BNWL-965
UC-80

FUEL CYCLE PARAMETERS
OF SODIUM COOLED FAST BREEDERS

July 1969

AEC RESEARCH &
DEVELOPMENT REPORT

BNWL- 965

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

PACIFIC NORTHWEST LABORATORY

RICHLAND, WASHINGTON

operated by

BATTELLE MEMORIAL INSTITUTE

for the

UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830

3 3679 00061 2293

BNWL-965
UC-80, Reactor
Technology

FUEL CYCLE PARAMETERS
OF SODIUM COOLED FAST BREEDERS

By

S. E. Nunn
D. E. Deonigi

Systems Engineering Department-
Physics and Engineering Division

July 1968

BATTELLE MEMORIAL INSTITUTE
PACIFIC NORTHWEST LABORATORY
RICHLAND, WASHINGTON

Printed in the United States of America
Available from
Clearinghouse for Federal Scientific and Technical Information
National Bureau of Standards, U.S. Department of Commerce
Springfield, Virginia 22151
Price: Printed Copy \$3.00; Microfiche \$0.65

FUEL CYCLE PARAMETERS
OF SODIUM COOLED FAST BREEDERS

S. E. Nunn
D. E. Deonigi

ABSTRACT

A study is made of the parameters influencing sodium-cooled fast breeder reactor performance. Doubling time is defined and factors influencing doubling time are discussed. Sensitivity of fuel cycle cost to plutonium price, turnaround time, separation cost, fabrication cost, load factor, and cost of money are determined. The LMFBR's influence on power cost to the U. S. economy is determined as a function of date of introduction, recycle turnaround time, and the doubling time. Fuel management as affected by core and blanket discharge frequency, fuel fabrication and separation cost, and blanket thickness are also discussed.

TABLE OF CONTENTS

INTRODUCTION	1
The Nuclear Fuel Cycle	1
Cost of Nuclear Fuel Cycle	4
Fuel Cycle Optimization	5
INTRODUCTION TO FAST BREEDER REACTORS	8
Doubling Time	10
CALCULATION OF DOUBLING TIMES	12
Variations in Doubling Times for Two Sample Reactors	15
Out-of-Reactor Time	15
Core Size	18
Number of Regions	18
Fuel Exposure	21
Effect of Blanket Discharge Interval	25
Conclusions	25
FUEL CYCLE COST	27
AEC Task Force Data	27
Fuel Cycle Times	29
Fuel Cycle Cost Projections	29
Fuel Cycle Cost Calculations	37
Plutonium Cost	37
Turnaround Time	40
Fuel Exposure	40
Cost of Money	44
Reprocessing Cost	46
Fabrication Cost	50
Load Factor	53
Summary on Fuel Cycle Costs	53
LMFBR'S IN THE U. S. POWER ECONOMY	60
Description of Model	60
Effect of Recycle Time	65
Doubling Time	67
Conclusions	75
LMFBR FUEL MANAGEMENT	76
Effect of Refueling Interval	76
Blanket Thickness	81
Conclusions	83
REFERENCES	85

LIST OF TABLES

<u>Number</u>	<u>Title</u>	<u>Page</u>
I	Eta Values for Fissile Nuclide at Three Neutron Energies	9
II	Parameters Used for Calculating Doubling Times	16
III	The Effect of Exposure on Out-of-Reactor Inventory	24
IV	Design Criteria of the Two Reference Reactors	28
V	Table of Relative Merit	56
VI	Reference Oxide Fuel Cycle Costs, mills/kwhe	58
VII	Reference Carbide Fuel Cycle Costs, mills/kwhe	59
VIII	Comparison of Three Increasing Uranium Cost Cases	69
IX	Fuel Cycle Costs, mills/kwhe	75
X	Breakdown of Processing Cost	78

LIST OF FIGURES

<u>Number</u>	<u>Title</u>	<u>Page</u>
1	The Nuclear Fuel Cycle	2
2	Fuel Cycle Cost as a Function of Fuel Exposure	6
3	Effect of Out-of-Reactor Time and Corresponding Amount of Out-of-Reactor Fissile Material on Breeder Reactor Doubling Time	17
4	Effect of Core Fissile Material on Breeder Reactor Doubling Time	19
5	Effect of the Number of Reactor Regions on Breeder Reactor Doubling Time	20
6	Doubling Time as a Function of Exposure and Out-of-Reactor Time (low gain breeder)	22
7	Doubling Time as a Function of Exposure and Out-of-Reactor Time (high gain breeder)	23
8	Effect of Changing the Frequency of Blanket Discharge on Reactor Doubling Time	26
9	Fuel Cycle Time	30
10	Unit Fuel Reprocessing Cost Projection for Oxide and Carbide LMFBR's	34
11	Unit Fuel Fabrication Cost of Oxide Core and Blanket	35
12	Unit Fuel Fabrication Cost of Carbide Core and Blanket	36
13	Fuel Cycle Cost as a Function of Pu Cost	38
14	Incremental Change in Fuel Cycle Cost with Changes in Pu Price	39
15	Fuel Cycle Cost as a Function of Turnaround Time	41
16	Incremental Change in Fuel Cycle Cost with Changes in Turnaround Time	42
17	Effect of Exposure on Fuel Cycle Costs for Various Fabrication Costs	43
18	The Effect of Net Cost of Money on Fuel Cycle Cost	45

LIST OF FIGURES (Continued)

<u>Number</u>	<u>Title</u>	<u>Page</u>
19	Incremental Change in Fuel Cycle with Change in the Net Cost of Money	47
20	Fuel Cycle Cost as a Function of Reprocessing Cost	48
21	Effect of Reprocessing Cost on Fuel Cycle Cost	49
22	Fuel Cycle Cost as a Function of Fuel Fabrication Cost	51
23	Incremental Change in Fuel Cycle Cost with Changes in Fabrication Cost	52
24	Effect of Load Factor on Fuel Cycle Cost	54
25	Incremental Change in Fuel Cycle Cost with Changes in Load Factor	55
26	Information Flow Diagram in SATF Model	61
27	Effect of Recycle Time on Power Costs of LWR's and LMFBR's from 1970-2020	66
28	Effect of Doubling Time on the Present-Worth Power Cost With Constant and Changing Uranium Prices	68
29	Effect of Doubling Time on the Present-Worth Power Cost	71
30	Indifference Pu Value for LWR Economy	72
31	Pu Price in a Mixed Power Economy	74
32	Effect of the Number of Blanket Regions on Fuel Cycle Cost for a 3-Region Core Reactor	77
33	Effect of the Number of Blanket Regions on Fuel Cycle Costs for a 6-Region Core	80
34	Effect of Blanket Thickness on Fuel Cycle Costs	82

INTRODUCTION

The Nuclear Fuel Cycle

The fuel cycle of a nuclear power plant differs from that of a fossil power plant in at least two important aspects: the value of the "ashes" and the cost required to prepare the fuel for "burning." Unlike a fossil plant, which simply burns its fuel and disposes of the ashes, a nuclear power plant produces ashes that have considerable value. The ashes from a light water reactor (LWR) consist of depleted uranium and plutonium. The breeder reactor, which produces or breeds fuel faster than it consumes fuel, actually yields "ashes" having greater value than the original fuel. Unlike a fossil fuel, a nuclear fuel also requires a special encapsulation to safely contain radioactive isotopes.

Figure 1 describes the nuclear fuel cycle. As the figure shows, the enriched-uranium fuel cycle begins when the uranium ore (U_3O_8) is mined. Natural uranium ore contains 1 part of the fissionable U^{235} in 140 parts of fertile U^{238} . (Although this concentration of U^{235} can be used in some reactor types, notably the D_2O moderated reactors, the concentration of fissile material used in most other reactor types must be greater than that in natural uranium.) The uranium ore is then enriched by taking advantage of the preferential diffusion rates for U^{235} as compared with the heavier U^{238} . But to take advantage of this phenomenon, uranium must first be converted to a convenient gaseous form, UF_6 . Then the UF_6 is pumped through the gaseous diffusion barriers, yielding a UF_6 that has a higher concentration of U^{235} and a depleted uranium that has

FIGURE 1 THE NUCLEAR FUEL CYCLE

a lower concentration of U^{235} . In the case of the LWR fuel cycle, this enriched UF_6 is then converted to UO_2 ; a stable solid that, when contained in Zr cladding, is ready for use as a reactor fuel. During irradiation, the reactor fuel undergoes a chain reaction that produces both heat and neutrons. After the fuel has resided in the reactor from three to four years, the fissile concentration is sufficiently depleted to require refueling. When discharged from the reactor, the depleted fuel requires about three months for its radioactivity to subside enough to permit easy fuel handling. The depleted fuel is then shipped in a large protective cask to a reprocessing facility where the uranium, plutonium, and fission products are chemically separated, the depleted uranium being reused as feed to the uranium diffusion cascade, the plutonium recycled in LWR's or used as fuel for breeder reactors, and the fission products stored in special containers.

The plutonium-fueled breeder reactor does not directly involve the uranium diffusion cascade. Its only uranium requirement is U^{238} as a fertile material. Thus either depleted or natural uranium would satisfy this requirement. The fuel for plutonium-fueled breeders will be initially supplied by LWR's and ultimately by the breeding "gain" of the breeder reactors. Fuel fabrication is required for two distinct types of fuels, the core material, which is approximately 15% plutonium in depleted uranium, and the blanket material, which contains only depleted uranium. These fuels may be contained in the same rod or separate rods, depending on the reactor design. The in-reactor portion of the fuel cycle will last 3 or 4 years, much like the LWR's. Again, special casks are required

for shipping the fuel from the reactor site to a reprocessing plant. Reprocessing will probably be accomplished by using a mixture of core and blanket fuel elements, thus reducing the average fissile content and associated criticality problem. After reprocessing, the amount of plutonium in excess of that required to refuel the reactor is available for sale. The plutonium used for refueling is converted in preparation for fuel fabrication, which completes the breeder fuel cycle.

The optimum fuel cycle for a given reactor concept is determined by the total costs involved. Prominent among these costs are the price of U_3O_8 and the price for plutonium. Thus if the price of plutonium is high, the optimum fueling strategy for the light water reactor would be to burn enriched uranium and sell the plutonium produced; but if the price of plutonium is low, the optimum strategy would be to recycle the plutonium in the light water reactor. The breeder reactor, however, is not as sensitive to fuel price variations, which is one of its virtues. And if the breeder reactor has a great enough gain, its optimum fuel cycle becomes entirely independent of a fuel price variation. Such independence requires an annual gain approximately equal to the interest rate on money.

Cost of Nuclear Fuel Cycle

As mentioned earlier, a large share of the nuclear fuel cycle cost is involved in preparing the fuel for "burning" and in reprocessing the "ashes." During the life of a reactor an amount of money equal from two to three times the initial capital investment will be spent on the fuel cycle. However, because the expenditures for the fuel cycle, in contrast

with those for capital investment, take place shortly before any revenue is recovered from electrical power generation, the fuel cycle only accounts for about one-third of the levelized power cost. The most important costs in the nuclear fuel cycle are fabrication cost, reprocessing cost, and, for converter reactors (LWR's) and advanced converters, the fissile depletion cost.

The time involved in each of these processes is also an important factor because the speed with which each process can be executed in the fuel cycle determines how much material must be in the "pipe line" to keep a reactor operating. And since the investment required to provide this material precedes the recovery of revenue from electrical power operation, improving the yield of electrical energy per kilogram of fissile material will reduce the working capital costs.

Fuel Cycle Optimization

An examination of the costs involved in the nuclear fuel cycle suggests two general types of costs: one that is independent of the fuel exposure, such as reprocessing cost, which is expressed in \$/kg regardless of the fuel exposure; and one that is highly dependent on the fuel exposure, such as the enrichment cost, which rises rapidly with exposure. Figure 2 shows both the dependent and independent costs plotted against fuel exposure.

Fabrication and reprocessing costs decline on a curve having a hyperbolic shape, whereas costs that are dependent on the fuel exposure, such as fissile-depletion and working capital costs, increase almost

FIGURE 2. FUEL CYCLE COST AS A FUNCTION OF FUEL EXPOSURE

linearly with fuel exposure. When these costs are summed, a curve representing the total fuel-cycle cost reaches a minimum at an exposure defined as the optimum exposure.

The optimum exposure can be affected by any of the costs incurred during the fuel cycle. For example, if the fabrication costs decrease with time, the optimum exposure will become less. But if interest rates decrease or plutonium price decreases, the optimum will shift to a higher exposure.

Each reactor design has been analyzed to determine its optimum exposure for a specific set of conditions. However, if the conditions of an optimum exposure change, then the corresponding fuel cycle could change the power costs as much as 0.1 to 0.2 mill/kwhe. Because costs of this magnitude equal almost \$1,000,000/year for a 1,000 MWe reactor, it is obvious that there should be a continual review of the nuclear fuel cycle. This type of optimization would also apply to LWR's.

In this report, we will discuss the different aspects of the fuel cycle associated with the Sodium Cooled Plutonium Breeders. The first section will be very general and some parts of it can be applied to all types of breeder reactors. In the later sections, we will discuss the sodium-cooled reactor types in detail and indicate the cost incentive for changing certain parameters.

INTRODUCTION TO FAST BREEDER REACTORS

Reactors that would produce more fuel than they consume during operation have been of interest since the earlier days of reactor development work. To obtain a sizeable excess production of fissionable isotopes requires operating these reactors with a high energy (or fast) neutron flux. These requirements cause some good and bad effects which will be discussed.

The conversion ratio, which is an indicator of reactor performance, tells how many fissionable atoms are produced for the number of fissionable atoms destroyed. If this ratio is less than one, and there is no net gain in fissionable material, the reactor is defined as a converter reactor. A typical reactor of this type would be the thermal spectrum Yankee reactor which has a conversion ratio of $0.53^{(1)}$ and burns U^{235} . The (fast) Fermi reactor, which also burns U^{235} , has a conversion ratio of $1.20^{(1)}$ and is a breeding reactor. When the conversion ratio is greater than 1.0, it is referred to as the breeding ratio. Advanced plutonium fueled fast reactors may have breeding ratios of $1.6^{(1)}$ or possibly higher.

To see how much effect the neutron energy spectrum has on the breeding potential of a certain isotope, the parameter η (the ratio of neutrons produced per neutron absorbed in the fissile isotope) is significant. In the following table, η values are given for three fissile isotopes at three neutron energies.

TABLE I
ETA VALUES FOR FISSILE NUCLIDE AT THREE NEUTRON ENERGIES

	<u>10^4 ev</u>	<u>10^5 ev</u>	<u>10^6 ev</u>
U^{233}	2.22	2.26	2.40
U^{235}	1.99	1.90	2.32
Pu^{239}	1.87	2.41	2.99

The relationship of the breeding ratio, η , losses, and fast effect is

$$\text{B.R.} = \eta - 1 - \text{losses} + \text{fast effect.}$$

From η one neutron is subtracted to sustain the chain reaction. Also subtracted in the breeding ratio formula are the losses due to parasitic absorption and other sources. However, the fast effect (the fissioning of the fertile material, in this case U^{238} , by fast neutrons) is added since it represents a gain in neutrons. At high energies the fast effect will come very close to cancelling out the losses, and under these conditions a simplified form of the above equation can be used:

$$\text{B.R.} = \eta - 1.$$

If we then compare the breeding ratios of three isotopes at 10^6 ev, we can obtain a good indicator of the three isotopes under very high flux. The following values are obtained:

$$Pu^{239} = 1.99, \quad U^{235} = 1.32, \quad U^{233} = 1.40.$$

Plutonium is decidedly superior to the two uranium isotopes for this case. If we then compare them at 10^5 ev under the same assumptions the following ratios are obtained:

$$Pu^{239} = 1.41, \quad U^{235} = .90, \quad U^{233} = 1.26.$$

Here plutonium has started to lose its advantage over U^{233} and U^{235} , even though the U^{235} ratio now finds itself in the converter region. Further reduction to 10^4 ev causes the Pu^{239} breeding ratio to drop below 1.0, leaving U^{233} as the only isotope having a conversion ratio greater than 1.0. The conclusion that can be reached from this is that U^{233} is not affected by the neutron energy as much as plutonium, and with lower energies, U^{233} would have an advantage over plutonium. But with an increase in neutron energy, plutonium shows decided advantages over both U^{233} and U^{235} .

Doubling Time

In the study of breeder reactors, the doubling time is often used to indicate the merit of specific reactors. It would seem that this is a good indication of fast reactor characteristics, but a problem soon arises over the meaning of doubling time. In the following section we will explain the different types of doubling time and what they mean.

The simplest type of doubling time is that of just the core itself. This doubling time is considered to be the operating time required for a reactor to breed enough extra fuel to reproduce the original core. In this case no considerations are given to any of the variables outside of the reactor.

The first example of doubling time, although quite simple to determine with respect to other types, really does not give the whole picture of whether the reactor is economically attractive. A reactor could have a very good core doubling time but at the same time require a very large out-of-reactor inventory.

It would seem that since the core doubling time really does not consider all the important parameters of the fuel cycle, a doubling time of the whole reactor system would be of more value. This doubling time would be considered as the simple doubling time of the reactor system. The reactor system or fuel cycle consists of the following sections (see Figure 1):

1. The fuel contained in the core of the reactor itself.
2. The fuel at the reactor that is kept in inventory outside of the core.
3. The fuel in the separations stream necessary to support this reactor.
4. The fuel in the fabrication plant that is used to support this reactor.

This reactor system can then be considered to be in two main parts: in the reactor core and in the out-of-reactor inventory, or pipe line. In brief, simple doubling time is the period of time required for the reactor to breed enough extra fuel to start another complete reactor system like itself.

In the previous case the extra bred fuel was not used until enough was stockpiled to start a new reactor. However, as the number of reactors increase, there will develop a market for plutonium as soon as it is processed. This would also lead to another type of doubling time which we will call the reactor system compound doubling time. The difference between it and the simple doubling time is that the extra fuel, as it is made available, is assumed to be sold to a new breeder reactor. This in effect causes the fuel, which in the previous case was only marking time in inventory, to start breeding more fuel in the new reactors.

A compound core-doubling time can also be determined by using the same conditions as the compound system doubling time but without considering the out-of-reactor inventory.

CALCULATION OF DOUBLING TIMES

The computer code CYCLES was written to show what effect various fuel cycle parameters would have on doubling times. It determines both the simple and compound doubling time.

The reactor characteristics (input data) included the following: breeding ratio, alpha, weight of fissile material in core, core fuel exposure, number of regions in core, plant factor, heel (spare nuclear fuel), megawatts thermal, megawatts electrical. The code determines the number of grams of fissionable material destroyed/MWD by Equation (1).

$$\text{GDPMWD} = (1.07)(1 + \text{Alpha}) / (1 + \text{Fast Effect}) \quad (1)$$

where:

GDPMWD = Grams of fissile isotope destroyed/MWD

1.07 = Ratio of fissile isotope fissioned/MWD

Alpha = Ratio of capture to fission cross section of
fissile isotopes

Fast Effect = Fraction of fissions in fertile material.

The amount of fissile isotopes produced per MWD is then defined as:

$$\text{GPPMWD} = (\text{GDPMWD})(\text{Breeding ratio}). \quad (2)$$

Then by subtracting Equation (1) from Equation (2), the net gain in fissionable isotopes/MWD is obtained. The plant factor and the power of the reactor are then used to calculate the net Kg of fissile isotopes

produced per day. This can then be used to determine the simple doubling time:

$$\text{Simple doubling time in years} = \frac{\text{Kg of Pu in Core}}{365(\text{Kg fissile produced/day})} \quad (3)$$

The simple doubling time in Equation (3) considers only the core and makes no allowance for out-of-reactor time or fuel availability for another reactor, and does not consider any of the fissioned material out of the core which is in inventory or the process stream.

The simple doubling time is calculated after adjustments are made by the code for different exposures and out-of-reactor times, which will affect both the availability of the fuel produced and the amount of out-of-reactor inventory needed. When the reactor is in equilibrium and discharges a region of its core at certain intervals, the net gain in fissile material is shown in Equation (4).

$$\text{Gain} = \frac{(\text{Number of days between discharge}) \times (\text{Net Kg of fuel produced/day})}{1} \quad (4)$$

or $\text{Gain} = \text{Net Kg of fuel gained/cycle}$

Fractional gain with respect to the total reactor system can then be calculated by the following Equation (5).

$$\text{PGAIN} = \frac{\text{Gain (Kg/cycle)}}{\text{Core(Kg)} + \text{Heel(Kg)} + \text{Out-of-Reactor(Kg)}} \quad (5)$$

$\text{PGAIN} = \text{Fractional gain/cycle.}$

From this, the number of cycles to double can be calculated as follows:

$$\text{Cycles to Double} = \frac{1}{\text{PGAIN}} \quad (6)$$

The simple doubling time, including the displacement due to availability after final discharge of the fuel, will be:

$$\text{SYRTD} = \frac{\text{Cycles} \times \text{DAYS}}{365} + \text{X-Time}, \quad (7)$$

where:

SYRTD = Years for simple system to double

DAYS = Days between discharge

X-Time = Total time for out-of-reactor reprocessing in years.

This equation can be equated to (3) if Heel(Kg) = 0 and out-of-reactor(Kg) = 0 in Equation (5) and X-Time = 0 in Equation (7).

The same series of equations from (4) through (7), except for a very important change in Equation (6), were used for calculating the compound doubling time. In the compound case, fuel is made available from reprocessing as soon as it is allowed to compound in a new reactor. This reduces the number of cycles required. In Equation (8) the number of cycles needed to double the reactor system are determined in the following way:

$$2 = (1 + \text{PGAIN})^{\text{Cycles}}.$$

Taking the log of both sides and rearranging terms, one obtains

$$\begin{aligned} .69315 &= [\text{Log}(1 + \text{PGAIN})(\text{Cycles})] \\ \text{Cycles to Double} &= \frac{.69315}{\text{Log}(1 + \text{PGAIN})} \end{aligned} \quad (8)$$

Cycles = Number of cycles for compound doubling

PGAIN = Gain per cycle.

The compound core doubling time can be obtained from Equation (7) by reducing Heel(Kg) = 0 and out-of-reactor(Kg) = 0 in Equation (5) and

X-Time = 0 in Equation (7), and using Equation (8) instead of Equation (6) to obtain the Cycles to Double.

Sample printouts from this program are given in Appendix A of this report.

Variations in Doubling Times for two Sample Reactors

Table II shows the parameters used for two breeder reactor designs that cover an interesting range of performance. They are designated as high and low gain breeders having a breeding ratio of 1.4 and 1.2 respectively. The doubling times discussed in the previous sections are also shown in Table II.

Changes in doubling time due to specific variations of reactor system parameters were calculated by the computer code CYCLES. (See Appendix A for some examples.) In the following sections the compound system doubling time was used as the basis for these results.

Out-of-Reactor Time

Out-of-reactor time is the time spent by fissile material outside the reactor core. The major causes of out-of-reactor time are spent-fuel processing, fuel-element fabrication, transportation, and storage.

Figure 3 shows that an increase in out-of-reactor time also increases the out-of-reactor inventory of fissile material. For example, if the out-of-reactor time increases from 1 to 3 years, the out-of-reactor fissile material that must be doubled increases from 1460 to 4380 kilograms.

Note also in Figure 3 that although the slopes of the two doubling times are very different, the percentage change corresponding to an incremental

TABLE II

PARAMETERS USED FOR CALCULATING DOUBLING TIMES

	Low-Gain Breeder, 1000 MWe	High-Gain Breeder, 1000 MWe
Breeding Ratio	1.20	1.40
Kg Fissile in Core	2,000	2,000
Number of Zones	3	3
Plant Capacity Factor	0.8	0.8
Plant Efficiency	.4	.4
Exposure, MWD/MT 20% Enrichment	100,000	100,000
Equivalent Fissile Exposure, MWD/MT	500,000	500,000
ALPHA	.1	.1
Out-of-Reactor Inventory, Kg	1,460	1,460
Out-of-Reactor Time, years	1.0	1.0
Cycle Time, years	1.0	1.0
Simple Core Doubling Time, years	14.0	7.0
Simple System Doubling Time, years	28.9	15.0
Compound Core Doubling Time, years	9.8	5.0
Compound System Doubling Time, years	17.9	9.5

FIGURE 3. EFFECT OF OUT-OF-REACTOR TIME AND CORRESPONDING AMOUNT OF OUT-OF-REACTOR FISSILE MATERIAL ON BREEDER REACTOR DOUBLING TIME

change in out-of-reactor time from one year to six months reduces the doubling time of the low-gain breeder 22.8% and that of the high gain breeder 24.2%. However, in absolute terms doubling time of the low-gain breeder is reduced 4.0 years and that of the high-gain breeder almost 2.3 years. If the out-of-reactor time is zero, the low-gain breeder would double in 9.8 years, the high-gain breeder in 5.0 years.

Core Size

Figure 4 shows the decrease in compound doubling time due to the core size being reduced by increasing specific power. (Here again the percentage change is almost equal while the two slopes are different.) If the example core size is reduced from 2000 kilograms to 1000 kilograms, the compound doubling time would be decreased by about 25%. However, such a reduction in core size would require specific power levels of 600 watts per gram, whereas the present-day proposed design range for oxide fuels is between 150 and 340 watts/gram.

Number of Regions

During this study it was found that the compound doubling time is affected very little by changes in the number of refueling regions. A slight improvement was made by increasing the number of regions from 1 to 2, as shown in Figure 5, but thereafter the effect on the compound doubling time was extremely small.

FIGURE 4. EFFECT OF CORE FISSILE MATERIAL ON BREEDER REACTOR DOUBLING TIME

FIGURE 5. EFFECT OF THE NUMBER OF REACTOR REGIONS ON BREEDER REACTOR DOUBLING TIME

Fuel Exposure

Figures 6 and 7 show that fuel exposure has a profound effect on the compound doubling time of breeder reactors. However, before discussing these two figures, two observations should be made. First, the breeding ratio used in calculating the data in Figures 6 and 7 was constant, whereas in the real world there would be a reduction in the breeding ratio as the exposure increases, and hence an increase in the doubling times. Secondly, no attempt was made here to calculate the increase in compound doubling time brought about by a reduction in the 0.8 plant factor. Such a reduction could be caused by frequent charge-discharge operations at reduced exposures.

One can see in Figures 6 and 7 that at an out-of-reactor time of zero, the compound doubling time increases slowly as the exposure increases. The reason for this is that at higher exposures the excess plutonium is not introduced as often into other breeders; hence it begins "compounding" at a later date than the excess plutonium in a breeder operating at a lower exposure.

One can also see from Figures 6 and 7 that as the out-of-reactor time increases from zero, the compound doubling time is very much longer at low exposures and sharply decreases as the exposure increases. The reason for the great initial difference between the zero out-of-reactor time curve and the other curves is that at low exposures an increase in the out-of-reactor time greatly increases the amount of out-of-reactor inventory. For example, Table III shows that at an out-of-reactor time of 1 year, the out-of-reactor inventory increases from

FIGURE 6. DOUBLING TIME AS A FUNCTION OF EXPOSURE AND OUT-OF-REACTOR TIME (LOW GAIN BREEDER)

FIGURE 7. DOUBLING TIME AS A FUNCTION OF EXPOSURE AND OUT-OF-REACTOR TIME (HIGH GAIN BREEDER)

1460 Kg with a fuel exposure of 100,000 MWD/MT to 14,600 Kg with a fuel exposure of 10,000 MWD/MT. This factor of 10 difference in out-of-reactor inventory will require that the reactor double more than five times the total fissile inventory at an exposure of 10,000 MWD/MT than at an exposure of 100,000 MWD/MT exposure.

TABLE III

THE EFFECT OF EXPOSURE ON OUT OF REACTOR INVENTORY

Turnaround Time of 1 year

<u>Fuel Exposure, MWD/MT</u>	<u>Fissile Exposure, MWD/MT</u>	<u>Core Inventory, Kg</u>	<u>Out-of-Reactor Inventory, Kg</u>	<u>Total Inventory Kg</u>
4,000	20,000	2,000	36,500	38,500
10,000	50,000	2,000	14,600	16,600
20,000	100,000	2,000	7,300	9,300
40,000	200,000	2,000	3,650	5,650
100,000	500,000	2,000	1,460	3,460
200,000	1,000,000	2,000	730	2,730

Eventually, however, the compound doubling time at the higher exposures reaches a minimum and begins to increase. This increase is due to the out-of-reactor inventory no longer decreasing enough to override the delay in introducing the excess plutonium into another reactor.

