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DECOST - Computer Routine for Decommissioning Cost and Funding Analysis

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B. C. Mingst

Division of Waste Management
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Abstract

When a nuclear facility reaches the end of its useful life, it must be placed in a condition such that the public continues to be protected from the radioactive hazards associated with the site. The process of returning the site to these conditions is called decontamination and decommissioning (D/D) or just decommissioning. The process includes the removal of the radioactively contaminated and activated materials from the site to appropriate disposal sites or the containment of the materials away from the general public. These operations are done by and/or financed by either the licensed operator or by some branch of government.

One of the major controversies surrounding the decommissioning of nuclear facilities is the lack of financial information on just what the eventual costs will be. The Nuclear Regulatory Commission has studies underway[1,6] to analyse the costs of decommissioning of nuclear fuel cycle facilities and some other similar studies have also been done by other groups[2,3,4,5]. These studies almost all deal only with the final cost outlays needed to finance decommissioning in an unchangeable set of circumstances. Funding methods and planning to reduce the costs and financial risks are usually not attempted. The DECOST program package is intended to fill this void and allow wide-ranging study of the various options available when planning for the decommissioning of nuclear facilities.

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DECOST

1.1 Introduction

The DECOST program package is a flexible model designed to calculate the costs of and evaluate the payments for decommissioning nuclear facilities, including post-decommissoning costs, under varying economic and planning conditions. It is primarily designed for application in decisionmaking and treats all similar facilities generically, but will give accurate results for individual facilities if it is provided with the data specific to that facility. The program will currently work for boiling-water reactors (BWR), pressurized-water reactors (PWR), high-temperature gas-cooled reactors (HTGR), and low-level waste disposal sites (LLWS). The program can easily be extended to other facilities (not restricted to nuclear facilities) by addition of the appropriate data. (See Section 4 for instructions on how to do this). The decrease in costs over a period of time caused by radioactive decay are included in the model. Several of the subroutines are easily separated from the main package and can be run independently or within another program.

The generic data for reactor decommissioning used in this version is taken from the AIF/NESP-009 study. The generic data for LLWS's was taken from the Report of the Special Advisory Committee on Nuclear Waste Disposal No. 142, Kentucky, October 1977. The use of these data in this program does not constitute or imply NRC approval or certification of the results of any of the studies used in this model nor does this imply approval of any of the decommissioning modes or funding methods analyzed.

1.2 Abilities and Limitations of the Program

In this version of DECOST, there are five possible modes of decommissioning power reactors: immediate dismantling, indefinite mothballing, indefinite entombment, mothballing followed by delayed dismantling, and entombment followed by delayed dismantling. Reactor installations in this version include the reactor, one cooling tower, and all auxiliary buildings needed for operation of 1150 MWe plant of the indicated type. Mothballing a reactor includes removal of fuel and source material and decontamination of auxiliaries. The site is then monitored and guarded to prevent unauthorized access. Entombing a reactor includes removal of the fuel and source material, decontamination of access areas, and construction of the entombment structure around the vessel and heat exchangers (if any). The site is then monitored and guarded to prevent unauthorized access. Dismantling a reactor includes removal of fuel and source material, vessel internals, and the core cavity concrete and steel liners. The facility can then be released for unrestricted use. If the entire reactor facility is dismantled, the site is placed in a condition essentially the same as before construction of the plant.

There are four possible modes of decommissioning LLW sites: no expected trench cap work or water management, periodic trench cap reworking, trench water management, and both trench cap rework and trench water management. All modes of LLWS decommissioning include surveillance, monitoring, and minor maintenance of the site. Low-level waste disposal sites include all buildings, trenches, and grounds to the site fence. Monitoring, surveillance, and minor maintenance of the site includes the collecting and analyzing of monitor station samples; and keeping the site, security fence, and samplers in good condition. Trench-cap reworking is the reworking of each trench cap every 20 years. Trench water management includes the routine removal of water from the trenches (10,000 gallons per year for the site), evaporation and/or solidification of the water, and re-burial of the solidified product.

Methods of decommissioning not currently in the DECOST program can be used, and facilities not currently in the DECOST program can be addressed by the addition of the appropriate data (see section 4).

In this version of DECOST there are seven possible methods of funding the decommissioning of the facilities: use of a constant-fee sinking fund; use of an escalating-fee sinking fund; use of a deposit to cover the costs at the expected end-of-life; use of a deposit to cover the decommissioning costs at the time of the deposit; use of the previous method but with net earnings returned to the utility; use of straight-line, negative salvage value depreciation of the facility; and use of adjusted straight-line, negative salvage value depreciation of the facility. A constant-fee sinking fund is the annual deposit of a fixed amount in an interest-bearing account such that at the end-of-life of the facility there will be sufficient funds in the account to cover the decommissioning costs (including inflation). An escalating-fee sinking fund is the same as a constant-fee sinking fund except that the annual deposits increase at the inflation rate to reach the same amount at the end-of-life. The first method of deposit allows a deposit to be made in an interest-bearing account such that, at the time of decommissioning, the fund will be sufficient to cover the costs (including inflation). The second method of deposit requires that the costs of decommissioning at the time of deposit be placed in the interest-bearing account. This will result in a surplus of funds at the time of decommissioning. The third method of deposit allows the surplus funds generated by the previous method to be returned to the utility (or deficits paid by the utility) in order to use the funds more efficiently. The method of straight-line, negative salvage value depreciation maintains a fund that will grow at a constant rate (no interest) that will take the fund to the value of the decommissioning cost expected at the end of facility life. The adjusted, straight-line, negative salvage value depreciation method allows the annual payments to the fund to be increased yearly according to the inflation rate.

The total value of funds needed for decommissioning the facility at the time of decommissioning is always a part of the output. Provision is made in the program for backfitting funding to existing facilities. (See input instructions section 5.)

The results of the program runs can be compared in any of three monetary systems: inflated dollars (unadjusted), discounted 1975 dollars (effective interest adjusted), and constant 1975 dollars (inflation adjusted). In the last case, the inflation rate of reactor costs can be different than the overall national inflation rate. The program will only accept constant interest and inflation rates.

The program output includes the funds needed to decommission the facility at the time of decommissioning, the fraction of costs covered by the chosen funding method, the actual expenditures made to the fund, and the charge rates (mills per kWhr or $ per cubic foot of waste) needed to generate these funds.

The program will do single case calculations or parametric studies (sensitivity analyses). Parametric studies can be made of any of the following variables; inflation rate, interest rate, tax rate, decommissioning mode used, and funding method used; versus actual facility lifetime, actual delay to final decommissioning, or any of the other listed variables. For single cases the program can also determine the methods of decommissioning that are possible with the funds on hand at the time of decommissioning.

2.0 Model Description

2.0.1 Compounding Formulas

Throughout the model, compounding of interest and inflation is a central problem. Methods used in the references to calculate these effects include series calculations (ref. 1) and approximations (ref. 7). Since series calculations take a long time and are not easy to work with, in this model the series calculations are transformed to analytic equations by the following method:

Given $$\sum_{i=1}^{N}(1+A)^{i-1} = 1+(1+A)+(1+A)^2+ \ldots +(1+A)^{N-1} = \text{Sum}$$

where A can be Y, X, or X*TAU.

$$\text{Sum} = [(1+A)+(1+A)^2+(1+A)^3+ \ldots +(1+A)^N] / (1+A).$$

One can see that the term in the brackets is the same as the original sum, with the addition of two terms: $(1+A)^N$ and -1. Therefore the term in the brackets is just: $\text{Sum} + (1+A)^N - 1$, and

$$\text{Sum} = [\text{Sum} + (1+A)^N - 1] / (1+A).$$

Solving for Sum, we get:

$$\text{Sum} = \frac{1}{A} * ((1+A)^N - 1).$$

Similarly, a summation of the form:

$$\sum_{i=1}^{N} (1+C)^i * (1+B)^{N-i} \text{ is equal to:}$$

$$((1+B)^N - (1+C)^N) / D \quad \text{where } D = (B-C) / (1+C)$$

Thus when terms of the forms $((1+A)^N - 1) / A$ or $((1+B)^N - (1+C)^N) / D$ appear, they are merely simplified forms of the standard series equations.

2.1 Major Routines in the Model

2.1.1 *COST* Cost of decommissioning subroutine

The subroutine *COST* is the central routine in the DECOST package. It calculates the funds needed, funds available, payments needed, and charge rates for the various scenarios. It can be run outside of the package without modification. Individual case parameters are transferred from the *DECOST* or *STORE* routines, and the costs and funds are calculated in this routine and its subroutines.

The main input parameters in the package are defined below:

X: interest rate (discount rate)
Y: inflation rate (escalation rate)
T: tax rate
IDECOM: method of decommissioning
IFND: method of funding
TRSU: time to reactor (fund) startup
ERL: expected (planned) reactor lifetime
ARL: actual reactor lifetime
IRT: reactor (facility) type
PD: planned delay to final decommissioning
AD: actual delay to final decommissioning

ACST(IRT): the annual costs for decommissioning (in 1975 dollars)
CINIT(IDECOM,IRT): the initial capital outlay (in 1975 dollars) needed to decommission the reactor

ACST and CINIT values are already incorporated into the model as part of the data.

The tax adjustment parameter (TAU) is:

$$TAU = 1 - T$$

The effective interest rate (Z) is:

$$Z = (X * TAU - Y) / (1+Y)$$

The final value of the cost of decommissioning (FV) at the end of the expected facility life time is

$$FV = [CINIT(IDECOM,IRT) * TAU + FPD(IDECOM)] * (1+Y)^{TRSU+ERL} + CAPFNL$$

FPD(IDECOM) is the 1975 fund for post-decommissioning costs and is equal to:

$$FPD(IDECOM) = ACST(IDECOM) * TAU * [1 - (\frac{1+Y}{1 + X * TAU})^{PD}] / Z$$

$$\text{or} \quad ACST(IDECOM) * TAU / Z$$

depending on whether there is or is not a second step in decommissioning PD years after the first step.

CAPFNL is the amount of capital needed at the expected end of reactor life to cover the final mode of decommissioning (if any) at the end of the planned delay period.

$$CAPFNL = CSTEND * TAU / (1 + X * TAU)^{PD}$$

where CSTEND is the final cost of decommissioning at the end of the planned delay period.

$$CSTEND = DCC * (1 + Y)^{TRSU+ERL+PD}$$

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where DCC is the 1975 decommissioning capital cost for the final mode of decommissioning, is calculated in *TIMEFN*, and depends on radioactive decay.

COST calls the subroutine *DECFND* to find FVARL- the actual fund available at the end of the actual facility lifetime.

If one wants results for the period before initial decommissioning, *COST* calculates the actual cost (FVCOST) at ARL;

$$FVCOST = FV * (1+Y)^{ARL-ERL}$$

and the fraction of costs (FRAC) covered by the fund at ARL;

$$FRAC = FVARL / FVCOST.$$

If one wants results for the period after initial decommissioning, *COST* calculates the final value of the decommissioning fund (FVDF).

$$FVDF = (FV - CAPITL) + ANNUAL * [(1+Y)^{AD} - (1 + X * TAU)^{AD}] / Z$$

where CAPITL is the capital outlay for original decommissioning

$$CAPITL = CINIT(IDECOM,IRT) * TAU * (1+Y)^{TRSU+ERU},$$

and ANNUAL is the annual cost of decommissioning

$$ANNUAL = ACST(IDECOM) * TAU * (1+Y)^{TRSU+ERL}.$$

TIMEFN is called to get a value of DCC for the actual delay time and FVCOST is calculated the same as before.

$$FVCOST = DCC * (1+Y)^{TRSU+ERL+AD}$$

FRAC is calculated the same as before.

$$FRAC = FVDF / FVCOST$$

In either of the above cases (before or after decommissioning) the subroutine *COST* calls the subroutine *MONEY* to translate the values calculated into the desired comparison system.

2.1.2 *DECFND* Decommissioning Funding Subroutine

Subroutine *DECFND* supplies *COST* with the appropriate fund values for the different methods of funding chosen.

The final value of the fund (FVARL) at ARL is:

for IFND = 1 (flat rate sinking fund):

$$FVARL = ANN_1 * RATE * ((1 + X * TAU)^{ARL} - 1) / (X * TAU)$$

for IFND = 2 (escalating-fee sinking fund):

$$FVARL = ANN_2 * RATE * ((1 + X * TAU)^{ARL} - (1+Y)^{ARL}) / Z$$

for IFND = 3 or 4 (deposit):

$$FVARL = DEP_{3-4} * (1 + X * TAU)^{ARL}$$

for IFND = 5 (deposit):

$$FVARL = DEP_5 * (1+Y)^{ARL}$$

for IFND = 6 (St.-line depreciation):

$$FVARL = ANN_6 * RATE * ARL$$

for IFND = 7 (adjusted st.-line depreciation):

$$FVARL = ANN_7 * RATE * (1+Y) * ((1+Y)^{ARL} - 1) / Y$$

The charge rate (CR) is

$$CR_1 = ANN * FACT * .15855 / TAU$$

$$CR_2 = ANN * FACT * .15855 * (1+Y)^{ARL} / TAU$$

$$CR_{3-4} = DEP_{3-4} * FACT * .15855 / (ERL * TAU)$$

$$CR_5 = DEP_5 * FACT * .15855 * (1/TAU - RET) / ERL$$

where $RET = (X * TAU - Y) * ((1+Y)^{ERL} -1) / Y$

$$CR_6 = ANN_6 * FACT * .15855 / TAU$$

$$CR_7 = ANN_7 * FACT * .15855 * (1+Y)^{ARL}/ TAU$$

and the net outlay at ARL (CASH) is:

$$CASH = [CRF*ARL/TAU-RTN] + ANN*ESCL*RATE*ARL/TAU$$

where $RTN_5 = (X * TAU - Y) * ((1+Y)^{ARL} - 1) / Y$

and $CRF_{3-4-5} = DEP * (X2*TAU) * (1+X2*TAU)^{ERL} / ((1+X2*TAU)^{ERL}-1)$

The annual contribution (ANN) to the sinking fund is:

$$ANN_1 = FV * X / ((1 + X * TAU)^{ERL} - 1)$$

$$ANN_2 = FV * Z / ((1 + X * TAU)^{ERL} - (1+Y)^{ERL})$$

$$ANN_6 = FV / ERL$$

$$ANN_7 = FV * Y / (((1+Y)^{ERL} - 1) * (1+Y))$$

The deposit made (DEP) is:

$$DEP_3 = FV / (1 + X * TAU)^{ERL}$$

$$DEP_{4-5} = FV / (1+Y)^{ERL}$$

X2 is the rate of interest that the utility pays on borrowed funds.

RATE is the factor for changes in the rate of fill for a LLW site (RATE=1 normally and = ERL/ARL otherwise). FACT is the factor that changes mills per kilowatt-hours into dollars per cubic foot for LLW sites.

FACT = ERL / 21. / CAP / .15855

where CAP is the capacity ratio of low-level waste disposal site to the generic-sized low-level waste disposal site volume of 21 million cubic feet.

