3 3679 00049 3892

User Manual for Pactolus: A Code for Computing Power Costs

H. D. Huber
C. H. Bloomster

February 1979

Prepared for
the U.S. Department of Energy
under Contract EY-76-C-06-1830

Pacific Northwest Laboratory
Richland, Washington 99352

CONTENTS

LIST OF FIGURES	v
LIST OF TABLES	v
1.0 INTRODUCTION	1
2.0 DESCRIPTION OF PROGRAM	5
3.0 INPUT DATA TO PACTOLUS	11
3.1 PREPARATION OF FOSSIL INPUT DATA	11
3.1.1 Fossil Input Data Format	27
3.1.2 Fossil Test Case Input	33
3.1.3 Other Energy System Input	36
3.2 PREPARATION OF NUCLEAR INPUT DATA	37
3.2.1 General Reactor Parameters	39
3.2.2 Reactor Fuel Burnup Data	42
3.2.3 Nuclear Fuel Cycle and General Control Parameters	49
3.2.4 Financial and Tax Structure	68
3.2.5 Isotope Prices and Cost Schedule for Nuclear Fuel Cycle Processes	70
3.2.6 Nuclear Input Data Format	75
3.2.7 Nuclear Test Case Input	93
4.0 OUTPUT RESULTS FROM PACTOLUS	101
4.1 DESCRIPTION OF FOSSIL OUTPUT	101
4.2 FOSSIL TEST CASE OUTPUT	109
4.3 DESCRIPTION OF NUCLEAR OUTPUT	119
4.4 NUCLEAR TEST CASE OUTPUT	135
REFERENCES	157
ACKNOWLEDGEMENTS	159

LIST OF FIGURES

1	Executive Flow Diagram of PACTOLUS	6
2	Detailed Flow Diagram of PACTOLUS	9
3	Fossil Plant Deck Setup for PACTOLUS	12
4	Piece-Wise Linear Approximation to Capacity Factor Curve	14
5	Fossil Test Case Input	35
6	Nuclear Plant Deck Setup for PACTOLUS	38
7	Uranium Fuel Cycle for Light Water Reactor	50
8	Shipping and Process Time Sequences and Schedule of Events in Nuclear Fuel Cycle	58
9	Nuclear Test Case Input	95
10	Fossil Test Case Output	111
11	Nuclear Test Case Output	137

LIST OF TABLES

1	Fossil Plant Input Data Format to PACTOLUS	29
2	Nuclear Plant Input Data Format to PACTOLUS	77

User Manual for PACTOLUS:
A Code for Computing Power Costs

1.0 INTRODUCTION

PACTOLUS^(a) is a computer code for calculating the cost of generating electricity. The code was originally developed at the Pacific Northwest Laboratory (PNL)^(b) in 1967 for the U.S. Atomic Energy Commission. Since that time, PACTOLUS has been used extensively at PNL and elsewhere. Since its original documentation, PACTOLUS has undergone numerous modifications to improve its analytical capabilities and report writing clarity. This user manual, which includes the latest modifications, provides the first updating of the PACTOLUS documentation since 1970.

The current version of PACTOLUS is a powerful analytical tool for energy cost analysis. Through appropriate definition of the input data, PACTOLUS can calculate the cost of generating electricity from a wide variety of power plants, including nuclear, fossil, geothermal, solar, and other types of advanced energy systems.

The purpose of PACTOLUS is to develop cash flows and calculate the unit busbar power cost (mills/kWh) over the entire life of a power plant. The cash flow information is calculated in PACTOLUS by two principal models: the Fuel Model and the Discounted Cash Flow Model. The Fuel Model is an engineering cost model which calculates the cash flow for the fuel cycle costs over the project lifetime based on input data defining the fuel material requirements, the unit costs of fuel materials and processes, the process lead and lag times, and the schedule of the capacity factor for the plant. For nuclear plants, the Fuel

-
- (a) The name PACTOLUS is derived from the Pactolus river in Lydia, Asia Minor, which is famous for its golden sands. In mythology, it is supposed to have run gold, hence the connotation of cash flow.
- (b) Pacific Northwest Laboratory is operated for the Department of Energy by Battelle Memorial Institute.

Model calculates the cash flow for the entire nuclear fuel cycle. For fossil plants, the Fuel Model calculates the cash flow for the fossil fuel purchases.

The Discounted Cash Flow Model combines the fuel costs generated by the Fuel Model with input data on the capital costs, capital structure, licensing time, construction time, rates of return on capital, tax rates, operating costs, and depreciation method of the plant to calculate the cash flow for the entire lifetime of the project. The financial and tax structure for both investor-owned utilities and municipal utilities can be simulated through varying the rates of return on equity and debt, the debt-equity ratios, and tax rates.

The Discounted Cash Flow Model uses discounted cash flow analysis to calculate the unit busbar cost of power based on the principal that the present worth of the revenues will be equal to the present worth of the expenses including the return on investment over the economic life of the project. The cost of power can be derived either as a single levelized cost for the project lifetime or as an annual cost in current dollars for each year of the project lifetime. The cost data can be input either in constant dollars referenced to a base year or in current (escalated) dollars provided that the two are not intermixed in the input data.

Two earlier publications^(1,2) described a user manual and the theoretical concepts for the original version of PACTOLUS. The current user manual explains how to prepare the input data, execute cases, and interpret the output results with the updated version of PACTOLUS. It does not serve as a programmer's manual for modifying the code. The input data and output results are illustrated for two test cases, one fossil and one nuclear, to aid users in applying the code.

This user manual is comprised of four sections. Section 1 introduces the user to the background and purpose of the code and the scope of the user manual. Section 2 provides an overview of the code. Section 3 describes in detail the preparation of the input data for a fossil plant and a nuclear plant. This section includes two tables that describe the input data format for fossil and nuclear plants and a listing of the input data for one fossil and one nuclear

test case. This section also briefly describes how the code can be applied to calculate the cost of power from other advanced energy systems through appropriate definition of the input data. Section 4 lists and explains the output obtained from the fossil test case and nuclear test case defined in Section 3.

2.0 DESCRIPTION OF PROGRAM

The executive flow diagram for PACTOLUS is shown in Figure 1. PACTOLUS is composed of two main components: the Fuel Model and the Discounted Cash Flow Model. The Fuel Model is composed of two parts according to plant type. The Fuel Model for nuclear plants calculates the cash flow for the entire nuclear fuel cycle. The Fuel Model for fossil plants calculates the cash flow for the fossil fuel purchases. The Discounted Cash Flow Model combines the fuel costs from the Fuel Model with the powerplant capital costs and operating expenses to generate the cash flow for the powerplant. Based on the powerplant cash flow and the electricity generated, the unit busbar cost of electricity is calculated by equating the present worth of the revenues and expenses.

The nuclear fuel cycle consists of the processing of nuclear fuel from its initial state as a uranium or thorium ore through its irradiation in the nuclear reactor and its subsequent treatment after discharge from the reactor. Through appropriate definition of the input data, the Fuel Model for nuclear plants can calculate the cash flow for a wide variety of nuclear fuel cycles, including fuel cycles for light water reactors, heavy water reactors, high temperature reactors, and fast breeder reactors. The uranium fuel cycle with uranium and plutonium recycle for a light water reactor is described in detail in Section 3.2.

The principal input requirements for calculating the cash flow of the nuclear fuel cycle are the reactor burnup data, the unit cost schedules of fuel materials and processes in the fuel cycle, the shipping times and process times, and the schedule of the capacity factor for the plant. The reactor burnup data consist of the material balances of reactor fuel isotopes at charge times and discharge times over the reactor operating lifetime. These data, which are generated externally from reactor fuel burnup codes or obtained from historical records of operating reactors, are read by a preprocessing subroutine in PACTOLUS called CLOTHO. Subroutine CLOTHO adjusts the charge times and discharge times of the burnup data to account for the schedule of the capacity factor defined for the plant. The adjusted burnup data are used by the Fuel Model to calculate the cash flow for the nuclear fuel cycle.

FIGURE 1. Executive Flow Diagram of PACTOLUS

Fuel cycle costs prior to irradiation are calculated for the purchase of fuel materials, uranium enrichment, fabrication of fuel elements, and shipping of fuel between processing locations. Fuel cycle costs after irradiation are calculated for shipping and treatment of the discharged fuel. The discharged fuel is either shipped to a chemical reprocessing plant or stored at the reactor site prior to shipment without reprocessing to a waste storage site. If the discharged fuel is chemically reprocessed, credits are received for the residual values in the irradiated fuel.

The fuel cycle costs are calculated using unit cost data input for each process and material flow requirements calculated in the Fuel Model. The times at which the costs and credits are incurred in the cash flow accounting for the fuel cycle are calculated in the Fuel Model from the charge and discharge times of the adjusted reactor burnup data and input shipping and process times in the fuel cycle.

The Fuel Model for fossil plants calculates the cash flow for the fossil fuel purchases. The principal input requirements are the fuel heat rate, the initial fuel inventory, the unit cost schedule of the fuel, the plant size (MWe), and the schedule of the capacity factor for the plant. The quantity (MBtu) of fuel purchased in each year is calculated based on the plant size, the plant capacity factor in that year, and the heat rate of the fuel. The cost (\$million) of the fuel purchased in each year is calculated based on the quantity of fuel purchased and the unit cost of the fuel in that year.

The Discounted Cash Flow Model combines the fuel costs generated by the Fuel Model with the powerplant capital costs, capital structure, licensing time, construction time, rates of return on capital, tax rates, operating (O&M) costs, and depreciation method to calculate the cash flow for the powerplant. Based on the powerplant cash flow and the electricity generated, the unit busbar cost of electricity is calculated by using discounted cash flow analysis. In the Discounted Cash Flow Model, all costs and revenues are assumed to be incurred at midyear. The cost of electricity can be computed either as a single levelized cost or as an annual cost in current (escalated) dollars for each year of the powerplant lifetime.

The PACTOLUS code is programmed in FORTRAN IV and is currently operational on three computer installations: the CDC Cyber 74 and UNIVAC 1100/44 at PNL and the IBM 370/168 at DOE headquarters. The code is designed in modular fashion using 41 subroutines with approximately 6000 FORTRAN statements. The flow diagram in Figure 2 shows the sequence of major subroutines called by the main program, the Fuel Model, and the Discounted Cash Flow Model.

Three important computer resources used by a computer code are the computer memory requirements, computer time, and auxiliary storage requirements. The computer memory requirements of PACTOLUS depend upon the program dimensions. The current dimensions provide for simulating up to 60 years of project lifetime. This includes the licensing time, construction time, shipping and process times in the nuclear fuel cycle, and plant operating lifetime. Up to 10 years are dimensioned for the plant licensing time. The construction time, which is assumed to run concurrently with the licensing time, can be either greater than or less than the licensing time in the code. With the current dimensions, the PACTOLUS code requires approximately 52,000 decimal words of computer memory on the Cyber 74 computer.

The PACTOLUS code requires 34 seconds to compile on the FTN version 4.5 compiler at optimization level 0 on the CDC Cyber 74 computer. Typical sample cases require approximately 2 seconds of CPU time to execute on the Cyber 74 computer.

The auxiliary storage requirements consist of one disk or tape file for intermediate storage of the adjusted reactor burnup data calculated by subroutine CLOTHO for use by the Fuel Model for nuclear plants. A disk file has commonly been used for this purpose at PNL.

FIGURE 2. Detailed Flow Diagram of PACTOLUS

3.0 INPUT DATA TO PACTOLUS

3.1 PREPARATION OF FOSSIL INPUT DATA

Figure 3 shows the order of the cards in a deck setup for calculating fossil power costs with PACTOLUS. Table 1 in Section 3.1.1 describes the input data format for a fossil plant. This information includes the card type number, general card description and FORTRAN format, the number of cards of that type, the card field, the data format (H is alphanumeric, I is integer, R is floating point), the data columns, a description of the information in the data columns, and the FORTRAN name used for the data in the program.

The card type number is provided as a reference aid in relating the user manual to the preparation of input data decks. The type number is not punched on the data cards. Only the data are punched in the specified columns shown in Table 1.

All integer data should be right-adjusted in the columns, all alphanumeric data left-adjusted, and floating point data should be punched with a decimal point.

The escalation rates in Table 1 allow the user to escalate the operating (O&M) costs and fuel costs at a compound rate over the project lifetime to reflect a combination of inflation, supply/demand, and other effects such as environmental and engineering changes. With this definition of escalation, inflation is just one of several factors that can contribute to cost or price escalation.

In preparing an input deck, it is mandatory that the cards of each type be present in the proper order. Multiple fossil cases can be input to PACTOLUS in one deck setup by repeating the set of cards 1-9A or 9B before the end-of-file card in the input data stream shown in Figure 3.

A sample input data deck for calculating fossil power costs is shown for an 800 MWe coal plant in Figure 5 in Section 3.1.2. The output generated by PACTOLUS using this input data is described in Section 4.1.

FIGURE 3. Fossil Plant Deck Setup for PACTOLUS

Referring to Table 1, we shall now discuss the preparation of the fossil input data for the operation of PACTOLUS. No comment is made on parameters that are self-explanatory. The control cards are specific to the user's computer installation and are not discussed here.

Card Type 1 -- Plant Type and Title Identification

Card Type 1 starts an input data deck by identifying the plant type and case title. The plant abbreviation FOSS is punched in columns 1-4 to calculate fossil power costs with PACTOLUS. Any title punched in columns 15-80 will appear as a heading of the output.

Card Type 2 -- Capacity Factor History

Card Type 2 allows up to a maximum of six X-Y data points, (X_1, Y_1) , (X_2, Y_2) , ..., (X_6, Y_6) , to describe the capacity factor history during the operation of the plant. The abscissa X defines the time in years from power production startup and the ordinate Y defines the capacity factor as a fraction at time X. The initial time X_1 must be 0. The user can enter six or less data points depending upon the number of points required to approximate the capacity factor curve to the user's desired accuracy by straight-line interpolation. The last time X_N , $(N \leq 6)$, must be greater than or equal to the plant operating lifetime.

An example of a piece-wise linear approximation to a capacity factor curve is shown in Figure 4. This approximation can be specified by the following five points:

(0.,.25), (1.,.50), (2.,.65), (15.,.65), (30.,.40)

In the discounted cash flow analysis, the code uses the average annual capacity factor, which it obtains by linearly interpolating the capacity factor data points to midyear. For example, the average annual capacity factor is 0.375 in the first year, 0.575 in the second year, and so forth.

The code linearly interpolates the capacity factor data points according to the following equation:

$$\text{Capacity Factor (time = } t) = Y_n + B(t - X_n)$$

FIGURE 4. Piece-Wise Linear Approximation to Capacity Factor Curve

where

Y_n = capacity factor at time X_n

X_n = time defined on Card Type 2, immediately preceding t , i.e., $X_n < t$

B = slope calculated in the code, i.e.,

$$\frac{Y_{n+1} - Y_n}{X_{n+1} - X_n}, \quad X_n < t < X_{n+1}$$

t = current time, years since power production startup.

Card Type 3 -- Control and Fuel Card

Card Type 3 controls several options available to the user. This includes two methods for depreciating the capital expenses, the fuel inventory accounting option, and two methods for calculating the power costs. The depreciation methods available are the straight line method and the sum-of-years-digits method. The fuel inventory accounting option should currently be specified as the direct fuel expense method (NOP=5). With this method of fuel inventory valuation, the annual fuel expenses are calculated as the sum of annual fuel purchases and the straight-line depletion of the initial fuel inventory over the operating lifetime of the plant. Since the annual fuel expenses are an allowable deduction from the federal taxable income, the inventory accounting method affects the income tax payments and net profit. Other common methods of inventory valuation which are programmed into the code but not operational are as follows: first in-first out (FIFO), last in-first out (LIFO), weighted average cost, and standard cost.

The busbar power costs can be calculated as either a lifecycle levelized cost or an annual current dollar cost. The levelized method calculates a single power cost which will recover all costs over the life of the plant. The levelized cost is expressed in units of mills/kWh. This method is illustrated by the nuclear test case input in Section 3.2.7 and nuclear output in Section 4.4.

The annual current dollar method calculates the year-by-year power cost in current (escalated) dollars. The current dollar costs are also expressed in units of mills/kWh. The current dollar method requires that the user also specify the annual inflation rate, the after-tax discount rate, and the base year for calculating the equivalent levelized cost of power in constant dollars of the base year. This method is illustrated by the fossil test case input in Section 3.1.2 and fossil output in Section 4.2.

Card Type 3 also defines the plant size (MWe) and several fuel parameters. These include the number (NCDS) of Type 9A or 9B cards for defining the fuel cost schedule, the heat rate of the fuel (Btu/kWh), and the initial fuel inventory (days) at 100% capacity factor (full power). The initial fuel inventory is

assumed to be purchased at midyear in the final year of plant construction.^(a) This inventory is financed with capital using the same bond-equity ratio, bond interest rate, and after-tax return on equity as for the capital expenses.

Card Type 4 -- Capital Structure and Financial Parameters

Card Type 4 defines the capital structure and several other financial parameters. The capital cost of the plant is input in dollars per kilowatt. The capital structure is described by defining the fraction of initial investment in bonds, the bond interest rate (fractional), and the after-tax rate of return on equity (fractional).

Other financial parameters specified on this card include the interim capital replacement rate per year (fraction of the plant capital cost) and the percentage plant investment tax credit. The investment tax credit is designed to reduce tax liability by a specified percentage of the capital investment and interim capital replacements in any given year.

Card Type 5 -- Fixed and Variable O&M Costs

Card Type 5 is the operation and maintenance (O&M) cost card. It defines the annual plant fixed O&M cost, excluding insurance, and the annual plant variable O&M cost. The latter is input by the user at 100% capacity factor and then multiplied by the average annual capacity factor in the code to obtain the annual variable O&M cost.

As an option, both types of O&M costs can be escalated to reflect the combined effects of inflation, supply/demand, and other effects such as environmental and engineering changes. The user specifies a separate compound escalation rate and base year for each, the latter corresponding to the initial fixed and variable O&M cost entered in columns 1-10 and 31-40, respectively. The O&M costs are calculated in PACTOLUS at midyear.

-
- (a) It is assumed that the initial fuel inventory will have zero salvage value in the final year of plant operation and that the initial fuel inventory acts as a reserve which is depleted through wastage and losses over the life of the plant.

Card Type 6 -- Taxes and Insurance

Card Type 6 defines taxes and insurance. This includes the federal income tax, state income tax, state gross revenue tax, and property tax on the net plant value and initial fuel inventory. Property insurance is also defined as a fraction of the net plant value and initial fuel inventory.

The last item [D(24)] on the card provides an option to define a salvage credit or decommissioning cost for the plant. A salvage credit is defined by setting D(24) to a positive dollar value. A decommissioning cost is defined by setting D(24) to a negative dollar value. If the parameter D(24) is set to a nonzero value, PACTOLUS will generate the cash flow information one year past the final year of power production to provide for the salvage or decommissioning of the plant.

Card Type 7 -- Startup and Times Card

Card Type 7 defines the power production startup year, the depreciable life, construction time, operating life, and licensing time for the plant. The latter four times must be defined as integral real numbers in years (not fractional years). The power production startup date is assumed to be at January 1 of the startup year.

The current program dimensions allow up to a maximum of 10 years for plant licensing time. If more licensing time is required, the user must modify the code by increasing the dimensions of the licensing cost variable COSTLC(I) described on the next card. The construction time, which is assumed to run concurrently with the licensing time, can be either greater than or less than the licensing time in the code.

The PACTOLUS code distributes the capital cost of the plant over the construction years using an expenditure profile expressed by the following continuous distribution function:

$$C(t) = 100/[1 + \exp K(a-t)]$$

where:

$C(t)$ = cumulative percent expenditure at time t

$K = 0.0847$

a = 60 percent time point of the construction period

t = time in years from the start of construction, $t \leq TCONST$

Card Type 8 -- Licensing Costs (Can Be a Blank Card)

Card Type 8 defines the licensing costs in the years specified for the licensing time (TLICEN) on Card Type 7. This card should be present as a blank card if the licensing time on Card Type 7 is 0. The licensing costs are entered in millions of dollars, starting with the first year prior to power production startup and continuing up to TLICEN years prior to power production startup.

If less than 10 years are specified for the licensing time on Card Type 7, any columns remaining on Card Type 8 after defining licensing costs through TLICEN years should be left blank.

Card Types 9A and 9B -- Fuel Cost Schedule

The fuel cost schedule is defined using Card Types 9A or 9B. Card Type 9A is used if NCDS is set to 1 on Card Type 3; Card Type 9B is used if NCDS is set greater than 1. These card types provide two alternative means for defining the fuel cost schedule.

PACTOLUS calculates the fuel costs at the time in the year in which the costs occur. The fossil fuel is assumed to be purchased at midyear (e.g., 1985.5, 1986.5, etc.), so the fossil fuel costs are calculated in PACTOLUS at midyear. As will be seen later in the description of Figure 8 in Section 3.2.3, the nuclear fuel cycle costs occur throughout the year (e.g., 1979.43, 1979.89, 1983.59, etc.) and so are calculated exactly at the time in the year in which the costs occur (i.e., 1979.43, 1979.89, 1983.59, etc.).

Card Type 9A provides for a compound fuel escalation rate. This card requires that the user define a base year, the reference cost of fuel in the base year ($\$/MBtu$), and a compound fuel escalation rate (% per year). Card Type 9A allows the user to input the reference cost for any specific time during the base year, e.g., at time 1985.0 (January 1, 1985), 1985.5 (midyear of

1985), 1985.39, 1985.67, and so forth. The base year must be specified prior to or at the final year of plant construction, since the initial fuel inventory is assumed to be purchased in the final year of plant construction. Only one Type 9A card is used to define the fuel cost schedule.

If Card Type 9A is used to define the fuel cost schedule, PACTOLUS calculates the fuel costs as follows:

$$\text{Fuel Cost (time = } t) = \text{Fuel Cost (time = } t_0) * [1. + 0.01 * \text{Percent}]^{t-t_0}$$

where

Fuel Cost (time = t) = fuel cost at current time t

Fuel Cost (time = t_0) = fuel cost at base time t_0 defined on Card Type 9A

Percent = percent escalation rate defined on Card Type 9A

For example, assume that Card Type 9A is used to define the base year as 1985.0, the cost of fossil fuel in the base year as \$5/MBtu, and the compound escalation rate as 5%. The reference cost in the base year is then assumed to be at the beginning of the year, i.e., January 1, 1985. Then, PACTOLUS calculates fossil fuel costs at 1985.5 (midyear of 1985) and at 1986.5 (midyear of 1986) as follows:

$$\text{Fossil Fuel Cost at 1985.5} = 5. * [1.05]^{0.5} = \$5.12/\text{MBtu}$$

$$\text{Fossil Fuel Cost at 1986.5} = 5. * [1.05]^{1.5} = \$5.38/\text{MBtu}$$

An analogous definition of compound escalation rates can be formulated for nuclear fuel cycle costs using Card Type 31A described in Section 3.2.5.

Card Type 9B defines the fuel costs in successive calendar years. The number of Type 9B cards must equal NCDS. Each Type 9B card defines a calendar year and the cost of fuel (¢/MBtu) in that year.

Card Type 9B allows the user to either define the fuel costs in every calendar year or to skip some calendar years. PACTOLUS linearly interpolates between successive calendar years to obtain the fuel costs at the time in the year in which the fuel is purchased. For example, consider the cost schedule shown in the figure below in which the fuel cost is defined using Card Type 9B as \$5./MBtu at January 1, 1980 and \$10./MBtu at January 1, 1982.

Since the fossil fuel is assumed to be purchased at midyear, PACTOLUS linearly interpolates the fuel costs between January 1, 1980 and January 1, 1982 to obtain \$6.25/MBtu as the fuel cost at midyear of 1980 (i.e., 1980.5) and \$8.75/MBtu as the fuel cost at midyear of 1981 (i.e., 1981.5). An analogous definition of cost schedules using successive calendar years can be formulated for nuclear fuel cycle costs using Card Type 31B described in Section 3.2.5.

Card Type 9B allows the user the flexibility to input a wide variety of fuel cost schedules: specific fuel costs each calendar year, step function costs in successive calendar years, uniform annual increases or decreases through linear interpolation between specified years, or any combination of these schedules. The current program dimensions allow up to a maximum of 60 Type 9B cards. The first calendar year must be specified prior to or at the final year of plant construction; the last calendar year must be specified at one or more years after the final year of power production.^(a) The number

(a) For example, if 2009 is the final year of power production, the final purchase of fossil fuel is assumed to occur at 2009.5, so the code requires that fossil fuel costs be defined at 2010 (i.e., January 1, 2010) or beyond in order to interpolate fuel costs to 2009.5.

(NCDS) of Type 9B cards is left to the user's discretion, depending on the complexity of the fuel cost schedule. It should be pointed out that Card Type 9B allows the user to input costs for any specific time during a year, e.g., at time 1985.0, 1985.5, 1985.39, 1985.67, and so forth.

To illustrate the two methods for defining the fuel cost schedule, consider a fossil plant with the following construction, startup, and operating times together with the following four scenarios of fuel cost schedules.

Plant Construction, Startup, and Operating Times

Assume plant construction is completed in December, 1979 with power startup scheduled for January 1, 1980 and an operating lifetime of 30 years.

Scenario A

Fuel costs remain constant at a price of \$1/MBtu in constant 1978 dollars over the operating lifetime of the plant.

Scenario B

Fuel costs of \$1/MBtu at January 1, 1978 increase at a compound rate of 5% in constant 1978 dollars over the operating lifetime of the plant.

Scenario C

Fuel costs of \$1/MBtu at January 1, 1978 increase at a compound rate of 5% in current dollars over the operating lifetime of the plant.

Scenario D

Fuel costs change over the operating lifetime of the plant according to steps 1 through 12 defined as follows:

- 1) fuel costs of \$1/MBtu at January 1, 1978 remain constant through December 31, 1979
- 2) fuel costs increase linearly to \$1.50 at February 12, 1982
- 3) fuel costs remain constant at \$1.50 through December 31, 1985
- 4) fuel costs jump in a step-function fashion to \$2.00 at January 1, 1986
- 5) fuel costs remain constant at \$2.00 through October 25, 1990

- 6) fuel costs drop in a step-function fashion to \$1.83 at October 26, 1990
- 7) fuel costs remain constant at \$1.83 through December 31, 1991
- 8) fuel costs drop in a step-function fashion to \$1.77 at January 1, 1992
- 9) fuel costs decline linearly to \$1.50 at January 1, 1995
- 10) fuel costs remain constant at \$1.50 through December 31, 1995
- 11) fuel costs drop in a step-function fashion to \$1.00 at January 1, 1996
- 12) fuel costs remain constant at \$1.00/MBtu through December 31, 2009.

These steps are shown in the figure for the fuel cost schedule given below. Assume that all fuel costs are in constant 1978 dollars.

Referring to the above fossil plant, we shall now describe the methods for defining the four scenarios of fuel cost schedules using Card Type 9A or 9B. Following this description, the options for calculating either the levelized cost of power or the annual cost of power in current dollars using Card Type 3 are discussed.

Scenario A

The fuel cost schedule is defined using either Card Type 9A or 9B as described below.

- a) If Card Type 9A is used, set NCDS to 1 on Card Type 3 and define the following values for the parameters on Card Type 9A:

TIME(1) = 1978, FSCHED(1) = 100¢/MBtu, PCINFL = 0.

- b) If Card Type 9B is used, set NCDS to 2 on Card Type 3 and define the following values for the parameters on the two Type 9B cards:

Card 1 TIME(1) = 1978., FSCHED(1) = 100¢/MBtu

Card 2 TIME(2) = 2010., FSCHED(2) = 100¢/MBtu

Scenario B

The fuel cost schedule is defined using Card Type 9A as described below.

Set NCDS to 1 on Card Type 3 and define the following values for the parameters on Card Type 9A:

TIME(1) = 1978., FSCHED(1) = 100¢/MBtu, PCINFL = 5.

Scenario C

Scenario C is similar to Scenario B except that the fuel costs are defined in current dollars. The fuel cost schedule is defined using Card Type 9A exactly as in Scenario B.

Scenario D

Scenario D illustrates how to define the fuel cost schedule when the escalation rate is not constant and is both increasing and decreasing over the operating lifetime of the plant. The fuel cost schedule is defined using Card Type 9B as described below.

Set NCDS to 13 on Card Type 3 and define the following values for the parameters on the thirteen Type 9B cards:

<u>Card 1</u>	TIME(1) = 1978.,	FSCHED(1) = 100¢/MBtu
<u>Card 2</u>	TIME(2) = 1980.,	FSCHED(2) = 100¢/MBtu
<u>Card 3</u>	TIME(3) = 1982.12.,	FSCHED(3) = 150¢/MBtu
<u>Card 4</u>	TIME(4) = 1985.99.,	FSCHED(4) = 150¢/MBtu
<u>Card 5</u>	TIME(5) = 1986.,	FSCHED(5) = 200¢/MBtu
<u>Card 6</u>	TIME(6) = 1990.816.,	FSCHED(6) = 200¢/MBtu
<u>Card 7</u>	TIME(7) = 1990.817.,	FSCHED(7) = 183¢/MBtu
<u>Card 8</u>	TIME(8) = 1991.99.,	FSCHED(8) = 183¢/MBtu
<u>Card 9</u>	TIME(9) = 1992.,	FSCHED(9) = 177¢/MBtu
<u>Card 10</u>	TIME(10) = 1995.,	FSCHED(10) = 150¢/MBtu
<u>Card 11</u>	TIME(11) = 1995.99.,	FSCHED(11) = 150¢/MBtu
<u>Card 12</u>	TIME(12) = 1996.,	FSCHED(12) = 100¢/MBtu
<u>Card 13</u>	TIME(13) = 2010.,	FSCHED(13) = 100¢/MBtu

Referring to steps 7 and 8 in the figure for the fuel cost schedule in Scenario D, observe that the fuel cost was held constant at \$1.83 from October 26, 1990 through December 31, 1991 and then dropped in a step-function fashion to \$1.77 at January 1, 1992 by the use of Cards 7, 8, and 9. Note that 1982.12 was used to approximate February 12, 1982; 1990.816 was used for October 25, 1990; 1990.817 was used for October 26, 1990; and 1991.99 was used for December 31, 1991. Note also that if Card 8 were absent, the fuel costs would then decrease linearly from \$1.83 at October 26, 1990 to \$1.77 at January 1, 1992.

The fuel cost data for Scenarios A, B, and D are defined in constant 1978 dollars. Assume that the capital costs, O&M costs, and all other input costs are also consistently defined in constant 1978 dollars. Then the user can specify that PACTOLUS calculate either the levelized cost of power in constant 1978 dollars or the annual cost of power.

The levelized cost of power is the option most frequently selected when the cost data are in constant dollars. This option is selected by setting the

parameter IECOST to 0 on Card Type 3. The option to calculate the levelized cost of power is illustrated by the nuclear input data in Section 3.2.7 and the nuclear output in Section 4.4.

The annual cost of power can also be calculated for Scenarios A, B, and D by setting the parameter IECOST to 1, the overall inflation rate (OPCINF) to 0, the societal discount rate (SDRATE) to 0, and the base year (BASEYR) to 1978 on Card Type 3. Note that when the inflation rate is zero, constant dollars and current dollars are the same.

The fuel cost data for Scenario C are defined in current dollars. Assume that the capital costs, O&M costs, and all other input costs are also consistently defined in current dollars. Then the user can specify that PACTOLUS calculate either the levelized cost of power in current dollars or the annual cost of power in current dollars. The annual cost of power in current dollars is the option most frequently selected when the cost data are in current dollars.

The fuel cost data described for Scenario D can also be defined in current dollars. In this case, either the annual or the levelized costs of power can be calculated in current dollars.

The option to calculate the levelized cost of power in current dollars is selected by setting the parameter IECOST to 0 on Card Type 3. The option to calculate the annual cost of power in current dollars is selected by setting the parameter IECOST to 1 on Card Type 3 and defining the overall inflation rate (OPCINF), the societal discount rate (SDRATE), and the base year (BASEYR) on Card Type 3. The last three parameters enable PACTOLUS to also calculate the equivalent levelized cost of power in constant dollars of the base year. The option to calculate the annual cost of power in current dollars is illustrated by the fossil input data in Section 3.1.2 and the fossil output in Section 4.2.

