissioning overhead costs
d. undistributed costs

Pre-decommissioning engineering and planning is assumed to be a joint effort between the reactor utility's in-house staff and the Decommissioning Operations Contractor (DOC). The costs incurred during this planning phase consist of utility and DOC overhead staffing costs and the costs of special decommissioning equipment and materials that must be procured before the start of active decommissioning.

Active decommissioning costs are calculated by the CECP using unit cost factors, which incorporate work difficulty factors. These costs include labor, material, packaging, transportation, and burial costs associated with all aspects of decommissioning operations leading up to license termination. Such operations include:

1. Removal and disposal of small contaminated components (piping, valves, pumps, tanks, heat exchangers, ion exchangers, etc.).
2. Surface decontamination of concrete and metal surfaces, including treatment and disposal of all cleaning water waste.
3. Removal and disposal of large, complex structures, including the biological shield, reactor pressure vessel and internals, steam generators (PWR plants) or turbine and condenser (BWR plants), HVAC systems, fuel-handling cranes and building cranes, etc. Subcontractor personnel, in addition to the DOC labor staff, are required for these operations.
4. Removal and disposal of spent fuel racks and treatment and disposal of spent fuel pool water. It is assumed these tasks will be performed by subcontractor personnel.
5. Chemical decontamination of system components and piping, also performed by subcontractor personnel.

Overhead costs consist of DOC staff and utility staff salaries during periods of active decommissioning. Staffing levels will vary with each period according to the amount of active decommissioning work scheduled.

The last category, undistributed costs, consists of property taxes, nuclear liability insurance costs, regulatory costs, energy costs, and environmental monitoring costs. All these undistributed costs are supplied by the user from a specially prepared data entry screen.

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ACTIVE DECOMMISSIONING COST CALCULATIONS

Many decommissioning tasks, such as items 1 and 2 of the previous section, are relatively simple and repetitive. Such tasks are well suited to a unit cost factor analysis. Other tasks (items 3, 4, and 5) involve the removal of large, complex components or the performance of a highly specialized operation. These tasks require individual treatment.

Unit Cost Factors

For simple, repetitive tasks, the CECP calculates labor costs using a unit cost factor approach. A unit cost is simply the labor and material cost associated with the removal of one unit of material or the decontamination of one square unit of surface. A unit may be a valve, a pump, a tank, a meter of piping, a square meter of concrete, etc. To derive unit costs, the CECP requires that the user specify the following for each type of task:

1. work duration, assuming ideal working conditions and no work breaks
2. crew composition, i.e., number of laborers, number of craft workers, etc.
3. labor rates for each crew member, including all overhead
4. material costs (typically plastic, absorbent material, and blow torch gases)
5. work difficulty factors
6. nonproductive time factors

Items 5 and 6 require some explanation. The time required to perform a decommissioning task is invariably greater than anticipated because of unavoidable external factors: workers must often wear respiratory protection or work on scaffolding. To account for each of these external factors, the CECP allows the user to specify a work difficulty factor, expressed as a percent increase in time. If the user specifies a respiratory adjustment factor of 20%, for example, the task duration increases by 20%. Similarly, a height adjustment factor of 10% increases task duration time by 10%. Assuming these factors are additive, both factors together will increase the work duration by 30%. Thus, for this example, the overall work difficulty factor is 1.30.

Nonproductive time factors (item 6) must be considered because a significant portion of an eight-hour work shift is nonproductive. Nonproductive shift time consists of work breaks, suiting-up and unsuiting in anticontamination clothing, and time devoted to ALARA-related activities. The CECP requires the user to supply times for each of these nonproductive activities. The CECP then adds up these times to arrive at the total nonproductive time per shift. The nonproductive time factor is simply the ratio of available time to productive time. Total nonproductive time is typically about 175 minutes per shift, giving a productive time of 305 minutes or a nonproductive time factor of 480/305 or 1.574.