ESCL is the escalation adjustment factor for escalating-fee funds.

$$ESCL = ((1+Y)^{ARL} - 1) * (1+Y) / (Y * ARL)$$

The factor .15855 converts $M/yr into mills per kilowatt-hour for a 1.2 GWe plant operating at a 60% capacity factor. (.15855 * [$M/yr] = mills/kwhr)

$$.15855 = \left(\frac{10^9 \text{ mills}}{\$M}\right) * \left(\frac{1 \text{ year}}{8760 \text{ hr}}\right) * \left(\frac{1}{1.2\times10^6 \text{ kw}}\right) * \left(\frac{1}{.60}\right)$$

2.1.3 *MONEY* Value of Money Subroutine

The subroutine *MONEY* translates the calculated funds and costs into the system desired by the user. It will translate from unadjusted (inflated) dollars to escalated or discounted dollars.

If MNY = 1, the subroutine merely returns control to the *COST* subroutine.

If not, the factor A represents the comparison rate,

A = Y,Z,or Y2 for MNY = 2,3, or 4.

The subroutine therefore gives results in constant 1975 dollars, discounted 1975 dollars, or constant 1975 dollars with the inflation rate on reactors (Y) different from the general inflation rate (Y2); when MNY = 2,3, or 4 respectively.

The values of FVCOST and CR are then:

$$FVCOST = FVCOST_0 \text{ (original) } / (1+A)^{YR}$$

$$CR = CR_0 \text{ (original) } / (1+A)^{YR}$$

where YR is the number of years from 1975, and is equal to TRSU+RL (the sum of the time to facility startup and the facility lifetime).

The total outlays (CASH) are then:

if IFND = 1,3,4, or 6:

$$CASH = CASH_0 \ (1 - 1/(1+A)^{PL}) \ / \ (A * RL) \ / \ (1+A)^{TRSU}$$

if IFND = 2 or 7:

$$CASH = CASH_0 * Y * (R^{RL} - 1) \ / \ ((1+Y)^{RL} - 1) / \ (Y-A) \ / \ (1+A)^{TRSU}$$

where R = (1+Y) / (1+A).

if IFND = 5;

$$CASH = CASH_0 + CRF * ((1 - 1/(1+A)^{RL})/A - RL) + DEP * (Y - X * TAU) * (1+Y) * [(R^{RL}-1)/(Y-A) - (1+Y)^{RL}/Y]$$

2.1.4 *TIMEFN* Radioactive Decay Time Function of Dismantling Costs

The subroutine *TIMEFN* calculates the 1975 costs of dismantling a reactor as affected by radioactive decay. All radioactive decay is assumed to bring savings by allowing different treatment of some portion of dismantling. This savings is assumed to be in the form of a step-function at a given time (breakpoint). This routine can be run apart from the main routine without modification.

BP(#,IRT) is a breakpoint. Radioactive decay at this point has brought a discount of some kind.

DC(#,IRT,IDECOM) is the dismantling cost for a reactor after the previous breakpoint.

There are up to 2 breakpoints (3 values of DC) for a reactor in this version of the code.
If the delay time is less than BP(1,IRT), DCC= DC(1,IRT,IDECOM).
If the delay time is between BP(1,IRT) and BP(2,IRT), DCC = DC(2,IRT,IDECOM).
If the delay time is greater than BP(2,IRT), DCC = DC(3,IRT,IDECOM).

IDECOM, in this case, is the original method of decommissioning; mothballing or entombment.

2.2 Other Model Routines

2.2.1 *POSDEC* Possible Decommissioning Subroutine

Subroutine *POSDEC* determines which (if any) methods of decommissioning can be paid for by existing funds at the actual end of reactor life. The subroutine can run apart from the main program without modification. The routine can be given the funds available from another source or it will calculate the funds available by using the *COST* subroutine.

If X*TAU>Y, the program works through the available modes of decommissioning from the least expensive to the most expensive methods. If X*TAU<Y, then only dismantling is checked. (If any step is unsuccessful the subroutine moves to the next mode of initial decommissioning.)

(1) Check for the ability to mothball indefinitely:

If $FVARL > [CINIT(IRT,mothball) + ACST(mothball)/Z] * TAU * (1+Y)^{ARL+TRSU}$

mothballing is possible.

(2) Check for the ability to mothball and entomb after some delay to build up funds:

The subroutine *SUBDLY* is called to calculate the delay time needed to build the fund. If the delay time is less than 1,000 years the delayed entombment is successful.

(3) Check for the ability to mothball and delay dismantling:

SUBDLY is called and if the delay time is less than 1,000 years, this step is successful.

(4) Check for the ability to entomb indefinitely:

If FVARL > [CINIT(IRT,entomb) + ACST(entomb)/Z] * TAU * $(1+Y)^{ARL+TRSU}$

entombment is successful.

(5) Check for entombment with delayed dismantling:

SUBDLY is called and if the delay time is less than 1,000 years, then this step is successful.

(6) Check for the ability to dismantle immediately:

If FVARL > [CINIT(IRT,dismantle) + ACST(dismantle)/Z] * TAU * $(1+Y)^{ARL+TRSU}$

this step is successful.

2.2.2 *SUBDLY* Delayed Decommissioning Subroutine

The subroutine *SUBDLY* calculates the delay time to final decommissioning given the initial and final modes of decommissioning a reactor, and the funds in the bank at initial decommissioning. This routine can run outside of the main routine without modification.

For delayed dismantling, the delay time until financial ability to decommissioning is:

DELAY = [log (DCC(#,IDECOM,IRT)) - ACST($IDECOM_i$)/Z + PLUS1] / DENOM

where PLUS1 = log [$(1+Y)^{ARL+TRSU}$] - log (FVARL - YINIT),

DENOM = log (1 + X * TAU) - log (1+Y),

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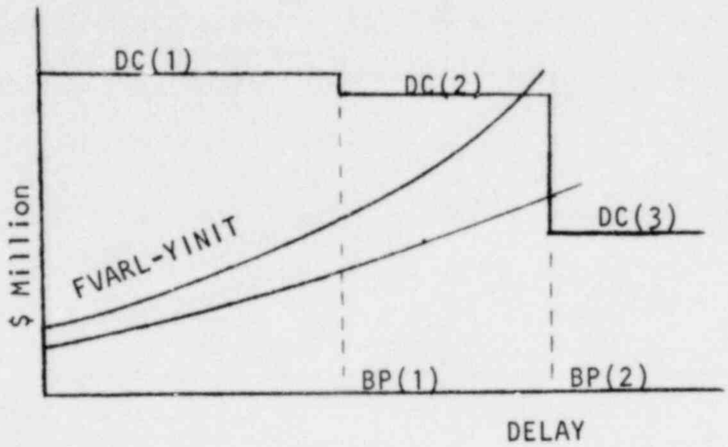
and

$$YINIT = [CINIT(IDECOM_i, IRT) + ACST(IDECOM_i)/Z] * TAU * (1+Y)^{TRSU+ARL}.$$

Since, in this version, the variable DC takes on three values depending on time (DELAY), three separate calculations are made to determine if DELAY is affected by the step functions at the breakpoints (see graph).



2.3 Computer Control Routines

2.3.1 *DECOST* Control Routine

This routine is the main control routine and controls the input. It also controls the output of the program for single case calculations. All data is tested and input errors are noted. Control is transferred to the *SWITCH* subroutine at this point if a parametric study is to be made. If a parametric study is not be made, the routine goes directly to the *COST* subroutine, receives the output, and prints the results. The program checks to see if the actual facility lifetime is different than the expected facility lifetime. If this is the case, the routine will transfer control to be *POSDEC* (possible decommissioning) subroutine. When control is returned to the *DECOST* routine, the program returns to the input for more data. The program is stopped by a blank input card.

2.3.2 *SWITCH* Parametric Study Control Switching Routine

The *SWITCH* subroutine takes control from the *DECOST* routine for parametric studies. The independent variables (inflation rate, interest rate, tax rate, decommissioning mode, or funding method) are chosen, the step sizes for variation of the independent and the comparison variable are found, and the independent variables are prepared for calculation against the comparison variable (any of the above variables plus facility lifetime and final decommissioning delay time). Control is then transferred to the *STORE* subroutine which stores the results for each independent variable case. When control is returned to *SWITCH*, the subroutine *TABLE* prints out the values stored by *STORE*. Control is then returned to *DECOST*.

2.3.3 *STORE* Subroutine

The *STORE* subroutine receives the individual cases for parametric variation, feeds them into the *COST* subroutine, and stores the output for that case set before returning control to *SWITCH* for printout. In addition, *STORE* checks for unworkable combinations of reactor type, decommissioning method, inflation rate, tax rate, and interest rate. In these cases, the output values are set to 10^{20} to deliberately overrun the output formats. In this way, an unworkable combination is indicated by a series of asterisks on printout.

2.3.4 *TABLE* Subroutine

The *TABLE* subroutine prints the results of the parametric studies for each independent variable case in a tabular form.

3.0 Data Used

The data used for the generic numbers in this model are listed in the following tables. Reactor data is from the AIF/NESP-009 study, and LLWS data is extended to a generic site from the Report of the Special Advisory Committee on Nuclear Waste Disposal No. 142 Kentucky, October 1977. Since the latter data is in 1977 dollars, the data in the program is reduced by a factor 1.154 - which is the national inflation recorded for the period 1975-1977. The LLWS data used for decommissioning methods 3 and 4 are averages of four similar methods using different suppliers' equipment. Results from the Battelle PWR decommissioning report (without the 25% contingency factor and adjusted for inflation) are shown in parentheses.

TABLE 1a

Decommissioning Capital Costs ($M 1975) for Entire Installation

	Mothball	Entomb	Dismantle
BWR	2.45	7.58	31.1
PWR	2.31(NA)	7.40 (8.17)	26.9 (27.3)
HTGR	2.30	5.70	28.0

TABLE 1b

Decommissioning Capital Costs ($M 1975) for Reactor Only

	Mothball	Entomb	Dismantle
BWR	2.45	7.58	20.9
PWR	2.31(NA)	7.40(8.17)	17.4(22.1)
HTGR	2.30	5.70	17.1

TABLE 2a

Capital Costs of Dismantling after a Delay Period "t" for Entire Installation ($M 1975)

	t_1	t_2	t_3
BWR - mothball	28.7	21.7	11.7
BWR - entomb	27.8	23.8	11
PWR - mothball	24.6(NA)	19.5(NA)	11.0(NA)
PWR - entomb	23.4(NA)	21.0(23.8)	10.8(19.6)
HTGR - mothball	25.8	25.1	15.5
HTGR - entomb	24.5	24.5	14.5

TABLE 2b

Capital Costs of Dismantling after a Delay Period "t" after Initial Mothball or Entombment for Reactor Only ($M 1975)

	t_1	t_2	t_3
BWR - mothball	18.5	11.5	1.5
BWR - entomb	18.1	14.1	1.5
PWR - mothball	15.1(NA)	10.0(NA)	1.5(NA)
PWR - entomb	14.1(NA)	11.7(18.6)	1.5(14.4)
HTGR - mothball	14.9	14.2	4.6
HTGR - entomb	14.6	14.6	4.6

TABLE 3

"t" Values for Tables 2a and 2b

	t_1	t_2	t_3
BWR	0 yr	52 yr	104 yr
PWR	0 yr(0)	85 yr(2.5)	108 yr(50)
HTGR	0 yr	42 yr	65 yr

TABLE 4

Annual Costs of Decommissioning
($M 1975)

mothball:	.167(NA)
entomb:	.058(.052 for "safe storage")
dismantle:	.000(.000)

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TABLE 5

Low Level Waste Sites

Purpose	Decommissioning Mode Used 1	2	3	4
Capital Costs (1977 $K)				
Tractor	8	8	8	8
Evaporator	-	-	475	475
Total	8	8	483	483
Annual Costs (1977 $K)				
Bldg. and fence maint.	5	5	5	5
Vegetative cover maint. (seed and Fertilizer)	1	1	1	1
Trench capping:				
*materials:	-	10		10.7
*labor:	-	12		12.9
*contingency:	-	2	3	2.1
*equip. rental:	-	17		18.2
Labor	12	12	14.5	14.5
Equipment replacement	2	2	2	2
Surveillance and monitoring	20	20	25	25
Water management:				
Evaporator replacement:	-	-	7.15	7.15
*Drums, cement, excavation, maint.	-	-	5.8	5.8
Total constant costs (annual)	40	40	54.6	54.6
*Total volume dependent costs (annual)	-	41	88	49.7
Total	40	81	63.4	104.3

4.0 Extending the Program

4.1 New Facilities (temporary addition to the program)

Data for certain reactor types must be replaced by the new facility data. It does not matter which facility is replaced so long as the annual costs and capital costs of decommissioning the new facility are treated the same way as those for the facility that is replaced. Note: one must determine if the annual decommissioning costs of the new facility have a high dependence on a variable that is directly realated to the actual length of time the facility operates. If this is the case, the low-level waste site sections of the program must be used, and some minor program changes may have to be made.

4.2 New Facilities (permanent addition to program)

Addition of new facilities to the program requires some array dimension increases and minor program changes. Any variable or routine that depends on the variable IRT must be checked or changed. All facility data is in the BLOCK DATA subroutine.

Possible program changes will be needed in routines DECOST, SWITCH, STORE, COST, BLOCK DATA, and DECFND. Dimension changes must be made in the COST, BLOCK DATA, TIMEFN, POSDEC, and SUBDLY routines.

4.3 New Data

Simply replace the existing data with the data that is to be used (e.g., the Battelle numbers included in tables 1-4 can be used).

4.4 Variable Interest Rates

A projected interest and/or inflation rate variation can be built into the package by setting up a driver routine such that outputs on a year-by-year basis are fed back into the program. This will also require slight modification of the *DECFND* subroutine to allow for an initial deposit <u>and</u> annual payments for the sinking fund and negative salvage value depreciation funding methods.

5.0 Input Instructions

Spaces

The variables on the first card are read in the following order:

The variable IBA. (1-5)

The variable IBA determined certain options in the program.

For reactors (IRT is not 7), IBA is assigned as follows:

0) If results are desired for the pre-decommissioning period.
1) If results are desired for the post-decommissioning period.

For low-level waste sites (IRT is 7), IBA is assigned as follows:

0) If the site is filled at a constant rate regardless of the time that it is closed.

1) If the site is filled at a rate that will fill the site at the time of closure of the site regardless of the time that the site operates.

The mode of decommissioning to be used; IDECOM. (6-10)

IDECOM is an integer that represents the mode of decomissioning.

It's value is:
1) Immediate dismantling or no trench maintenance
2) Indefinite mothballing or trench cap reworking
3) Indefinite entombent or trench water management
4) Mothball with delayed dismantle or 2 and 3 combined
5) Entombment with delayed dismantle or (not applicable)

(the first description is for reactors & the second is for a LLWS)

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Spaces

The reactor or facility type; IRT. (11-15)

IRT must be in integer form and is assigned as follows:

1) BWR- entire installation
2) PWR- entire installation
3) HTGR- entire installation
4) BWR- reactor only
5) PWR- reactor only
6) HTGR-reactor only
7) LLWS

The time to planned facility startup; TRSU. (16-20)

TRSU represents the number of years from 1975 until the facility begins operation. In this way existing facilities and facilities planned for in the future may be done. TRSU may be any real number. To backfit a funding method to an existing facility set TRSU to the time from 1975 to the start of the fund.

The expected (planned) facility life; ERL. (21-25)

ERL must be in years, and represents the facility lifetime expected from startup to final shutdown. To backfit a funding method to an existing facility set ERL to the time from the start of the fund to the expected facility shutdown.

The actual facility life; ARL. (26-30)

ARL is the length of time that the facility actually operates, and can be any non-negative number of years.

Spaces

To backfit a funding method to an existing facility, set ARL to the time from the start of the fund to the actual facility shutdown.