Effect of Blanket Discharge Interval

The discharge of a reactor's blanket regions at different times with respect to the core has an effect on the doubling time. If the blankets are discharged more frequently than the core regions, the doubling time will be shortened since the bred fuel will be reprocessed sooner and allowed to enter the system faster. If the blankets are left in the reactor longer, the effect is just the opposite, and the bred fuel does not enter the system as fast. The results obtained from changing the blanket discharge interval are shown in Figure 8.

This effect can be thought of in terms of an annual interest rate remaining the same, but because the frequency of compounding this interest rate is varied, the overall return varies.

Conclusions

Although the effects of different parameters on the doubling time can give a good indication of the performance of a reactor system, thorough cost analysis is needed before one can estimate the total incentive for changing these parameters. The doubling time indicates the increased production of fissionable material in a period of time but does not include the cost of producing such an increase. In the remainder of this report, the cost of producing an increase in fissionable material will be dealt with in detail.

FIGURE 8. EFFECT OF CHANGING THE FREQUENCY OF BLANKET DISCHARGES ON REACTOR DOUBLING TIME

FUEL CYCLE COST

AEC Task Force Data

In August 1966 a group of AEC task forces⁽²⁾ made up of national laboratory and industrial personnel was organized to investigate the performance of reactor systems. The LMFBR task force was set up to generate LMFBR reactor performance characteristics. This resulted in four LMFBR designs using plutonium fuel:

1. A reference oxide⁽³⁾ fueled LMFBR based on technology that would be made available by 1980,
2. A reference carbide⁽⁴⁾ fueled LMFBR based on technology that could be available in 1984,
3. An advanced oxide⁽³⁾ fueled LMFBR which would have significant improvements in breeding gain and be available 10 years after the reference oxide,
4. An advanced carbide⁽⁴⁾ fueled LMFBR which would be available 10 years after the reference carbide design.

This report will use the reference oxide and reference carbide designs to show the effects of various fuel cycle parameters on the fuel-cycle costs and doubling time. The major characteristics for these two reactor designs are given in Table IV.

The Systems Analysis Task Force was given the task of developing a model of the U. S. Power Economy so that the potential value of a particular reactor design could be evaluated in competition with fossil plants and other nuclear reactors, such as the LWR. Although one can measure the effects of various fuel cycle parameters on the fuel cycle cost and doubling time, the true importance of these parameters in the

TABLE IV
DESIGN CRITERIA OF THE TWO REFERENCE REACTORS

	Oxide ⁽³⁾	Carbide ⁽⁴⁾
Thermal, MW	2,500	2,700
Thermal conversion ratio, %	40	37
Electrical, MW	1,000	1,000
Time between refuelings, full power days	153	234
In-core fuel residence time, full power days	459	702
Average out-of-reactor time for 30-year life, days	275*	280*
Specific power, MWD/MT of heavy metal		
Core	175	113
Axial blanket	6	4.26
Radial blanket	10	5.43
Exposure, MWD/MT of heavy metal		
Core	80,000	79,000
Axial blanket	2,500	3,000
Radial blanket	8,100	3,800
Reference material, initial tonnes heavy metal		
Core	12.6	20.3
Axial blanket	7.3	12.7
Radial blanket	26.0	63.7
Amount of region discharged per fueling		
Core	1/3	1/3
Axial blanket	1/3	1/3
Radial blanket	1/5	1/3
Average enrichment startup, % fissile Pu	15.6	12.5
In-core specific inventory, Kg fissile Pu/MWe	2.0	2.5
Breeding ratio	1.27	1.45**
Simple core doubling time, years	12.2	6.1
Simple system doubling time, years	not available	8.6
Compound system doubling time, years	15.0	not available
Price of Pu, \$/g	10*	10*
Net cost of money, %/year	7*	7*
Shipping of fabricated fuel to reactor, \$/kg	2*	1.2*
Fabrication cost, \$/kg		
Core	382*	200*
Blanket	95*	54*
Average core and blanket	209*	93*
Average reprocessing cost of blanket and core, \$/kg	29*	28*
Shipping to reprocessing, \$/kg	16.2*	6.9*
Loss of Pu, %	1*	1*

Load factor 85% for the first 15 years, then dropping 2%/year to 55% in 30 years.

* The values used for our input to PACTOLUS.

** Approximate value.

overall nuclear economy one best evaluates by using a model such as that developed for the Systems Analysis Task Force. This model, which was developed at Pacific Northwest Laboratories, Richland, Washington, will be described in a later section of this report.

Fuel Cycle Times

The fuel cycle flow chart of a breeder reactor is shown in Figure 9. It represents two possible time scales for the out-of-reactor part of the fuel cycle: the first indicates the time one would expect if everything was quite carefully scheduled and the separations and reprocessing plants were at the same plant site. This time is given as 231 days, which would indicate quite optimal conditions, although with special techniques shorter times could be realized. The second time scale is that of a system in which the separation and fabrication plants are at separate sites and additional time is available for shipping and inventory. The number of days for out-of-reactor cycle in this case is 337 days, which would probably be the actual time required for the fuel cycle in the early years of LMFBR operation.

Fuel-Cycle Cost Projections

The unit cost of fuel fabrication and fuel reprocessing depend on the complexity of the fuel design, the fuel material, (oxide, carbide, metal, etc.), and the fuel enrichment. In addition, these costs are strongly dependent on the plant size utilized and the degree to which the plant capacity is utilized. In general, larger plants incur lower

FIGURE 9.

FUEL CYCLE TIME

costs when the larger capacity is utilized, with reprocessing plants being especially sensitive to this scaling effect.

Determining fabrication and reprocessing costs for a given plant size having a defined load is a relatively straightforward engineering cost problem. However, it is not easy to correctly choose the plant size and load to be used in fuel-cycle cost determinations, particularly in situations involving comparisons of competing reactor concepts.

One approach that has been used in reactor evaluation studies is to base cost comparisons on plants designed to serve a fixed amount of installed capacity, such as 15,000 MWe or 30,000 MWe. The implied assumption here is that different concepts reach a given level of maturity at the same time, regardless of how they got there or where they're going next. To gain acceptance, a new plant design must be competitive with an established plant design, even though there may be a very large fuel-cycle industry for the established design and a very small one for the new design.

One method for defining unit fuel-cycle costs as a function of time in an expanding industry is that represented by the FUELCO computer program.

For its input the FUELCO program requires estimates of fuel fabrication and reprocessing loads for the period of interest (up to 80 years may be specified); various cost constants to be used in cost scaling equations for the fuel preparation, fabrication, reprocessing, and conversion processes; upper size limits for plants (if desired, a different limit can be specified for each of the first 21 plants in a series); and

various optional economic parameters and constants. The FUELCO cost calculations are based on single-purpose fabrication plants and multipurpose reprocessing plants.

In the FUELCO calculations, the total annual processing requirements for each process in the system are summed up and a plant building schedule determined on the basis that whenever demand exceeds existing capacity, new plants are added to meet the load increase over a specified "lookahead" period, say, five years. A levelized cost (price for service) is then determined for each plant in the series. An averaging or "cost smearing" procedure then converts the unit costs for the individual plants to a more gradually changing schedule of unit costs over the entire time period of interest, starting from a specified initial value. A fundamental assumption in this "smearing" calculation is that the industry as a whole earns the specified return on investment, but that individual plants may earn more or less, depending on their randomly determined position in the cost-time curve.

For the present study, the FUELCO program was used with varying parameters to define a range of probable fuel cycle costs as a function of time for the reference oxide LMFBR and reference carbide LMFBR. For processing load determinations it was assumed that the oxide LMFBR was introduced in 1980, the carbide in 1984. Maximum market penetration was assumed for each type as if it were the only LMFBR in the system. After an initial growth restraint in which only 8 reactors were built in the first two-year period, 16 in the second two-year period, and 32 in the third two-year period, 75% of the total nuclear growth projection was

assigned to the LMFBR's, with the balance assigned to LWR's. The range of parameters used for these FUELCO calculations were as follows:

	<u>Low</u>	<u>High</u>
Maximum Plant Size Limit, MT/D		
Core fabrication	5	20
Blanket fabrication	20	20
Reprocessing	10	20

Plant Size Selection Basis for Fabrication

- (a) Incremental load increase during 5-year lookahead period.
- (b) 10% of the total load 5 years in the future.
- (c) 20% of total load 10 years in the future.

Plant Size Selection Basis for Reprocessing

- (a) Incremental load increase during 5-year lookahead period.
- (b) 20% of total load 5 years in the future.
- (c) 30% of total load 10 years in the future.

Cost of Money

- (a) 16% return on investment with 70% equity and 5% interest on debt.
- (b) 16% return on investment with 100% equity.

Reprocessing

- (a) Multipurpose plants for LMFBR's and LWR's.
- (b) Single purpose plants for LMFBR's.

Initial Price of Fabrication, \$/kg	<u>Core</u>	<u>Blanket</u>
Reference oxide LMFBR	335 to 400	68 to 100
Reference carbide LMFBR	200 to 250	60 to 90

The resulting range of costs (prices) projected through the year 2020 are shown in Figures 10, 11, and 12. The costs shown are for the weighted total costs of core and blanket fuel in the case of reprocessing, but in the case of fabrication the cost of core and blanket are separated. In

FIGURE 10. UNIT FUEL REPROCESSING COST PROJECTION FOR OXIDE AND CARBIDE LMFBR'S

FIGURE 11. UNIT FUEL FABRICATION COST OF OXIDE CORE AND BLANKET

FIGURE 12. UNIT FUEL FABRICATION COST OF CARBIDE CORE AND BLANKET

general, the highest costs are due to the assumed higher cost of money and the low costs are due to allowing the largest size plants to be built.

Fuel Cycle Cost Calculations

The fuel cycle costs were obtained by using the computer code PACTOLUS⁽⁵⁾ with inputs from the reference oxide and carbide cases listed in Table IV. The conditions assumed for these reactors were a useful life of 30 years, a load factor of 85% for the first 15 years, and an annual linear reduction of this load factor to 55% for the last year of operation. (See Appendix C for the reference oxide and reference carbide cases.) In Table IV is a condensed listing of the design criteria for the two reactors. Further information can be obtained in Appendix B and from References 3 and 4.

Plutonium Cost

The plutonium cost is that price the reactor operator must pay for the fuel. It is also the price the fuel manager sells the bred plutonium for, and the value placed upon it in inventory. The effect of plutonium cost on fuel cycle cost is shown in Figure 13 for both the reference oxide and carbide LMFBR's. The range of plutonium cost was from \$0-20/g, with \$10/g being the base case. The fuel cycle cost is given in mills/kwhe, and as indicated in Figure 13 increases in both cases with plutonium cost.

In Figure 14 the incremental change in fuel cycle cost is shown as a function of plutonium cost. As can be seen from the figure, the plutonium cost has a greater effect on the oxide reactor than the carbide reactor. A plutonium cost change from \$10-20/g will increase fuel cycle cost by

FIGURE 13. FUEL CYCLE COST AS A FUNCTION OF Pu COST

FIGURE 14. INCREMENTAL CHANGE IN FUEL CYCLE COST WITH CHANGES IN Pu PRICE

.4 mills/kwhe for the oxide and .3 mill/kwhe for the carbide LMFBR. The better performance of the carbide LMFBR makes it less sensitive to plutonium cost. It produces more plutonium in a given time period, and if the cost of plutonium is higher, the credits for the plutonium produced will also be high, and thus cancel some of the increased cost.

Turnaround Time

Shown in Figure 15 is the effect of turnaround (out-of-reactor) time on the fuel cycle costs for both series of reactors. The time is slightly different for the two base cases--275 days for the oxide and 280 days for the carbide. As Figure 15 clearly shows, the turnaround time does not affect the fuel cycle cost as much as the plutonium price does, but it is still quite significant.

Figure 16 shows the incremental change in fuel cycle cost with turnaround time. This effect is also greater for the oxide LMFBR. If the time of each base case is doubled, the fuel cycle cost will increase by .15 mill/kwhe for the carbide and .18 mill/kwhe for the oxide. A reduction in time by one-half will cause a reduction of .08 mill/kwhe for the carbide and .09 mill/kwhe for the oxide. An increase in turnaround time will delay the plutonium credits, and hence increase cost.

Fuel Exposure

The effect of fuel exposure on the fuel cycle cost for the reference oxide LMFBR is shown in Figure 17 for different fabrication costs. As the exposure with normal (\$210/kg) fabrication cost is increased, the change on the exposure at first is quite rapid, but soon drops off and

FIGURE 15. FUEL CYCLE COST AS A FUNCTION OF TURNAROUND TIME

FIGURE 16. INCREMENTAL CHANGE IN FUEL CYCLE COST WITH CHANGES IN TURNAROUND TIME

FIGURE 17. EFFECT OF EXPOSURE ON FUEL CYCLE COSTS FOR VARIOUS FABRICATION COSTS

approaches a minimum value asymptotically. The increase of the exposure from 70,000 to 80,000 MWD/MT causes a reduction in cost of .14 mill, whereas a change from 80,000 to 90,000 MWD/MT causes only an .08 mill reduction in fuel cycle cost. These results would indicate that the effect of exposure is more pronounced at exposures below 100,000 MWD/MT. Beyond this value the effect is much less, and the incentive to go to high exposures is not as great. And if the fabrication costs are reduced by one-half, the incentive to go to higher exposures is reduced even more, the reduction in cost being .03 mill/kwhe from 80,000 to 90,000 MWD/MT. Decreasing the cost of fabrication to one-fourth reduces the incentive even more, the reduction in cost being .02 mill/kwhe from 80,000 to 90,000 MWD/MT.

Fuel exposure affects the flow of nuclear fuel through the reactor. As the exposure is increased, the fuel is left in the reactor for a longer time and the flow is reduced. Reducing the material flow will also reduce the amount of material that must be fabricated and separated, and hence reduce the overall cost. Moreover, the cost of fabrication per kg is reduced, the sensitivity of the fuel costs to exposure will also be greatly reduced, as shown in Figure 17. This can be attributed to the fact that as the cost is reduced per unit weight of material, the cost of fabrication becomes a smaller portion of the total fuel cycle costs.

Cost of Money

In Figure 18 is shown how the cost of money affects the fuel cycle costs for both the carbide and oxide cases. This cost includes both bond

FIGURE 18.

THE EFFECT OF NET COST OF MONEY ON FUEL CYCLE COST

and stock rates combined to give overall cost. The equation used to determine the cost of money is shown as follows:

$$\begin{aligned}\text{Cost of money} &= \text{bond rate (\% bond financing)} \\ &+ \text{stock rate (\% stock financing)}.\end{aligned}$$

In this case, bond rate = 4.2%/yr, % bond financing = 52%

stock rate = 10%/yr, and % stock financing = 48%.

Substitute these values in the equation and the cost of money is found to be 7%/yr. Figure 19 shows the incremental change in fuel cycle cost with changes in cost of money.

The effect of interest is almost the same for both the oxide and the carbide cases. A reduction or increase of 1% in the cost of money will reduce or raise the fuel cycle cost by approximately .1 mill/kwhe.

Reprocessing Cost

The effect on fuel cycle cost of reprocessing charges is shown in Figure 20. In Figure 21 the changes in fuel cycle costs are plotted against the actual reprocessing charges.

Reprocessing cost affects the change in the fuel cycle cost more strongly in the case of the reference carbide than in the case of the reference oxide because the reference carbide must process a larger amount of fuel. The reason for this difference can be seen in Table IV. Comparing the exposures of all the fuel in the reactor, we find that the reference carbide LMFBR is not run to exposures as high as the oxide. If the cost of reprocessing is reduced to one-half the base cost considered, the fuel cycle cost would be reduced by .07 mill/kwhe for the reference

FIGURE 19. INCREMENTAL CHANGE IN FUEL CYCLE COST WITH CHANGE IN THE NET COST OF MONEY

FIGURE 20. FUEL CYCLE COST AS A FUNCTION OF REPROCESSING COST

FIGURE 21. EFFECT OF REPROCESSING COST ON FUEL CYCLE COST

carbide and .04 mill/kwhe for the reference oxide. But an increase of 50% would cause the fuel cycle cost to increase .07 mill/kwhe for the reference carbide case and .04 mill/kwhe for the reference oxide case.

Fabrication Cost

Percentage change in fabrication cost will have a greater effect than separation charges on fuel cycle costs, as shown in Figure 22 for the oxide and carbide cases.

Since the cost of fabricating the oxide fuel is more than twice that of the carbide, two comparisons should be drawn. If there is a percentage change in the cost of fabrication, the oxide will be more sensitive. For example, a reduction of 50% in fabrication charges will cause the fuel cycle cost to be reduced by .44 mill/kwhe for the oxide case and .32 mill/kwhe for the carbide case. If we then inspect Figure 23, which plots the change in power costs against change in fabrication cost, we find that for a change in actual dollars the reference carbide case is more sensitive; reduction of fabrication cost of \$50 cutting the fuel cycle cost by .33 mill/kwhe for the reference carbide case and .2 mill/kwhe for the reference oxide case.

In the total fuel cycle, the cost of fabrication is quite predominant. There are two important reasons for this. First, the cost of fabrication is much greater than the cost of separation. In the oxide case, this amounts to more than four times the cost of separations and in the carbide case twice the cost of separations. Also, the cost of fabrication is incurred before the power is sold, in effect adding an

FIGURE 22. FUEL CYCLE COST AS A FUNCTION OF FUEL FABRICATION COST

FIGURE 23. INCREMENTAL CHANGE IN FUEL CYCLE COST WITH CHANGES IN FABRICATION COST

interest charge, whereas the separations charges come after the power is sold.

Load Factor

The plant utilization or load factor effect on fuel cycle cost is shown in Figures 24 and 25, which respectively plot the actual fuel cycle cost and the incremental change of fuel cycle cost against the load factor.

The load factor affects both the carbide and oxide case, in a similar manner, as shown in Figure 25, although the carbide case is affected more. And if the load factor is reduced by 5% from a starting position of 80%, the fuel cycle costs will increase by .06 mill/kwhe for the carbide case and .05 mill/kwhe for the oxide case. The curve becomes even steeper, and hence even more sensitive, as the plant factor is further reduced.

Summary on Fuel Cycle Costs

In Table V is presented the relative merit of making certain changes in the reactor system. This table is drawn from the previous graphs of this section, the values being those of the slope of the lines through the base cases. From these tabulated values a number of cross comparisons can be made. One comparison that stands out is how the effect of fabrication cost on fuel cycle cost is different than the effect of separations costs. Fabrication affects the fuel cycle cost almost 50% more per dollar spent than does separations. The reason for this effect is due mainly to the different times in which the cost is incurred by the reactor system. Because the fabrication cost comes before the fuel is even used in the reactor for power, it has an added interest charge

FIGURE 24. EFFECT OF LOAD FACTOR ON FUEL CYCLE COST

FIGURE 25. INCREMENTAL CHANGE IN FUEL CYCLE COST WITH CHANGES IN LOAD FACTOR

compared with the separations costs. Separation costs occur after revenue has already been collected and will accumulate an interest credit before it is paid out to the separations plant.

TABLE V

TABLE OF RELATIVE MERIT

<u>Increase of</u>	Change of Fuel Cycle Cost for the Oxide <u>Reactor, mills/kwhe</u>	Change of Fuel Cycle Cost For the carbide <u>Reactor, mills/kwhe</u>
\$1/gm of Pu	+ .04	+ .03
100 days cycle time	+ .067	+ .052
1,000 MWD/MT Exposure	- .0075	
\$1/kg of Fabrication	+ .0042	+ .0072
\$1/kg of Separation	+ .0028	+ .005
.1% Cost of Money	+ .01	+ .01

Table V also shows that in the oxide case a change of 100 days in cycle time causes a .067 mill change in the fuel cycle cost, and that the carbide reactor has a change of .052 mill in fuel cycle cost, which is somewhat less than that of the oxide case. Under these conditions, the carbide case is affected less by cycle time because of its higher performance.

With respect to the price of plutonium, the carbide case is half as sensitive as that of the oxide. This can be attributed to that fact that the carbide is a more efficient producer of plutonium, and as the price

of plutonium increases, so also does the credit revenue, which helps reduce the effect of the price increase.

The cost of money affects both the reference oxide and the reference carbide cases in the same way: an increase of .1% in the cost of money will raise the fuel cycle cost by .01 mill in both cases.

Fuel exposure increases will cause a reduction in fuel cycle cost. In the case of the reference oxide reactor, this would be a reduction of .0075 mill/1000 MWD/MT for the base case. However, there is a limit to improving the fuel cycle cost by increasing exposure. Once the exposure level of 100,000 MWD/MT is reached, further reductions in fuel cycle cost require much higher exposure levels.

In Tables VI and VII a summary of the components of the fuel cycle cost are given for both the carbide and oxide reactors. The actual contribution to the fuel cycle cost of each component is given in mills/kwhe. The cost is further broken down into direct cost and return on investment which include revenue taxes, income taxes, bond interest, and return on equity.

TABLE VI

REFERENCE OXIDE FUEL CYCLE COSTS, mills/kWhe
(80% Load Factor)

<u>Cost Classification</u>	<u>Direct Cost</u>	<u>Return on Investment</u>	<u>Total</u>
<u>Initial Core</u>			
Fuel Purchases			
U ₃ O ₈	.0172	.0452	.0624
Separative Work	--	--	--
Pu Purchases	.0927	.3106	.4033
Property Tax	.0782	.0	.0782
Fabrication Costs	.0464	.1209	.1673
Fabrication Losses	.0008	.0319	.0327
Reprocessing Cost	.0032	-.0006	.0026
Reprocessing Losses	.0021	-.0006	.0015
Fuel Credits			
U ₃ O ₈	-.0005	.0001	-.0004
Separative Work	--	--	--
Pu Credits	-.0856	.0181	-.0675
<u>Replacement Fuel</u>			
Fuel Purchases			
U ₃ O ₈	.0089	.0007	.0096
Separative Work	--	--	--
Pu Purchases	2.0489	.1332	2.1821
<u>Fabrication</u>			
Fabrication Costs	.6793	.0442	.7235
Pre-Reactor Shipping	.0067	.0	.0067
Fabrication Losses	.0090	.001	.0100
<u>Reprocessing Costs</u>			
Reprocessing Cost	.0975	-.0036	.0934
Post-Reactor Shipping	.0583	.0	.0583
Reprocessing Losses	.0071	-.0028	.0043
<u>Fuel Credits</u>			
U ₃ O ₈ Credit	-.0202	-.0214	-.0416
Separative Work Credit	--	--	--
Pu Credit	-2.3548	.1296	-2.2252
TOTAL			1.5017

TABLE VII

REFERENCE CARBIDE FUEL CYCLE COSTS, mills/kWhe
(80% Load Factor)

<u>Cost Classification</u>	<u>Direct Cost</u>	<u>Return on Investment</u>	<u>Total</u>
<u>Initial Core</u>			
Fuel Purchases			
U ₃ O ₈	.0013	.0032	.0045
Separative Work	--	--	--
Pu Purchases	.1204	.4287	.5492
Property Tax	.0824	.0	.0824
Fabrication Costs	.0428	.1009	.1438
Fabrication Losses	.0010	.0547	.0557
Reprocessing Cost	.0129	-.0027	.0102
Reprocessing Losses	.0038	-.0008	.0030
Fuel Credits			
U ₃ O ₈	-.0013	.0003	-.0010
Separative Work	--	--	--
Pu Credits	-.1475	.0312	-.1163
<u>Replacement Fuel</u>			
Fuel Purchases			
U ₃ O ₈	.0169	.0005	.0174
Separative Work	--	--	--
Pu Purchases	1.6449	.0684	1.7133
<u>Fabrication</u>			
Fabrication Costs	.1645	.3834	.5479
Pre-Reactor Shipping	.0071	.0	.0071
Fabrication Losses	.3892	-.3816	.0076
<u>Reprocessing Costs</u>			
Reprocessing Cost	.1645	-.0096	.1549
Post-Reactor Shipping	.0439	.0	.0439
Reprocessing Losses	.0069	-.0032	.0037
<u>Fuel Credits</u>			
U ₃ O ₈ Credit	-.0164	.0014	-.0150
Separative Work Credit	--	--	--
Pu Credit	-2.2253	.1990	-2.0263
TOTAL			1.1860

LMFBR'S IN THE U. S. POWER ECONOMY

Description of Model

The Systems Analysis Task Force developed a computer model to represent the U. S. Electrical Power Economy during the period 1970 to 2020. This model represents only the U. S. electrical power economy, and does not show how the U. S. electrical power economy would be affected either by possible imports and exports of reactor technologies or by raw material. Figure 26 shows both the flow of information in the model and the codes used. The model has the following characteristics.

1. Electrical Energy Demand

The total need for electrical energy from new power plants between 1970 and 2020 is met by constructing fossil or nuclear power plants based on minimum cost to the consumer. Furthermore, the peak power demands, as well as the average power demand, are met during each biennium, or two-year period. The power demands are derived by extrapolating Federal Power Commission data from 1980 to 2020. These data are broken down into the power supply areas, each having nearly the same fossil-fuel power cost.

The system load factor was assumed to increase from the present 63% to 70% by 2020. And peak power was assumed to be supplied by other than central power stations, amounting to approximately 2% of the total electrical generation capacity and normally supplied by gas turbines, diesel generating plants, and hydro stations.

Since hydroelectric power was assumed to contribute only a small amount of capacity to the economy after 1970, it was included in the model as peaking capacity.

FIGURE 26.

INFORMATION FLOW DIAGRAM IN SATF MODEL

2. Fuel Materials

Natural resources were restricted to those available in the U. S. It was assumed that fossil resources would be unlimited and would be available at the as-burned costs experienced by large fossil plants built between 1960 and 1966.

Uranium and thorium prices were assumed to increase with the total amount consumed. As for the price-availability schedules, they were supplied by the AEC and are based on reasonably assured reserves. The model is capable of easily handling variations in the price availability schedules.

Since plutonium and U^{233} are produced during reactor operation and are of value to future reactor operations, they reduce or eliminate the need for natural resources (U_3O_8), which may be in limited supply. Because the model calculates the value of plutonium and U^{233} as substitutes for other natural resources, the price of plutonium and U^{233} are not inputs to the model but are data developed during the operation of the model.

3. Nuclear Technology

Each reactor technology is represented in the model, which chooses the operating history of a reactor's 30-year lifetime. The reactor history contains detailed cash flow information for each biennium, along with the requirements and production of fuel materials (U_3O_8 , plutonium, U^{233} , thorium). Each reactor technology has an earliest date of introduction, based on the successful completion of a proposed R&D program. For the LWR and fossil-fueled plants, the introduction date is 1970, and

there is no restriction on the rate at which these power reactors are introduced. A constraint on the allowed rate at which each reactor type is built simulates the difficulties encountered by a new technology seeking acceptance. The restriction on reactor introduction dates is such that no more than 8,000 MWe of capacity may be built during the first two years and no more than 16 and 32 GWe may be built during the second and third bienniums respectively. Eight years after the introduction date, this constraint is removed.

It was assumed that because of higher throughputs and improved technology, the fabrication and reprocessing costs would decline as the industry grows.

It was also assumed that the four reactor types discussed above in the section entitled Fuel Cycle Cost would gain acceptance at the maximum allowable rate. Thus a philosophy of "maximum penetration" was used for calculating the fabrication and reprocessing costs. Of course, everyone can't really win; however, this is a secondary decision which cannot easily be made with linear programming. This problem, according to present expectations, will be solved by iteration; consequently, the use of a solution based on the "maximum penetration" philosophy would be applied to recalculating the fabrication costs in such a way that those with few sales would find fabrication costs higher after iteration.