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

10-1-10

SECTION 3.1.1

FOSSIL INPUT DATA FORMAT

10/10/10

10/10/10

10/10/10

10/10/10

10/10/10

10/10/10

10/10/10

10/10/10

10/10/10

10/10/10

10/10/10

10/10/10

10/10/10

TABLE 1. Fossil Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
1	Plant Type and Title Identification (A4,10X,16A4,A2)	1	1	H	1-4	Plant type, code FOSS for fossil plant	IPLYTP
			2		5-14	Not used	
			3	H	15-80	Case title identification	TITLE(I), I=1 to 17
2	Capacity Factor History (12F6.0)	1	1	R	1-6	Initial time on capacity factor curve, yrs from plant power production startup. (Initial time must be 0.)	X2(1)
			2	R	7-12	Initial capacity factor at time X2(1), fraction	Y2(1)
			3	R	13-18	Second time on capacity factor curve, yrs from startup	X2(2)
			4	R	19-24	Second capacity factor at time X2(2), fraction	Y2(2)
			.				
			11	R	61-66	Sixth time on capacity factor curve, yrs from startup	X2(6)
3	Control and Fuel Card (3I5,3F10.0,15,3F10.0)	1	1	I	5	Depreciation option: 1=straight line, 2=sum-of-years-digits	LL2
			2	I	10	Fuel inventory accounting option: Code 5 for direct fuel expense method	NOP
			3	I	11-15	Number of cards for fuel cost schedule. See Card Type number 9A and 9B. If NCDS = 1, use one Card Type 9A; if NCDS > 1, use NCDS cards of Card Type 9B.	NCDS
			4	R	16-25	Plant size, MWe	GMWE
			5	R	26-35	Heat rate of fuel, Btu/kWh	HEATRT
			6	R	36-45	Initial fuel inventory at 100% capacity factor, days	FINVDY

TABLE 1. (cont'd) Fossil Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
3	Control and Fuel Card (cont'd) (3I15,3F10.0,I5, 3F10.0)		7	I	50	Option for calculating cost of power: 0=levelized cost of power, 1=annual cost of power in current dollars	IECOST
			8	R	51-60	Overall inflation rate, % per yr. Used only if IECOST=1, to calculate equivalent levelized cost of power in constant dollars of the base year defined below.	OPCINK
			9	R	61-70	Societal discount rate, % per yr. Used only if IECOST=1, to calculate equivalent levelized cost of power in constant dollars of the base year defined below.	SDRATE
			10	R	71-80	Base year. Used only if IECOST=1, to calculate equivalent levelized cost of power in constant dollars of the base year. See Section (800) of fossil output shown in Section 4.2 for an illustration.	BASEYR
4	Capital Structure and Financial Parameters (6F10.0)	1	1	R	1-10	Capital cost of plant, \$/kWe	CPIKWE
			2	R	11-20	Fraction of initial investment in bonds	D(4)
			3	R	21-30	Interest rate on bonds, fractional	D(5)
			4	R	31-40	Earning rate on equity (after taxes), fractional	D(6)
			5	R	41-50	Interim capital replacement rate per year, fraction of plant capital cost	D(18)
			6	R	51-60	Plant investment tax credit, % per year	PIVTCF
5	Fixed and Variable O&M Costs (6F10.0)	1	1	R	1-10	Plant fixed O&M cost, \$/yr	BCYR
			2	R	11-20	Base year, used only if escalating plant fixed O&M cost by the escalation rate defined in the next data item	BPCINF
			3	R	21-30	Escalation rate for plant fixed O&M cost, % per yr. Used only if escalating plant fixed O&M cost	BPCINF
			4	R	31-40	Variable plant O&M cost (multiplied in the computer code by the average annual capacity factor to obtain the yearly cost), \$/yr	VCYR

TABLE 1. (cont'd) Fossil Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
5	Fixed and Variable O&M Costs (cont'd) (6F10.0)		5	R	41-50	Base year, used only if escalating variable plant O&M cost by the escalation rate defined in the next data item.	TVCYR
			6	R	51-60	Escalation rate for variable plant O&M cost, % per yr. Used only if escalating variable plant O&M cost.	VPCINF
6	Taxes and Insurance (6F10.0)	1	1	R	1-10	Federal income tax rate, fractional	D(7)
			2	R	11-20	State income tax rate, fractional	D(15)
			3	R	21-30	State gross revenue tax rate, fractional	D(16)
			4	R	31-40	Property tax on net plant value and initial fuel inventory, fractional	D(17)
			5	R	41-50	Property insurance on net plant value and initial fuel inventory, fractional	D(19)
			6	R	51-60	Net salvage value of plant, \$. Positive denotes salvage value. Negative denotes decommissioning cost.	D(24)
7	Startup and Times Card (5F10.0)	1	1	R	1-10	Plant power production startup year	TSTART
			2	R	11-20	Plant depreciable life, yrs. (not fractional)	D(9)
			3	R	21-30	Plant construction time (-0), yrs. (not fractional)	TCONST
			4	R	31-40	Plant operating lifetime, yrs. (not fractional)	TLIFE
			5	R	41-50	Plant licensing time, yrs. (not fractional)	TLICEN
8	Licensing Costs (10F8.0)	1	Blank card if TLICEN=0 on Card Type number 7				
			1	R	1-8	Licensing cost one year prior to power production startup, \$ millions	COSTLC(1)
			2	R	9-16	Licensing cost two years prior to power production startup, \$ millions	COSTLC(2)
			.			Repeat up to TLICEN years prior to startup. The current dimensions allow up to 10 years for licensing time.	.
			10	R	73-80	Licensing cost 10 years prior to power production startup, \$ millions	COSTLC(10)

TABLE 1. (cont'd) Fossil Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
	<u>Fuel Cost Schedule</u>					If NCDS=1 on Card Type number 3, use Card Type 9A. If NCDS=1 on Card Type number 3, use Card Type 9B.	
9A	Compound Escalation Rate (3F10.0)	1	1	R	1-10	Base year for escalating fuel cost	TIME(1)
			2	R	11-20	Cost of fuel in base year, ¢/MBtu	FSCHED(1)
			3	R	21-30	Escalation rate for escalating fuel cost, % per year	PCINFL
9B	Cost Schedule Versus Time (2F10.0)	NCDS				Repeat for I=1 to NCDS cards	
			1	R	1-10	Calendar year when this cost applies	TIME(I)
			2	R	11-20	Cost of fuel in calendar year, ¢/MBtu	FSCHED(I)

SECTION 3.1.2

FOSSIL TEST CASE INPUT

(1)	FOSS	COAL PLANT 800 MWE SAMPLE CASE									
(2)	0.	0.25	1.0	0.50	2.0	0.65	15.0	0.65	30.0	0.40	
(3)	2	5	1800.		9470.		100.		15.	7.	1985.
(4)	427.5	0.50		0.04		0.085		0.0035	4.		
(5)	10350000.	1985.		1.		5680000.	1985.		1.		
(6)	0.48	0.09		0.03		0.0320		0.0025	0.		
(7)	1985.	30.		3.		30.		5.			
(8)	0.2	0.6		1.0		0.75		0.5			
(9A)	1984.	100.		5.							

(1) Plant Type and Title Card

Foss Fossil Plant
Title "Coal Plant 800 MWe Sample Case"

(2) Capacity Factor Curve

The points which specify the capacity factor curve:
(0.,.25), (1.,.50), (2.,.65), (15.,.65), (30.,.40)

(3) Control and Fuel Card

2 Sum-of-years-digits depreciation
5 Direct fuel expense inventory accounting
1 Type 9A card for fuel cost schedule
800 Plant size (MWe)
9470 Heat rate of fuel (Btu/kWh)
100 Initial fuel inventory (days)
1 Calculate annual cost of power
5% Inflation rate
7% Discount rate
1985 Base year

(4) Capital Structure and Financial Parameters

427.5 Capital cost of plant (\$/kWe)
0.50 Fraction of investment in bonds
0.04 Bond interest rate (fraction)
0.085 Return rate on equity (fraction)
0.0035 Interim capital replacement rate (fraction)
4. Plant investment tax credit (percent)

(5) Fixed and Variable O&M Costs

\$10,350,000 Plant fixed O&M cost
1985 Base year
1% Escalation rate
\$5,680,000 Plant variable O&M cost
1985 Base year
1% Escalation rate

(6) Taxes and Insurance

0.48 Federal income tax rate (fraction)
0.09 State income tax rate (fraction)
0.03 State gross revenue tax rate (fraction)
0.0320 Property tax rate (fraction)
0.0025 Property insurance rate (fraction)
0 Net salvage value (\$)

(7) Startup and Times Card

1985 Startup year of power production
30 Plant depreciable life (years)
3 Construction time (years)
30 Plant operating lifetime (years)
5 Licensing time (years)

(8) Licensing Costs

(0.2,1984), (0.6,1983), (1.0,1982), (0.75,1981), (0.5,1980)
in \$ millions

(9A) Compound Escalation of Fuel Costs

1984 Base year
100 Reference fuel cost in 1984 (¢/MBtu)
5% Escalation rate

FIGURE 5. Fossil Test Case Input

3.1.3 Other Energy System Input

Energy systems other than fossil and nuclear plants are most easily set up for PACTOLUS using the fossil input data format described in Sections 3.1 and 3.1.1. For those energy systems which require continued purchases of energy, such as geothermal energy systems, the fossil fuel quantities and price schedules can be redefined to accommodate the energy supply. For those energy systems which do not require purchases of energy, such as wind and some forms of solar energy, the energy supply costs should be set to zero. The other cost accounts in PACTOLUS - capital costs, fixed and variable operating costs, taxes, insurance, and so forth - are common to all energy systems.

3.2 PREPARATION OF NUCLEAR INPUT DATA

Figure 6 shows the order of the cards in a deck setup for calculating nuclear power costs with PACTOLUS. To place their order in proper perspective, the nuclear input data cards shown in Figure 6 can be grouped into five categories of interrelated cards as follows:

1. General Reactor Parameters - Card Types 1 to 3
2. Reactor Fuel Burnup Data - Card Types 4 to 16
3. Nuclear Fuel Cycle and General Control Parameters - Card Types 17 to 23
4. Plant Financial and Tax Structure - Card Types 24 to 28
5. Isotope Prices and Cost Schedule for Nuclear Fuel Cycle Processes - Card Types 29 to 31A or 31B

The description of the cards within each category given below is preceded by a brief discussion of the background needed to understand their functional role in PACTOLUS.

Table 2 in Section 3.2.6 describes the input data format of each card for a nuclear plant. The general discussion of the fossil input data format in Table 1 also applies to Table 2 for nuclear input data and consequently is not repeated here. The user should review the discussion at the beginning of Section 3.1 and apply it to Table 2.

Unless explicitly stated otherwise, the units \$/kg in Table 2 refer to \$/kg of heavy metal, which includes all of the isotopes of uranium, plutonium, and thorium.

The escalation rates in Table 2 allow the user to escalate the O&M costs, the fuel isotope costs, and the costs of the major processes in the nuclear fuel cycle at a compound rate over the project lifetime to reflect a combination of inflation, supply/demand, and other effects such as environmental and engineering changes. With this definition of escalation, inflation is just one of several factors that can contribute to cost or price escalation.

FIGURE 6. Nuclear Plant Deck Setup for PACTOLUS

A sample input data deck for calculating nuclear power costs for a 1000 MWe light water reactor is shown in Figure 9 in Section 3.2.7. The output generated by PACTOLUS using this input data is described in Section 4.3.

Multiple nuclear cases can be input to PACTOLUS in one deck setup by repeating the full set of cards 1-31A or 31B before the end-of-file card in the input data stream shown in Figure 6. The control switch ISFUEL defined on Card Type 1 in Section 3.2.1 provides a means for reducing the size of the data decks for cases after the first case when executing multiple cases with one deck setup.

Referring to Table 2 in Section 3.2.6, we shall now discuss the preparation of the nuclear input data for the operation of PACTOLUS. No comment is made on parameters that are self-explanatory. The cards within each of the five categories mentioned at the beginning of this section are described below in the order in which they appear in the input data deck.

3.2.1 General Reactor Parameters

The reactor fuel burnup data input to PACTOLUS is normally generated by reactor fuel burnup codes. Many burnup codes generate burnup data at a constant capacity or power factor. Two examples of such burnup codes are ALTHAEA⁽³⁾ and LEOPARD.⁽⁶⁾ However, the real capacity factors of nuclear reactors vary with time. PACTOLUS has the capability to convert the burnup data generated with a constant capacity factor defined on Card Type 3 to the varying capacity history defined on Card Type 2.

PACTOLUS is also designed to allow modifications of the reactor burnup data by scaling the reactor thermal power and the isotopic concentrations of the initial core and refueling batches that were originally used in the burnup code to generate the burnup data. These scaling parameters are defined on Card Type 3.

The cards defining the general reactor parameters are described below.

Card Type 1 -- Plant Type, Switches, and Title

Card Type 1 defines the plant type, the print switch IPDIS, the control switch ISFUEL, and the case title. The plant type NUCL must be punched in

columns 1-4 to calculate nuclear plant power costs with PACTOLUS. Any title punched in columns 15-80 will appear as a heading of the output.

The print switch IPDIS controls the printout of Sections (100), (700), and (800) in the nuclear output illustrated in Section 4.4. These sections are printed if IPDIS is set to 1 and omitted if IPDIS is set to 0.

The control switch ISFUEL allows the user the discretion to reduce the size of the data deck by omitting Card Types 2-16 from a given case after the first case when executing multiple cases with one deck setup. The switch ISFUEL must always be left blank or set to 0 for the first case and all Card Types 1-31A or 31B must be present for the first case. If ISFUEL is left blank or set to 0 for any subsequent case, Card Types 2-16 must also be present for that case. However, if ISFUEL is set to 1 for any subsequent case, Card Types 2-16 must be omitted from the data deck for that case. In that event, PACTOLUS uses the information on Card Types 2-16 from the previous case for the current case.

Card Type 2 -- Capacity Factor History

Card Type 2 defines the capacity factor history during the operation of the reactor over its lifetime. The description of this card is identical to the description of Card Type 2 for the fossil input data in Section 3.1.

Card Type 3 -- Reactor Parameters

Card Type 3 defines reactor parameters that affect the reactor fuel burnup data which is defined on Card Types 4-9. The first item [RTP] is the reactor thermal power in megawatts. The second item [VOL] is the reactor fuel volume in liters. This parameter is a carryover from the original version of PACTOLUS in which the reactor fuel mass balances to be charged or discharged were input on Card Types 4-9 in units of nuclei per barn centimeter rather than kilograms. The reactor fuel volume [VOL] was used to convert nuclei per barn centimeters to kilograms. In the current version of PACTOLUS, the fuel mass balances to be charged or discharged are input on Card Types 4-9 in kilograms. Consequently, the parameter VOL should be left blank.

The next three items [TPR, FMAS, and PWR]^(a) are scaling factors to modify the input reactor burnup data. These scaling factors were originally used for specialized runs, but are currently infrequently used. It is recommended that these items be set to 0 or left blank, in which case the code will cause the scaling factors TPR, FMAS, and PWR to be set internally to 1.

The sixth item [CLF] allows the user to input reactor burnup data on Card Types 4-9 that was generated by a burnup code at a constant capacity factor less than 100%. PACTOLUS then internally converts the burnup data so that it corresponds to a constant capacity factor of 100%. If the item CLF is 0 or left blank, PACTOLUS will assume that the input burnup data is at 100% capacity factor (full power).

The seventh item [NREGN] defines the number of refueling batches making up the reactor. The eighth item [NFUEL] lists the type of refueling scheme. PACTOLUS can simulate either graded refueling [NFUEL = 0] or single batch refueling [NFUEL = 1]. In graded refueling, a fraction of the reactor core, called a batch, is removed at each refueling interval. This is the most common refueling scheme. In single batch refueling, the entire reactor inventory is replaced periodically in an end-to-end process.

The ninth item [NPTS] lists the number of data points in the end-of-life burnup data on Card Types 11-16. These data points are used to interpolate the burnup data in each reactor region from the last discharge date less than the reactor operating lifetime to the end of the reactor life. This enables PACTOLUS to estimate the fuel material balance in each reactor region exactly at the final reactor shutdown time.

(a) The parameter TPR scales the isotopic concentrations of the charge batches in the initial core. The parameter FMAS scales the isotopic concentrations of the discharge batches in the initial core and the isotopic concentrations of all charge and discharge refueling batches after the initial core. The parameter PWR scales the reactor thermal power [input parameter RTP] and reactor electrical power. As an example, the reactor thermal power, the reactor electrical power, and the isotopic concentrations of the initial core and all refueling batches are increased by 20% by setting all three parameters [TPR, FMAS, and PWR] to 1.20.

The end-of-life burnup data is described in the discussion of the reactor fuel burnup data in Section 3.2.2. If NPTS is 0 or left blank, PACTOLUS will assume that two points are required, namely beginning of end of life and end of life. The parameter NPTS should be set to 0 or left blank.

The tenth item [IBUG] is a debug switch to control debug printout of the calculations used in PACTOLUS in processing the reactor burnup data. It is recommended that this item normally be left blank.

The last item [TLIFE] defines the reactor operating lifetime (years). This item must be defined as an integral real number (not fractional) and must have the same value as TLIFE on Card Type 23.

3.2.2 Reactor Fuel Burnup Data

In order to calculate power costs for a nuclear reactor, the reactor fuel burnup data must be defined over the reactor operating lifetime. In PACTOLUS, the burnup data consist of the material balances of the reactor fuel isotopes at charge times and discharge times over the reactor operating lifetime. This information is normally generated by reactor fuel burnup codes such as ALTHAEA or LEOPARD, but burnup data from any source can be input to PACTOLUS.

The material balances are read into PACTOLUS as kilograms of up to 12 isotopes. These isotopic concentrations are defined at charge and discharge times by the set of six cards beginning with Card Type 4 and ending with Card Type 9 in Table 2. The first three cards (Card Types 4-6) define the charge data and the last three cards (Card Types 7-9) define the discharge data.

A separate set of six cards (Card Types 4-9) must be input for each fueling region in the reactor to define the initial charge and discharge data for that region. This information defines the burnup data for the initial core in the reactor. In addition, a separate set of six cards (Card Types 4-9) must be input a sufficient number of times for each fueling region to refuel that region over the reactor operating lifetime at whatever capacity factor history is specified on Card Type 2. The significance of the capacity factor history is discussed further below.

The sequence for entering the burnup data into PACTOLUS is as follows:

- 1) Enter the material balances for the initial charge and discharge times for each fueling region in ascending order by region number. This information defines the burnup data for the initial core.
- 2) Enter the refueling burnup data for the regions in the time sequence in which the regions are discharged, i.e., in order of increasing discharge times.

The following two examples illustrate the sequence for entering the burnup data into PACTOLUS. As the first example, consider the burnup data shown for the sample nuclear case with three reactor fueling regions in Figure 9 of Section 3.2.7. The sequence of first three discharge times for the three reactor regions is as follows:

To illustrate the sequence for entering this burnup data into PACTOLUS, assume that the burnup data is labeled as follows:

Let Initial Fuel_N denote the burnup data for region N in the initial core

First Refuel_N denote the burnup data for region N in its first refueling batch

Second Refuel_N denote the burnup data for region N in its second refueling batch

t denote the years from startup at which time the reactor region is discharged.

Then the burnup data for the sample nuclear case in Figure 9 is entered into PACTOLUS in the following sequence:

Input Sequence of Burnup Data for First Example

Initial Fuel₁ (t = 1.363)
Initial Fuel₂ (t = 2.165)
Initial Fuel₃ (t = 2.966)
First Refuel₁ (t = 3.768)
First Refuel₂ (t = 4.570)
First Refuel₃ (t = 5.371)
Second Refuel₁ (t = 6.173)
Second Refuel₂ (t = 6.975)
Second Refuel₃ (t = 7.776),
and so forth.

Each line of input data above requires six cards consisting of Card Types 4-9. Eighteen cards (three sets of six cards consisting of Card Types 4-9) are required to define the material balances of the initial fuel core at charge and discharge times for all three reactor regions. Another set of eighteen cards (three sets of six cards consisting of Card Types 4-9) are required to define the first refueling batches for each of the three reactor regions. This process is repeated for subsequent refueling batches in each of the three reactor regions until a sufficient number of refueling data have been defined for each reactor region to refuel the reactor over its operating lifetime at whatever capacity factor history is specified on Card Type 2.

As the second example to illustrate the sequence for entering burnup data into PACTOLUS, consider the irregular sequence of discharge times for the three reactor regions shown below:

Sequence of Discharge Times for Second Example

Discharge Time in Years

The burnup data for this sequence of discharge times is entered into PACTOLUS in the following sequence:

Input Sequence of Burnup Data for Second Example

Initial Fuel₁ (t = 3.5)
Initial Fuel₂ (t = 2.0)
Initial Fuel₃ (t = 1.5)
First Refuel₃ (t = 3.0)
First Refuel₂ (t = 4.0)
Second Refuel₃ (t = 4.5)
Third Refuel₃ (t = 6.0)
Second Refuel₂ (t = 6.5)
First Refuel₁ (t = 7.0),
and so forth.

Observe that the burnup data for the initial core is entered in order of increasing region number. The refueling burnup data is entered in the time sequence in which the regions are discharged, i.e., in order of increasing discharge times.

Refueling batches that extend beyond the reactor operating lifetime are skipped by PACTOLUS as explained below in the description of the end-of-life data. However, if there are an insufficient number of refueling batches present to refuel the reactor over its operating lifetime at the capacity factor history defined on Card Type 2, PACTOLUS will terminate execution of the input data (bomb out).

As previously noted, the capacity factor in reactor burnup codes is often held constant. In that event, the material balance information generated by the burnup code and input into PACTOLUS on Card Types 4-9 corresponds to the constant capacity factor [CLF] defined on Card Type 3. However, the real capacity factor of a nuclear reactor varies over its operating lifetime. In order to account for this difference, PACTOLUS has the capability to convert burnup data generated using the constant capacity factor [CLF] defined on Card Type 3 to the varying capacity factor defined on Card Type 2. Specifically, PACTOLUS examines the times at which the input material balances are charged and discharged and corrects these times to the proper values by accounting for the capacity factor history. The capacity factor history is obtained by successive linear interpolation between the capacity factor data points defined on Card Type 2.

The mass balances to be charged or discharged are written to a disk file with the new corresponding charge or discharge time calculated by PACTOLUS corresponding to the capacity factor history defined on Card Type 2. During the subsequent cost accounting, PACTOLUS reads the corrected burnup data from the disk file for each fuel batch in the reactor regions over the lifetime of the reactor. For each fuel batch, the cost and timing of the cost of each process in the fuel cycle are calculated and stored to obtain the cash flows associated with the fuel cycle over the lifetime of the reactor. Expenses are incurred for the concentrations of fuel isotopes charged. If the discharged fuel from the reactor is chemically reprocessed, credits are received for the residual values in the irradiated fuel.

The material balances in each reactor region at the end of the reactor operating lifetime are accounted for by a set of end-of-life data. When PACTOLUS has determined that the corrected value of a discharge time has exceeded the reactor operating lifetime, it backs up and deletes the burnup data of the region which has exceeded the reactor lifetime. PACTOLUS then skips the remaining input burnup data defined by Card Types 4-9 until it gets to the end-of-life data.

At that point, PACTOLUS cycles through each fueling region and determines the correct charge times for the beginning of the end of life. The discharge time in each reactor region prior to final shutdown is used as the charge time at the beginning of end of life, unless the discharge time exceeded the reactor operating lifetime. In that event, the charge time for that region is used as the charge time at the beginning of end of life.

As an illustration, consider the charge and discharge times in the end-of-life data shown for the three reactor regions in Section (100) of the sample nuclear output in Figure 11. The discharge time of 31.2 years for fuel batch 22S in the third reactor region exceeded the reactor lifetime of 30 years. Consequently, the charge time of 26.2 years was used as the charge time at the beginning of end of life for fuel batch 22S. The discharge times of 27.8 years and 29.5 years for fuel batches 20S and 21S in the first two reactor regions did not exceed the reactor lifetime. Therefore, these two discharge times were used as the charge times for the first two reactor regions at the beginning of end of life. All three reactor regions were discharged in the final shutdown at the end of the reactor lifetime of 30 years.

The kilograms of each isotope charged at the beginning of end of life are the same as that charged in the previous charge time before end of life. PACTOLUS calculates the kilograms of each isotope discharged in each region at end of life by linearly interpolating the burnup rates in each region exactly to the end of the reactor operating lifetime.

Card Type 10 signals the beginning of the end-of-life data in the input data stream. The end-of-life data is represented by Card Types 11-16, which must be present for each fueling region in the reactor.

The format of the end-of-life cards is a carryover from the original version of PACTOLUS in which material balances were defined on the end-of-life cards. The format is similar to that of the burnup data on Card Types 4-9. However, in the current version of PACTOLUS, material balances are no longer defined on the end-of-life cards. Currently, the end-of-life data are used to inform PACTOLUS to linearly interpolate the burnup rates in each reactor region to obtain the material balances in that region at the final reactor shutdown time. This accounts for the two blank cards present for Card Types 11 and 12 in Table 2 where the charge concentrations normally appear and the two blank cards present for Card Types 14 and 15 where the discharge concentrations normally appear.

The cards defining the reactor burnup data and end-of-life data are described below.

Card Types 4 through 9 -- Reactor Burnup Data

Card Types 4-9 define the reactor burnup data, i.e., the material balances of up to 12 isotopes at charge and discharge times. This set of six cards must be repeated for each reactor fueling region for the life of the reactor. The user must input a sufficient number of burnup data sets so that the mass balance information can be used by PACTOLUS to generate a refueling history for the entire reactor operating lifetime at whatever capacity factor curve is defined on Card Type 2.

Card Type 10 -- End-of-Life Flag for Reactor Burnup Data

Card Type 10 is blank except for a 1 in column one to signal PACTOLUS that the end-of-life data follow the preceding reactor burnup data. As soon as any discharge time for a reactor region exceeds the reactor lifetime, PACTOLUS skips any remaining burnup data cards and proceeds to the end-of-life data.

Card Types 11 through 16 -- Reactor End-of-Life Data

Card Types 11-16 define the reactor end-of-life data. This set of six cards, three cards for beginning of end of life and three cards for end of life, must be repeated for each reactor refueling region. The end-of-life data cards must be entered in the order of increasing reactor region number. The end-of-life data are used to inform PACTOLUS to linearly interpolate the burnup rates in each reactor region to obtain the material balance in that region exactly at the final reactor shutdown time.

3.2.3 Nuclear Fuel Cycle and General Control Parameters

The processing of nuclear fuel from its natural state as a uranium or thorium ore through its irradiation in the nuclear reactor and its subsequent treatment after discharge from the reactor comprise the nuclear fuel cycle. Figure 7 illustrates the uranium fuel cycle for a light water reactor and shows the processes considered in PACTOLUS. The processes include the purchase of fuel materials, uranium enrichment, fuel fabrication, irradiation, chemical reprocessing (optional), storage of discharged fuel, and shipment of fuel between processing locations. Since PACTOLUS is primarily concerned with the cash flows associated with the nuclear fuel cycle, it is the cost and the timing of the cost for each process in the fuel cycle that is important. In addition to the fuel cycle for uranium, PACTOLUS can calculate nuclear power costs using any other fuel cycle. For illustrative purposes, we shall discuss only the uranium fuel cycle.

The uranium fuel cycle begins with the purchase of U_3O_8 , the refined form of uranium ore.^(a) The next step is the conversion of U_3O_8 to UF_6 (uranium hexafluoride). In PACTOLUS, these two steps are combined. The next step consists of the enrichment of UF_6 in the ^{235}U isotope by the gaseous diffusion cascade process. The enriched UF_6 is then shipped to a fabrication plant, which converts it to UO_2 (uranium dioxide) for the fabrication of finished fuel assemblies. The fuel assemblies are shipped to the nuclear reactor for irradiation.

(a) Although uranium is sold on the basis of its U_3O_8 content, its chemical form is either sodium diuranate or ammonium diuranate.

FIGURE 7. Uranium Fuel Cycle for Light Water Reactor

After discharge, the spent fuel is either shipped to a reprocessing plant or stored at the reactor site without reprocessing for subsequent shipment to a waste storage site. The reprocessing process includes the dissolution of the spent fuel, the extraction of the residual fuel values of uranium and plutonium as nitrates, the conversion of uranium to UF_6 in preparation for re-enrichment, and, in the case of plutonium recycle, the conversion of plutonium nitrate to plutonium oxide in preparation for shipment to the fabrication plant. After reprocessing, the waste products are shipped to a final disposal site.

Fuel cycle costs prior to irradiation are incurred for the purchase of fuel materials, conversion of U_3O_8 to UF_6 , uranium enrichment, fabrication of fuel elements, and shipment of fuel between processing locations. Fuel cycle costs after irradiation are incurred for storage of the spent fuel at the reactor site prior to shipment and either chemical reprocessing and shipment of the radioactive waste to permanent waste storage or shipment of the spent fuel without reprocessing and permanent storage of the spent fuel. The costs associated with the initial core and all subsequent fuel loadings during the reactor operating lifetime are included in the fuel cycle costs. We shall now discuss each of the fuel cycle costs in more detail, beginning with the fuel purchases and the conversion of U_3O_8 to UF_6 .

The fuel purchases are the direct expenses for nuclear fuel materials. The costs of U_3O_8 , Th, Pu, and all bred uranium are input as unit costs. The cost of U_3O_8 , Pu, and all bred uranium except ^{238}U can be varied according to specified price schedules using Card Types 29 and 31A or 31B. The cost of Th is input as a unit cost on Card Type 29 and the conversion of U_3O_8 to UF_6 is input as a unit cost on Card Type 18. A charge of \$3/kg of uranium is built into the code for the purchase of tails (depleted uranium).

The total fuel purchases are calculated in PACTOLUS from the unit costs and material requirements. The material requirements are calculated in PACTOLUS and include allowances for losses of fuel materials during fabrication and reprocessing (if reprocessing is specified by the user). The dollar values of

the fabrication and reprocessing losses are charged to the fabrication and reprocessing processes respectively. Separate fractional loss rates for core and blanket fuel fabrication losses and reprocessing losses can be input on Card Types 19 and 20.

The times of the cost occurrences for fuel purchases are calculated in PACTOLUS from input shipping and process times shown in Figure 8. The shipping and process times are discussed in detail further below.

Uranium enrichment costs are calculated in PACTOLUS using a cost model of the UF_6 gaseous diffusion cascade process. In this process, uranium feed material in the form of UF_6 is enriched in the ^{235}U isotope. The cost model of the diffusion cascade process is described in detail in reference 4. We shall first break down the cost of the enrichment process and then summarize the input parameters to the cost model.

Factors that contribute to the cost of enriched uranium are the cost of the feed material, the cost of the enrichment process, and the value of the depleted uranium waste material called tails. The cost of the feed material is the product of the feed rate times the unit cost of the feed material. The enrichment cost is the product of the separative work requirement times its unit cost. The separative work is a measure of the energy required for the enrichment process. Separative work requirements vary with the level of enrichment, which is obtained from the reactor burnup data. The costs of the feed material and enrichment process may be partially offset by a credit for the value of the tails, which equals the product of the tails flow rate times its unit value. Thus, the cost of the enriched uranium from the diffusion cascade process is the summation of the feed cost and the cost of the separative work minus the credit for the tails, if any is given.

The feed rate of UF_6 , the separative work requirement, and the flow rate of the tails are determined in the diffusion cascade model. The unit cost of the UF_6 feed material, expressed in \$/lb of U_3O_8 , and the unit cost of separative work are defined on Card Type 31A or 31B. Both of these unit costs can be varied according to any specified price schedule using Card Types 31A or 31B.

