THE ORKAND CORPORATION

MASTER

TR-78W-037

LEVELIZED NUCLEAR FUEL CYCLE COST PROGRAM
USER'S GUIDE

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July 28, 1978

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Prepared for:

Office of Energy Source Analysis
Energy Information Administration
Washington, D.C.

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COST PROGRAM USER'S GUIDE

September 5, 1978

Prepared for:

Office of Energy Source Analysis
Energy Information Administration
Washington, D.C.

THE ORKAND CORPORATION

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LEVELIZED NUCLEAR FUEL CYCLE COST PROGRAM USER'S GUIDE

I. OVERVIEW

PURPOSE

This report describes the Nuclear Analysis Division's Levelized Nuclear Fuel Cycle Cost Program. An emphasis is placed upon the description of the program, operation procedures, the interactive organization of the variable inputs, output reports and user procedures. Examples of the program execution are included to assist potential users in understanding the procedures required to exercise the model.

MODEL OVERVIEW

This model is designed to compute an electric utility's levelized fuel cost (mills per kilowatt-hour) for a "batch" of nuclear fuel. The code computes² and outputs both levelized quantities of fuel cycle services (such as pounds of uranium per kilowatt-hour). The levelized direct costs (such as mills per

killowatt-hour attributable to fabrication of fuel elements), and the carrying charges account for time value of money. All fuel cycle services from natural uranium purchase through waste disposal are covered, and the user can specify one of three modes each for uranium and plutonium recycle, no recycle, self-generated recycle only, or reprocessed uranium (plutonium) sale and/or purchase.

All phases of the nuclear fuel cycle are presented in Exhibit I-1. The model contains a list of 48 variables with initial default values and produces an output that contains requirements (per million KWhe), unit prices and direct, inventory and total mills per KWhe for the various fuel cycle components. The maximum output products are:

- Uranium oxide (U_3O_8)
- Uranium Hexafluoride conversion (UF_6)
- Enrichment, in separative work units (SWU)
- UO_2 fabrication (FAB)
- Storage of spent fuel (STOR)
- Spent fuel shipping (SHIP)
- Reprocessing of spent fuel (REPR)
- Reprocessing waste disposal (WSTE)
- Mixed (uranium-plutonium)-oxide fabrication (MOX)
- Recovered plutonium credit (P-CR)
- Recovered uranium credit (U-CR)

Once changes have been initiated for variable values, the output "product" schedule format is impacted by the new results as generated by the program. The variable mnemonics, variable description, units allowed, and default values of the variables are provided in Exhibit III-1. Some of these have ranges that, if exceeded, will cause the computer to respond with the message "is not a permissible value". Not all variables are physically independent, although the source code does not know it. BU, EO, PU, EI, and OL, as defined in Exhibit III-1 are related by a complex system of equations that must be made consistent externally. These variables depend on the design of a particular reactor core. The text message (see variable TEXT) can be altered to produce an identifying message for the individual trial. Specifics concerning the output products and interpretation are found in Chapter III. The equations used in the code are discussed in full detail in "AEC Gaseous Diffusion Plant Operations"¹ report.

¹"AEC Gaseous Diffusion Plant Operation", ORO-684, issued by the United States Atomic Energy Commission (AEC), January 1972, this report updates, and in a few instances supplements. The information contained in ORO-658.

Exhibit I-1

Phases of the Nuclear Fuel Cycle

II. OPERATION

OVERVIEW

The Levelized Nuclear Fuel Cycle Cost program is operational on EIA's IBM 370/168 computer system. The model source code is in FORTRAN and can be run in interactive or batch modes. There is no input or output data files allocated to the model when run interactively. The user's terminal is used for input of the parameters and the output report in the interactive mode. The FORTRAN program resides on disk under the data set name CN6434.GC1.REFCOST.FORT located on Catalog.

III. INPUT AND OUTPUT FILE SPECIFICATION

OVERVIEW

The Nuclear Levelized Fuel Cycle Cost program requires no input files. Input is supplied after a default listing of parameter values. See Exhibit III-1 for default values. These may be changed once the user is prompted to enter parameter symbols and their new values. Chapter IV, User Procedures, explains user activity in detail. The number of changes made is left to the user in accordance with what is being examined. Any of the parameters may be accessed as desired, although ranges of permissible values are placed on some. The user may continue changing or correcting changes for a given case until a computer prompt is responded to with only a carriage return.

The default values create a no recycle report for both uranium and plutonium. Once variables have been changed, recycle, no-recycle or sell results are indicated individually for uranium and

Exhibit III-1

Default Parameter Definitions and Values

MNEMONIC	Variable Description	Units Allowed	Default Value
\$UO	Price of Uranium Oxide (U ₃ O ₈)	\$/lb	40.00
\$UFB	Price of fuel (UO ₂) fabrication	\$/kg	100.00
\$SHF	Price of spent fuel shipping	\$/kghm*	16.00
\$PCR	Credit value of recovered plutonium	\$/gm	0.0
TA	Enrichment plant tails assay	% U-235	0.20
QP	Quantity of plutonium purchased for new batch of fuel LPR=2	gm	0.0
AF	Percent of uranium delivered as advanced feed	Percent	0.0
OL	Consumption of Uranium at powerplant	Percent	3.99
TM1	Lead time required for purchase of U ₃ O ₈	Months	18.00
TE	Lead time required for purchase of enrichment	Months	12.00
TR	Lead time required for delivery of reprocessed Uranium	Months	18.00
\$TAC	Price of disposal of spent fuel elements (LUR,LPR=0)	\$/kghm*	200.00

*kghm = kg of heavy metal

Exhibit III-1 -- Cont.

MNEMONIC	Variable Description	Units Allowed	Default Value
TEXT	Scenario title		-----
\$UF6	Price of UF ₆ conversion	\$/lb. u	2.00
\$PU	Market price of purchased plutonium	\$/gm	0.0
\$REP	Price of reprocessing services	\$/kgm*	250.00
BU	"Burnup" of discharged fuel (Thermal megawatt-days per metric ton of uranium)		29666.00
EO	Discharge percentage of U-235	Percent	1.09
QUR	Quantity of reprocessed uranium purchased for new batch LUR=2	kgu	0.0
CL	Percent material loss of UF ₆ conversion stage	Percent	0.50
UL	Percent loss of uranium during reprocessing	Percent	1.5
TM2	Lead time for U ₃ O ₈ purchase for advanced feed portion	Months	0.0
TF	Lead time for UO ₂ fabrication	Months	8.00
TP	Lead time for delivery of reprocessed plutonium at fabrication plant	Months	15.00
TNOR	Lag time until disposal of spent fuel rods (LUR,LPR=0)	Months	120.00
\$RU	Purchase Price of reprocessed uranium	\$/kgu	0.0

*kgm = kg of heavy metal

Exhibit III-1 -- Cont.

MNEMONIC	Variable Description	Units Allowed	Default Value
\$MFB	Price of mixed oxide fabrication	\$/kg _{hm} *	400.00
\$TRM	Price of disposal of high level waste (\$/kg of initial uranium)	\$/kg	45.50
EF	Thermal efficiency of nuclear powerplant	Percent	31.0
PU	Quantity of discharged plutonium	kg	7.16
ER	Percent of U-235 in purchased reprocessed uranium LUR=2	Percent	1.09
EL	Percent loss of material at enrichment stage	Percent	0.0
PL	Percent loss of plutonium at reprocessing plant	Percent	1.5
TC1	Lead time for UF ₆ conversion for non-advanced feed portion	Months	15.0
TO	Real time fuel batch is in reactor core	Months	37.82
TMFB	Lead time for mixed-oxide fabrication	Months	12.00
LUR	Logic variable for uranium recycle option 0 = no recycle, 1 = self-generated recycle, 2 = buy/sell reprocessed uranium	Absolute Value	0.00
\$SWU	Price of enrichment services (\$/separative work unit, SWU)	\$/SWU	75.00
\$STF	Storage cost for spent fuel	\$/kg _{hm} . Year**	6.00

*kg_{hm} = kg of heavy metal

**kg_{hm}.year = kg of heavy metal per year

Exhibit III-1 -- Cont.