The separative work required to convert natural uranium into enriched uranium is considered to be available at \$26/kg and in unlimited amounts.

4. Economic Structure

The method used by the model in arriving at the optimum choice of reactor and fossil plants to be built is such that the sum of all cash expenditures present-worthed at a rate of 7%/year are minimized over the period 1970 to 2020. The model also supplies the cost of power for other discount rates. The model actually considers an additional 20 years, plus a prorating of expenditures from plants which are not shut down at the end of the problem, so that "end effects" will not influence the solution between 1970 and 2020. The model makes no attempt to take price inflation or escalation into account, and all costs are expressed in terms of 1970 dollars. Expenditures for R&D programs designed to make a reactor technology available are not included in the model. Rather the savings calculated by the model from introducing a given design are used as a measure of the incentive for incurring the expense to develop that reactor design. The cost of power is based on that of a 1000 MW electrical plant; however, the model will not be restricted only to plants of the 1000 MWe size. The cost of electrical transmission and distribution is not included in the model.

In this report the reactors considered are light water reactors (LWR's) and the Liquid Metal Fast Breeder Reactors (LMFBR's). The LMFBR's consisted of the following reactors: reference oxide, reference carbide, advanced oxide and advanced carbide. The fuel cycle of the reference design was discussed in the previous section and more detailed information can be found in Appendix B for all of the designs. Their introduction sequence was considered to be as follows: reference oxide reactor,

reference carbide reactor 4 years after introduction of the reference oxide reactor, advanced oxide reactor 10 years after introduction of the reference oxide reactor, and the advanced carbide reactor 10 years after the introduction of the reference carbide. Reference data were developed from the designs submitted to the AEC by reactor designers.

Effect of Recycle Time

In previous sections of the report it was found that turnaround time had a profound effect on both doubling time and direct fuel cycle cost. The impact of changing the recycle time for fast breeders on the entire nuclear power economy was determined by using different recycle times and reoptimizing the nuclear power economy. This was done for recycle times of one-half the normal, about 150 days, and for twice the normal, about 600 days. In Figure 27 the results of these changes are shown with respect to the objective function (present worth cost of all power referred to 1970) and the recycle time. Present-worth time causes events occurring earlier in time to have a larger effect than changes in the future.

The recycle time has some very interesting effects on overall power cost for the electrical economy. It was found that the effect of doubling the recycle time has very little effect on the cost of power when compared with reducing the recycle by one-half. Reducing the recycle time by one-half saves \$2.5 billion, whereas doubling the recycle time will cost an additional .5 billion present-worth dollars for power.

The reference oxide reactor is chosen in 1980 for the case of one-half recycle time, but for normal recycle times, the reference carbide

FIGURE 27. EFFECT OF RECYCLE TIME ON POWER COSTS OF LWR'S & LMFBR'S FROM 1970 - 2020

is the first LMFBR chosen in large numbers. When the normal recycle time was doubled, advanced design characteristics were required before substantial numbers of LMFBR's were built. Thus, increased recycle times meant that better in-core performance was required before LMFBR's were adopted. The savings resulting from halving the recycle times were applied to all LMFBR's and this makes the relatively lower efficiency reference oxide design look attractive.

Doubling Time

The effect of doubling time on the present-worth cost of power was investigated by assuming that various degrees of LMFBR development were available.

Figure 28 shows the effect of LMFBR performance on the present worth of power costs. At the point marked RO, the LMFBR performance was limited to that of the reference oxide. The RC point represents the introduction of the reference oxide followed by and limited to the reference carbide. The point marked AC represents the effect of sequentially introducing all four of the reactors, beginning with the reference oxide and ending with the advanced carbide. The upper curve assumes that the uranium (U_3O_8) costs increase with consumption. Table VIII shows the price of uranium, annual separative duty, and cumulative tons of uranium for the three cases RO, RC, and AC under the condition of increasing uranium price. The lower curve in Figure 28 is based on a uranium cost fixed at \$8/lb U_3O_8 . Under the constant uranium cost conditions, the reference oxide reactor was not found economically attractive and a simple doubling time of at least 7 years was required for a cost savings.

FIGURE 28. EFFECT OF DOUBLING TIME ON THE PRESENT-WORTH POWER COST WITH CONSTANT AND CHANGING URANIUM PRICES

TABLE VIII

COMPARISON OF THREE INCREASING URANIUM COST CASES

RO Introduction 1980

Year	RO			RC			AC		
	LWR, Reference Oxide			LWR, Reference Oxide and Carbide			LWR, Reference Oxide and Carbide, Advanced Oxide and Carbide		
	U ₃ O ₈ Price, \$/lb	Separative Duty Kilotonnes Annual	Cumulative Tons U ₃ O ₈	U ₃ O ₈ Price, \$/lb	Separative Duty Kilotonnes Annual	Cumulative Tons U ₃ O ₈	U ₃ O ₈ Price, \$/lb	Separative Duty, Kilotonnes Annual	Cumulative Tons U ₃ O ₈
1970	7.25	3.85	22.91	7.25	3.85	22.91	7.25	3.71	22.40
1975	7.25	14.07	130.60	7.25	14.06	130.61	7.25	13.17	122.29
1980	7.25	17.58	247.89	7.25	17.70	245.76	7.25	18.64	241.08
1985	9.00	25.18	498.77	9.00	25.96	493.96	9.00	25.04	492.93
1990	11.25	25.22	668.69	11.25	24.60	660.69	11.25	21.37	645.28
1995	13.75	32.72	959.72	13.75	26.84	903.95	12.81	13.75	776.54
2000	18.15	39.75	1217.57	17.33	28.94	1090.62	13.75	7.82	824.91
2005	31.33	56.67	1745.50	22.50	27.03	1370.68	13.75	1.29	849.15
2010	41.17	62.80	2152.96	27.50	13.51	1460.22	13.75	0	833.20
2015	42.50	50.52	2691.29	27.50	2.36	1507.91	13.75	0	833.19
2020	42.50	36.79	2934.72	27.50	.71	1509.78	13.75	0	833.19

The cost of power was seen to be quite dependent on doubling times with increasing uranium prices. The present-worth power cost was \$8 billion more for the reference carbide reactor and \$16 billion more for the reference oxide reactor than for the more efficient advanced carbide reactor. Under constant uranium prices the effect is not quite as striking. The present-worth power cost was \$6 billion more for the reference carbide reactor and \$6 billion more for the oxide reactor than for the more efficient advanced carbide reactor.

Figure 29 shows the power costs of fast breeder reactors with different introduction times. The assumptions made in this case are that the price of uranium is increasing with time, and that the breeders are introduced at two different times, 1980 and 1986. Note that by delaying the introduction time six years the present-worth power cost of the advanced carbide reactor is increased \$4 billion, that the reference carbide reactor is increased \$3.5 billion, and that the reference oxide reactor is increased \$2 billion. This gives an incentive for reducing to a minimum the delays in introducing the fast reactors when the uranium cost is increasing.

Although the plutonium price is parameterized in Figures 13 and 14, the actual price will be set by the relative cost of power from LWR's and LMFBR's. The price will be determined when the power cycle cost of LMFBR's and LWR's are equal. Figure 30 shows the power cost of an LWR and each of the four LMFBR designs. The intersection of the RO and LWR lines shows a plutonium price of \$5/g fixed, which is lower than the plutonium recycle value in LWR's. The reference carbide reactor shows a

FIGURE 29. EFFECT OF DOUBLING TIME ON THE PRESENT-WORTH POWER COST

FIGURE 30. INDIFFERENCE Pu VALUE FOR LWR ECONOMY

plutonium price of \$7/g, which may be competitive with LWR's. The advanced LMFBR's show a plutonium price of \$15 to \$26/g. Note that only the advanced-carbide-reactor power costs do not rise with an increased plutonium price.

In a free economy the plutonium price would be set by the supply of and demand for U_3O_8 . The SATF Model of the U. S. Power Economy calculates a plutonium price as a function of time. This price is also influenced by reactor technology.

Figure 31 shows the range of expected plutonium prices for the period 1970 to 2020. The case considered applies to the delayed introduction time of 1986 for the reference oxide reactor and 1996 for the advanced oxide reactor. The shaded area shows the uncertainty of the values that would be expected. The peak of this curve will be determined by the introduction time of the advanced reactor: the earlier the introduction, the earlier the peak in plutonium price. The value of plutonium is determined by different reactor types at different points in time. From 1970 to 1990 the LWR-Pu recycle will determine the cost of plutonium. But from 1990 to 2004 the performance level of the LMFBR's will determine not only the peak price in plutonium, but also when this peak will occur. After 2004 the plutonium price will be set by the optimum user of the excess plutonium produced.

Table IX shows how a change in the predicted plutonium price affects the fuel cycle costs of the reference oxide reactor for different reactor startup times. Note that the fuel cycle cost increases from 1.33 mills/kwhe in 1980 to a high of 1.92 mills/kwhe in 1990, dropping to 1.3 mills/kwhe in 2000.

FIGURE 31. PU PRICE IN A MIXED POWER ECONOMY

TABLE IX

FUEL CYCLE COSTS, mills/kwhe

	<u>Year Introduced</u>	<u>Reference Oxide</u>
Constant \$10/g Pu	1980	1.46
Predicted trend in Pu price	1980	1.33
Predicted trend in Pu price	1990	1.92
Predicted trend in Pu price	1995	1.87
Predicted trend in Pu price	2000	1.30

In Figure 31 it can be seen that this change in fuel cycle cost follows the price change of plutonium during the period 1970-2020. However, the fuel cycle cost does peak earlier than the plutonium price. This can be attributed to the fact that although the initial core cost is lower for the 1990 introduction time than for the 1995 introduction time, the inventory costs over the 30-year life span of the reactor are lower for the reactor introduced in 1995.

Conclusions

Recycle time was found to affect the present worth of power. With an increase in recycle time, the LMFBR's would not be built and only a small change in present worth of power would be observed. A reduction in recycle time, however, would lower the present worth of power. Reduction in doubling time caused a decided improvement in the present-worth cost of power. Introduction time of the LMFBR's also has a strong effect on fuel cycle costs: the sooner the introduction time, the larger the present-worth dollar savings.

LMFBR FUEL MANAGEMENT

Effect of Refueling Interval

Although the effect of discharging blankets from a fast reactor at different times was shown in Figure 8 to have had very little effect on the doubling time, the discharge rate does have quite an effect on the economics of the fast reactor.

The reactor used for this section of the study was the Allis Chalmers⁽⁸⁾ reactor having an annular core. In Appendix B is a summary of the design characteristics. This design was chosen since its performance is typical of the oxide LMFBR's. However, the trends obtained should be adaptable to the other reactor designs. The normal configuration of this reactor requires three core regions and four blanket regions. At the time of discharge of one of the core regions, one of the blanket regions is also considered to be discharged. Moreover, changes were made in the amount of blanket material discharged with each refueling of the core region. The cases used were all of the blanket discharged (1 region case), one-half of the blanket discharged (2-region case), one-fourth of the blanket discharged (4-region case), and one-eighth of the blanket discharged (8 region case) with each region of the core.

The change in fuel cycle cost due to the number of blanket regions is shown in Figure 32 for two different sets of fabrication and chemical reprocessing costs. Table X shows the different costs for the two cases. The four-zone case is the normal refueling sequence of the reactor. Under these conditions, if the whole blanket is discharged each time in order to

FIGURE 32. EFFECT OF THE NUMBER OF BLANKET REGIONS ON FUEL CYCLE COST FOR A 3-REGION CORE REACTOR

obtain the plutonium more quickly, the great cost incurred by processing this large volume of fuel causes the power costs to increase rapidly. In the high-cost processing case the fuel cycle cost increases by 1 mill/kwhe, whereas in the low-cost processing case, the increase is .5 mill/kwhe. If, on the other hand, the number of regions in the blanket are increased to 8, and only 1/8 of the reactor is discharged each time, the fuel cycle cost is reduced by .3 mill/kwhe for the high-cost processing case and .1 mill/kwhe for the low-cost processing case.

TABLE X

BREAKDOWN OF PROCESSING COSTS

	<u>High Cost</u>	<u>Low Cost</u>
Core fabrication cost	\$360/kg	\$150/kg
Blanket fabrication cost	\$100/kg	\$ 33/kg
Chemical reprocessing cost of mixed core and blanket	\$ 54/kg	\$ 24/kg

As shown in the previous discussion, there was a decided reduction in fuel cycle cost when increasing the number of blanket regions. This effect, although it reduces the fuel cycle cost, also reduces the breeding ratio. When the blankets in this case are run to higher exposures, and hence cause a power shift into the blankets, there are two main effects. One effect is that the core regions are allowed to go to higher exposures and stay in longer. The other effect is that some of the plutonium produced in the blanket regions is consumed. The overall result is that every section of the reactor is run to higher exposures and stays in a longer period of time, and thus considerably reduces the reactor

throughput. When this is then balanced against the loss due to reducing the breeding ratio, the savings due to reduced throughput has the strongest effect, the result being a reduction in fuel cycle costs.

The number of regions of the core were then increased to six and a similar series of calculations made to show how the number of blankets would effect fuel cycle costs. The results are given in Figure 33 for the same high-cost and low-cost processing cases shown in Figure 32. At first glance it would look as though the 6-region case would incur a greater fuel cycle cost under the same conditions as the 3-region blanket case of the same type. But there is one complicating factor in the 6-region case: because the core is discharged twice as often as that of the 3-region case, the blanket is also discharged twice as often. Thus the 6-region core, 4-region blanket would be more comparable with the 3-region core, 2-region blanket case. In both cases, the discharged amount of blanket is the same, even though the 6-region core discharges half as much blanket, but does it twice as often, as the 3-region core. If we use the normal 3-region core, 4-region blanket as a base and compare it with the 6-region core and 8-region blanket for the same blanket throughput, we find that the fuel cycle cost is .1 mill/kwhe less for the high-cost processing and .08 mill/kwhe less for the low-cost processing.

This decrease in power cost can be attributed to the fact that the 6-region core, 8-region blanket case will have the advantage of having the core and blanket going to slightly higher exposures, and hence slightly reduce the flow of material through the reactor. This particular case of the 6-region core shows that a very rapid discharge of blankets at low

FIGURE 33. EFFECT OF THE NUMBER OF BLANKET REGIONS ON FUEL CYCLE COSTS FOR A 6-REGION CORE

exposures to obtain the plutonium as rapidly as possible soon causes extremely high fuel-cycle costs. For example, going from 4-region blanket to 2-region blanket causes the fuel cycle cost to increase by .8 mill/kwhe for the high reprocessing costs. Increasing this to a 1-region blanket would send the cost to well over 3 mills/kwhe.

From the results obtained, one may conclude that with high-cost processing more than 4-region blankets would be desirable. If, however, the costs can be maintained at the low-cost processing level, a 4-region blanket would be adequate.

Blanket Thickness

Another parameter which affects the fuel cycle cost is that of blanket thickness. In Figure 34 a cost comparison is made of the two different processing costs shown in Table X. For the low-cost processing case, the minimum cost is at a blanket thickness of about 5 cm. For the high-cost processing case a definite minimum is not visible, but it would seem to be approaching approximately 3 cm in thickness, almost half that of the low-cost processing case. Under the high-cost processing case, increasing the blanket thickness from 3 cm to 6 cm will increase the cost of the fuel cycle by .1 mill/kwhe, whereas the low-cost processing case causes a change of only .03 mill/kwhe over this range.

In the high-cost processing case there is a trade-off between less plutonium production due to loss of neutrons in the smaller blanket and a larger cost of processing a thicker blanket. In the low cost case the blanket can be thicker in order to improve plutonium production and still give a better power cost because it is not as sensitive as the high-cost case to the amount of blanket to be processed.

FIGURE 34. EFFECT OF BLANKET THICKNESS ON FUEL CYCLE COSTS

Conclusions

The rate of plutonium removal was found to have an important effect on fuel cycle cost. Very rapid removal of plutonium was found to cause a large increase in fuel cycle cost, about 1 to 2 mills/kwhe in some extreme cases. This can be attributed to the much larger blanket throughput causing a decided increase in processing costs, even though, under these conditions, the overall breeding ratio is increased. In optimizing the blanket, it was found that with increases in processing cost, the blanket thickness should be reduced. Although a thinner blanket reduces the overall breeding ratio, it also reduces the blanket throughput, which in turn lowers the processing cost.

REFERENCES

- (1) J. G. Yevick, editor, "Fast Reactor Technology: Plant Design," 1966, p 8.
- (2) "Potential Nuclear Power Growth Patterns - A Study in Systems Analysis," to be published by the Systems Analysis Task Force.
- (3) K. Buttrey, et al., "Liquid Metal Fast Breeder Reactor (LMFBR) Task Force Fuel Cycle Study," NAA-SR-MEMO-12604, January 10, 1968.
- (4) "The Analysis of Mixed Carbide Reactors for the AEC LMFBR Task Force Studies - Final Report," SCAP-3791-11, Westinghouse Electric Corporation, Advanced Reactors Division, October 1967.
- (5) J. H. Nail, "PACTOLUS: A Code for Computing Nuclear Power Costs, Part 1: User's Manual," BNWL-429, June 1967.
- (6) J. H. Nail, "CLOTHO: A Code for Communicating Reactor Mass Balance Data to Reactor Economics Codes," BNWL-770, June 1968.
- (7) W. I. Neef, "DAEDALUS: A Code to Generate a Linear Programming Simulation of a Nuclear Power Economy," BNWL-796, January 1968.
- (8) "Large Fast Reactor Design Study," ACNP-64503, Allis-Chalmers, Atomic Power Development Associates, Babcock and Wilcox Company, January 1964.

APPENDIX A

In this appendix are a few examples of the computer printout from the code CYCLES. The breeding ratio of these examples are 1.4 and the other parameters are given in the table at the start of each case.

CALCULATED BREEDER REACTOR DOUBLING TIMES

INPUT DATA

CALCULATED VALUES

MWT	2500.0	GRAMS DESTROYED PER MWD	.981
MWE	1000.0	GRAMS PRODUCED PER MWD	1.373
ALPHA	.1	EFFECTIVE POWER	2000.0
BREEDING RATIO	1.40	EFFECTIVE SPECIFIC POWER, CORE	.667
KG FISS IN CORE	3000.0	EFFECTIVE SPECIFIC POWER, CORE + EXTERNAL HEEL	.667
NUMBER OF ZONES	1.0	KG DESTROYED PER DAY	1.962
EXTERNAL HEEL	.0	KG PRODUCED PER DAY	2.746
CAPACITY FACTOR	.8	NET GRAMS PRODUCED PER MWD	.392
		NET KG PRODUCED PER DAY	.785
		SIMPLE INT CORE DT - YEARS	10.475

SIMPLE INTEREST DOUBLING TIMES

EXPOSURE HRD/KG OF FISSILE PU	NET KG'S OF PU PRODUCED PER CYCLE	DAYS IN REACTOR	DAYS BETWEEN DISCHARGES	OUT OF REACTOR TIME IN DAYS	CYCLE TIME IN DAYS	GAIN PER CYCLE	NUMBER OF CYCLES TO DOUBLE	NUMBER OF YEARS TO DOUBLE	OUT OF REACTOR INVENTORY IN KG'S
20.0	23.54	30.0	30.0	.00	30.0	1.00785	127.44	10.475	.000
50.0	58.85	75.0	75.0	.00	75.0	1.01962	50.98	10.475	.000
100.0	117.70	150.0	150.0	.00	150.0	1.03923	25.49	10.475	.000
200.0	235.40	300.0	300.0	.00	300.0	1.07847	12.74	10.475	.000
500.0	588.50	750.0	750.0	.00	750.0	1.19617	5.10	10.475	.000
1000.0	1177.00	1500.0	1500.0	.00	1500.0	1.39233	2.55	10.475	.000
20.0	23.54	30.0	30.0	30.00	60.0	1.00392	254.89	21.032	3000.000
50.0	58.85	75.0	75.0	30.00	105.0	1.00981	101.95	21.032	3000.000
100.0	117.70	150.0	150.0	30.00	180.0	1.01962	50.98	21.032	3000.000
200.0	235.40	300.0	300.0	30.00	330.0	1.03923	25.49	21.032	3000.000
500.0	588.50	750.0	750.0	30.00	780.0	1.09808	10.20	21.032	3000.000
1000.0	1177.00	1500.0	1500.0	30.00	1530.0	1.19617	5.10	21.032	3000.000

A-2

BNWL-965

20.0	23.54	30.0	30.0	91.25	121.2	1.00157	637.22	52.624	12000.000
50.0	58.85	75.0	75.0	91.25	166.2	1.00654	152.93	31.674	6000.000
100.0	117.70	150.0	150.0	91.25	241.3	1.01962	50.98	21.199	3000.000
200.0	235.40	300.0	300.0	91.25	391.3	1.03923	25.49	21.199	3000.000
500.0	588.50	750.0	750.0	91.25	841.3	1.09808	10.20	21.199	3000.000
1000.0	1177.00	1500.0	1500.0	91.25	1591.3	1.19617	5.10	21.199	3000.000
20.0	23.54	30.0	30.0	182.50	212.5	1.00098	1019.55	84.299	21000.000
50.0	58.85	75.0	75.0	182.50	257.5	1.00490	203.91	42.399	9000.000
100.0	117.70	150.0	150.0	182.50	332.5	1.01308	76.47	31.924	6000.000
200.0	235.40	300.0	300.0	182.50	482.5	1.03923	25.49	21.449	3000.000
500.0	588.50	750.0	750.0	182.50	932.5	1.09808	10.20	21.449	3000.000
1000.0	1177.00	1500.0	1500.0	182.50	1682.5	1.19617	5.10	21.449	3000.000
20.0	23.54	30.0	30.0	365.00	395.0	1.00056	1784.24	147.650	39000.000
50.0	58.85	75.0	75.0	365.00	440.0	1.00327	305.86	63.849	15000.000
100.0	117.70	150.0	150.0	365.00	515.0	1.00981	101.95	42.899	9000.000
200.0	235.40	300.0	300.0	365.00	665.0	1.02616	38.23	32.424	6000.000
500.0	588.50	750.0	750.0	365.00	1115.0	1.09808	10.20	21.949	3000.000
1000.0	1177.00	1500.0	1500.0	365.00	1865.0	1.19617	5.10	21.949	3000.000
20.0	23.54	30.0	30.0	730.00	760.0	1.00030	3313.69	274.358	75000.000
50.0	58.85	75.0	75.0	730.00	805.0	1.00178	560.75	117.224	30000.000
100.0	117.70	150.0	150.0	730.00	880.0	1.00654	152.93	64.848	15000.000
200.0	235.40	300.0	300.0	730.00	1030.0	1.01962	50.98	43.899	9000.000
500.0	588.50	750.0	750.0	730.00	1480.0	1.09808	10.20	22.949	3000.000
1000.0	1177.00	1500.0	1500.0	730.00	2230.0	1.19617	5.10	22.949	3000.000
20.0	23.54	30.0	30.0	1095.00	1125.0	1.00021	4843.31	401.080	111000.000
50.0	58.85	75.0	75.0	1095.00	1170.0	1.00123	815.65	170.598	45000.000
100.0	117.70	150.0	150.0	1095.00	1245.0	1.00436	229.40	97.273	24000.000
200.0	235.40	300.0	300.0	1095.00	1395.0	1.01569	63.72	55.374	12000.000
500.0	588.50	750.0	750.0	1095.00	1845.0	1.06539	15.29	34.424	6000.000
1000.0	1177.00	1500.0	1500.0	1095.00	2595.0	1.19617	5.10	23.949	3000.000

COMPOUND INTEREST DOUBLING TIMES

EXPOSURE MWD/KG OF FISSILE PU	NET KG'S OF PU PRODUCED PER CYCLE	DAYS IN REACTOR	DAYS BETWEEN DISCHARGES	OUT OF REACTOR TIME IN DAYS	CYCLE TIME IN DAYS	GAIN PER CYCLE	NUMBER OF CYCLES TO DOUBLE	NUMBER OF YEARS TO DOUBLE	OUT OF REACTOR INVENTORY IN KG'S
20.0	23.54	30.0	30.0	.00	30.0	1.00785	88.68	7.289	.000
50.0	58.85	75.0	75.0	.00	75.0	1.01962	35.68	7.332	.000
100.0	117.70	150.0	150.0	.00	150.0	1.03923	18.01	7.402	.000
200.0	235.40	300.0	300.0	.00	300.0	1.07847	9.18	7.542	.000
500.0	588.50	750.0	750.0	.00	750.0	1.19617	3.87	7.951	.000
1000.0	1177.00	1500.0	1500.0	.00	1500.0	1.39233	2.09	8.606	.000
20.0	23.54	30.0	30.0	30.00	60.0	1.00392	177.02	14.632	3000.000
50.0	58.85	75.0	75.0	30.00	105.0	1.01401	49.81	10.318	1200.000
100.0	117.70	150.0	150.0	30.00	180.0	1.03269	21.55	8.937	600.000
200.0	235.40	300.0	300.0	30.00	330.0	1.07133	10.06	8.350	300.000
500.0	588.50	750.0	750.0	30.00	780.0	1.18862	4.01	8.325	120.000
1000.0	1177.00	1500.0	1500.0	30.00	1530.0	1.38464	2.13	8.835	60.000
20.0	23.54	30.0	30.0	91.25	121.2	1.00194	357.38	29.624	9125.000
50.0	58.85	75.0	75.0	91.25	166.2	1.00885	78.67	16.415	3650.000
100.0	117.70	150.0	150.0	91.25	241.3	1.02439	28.76	12.069	1825.000
200.0	235.40	300.0	300.0	91.25	391.3	1.06017	11.86	10.001	912.500
500.0	588.50	750.0	750.0	91.25	841.3	1.17489	4.30	9.087	365.000
1000.0	1177.00	1500.0	1500.0	91.25	1591.3	1.36983	2.20	9.302	182.500
20.0	23.54	30.0	30.0	182.50	212.5	1.00111	626.08	51.958	18250.000
50.0	58.85	75.0	75.0	182.50	257.5	1.00571	121.66	25.499	7300.000
100.0	117.70	150.0	150.0	182.50	332.5	1.01770	39.51	16.736	3650.000
200.0	235.40	300.0	300.0	182.50	482.5	1.04879	14.55	12.460	1825.000
500.0	588.50	750.0	750.0	182.50	932.5	1.15777	4.73	10.222	730.000
1000.0	1177.00	1500.0	1500.0	182.50	1682.5	1.34978	2.31	9.997	365.000

A-4

BNWL-965

20.0	23.54	30.0	30.0	365.00	395.0	1.00060	1163.40	96.630	36499.999
50.0	58.85	75.0	75.0	365.00	440.0	1.00334	207.64	43.667	14600.000
100.0	117.70	150.0	150.0	365.00	515.0	1.01143	61.00	26.070	7300.000
200.0	235.40	300.0	300.0	365.00	665.0	1.03540	19.93	17.377	3650.000
500.0	588.50	750.0	750.0	365.00	1115.0	1.13195	5.59	12.491	1460.000
1000.0	1177.00	1500.0	1500.0	365.00	1865.0	1.31555	2.53	11.387	730.000
20.0	23.54	30.0	30.0	730.00	760.0	1.00031	2238.36	185.975	72999.999
50.0	58.85	75.0	75.0	730.00	805.0	1.00183	379.61	80.002	29200.000
100.0	117.70	150.0	150.0	730.00	880.0	1.00669	103.99	44.738	14600.000
200.0	235.40	300.0	300.0	730.00	1030.0	1.02285	30.67	27.212	7300.000
500.0	588.50	750.0	750.0	730.00	1480.0	1.09941	7.31	17.028	2920.000
1000.0	1177.00	1500.0	1500.0	730.00	2230.0	1.26390	2.96	14.163	1460.000
20.0	23.54	30.0	30.0	1095.00	1125.0	1.00021	3313.26	275.323	109500.000
50.0	58.85	75.0	75.0	1095.00	1170.0	1.00126	551.58	116.338	43799.999
100.0	117.70	150.0	150.0	1095.00	1245.0	1.00473	146.99	63.405	21900.000
200.0	235.40	300.0	300.0	1095.00	1395.0	1.01687	41.42	37.046	10950.000
500.0	588.50	750.0	750.0	1095.00	1845.0	1.07974	9.03	21.564	4380.000
1000.0	1177.00	1500.0	1500.0	1095.00	2595.0	1.22678	3.39	16.937	2190.000