The planned delay to final dismantling; PD. (31-35)

PD may be any non-negative real number, and represents the planned number of years after plant shutdown that final dismantling will take place. Note that initial decomissioning is assumed to take no time, so delays less than initial decommissioning construction times are meaningless. [This variable is not applicable to a LLWS.]

The actual delay to final dismantling; AD. (36-40)

AD may be any non-negative real number, and represents the number of years that final dismantling is actually delayed. [This variable is not applicable to a LLWS.]

The ratio of the capacity of the LLWS to the generic LLWS capacity; CAPSLB. (41-45)

CAPSLB is a real number greater than 0. [This variable is not used for reactors.] The generic LLWS capacity is 21 million cu. ft.

The variables on the second card are read in the following order: spaces

The annual interest rate; X. (1-5)

X must be in the form of a fraction (i.e. 8% = .08).

This is the interest to be gained in an interest-bearing account by the fund set up to pay for decommissioning.

The annual inflation rate; Y. (6-10)

Y must be in the form of a fraction (i.e. 6% = .06).

Y represents the inflation rate of reactor costs, and not necessarily the general inflation rate.

The interest rate on borrowed funds; X2. (11-15)

X2 must be in the form of a fraction (i.e., 10% = .10)

X2 is the rate of interest a utility must pay if it borrows money.

The general inflation rate; Y2. (16-20)

Y2 must be in the form of a fraction (i.e., 5% = .05).

Y2 represents the general inflation rate to be used for comparison if MNY is 4.

The tax rate; T. (21-25)

T must be in the form of a fraction (i.e. 40% = .40).

T is the tax that the utility must pay on its earings.

Spaces

The depreciation time; TDEPR. (26-30)

TDEPR is the time (in years) that the utility uses for negative salvage value depreciation funding (IFND = 6,7). If left as zero, the program will calculate what is needed.

The plant capital cost; PC. (31-35)

PC is the total capital cost to be depreciated for negative salvage value depreciation funding (IFND=6,7). PC must be in millions of dollars at the time of completion of the plant.

The type of funding to be used; IFND. (36-40)

IFND must be an integer and is assigned as follows:

1) Constant-fee sinking fund
2) Escalating-fee sinking fund
3) Deposit to cover costs at facility shutdown
4) Deposit to cover costs at facility startup
5) Same as 4) but net earnings returned to utility
6) Straight-line negative salvage value depreciation
7) Adjusted, straight-line negative salvage value depreciation

spaces

The variable MNY (41-45)

MNY determines the type of monetary system to be used for comparison. MNY must be an integer and is assigned as follows:

1) Inflated dollars (unadjusted)
2) Constant 1975 dollars (inflation adjusted)
3) Discounted 1975 dollars (effective interest adjusted)
4) Constant 1975 dollars (inflation adjusted at a rate, Y2, which is different from the reactor inflation rate, Y)

The variable NLOOPS. (46-50)

The variable NLOOPS determines the number of variables in the parametric study. NLOOPS is normally an integer between 0 and 4. However, if NLOOPS is less than 0, the program will change some automatic modes when single cases are read. If NLOOPS is 0 and ARL does not equal ERL, the program will check to see what methods of decommissioning are financially possible. If NLOOPS is less than 0 and ARL does not equal ERL, the program will not check on other modes of decommissioning.

If NLOOPS is greater than 0, another card will be read to direct the parametric study. The variables read on this third card are as follows:

		spaces
IO-	the parameter to be varied as the comparison variable (1-7)	(1- 5)
STP-	the step size of the comparison variable (real number not 0)	(6-10)
I(1)-	the first parameter to be varied (1-5)	(11-15)
SMIN(1)-	the minimum value of the first parameter (real number)	(16-20)
STEP(1)-	the step size of the first parameter (real number not 0)	(21-25)
I(2)-	the second parameter to be varied (1-5)	(26-30)
SMIN(2)-	the minimum value of the second parameter (real number)	(31-35)
STEP(2)-	the step size of the second parameter (real number not 0)	(36-40)
I(3)-	the third parameter to be varied (1-5)	(41-45)
SMIN(3)-	the minimum value of the third parameter (real number)	(46-50)
STEP(3)-	the step size of the third parameter (real number not 0)	(51-55)
I(4)-	the fourth parameter to be varied (1-5)	(56-60)
SMIN(4)-	the minimum value of the fourth parameter (real number)	(61-65)
STEP(4)-	the step sizes of the fourth parameter (real number not 0)	(66-70)

The parameters are (the value of I(n) is assigned) as follows:

1)	interest rate, X	8 steps	
2)	inflation rate, Y	8 steps	
3)	tax rate, T	8 steps	number of steps
4)	decommissioning mode, IDECOM	4 steps	made if variable
5)	funding method, IFND	6 steps	is comparison
6)	facility lifetime, ARL	8 steps	variable.
7)	delay to dismantling, AD	8 steps	

The mid-range value of the parameters X, Y, and T will be that value indicated on the first data card. The parameters IDECOM and IFND have their largest value set on the first data card.

If the parameter X, Y, or T is to be the comparison variable, its mid-range value is that indicated on the first data card. If the comparison variable is ARL or AD, its maximum value is that indicated on the first data card. If the comparison variable is IDECOM, the comparison always works for the values 1-5. If the comparison variable is IFND, the comparison always works for the values 1-7.

6.0 Sample Problems

(x's indicate blanks)

1) A BWR is on-line in 1970, and has an expected life of 30 years. Decomissioning is to be funded by a deposit with excess funds returned. The fund earns 6% annually and the utility must pay 8% annually for borrowed funds. The tax rate is assumed to be zero. Inflation rates for the operating period are expected to average from 3% to 7% annually. What method of decommissioning is the most economic?

Enter on the first card:

(1- 5)	xxxx0	(initial decommissioning)
(6-10)	xxxx5	(method of decommissioning - cannot be 0)
(11-15)	xxxx1	(BWR installation)
(16-20)	xx-5.	(1970 startup)
(21-25)	xx30.	(expected years of life)
(26-30)	xx30.	(actual years of life)
(31-35)	x104.	(delay to final dismantle for a BWR)
(36-40)	xxxxx	(not applicable - IBA=0)
(41-45)	xxxxx	(not applicable - not LLWS)

Enter on the second card:

(1- 5)	xx.06	(annual interest rate)
(6-10)	xx.05	(middle of inflation range to be studied)
(11-15)	xx.08	(interest on borrowed money)

(16-20)	xxxxx	(not applicable)
(21-25)	xxxxx	(not applicable)
(26-30)	xxxxx	(not applicable)
(31-35)	xxxxx	(not applicable)
(36-40)	xxxx5	(deposit with funds returned)
(41-45)	xxxx1	(inflated (year 2000) dollars)
(46-50)	xxxx1	(one parameter to be varied)

Enter on the third card:

(1- 5)	xxxx4	(decommissioning mode is the comparison variable)
(6-10)	xxx1.	(ignored in this case - but can't be 0)
(11-15)	xxxx2.	(inflation rate to be varied)
(16-20)	xx.03	(minimum value of inflation)
(21-25)	xx.02	(step size for inflation variations)

(2) A PWR is planned to be added to a station in 1985 and is expected to operate for 35 years. The plant is to be dismanted immediately on shutdown. Decommissioning is to be funded by a constant-fee sinking fund. The expected interest rate is 6%, the general inflation rate is expected to be 4%, the tax rate is zero, and the decommissioning costs are expected to inflate at a rate of 5% per year. If the reactor shuts down prematurely at the end of 30 years of operation, what is the shortage of funds at decommissioning, and what can be done for decommissioning with the funds on hand?

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Enter on the first card:

(1- 5)	xxxx0	(initial decommissioning)
(6-10)	xxxx1	(dismantling)
(11-15)	xxxx5	(PWR reactor)
(16-20)	xx10.	(1985 startup)
(21-25)	xx35.	(expected lifetime)
(26-30)	xx30.	(actual lifetime)
(31-35)	xxxxx	(not applicable)
(36-40)	xxxxx	(not applicable)
(41-45)	xxxxx	(not applicable)

Enter on the second card:

(1- 5)	xx.06	(interest rate)
(6-10)	xx.05	(reactor inflation rate)
(11-15)	xxxxx	(not applicable)
(16-20)	xx.04	(general inflation rate)
(21-25)	xxxxx	(tax rate)
(26-30)	xxxxx	(not applicable)
(31-35)	xxxxx	(not applicable)
(36-40)	xxxx1	(constant-fee sinking fund)
(41-45)	xxxx4	(constant 1975 dollars)
(46-50)	xxxx0	(no parametric study)

No third card.

1635 103

3) A low-level waste site, with a capacity of 15 million cubic feet, will be opened in 1980. The site is expected to be filled at a rate that will fill site to capacity in 20 years (750,000 cu. ft. per year). What will be the effect on the funds available for decommissioning for the different modes of decommissioning, if the fill rate varies from twice the expected rate of fill (10 year operation) to half the expected rate (40 year operation)? The interest rate is 6 1/2%, the inflation rate is 5%, and the tax rate is zero. The method of funding is to be an escalating-fee sinking fund.

Enter on the first card:

(1- 5)	xxxx1	(variable fill rate)
(6-10)	xxxx4	(largest value of decommissioning mode)
(11-15)	xxxx7	(LLWS)
(16-20)	xxx5.	(1980 startup)
(21-25)	xx20.	(expected life)
(26-30)	xx40.	(maximum life)
(31-35)	xxxxx	(not applicable)
(36-40)	xxxxx	(not applicable)
(41-45)	.7143	(15/21, capacity ratio)

Enter on the second card:

(1- 5)	x.065	(interest)
(6-10)	xx.05	(inflation)
(11-15)	xxxxx	(not applicable)

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(16-20)	xxxxx	(not applicable)
(21-25)	xxxxx	(tax rate)
(26-30)	xxxxx	(not applicable)
(31-35)	xxxxx	(not applicable)
(36-40)	xxxx2	(escalating-fee sinking fund)
(41-45)	xxxx2	(constant 1975 dollars)
(46-50)	xxxx1	(one parameter to be varied)

Enter on the third card:

(1- 5)	xxxx6	(LLWS lifetime to be varied)
(6-10)	xxx4.	(step size for lifetime variation)
(11-15)	xxxx4	(decommissioning mode to vary)
(16-20)	xxx1.	(minimum value of decommissioning mode)
(21-25)	xxx1.	(step size for decommissioning mode)

4) A PWR installation comes on-line in 1975 and operates for 30 years. The inflation rate is 5%, the interest rate is 7%, and the utility pays 9% interest on borrowed funds. The installation is to be dismantled at shutdown. Compare the funding methods with a tax rate varying from 0 to 60%.

Enter on the first card:

(1- 5)	xxxx0	(initial decommissioning)
(6-10)	xxxx1	(dismantling)
(11-15)	xxxx2	(PWR installation)

(16-20) xxx0. (1975 startup)

(21-25) xx30. (expected life)

(26-30) xx30. (actual life)

(31-35) xxxxx (not applicable)

(36-40) xxxxx (not applicable)

(41-45) xxxxx (not applicable)

Enter on the second card:

(1- 5) xx.07 (interest rate)

(6-10) xx.05 (inflation rate)

(11-15) xx.09 (utility interest rate)

(16-20) xxxxx (not applicable)

(21-25) xx.30 (tax rate - middle of range)

(26-30) xxxxx (let program pick TDEPR)

(31-35) 1200. (PWR plant cost)

(36-40) xxxx7 (funding method - can't be zero)

(41-45) xxxx1 (inflated dollars)

(46-50) xxxx1 (one parameter to be varied)

Enter on the third card:

(1- 5) xxxx5 (funding method to be comparison variable)

(6-10) xxx1. (ignored - but cannot be zero)

(11-15) xxxx3 (tax rate variation)

(16-20) xxx0. (minimum value of tax rate)

(21-25) xx.10 (step size for tax rate variation)

Key to Computer Output For Sample Problem

```
THERE ARE SEVEN TYPES OF FACILITIES
    1- BWR I    BWR INSTALLATION
    2- PWR I    PWR INSTALLATION
    3- HTGRI    HTGR INSTALLATION
    4- BWR O    BWR REACTOR ONLY
    5- PWR O    PWR REACTOR ONLY
    6- HTGRO    HTGR REACTOR ONLY
    7-  LLWS    LOW-LEVEL SHALLOW-LAND WASTE SITE

THERE ARE FIVE MODES OF DECOMMISSIONING
    1-    IMMEDIATE DISMANTLING/ NO TRENCH WORK
    2-    INDEFINITE MOTHBALLING/ TRENCH CAP RE-WORK
    3-    INDEFINITE ENTOMBMENT/ TRENCH WATER MANAGEMENT
    4-    MOTHBALLING FOR ESDLY YEARS FOLLOWED BY DISMANTLING/ COMBINATION OF 2 AND 3
    5-    ENTOMBMENT FOR ESDLY YEARS FOLLOWED BY DISMANTLING/ NOT APPLICABLE

THERE ARE SEVEN METHODS OF FUNDING DECOMMISSIONING
    1-  CFSF    USE OF A CONSTANT-FEE SINKING FUND TO COVER DECOMMISSIONING COSTS AT ERL
    2-  EFSF    USE OF AN ESCALATING-FEE SINKING FUND TO COVER DECOMMISSIONING COSTS AT ERL
    3- D ERL    A DEPOSIT AT TRSU TO COVER DECOMMISSIONING COSTS AT ERL
    4- D TRS    A DEPOSIT AT TRSU TO COVER THE DECOMMISSIONING COSTS AT TRSU
    5- D RTN    SAME AS 4- BUT NET EARNINGS ON FUND RETURNED TO UTILITY
    6- SLDPR    USE OF STRAIGHT-LINE NEGATIVE SALVAGE VALUE DEPRECIATION
    7- ASLDP    USE OF ADJUSTED STRAIGHT-LINE NEGATIVE SALVAGE VALUE DEPRECIATION

THERE ARE FOUR WAYS TO COMPARE MONEY
    1- INFLD    INFLATED (UNADJUSTED) DOLLARS
    2- CONST    CONSTANT 1975 DOLLARS (INFLATION ADJUSTED)
    3- DISCT    DISCOUNTED 1975 DOLLARS (EFFECTIVE INTEREST ADJUSTED)
    4- CNST2    CONSTANT 1975 DOLLARS (INFLATION ADJUSTED AT A DIFFERENT RATE (INFL2))

      FTYPE - TYPE OF FUNDING USED FOR INITIAL DECOMMISSIONING (1-7)
      RTYPE - REACTOR TYPE (1-7)
      MTYPE - TYPE OF MONEY COMPARISON USED (1-4)
      DECOM - THE TYPE OF DECOMMISSIONING USED (1-5)
       TRSU - TIME TO REACTOR STARTUP (YEARS)
        ERL - EXPECTED REACTOR LIFETIME (YEARS)
        APL - ACTUAL REACTOR LIFETIME (YEARS)
      ESDLY - THE PLANNED DELAY TO FINAL DISMANTLING (YEARS)
      ACDLY - THE ACTUAL DELAY TO FINAL DISMANTLING (YEARS)
        INT - THE ANNUAL INTEREST RATE (FRACTION)
       INT2 - INTEREST RATE PAID BY UTILITY (FRACTION)
       INFL - THE ANNUAL INFLATION RATE (FRACTION)
      INFL2 - THE INFLATION RATE USED FOR COMPARISON IF MTYPE = 4 (FRACTION)
        TAX - THE ANNUAL TAX RATE (FRACTION)
      TDEPR - THE DEPRECIATION TIME FOR THE PLANT FOR IFND=6,7 (YEARS)
       PCST - THE CAPITAL COST FOR THE PLANT ($M)
      CAPSL - THE VOLUME RATIO OF A LLWS TO THE GENERIC LLWS
       FILL - THE TIME AT WHICH LLWS IS FILLED (ERL OR ARL)
      ACOST - ACTUAL COST OF DECOMMISSIONING AT THE INDICATED TIME ($M)
       FRAC - THE FRACTION OF DECOMMISSIONING COSTS PAID FOR BY THE FUND
       CASH - ACTUAL PAYMENTS MADE TO THE FUND ($M)
      CHRGE - CHARGES TO PAY FOR DECOMMISSIONING (M/KWH OR M/CU. FT. FOR A LLWS) AT THE TIME INDICATED

      ***** - THAT COMBINATION OF REACTOR TYPE, DECOMMISSIONING MODE, INTEREST RATE, AND INFLATION RATE IS NOT POSSIBLE
```

RTYPE = BWR I   TRSU = -5.0 YRS.   ERL = 30.0 YRS.   ESDLY =104.0 YRS.   CAPSL =-.000

MTYPE = INFLD   INT2 = .080   INFL2 =-.000   PLCST = -0.   TDEPR =***** YRS.

