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WORKING PAPER

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Subject: GCFM Users Guide Revision for Model Version 5.0

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ABSTRACT:

This working paper details FORTRAN code corrections to Version 4.0 of the Geothermal Loan Guaranty Cash Flow Model and Manual updates relating to Versions 4.0 and 5.0. The pages of this paper are intended to replace selected pages in MTR80W160 to reflect changes to the model.

DISCLAIMER

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NOTICE

1.0 INTRODUCTION

This paper documents alterations made to the MITRE/DOE Geothermal Cash Flow Model (GCFM) in the period of September 1980 through September 1981.

Version 4.0 of GCFM was installed on the computer at the DOE San Francisco Operations Office in August 1980. This Version has also been distributed to about a dozen geothermal industry firms, for examination and potential use.

During late 1980 and 1981, a few errors detected in the Version 4.0 code were corrected, resulting in Version 4.1. If you are currently using GCFM Version 4.0, it is suggested that you make the changes to your code that are described in Section 2.0. User's manual changes listed in Section 3.0 and Section 4.0 should then also be made.

During the spring and summer of 1981 two new features were added to GCFM, resulting in Version 5.0. These two changes are:

I. Enhancement of the debt amortization code to allow the user to select either a constant principal payment amortization schedule or a constant payment (interest + principal) amortization schedule. The user will be allowed to establish a grace period during which no principal repayments will be made.

II. Inclusion of a facility to allow the user the option of using a Field project revenue stream as the fuel cost for a Power Plant project. This involves a direct pass-through of field revenue values from the financial module to the power plant module where the user has the option of using this series of values as the cost of fuel. This saves the user the time necessary to perform this operation by manual data entry. This will be accomplished by saving the fluid breakeven and market price revenue streams in a buffer for use by power plant financial runs.

Version 5.0 was installed at the DOE San Francisco Operations Office in July 1981.

The computer code for Version 5.0 has been transmitted to the Argonne National Energy Software Center. It can be obtained from the Center for a nominal fee, by writing:

Jan Mockler
Argonne National Energy Software Center
9700 South Cass Avenue
Argonne, Illinois 60439
Telephone: (312) 972-7250

This paper documents:

- Computer code alterations necessary to upgrade Version 4.0 to Version 4.1.
- User's manual updates for Version 4.1 and Version 5.0.
- A short installation guide.

The pages that document the user's manual updates are designed to replace specific pages in the User's Manual (MITRE Technical Report MTR80W160, The MITRE Corporation, McLean, Virginia, 22102, November 1980). In a few cases, pages are to be added to the manual.

2.0 FORTRAN CODE CHANGES FOR GCFM VERSION 4.0

During the first six months of 1981, several have been made in the FORTRAN code of GCFM. These changes are listed in this section as the final changes to Version 4.0, creating Version 4.1.

If you are using a copy of Version 4.0, we recommend that you incorporate these changes into your version, since they will eliminate minor difficulties encountered since December of 1980. If you are using a copy of Version 5.0, you don't have to do anything because these changes have already been incorporated into that version.

In following pages, each change is described by:

1) The segment name, the subroutine name, and the approximate segment line number of the altered line.

2) The altered line and surrounding lines.

3) Underlining of the part(s) of the line that must be altered.

Change 1 - Segment 'FLOW' - Subroutine 'CASH' - new lines
Approximate Line - FLOW#938

```
    C
          IF(NDBG .GT. 2) NP1 = 1
          IF(NDBG .GT. 2) NP2 = 2
          IF(NDBG .GT. 2) NP3 = 3
          DO 3590 ISW=1,2
    C     ROUTINE TO CALCULATE DCFROR FOR MARKET PRICE
```

Change 2 - Segment 'FLOW' - Subroutine 'CASH' - change
Approximate Line - FLOW#944

```
    C
          CALL PWORTH(LIFE,LINE,RTX,CF,PW,DSCR,PVAL1,CFTOT1,DSCF1,ISW,X,Z,
         1    DRT)
```

Change 3 - Segment 'FLOW' - Subroutine 'CASH' - change
Approximate Line - FLOW#951

```
          DO 4000 I=1,50
          CALL PWORTH(LIFE,LINE,RTX,CF,PW,DSCR,PVAL1,CFTOT1,DSCF1,ISW X,Z,
         1    DRT)
```

Change 4 - Segment 'FLOW' - Subroutine 'CASH' - delete lines
Approximate Line - fLOW#958

All lines between the line reading " 4005 CONTINUE " and the line "   IF(ABS(DRT) .LT. 0.0025) GO TO 4010 " should be deleted.