The remaining input parameters to the cost model of the diffusion cascade process are defined on Card Type 18. Two options are available for defining the tails composition. In the first option, the tails composition can be input by the user to simulate a uniform operation of the diffusion plant. In the second option, the diffusion model will select the optimum (lowest cost) tails composition for the enrichment and economic factors pertaining to a specific nuclear fuel. Input data is also required on the ^{235}U composition of the feed, the unit value of the tails, and time required for uranium conversion (U_3O_8 to UF_6) and enrichment.

A summary of the equations and parameters for calculating enriched uranium costs and the optimum tails composition in the diffusion cascade model is given below.

Cost Equation for Enriched Uranium

$$C_p = \frac{C_s \Delta + C_f F - C_w W}{P}$$

where:

C_p = unit cost of the product (enriched uranium), \$/kg of uranium

C_s = unit cost of separative work, \$/kg of separative work

C_f = unit cost of feed as UF_6 (includes the charge of converting U_3O_8 to UF_6), \$/kg of uranium

C_w = unit cost of tails, \$/kg of uranium

Δ/P = ratio of the separative work to the product flow rate, kg of separative work/kg of product

F/P = ratio of the feed flow rate to the product flow rate, kg of feed/kg of product

W/P = ratio of the tails flow rate to the product flow rate, kg of tails/kg of product

$$\text{and } \frac{\Delta}{P} = \frac{W}{P} \Phi(X_w) + \Phi(X_p) - \frac{F}{P} \Phi(X_f)$$

X_w = tails stream composition, weight fraction of ^{235}U in tails

X_p = product stream composition, weight fraction of ^{235}U in product

X_f = feed stream composition, weight fraction of ^{235}U in feed

$$\Phi(X_i) = (1 - 2X_i) \ln[(1 - X_i)/X_i]$$

X_i = composition of i th flow stream fraction.

Note that $F = P + W$.

Optimum Tails Composition

The optimum tails composition is defined as the composition that minimizes the unit cost of the enriched uranium. This composition is found by setting the derivative with respect to X_w of the cost equation for enriched uranium to zero. This yields:

$$\frac{C_f - C_w}{C_s} = \Phi(X_f) - \Phi(X_o) - (X_f - X_o)\Phi'(X_o)$$

where:

X_o = optimum tails composition

X_f = feed materials composition

This defines the optimum tails composition (X_o) in terms of the price schedule parameters C_f , C_s , and C_w , and the feed composition X_f . The above equation is solved by iteration for the optimum tails composition (X_o). Note that the desired product enrichment (X_p) does not affect the optimum tails composition (X_o).

The next fuel cycle costs considered in PACTOLUS are the fabrication costs. These are the costs of converting the raw fuel materials into finished fuel

assemblies for use in the nuclear reactor. This includes the cost of cladding and assembly hardware. The fabrication costs may also include some conversion steps, such as U_3O_8 to UO_2 , UF_6 to UO_2 , and $Pu(NO_3)_4$ to PuO_2 , depending upon the fuel cycle and reactor type.

Fabrication costs are calculated from unit cost data and material flow requirements. The unit costs for the fabrication of core and blanket fuels are defined on Card Type 31A or 31B and can be varied according to any specified price schedule. The material requirements are calculated in PACTOLUS and include allowances for processing losses of materials during fabrication. Loss rates for core and blanket fuels during fabrication can be defined on Card Type 19. The fabrication time is defined on Card Type 23. It is used to calculate the time at which the fabrication cost is incurred, which is at the end of the fabrication process.

An incremental fabrication cost penalty can be defined according to any specified price schedule on Card Type 31A or 31B for handling recycled fuels containing ^{233}U or Pu in the fabrication process. The option to reprocess fuels discharged from the reactor and to recycle fuels containing ^{233}U or Pu is selected by leaving the parameter THROW blank or setting it to 0 on Card Type 20.

Fuel discharged from the reactor can be either shipped to a chemical reprocessing plant or stored at the reactor site without reprocessing for subsequent shipment to a waste storage site. The option to reprocess discharged fuels is selected by leaving the parameter THROW blank or setting it to 0 on Card Type 20. When the discharged fuel is reprocessed, the parameter THROCG on Card Type 20 is ignored.

Chemical reprocessing allows recovery of uranium nitrate, plutonium nitrate, and other valuable products from the mixture of fuel and fission products discharged from the reactor. Credits are obtained for the reclaimed values in the discharged fuel to partially offset the fuel cycle costs. Depending upon the fuel cycle and reactor type, the uranium nitrate can be converted to UF_6 and recycled for re-enrichment. The plutonium nitrate can be converted to plutonium oxide and recycled to the fabrication facility where it is used for the fabrication of fuel elements.

Two options are available for calculating chemical reprocessing costs in PACTOLUS. The first option is selected by setting the parameter ISEP to 1 on Card Type 17. With this option, chemical reprocessing costs are calculated from unit cost data and material flow requirements. The unit costs of reprocessing core and blanket fuels are defined on Card Type 31A or 31B and can be varied according to any specified price schedule. The material flow requirements are calculated in PACTOLUS. The material flow requirements and unit cost data are based on the original weight of fuel charged into the reactor.

An allowance for losses of materials during reprocessing can be specified by setting the reprocessing loss rate greater than 0 on Card Type 20. The material losses are added to the fuel purchases, but are charged against the reprocessing costs. The reprocessing time, which is used in calculating the time of occurrence of the reprocessing cost and reclaimed fuel credits is defined on Card Type 20.

The second method for calculating reprocessing costs is selected by setting the parameter ISEP to 0 on Card Type 17. With this method, the reprocessing costs are calculated using a model of the costs for the Nuclear Fuel Services (NFS) plant⁽⁵⁾ near West Valley, New York. The NFS cost model is based on daily operating costs, daily throughput, and reprocessing losses. These parameters are defined on Card Type 20. However, since the NFS plant is currently being decommissioned, its cost model is probably obsolete and it is recommended that it not be used.

The option not to reprocess the discharged fuel from the reactor is selected by setting the parameter THROW to 1 on Card Type 20. With this option, the discharged fuel is stored at the reactor site for subsequent shipment to a waste storage site. When the discharged fuel is not reprocessed, the parameter THROCG defines the one time charge in \$/kg of heavy metal for storage of the spent fuel at the permanent storage site. This charge is incurred after each discharge of spent fuel in the year calculated as follows: $\text{time of year of discharge} + [\text{post-reactor cooling time (COOL, days)} + \text{shipping time to permanent storage (SHPSEP, days)}] / 365.3$. Since the discharged fuel is

not being reprocessed, the input unit core and blanket reprocessing costs [SRATO(I) and BLKSEP(I) on Card Type 31A or 31B] are set to 0 by PACTOLUS (subroutine CINPUT).

In the nuclear fuel cycle, shipping costs are incurred in transporting fuel material between processing locations prior to and after irradiation. Shipping charges are calculated in PACTOLUS as the product of unit shipping costs times the quantity of material shipped. The unit shipping costs are defined on Card Types 21 and 22 for six categories of shipping as follows:

- shipping of standard fuels to fabrication
- shipping of recycle fuels to fabrication
- shipping of standard fuels from fabrication to reactor
- shipping of recycle fuels from fabrication to reactor
- shipping from reactor to reprocessing plant
- shipping from reprocessing plant to waste storage site

Card Types 21 and 22 also define the shipping times, which are used in PACTOLUS to calculate the time of the cost occurrence for the shipping charges.

The processes which comprise the nuclear fuel cycle occur sequentially in time. The point in time at which each process occurs is calculated from the input shipping times and process lead and lag times. The sequence of shipping times and process times in the fuel cycle are shown in Figure 8. The time at which each event or step in the fuel cycle occurs in PACTOLUS is shown above the shipping and process times in Figure 8.

To illustrate the schedule of events occurring in the fuel cycle, consider the initial core charge (reactor startup date) as a reference point and the sample schedule of shipping and process times shown below. Assume that the option to reprocess the discharged fuel from the reactor is included. The card type on which each shipping and process time is defined is also shown.

SHIPPING AND PROCESS TIMES	
UBUYTM	- URANIUM CONVERSION AND ENRICHMENT TIME, DAYS (CARD 18)
SHPFAB	- SHIPPING TIME TO FABRICATION, DAYS (CARD 21)
TFAB	- FABRICATION TIME, DAYS (CARD 23)
SHPREA	- SHIPPING TIME TO REACTOR, DAYS (CARD 21)
PRI	- PRE-REACTOR INVENTORY TIME, DAYS (CARD 23)
	REACTOR IRRADIATION
COOL	- POST-REACTOR COOLING TIME, DAYS (CARD 23)
SHPSEP	- AND SHIPPING TIME TO REPROCESSING, DAYS (CARD 21)
TSEP	- REPROCESSING TIME, DAYS (CARD 20)
SHPDES	- SHIPPING TIME TO FINAL DESTINATION, DAYS (CARD 21)

FIGURE 8. Shipping and Process Time Sequences and Schedule of Events in Nuclear Fuel Cycle

<u>Process Time</u>	<u>Card Type</u>	<u>Parameter</u>	<u>Sample Value</u>
Uranium Conversion and Enrichment Time, Days	18	UBUYTM	100
Shipping Time to Fabrication, Days	21	SHPFAB	10
Fabrication Time, Days	23	TFAB	60
Shipping Time to Reactor, Days	21	SHPREA	10
Pre-Reactor Inventory Time, Days	23	PRI	30
Reactor Startup Time, Year	23	TSTART	1980
Time of Initial Charge in Reactor, Years (Burnup Data)			3
Post-Reactor Cooling Time, Days	23	COOL	120
Shipping Time to Reprocessing, Days	21	SHPSEP	20
Reprocessing Time, Days	20	TSEP	40
Shipping Time to Final Destination, Days	21	SHPDES	30

Assume that the reactor startup with the initial fuel core is on January 1, 1980. Then the schedule of events and times at which the events occur in the nuclear fuel cycle associated with the initial core are calculated in FACTOLUS as follows:

<u>Event in Nuclear Fuel Cycle</u>	<u>Time of Event</u>	<u>Time at Which Cost of Event is Discounted in Discounted Cash Flow Model</u>
1) Uranium Purchase = $1980 - (30+10+60+10+100)/365.3$	= 1979.43	1979.5
2) Plutonium Purchase = $1980 - (30+10+60+10)/365.3$	= 1979.70	1979.5
3) Shipment to Fabrication = $1980 - (30+10+60)/365.3$	= 1979.73	1979.5
4) Fabrication = $1980 - (30+10)/365.3$	= 1979.89	1979.5
5) Shipment to Reactor = $1980 - (30)/365.3$	= 1979.92	1979.5
6) Shipment to Reprocessing = $1983 + (120+20)/365.3$	= 1983.38	1983.5
7) Reprocessing = $1983 + (120+20+40)/365.3$	= 1983.49	1983.5
8) Shipment to Final Destination = $1983 + (120+20+40+30)/365.3$	= 1983.59	1983.5

These figures show that the uranium for the initial core charged in January of 1980 is purchased at 1979.43, i.e., in June of 1979; the fabrication of the initial core is completed at 1979.89, i.e., in November of 1979; and the chemical reprocessing of the fuel from the initial core discharge is completed at 1983.49, i.e., in June of 1983. In PACTOLUS, the receipt of the fuel credits from the reprocessed fuel is assumed to occur after the waste material from the reprocessing plant is shipped to the final site for storage. Thus, in the sample schedule shown above, the point of receipt of the fuel credits from the reprocessed fuel in the initial core discharge is at 1983.59, i.e., in July of 1983.

In the Nuclear Fuel Model, the costs and revenues associated with each step in the fuel cycle are calculated exactly at the time in the year in which they occur. Thus, the cost of the uranium purchased for the initial core in the above example is calculated in the Nuclear Fuel Model by linearly interpolating the price schedule for uranium to 1979.43, i.e., June of 1979. In the Discounted Cash Flow Model, all costs and revenues are then discounted as though they occurred at midyear. No further adjustment or discounting is made between the Nuclear Fuel Model and the Discounted Cash Flow Model to get to midyear.

Therefore, as shown in the above figures, the costs of all pre-irradiation events (1-5) in the sample schedule shown for the initial core fuel cycle are discounted at midyear of 1979 in the Discounted Cash Flow Model in PACTOLUS. The costs of all post-irradiation events are discounted at midyear of 1983. The latter costs are partially offset by the credits received, also discounted at midyear of 1983, from the reprocessed fuel.

The cards defining the general control parameters and parameters for the nuclear fuel cycle are now described.

Card Type 17 -- Control Card

Card Type 17 is a control card which controls several options available to the user. The first item [NCR] defines the number of initial core regions. The second item [NBR] defines the number of initial blanket regions. The

third item [NCDS] defines an option for inputting the unit cost schedule of processes in the nuclear fuel cycle using either Card Type 31A or Card Type 31B. If NCDS is set to 1, Card Type 31A must be used. Two Type 31A cards are required. If NCDS is set greater than 1, Card Type 31B must be used. The number of Type 31B cards must equal NCDS. The distinction between these two types of cards is discussed in the description of Card Types 31A and 31B.

The parameter ISEP specifies the method of calculating reprocessing costs. It should first be emphasized that the discharged fuel from the reactor is reprocessed only if the parameter THROW on Card Type 20 is left blank or set to 0. If this parameter is set to 1, the discharged fuel is not reprocessed. In that event, no reprocessing costs are calculated and no credits are received from the residual values in the irradiated fuel.

The first method of calculating reprocessing costs [ISEP = 0] is a carry-over from the original version of PACTOLUS. It calculates reprocessing costs using a computational model similar to the Nuclear Fuel Services (NFS) plant processing schedule. The first three items [SEPCST, THRUPT, and REPOS] on Card Type 20 comprise the input parameters to the NFS cost model. Although the NFS cost model is still in the code, it is not recommended for calculating reprocessing costs due to obsolescence.

The second method [ISEP = 1] calculates reprocessing costs from input cost data and material flow. This is the method recommended for calculating reprocessing costs. The material flow is calculated in PACTOLUS. The unit costs (\$/kg) for core reprocessing [SRAT0(I)] and blanket reprocessing [BLKSEP(I)] are defined on Card Type 31A or 31B. In addition, the two parameters REPOS and TSEP on Card Type 20 must also be defined. The parameter REPOS defines the fractional loss rate of materials during reprocessing. The parameter TSEP defines the reprocessing time in days.

The parameter IPU on Card Type 17 provides an option for calculating the prices of ^{239}Pu and ^{241}Pu isotopes in PACTOLUS. If IPU is set to 0, the prices of ^{239}Pu and ^{241}Pu isotopes are calculated as the product of the unit cost

data [PISO(3) and PISO (4)] on Card Type 29 times the plutonium price escalation factor [PRATO(I)] on Card Type 31A or 31B. If IPU is set to 1, the prices of ^{239}Pu and ^{241}Pu isotopes are calculated as the product of the 90% enriched uranium price calculated in PACTOLUS times the plutonium price escalation factor [PRATO(I)] on Card Type 31A or 31B. Thus, with the latter option, the price of ^{239}Pu and ^{241}Pu isotopes are identical.

Card Type 17 also provides two methods for depreciating the capital expenses, an inventory accounting option, and two methods for calculating the power costs. These options have already been described in the discussion of Card Type 3 for the fossil input data in Section 3.1.

Card Type 18 -- Gaseous Diffusion Cascade Parameters for Uranium Enrichment

Card Type 18 defines six input parameters to a cost model of the UF_6 gaseous diffusion cascade process. In this process, uranium feed material in the form of UF_6 is enriched in the ^{235}U isotope.

The first parameter [IXTL] defines an option for determining the tails composition. If IXTL is set to 0, the tails composition is set by the parameter XT in weight fraction of ^{235}U . If IXTL is set to 1, the model will calculate the optimum (lowest cost) tails composition based on the enrichment and economic factors pertaining to a specific nuclear fuel.

Next, the parameter CW defines the value of tails (\$/kg of uranium); the parameter XF defines the feed composition (weight fraction of ^{235}U); the parameter UCONV defines the unit cost (\$/kg of uranium) of converting U_3O_8 to UF_6 ; and the parameter UBUYTM defines the time (days) required for uranium conversion and enrichment. It is recommended that the unit shipping cost from fuel purchase to the enrichment facility in Figure 7 be lumped with the unit cost of converting U_3O_8 to UF_6 .

Additional inputs required for the cost model of the diffusion cascade process are defined on Card Type 31A or 31B. These include the separative

work charge [CSX(I)] in \$/kg of separative work and the uranium feed price [CFX(I)] in \$/lb of U_3O_8 .

Card Type 19 -- Fabrication Card

Card Type 19 defines the losses of fuel material during fabrication. The fabrication process consists of the conversion of the raw fuel materials into finished fuel assemblies for use in the reactor.

The parameters CORLOS and BLKLOS define the fractional losses of fuel materials during the fabrication of core and blanket fuels respectively. PACTOLUS allows for these fuel losses by adding the fractional material losses to the fuel purchases. The fuel losses are assumed to have the same unit dollar values as the initial fuel material used in the fabrication process. The dollar value of the losses is charged to the fabrication process and not to the fuel purchases.

Although Card Type 19 is labeled the Fabrication Card, several parameters for the fabrication process are defined on other cards. We shall now also summarize these input parameters.

The fabrication costs are calculated from unit cost data and material flow. The material flow is calculated in PACTOLUS. The unit costs (\$/kg) incurred in the fabrication of core and blanket fuels are defined by the parameters CORFAB(I) and BLKFAB(I) respectively on Card Type 31A or 31B. An additional cost (\$/kg) for handling recycle fuels during fabrication can also be defined by the parameter DELFAB(I) on Card Type 31A or 31B. The fabrication time (days) is defined by the parameter TFAB on Card Type 23.

The remaining parameter SALT on Card Type 19 is not concerned with fuel fabrication. The parameter SALT defines the recoverable cost (\$) of fluoride salt from molten salt breeder reactors (MSBR) or molten salt converter reactors (MSCR). This is part of the total capital cost of the plant as noted in the description of Card Type 24.

Card Type 20 -- Reprocessing Card

Card Type 20 defines input parameters that control the chemical reprocessing of the discharged fuel from the reactor. If the parameter THROW is set to 1, the discharged fuel is stored at the reactor site without reprocessing for subsequent shipment to a waste storage site. In that event, the parameter THROCG defines the one time charge in \$/kg of heavy metal for storage of the spent fuel at the permanent storage site.^(a) The cost of shipping the spent fuel from the reactor to the permanent storage site should be included in the storage charge (\$/kg of heavy metal) defined by the parameter THROCG. The permanent storage charge is incurred after each discharge of spent fuel in the year calculated as follows: time of year of discharge + [post-reactor cooling time (COOL, days) + shipping time to permanent storage (SHPSEP, days)]/365.3.

If the discharged fuel is not reprocessed, the following parameters related to reprocessing are set to 0 by PACTOLUS (subroutine CINPUT): the operating cost and throughput of the NFS reprocessing plant [SEPCST and THRUPT], the reprocessing loss rate [REPL0S], and the reprocessing time [TSEP] defined on Card Type 20; the core and blanket reprocessing costs and their escalation factors [SRATO(1), BLKSEP(1), PCINF7, and PCINF9] defined on Card Type 31A and the core and blanket reprocessing costs [SRATO(I) and BLKSEP(I)] defined on Card Type 31B.

If the parameter THROW is left blank or set to 0, the discharged fuel is shipped to a chemical reprocessing plant. In that event, the parameter THROCG on Card Type 20 is ignored. The reprocessing process includes the dissolution of the spent irradiated fuel, the recovery as nitrates of the residual fuel values of uranium and plutonium, the storage of waste products, the conversion

(a) The charge for temporarily storing the discharged fuel at the reactor site, for example, the reactor cooling basin or some other site at the reactor, can be included in the fixed and variable O&M costs defined on Card Type 26. The capital cost for construction of an enlarged cooling basin or other site at the reactor for temporarily storing the discharged fuel prior to shipment without reprocessing to the permanent storage site should be included in the plant capital costs defined on Card Type 24.

of uranium to UF_6 in preparation for reenrichment, and in the case of plutonium recycle, the conversion of plutonium nitrate to plutonium oxide in preparation for shipment to the fabrication plant.

Two methods were described on Card Type 17 for calculating reprocessing costs through the variable ISEP. The first method [ISEP = 0] calculates reprocessing costs based on a cost model of the Nuclear Fuel Services (NFS) reprocessing plant. The first three items on Card Type 20 comprise the input parameters to the NFS cost model. The parameter SEPCST defines the daily operating cost (\$/day) of the reprocessing plant; the parameter THRUPT defines the reprocessing plant throughput (kg/day); and the parameter REPLoS defines the fractional loss rate of fuel materials during reprocessing. As previously observed in the description of Card Type 17, this method is no longer recommended since the NFS plant is being decommissioned.

The current method recommended for calculating reprocessing costs is obtained by setting ISEP to 1 on Card Type 17. With this method, chemical reprocessing costs are calculated from input unit cost data defined on Card Type 31A or 31B and the material flow calculated in PACTOLUS. The parameter SRATO(I) on Card Type 31A or 31B defines the unit cost (\$/kg) of reprocessing core fuels. The parameter BLKSEP(I) on Card Type 31A or 31B defines the unit cost (\$/kg) of reprocessing blanket fuels. Both of these unit costs can be varied according to any specified price schedule using Card Type 31A or 31B. In addition, the two parameters REPLoS and TSEP on Card Type 20 must also be defined. The parameter REPLoS defines the fractional loss rate of fuel materials during reprocessing. The parameter TSEP defines the reprocessing time in days.

Card Type 21 -- Shipping Card

Card Type 21 is the shipping card which defines the unit shipping costs (\$/kg) and corresponding shipping times (days) for transporting fuel materials between processing locations in the nuclear fuel cycle. The shipping

charges are calculated in PACTOLUS from the unit shipping costs and the quantity of fuel material shipped.

Four unit shipping costs and times are available on Card Type 21, any one or several of which may be appropriate (See Figure 7). These shipping costs and times are categorized as follows:

- 1) CSHP1 and SHPFAB, the unit shipping cost and time between enrichment and fabrication.
- 2) CSHP2 and SHPREA, the unit shipping cost and time from fabrication to reactor.
- 3) CSHP3 and SHPSEP, the unit shipping cost from reactor cooling basin to reprocessing and the shipping time from reactor cooling basin to reprocessing (or permanent storage if the discharged fuel is not reprocessed).
- 4) CSHP4 and SHPDES, the unit shipping cost and time from reprocessing to final storage of the waste materials.

It is recommended that the unit shipping cost between fuel purchase and enrichment be included with the unit cost [UCONV] of converting U_3O_8 to UF_6 on Card Type 18. The one time charge (\$/kg of heavy metal) for permanent storage of the radioactive wastes after reprocessing should be included with the unit shipping cost [CSHP4] from reprocessing to permanent storage.^(a) If the discharged fuel is not reprocessed, the three post-reactor shipping parameters, CSHP3, CSHP4, and SHPDES, are ignored by PACTOLUS. In this case, the unit cost of shipping the spent fuel from the reactor site to permanent storage should be included in the permanent storage charge for the spent fuel, defined by the parameter THROCG on Card Type 20.

(a) The charge for temporarily storing the discharged fuel at the reactor site, for example, the reactor cooling basin or some other site at the reactor, prior to shipment to the reprocessing facility can be included in the fixed and variable O&M costs defined on Card Type 26.

Card Type 22 -- Shipping Card (cont'd)

Card Type 22 defines unit shipping costs (\$/kg) for recycle fuels, i.e., fuels that contain ^{233}U or Pu isotopes in the reactor burnup data. The shipping charges for recycle fuels are calculated in PACTOLUS from the unit shipping costs and the quantity of recycle fuels shipped.

PACTOLUS checks for the presence of ^{233}U or Pu isotopes in the reactor burnup data for each fuel batch. For standard fuels, i.e., fuels without ^{233}U or Pu isotopes in the reactor burnup data, the code uses the cost parameters CSHP1 and CSHP2 defined on Card Type 21 to calculate the pre-reactor shipping costs. For recycle fuels, the code uses the cost parameters DLSHP1 and DLSHP2 defined on Card Type 22 to calculate the pre-reactor shipping costs. For both standard and recycle fuels, the code uses the pre-reactor shipping times SHPFAB and SHPREA defined on Card Type 21.

Two unit shipping costs (\$/kg) are defined for recycle fuels on Card Type 22. These are categorized as follows: .

- 1) DLSHP1, the unit cost of shipping recycle fuels to fabrication.
- 2) DLSHP2, the unit cost of shipping recycle fuels from fabrication to reactor.

Card Type 23 -- Startup and Process Times

Card Type 23 describes the reactor startup date and the process times. This includes the production startup year, the licensing time (years), the construction time (years), the fuel fabrication time (days), the pre-reactor inventory time (days), the post-reactor cooling time (days), and the reactor operating lifetime (years). All of these times must be defined as integral real numbers (not fractional). The power production startup date is assumed to be at January 1 of the startup year.

The current program dimensions allow up to a maximum of ten years for reactor licensing time. If more licensing time is required, the user must modify the code by increasing the dimensions of the licensing cost variable COSTLC(I) described on Card Type 28.

3.2.4 Financial and Tax Structure

The plant capital costs, O&M costs, financial parameters, and tax rates are necessary inputs to PACTOLUS in order to calculate the cost of power from power generating plants. Information on the financial and tax structure is combined with the fuel costs generated by the costs of materials and processes, material flow, and engineering cost models in PACTOLUS to calculate the cash flow for the entire project lifetime.

PACTOLUS generates the basic accounting information contained in cash flow budgets, income statements, and balance sheets over the project lifetime. Using discounted cash flow analysis and standard methods for depreciation and debt repayment, PACTOLUS calculates the unit busbar cost of power based on the principle that the present worth of the revenues will be equal to the present worth of the expenses including investment return over the economic life of the project. The unit cost of power can be derived either as a single levelized cost for the project lifetime or as an annual cost in current dollars for each year of the project lifetime.

The cards defining the financial and tax structure of the powerplant are described below.

Card Type 24 -- Plant Capital Costs

Card Type 24 is the plant construction cost card. This card defines the cost (\$) of the moderator, control system, pressure vessel, turbines, heat exchangers, and the reactor site. The last item [CSTOTH] provides an aggregate input of all other capital costs. This is frequently used to define the total capital cost of the plant with the other items left blank. PACTOLUS adds items 3 through 8 on this card and item 3 [SALT] on Card Type 19 to obtain the total capital cost of the plant.

Card Type 25 -- Plant Operation and Financial Parameters

Card Type 25 defines the reactor thermal-to-electrical conversion efficiency, the capital bond fraction, the bond interest rate, the after-tax

return to equity, the interim capital replacements, and several other financial parameters. PACTOLUS calculates the interim capital replacements in any year after startup as a fraction [D(18)] of the initial capital cost.

Card Type 25 also provides an option to define a salvage credit or decommissioning cost for the plant. A salvage credit is defined by setting D(24) to a positive dollar value. A decommissioning cost is defined by setting D(24) to a negative dollar value. If the parameter D(24) is set to a nonzero value, PACTOLUS will generate the cash flow information one year past the final year of power production to provide for the salvage or decommissioning of the plant.

The last item [PIVTCP] defines the percentage plant investment tax credit. The investment tax credit is designed to reduce tax liability by a specified percentage of the initial capital investment and interim capital replacements in any given year.

Card Type 26 -- Fixed and Variable O&M Costs

Card Type 26 is the O&M cost card. The description of this card is identical to the description of Card Type 5 for the fossil input data in Section 3.1. For both nuclear and fossil plants, the O&M costs are calculated in PACTOLUS at midyear.

Card Type 27 -- Taxes and Insurance

Card Type 27 defines taxes and insurance. The federal income tax, state income tax, state gross revenue tax, and property tax on the net plant value and initial fuel core are input as fractional rates.

Property insurance is input as a fraction of the net plant value and initial fuel core. Nuclear liability insurance may be input in dollars per year [CINS] or dollars per year per megawatt [D(21)] or both. PACTOLUS adds the costs calculated using these two parameters [CINS and D(21)] to obtain the cost of nuclear liability insurance.

Card Type 28 -- Licensing Costs

Card Type 28 defines the licensing costs. The description of this card is identical to the description of Card Type 8 for the fossil input data in Section 3.1.

3.2.5 Isotope Prices and Cost Schedule for Nuclear Fuel Cycle Processes

The relative prices of the major factors that contribute to the cost of nuclear fuel may change significantly over time due to price escalation. This includes increases in prices due to a combination of inflation, supply/demand, and other effects such as environmental and engineering changes. In calculating nuclear power costs, the analyst may want to include the price escalation of the factors that contribute to the cost of the nuclear fuel into the calculations. PACTOLUS provides this capability by permitting the user to input unit cost data for the fuel isotopes and the major processing steps in the nuclear fuel cycle according to any specified price escalation schedule over time. In particular, the unit costs of the fuel isotopes and fuel cycle processes can either be held constant or escalated over the lifetime of the reactor.

Two options are available for entering this cost data into PACTOLUS, depending upon the value of the parameter NCDS defined on Card Type 17. If NCDS is set to 1, the cost data is input using Card Type 31A. The number of Type 31A cards required is two. This option provides a convenient means for defining a compound price escalation rate for each cost item over the lifetime of the reactor. The cost data for each item on the first card is referenced to a base year. Separate price escalation rates can be defined for each cost item on the second card. Constant cost data for any item can be input by setting the escalation rate for that item to 0.

If NCDS is set to an integer greater than 1, the cost data is input using Card Type 31B. The number of Type 31B cards is NCDS. This option defines the cost of each item in successive calendar years over the lifetime of the reactor. Constant cost data for any item can be input by entering a

constant cost for that item in successive calendar years. The cost of any item can be escalated by defining increased costs for that item in successive calendar years.

The unit prices of eleven standard isotopes commonly used in nuclear fuel cycles are defined on Card Type 29. Card Type 30 permits the user to define an additional nine isotopes and their atomic weights as needed in the fuel cycle. The prices of the standard isotopes of uranium, including ^{233}U , ^{234}U , ^{235}U , and ^{236}U , along with ^{233}Pa can be escalated by means of the uranium price escalation factor defined on Card Type 31A or 31B. The price of any one of these uranium isotopes or ^{233}Pa is calculated in PACTOLUS as the product of the unit price for that isotope defined on Card Type 29 times the uranium price escalation factor. This escalation factor can be varied according to any price escalation schedule using Card Type 31A or 31B to escalate the prices of the standard isotopes of uranium defined above or the price of ^{233}Pa .

The prices of the standard plutonium isotopes, including ^{239}Pu , ^{240}Pu , ^{241}Pu , and ^{242}Pu , can be escalated by means of the plutonium price escalation factor defined on Card Type 31A or 31B. The plutonium isotope price is calculated as the product of the unit price for that isotope defined on Card Type 29 times the plutonium price escalation factor. It should be noted that the parameter IPU on Card Type 17 defines a special option for calculating the price of ^{239}Pu and ^{241}Pu . If IPU is set to 0, the prices of ^{239}Pu and ^{241}Pu are calculated as described above. If IPU is set to 1, the price of ^{239}Pu and ^{241}Pu is computed as the product of the 90% enriched uranium price calculated in PACTOLUS times the plutonium price escalation factor. This escalation factor can be varied according to any specified price escalation schedule using Card Type 31A or 31B to escalate the prices of the standard plutonium isotopes.

PACTOLUS currently does not provide for price escalation of ^{238}U or ^{232}Th isotopes. In addition, the prices of any variable isotopes defined by the user on Card Type 30 also cannot be escalated.

The unit costs of the major processing steps in the nuclear fuel cycle can be escalated using Card Type 31A or 31B. This includes the cost of uranium enrichment, the cost of fuel fabrication, and the cost of chemical reprocessing. Specifically, the uranium feed price and the separative work charge can be separately escalated for the uranium enrichment process; the core fabrication cost, the blanket fabrication cost, and the additional fabrication cost when handling recycle fuels can be separately escalated for the fabrication process; and the core reprocessing cost and the blanket reprocessing cost can be separately escalated for the chemical reprocessing of the spent fuel.