INT = .060   TAX = -0.000   FTYPE = 5.000   ARL = 30.000   ACDLY = -0.000

FOR THE PERIOD BEFORE INITIAL DECOMMISSIONING

INFLATION RATE	TYPE OF DECOMMISSIONING 1.000	2.000	3.000	4.000	5.000
	COST TO DECOMMISSION, FRACTION COVERED, ACTUAL EXPENDITURES, AND CHARGE RATE - M/KWH OR $/CU FT				
.030	65.1	17.1	20.0	17.8	21.0
	1.0000	1.0000	1.0000	1.0000	1.0000
	33.200	8.736	10.218	9.058	10.714
	.1755	.0462	.0540	.0479	.0566
.050	105.3	67.7	46.3	60.3	52.7
	1.0000	1.0000	1.0000	1.0000	1.0000
	48.746	31.324	21.426	27.912	24.415
	.2576	.1655	.1132	.1475	.1290
.070	168.8	**********	**********	342.4	258.3
	1.0000	**********	**********	1.0000	1.0000
	80.035	**********	**********	162.370	122.474
	.4230	**********	**********	.8581	.6473

Sample Problem

Case 1

1635 108

RTYPE	DECOM	TRSU	ERL	ARL	ESDLY	TDEPR	PCST	INT	INFL	INT2	INFL2	TAX	FTYPE	MTYPE	ACOST	FRAC	CASH	CHRGE
PWR 0	1	10.0	35.0	30.0	-0.0	*****	-0.	.060	.050	-.000	.040	-.000	CFSF	CNST2	25.5	.905	16.39	.0463

CAN ENTOMB INDEFINITELY AT ARL
CAN ENTOMB AT ARL AND DISMANTLE AFTER 96. YEARS

Sample Problem
Case 2

RTYPE = LLWS TRSU = 5.0 YRS. ERL = 20.0 YRS. ESDLY = -0.0 YRS. CAPSL = .714

MTYPE = CONST INT2 =-.000 INFL2 =-.000 PLCST = -0. TDEPR =***** YRS.

INT = .065 INFL = .050 TAX = -0.000 FTYPE = 2.000 ACDLY = -0.000

FOR THE PERIOD BEFORE INITIAL DECOMMISSIONING

LLWS IS FILLED AT A RATE THAT WILL FILL IT AT ARL

ACTUAL YEARS OF SERVICE

COST TO DISMANTLE, FRACTION COVERED, ACTUAL SPENDING, AND FINAL CHARGE RATE - M/KWH OR $/CU FT

MODE OF DECOMMISSIONING	8.000	12.000	16.000	20.000	24.000	28.000	32.000	36.000	40.000
1.000	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	.8435	.8927	.9448	1.0000	1.0584	1.1202	1.1856	1.2548	1.3280
	.997	1.140	1.225	1.282	1.321	1.350	1.371	1.387	1.399
	.1233	.1233	.1233	.1233	.1233	.1233	.1233	.1233	.1233
2.000	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
	.8435	.8927	.9448	1.0000	1.0584	1.1202	1.1856	1.2548	1.3280
	1.728	1.975	2.123	2.221	2.289	2.338	2.375	2.403	2.425
	.2137	.2137	.2137	.2137	.2137	.2137	.2137	.2137	.2137
3.000	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
	.8435	.8927	.9448	1.0000	1.0584	1.1202	1.1856	1.2548	1.3280
	1.660	1.897	2.039	2.133	2.199	2.246	2.281	2.308	2.329
	.2053	.2053	.2053	.2053	.2053	.2053	.2053	.2053	.2053
4.000	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
	.8435	.8927	.9448	1.0000	1.0584	1.1202	1.1856	1.2548	1.3280
	2.378	2.718	2.922	3.057	3.150	3.218	3.269	3.307	3.337
	.2941	.29[illegible]1	.2941	.2941	.2941	.2941	.2941	.2941	.2941

Sample Problem

Case 3

1635 110

RTYPE = PWR   TRSU = 0.0 YRS.   ERL = 30.0 YRS.   ESDLY = -0.0 YRS.   CAPSL = -.000

NTYPE = INFLD   INT2 = .090   INFL2 = -.000   PLCST =1200.   TDEPR =***** YRS.

INT = .070   INFL = .050   DECOM = 1.000   ARL = 30.000   ACDLY = -0.000

FOR THE PERIOD BEFORE INITIAL DECOMMISSIONING

COST TO DECOMMISSION, FRACTION COVERED, ACTUAL EXPENDITURES, AND CHARGE RATE - M/KWH OR $/CU FT

TAX RATE	TYPE OF FUNDING USED 1.000	2.000	3.000	4.000	5.000	6.000	7.000
0.000	116.3	116.3	116.3	116.3	116.3	116.3	116.3
	1.0000	1.0000	1.0000	1.7613	1.0000	1.0000	1.0000
	36.923	35.515	44.598	78.550	42.806	116.260	116.260
	.1951	.3489	.2357	.4151	.2262	.6144	1.1420
.100	104.6	104.6	104.6	104.6	104.6	104.6	104.6
	1.0000	1.0000	1.0000	1.4465	1.0000	1.0000	1.0000
	41.840	43.244	50.025	72.361	51.451	116.260	116.260
	.2211	.4248	.2644	.3824	.2719	.6144	1.1420
.200	93.0	93.0	93.0	93.0	93.0	93.0	93.0
	1.0000	1.0000	1.0000	1.1864	1.0000	1.0000	1.0000
	47.319	52.723	55.920	66.345	57.766	116.260	116.260
	.2501	.5179	.2955	.3506	.3053	.6144	1.1420
.300	81.4	81.4	81.4	81.4	81.4	81.4	81.4
	1.0000	1.0000	1.0000	.9718	1.0000	1.0000	1.0000
	53.405	63.420	62.277	60.522	61.773	116.260	116.260
	.2822	.6230	.3291	.3199	.3265	.6144	1.1420
.400	69.8	69.8	69.8	69.8	69.8	69.8	69.8
	1.0000	1.0000	1.0000	.7950	1.0000	1.0000	1.0000
	60.139	69.736	69.077	54.914	63.493	116.260	116.260
	.3178	.6850	.3651	.2902	.3356	.6144	1.1420
.500	58.1	58.1	58.1	58.1	58.1	58.1	58.1
	1.0000	1.0000	1.0000	.6494	1.0000	1.0000	1.0000
	67.563	76.470	76.287	49.543	62.947	116.260	116.260
	.3571	.7511	.4032	.2618	.3327	.6144	1.1420
.600	46.5	46.5	46.5	46.5	46.5	46.5	46.5
	1.0000	1.0000	1.0000	.5298	1.0000	1.0000	1.0000
	75.717	83.621	83.860	44.429	60.157	116.260	116.260
	.4002	.8214	.4432	.2348	.3179	.6144	1.1420

7.0 Comments on Low-Level Disposal Sites

The data for decommissioning low-level waste disposal sites appears considerably more detailed and easier to obtain than that for reactors. The program as it stands now should be able to accurately predict the costs of decommissioning a LLWS by using the actual volume (capacity) of the site in CAPSLB and (for greater accuracy) by using data supplied from the site and by suppliers of equipment used at the site in Table 5- as it is detailed enough for this purpose.

Note that after a low-level waste disposal site is released from administrative controls, the maintenance fund will return its full (inflated) value to the treasury from which it came as there are no "dismantling" costs similar to reactor dismantling needed.

TABLE 6

The number of years when the total annual payments made to that date are more than the amount needed to pay the costs forever with a deposit at year 1.

$$N = (1 + \text{inflation}) / (\text{interest} - \text{inflation})$$

		Interest			
		.06	.08	.10	.12
	.04	52	26	17	13
Inflation	.06	-	53	26	18
	.08	-	-	54	27
	.10	-	-	-	54

TABLE 7

If a deposit is made to pay costs for 'N' years, (a) 5% and (b) 10% more of a deposit will pay the costs forever.

$$N = \log\left(\frac{\text{increase}}{1 + \text{increase}}\right) / \log\left(\frac{1 + \text{inflation}}{1 + \text{interest}}\right)$$

7a 5%

		Interest			
		.06	.08	.10	.12
	.04	160	81	54	14
	.06	-	163	82	55
Inflation	.08	-	-	166	84
	.10	-	-	-	169

7b 10%

		Interest			
		.06	.08	.10	.12
	.04	126	64	43	32
	.06	-	128	65	43
Inflation	.08	-	-	131	66
	.10	-	-	-	133

REFERENCES

(1) Technology, Safety, and Costs of Decommissioning a Referrnce Pressurized Water Reactor Power Station. NUREG/CR-0130, Battelle, Pacific Northwest Laboratory for U.S. Nuclear Regulatory Commission, June 1978

(2) An Engineering Evaluation of Nuclear Power Reactor Decommissioning Alternatives. AIF/NESP-009, Atomic Industrial Forum, Inc., Nov. 1976

(3) A Preliminary Report on Light Water Reactor Decommissioning Costs GU 5295, Gulf United Nuclear Fuels Corporation, Jan. 1973

(4) Report of the Special Advisory Committee on Nuclear Waste Disposal. No. 142, Kentucky, Oct. 1977

(5) Economic Analysis of Funding Arrangements for Maintenance, Surveillance, and Contingency Costs Associted with Burial of Low-Level Radioactive Waste in South Carolina, AE 379, Dept. of Agricultural Economics and Rural Sociology, Clemson University for South Carolina Department of Health and Environmental Control, Dec. 1974

(6) Technology, Safety and Costs of Decommissioning a Reference Nuclear Fuel Reprocessing Plant. NUREG-0278, Battelle, Pacific Northwest Laboratory for U.S. Nuclear Regulatory Commission, Oct. 1977.

(7) Statement to the ACRS Subcommittee of Nuclear Power Plants Regarding Decommissioning Nuclear Power Generating Units, An Economic Analysis Jack Roberts, USNRC, June 29, 1977