CALCULATED BREEDER REACTOR DOUBLING TIMES

INPUT DATA		CALCULATED VALUES	
MWT	2500.0	GRAMS DESTROYED PER MWD	.981
MWE	1000.0	GRAMS PRODUCED PER MWD	1.373
ALPHA	.1	EFFECTIVE POWER	2000.0
BREEDING RATIO	1.40	EFFECTIVE SPECIFIC POWER, CORE	2.000
KG FISS IN CORE	1000.0	EFFECTIVE SPECIFIC POWER, CORE + EXTERNAL HEEL	2.000
NUMBER OF ZONES	3.0	KG DESTROYED PER DAY	1.962
EXTERNAL HEEL	.0	KG PRODUCED PER DAY	2.746
CAPACITY FACTOR	.8	NET GRAMS PRODUCED PER MWD	.392
		NET KG PRODUCED PER DAY	.785
		SIMPLE INT CORE DT - YEARS	3.492

SIMPLE INTEREST DOUBLING TIMES

EXPOSURE RNG/KG OF FISSILE PU	NET KG'S OF PU PRODUCED PER CYCLE	DAYS IN REACTOR	DAYS BETWEEN DISCHARGES	OUT OF REACTOR TIME IN DAYS	CYCLE TIME IN DAYS	GAIN PER CYCLE	NUMBER OF CYCLES TO DOUBLE	NUMBER OF YEARS TO DOUBLE	OUT OF REACTOR INVENTORY IN KG'S
20.0	2.62	10.0	3.3	.00	10.0	1.00262	382.33	3.492	.000
50.0	6.54	25.0	8.3	.00	25.0	1.00654	152.93	3.492	.000
100.0	13.08	50.0	16.7	.00	50.0	1.01308	76.47	3.492	.000
200.0	26.16	100.0	33.3	.00	100.0	1.02616	38.23	3.492	.000
500.0	65.40	250.0	83.3	.00	250.0	1.06539	15.29	3.492	.000
1000.0	130.73	500.0	166.7	.00	500.0	1.13078	7.65	3.492	.000
20.0	2.62	10.0	3.3	30.00	40.0	1.00065	1529.34	14.049	3000.000
50.0	6.54	25.0	8.3	30.00	55.0	1.00280	356.84	8.229	1333.333
100.0	13.08	50.0	16.7	30.00	80.0	1.00785	127.44	5.902	666.667
200.0	26.16	100.0	33.3	30.00	130.0	1.01962	50.98	4.738	333.333
500.0	65.40	250.0	83.3	30.00	280.0	1.04904	20.39	4.738	333.333
1000.0	130.73	500.0	166.7	30.00	530.0	1.09808	10.20	4.738	333.333

A-6

BNWL-965

20.0	2.52	10.0	3.3	91.25	101.2	1.00025	3951.07	36.333	9333.333
50.0	6.54	25.0	8.3	91.25	116.2	1.00140	713.68	16.544	3666.667
100.0	13.08	50.0	16.7	91.25	141.2	1.00436	229.40	10.725	2000.000
200.0	26.16	100.0	33.3	91.25	191.3	1.01308	76.47	7.233	1000.000
500.0	65.39	250.0	83.3	91.25	341.3	1.03923	25.49	6.069	666.667
1000.0	130.78	500.0	166.7	91.25	591.2	1.09808	10.20	4.905	333.333
20.0	2.62	10.0	3.3	182.50	192.5	1.00014	7392.47	68.011	18333.334
50.0	6.54	25.0	8.3	182.50	207.5	1.00078	1274.45	29.597	7333.333
100.0	13.08	50.0	16.7	182.50	232.5	1.00280	356.84	16.794	3666.667
200.0	26.16	100.0	33.3	182.50	282.5	1.00872	114.70	10.975	2000.000
500.0	65.39	250.0	83.3	182.50	432.5	1.03269	30.59	7.483	1000.000
1000.0	130.78	500.0	166.7	182.50	682.5	1.07847	12.74	6.319	666.667
20.0	2.62	10.0	3.3	365.00	375.0	1.00007	14404.13	132.545	36666.667
50.0	6.54	25.0	8.3	365.00	390.0	1.00042	2395.97	55.703	14666.666
100.0	13.08	50.0	16.7	365.00	415.0	1.00157	637.21	30.097	7333.333
200.0	26.16	100.0	33.3	365.00	465.0	1.00560	178.42	17.294	3666.667
500.0	65.39	250.0	83.3	365.00	615.0	1.02452	40.78	10.311	1666.667
1000.0	130.78	500.0	166.7	365.00	865.0	1.06539	15.29	7.983	1000.000
20.0	2.62	10.0	3.3	730.00	740.0	1.00004	28304.03	260.484	72999.999
50.0	6.54	25.0	8.3	730.00	755.0	1.00022	4639.08	107.915	29333.333
100.0	13.08	50.0	16.7	730.00	780.0	1.00083	1197.97	56.702	14666.666
200.0	26.16	100.0	33.3	730.00	830.0	1.00314	318.61	31.097	7333.333
500.0	65.39	250.0	83.3	730.00	980.0	1.01635	61.17	15.966	3000.000
1000.0	130.78	500.0	166.7	730.00	1230.0	1.04904	20.39	11.311	1666.667
20.0	2.62	10.0	3.3	1095.00	1105.0	1.00002	42339.98	389.666	109666.666
50.0	6.54	25.0	8.3	1095.00	1120.0	1.00015	6882.25	160.129	44000.000
100.0	13.08	50.0	16.7	1095.00	1145.0	1.00057	1758.76	83.309	22000.000
200.0	26.16	100.0	33.3	1095.00	1195.0	1.00218	458.80	44.899	11000.000
500.0	65.39	250.0	83.3	1095.00	1345.0	1.01154	86.66	22.786	4666.667
1000.0	130.78	500.0	166.7	1095.00	1595.0	1.03923	25.49	14.639	2333.333

COMPOUND INTEREST DOUBLING TIMES

EXPOSURE MW/D/KG OF FISSILE PU	NET KG'S OF PU PRODUCED PER CYCLE	DAYS IN REACTOR	DAYS BETWEEN DISCHARGES	OUT OF REACTOR TIME IN DAYS	CYCLE TIME IN DAYS	GAIN PER CYCLE	NUMBER OF CYCLES TO DOUBLE	NUMBER OF YEARS TO DOUBLE	OUT OF REACTOR INVENTORY IN KG'S
20.0	2.62	10.0	3.3	.00	10.0	1.00262	265.36	2.423	.000
50.0	6.54	25.0	8.3	.00	25.0	1.00654	106.35	2.428	.000
100.0	13.08	50.0	16.7	.00	50.0	1.01308	53.35	2.436	.000
200.0	26.16	100.0	33.3	.00	100.0	1.02616	26.85	2.452	.000
500.0	65.39	250.0	83.3	.00	250.0	1.06539	10.94	2.498	.000
1000.0	130.78	500.0	166.7	.00	500.0	1.13078	5.64	2.575	.000
20.0	2.62	10.0	3.3	30.00	40.0	1.00065	1060.41	9.766	3000.000
50.0	6.54	25.0	8.3	30.00	55.0	1.00297	233.56	5.415	1200.000
100.0	13.08	50.0	16.7	30.00	80.0	1.00817	85.15	3.970	600.000
200.0	26.16	100.0	33.3	30.00	130.0	1.02012	34.80	3.260	300.000
500.0	65.39	250.0	83.3	30.00	200.0	1.05838	12.22	2.871	120.000
1000.0	130.78	500.0	166.7	30.00	530.0	1.12338	5.96	2.803	60.000
20.0	2.62	10.0	3.3	91.25	101.2	1.00026	2683.77	24.759	9125.000
50.0	6.54	25.0	8.3	91.25	116.2	1.00141	493.27	11.512	3650.000
100.0	13.08	50.0	16.7	91.25	141.2	1.00463	150.08	7.103	1825.000
200.0	26.16	100.0	33.3	91.25	191.3	1.01368	51.03	4.910	912.500
500.0	65.39	250.0	83.3	91.25	341.3	1.04790	14.81	3.632	365.000
1000.0	130.78	500.0	166.7	91.25	591.2	1.11059	6.61	3.267	182.500
20.0	2.62	10.0	3.3	182.50	192.5	1.00014	5102.17	47.095	18250.000
50.0	6.54	25.0	8.3	182.50	207.5	1.00079	880.21	20.596	7300.000
100.0	13.08	50.0	16.7	182.50	232.5	1.00281	246.81	11.770	3650.000
200.0	26.16	100.0	33.3	182.50	282.5	1.00926	75.21	7.369	1825.000
500.0	65.39	250.0	83.3	182.50	432.5	1.03780	18.68	4.766	730.000
1000.0	130.78	500.0	166.7	182.50	682.5	1.09581	7.58	3.959	365.000

A-8

BNWL-965

20.0	2.62	10.0	3.3	365.00	375.0	1.00007	9940.49	91.781	36499.999
50.0	6.54	25.0	8.3	365.00	390.0	1.00042	1654.04	38.763	14600.000
100.0	13.08	50.0	16.7	365.00	415.0	1.00158	440.27	21.104	7300.000
200.0	26.16	100.0	33.3	365.00	465.0	1.00562	123.58	12.286	3650.000
500.0	65.39	250.0	83.3	365.00	615.0	1.02658	26.42	7.032	1460.000
1000.0	130.78	500.0	166.7	365.00	865.0	1.07559	9.51	5.343	730.000
20.0	2.62	10.0	3.3	730.00	740.0	1.00004	19623.08	181.206	72999.999
50.0	6.54	25.0	8.3	730.00	755.0	1.00022	3201.85	75.102	29200.000
100.0	13.08	50.0	16.7	730.00	780.0	1.00084	827.20	39.771	14600.000
200.0	26.16	100.0	33.3	730.00	830.0	1.00315	220.31	22.119	7300.000
500.0	65.39	250.0	83.3	730.00	980.0	1.01668	41.90	11.566	2920.000
1000.0	130.78	500.0	166.7	730.00	1230.0	1.05316	13.38	8.111	1460.000
20.0	2.62	10.0	3.3	1095.00	1105.0	1.00002	29301.74	270.596	109499.998
50.0	6.54	25.0	8.3	1095.00	1120.0	1.00015	4749.98	111.447	43800.000
100.0	13.08	50.0	16.7	1095.00	1145.0	1.00057	1214.12	58.439	21900.000
200.0	26.16	100.0	33.3	1095.00	1195.0	1.00219	317.04	31.953	10950.000
500.0	65.39	250.0	83.3	1095.00	1345.0	1.01215	57.38	16.100	4380.000
1000.0	130.78	500.0	166.7	1095.00	1595.0	1.04100	17.25	10.878	2190.000

CALCULATED BREEDER REACTOR DOUBLING TIMES

INPUT DATA		CALCULATED VALUES	
MWT	2500.0	GRAMS DESTROYED PER MWD	.981
MWE	1000.0	GRAMS PRODUCED PER MWD	1.373
ALPHA	.1	EFFECTIVE POWER	2000.0
BREEDING RATIO	1.40	EFFECTIVE SPECIFIC POWER, CORE	1.000
KG FISS IN CORE	2000.0	EFFECTIVE SPECIFIC POWER, CORE + EXTERNAL HEEL	1.000
NUMBER OF ZONES	3.0	KG DESTROYED PER DAY	1.962
EXTERNAL HEEL	.0	KG PRODUCED PER DAY	2.746
CAPACITY FACTOR	.8	NET GRAMS PRODUCED PER MWD	.392
		NET KG PRODUCED PER DAY	.785
		SIMPLE INT CORE DT - YEARS	6.983

SIMPLE INTEREST DOUBLING TIMES

EXPOSURE MWD/KG OF FISSILE PU	NET KG'S OF PU PRODUCED PER CYCLE	DAYS IN REACTOR	DAYS BETWEEN DISCHARGES	OUT OF REACTOR TIME IN DAYS	CYCLE TIME IN DAYS	GAIN PER CYCLE	NUMBER OF CYCLES TO DOUBLE	NUMBER OF YEARS TO DOUBLE	OUT OF REACTOR INVENTORY IN KG'S
20.0	5.23	20.0	6.7	.00	20.0	1.00262	382.33	6.983	.000
50.0	13.06	50.0	16.7	.00	50.0	1.00654	152.93	6.983	.000
100.0	26.16	100.0	33.3	.00	100.0	1.01308	76.47	6.983	.000
200.0	52.31	200.0	66.7	.00	200.0	1.02616	38.23	6.983	.000
500.0	130.78	500.0	166.7	.00	500.0	1.06539	15.29	6.983	.000
1000.0	261.56	1000.0	333.3	.00	1000.0	1.13078	7.65	6.983	.000
20.0	5.23	20.0	6.7	30.00	50.0	1.00098	1019.55	18.704	3333.333
50.0	13.06	50.0	16.7	30.00	80.0	1.00392	254.89	11.721	1333.333
100.0	26.16	100.0	33.3	30.00	130.0	1.00981	101.95	9.393	666.667
200.0	52.31	200.0	66.7	30.00	230.0	1.01962	50.98	9.393	666.667
500.0	130.78	500.0	166.7	30.00	530.0	1.04904	20.39	9.393	666.667
1000.0	261.56	1000.0	333.3	30.00	1030.0	1.09808	10.20	9.393	666.667

A-10

BNWL-965

20.0	5.23	20.0	6.7	91.25	111.2	1.00046	2166.55	39.822	9333.333
50.0	13.08	50.0	16.7	91.25	141.2	1.00218	458.80	21.200	4000.000
100.0	26.16	100.0	33.3	91.25	191.3	1.00654	152.93	14.216	2000.000
200.0	52.31	200.0	66.7	91.25	291.2	1.01569	63.72	11.889	1333.333
500.0	130.78	500.0	166.7	91.25	591.2	1.04904	20.39	9.561	666.667
1000.0	261.56	1000.0	333.3	91.25	1091.3	1.09808	10.20	9.561	666.667
20.0	5.23	20.0	6.7	182.50	202.5	1.00025	3951.07	72.666	18666.667
50.0	13.08	50.0	16.7	182.50	232.5	1.00140	713.68	33.088	7333.333
100.0	26.16	100.0	33.3	182.50	282.5	1.00436	229.40	21.450	4000.000
200.0	52.31	200.0	66.7	182.50	382.5	1.01308	76.47	14.466	2000.000
500.0	130.78	500.0	166.7	182.50	682.5	1.03923	25.49	12.139	1333.333
1000.0	261.56	1000.0	333.3	182.50	1182.5	1.09808	10.20	9.811	666.667
20.0	5.23	20.0	6.7	365.00	385.0	1.00014	7392.47	136.022	36666.667
50.0	13.08	50.0	16.7	365.00	415.0	1.00078	1274.45	59.194	14666.666
100.0	26.16	100.0	33.3	365.00	465.0	1.00280	356.84	33.588	7333.333
200.0	52.31	200.0	66.7	365.00	565.0	1.00872	114.70	21.950	4000.000
500.0	130.78	500.0	166.7	365.00	865.0	1.03269	30.59	14.966	2000.000
1000.0	261.56	1000.0	333.3	365.00	1365.0	1.07847	12.74	12.639	1333.333
20.0	5.23	20.0	6.7	730.00	750.0	1.00007	14404.13	265.089	73333.333
50.0	13.08	50.0	16.7	730.00	780.0	1.00042	2395.97	111.405	29333.333
100.0	26.16	100.0	33.3	730.00	830.0	1.00157	637.21	60.193	14666.666
200.0	52.31	200.0	66.7	730.00	930.0	1.00560	178.42	34.588	7333.333
500.0	130.78	500.0	166.7	730.00	1230.0	1.02452	40.78	20.622	3333.333
1000.0	261.56	1000.0	333.3	730.00	1730.0	1.06539	15.29	15.966	2000.000
20.0	5.23	20.0	6.7	1095.00	1115.0	1.00005	21413.17	394.108	109999.999
50.0	13.08	50.0	16.7	1095.00	1145.0	1.00028	3517.60	163.621	44000.000
100.0	26.16	100.0	33.3	1095.00	1195.0	1.00109	917.59	86.798	22000.000
200.0	52.31	200.0	66.7	1095.00	1295.0	1.00392	254.89	49.554	11333.333
500.0	130.78	500.0	166.7	1095.00	1595.0	1.01962	50.98	26.277	4666.667
1000.0	261.56	1000.0	333.3	1095.00	2095.0	1.05605	17.84	19.294	2666.667

COMPOUND INTEREST DOUBLING TIMES

EXPOSURE MWD/KG OF FISSILE PU	NET KG'S OF PU PRODUCED PER CYCLE	DAYS IN REACTOR	DAYS BETWEEN DISCHARGES	OUT OF REACTOR TIME IN DAYS	CYCLE TIME IN DAYS	GAIN PER CYCLE	NUMBER OF CYCLES TO DOUBLE	NUMBER OF YEARS TO DOUBLE	OUT OF REACTOR INVENTORY IN KG'S
20.0	5.23	20.0	6.7	.00	20.0	1.00262	265.36	4.847	.000
50.0	13.08	50.0	16.7	.00	50.0	1.00654	106.35	4.856	.000
100.0	26.16	100.0	33.3	.00	100.0	1.01308	53.35	4.872	.000
200.0	52.31	200.0	66.7	.00	200.0	1.02616	26.85	4.903	.000
500.0	130.78	500.0	166.7	.00	500.0	1.06539	10.94	4.997	.000
1000.0	261.56	1000.0	333.3	.00	1000.0	1.13078	5.64	5.150	.000
20.0	5.23	20.0	6.7	30.00	50.0	1.00105	662.88	12.190	3000.000
50.0	13.08	50.0	16.7	30.00	80.0	1.00409	169.95	7.843	1200.000
100.0	26.16	100.0	33.3	30.00	130.0	1.01006	69.25	6.406	600.000
200.0	52.31	200.0	66.7	30.00	230.0	1.02274	30.82	5.712	300.000
500.0	130.78	500.0	166.7	30.00	530.0	1.06169	11.58	5.370	120.000
1000.0	261.56	1000.0	333.3	30.00	1030.0	1.12697	5.80	5.378	60.000
20.0	5.23	20.0	6.7	91.25	111.2	1.00047	1474.49	27.181	9125.000
50.0	13.08	50.0	16.7	91.25	141.2	1.00231	299.81	13.940	3650.000
100.0	26.16	100.0	33.3	91.25	191.3	1.00684	101.71	9.539	1825.000
200.0	52.31	200.0	66.7	91.25	291.2	1.01796	38.94	7.362	912.500
500.0	130.78	500.0	166.7	91.25	591.2	1.05530	12.88	6.131	365.000
1000.0	261.56	1000.0	333.3	91.25	1091.3	1.11984	6.12	5.843	182.500
20.0	5.23	20.0	6.7	182.50	202.5	1.00026	2683.77	49.519	18250.000
50.0	13.08	50.0	16.7	182.50	232.5	1.00141	493.27	23.024	7300.000
100.0	26.16	100.0	33.3	182.50	282.5	1.00463	150.08	14.206	3650.000
200.0	52.31	200.0	66.7	182.50	382.5	1.01368	51.03	9.820	1825.000
500.0	130.78	500.0	166.7	182.50	682.5	1.04790	14.81	7.264	730.000
1000.0	261.56	1000.0	333.3	182.50	1182.5	1.11059	6.61	6.535	365.000

A-12

BNWL-965

20.0	5.23	20.0	6.7	365.00	385.0	1.00014	5102.17	94.190	36499.999
50.0	13.08	50.0	16.7	365.00	415.0	1.00079	880.21	41.192	14600.000
100.0	26.16	100.0	33.3	365.00	465.0	1.00281	246.81	23.539	7300.000
200.0	52.31	200.0	66.7	365.00	565.0	1.00926	75.21	14.737	3650.000
500.0	130.78	500.0	166.7	365.00	865.0	1.03780	18.68	9.531	1460.000
1000.0	261.56	1000.0	333.3	365.00	1365.0	1.09581	7.58	7.919	730.000
20.0	5.23	20.0	6.7	730.00	750.0	1.00007	9940.49	183.561	72999.999
50.0	13.08	50.0	16.7	730.00	780.0	1.00042	1654.04	77.527	29200.000
100.0	26.16	100.0	33.3	730.00	830.0	1.00158	440.27	42.207	14600.000
200.0	52.31	200.0	66.7	730.00	930.0	1.00562	123.58	24.571	7300.000
500.0	130.78	500.0	166.7	730.00	1230.0	1.02658	26.42	14.065	2920.000
1000.0	261.56	1000.0	333.3	730.00	1730.0	1.07559	9.51	10.687	1460.000
20.0	5.23	20.0	6.7	1095.00	1115.0	1.00005	14778.87	272.934	109499.998
50.0	13.08	50.0	16.7	1095.00	1145.0	1.00029	2427.92	113.864	43800.000
100.0	26.16	100.0	33.3	1095.00	1195.0	1.00109	633.73	60.875	21900.000
200.0	52.31	200.0	66.7	1095.00	1295.0	1.00404	171.94	34.405	10950.000
500.0	130.78	500.0	166.7	1095.00	1595.0	1.02050	34.16	18.599	4380.000
1000.0	261.56	1000.0	333.3	1095.00	2095.0	1.06242	11.45	13.454	2190.000

CALCULATED BREEDER REACTOR DOUBLING TIMES

INPUT DATA		CALCULATED VALUES	
NET	2500.0	GRAMS DESTROYED PER MWD	.981
AGE	1000.0	GRAMS PRODUCED PER MWD	1.373
ALPHA	.1	EFFECTIVE POWER	2000.0
BREEDING RATIO	1.40	EFFECTIVE SPECIFIC POWER, CORE	.667
KG FISS IN CORE	3000.0	EFFECTIVE SPECIFIC POWER, CORE + EXTERNAL HEEL	.667
NUMBER OF ZONES	3.0	KG DESTROYED PER DAY	1.962
EXTERNAL HEEL	.0	KG PRODUCED PER DAY	2.746
CAPACITY FACTOR	.8	NET GRAMS PRODUCED PER MWD	.392
		NET KG PRODUCED PER DAY	.785
		SIMPLE INT CORE DT - YEARS	10.475

SIMPLE INTEREST DOUBLING TIMES

EXPOSURE MWD/KG OF FISSILE MU	NET KG'S OF PU PRODUCED PER CYCLE	DAYS IN REACTOR	DAYS BETWEEN DISCHARGES	OUT OF REACTOR TIME IN DAYS	CYCLE TIME IN DAYS	GAIN PER CYCLE	NUMBER OF CYCLES TO DOUBLE	NUMBER OF YEARS TO DOUBLE	OUT OF REACTOR INVENTORY IN KG'S
20.0	7.85	30.0	10.0	.00	30.0	1.00262	382.33	10.475	.000
50.0	19.62	75.0	25.0	.00	75.0	1.00654	152.93	10.475	.000
100.0	39.23	150.0	50.0	.00	150.0	1.01308	76.47	10.475	.000
200.0	78.47	300.0	100.0	.00	300.0	1.02616	38.23	10.475	.000
500.0	196.17	750.0	250.0	.00	750.0	1.06539	15.29	10.475	.000
1000.0	392.33	1500.0	500.0	.00	1500.0	1.13078	7.65	10.475	.000
20.0	7.85	30.0	10.0	30.00	60.0	1.00131	764.67	21.032	3000.000
50.0	19.62	75.0	25.0	30.00	105.0	1.00392	254.89	17.540	2000.000
100.0	39.23	150.0	50.0	30.00	180.0	1.00981	101.95	14.049	1000.000
200.0	78.47	300.0	100.0	30.00	330.0	1.01962	50.98	14.049	1000.000
500.0	196.17	750.0	250.0	30.00	780.0	1.04904	20.39	14.049	1000.000
1000.0	392.33	1500.0	500.0	30.00	1530.0	1.09808	10.20	14.049	1000.000

A-14

BNWL-965

20.0	7.85	30.0	10.0	91.25	121.2	1.00060	1656.80	45.642	10000.000
50.0	19.62	75.0	25.0	91.25	166.2	1.00280	356.84	24.691	4000.000
100.0	39.23	150.0	50.0	91.25	241.3	1.00785	127.44	17.708	2000.000
200.0	78.47	300.0	100.0	91.25	391.3	1.01962	50.98	14.216	1000.000
500.0	196.17	750.0	250.0	91.25	841.3	1.04904	20.39	14.216	1000.000
1000.0	392.33	1500.0	500.0	91.25	1591.3	1.09808	10.20	14.216	1000.000
20.0	7.85	30.0	10.0	182.50	212.5	1.00036	2803.91	77.320	19000.001
50.0	19.62	75.0	25.0	182.50	257.5	1.00178	560.75	38.908	8000.000
100.0	39.23	150.0	50.0	182.50	332.5	1.00560	178.42	24.941	4000.000
200.0	78.47	300.0	100.0	182.50	482.5	1.01569	63.72	17.958	2000.000
500.0	196.17	750.0	250.0	182.50	932.5	1.04904	20.39	14.466	1000.000
1000.0	392.33	1500.0	500.0	182.50	1682.5	1.09808	10.20	14.466	1000.000
20.0	7.85	30.0	10.0	365.00	395.0	1.00020	5098.30	140.679	37000.000
50.0	19.62	75.0	25.0	365.00	440.0	1.00109	917.60	63.849	15000.000
100.0	39.23	150.0	50.0	365.00	515.0	1.00357	280.37	39.408	8000.000
200.0	78.47	300.0	100.0	365.00	665.0	1.01121	89.21	25.441	4000.000
500.0	196.17	750.0	250.0	365.00	1115.0	1.03923	25.49	18.458	2000.000
1000.0	392.33	1500.0	500.0	365.00	1865.0	1.09808	10.20	14.966	1000.000
20.0	7.85	30.0	10.0	730.00	760.0	1.00010	9688.01	267.425	73000.000
50.0	19.62	75.0	25.0	730.00	805.0	1.00059	1682.31	117.226	30000.000
100.0	39.23	150.0	50.0	730.00	880.0	1.00218	458.80	64.849	15000.000
200.0	78.47	300.0	100.0	730.00	1030.0	1.00713	140.19	40.407	8000.000
500.0	196.17	750.0	250.0	730.00	1480.0	1.03269	30.59	22.949	3000.000
1000.0	392.33	1500.0	500.0	730.00	2230.0	1.07847	12.74	19.458	2000.000
20.0	7.85	30.0	10.0	1095.00	1125.0	1.00007	14404.13	397.634	110000.001
50.0	19.62	75.0	25.0	1095.00	1170.0	1.00042	2396.06	167.114	44000.001
100.0	39.23	150.0	50.0	1095.00	1245.0	1.00157	637.22	90.290	22000.000
200.0	78.47	300.0	100.0	1095.00	1395.0	1.00560	178.42	51.882	11000.000
500.0	196.17	750.0	250.0	1095.00	1845.0	1.02452	40.78	30.933	5000.000
1000.0	392.33	1500.0	500.0	1095.00	2595.0	1.06539	15.29	23.949	3000.000

APPENDIX B

SUMMARY OF CARBIDE REACTOR CHARACTERISTICS

	<u>Reference Design</u>	<u>Advanced Design</u>
Fuel Material	Modified (U-Pu)C	(U-Pu)C
Total heat output (MWt)	2700	2550
Mixed-mean outlet temperature, °F	1000	1050
Cladding surface temperature limit, °F	1300	1350
Fuel center temperature limit, °F	2350	3800
Average core linear fuel rating, kW/ft	13.4	34.4
Average core specific power, equilibrium, kW/kg metal	113	168
Avg. in-core specific fissile inventory, Kg Pu/MWe	2.55	1.3
Average discharge burnup, MWd/MT	80,000	110,000
Fuel Pellet Diameter, in.	0.246	0.334
Fuel rod OD, in.	0.286	0.400
Cladding thickness, in.	0.012	0.014
Fuel rod pitch, in.	0.378	0.520
Active fuel length, in.	48	58
Net electrical output, MWe	1000	1000
Total thermal power, MWt	2700	2550
% Power/Region		
Core	85.2	90
Axial blanket	2.0	2
Radial blanket	12.8	8
Average specific power, MWt/MT		Average
Region		
Core	113	167.9
Axial blanket	4.26	9.02
Radial blanket	5.43	8.46
Average burnup, MWdt/MT		Average
Region		
Core	79,000	110,300
Axial blanket	3,000	5,930
Radial blanket	3,800	8,340
Reference Material (initial tonnes heavy metal)		
Core	20.3	13.667
Axial blanket	12.7	5.654
Radial blanket	63.7	24.113