MNEMONIC	Variable Description	Units Allowed	Default Value
\$UCR	Credit value of reprocessed uranium	\$/kg	0.0
EI	Leading (initial) enrichment	% U-235	3.20
PVAL	Fissile value of plutonium relative to uranium		1.25
RCC	Carrying charge in percent per month	Percent	0.92
FL	Percent loss of material at UO ₂ fabrication stage	Percent	1.00
ML	Percent loss of material at mixed-oxide fabrication plant	Percent	1.00
TC2	Lead time for conversion of advanced feed	Months	0.0
TS	Storage time for spent fuel before reprocessing (LUR and LPR = 0)	Months	24.00
TUR	Lead time for purchase of reprocessed uranium (LUR = 2)	Months	15.00
LPR	Logic variable for plutonium recycle, 0 = no recycle, 1 = self-generated recycle, 2 = buy/sell reprocessed plutonium	Absolute Value	0.00

plutonium. The first of the output results, feed-to-product ratio is the ratio of input uranium required at the enrichment plant to output enriched uranium product (PRNT = 2). The SWU-to-product ratio is the ratio of required separative work units to enriched uranium product (PRNT = 2).

The product definitions are given below:

- U308 - Uranium Oxide (yellow cake)
- UF6 - Uranium hexafluoride conversion
- SWU - Enrichment
- FAB - UO_2 Fabrication
- STOR - Storage of spent fuel
- SHIP - Spent fuel shipping
- REPR - Reprocessing of spent fuel
- WSTE - High level (reprocessing waste disposal
- P-CR - Recovered plutonium credit
- U-CR - Recovered uranium credit
- MOX - Mixed (uranium-plutonium) oxide fabrication
- PLUT - Purchased plutonium
- RE-U - Purchased reprocessed uranium

The output of the Nuclear Levelized Fuel Cycle Cost program includes a summary of the input data. A default listing of parameter values is displayed before the user is initially prompted for the symbols and values of any variables that are to be changed. Exhibit III-2 identifies the initial output. One symbol and corresponding new value may be entered at a time. After the user indicates that all the changes have been made, the Table of Input Parameter Values is displayed for PRNT = 2 (see Exhibit III-3). The guidelines (recycle, dump, sell) for uranium and plutonium are included in this portion of the output.

The Table of Output Results includes the feed-to-product ratio, SWU-to-product ratio, the effective values and the products. Exhibit III-4 shows the table and the detail involved with the mills per KWhe for the products.

After the table has been displayed the user will be prompted to make changes to the variables for another iteration of the program.

Exhibit III-2

Table of Default Parameter Values

++ TABLE OF DEFAULT PARAMETER VALUES ++

\$UD	=	40.00	\$UF6	=	2.00	\$RU	=	0.0	\$SMU	=	75.00
\$UFB	=	100.00	\$FU	=	0.0	\$MFB	=	400.00	\$STF	=	6.00
\$SHF	=	16.00	\$REP	=	250.00	\$TRM	=	45.50	\$UCR	=	0.0
\$PCR	=	0.0	BU	=	29666.00	EF	=	31.00	EI	=	3.20
TA	=	0.20	EO	=	1.09	FU	=	7.16	PVAL	=	1.25
QP	=	0.0	QUR	=	0.0	ER	=	1.09	RCC	=	0.92
AF	=	0.0	CL	=	0.50	EL	=	0.0	FL	=	1.00
OL	=	3.99	UL	=	1.50	PL	=	1.50	ML	=	1.00
TM1	=	18.00	TM2	=	0.0	TC1	=	15.00	TC2	=	0.0
TE	=	12.00	TF	=	8.00	TD	=	37.82	TS	=	24.00
TR	=	18.00	TF	=	15.00	TMFB	=	12.00	TUR	=	15.00
\$TAC	=	200.00	TNOR	=	120.00	LUR	=	0.0	LPR	=	0.0
TEXT	=										

EIA AAR 1977 SERIES C EQ CYCLE 12-9-77

Table of Output Results

EIA AAR 1977 SERIES C EQ CYCLE 12-9-77
 ***** NO RECY URANIUM - NO RECY PLUTONIUM *****

+++ TABLE OF OUTPUT RESULTS +++

PRODUCT	REQUIREMENT (PER MILLION KWHE)	UNIT PRICE	MILLS PER KWHE		
			DIRECT	INVENTORY	TOTAL
U308	70.20 LB(U308)	@ 40.00 \$/LB(U308)	2.81	1.08	3.89
UF6	59.23 LB(U)	@ 2.00 \$/LB(U)	0.12	0.04	0.16
SWU	21.72 KG-SWU	@ 75.00 \$/KG-SWU	1.63	0.52	2.15
FAB	4.53 KG(U)	@ 100.00 \$/KG(U)	0.45	0.13	0.58
STOR	45.31 KGHM-YR	@ 6.00 \$/KGHM-YR	0.27	-0.16	0.11
SHIP	4.53 KGHM	@ 16.00 \$/KGHM	0.07	-0.06	0.02
WSTE	4.53 KGHM	@ 200.00 \$/KGHM	0.91	-0.69	0.21
TOTAL			6.26	0.87	7.13

Exhibit III-3 — (cont.)

EIA AAR 1977 SERIES C:EQ CYCLE 12-9-77
 ***** RECYCLE URANIUM - RECYCLE PLUTONIUM *****

+++ TABLE OF OUTPUT RESULTS +++

PRODUCT	REQUIREMENT (PER MILLION KWHE)	UNIT PRICE	MILLS PER KWHE		
			DIRECT	INVENTORY	TOTAL
U308	37.44 LB(U308)	@ 40.00 \$/LB(U308)	1.50	0.58	2.07
UF6	31.45 LB(U)	@ 2.00 \$/LB(U)	0.06	0.02	0.09
RE-U	3.32 KG(U)	@ 227.73 \$/KG(U)	0.76	0.27	1.02
SWU	14.56 KG-SWU	@ 75.00 \$/KG-SWU	1.09	0.35	1.44
FAB	3.51 KG(U)	@ 100.00 \$/KG(U)	0.35	0.10	0.45
PLUT	31.95 GM(PU)	@ 28.15 \$/GM(PU)	0.90	0.32	1.22
MOX	1.02 KGHM	@ 400.00 \$/KGHM	0.41	0.13	0.54
STOR	9.06 KGHM-YR	@ 6.00 \$/KGHM-YR	0.05	-0.02	0.03
SHIP	4.53 KGHM	@ 16.00 \$/KGHM	0.07	-0.03	0.04
REPR	4.53 KGHM	@ 250.00 \$/KGHM	1.13	-0.45	0.68
WSTE	4.53 KGHM	@ 45.50 \$/KGHM	0.21	-0.08	0.12
SUBTOTAL			6.53	1.18	7.71
U-CR	3.32 KG(U)	@ 227.73 \$/KG(U)	-0.76	0.29	-0.47
P-CR	31.95 GM(PU)	@ 28.15 \$/GM(PU)	-0.90	0.35	-0.55
TOTAL			4.88	1.82	6.69

Exhibit III-3 — (cont.)