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FORTRAN LISTING

```
*DECK DECOST
      PROGRAM DECOST(INPUT,OUTPUT)
C-
C-
C-        THIS PROGRAM IS DESIGNED TO CALCULATE THE COSTS OF, AND
C-    EVALUATE THE PAYMENT FOR DECOMMISSIONING OF NUCLEAR POWER REACTORS
C-    UNDER VARYING CONDITIONS.  THE PROGRAM IS BASED ON THE AIF/NESP-009
C-    STUDY AND THE REPORT OF THE SPECIAL ADVISORY COMMITTEE ON
C-    NUCLEAR WASTE DISPOSAL NO. 142 KENTUCKY, OCT. 1977.
C-    THE PROGRAM IS BASED ON NUCLEAR REACTORS OF APPROXIMATELY 1150
C-    MEGAWATTS ELECTRICAL POWER OUTPUT AND LLW BURIAL SITES OF  21
C-    MILLION CUBIC FOOT CAPACITY.  THE PROGRAM WILL WORK FOR BOILING-
C-    WATER, PRESSURIZED-WATER, AND HIGH-TEMPERATURE GAS-COOLED REACTORS
C-    IN ANY OF FIVE DECOMMISSIONING MODES; DISMANTLING, MOTHBALLING,
C-    ENTOMBMENT, MOTHBALLING AND DISMANTLING, AND ENTOMBMENT AND
C-    DISMANTLING.  IT WILL ALSO WORK FOR LLW BURIAL SITES IN ANY OF
C-    FOUR DECOMMISSIONING MODES; NO TRENCH MAINTENANCE, TRENCH CAP
C-    RE-WORKING, TRENCH WATER MANAGEMENT, AND A COMBINATION OF THE TWO
C-    MAINTENANCE METHODS.
C-        THE PROGRAM WILL ALSO PERFORM A PARAMETRIC STUDY OF ANY OR ALL
C-    OF FIVE VARIABLES VERSUS REACTOR LIFETIME, PREMATURE DISMANTLING,
C-    OR ANY OF THE OTHER FOUR VARIABLES.   THE POSSIBLY PARAMETRIC
C-    VARIABLES ARE THE ANNUAL INTEREST (DISCOUNT) RATE, ANNUAL INFLATION
C-    (ESCALATION) RATE, ANNUAL TAX RATE, DECOMMISSIONING MODE USED,
C-    AND THE FUNDING METHOD USED.  DECOST INCLUDES ANNUAL AND CAPITAL
C-    COSTS FOR ALL MODES AND DELAY PERIODS OF DECOMMISSIONING.
C-
C-                  -OPERATION-
C-
C-     ALL VARIABLES ARE READ IN CONSECUTIVE 5-SPACE FORMATS.
C-
C-              THE INPUT VARIABLES ARE (IN ORDER):
C-
```

```
C-         1ST CARD- REACTOR PARAMETERS
C-
C-      IBA-      FOR REACTORS (IF IRT.NE.7)
C-         - EQUALS 0 IF USER DESIRES FIGURES FOR PERIOD BEFORE INITIAL
C-           DECOMMISSIONING (AT ARL)
C-         - EQUALS 1 IF USER DESIRES FIGURES FOR PERIOD AFTER
C-           SUCCESSFUL INITIAL DECOMMISSIONING (AT AD)
C-               FOR LOW-LEVEL WASTE SITES  (IF IRT.EQ.7)
C-         - EQUALS 0 IF ANY STOPPAGE IS AT NORMAL FILL RATE
C-         - EQUALS 1 IF FAST (OR SLOW) FILL RATE
C-   IDECOM- MODE OF DECOMMISSIONING (1-5);
C-           1) IMMEDIATE DISMANTLING/ NO TRENCH MAINTENANCE
C-           2) INDEFINITE MOTHBALLING/ TRENCH CAP RE-WORKING
C-           3) INDEFINITE ENTOMBMENT/ TRENCH WATER MANAGEMENT
C-           4) MOTHBALLING WITH DELAYED DISMANTLING/ 2 AND 3 COMBINED
C-           5) ENTOMBMENT WITH DELAYED DISMANTLING/ NOT APPLICABLE
C-      IRT- REACTOR TYPE (1-7);
C-           1) BWR INSTALLATION
C-           2) PWR INSTALLATION
C-           3) HTGR INSTALLATION
C-           4) BWR REACTOR ONLY
C-           5) PWR REACTOR ONLY
C-           6) HTGR REACTOR ONLY
C-           7) LLWS
C-     TRSU- TIME (FROM 1975) TO REACTOR STARTUP (YEARS)
C-      ERL- ESTIMATED (PLANNED) REACTOR LIFETIME (YEARS)
C-      ARL- ACTUAL REACTOR LIFETIME (YEARS)
C-       PD- PLANNED DELAY TO FINAL DISMANTLING (YEARS)
C-           NORMALLY SET AS;
C-            BWR- 104.
C-            PWR- 108.
C-           HTGR-  65.
C-           LLWS- NOT APPLICABLE
```

```
C-        AD- ACTUAL DELAY TO FINAL DISMANTLING (YEARS)
C-    CAPSLB- RATIO OF LLWS VOLUME TO 21 MILLION CU.FT.
C-
C-         2ND CARD- ECONOMIC PARAMETERS
C-
C-         X- ANNUAL INTEREST RATE (FRACTION),(MUST BE .GT.-1)
C-         Y- ANNUAL INFLATION RATE (FRACTION),(MUST BE .GT.-1)
C-        X2- ANNUAL INTEREST PAID BY UTILITY (FRACTION),(MUST BE .GT.-1)
C-        Y2- A SECOND INFLATION (OR INTEREST) RATE TO ALLOW COMPARISONS
C-            TO OTHER MONEY SCALES (SEE MNY),(FRACTION,MUST BE .GT. -1)
C-         T- THE TAX RATE ON ANNUAL EARNINGS (FRACTION),(MUST BE .GT.-1)
C-     TDEPR- THE DEPRECIATION TIME USED FOR IFND= 6,7 (YEARS)
C-            IF .EQ. 0, THE ROUTINE WILL CALCULATE THE NECESSARY
C-            DEPRECIATION TIME.
C-        PC- THE TOTAL CAPITAL COST TO BUILD THE PLANT AT THE TIME OF
C-            STARTUP ($M).
C-      IFND- THE TYPE OF FUNDING USED
C-            1) CONSTANT FEE SINKING FUND TO COVER EXPECTED COST AT ERL+
C-               TRSU.
C-            2) ESCALATING FEE SINKING FUND TO COVER EXPECTED COST AT
C-               ERL+TRSU.
C-            3) DEPOSIT AT TRSU TO COVER EXPECTED COST AT ERL+TRSU
C-            4) DEPOSIT AT TRSU TO COVER EXPECTED COST AT TRSU
C-            5) SAME AS 4) BUT NET EARNINGS RETURNED TO UTILITY.
C-            6) STRAIGHT-LINE, NEGATIVE SALVAGE VALUE DEPRECIATION.
C-            7) ADJUSTED, STRAIGHT-LINE, NEGATIVE SALVAGE VALUE
C-               DEPRECIATION.
C-       MNY- TYPE OF MONETARY SYSTEM TO BE USED FOR COMPARISON (1-4)
C-            1- INFLATED (UNADJUSTED) DOLLARS
C-            2- CONSTANT 1975 DOLLARS (INFLATION ADJUSTED)
C-            3- DISCOUNTED 1975 DOLLARS (EFFECTIVE INTEREST ADJUSTED)
C-            4- CONSTANT 1975 DOLLARS (INFLATION OF FACILITY COSTS IS
C-               NOT EQUAL TO THE GENERAL INFLATION RATE (Y2))
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```
C-    NLOOPS- NUMBER OF VARIABLES (1-4) IN PARAMETRIC STUDY.
C-            THE PROGRAM WILL NORMALLY MAKE SEPARATE CALCULATIONS TO
C-            DETERMINE THE FINANCIALLY POSSIBLE METHODS OF DECOMMISSION-
C-            ING ONLY IF ARL .NE. ERL AND NLOOPS.EQ. 0.    IF NLOOPS
C-            .LT. 0, THE PROGRAM DOES THE CALCULATIONS IF ARL .EQ. ERL.
C-
C-         DECOST IS STOPPED BY A BLANK INPUT CARD AT THE END OF THE DATA
C-    DECK (IDECOM=0).  IF NLOOPS EQUALS 0, THE PROGRAM WILL NOT DO A
C-    PARAMETRIC STUDY.  IN THIS CASE, IF ARL DOES NOT EQUAL ERL, THE
C-    PROGRAM WILL FIND OUT WHAT METHODS OF DECOMMISSIONING ARE AVAILABLE
C-    WITH THE FUNDS AT HAND AT THE TIME THE REACTOR IS ACTUALLY SHUT
C-    DOWN.  IFNLOOPS IS GREATER THAN ZERO, A PARAMETRIC STUDY IS
C-    INDICATED AND THE NEXT DATA CARD SHOULD CONTAIN THESE VARIABLES:
C-         I0- THE PARAMETER TO BE VARIED AS THE COMPARISON VARIABLE(1-7)
C-        STP- THE STEP SIZE OF THE COMPARISON VARIABLE
C-       I(1)- THE 1ST PARAMETER TO BE VARIED (1-5)
C-    SMIN(1)- THE MINIMUM VALUE OF THE 1ST PARAMETER
C-    STEP(1)- THE 1ST STEP SIZE
C-       I(2)- THE 2ND PARAMETER TO BE VARIED (1-5)
C-    SMIN(2)- THE MINIMUM VALUE OF THE 2ND PARAMETER
C-    STEP(2)- THE 2ND STEP SIZE
C-       I(3)- THE 3RD PARAMETER TO BE VARIED (1-5)
C-    SMIN(3)- THE MINIMUM VALUE OF THE 3RD PARAMETER
C-    STEP(3)- THE 3RD STEP SIZE
C-       I(4)- THE 4TH PARAMETER TO BE VARIED (1-5)
C-    SMIN(4)- THE MINIMUM VALUE OF THE 4TH PARAMETER
C-    STEP(4)- THE 4TH STEP SIZE
C-    THE PARAMETERS ARE (THE VALUE OF I(N) OR I0 IS):
C-         1) INTEREST RATE (X)
C-         2) INFLATION RATE (Y)
C-         3) TAX RATE (T)
C-         4) DECOMMISSIONING MODE (IDECOM)
C-         5) FUNDING METHOD (IFND)
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```
C-        6) REACTOR LIFETIME (ARL)
C-        7) DELAY TO FINAL DISMANTLING (AD)
C-        THE MID-RANGE VALUE OF THE PARAMETERS X,Y, AND T WILL BE THAT
C-   VALUE INDICATED ON THE FIRST DATA CARD.  THE PARAMETERS IDECOM
C-   AND  IFND HAVE THEIR LARGEST VALUE SET ON THE FIRST DATA CARD.  IN
C-   THIS WAY A CRUDE SENSITIVITY ANALYSIS MAY BE DONE FOR A GIVEN BASE
C-   CASE.   IF THE VARIABLE IS TO BE THE COMPARISON VARIABLE (I0), THE
C-   ONLY CHANGE FROM THE ABOVE IS THAT IDECOM WILL ALWAYS VARY 1-5,
C-   AND IFND WILL ALWAYS VARY 1-7.
C-                 NOTE THAT THESE PARAMETER VARIATIONS ARE NOT IN A
C-   NESTED LOOP FORM.  THE PROGRESSION MAY BE REVERSED BY MAKING THE
C-   VALUE OF STEP NEGATIVE, AND SWITCHING THE LARGEST AND SMALLEST
C-   VALUES OF THE PARAMETER DESIRED.
C-        FOR A CALCULATION TO [BACKFIT[ A SINKING FUND TO AN EXISTING
C-   REACTOR SET TRSU EQUAL TO THE TIME TO THE START OF THE SINKING FUND
C-   (FROM 1975), SET ERL EQUAL TO THE ESTIMATED (PLANNED) REMAINING
C-   REACTOR LIFETIME, AND SET ARL EQUAL TO THE ACTUAL REMAINING REACTOR
C-   LIFETIME.
C-
C-    ROUTINE DECOST IS CALLED BY THE USER.
C-    SUBROUTINES CALLED BY DECOST:
C-         *SWITCH*
C-         * COST *
C-         *POSDEC*
C-
C-
      DIMENSION I(4),STEP(4),SMIN(4),RATE(2)
      COMMON/ TRANS/ IRT,MNY,IFLAG,TRSU,ERL,PD,CAPSLB,X2,Y2,TDEPR,PC,
     *FVCOST,FRAC,CASH,DUM,FVARL,CMKWHR,DUMMY(50)
      COMMON/ TABL / TABR(7),TABM(4),TABF(7)
      DATA RATE/ 'ERL','ARL'/
      PRINT 250
      PRINT 251
```

```
      PRINT 252
      PRINT 253
      IP=-1
      NO=0
    1 READ 100,IBA,IDECOM,IRT,TRSU,ERL,ARL,PD,AD,CAPSLB
      IF (IDECOM.EQ.0) STOP
      READ 101,X,Y,X2,Y2,T,TDEPR,PC,IFND,MNY,NLOOPS
      PRINT 208
      NO=NO+1
      IF(IDECOM.LT.0.OR.IDECOM.GT.5.OR.IRT.LT.1.OR.IRT.GT.7.OR.PD.LT.0.0
     *.OR.AD.LT.0.0.OR.IBA.LT.0.OR.IBA.GT.1.OR.NLOOPS.GT.5.OR.IFND.LT.1.
     *OR.IFND.GT.7.OR.X.LT.-.99.OR.Y.LT.-.99.OR.Y2.LT.-.99.OR.ERL.LT.1.0
     *.OR.MNY.LT.1.OR.MNY.GT.4.OR.CAPSLB.LT.-.01
     *.OR.PC.LT.0..OR.T.LT.-.99) GO TO 4
      IF (TDEPR.LT.1.) GO TO 91
      IFLAG=0
      GO TO 92
   91 TDEPR= 1. E 10
      IFLAG=1
   92 IF (NLOOPS.LT.1) GO TO 2
C-
C-    THIS SECTION IS FOR PARAMETRIC STUDIES
C-
      IP=-1
      READ 102,I0,STP,((I(J),SMIN(J),STEP(J)),J=1,NLOOPS)
      IF (I0.LT.1.OR.I0.GT.7) GO TO 4
      DO 15 L=1,NLOOPS
      IF(I(L).GT.5.OR.I(L).LT.1.OR.STEP(L).LT..00001.AND.STEP(L).
     *GT.-.00001) GO TO 4
      CALL SWITCH(I0,STP,I(L),SMIN(L),STEP(L),X,Y,T,IDECOM,IFND,ARL,AD,
     *IBA)
   15 CONTINUE
      GO TO 1
```

```
C-
C-   THIS SECTION IS FOR CASE-BY-CASE CALCULATIONS
C-
     2 IF (X*(1.-T).GT.Y+.00001) GO TO 21
       IF (IRT.EQ.7.OR.IDECOM.EQ.2.OR.IDECOM.EQ.3) GO TO 5
    21 CALL COST(X,Y,T,IDECOM,IFND,ARL,AD,IBA)
       IF(IP.EQ.IBA*10+IRT) GO TO 22
       IP=IBA*10+IRT
       PRINT 201
       IF (IBA.GT.0) GO TO 61
       PRINT 202
        GO TO 62
    61 PRINT 203
    62 IF (IRT.GT.6) GO TO 63
       PRINT 204
       GO TO 64
    63 PRINT 205
    64 PRINT 206
       PRINT 209
    22 PRINT 210,TABR(IRT),IDECOM,TRSU,ERL
       IF (IBA.GT.0) GO TO 51
       PRINT 211,ARL,PD
       GO TO 52
    51 PRINT 211,PD,AD
    52 IF (IRT.GT.6) GO TO 53
       PRINT 212,TDEPR,PC
       GO TO 54
    53 PRINT 213,CAPSLB,RATE(IBA+1)
    54 PRINT 214,X,Y,X2,Y2,T,TABF(IFND),TABM(MNY),FVCOST,FRAC,CASH,CMKWHR
       IF(ARL.NE.ERL.AND.NLOOPS.GT.-1.OR.ARL.EQ.ERL.AND.NLOOPS.LT.0)
      *GO TO 6
       GO TO 1
     4 PRINT 255,NO
```