SUMMARY OF OXIDE REACTOR CHARACTERISTICS

	<u>Advanced Design</u>	<u>Reference Design</u>
Net electrical Power, MWe	1000	1000
Thermal power, MWt	2300	2500
Net thermal efficiency, %	43.5	40.0
Reactor configuration	Regular Hexagonal	Modular
Number of modules	--	3
Reactor outlet temperature, °F	1200	1060
Reactor ΔT , °F	300	300
Reactor ΔP , psi	150	100
Peak sodium velocity, ft/sec	38	25
Refueling interval, fuel power days	140	153
Sodium-void reactivity worth (core and axial blankets), \$	11	-0.23
Doppler constant, Tdk/dt , core and blankets	-0.0102	-0.0094
Breeding ratio	1.31	1.27
Equilibrium cycle in-core specific fissile inventory, kg Pu/MWe	1.60	2.63
Total (in-core plus ex-core) specific fissile inventory at 0.8 CF	2.3	3.9
Compound doubling time, yrs.	7	15
Average enrichment feed fuel, % Pu	21	25
Average enrichment startup, % Pu	19	22
Core region		
Active height, ft.	4.0	4.0
Diameter, ft. (single module)	6.5	4.5
Number of control rods	19	21
Number of fuel elements	189	252
Number of fuel pins per element	217	217
Fuel-pin diameter, in.	0.23	0.25
Fuel loading, kg heavy metal	9155	12,583

	<u>Advanced Design</u>	<u>Reference Design</u>
Core region (continued)		
Startup fissile loading, kg Pu	1264	1962
Equilibrium cycle fissile loading, kg Pu	1273	2027
In-core fuel residence time, full power days	420	459
Fuel ex-core, holdup time, days	240	300
Core power, Mwt	2103	2197
Average specific power, Mwt/MT	230	175
Fuel average discharge exposure, MWd/MT	97,000	80,000
Peak linear heat rating, kw/ft	20	16
Hot-spot cladding temperature, °F	1358	1230
Axial blanket		
Length, ft. (each end)	1.5	1.0
Fuel loading, kg heavy metal	7494	7325
Startup fissile loading, kg Pu	0	0
Equilibrium cycle fissile loading, kg Pu	73	63
Axial blanket power, Mwt	45	40
Average specific power, MWt/MT	6.0	5.5
Fuel average discharge exposure, MWd/MT	2500	2500
Radial blanket		
Number of fuel elements	114	234
Fuel loading, kg heavy metal	13,897	26,671
Startup fissile loading, kg U ²³⁵	239	523
Equilibrium cycle fissile loading, kg Pu	256	538
Fuel average residence time, full power days	550	825
Ex-core fuel holdup time, days	240	300
Radial blanket power, MWt	152	263
Average specific power, MWt/MT	10.9	9.9
Fuel average discharge exposure, MWd/MT	6000	8100

GENERAL DESIGN CHARACTERISTICS
FOR THE ALLIS-CHALMERS FAST REACTOR

Reactor Output, thermal, MW

Core	2125
Inner radial blanket	185
Outer radial blanket	190
Total	2500

Reactor Output, MWe

Total	1000
-------	------

Nuclear Data

Critical mass (Pu-239 + Pu-241), Kg	2910
(U-238 + Pu-240)/(Pu-239 + Pu-241)	4.57
Breeding Ratio	
Core	0.52
Radial blanket	0.76
Axial blanket	0.04
Total	1.32
Median Fission Energy, kev	190
Mean Neutron life time, sec.	4.1×10^{-7}
Fissile Pu Destruction rate (core) Kg/full power year	1040
Fissile Pu production rate (total, Kg) full power year	1370
Doubling time, years, 100% load factor	14.7
Fuel life, full power days	836

Core Performance

Power density, Kw/e	282
Specific power, Kw/Kg Pu (fissile)	733
Average linear heat generation, Kw/ft	8.6
Average in-core specific fissile inventory, Kg Pu/MWe	2.9
Power Distribution	
$(P_{\max}/P_{\text{av}})_{\text{axial}}$	1.29
$(P_{\max}/P_{\text{av}})_{\text{radial}}$	1.18
$(P_{\max}/P_{\text{av}})$	1.52

Core Fuel Dimensions

Fuel assemblies, number	498
Pins per assembly, number	123
Width of hexagonal assembly (flats), in.	4.45
Pin outside diameter, in.	0.300
Length of pin, ft.	
Core fuel portion	4.0
Axial blanket portion	0.5
Fission gas reservoir	0.5
Total	5.0
Pellet material, mixture	PuO ₂ -UO ₂
Pellet density, Percent of theoretical	95
Cladding material	316 SS
Cladding thickness, in.	0.028

Sodium flow (assembly at flux peak), lb/hr	2.158 x 10 ⁵
Pressure drop through pins (assembly at flux peak), psi	36.5

Radial Blanket Fuel Dimensions

Blanket assemblies, No.	
Inner radial blanket	276
Outer radial blanket	582
Total	858
Pins per assembly, No.	37
Width of hexagonal assembly, in.	4.45
Pin outside diameter, in.	0.607
Length of pins, ft.	6
Pellet Material	UO ₂
Pellet density, % of theoretical	95
Cladding thickness, in.	0.015
Cladding Material	316 SS
Sodium flow (assembly at flux peak of inner blanket), lb/hr	6.9 x 10 ⁴
Pressure drop through pins (assembly at flux peak of inner blanket), psi	6.5

Primary System

Total coolant flow rate (including 5% by-pass flow), gpm	2.8 x 10 ⁵
Overall coolant temperature rise, °F	250
Coolant temperature rise through core, °F	263
Coolant temperature rise through radial blanket, °F	263
Coolant inlet temperature, °F	950
Overall core pressure drop, psi	app. 45
Coolant loops, No.	6
Primary heat exchangers, No.	6
Primary pumps, No.	6
Material of primary system	316 SS
Reactor vessel	
Outside diameter, ft.	20
Overall height, ft.	25
Material	316 SS

APPENDIX C

NUCLEAR POWER COSTS
AS CALCULATED
BY THE

PACTOLUS CODE
ON
WINTER 67-68

ADVANCED CONCEPTS AND ANALYSIS SECTION

BATTELLE MEMORIAL INSTITUTE
PACIFIC NORTHWEST LABORATORIES

POST OFFICE BOX 999
RICHLAND, WASHINGTON 99352

TELEPHONE, AREA CODE 509, 942-1111 EXT 3796
CABLE ADDRESS, BAT NOR LAB

C-1

BMTL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

REACTOR DESCRIPTION

REACTOR STARTUP DATE	1980.0	
REACTOR POWER	2500.0	MW(TH)
ELECTRICAL CONV. EFF	40.0	PCT
TONS OF FUEL IN REACTOR	46.6	TONNE
REACTOR LIFETIME	30.0	YRS

PLANT CHARGES

BOND INTEREST RATE	4.2	PCT
EARNING RATE ON EQUITY (AFTER TAX)	10.0	PCT
NUCLEAR LIABILITY COST PER YEAR	317000.0	\$/YR
NUCLEAR LIABILITY COST PER MWYE	-.0	\$/MWY
PROPERTY INSURANCE	.3	PCT/YR
PLANT BASE OPERATING COST	1117000.0	\$/YR
FEDERAL INCOME TAX RATE	50.0	PCT
STATE INCOME TAX RATE	3.0	PCT
PROPERTY TAX RATE	3.2	PCT/YR
STATE GROSS REVENUE TAX RATE	4.0	PCT
COMBINED STATE AND LOCAL TAXES	-.0	\$/YR
INTERIM CAPITAL REPLACEMENTS	.4	PCT/YR

PLANT CONSTRUCTION

CONSTRUCTION TIME	3.0	YRS
MODERATOR COST (THERMAL REACTORS)	-.0	\$
FLUORIDE SALT COST	.0	\$
COST OF CONTROL SYSTEM	-.0	\$
COST OF TURBINE GENERATORS	-.0	\$
COST OF PRESSURE VESSEL	-.0	\$
COST OF HEAT EXCHANGERS	-.0	\$
COST OF REACTOR SITE PREPARATION	-.0	\$
OTHER CAPITAL COSTS	149600000.0	\$
NET SALVAGE VALUE OF PLANT	-.0	\$
RECOVERABLE LAND COST	-.0	\$

FIXED PROCESS TIMES

URANIUM ENRICHMENT AND LEAD TIME	42.0	DAYS
PRE-FABRICATION SHIPPING TIME	8.0	DAYS
TIME IN FABRICATION	26.0	DAYS
SHIP FROM FABRICATOR TO REACT SITE	12.0	DAYS
PRE REACTOR INVENTORY TIME	30.0	DAYS
POST REACTOR COOLING	120.0	DAYS
TIME TO SHIP FUEL TO REPROCESS SITE	24.0	DAYS
(REPROCESSING TIME DETERMINED BY SIZE OF BATCH)		
SHIP TO FINAL DESTINATION	30.0	DAYS

SHIPPING CHARGES

PRE-FABRICATION SHIPPING COST, (U)	-.0	\$/KG
FABRICATOR TO REACTOR SITE (U)	2.0	\$/KG
PRE-FABRICATION SHIPPING COST (RECYC)	-.0	\$/KG
FABRICATOR TO REACTOR SITE (RECYC)	-.0	\$/KG
REACTOR SITE TO REPROCESSING PLANT	16.2	\$/KG

COST TO SHIP TO FINAL DESTINATION	-.0	\$/KG
-----------------------------------	-----	-------

REPROCESSING CHARGES

REPROCESSING PLANT THROUGHPUT	-.0	KG/DAY
REPROCESSING PLANT OPERATING COST	-.0	\$/DAY

FIRST CORE PURCHASE

FABRICATION CHARGE	9738040.9	\$
SHIPPING CHARGE	92721.1	\$
FUEL PURCHASE	23133700.0	\$
FUEL FABRICATION LOSSES	104108.3	\$

URANIUM CASCADE PRICE SCHEDULE PARAMETERS

COST OF FEED (SEE TABLE 2)		
CONVERSION COST	2.20	\$/KG
FEED COMPOSITION	.7110	PCT
COST OF SEPARATIVE DUTY	26.00	\$/KG
TAILS VALUE	.00	\$/KG

ISOTOPE PRICES

U233	14.0	\$/GM	U235	-.0	\$/GM	PU239	10.0	\$/GM	PU241	10.0	\$/GM
TH232	.0	\$/GM	U238	-.0	\$/GM	U234	-.0	\$/GM	PU240	-.0	\$/GM
PA233	-.0	\$/GM	U236	-.0	\$/GM	PU242	-.0	\$/GM	NP237	-.0	\$/GM
000000	-.0	\$/GM	000000	-.0	\$/GM	000000	-.0	\$/GM	000000	-.0	\$/GM
000000	-.0	\$/GM	000000	-.0	\$/GM	000000	-.0	\$/GM	000000	-.0	\$/GM

C-2

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

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
1980	85.0	14.677	.000	4.845	.336	.046	.188	.096	.688	20.189
1981	85.0	14.677	14.194	4.845	.672	.046	.376	.136	.688	6.569
1982	85.0	14.677	16.541	4.845	.672	.046	.376	.141	.688	4.217
1983	85.0	14.677	16.458	4.845	.672	.046	.376	.141	.688	4.299
1984	85.0	14.677	25.123	4.845	.672	.046	.376	.142	.688	-4.365
1985	85.0	14.677	16.761	4.845	.672	.046	.376	.141	.688	3.997
1986	85.0	14.677	16.761	4.845	.672	.046	.376	.141	.688	3.997
1987	85.0	14.677	16.761	4.845	.672	.046	.376	.141	.688	3.997
1988	85.0	14.677	16.761	4.845	.672	.046	.376	.141	.688	3.997
1989	85.0	14.677	16.761	4.845	.672	.046	.376	.141	.688	3.997
1990	85.0	14.677	16.761	4.845	.672	.046	.376	.141	.688	3.997
1991	85.0	14.677	16.761	4.845	.672	.046	.376	.141	.688	3.997
1992	85.0	14.677	16.761	4.845	.672	.046	.376	.141	.688	3.997
1993	85.0	14.709	16.761	4.845	.672	.046	.376	.141	.688	4.029
1994	85.0	14.677	16.761	4.845	.672	.046	.376	.141	.688	3.997
1995	84.0	14.677	16.761	4.845	.672	.046	.376	.141	.680	3.997
1996	82.0	14.645	16.761	4.845	.672	.046	.376	.141	.664	3.965
1997	80.0	14.677	16.761	4.845	.672	.046	.376	.141	.648	3.997
1998	78.0	14.677	16.761	4.845	.672	.046	.376	.141	.632	3.997
1999	76.0	14.677	8.381	4.845	.672	.046	.376	.141	.616	12.378
2000	74.0	14.677	16.761	2.423	.672	.023	.376	.071	.599	1.481
2001	72.0	7.339	16.761	4.845	.336	.046	.188	.141	.583	-3.866
2002	70.0	14.677	16.761	4.845	.672	.046	.376	.141	.567	3.997
2003	68.0	14.677	8.381	2.423	.672	.023	.376	.071	.551	9.861
2004	66.0	7.339	16.761	4.845	.336	.046	.188	.141	.535	-3.866
2005	64.0	14.677	8.381	4.845	.672	.023	.376	.108	.518	12.322
2006	62.0	7.339	16.761	2.423	.336	.046	.188	.104	.502	-6.326
2007	60.0	14.677	8.381	2.423	.672	.023	.376	.108	.486	9.899
2008	58.0	7.339	16.761	4.845	.336	.046	.188	.104	.470	-3.904
2009	56.0	7.339	8.381	2.423	.336	.023	.188	.071	.454	1.998
2010	1.3	.000	34.362	.000	1.689	.000	.946	.155	.011	-31.572

C-3

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

TABLE 2
VARIABLE PARAMETERS

YEAR	REPROCESSING CHARGE, \$/KG,		REPROCESSING TIME, DAYS		FABRICATION CHARGE, \$/KG,		U233 OR PU FAB PENALTY	PU PRICE	U233 PRICE	U FEED PRICE
	BLKT	CORE	BLKT	CORE	BLKT	CORE	\$/KG	\$/GM	\$/GM	\$/LB U308
1977					209.0	209.0	-.0	10.0	14.00	8.00
1978					209.0	209.0	.0	10.0	14.00	8.00
1979					209.0	209.0	.0	10.0	14.00	8.00
1980	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1981	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1982	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1983	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1984	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1985	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1986	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1987	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1988	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1989	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1990	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1991	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1992	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1993	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1994	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1995	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1996	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1997	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1998	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
1999	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
2000	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
2001	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
2002	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
2003	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
2004	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
2005	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
2006	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
2007	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
2008	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
2009	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00
2010	29.0	29.0	25.0	25.0	209.0	209.0	.0	10.0	14.00	8.00

C-4

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

URANIUM PURCHASES AND CREDITS

YEAR	URANIUM PRICE \$/LB	TAILS COMPOSITION PCT	90 PCT ENR URANIUM PRICE \$/GM	U308 PURCHASED TONS	SEPARATIVE WORK PURCHASED TONS	TAILS PRODUCED TONS	EQUIVALENT U308 CREDITED TONS	EQUIVALENT SEPARATIVE WORK CREDITED TONS	TAILS CONSUMED TONS
1977	8.00	.000	.00	.0	.0	.0	.0	.0	.0
1978	8.00	.000	.00	.0	.0	.0	.0	.0	.0
1979	8.00	.240	10.97	115.5	51.7	53.8	.0	.0	.0
1980	8.00	.000	10.97	.0	.0	-21.2	.0	.0	.0
1981	8.00	.240	10.97	.0	.0	-21.2	40.5	17.7	13.5
1982	8.00	.240	10.97	.0	.0	-21.2	33.9	13.3	8.7
1983	8.00	.240	10.97	.0	.0	-21.2	6.1	.9	-14.8
1984	8.00	.240	10.97	.0	.0	-21.2	4.7	.3	-25.9
1985	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1986	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1987	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1988	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1989	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1990	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1991	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1992	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1993	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1994	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1995	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1996	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1997	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1998	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
1999	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-10.0
2000	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
2001	8.00	.000	10.97	.0	.0	-10.6	.0	.0	-19.9
2002	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-19.9
2003	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-10.0
2004	8.00	.000	10.97	.0	.0	-10.6	.0	.0	-19.9
2005	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-10.0
2006	8.00	.000	10.97	.0	.0	-10.6	.0	.0	-19.9
2007	8.00	.000	10.97	.0	.0	-21.2	.0	.0	-10.0
2008	8.00	.000	10.97	.0	.0	-10.6	.0	.0	-19.9
2009	8.00	.000	10.97	.0	.0	-10.6	.0	.0	-10.0
2010	8.00	.000	10.97	.0	.0	.0	.0	.0	-52.3

C-5

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FRAC

TABLE 3
FUEL DISCHARGE SUMMARY

DISCHARGE NUMBER	CASE NUMBER	DISCHARGE TIME, YRS AFTER STARTUP	CALENDAR TIME	RESIDENCE TIME, YRS	TONNES DISCHARGED	FUEL EXPOSURE MWD/TONNE	INITIAL ENRICHMENT	FINAL ENRICHMENT
1	1F	.49	1980.	.49	4.2	80000.0	15.71	13.66
2	2F	.49	1980.	.49	2.4	2500.0	.29	.82
3	3F	.49	1980.	.49	3.2	8100.0	2.50	3.08
4	4F	.49	1980.	.49	1.7	8100.0	1.50	2.20
5	5F	.99	1980.	.99	4.2	80000.0	15.71	14.92
6	6F	.99	1980.	.99	2.4	2500.0	.29	1.35
7	7F	.99	1980.	.99	3.2	8100.0	2.50	3.47
8	8F	.99	1980.	.99	1.7	8100.0	1.50	3.17
9	9F	1.48	1981.	1.48	4.2	80000.0	15.71	15.87
10	10F	1.48	1981.	1.48	2.4	2500.0	.29	1.85
11	11F	1.48	1981.	1.48	3.2	8100.0	2.50	4.03
12	12F	1.48	1981.	1.48	1.7	8100.0	1.50	3.72
13	15F	1.97	1981.	1.97	3.2	8100.0	2.50	4.36
14	16F	1.97	1981.	1.97	1.7	8100.0	1.50	4.55
15	20F	2.47	1982.	2.47	1.7	8100.0	1.50	4.57
16	24F	2.96	1982.	2.96	1.7	8100.0	1.50	4.70
17	28F	3.46	1983.	3.46	1.7	8100.0	1.50	4.88
18	32F	3.95	1983.	3.95	1.7	8100.0	1.50	5.02
19	13F	1.97	1981.	1.48	4.2	80000.0	17.64	16.27
20	14F	1.97	1981.	1.48	2.4	2500.0	.29	1.85
21	17F	2.47	1982.	1.48	4.2	80000.0	17.64	16.28
22	18F	2.47	1982.	1.48	2.4	2500.0	.29	1.85
23	19F	2.47	1982.	1.97	3.2	8100.0	.31	3.06
24	21F	2.96	1982.	1.48	4.2	80000.0	17.64	16.26
25	22F	2.96	1982.	1.48	2.4	2500.0	.29	1.85
26	23F	2.96	1982.	1.97	3.2	8100.0	.31	3.21
27	25F	3.46	1983.	1.48	4.2	80000.0	17.64	16.26
28	26F	3.46	1983.	1.48	2.4	2500.0	.29	1.85
29	27F	3.46	1983.	1.97	3.2	8100.0	.31	3.37
30	29F	3.95	1983.	1.48	4.2	80000.0	17.64	16.26
31	30F	3.95	1983.	1.48	2.4	2500.0	.29	1.85
32	31F	3.95	1983.	1.97	3.2	8100.0	.31	3.49
33	33F	4.44	1984.	1.48	4.2	80000.0	17.64	16.26
34	34F	4.44	1984.	1.48	2.4	2500.0	.29	1.85

C-6

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

TABLE 3
FUEL DISCHARGE SUMMARY

DISCHARGE NUMBER	CASE NUMBER	DISCHARGE TIME, YRS AFTER STARTUP	CALENDAR TIME	RESIDENCE TIME, YRS	TONNES DISCHARGED	FUEL EXPOSURE MWD/TONNE	INITIAL ENRICHMENT	FINAL ENRICHMENT
35	35F	4.44	1984.	1.97	3.2	8100.0	.31	3.42
36	36F	4.44	1984.	3.95	1.7	8100.0	.30	4.53
37	37F	4.94	1984.	1.48	4.2	80000.0	17.64	16.26
38	38F	4.94	1984.	1.48	2.4	2500.0	.29	1.85
39	39F	4.94	1984.	1.97	3.2	8100.0	.31	3.42
40	40F	4.94	1984.	3.95	1.7	8100.0	.30	4.53
41	41F	5.43	1985.	1.48	4.2	80000.0	17.64	16.26
42	42F	5.43	1985.	1.48	2.4	2500.0	.29	1.85
43	43F	5.43	1985.	1.97	3.2	8100.0	.31	3.42
44	44F	5.43	1985.	3.95	1.7	8100.0	.30	4.53
45	45F	5.92	1985.	1.48	4.2	80000.0	17.64	16.26
46	46F	5.92	1985.	1.48	2.4	2500.0	.29	1.85
47	47F	5.92	1985.	1.97	3.2	8100.0	.31	3.42
48	48F	5.92	1985.	3.95	1.7	8100.0	.30	4.53
49	49F	6.42	1986.	1.48	4.2	80000.0	17.64	16.26
50	50F	6.42	1986.	1.48	2.4	2500.0	.29	1.85
51	51F	6.42	1986.	1.97	3.2	8100.0	.31	3.42
52	52F	6.42	1986.	3.95	1.7	8100.0	.30	4.53
53	53F	6.91	1986.	1.48	4.2	80000.0	17.64	16.26
54	54F	6.91	1986.	1.48	2.4	2500.0	.29	1.85
55	55F	6.91	1986.	1.97	3.2	8100.0	.31	3.42
56	56F	6.91	1986.	3.95	1.7	8100.0	.30	4.53
57	57F	7.40	1987.	1.48	4.2	80000.0	17.64	16.26
58	58F	7.40	1987.	1.48	2.4	2500.0	.29	1.85
59	59F	7.40	1987.	1.97	3.2	8100.0	.31	3.42
60	60F	7.40	1987.	3.95	1.7	8100.0	.30	4.53
61	61F	7.90	1987.	1.48	4.2	80000.0	17.64	16.26
62	62F	7.90	1987.	1.48	2.4	2500.0	.29	1.85
63	63F	7.90	1987.	1.97	3.2	8100.0	.31	3.42
64	64F	7.90	1987.	3.95	1.7	8100.0	.30	4.53
65	65F	8.39	1988.	1.48	4.2	80000.0	17.64	16.26
66	66F	8.39	1988.	1.48	2.4	2500.0	.29	1.85
67	67F	8.39	1988.	1.97	3.2	8100.0	.31	3.42
68	68F	8.39	1988.	3.95	1.7	8100.0	.30	4.53

C-7

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

TABLE 3
FUEL DISCHARGE SUMMARY

DISCHARGE NUMBER	CASE NUMBER	DISCHARGE TIME, YRS AFTER STARTUP	CALENDAR TIME	RESIDENCE TIME, YRS	TONNES DISCHARGED	FUEL EXPOSURE MWD/TONNE	INITIAL ENRICHMENT	FINAL ENRICHMENT
69	69F	8.88	1988.	1.48	4.2	80000.0	17.64	16.26
70	70F	8.88	1988.	1.48	2.4	2500.0	.29	1.85
71	71F	8.88	1988.	1.97	3.2	8100.0	.31	3.42
72	72F	8.88	1988.	3.95	1.7	8100.0	.30	4.53
73	73F	9.38	1989.	1.48	4.2	80000.0	17.64	16.26
74	74F	9.38	1989.	1.48	2.4	2500.0	.29	1.85
75	75F	9.38	1989.	1.97	3.2	8100.0	.31	3.42
76	76F	9.38	1989.	3.95	1.7	8100.0	.30	4.53
77	77F	9.87	1989.	1.48	4.2	80000.0	17.64	16.26
78	78F	9.87	1989.	1.48	2.4	2500.0	.29	1.85
79	79F	9.87	1989.	1.97	3.2	8100.0	.31	3.42
80	80F	9.87	1989.	3.95	1.7	8100.0	.30	4.53
81	81F	10.37	1990.	1.48	4.2	80000.0	17.64	16.26
82	82F	10.37	1990.	1.48	2.4	2500.0	.29	1.85
83	83F	10.37	1990.	1.97	3.2	8100.0	.31	3.42
84	84F	10.37	1990.	3.95	1.7	8100.0	.30	4.53
85	85F	10.86	1990.	1.48	4.2	80000.0	17.64	16.26
86	86F	10.86	1990.	1.48	2.4	2500.0	.29	1.85
87	87F	10.86	1990.	1.97	3.2	8100.0	.31	3.42
88	88F	10.86	1990.	3.95	1.7	8100.0	.30	4.53
89	89F	11.35	1991.	1.48	4.2	80000.0	17.64	16.26
90	90F	11.35	1991.	1.48	2.4	2500.0	.29	1.85
91	91F	11.35	1991.	1.97	3.2	8100.0	.31	3.42
92	92F	11.35	1991.	3.95	1.7	8100.0	.30	4.53
93	93F	11.85	1991.	1.48	4.2	80000.0	17.64	16.26
94	94F	11.85	1991.	1.48	2.4	2500.0	.29	1.85
95	95F	11.85	1991.	1.97	3.2	8100.0	.31	3.42
96	96F	11.85	1991.	3.95	1.7	8100.0	.30	4.53
97	97F	12.34	1992.	1.48	4.2	80000.0	17.64	16.26
98	98F	12.34	1992.	1.48	2.4	2500.0	.29	1.85
99	99F	12.34	1992.	1.97	3.2	8100.0	.31	3.42
100	100F	12.34	1992.	3.95	1.7	8100.0	.30	4.53
101	101F	12.83	1992.	1.48	4.2	80000.0	17.64	16.26
102	102F	12.83	1992.	1.48	2.4	2500.0	.29	1.85