Once all the parameters have been supplied, the CECP calculates unit costs as

$$\text{Unit Cost} = rwlt$$

where

r = hourly labor rate of crew, including all overhead and material costs,

w = overall work difficulty factor (defined above),

l = nonproductive time factor (defined above), and

t = task completion time, assuming ideal working conditions and no work breaks.

Complex Equipment and Operations

Because of their size and complexity, some large components (e.g., steam generators and the reactor pressure vessel) cannot be analyzed by the simple unit cost factor approach. For these components, the CECP bases its costs estimates on the results of ongoing comprehensive decommissioning cost studies of a reference PWR plant and then uses a set of scaling factors to arrive at costs for components whose sizes differ from the reference plant.

Certain major decommissioning operations, such as the chemical decontamination of a nuclear steam supply system (NSSS), are also too complex to permit a simple unit cost factor analysis. Because each of these operations is unique, a unique cost algorithm is being developed for each. Thus the type and amount of input data required from the user to properly calculate costs will vary from operation to operation. Most of these operations involve the use of *specialty contractors* whose contract fees make up the bulk of the decommissioning costs for such operations. Unfortunately, contract fees for these special operations are quite speculative at this time, so the potential range of costs is quite large. As experience is gained in plant decommissioning, a narrower range of probable costs should emerge.

Packaging, Transportation and Disposal Costs

Although the discussion so far has been limited to labor costs, similar unit cost analyses are also being developed for use by the CECP in determining packaging, transportation and disposal costs. Packaging costs are based on the costs of typical disposal containers, the costs of which are supplied to the user in default files. The user may, of course, change these costs, as desired. Algorithms for determining transportation costs are based on truck transportation rate schedules in current use. The algorithms are based on truck distances from the reactor site to the low-level burial site, the nature of the cargo, and the types of packaging. Burial cost algorithms are determined from rate schedules now in effect at the low-level waste sites. These algorithms include burial charges, crane surcharges, curie surcharges, and cask liner surcharges, where applicable.

DECOMMISSIONING SCHEDULES

Because decommissioning costs are time- and activity-dependent, the CECP will require that the user create a decommissioning schedule as part of the data entry process. The schedule is composed of several sequential periods, each one of which is defined by the user to cover a particular phase of decommissioning. The first period would typically be a planning and preparation phase, the second period might consist of defueling operations and layup, and so on.

The user must supply the lengths, in years, for each decommissioning period. Because realistic values for these periods may be difficult to determine at first, the user may start with tentative values, then run the CECP to determine active decommissioning man-hour requirements. Based on these requirements, the user may then update the period lengths to be consistent with the manpower requirements.

The CECP will use the decommissioning schedule to calculate occupational radiation exposures. For simplicity, radiation dose rates are based solely on cobalt-60. It is assumed that this nuclide is by far the most significant source of occupational radiation exposure. The dose rates for the various decommissioning activities entered by the user are values at reactor shutdown. The CECP will use these shutdown dose rates, the decommissioning schedule, and the decay rate of cobalt-60 to calculate the actual dose rates prevailing at the times the activities are performed.

DEVELOPMENT OF THE CECP

The CECP is being developed to support the analysis of the reference PWR plant mentioned previously. The analysis consists of:

- Determining the decontamination, packaging, and sectioning requirements for each piece of contaminated equipment or material. This includes concrete surfaces and metal linings.
- Determining the sectioning methods and times involved, including appropriate work difficulty and nonproductive time factors
- Determining the crew sizes and makeup for each decommissioning task
- Determining overhead staffing levels
- Determining the decommissioning schedule and sequence of work
- Calculating costs and occupational radiation exposure for all tasks.

The CECP is being used to test and refine many of the algorithms used in this analysis. Because of its modularity, the CECP easily accommodates the new algorithms as they are being developed. As the analysis proceeds, modules are being updated or replaced by other, more useful ones. All this is being done with minimal impact on the overall structure of the program.