EIA AAR 1977 SERIES C EQ CYCLE 12-9-77
 ***** RECYCLE URANIUM — MARKET PLUTONIUM *****

+++ TABLE OF OUTPUT RESULTS +++

PRODUCT	REQUIREMENT (PER MILLION KWHE)	UNIT PRICE	MILLS PER KWHE		
			DIRECT	INVENTORY	TOTAL
U308	50.51 LB(U308)	@ 40.00 \$/LB(U308)	2.02	0.78	2.80
UF6	42.53 LB(U)	@ 2.00 \$/LB(U)	0.09	0.03	0.12
RE-U	4.28 KG(U)	@ 227.73 \$/KG(U)	0.98	0.34	1.32
SWU	19.44 KG-SWU	@ 75.00 \$/KG-SWU	1.46	0.47	1.93
FAB	4.53 KG(U)	@ 100.00 \$/KG(U)	0.45	0.13	0.58
STGR	9.06 KGHM-YR	@ 6.00 \$/KGHM-YR	0.05	-0.02	0.03
SHIP	4.53 KGHM	@ 16.00 \$/KGHM	0.07	-0.03	0.04
REFR	4.53 KGHM	@ 250.00 \$/KGHM	1.13	-0.45	0.68
WSTE	4.53 KGHM	@ 45.50 \$/KGHM	0.21	-0.08	0.12
	SUBTOTAL		6.46	1.16	7.62
U-CR	4.28 KG(U)	@ 227.73 \$/KG(U)	-0.98	0.38	-0.60
P-CR	31.95 GM(PU)	@ 28.15 \$/GM(PU)	-0.90	0.35	-0.55
	TOTAL		4.58	1.88	6.47

Exhibit III-3 — (cont.)

EIA AAR 1977 SERIES C EQ CYCLE 12-9-77
 ***** MARKET URANIUM - MARKET PLUTONIUM *****

+++ TABLE OF OUTPUT RESULTS +++

PRODUCT	REQUIREMENT (PER MILLION KWHE)	UNIT PRICE	MILLS PER KWHE		
			DIRECT	INVENTORY	TOTAL
U308	70.20 LB(U308) @	40.00 \$/LB(U308)	2.81	1.08	3.89
UF6	59.23 LB(U) @	2.00 \$/LB(U)	0.12	0.04	0.16
SWU	21.72 KG-SWU @	75.00 \$/KG-SWU	1.63	0.52	2.15
FAB	4.53 KG(U) @	100.00 \$/KG(U)	0.45	0.13	0.58
STOR	9.06 KGHM-YR @	6.00 \$/KGHM-YR	0.05	-0.02	0.03
SHIP	4.53 KGHM @	16.00 \$/KGHM	0.07	-0.03	0.04
REPR	4.53 KGHM @	250.00 \$/KGHM	1.13	-0.45	0.68
WSTE	4.53 KGHM @	45.50 \$/KGHM	0.21	-0.08	0.12
SUBTOTAL			6.47	1.19	7.66
U-CR	4.2E KG(U) @	227.73 \$/KG(U)	-0.98	0.38	-0.60
P-CR	31.9E GM(PU) @	28.15 \$/GM(PU)	-0.90	0.35	-0.55
TOTAL			4.60	1.91	6.51

ENTER THE NAMES OF PARAMETERS TO BE CHANGED AND THEIR NEW VALUES

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IV. USER PROCEDURES

PURPOSE

The purpose of this section is to illustrate the Nuclear Levelized Fuel Cycle Cost program execution procedures for potential users. The procedures assume that the user is able to logon to TSO. Detailed knowledge of TSO is not necessary in executing the model.

EXECUTION PROCEDURES

The Nuclear Levelized Fuel Cycle Cost program is a FORTRAN program which is executed interactively in TSO. The program is named:

CN6434.GC1.REFCOST.FORT

and is located on Catalog. In order to execute the model, the user must be on TSO and enter the command:

RUN 'CN6434.GC1.REFCOST.FORT' FORT

The Table of Default Parameter Values will be displayed and followed with the prompt for changes to the variables. Exhibit IV-1 presents an example execution of the model. User inputs are underlined. Variables can be modified and changed until a

Exhibit IV-1

Execution of the Model

```

READY
RUN 'CN6434.GC1.REFCOST.FORT' FORT
G1 COMPILER ENTERED
SOURCE ANALYZED
PROGRAM NAME = MAIN
* NO DIAGNOSTICS GENERATED
SOURCE ANALYZED
PROGRAM NAME = READ
* NO DIAGNOSTICS GENERATED
*STATISTICS* NO DIAGNOSTICS THIS STEP :

```

++ TABLE OF DEFAULT PARAMETER VALUES ++

\$UD = 40.00	\$UF6 = 2.00	\$RU = 0.0	\$SWU = 75.00
\$UFR = 100.00	\$FU = 0.0	\$HFB = 400.00	\$STF = 6.00
\$SHF = 16.00	\$REF = 250.00	\$TRM = 45.50	\$UCR = 0.0
\$PCR = 0.0	BU = 29666.00	EF = 31.00	EI = 3.20
TA = 0.20	EO = 1.09	PU = 7.16	EVAL = 1.25
QP = 0.0	QUR = 0.0	ER = 1.09	RCC = 0.92
AF = 0.0	CL = 0.50	EL = 0.0	FL = 1.00
OL = 3.29	UL = 1.50	PL = 1.50	HL = 1.00
TM1 = 18.00	TM2 = 0.0	TC1 = 15.00	TC2 = 0.0
TE = 12.00	TF = 8.00	TO = 37.82	TS = 24.00
TR = 18.00	TP = 15.00	TMFB = 12.00	TUR = 15.00
\$TAC = 200.00	THOR = 120.00	LUR = 0.0	LFR = 0.0
TEXT =			