C-8

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

TABLE 3
FUEL DISCHARGE SUMMARY

DISCHARGE NUMBER	CASE NUMBER	DISCHARGE TIME, YRS AFTER STARTUP	CALENDAR TIME	RESIDENCE TIME, YRS	TONNES DISCHARGED	FUEL EXPOSURE MWD/TONNE	INITIAL ENRICHMENT	FINAL ENRICHMENT
103	103F	12.83	1992.	1.97	3.2	8100.0	.31	3.42
104	104F	12.83	1992.	3.95	1.7	8100.0	.30	4.53
105	105F	13.33	1993.	1.48	4.2	80000.0	17.64	16.26
106	106F	13.33	1993.	1.48	2.4	2500.0	.29	1.85
107	107F	13.33	1993.	1.97	3.2	8100.0	.31	3.42
108	108F	13.33	1993.	3.95	1.7	8100.0	.30	4.53
109	109F	13.82	1993.	1.48	4.2	80000.0	17.64	16.26
110	110F	13.82	1993.	1.48	2.4	2500.0	.29	1.85
111	111F	13.82	1993.	1.97	3.2	8100.0	.31	3.42
112	112F	13.82	1993.	3.95	1.7	8100.0	.30	4.53
113	113F	14.31	1994.	1.48	4.2	80000.0	17.64	16.26
114	114F	14.31	1994.	1.48	2.4	2500.0	.29	1.85
115	115F	14.31	1994.	1.97	3.2	8100.0	.31	3.42
116	116F	14.31	1994.	3.95	1.7	8100.0	.30	4.53
117	117F	14.81	1994.	1.48	4.2	80000.0	17.64	16.26
118	118F	14.81	1994.	1.48	2.4	2500.0	.29	1.85
119	119F	14.81	1994.	1.97	3.2	8100.0	.31	3.42
120	120F	14.81	1994.	3.95	1.7	8100.0	.30	4.53
121	121F	15.30	1995.	1.48	4.2	80000.0	17.64	16.26
122	122F	15.30	1995.	1.48	2.4	2500.0	.29	1.85
123	123F	15.30	1995.	1.98	3.2	8100.0	.31	3.42
124	124F	15.30	1995.	3.95	1.7	8100.0	.30	4.53
125	125F	15.80	1995.	1.49	4.2	80000.0	17.64	16.26
126	126F	15.80	1995.	1.49	2.4	2500.0	.29	1.85
127	127F	15.80	1995.	1.98	3.2	8100.0	.31	3.42
128	128F	15.80	1995.	3.96	1.7	8100.0	.30	4.53
129	129F	16.31	1996.	1.50	4.2	80000.0	17.64	16.26
130	130F	16.31	1996.	1.50	2.4	2500.0	.29	1.85
131	131F	16.31	1996.	1.99	3.2	8100.0	.31	3.42
132	132F	16.31	1996.	3.97	1.7	8100.0	.30	4.53
133	133F	16.82	1996.	1.52	4.2	80000.0	17.64	16.26
134	134F	16.82	1996.	1.52	2.4	2500.0	.29	1.85
135	135F	16.82	1996.	2.01	3.2	8100.0	.31	3.42
136	136F	16.82	1996.	3.99	1.7	8100.0	.30	4.53

C-9

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

TABLE 3
FUEL DISCHARGE SUMMARY

DISCHARGE NUMBER	CASE NUMBER	DISCHARGE TIME, YRS AFTER STARTUP	CALENDAR TIME	RESIDENCE TIME, YRS	TONNES DISCHARGED	FUEL EXPOSURE MWD/TONNE	INITIAL ENRICHMENT	FINAL ENRICHMENT
137	137F	17.34	1997.	1.54	4.2	80000.0	17.64	16.26
138	138F	17.34	1997.	1.54	2.4	2500.0	.29	1.85
139	139F	17.34	1997.	2.04	3.2	8100.0	.31	3.42
140	140F	17.34	1997.	4.01	1.7	8100.0	.30	4.53
141	141F	17.86	1997.	1.56	4.2	80000.0	17.64	16.26
142	142F	17.86	1997.	1.56	2.4	2500.0	.29	1.85
143	143F	17.86	1997.	2.06	3.2	8100.0	.31	3.42
144	144F	17.86	1997.	4.04	1.7	8100.0	.30	4.53
145	145F	18.40	1998.	1.58	4.2	80000.0	17.64	16.26
146	146F	18.40	1998.	1.58	2.4	2500.0	.29	1.85
147	147F	18.40	1998.	2.09	3.2	8100.0	.31	3.42
148	148F	18.40	1998.	4.08	1.7	8100.0	.30	4.53
149	149F	18.94	1998.	1.60	4.2	80000.0	17.64	16.26
150	150F	18.94	1998.	1.60	2.4	2500.0	.29	1.85
151	151F	18.94	1998.	2.12	3.2	8100.0	.31	3.42
152	152F	18.94	1998.	4.13	1.7	8100.0	.30	4.53
153	153F	19.48	1999.	1.62	4.2	80000.0	17.64	16.26
154	154F	19.48	1999.	1.62	2.4	2500.0	.29	1.85
155	155F	19.48	1999.	2.15	3.2	8100.0	.31	3.42
156	156F	19.48	1999.	4.18	1.7	8100.0	.30	4.53
157	157F	20.04	2000.	1.64	4.2	80000.0	17.64	16.26
158	158F	20.04	2000.	1.64	2.4	2500.0	.29	1.85
159	159F	20.04	2000.	2.18	3.2	8100.0	.31	3.42
160	160F	20.04	2000.	4.24	1.7	8100.0	.30	4.53
161	161F	20.60	2000.	1.67	4.2	80000.0	17.64	16.26
162	162F	20.60	2000.	1.67	2.4	2500.0	.29	1.85
163	163F	20.60	2000.	2.21	3.2	8100.0	.31	3.42
164	164F	20.60	2000.	4.30	1.7	8100.0	.30	4.53
165	165F	21.18	2001.	1.69	4.2	80000.0	17.64	16.26
166	166F	21.18	2001.	1.69	2.4	2500.0	.29	1.85
167	167F	21.18	2001.	2.24	3.2	8100.0	.31	3.42
168	168F	21.18	2001.	4.36	1.7	8100.0	.30	4.53
169	169F	21.76	2001.	1.72	4.2	80000.0	17.64	16.26
170	170F	21.76	2001.	1.72	2.4	2500.0	.29	1.85

C-10

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

TABLE 3
FUEL DISCHARGE SUMMARY

DISCHARGE NUMBER	CASE NUMBER	DISCHARGE TIME, YRS AFTER STARTUP	CALENDAR TIME	RESIDENCE TIME, YRS	TONNES DISCHARGED	FUEL EXPOSURE MWD/TONNE	INITIAL ENRICHMENT	FINAL ENRICHMENT
171	171F	21.76	2001.	2.27	3.2	8100.0	.31	3.42
172	172F	21.76	2001.	4.42	1.7	8100.0	.30	4.53
173	173F	22.35	2002.	1.75	4.2	80000.0	17.64	16.26
174	174F	22.35	2002.	1.75	2.4	2500.0	.29	1.85
175	175F	22.35	2002.	2.31	3.2	8100.0	.31	3.42
176	176F	22.35	2002.	4.49	1.7	8100.0	.30	4.53
177	177F	22.95	2002.	1.78	4.2	80000.0	17.64	16.26
178	178F	22.95	2002.	1.78	2.4	2500.0	.29	1.85
179	179F	22.95	2002.	2.35	3.2	8100.0	.31	3.42
180	180F	22.95	2002.	4.56	1.7	8100.0	.30	4.53
181	181F	23.56	2003.	1.81	4.2	80000.0	17.64	16.26
182	182F	23.56	2003.	1.81	2.4	2500.0	.29	1.85
183	183F	23.56	2003.	2.39	3.2	8100.0	.31	3.42
184	184F	23.56	2003.	4.63	1.7	8100.0	.30	4.53
185	185F	24.19	2004.	1.84	4.2	80000.0	17.64	16.26
186	186F	24.19	2004.	1.84	2.4	2500.0	.29	1.85
187	187F	24.19	2004.	2.43	3.2	8100.0	.31	3.42
188	188F	24.19	2004.	4.70	1.7	8100.0	.30	4.53
189	189F	24.82	2004.	1.87	4.2	80000.0	17.64	16.26
190	190F	24.82	2004.	1.87	2.4	2500.0	.29	1.85
191	191F	24.82	2004.	2.47	3.2	8100.0	.31	3.42
192	192F	24.82	2004.	4.78	1.7	8100.0	.30	4.53
193	193F	25.47	2005.	1.91	4.2	80000.0	17.64	16.26
194	194F	25.47	2005.	1.91	2.4	2500.0	.29	1.85
195	195F	25.47	2005.	2.52	3.2	8100.0	.31	3.42
196	196F	25.47	2005.	4.87	1.7	8100.0	.30	4.53
197	197F	26.13	2006.	1.94	4.2	80000.0	17.64	16.26
198	198F	26.13	2006.	1.94	2.4	2500.0	.29	1.85
199	199F	26.13	2006.	2.57	3.2	8100.0	.31	3.42
200	200F	26.13	2006.	4.96	1.7	8100.0	.30	4.53
201	201F	26.81	2006.	1.98	4.2	80000.0	17.64	16.26
202	202F	26.81	2006.	1.98	2.4	2500.0	.29	1.85
203	203F	26.81	2006.	2.62	3.2	8100.0	.31	3.42
204	204F	26.81	2006.	5.05	1.7	8100.0	.30	4.53

C-11

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

TABLE 3
FUEL DISCHARGE SUMMARY

DISCHARGE NUMBER	CASE NUMBER	DISCHARGE TIME, YRS AFTER STARTUP	CALENDAR TIME	RESIDENCE TIME, YRS	TONNES DISCHARGED	FUEL EXPOSURE MWD/TONNE	INITIAL ENRICHMENT	FINAL ENRICHMENT
205	205F	27.50	2007.	2.03	4.2	80000.0	17.64	16.26
206	206F	27.50	2007.	2.03	2.4	2500.0	.29	1.85
207	207F	27.50	2007.	2.68	3.2	8100.0	.31	3.42
208	208F	27.50	2007.	5.15	1.7	8100.0	.30	4.53
209	209F	28.21	2008.	2.07	4.2	80000.0	17.64	16.26
210	210F	28.21	2008.	2.07	2.4	2500.0	.29	1.85
211	211F	28.21	2008.	2.73	3.2	8100.0	.31	3.42
212	212F	28.21	2008.	5.25	1.7	8100.0	.30	4.53
213	213F	28.93	2008.	2.12	4.2	80000.0	17.64	16.26
214	214F	28.93	2008.	2.12	2.4	2500.0	.29	1.85
215	215F	28.93	2008.	2.80	3.2	8100.0	.31	3.42
216	216F	28.93	2008.	5.37	1.7	8100.0	.30	4.53
217	217F	29.67	2009.	2.17	4.2	80000.0	17.64	16.26
218	218F	29.67	2009.	2.17	2.4	2500.0	.29	1.85
219	219F	29.67	2009.	2.87	3.2	8100.0	.31	3.42
220	220F	29.67	2009.	5.49	1.7	8100.0	.30	4.53
221	221F	30.02	2010.	.35	4.2	12341.0	17.64	17.45
222	221F	30.02	2010.	.35	2.4	385.7	.29	.53
223	221F	30.02	2010.	1.82	3.2	4987.1	.31	2.21
224	221F	30.02	2010.	4.55	1.7	6543.6	.30	3.73
225	221F	30.02	2010.	1.82	4.2	65674.3	17.64	16.53
226	221F	30.02	2010.	1.82	2.4	2052.3	.29	1.57
227	221F	30.02	2010.	1.09	3.2	2962.1	.31	1.43
228	221F	30.02	2010.	3.89	1.7	5531.1	.30	3.21
229	221F	30.02	2010.	1.09	4.2	39007.6	17.64	17.00
230	221F	30.02	2010.	1.09	2.4	1219.0	.29	1.05
231	221F	30.02	2010.	.35	3.2	937.1	.31	.66
232	221F	30.02	2010.	3.22	1.7	4518.6	.30	2.68
233	221F	30.02	2010.	2.53	3.2	7012.1	.31	3.00
234	221F	30.02	2010.	2.53	1.7	3506.1	.30	2.15
235	221F	30.02	2010.	1.82	1.7	2493.6	.30	1.62
236	221F	30.02	2010.	1.09	1.7	1481.1	.30	1.09
237	221F	30.02	2010.	.35	1.7	468.6	.30	.55
238	221F	30.02	2010.	5.20	1.7	7556.1	.30	4.25

C-12

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBF EX-55

FBAC

TABLE 3
FUEL DISCHARGE SUMMARY

DISCHARGE NUMBER	CASE NUMBER	DISCHARGE TIME, YRS AFTER STARTUP	CALENDAR TIME	RESIDENCE TIME, YRS	TONNES DISCHARGED	FUEL EXPOSURE MWD/TONNE	INITIAL ENRICHMENT	FINAL ENRICHMENT
---------------------	----------------	---	------------------	------------------------	----------------------	-------------------------------	-----------------------	---------------------

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

TABLE 4
REACTOR PROPERTIES TABLE

AVERAGE PLANT CAPACITY FACTOR, PER-CENT	76.1
INITIAL FULL POWER SPECIFIC POWER, MW/TONNE HEAVY METAL	53.7
YIELD, FISSILE KG PER MWE-YEAR	.203
YIELD, KG PU PER MWE-YEAR	.235
YIELD, KG U235 PER MWE-YEAR	-.032
YIELD, KG U233 PER MWE-YEAR	.000
SPECIFIC INVENTORY, KG OF FISSILE MATERIAL PER MEGAWATT ELECTRICAL	2.55
TONNE OF U308 MINED PER MWE-YEAR	.001
TONNE OF U308 MINED PER MW-YR (THERMAL)	.001
KILOGRAMS FISSIONED PER TONNE OF U308 MINED	724.63
KG SEPARATIVE DUTY PER MWE-YR	.85
TONS OF U308 CONSUMED	30.2
TONS OF SEPARATIVE DUTY CONSUMED	19.4
KG FABRICATED PER MWE-YR	105.7

C-14

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

TABLE 5
KILOGRAMS FABRICATED EACH YEAR
(BEFORE LOSSES)

YEAR	TH232	PA233	U233	U234	U235	U236	U238	PU239	PU240	PU241	PU242
1977	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1978	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1979	.0	.0	.0	.0	571.7	.0	43594.3	1641.5	657.0	332.6	100.4
1980	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1981	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1982	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1983	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1984	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1985	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1986	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1987	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1988	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1989	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1990	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1991	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1992	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1993	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1994	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1995	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1996	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1997	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1998	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
1999	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
2000	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
2001	.0	.0	.0	.0	30.1	.0	10572.6	686.1	281.3	52.8	21.1
2002	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
2003	.0	.0	.0	.0	30.1	.0	10572.6	686.1	281.3	52.8	21.1
2004	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
2005	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
2006	.0	.0	.0	.0	30.1	.0	10572.6	686.1	281.3	52.8	21.1
2007	.0	.0	.0	.0	30.1	.0	10572.6	686.1	281.3	52.8	21.1
2008	.0	.0	.0	.0	60.3	.0	21145.2	1372.2	562.5	105.5	42.2
2009	.0	.0	.0	.0	30.1	.0	10572.6	686.1	281.3	52.8	21.1
2010	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

C-15

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

TABLE 5
KILOGRAMS FABRICATED EACH YEAR
(BEFORE LOSSES)

YEAR	NP237	U-235	U-238	MOX	U-235	U-238	MOX	U-235	U-238	FISS PRD	TOTAL
1977	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1978	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1979	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	46807.4
1980	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1981	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1982	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1983	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1984	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1985	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1986	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1987	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1988	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1989	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1990	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1991	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1992	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1993	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1994	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1995	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1996	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1997	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1998	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
1999	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
2000	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
2001	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	11643.9
2002	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
2003	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	11643.9
2004	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
2005	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
2006	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	11643.9
2007	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	11643.9
2008	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	23287.8
2009	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	11643.9
2010	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

C-16

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

TABLE 6
KILOGRAMS REPROCESSED EACH YEAR
(AFTER LOSSES)

YEAR	TH232	PA233	U233	U234	U235	U236	U238	PU239	PU240	PU241	PU242
1977	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1978	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1979	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1980	.0	.0	.0	.0	110.2	.0	10472.7	525.6	193.1	76.1	32.9
1981	.0	.0	.0	.0	191.7	.0	20212.6	1297.1	475.8	140.4	79.6
1982	.0	.0	.0	.0	119.3	.0	19892.1	1522.1	579.4	85.8	43.8
1983	.0	.0	.0	.0	64.5	.0	19907.0	1558.0	582.4	85.8	43.8
1984	.0	.0	.0	.0	49.6	.0	19889.1	1582.8	585.4	85.8	43.8
1985	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1986	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1987	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1988	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1989	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1990	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1991	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1992	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1993	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1994	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1995	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1996	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1997	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1998	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
1999	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
2000	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
2001	.0	.0	.0	.0	18.8	.0	9954.0	792.4	292.7	42.9	21.9
2002	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
2003	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
2004	.0	.0	.0	.0	18.8	.0	9954.0	792.4	292.7	42.9	21.9
2005	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
2006	.0	.0	.0	.0	18.8	.0	9954.0	792.4	292.7	42.9	21.9
2007	.0	.0	.0	.0	37.6	.0	19908.0	1584.8	585.4	85.8	43.8
2008	.0	.0	.0	.0	18.8	.0	9954.0	792.4	292.7	42.9	21.9
2009	.0	.0	.0	.0	18.8	.0	9954.0	792.4	292.7	42.9	21.9
2010	.0	.0	.0	.0	122.0	.0	52190.2	3237.7	1161.0	183.6	86.1

C-17

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FFAC

TABLE 6
KILOGRAMS REPROCESSED EACH YEAR
(AFTER LOSSES)

YEAR	NP237	U-235	U-238	MOX	U-235	U-238	MOX	U-235	U-238	FISS PRD	TOTAL
1977	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1978	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1979	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1980	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	11410.5
1981	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22397.4
1982	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22242.4
1983	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22241.4
1984	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22236.5
1985	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1986	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1987	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1988	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1989	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1990	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1991	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1992	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1993	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1994	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1995	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1996	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1997	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1998	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
1999	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
2000	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
2001	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	11122.7
2002	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
2003	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
2004	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	11122.7
2005	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
2006	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	11122.7
2007	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	22245.4
2008	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	11122.7
2009	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	11122.7
2010	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	56980.5

C-18

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

REFERENCE OXIDE-FUELED LMFBR EX-55

FBAC

INPUT DATA

CARD 1

BOND REPAYMENT PROPORTIONAL
SUM OF YEARS DIGITS DEPRECIATION

CARD 2

PLANT INVESTMENT, \$M	149.6000	(INITIAL FINANCING)
PROJECT LIFE, YEARS	30.5698	
NONFUEL WORKING CAPITAL, \$M	.0000	(INITIAL FINANCING)
FRACTION OF INITIAL INVESTMENT IN BONDS	.5200	
BOND INTEREST RATE	.0423	
EQUITY EARNING RATE (AFTER TAXES)	.1000	
FEDERAL INCOME TAX RATE	.5000	

CARD 3

REACTOR POWER, MWE	1000.0000	
DEPRECIABLE LIFE, YEARS	30.0000	
NONFUEL VARIABLE OPERATING COST FACTOR	.8100	
INITIAL CORE INVESTMENT, \$M	33.0686	(INITIAL FINANCING)

FIRST YEAR OF OPERATION 1980

CARD 4

STATE INCOME TAX RATE	.0300	
STATE GROSS REVENUE TAX RATE	.0400	
PROPERTY TAX RATE	.0320	
INTERIM CAPITAL REPLACEMENTS, \$M/YR	.5236	
PROPERTY INSURANCE, \$M/YR	.3740	
NUCLEAR LIABILITY, \$M/YR	.3170	
NUCLEAR LIABILITY, \$M/MWYE	.0000	

CARD 5

RECOVERABLE COST OF LAND, \$M	.0000	(INITIAL FINANCING)
NET SALVAGE VALUE OF PLANT, \$M	.0000	
RECOVERABLE MODERATOR AND SALT, \$M	.0000	(INITIAL FINANCING)
REACTOR OPERATING LIFE, YEARS	30.0246	

C-19

BNWL-965

ANNUAL INPUT DATA, EXPENSES IN \$M/YR

PROBLEM IDENTIFICATION REFERENCE OXIDE-FUELED LMFBR EX-55

YEAR	LOAD FACTOR	FUEL PURCHASES	FABRICATION COST	REPROCESS COST	U-PU CREDIT	BASE OPERATING COST	VARIABLE OPERATING COST	SPECIFIED BOND PAYMENTS
1 1980	.85000	14.67702	4.95722	.55453	.00000	1.11700	.68850	.00000
2 1981	.85000	14.67702	4.95722	1.11866	14.18396	1.11700	.68850	.00000
3 1982	.85000	14.67702	4.95722	1.12315	16.54060	1.11700	.68850	.00000
4 1983	.85000	14.67702	4.95722	1.12239	16.45794	1.11700	.68850	.00000
5 1984	.85000	14.67702	4.95722	1.12373	25.12319	1.11700	.68850	.00000
6 1985	.85000	14.67702	4.95722	1.12418	16.76146	1.11700	.68850	.00000
7 1986	.85000	14.67702	4.95722	1.12418	16.76146	1.11700	.68850	.00000
8 1987	.85000	14.67702	4.95722	1.12418	16.76146	1.11700	.68850	.00000
9 1988	.85000	14.67702	4.95722	1.12418	16.76146	1.11700	.68850	.00000
10 1989	.85000	14.67702	4.95722	1.12418	16.76146	1.11700	.68850	.00000
11 1990	.85000	14.67702	4.95722	1.12418	16.76146	1.11700	.68850	.00000
12 1991	.85000	14.67702	4.95722	1.12418	16.76146	1.11700	.68850	.00000
13 1992	.85000	14.67702	4.95722	1.12418	16.76146	1.11700	.68850	.00000
14 1993	.85000	14.70871	4.95722	1.12418	16.76146	1.11700	.68850	.00000
15 1994	.85000	14.67702	4.95722	1.12418	16.76146	1.11700	.68850	.00000
16 1995	.84000	14.67702	4.95722	1.12418	16.76146	1.11700	.68040	.00000
17 1996	.82000	14.64533	4.95722	1.12418	16.76146	1.11700	.66420	.00000
18 1997	.80000	14.67702	4.95722	1.12418	16.76146	1.11700	.64800	.00000
19 1998	.78000	14.67702	4.95722	1.12418	16.76146	1.11700	.63180	.00000
20 1999	.76000	14.67702	4.95722	1.12418	8.38073	1.11700	.61560	.00000
21 2000	.74000	14.67702	2.47861	1.08647	16.76146	1.11700	.59940	.00000
22 2001	.72000	7.33851	4.95722	.59981	16.76146	1.11700	.58320	.00000
23 2002	.70000	14.67702	4.95722	1.12418	16.76146	1.11700	.56700	.00000
24 2003	.68000	14.67702	2.47861	1.08647	8.38073	1.11700	.55080	.00000
25 2004	.66000	7.33851	4.95722	.59981	16.76146	1.11700	.53460	.00000
26 2005	.64000	14.67702	4.90113	1.12418	8.38073	1.11700	.51840	.00000
27 2006	.62000	7.33851	2.53470	.56209	16.76146	1.11700	.50220	.00000
28 2007	.60000	14.67702	2.47861	1.12418	8.38073	1.11700	.48600	.00000
29 2008	.58000	7.33851	4.95722	.56209	16.76146	1.11700	.46980	.00000
30 2009	.56000	7.33851	2.47861	.56209	8.38073	1.11700	.45360	.00000
31 2010	.01330	.00000	.00000	2.78922	34.36157	.02752	.01078	.00000

C-20

BNWL-965

EXPENSES BEFORE FEDERAL INCOME TAX, \$M

PROBLEM IDENTIFICATION REFERENCE OXIDE-FUELED LMFBR EX-55

YEAR	5.867 PCT PRESENT WORTH FACTOR	FUEL OPERATING EXPENSES	PRORATED 31 YR FUEL EXPENSES	NON-FUEL OPERATING EXPENSES	DEPRECIATION	BOND INTEREST	TOTAL STATE INCOME AND REVENUE TAXES
1 1980	.94458	20.18877	4.46994	8.34189	9.61671	4.01798	1.59558
2 1981	.89224	6.56894	4.46994	8.14764	9.36480	4.27158	1.60136
3 1982	.84279	4.21679	4.46994	7.95393	9.04420	4.25278	1.61735
4 1983	.79609	4.29870	4.46994	7.76079	8.72474	4.18270	1.63483
5 1984	.75197	-4.36522	4.46994	7.56821	8.40639	4.11187	1.65229
6 1985	.71030	3.99697	4.46994	7.37618	8.08918	3.84787	1.67548
7 1986	.67094	3.99697	4.46994	7.18472	7.77309	3.75385	1.69353
8 1987	.63376	3.99697	4.46994	6.99381	7.45812	3.65586	1.71165
9 1988	.59863	3.99697	4.46994	6.80346	7.14428	3.55365	1.72984
10 1989	.56546	3.99697	4.46994	6.61367	6.83157	3.44697	1.74811
11 1990	.53412	3.99697	4.46994	6.42444	6.51999	3.33555	1.76648
12 1991	.50452	3.99697	4.46994	6.23576	6.20953	3.21910	1.78495
13 1992	.47657	3.99697	4.46994	6.04765	5.90019	3.09733	1.80353
14 1993	.45016	4.02866	4.46994	5.86009	5.59198	2.96991	1.82222
15 1994	.42521	3.99697	4.46994	5.67309	5.28490	2.83720	1.84103
16 1995	.40165	3.99697	4.41735	5.47855	4.97895	2.69749	1.83370
17 1996	.37939	3.96527	4.31217	5.27647	4.67412	2.55575	1.80011
18 1997	.35836	3.99697	4.20700	5.07495	4.37041	2.41586	1.76640
19 1998	.33850	3.99697	4.10182	4.87398	4.06783	2.27930	1.73255
20 1999	.31975	12.37769	3.97665	4.67358	3.76638	2.14558	1.69856
21 2000	.30203	1.48064	3.89147	4.47373	3.46605	2.19919	1.65890
22 2001	.28529	-3.86592	3.78630	4.27444	3.16685	2.02709	1.62596
23 2002	.26948	3.99697	3.68112	4.07571	2.86878	1.73810	1.59648
24 2003	.25455	9.86137	3.57595	3.87754	2.57183	1.61593	1.56194
25 2004	.24044	-3.86592	3.47077	3.67993	2.27601	1.62640	1.52338
26 2005	.22711	12.32160	3.36560	3.48287	1.98132	1.34633	1.49348
27 2006	.21453	-6.32616	3.26042	3.28637	1.68775	1.41669	1.45301
28 2007	.20264	9.89908	3.15525	3.09044	1.39530	1.09178	1.42435
29 2008	.19141	-3.90364	3.05007	2.89506	1.10398	1.11549	1.38519
30 2009	.18080	1.99848	2.94490	2.70024	5.87526	.84776	1.20287
31 2010	.17078	-31.57235	.06997	.35027	.00000	.64758	.00536

CALCULATION OF FEDERAL INCOME TAX, \$M

PROBLEM IDENTIFICATION: REFERENCE OXIDE-FUELED LMFR EX-55

YEAR	POWER UNITS (M MWH)	TOTAL POWER SALES	TOTAL TAX DEDUCTIBLE EXPENSES	TAXABLE INCOME (FEDERAL)	FEDERAL INCOME TAX	TOTAL CASH EXPENDITURES	TOTAL CASH RECEIPTS
1 1980	7.44600	34.72353	28.04210	6.68143	3.34072	33.46696	34.72353
2 1981	7.44600	34.72353	27.85531	6.86822	3.43411	20.27565	34.72353
3 1982	7.44600	34.72353	27.33821	7.38532	3.69266	18.00433	34.72353
4 1983	7.44600	34.72353	26.77300	7.95053	3.97527	18.19319	34.72353
5 1984	7.44600	34.72353	26.20870	8.51483	4.25742	9.63629	34.72353
6 1985	7.44600	34.72353	25.45865	9.26488	4.63244	18.20467	34.72353
7 1986	7.44600	34.72353	24.87513	9.84840	4.92420	18.32302	34.72353
8 1987	7.44600	34.72353	24.28938	10.43415	5.21708	18.44310	34.72353
9 1988	7.44600	34.72353	23.70118	11.02236	5.51118	18.56504	34.72353
10 1989	7.44600	34.72353	23.11027	11.61326	5.80663	18.68898	34.72353
11 1990	7.44600	34.72353	22.51639	12.20714	6.10357	18.81505	34.72353
12 1991	7.44600	34.72353	21.91928	12.80425	6.40213	18.94340	34.72353
13 1992	7.44600	34.72353	21.31863	13.40490	6.70245	19.07419	34.72353
14 1993	7.44600	34.72353	20.71414	14.00939	7.00470	19.23926	34.72353
15 1994	7.44600	34.72353	20.10615	14.61738	7.30869	19.34337	34.72353
16 1995	7.35840	34.31501	19.40604	14.90898	7.45449	19.28731	34.31501
17 1996	7.18320	33.49798	18.61862	14.87937	7.43968	19.00513	33.49798
18 1997	7.00800	32.68096	17.83462	14.84634	7.42317	18.78509	32.68096
19 1998	6.85280	31.86393	17.05550	14.80844	7.40422	18.53132	31.86393
20 1999	6.65760	31.04691	16.28075	14.76616	7.38308	26.65651	31.04691
21 2000	6.48240	30.22989	15.69935	14.54053	7.27027	15.40714	30.22989
22 2001	6.30720	29.41286	14.88065	14.53221	7.26611	9.82419	29.41286
23 2002	6.13200	28.59584	13.96020	14.63564	7.31782	17.51058	28.59584
24 2003	5.95680	27.77881	13.20320	14.57562	7.28781	23.11226	27.77881
25 2004	5.78160	26.96179	12.57648	14.38531	7.19265	9.05363	26.96179
26 2005	5.60640	26.14476	11.66959	14.47518	7.23759	25.05914	26.14476
27 2006	5.43120	25.32774	11.10424	14.22350	7.11175	6.04858	25.32774
28 2007	5.25600	24.51072	10.15713	14.35359	7.17680	22.11427	24.51072
29 2008	5.08080	23.69369	9.54979	14.14390	7.07195	7.97216	23.69369
30 2009	4.90560	22.87667	13.57103	9.30564	4.65282	11.07801	22.87667
31 2010	.11655	.54352	1.07318	-.52966	-.26483	-30.95794	.54352