The cards describing the unit prices of the isotopes and the unit costs of the nuclear fuel recycle processes are defined below.

Card Types 29 and 30 -- Isotope Prices

Card Types 29 and 30 are isotope unit price cards. Card Type 29 defines the unit prices (\$/gram) of eleven standard isotopes commonly used in nuclear fuel cycles. Card Type 30 permits the unit prices (\$/gram) and atomic weights of an additional nine isotopes to be defined if needed, depending upon the nuclear fuel cycle.

PACTOLUS uses the price of enriched uranium calculated from the cost model of the uranium diffusion cascade process (ignoring the unit prices of ^{235}U , ^{236}U , and ^{238}U on Card Type 29) unless the ratio $[(^{233}\text{U})/^{233}\text{U} + ^{235}\text{U} + ^{238}\text{U}] > 1 * 10^{-4}$ for a given fuel batch in the reactor burnup data. In that event, the code uses the input prices of ^{235}U , ^{236}U , and ^{238}U , defined on Card Type 29 in the calculation for that fuel batch, after escalating the input prices of ^{235}U and ^{236}U by means of the uranium price escalation factor defined on Card Type 31A or 31B. The cost model of the uranium diffusion cascade process is summarized in Section 3.2.3. The price of enriched uranium calculated from this cost model is a function of the separative work charge and uranium feed price defined on Card Type 31A or 31B. If the latter two prices escalate with time, the price of enriched uranium calculated from the cost model of the uranium diffusion cascade process will also escalate with time.

Card Types 29 and 30 must always be present in the input data deck. However, Card Type 30 is used in the calculations in PACTOLUS only if material balances of the additional isotopes it defines are present in the reactor

burnup data defined on Card Types 5 and 8. Otherwise, the information on Card Type 30 is not used and it is recommended that it be input as a blank card. If any additional isotopes are defined on Card Type 30, PACTOLUS expects that the first two entries must be the atomic weight (237) and unit price of ^{237}Np . Isotopes other than ^{237}Np do not require any special order on Card Type 30. However, the material balances of these isotopes must also be defined in the burnup data on Card Types 5 and 8 in order for the atomic weights and unit prices of the additional isotopes on Card Type 30 to be used in the calculations in PACTOLUS.

Card Type 31A or 31B -- Cost Schedule for Nuclear Fuel Cycle

Card Types 31A and 31B define unit cost schedules for fuel isotopes and processes in the nuclear fuel cycle. The latter include costs incurred in the uranium enrichment process, the fabrication process, and chemical reprocessing. Card Type 31A is used if NCDS is set to 1 on Card Type 17; Card Type 31B is used if NCDS is set to an integer greater than 1. These card types provide two alternative means for entering the cost data.

Card Types 31A and 31B for the nuclear plant are analogous to Card Types 9A and 9B for the fossil plant. The definition of cost schedules for fossil plants is illustrated in the discussion of Card Types 9A and 9B in Section 3.1. The user should carefully review the discussion of Card Types 9A and 9B and apply it to Card Types 31A and 31B.

Card Type 31A allows the user to define separate compound price escalation rates for each of the unit costs related to the fuel isotopes and the nuclear fuel cycle processes. Two cards are required. The first card defines a base year and nine unit costs related to the fuel isotopes and the fuel cycle processes referenced to the base year. The base year must be specified before or at the year in which the first fuel cycle cost is incurred. The time of the first fuel cycle cost is obtained by subtracting all pre-reactor shipping and process times from the power startup year, as illustrated in Figure 8. The second card repeats the base year and defines nine separate price escalation rates for each of the unit costs on the first card.

Card Type 31B defines the unit cost data related to the fuel isotopes and the fuel cycle processes in successive calendar years spanning the lifetime of the reactor. The number of cards must equal NCDS. Each card defines a calendar year and nine unit costs related to the fuel isotopes and the fuel cycle processes in that year. The current program dimensions allow up to a maximum of 60 Type 31B cards. The first calendar year must be specified before or at the year in which the first fuel cycle cost is incurred. Due to the current formulation of the code, the last calendar year must be specified at three or more years after the year in which the final fuel cycle cost is incurred. The time of the final fuel cycle cost is obtained by adding all post-reactor shipping and process times to the final year of reactor power production, as illustrated in Figure 8. The number (NCDS) of Type 31B cards is left to the user's discretion, depending upon the accuracy desired from straight-line interpolation of the cost data between successive calendar years.

SECTION 3.2.6

NUCLEAR INPUT DATA FORMAT

TABLE 2. Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
1	Plant Type, Switches and Title Identification (A4,6X,2I2,16A4,A2)	1	1	H	1-4	Plant type, code NUCL for nuclear plant	IPLTYP
			2	I	12	Print switch to control printout of reactor burnup (charge-discharge) data, Table 5 (kilograms of isotopes fabricated each year, before losses), and Table 6 (kilograms of isotopes reprocessed each year, after losses) in the nuclear output. 0, no printout of these items [Sections (100), (700), and (800) in the nuclear output illustrated in Section 4.4] 1, printout	IPDIS
			3	I	14	Control switch to omit Card Types 2-16 from the data for a given case after the first case when executing multiple cases with one deck setup. If only one case is present in the data deck, this switch must be left blank or set to 0 and all Card Types 1-31A or 31B must be present in the data deck. 0, include all card types in the data deck 1, omit Card Types 2-16 from the data deck for the given case after the first case. (In this case, PACTOLUS uses the information on Card Types 2-16 from the previous case).	ISFUEL
			4	H	15-80	Case title identification	TITLE(1), 1=1 to 17
2	Capacity Factor History (12F6.0)	1	1	R	1-6	Initial time on capacity factor curve, yrs. from plant power production startup	X2(1)
			2	R	7-12	Initial capacity factor at time X2(1), fraction	Y2(1)
			3	R	13-18	Second time on capacity factor curve, yrs. from startup.	X2(2)
			4	R	19-24	Second capacity factor at time X2(2), fraction	Y2(2)
			:				
			11	R	61-66	Sixth time on capacity factor curve, yrs from startup	X2(6)
			12	R	67-72	Sixth capacity factor at time X2(6), fraction	Y2(6)

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
3	Reactor Parameters (6F10.0,I5,3I1, F8.0)	1					
			1	R	1-10	Reactor thermal power, MWth	RTP
			2	R	11-20	Total reactor active fuel volume, liters (Leave blank)	VOL
			3	R	21-30	Scaling factor for isotopic concentrations of charge batches in initial core (A zero or blank will cause the code to use 1.0 for TPR)	TPR
			4	R	31-40	Scaling factor for isotopic concentrations of discharge batches in initial core and isotopic concentrations of all charge and discharge refueling batches (A zero or blank will cause the code to use 1.0 for FMAS)	FMAS
			5	R	41-50	Scaling factor for reactor thermal power (A zero or blank will cause the code to use 1.0 for PWR)	PWR
			6	R	51-60	Constant capacity factor (fraction) of input reactor burnup data if not 100%. If CLF is zero or blank, the code will assume the input burnup data is at 100% (full power)	CLF
			7	I	61-65	Number of fuel regions in one complete reactor loading	NREGN
			8	I	70	Type of refueling scheme 0, Graded refueling in which batches or fractions of the reactor core are replaced periodically 1, Single batch refueling in which the entire reactor inventory is replaced periodically	NFUEL
			9	I	71	Total number of data points in the end-of-life data, includ- ing first and last points. If input is 0 or blank, the code will assume that two points are required, namely, beginning and end-of-life. Currently, this field should be left blank.	NPTS
			10	I	72	Debug print switch to control debug printout of calculations in processing reactor burnup data. (Recommend that IBUG be left blank or set to 0). 0 = no debug printout 1 = debug printout	IBUG
			11	R	73-80	Reactor operating lifetime, years (not fractional). Enter same value as for FLIFE on Card Type 23.	TLIFE

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
	Reactor Burnup Data	Repeat the following set of 6 cards (type no.'s 4 through 9) for each fueling batch or region over the operating lifetime of the reactor.					
4	Reactor Materials Charged per Batch (8E10.4)	1		R	1-10	Kilograms of ^{232}Th	C02
		2		R	11-20	Kilograms of ^{233}Pa	C13
		3		R	21-30	Kilograms of ^{233}U	C23
		4		R	31-40	Kilograms of ^{234}U	C24
		5		R	41-50	Kilograms of ^{235}U	C25
		6		R	51-60	Kilograms of ^{236}U	C26
		7		R	61-70	Kilograms of ^{238}U	C28
		8		R	71-80	Kilograms of ^{237}Np	C37
5	Reactor Materials Charged (cont'd) (4E10.4)	1		R	1-10	Kilograms of ^{239}Pu	C49
		2		R	11-20	Kilograms of ^{240}Pu	C40
		3		R	21-30	Kilograms of ^{241}Pu	C41
		4		R	31-40	Kilograms of ^{242}Pu	C42
6	Fuel Lifetime and Exposure (215,2E10.4, 15, 14,A1)	1		I	5	Specification of charge or discharge Set to 1 to signal that the materials on the two preceding cards were charged	NFINAL
		2		I	6-10	Refueling batch or region number, identifying the portion of the reactor which is being refueled--one of the sequence of integers from 1 up to NREGN. This number is used to relate each end-of-life batch to the corresponding previously discharged batch during the reactor life.	NR
		3		R	11-20	Time materials were charged, years since startup	TIME
		4		R	21-30	Fuel exposure, Mwd/ton, normally zero for material charged (can be left blank as currently not used)	EXP

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
6	Fuel Lifetime and Exposure (cont'd) (2I5,2E10.4,I5, I4,A1)		5	I	31-35	Currently not used	ICOR
			6	I	36-39	Integer batch or region identification number used to successively identify refueling batches (Must be present, recommend consecutive integers starting with 1)	ACASE
			7	H	40	Single alphabetic character or integer further identifying the region or batch (Can be left blank if user desires)	BCASE
7	Reactor Materials Discharged per Batch (8E10.4)		1	R	1-10	Kilograms of ²³² Th	C02
			2	R	11-20	Kilograms of ²³³ Pa	C13
			3	R	21-30	Kilograms of ²³³ U	C23
			4	R	31-40	Kilograms of ²³⁴ U	C24
			5	R	41-50	Kilograms of ²³⁵ U	C25
			6	R	51-60	Kilograms of ²³⁶ U	C26
			7	R	61-70	Kilograms of ²³⁸ U	C28
			8	R	71-80	Kilograms of ²³⁷ Np	C37
8	Reactor Materials Discharged (cont'd) (4E10.4)		1	R	1-10	Kilograms of ²³⁹ Pu	C49
			2	R	11-20	Kilograms of ²⁴⁰ Pu	C40
			3	R	21-30	Kilograms of ²⁴¹ Pu	C41
			4	R	31-40	Kilograms of ²⁴² Pu	C42
9	Fuel Lifetime and Exposure (2I5,2E10.4,I5, I4,A1)		1	I	5	Specification of charge or discharge Set to 3 to signal that the materials on the two preceding cards were discharged.	NFINAL
			2	I	6-10	Refueling batch or region number, identifying the portion of the reactor which is being refueled--one of the sequence of integers from 1 up to NREGN. (Same number as on Card Type 6). This number is used to relate each end-of-life batch to the corresponding previously discharged batch during the reactor life.	NR

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
9	Fuel Lifetime and Exposure (cont'd) (2I5,2E10.4,I5, I4,A1)		3	R	11-20	Time materials were discharged, years since startup	TIME
			4	R	21-30	Fuel exposure, MWD/ton (can be left blank as currently not used)	EXP
			5	I	31-35	Currently not used	ICOR
			6	I	36-39	Integer batch or region identification number used to successively identify refueling batches. (Same number as on Card Type 6).	ACASE
			7	H	40	Single alphabetic character or integer further identifying the region or batch (same as on Card Type 6)	BCASE
10	Reactor End-of-Life Flag (11)					Blank except for a 1 in column 1 to signal that the reactor end-of-life data follows this card. Repeat the following set of 6 cards (3 cards for beginning and 3 cards for end of life) defined by Card Type no.'s 11 through 16 for each refueling batch or reactor region.	
			1	I	1	Enter 1 in Column 1 to signal that the reactor end-of-life data follow this card.	
11	Reactor Materials Charged per Batch	Blank card					
12	Reactor Materials Charged (cont'd)	Blank Card					
13	Fuel Lifetime and Exposure (2I5,2E10.4,I5, I4,A1)		1	I	5	Specification of charge or discharge Set to 1 to signal charge	NFINAL
			2	I	6-10	Refueling batch or region number	NR
			3	R	11-20	Time materials were charged. Enter numerical value for reactor operating lifetime TLIFE.	TIME
			4	R	21-30	Leave blank	EXP
			5	I	31-35	Leave blank	ICOR
			6	I	36-39	Leave blank	ACASE
			7	H	40	Leave blank	BCASE

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
14	Reactor Materials Discharged per Batch	Blank card					
15	Reactor Materials Discharged (cont'd)	Blank card					
16	Fuel Lifetime and Exposure (215,2E10.4,15,14,A1)		1	I	5	Specification of charge or discharge Set to 3 to signal discharge	NFINAL
			2	I	6-10	Refueling batch or region number	NR
			3	R	11-20	Time materials were discharged. Enter numerical value for reactor operating lifetime ILIFE.	
			4	R	21-30	Leave blank	EXP
			5	I	31-35	Leave blank	ICOR
			6	I	36-39	Leave blank	ACASE
			7	H	40	Leave blank	BCASE
17	Control Card (915,3F10.0)	1					
			1	I	1-5	Number of initial core regions	NCR
			2	I	6-10	Number of initial blanket regions	NBR
			3	I	11-15	Card type option for defining the fuel cycle cost schedule (See Card Type number 31A or 31B). If NCDS = 1, use Card Type 31A; if NCDS > 1, use Card Type 31B.	NCDS
			4	I	20	Reprocessing cost option (Recommend that ISEP be set to 1) 0, reprocessing as described by first 3 parameters on Card Type 20 using NFS cost model 1, reprocessing cost based on unit costs on fuel cycle cost schedule cards (SRAT0, BLKSEP), Card type 31A or 31B.	ISEP

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
17	Control Card (cont'd) (9I5,3F10.0)		5	I	25	Price cost option for ^{239}Pu and ^{241}Pu 0, price of ^{239}Pu and ^{241}Pu is product of price of ^{239}Pu and ^{241}Pu shown on Card Type 29 and PRATO on fuel cycle cost schedule cards, Card Type 31A or 31B. 1, price of ^{239}Pu and ^{241}Pu is product of calculated 90% enriched uranium price in PACTOLUS and PRATO on fuel cycle cost schedule cards, Card Type 31A or 31B.	IPU
			6	I	30	Depreciation Option 1 = straight line 2 = sum-of-years-digits	IL2
			7	I	35	Inventory accounting option. Set to 5 for direct fuel expense method.	NOP
			8	I	40	Debug print switch 0 = no debug printout 1 = some debug printout 9 = all debug printout	IPR
			9	I	45	Option for calculating cost of power 0 = levelized cost of power 1 = annual cost of power in current dollars	IECOST
			10	R	46-55	Overall inflation rate, % per year. Used only if IECOST=1, to calculate equivalent levelized cost of power in constant dollars of the base year defined below.	OPCINF
			11	R	56-65	Societal discount rate, % per year. Used only if IECOST=1, to calculate equivalent levelized cost of power in constant dollars of the base year defined below.	SDRATE
			12	R	66-75	Base year. Used only if IECOST=1, to calculate equivalent levelized cost of power in constant dollars of the base year. See Section (800) of fossil output shown in Section 4.2 for an illustration.	BASEYR

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
18	Gaseous Diffusion Cascade Parameters for Uranium Enrichment (110,5F10.0)	1	1	I	10	Option for defining tails composition 0, use input tails composition 1, code calculates optimum tails composition	IXTL
			2	R	11-20	Tails value, \$/kg of uranium	CW
			3	R	21-30	Tails composition, weight fraction of ^{235}U	XT
			4	R	31-40	Feed composition, weight fraction of ^{235}U	XF
			5	R	41-50	U ₃ O ₈ to UF ₆ conversion charge, \$/kg of uranium	UCONV
			6	R	51-60	Uranium conversion and enrichment time, days	UGUYTM
19	Fabrication Card (3F10.0)		1	R	1-10	Core fabrication losses, fraction	CORLOS
			2	R	11-20	Blanket fabrication losses, fraction. Should be the same as core.	BLKLOS
			3	R	21-30	Recoverable cost of salt for MSER or MSCR, \$.	SALT
20	Reprocessing Card (6F10.0)		1	R	1-10	Reprocessing plant operating cost, \$/day (NFS cost model only, leave blank if ISEP=1 on Card Type 17)	SEPCSI
			2	R	11-20	Reprocessing plant throughput, kg/day (NFS cost model only, leave blank if ISEP=1 on Card Type 17)	THRUPT
			3	R	21-30	Reprocessing losses, fraction (Used both if ISEP=0 or ISEP=1 on Card Type 17)	REPL0S
			4	R	31-40	Reprocessing time, days. (Used only if ISEP=1 on Card Type 17)	TSEP
			5	R	41-50	Switch controlling reprocessing of discharged fuel bTank or 0., discharged fuel from the reactor is chemically reprocessed and recycled. 1., discharged fuel from the reactor is not chemically reprocessed and is not recycled	THROW

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
20	Reprocessing Card (cont'd) (6F10.0)		6	R	51-60	One-time charge for permanent storage of discharged fuel when there is no chemical reprocessing, \$/kg. This parameter is ignored if the discharged fuel is chemically reprocessed.	THROCG
21	Shipping Card (8F10.0)	1	1	R	1-10	Shipping cost, enrichment to fabrication, \$/kg	CSHP1
			2	R	11-20	Shipping time, enrichment to fabrication, days	SHPFAB
			3	R	21-30	Shipping cost, fabrication to reactor, \$/kg	CSHP2
			4	R	31-40	Shipping time, fabrication to reactor, days	SHPREA
			5	R	41-50	Shipping cost, reactor to processing, \$/kg	CSHP3
			6	R	51-60	Shipping time, reactor to reprocessing (or permanent storage if no reprocessing), days	SHPSEP
			7	R	61-70	Shipping cost, reprocessing to final destination, \$/kg	CSHP4
			8	R	71-80	Shipping time, reprocessing to final destination, days	SHPDES
22	Shipping Card (cont'd) (2F10.0)	1	1	R	1-10	Shipping cost for recycle fuel, pre-fabrication, \$/kg	DLSHP1
			2	R	11-20	Shipping cost for recycle fuel, fabrication to reactor, \$/kg	DLSHP2
23	Startup and Process Times (3F10.0)	1	1	R	1-10	Reactor power production startup date, year	TSTART
			2	R	11-20	Construction time (>0), years (not fractional)	TCONST
			3	R	21-30	Fabrication time, days	TFAB
			4	R	31-40	Pre-reactor inventory time, days	PRI
			5	R	41-50	Post-reactor cooling time, days	COOL
			6	R	51-60	Depreciable life, years (not fractional)	D(9)
			7	R	61-70	Reactor operating life time, years (not fractional)	TLIFE
			8	R	71-80	Licensing time, years (not fractional)	TLICEN

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
24	Plant Capital Costs (8F10.0)	1	1	R	1-10	Moderator cost, \$	CSTM00
			2	R	11-20	Moderator loss rate, % per year	CML0SS
			3	R	21-30	Cost of control system, \$	CSTCON
			4	R	31-40	Cost of pressure vessel, \$	CSTPR
			5	R	41-50	Cost of turbines, \$	CSTTG
			6	R	51-60	Cost of heat exchangers, \$	CSTHT
			7	R	61-70	Cost of reactor site preparation, \$	CSTRS
			8	R	71-80	All other capital costs, including construction and materials, \$	CSTOTH
25	Plant Operation and Financial Parameters (7F10.0)	1	1	R	1-10	Thermal-to-electrical conversion efficiency, fraction	EFF
			2	R	11-20	Fraction of initial investment in bonds	D(4)
			3	R	21-30	Interest rate on bonds, fractional	D(5)
			4	R	31-40	Earning rate on equity (after taxes), fractional	D(6)
			5	R	41-50	Interim capital replacement rate per year, fraction of plant capital cost	D(18)
			6	R	51-60	Net salvage value of plant, \$ positive, salvage value negative, decommissioning cost	D(24)
			7	R	61-70	Plant investment tax credit, % per year	PIVTCR
26	Fixed and Variable O&M Costs (6F10.0)	1	1	R	1-10	Plant fixed O&M cost, \$/yr	BCYR
			2	R	11-20	Base year, used only if escalating plant fixed O&M cost by the escalation rate defined in the next data item	TBCYR
			3	R	21-30	Escalation rate for plant fixed O&M cost, % per year. Used only if escalating plant fixed O&M cost.	BPCINF

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
26	<u>Fixed and Variable O&M Costs (cont'd)</u> (6F10.0)		4	R	31-40	Variable plant O&M cost (multiplied in the code by the average annual capacity factor to obtain yearly cost), \$/yr	VCYR
			5	R	41-50	Base year, used only if escalating variable plant O&M cost by the escalation rate defined in the next data item	TVCYR
			6	R	51-60	Escalation rate for variable plant O&M cost, % per year. Used only if escalating variable plant O&M cost	VPCINF
27	<u>Taxes and Insurance</u> (7F10.0)	1	1	R	1-10	Federal income tax rate, fractional	D(7)
			2	R	11-20	State income tax rate, fractional	D(15)
			3	R	21-30	State gross revenue tax rate, fractional	D(16)
			4	R	31-40	Property tax on net plant value and initial core, fractional	D(17)
			5	R	41-50	Property insurance on net plant value and initial core, fractional	D(19)
			6	R	51-60	Nuclear liability insurance, \$/yr	CINS
			7	R	61-70	Nuclear liability insurance, \$/MWe per yr	D(21)
28	<u>Licensing Costs</u> (10F8.0)	1	Blank card if TLICEN = 0 on Card Type 23				
			1	R	1-8	Licensing cost one year prior to power production startup, \$ millions	COSTLC(1)
			2	R	9-16	Licensing cost two years prior to power production startup, \$ millions	COSTLC(2)
			.			Repeat up to TLICEN years prior to startup. The current code dimensions allow up to 10 years for licensing time.	
29	<u>Standard Isotope Prices</u> (11F5.0)	1	10	R	73-80	Licensing cost ten years prior to power production startup, \$ millions	COSTLC(10)
			1	R	1-5	²³³ U price, \$/gram	PISO(1)
			2	R	6-10	²³⁵ U price, \$/gram	PISO(2)
			3	R	11-15	²³⁹ Pu price, \$/gram	PISC(3)

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
29	Standard Isotope Prices (cont'd) (11F5.0)		4	R	16-20	²⁴¹ Pu price, \$/gram	PISO(4)
			5	R	21-25	²³² Th price, \$/gram	PISO(5)
			6	R	26-30	²³⁸ U price, \$/gram	PISO(6)
			7	R	31-35	²³⁴ U price, \$/gram	PISO(7)
			8	R	36-40	²⁴⁰ Pu price, \$/gram	PISO(8)
			9	R	41-45	²³³ Pa price, \$/gram	PISO(9)
			10	R	46-50	²³⁶ U price, \$/gram	PISO(10)
			11	R	51-55	²⁴² Pu price, \$/gram	PISO(11)
30	Variable Isotope Prices [9(13,F5.0)]	1	1	I	1-3	Isotope atomic weight	MWT(12)
			2	R	4-8	Isotope price, \$/gram	PISO(12)
			3	I	9-11	Isotope atomic weight	MWT(13)
			4	R	12-16	Isotope price, \$/gram	PISO(13)
			5	I	17-19	Isotope atomic weight	MWT(14)
			6	R	20-24	Isotope price, \$/gram	PISO(14)
			7	I	25-27	Isotope atomic weight	MWT(15)
			8	R	28-32	Isotope price, \$/gram	PISO(15)
			9	I	33-35	Isotope atomic weight	MWT(16)
			10	R	36-40	Isotope price, \$/gram	PISO(16)
			11	I	41-43	Isotope atomic weight	MWT(17)
			12	R	44-48	Isotope price, \$/gram	PISO(17)
			13	I	49-51	Isotope atomic weight	MWT(18)
			14	R	52-56	Isotope price, \$/gram	PISO(18)

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
30	Variable Isotope Prices (cont'd) [9(I3,F5.0)]		15	I	57-59	Isotope atomic weight	MWT(19)
			16	R	60-64	Isotope price, \$/gram	PISO(19)
			17	I	65-67	Isotope atomic weight	MWT(20)
			18	R	68-72	Isotope price, \$/gram	PISO(20)
	Cost Schedule for Fuel Cycle Processes				If NCDS=1 on Card Type 17, use Card Type 31A. If NCDS=1 on Card Type 17, use Card Type 31B.		
31A	Compound Escalation Rate {10F7.0}	2	1	R	1-7	Base year for escalating fuel costs	TIME(1)
			2	R	8-14	Additional fabrication cost when handling recycle fuels, \$/kg in base year	DELFAB(1)
			3	R	15-21	Core fabrication cost, \$/kg in base year	CORFAB(1)
			4	R	22-28	Blanket fabrication cost, \$/kg in base year	BLKFAB(1)
			5	R	29-35	Separative work charge, \$/kg of separative work in base year	CSX(1)
			6	R	36-42	Uranium feed price, \$/lb of U ₃ O ₈ in base year	CFX(1)
			7	R	43-49	Uranium isotope price escalation factor (applied to the prices of all uranium isotopes except ²³⁸ U and also applied to the price of ²³³ Pa shown on Card Type 29), fraction in base year.	PU233(1)
			8	R	50-56	Core reprocessing cost, \$/kg in base year	SRATO(1)
			9	R	57-63	Plutonium isotope price escalation factor (applied to the prices of all plutonium isotopes shown on Card Type 29 or calculated 90% enriched uranium price as defined by IPU, Card Type 17), fraction in base year.	PRATO(1)
			10	R	64-70	Blanket reprocessing cost, \$/kg in base year	BLKSEP(1)

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
31A	Compound Escalation Rate (cont'd) (10F7.0)	Second Card	Type 31A				
			1	R	1-7	Base year for escalating fuel costs	TIME(1)
			2	R	8-14	Escalation rate for escalating additional fabrication cost, % per year	PCINF1
			3	R	15-21	Escalation rate for escalating core fabrication cost, % per year	PCINF2
			4	R	22-28	Escalation rate for escalating blanket fabrication cost, % per year	PCINF3
			5	R	29-35	Escalation rate for escalating separative work charge, % per year	PCINF4
			6	R	36-42	Escalation rate for escalating uranium feed price, % per year	PCINF5
			7	R	43-49	Escalation rate for escalating uranium isotope price escalation factor, % per year	PCINF6
			8	R	50-56	Escalation rate for escalating core reprocessing cost, % per year	PCINF7
			9	R	57-63	Escalation rate for escalating plutonium isotope price escalation factor, % per year	PCINF8
			10	R	64-70	Escalation rate for escalating blanket reprocessing cost, % per year	PCINF9
31B	Cost Schedule Versus Time (10F7.0)	NCDS	Repeat for 1=1 to NCDS cards.				
			1	R	1-7	Calendar year when these costs apply	TIME(1)
			2	R	8-14	Additional fabrication cost when handling recycle fuels, \$/kg in calendar year	DELFA3(1)
			3	R	15-21	Core fabrication cost, \$/kg in calendar year	CORFAB(1)
			4	R	22-28	Blanket fabrication cost, \$/kg in calendar year	BLKFAB(1)

TABLE 2. (cont'd) Nuclear Plant Input Data Format to PACTOLUS

Card Type	Card Description and Format	No. of Cards	Field	Data Type	Columns	Data Description	Data Name
31B	Cost Schedule Versus Time (cont'd) (10F7.0)		5	R	29-35	Separative work charge, \$/kg of separative work in calendar year	CSX(I)
			6	R	36-42	Uranium feed price, \$/lb of U ₃ O ₈ in calendar year	CFX(I)
			7	R	43-49	Uranium isotope price escalation factor (applied to the prices of all uranium isotopes except ²³⁸ U and also applied to price of ²³³ Pa shown on Card Type 29), fraction in calendar year	PU233(I)
			8	R	50-56	Core reprocessing cost, \$/kg in calendar year	SRATO(I)
			9	R	57-63	Plutonium isotope price escalation factor (applied to the prices of all plutonium isotopes shown on Card Type 29 or calculated 90% enriched uranium price as defined by IPU, Card Type 17), fraction in calendar year	PRATO(I)
			10	R	64-70	Blanket reprocessing cost, \$/kg in calendar year	BLKSEP(I)

SECTION 3.2.7

NUCLEAR TEST CASE INPUT

Card Types												
(1)	NUCL	1	1.0	0.50	2.0	0.65	15.	0.65	30.	0.40		
(2)	0.	0.25	1.0	0.50	2.0	0.65	15.	0.65	30.	0.40		
(3)	3102.4										3	0 30.
(4)								601.8			25565.3	
(5)		1	1	0.0	0.0		15					
(6)								289.1	53.4	25285.8		
(7)												
(8)	107.1		31.4	12.7		2.4	15					
(9)	3	1	1.363					745.8		25421.5		
Card Types (4) - (9)	1	2	0.0				25	210.9	88.7	24898.7		Initial Core
repeated for each												
fueling region	127.2		55.2	27.7		10.1	25					
over the operating	3	2	2.155					876.6		25290.4		
lifetime of the												
reactor.												
	1	3	0.0				35	200.6	111.1	24646.2		
	133.7		63.4	33.8		14.9	35					
	3	3	2.966					876.6		25290.4		
	1	1	1.363				45	201.1	111.0	24645.6		Refueling Batches
	134.0		63.2	34.1		15.0	45					
	3	1	3.768					876.6		25290.4		
	1	2	2.155				55	201.1	111.0	24645.6		
	134.0		63.2	34.1		15.0	55					
	3	2	4.570					781.6	24.4	25211.8		
	105.0		30.8	11.2		2.4	65	210.4	116.7	24580.6		
	1	3	2.966									
	145.5		74.6	44.1		25.5	65	759.6	39.9	25155.5		
	3	3	5.371									
	124.4		54.0	24.4		9.8	75	217.4	125.9	24531.4		
	1	1	3.768									
	150.7		80.2	49.7		34.9	75	767.5	49.6	25112.5		
	3	1	6.173									
	131.0		62.1	29.7		14.6	85	229.4	134.1	24493.6		
	1	2	4.570									
	154.6		82.3	52.3		39.1	85	767.5	49.5	25112.0		
	3	2	6.975									
	131.3		62.0	30.1		14.7	95					
	1	3	5.371									

FIGURE 9. Nuclear Test Case Input

		154.6	82.3	52.3	.0	229.6	134.0	24493.3	
		3	7.776		39.2				
(4)					.0	95			
(5)		131.3	62.0	30.1	14.7	767.5	49.5	25112.0	
(6)		1	6.173		.0	105			
(7)					.0	229.6	134.0	24493.3	
(8)		154.6	82.3	52.3	39.2				
(9)		3	8.578		.0	105			
Card Types (4) - (9) repeated for each fueling region over the operating lifetime of the reactor.		147.3	73.0	38.8	24.9	769.2	51.9	25067.3	Refueling Batches (Cont'd)
		1	6.975		.0	115			
		158.7	85.5	56.0	47.8	240.7	135.2	24456.1	
		3	9.380		.0	115			
		148.3	78.7	43.9	34.1	773.3	56.0	25032.6	
		1	7.776		.0	125			
		161.8	87.3	58.3	54.8	249.2	138.5	24425.1	
		3	10.182		.0	125			
		151.4	80.6	46.0	38.3	773.1	59.6	25018.2	
		1	8.578		.0	135			
		162.4	88.0	59.2	47.9	251.4	141.3	24412.2	
		3	10.983		.0	135			
		151.4	80.6	46.0	38.4	773.1	59.5	25018.1	
		1	9.380		.0	145			
		162.8	88.0	59.2	48.0	251.5	141.7	24412.1	
		3	11.785		.0	145			
		151.4	80.6	46.1	38.4	767.8	59.5	25023.3	
		1	10.182		.0	155			
		162.7	88.0	59.1	47.9	251.4	140.4	24421.8	
		3	12.580		.0	155			
		155.7	83.8	49.4	46.8	759.6	60.0	25012.1	
		1	10.983		.0	165			
		164.1	89.1	60.3	64.0	255.0	139.0	24422.1	
		3	13.361		.0	165			
		158.5	85.5	51.4	53.7	748.7	61.5	25007.7	
		1	11.785		.0	175			
		164.9	89.8	61.0	68.8	258.2	138.4	24427.7	
		3	14.130		.0	175			
		159.6	86.3	52.2	56.8	740.8	62.7	25008.8	
		1	12.580		.0	185			
		165.2	90.0	61.2	70.8	260.7	137.9	24439.6	
		3	14.884		.0	185			

FIGURE 9 (cont'd). Nuclear Test Case Input

(4)					.0	727.8	62.7	25021.8	
(5)	159.7	86.3	52.2	56.9					
(6)	1	13.361		195					
(7)				.0	258.2	136.1	24459.4		
(8)	164.7	90.0	60.9	70.8					
(9)	3	15.626		195					
Card Types (4) - (9) repeated for each fueling region over the operating life- time of the reactor.	159.7	86.4	52.1	56.8		714.8	62.4	25035.4	Refueling Batches (Cont'd)
	1	14.130		205					
	164.2	90.0	60.7	70.6		257.1	133.9	24482.9	
	3	16.354		205					
	161.1	87.4	53.2	62.8		709.4	61.8	25032.0	
	1	14.884		215					
	164.8	90.4	61.1	74.8		260.8	132.1	24489.9	
	3	17.068		215					
	161.8	88.0	53.8	67.5		698.9	61.4	25036.5	
	1	15.626		225					
	164.8	90.6	61.1	74.2		260.9	130.2	24503.4	
	3	17.770		225					
	161.7	88.2	53.9	69.4		688.7	61.1	25043.8	
	1	15.354		235					
	164.5	90.6	61.0	74.4		260.9	128.3	24520.4	
	3	18.457		235					
	161.4	88.2	53.7	69.4		678.3	60.4	25055.7	
	1	17.068		245					
	164.0	90.6	60.7	79.3		260.0	126.1	24540.7	
	3	19.142		245					
	161.0	88.2	53.4	69.2		667.9	59.4	25068.1	
	1	17.770		255					
	163.6	90.5	60.4	79.0		259.3	123.7	24561.7	
	3	19.703		255					
	161.6	88.5	53.8	79.3		660.0	58.7	25071.5	
	1	18.457		265					
	163.7	90.7	60.4	81.9		261.0	121.6	24575.4	
	3	20.440		265					
	161.7	88.9	53.9	76.6		649.5	57.8	25079.4	
	1	19.132		275					
	163.4	90.7	60.3	84.2		260.5	119.2	24592.2	
	3	21.074		275					
	161.5	88.9	53.8	78.0		639.1	57.0	25089.5	
	1	19.703		285					

FIGURE 9 (cont'd). Nuclear Test Case Input

[illegible]

FIGURE 9 (cont'd). Nuclear Test Case Input

(25)	0.42222	0.50	0.54	0.085	0.0035	-78000000.4.
(26)	8040000.			4373000.		
(27)	0.48	0.09	0.03	0.032	0.0025	332000. 0.
(28)	0.7	0.6	1.0	0.75	0.5	
(29)	50. 0.	40.4	40.4	0.125		
(30)						
(318)	1994.	72.6	100.	0.	77.	38. 1. 225. 1. 0.
	1995.	49.6	75.	0.	77.	39. 1. 225. 1. 0.
	1995.	48.2	71.	0.	100.	42. 1. 225. 1. 0.
	2000.	48.2	71.	0.	100.	40.7 1. 225. 1. 0.
	2010.	46.2	69.	0.	100.	65. 1. 225. 1. 0.
(318)	2017.	46.2	65.	0.	100.	65. 1. 225. 1. 0.