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```

ENTER THE NAMES OF PARAMETERS TO BE CHANGED AND THEIR NEW VALUES
PRNT 0
NEW VALUE FOR PRINT OPTION = 0

```

```

DIRECT + INVENTORY = TOTAL MILLS/KWH -> 6.26 + 0.87 = 7.13
ENTER THE NAMES OF PARAMETERS TO BE CHANGED AND THEIR NEW VALUES
PRNT 1
NEW VALUE FOR PRINT OPTION = 1

```

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 NUCLEAR ENERGY ANALYSIS DIVISION
 LEVELIZED NUCLEAR FUEL CYCLE COST CODE

Exhibit IV-1 - (cont.)

EIA AAR 1977 SERIES C EQ CYCLE 12-9-77
 ***** NO RECY URANIUM - NO RECY PLUTONIUM *****

+++ TABLE OF OUTPUT RESULTS +++

PRODUCT	REQUIREMENT (PER MILLION KWHE)	UNIT PRICE	MILLS PER KWHE		
			DIRECT	INVENTORY	TOTAL
U308	70.20 LB(U308) @	40.00 \$/LB(U308)	2.81	1.08	3.89
UF6	59.23 LB(U) @	2.00 \$/LB(U)	0.12	0.04	0.16
SWU	21.72 KG-SWU @	75.00 \$/KG-SWU	1.63	0.52	2.15
FAB	4.53 KG(U) @	100.00 \$/KG(U)	0.45	0.13	0.58
STOR	45.31 KGHM-YR @	6.00 \$/KGHM-YR	0.27	-0.15	0.11
SHIP	4.53 KGHM @	16.00 \$/KGHM	0.07	-0.06	0.02
WSTE	4.53 KGHM @	200.00 \$/KGHM	0.91	-0.69	0.21
TOTAL			6.26	0.87	7.13

ENTER THE NAMES OF PARAMETERS TO BE CHANGED AND THEIR NEW VALUES

LUR 1
 NEW VALUE FOR LUR = 1
 LPR 1
 NEW VALUE FOR LPR = 1

ENERGY INFORMATION ADMINISTRATION - OFFICE OF ENERGY SOURCE ANALYSIS
 NUCLEAR ENERGY ANALYSIS DIVISION
 LEVELIZED NUCLEAR FUEL CYCLE COST CODE

EIA AAR 1977 SERIES C EQ CYCLE 12-9-77
 ***** RECYCLE URANIUM - RECYCLE PLUTONIUM *****

+++ TABLE OF OUTPUT RESULTS +++

PRODUCT	REQUIREMENT (PER MILLION KWHE)	UNIT PRICE	MILLS PER KWHE		
			DIRECT	INVENTORY	TOTAL
U308	37.44 LB(U308) @	40.00 \$/LB(U308)	1.50	0.58	2.07
UF6	31.45 LB(U) @	2.00 \$/LB(U)	0.06	0.02	0.09
RE-U	3.32 KG(U) @	227.73 \$/KG(U)	0.76	0.27	1.02
SWU	14.56 KG-SWU @	75.00 \$/KG-SWU	1.09	0.35	1.44
FAB	3.51 KG(U) @	100.00 \$/KG(U)	0.35	0.10	0.45
PLUT	31.95 GM(PU) @	28.15 \$/GM(PU)	0.90	0.32	1.22
MOX	1.02 KGHM @	400.00 \$/KGHM	0.41	0.13	0.54
STOR	9.06 KGHM-YR @	6.00 \$/KGHM-YR	0.05	-0.02	0.03
SHIP	4.53 KGHM @	16.00 \$/KGHM	0.07	-0.03	0.04
REPR	4.53 KGHM @	250.00 \$/KGHM	1.13	-0.45	0.68
WSTE	4.53 KGHM @	45.50 \$/KGHM	0.21	-0.08	0.12
SUBTOTAL			6.53	1.18	7.71
U-CR	3.32 KG(U) @	227.73 \$/KG(U)	-0.76	0.27	-0.47
P-CR	31.95 GM(PU) @	28.15 \$/GM(PU)	-0.90	0.35	-0.55
TOTAL			4.88	1.82	6.69

ENTER THE NAMES OF PARAMETERS TO BE CHANGED AND THEIR NEW VALUES

LUR 1
 NEW VALUE FOR LUR = 1
 LPR 2
 NEW VALUE FOR LPR = 2

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LEFT BLANK

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satisfactory run is obtained. The changes are finalized when the carriage return is employed on a new line without any entry. The changes are analyzed and the Table of Input Parameter Values (PRNT = 2) presents the actual values used in the run. This table is followed by the Table of Output Results and the user is prompted for any new changes to the variables, which, if not changed will remain at the default values. If new values are supplied, then a new set of tables and results are created.

At the end of execution, the user should enter the following command:

```
DELETE CN6434.GC1.REFCOST.FORT.OBJ
```

This command will delete the object module created when running the model.

To successfully execute the model, there are two commands that the user must enter. The two TSO commands are:

- RUN 'CN6434.GC1.REFCOST.FORT' FORT
- DELETE CN6434.GC1.REFCOST.FORT.OBJ

Other than the two commands, the user needs to only enter responses to the program prompts.

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V. UPDATING PROCEDURES

For the Levelized Nuclear Fuel Cost Model (LNFCM), there are no updating procedures. The equations in the model remain unchanged over time. The parameters are input by the user.

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VI. ANNOTATED PROGRAM LISTING

Exhibit VI-1 presents a listing of the levelized Nuclear Fuel Cost Model (LNFCM). Although the source code contains some documentation, we have attempted to augment these comments with descriptions of the methodology, nature of input data, the interim processes and analysis results. The program is stored as DSN:

CN6434.GC1.REFCOST.FORT

Exhibit VI-1

Levelized Nuclear Fuel Cost Model (LNFCM) Program

This model is programmed to compute an electric utility's levelized fuel cost (mills per kilowatt-hour) for a "batch" of nuclear fuel. The code computes the levelized quantities of fuel cycle services (such as pounds of uranium per kilowatt-hour); the levelized direct costs (such as mills per kilowatt-hour attributable to fabrication of fuel elements); and the carrying charges which account for time value of money. All fuel cycle services from natural uranium purchase through waste disposal are covered. The user can specify one of three modes each for uranium and plutonium recycle; no recycle; self-generated recycle only; or reprocessed uranium (plutonium) sale and/or purchase.

1.	C	*POLICY ANALYSIS QUALITY* NUCLEAR FUEL CYCLE COST CODE	00000010
2.	C	GENE CLARK, EIA - OFFICE OF ENERGY SOURCE ANAL.	00000020
3.	C	VERSION 8/25/78	00000030

The following "Integer", "REAL", and "LOGICAL" statements define the initial fixed or unvarying quantities of the variables used in the computations of the program. The "Equivalence" statements define the variables that can share storage locations. These variables present the phases of the nuclear fuel cycle (Mining; Milling; Conversion; Enrichment; Fabrication; Power production; and Reprocessing), mass-flow interactions, and levelized cost accounting. These variables' descriptions are presented in Exhibit III-1 of Chapter 3.

4.	INTEGER*4	LF/0/, LUR/0/, LPR/0/, LLUR/0/, LUR/0/, LLPR/0/, LPR/0/	00000040
5.	INTEGER*4	LAB(13)/'U308', 'UF6', 'RE-U', 'SWU', 'FAB', 'PLUT',	00000050
6.	X	'MOX', 'STOR', 'SHIP', 'REFR', 'WSTE', 'U-CR', 'P-CR'//	00000060
7.	REAL*8	\$UNIT(13)/'LB(U308)', 'LB(U)', 'KG(U)', 'KG-SWU',	00000070
8.	X	'KG(U)', 'GM(PU)', 'KGHM', 'KGHM-YR', 'KGHM',	00000080
9.	X	'KGHM', 'KGHM', 'KG(U)', 'GM(PU)'//	00000090
10.	REAL*4	BU/29666./, EF/31.0/, EI/3.2/, TA/0.20/, ED/1.09/, ER/1.09/	00000100
11.	REAL*4	PU/7.16/, PVAL/1.25/, QDP/0.00/, QDUR/0.00/, QUR/0.00/	00000110
12.	REAL*4	\$UD/40.0/, \$UF6/2.00/, \$SWU/75.0/, \$UFB/100./, \$STF/6.00/	00000120
13.	X	\$SHF/16.0/, \$TRM/45.5/, \$REF/250.0/, \$TAC/200.0/, \$MFB/400.0/	00000130
14.	X	\$PU/0.0/, \$RU/0.0/, \$UCR/0.0/, \$FCR/0.0/	00000140
15.	REAL*4	RCC/0.916667/, AF/0.0/, PAR(3)	00000150
16.	REAL*4	TM1/18.0/, TM2/0.0/, TC1/15.0/, TC2/0.0/, TE/12.0/, TF/8.0/	00000160
17.	X	TO/37.82/, TS/24.0/, TR/18.0/, TP/15.0/, TMFB/12.0/, TUR/15.0/	00000170
18.	REAL*4	CL/0.5/, EL/0.0/, FL/1.0/, OL/3.99/, UL/1.5/, PL/1.5/, RL/1./	00000180
19.	LOGICAL	RCYCL/, FIRST/, FALSE./	00000190
20.	REAL*4	C(13), CI(13), \$(13), Q(13), TNOR/120.0/	00000200

Exhibit VI-1 - (Cont.)

