CONF-921149--1

PNL-SA--21597

DE93 005033

ESTIMATION OF DECOMMISSIONING COSTS: HISTORY AND STATUS

R.I. Smith

November 1992

Presented at the
Energy Information
Administration Workshop
in Nuclear Issues: Current
and Future
November 12, 1992
Washington, D.C.

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

ESTIMATION OF DECOMMISSIONING COSTS:
HISTORY AND STATUS

Richard I. Smith, P.E.
Pacific Northwest Laboratory

Introduction

In the mid-1970s, the subject of the cost of decommissioning nuclear power stations became a topic of considerable interest to the industry. A number of early demonstration plants in the U.S. had been retired and most had been entombed. Only one plant, the Elk River Reactor (a small boiling water facility) had been totally dismantled and removed from the site (Welsh 1974). Thus, there was a very limited data base from which to develop estimates for decommissioning the much larger stations then under construction and coming into service.

Some early estimates (Skinner 1977) simply estimated by a simple proportion: the cost of the Elk River effort,multiplied by the ratio of the reactor energy output ratings, from the 58.2 thermal megawatts of Elk River to the 3300 thermal megawatts (1100 electrical megawatts) of the newer reactor stations. This approach gave no consideration to the actual details of the undertaking, and resulted in decommissioning cost estimates that rivaled the cost of construction, in the same year's dollars.

The huge estimates that resulted from this approach and the resulting outcry against nuclear power development caused the nuclear industry to fund a study to examine in more detail the actual activities and costs associated with decommissioning. This effort, based on information derived from the Elk River dismantlement and from the entombment of several early demonstration reactors, was documented in AIF/NES-009 (Manion and LaGuardia 1976), for a generic pressurized water reactor (PWR) and a generic boiling water reactor (BWR), both stations with generating capacities of 1000 electrical megawatts.

Subsequently, the U.S. Nuclear Regulatory Commission (NRC), which is charged with assuring the health and safety of the public in matters related to nuclear energy, contracted with the Pacific Northwest Laboratory (PNL) to perform detailed analyses of the technology, safety and costs of decommissioning a reference PWR and a reference BWR power station. These analyses, using a detailed engineering approach and documented in NUREG/CR-0130 and NUREG/CR-0672 (Smith 1978) and (Oak 1980), respectively, provided an in-depth examination of the activities (and related costs) associated with complete dismantlement and removal of retired nuclear reactor power stations.

About five years later, the nuclear industry sponsored another study for estimating decommissioning costs using an approach known as the Unit Cost Factor (UCF) method. This methodology is documented in AIF/NESP-0036 (LaGuardia 1986), and forms the basis for many of the estimates prepared by (or for) utilities for use in making submissions to their utility rate commissions to recover future decommissioning costs through current rates. Each of the estimating approaches mentioned above is discussed in more detail in subsequent sections of this paper.

The Simple Proportional Approach

This method, first applied in the mid-1970s, used a simple proportion for estimating the cost of decommissioning a plant whose thermal energy output was different from the reference plant, the Elk River

Reactor. The equation for estimating the cost of a facility different from the Elk River station is shown in the following relationship.

$$\text{Cost of } i^{th} \text{ plant} = \frac{\text{Cost of Elk River Dismantlement} \times i^{th} \text{ plant energy output}}{\text{Elk River energy output}}$$

Reactors of a similar type (e.g., a PWR or a BWR) have similar numbers of components and lengths of piping, albeit of different sizes, even when the thermal energy outputs are significantly different, and the activities necessary to decommission them are quite similar. Thus, the labor component of the cost will be rather similar even though the waste disposal and other costs will be larger for a larger facility. As a result, the appropriate function for extrapolating decommissioning costs is more nearly of the form A + BX, where X is the ratio of the thermal energy output of the i^{th} reactor to that of the reference reactor.

The simple proportional approach grossly overestimates the cost of decommissioning a large reactor station. For example, using this approach, the cost to decommission a 3300 thermal megawatt station would be

$$\frac{\$6.15 \text{ million} \times 3300 \text{ thermal megawatts}}{58 \text{ thermal megawatts}} = \$350 \text{ million, in 1974 dollars}$$

This result suggested that the cost to decommission a large reactor station would equal or exceed the cost of its construction, a situation that would be very damaging to the economics of nuclear power generation.