FIGURE 9 (cont'd). Nuclear Test Case Input

100

101

102

103

104

105

106

107

108

109

110

111

112

113

114

115

116

117

118

119

120

121

122

123

124

125

126

127

128

129

130

131

132

4.0 OUTPUT RESULTS FROM PACTOLUS

4.1 DESCRIPTION OF FOSSIL OUTPUT

Complete output from the sample input data for the fossil plant in Section 3.1.2 is shown in Figure 10 of Section 4.2. The circled numbers in the output correspond to the numbers in parentheses in this section. The output report is divided into the following sections:

- (100) Input Summary
- (200) Fuel Costs and O&M Costs
- (300) Additional Input Summary
- (400) Annual Cash Flow Table
- (500) Annual Tax Deductible Expenses
- (600) Annual Income Statement
- (700) Annual Payment of Investments (Capital Structure)
- (800) Cost of Power

Referring to Figure 10, we shall now summarize the salient output in each section.

(100) Input Summary

Some of the more frequently changed input parameters from Card Type 2 through 7 are summarized with descriptive labels. The input data points on the capacity factor curve are printed, together with the calculated slope between successive data points.

Several quantities calculated from the input parameters are also printed in this section of the output. The electrical conversion efficiency is calculated as the product of 3413 Btu/kWh times the reciprocal of the heat rate of the fuel (Btu/kWh). The power level (MWth) is calculated as the product

of the power level (MWe) times the reciprocal of the electrical conversion efficiency. The fuel inventory in dollars is calculated as follows:

$$\text{FINVDL} = \text{Plant Size} * \text{Fuel Inventory in Days} * \text{Heat Rate} * \text{Unit Cost} * \text{Conversion Factor}$$

where:

FINVDL = initial fuel inventory purchased in the final year of plant construction, \$

Plant Size = plant size, input in MWe

Fuel Inventory in Days = initial fuel inventory at 100% capacity factor, input in days

Heat Rate = heat rate of the fuel, input in Btu/kWh

Unit Cost = unit cost of the fuel at midyear in the final year of plant construction, obtained from the input fuel cost schedule in ¢/MBtu

Conversion Factor = $1000 \text{ kWe/MWe} * 24 \text{ hours/day} * 10^{-6} \text{ MBtu/Btu} * 10^{-2}$
dollars/cents to convert the above equation to dollars.

The total capital cost of the plant is calculated as the product of the input unit capital cost (\$/kWe) times the plant size (kWe).

(200) Fuel Costs and O&M Costs

The average annual capacity factor, the annual fuel cost schedule, the annual fuel purchases, and the annual fuel expenses are printed, starting with the first year of power production. The average annual capacity factor in year 1985, for example, is 37.5%, which is obtained by linear interpolation to midyear between the input capacity factors of 25% and 50% at 0 and 1 year from power startup respectively, as shown in Figure 4 of Section 3.1.

The fuel cost schedule is input on Card Type 9A or 9B. The fuel cost schedule is printed annually at midyear in this section of the output. The quantity of fuel purchased annually is calculated as follows:

$$FPURQ_{(N)} = \text{Plant Size} * \text{Capacity Factor}_{(N)} * \text{Heat Rate} * \text{Conversion Factor}$$

where:

$FPURQ_{(N)}$ = quantity of fuel purchased in year N, MBtu

Plant Size = plant size, input in MWe

$\text{Capacity Factor}_{(N)}$ = average annual capacity factor in year N

Heat Rate = heat rate of the fuel, input in Btu/kWh

Conversion Factor = $1000 \text{ kWe/MWe} * 8760 \text{ hrs/yr} * 10^{-6} \text{ MBtu/Btu}$
to convert the above equation to MBtu/yr.

The cost of fuel purchased annually at midyear is calculated as follows:

$$FPURC_{(N)} = FPURQ_{(N)} * \text{Unit Cost}_{(N)} * \text{Conversion Factor}$$

where:

$FPURC_{(N)}$ = cost of fuel purchased in year N, \$M

$FPURQ_{(N)}$ = quantity of fuel purchased in year N, MBtu

$\text{Unit Cost}_{(N)}$ = unit cost of fuel at midyear in year N, ¢/MBtu

Conversion Factor = 10^{-8} to convert the above equation to millions of dollars.

The annual fuel expenses are the sum of the annual fuel purchases and the straight-line depletion of the capitalized initial fuel inventory over the operating lifetime of the plant.^(a) All fuel costs after the initial inventory are expensed in the year in which they are incurred.

The annual fixed O&M cost and variable O&M cost, which are calculated at midyear, are also printed. The variable O&M cost is calculated as the variable O&M cost defined on Card Type 5 multiplied by the average annual capacity factor.

(a) This assumes that the initial fuel inventory will have zero salvage value in the final year of plant operation and that the initial fuel inventory acts as a reserve which is depleted through wastage and losses over the life of the plant.

(300) Additional Input Summary

Parameters from Card Types 3 through 8 are summarized. This output duplicates some of the output in Section (100). Up to 10 years of licensing costs are printed, culminating in the final year before power production. If the licensing time (TLICEN) on Card Type 7 is 0, zeroes are printed for the licensing costs.

(400) Annual Cash Flow Table

The annual cash flow data are printed for the major expenses. The average annual capacity factor is shown. The capital costs of the plant are distributed over the construction time according to the expenditure profile discussed in the description of Card Type 7 in Section 3.1^(a). The fuel costs are summarized, beginning with the initial fuel inventory purchased in the final year of plant construction, and continuing with the subsequent fuel purchases over the operating lifetime of the plant.

The plant O&M costs are calculated as the sum of the plant fixed O&M costs and the plant variable O&M costs printed in Section (200). The interim capital replacements are calculated as a fraction [D(18), defined on Card Type 4] of the total plant capital cost, beginning with the first year of plant operation.

The property taxes and insurance are printed. The property tax is calculated as a fraction [D(17), defined on Card Type 6] of the net plant value (initial capital cost + interim capital replacements - cumulative straight-line depreciation) and the original cost of the initial fuel inventory. The property insurance is calculated as a fraction [D(19), defined on Card Type 6] of the net plant value and the original cost of the initial fuel inventory.

The total costs are the sum of capital costs, fuel costs, plant O&M costs, interim capital replacements, property taxes, and property insurance.

(a) The licensing costs are included in the capital costs according to the annual input schedule defined for the licensing costs on Card Type 8.

An investment tax credit is calculated which reduces tax liability by a specified percentage [PIVTCR, defined on Card Type 4] of the capital investment and interim capital replacements in any given year. The first investment tax credit is applied in the first year of plant operation for the total initial capital costs and the first-year interim capital replacements. In subsequent years, the investment tax credit is calculated as a percentage of the interim capital replacements.

(500) Annual Tax Deductible Expenses

The present worth discount factor is calculated using the midyear discounting convention from the formula $1/[1+i]^{(N-0.5)}$, where i is the after-tax cost of capital and N is the number of years from the present. Under the midyear discounting convention, all costs and revenues are assumed to be incurred at midyear. The after-tax cost of capital (%) using the effective bond interest rate after income taxes is shown at the top of the column labeled "Present Worth Factor."^(a)

The annual operating expenses are the sum of the annual fuel expenses, the plant O&M costs, and the property taxes and insurance. The total deductible operating expenses are the sum of the annual operating expenses, the bond interest, and the depreciation.

The state taxable income is calculated by subtracting the state gross revenue taxes from the total power sales, which are printed in Section (600). The state income taxes, which are deductible from the federal taxable income, are the product of the state income tax rate [D(15), defined on Card Type 6] and the state taxable income. Negative income taxes^(b) shown for any year are interpreted as tax credits for that year.

-
- (a) After-tax cost of capital (fraction) = bond interest rate * $[1 - \{(\text{federal tax rate}) * (1 - \text{state tax rate}) + \text{state tax rate}\}]$ * fraction of investment in bonds + equity return rate * fraction of investment in equity.
- (b) It is assumed that the firm has income, and hence tax liability, from other operations which is sufficient to absorb all negative income taxes.

(600) Annual Income Statement

The power output is printed in millions of megawatt-hours. The total power sales are the product of the power output times the annual unit cost of power. In this sample case, the annual unit cost of power is the annual cost of power in current dollars based on full cost recovery shown in Section (800).

The state gross revenue taxes are the product of the total power sales times the state gross revenue tax rate [D(16), defined on Card Type 6].

The total tax deductible expenses are the sum of the total deductible operating expenses and the state income tax shown in Section (500). The federal taxable income is derived by subtracting the total tax deductible expenses and revenue taxes from the total power sales. The federal income tax is the product of the federal taxable income times the federal income tax rate [D(7), defined on Card Type 6].

(700) Annual Payout of Investments

The net cash flow is obtained by subtracting the expenses from the revenues and adding the investment tax credit as follows:

total power sales - [revenue taxes + capital costs + fuel cost + plant O&M cost + interim capital replacements + property taxes and insurance + bond interest + state income tax + federal income tax + earnings on unrecovered equity] + investment tax credit

Debt and equity are incurred at the input debt-to-equity ratio [D(4), defined on Card Type 4] when expenses exceed revenues and repaid in the same ratio when revenues exceed expenses. The amount of bonds incurred or repaid is the product of the net cash flow times the fraction of initial investment in bonds [D(4), defined on Card Type 4]. The amount of equity incurred or recovered is obtained by subtracting the bond indebtedness or repayment from the net cash flow. At the end of the project life, debt and equity are exactly repaid and the project exactly earns the specified rate of return.

(800) Cost of Power

The annual cost of power in current dollars is computed for the fossil sample case. The current dollar costs are expressed in units of mills/kWh. The option to calculate the life cycle levelized cost of power is illustrated with the nuclear sample case. The annual power costs are calculated in current dollars in four different bases:

1) Full Cost Recovery Basis

These equations are the same principle to those used to calculate the levelized cost of power for the entire life cycle, except that the capital cost component each year reflects initial investment, capital additions, and the depreciation expenses. For example,

let $A_{(N)}$ = capital investment at beginning of year (N)

let $B_{(N)}$ = capital investment at end of year (N)

then $B_{(N)} = A_{(N)} + \text{capital additions}_{(N)} - \text{depreciation}_{(N)}$

and $A_{(N+1)} = B_{(N)}$

For clarity, we will eliminate expressions for the treatment of the other expenses since those expressions parallel the treatment used in calculating the levelized cost of power. Then the unit cost of power in year N, as related to capital, is as follows:

$$ACP_{(N)} = \frac{PW_{(N-1)} * A_{(N)} - PW_{(N)} * B_{(N)}}{PW_{(N)} * \text{Power Production}_{(N)}}$$

where

$ACP_{(N)}$ = annual cost of power in year N, mills/kWh, and

$PW_{(N)}$ = present worth factor in year N, derived from the capitalization inputs.

The total unit cost of power, in addition to the capital cost component, includes provisions for all other costs for each year. Expenses and credits incurred in the years prior to power production are assigned to the first year of power production.

2) Out of Pocket Cost Basis

The out of pocket costs each year are divided by the annual power production in that year to calculate the unit cost of power production. The out of pocket costs include all operating and fuel costs, interest expense, and income and revenue taxes. The sunk costs are excluded.

3) Fuel and Operating Cost Basis

The fuel and operating costs only each year are divided by the annual power production to determine the unit cost of power production on this basis. This differs from the out of pocket cost by excluding interest expense and income and revenue taxes.

4) Fuel Supply Cost Basis

The annual fuel supply purchases are divided by the annual power production to calculate the unit cost of power production in this basis. This differs from the fuel and operating cost basis by excluding operating costs.

In addition to calculating power costs in four bases, the equivalent levelized cost of power is also calculated in constant dollars referenced to the base year defined on Card Type 3. The annual revenues from the full cost recovery basis are deflated to the base year, based on the inflation rate and base year defined on Card Type 3. Then the levelized cost of power is calculated as follows:

$$LCP = \frac{\sum_{N=1, NY} \text{Annual Revenues}_{(N)} * PW_{(N)}}{\sum_{N=1, NY} \text{Annual Power Production}_{(N)} * PW_{(N)}}$$

where

LCP = levelized cost of power referenced to the base year, mills/kWh

N = year of power production

NY = last year of power production

$PW_{(N)}$ = present worth factor for year N based on the societal discount rate specified on Card Type 3.

SECTION 4.2

FOSSIL TEST CASE OUTPUT

PACTOLUS CASH FLOW AND POWER COSTS

(100)

COAL PLANT 800 MWE SAMPLE CASE

POWERPLANT DESCRIPTION

STARTUP DATE	1985.0	
THERMAL POWER LEVEL	2219.7	MW (TH)
ELECTRICAL POWER LEVEL	800.0	MWE
ELECTRICAL CONV. EFF	36.0	PCT
LIFETIME	30.0	YRS
HEAT RATE OF FUEL	9470.0	BTU/KWHR
FUEL INVENTORY, DAYS	100.0	DAYS
FUEL INVENTORY, \$	18631415.8	\$
BOND INTEREST RATE	4.0	PCT
EARNING RATE ON EQUITY (AFTER TAX)	4.5	PCT
PROPERTY INSURANCE	.3	PCT/YR
PLANT FIXED OPERATING COST	10350000.0	\$/YR
FEDERAL INCOME TAX RATE	48.0	PCT
STATE INCOME TAX RATE	9.0	PCT
PROPERTY TAX RATE	3.2	PCT/YR
STATE GROSS REVENUE TAX RATE	3.0	PCT
COMBINED STATE AND LOCAL TAXES	0.0	\$/YR
INTERIM CAPITAL REPLACEMENTS	.4	PCT/YR

CAPITAL COSTS

CONSTRUCTION TIME	3.0	YRS
TOTAL CAPITAL COST	342000000.0	\$
NET SALVAGE VALUE OF PLANT	0.0	\$
LAND AND LAND RIGHTS	0.0	\$

THE CAPACITY FACTOR PERCENTAGE VARIES AS FOLLOWS

25.00% AT	0.00 YEARS, CHANGING BY	25.00% /YEAR TO
50.00% AT	1.00 YEARS, CHANGING BY	15.00% /YEAR TO
65.00% AT	2.00 YEARS, CHANGING BY	0.00% /YEAR TO
65.00% AT	15.00 YEARS, CHANGING BY	-1.67% /YEAR TO
40.00% AT	30.00 YEARS.	

FIGURE 10. Fossil Test Case Output

(200)

PACTOLUS CASH FLOW AND POWER COSTS

COAL PLANT 400 MWE SAMPLE CASE

TABLE 1
YEARLY COSTS IN MILLIONS OF DOLLARS

YEAR	CAPACITY FACTOR PCT	FUEL PURCHASE \$/MTHU	COST SCHEDULE \$/MTHU	FUEL PURCHASE \$/M	FIXED O&M COST	VARIABLE O&M COST	ANNUAL FUEL EXPENSES
1985	37.5	24237160.	107.533	26.777	10.402	2.141	27.398
1986	47.5	38160312.	112.973	43.111	10.506	3.315	43.732
1987	65.0	43137744.	118.621	51.171	10.611	3.785	51.792
1988	65.0	43137744.	124.552	53.729	10.717	3.823	54.350
1989	65.0	43137744.	130.780	56.416	10.824	3.861	57.037
1990	65.0	43137744.	137.319	59.236	10.932	3.900	59.657
1991	65.0	43137744.	144.185	62.198	11.042	3.939	62.619
1992	65.0	43137744.	151.394	65.308	11.152	3.978	65.925
1993	65.0	43137744.	158.964	68.573	11.263	4.018	69.194
1994	65.0	43137744.	166.912	72.002	11.376	4.058	72.623
1995	65.0	43137744.	175.258	75.602	11.490	4.099	76.223
1996	65.0	43137744.	184.021	79.382	11.605	4.140	80.003
1997	65.0	43137744.	193.222	83.351	11.721	4.181	83.972
1998	65.0	43137744.	202.853	87.519	11.838	4.223	88.140
1999	65.0	43137744.	213.027	91.895	11.956	4.265	92.516
2000	64.2	42514696.	223.678	95.253	12.076	4.252	95.874
2001	62.5	41478600.	234.862	97.417	12.197	4.183	98.039
2002	60.4	40372534.	246.605	99.561	12.319	4.113	100.182
2003	59.2	39266408.	258.935	101.675	12.442	4.040	102.296
2004	57.5	38160312.	271.882	103.751	12.566	3.965	104.372
2005	55.3	37054216.	285.476	105.781	12.692	3.889	106.402
2006	54.2	35945120.	299.750	107.754	12.819	3.811	108.376
2007	52.5	34842024.	314.738	109.661	12.947	3.730	110.282
2008	50.4	33735928.	330.474	111.489	13.077	3.648	112.110
2009	49.2	32623832.	346.998	113.225	13.207	3.564	113.946
2010	47.5	31523736.	364.348	114.856	13.339	3.477	115.677
2011	45.4	30417640.	382.565	116.367	13.473	3.389	116.988
2012	44.2	29311544.	401.694	117.743	13.607	3.298	118.364
2013	42.5	28205448.	421.778	118.964	13.744	3.206	119.586
2014	40.8	27099352.	442.867	120.014	13.881	3.111	120.635
2015	0.0	0.	0.000	0.000	0.000	0.000	0.000
TOTAL		1146465504.	7148.354	2609.781	361.819	113.399	2328.413
2015-TOTAL		471253058.	2377.876	910.059	139.154	45.116	317.493

FIGURE 10 (cont'd). Fossil Test Case Output

(300)

PACTOLUS CASH FLOW AND POWER COSTS

COAL PLANT 800 MWE SAMPLE CASE

INPUT DATA

CARD 3

BOND REPAYMENT PROPORTIONAL
SUM OF YEARS DIGITS DEPRECIATION
DIRECT FUEL EXPENSE INVENTORY ACCOUNTING

CARDS 4, 5, AND 7

PLANT INVESTMENT, \$M	345.0500	(INITIAL FINANCING)
PROJECT LIFE, YEARS	30.0001	
NONFUEL WORKING CAPITAL, \$M	0.0000	(INITIAL FINANCING)
FRACTION OF INITIAL INVESTMENT IN BONDS	.5000	
BOND INTEREST RATE	.0400	
EQUITY EARNING RATE (AFTER TAXES)	.0850	
FEDERAL INCOME TAX RATE	.4800	
PLANT PERCENT INVESTMENT TAX CREDIT	4.0000	

CARDS 3, 5, AND 7

POWERPLANT LEVEL, MWE	800.0000	
DEPRECIABLE LIFE, YEARS	30.0000	
PLANT FIXED OPERATING COST, \$M/YR	10.3500	
PLANT VARIABLE OPERATING COST, \$M/YR	5.6800	
NONFUEL VARIABLE OPERATING COST, \$M/YR	0.0000	(AT 100% PLANT FACTOR)
INITIAL FUEL INVENTORY, \$M	18.6314	(INITIAL FINANCING)
FIRST YEAR OF OPERATION	1985	

CARDS 4 AND 6

STATE INCOME TAX RATE	.0900
STATE GROSS REVENUE TAX RATE	.0300
PROPERTY TAX RATE	.0320
INTERIM CAPITAL REPLACEMENTS, \$M/YR	1.2077
PROPERTY INSURANCE, \$M/YR	.8626

CARDS 6, 7, AND 8

RECOVERABLE COST OF LAND, \$M	0.0000	(INITIAL FINANCING)
NET SALVAGE VALUE OF PLANT, \$M	0.0000	
LICENSING TIME, YEARS	5.0	

YEARS PRIOR TO POWER PRODUCTION	LICENSING COSTS, \$M
-----	-----

1984	.200
1983	.600
1982	1.000
1981	.750
1980	.500
1979	-0.000
1978	-0.000
1977	-0.000
1976	-0.000
1975	-0.000

FIGURE 10 (cont'd). Fossil Test Case Output

(400)

PACTOLUS CASH FLOW AND POWER COSTS

COAL PLANT 800 MWE SAMPLE CASE

CASH FLOW TABLE POWER PLANT, \$ MILLIONS

YEAR	CAPACITY FACTOR	CAPITAL COSTS	FUEL COSTS	PLANT O&M COSTS	INTERIM CAPITAL REPLACEMENT	PROPERTY TAXES INSURANCE	TOTAL COSTS	TAX CREDIT
1 1980	0.00000	.20000	0.00000	0.00000	0.00000	0.00000	.20000	0.00000
2 1981	0.00000	.60000	0.00000	0.00000	0.00000	0.00000	.60000	0.00000
3 1982	0.00000	31.35474	0.00000	0.00000	0.00000	0.00000	31.35474	0.00000
4 1983	0.00000	126.43107	0.00000	0.00000	0.00000	1.17834	127.60941	0.00000
5 1984	0.00000	124.46416	18.63142	0.00000	0.00000	7.61021	150.70561	0.00000
6 1985	.37500	0.00000	26.77684	12.54224	1.20768	12.54701	53.07377	13.85031
7 1986	.57500	0.00000	43.11071	13.32075	1.20768	12.19048	70.12961	.04831
8 1987	.65000	0.00000	51.17054	14.39565	1.20768	11.83117	78.60507	.04831
9 1988	.65000	0.00000	53.72306	14.53564	1.20768	11.46906	80.94546	.04831
10 1989	.65000	0.00000	56.41552	14.63504	1.20768	11.10422	83.41245	.04831
11 1990	.65000	0.00000	59.23629	14.83189	1.20768	10.73657	86.01243	.04831
12 1991	.65000	0.00000	62.19811	14.98821	1.20768	10.36615	88.75215	.04831
13 1992	.65000	0.00000	65.30301	15.13001	1.20768	9.99246	91.63866	.04831
14 1993	.65000	0.00000	68.57341	15.24131	1.20768	9.61693	94.67934	.04831
15 1994	.65000	0.00000	72.00208	15.43413	1.20768	9.23823	97.88211	.04831
16 1995	.65000	0.00000	75.60219	15.53847	1.20768	8.85670	101.25503	.04831
17 1996	.65000	0.00000	79.38230	15.74435	1.20768	8.47239	104.80672	.04831
18 1997	.65000	0.00000	83.35141	15.90179	1.20768	8.08531	108.54619	.04831
19 1998	.65000	0.00000	87.51198	16.06001	1.20768	7.69544	112.48291	.04831
20 1999	.65000	0.00000	91.89493	16.22142	1.20768	7.30280	116.62683	.04831
21 2000	.64167	0.00000	95.25263	16.32841	1.20768	6.90738	119.69610	.04831
22 2001	.62500	0.00000	97.41746	16.36813	1.20768	6.50919	121.51446	.04831
23 2002	.60433	0.00000	99.56265	16.43126	1.20768	6.10821	123.30780	.04831
24 2003	.59167	0.00000	101.67461	16.48178	1.20768	5.70446	125.06852	.04831
25 2004	.57500	0.00000	103.75106	16.53165	1.20768	5.29793	126.78832	.04831
26 2005	.55833	0.00000	105.78097	16.56088	1.20768	4.88862	128.45816	.04831
27 2006	.54167	0.00000	107.75450	16.62944	1.20768	4.47654	130.06816	.04831
28 2007	.52500	0.00000	109.66092	16.67732	1.20768	4.06168	131.60760	.04831
29 2008	.50833	0.00000	111.48861	16.72449	1.20768	3.64404	133.06481	.04831
30 2009	.49167	0.00000	113.22490	16.77093	1.20768	3.22362	134.42713	.04831
31 2010	.47500	0.00000	114.85611	16.81663	1.20768	2.80042	135.68884	.04831
32 2011	.45833	0.00000	116.36738	16.86157	1.20768	2.37445	136.81107	.04831
33 2012	.44167	0.00000	117.74263	16.90572	1.20768	1.94570	137.80172	.04831
34 2013	.42500	0.00000	119.96448	16.94907	1.20768	1.51417	138.63540	.04831
35 2014	.40833	-0.00000	120.01417	16.99160	0.00000	0.00000	137.00577	0.00000
TOTAL		345.05000	2628.41290	475.21865	35.02257	217.75046	3701.45459	15.20290
PA-TOTAL		285.37091	924.49252	184.27222	14.24434	107.87673	1516.65732	11.01549
AVERAGE PLANT CAPACITY FACTOR			.57583					

FIGURE 10 (cont'd). Fossil Test Case Output

(500)

FACILITY CASH FLOW AND POWER COSTS

COAL PLANT 600 MWE SAMPLE CASE

ANNUAL TAX DEDUCTIBLE EXPENSES, \$ MILLIONS

YEAR	5.196 PCT PRESENT WORTH FACTOR	OPERATING EXPENSES	BOND INTEREST	DEPRECIATION	TOTAL DEDUCTIBLE OPERATING EXPENSES	STATE INCOME TAX
1 1980	.97499	0.00000	0.00000	0.00000	0.00000	0.00000
2 1981	.92683	0.00000	.00400	0.00000	.00400	-.00036
3 1982	.88104	0.00000	.01621	0.00000	.01621	-.00146
4 1983	.83752	1.17334	.58414	0.00000	1.65748	-.16762
5 1984	.79615	7.61021	4.45947	0.00000	12.06968	-1.08627
6 1985	.75682	52.43714	7.62514	22.26129	82.37356	3.75029
7 1986	.71944	69.74298	6.34014	22.65160	99.23472	2.75534
8 1987	.68390	78.01844	6.39884	21.83944	106.25671	2.57699
9 1988	.65012	80.35864	5.97376	21.03247	107.36508	2.40519
10 1989	.61800	82.62582	5.56446	20.23069	108.62137	2.23992
11 1990	.58743	85.42581	5.17135	19.43411	110.03189	2.08114
12 1991	.55846	88.16552	4.79503	18.64272	111.60327	1.92879
13 1992	.53087	91.05203	4.43391	17.85652	113.34246	1.78284
14 1993	.50465	94.09276	4.08851	17.07552	115.25679	1.64324
15 1994	.47972	97.29549	3.75873	16.23972	117.35394	1.50995
16 1995	.45602	100.66840	3.44447	15.52911	119.64198	1.38294
17 1996	.43350	104.22009	3.14562	14.76369	122.12940	1.26216
18 1997	.41208	107.95956	2.86208	14.00346	124.82511	1.14756
19 1998	.39173	111.89629	2.59374	13.24844	127.73547	1.03911
20 1999	.37238	116.04020	2.34051	12.43880	130.87931	.93676
21 2000	.35398	119.10947	2.10227	11.75396	132.96570	.84047
22 2001	.33650	120.92793	1.87992	11.01452	133.82127	.75020
23 2002	.31987	122.72117	1.67036	10.29026	134.67180	.66591
24 2003	.30407	124.48139	1.47649	9.55121	135.50959	.58756
25 2004	.28905	126.20169	1.29720	8.82734	136.32624	.51509
26 2005	.27478	127.87153	1.13239	8.10868	137.11259	.44848
27 2006	.26120	129.48153	.98195	7.39520	137.85868	.38768
28 2007	.24830	131.02037	.84577	6.68692	138.55366	.33264
29 2008	.23603	132.47818	.72377	5.98383	139.18576	.28333
30 2009	.22437	133.84050	.61582	5.28594	139.74227	.23971
31 2010	.21329	135.09421	.52184	4.59325	140.20930	.20172
32 2011	.20276	136.22444	.44171	3.90574	140.57189	.16933
33 2012	.19274	137.21510	.37532	3.22343	140.81385	.14250
34 2013	.18322	138.04878	.32259	2.54632	140.91768	.12119
35 2014	.17417	137.62632	.28339	13.54859	151.45880	.11454
TOTAL		5321.38201	89.37096	380.07257	3790.32555	13.02686
PA-TOTAL		1209.64166	43.67311	191.34593	1439.66070	17.42602

FIGURE 10 (cont'd). Fossil Test Case Output

(600)