```

21. INTEGER*4 PRNT//PRNT//
22. REAL*8 NMREC(3)// DUMP '','RECYCLE ','' SELL '//
23. INTEGER*4 TERM/5//BLANK// '//,NPAR/49//,LTX//TEXT//,INCR/0//
24. INTEGER*4 NM(49)//$UD '$UF6','$RU '$SWU','$UFB','$FU '$,
25. 1 '$MFB','$STF','$SHF','$REP','$TRM','$UCR','$PCR',
26. 2 '$BU '$EF '$EI '$TA '$EO '$PU '$FVAL',
27. 3 '$QP '$QUR '$ER '$RCC '$AF '$CL '$EL '$,
28. 4 '$FL '$OL '$UL '$FL '$ML '$TM1 '$TM2 '$,
29. 5 '$TC1 '$TC2 '$TE '$TF '$TO '$TS '$TR '$,
30. 6 '$TF '$TMFB '$TUR '$TAC '$TNOR '$LUR '$LFR '$****//.PORT/2
31. REAL*4 V(49)
32. INTEGER*2 TEXT(36)/8* ' ','NE','D ','19','77','R','$EF'$ C','$AS'
33. X '$E '$FW'$R '$EQ'$C '$YC'$LE'$ 1','0-','9-','75',
34. X 9* ' '//,BLANK2// '//
35. EQUIVALENCE (PAR(1),VALUE),(PAR(2),U1),(PAR(3),S1)
36. EQUIVALENCE ($ (1),V(1),$UD),( $ (2),V(2),$UF6),( $ (3),V(3),$RU),
37. 2 ($ (4),V(4),$SWU),( $ (5),V(5),$UFB),( $ (6),V(6),$FU),
38. 3 ($ (7),V(7),$MFB),( $ (8),V(8),$STF),( $ (9),V(9),$SHF),
39. 4 ($ (10),V(10),$REP),( $ (11),V(11),$TRM),
40. 5 ($ (12),V(12),$UCR),( $ (13),V(13),$PCR),
41. 6 (V(14),BU),(V(15),EF),(V(16),EI),(V(17),TA),(V(18),EO),
42. 7 (V(19),PU),(V(20),FVAL),(V(21),QQP),(V(22),QQUR),
43. 8 (V(23),ER),(V(24),RCC),(V(25),AF),(V(26),CL),
44. 9 (V(27),EL),(V(28),FL),(V(29),OL),(V(30),UL),
45. A (V(31),FL),(V(32),ML),(V(33),TM1),(V(34),TM2),
46. B (V(35),TC1),(V(36),TC2),(V(37),TE),(V(38),TF),
47. C (V(39),TO),(V(40),TS),(V(41),TR),(V(42),TF),
48. D (V(43),TMFB),(V(44),TUR),(V(45),TAC),
49. E (V(46),TNOR)
50. EQUIVALENCE (C(1),CU),(C(2),CC),(C(3),CUR),(C(4),CE),(C(5),CF),
51. X (C(6),CFU),(C(7),CMFB),
52. X (C(8),CSTF),(C(9),CSF),(C(10),CREP),(C(11),CTRM)
53. X (C(12),CRU),(C(13),CRF)
54. EQUIVALENCE (CI(1),UI),(CI(2),CUI),(CI(3),CURI),(CI(4),ENI),
55. X (CI(5),FI),(CI(6),FUI),
56. X (CI(7),FMOXI),(CI(8),SI),(CI(9),SHI),(CI(10),RI),(CI(11),TRMI)
57. X (CI(12),CRUI),(CI(13),CRFI)
58. EQUIVALENCE (Q(3),QUR),(Q(4),QE),(Q(5),QF),(Q(6),QF),
59. X (Q(7),QMFB),(Q(8),QSTF),(Q(9),QSF),(Q(10),QREP),
60. X (Q(11),QTRM)
61. FIRST=.FALSE.
62. V(47)=LUR
63. V(48)=LFR

```


Exhibit VI-1 — (Cont.)

The following statements display the table of default parameter values and option selection criteria in an interactive mode.

```

64.      WRITE(LP,1)
65.      1   FORMAT('1')
66.      WRITE(LP,3401)
67.      3401 FORMAT(//,16X,'++ TABLE OF DEFAULT PARAMETER VALUES ++',/)
68.      DO 3222 I=1,45,4
69.      II=I+3
70.      3222 WRITE(LP,3223)((NM(K),V(K)),K=I,II)
71.      3223 FORMAT(4(' ',A4,' = ',F10.2))
72.      WRITE(LP,3224)TEXT
73.      3224 FORMAT(' TEXT = ',/,1X,36A2,/)
74.      GO TO 1993
75.      1997 FIRST=.TRUE.
76.      IF(INCR.EQ.0.OR.ISAVE.LT.1.OR.ISAVE.GT.48)GO TO 1993
77.      V(ISAVE)=V(ISAVE) + STEP
78.      INCR=INCR - 1
79.      GO TO 2012

```

The following statements request the user to enter the name of parameters to be changed and their new values. A null (blank) name as a first item will end the execution, and a null (blank) name entered after the first or several changes will cause the program to reiterate through the computations with the new parameter values.

```

80.      1993 WRITE(LP,1994)
81.      1994 FORMAT('1ENTER THE NAMES OF PARAMETERS TO BE CHANGED AND THEIR NEW
82.      X VALUES')
83.      1998 CALL READ(NAME,PAR)
84.      IF(NAME.EQ.BLANK.AND.FIRST)STOP
85.      IF(NAME.EQ.BLANK.AND..NOT.FIRST)GO TO 2012
86.      FIRST=.FALSE.
87.      IF(NAME.NE.LTXT)GO TO 2200
88.      READ(TERM,2445)TEXT
89.      2445 FORMAT(36A2)
90.      ISTRF=36
91.      100 IF(TEXT(ISTRF).NE.BLANK2)GO TO 201
92.      ISTRF=ISTRF - 1
93.      IF(ISTRF.GT.0)GO TO 100
94.      201 ISTRF=(ISTRF+1)/2
95.      ISTRF=2*ISTRF
96.      LMARG=(36-ISTRF)/2
97.      IF(ISTRF.EQ.36)GO TO 204
98.      DO 202 I=1,ISTRF
99.      202 TEXT(37-I-LMARG)=TEXT(ISTRF-I+1)
100.     DO 203 I=1,LMARG
101.     203 TEXT(I)=BLANK2
102.     204 WRITE(LP,2446)TEXT
103.     2446 FORMAT(' NEW TEXT = ',/,1X,36A2)

```

Exhibit VI-1 — (Cont.)

The following logic variables "LUR" and "LPR" present the options for uranium and plutonium recycle; the options are:

0 = no recycle

1 = self-generated recycle

2 = buy/sell reprocessed uranium or plutonium

The user can enter any two digit integer and it will default to one of the options above. (GT 2 = 2, LT 0 = 0).

```
104.          GO TO 1998
105.      2449 LUR=VALUE + 0.1
106.          IF (LUR.LT.0) LUR=0
107.          IF (LUR.GT.2) LUR=2
108.          WRITE(LP,2098) LUR
109.      2098 FORMAT(' NEW VALUE FOR LUR =',I2)
110.          GO TO 1998
111.      2100 LPR=VALUE + 0.1
112.          IF (LPR.LT.0) LPR=0
113.          IF (LPR.GT.2) LPR=2
114.          WRITE(LP,2099) LPR
115.      2099 FORMAT(' NEW VALUE FOR LPR =',I2)
116.          GO TO 1998
117.      2200 IF (NAME.NE.PRNT) GO TO 2211
118.          POPT=VALUE+0.1
119.          WRITE(LP,2201) POPT
120.      2201 FORMAT(' NEW VALUE FOR PRINT OPTION =',I2)
```

Exhibit VI-1 — (Cont.)

The system will respond to the acceptable changes by displaying the new values entered and the parameter name. The system rejects nonpermissible values for specific variables and displays a message that it is not a permissible value for the variable name. The following variables cannot obtain a zero value.

- Burnup (BU) of discharged fuel (thermal megawatt-days per metric ton of uranium).
- Thermal efficiency of nuclear power-plant (EF).
- Fissile value of plutonium relative to uranium (PVAL).

The following variables cannot obtain a "100" percent value:

- Percent material loss of UF₆ conversion stage (CL).
- Percent loss of material at enrichment stage (EL).
- Percent loss of material at UO₂ fabrication stage (FL).
- Consumption of uranium at powerplant (OL).
- Percent loss of uranium during reprocessing (UL).
- Percent loss of plutonium at reprocessing plant (PL).
- Percent loss of material at mixed-oxide fabrication plant (ML).