C-22

BNWL-965

PAYOUT OF INVESTMENTS, \$M

PROBLEM IDENTIFICATION

REFERENCE OXIDE-FUELED LMFBR EX-55

YEAR	TOTAL CASH FLOW	OUTSTANDING BONDS	EQUITY CAPITAL NOT RECOVERED	BOND INTEREST	EARNINGS ON UNRECOVERED EQUITY	BONDS REPAID	RECOVERY OF EQUITY
1 1980	1,25657	94,98765	87,69091	4,01798	8,76809	-5,99534	-5,53416
2 1981	14,44788	100,98299	93,21507	4,27158	9,32151	,44449	,41030
3 1982	16,71920	100,53850	92,80477	4,25278	9,28048	1,65669	1,52925
4 1983	16,53035	98,88181	91,27552	4,18270	9,12755	1,67445	1,54564
5 1984	25,08724	97,20736	89,72988	4,11187	8,97299	6,24124	5,76114
6 1985	16,51886	90,96612	83,96873	3,84787	8,39687	2,22254	2,05158
7 1986	16,40052	88,74358	81,91716	3,75385	8,19172	2,31657	2,13837
8 1987	16,28043	86,42701	79,77878	3,65586	7,97788	2,41628	2,23041
9 1988	16,15849	84,01073	77,54837	3,55365	7,75484	2,52200	2,32800
10 1989	16,03455	81,48873	75,22037	3,44697	7,52204	2,63408	2,43146
11 1990	15,90848	78,85465	72,78891	3,33555	7,27889	2,75290	2,54114
12 1991	15,78013	76,10175	70,24777	3,21910	7,02478	2,87885	2,65740
13 1992	15,64934	73,22290	67,59037	3,09733	6,75904	3,01235	2,78063
14 1993	15,48427	70,21055	64,80975	2,96991	6,48097	3,13736	2,89603
15 1994	15,38016	67,07319	61,91372	2,83720	6,19137	3,30283	3,04876
16 1995	15,02771	63,77037	58,86496	2,69749	5,88650	3,35074	3,09299
17 1996	14,49285	60,41963	55,77197	2,55575	5,57720	3,30715	3,05275
18 1997	13,89587	57,11248	52,71922	2,41586	5,27192	3,22821	2,97988
19 1998	13,33262	53,88427	49,73933	2,27930	4,97393	3,16128	2,91810
20 1999	4,39040	50,72299	46,82123	2,14558	4,68212	-1,26740	-1,16991
21 2000	14,82275	51,99040	47,99114	2,19919	4,79911	4,06871	3,75573
22 2001	19,58867	47,92169	44,23541	2,02709	4,42354	6,83178	6,30626
23 2002	11,08526	41,08990	37,92915	1,73810	3,79291	2,88821	2,66604
24 2003	4,66655	38,20170	35,26311	1,61593	3,52631	-1,24736	-1,22833
25 2004	17,90816	38,44906	35,49144	1,62640	3,54914	6,62096	6,11166
26 2005	1,08563	31,82810	29,37978	1,34633	2,93798	-1,66331	-1,53537
27 2006	19,27916	33,49141	30,91515	1,41669	3,09151	7,68090	7,09006
28 2007	2,39645	25,81051	23,82509	1,09178	2,38251	-1,56048	-1,51737
29 2008	15,72154	26,37099	24,34246	1,11549	2,43425	6,32933	5,84246
30 2009	11,79866	20,04166	18,49999	,84776	1,85000	4,73247	4,36843
31 2010	31,50146	15,30919	14,13156	,64758	1,41316	15,30918	14,13155

FIXED CHARGE CALCULATIONS

PROBLEM IDENTIFICATION: REFERENCE OXIDE-FUELED LMFBR EX-55

FIXED CHARGE RATE ON DEPRECIABLE CAPITAL .1360 (INCLUDES PLANT PROPERTY TAX, INSURANCE, REPLACEMENTS, SALVAGE)

FIXED CHG RATE ON NONDEPRECIABLE INVESTMENT .1260

CONSTANT ANNUAL INCOME REQUIRED, \$M 32.7576

TOTAL TAX-DEDUCTIBLE EXPENSES, \$M 20.6833

FUEL WORKING CAPITAL, \$M 40.8722 (EXCESS OF FUEL COST OVER AMORTIZED, RECOVERABLE D2O OR SALT)

POWER COST, MILLS/KWHE 4.6634

COST OF POWER CALCULATION

FUEL CYCLE ANALYSIS

PROBLEM IDENTIFICATION

REFERENCE OXIDE-FUELED LMFBR EX-55

POWER COST, MILLS/KWHE

4.6634

	CASH PER KWH	CASH TO EQUITY	EQUITY RETURN	BOND INTEREST	BONDS REPAID	REVENUE TAXES	TOTAL
DEPRECIABLE PLANT	1.2414	.8597	.4328	.3856	.6040	.6151	2.8972
OPERATING AND MAINTENANCE COSTS (1)	.3037	.3037	.0027	.0000	.0000	.0000	.3065
FUEL CYCLE COSTS (2)	.6810	.5967	.2690	.0852	.1335	.3753	1.4598
TOTAL	2.2262	1.7601	.7045	.4709	.7375	.9904	4.6634

(1) DETAILS OF OPERATING AND MAINTENANCE COSTS

OPERATING EXPENSES	.2570	.2570	.0030	-.0000	-.0000	.0000	.2600
RECOVERABLE LAND COSTS	.0000	.0000	-.0000	.0000	.0000	.0000	.0000
NUCLEAR LIABILITY	.0467	.0467	-.0003	.0000	.0000	.0000	.0465

(2) DETAILS OF FUEL CYCLE COSTS

FUEL PURCHASES							2.6020
INITIAL CORE	.1700	.1110	.0689	.0596	.0934	.2030	.5359
REPLACEMENT FUEL	1.9806	1.9806	.0014	.0000	.0000	.0841	2.0661
FABRICATION							.9257
INITIAL CORE	.0730	.0477	.0296	.0256	.0401	.0872	.2302
REPLACEMENT FUEL	.6690	.6690	-.0006	.0000	.0000	.0272	.6955
REPROCESSING							.1568
INITIAL CORE	.0109	.0109	-.0071	.0000	.0000	.0044	.0082
REPLACEMENT FUEL	.1516	.1516	-.0044	.0000	.0000	.0013	.1486
FUEL CREDIT							-2.2247
INITIAL CORE	-.1275	-.1275	.0828	.0000	.0000	-.0513	-.0960
REPLACEMENT FUEL	-2.2466	-2.2466	.0984	.0000	.0000	.0194	-2.1287
MODERATOR AND FUEL CARRIER RECOVERY	.0000	.0000	.0000	.0000	.0000	.0000	.0000

C-25

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

REACTOR DESCRIPTION

REACTOR STARTUP DATE	1980.0	
REACTOR POWER	2700.0	MW(TH)
ELECTRICAL CONV. EFF	37.0	PCT
TONS OF FUEL IN REACTOR	96.6	TONNE
REACTOR LIFETIME	30.0	YRS

PLANT CHARGES

BOND INTEREST RATE	4.2	PCT
EARNING RATE ON EQUITY (AFTER TAX)	10.0	PCT
NUCLEAR LIABILITY COST PER YEAR	317000.0	\$/YR
NUCLEAR LIABILITY COST PER MWYE,	-0	\$/MWY
PROPERTY INSURANCE	.3	PCT/YR
PLANT BASE OPERATING COST	1117000.0	\$/YR
FEDERAL INCOME TAX RATE	50.0	PCT
STATE INCOME TAX RATE	3.0	PCT
PROPERTY TAX RATE	3.2	PCT/YR
STATE GROSS REVENUE TAX RATE	4.0	PCT
COMBINED STATE AND LOCAL TAXES	-0	\$/YR
INTERIM CAPITAL REPLACEMENTS	.4	PCT/YR

PLANT CONSTRUCTION

CONSTRUCTION TIME	3.0	YRS
MODERATOR COST (THERMAL REACTORS)	-0	\$
FLUORIDE SALT COST	.0	\$
COST OF CONTROL SYSTEM	-0	\$
COST OF TURBINE GENERATORS	-0	\$
COST OF PRESSURE VESSEL	-0	\$
COST OF HEAT EXCHANGERS	-0	\$
COST OF REACTOR SITE PREPARATION	-0	\$
OTHER CAPITAL COSTS	14960000.0	\$
NET SALVAGE VALUE OF PLANT	-0	\$
RECOVERABLE LAND COST	-0	\$

FIXED PROCESS TIMES

URANIUM ENRICHMENT AND LEAD TIME	42.0	DAYS
PRE-FABRICATION SHIPPING TIME	8.0	DAYS
TIME IN FABRICATION	26.0	DAYS
SHIP FROM FABRICATOR TO REACT SITE	14.0	DAYS
PRE REACTOR INVENTORY TIME	30.0	DAYS
POST REACTOR COOLING	120.0	DAYS
TIME TO SHIP FUEL TO REPROCESS SITE	27.0	DAYS
(REPROCESSING TIME DETERMINED BY SIZE OF BATCH)		
SHIP TO FINAL DESTINATION	30.0	DAYS

SHIPPING CHARGES

PRE-FABRICATION SHIPPING COST.(U)	-0	\$/KG
FABRICATOR TO REACTOR SITE(U)	1.2	\$/KG
PRE-FABRICATION SHIPPING COST(RECYC)	-0	\$/KG
FABRICATOR TO REACTOR SITE(RECYC)	-0	\$/KG
REACTOR SITE TO REPROCESSING PLANT	6.9	\$/KG

COST TO SHIP TO FINAL DESTINATION	-0	\$/KG
-----------------------------------	----	-------

REPROCESSING PLANT THROUGHPUT	-0	KG/DAY
REPROCESSING PLANT OPERATING COST	-0	\$/DAY

FIRST CORE PURCHASE

FABRICATION CHARGE	8984720.3	\$
SHIPPING CHARGE	115931.9	\$
FUEL PURCHASE	25587891.0	\$
FUEL FABRICATION LOSSES	115149.7	\$

URANIUM CASCADE PRICE SCHEDULE PARAMETERS

COST OF FEED (SEE TABLE 2)		
CONVERSION COST	2.20	\$/KG
FEED COMPOSITION	.7110	PCT
COST OF SEPARATIVE DUTY	26.00	\$/KG
TAILS VALUE	.00	\$/KG

ISOTOPE PRICES

U233	14.0	\$/GM	U235	-0	\$/GM	PU239	10.0	\$/GM	PU241	10.0	\$/GM
TH232	.0	\$/GM	U238	-0	\$/GM	U234	-0	\$/GM	PU240	-0	\$/GM
PA233	-0	\$/GM	U236	-0	\$/GM	PU242	-0	\$/GM	NP237	-0	\$/GM
Am241	-0	\$/GM	Am243	-0	\$/GM	Am245	-0	\$/GM	Am247	-0	\$/GM
Am249	-0	\$/GM	Am251	-0	\$/GM	Am253	-0	\$/GM	Am255	-0	\$/GM

C-26

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

F&AD

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
1980	85.0	8.797	.000	1.021	.000	.013	.000	.040	.688	9.871
1981	85.0	9.054	8.209	2.995	1.209	.039	.300	.122	.688	5.509
1982	85.0	17.828	20.239	5.989	.902	.077	.223	.127	.688	4.908
1983	85.0	8.961	11.274	2.995	.902	.039	.223	.091	.688	1.936
1984	85.0	9.054	11.989	2.995	1.803	.039	.447	.150	.688	2.498
1985	85.0	17.828	24.675	5.989	.902	.077	.223	.136	.688	.481
1986	85.0	8.961	12.338	2.995	.902	.039	.223	.096	.688	.877
1987	85.0	9.054	12.338	2.995	1.803	.039	.447	.151	.688	2.151
1988	85.0	17.828	24.675	5.989	.902	.077	.223	.136	.688	.481
1989	85.0	8.961	12.338	2.995	.902	.039	.223	.096	.688	.877
1990	85.0	9.054	12.338	2.995	1.803	.039	.447	.096	.688	2.095
1991	85.0	17.828	24.675	5.989	.902	.077	.223	.192	.688	.536
1992	85.0	8.961	12.338	2.995	.902	.039	.223	.096	.688	.877
1993	85.0	9.054	12.338	2.995	1.803	.039	.447	.096	.688	2.095
1994	85.0	17.828	24.675	5.989	.902	.077	.223	.192	.688	.536
1995	84.0	8.961	12.338	2.995	.902	.039	.223	.096	.680	.877
1996	82.0	8.961	12.338	2.995	1.803	.039	.447	.096	.664	2.002
1997	80.0	17.921	24.675	2.995	.902	.039	.223	.151	.648	-2.444
1998	78.0	8.961	12.338	5.989	.902	.077	.223	.136	.632	3.951
1999	76.0	8.961	12.338	2.995	.902	.039	.223	.096	.616	.877
2000	74.0	8.961	12.338	2.995	.902	.039	.223	.096	.599	.877
2001	72.0	8.961	12.338	2.995	1.803	.039	.447	.096	.583	2.002
2002	70.0	8.961	12.338	2.995	.902	.039	.223	.151	.567	.933
2003	68.0	8.961	24.675	2.995	.902	.039	.223	.096	.551	-11.460
2004	66.0	8.961	12.338	2.995	.902	.039	.223	.096	.535	.877
2005	64.0	8.961	12.338	2.995	.902	.039	.223	.096	.518	.877
2006	62.0	8.961	12.338	2.995	.902	.039	.223	.096	.502	.877
2007	60.0	8.961	12.338	2.995	.902	.039	.223	.096	.486	.877
2008	58.0	8.961	.000	2.995	.902	.039	.223	.096	.470	13.215
2009	56.0	8.961	12.338	2.995	.000	.039	.000	.040	.454	-.303
2010	1.3	.000	43.846	.000	3.607	.000	.894	.197	.011	-39.149

C-27

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

TABLE 2
VARIABLE PARAMETERS

YEAR	REPROCESSING CHARGE, \$/KG,		REPROCESSING TIME, DAYS		FABRICATION CHARGE, \$/KG,		U233 OR PU FAB PENALTY	PU PRICE	U233 PRICE	U FEED PRICE
	BLKT	CORE	BLKT	CORE	BLKT	CORE	\$/KG	\$/GM	\$/GM	\$/LB U308
1977					93.0	93.0	-.0	10.0	14.00	8.00
1978					93.0	93.0	.0	10.0	14.00	8.00
1979					93.0	93.0	.0	10.0	14.00	8.00
1980	.0	.0	.0	.0	93.0	93.0	.0	10.0	14.00	8.00
1981	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1982	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1983	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1984	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1985	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1986	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1987	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1988	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1989	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1990	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1991	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1992	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1993	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1994	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1995	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1996	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1997	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1998	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
1999	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
2000	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
2001	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
2002	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
2003	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
2004	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
2005	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
2006	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
2007	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
2008	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00
2009	.0	.0	.0	.0	93.0	93.0	.0	10.0	14.00	8.00
2010	28.0	28.0	25.0	25.0	93.0	93.0	.0	10.0	14.00	8.00

C-28

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

URANIUM PURCHASES AND CREDITS									
YEAR	URANIUM PRICE ,\$/LB	TAILS COMPOSITION PCT	90 PCT ENR URANIUM PRICE ,\$/GM	U308 PURCHASED TONS	SEPARATIVE WORK PURCHASED TONS	TAILS PRODUCED TONS	EQUIVALENT U308 CREDITED TONS	EQUIVALENT SEPARATIVE WORK CREDITED TONS	TAILS CONSUMED TONS
1977	8.00	.000	.00	.0	.0	.0	.0	.0	.0
1978	8.00	.000	.00	.0	.0	.0	.0	.0	.0
1979	8.00	.000	10.97	.0	.0	-93.5	.0	.0	.0
1980	8.00	.000	10.97	.0	.0	-9.8	.0	.0	.0
1981	8.00	.000	10.97	.0	.0	-62.2	.0	.0	-9.6
1982	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-60.2
1983	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.9
1984	8.00	.000	10.97	.0	.0	-62.2	.0	.0	-29.9
1985	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-59.6
1986	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
1987	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
1988	8.00	.000	10.97	.0	.0	-62.2	.0	.0	-59.6
1989	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
1990	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
1991	8.00	.000	10.97	.0	.0	-62.2	.0	.0	-59.6
1992	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
1993	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
1994	8.00	.000	10.97	.0	.0	-62.2	.0	.0	-59.6
1995	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
1996	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
1997	8.00	.000	10.97	.0	.0	-62.2	.0	.0	-59.6
1998	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
1999	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
2000	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
2001	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
2002	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
2003	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-59.6
2004	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
2005	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
2006	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
2007	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
2008	8.00	.000	10.97	.0	.0	-31.1	.0	.0	.0
2009	8.00	.000	10.97	.0	.0	-31.1	.0	.0	-29.8
2010	8.00	.000	10.97	.0	.0	.0	.0	.0	-120.9

C-29

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

TABLE 3
FUEL DISCHARGE SUMMARY

DISCHARGE NUMBER	CASE NUMBER	DISCHARGE TIME, YRS AFTER STARTUP	CALENDAR TIME	RESIDENCE TIME, YRS	TONNES DISCHARGED	FUEL EXPOSURE MWD/TONNE	INITIAL ENRICHMENT	FINAL ENRICHMENT
1	1L	.75	1980.	.75	6.8	28630.0	12.75	12.51
2	2L	.75	1980.	.75	4.2	500.0	.30	.62
3	3L	1.51	1981.	1.51	6.8	56170.0	12.75	12.39
4	4L	1.51	1981.	1.51	4.2	1240.0	.30	1.09
5	5L	1.51	1981.	1.51	21.2	1780.0	.30	1.11
6	6L	2.26	1982.	2.26	6.8	83400.0	12.75	11.78
7	7L	2.26	1982.	2.26	4.2	1990.0	.30	1.57
8	8L	2.26	1982.	2.26	21.2	2680.0	.30	1.51
9	9L	3.01	1983.	3.01	21.2	2680.0	.30	1.59
10	10L	3.01	1983.	2.26	6.8	81530.0	13.26	12.64
11	11L	3.01	1983.	2.26	4.2	2490.0	.31	1.89
12	12L	3.76	1983.	2.26	6.8	80400.0	13.41	12.82
13	13L	3.76	1983.	2.26	4.2	2750.0	.31	2.06
14	14L	3.76	1983.	2.26	21.2	3570.0	.30	1.84
15	15L	4.52	1984.	2.26	6.8	79360.0	13.41	12.83
16	16L	4.52	1984.	2.26	4.2	3000.0	.31	2.22
17	17L	4.52	1984.	2.26	21.2	3870.0	.30	1.96
18	18L	5.27	1985.	2.26	6.8	79360.0	13.41	12.83
19	19L	5.27	1985.	2.26	4.2	3000.0	.31	2.22
20	20L	5.27	1985.	2.26	21.2	3870.0	.30	1.96
21	21L	6.02	1986.	2.26	6.8	79360.0	13.41	12.83
22	22L	6.02	1986.	2.26	4.2	3000.0	.31	2.22
23	23L	6.02	1986.	2.26	21.2	3870.0	.30	1.96
24	24L	6.77	1986.	2.26	6.8	79360.0	13.41	12.83
25	25L	6.77	1986.	2.26	4.2	3000.0	.31	2.22
26	26L	6.77	1986.	2.26	21.2	3870.0	.30	1.96
27	27L	7.53	1987.	2.26	6.8	79360.0	13.41	12.83
28	28L	7.53	1987.	2.26	4.2	3000.0	.31	2.22
29	29L	7.53	1987.	2.26	21.2	3870.0	.30	1.96
30	30L	8.28	1988.	2.26	6.8	79360.0	13.41	12.83
31	31L	8.28	1988.	2.26	4.2	3000.0	.31	2.22
32	32L	8.28	1988.	2.26	21.2	3870.0	.30	1.96
33	33L	9.03	1989.	2.26	6.8	79360.0	13.41	12.83
34	34L	9.03	1989.	2.26	4.2	3000.0	.31	2.22

C-30

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

TABLE 3
FUEL DISCHARGE SUMMARY

DISCHARGE NUMBER	CASE NUMBER	DISCHARGE TIME, YRS AFTER STARTUP	CALENDAR TIME	RESIDENCE TIME, YRS	TONNES DISCHARGED	FUEL EXPOSURE MWD/TONNE	INITIAL ENRICHMENT	FINAL ENRICHMENT
35	35L	9.03	1989.	2.26	21.2	3870.0	.30	1.96
36	36L	9.78	1989.	2.26	6.8	79360.0	13.41	12.83
37	37L	9.78	1989.	2.26	4.2	3000.0	.31	2.22
38	38L	9.78	1989.	2.26	21.2	3870.0	.30	1.96
39	39L	10.54	1990.	2.26	6.8	79360.0	13.41	12.83
40	40L	10.54	1990.	2.26	4.2	3000.0	.31	2.22
41	41L	10.54	1990.	2.26	21.2	3870.0	.30	1.96
42	42L	11.29	1991.	2.26	6.8	79360.0	13.41	12.83
43	43L	11.29	1991.	2.26	4.2	3000.0	.31	2.22
44	44L	11.29	1991.	2.26	21.2	3870.0	.30	1.96
45	45L	12.04	1992.	2.26	6.8	79360.0	13.41	12.83
46	46L	12.04	1992.	2.26	4.2	3000.0	.31	2.22
47	47L	12.04	1992.	2.26	21.2	3870.0	.30	1.96
48	48L	12.80	1992.	2.26	6.8	79360.0	13.41	12.83
49	49L	12.80	1992.	2.26	4.2	3000.0	.31	2.22
50	50L	12.80	1992.	2.26	21.2	3870.0	.30	1.96
51	51L	13.55	1993.	2.26	6.8	79360.0	13.41	12.83
52	52L	13.55	1993.	2.26	4.2	3000.0	.31	2.22
53	53L	13.55	1993.	2.26	21.2	3870.0	.30	1.96
54	54L	14.30	1994.	2.26	6.8	79360.0	13.41	12.83
55	55L	14.30	1994.	2.26	4.2	3000.0	.31	2.22
56	56L	14.30	1994.	2.26	21.2	3870.0	.30	1.96
57	57L	15.05	1995.	2.26	6.8	79360.0	13.41	12.83
58	58L	15.05	1995.	2.26	4.2	3000.0	.31	2.22
59	59L	15.05	1995.	2.26	21.2	3870.0	.30	1.96
60	60L	15.81	1995.	2.27	6.8	79360.0	13.41	12.83
61	61L	15.81	1995.	2.27	4.2	3000.0	.31	2.22
62	62L	15.81	1995.	2.27	21.2	3870.0	.30	1.96
63	63L	16.59	1996.	2.29	6.8	79360.0	13.41	12.83
64	64L	16.59	1996.	2.29	4.2	3000.0	.31	2.22
65	65L	16.59	1996.	2.29	21.2	3870.0	.30	1.96
66	66L	17.38	1997.	2.32	6.8	79360.0	13.41	12.83
67	67L	17.38	1997.	2.32	4.2	3000.0	.31	2.22
68	68L	17.38	1997.	2.32	21.2	3870.0	.30	1.96

C-31

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

TABLE 3
FUEL DISCHARGE SUMMARY

DISCHARGE NUMBER	CASE NUMBER	DISCHARGE TIME, YRS AFTER STARTUP	CALENDAR TIME	RESIDENCE TIME, YRS	TONNES DISCHARGED	FUEL EXPOSURE MWD/TONNE	INITIAL ENRICHMENT	FINAL ENRICHMENT
69	69L	18.18	1998.	2.37	6.8	79360.0	13.41	12.83
70	70L	18.18	1998.	2.37	4.2	3000.0	.31	2.22
71	71L	18.18	1998.	2.37	21.2	3870.0	.30	1.96
72	72L	19.00	1999.	2.42	6.8	79360.0	13.41	12.83
73	73L	19.00	1999.	2.42	4.2	3000.0	.31	2.22
74	74L	19.00	1999.	2.42	21.2	3870.0	.30	1.96
75	75L	19.84	1999.	2.47	6.8	79360.0	13.41	12.83
76	76L	19.84	1999.	2.47	4.2	3000.0	.31	2.22
77	77L	19.84	1999.	2.47	21.2	3870.0	.30	1.96
78	78L	20.70	2000.	2.52	6.8	79360.0	13.41	12.83
79	79L	20.70	2000.	2.52	4.2	3000.0	.31	2.22
80	80L	20.70	2000.	2.52	21.2	3870.0	.30	1.96
81	81L	21.58	2001.	2.58	6.8	79360.0	13.41	12.83
82	82L	21.58	2001.	2.58	4.2	3000.0	.31	2.22
83	83L	21.58	2001.	2.58	21.2	3870.0	.30	1.96
84	84L	22.48	2002.	2.64	6.8	79360.0	13.41	12.83
85	85L	22.48	2002.	2.64	4.2	3000.0	.31	2.22
86	86L	22.48	2002.	2.64	21.2	3870.0	.30	1.96
87	87L	23.41	2003.	2.71	6.8	79360.0	13.41	12.83
88	88L	23.41	2003.	2.71	4.2	3000.0	.31	2.22
89	89L	23.41	2003.	2.71	21.2	3870.0	.30	1.96
90	90L	24.36	2004.	2.78	6.8	79360.0	13.41	12.83
91	91L	24.36	2004.	2.78	4.2	3000.0	.31	2.22
92	92L	24.36	2004.	2.78	21.2	3870.0	.30	1.96
93	93L	25.34	2005.	2.86	6.8	79360.0	13.41	12.83
94	94L	25.34	2005.	2.86	4.2	3000.0	.31	2.22
95	95L	25.34	2005.	2.86	21.2	3870.0	.30	1.96
96	96L	26.35	2006.	2.94	6.8	79360.0	13.41	12.83
97	97L	26.35	2006.	2.94	4.2	3000.0	.31	2.22
98	98L	26.35	2006.	2.94	21.2	3870.0	.30	1.96
99	99L	27.39	2007.	3.03	6.8	79360.0	13.41	12.83
100	100L	27.39	2007.	3.03	4.2	3000.0	.31	2.22
101	101L	27.39	2007.	3.03	21.2	3870.0	.30	1.96
102	102L	28.47	2008.	3.13	6.8	79360.0	13.41	12.83