Estimated Costs for Decommissioning Generic Reactors

To combat the financial hysteria produced in some circles by the estimates derived from the simple proportional approach, the nuclear industry, through the Atomic Industrial Forum (AIF), commissioned a study to estimate in a more defendable manner the costs of decommissioning power reactors. This study, documented in AIF/NESP-009 (Manion and LaGuardia 1976), utilized information on the times, costs, and radiation dose rates for accomplishing various dismantlement efforts that were developed during the dismantlement of the Elk River reactor to estimate the same parameters for a generic PWR and a generic BWR, both having generating capacities of 1000 electrical megawatts. Because generic reactors were used, plant-specific details were not used in the analysis. However, the principal plant systems were known reasonably well, even though generic, and the activities required to dismantle and remove these systems were estimated. This study was the first documented use of the unit cost factor approach to estimate decommissioning costs. Subsequent analyses have suggested that this early study was somewhat overly simplified and probably too optimistic in its estimates of costs and radiation doses to be expected during immediate dismantlement.

Detailed Engineering Estimates for Reference Reactors

While the AIF study was under way, the NRC decided that, in order for it to carry out its charter to protect the health and safety of the public in matters related to nuclear energy, it needed to establish the basis for the level of funding necessary to accomplish decommissioning, to assure that those funds would be available when needed. In 1976, PNL was contracted to perform a detailed analysis of the activities necessary to decommission two reference nuclear power stations, a PWR (Trojan Nuclear Plant) and a BWR

(Washington Nuclear Project Unit 2). Both of these stations were large units (about 1100 electrical megawatts each), and were fairly typical of the large stations that were coming into service in the mid-1970s and early 1980s.

These analyses, documented in NUREG/CR-0130 (Smith 1978) and NUREG/CR-0672 (Oak 1980), were extensive and quite detailed. Each plant was visited and examined at length. Drawings and construction photos were used to determine where the various piping systems and associated equipment were located and to develop plans for the decontamination and removal of the radioactive materials. Detailed work plans and schedules were developed for the cutting and packaging of the activated materials from the reactor vessel and for the associated contaminated piping and equipment. Estimates of radiation dose rates throughout the facilities were developed from survey data from a number of similar nuclear reactor power stations that had been in service for more than 5 years. Estimates of the manpower required to perform each of the planned activities were developed, and a sequencing of those activities was developed for efficient scheduling of staff labor. Estimates were developed for the radiation doses and costs associated with those activities. Estimates were developed for the packaging, transport, and disposal of the removed radioactive materials. The cost of demolition of the decontaminated facilities was also estimated, even though demolition is not required by the NRC for the termination of the facility nuclear license.

The cost estimates derived from these studies (without demolition), periodically updated for cost escalation and to reflect changes in regulatory requirements, have been incorporated into the NRC's Final Rule on Decommissioning (Federal Register, 53 FR 24018, June 27, 1988). This rule provides, among other things, a formula for determining the minimum amount of decommissioning funding that must be assured by a nuclear power station owner in order to obtain and maintain his license to operate the plant. Because these studies are the basis of the NRC rule on funding requirements, they are frequently introduced into hearings before state and federal utility rate commissions related to funding of decommissioning costs.

The Unit Cost Factor Approach for Cost Estimation

The methodology originally used in AIF/NESP-009 (Manion and LaGuardia 1976) was further developed and documented in AIF/NESP-036 (LaGuardia 1986). The purpose of this documentation was to provide a systematic set of guidelines to be used by utilities in preparing decommissioning cost estimates. These estimates would be submitted to utility rate commissions, to support operating utility requests for rate adjustments that would permit the collection of the funds necessary for decommissioning during the operating lifetimes of their nuclear power stations.