```

121.      GO TO 1998
122.      2211 DO 2000 I=1,NPAR
123.          IF(NAME.EQ.NM(I))GO TO 2010
124.      2000 CONTINUE
125.          I=NPAR
126.      2010 IF(S1.EQ.0.0.OR.I.GE.47)GO TO 2500
127.          INCR=S1-0.99
128.          STEP=(U1-VALUE)/INCR
129.          ISAVE=I
130.          JKL=INCR+1
131.          WRITE(LP,399)NM(I),JKL,STEP,VALUE
132.      399  FORMAT(20X,' *** PARAMETER RANGE OPTION ***',/,',',7X,
133.          X A4,' WILL BE INCREMENTED IN',I3,' STEPS OF STEP SIZE',F7.3,/,
134.          X ' ',12X,' STARTING AT A VALUE OF',F9.3)
135.      2500 IF((I.EQ.14.OR.I.EQ.15.OR.I.EQ.20).AND.VALUE.EQ.0.0)GO TO 2601
136.          GO TO 2650
137.      2601 WRITE(LP,2602)NM(I)
138.      2602 FORMAT(' -> -> ZERO IS NOT A PERMISSIBLE VALUE FOR ',A4,' <- <-')
139.          GO TO 1998
140.      2650 IF((I.GT.25.AND.I.LT.33).AND.VALUE.EQ.100.0)GO TO 2699

```

Exhibit VI-1 — (Cont.)

```

141.      GO TO 2698
142.      2699 WRITE(LP,2697)NM(I)
143.      2697 FORMAT(' -> -> 100.0 IS NOT A PERMISSIBLE VALUE FOR ',A4,' <- <-')
144.      GO TO 1998
145.      2698 V(I)=VVALUE
146.      IF(I.EQ.47)GO TO 2449
147.      IF(I.EQ.48)GO TO 2100
148.      IF(I.EQ.21)QF=V(I)
149.      IF(I.EQ.22)QUR=V(I)
150.      IF(I.EQ.22)QQUR=QUR
151.      IF(I.NE.ISAVE)WRITE(LP,2011)V(I),NM(I)
152.      2011 FORMAT(' NEW VALUE OF ',F10.2,' ENTERED FOR PARAMETER NAME ',
153.      X A4)
154.      GO TO 1998
155.      2012 CONTINUE
156.      IF(FOPT.NE.0)WRITE(LP,1)

```

The following statements of the program produce the headings and specified categorization of the modified input parameter values and a table of output results. The possible categories are:

- No recycle (Dump)
- Self-generated recycle (Recycle)
- Buy/sell reprocessed (Sell)
uranium or plutonium

```

157.      NU=LUR+1
158.      NP=LPR+1
159.      IF(FOPT.NE.0)WRITE(LP,81)TEXT,NMREC(NU),NMREC(NP)
160.      IF(FOPT.NE.2)GO TO 3407
161.      WRITE(LP,3402)
162.      3402 FORMAT('/',18X,'++ TABLE OF INPUT PARAMETER VALUES ++',/)
163.      DO 2222 I=1,45,4
164.      II=I+3
165.      2222 WRITE(LP,2223)((NM(K),V(K)),K=I,II)
166.      2223 FORMAT(4(' ',A4,' =',F10.2))
167.      3407 IF(FOPT.NE.0)WRITE(LP,3408)
168.      3408 FORMAT('/', 20X,'+++ TABLE OF OUTPUT RESULTS +++')

```

Exhibit VI-1 — (Cont.)

The following process computes the recovery factors for the following stages:

- Uranium hexafluoride (UF₆) conversion stage
- Enrichment stage
- Fabrication stage
- Uranium consumption at power plant
- Uranium reprocessing
- Plutonium at reprocessing plant
- Mixed-oxide fabrication plant.

```
169.      C
170.      C COMPUTE PROCESS MASS RECOVERY FACTORS
171.      C
172.      NU=LUR+1
173.      NP=LPR+1
174.      RCYCL=LUR.NE.0.OR.LPR.NE.0
175.      KWH=240.0*BU*EF
176.      RCVF = 1.0 - FL/100.0
177.      RCVE = 1.0 - EL/100.0
178.      RCVC = 1.0 - CL/100.0
179.      RCVO = 1.0 - OL/100.0
180.      RCVU = 1.0 - UL/100.0
181.      RCVF = 1.0 - FL/100.0
182.      RCVU = 1.0 - ML/100.0
183.      SAVTS=TS
184.      IF(.NOT.RCYCL)TS=TNDK
```

Exhibit VI-1 — (Cont.)

The following process computes the feed component, or normal uranium feed per unit of product, and the separative work per unit of product;

where XP = assay of product desired, weight fraction U-235

XF = assay of normal feed, 0.00711 weight fraction U-235

XT = assay of cascade tails, 0.002 weight fraction U-235

```

185.  C
186.  C  MASS FLOWS
187.  C
188.  C  NO RECYCLE
189.  C
190.      QF = 1.0
191.      QRF=PU*RCVF
192.      QRU=QF*RCVU*RCVU
193.      XP = EI / 100.0
194.      XF = 0.00711
195.      XT = TA / 100.0
196.      VF = (2.0*XF-1.0)*ALOG(XF/(1.0-XF))
197.      VF = (2.0*XF-1.0)*ALOG(XF/(1.0-XF))
198.      VT = (2.0*XT-1.0)*ALOG(XT/(1.0-XT))
199.      FP = (XF - XT)/(XF - XT)
200.      SP = VF - VT - FP * (VF - VT)
201.      QE = QF * SP / RCVF
202.      QC = QF * FP / (RCVF * RCVE)
203.      QU = QC / RCVU
204.      QSTF = QF * TS / 12.0
205.      QSF=QF
206.      EFFF=FP/(RCVF*RCVE*RCVC)
207.      EFSP=SP/RCVF
208.      IF(FOPT.EQ.2)WRITE(LP,3409)FP,EFFF,SP,EFSP
209. 3409 FORMAT('0',10X,'FEED-TO-PRODUCT RATIO'='F7.3,
210.      X' (EFFECTIVE ='F7.3,')',/,
211.      X' ',10X,'SWU-TO-PRODUCT RATIO'='F7.3,
212.      X' (EFFECTIVE ='F7.3,')',/,
213.      TBE=TR
214.      IF(RCYCL)GO TO 170
215.      TBE=TNOR
216.      QTAC = QF
217.      GO TO 220

```

Exhibit VI-1 — (Cont.)

The following process computes the uranium oxide (U_3O_8) and enrichment savings produced by recycling the discharged fuel.

```

218. C
219. C RECYCLE
220. C
221. 170 QS = QF
222. QREP = QF
223. QTRM = QF
224. C
225. C URANIUM MASS-FLOW CREDITS
226. C
227. IF(LUR.EQ.0)GO TO 180
228. XR = ED/100.0
229. SER=ER
230. IF(ER.EQ.0.0)ER=ED
231. IF(LUR.EQ.2)XR=ER/100.0
232. VR = (2.0*XR-1.0)*ALOG(XR/(1.0-XR))
233. FPQU = (XF-XT)/(XR-XT)
234. QUUC = RCV0*RCVU*QU/FPQU
235. IF(LUR.EQ.2)QUUC=QUR/FPQU
236. SPQU=VF-VT-FFQU*(VR-VT)
237. QEUC=(QE-SPQU*QF)*QUUC/QU

```

The plutonium recycle is computed by multiplying the discharged fuel containing PU grams of plutonium, which is assumed to be the fissile value of plutonium relative to uranium (PVAL) by the equivalent weight of U-235. PU x PVAL amount of plutonium is mixed with enough natural uranium to give the equivalent of the initial enrichment fuel.