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      GO TO 1
    5 PRINT 207,X,T,Y,IDECOM,NO
      GO TO 1
    6 IF(IRT.LT.7) CALL POSDEC(X,Y,T,IDECOM,IFND,ARL,FVARL)
      GO TO 1
  100 FORMAT (3I5,6F5.1)
  101 FORMAT (7F5.2,3I5)
  102 FORMAT(I5,F5.2,4(I5,F5.2,F5.2))
  250 FORMAT('1THERE ARE SEVEN TYPES OF FACILITIES'/5X,'1- BWR I   BWR I
     *NSTALLATION'/5X,'2- PWR I   PWR INSTALLATION'/5X,'3- HTGRI   HTGR
     *INSTALLATION'/ 5X,'4- BWR O   BWR REACTOR ONLY'/ 5X,'5- PWR O   PW
     *R REACTOR ONLY'/ 5X,'6- HTGRO   HTGR REACTOR ONLY'/ 5X,'7-  LLWS
     * LOW-LEVEL SHALLOW-LAND WASTE SITE'//' THERE ARE FIVE MODES OF DEC
     *OMMISSIONING'/  5X,'1-   IMMEDIATE DISMANTLING/ NO TRENCH WORK'/5X
     *,'2-   INDEFINITE MOTHBALLING/ TRENCH CAP RE-WORK'/5X,'3-   INDEFI
     *NITE ENTOMBMENT/ TRENCH WATER MANAGEMENT'/5X,'4-   MOTHBALLING FOR
     * ESDLY YEARS FOLLOWED BY DISMANTLING/ COMBINATION OF 2 AND 3'/
     *5X,'5-   ENTOMBMENT FOR ESDLY YEARS FOLLOWED BY DISMANTLING/ NOT A
     *PPLICABLE')
  251 FORMAT('0THERE ARE SEVEN METHODS OF FUNDING DECOMMISSIONING'/
     *    5X,'1-  CFSF   USE OF A CONSTANT-FEE SINKING FUND TO COVER DECO
     *MMISSIONING COSTS AT ERL'/ 5X,'2-  EFSF   USE OF AN ESCALATING-FEE
     * SINKING FUND TO COVER DECOMMISSIONING COSTS AT ERL'/ 5X,
     *'3- D ERL   A DEPOSIT AT TRSU TO COVER DECOMMISSIONING COSTS AT ER
     *L'/  5X,'4- D TRS   A DEPOSIT AT TRSU TO COVER THE DECOMMISSIONING
     * COSTS AT TRSU'/  5X,'5- D RTN   SAME AS 4- BUT NET EARNINGS ON FU
     *ND RETURNED TO UTILITY'/  5X,'6- SLDPR   USE OF STRAIGHT-LINE NEGA
     *TIVE SALVAGE VALUE DEPRECIATION'/  5X,'7- ASLDP   USE OF ADJUSTED
     *STRAIGHT-LINE NEGATIVE SALVAGE VALUE DEPRECIATION'/  '0THERE ARE F
     *OUR WAYS TO COMPARE MONEY'/    5X,'1- INFLD   INFLATED (UNADJUSTED
     *) DOLLARS'/   5X,'2- CONST   CONSTANT 1975 DOLLARS (INFLATION ADJU
     *STED)'/  5X,'3- DISCT   DISCOUNTED 1975 DOLLARS (EFFECTIVE INTERES
     *T ADJUSTED)'/  5X,'4- CNST2   CONSTANT 1975 DOLLARS (INFLATION ADJ
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```
   *USTED AT A DIFFERENT RATE (INFL2))"/ 2(" "/))
255 FORMAT("0",25X,"INPUT FOR CASE",I3," IS OUT OF BOUNDS"/" ")
252 FORMAT(10X,"FTYPE = TYPE OF FUNDING USED FOR INITIAL DECOMMISSIONI
   *NG (1-7)"/10X,"RTYPE = REACTOR TYPE (1-7)"/10X,"MTYPE = TYPE OF MO
   *NEY COMPARISON USED (1-4)"/10X, "DECOM = THE TYPE OF DECOMMISSIONI
   *NG USED (1-5)"/ 11X,"TRSU = TIME TO REACTOR STARTUP (YEARS)"/
   *12X,"ERL = EXPECTED REACTOR LIFETIME (YEARS)"/ 12X,"ARL = ACTUAL R
   *EACTOR LIFETIME (YEARS)"/ 10X,"ESDLY = THE PLANNED DELAY TO FINAL
   *DISMANTLING (YEARS)"/ 10X,"ACDLY = THE ACTUAL DELAY TO FINAL DISMA
   *NTLING (YEARS)"/  12X,"INT = THE ANNUAL INTEREST RATE (FRACTION)"/
   *11X, "INT2 = INTEREST RATE PAID BY UTILITY (FRACTION)"/
   * 11X, "INFL = THE ANNUAL INFLATION RATE (FRACTION)"/ 10X, "INFL2 =
   * THE INFLATION RATE USED FOR COMPARISON IF MTYPE = 4 (FRACTION)")
253 FORMAT(12X,"TAX = THE ANNUAL TAX RATE (FRACTION)"/
   * 10X, "TDEPR = THE DEPRECIATION TIME FOR THE PLANT FOR IFND=6,7 (Y
   *EARS)"/ 11X, "PCST = THE CAPITAL COST FOR THE PLANT ($M)"/
   * 10X, "CAPSL = THE VOLUME RATIO OF A LLWS TO THE GENERIC LLWS"/
   * 11X, "FILL = THE TIME AT WHICH LLWS IS FILLED (ERL OR ARL)"/
   * 10X, "ACOST = ACTUAL COST OF DECOMMISSIONING AT THE INDICATED TIM
   *E ($M)"/ 11X, "FRAC = THE FRACTION OF DECOMMISSIONING COSTS PAID F
   *OR BY THE FUND"/ 11X, "CASH = ACTUAL PAYMENTS MADE TO THE FUND ($M
   *)"/ 10X, "CHRGE = CHARGES TO PAY FOR DECOMMISSIONING (M/KWH OR $/C
   *U. FT. FOR A LLWS) AT THE TIME INDICATED"/" "/ 10X,"***** = THAT C
   *OMBINATION OF REACTOR TYPE, DECOMMISSIONING MODE, INTEREST RATE, A
   *ND INFLATION RATE IS NOT POSSIBLE")
201 FORMAT("1RTYPE DECOM  TRSU  ERL")
202 FORMAT("+",24X," ARL  ESDLY")
203 FORMAT("+",24X,"ESDLY ACDLY")
204 FORMAT("+",36X,"TDEPR  PCST")
205 FORMAT("+",36X,"CAPSL  FILL")
206 FORMAT("+",48X," INT   INFL  INT2 INFL2  TAX  FTYPE MTYPE     ACOS
   *T    FRAC    CASH   CHRGE")
207 FORMAT("0THE INTEREST RATE",F6.3," TIMES THE TAX RATE",F6.3,
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     * ' IS LESS THAN THE INFLATION RATE',F6.3/' THE METHOD OF DECOMMISS
     *IONING CHOSEN',I3,' CANNOT BE COMPLETED (CASE',I3,')')
  208 FORMAT(' ')
  209 FORMAT(' ',15('----- '),1X,4(3X,'-----'))
  210 FORMAT(1X,A5,2X,I2,3X,2(F5.1,1X))
  211 FORMAT('+',24X,2(F5.1,1X))
  212 FORMAT('+',36X,F5.1,1X,F5.0)
  213 FORMAT('+',36X,F5.1,2X,A3)
  214 FORMAT('+',48X,5(F5.3,1X),2(A5,1X),2X,F7.1,1X,F7.3,1X,F7.2,
     *1X,F7.4)
      END
*DECK SWITCH
C-
C-----------------------------------------------------------------------
C-
      SUBROUTINE SWITCH(K0,STP,K,SMIN,STEP,X1,Y1,T1,IDEC1,IFND1,ARL1,
     *AD1,IBA)
      DIMENSION KX(5),POUT(7)
      COMMON/ TRANS/ IRT,MNY,IDUM,TRSU,ERL,PD,CAPSLB,X2,Y2,TDEPR,PC,
     *DUM(6),AMATRX(10,4),DUM1(10)
      COMMON/ LABELS/ B(20),DUMMY(47)
      COMMON/ INDEXS/ A(7),N(7)
      COMMON/ TABL / TABR(7),TABM(4),TABF(7)
C-
C-        SUBROUTINE *SWITCH* CONTROLS THE PARAMETRIC STUDIES.
C-    VARIATIONS IN THIS ROUTINE ARE THE INDEPENDENT VARIABLES DESIRED
C-    BY THE USER.
C-
C-    SUBROUTINE *SWITCH* CALLED BY:
C-         -DECOST-
C-    SUBROUTINES CALLED BY *SWITCH*:
C-         *STORE*
C-         *TABLE*
```

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```
C-
      MT=0
C-
C-    THIS SECTION PRINTS THE OUTPUT TABLE HEADINGS
C-
      POUT(1)=X1
      POUT(2)=Y1
      POUT(3)=T1
      POUT(4)=FLOAT(IDEC1)
      POUT(5)=FLOAT(IFND1)
      POUT(6)=ARL1
      POUT(7)=AD1
      PRINT 200,TABR(IRT),TRSU,ERL,PD,CAPSLB,TABM(MNY),X2,Y2,PC,TDEPR
      NK0=N(K0)
      N1=0
      DO 15 NN=1,7
      IF(NN.EQ.K.OR.NN.EQ.K0) GO TO 15
      N1=N1+1
      KX(N1)=NN
   15 CONTINUE
      PRINT 201,((A(KX(L)),POUT(KX(L))),L=1,5)
      INDEX=7*IBA+IRT
      GO TO (6,6,6,6,6,6,8,7,7,7,7,7,7,9),INDEX
    6 PRINT 211
      GO TO 10
    7 PRINT 212
      GO TO 10
    8 PRINT 211
      PRINT 213
      GO TO 10
    9 PRINT 211
      PRINT 214
   10 PRINT 202,(B(4*K-4+L1),L1=1,4)
```


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```
      IF (K.EQ.K0) GO TO 90
      IF(K0.EQ.5.OR.K0.EQ.4) STP=1.0
      POUT(4)=5.
      POUT(5)=7.
      GO TO (1,2,3,4,5),K
C-
C-    THIS SECTION VARIES THE DISCOUNT RATE.
C-
    1 JX=2.*(X1-SMIN)/STEP+1.0001
      DO 11 M=1,JX
      X=STEP*(M-1)+SMIN
      AMATRX(1,1)=X
      DO 12 IT=2,NK0
      DELTA=POUT(K0)-STP*(NK0-IT)
      CALL STORE(X,Y1,T1,IDEC1,IFND1,ARL1,IBA,AD1,K0,DELTA,IT)
   12 CONTINUE
      CALL TABLE(K0,NK0,MT,IBA)
   11 CONTINUE
      RETURN
C-
C-    THIS SECTION VARIES THE ESCALATION RATE.
C-
    2 JY=2.*(Y1-SMIN)/STEP+1.0001
      DO 21 M=1,JY
      Y=STEP*(M-1)+SMIN
      AMATRX(1,1)=Y
      DO 22 IT=2,NK0
      DELTA=POUT(K0)-STP*(NK0-IT)
      CALL STORE(X1,Y,T1,IDEC1,IFND1,ARL1,IBA,AD1,K0,DELTA,IT)
   22 CONTINUE
      CALL TABLE(K0,NK0,MT,IBA)
   21 CONTINUE
      RETURN
```

```
C-
C-   THIS SECTION VARIES THE TAX RATE
C-
   3 JT=2.*(T1-SMIN)/STEP+1.0001
     DO 31 M=1,JT
     T=STEP*(M-1)+SMIN
     AMATRX(1,1)=T
     DO 32 IT=2,NK0
     DELTA=POUT(K0)-STP*(NK0-IT)
     CALL STORE(X1,Y1,T,IDEC1,IFND1,ARL1,IBA,AD1,K0,DELTA,IT)
  32 CONTINUE
     CALL TABLE(K0,NK0,MT,IBA)
  31 CONTINUE
     RETURN
C-
C-    THIS SECTION VARIES THE DECOMMISSIONING MODE.
C-
   4 JD=1.0001+(IDEC1-SMIN)/STEP
     DO 41 M=1,JD
     IDEC=SMIN+(M-1)*STEP
     AMATRX(1,1)=FLOAT(IDEC)
     DO 42 IT=2,NK0
     DELTA=POUT(K0)-STP*(NK0-IT)
     CALL STORE(X1,Y1,T1,IDEC,IFND1,ARL1,IBA,AD1,K0,DELTA,IT)
  42 CONTINUE
     CALL TABLE(K0,NK0,MT,IBA)
  41 CONTINUE
     RETURN
C-
C-    THIS SECTION VARIES THE FUNDING METHOD.
C-
   5 JF=1.0001+(IFND1-SMIN)/STEP
     DO 51 M=1,JF
```

```
      IFND=STEP*(M-1)+SMIN
      AMATRX(1,1)=FLOAT(IFND)
      DO 52 IT=2,NK0
      DELTA=POUT(K0)-STP*(NK0-IT)
      CALL STORE(X1,Y1,T1,IDEC1,IFND,ARL1,IBA,AD1,K0,DELTA,IT)
   52 CONTINUE
      CALL TABLE(K0,NK0,MT,IBA)
   51 CONTINUE
      RETURN
   90 PRINT 290
      RETURN
  200 FORMAT('1'/' RTYPE = ',A5,4X,'TRSU =',F5.1,' YRS.',8X,'ERL =',F5.1
     *,' YRS.',6X,'ESDLY =',F5.1,' YRS.',6X,'CAPSL =',F5.3//' MTYPE = ',
     *A5,3X,' INT2 =',F5.3,4X,'INFL2 =',F5.3,4X,'PLCST =',F5.0,4X,'TDEPR
     * =',F5.2,' YRS.')
  201 FORMAT('0',5(A7,F7.3,6X))
  202 FORMAT(' ',A8,A7/' ',A8,A7)
  211 FORMAT('0',34X,'FOR THE PERIOD BEFORE INITIAL DECOMMISSIONING')
  212 FORMAT('0',34X,'FOR THE PERIOD AFTER SUCCESSFUL INITIAL DECOMMISSI
     *ONING')
  213 FORMAT('0',34X,'LLWS',     ' IS FILLED AT A RATE THAT WILL FILL IT
     *AT ERL')
  214 FORMAT('0',34X,'LLWS',     ' IS FILLED AT A RATE THAT WILL FILL IT
     *AT ARL')
  290 FORMAT('0'/'0***** I0 CANNOT EQUAL I(L) ON INPUT. *****')
      END
*DECK STORE
C-
C-----------------------------------------------------------------------
C-
      SUBROUTINE STORE(X,Y,T,IDEC,IFND,ARL,IBA,AD,K0,DELTA,IT)
      COMMON/ TRANS/ IRT,IDUM(2),DUM(8),FVCOST,FRAC,CASH,DUM1(2),CMKWHR,
     *AMATRX(10,4),ABSC(10)
```

```
C-
C-         SUBROUTINE *STORE* TAKES THE PARAMETERS FED TO IT BY *SWITCH*
C-    AND STORES THE COSTS AND FUNDS CALCULATED BY *COST* IN PREPARATION
C-    FOR OUTPUT.  VARIATIONS IN THIS ROUTINE ARE THE COMPARISON
C-    VARIABLE.
C-
C-    SUBROUTINE *STORE* CALLED BY:
C-         *SWITCH*
C-    SUBROUTINES CALLED BY *STORE*:
C-         *COST*
C-
      TAU=1.-T
      GO TO (1,2,3,4,5,6,7),K0
C-
C-    THIS SECTION IS FOR DISCOUNT RATE VARIATION.
C-
    1 IF (DELTA*TAU.GT.Y+.00001) GO TO 12
      IF (IRT.EQ.7.OR.IDEC.EQ.2.OR.IDEC.EQ.3) GO TO 80
   12 CALL COST(DELTA,Y,T,IDEC,IFND,ARL,AD,IBA)
      GO TO 100
C-
C-    THIS SECTION IS FOR ESCALATION RATE VARIATION.
C-
    2 IF (DELTA.LT.X*TAU-.00001) GO TO 22
      IF (IRT.EQ.7.OR.IDEC.EQ.2.OR.IDEC.EQ.3) GO TO 80
   22 CALL COST(X,DELTA,T,IDEC,IFND,ARL,AD,IBA)
      GO TO 100
C-
C-   THIS SECTION IS FOR TAX RATE VARIATION
C-
    3 IF(X*(1.-DELTA).GT.Y+.00001) GO TO 32
      IF(IRT.EQ.7.OR.IDEC.EQ.2.OR.IDEC.EQ.3) GO TO 80
   32 CALL COST(X,Y,DELTA,IDEC,IFND,ARL,AD,IBA)
```

```
      GO TO 100
C-
C-    THIS SECTION IS FOR DECOMMISSIONING VARIATION.
C-
    4 IDEL=DELTA+0.0001
      IF (X*TAU.GT.Y+.00001) GO TO 42
      IF (IRT.EQ.7.OR.IDEL.EQ.2.OR.IDEL.EQ.3) GO TO 80
   42 CALL COST(X,Y,T,IDEL,IFND,ARL,AD,IBA)
      GO TO 100
C-
C-    THIS SECTION IS FOR FUNDING VARIATION.
C-
    5 IDEL=DELTA+.0001
      IF (X*TAU.GT.Y+.00001) GO TO 52
      IF (IRT.EQ.7.OR.IDEC.EQ.2.OR.IDEC.EQ.3) GO TO 80
   52 CALL COST(X,Y,T,IDEC,IDEL,ARL,AD,IBA)
      GO TO 100
C-
C-    THIS SECTION IS FOR REACTOR LIFETIME VARIATION.
C-
    6 IF (X*TAU.GT.Y+.00001) GO TO 62
      IF (IRT.EQ.7.OR.IDEC.EQ.2.OR.IDEC.EQ.3) GO TO 80
   62 CALL COST(X,Y,T,IDEC,IFND,DELTA,AD,IBA)
      GO TO 100
C-
C-    THIS SECTION IS FOR DELAY VARIATION.
C-
    7 IF (X*TAU.GT.Y+.00001) GO TO 72
      IF (IRT.EQ.7.OR.IDEC.EQ.2.OR.IDEC.EQ.3) GO TO 80
   72 CALL COST(X,Y,T,IDEC,IFND,ARL,DELTA,IBA)
C-
  100 AMATRX(IT,1)=FVCOST
      AMATRX(IT,2)=FRAC
```