The basic tool in this methodology is the Unit Cost Factor (UCF). In this approach, a number of operations that are utilized in decommissioning are examined to develop a cost basis for a single (unit) operation. For example, a UCF for the removal and packaging for disposal of contaminated piping 2.5 to 8 inches in diameter consists of nine separate steps, each with an assigned time duration. Difficulty factors are applied to the cumulative time duration to obtain an adjusted time duration, i.e., height adjustment (15%), respiratory protection adjustment (38%), radiation dose minimization activities adjustment (15%), plus two overall multipliers of the adjusted time duration, protective clothing use (23%) and time lost on work breaks (8.33%). Through application of these factors, the estimated time duration for making a single cut through a piece of 2.5- to 8-inch diameter pipe is increased from 65 minutes to 134 minutes. An estimate is made of the types, quantities, and costs of supplies associated with a single cut. An average radiation dose rate is estimated for the activities performed. A crew is defined to accomplish the task, comprised of 2 laborers, 1 craftsman, and 0.5 foreman, and their appropriate labor rates are assigned. The designated crew is utilized for the adjusted duration of 134 minutes, and both a cumulative radiation dose and a labor cost are calculated for that single cut. Then, those unit values are assigned to every cut of contaminated piping whose diameter is in the range of 2.5 to 8 inches, throughout the decommissioning operations. The total cost associated with removal of a given system within the plant is simply the product of the number of unit operations of a given type multiplied by the unit cost of that operation, summed over all types of operations required to remove that system. The cumulative radiation dose for system removal is the product of the cumulative radiation dose for each unit operation multiplied by the number of operations of that type, and summed over all types of operations required to remove that system.

The UCF methodology provides reasonable estimates of direct manpower costs and radiation doses if careful attention is paid to the magnitude of the difficulty adjustment factors, and if those factors are allowed to vary between tasks. Historically, the usual approach was to assign conservative (large) values to these factors and to apply the derived UCF to every operation of that type throughout the decommissioning campaign. As a result, the composite estimates of cost and radiation dose tend to be somewhat inflated, and the resultant longer direct labor durations tend to extend the total length of the decommissioning period, thereby increasing the overhead labor costs which are already the largest part of the total labor cost.

Differences Between D&D Cost Estimates

It is important to understand the reasons why the D&D funding requirements specified by NRC in 10 CFR 50.75 ($105 M to $135 M in 1986 dollars) are significantly smaller than the estimates usually presented by nuclear utilities to their Public Utilities Commissions (PUC) for inclusion into the utilities rate base. The NRC funding requirement is designed to be sufficient to decontaminate the reactor station to levels acceptable for unrestricted use, thereby permitting termination of the NRC license. It is not within the scope of the NRC's responsibilities to assure that funds will be available for post-decontamination demolition of the site structures or for restoration of the site to "green field" conditions.

On the other hand, the nuclear utility does have to be concerned with funding any possible post-decontamination demolition and site restoration that might be required by local or state authorities, and those costs are legitimately a part of the total decommissioning cost for a site. Examination of a number of D&D cost estimates that include demolition and site restoration shows that these latter efforts can comprise about 40% of the total decommissioning cost. Unfortunately, some PUCs have taken the position that the NRC's funding requirement is the only cost that is recoverable via the rate base, leaving a significant shortfall upon the utility. However, other PUCs have taken a more reasonable approach and are allowing recovery of the demolition and site restoration costs through the rate structure.

Escalation of NRC's Funding Requirement

Because updating a D&D cost estimate can be an expensive and time-consuming effort, the NRC has provided a formula whereby a licensee can escalate his earlier estimate to current-year dollars with a minimum of effort. The basis for the escalation formula is the assumption that D&D license termination costs can be separated into three cost elements: labor and materials, energy, and low-level waste disposal, with each cost element escalating at its own rate. Thus, the formula takes the following form:

$$COSTx = COST_y \, [A_y L_x + B_y E_x + C_y B_x] + [GTCC]_x + T_x + I_x$$

where A_y is the fraction of $COST_y$ due to labor and materials

L_x is the escalation ratio for labor and materials from Year Y to Year X

B_y is the fraction of $COST_y$ due to energy expenditures

E_x is the escalation ratio for energy from Year Y to Year X

C_y is the fraction of $COST_y$ due to LLW disposal

B_x is the escalation ratio for LLW disposal from Year Y to Year X

The final three terms, $[GTCC]_x$, T_x, and I_x represent: the cost of repository disposal for Greater-Than Class C materials; the cost of property taxes; and the cost of nuclear insurance during the decommissioning period, respectively. These latter three cost elements were not included in the original NRC cost basis for Year Y, and are therefore added in current-year dollars. The factors L_x and E_x are evaluated using national indices compiled by the U.S. Bureau of Labor Statistics. B_x is the factor most difficult to evaluate, since it depends upon the base disposal rates at the operating LLW disposal sites and upon the surcharges mandated by the Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA-85), which are dependent upon the status of the Waste Compact in which the waste generator resides. The value of B_x is given by:

$$B_x = (R_x + \sum S_{xi})/(R_y + \sum S_{yi})$$

where the Rs are the basic disposal rates in Years Y and X, and S_{xi} and S_{yi} are the appropriate surcharges mandated by LLRWPAA-85. The Act specified three categories of waste generator for purposes of applying surcharges: 1) the waste generator resides within the boundaries of a compact that contains an operating LLW disposal facility, 2) the waste generator resides within a compact which does not have an operating LLW disposal facility but which has made the required progress toward having such a facility, and 3) the waste generator resides within a compact which does not have an operating LLW disposal facility and which has not made the required progress towards having an operating LLW disposal facility. The magnitudes of these surcharges are shown as a function of time from initiation in 1986 through 1992 in Figure 1. When one considers that the current basic disposal rates for LLW disposal are in the \$30 to \$40 range, it is obvious that the impact of these surcharges can be very significant, increasing the cost of LLW disposal by factors of 3 to 4.

D&D Schedules Extended by Spent Fuel Storage Requirements

When the early studies of D&D costs were performed, reprocessing of the spent nuclear fuel (SNF) was the planned method of disposal. It was assumed that the fuel from the final core discharge could be shipped after 120 days cooling in the spent fuel storage pool, so that the pool was emptied of fuel during the first 6 to 9 months following reactor shutdown, and that decontamination and dismantlement of the reactor systems could commence during that first year. The situation is quite different today. Spent fuel must be stored in a wet pool for 5 to 7 years following discharge, until the fission product decay heat emission rate has fallen sufficiently to permit storage of the SNF in a dry environment without overheating the fuel rod cladding. Thus, unless the utility has storage space available in another pool in its system, the fuel pool must remain in service for that 5 to 7 year period, and the NRC will not permit dismantlement of the reactor systems until the pool is empty, for fear that dismantlement of the reactor system might compromise the integrity of the spent fuel pool system. As a result, the original three decommissioning alternatives defined by NRC (DECON, SAFSTOR, and ENTOMB) have had to be revised to accommodate the extended pool storage. DECON (immediate decontamination and dismantlement) is no longer possible for most utilities. All of the alternatives now begin with reactor facility deactivation (except for the pool support systems) and a short

(5 to 7 years) safe storage period during which time the fuel pool has been emptied. At that point in time, the owner can choose to 1) perform a deferred decontamination and dismantlement, 2) go into an extended safe storage period (without pool storage operations), to be followed by deferred decontamination and dismantlement, or 3) entomb the radioactive material within the reactor facility and monitor the site until license termination. The endpoint of all alternatives is the release of the site for unrestricted use within 60 years following reactor shutdown.