```

238. C
239. C PU MASS-FLOW CREDITS
240. C
241. 180 IF(LFR.EQ.0)GO TO 209
242. IF(LFR.EQ.1.AND.QF.EQ.0.0)QF=PU*RCVP
243. PXX=QF
244. FM=FXX*RCVM/(1000.*PVAL*(XF-XF))
245. QEFC=QE*FM
246. QUFC=QU*FM*(FF-1.0)/FF
247. QMFB=FM*QF
248. 209 IF(LUR.EQ.0)GO TO 210
249. QU=QU-QUUC
250. QC=QC-QUUC
251. QE=QE-QEUC
252. 210 IF(LFR.EQ.0)GO TO 219
253. QU=QU-QUFC
254. QC=QC-QUFC
255. QE=QE-QEFC
256. QF=QF-QMFB
257. 219 IF(LUR.EQ.1)QUR=QF*RCV0*RCVU

```

Exhibit VI-1 — (Cont.)

The following process computes the direct costs and requirements of all phases of the nuclear fuel cycle, accounting for price of uranium oxide (U_3O_8), price of uranium hexafluoride (UF_6) conversion, price of UF_6 enrichment, UO_2 fabrication, spent fuel storage cost, and spent fuel shipping cost.

```

258.      C
259.      C  COMPUTE DIRECT COSTS AND REQUIREMENTS
260.      C
261.      220  CU=QU*UO*2.59985
262.           Q(1)=QU*2.59985
263.           CC=QC*UF6*2.20462
264.           Q(2)=QC*2.20462
265.           CE=QE*SWU
266.           CF=QF*UFB
267.           CSTF=QSTF*STF
268.           CSF=QSF*SHF
269.           IF(.NOT.RCYCL)GO TO 230
270.           IF(LUR.EQ.0)GO TO 398

```

The following process computes the uranium cost credits as a function of discharged percentage of U-235, assay of normal feed of U-235, and assay of cascade tails of U-235.

```

271.      C
272.      C  URANIUM COST CREDITS
273.      C
274.      XR = ED/100.0
275.      VR = (2.0*XR-1.0)*ALOG(XR/(1.0-XR))
276.      FPR = (XR-XT)/(XF-XT)
277.      CUC = RCVO * RCVU * RCVE * FPR * (UO*2.59985+UF6*2.20462)*QF
278.      SPR = VR - VT - FPR*(VF - VT)
279.      CUCE = RCVO * RCVU * SPR * SWU * QF
280.      CRU=CUC+CUCE
281.      $RU=$RU
282.      $UCR=$UCR
283.      IF($RU.NE.0.0)CRU=$RU*QF*RCVO*RCVU
284.      IF($RU.EQ.0.0)$RU=CRU/(QF*RCVO*RCVU)
285.      CRU=-CRU
286.      Q(12)=QF*RCVO*RCVU
287.      IF($UCR.EQ.0.0)$UCR=$RU

```


Exhibit VI-1 — (Cont.)

The plutonium credits are now computed as a function of market price of purchased plutonium and recovery factors.

```

288.      C
289.      C      PU CREDITS
290.      C
291.      398  IF(LPR.EQ.0)GO TO 397.
292.          XPU = PU*RCVP*RCUM
293.          XPP=90.0/100.0
294.          FPP = (XPP - XT)/(XF - XT)
295.          VFP = (2.0*XPP-1.)*ALOG(XPP/(1.0-XPP))
296.          SPP = VFP - VT - FPP*(VF - VT)
297.          CPC=XPU*FPP*($UO*2.59985+$UF6*2.20462)/(RCVE*RCVF*RCVC*1000.)
298.          CFCE = XPU*SPP*$SWU/(RCVF*1000.)
299.          CRF=0.70*(CPC+CFCE)/0.90
300.          S$PU=$PU
301.          IF($PU.NE.0.0)CRF=$PU*PU*RCVP
302.          IF($PU.EQ.0.0)$PU=CRF/(PU*RCVP)
303.          Q(13)=PU*RCVP
304.          CRF=-CRF
305.          S$PCR=$PCR
306.          IF($PCR.EQ.0.0)$PCR=$PU
307.          CMFB=QMFB*$MFB
308.          CFU=QF*$FU
309.      397.  CUR=QUR*$RU
310.          CTRM=QTRM*$TRM
311.          CREF=QREF*$REF
312.          GO TO 231
313.      230.  CTRM=QF*$TAC
314.          QTRM=QF
315.          CTRM=QTAC*$TAC
316.          $SAVE=$TRM
317.          $TRM=$TAC
318.      231.  CONTINUE

```

Exhibit VI-1 — (Cont.)

The inventory carrying charges computed as a unit direct cost for stage i occurring at time T_i ,

where i = enrichment
 fabrication
 power production
 reprocessing, etc.

with respect to initial energy production from fuel. Carrying (indirect) charges are outputted from RCC times the value of the i th component of the fuel (direct) cost. Before or after energy production, the value of i th component is just the direct cost (from unit price). However, during energy production, the value of fuel is depreciated, or appreciated linearly.

```

319.      C
320.      C      INVENTORY CARRYING CHARGES
321.      C
322.      RM = (1.0 + RCC/100.0)
323.      UI1 = (1.0-AF)*CU*(RM**TM1 - 1.0)
324.      UI2 = AF*CU*(RM**TC1 - 1.0)
325.      CI1 = (1.0-AF)*CC*(RM**TC1 - 1.0)
326.      CI2 = AF*CC*(RM**TC2 - 1.0)
327.      CUI=CI1 + CI2 + 0.5*CC*(RM**TO - 1.0)
328.      UI = UI1 + UI2 + 0.5*(CU)*(RM**TO-1.0)
329.      ENI = CE*(RM**TE-1.0)+0.5*(CE)*(RM**TO-1.0)
330.      FI = CF*(RM**TF-1.0)+0.5*CF*(RM**TO-1.0)
331.      PUT=CPU*(RM**TF-1.0)+0.5*(CPU*(RM**TO-1.0))
332.      FMOXI=CMFI*((RM**TFB-1.0)+0.5*(RM**TO-1.0))
333.      CRUT=(-CRU)*((RM**TR-1.0)+0.5*(RM**TO-1.0))
334.      CRP=(-CRP)*((RM**TR-1.0)+0.5*(RM**TO-1.0))
335.      CURT=CUR*((RM**TUR-1.0)+0.5*(RM**TO-1.0))
336.      SI = CSTF*(1.0/RM**TO+0.5*TS)-1.0)
337.      SHI = CSF*(1.0/RM**TO+TS)-1.0)
338.      RI = CREP*(1.0/RM**TO+TR)-1.0)
339.      TRNI=CTRN*(1.0/RM**TO+TBE)-1.0)

```

Exhibit VI-1 — (Cont.)

The following process outputs the result of equations and analysis performed previously. The output presents the initial default parameter values, the name of variables and value of parameters changed, the option criteria selected for the input parameter values, and a table of output results. The output results present the product name and levelized quantities of fuel cycle services (in "industry-units" to produce one Kwh of electricity) such as pounds of uranium per kilowatt-hour, the levelized direct costs (such as mills per kilowatt-hour attributable to fabrication of fuel elements), and the carrying charges (mills per kilowatt-hour of electricity).

- Uranium oxide (U_3O_8)
- Uranium hexafluoride conversion (UF6)
- Separative work unit (SWU)
- UO_2 fabrication (FAB)
- Storage of spent fuel (STOR)
- Spent fuel shipping (SHIP)
- Reprocessing of spent fuel (REPR)
- Reprocessing waste disposal (SWTE)
- Recovered plutonium credit (P-CR)
- Recovered uranium credit (U-CR).