```
      AMATRX(IT,3)=CASH
      AMATRX(IT,4)=CMKWHR
      ABSC(IT)=DELTA
      RETURN
C-
C-    THIS SECTION IS FOR UNWORKABLE COMBINATIONS
C-
   80 DO 90 N=1,4
      AMATRX(IT,N)=1.0 E 20
   90 CONTINUE
      ABSC(IT)=DELTA
      RETURN
      END
C-
C--------------------------------------------------------------------
C-
*DECK TABLE
      SUBROUTINE TABLE(K0,NK0,MT,IBA)
      COMMON/ TRANS/ IDUM(3),DUMMY(14),AMATRX(10,4),ABSC(10)
      COMMON/ LABELS/ DUMMY1(20),TH(3,7),ASTRIX(2),TD(12,2)
C-
C-    SUBROUTINE *TABLE* PRINTS OUT TABLES FOR *SWITCH*.
C-
C-    SUBROUTINE *TABLE* CALLED BY:
C-         *SWITCH*
C-    SUBROUTINES CALLED BY *TABLE*:
C-              NONE
C-
      MT=MT+1
      IF (MT.GT.1) GO TO 2
      PRINT 201,(TH(L,K0),L=1,3),(ABSC(L1),L1=2,NK0)
      PRINT 202,(ASTRIX(1),ASTRIX(2),L2=2,NK0)
      IF (K0.NE.4) GO TO 1
```

```
      PRINT 205,(TD(L,IBA+1),L=1,12)
      GO TO 2
    1 PRINT 206,(TD(L,IBA+1),L=1,12)
    2 PRINT 204,AMATRX(1,1)
      PRINT 207,(AMATRX(IA,1),IA=2,NK0)
      PRINT 208,(AMATRX(IA,2),IA=2,NK0)
      PRINT 209,(AMATRX(IA,3),IA=2,NK0)
      PRINT 208,(AMATRX(IA,4),IA=2,NK0)
      PRINT 202,(ASTRIX(1),ASTRIX(2),IP=2,NK0)
      RETURN
  201 FORMAT(' ',38X,3A8/10X,'* ',3(3(F9.3,2X),'* '))
  202 FORMAT(' ',16('*'), 9(A8,A3))
  204 FORMAT('0 ',F6.3,'  *')
  205 FORMAT(10X,'*     ',5A8)
  206 FORMAT(10X,'*     ',12A8,'     *')
  207 FORMAT('+',9X,'* ',3(3(F9.1,2X),'* '))
  208 FORMAT(10X,'* ',3(3(F9.4,2X),'* '))
  209 FORMAT(10X,'* ',3(3(F9.3,2X),'* '))
      END
*DECK COST
C-
C-----------------------------------------------------------------------
C-
      SUBROUTINE COST(X,Y,T,IDECOM,IFND,ARL,AD,IBA)
      COMMON/ TRANS/ IRT,IDUM(2),TRSU,ERL,PD,CAP,DUM(4),FVCOST,FRAC,
     *DUMMY,FV,FVARL,DUM1(51)
      COMMON/ CLIST/ CINIT(5,7),ACST(5),ACSTLL(10)
C-
C-         COST AND THE SUBROUTINE DECFND CALCULATE THE COSTS AND FUNDS
C-    FOR THE PROGRAM.  Z IS THE EFFECTIVE INTEREST RATE, FPD IS THE
C-   FUND FOR POST DECOMMISSIONING, DCC IS THE FINAL DISMANTLING CAPITAL
C-   COST, CINIT IS THE INITIAL COST OF DECOMMISSIONING, AND ACST IS THE
C-    ANNUAL COST OF DECOMMISSIONING.
```

```
C-
C-    OTHER SIGNIFICANT VARIABLES USED IN THE *COST* ROUTINE ARE:
C-       FPD- FUND FOR POST DECOMMISSIONING ($ MILLION)
C-       PRV- PRESENT VALUE (COST) OF DECOMMISSIONING ($M)
C-        FV- FUTURE VALUE OF DECOMMISSIONING AT TRSU + ERL YEARS ($M)
C-     FVARL- FUTURE VALUE OF FUND AT ARL + TRSU ($M)
C-     CINIT- INITIAL COST OF DECOMMISSIONING ($M)
C-      FRAC- RATIO ACTUAL FUNDS TO ACTUAL COSTS
C-    CAPFNL- CAPITAL NEEDED AT INITIAL DECOMMISSIONING TO COVER FINAL
C-            DISMANTLING (IF ANY) ($M)
C-       DCC- CAPITAL COSTS OF DISMANTLING ($M)
C-      FVDF- FINAL VALUE OF POST-DECOMMISSIONING FUND AT FINAL
C-            DISMANTLING ($M)
C-      CASH- ACTUAL FUNDS PAID ($M) OR ANNUAL PAYMENTS ($M/YR)
C-    FVCOST- COST OF DECOMMISSIONING AT ARL+TRSU ($M)
C-
C-    THIS ROUTINE CAN RUN ON ITS OWN OUTSIDE OF -DECOST- WITHOUT
C-    MODIFICATION, AND IS THE CENTRAL ROUTINE OF THE PACKAGE.
C-    IF ONE USES THIS ROUTINE OUTSIDE OF THE DECOST PACKAGE, ONE MUST
C-    BE SURE NOT TO LET X*TAU .LE. Y WITH IDECOM = 2 OR 3 OR
C-    IRT .GT. 6.
C-
C-     SUBROUTINE *COST* CALLED BY:
C-          -DECOST-
C-          * STORE*
C-          *POSDEC*
C-     SUBROUTINES CALLED BY *COST*:
C-          *TIMEFN*
C-          *DECFND*
C-          * MONEY*
C-
      TAU=1.-T
      Z=(X*TAU-Y)/(1.+Y)
```

```
      CAPFNL=0.
      IF (IRT.GT.6) GO TO 21
      IF(IDECOM.GT.3.OR.IDECOM.LT.2) GO TO 10
      FPD=ACST(IDECOM)*TAU/Z
      GO TO 20
   10 R=PD
      IF (Z.GT..00001 .OR.Z.LT.-.00001) R=(1.-((1.+Y)/(1.+X*TAU))**PD)/Z
      FPD=ACST(IDECOM)*TAU*R
      CALL TIMEFN(PD,IDECOM,DCC,IRT)
      CSTEND=DCC*(1.+Y)**(TRSU+ERL+PD)
      CAPFNL=CSTEND*TAU/(1.+X*TAU)**PD
   20 PRV=CINIT(IDECOM,IRT)*TAU+FPD
      CHI=(1.+Y)**(TRSU+ERL)
      FV=PRV*CHI+CAPFNL
      CALL DECFND(X,Y,Z,T,IFND,ARL,IBA,CRF,DEP)
      IF (IBA.GT.0.AND.IRT.LT.7) GO TO 30
C-
C-       EARLY-DECOMMISSIONING
C-
      FVCOST=FV*(1.+Y)**(ARL-ERL)
      FRAC=FVARL/FVCOST
      CALL MONEY(X,Y,Z,T,ARL,0.,IFND,CRF,DEP)
      RETURN
C-
C-        POST-DECOMMISSIONING
C-
   30 ESC=(1.+Y)**AD
      DISC=(1.+X*TAU)**AD
      FVDF=((FV-CINIT(IDECOM,IRT)*TAU*CHI)-CHI*ACST(IDECOM)*TAU*AD)*DISC
      IF (Z.LT.-.00001.OR.Z.GT..00001) FVDF=FVDF+ACST(IDECOM)*TAU*CHI*
     *((AD-1./Z)*DISC+ESC/Z)
      CALL TIMEFN(AD,IDECOM,DCC,IRT)
      FVCOST=DCC*TAU*CHI*ESC
```

```
      FRAC=1.
      IF (FVCOST.GT..00001.OR.FVCOST.LT.-.00001) FRAC=FVDF/FVCOST
      CALL MONEY(X,Y,Z,T,ERL,AD,IFND,CRF,DEP)
      RETURN
C-
C-     THIS SECTION IS FOR LLW BURIAL GROUNDS.
C-
   21 A=ACSTLL(IDECOM)+CAP*ACSTLL(5+IDECOM)
      FPD=A*TAU/Z
      GO TO 20
      END
*DECK DATA
C-
C-----------------------------------------------------------------------
C-
      BLOCK DATA
      COMMON/ CLIST/ CINIT(5,7),ACST(5),ACSTLL(10)
      COMMON/ TIME / BP(2,6),DC(3,2,6)
      COMMON/ LABELS/ B(20),TH(3,7),ASTRIX(2),TD(12,2)
      COMMON/ INDEXS/ A(7),N(7)
      COMMON/ TABL / TABR(7),TABM(4),TABF(7)
C-
C-    EACH FIVE VALUES OF CINIT ARE FOR THE FIVE MODES OF DECOMMISSION-
C-    ING A FACILITY.  THE VALUES OF ACST ARE THE ANNUAL COSTS FOR THE
C-    FIVE MODES OF DECOMMISSIONING A REACTOR.  THE VALUES OF ACSTLL ARE
C-    THE CONSTANT AND VOLUME-DEPENDENT ANNUAL COSTS FOR DECOMMISSIONING
C-    A LLW SITE.
C-         THE VALUES OF BP(=,IRT) INDICATE THE TIME BREAKPOINTS IN THE
C-    CONSTANT COSTS OF DISMANTLING A REACTOR.  THE VALUES OF DC(=,ID,
C-    IRT) INDICATE THE CONSTANT COSTS OF FINAL DISMANTLING OF A REACTOR
C-    BASED ON THE INITIAL MODE OF DECOMMISSIONING (ID).
C-
      DATA CINIT/  31.1,2.45,7.58,2.45,7.58,
```

```
     *          26.9,2.31,7.40,2.31,7.40,
     *          28.0,2.30,5.70,2.30,5.70,
     *          20.9,2.45,7.58,2.45,7.58,
     *          17.4,2.31,7.40,2.31,7.40,
     *          17.1,2.30,5.70,2.30,5.70,
     *          .007,.007,.419,.419,1.E 20/
      DATA ACST/   0.,.167,.058,.167,.058/
      DATA ACSTLL/ .035,.035,.047,.047,0.,0.,.036,.0076,.043,0./
      DATA BP/     52.,104.,85.,108.,42.,65.,
     *          52.,104.,85.,108.,42.,65./
      DATA DC/     28.7, 21.7, 11.7, 27.8, 23.8, 11.2,
     *          24.6, 19.5, 11.0, 23.4, 21.0, 10.8,
     *          25.8, 25.1, 15.5, 24.5, 24.5, 14.5,
     *          18.5, 11.5,  1.5, 18.1, 14.1,  1.5,
     *          15.1, 10.0,  1.5, 14.1, 11.7,  1.5,
     *          14.9, 14.2,  4.6, 14.6, 14.6,  4.6/
C-
C-    THE FOLLOWING ARE OUTPUT VARIABLES
C-
      DATA A/'  INT =',' INFL =','  TAX =','DECOM =','FTYPE =','  ARL ='
     *,'ACDLY ='/
      DATA B/ 'INTEREST','        ','  RATE  ','        ',
     *        'INFLATIO','N       ','  RATE  ','        ',
     *        '  TAX   ','        ','  RATE  ','        ',
     *        '    MODE',' OF     ','DECOMMIS','SIONING',
     *        'TYPE OF ','        ','FUNDING ','        '/
      DATA N/ 10,10,10,6,8,10,10/
      DATA ASTRIX/ '********','***'/
      DATA TH      /'YEARLY I','NTEREST ','RATE    ',
     *          'YEARLY I','NFLATION',' RATE   ',
     *          'ANNUAL T','AX RATE ','        ',
     *          'TYPE OF ','DECOMMIS','SIONING ',
     *          'TYPE OF ','FUNDING ','USED    ',
```