One of the advantages of a program such as the CECP is that it will allow one to make changes in one or two parameters and then run the program to quickly assess the changes in decommissioning costs. As a case in point, consider the following example. One way to decontaminate concrete surfaces is to chip off a layer of the concrete. During the PWR analysis, it was decided that the depth of this concrete layer should be increased from 0.01 meters to 0.03 meters. The changes were made in the CECP, and the program was run. The results showed that, not only had labor charges increased, as was to be expected, but because more man-hours were involved, the CECP modified the decommissioning schedule to reflect the increased man-hours. This increase in turn resulted in increased overhead costs and increased undistributed costs, including laundry services and small tool and minor equipment costs. Thus a small increase in one area created changes in several other areas, resulting in larger increases in costs than might otherwise be expected.

THE CECP PROGRAM STRUCTURE

The CECP main menu is shown in Fig. 1. The CECP is modular; the user can only work with one menu item at a time, and the CECP can only open files and perform calculations pertinent to the task at hand. These restrictions increase data access speed, minimize errors, and permit greatly simplified software maintenance.

The user's first task is to enter certain general data that the CECP will need later in calculating site-specific costs. This is done by selecting A, B, and C from the main menu. For example, when the user types A, a file menu appears, from which the user selects the data file the CECP is to work with. A data entry screen then appears (Fig. 2), permitting the user to enter labor costs, burial costs, overhead costs, consumables costs, physical constants (e.g., the density of reinforced concrete), and so on. The user may then modify whatever values desired and then save this new information to a file. In fact, data may be saved to several files during the same session. The next time the user accesses item A, several files will be available to choose from: the default file (which is always available), and the files created by the user. Any of these files may be loaded into memory and used as a basis for creating a new file.

Fig. 1. CECP main menu.

Data for items B and C are entered in the same way. If the user does not supply his or her own files for A, B, and C, the CECP will use the default files.

Having entered general information into the data base, the user now enters site-specific data. Data for menu items 1, 2, and 3 are entered first, in any order, then data for items 4 through 8, in any order. Menu item 1 consists of general plant data: reactor type, site area, distances to low- level waste sites, average electrical consumption at shutdown, and so on. Menu item 2 allows the user to set up the decommissioning schedule. In the data entry screen for menu item 3, the user lists the special tools and equipment that must be purchased to carry out decommissioning tasks. The data entry screens for menu items 4, 5, and 6 are formatted in such a fashion as to allow the user an easy way to an enter an inventory of plant components and building structures that will be removed and/or decontaminated. Menu item 7 is used for entering job descriptions, salaries, and utility and DOC staffing levels for each decommissioning period. Finally, menu item 8 is used for entering undistributed costs for each period. When items 4, 5, 6, 7, or 8 are selected, the CECP requests the user to specify which input files (from A through C and 1 and 2) to use. For each of the items 4 through 8, the CECP calculates cost and exposure information in detail and then writes the results to appropriate output files. To get a complete site summary, combining data from items 1 through 8, the user selects item 9. The overall method for entering data is outlined in Fig. 3.

MENU ITEM A: LABOR RATES, BURIAL COSTS, CONSTANTS

1	Laborer hourly rate	25.36
2	Craft hourly rate	47.79
3	Foreman hourly rate	52.73
4	Radiation operator hourly rate	35.58
5	Engineer hourly rate	57.09
6	Average shift differential (%)	5.00
7	Profit on equipment and material (%)	15.00
8	Utility overhead (%)	42.00
9	DOC overhead (%)	110.00
10	DOC profit (%)	15.00
11	Density of poured concrete (lbs/ft3)	144.00
12	Density of reinforced conc (lbs/ft3)	150.00
13	Density of stainless steel (lbs/ft3)	500.00
14	LSA drum ($ ea)	25.82
15	Plastic sheets/bags ($/sq ft)	0.04
16	Blotting paper ($/sq ft)	0.32
17	Gas torch consumables ($/hr)	6.75
18	Burial costs/ft3 at geologic repos ($)	6100.00
19	Transportation escalation factor	1.00
20	License termination survey cost	1167663.00
21	Size of standard box (ft3)	96.00

43 Records

↑↓ Home End PgUp PgDn Select item ↵ Enter Data Save Alt-X Quit

Fig. 2. Data entry screen for menu item A.