```

340.      C                                00003400
341.      C      PRINT RESULTS              00003410
342.      C                                00003420
343.      81  FORMAT(//, ' ENERGY INFORMATION ADMINISTRATION - OFFICE OF ENERGY 500003430
344.           XSOURCE ANALYSIS ',//,20X,      00003440
345.           X 'NUCLEAR ENERGY ANALYSIS DIVISION'      00003441
346.           X,/,17X, 'LEVELIZED NUCLEAR FUEL CYCLE COST CODE',      00003442
347.           X //,1X,36A2,/,13X, '***** ',AB, 'URANIUM - ',AB, 'PLUTONIUM *****') 00003450
348.           IF (PORT.NE.0)WRITE(LP,101)      00003460
349.      101  FORMAT(//, ' PRODUCT',4X, 'REQUIREMENT',6X, 'UNIT PRICE',13X,      00003470
350.           X 'MILLS PER KWHE',/,11X, '(PER MILLION',23X,      00003480
351.           X '-----',/,15X, 'KWHE)',27X, 'DIRECT',      00003490
352.           X 2X, 'INVENTORY',2X, 'TOTAL',//)      00003500
353.           TUITI = 0.0      00003510
354.           TOTI = 0.0      00003520
355.           DO 200 I=1,11      00003530

```

Exhibit VI-1 — (Cont.)

```

356.      CI(I)= 1.0E06 * CI(I)/KWH
357.      Q(I)=1.0E09*Q(I)/KWH
358.      TOTD=TOTD + C(I)
359.      TOTI = TOTI + CI(I)
360.      190  TOT = C(I) + CI(I)
361.      IF(POPT.GT.0)WRITE(LP,102)LAB(I),Q(I),%UNIT(I),%(I),%UNIT(I),C(I)
362.      XCI(I),TOT
363.      200  CONTINUE
364.      IF(.NOT.RCYCL)GO TO 410
365.      102  FORMAT(2X,A4,F9.2,1X,A8,' @',F7.2,' %',A8,F8.2,F10.2,F9.2)
366.      TOT = TOTD + TOTI
367.      IF(POPT.GT.0)WRITE(LP,103)TOTD,TOTI,TOT
368.      103  FORMAT(/,14X,'SUBTOTAL',22X,F8.2,F10.2,F9.2,/)
369.      DO 400 I=12,13
370.      C(I)=1.0E06*C(I)/KWH
371.      IF(C(I).GT.(-0.01))GO TO 400
372.      CI(I)=1.0E06*CI(I)/KWH
373.      Q(I)=1.0E09*Q(I)/KWH
374.      TOTD=TOTD+C(I)
375.      TOTI=TOTI+CI(I)
376.      TOT=C(I)+CI(I)
377.      IF(POPT.GT.0)WRITE(LP,102)LAB(I),Q(I),%UNIT(I),%(I),%UNIT(I),C(I)
378.      XCI(I),TOT
379.      104  FORMAT(/,17X,'TOTAL',22X,F8.2,F10.2,F9.2,/)
380.      400  CONTINUE
381.      410  TOT=TOTD+TOTI
382.      IF(POPT.NE.0)WRITE(LP,104)TOTD,TOTI,TOT
383.      IF(POPT.EQ.0)WRITE(LP,411)TOTD,TOTI,TOT
384.      411  FORMAT(' DIRECT + INVENTORY = TOTAL MILLS/KWH ->',F8.2, ' + '
385.      X F6.2,' = ',F8.2)
386.      $RU=$$RU
387.      $UCR=$$UCR
388.      $PU=$$PU
389.      $PCR=$$PCR
390.      TS=SAVTS
391.      ER=SER
392.      QP=QQP
393.      QUR=QQUR
394.      IF(.NOT.RCYCL)$JRM=$$SAVE
395.      DO 1200 I=1,13
396.      1200 C(I)=0.0
397.      GO TO 1997
398.      END
399.      SUBROUTINE READ (TEXT, PAR)
400.      INTEGER*2 DIG (10) // 0', 1', 2', 3', 4', 5', 6', 7',
401.      1 ' 8', 9' //, NUMBER (70), BLANK2 // '//,DOT' //
402.      LOGICAL*1 T (4), IMAGE (140)
403.      LOGICAL*1 CARD(72)
404.      LOGICAL*4 LDEC /.FALSE./,FOND
405.      INTEGER*4 BLANK4 // '//, LU /5/,SAVE,TEXT
406.      REAL*4 PAR(3)
407.      EQUIVALENCE (NUMBER(1),IMAGE(1)), (T(1),SAVE)
408.      C
409.      C      INITIALIZE RETURN ARRAYS
410.      C
411.      NPAR = 0
412.      SAVE=BLANK4
413.      TEXT = BLANK4
414.      DO 10 I = 1, 3
415.      10  PAR (I) = 0.0
416.      READ (LU, 1001) (CARD(KK),KK=1,70)
417.      1001 FORMAT (70A1)
418.      C
419.      C      SHAFT CARD IMAGES TO INTEGER*2 ARRAY
420.      C      <<HIP, HIP, ARRAY!!>>

```

Exhibit VI-1 — (Cont.)

```

421.      DO 20 I = 1, 70
422.      NUMBER(I)=BLANK2
423.      20  IMAGE (2*I) = CARD (I)
424.      C
425.      C  LOOK FOR 1ST NON-BLANK (I = COLUMN POINTER)
426.      C
427.      DO 30 I = 1, 70
428.      IF (NUMBER(I).NE.BLANK2) GO TO 40
429.      30  CONTINUE
430.      RETURN
431.      C
432.      C  FILL IN TEXT ARRAY
433.      C
434.      40  K = I + 3
435.      DO 50 J = I, K
436.      IF (NUMBER(J) .EQ. BLANK2) GO TO 60
437.      50  T (J-I+1) = CARD (J)
438.      60  TEXT=SAVE
439.      C
440.      C  LOOK FOR SUCCESSIVE NUMBERS
441.      C
442.      65  NPAR = NPAR + 1
443.      FOND=.FALSE.
444.      IF (NPAR .GT. 3) RETURN
445.      LDEC = .TRUE.
446.      70  J = J + 1
447.      IF (J .GT. 70) RETURN
448.      C
449.      C  J = COLUMN POINTER
450.      C
451.      C  CHECK FOR DECIMAL POINT
452.      C
453.      IF (NUMBER(J) .NE. DOT) GO TO 80
454.      FOND=.TRUE.
455.      LDEC = .FALSE.
456.      P = 10.0
457.      GO TO 70
458.      C
459.      C  LOOK FOR DIGIT MATCH
460.      C  <<THE MATCH GAME>>
461.      80  DO 90 K= 1, 10
462.      IF (NUMBER(J) .EQ. DIG(K)) GO TO 100
463.      90  CONTINUE
464.      C
465.      C  DELIMITER ENCOUNTERED
466.      C
467.      IF (FOND) GO TO 65
468.      GO TO 70
469.      C
470.      C  DIGIT MATCH FOUND
471.      C
472.      100 FOND=.TRUE.
473.      IF (LDEC) GO TO 110
474.      PAR (NPAR) = PAR (NPAR) + (K-1)/P
475.      P = P*10.0
476.      GO TO 70
477.      110 PAR (NPAR) = PAR (NPAR) * 10.0 + K - 1
478.      GO TO 70
479.      END

```