PACTOLUS CASH FLOW AND POWER COSTS

COAL PLANT 800 MWE SAMPLE CASE

ANNUAL INCOME STATEMENT, \$ MILLIONS

YEAR	POWER UNITS (M MWH)	TOTAL POWER SALES	REVENUE TAXES	TOTAL TAX DEDUCTIBLE EXPENSES	TAXABLE INCOME (FEDERAL)	FEDERAL INCOME TAX
1 1980	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2 1981	0.00000	0.00000	0.00000	.00364	-.00364	-.00175
3 1982	0.00000	0.00000	0.00000	.01475	-.01475	-.00708
4 1983	0.00000	0.00000	0.00000	1.69486	-1.69486	-.81353
5 1984	0.00000	0.00000	0.00000	10.98341	-10.98341	-5.27204
6 1985	2.63016	128.33801	3.85014	86.16385	36.32402	18.39553
7 1986	4.03291	133.86561	4.01597	101.93007	27.85958	13.37260
8 1987	4.55894	139.06174	4.17185	108.83370	26.05615	12.50637
9 1988	4.55894	138.23655	4.14710	109.77028	24.31918	11.67321
10 1989	4.55894	137.63858	4.12916	110.86130	22.64313	10.87110
11 1990	4.55894	137.27385	4.11822	112.11303	21.04260	10.10045
12 1991	4.55894	137.14870	4.11446	113.53206	19.50218	9.36105
13 1992	4.55894	137.26964	4.11810	115.12530	18.02645	8.65289
14 1993	4.55894	137.64432	4.12933	116.90003	16.61496	7.97518
15 1994	4.55894	138.27959	4.14839	118.86389	15.26731	7.32831
16 1995	4.55894	139.18350	4.17550	121.02492	13.98307	6.71187
17 1996	4.55894	140.36429	4.21093	123.39156	12.76181	6.12567
18 1997	4.55894	141.83070	4.25432	125.97267	11.60111	5.56949
19 1998	4.55894	143.59187	4.30776	128.77757	10.50854	5.04314
20 1999	4.55894	145.65748	4.36972	131.81607	9.47168	4.54641
21 2000	4.53050	146.70544	4.40116	133.80617	8.49511	4.07909
22 2001	4.38363	146.55347	4.39660	134.57147	7.58539	3.64099
23 2002	4.26670	146.46477	4.39394	135.33771	6.73311	3.23189
24 2003	4.14981	146.43092	4.39293	136.09715	5.94084	2.85160
25 2004	4.03291	146.44278	4.39328	136.84133	5.20816	2.49992
26 2005	3.91602	146.49843	4.39471	137.56107	4.53464	2.17663
27 2006	3.79312	146.56311	4.39689	138.24635	3.91986	1.88153
28 2007	3.63222	146.64917	4.39948	138.88630	3.36339	1.61443
29 2008	3.56533	146.73600	4.40208	139.46911	2.86481	1.37511
30 2009	3.44843	146.80996	4.40430	139.98197	2.42369	1.16337
31 2010	3.33154	146.85632	4.40569	140.41102	2.03961	.97901
32 2011	3.21464	146.85915	4.40577	140.74122	1.71215	.82183
33 2012	3.09774	146.80127	4.40404	140.95636	1.44087	.69162
34 2013	2.98085	146.66416	4.39992	141.03887	1.22536	.58818
35 2014	2.86395	157.45509	4.72365	151.57334	1.15910	.55589
TOTAL	121.16270	4285.66665	128.57600	3823.35241	333.93825	160.29036
PW-TOTAL	49.80363	1663.79701	50.51391	1457.08671	176.19639	84.57427

FIGURE 10 (cont'd). Fossil Test Case Output

(700)

PACTOLUS CASH FLOW AND POWER COSTS

COAL PLANT 800 MWE SAMPLE CASE

PAYOUT OF INVESTMENTS, \$ MILLIONS

YEAR	NET CASH FLOW	OUTSTANDING BONDS	EQUITY CAPITAL NOT RECOVERED	BOND INTEREST	EARNINGS ON UNRECOVERED EQUITY	BONDS PAID	RECOVERY OF EQUITY
1 1980	-1.20000	0.00000	0.00000	0.00000	0.00000	-1.00000	-1.00000
2 1981	-1.61033	.10000	.10000	.00400	.00550	-1.30520	-1.30520
3 1982	-53.33685	.40520	.40520	.01621	.03444	-16.69843	-16.69843
4 1983	-188.76621	17.10362	17.10362	.64414	1.45381	-34.38310	-34.38310
5 1984	-158.29334	111.48673	111.48673	4.45947	9.47637	-79.14167	-79.14167
6 1985	19.25005	190.62840	190.62840	7.62514	16.20341	19.62502	19.62502
7 1986	22.06493	171.00338	171.00338	6.84014	14.53529	11.03249	11.03249
8 1987	21.25281	159.97089	159.97089	6.39884	13.59753	10.62641	10.62641
9 1988	20.44584	149.34448	149.34448	5.97378	12.69428	10.22292	10.22292
10 1989	19.64406	139.12156	139.12156	5.56486	11.82533	9.82203	9.82203
11 1990	18.84748	129.29353	129.29353	5.17198	10.99846	9.42374	9.42374
12 1991	18.05603	119.87579	119.87579	4.79503	10.18944	9.02804	9.02804
13 1992	17.26390	110.84775	110.84775	4.43331	9.42206	8.63495	8.63495
14 1993	16.43883	102.21280	102.21280	4.09551	8.68809	8.24445	8.24445
15 1994	15.71303	93.96835	93.96835	3.78873	7.98731	7.85654	7.85654
16 1995	14.94248	86.11181	86.11181	3.44447	7.31950	7.47124	7.47124
17 1996	14.17706	78.64057	78.64057	3.14562	6.68445	7.08853	7.08853
18 1997	13.41684	71.55204	71.55204	2.86208	6.08192	6.70842	6.70842
19 1998	12.66181	64.84362	64.84362	2.59374	5.51171	6.33090	6.33090
20 1999	11.91197	58.51272	58.51272	2.34051	4.97358	5.95599	5.95599
21 2000	11.16733	52.55071	52.55071	2.10227	4.46732	5.58367	5.58367
22 2001	10.42783	46.57306	46.57306	1.87492	3.99271	5.21394	5.21394
23 2002	9.69364	41.75912	41.75912	1.67035	3.54953	4.84682	4.84682
24 2003	8.96458	36.91230	36.91230	1.47649	3.13755	4.48229	4.48229
25 2004	8.24072	32.43001	32.43001	1.29720	2.75655	4.12036	4.12036
26 2005	7.52205	28.30965	28.30965	1.13239	2.40632	3.76102	3.76102
27 2006	6.80857	24.54863	24.54863	.98195	2.08663	3.40429	3.40429
28 2007	6.10023	21.14434	21.14434	.85577	1.79727	3.05015	3.05015
29 2008	5.39721	18.09420	18.09420	.72377	1.53501	2.69860	2.69860
30 2009	4.69332	15.39559	15.39559	.61582	1.30863	2.34966	2.34966
31 2010	4.00662	13.04594	13.04594	.52184	1.10890	2.00331	2.00331
32 2011	3.31912	11.04263	11.04263	.44171	.93862	1.65956	1.65956
33 2012	2.63681	9.38307	9.38307	.37532	.79756	1.31840	1.31840
34 2013	1.95369	8.06467	8.06467	.32259	.68550	.97985	.97985
35 2014	1.415364	7.08492	7.08492	.28333	.60221	7.08482	7.08482
TOTAL	-1.00000	2221.77401	2221.77401	86.87056	188.85079	-1.00000	-1.00000
PA-TOTAL	-126.46246	1216.82764	1216.82764	46.67311	103.43035	-13.23123	-63.23123

FIGURE 10 (cont'd). Fossil Test Case Output

(800)

PACTOLUS CASH FLOW AND POWER COSTS

COAL PLANT 800 MWE SAMPLE CASE

ANNUAL COST OF POWER IN CURRENT DOLLARS
MILLS PER KWHR

		BASED ON FULL COST RECOVERY	BASED ON YEARLY OUT OF POCKET COST ONLY	BASED ON YEARLY FUEL AND OPER. COSTS ONLY	BASED ON YEARLY FUEL SUPPLY COSTS ONLY
1	1983	0.00	0.00	0.00	0.30
2	1984	0.00	0.00	0.00	0.30
3	1985	0.00	0.00	0.00	0.00
4	1986	0.00	0.00	0.00	0.00
5	1987	0.00	0.00	0.00	0.30
6	1988	48.79	32.98	20.18	10.18
7	1989	33.19	24.13	17.44	10.59
8	1990	30.50	22.87	17.24	11.22
9	1991	30.32	23.06	17.76	11.79
10	1992	30.19	23.30	18.30	12.37
11	1993	30.11	23.58	18.87	12.99
12	1994	30.08	23.90	19.47	13.64
13	1995	30.11	24.27	20.10	14.33
14	1996	30.19	24.68	20.77	15.04
15	1997	30.33	25.14	21.47	15.79
16	1998	30.53	25.66	22.21	16.58
17	1999	30.79	26.22	22.99	17.41
18	2000	31.11	26.84	23.81	18.28
19	2001	31.50	27.52	24.67	19.20
20	2002	31.95	28.26	25.58	20.16
21	2003	32.60	29.13	26.60	21.16
22	2004	33.43	30.15	27.72	22.22
23	2005	34.33	31.23	28.90	23.33
24	2006	35.29	32.36	30.14	24.50
25	2007	36.31	33.60	31.44	25.73
26	2008	37.41	34.89	32.80	27.01
27	2009	38.58	36.25	34.24	28.36
28	2010	39.83	37.69	35.74	29.78
29	2011	41.16	39.22	37.32	31.27
30	2012	42.57	40.84	38.98	32.83
31	2013	44.08	42.56	40.73	34.48
32	2014	45.66	44.38	42.56	36.20
33	2015	47.39	46.30	44.48	38.01
34	2016	49.20	48.33	46.51	39.91
35	2017	51.98	49.82	47.84	41.91

EQUIVALENT LEVELIZED COST OF POWER IN 1985 CONSTANT DOLLARS 24.98 MILLS PER KWHR
(FULL COST RECOVERY BASIS)

FIGURE 10 (cont'd). Fossil Test Case Output

4.3 DESCRIPTION OF NUCLEAR OUTPUT

The output from the sample input data for the nuclear plant in Section 3.2.7 is shown in Figure 11 of Section 4.4. The circled numbers in the output correspond to the numbers in parentheses in this section. The output report is divided into the following sections:

- (100) Reactor Burnup Data
- (200) Plant Financial and Fuel Cycle Parameters
- (300) Annual Fuel Cycle Costs
- (400) Cost Schedules for Fuel Cycle Processes
- (500) Annual Fuel Purchases for Uranium Enrichment and
Annual Fuel Credits from Reprocessed Fuel
- (600) Reactor Performance Characteristics
- (700) Annual Fuel Fabrication (Before Losses)
- (800) Annual Chemical Reprocessing (After Losses)
- (900) Input Summary of Capital Structure and Financial Parameters
- (1000) Annual Fuel Cycle Costs and O&M Costs
- (1100) Annual Fuel Expenses and Non-Fuel Operating Expenses
- (1200) Annual Cash Flow Table
- (1300) Annual Tax Deductible Expenses
- (1400) Annual Income Statement
- (1500) Annual Payout of Investments (Capital Structure)
- (1600) Cost of Power

Referring to Figure 11, we shall now summarize the salient output in each section.

(100) Reactor Burnup Data

The general reactor parameters and reactor burnup data are printed in this section of the output. This includes the scaling factors defined on Card Type 3 to modify the input burnup data, the capacity factor history defined on Card Type 2, the burnup data defined on Card Types 4-9, and the end-of-life data generated by Card Types 11-16.

Adjusted values of the original reactor burnup data defined on Card Types 4-9 are printed for the initial core and the refueling batches in each of the reactor regions over the operating lifetime of the reactor. Specifically, the charge times and discharge times have been adjusted by PACTOLUS from the original values defined on Card Types 4-9 to account for the capacity factor history defined on Card Type 2.

The 12 isotopes in the reactor burnup data are listed across the page, together with a column labeled "TIME" as headings for columns of output. The individual rows describe the kilograms of each of the 12 isotopes in a charge batch labeled "CHG" or a discharge batch labeled "DISCHG." These rows alternate between charge and discharge batches. The adjusted time in years from startup at which the charge or discharge occurred as well as any identifying case numbers for the charge and discharge batch (the parameters ACASE and BCASE, defined on Card Types 6 and 9) appear at the right end of each row of output.

The adjustments to the input burnup data can be illustrated by the output in Section (100) of Figure 11 for the initial core in region one. The discharge time for the initial core in region one was increased from 1.363 years to 2.6 years. This increase is due to the fact that the capacity factor defined on Card Type 2 is less than the capacity factor of 1 (CLF on Card Type 3), which was used to generate the burnup data at full power from the burnup code ALTHAEA. Thus, the initial core in region one was irradiated over a longer period of time at a lower capacity factor (power factor) to achieve the isotopic concentrations defined in the burnup data at discharge time.

The rows of alternate charge and discharge batches repeat until the corrected value of a discharge time has exceeded the reactor operating lifetime. At that point, PACTOLUS backs up, deletes the burnup data of the region which has exceeded the reactor operating lifetime (TLIFE, defined on Card Type 23), and instead calculates the end-of-life data for each reactor region at the final shutdown time of the reactor. This is shown by printing the message "The previous region would have gone past TLIFE years. This region will be deleted and the following regions comprise the shutdown of the reactor at TLIFE years."

The material balance information printed after this message reports the charge and discharge data for the end of life triggered by Card Types 11-16. For the end-of-life calculations, PACTOLUS cycles through each reactor region, determines the corrected final charge time for each region, and interpolates the material balance in each region to exactly TLIFE years for the shutdown time of the region.

(200) Plant Financial and Fuel Cycle Parameters

The financial and tax structure of the plant, together with parameters for the fuel cycle processes, are printed in this section of the output. The financial and tax parameters are defined primarily on Card Types 24-27. These parameters include the capital cost and capital structure of the plant, the plant fixed O&M cost, and taxes and insurance.

The process lead and lag times, shipping times, and unit shipping costs for the fuel cycle processes are listed from Card Types 18 and 20-23. The input parameters to the NFS cost model for chemical reprocessing are listed from Card Type 20 under the heading labeled "Reprocessing Charges."

The parameter name and card type defining each shipping and process time shown in this output are as follows:

<u>Name of Process Time in Output</u>	<u>Card Type</u>	<u>Parameter</u>
Uranium Enrichment and Lead Time, Days	18	UBUYTM
Pre-fabrication Shipping Time, Days	21	SHPFAB
Time in Fabrication, Days	23	TFAB
Ship from Fabricator to Reactor Site, Days	21	SHPREA
Pre-reactor Inventory Time, Days	23	PRI
Post-reactor Cooling, Days	23	COOL
Time to Ship Fuel to Reprocess Site (or permanent storage if no reprocessing), Days	21	SHPSEP
Time in Reprocessing, Days	20	TSEP
Ship to Final Destination, Days	21	SHPDES

The parameter name and card type defining each unit shipping charge shown in this output are as follows:

<u>Name of Shipping Charge in Output</u>	<u>Card Type</u>	<u>Parameter</u>
Pre-fabrication Shipping Cost (U) \$/kg	21	CSHP1
Fabricator to Reactor Site (U), \$/kg	21	CSHP2
Pre-fabrication Shipping Cost (Recycle), \$/kg	22	DLSHP1
Fabricator to Reactor Site (Recycle), \$/kg	22	DLSHP2
Reactor Site to Reprocessing Plant, \$/kg	21	CSHP3
Cost to Ship to Final Destination, \$/kg	21	CSHP4

The costs associated with the initial fuel core are calculated in PACTOLUS and summarized in this section of the output. This includes the cost of fuel purchases for the initial core, the shipping charges to the fabrication facility and the reactor, the fabrication charge, and the cost of the fuel material losses during fabrication. The cost items included in the fuel purchases are defined in the description of Section (300) of the

output. The total of these costs is printed as the cost of the initial fuel inventory in Section (900) of the output.

Several input parameters to the cost model of the gaseous diffusion cascade process for uranium enrichment are listed from Card Type 18 under the heading labeled "Uranium Cascade Price Schedule Parameters." The unit isotope prices are listed from Card Type 29 and 30.

(300) Annual Fuel Cycle Costs

The annual cash flow is printed for the nuclear fuel cycle processes. The output shows on an annual basis the average annual capacity factor, the fuel purchases, fuel credits, fabrication charges, reprocessing charges, pre-reactor shipping charges, post-reactor shipping charges, charges for fuel losses, and the total of these charges. The charges vary widely from one year to the next, depending on the fuel cycle processes that take place during a given year. This is a function of the process lead and lag times and shipping times defined for the fuel cycle processes and the charge and discharge times of the reactor defined in the reactor burnup data. In the total column, most years show net charges but some show net credits.

The listed fuel purchases are the sum of the costs for U_3O_8 purchased, the conversion of U_3O_8 to UF_6 , and the separative work in the ^{235}U enrichment process, offset by the credit given for the waste or tails in the enrichment process.

The listed fuel credits are the sum of U_3O_8 credits, separative work credits, and fissile Pu credits reclaimed from the chemical reprocessing of the discharged fuel.

The pre-reactor shipping charges include the shipping charges for standard and recycle fuels to the fabrication facility and the shipping charges for standard and recycle fuels from fabrication to the reactor. If the discharged fuel is reprocessed, the post-reactor shipping charges include the shipping charges to the reprocessing facility, the shipping charges to the waste storage site, and the one time charge in \$/kg of heavy metal for storage

of the radioactive wastes at the permanent storage site. If the discharged fuel is not reprocessed, the post-reactor shipping charges include the shipping charges to the permanent storage site and the one time charge in \$/kg of heavy metal for storage of the spent fuel at the permanent storage site.

The charges for fuel losses are the sum of the dollar values of the fuel material losses incurred during fabrication and reprocessing.

(400) Cost Schedules for Fuel Cycle Processes

The unit cost schedules for the fuel cycle processes and the unit prices of ^{233}U and ^{239}Pu isotopes are shown on an annual basis. The fuel cycle cost schedules are defined on Card Type 31A or 31B. The output shows the unit costs for uranium feed (\$/lb of U_3O_8) and separative work (\$/kg of separative work) in the uranium enrichment process (last two columns); the unit costs for core fabrication, blanket fabrication, and the additional fabrication cost penalty when handling recycle fuels (columns 6-8); and the unit costs for chemical reprocessing of core and blanket fuels (columns 2-3). Note that the cost of converting U_3O_8 to UF_6 prior to the enrichment of UF_6 in the ^{235}U isotope appears in the output as part of the costs for the fuel purchases printed in Section (300). The unit cost of converting U_3O_8 to UF_6 (\$/kg of uranium) is defined on Card Type 18 in the input data.

The reprocessing time defined on Card Type 20 is also shown. It should be noted that the reprocessing charge and reprocessing time are shown as zero in those years in which reprocessing does not take place. This depends upon the discharge times of the reactor, the post-reactor process times, and the post-reactor shipping times.

The unit price of ^{233}U is the product of its unit price on Card Type 29 times the uranium price escalation factor on Card Type 31A or 31B. The unit price of ^{239}Pu is the product of its unit price on Card Type 29 times the plutonium price escalation factor on Card Type 31A or 31B.

(500) Annual Fuel Purchases for Uranium Enrichment and Annual Fuel Credits from Reprocessed Fuel

The results calculated by the cost model of the gaseous diffusion cascade process for uranium enrichment and the fuel credits recovered from the chemical reprocessing of the discharged fuel are shown on an annual basis. The first column (after the year column) lists the uranium feed price (\$/lb of U_3O_8) used in the diffusion cascade process. The uranium feed price is defined by a unit cost schedule on Card Type 31A or 31B.

The next five columns describe the output results from the cost model of the diffusion cascade process. This includes the percentage tails composition (weight percent of ^{235}U), the price of 90% enriched uranium (\$/gm of contained ^{235}U) calculated at the time of uranium purchase (see Figure 8), the gross tons of U_3O_8 purchased in order to supply the uranium for the reactor annually, the tonnes of separative work purchased, and the tonnes of tails produced. The tails composition can be either specified by the user on Card Type 18 by setting the parameter IXTL to 0 and defining the parameter XT (weight fraction of ^{235}U in the tails) or calculated in the diffusion cascade model by setting the parameter IXTL to 1.

The last three columns show the uranium credits reclaimed by chemical reprocessing of the discharged fuel. This includes the tons of U_3O_8 credits, the tonnes of separative work credits, and the tonnes of tails consumed. The tonnes of tails consumed are the theoretical amount which when added to the tonnes of discharged fuel adjust the ^{235}U content of the discharged fuel to the natural concentration.

The results from the cost model of the diffusion cascade process (columns 2-6 after the year column) and the uranium credits reclaimed by chemical reprocessing of the discharged fuel (last three columns) are shown as zero in those years (e.g., 1982) in which uranium enrichment or chemical reprocessing do not take place in the fuel cycle.

(600) Reactor Performance Characteristics

Fourteen statistics are printed to summarize the performance characteristics of the nuclear fuel cycle and the reactor. The capacity factor data points defined on Card Type 2 are also printed. The description of the calculation of the statistics is given below:

- 1) Initial full power specific power (MWth) produced by the reactor per tonne of heavy metal = reactor power level (MWth) in Section (200)/tonnes of heavy metal in the initial core in Section (100).
- 2) Yield (kg) of fissile material per MWe-Yr =
[total kg of ^{233}U , ^{235}U , ^{239}Pu , and ^{241}Pu reprocessed (after losses) in Section (800) - total kg of ^{233}U , ^{235}U , ^{239}Pu , and ^{241}Pu fabricated (before losses) in Section (700)]/total MWe-Yr

where:

total MWe-Yr = reactor power level (MWth) in Section (200) * electrical conversion efficiency (fraction) in Section (200) * average capacity factor (fraction) in Section (600) * reactor lifetime (yrs) in Section (200).

A negative yield indicates that fissile material was consumed. Observe that statistic 2 = the sum of statistics 3, 4, and 5.

- 3) Yield (kg) of fissile Pu per MWe-Yr =
[total kg of ^{239}Pu and ^{241}Pu reprocessed (after losses) in Section (800) - total kg of ^{239}Pu and ^{241}Pu fabricated (before losses) in Section (700)]/total MWe-Yr.
- 4) Yield (kg) of ^{235}U per MWe-Yr =
[kg of ^{235}U reprocessed (after losses) in Section (800) - kg of ^{235}U fabricated (before losses) in Section (700)]/total MWe-Yr.
- 5) Yield (kg) of ^{233}U per MWe-Yr =
[kg of ^{233}U reprocessed (after losses) in Section (800) - kg of ^{233}U fabricated (before losses) in Section (700)]/total MWe-Yr.

- 6) Specific inventory (kg) of fissile material per MWe =

$$[1/\text{statistic 1}] * \text{weight fraction of fissile material in the initial core in Section (100)} * 1000/\text{electrical conversion efficiency (fraction) in Section (200)}.$$
- 7) Tons of U_3O_8 mined per MWe-Yr =

$$[\text{tons of } \text{U}_3\text{O}_8 \text{ purchased in Section (500)} - \text{equivalent tons of } \text{U}_3\text{O}_8 \text{ credits in the discharged fuel in Section (500)}]/\text{total MWe-Yr}.$$
- 8) Tons of U_3O_8 mined per MWth-Yr =

$$\text{statistic 7} * \text{electrical conversion efficiency (fraction) in Section (200)}.$$
- 9) Kg fissioned per ton of U_3O_8 mined is currently not used.
- 10) Kg of separative work per MWe-Yr =

$$[\text{tonnes of separative work purchased in Section (500)} - \text{tonnes of equivalent separative work credits in the discharged fuel}] * 1000/\text{total MWe-Yr}.$$
- 11) Tons of U_3O_8 consumed over the lifetime of the reactor =

$$\text{statistic 7} * \text{total MWe-Yr}.$$
- 12) Tonnes of separative work consumed over the lifetime of the reactor =

$$\text{statistic 10} * \text{total MWe-Yr}/1000.$$
- 13) Kg of fuel fabricated (after losses) per MWe-Yr =

$$[\text{total kg of fuel fabricated (before losses) over the lifetime of the reactor in Section (700)}] * [1 - \text{fabrication loss rate (fraction) defined on Card Type 19}]/\text{total MWe-Yr}.$$
- 14) Average plant capacity factor (percent) =

$$\sum_{\text{life of the reactor}} \frac{[\text{average annual capacity factor in Section 300}]}{\text{reactor lifetime}}$$

(700) Annual Fuel Fabrication (Before Losses)

The kilograms of fuel fabricated are shown by isotope (before fabrication losses) in this section of the output. The output lists up to 20 isotopes which can be used in the fabrication process. The isotopes are defined on Card Types 29 and 30 in the input data. Up to 12 of these isotopes can currently be input in the reactor burnup data on Card Types 4, 5, 7, and 8.

The next to last column was originally designed to show the total fission products generated during fuel irradiation. This column is currently not being used. The last column is the total kilograms of the 20 isotopes passing annually through the fabrication process before fabrication losses.

(800) Annual Chemical Reprocessing (After Losses)

The kilograms of discharged fuel that are chemically reprocessed are shown by isotope (after reprocessing losses) in this section of the output. The format of this output is similar to the format described in Section (700) for the fabrication process. The reprocessing loss rate is defined as a fraction on Card Type 20.

(900) Input Summary of Capital Structure and Financial Parameters

The input data describing the capital structure, tax rates, and financial parameters of the plant are summarized. The input data listed are defined primarily on Card Types 17 and 24-28. The output in this section restates some of the output previously printed in Section (200).

(1000) Annual Fuel Cycle Costs and O&M Costs

The average annual capacity factor, the cash flow for the nuclear fuel cycle, and the plant fixed and variable O&M costs are shown for each year. The totals and present worth totals of these expenses are also shown after the final year of reactor operation. The average annual capacity factor in year 1985, for example, is 0.375, which is obtained by linear interpolation to midyear between the input capacity factors of 0.25 and 0.50 at 0 and 1 year from power startup, respectively, as shown in Figure 4 of Section 3.1.

The annual cash flow for the fuel cycle shows the fuel purchases, fabrication charges, reprocessing charges, and the fuel credits obtained by reprocessing the discharged fuel. The cash flow shown for the fuel cycle is similar to that described in Section (300) with the exceptions noted below in which some costs have been aggregated in the columns labeled "Fabrication Cost" and "Reprocessing Cost."

The fabrication costs shown in Section (1000) include the cost of fabrication, the cost of fuel losses during fabrication, and the pre-reactor shipping costs. The reprocessing costs include the cost of reprocessing, the costs of fuel losses during reprocessing, and the post-reactor shipping costs.

If the discharged fuel is not reprocessed, the shipping charges to the permanent storage site and the one time charge in \$/kg of heavy metal for storage of the spent fuel at the permanent storage site are printed in the column labeled "Reprocessing Cost." There are no fuel credits if the discharged fuel is not reprocessed.

(1100) Annual Fuel Expenses and Non-Fuel Operating Expenses

The current fuel expenses, the annual fuel expenses, and the non-fuel operating expenses are shown annually for the operating lifetime of the reactor. The totals and present worth totals of these expenses are also shown after the final year of reactor operation.

The current fuel expenses are calculated by summing the fuel purchases, the fabrication costs, and the reprocessing costs and subtracting the fuel credits. These items are printed in Section (1000). The annual fuel expenses are the sum of the current fuel expenses and the straight-line depletion of the capitalized initial fuel core over the operating lifetime of the reactor. All fuel costs after the initial core are expensed in the year in which they are incurred.

The non-fuel operating expenses are the sum of the following costs:
1) the plant fixed O&M cost, 2) the variable plant O&M cost, 3) the nuclear liability insurance, 4) the property insurance, and 5) the property taxes. Peroperty taxes and property insurance apply to the net plant value (initial capital cost + interim capital replacements - cumulative straight-line depreciation) and the original cost of the initial core.

(1200) Annual Cash Flow Table

The annual cash flow information is printed for the major expenses. The average annual capacity factor is shown for the operating lifetime of the reactor. The capital costs of the reactor are distributed over the construction time according to the expenditure profile discussed in the description of Card Type 7 in Section 3.1.^(a) The decommissioning cost is shown in the capital cost column (for convenience) in the last year when the reactor is being decommissioned.

The fuel costs are printed, beginning with the cost of the initial fuel core and continuing with the subsequent fuel costs over the lifetime of the reactor. The latter fuel costs are the current fuel expenses printed in Section (1100).

The plant O&M costs are calculated as the sum of the plant fixed O&M costs and the plant variable O&M costs printed in Section (1000). The interim capital replacements are calculated as a fraction $[D(18)]$, defined on Card Type 25] of the total plant capital cost, beginning with the first year of plant operation. No plant O&M costs or interim capital replacements are assessed in the last year when the plant (reactor) is being decommissioned.

The property taxes, property insurance, and nuclear liability insurance are printed in the column labeled "Property Taxes and Insurance." The property tax is calculated as a fraction $[D(17)]$, defined on Card Type 27] of the net plant value and original cost of the initial fuel core. The property insurance is calculated as a fraction $[D(19)]$, defined on Card Type 27] of the net plant value and original cost of the initial fuel core. No property taxes or insurance are assessed in the last year when the plant is being decommissioned.

The total costs are the sum of capital costs, fuel costs, plant O&M costs, interim capital replacements, and property taxes and insurance. An investment tax credit is calculated which reduces tax liability by a specified percentage $[PIVTCR, \text{ defined on Card Type 25}]$ of the capital investment and interim capital replacements in any given year. The first investment tax credit is applied in

(a) The licensing costs are included in the capital costs according to the annual input schedule defined for the licensing costs on Card Type 28.

the first year of plant operation for the total initial capital costs and the first-year interim capital replacements. In subsequent years, the investment tax credit is calculated as a percentage of the interim capital replacements.

(1300) Annual Tax Deductible Expenses

The present worth discount factor is calculated using the midyear discounting convention from the formula $1/[1+i]^{(N-0.5)}$, where i is the after-tax cost of capital and N is the number of years from the present. Under the midyear discounting convention, all costs and revenues are assumed to be incurred at midyear. The after-tax cost of capital (%) using the effective bond interest rate after income taxes is shown at the top of the column labeled "Present Worth Factor."^(a)

The annual operating expenses are the sum of the annual fuel expenses and the non-fuel operating expenses printed in Section (1100). The total deductible operating expenses are the sum of the annual operating expenses, the bond interest, and the depreciation.

The state taxable income is calculated by subtracting the state gross revenue taxes from the total power sales, which are printed in Section (1400). The state income taxes, which are deductible from the federal taxable income, are the product of the state income tax rate [D(15), defined on Card Type 27] and the state taxable income. Negative income taxes^(b) shown for any year are interpreted as tax credits for that year.

(1400) Annual Income Statement

The power output is printed in millions of megawatt-hours. The total power sales are the product of the power output times the annual unit cost of power. In this sample case, the annual unit cost of power is the levelized cost of power shown in Section (1600).

-
- (a) After-tax cost of capital (fraction) = bond interest rate * $[1 - \{(\text{federal tax rate}) * (1 - \text{state tax rate}) + \text{state tax rate}\}]$ * fraction of investment in bonds + equity return rate * fraction of investment in equity.
- (b) It is assumed that the firm has income, and hence tax liability, from other operations which is sufficient to absorb all negative income taxes.

The state gross revenue taxes are the product of the total power sales times the state gross revenue tax rate [D(16), defined on Card Type 27].

The total tax deductible expenses are the sum of the total deductible operating expenses and the state income tax shown in Section (1300). The federal taxable income is derived by subtracting the total tax deductible expenses and revenue taxes from the total power sales. The federal income tax is the product of the federal taxable income times the federal income tax rate [D(7), defined on Card Type 27].

(1500) Annual Payout of Investments

The net cash flow is obtained by subtracting the expenses from the revenues and adding the investment tax credit as follows:

total power sales - [revenue taxes + capital costs + fuel cost + plant O&M cost + interim capital replacements + property taxes and insurance + bond interest + state income tax + federal income tax + earnings on unrecovered equity] + investment tax credit

Debt and equity are incurred at the input debt-to-equity ratio [D(4), defined on Card Type 25] when expenses exceed revenues and repaid in the same ratio when revenues exceed expenses. The amount of bonds incurred or repaid is the product of the net cash flow times the fraction of initial investment in bonds [D(4), defined on Card Type 25]. The amount of equity incurred or recovered is obtained by subtracting the bond indebtedness or repayment from the net cash flow. At the end of the project life, debt and equity are exactly repaid and the project exactly earns the specified rate of return.