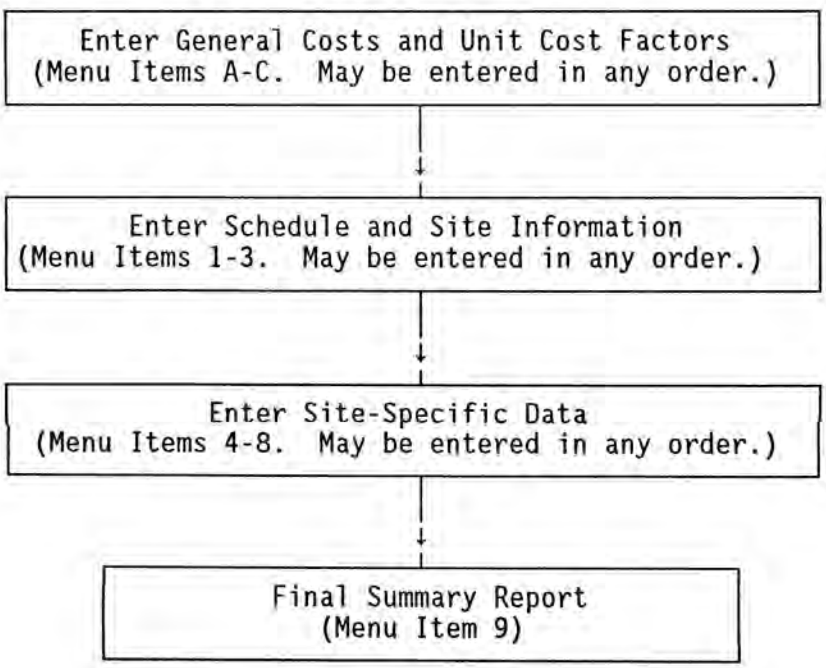

Fig. 3. Flow diagram for entering data into the CECP.

RESULTS OF CECP CALCULATIONS

The decommissioning costs calculated by the CECP appear in the output files. Because they are in text format, these files may be examined, re-formatted, and printed out using any word processing program.

The results for a decommissioning project are contained in five output files:

- a detailed Building Decon file, created from Menu Item 4
- a detailed Balance of Plant file, created from Menu Item 5
- a detailed Nuclear Steam Supply System file, created from Menu Item 6
- a detailed Manpower Costs file, created from Menu Item 7
- a summary file, created from Menu Item 9.

LESSONS LEARNED

Programs like the CECP and other database-type programs are good at maintaining exhaustive and detailed plant inventories of contaminated equipment and material, and it is easy for such programs to apply unit cost factor analysis to the simple, repetitive tasks involved in removing and disposing of these items. Thus, costs associated with the disposition of plant equipment and material are reasonably well understood.

However, as mentioned earlier, more complicated tasks, such as dismantling and disposing of steam generators, sectioning and removing a reactor pressure vessel and its internals, or decontaminating an NSSS system, are much too complex to use the unit cost factor approach. As far as these operations are concerned, each plant is unique. The methods used at one plant may not work at another. Without a great deal more decommissioning experience, it will be difficult to establish a reliable set of data parameters that defines these operations. Furthermore, much of the cost of these operations comes from contract fees. Such fees are bound to vary greatly from plant to plant and from contractor to contractor. Until such complex operations are actually carried out at a variety of plants, costs will remain largely speculative. All that can be said at this point is that these costs are high, of the same order of magnitude as the costs associated with the other more well-known costs.

Thus, the CECP can be expected to give good estimates for many of the decommissioning activities envisioned to occur at nuclear power plants. But until decommissioning methods for complex operations are better understood and standardized, the costs that will be calculated by the CECP for these operations will remain somewhat speculative estimates, based largely on engineering judgment.