```
     *              'ACTUAL Y','EARS OF ','SERVICE ',
     *              'ACTUAL Y','EARS OF ','DELAY    '/
      DATA TD/ 'COST TO ','DECOMMIS','SION, FR','ACTION C','OVERED, ',
     *         'ACTUAL E','XPENDITU','RES, AND',' CHARGE ','RATE -  ',
     *         'M/KWH OR',' $/CU FT','COST TO ','DISMANTL','E, FRACT',
     *         'ION COVE','RED, ACT','UAL SPEN','DING, AN','D FINAL ',
     *         'CHARGE R','ATE  -  ','M/KWH OR',' $/CU FT'/
      DATA TABR/'BWR I','PWR I','HTGRI','BWR O','PWR O','HTGRO',' LLWS'/
      DATA TABF/' CFSF',' EFSF','D ERL','D TRS','D RTN','SLDPR','ASLDP'/
      DATA TABM/ 'INFLD','CONST','DISCT','CNST2'/
      END
*DECK DECFND
C-
C------------------------------------------------------------------------
C-
      SUBROUTINE DECFND(X,Y,Z,T,IFND,ARL,IBA,CRF,DEP)
      COMMON/ TRANS/ IRT,IDUM,IFLAG,DUM,ERL,DUM1,CAP,X2,DUMMY,TDEPR,PC,
     *DUM2(2),CASH,FV,FVARL,CMKWHR,DUMMY1(50)
C-
C-    THIS ROUTINE SUPPLIES *COST* WITH THE APPROPRIATE FUND VALUES FOR
C-    THE DIFFERENT METHODS OF FUNDING CHOSEN.
C-    NOTE:  THE FACTOR IN THE FORMULAS FOR COSTS IN MILLS PER KWHR
C-    (CMKWHR) SHOULD BE DIVIDED BY THE NUMBER OF 1.2 GWE REACTORS THAT
C-    THE FACILITY SERVES. (NOT LLWS.)
C-
C-    SUBROUTINE *DECFND* CALLED BY:
C-         * COST *
C-    SUBROUTINES CALLED BY *DECFND*:
C-            NONE
C-
      RATE=1.
      FACT=1.
      CRF=0.
```

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```
      ANN=0.
      ESCL=1.
      RET=0.
      RTN=0.
      TAU=1.-T
      ESC=(1.+Y)**ERL
      ESC1=(1.+Y)**ARL
      DISC=(1.+X*TAU)**ERL
      DISC1=(1.+X*TAU)**ARL
      GO TO (10,20,30,40,50,60,70),IFND
   10 ANN=FV/ERL
      IF (DISC.GT.1.00001.OR.DISC.LT..9999) ANN=FV*X*TAU/(DISC-1.)
      GO TO 100
   20 ANN=FV/ERL/DISC
      IF (Z.GT.00001 .OR.Z.LT.-.00001) ANN=FV*Z/(DISC-ESC)
      IF (Y.GT.-.00001.AND.Y.LT..00001.OR.ARL.GT.-.1.AND.ARL.LT..1) GO
     *TO 100
      ESCL=(ESC1-1.)/Y/ARL*(1.+Y)
      GO TO 100
   30 DEP=FV/DISC
      GO TO 100
   50 RET=ERL*X*TAU
      IF(Y.LT.-.0001.OR.Y.GT..0001) RET=(X*TAU-Y)*(ESC-1.)/Y
   40 DEP=FV/ESC
      GO TO 100
   60 IF (IFLAG.LT.1) GO TO 66
      ANN=FV/ERL
      IF (PC.GT.1.) TDEPR=1./(ANN/(PC*ESC)+1./ERL)
      GO TO 100
   66 ANN=PC*ESC*(1./TDEPR-1./ERL)
      GO TO 100
   70 IF (IFLAG.LT.1) GO TO 77
      ANN=FV/ERL
```

```
      TDEPR=1./(ANN/(PC*ESC)+1./ERL)
      IF (Y.LT..00001.AND.Y.GT.-.00001) GO TO 100
      ANN=FV*Y/((ESC-1.)*(1.+Y))
      IF (PC.GT..1) TDEPR=ALOG(1.+1./(ANN*(1.+Y)/(PC*ESC*Y)+1./(ESC-1.))
     *)/ALOG(1.+Y)
      IF(ARL.GT..1) ESCL=(ESC1-1.)*(1.+Y)/(Y*ARL)
      GO TO 100
   77 ANN=PC*ESC*(1./TDEPR-1./ERL)
      IF (Y.GT.-.00001.AND.Y.LT..00001) GO TO 100
      ANN=PC*ESC*Y/(1.+Y)*(1./((1.+Y)**TDEPR-1.)-1./(ESC-1.))
      IF (ARL.GT..1) ESCL=(ESC1-1.)*(1.+Y)/(Y*ARL)
  100 IF (IRT.LT.7) GO TO (11,21,31,31,51,61,71),IFND
C-
C-     THIS SECTION IS FOR LOW LEVEL BURIAL SITES.
C-
      FACT=ERL/21./CAP/.15855
      IF (IBA.EQ.0) GO TO (11,21,31,31,51,61,71),IFND
      IF (ARL.LT.-.1.OR.ARL.GT..1) RATE=ERL/ARL
      GO TO (11,21,31,31,51,61,71),IFND
C-
   11 CMKWHR= ANN*FACT*.15855/TAU
      FVARL= ANN*RATE*ARL
      IF (X*TAU.LT.-.00001.OR.X*TAU.GT..00001) FVARL=ANN*RATE*(DISC1-1.)
     */X/TAU
      GO TO 102
   21 CMKWHR= ANN*FACT*.15855*ESC1/TAU
      FVARL= ANN*RATE*ARL*DISC1
      IF (Z.GT.00001 .OR.Z.LT.-.00001) FVARL=ANN*RATE*(DISC1-ESC1)/Z
      GO TO 102
   31 CMKWHR= DEP*FACT*.15855/(TAU*ERL)
      FVARL=DEP*DISC1
      GO TO 101
   51 CMKWHR= DEP*FACT*.15855*(1./TAU-RET)/ERL
```

```
      FVARL=DEP*ESC1
      RTN=DEP*(X*TAU-Y)*(ESC1-1.)/Y
      GO TO 101
   61 CMKWHR= ANN*FACT*.15855/TAU
      FVARL=ANN*RATE*ARL
      GO TO 102
   71 CMKWHR= ANN*FACT*.15855*ESC1/TAU
      FVARL=ANN*RATE*ARL
      IF (Y.LT.-.0001.OR.Y.GT..0001) FVARL=ANN*RATE*(1.+Y)*(ESC1-1.)/Y
      GO TO 102
  101 DIS2=(1.+X2*TAU)**ERL
      IF(DIS2.LT..9999.OR.DIS2.GT.1.0001) GO TO 111
      CRF=DEP/ERL
      GO TO 102
  111 CRF=DEP*X2*TAU*DIS2/(DIS2-1.)
      CMKWHR=(FACT*.15855)*(CRF/TAU-DEP*RET/ERL)
  102 CASH=(CRF*ARL/TAU-RTN)+ANN*ESCL*RATE*ARL/TAU
      RETURN
      END
*DECK MONEY
C-
C-----------------------------------------------------------------------
C-
      SUBROUTINE MONEY(X,Y,Z,T,RL,D,IFND,CRF,DEP)
      COMMON/ TRANS/ IDUM,MNY,IDUM1,TRSU,DUM(3),X2,Y2,DUMMY(2),FVCOST,
     *DUM1,CASH,DUM2(2),CMKWHR,DUMMY1(50)
C-
C-   SUBROUTINE *MONEY* TRANSLATES THE MONEY VALUES TO BE OUTPUT FROM
C-   UNADJUSTED DOLLARS TO THE APPROPRIATE VALUES FOR THE MONEY
C-   COMPARISON DESIRED.
C-
C-    SUBROUTINE *MONEY* CALLED BY:
C-         * COST *
```

```
C-     SUBROUTINES CALLED BY *MONEY*:
C-          NONE
C-
       TAU=1.-T
       GO TO (100,1,2,3),MNY
     1 A=Y
       GO TO 4
     2 A=Z
       GO TO 4
     3 A=Y2
     4 YR=TRSU+RL+D
       F=(1.+A)**YR
       FVCOST=FVCOST/F
       CMKWHR=CMKWHR/F
       GO TO (10,20,10,10,50,10,20),IFND
    10 IF (A.GT.-.00001.AND.A.LT..00001.OR. RL.GT.-.1.AND. RL.LT..1) GO T
      *O 99
    12 CASH=CASH*(1.-(1.+A)**(-RL))/A/RL
       GO TO 99
    20 IF ( RL.LT..1.AND. RL.GT.-.1) GO TO 99
       IF(A.LT.Y+.0001.AND.A.GT.Y-.0001) GO TO 21
       IF (Y.LT..0001.AND.Y.GT.-.0001) GO TO 12
       RAT=(1.+Y)/(1.+A)
       CASH=CASH*(RAT** RL-1.)*Y/(Y-A)/((1.+Y)** RL-1.)
       GO TO 99
    21 IF (Y.GT..0001.OR.Y.LT.-.0001) CASH=CASH*Y*RL/((1.+Y)*(F-1.))
       GO TO 99
    50 IF (A.LT..00001.AND.A.GT.-.00001) GO TO 99
       TERM2=RL
       IF (Y.GT..00001.OR.Y.LT.-.00001) TERM2=(1.+Y)**RL/Y
       TERM1=RL
       IF (Y.LT.A-.0001.OR.Y.GT.A+.0001) TERM1=(((1.+Y)/(1.+A))**RL-1.)
      */(Y-A)
```

```
      CASH=CASH+CRF*((1.-(1.+A)**(-RL))/A-RL)+DEP*(Y-X*TAU)*(1.+Y)*
     *(TERM1-TERM2)
   99 CASH=CASH*(1.+A)**(-TRSU)
  100 RETURN
      END
*DECK TIMEFN
C-
C------------------------------------------------------------------------
C-
      SUBROUTINE TIMEFN (D,IDECOM,DCC,IRT)
      COMMON/ TIME/ BP(2,6),DC(3,2,6)
C-
C-    TIMEFN GIVES THE CAPITAL COSTS FOR FINAL DISMANTLING AS
C-    A FUNCTION OF TIME AFTER INITIAL DECOMMISSIONING, REACTOR TYPE,
C-    AND MODE OF DECOMMISSIONING.  THIS ROUTINE CAN STAND ON ITS OWN.
C-
C-    SUBROUTINE *TIMEFN* CALLED BY:
C-         * COST *
C-    SUBROUTINES CALLED BY *TIMEFN*:
C-            NONE
C-
      IF (IDECOM.LT.2) GO TO 1
      ID=IDECOM
      IF (ID.GT.3) ID=ID-2
      ID=ID-1
      DCC=DC(1,ID,IRT)
      IF (D.GE.BP(1,IRT)) DCC=DC(2,ID,IRT)
      IF (D.GE.BP(2,IRT)) DCC=DC(3,ID,IRT)
      RETURN
    1 DCC=0.
      RETURN
      END
*DECK POSDEC
```

```
C-
C-----------------------------------------------------------------------
C-
      SUBROUTINE POSDEC(X,Y,T,IDECOM,IFND,ARL,CAPITL)
      COMMON/ TRANS/ IRT,IDUM(2),TRSU,ERL,PD,DUM(9),FVARL,DUMMY(51)
      COMMON/ CLIST/ CINIT(5,7),ACST(5),ACSTLL(10)
C-
C-         SUBROUTINE POSDEC DETERMINES WHICH (IF ANY) METHODS OF
C-    DECOMMISSIONING CAN BE PAID FOR BY EXISTING FUNDS AT ARL+TRSU.
C-   FUNDS CAN BE INPUT DIRECTLY IN CAPITL OR THE ROUTINE WILL CALCULATE
C-   THE FUNDS THAT EXIST ON ITS OWN.  THIS ROUTINE CAN RUN OUTSIDE OF
C-   -DECOST- WITHOUT MODIFICATION.  THE MONEY MUST BE IN UNADJUSTED
C-   DOLLARS.  THIS ROUTINE CANNOT BE APPLIED TO LLW BURIAL SITES.
C-
C-    SUBROUTINE *POSDEC* CALLED BY:
C-         -DECOST-
C-    SUBROUTINES CALLED BY *POSDEC*:
C-         * COST *
C-         *SUBDLY*
C-
      TAU=1.-T
      I=0
      Z=(X*TAU-Y)/(1.+Y)
      IF(CAPITL.GT.0.) GO TO 1
      CALL COST(X,Y,T,IDECOM,IFND,ARL,PD,0)
      GO TO 2
    1 FVARL=CAPITL
    2 ESC=(1.+Y)**(ARL+TRSU)
      IF(Y.GE.X*TAU-.00001) GO TO 8
      DO  3 K=1,3
C-
C-         THIS SECTION IS FOR INDEFINITE MOTHBALLING, INDEFINITE
C-    ENTOMBMENT, AND DISMANTLING.
```

```
C-
      ID=K+1
      IF(ID.EQ.4) ID=1
      XINIT=(CINIT(ID,IRT)+ACST(ID)/Z)*TAU*ESC
      IF(FVARL.LT.XINIT-.001) GO TO 3
      I=1
      IF(K.EQ.3) GO TO 6
      IF (K.EQ.2) GO TO 4
      PRINT 211
C-
C-         THIS SECTION IS FOR DELAYED ENTOMBMENT.
C-
      CALL SUBDLY(X,Y,TAU,1,K,ESC,IRT,FVARL,DELAY)
      IF(DELAY.LT.-.1) GO TO 5
      IF (DELAY.GT.1000.) GO TO 3
      PRINT 212,DELAY
      GO TO 5
C-
C-         THIS SECTION IS FOR DELAYED DISMANTLING.
C-
    4 PRINT 214
    5 CALL SUBDLY(X,Y,TAU,2,K,ESC,IRT,FVARL,DELAY)
      IF(DELAY.LT.-.1.OR.DELAY.GT.1000.) GO TO 3
      IF (K.EQ.1) GO TO 7
      PRINT 215,DELAY
      GO TO 3
    7 PRINT 213,DELAY
      GO TO 3
    6 PRINT 216
    3 CONTINUE
C-
C         THIS SECTION IS FOR NO DECOMMISSIONING POSSIBLE.
C-
```

```
      IF (I.EQ.0) PRINT 210
      RETURN
    8 XINIT=CINIT(1,IRT)*TAU*ESC
      IF(FVARL.LT.XINIT-.001) GO TO 9
      PRINT 216
      RETURN
    9 PRINT 210
      RETURN
  210 FORMAT(15X,'CANNOT PAY FOR ANY DECOMMISSIONING')
  211 FORMAT(15X,'CAN MOTHBALL INDEFINITELY AT ARL')
  212 FORMAT(15X,'CAN MOTHBALL AT ARL AND ENTOMB INDEFINITELY AFTER',F6.
     *0,' YEARS')
  213 FORMAT(15X,'CAN MOTHBALL AT ARL AND DISMANTLE AFTER',F6.0,' YEARS'
     *)
  214 FORMAT(15X,'CAN ENTOMB INDEFINITELY AT ARL')
  215 FORMAT(15X,'CAN ENTOMB AT ARL AND DISMANTLE AFTER',F6.0,' YEARS')
  216 FORMAT(15X,'CAN DISMANTLE AT ARL')
      END
*DECK SUBDLY
C-
C-----------------------------------------------------------------------
C-
      SUBROUTINE SUBDLY(X,Y,TAU,INDEX,I,ESC,IRT,FVARL,DELAY)
      COMMON/ CLIST/ CINIT(5,7),ACST(5),ACSTLL(10)
      COMMON/ TIME / BP(2,6),DC(3,2,6)
C-
C-    SUBDLY CALCULATES THE DELAY TIME TO FINAL DECOMMISSIONING GIVEN
C-    THE INITIAL MODE (I) AND FINAL MODE (INDEX) OF DECOMMISSIONING AND
C-    THE FUNDS IN THE BANK (FVARL) AT INITIAL DECOMMISSIONING.  THIS
C-    ROUTINE CAN STAND ON ITS OWN.
C-
C-    SUBROUTINE *SUBDLY* CALLED BY:
C-         *POSDEC*
```


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```
C-     SUBROUTINES CALLED BY *SUBDLY*:
C-             NONE
C-
       I2=2
       INITD=I+1
       Z=(X*TAU-Y)/(1.+Y)
       YINIT=(CINIT(INITD,IRT)+ACST(INITD)/Z)*TAU*ESC
       IF(FVARL.LT.YINIT) GO TO 3
       DENOM=ALOG(1.+X*TAU)-ALOG(1.+Y)
       PLUS1=ALOG(ESC)-ALOG(FVARL-YINIT)
       IF(INDEX.LT.2) GO TO 2
C-
C-          DELAYED DISMANTLING
C-
       PLUS=(DC(1,I,IRT)-ACST(INITD)/Z)*TAU
       IF (PLUS.LE.0.) GO TO 3
       DELAY=(ALOG(PLUS)+PLUS1)/DENOM
       IF (DELAY.LT.BP(1,IRT)) RETURN
C-
C-     TO EXTEND TO MORE BREAKPOINTS, INCREASE I2 STOP VARIABLE TO THE
C-     NUMBER OF BREAKPOINTS.
C-     DO 4 I2=2,2
C-
       PLUS=(DC(I2,I,IRT)-ACST(INITD)/Z)*TAU
       IF (PLUS.LE.0.) GO TO 1
       DELAY=(ALOG(PLUS)+PLUS1)/DENOM
       IF(DELAY.LT.BP(I2-1,IRT)) GO TO 1
       IF(DELAY.LT.BP(I2,IRT)) RETURN
     4 CONTINUE
       PLUS=(DC(I2+1,I,IRT)-ACST(INITD)/Z)*TAU
       IF (PLUS.LE.0.) GO TO 5
       DELAY=(ALOG(PLUS)+PLUS1)/DENOM
       IF (DELAY.GT.BP(I2,IRT)) RETURN
```

```
    5 DELAY=BP(I2,IRT)
      RETURN
    1 DELAY=BP(I2-1,IRT)
      RETURN
C-
C-          DELAYED ENTOMBMENT
C-
    2 PLUS=(CINIT(3,IRT)-CINIT(2,IRT)+(ACST(3)-ACST(2))/Z)*TAU
      IF (PLUS.LE.0.) GO TO 3
      DELAY=(ALOG(PLUS)+PLUS1)/DENOM
      RETURN
    3 DELAY=-1.
      RETURN
      END
..
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16. ABSTRACT *(200 words or less)*

When a nuclear facility reaches the end of its useful life, it must be placed in a condition such that the public continues to be protected from the radioactive hazards associated with the site. The process of returning the site to these conditions is called decontamination and decommissioning or just decommissioning.. The process includes the removal of the radioactively contaminated and activated materials from the site to appropriate disposal sites or the containment of the materials away from the general public.

One of the major controversies surrounding the decommissioning of nuclear facilities is the lack of financial information on just what the eventual costs will be. The DECOST program package is intended to allow planning to reduce the costs and financial risks of all types of nuclear facilities, and allow wide ranging study of the various options available when planning for decommissioning of nuclear facilities.

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