(1600) Cost of Power

The life cycle levelized busbar cost of power is calculated for the nuclear test case. This method of calculating the power cost is selected by setting the parameter IECOST to 0 on Card Type 17 in the nuclear input data. The option to calculate the annual cost of power in current dollars by setting IECOST to 1 is illustrated with the fossil test case.

The levelized unit cost of power is calculated by equating the present worth of the revenues and expenses over the economic life of the plant. The computed cost of power enables the firm to exactly recover its debt and equity capital, interest on debt, return on equity and all operating costs and taxes over the lifetime of the plant.

The revenues are derived from the sale of power. The expenses are the sum of the capital costs, the fuel cycle costs, and all operating costs, offset by the credits recovered by reprocessing the discharged fuel and by the net salvage credit of the plant. The revenues and expenses are both discounted at the effective cost of capital to obtain the present worth of the revenues and expenses.

The equation for calculating the levelized unit cost of power is as follows:

$$LCP = \frac{\sum_{N=1, NY} [\text{Present Worth of Expenses}_{(N)} - \text{Present Worth of Tax Credits}_{(N)}]}{\text{Present Worth of Power Production}_{(N)} * (1 - \text{Revenue Tax Rate}) * (1 - \text{Combined Federal and State Income Tax Rate})}$$

where:

LCP = levelized unit cost of power

N = year of power production

NY = last year of power production

Note that the power production is discounted. This is equivalent to discounting the revenues, because of the following relation:

$$LCP * \sum_{N=1, NY} \text{Present Worth of Power Production}_{(N)} = \sum_{N=1, NY} \text{Present Worth of Revenues}_{(N)}$$

The first two columns of the output in Section (1600) break down the unit cost of power in mills/kWh and equivalent annual costs in millions of dollars into its various components. This includes the initial plant capital costs, interim capital replacements, fuel supply costs, operating expenses, property taxes and insurance, revenue taxes, state income taxes, federal income taxes, and bond interest. The rate of return on investment is included in the distributed cost of power for each capitalized component. The deductible nature of bond interest causes this expense to be partially included in the rate of return (the part which is included in the present worth factor) and the remainder to be accounted for separately in the bond interest component. The first two columns include the reduction in costs obtained by defining an investment tax credit on Card Type 25 in the input data.

The last two columns of the output reallocate the taxes and bond interest to the direct cost components for the plant: initial capital costs, interim capital replacements, fuel supply, operating expenses, and property taxes and insurance. These two columns show the costs without the investment tax credit. Consequently, the difference between the total cost of power (bottom line) in the last two columns and the total cost of power in the first two columns shows the reduction in the cost of power obtained from the investment tax credit.

The final page of the output breaks down the fuel supply cost (mills/kWh) shown in the third column of the previous page into the component parts of the fuel cycle. This includes the cost of fuel purchases, shown separately for the initial core and fuel replacements; the cost of fuel fabrication, separated into the initial core and fuel replacements; the cost of reprocessing the discharged fuel; and the fuel credits recovered by reprocessing the discharged fuel.

SECTION 4.4

NUCLEAR TEST CASE OUTPUT

(100)

PACTOLUS CASH FLOW AND POWER COSTS
LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

REACTOR BURNUP (CHARGE-DISCHARGE) DATA

REACTOR THERMAL POWER, MW(TH)	3103.400	REACTOR ACTIVE FUEL VOLUME, LITERS	-0.000
SCALING FACTOR FOR REACTOR POWER	1.000	SCALING FACTOR FOR REACTOR INVENTORY	1.000
SCALING FACTOR FOR THERMAL POWER	1.000	CONSTANT CAPACITY FACTOR OF BURNUP INPUT DATA	1.000
NUMBER OF FUEL REGIONS IN ONE COMPLETE REACTOR LOADING	3	NUMBER OF POINTS IN END-OF-LIFE DATA	2
		REACTOR OPERATING LIFE, YEARS	30.000

THE CAPACITY FACTOR PERCENTAGE VARIES AS FOLLOWS

25.00% AT	0.00 YEARS, CHANGING BY	25.00%/YEAR TO
50.00% AT	1.00 YEARS, CHANGING BY	15.00%/YEAR TO
65.00% AT	2.00 YEARS, CHANGING BY	0.00%/YEAR TO
65.00% AT	15.00 YEARS, CHANGING BY	-1.67%/YEAR TO
40.00% AT	30.00 YEARS,	

KILOGRAMS OF ISOTOPES

	TH232	PA233	U233	U234	U235	U236	U238	NP237	PU239	PU240	PU241	PU242	TIME
--	-------	-------	------	------	------	------	------	-------	-------	-------	-------	-------	------

CHG	0.0	0.0	0.0	0.0	601.4	0.0	25565.3	0.0	0.0	0.0	0.0	0.0	15
DISCHG	0.0	0.0	0.0	0.0	289.1	51.4	25285.8	0.0	107.1	31.4	12.7	2.4	15
CHG	0.0	0.0	0.0	0.0	745.8	0.0	25421.5	0.0	0.0	0.0	0.0	0.0	25
DISCHG	0.0	0.0	0.0	0.0	210.9	88.7	24898.7	0.0	127.2	55.2	27.7	10.1	25
CHG	0.0	0.0	0.0	0.0	876.6	0.0	25290.4	0.0	0.0	0.0	0.0	0.0	35
DISCHG	0.0	0.0	0.0	0.0	208.6	111.1	24846.2	0.0	133.7	63.4	33.8	14.3	35
CHG	0.0	0.0	0.0	0.0	876.6	0.0	25290.4	0.0	0.0	0.0	0.0	0.0	45
DISCHG	0.0	0.0	0.0	0.0	201.1	111.0	24685.6	0.0	134.0	63.2	34.1	15.0	45
CHG	0.0	0.0	0.0	0.0	876.6	0.0	25290.4	0.0	0.0	0.0	0.0	0.0	55
DISCHG	0.0	0.0	0.0	0.0	201.1	111.0	24645.6	0.0	134.0	63.2	34.1	15.0	55
CHG	0.0	0.0	0.0	0.0	741.6	24.4	25211.4	0.0	105.0	30.3	11.2	2.4	65
DISCHG	0.0	0.0	0.0	0.0	210.4	116.7	24580.6	0.0	145.5	74.6	44.1	25.5	65
CHG	0.0	0.0	0.0	0.0	753.8	39.3	25155.5	0.0	124.4	54.0	24.4	9.3	75
DISCHG	0.0	0.0	0.0	0.0	217.4	125.9	24531.4	0.0	150.7	60.2	49.7	34.9	75
CHG	0.0	0.0	0.0	0.0	767.5	43.6	25112.5	0.0	131.0	62.1	29.7	14.3	85
DISCHG	0.0	0.0	0.0	0.0	229.4	134.1	24493.6	0.0	154.6	82.3	52.3	39.1	85
CHG	0.0	0.0	0.0	0.0	767.5	49.5	25112.0	0.0	131.3	62.0	30.1	14.7	95
DISCHG	0.0	0.0	0.0	0.0	229.6	134.0	24493.3	0.0	154.6	82.3	52.3	39.2	95
CHG	0.0	0.0	0.0	0.0	767.5	49.5	25112.0	0.0	131.3	62.0	30.1	14.7	105
DISCHG	0.0	0.0	0.0	0.0	229.6	134.0	24493.3	0.0	154.6	82.3	52.3	39.2	105
CHG	0.0	0.0	0.0	0.0	769.2	51.3	25067.3	0.0	142.3	73.0	38.8	24.3	115
DISCHG	0.0	0.0	0.0	0.0	240.7	135.2	24456.1	0.0	158.7	85.5	56.0	47.8	115
CHG	0.0	0.0	0.0	0.0	773.3	56.0	25032.6	0.0	148.3	78.7	43.9	34.1	125
DISCHG	0.0	0.0	0.0	0.0	249.2	138.5	24425.1	0.0	161.8	87.3	58.3	54.9	125
CHG	0.0	0.0	0.0	0.0	773.1	59.6	25018.2	0.0	151.4	80.6	46.0	38.3	135
DISCHG	0.0	0.0	0.0	0.0	251.4	141.3	24412.2	0.0	162.8	88.0	59.2	57.3	135
CHG	0.0	0.0	0.0	0.0	773.1	59.5	25018.1	0.0	151.4	80.6	46.0	38.4	145
DISCHG	0.0	0.0	0.0	0.0	251.5	141.2	24412.1	0.0	162.8	88.0	59.2	58.0	145
CHG	0.0	0.0	0.0	0.0	767.8	59.5	25023.3	0.0	151.5	80.6	46.1	38.4	155
DISCHG	0.0	0.0	0.0	0.0	251.4	140.4	24421.8	0.0	162.7	88.0	59.1	57.3	155
CHG	0.0	0.0	0.0	0.0	759.6	60.0	25012.1	0.0	155.7	83.8	49.4	46.8	165
DISCHG	0.0	0.0	0.0	0.0	256.0	139.8	24422.1	0.0	164.1	89.1	60.3	64.0	165
CHG	0.0	0.0	0.0	0.0	748.7	61.5	25007.7	0.0	158.5	85.5	51.4	53.7	175
DISCHG	0.0	0.0	0.0	0.0	258.2	138.4	24427.7	0.0	164.9	89.8	61.0	68.8	175
CHG	0.0	0.0	0.0	0.0	740.8	62.7	25008.8	0.0	153.6	86.3	52.2	56.8	185
DISCHG	0.0	0.0	0.0	0.0	260.7	137.3	24439.6	0.0	165.2	90.0	61.2	70.8	185
CHG	0.0	0.0	0.0	0.0	727.8	62.7	25021.8	0.0	159.7	86.3	52.2	56.9	195
DISCHG	0.0	0.0	0.0	0.0	258.2	136.1	24459.4	0.0	164.7	90.0	60.9	70.9	195
CHG	0.0	0.0	0.0	0.0	714.8	62.4	25015.4	0.0	153.7	86.4	52.1	56.8	205
DISCHG	0.0	0.0	0.0	0.0	257.1	133.9	24482.9	0.0	164.2	90.0	60.7	70.6	205
CHG	0.0	0.0	0.0	0.0	709.4	61.8	25032.0	0.0	161.1	87.4	53.2	62.3	215
DISCHG	0.0	0.0	0.0	0.0	268.8	132.1	24489.9	0.0	164.8	90.4	61.1	74.8	215
CHG	0.0	0.0	0.0	0.0	638.9	61.4	25031.5	0.0	161.8	88.0	53.8	67.5	225
DISCHG	0.0	0.0	0.0	0.0	260.9	130.2	24503.4	0.0	164.8	90.6	61.1	78.2	225
THE PREVIOUS REGION WOULD HAVE GONE PAST TLIFE YEARS. THIS REGION WILL BE DELETED AND THE FOLLOWING REGIONS COMPRISE THE SHUTDOWN OF THE REACTOR AT TLIFE YEARS.													
CHG	0.3	0.0	0.0	0.0	698.9	61.4	25036.5	0.0	161.8	88.0	53.8	67.5	225
DISCHG	0.0	0.0	0.0	0.0	362.0	114.3	24626.5	0.0	164.1	90.0	59.4	75.7	225
CHG	0.0	0.0	0.0	0.0	714.8	62.4	25035.4	0.0	159.7	86.4	52.1	56.8	225
DISCHG	0.0	0.0	0.0	0.0	525.3	92.8	24406.6	0.0	161.6	87.9	55.7	62.5	225
CHG	0.0	0.0	0.0	0.0	709.4	61.3	25032.0	0.0	161.1	87.4	53.2	62.8	225
DISCHG	0.0	0.0	0.0	0.0	666.9	68.5	24986.6	0.0	161.5	87.7	53.9	63.9	225
END DATA													

End of Life

FIGURE 11. Nuclear Test Case Output

(200)

PACTOLUS CASH FLOW AND POWER COSTS

LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

POWERPLANT DESCRIPTION				FIXED PROCESS TIMES				
STARTUP DATE	1985.0			URANIUM ENRICHMENT AND LEAD TIME	200.0	DAYS		
THERMAL POWER LEVEL	3103.4	MW(TH)		PRE-FABRICATION SHIPPING TIME	30.0	DAYS		
ELECTRICAL CONV. EFF	32.2	PCT		TIME IN FABRICATION	60.0	DAYS		
TONS OF FUEL IN REACTOR	74.5	TONNE		SHIP FROM FABRICATOR TO REACT SITE	10.0	DAYS		
LIFETIME	30.0	YRS		PRE REACTOR INVENTORY TIME	60.0	DAYS		
				POST REACTOR COOLING	150.0	DAYS		
				TIME TO SHIP FUEL TO REPROCESS SITE	30.0	DAYS		
				TIME IN REPROCESSING	60.0	DAYS		
				SHIP TO FINAL DESTINATION	30.0	DAYS		
PLANT CHARGES				SHIPPING CHARGES				
BOND INTEREST RATE	4.0	PCT		PRE-FABRICATION SHIPPING COST, (U)	10.0	\$/KG		
EARNING RATE ON EQUITY (AFTER TAX)	3.5	PCT		FABRICATOR TO REACTOR SITE (U)	10.0	\$/KG		
NUCLEAR LIABILITY COST PER YEAR	332003.0	\$/YR		PRE-FABRICATION SHIPPING COST(RECYC)	10.0	\$/KG		
NUCLEAR LIABILITY COST PER MWYE	0.0	\$/MWY		FABRICATOR TO REACTOR SITE(RECYC)	10.0	\$/KG		
PROPERTY INSURANCE	.3	PCT/YR		REACTOR SITE TO REPROCESSING PLANT	25.0	\$/KG		
PLANT FIXED OPERATING COST	6040030.0	\$/YR		COST TO SHIP TO FINAL DESTINATION	50.0	\$/KG		
FEDERAL INCOME TAX RATE	43.0	PCT		REPROCESSING CHARGES				
STATE INCOME TAX RATE	1.0	PCT		REPROCESSING PLANT THROUGHPUT	0.0	KG/DAY		
PROPERTY TAX RATE	3.7	PCT/YR		REPROCESSING PLANT OPERATING COST	0.0	\$/DAY		
STATE GROSS REVENUE TAX RATE	3.0	PCT		FIRST CORE PURCHASE				
COMBINED STATE AND LOCAL TAXES	0.0	\$/YR		FABRICATION CHARGE	7512590.7	\$		
INSTRUM CAPITAL REPLACEMENT	.4	PCT/YR		SHIPPING CHARGE	1570021.0	\$		
				FUEL PURCHASE	65344012.4	\$		
CAPITAL COSTS				FUEL FABRICATION LOSSES	653440.3	\$		
CONSTRUCTION TIME	3.0	YRS		URANIUM CASCADE PRICE SCHEDULE PARAMETERS				
TOTAL CAPITAL COST	760000000.0	\$		COST OF FUEL (SEE TABLE 2)				
NET SALVAGE VALUE OF PLANT	-760000000.0	\$		CONVERSION COST	3.50	\$/KG		
LAND AND LAND RIGHTS	0.0	\$		FUEL COMPOSITION	.7110	PCT		
				COST OF SEPARATIVE DUTY (SEE TABLE 2)				
				TAILS VALUE	0.30	\$/KG		
ISOTOPE PRICES								
U235	30.00	\$/G	U235	0.00	\$/G	PU239	40.40	\$/G
U238	.31	\$/G	U238	-0.00	\$/G	U234	-0.00	\$/G
PA233	-0.00	\$/G	U236	-0.00	\$/G	PU242	-0.00	\$/G
	-0.00	\$/G		-0.00	\$/G		-0.00	\$/G
	-0.30	\$/G		-0.00	\$/G		-0.00	\$/G
				-0.00	\$/G		-0.00	\$/G
						PU241	40.40	\$/G
						PU240	-0.00	\$/G
						NP237	-0.00	\$/G
							-0.00	\$/G
							-0.00	\$/G

FIGURE 11 (cont'd). Nuclear Test Case Output

(300)

PACTOLUS CASH FLOW AND POWER COSTS

LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

TABLE 1
YEARLY COSTS IN MILLIONS OF DOLLARS

YEAR	CAPACITY FACTOR PCT	FUEL PURCHASE	FUEL CREDIT	FABRICATION CHARGE	REPROCESSING CHARGE	PRE-REACTOR SHIPPING CHARGE	POST-REACTOR SHIPPING CHARGE	FUEL LOSS CHARGE	VARIABLE OPERATING CHARGE	TOTAL
1985	37.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.640	0.000
1986	57.5	26.933	0.000	0.000	0.000	0.000	0.000	.269	2.514	27.298
1987	65.0	27.025	0.000	2.250	0.000	.523	0.000	0.000	2.842	29.798
1988	65.0	0.000	10.834	2.116	5.888	.523	1.334	.399	2.842	.025
1989	65.0	23.278	9.840	3.296	5.888	.523	1.306	.434	2.842	33.486
1990	65.0	23.140	10.118	0.000	5.888	.262	1.830	.467	2.842	27.529
1991	65.0	24.316	0.000	3.246	5.888	.262	.630	.490	2.842	34.831
1992	65.0	31.638	10.231	3.226	0.000	.523	1.250	0.000	2.842	26.479
1993	65.0	6.521	10.303	3.211	5.888	.523	1.830	.501	2.842	6.230
1994	65.0	32.617	11.572	3.193	5.888	.523	1.830	.538	2.842	33.076
1995	65.0	34.437	12.393	3.176	5.888	.262	1.839	.581	2.842	33.835
1996	65.0	25.007	0.000	0.000	5.888	.262	.630	.611	2.842	35.397
1997	65.0	36.463	13.270	3.158	5.888	.523	1.839	0.000	2.842	34.651
1998	65.0	37.370	13.451	3.141	0.000	.523	1.259	.624	2.842	29.467
1999	65.0	7.975	13.625	3.123	5.888	.523	1.839	.633	2.842	6.406
2000	64.2	37.323	14.572	3.111	5.888	.262	1.839	.653	2.806	35.059
2001	62.5	30.163	15.339	0.000	5.888	.262	1.838	.673	2.733	23.541
2002	60.8	38.653	0.000	3.106	0.000	.523	0.000	0.000	2.660	42.276
2003	59.2	41.480	15.715	3.088	5.888	.523	1.338	.684	2.587	4.837
2004	57.5	39.271	15.930	3.076	5.888	.262	1.838	.691	2.514	35.146
2005	55.8	30.746	16.134	0.000	5.888	.262	1.839	.694	2.442	23.394
2006	54.2	31.561	0.000	3.064	0.000	.523	0.000	0.000	2.369	12.146
2007	52.5	33.427	16.677	3.051	5.888	.523	1.830	.702	2.296	34.804
2008	50.8	31.354	17.076	0.000	5.888	0.000	1.831	.714	2.223	22.769
2009	49.2	8.658	0.000	3.936	0.000	.523	0.000	0.000	2.150	12.220
2010	47.5	40.042	17.402	3.017	5.888	.262	1.832	.714	2.077	34.417
2011	45.8	32.207	17.244	0.000	5.888	.252	1.833	.266	2.004	23.272
2012	44.2	8.557	0.000	2.988	0.000	.523	0.000	.456	1.931	12.524
2013	42.5	31.410	17.155	0.000	5.888	0.000	1.334	.720	1.859	23.285
2014	40.8	9.659	0.000	2.959	5.888	.523	.632	0.000	1.786	18.659
2015	0.0	0.000	106.745	0.000	17.663	0.000	7.056	1.442	0.000	-82.573

FIGURE 11 (cont'd). Nuclear Test Case Output

(400)

PACTOLUS CASH FLOW AND POWER COSTS

LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

TABLE 2
VARIABLE PARAMETERS

YEAR	REPROCESSING CHARGE, \$/KG		REPROCESSING TIME, DAYS		FABRICATION CHARGE, \$/KG		U233 OR PU FAB PENALTY	PJ239 PRICE	J233 PRICE	U FEED PRICE	SEPARATIVE DUTY CHARGE
	BLKT	CORE	BLKT	CORE	BLKT	CORE	\$/KG	\$/CM	\$/CM	\$/L3 U308	\$/KG
1982					0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983					0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984					0.00	100.00	72.50	40.40	30.00	38.00	77.00
1985	0.00	0.00	0.00	0.00	0.00	95.83	68.77	40.40	30.00	39.17	77.00
1986	0.00	0.00	0.00	0.00	0.00	91.57	64.33	40.40	30.00	38.33	77.00
1987	0.00	0.00	0.00	0.00	0.00	87.50	61.10	40.40	30.00	38.50	77.00
1988	0.00	225.00	0.00	60.00	0.00	83.33	57.27	40.40	30.00	38.67	77.00
1989	0.00	225.00	0.00	60.00	0.00	79.17	53.43	40.40	30.00	38.83	77.00
1990	0.00	225.00	0.00	60.00	0.00	75.00	49.60	40.40	30.00	39.00	77.00
1991	0.00	225.00	0.00	60.00	0.00	70.60	49.46	40.40	30.00	39.60	81.60
1992	0.00	0.00	0.00	0.00	0.00	70.20	49.32	40.40	30.00	40.20	86.20
1993	0.00	225.00	0.00	60.00	0.00	73.60	49.18	40.40	30.00	40.80	90.80
1994	0.00	225.00	0.00	60.00	0.00	73.40	49.04	40.40	30.00	41.40	95.40
1995	0.00	225.00	0.00	60.00	0.00	73.60	48.90	40.40	30.00	42.00	100.00
1996	0.00	225.00	0.00	60.00	0.00	72.60	48.76	40.40	30.00	43.54	100.00
1997	0.00	225.00	0.00	60.00	0.00	72.20	48.62	40.40	30.00	45.08	100.00
1998	0.00	0.00	0.00	0.00	0.00	71.80	48.48	40.40	30.00	46.62	100.00
1999	0.00	225.00	0.00	60.00	0.00	71.40	48.34	40.40	30.00	48.16	100.00
2000	0.00	225.00	0.00	60.00	0.00	71.00	48.20	40.40	30.00	49.70	100.00
2001	0.00	225.00	0.00	60.00	0.00	70.80	48.07	40.40	30.00	51.23	100.00
2002	0.00	0.00	0.00	0.00	0.00	70.60	47.94	40.40	30.00	52.76	100.00
2003	0.00	225.00	0.00	60.00	0.00	70.40	47.81	40.40	30.00	54.29	100.00
2004	0.00	225.00	0.00	60.00	0.00	70.20	47.68	40.40	30.00	55.82	100.00
2005	0.00	225.00	0.00	60.00	0.00	70.00	47.55	40.40	30.00	57.35	100.00
2006	0.00	0.00	0.00	0.00	0.00	69.80	47.42	40.40	30.00	58.88	100.00
2007	0.00	225.00	0.00	60.00	0.00	69.60	47.29	40.40	30.00	60.41	100.00
2008	0.00	225.00	0.00	60.00	0.00	69.40	47.16	40.40	30.00	61.94	100.00
2009	0.00	0.00	0.00	0.00	0.00	69.20	47.03	40.40	30.00	63.47	100.00
2010	0.00	225.00	0.00	60.00	0.00	69.00	46.90	40.40	30.00	65.00	100.00
2011	0.00	225.00	0.00	60.00	0.00	68.43	46.80	40.40	30.00	65.00	100.00
2012	0.00	0.00	0.00	0.00	0.00	67.86	46.70	40.40	30.00	65.00	100.00
2013	0.00	225.00	0.00	60.00	0.00	67.29	46.60	40.40	30.00	65.00	100.00
2014	0.00	225.00	0.00	60.00	0.00	66.71	46.50	40.40	30.00	65.00	100.00
2015	0.00	225.00	0.00	60.00	0.00	66.14	46.40	40.40	30.00	65.00	100.00

FIGURE 11 (cont'd). Nuclear Test Case Output

(500)

PACTOLUS CASH FLOW AND POWER COSTS

LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

TABLE 3
URANIUM PURCHASES AND CREDITS

YEAR	URANIUM PRICE \$/LB	TAILS COMPOSITION PCT	90 PCT ENR URANIUM PRICE \$/GM	U3O8 PURCHASED TONS	SEPARATIVE WORK PURCHASED TONNE	TAILS PRODUCED TONNE U	EQUIVALENT U3O8 CREDITED TONS	EQUIVALENT SEPARATIVE WORK CREDITED TONNE	TAILS CONSUMED TONNE U
1932	0.00	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0
1933	0.00	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0
1934	38.00	.200	39.45	531.1	313.6	329.3	0.0	0.0	0.0
1935	38.17	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0
1936	38.33	.200	39.67	211.8	134.2	136.5	0.0	0.0	0.0
1937	38.50	.200	39.78	211.8	134.2	136.5	0.0	0.0	0.0
1938	38.67	.200	39.79	0.0	0.0	0.0	59.9	14.7	20.7
1939	38.33	.200	39.88	187.4	113.4	117.9	40.4	3.8	6.1
1940	39.00	.200	40.53	181.9	108.7	113.7	37.9	2.7	4.5
1941	39.60	.200	42.34	183.9	110.5	115.3	0.0	0.0	0.0
1942	40.20	.200	44.15	183.9	110.5	115.3	38.1	2.7	4.6
1943	40.80	.200	44.78	0.0	0.0	0.0	38.1	2.7	4.6
1944	41.40	.200	45.95	183.9	110.5	115.3	40.4	4.0	6.5
1945	42.10	.200	47.70	184.3	111.0	115.7	42.2	4.9	7.3
1946	43.54	.200	48.66	185.4	111.3	116.5	0.0	0.0	0.0
1947	45.33	.200	49.63	185.4	111.3	116.5	45.3	6.6	10.2
1948	46.62	.200	50.59	185.4	111.3	116.5	45.3	6.6	10.2
1949	48.16	.200	50.75	0.0	0.0	0.0	45.3	6.6	10.2
2000	49.70	.200	51.57	184.0	110.7	115.4	43.1	8.2	12.4
2001	51.23	.200	52.58	181.9	109.0	113.8	50.3	9.5	14.1
2002	52.76	.200	53.62	179.1	106.6	111.7	0.0	0.0	0.0
2003	54.29	.200	53.70	0.0	0.0	0.0	50.8	9.8	14.5
2004	55.82	.200	54.69	177.1	104.9	110.1	50.8	9.9	14.6
2005	57.35	.200	55.80	173.7	102.3	107.6	50.8	9.8	14.5
2006	58.83	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0
2007	60.41	.200	56.93	170.4	99.2	105.0	52.0	10.5	15.4
2008	61.34	.200	58.10	169.0	98.0	104.0	52.5	10.8	15.8
2009	63.47	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0
2010	65.00	.200	58.94	166.3	95.8	101.9	53.1	11.2	16.3
2011	65.00	.200	58.94	170.4	99.2	105.0	52.5	10.8	15.8
2012	65.00	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0
2013	65.00	.200	58.94	169.0	96.0	104.0	52.2	10.6	15.5
2014	65.00	0.000	0.00	0.0	0.0	0.0	0.0	0.0	0.0
2015	65.00	.200	58.94	0.0	0.0	0.0	406.2	184.9	212.3
				4357.1	2605.7	2723.5	1352.2	341.3	446.7

Net tons of U₃O₈ purchased = 3004.9

Net tonnes of separative work purchased = 2264.4

FIGURE 11 (cont'd). Nuclear Test Case Output

(600)

PACTOLUS CASH FLOW AND POWER COSTS
LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

Statistic		TABLE 4 REACTOR PROPERTIES TABLE
1	INITIAL FULL POWER SPECIFIC POWER, MW/TONNE HEAVY METAL	39.5
2	YIELD, FISSILE KG PER MWE-YEAR	-622
3	YIELD, KG PU PER MWE-YEAR	.066
4	YIELD, KG U235 PER MWE-YEAR	-688
5	YIELD, KG U233 PER MWE-YEAR	0.000
6	SPECIFIC INVENTORY, KG OF FISSILE MATERIAL PER MEGAWATT ELECTRICAL	2.25
7	TONS OF U308 MINED PER MWE-YEAR	.174
8	TONS OF U308 MINED PER MONTH-YEAR	.056
9	KILOGRAMS FISSIONED PER TON OF U308 MINED	0.00
10	KG SEPARATIVE DUTY PER MWE-YR	131.08
11	TONS OF U308 CONSUMED	3004.6
12	TONNES OF SEPARATIVE DUTY CONSUMED	2264.3
13	KG FABRICATED PER MWE-YR	36.4
14	AVERAGE PLANT CAPACITY FACTOR, PER-CENT	57.6
THE CAPACITY FACTOR PERCENTAGE VARIES AS FOLLOWS		
25.00% AT	0.00 YEARS, CHANGING BY	25.00 %/YEAR TO
50.00% AT	1.00 YEARS, CHANGING BY	15.00 %/YEAR TO
65.00% AT	2.00 YEARS, CHANGING BY	0.00 %/YEAR TO
65.00% AT	15.00 YEARS, CHANGING BY	-1.67 %/YEAR TO
40.00% AT	30.00 YEARS.	