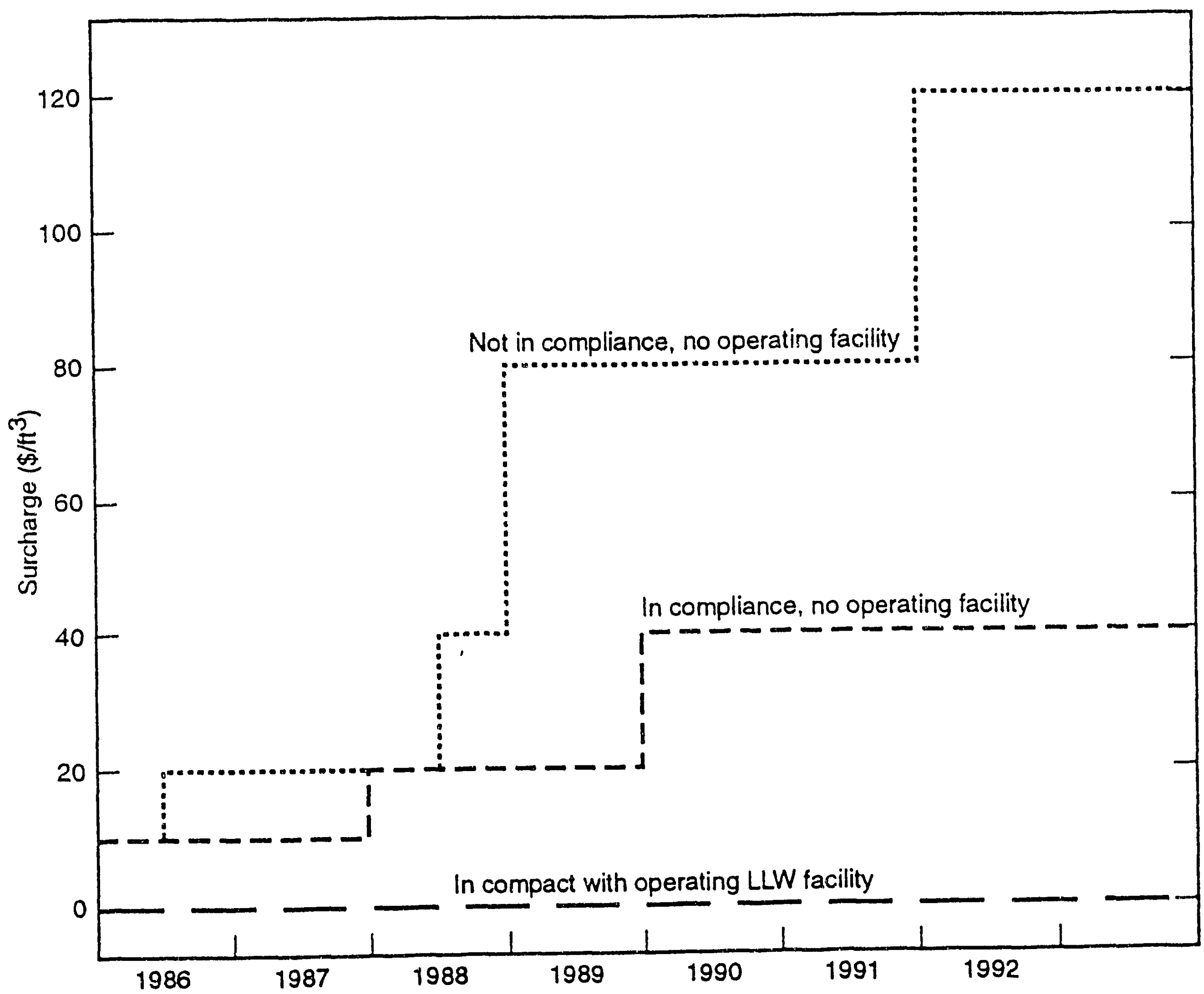

FIGURE 1. Time-Dependence of LLRWPAA-85 Surcharges

Summary

- The methodology for making D&D cost estimates is well-established. With computerized systems, the estimates can be made relatively quickly and with adequate precision to assure sufficient funding for decommissioning.

- NRC's funding requirement covers only decontamination and release of the facility and site for unrestricted use. It does not include any subsequent demolition of structures or site restoration.

- While labor is the largest single cost element in decommissioning, low-level waste disposal is becoming an ever-increasing fraction of the total cost, due to the escalation of disposal rates and to the application of surcharges mandated by the Low-Level Radioactive Waste Policy Amendments Act of 1985.

- Dismantlement of a shutdown reactor facility cannot begin until the spent fuel pool has been emptied. Generally, the pool cannot be emptied in less than 5 to 7 years following shutdown, thereby delaying decontamination and dismantlement for at least that long.

- Bases for reactor decommissioning are well in-hand, but little actual experience has been gained for large LWRs.

References

Manion, W.J. and T.S. LaGuardia, 1976. An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives, AIF/NESP-009, Nuclear Energy Services for the Atomic Industrial Forum, Washington, D.C.

LaGuardia, T.S., et al, 1986. Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates, AIF/NESP-036, TLG Engineering, Inc. for the Atomic Industrial Forum, Washington, D.C.

Oak, H.D, G.M. Holter, W.E. Kennedy, and G.J. Konzek, 1980. Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station, NUREG/CR-0672, Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission, Washington, D.C.

Skinner, Peter, 1977. "Comparative Economics", testimony before the New York Public Service Commission, Albany, New York, December 2, 1977.

Smith, R.I., G.J. Konzek, and W.E. Kennedy, 1978. Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station, NUREG/CR-0130, Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission, Washington, D.C.

Welsh, Elden J., 1974. Final Program Report: AEC-Elk River Reactor, COO-651-93, United Power Association, Elk River, Minnesota.

END

DATE
FILMED
5/05/93