C-32

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

TABLE 3
FUEL DISCHARGE SUMMARY

DISCHARGE NUMBER	CASE NUMBER	DISCHARGE AFTER STARTUP	TIME, YRS CALENDAR TIME	RESIDENCE TIME, YRS	TONNES DISCHARGED	FUEL EXPOSURE MWD/TONNE	INITIAL ENRICHMENT	FINAL ENRICHMENT
103	103L	28.47	2008.	3.13	4.2	3000.0	.31	2.22
104	104L	28.47	2008.	3.13	21.2	3870.0	.30	1.96
105	105L	29.60	2009.	3.25	6.8	79360.0	13.41	12.83
106	106L	29.60	2009.	3.25	4.2	3000.0	.31	2.22
107	107L	29.60	2009.	3.25	21.2	3870.0	.30	1.96
108	108L	30.02	2010.	2.63	6.8	62700.1	13.41	12.96
109	108L	30.02	2010.	2.63	4.2	2370.2	.31	1.82
110	108L	30.02	2010.	1.55	6.8	36245.4	13.41	13.16
111	108L	30.02	2010.	1.55	4.2	1370.2	.31	1.18
112	108L	30.02	2010.	1.55	21.2	1767.5	.30	1.06
113	108L	30.02	2010.	.43	6.8	9790.7	13.41	13.34
114	108L	30.02	2010.	.43	4.2	370.1	.31	.55
115	108L	30.02	2010.	.43	21.2	477.4	.30	.50
116	108L	30.02	2010.	2.63	21.2	3057.6	.30	1.61

C-33

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

TABLE 4
REACTOR PROPERTIES TABLE

AVERAGE PLANT CAPACITY FACTOR, PER-CENT	76.1
INITIAL FULL POWER SPECIFIC POWER, MW/TONNE HEAVY METAL	27.9
YIELD, FISSILE KG PER MWE-YEAR	.469
YIELD, KG PU PER MWE-YEAR	.500
YIELD, KG U235 PER MWE-YEAR	-.031
YIELD, KG U233 PER MWE-YEAR	.000
SPECIFIC INVENTORY, KG OF FISSILE MATERIAL PER MEGAWATT ELECTRICAL	2.84
TONNE OF U308 MINED PER MWE-YEAR	.000
TONNE OF U308 MINED PER MW-YR (THERMAL)	.000
KILOGRAMS FISSIONED PER TONNE OF U308 MINED	.00
KG SEPARATIVE DUTY PER MWE-YR	.00
TONS OF U308 CONSUMED	.0
TONS OF SEPARATIVE DUTY CONSUMED	.0
KG FABRICATED PER MWE-YR	984.0

C-34

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

TABLE 5
KILOGRAMS FABRICATED EACH YEAR
(BEFORE LOSSES)

YEAR	TH232	PA233	U233	U234	U235	U236	U238	PU239	PU240	PU241	PU242
1977	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1978	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1979	.0	.0	.0	.0	279.4	.0	93214.6	2131.5	852.8	430.1	142.5
1980	.0	.0	.0	.0	30.1	.0	9770.0	836.8	319.4	49.7	25.1
1981	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
1982	.0	.0	.0	.0	186.8	.0	62017.1	1693.6	646.9	99.4	50.2
1983	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
1984	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
1985	.0	.0	.0	.0	186.8	.0	62017.1	1693.6	646.9	99.4	50.2
1986	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
1987	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
1988	.0	.0	.0	.0	186.8	.0	62017.1	1693.6	646.9	99.4	50.2
1989	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
1990	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
1991	.0	.0	.0	.0	186.8	.0	62017.1	1693.6	646.9	99.4	50.2
1992	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
1993	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
1994	.0	.0	.0	.0	186.8	.0	62017.1	1693.6	646.9	99.4	50.2
1995	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
1996	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
1997	.0	.0	.0	.0	186.8	.0	62017.1	1693.6	646.9	99.4	50.2
1998	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
1999	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
2000	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
2001	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
2002	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
2003	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
2004	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
2005	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
2006	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
2007	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
2008	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
2009	.0	.0	.0	.0	93.4	.0	31008.5	846.8	323.5	49.7	25.1
2010	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

C-35

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

TABLE 5
KILOGRAMS FABRICATED EACH YEAR
(BEFORE LOSSES)

YEAR	HP237	U-235	U-238	MOX	U-235	U-238	MOX	U-235	U-238	FISS PRD	TOTAL
1977	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1978	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1979	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	97050.9
1980	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	11031.1
1981	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
1982	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	64694.1
1983	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
1984	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
1985	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	64694.1
1986	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
1987	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
1988	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	64694.1
1989	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
1990	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
1991	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	64694.1
1992	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
1993	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
1994	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	64694.1
1995	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
1996	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
1997	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	64694.1
1998	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
1999	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
2000	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
2001	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
2002	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
2003	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
2004	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
2005	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
2006	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
2007	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
2008	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
2009	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	32347.1
2010	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

C-36

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

TABLE 6
KILOGRAMS REPROCESSED EACH YEAR
(AFTER LOSSES)

YEAR	TH232	PA233	U233	U234	U235	U236	U238	PU239	PU240	PU241	PU242
1977	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1978	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1979	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1980	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1981	.0	.0	.0	.0	106.0	.0	39731.4	1580.4	573.7	219.3	95.6
1982	.0	.0	.0	.0	77.4	.0	29883.9	933.7	292.6	87.7	46.8
1983	.0	.0	.0	.0	76.1	.0	29867.0	1063.2	327.8	55.6	23.9
1984	.0	.0	.0	.0	149.2	.0	59523.9	2304.3	664.6	111.3	47.8
1985	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
1986	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
1987	.0	.0	.0	.0	147.9	.0	59491.1	2339.0	665.0	111.5	47.8
1988	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
1989	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
1990	.0	.0	.0	.0	147.9	.0	59491.1	2339.0	665.0	111.5	47.8
1991	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
1992	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
1993	.0	.0	.0	.0	147.9	.0	59491.1	2339.0	665.0	111.5	47.8
1994	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
1995	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
1996	.0	.0	.0	.0	147.9	.0	59491.1	2339.0	665.0	111.5	47.8
1997	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
1998	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
1999	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
2000	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
2001	.0	.0	.0	.0	147.9	.0	59491.1	2339.0	665.0	111.5	47.8
2002	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
2003	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
2004	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
2005	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
2006	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
2007	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
2008	.0	.0	.0	.0	74.0	.0	29745.5	1169.5	332.5	55.7	23.9
2009	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2010	.0	.0	.0	.0	326.2	.0	120586.8	4139.7	1310.5	210.0	97.2

C-37

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

TABLE 6
KILOGRAMS REPROCESSED EACH YEAR
(AFTER LOSSES)

YEAR	NP237	U-235	U-238	MOX	U-235	U-238	MOX	U-235	U-238	FISS PRD	TOTAL
1977	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1978	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1979	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1980	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1981	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	42306.3
1982	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31322.0
1983	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31413.5
1984	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	62801.1
1985	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
1986	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
1987	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	62802.3
1988	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
1989	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
1990	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	62802.3
1991	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
1992	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
1993	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	62802.3
1994	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
1995	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
1996	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	62802.3
1997	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
1998	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
1999	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
2000	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
2001	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	62802.3
2002	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
2003	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
2004	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
2005	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
2006	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
2007	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
2008	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	31401.2
2009	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2010	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	126670.4

C-38

BNWL-965

WINTER 67-68

REACTOR AND FUEL CYCLE DESCRIPTION

CARBIDE-FUELED LMFBR EX-52

FBAD

INPUT DATA

CARD 1

BOND REPAYMENT PROPORTIONAL
SUM OF YEARS DIGITS DEPRECIATION

CARD 2

PLANT INVESTMENT, \$M	149.6000	(INITIAL FINANCING)
PROJECT LIFE, YEARS	30.5781	
NONFUEL WORKING CAPITAL, \$M	.0000	(INITIAL FINANCING)
FRACTION OF INITIAL INVESTMENT IN BONDS	.5200	
BOND INTEREST RATE	.0423	
EQUITY EARNING RATE (AFTER TAXES)	.1000	
FEDERAL INCOME TAX RATE	.5000	

CARD 3

REACTOR POWER, MWE	999.0000	
DEPRECIABLE LIFE, YEARS	30.0000	
NONFUEL VARIABLE OPERATING COST FACTOR	.8100	
INITIAL CORE INVESTMENT, \$M	34.8037	(INITIAL FINANCING)

FIRST YEAR OF OPERATION 1980

CARD 4

STATE INCOME TAX RATE	.0300
STATE GROSS REVENUE TAX RATE	.0400
PROPERTY TAX RATE	.0320
INTERIM CAPITAL REPLACEMENTS, \$M/YR	.5236
PROPERTY INSURANCE, \$M/YR	.3740
NUCLEAR LIABILITY, \$M/YR	.3170
NUCLEAR LIABILITY, \$M/MWYE	.0000

CARD 5

RECOVERABLE COST OF LAND, \$M	.0000	(INITIAL FINANCING)
NET SALVAGE VALUE OF PLANT, \$M	.0000	
RECOVERABLE MODERATOR AND SALT, \$M	.0000	(INITIAL FINANCING)
REACTOR OPERATING LIFE, YEARS	30.0246	

C-39

BNWL-965

ANNUAL INPUT DATA, EXPENSES IN \$M/YR

PROBLEM IDENTIFICATION CARBIDE-FUELED LMFBR EX-52

YEAR	LOAD FACTOR	FUEL PURCHASES	FABRICATION COST	REPROCESS COST	U-PU CREDIT	BASE OPERATING COST	VARIABLE OPERATING COST	SPECIFIED BOND PAYMENTS
1 1980	.85000	8.79747	1.07400	.00000	.00000	1.11700	.68850	.00000
2 1981	.85000	9.05353	3.07366	1.59057	8.20850	1.11700	.68850	.00000
3 1982	.85000	17.82815	6.14731	1.17158	20.23915	1.11700	.68850	.00000
4 1983	.85000	8.96056	3.07366	1.17584	11.27422	1.11700	.68850	.00000
5 1984	.85000	9.05353	3.07366	2.35968	11.98872	1.11700	.68850	.00000
6 1985	.85000	17.82815	6.14731	1.18062	24.67512	1.11700	.68850	.00000
7 1986	.85000	8.96056	3.07366	1.18062	12.33756	1.11700	.68850	.00000
8 1987	.85000	9.05353	3.07366	2.36125	12.33756	1.11700	.68850	.00000
9 1988	.85000	17.82815	6.14731	1.18062	24.67512	1.11700	.68850	.00000
10 1989	.85000	8.96056	3.07366	1.18062	12.33756	1.11700	.68850	.00000
11 1990	.85000	9.05353	3.07366	2.30573	12.33756	1.11700	.68850	.00000
12 1991	.85000	17.82815	6.14731	1.23614	24.67512	1.11700	.68850	.00000
13 1992	.85000	8.96056	3.07366	1.18062	12.33756	1.11700	.68850	.00000
14 1993	.85000	9.05353	3.07366	2.30573	12.33756	1.11700	.68850	.00000
15 1994	.85000	17.82815	6.14731	1.23614	24.67512	1.11700	.68850	.00000
16 1995	.84000	8.96056	3.07366	1.18062	12.33756	1.11700	.68040	.00000
17 1996	.82000	8.96056	3.07366	2.30573	12.33756	1.11700	.66420	.00000
18 1997	.80000	17.92112	3.07366	1.23614	24.67512	1.11700	.64800	.00000
19 1998	.78000	8.96056	6.14731	1.18062	12.33756	1.11700	.63180	.00000
20 1999	.76000	8.96056	3.07366	1.18062	12.33756	1.11700	.61560	.00000
21 2000	.74000	8.96056	3.07366	1.18062	12.33756	1.11700	.59940	.00000
22 2001	.72000	8.96056	3.07366	2.30573	12.33756	1.11700	.58320	.00000
23 2002	.70000	8.96056	3.07366	1.23614	12.33756	1.11700	.56700	.00000
24 2003	.68000	8.96056	3.07366	1.18062	24.67512	1.11700	.55080	.00000
25 2004	.66000	8.96056	3.07366	1.18062	12.33756	1.11700	.53460	.00000
26 2005	.64000	8.96056	3.07366	1.18062	12.33756	1.11700	.51840	.00000
27 2006	.62000	8.96056	3.07366	1.18062	12.33756	1.11700	.50220	.00000
28 2007	.60000	8.96056	3.07366	1.18062	12.33756	1.11700	.48600	.00000
29 2008	.58000	8.96056	3.07366	1.18062	.00000	1.11700	.46980	.00000
30 2009	.56000	8.96056	3.07366	.00000	12.33756	1.11700	.45360	.00000
31 2010	.01330	.00000	.00000	4.69772	43.84628	.02752	.01076	.00000

C-40

BNWL-965

EXPENSES BEFORE FEDERAL INCOME TAX, \$M

PROBLEM IDENTIFICATION CARBIDE-FUELED LMFBF EX-52

YEAR	5.867 PCT PRESENT WORTH FACTOR	FUEL OPERATING EXPENSES	PRORATED 31 YR FUEL EXPENSES	NON-FUEL OPERATING EXPENSES	DEPRECIATION	BOND INTEREST	TOTAL STATE INCOME AND REVENUE TAXES
1 1980	.94458	9.87147	1.65966	8.39742	9.61671	4.05614	1.51413
2 1981	.89224	5.50925	1.65966	8.20131	9.36480	4.14173	1.52500
3 1982	.84279	4.90790	1.65966	8.00576	9.04420	4.14866	1.54028
4 1983	.79609	1.93584	1.65966	7.81077	8.72474	4.14432	1.55584
5 1984	.75197	2.49813	1.65966	7.61634	8.40639	4.07589	1.57328
6 1985	.71030	.48097	1.65966	7.42246	8.08918	4.01735	1.59037
7 1986	.67094	.67728	1.65966	7.22915	7.77309	3.91253	1.60879
8 1987	.63376	2.15087	1.65966	7.03639	7.45812	3.81179	1.62705
9 1988	.59863	.48097	1.65966	6.84419	7.14428	3.73467	1.64454
10 1989	.56546	.87728	1.65966	6.65255	6.83157	3.61779	1.66318
11 1990	.53412	2.09535	1.65966	6.46147	6.51999	3.50428	1.68167
12 1991	.50452	.53649	1.65966	6.27094	6.20953	3.41239	1.69945
13 1992	.47657	.87728	1.65966	6.08098	5.90019	3.28230	1.71833
14 1993	.45016	2.09535	1.65966	5.89157	5.59198	3.15356	1.73712
15 1994	.42521	.53649	1.65966	5.70273	5.28490	3.04553	1.75524
16 1995	.40165	.87728	1.64013	5.50634	4.97895	2.89833	1.74913
17 1996	.37939	2.00238	1.60108	5.30241	4.67412	2.75548	1.71747
18 1997	.35836	-2.44420	1.56203	5.09903	4.37041	2.63852	1.68498
19 1998	.33850	3.95094	1.52293	4.89622	4.06783	2.42640	1.65530
20 1999	.31975	.87728	1.48393	4.69396	3.76638	2.35200	1.62144
21 2000	.30203	.87728	1.44488	4.49227	3.46605	2.21513	1.58940
22 2001	.28529	2.00238	1.40583	4.29113	3.16685	2.07972	1.55727
23 2002	.26948	.93280	1.36678	4.09055	2.86878	1.97059	1.52430
24 2003	.25455	-11.46028	1.32773	3.89053	2.57183	1.84101	1.49189
25 2004	.24044	.87728	1.28868	3.69107	2.27601	1.44070	1.46755
26 2005	.22711	.87728	1.24963	3.49216	1.98132	1.29774	1.43544
27 2006	.21453	.87728	1.21057	3.29382	1.68775	1.15585	1.40325
28 2007	.20264	.87728	1.17152	3.09603	1.39530	1.01509	1.37097
29 2008	.19141	13.21484	1.13247	2.89880	1.10398	.87551	1.33861
30 2009	.18080	-.30334	1.09342	2.70213	5.87526	1.00855	1.14618
31 2010	.17078	-39.14856	.02598	.35212	.00000	.80414	-.00062

C-41

BNWL-965

CALCULATION OF FEDERAL INCOME TAX, \$M

PROBLEM IDENTIFICATION CARBIDE-FUELED LMFBR EX-52

YEAR	POWER UNITS (M MWH)	TOTAL POWER SALES	TOTAL TAX DEDUCTIBLE EXPENSES	TAXABLE INCOME (FEDERAL)	FEDERAL INCOME TAX	TOTAL CASH EXPENDITURES	TOTAL CASH RECEIPTS
1 1980	7.43855	32.35504	25.24406	7.11099	3.55549	23.33852	32.35504
2 1981	7.43855	32.35504	24.89250	7.46254	3.73127	19.49043	32.35504
3 1982	7.43855	32.35504	24.39857	7.95644	3.97824	18.95577	32.35504
4 1983	7.43855	32.35504	23.89533	8.45971	4.22986	16.05591	32.35504
5 1984	7.43855	32.35504	23.33156	9.02348	4.51174	16.72309	32.35504
6 1985	7.43855	32.35504	22.77902	9.57603	4.78801	14.80542	32.35504
7 1986	7.43855	32.35504	22.18321	10.17183	5.08592	15.32474	32.35504
8 1987	7.43855	32.35504	21.59301	10.76204	5.38102	16.71892	32.35504
9 1988	7.43855	32.35504	21.02734	11.32770	5.66385	15.15716	32.35504
10 1989	7.43855	32.35504	20.42475	11.93029	5.96514	15.68175	32.35504
11 1990	7.43855	32.35504	19.82706	12.52799	6.26399	17.02607	32.35504
12 1991	7.43855	32.35504	19.25197	13.10307	6.55154	15.58203	32.35504
13 1992	7.43855	32.35504	18.64147	13.71358	6.85679	16.05698	32.35504
14 1993	7.43855	32.35504	18.03390	14.32115	7.16057	17.40822	32.35504
15 1994	7.43855	32.35504	17.44805	14.90699	7.45350	15.97156	32.35504
16 1995	7.35104	31.97439	16.77287	15.20152	7.60076	16.25710	31.97439
17 1996	7.17601	31.21309	16.05055	15.16254	7.58127	17.12712	31.21309
18 1997	7.00099	30.45180	15.35498	15.09681	7.54841	12.41183	30.45180
19 1998	6.82596	29.69050	14.56874	15.12176	7.56088	18.58694	29.69050
20 1999	6.65094	28.92920	13.91772	15.01146	7.50574	15.22203	28.92920
21 2000	6.47591	28.16791	13.20774	14.96017	7.48009	14.96264	28.16791
22 2001	6.30089	27.40661	12.50080	14.90581	7.45291	15.82729	27.40661
23 2002	6.12586	26.64532	11.82100	14.82432	7.41216	14.48341	26.64532
24 2003	5.95084	25.88402	11.12299	14.76103	7.38052	1.82626	25.88402
25 2004	5.77582	25.12273	10.16401	14.95872	7.47936	14.03886	25.12273
26 2005	5.60079	24.36143	9.45629	14.90515	7.45257	13.78106	24.36143
27 2006	5.42577	23.60014	8.75124	14.84890	7.42445	13.52240	23.60014
28 2007	5.25074	22.83884	8.04892	14.78993	7.39496	13.26285	22.83884
29 2008	5.07572	22.07755	7.34938	14.72817	7.36409	25.33994	22.07755
30 2009	4.90069	21.31625	11.82554	9.49072	4.74536	8.81392	21.31625
31 2010	.11643	.50645	1.18162	-.67517	-.33759	-38.61104	.50645

C-42

BNWL-965

PAYOUT OF INVESTMENTS, \$M

PROBLEM IDENTIFICATION CARBIDE-FUELED LMFBR EX-52

YEAR	TOTAL CASH FLOW	OUTSTANDING BONDS	EQUITY CAPITAL NOT RECOVERED	BOND INTEREST	EARNINGS ON UNRECOVERED EQUITY	BONDS REPAID	RECOVERY OF EQUITY
1 1980	9.01653	95.88992	88.51377	4.05614	8.85138	-2.02332	-1.86768
2 1981	12.86461	97.91323	90.38145	4.14173	9.03814	-.16394	-.15133
3 1982	13.39927	98.07717	90.53277	4.14866	9.05328	.10261	.09472
4 1983	16.29914	97.97456	90.43806	4.14432	9.04381	1.61773	1.49329
5 1984	15.63196	96.35683	88.94477	4.07589	8.89448	1.38402	1.27756
6 1985	17.54963	94.97281	87.66721	4.01735	8.76672	2.47809	2.28747
7 1986	17.03031	92.49472	85.37974	3.91253	8.53797	2.38150	2.19831
8 1987	15.63612	90.11322	83.18144	3.81179	8.31814	1.82322	1.68297
9 1988	17.19789	88.29000	81.49846	3.73467	8.14985	2.76296	2.55042
10 1989	16.67329	85.52705	78.94804	3.61779	7.89480	2.68356	2.47713
11 1990	15.32897	82.84349	76.47091	3.50428	7.64709	2.17235	2.00525
12 1991	16.77302	80.67113	74.46567	3.41239	7.44657	3.07531	2.83875
13 1992	16.29806	77.59582	71.62692	3.28230	7.16269	3.04360	2.80947
14 1993	14.94683	74.55223	68.81744	3.15356	6.88174	2.55399	2.35753
15 1994	16.38349	71.99824	66.45991	3.04553	6.64599	3.47983	3.21215
16 1995	15.71729	68.51841	63.24777	2.89833	6.32478	3.37698	3.11721
17 1996	14.08597	65.14143	60.13056	2.75548	6.01306	2.76506	2.55236
18 1997	18.03997	62.37637	57.57819	2.63852	5.75782	5.01469	4.62894
19 1998	11.10356	57.36169	52.94925	2.42640	5.29493	1.75876	1.62347
20 1999	13.70718	55.60293	51.32578	2.35200	5.13258	3.23575	2.98685
21 2000	13.20527	52.36718	48.33893	2.21513	4.83389	3.20125	2.95500
22 2001	11.57933	49.16593	45.38394	2.07972	4.53839	2.57983	2.38138
23 2002	12.16191	46.58610	43.00255	1.97059	4.30026	3.06335	2.82771
24 2003	24.05777	43.52274	40.17484	1.84101	4.01748	9.46362	8.73565
25 2004	11.08387	34.05912	31.43919	1.44070	3.14392	3.37961	3.11964
26 2005	10.58038	30.67951	28.31955	1.29774	2.83196	3.35435	3.09633
27 2006	10.07774	27.32516	25.22323	1.15585	2.52232	3.32777	3.07179
28 2007	9.57600	23.99739	22.15144	1.01509	2.21514	3.29980	3.04597
29 2008	-3.26239	20.69759	19.10547	.87551	1.91055	-3.14519	-2.90325
30 2009	12.50233	23.84278	22.00872	1.00855	2.20087	4.83231	4.46060
31 2010	39.11749	19.01047	17.54813	.80414	1.75481	19.01044	17.54810

C-43

BNWL-965

FIXED CHARGE CALCULATIONS

PROBLEM IDENTIFICATION CARBIDE-FUELED LMFBR EX-52

FIXED CHARGE RATE ON DEPRECIABLE CAPITAL	.1360	(INCLUDES PLANT PROPERTY TAX, INSURANCE, REPLACEMENTS, SALVAGE)
FIXED CHG RATE ON NONDEPRECIABLE INVESTMENT	.1260	
CONSTANT ANNUAL INCOME REQUIRED, \$M	30.5232	
TOTAL TAX-DEDUCTIBLE EXPENSES, \$M	17.9590	
FUEL WORKING CAPITAL, \$M	44.7603	(EXCESS OF FUEL COST OVER AMORTIZED, RECOVERABLE D2O OR SALT)
POWER COST, MILLS/KWHE	4.3496	

C-44

BNWL-965

COST OF POWER CALCULATION

FUEL CYCLE ANALYSIS

PROBLEM IDENTIFICATION CARBIDE-FUELED LMFBR EX-52

POWER COST, MILLS/KWHE 4.3496

	CASH PER KWH	CASH TO EQUITY	EQUITY RETURN	BOND INTEREST	BONDS REPAID	REVENUE TAXES	TOTAL
DEPRECIABLE PLANT	1.2427	.8606	.4332	.3920	.6018	.6125	2.9001
OPERATING AND MAINTENANCE COSTS (1)	.3040	.3040	.0027	.0000	.0000	.0000	.3068
FUEL CYCLE COSTS (2)	.3082	.2193	.2980	.0912	.1400	.3943	1.1428
TOTAL	1.8549	1.3839	.7339	.4832	.7418	1.0068	4.3496
(1) DETAILS OF OPERATING AND MAINTENANCE COSTS							
OPERATING EXPENSES	.2573	.2573	.0030	-.0000	-.0000	.0000	.2603
RECOVERABLE LAND COSTS	.0000	.0000	-.0000	.0000	.0000	.0000	.0000
NUCLEAR LIABILITY	.0468	.0468	-.0003	.0000	.0000	.0000	.0465
(2) DETAILS OF FUEL CYCLE COSTS							
FUEL PURCHASES							2.2227
INITIAL CORE	.1882	.1229	.0763	.0670	.1029	.2315	.6006
REPLACEMENT FUEL	1.5837	1.5837	-.0129	.0000	.0000	.0512	1.6221
FABRICATION							.7421
INITIAL CORE	.0678	.0442	.0275	.0241	.0371	.0834	.2163
REPLACEMENT FUEL	.5337	.5337	-.0140	.0000	.0000	.0061	.5258
REPROCESSING							.2105
INITIAL CORE	.0231	.0231	-.0150	.0000	.0000	.0093	.0174
REPLACEMENT FUEL	.1991	.1991	-.0067	.0000	.0000	.0006	.1931
FUEL CREDIT							-2.0324
INITIAL CORE	-.1548	-.1548	.1005	.0000	.0000	-.0623	-.1165
REPLACEMENT FUEL	-2.1327	-2.1327	.1423	.0000	.0000	.0745	-1.9159
MODERATOR AND FUEL CARRIER RECOVERY	.0000	.0000	.0000	.0000	.0000	.0000	.0000

C-45

BNWL-965

DISTRIBUTIONNumber of Copies

224	<u>Division of Technical Information Extension</u>
1	<u>Argonne National Laboratory</u> K. A. Hub
17	<u>AEC, Division of Reactor Development and Technology</u> L. J. Colby (12) W. H. McVey G. E. Sinclair S. Strauch M. Whitman J. G. Yevick
1	<u>AEC, RL</u> C. L. Robinson
2	<u>AEC, RDT Site Representative</u> P. G. Holsted
2	<u>AEC Chicago Patent Group</u> G. H. Lee R. K. Sharp
6	<u>Atlantic Richfield Hanford Company</u> A. E. Smith Document Classification and Custody (5)
1	<u>Atomics International</u> S. Golan
3	<u>Battelle Memorial Institute</u>
1	<u>Brookhaven National Laboratory</u> C. J. Raseman
7	<u>Douglas United Nuclear, Inc.</u> Files Control Center (6) R. Nilson
1	<u>General Atomic, Division of General Dynamics</u> W. I. Neef

1 Los Alamos Scientific Laboratory
 J. Williams

1 Oak Ridge National Laboratory
 Union Carbide Corporation
 R. Carlsmith

4 Richland Operations Office
 R. K. Sharp (2)
 Technical Information Library (1)
 C. L. Robinson (Research and Development
 Division) (1)

2 Westinghouse Electric Corporation, APD
 C. A. Anderson
 J. Wright

134 Battelle-Northwest
 F. W. Albaugh
 E. R. Astley
 C. A. Bennett
 T. K. Bierlein
 C. H. Bloomster
 J. G. Bradley
 R. F. Corlett
 G. M. Dalen
 F. G. Dawson, Jr.
 D. E. Deonigi
 D. R. deHalas
 J. C. Fox
 E. A. Eschbach
 D. P. Granquist
 D. R. Haffner
 R. J. Hennig
 P. A. Horton
 B. B. Lane
 E. T. Merrill
 S. E. Nunn (100)
 R. G. Rau
 W. A. Reardon
 W. D. Richmond
 C. A. Rohrmann
 E. A. Schnaible
 R. E. Shaver
 J. R. Sheff
 R. E. Shippert
 C. R. Tipton, Jr.
 H. H. Van Tuyl
 E. E. Voiland
 Technical Information Files (5)