FIGURE 11 (cont'd). Nuclear Test Case Output

PACTOLUS CASH FLOW AND POWER COSTS
 LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

TABLE 5
 KILOGRAMS FABRICATED EACH YEAR
 (BEFORE LOSSES)

YEAR	T4232	PA233	U233	U234	U235	U236	U238	PU239	PU240	PU241	PU242
1952	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1953	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1954	0.0	0.0	0.0	0.0	2246.7	0.0	77047.7	0.0	0.0	0.0	0.0
1955	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1956	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1957	0.0	0.0	0.0	0.0	685.5	0.0	25545.9	0.0	0.0	0.0	0.0
1958	0.0	0.0	0.0	0.0	685.5	0.0	25545.9	0.0	0.0	0.0	0.0
1959	0.0	0.0	0.0	0.0	719.5	24.6	25466.5	106.1	31.1	11.5	2.4
1960	0.0	0.0	0.0	0.0	767.5	40.3	25409.6	125.7	54.5	25.1	9.9
1961	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1962	0.0	0.0	0.0	0.0	775.3	50.1	25366.2	132.3	62.7	30.6	14.7
1963	0.0	0.0	0.0	0.0	775.3	50.0	25365.7	132.6	62.6	31.0	14.8
1964	0.0	0.0	0.0	0.0	775.3	50.0	25365.7	132.6	62.6	31.0	14.8
1965	0.0	0.0	0.0	0.0	777.0	52.4	25320.5	143.7	73.7	39.9	25.2
1966	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1967	0.0	0.0	0.0	0.0	711.1	56.6	25265.5	149.8	79.5	45.2	34.4
1968	0.0	0.0	0.0	0.0	780.9	60.2	25270.9	152.9	81.4	47.3	36.7
1969	0.0	0.0	0.0	0.0	780.9	60.1	25270.8	152.9	81.4	47.3	36.8
2000	0.0	0.0	0.0	0.0	775.6	60.1	25276.1	151.0	81.4	47.4	36.8
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.0	0.0	0.0	0.0	767.3	60.6	25264.7	157.3	84.6	50.5	47.3
2003	0.0	0.0	0.0	0.0	756.3	62.1	25260.3	160.1	86.4	52.9	54.2
2004	0.0	0.0	0.0	0.0	743.3	63.3	25261.4	161.2	87.2	53.7	57.4
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	0.0	0.0	0.0	0.0	735.2	63.3	25274.5	161.3	87.2	53.7	57.5
2007	0.0	0.0	0.0	0.0	722.0	63.0	25288.3	161.3	87.3	53.6	57.4
2008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009	0.0	0.0	0.0	0.0	716.6	62.4	25284.8	162.7	88.3	54.8	63.4
2010	0.0	0.0	0.0	0.0	706.0	62.0	25289.4	163.4	88.9	55.4	63.2
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012	0.0	0.0	0.0	0.0	722.0	63.0	25288.3	161.3	87.3	53.6	57.4
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	0.0	0.0	0.0	0.0	716.6	62.4	25284.8	162.7	88.3	54.8	63.4
					18386.4	1066.5	609033.5	2832.9	1456.4	839.6	758.7

FIGURE 11 (cont'd). Nuclear Test Case Output

PACTOLUS CASH FLOW AND POWER COSTS
LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

TABLE 5
KILOGRAMS FABRICATED EACH YEAR
(BEFORE LOSSES)

YEAR	NP237									FISS PRO	TOTAL
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	79294.3
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26431.3
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26431.3
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26431.7
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.6
1991	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26431.9
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.0
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.5
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.4
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.3
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.4
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.7
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.3
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.5
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.7
2007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.9
2008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26433.0
2010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26433.2
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26432.9
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26433.0

634373.9

FIGURE 11 (cont'd). Nuclear Test Case Output

(800)

PACTOLUS CASH FLOW AND POWER COSTS

LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

TABLE 6
KILOGRAMS REPROCESSED EACH YEAR
(AFTER LOSSES)

YEAR	TH232	PA233	U233	U234	U235	U236	U238	PU239	PU240	PU241	PU242
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	0.0	0.0	0.0	0.0	256.2	52.9	25032.9	106.0	31.1	12.3	2.4
1989	0.0	0.0	0.0	0.0	208.8	87.8	24649.7	125.9	54.6	26.7	10.0
1990	0.0	0.0	0.0	0.0	198.6	110.0	24399.7	132.4	62.9	32.5	14.8
1991	0.0	0.0	0.0	0.0	199.1	109.9	24399.1	132.7	62.6	32.9	14.9
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	0.0	0.0	0.0	0.0	199.1	109.9	24399.1	132.7	62.6	32.9	14.9
1994	0.0	0.0	0.0	0.0	208.3	115.5	24334.8	144.0	73.9	42.5	25.2
1995	0.0	0.0	0.0	0.0	215.2	124.6	24286.1	149.2	79.4	47.3	34.6
1996	0.0	0.0	0.0	0.0	227.1	132.8	24248.7	153.1	81.5	50.5	38.7
1997	0.0	0.0	0.0	0.0	227.3	132.7	24248.4	153.1	81.5	50.5	38.8
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0.0	227.3	132.7	24248.4	153.1	81.5	50.5	38.8
2000	0.0	0.0	0.0	0.0	238.3	133.8	24211.5	157.1	84.6	54.0	47.3
2001	0.0	0.0	0.0	0.0	246.7	137.1	24180.8	160.2	86.4	56.2	54.3
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.0	0.0	0.0	.1	248.9	139.9	24168.1	161.2	87.1	57.1	57.3
2004	0.0	0.0	0.0	.1	249.0	139.8	24168.0	161.2	87.1	57.1	57.4
2005	0.0	0.0	0.0	.1	248.9	139.0	24177.6	161.1	87.1	57.0	57.3
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2007	0.0	0.0	0.0	0.0	253.4	137.6	24177.9	162.5	88.2	58.2	63.4
2008	0.0	0.0	0.0	0.0	255.6	137.0	24183.4	163.3	88.9	58.8	68.1
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	0.0	0.0	0.0	0.0	258.1	136.5	24195.2	163.5	89.1	59.0	70.1
2011	0.0	0.0	0.0	0.0	255.6	134.7	24214.8	163.1	89.1	58.8	70.1
2012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2013	0.0	0.0	0.0	0.0	254.5	132.6	24238.1	162.6	89.1	58.5	69.9
2014	0.0	0.0	0.0	0.0	258.2	130.8	24245.0	163.2	89.5	58.9	74.1
2015	0.0	0.0	0.0	0.0	1538.6	272.0	73663.6	482.3	262.9	163.1	200.2
					6502.8	2879.6	584076.9	3643.5	1900.6	1176.1	1122.6

FIGURE 11 (cont'd). Nuclear Test Case Output

PACTOLUS CASH FLOW AND POWER COSTS
LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

TABLE 6
KILOGRAMS REPROCESSED EACH YEAR
(AFTER LOSSES)

YEAR	NP237										FISS PRO	TOTAL
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

601301.8

FIGURE 11 (cont'd). Nuclear Test Case Output

(900)

PACTOLUS CASH FLOW AND POWER COSTS
LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

INPUT DATA

CARD 17

BOND REPAYMENT PROPORTIONAL
SUM OF YEARS DIGITS DEPRECIATION
DIRECT FUEL EXPENSE INVENTORY ACCOUNTING

CARDS 24 AND 25

PLANT INVESTMENT, \$M	783.0500	(INITIAL FINANCING)
PROJECT LIFE, YEARS	30.7331	
NONFUEL WORKING CAPITAL, \$M	0.0000	(INITIAL FINANCING)
FRACTION OF INITIAL INVESTMENT IN BONDS	.5000	
BOND INTEREST RATE	.0400	
EQUITY EARNING RATE (AFTER TAXES)	.0850	
FEDERAL INCOME TAX RATE	.4600	
PLANT PERCENT INVESTMENT TAX CREDIT	4.0000	

CARD 26

POWERPLANT LEVEL, MWE	999.9775	
DEPRECIABLE LIFE, YEARS	30.0000	
PLANT FIXED OPERATING COST, \$M/YR	3.0400	
PLANT VARIABLE OPERATING COST, \$M/YR	4.3730	
NONFUEL VARIABLE OPERATING COST, \$M/YR	0.0000	(AT 100% PLANT FACTOR)
INITIAL FUEL INVENTORY, \$M	75.1801	(INITIAL FINANCING)
FIRST YEAR OF OPERATION	1985	

CARD 27

STATE INCOME TAX RATE	.0990	
STATE GROSS REVENUE TAX RATE	.0300	
PROPERTY TAX RATE	.0320	
INTERIM CAPITAL REPLACEMENTS, \$M/YR	2.7407	
PROPERTY INSURANCE, \$M/YR	1.9576	
NUCLEAR LIABILITY, \$M/YR	.3326	
NUCLEAR LIABILITY, \$M/MWYE	0.0000	

CARDS 23 AND 28

RECOVERABLE COST OF LAND, \$M	0.0000	(INITIAL FINANCING)
NET SALVAGE VALUE OF PLANT, \$M	-78.0000	
RECOVERABLE MODERATOR AND SALT, \$M	0.0000	(INITIAL FINANCING)
REACTOR OPERATING LIFE, YEARS	30.0000	
LICENSING TIME, YEARS	5.0	

YEARS PRIOR TO POWER PRODUCTION	LICENSING COSTS, \$M
-----	-----

1984	.200
1983	.600
1982	1.000
1981	.750
1980	.500
1979	-0.000
1978	-0.000
1977	-0.000
1976	-0.000
1975	-0.000

FIGURE 11 (cont'd). Nuclear Test Case Output

(1000)

PACTOLUS CASH FLOW AND POWER COSTS
LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

ANNUAL INPUT DATA, EXPENSES IN \$M/YR

YEAR	CAPACITY FACTOR	FUEL PURCHASES	FABRICATION COST	REPROCESS COST	U-PU CREDIT	FIXED O&M COST	VARIABLE O&M COST
1 1985	.37500	0.00000	0.00000	0.00000	0.00000	8.04000	1.63988
2 1986	.57500	28.93872	.26939	0.00000	0.00000	8.04000	2.51448
3 1987	.65000	27.02496	2.77152	0.00000	0.00000	8.04000	2.64245
4 1988	.65000	0.00000	2.90925	7.14917	10.83380	8.04000	2.84245
5 1989	.65000	26.27307	4.11291	7.93517	9.84036	8.04000	2.84245
6 1990	.65000	29.14015	.57553	7.93118	10.11810	8.04000	2.84245
7 1991	.65000	24.11621	3.84260	6.67259	0.00000	8.04000	2.84245
8 1992	.65000	31.69796	3.75131	1.26020	10.23051	8.04000	2.84245
9 1993	.65000	6.52056	4.07887	7.93351	10.30321	8.04000	2.84245
10 1994	.65000	32.61669	4.07034	7.96117	11.57173	8.04000	2.84245
11 1995	.65000	34.43734	3.81743	7.97762	12.39306	8.04000	2.84245
12 1996	.65000	28.00661	.65978	6.73059	0.00000	8.04000	2.84245
13 1997	.65000	36.46282	3.83160	7.77650	13.26391	8.04000	2.84245
14 1998	.65000	37.37036	4.07326	1.47446	13.45118	8.04000	2.84245
15 1999	.65000	7.97496	4.06279	7.99343	13.62508	8.04000	2.84245
16 2000	.64167	37.82921	3.79332	8.00827	14.57181	8.04000	2.60601
17 2001	.62500	30.16346	.69168	8.01901	15.33947	8.04000	2.73313
18 2002	.60633	36.65256	3.62313	0.00000	0.00000	8.04000	2.66024
19 2003	.59167	8.47396	4.04723	8.82406	15.71454	8.04000	2.58736
20 2004	.57500	19.27136	3.77162	8.82619	15.93010	8.04000	2.51448
21 2005	.55833	30.79554	.76326	8.82873	16.13352	8.04000	2.44159
22 2006	.54167	8.56076	3.58733	0.00000	0.00000	8.04000	2.36871
23 2007	.52500	33.42681	4.01695	8.83705	16.67662	8.04000	2.29583
24 2008	.50833	31.35375	.44906	8.84310	17.07649	8.04000	2.22294
25 2009	.49167	8.65772	3.56180	0.00000	0.00000	8.04000	2.15006
26 2010	.47500	40.04198	3.72851	8.84795	17.48196	8.04000	2.07718
27 2011	.45833	32.26658	.26168	8.84706	17.24374	8.04000	2.00429
28 2012	.44167	8.55672	3.96739	0.00000	0.00000	8.04000	1.93141
29 2013	.42500	31.91047	.45463	8.84738	17.15775	8.04000	1.85853
30 2014	.40833	8.65772	3.48215	6.51958	0.00000	8.04000	1.78564
31 2015	0.00000	0.00000	0.00000	26.17157	105.74520	0.00000	0.00000
TOTAL		745.35602	82.92538	192.61584	387.62805	241.20000	75.54357
PM-TOTAL		286.02422	32.05574	66.94819	117.37661	96.23485	31.05200

FIGURE 11 (cont'd). Nuclear Test Case Output

(1100)

PACTOLUS CASH FLOW AND POWER COSTS

LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

FUEL AND OPERATING EXPENSES, \$ MILLIONS

	YEAR	CURRENT FUEL EXPENSES	ANNUAL FUEL EXPENSES	NON-FUEL OPERATING EXPENSES
1	1985	0.00000	2.50600	39.62081
2	1986	27.20811	29.71411	39.68631
3	1987	29.79448	32.30449	39.19887
4	1988	.02482	2.53862	38.37716
5	1989	30.48579	32.99179	37.54914
6	1990	27.52875	30.03476	36.71452
7	1991	34.83139	37.33739	35.87420
8	1992	26.47836	28.98496	35.02727
9	1993	4.22374	10.73574	34.17404
10	1994	33.07647	35.58247	33.31451
11	1995	33.83939	36.34539	32.44867
12	1996	35.39638	37.90298	31.57853
13	1997	34.65102	37.15702	30.69802
14	1998	23.46690	31.97291	29.81333
15	1999	6.40610	4.91210	28.32228
16	2000	35.05899	37.56499	27.98848
17	2001	23.54968	26.04668	27.01194
18	2002	42.27569	44.78170	26.02909
19	2003	4.83671	7.34271	25.03995
20	2004	35.14607	37.65207	24.04449
21	2005	23.39401	25.90001	23.04274
22	2006	12.14309	14.65409	22.03467
23	2007	34.80419	37.31019	21.02031
24	2008	22.76942	25.27542	19.99364
25	2009	17.21952	14.72552	18.97267
26	2010	34.41660	36.92260	17.93940
27	2011	23.27153	25.77758	16.89982
28	2012	12.52411	15.03011	15.85394
29	2013	23.25473	25.76073	14.80175
30	2014	18.65945	21.16545	13.74326
31	2015	-82.57334	-82.57334	2.59371
TOTAL		633.16319	708.34923	540.01190
PW-TOTAL		267.65153	297.64716	374.52617

FIGURE 11 (cont'd). Nuclear Test Case Output

PACTOLUS CASH FLOW AND POWER COSTS
LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

CASH FLOW TABLE POWER PLANT, \$ MILLIONS

YEAR	CAPACITY FACTOR	CAPITAL COSTS	FUEL COSTS	PLANT C&M COSTS	INTERIM CAPITAL REPLACEMENT	PROPERTY TAXES INSURANCE	TOTAL COSTS	TAX CREDIT
1 1980	0.00000	.20000	0.00000	0.00000	0.00000	0.00000	.20000	0.00000
2 1981	0.00000	.60000	0.00000	0.00000	0.00000	0.00000	.60000	0.00000
3 1982	0.00000	74.79152	0.00000	0.00000	0.00000	0.00000	74.79152	0.00000
4 1983	0.00000	424.23315	0.00000	0.00000	0.00000	2.60791	426.84106	0.00000
5 1984	0.00000	283.22533	75.18009	0.00000	0.00000	17.24395	375.64937	0.00000
6 1985	.37500	0.00000	0.00000	9.67988	2.74063	29.94094	42.36149	31.43163
7 1986	.57500	0.00000	27.20811	10.55448	2.74062	29.13183	69.63509	.10963
8 1987	.65000	0.00000	23.79848	10.88245	2.74062	28.31642	71.73803	.10963
9 1988	.65000	0.00000	.02462	10.88245	2.74063	27.45471	41.14246	.10963
10 1989	.65000	0.00000	30.48579	10.88245	2.74062	26.66669	70.77561	.10963
11 1990	.65000	0.00000	27.52375	10.88245	2.74062	25.83237	68.98425	.10963
12 1991	.65000	0.00000	34.83139	10.88245	2.74062	24.99175	73.44627	.10963
13 1992	.65000	0.00000	26.47895	10.88245	2.74062	24.14432	64.24691	.10963
14 1993	.65000	0.00000	8.22974	10.88245	2.74062	23.29159	45.14445	.10963
15 1994	.65000	0.00000	33.07647	10.88245	2.74062	22.43206	64.13165	.10963
16 1995	.65000	0.00000	33.83939	10.88245	2.74062	21.56622	69.02873	.10963
17 1996	.65000	0.00000	35.39698	10.88245	2.74062	20.69405	69.71418	.10963
18 1997	.65000	0.00000	34.65102	10.88245	2.74062	19.81563	68.08978	.10963
19 1998	.65000	0.00000	29.46690	10.88245	2.74062	18.93088	62.02031	.10963
20 1999	.65000	0.00000	6.40610	10.88245	2.74062	18.03983	38.06905	.10963
21 2000	.64167	0.00000	35.05899	10.84601	2.74062	17.14248	65.78815	.10963
22 2001	.62500	0.00000	23.54068	10.77313	2.74062	16.23852	53.29329	.10963
23 2002	.60833	0.00000	42.27569	10.70024	2.74062	15.32885	71.04546	.10963
24 2003	.59167	0.00000	4.83671	10.62736	2.74062	14.41259	32.61733	.10963
25 2004	.57500	0.00000	35.14607	10.55448	2.74062	13.49002	61.93124	.10963
26 2005	.55833	0.00000	23.39401	10.48159	2.74062	12.56114	49.17742	.10963
27 2006	.54167	0.00000	12.14803	10.40871	2.74062	11.62597	36.92344	.10963
28 2007	.52500	0.00000	34.80419	10.33583	2.74062	10.68449	58.56518	.10963
29 2008	.50833	0.00000	27.76342	10.26294	2.74062	9.73670	45.50374	.10963
30 2009	.49167	0.00000	12.21952	10.19006	2.74062	8.78261	33.93286	.10963
31 2010	.47500	0.00000	34.41660	10.11718	2.74062	7.82222	55.03667	.10963
32 2011	.45833	0.00000	23.27156	10.04429	2.74062	6.85553	42.91207	.10963
33 2012	.44167	0.00000	12.52411	9.97141	2.74062	5.88253	31.11872	.10963
34 2013	.42500	0.00000	23.25473	9.89853	2.74062	4.90323	40.79716	.10963
35 2014	.40833	0.00000	18.65945	9.82564	0.00000	3.91762	32.40271	0.00000
36 2015	0.00000	73.00000	-82.57334	0.00000	0.00000	0.00000	-4.57334	0.00000
TOTAL		361.05000	704.34326	116.74357	75.47957	540.52647	2506.14891	34.50119
PM-TOTAL		660.35544	327.50632	127.26655	32.32713	262.72288	1410.19869	24.99834
AVERAGE PLANT CAPACITY FACTOR			.57583					

FIGURE 11 (cont'd). Nuclear Test Case Output

(1300)

PACTOLUS CASH FLOW AND POWER COSTS

LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

ANNUAL TAX DEDUCTIBLE EXPENSES, \$ MILLIONS

YEAR	5.136 PCT PRESENT WORTH FACTOR	OPERATING EXPENSES	BOND INTEREST	DEPRECIATION	TOTAL DEDUCTIBLE OPERATING EXPENSES	STATE INCOME TAX
1 1980	.97494	0.00000	0.00000	0.00000	0.00000	0.00000
2 1981	.92683	0.00000	.00400	0.00000	.00400	-.00036
3 1982	.88104	0.00000	.01621	0.00000	.01621	-.00146
4 1983	.83752	2.60791	1.51288	0.00000	4.12079	-.37087
5 1984	.79615	17.24395	10.10084	0.00000	27.34479	-2.46103
6 1985	.75682	42.12642	17.35703	50.51945	110.00320	-1.92550
7 1986	.71944	69.40042	17.28835	51.40513	138.09490	-.11765
8 1987	.68350	71.50336	17.00387	49.56201	139.07525	1.48979
9 1988	.65012	40.50778	16.38740	47.73069	105.22587	4.44623
10 1989	.61800	70.54093	15.87270	45.91115	132.32478	2.00733
11 1990	.58748	66.74950	15.42049	44.10340	126.27348	2.55195
12 1991	.55846	73.21159	14.92734	42.38743	130.44697	2.17633
13 1992	.53047	64.01224	14.46988	40.52326	119.02537	3.20428
14 1993	.50405	44.50978	13.16078	38.75087	97.62144	5.13053
15 1994	.47972	68.89648	13.24209	36.93027	119.12934	3.19492
16 1995	.45602	68.79406	12.73161	35.24146	116.76713	3.40752
17 1996	.43350	69.47951	12.21205	33.50444	115.19600	3.54832
18 1997	.41208	67.85510	11.65025	31.77320	111.32459	3.89735
19 1998	.39171	61.78624	11.14422	30.06575	102.99621	4.64690
20 1999	.37235	37.83438	10.53038	28.36409	76.72886	7.01096
21 2000	.35398	65.55348	9.67530	26.67422	101.50360	4.56682
22 2001	.33650	53.05862	9.07532	24.93613	87.13067	5.53955
23 2002	.31987	70.61079	8.38171	23.32984	102.52234	3.79746
24 2003	.30407	32.38265	7.87451	21.67533	61.93250	7.09371
25 2004	.28905	61.69657	7.03223	20.03261	89.76140	4.32228
26 2005	.27473	48.94275	6.47844	18.40168	73.82286	5.30991
27 2006	.26120	36.68877	5.82947	16.78253	59.30117	6.26003
28 2007	.24830	58.33051	5.06622	15.17517	78.59189	4.16703
29 2008	.23603	45.27507	4.56319	13.57960	63.41786	5.17586
30 2009	.22437	31.69819	3.94377	11.99562	49.63778	6.05923
31 2010	.21329	54.66200	3.23690	10.42363	68.52262	4.00276
32 2011	.20275	42.67740	2.74747	8.86362	54.28850	4.92699
33 2012	.19274	30.88405	2.17137	7.31520	40.37062	5.82277
34 2013	.18322	40.56249	1.50755	5.77857	47.84861	4.79291
35 2014	.17417	34.50871	.95455	30.74692	66.61019	2.74754
36 2015	.16557	-82.57334	.04114	0.00000	-82.53219	.40790
TOTAL		1565.61933	305.29965	862.52957	2733.44855	116.82893
PR-TOTAL		607.65689	152.50141	-11.54385	1251.70135	30.21437

FIGURE 11 (cont'd). Nuclear Test Case Output

(400)

PACTOLUS CASH FLOW AND POWER COSTS
LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

ANNUAL INCOME STATEMENT, \$ MILLIONS

YEAR	POWER UNITS (M MWH)	TOTAL POWER SALES	REVENUE TAXES	TOTAL TAX DEDUCTIBLE EXPENSES	TAXABLE INCOME (FEDERAL)	FEDERAL INCOME TAX
1 1960	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2 1961	0.00000	0.00000	0.00000	.00164	-.00364	-.00175
3 1962	0.00000	0.00000	0.00000	.01475	-.01475	-.00708
4 1963	0.00000	0.00000	0.00000	3.74992	-3.74992	-1.79996
5 1964	0.00000	0.00000	0.00000	24.83376	-24.83376	-11.94420
6 1965	3.23763	91.96774	2.75903	108.67769	-19.46898	-9.34511
7 1966	5.04103	141.01720	4.23052	137.97625	-1.18956	-.57099
8 1967	5.63355	159.41075	4.78232	139.56563	15.06339	7.23043
9 1968	5.63355	159.41075	4.78232	109.67210	44.95633	21.57904
10 1969	5.63355	159.41075	4.78232	134.33211	29.29632	9.74223
11 1970	5.63355	159.41075	4.78232	128.32541	25.60302	12.36545
12 1971	5.63355	159.41075	4.78232	132.62330	22.00513	10.56246
13 1972	5.63355	159.41075	4.78232	122.22965	32.33878	15.55141
14 1973	5.63355	159.41075	4.78232	102.75206	51.57636	24.90065
15 1974	5.63355	159.41075	4.78232	122.32425	32.30417	15.53680
16 1975	5.63355	159.41075	4.78232	120.17464	34.45376	16.53782
17 1976	5.63355	159.41075	4.78232	118.74492	35.88351	17.22408
18 1977	5.63355	159.41075	4.78232	115.22194	39.40649	18.91511
19 1978	5.63355	159.41075	4.78232	107.64311	46.98332	22.55295
20 1979	5.63355	159.41075	4.78232	83.73982	70.88961	34.02653
21 2000	5.62349	157.36702	4.72101	106.47042	46.17559	22.16429
22 2001	5.47338	153.27957	4.59819	32.67022	56.01096	26.88526
23 2002	5.33326	149.19211	4.47576	106.31980	38.33655	18.43034
24 2003	5.13714	145.10466	4.35314	69.02621	71.72531	34.42815
25 2004	5.04103	141.01720	4.23052	33.08358	43.70301	20.97744
26 2005	4.89491	136.92975	4.10789	79.11277	51.68908	25.77076
27 2006	4.74879	132.84229	3.96527	65.56120	63.29583	30.38200
28 2007	4.60267	128.75484	3.86265	52.75892	42.13327	20.22397
29 2008	4.45656	124.66738	3.74002	68.59371	52.33365	25.12015
30 2009	4.31044	120.57993	3.61740	55.69701	61.26552	29.40745
31 2010	4.16433	116.49247	3.49477	72.52538	40.47232	19.42671
32 2011	4.01821	112.40502	3.37215	59.21549	49.81737	23.91234
33 2012	3.87209	108.31756	3.24953	46.19339	58.87465	20.25983
34 2013	3.72598	104.23011	3.12690	52.64153	48.46168	23.26160
35 2014	3.57986	100.14265	3.00428	69.33773	27.78365	13.33471
36 2015	0.00000	0.00000	0.00000	-82.12429	82.12429	1.97966
TOTAL	151.44998	4236.54723	127.09342	2850.27749	1259.27032	567.00976
PM-TOTAL	62.25314	1741.46342	52.24390	1269.31572	399.30180	185.46707

FIGURE 11 (cont'd). Nuclear Test Case Output

(1500)

PACTOLUS CASH FLOW AND POWER COSTS

LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

PAYOUT OF INVESTMENTS, \$ MILLIONS

YEAR	NET CASH FLOW	OUTSTANDING BONDS	EQUITY CAPITAL NOT RECOVERED	BOND INTEREST	EARNINGS ON UNRECOVERED EQUITY	BONDS REPAID	RECOVERY OF EQUITY
1 1980	-20000	0.00000	0.00000	0.00000	0.00000	-10000	-10000
2 1981	-161033	.10000	.10000	.00000	.00000	-130520	-130520
3 1982	-74.53363	.40520	.40520	.01621	.03444	-37.41682	-37.41682
4 1983	-423.33753	37.02201	37.32201	1.51208	3.21487	-214.69899	-214.69899
5 1984	-397.00926	252.52100	252.52100	10.10084	21.46429	-196.40463	-196.40463
6 1985	33.43376	448.92563	448.92563	17.95703	39.15468	16.71688	16.71688
7 1986	13.32377	432.20875	432.20875	17.28835	36.73774	6.96138	6.96138
8 1987	21.12355	425.24667	425.24667	17.00987	36.14598	10.56197	10.56197
9 1988	35.73472	414.68439	414.68439	16.53740	35.24822	17.86736	17.86736
10 1989	22.81070	390.81754	390.81754	15.87270	33.72949	11.30535	11.30535
11 1990	24.62734	385.51219	385.51219	15.42049	32.76454	12.31369	12.31369
12 1991	21.90318	373.19850	373.19850	14.92734	31.72187	10.95159	10.95159
13 1992	26.45453	362.24630	362.24630	14.48988	30.79099	13.22730	13.22730
14 1993	35.53487	349.01961	349.01961	13.96078	29.66667	17.96743	17.96743
15 1994	25.52396	331.05217	331.05217	13.24209	28.13943	12.76198	12.76198
16 1995	25.97772	318.29019	318.29019	12.73161	27.05467	12.98886	12.98886
17 1996	26.08520	305.30133	305.30133	12.21205	25.95861	13.04410	13.04410
18 1997	27.30365	292.25723	292.25723	11.63029	24.84186	13.65133	13.65133
19 1998	30.69181	278.60540	278.60540	11.14422	23.68146	15.34581	15.34581
20 1999	42.72406	263.25959	263.25959	10.53038	22.37707	21.36203	21.36203
21 2000	24.93319	241.89757	241.89757	9.67590	20.56129	14.99960	14.99960
22 2001	34.71046	226.89737	226.89737	9.07592	19.28633	17.35523	17.35523
23 2002	25.35987	209.54274	209.54274	8.38171	17.81113	12.67993	12.67993
24 2003	42.11411	196.86281	196.86281	7.87451	16.73334	21.05705	21.05705
25 2004	27.68964	175.80575	175.80575	7.03223	14.94349	13.84432	13.84432
26 2005	32.42827	161.96033	161.96033	6.47844	13.76668	16.21414	16.21414
27 2006	37.19284	145.74650	145.74650	5.82987	12.38548	18.59142	18.59142
28 2007	26.15122	127.15538	127.15538	5.08622	10.88821	13.07561	13.07561
29 2008	30.97127	114.07977	114.07977	4.56319	9.69678	15.48564	15.48564
30 2009	35.34335	98.59413	98.59413	3.94377	8.38050	17.67417	17.67417
31 2010	24.46613	80.91936	80.91936	3.21680	6.67820	12.23310	12.23310
32 2011	28.30523	68.68686	68.68686	2.74747	5.83838	14.40261	14.40261
33 2012	33.13081	54.28425	54.28425	2.17137	4.61416	16.59541	16.59541
34 2013	27.63005	37.68884	37.68884	1.50755	3.20355	13.82502	13.82502
35 2014	45.67044	23.86332	23.86332	.95455	2.02842	22.83522	22.83522
36 2015	2.05772	1.02860	1.02860	.04114	.08743	1.02860	1.02860
TOTAL	-1.00000	7632.49119	7632.49119	305.23965	548.76175	-1.00000	-1.00000
PA-TOTAL	-336.22916	3812.53520	3812.53520	152.50141	324.06549	-148.11458	-198.11458

FIGURE 11 (cont'd). Nuclear Test Case Output

PACTOLUS CASH FLOW AND POWER COSTS				
LIGHT WATER REACTOR 1000 MWE SAMPLE CASE				
I N S T A L L E D C O S T	783.07	\$ PER KWE (GROSS)		
	783.07	\$ PER KWE (NET)		
	DISTRIBUTION OF POWER COSTS			
	MILLS PER KWHR	ANNUAL (\$ MILLIONS)	MILLS PER KWHR	ANNUAL (\$ MILLIONS)
C O S T O F P O W E R	27.37	145.492		
C O S T D I S T R I B U T I O N				
INITIAL PLANT	10.01	55.170	15.75	81.932
INTERIM CAPITAL REPLACEMENTS	.52	2.761	.66	3.447
FUEL SUPPLY	5.26	27.362	5.97	31.071
OPERATING EXPENSES	2.04	10.634	2.11	10.963
PROPERTY TAXES AND INSURANCE	4.22	21.949	4.35	22.620
STATE REVENUE TAX	.84	4.365		
STATE INCOME TAX	.61	3.193		
FEDERAL INCOME TAX	2.58	13.406		
BOND INTEREST	1.29	6.712		
TOTAL	27.97	145.492	28.85	150.042
INTERNAL POWER CONSUMPTION 0.0 MWE	0.000	0.000		
NET POWER OUTPUT 1000.0 MWE				
GROSS POWER OUTPUT 1000.0 MWE				
LAST TWO COLUMNS SHOW COST WITHOUT TAX CREDIT				

FIGURE 11 (cont'd). Nuclear Test Case Output

PACTOLUS CASH FLOW AND POWER COSTS
 LIGHT WATER REACTOR 1000 MWE SAMPLE CASE

C O S T D I S T R I B U T I O N O F F U E L S U P P L Y

	MILLS P/R KWHR	
FUEL PURCHASES	6.07	
INITIAL CORE		1.33
REPLACEMENT		4.74
FABRICATION	.74	
INITIAL CORE		.21
REPLACEMENT		.53
REPROCESSING	1.11	
FUEL CREDIT	-1.94	
TOTAL FUEL CYCLE COST	5.98	

FIGURE 11 (cont'd). Nuclear Test Case Output

REFERENCES

1. J. H. Nail, PACTOLUS: A Code for Computing Nuclear Power Costs, Part 1: User's Manual, BNWL-429, Battelle, Pacific Northwest Laboratories, Richland, WA 99352, June 1967.
2. C. H. Bloomster, et al., PACTOLUS: A Code for Computing Nuclear Power Costs, BNWL-1169, Battelle, Pacific Northwest Laboratories, Richland, WA, January 1970.
3. E. T. Merrill, ALTHAEA: Part 1 - A One-Dimensional Two-Group Diffusion Code with an Effective Four-Group Burnup, BNWL-462, Battelle, Pacific Northwest Laboratories, Richland, WA 99352, July 1967.
4. D. E. Deonigi, et al., UCOST - A Computer Code for Calculating the Cost of Enriched Uranium, BNWL-189, Battelle, Pacific Northwest Laboratories, Richland, WA 99352, February 1966.
5. T. C. Runion, NFS Chemical Processing Plant - Capability and Cost Bases, 1962 Nuclear Congress, Paper No. 42, June 1962.
6. R. F. Barry, LEOPARD - A Spectrum Dependent Non-Spatial Depletion Code for IBM-7094, WCAP-3269-26, UC-80, Westinghouse Electric Corporation, September 1963.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the advice and comments of Ed Merrill in the improvement of the PACTOLUS computer code and the preparation of this user manual.

DISTRIBUTION

No. of
Copies

OFFSITE

1	A. A. Churm DOE Patent Division 9800 S. Cass Avenue Argonne, IL 60439
20	Chan Stalvey Department of Energy Room 7002F 2000 M Street, N.W. Washington, D.C. 20461
27	DOE Technical Information Center

ONSITE

	DOE Richland Operations
1	Office H. E. Ransom
64	Pacific Northwest Laboratory C. H. Bloomster (30) N. E. Carter D. E. Deonigi M. D. Erickson L. L. Fassbender H. D. Huber (20) E. T. Merrill R. G. Rau J. J. Thomas Technical Information (5) Publishing Coordination (2)