Change 5 - Segment 'FLOW' - Subroutine 'CASH' - change
Approximate Lines - FLOW#952-970

There are three debug output lines in this section of code. They should be changed to read as follows:

```
1st - "     IF(NDBG .EQ. 3 .OR. NDBG .EQ. 4) WRITE(10,*) NP1,I,X,PW,RTX,DRT,Z"
2nd - "     IF(NDBG .EQ. 3 .OR. NDBG .EQ. 4) WRITE(10,*) NP2,I,X,PW,RTX,DRT,Z"
3rd - "     IF(NDBG .EQ. 3. OR. NDBG. EQ. 4) WRITE(10,*) NP3,I,X,PW,RTX,DRT,Z"
```

Change 6 - Segment 'FLOW' - Subroutine 'CASH' - change
Approximate Line - FLOW#1074

```
    C
          CALL PWORTH(LIFE,LINE,RTX,CF,PW,DSCR,PVAL1,CFTOT1,DSCF1,ISW,X,Z,
         1    DRT)
```

Change 7 - Segment 'FLOW' - Subroutine 'CASH' - change
Approximate Line - FLOW#1081

```
      DO 5010 I=1,50
      CALL PWORTH(LIFE,LINE, RTX,CF,PW,DSCR,PVAL1,CFTOT1,DSCF1,ISW,X,Z,
     1    DRT)
```

Change 8 - Segment 'FLOW' - Subroutine 'CASH' - delete lines
Approximate Line - FLOW#958

All lines between the line reading " 5030 CONTINUE " and the line reading "   IF(ABS(DRT) .LT. 0.0025) GO TO 5020 " should be deleted.

Change 9 - Segment 'FLOW' - Subroutine 'CASH' - change
Approximate Lines - FLOW#1082-1092

There are three debug output lines in this section of code. They should be changed to read as follows:

```
1st - "      IF(NDBG .EQ. 3 .OR. NDBG .EQ. 4) WRITE(10,*) NP1,I,X,PW,RTX,DRT,Z"
2nd - "      IF(NDBG .EQ. 3 .OR. NDBG .EQ. 4) WRITE(10,*) NP2,I,X,PW,RTX,DRT,Z"
3rd - "      IF(NDBG .EQ. 3 .OR. NDBG .EQ. 4) WRITE(10,*) NP3,I,X,PW,RTX,DRT,Z"
```

Change 10 - Segment 'FLOW' - Subroutine 'CASH' - change
Approximate Lines - FLOW#1377-1382

```
      END
      SUBROUTINE PWORTH(LIFE,LINE,RT,CF,PW,DSCR,PVAL,CFT,DSCF,ISW,XDM
     1,  ZDM,DRT)
C---$CONTROL SEGMENT=FLOW
C***  SUBROUTINE PWORTH(LIFE,LINE,RT,CF,PW,DSCR,PVAL,CFT,DSCF,ISW,XDM
C*** 1,  ZDM,DRT)
C
```

Change 11 - Segment 'FLOW' - Subroutine 'CASH' - change
Approximate Line - FLOW#335

```
      COMMON /PRP/ NSDEEP,LROCK,NPWEL,NIWEL,NEWEL,
     1 TEMP,BPRES,DEPTH,SPACE,FLOW,CPWEL,CIWEL,CEWEL,EWP,EWI,EWE,
     2 SUCCR(50),OMFR(5),SALV(5),C(6),PFLOW,RFLOW,FELECT,CSTDWP,PPM,
     3 CMWEL, ECSTP(9),RXTRA(3)
```

Change 12 - Segment 'FLOW' - Subroutine 'CASH' - change
Approximate Line - FLOW#472

```
      WLIEXP(IYR) = WLIEXP(IYR)*XC(2)
      IF(IYR .LT. LINE) ECST(IYR) = ECSTP(IYR)*XC(1)
      IF(IYR .LT. LINE) TECST = TECST + ECST(IYR)
```

Change 13 - Segment 'FLOW' - Subroutine 'CASH' - change
Approximate Line - FLOW#747.1

```
      QINTR        = DBTRT(IY)/4.0
      SUMOUT       = DEBT(IY)
C
      DO 2320 J=1,4
      XINTR(IY) = XINTR(IY) + DEBT(IY)*QINTR
      DEBT(IY)  = DEBT(IY)-QPMT
      SUMOUT     = SUMOUT + DEBT(IY)
 2320 CONTINUE
C
C     CALCULATE DFEE BASED ON AVERAGE OUTSTANDING LOAD BALANCE
      DFEE(IY)     = SUMOUT/5.0*FERT
C
```

Change 14 - Segment 'FLOW' - Subroutine 'CONSTR' - new lines
Approximate Line - FLOW#1258

```
      DO 200 I=1,LINE1
      NPASS = 0
      FEE(1) = 0.0
      QINV(1) = TOTCAP(I)/4.0
      QINV(2) = QUINV(1)
      QINV(3) = QINV(1)
      QINV(4) = QINV(1)

C
```

Change 15 - Segment 'FLOW' - Subroutine 'CONSTR' - change
Approximate Line - FLOW#1282

```
C     DEFINE CAPITAL INVESTMENT IF ITERATING FOF FEE.
      IF(NPASS .NE. 1) QINV(1) = TOTCAP(I)/4.0 + FEE(NPASS-1)

C
```

Change 16 - Segment 'FLOW' - Subroutine 'CONSTR' - change
Approximate Line - FLOW#1290

```
C       INITIALIZE FEE WORK AREA.
        FBASE = DEPREV

C
```

Change 17 - Segment 'FLOW' - Subroutine 'CONSTR'
Approximate Line - FLOW#1302

```
C       ADD WORKING CAPITAL INTO THE LAST QUARTER OF THE CONSTRUCTION
C       PERIOD
        IF(I .EQ. LINE1 .AND. J .EQ. 4) QINV(4) = QINV(4) + WKGCAP
C
C       CALCULATE QUARTERLY EQUITY REQUIREMENT.
```

Change 18 - Segment 'FLOW' - Subroutine 'CONSTR' - change
Approximate Line - FLOW#1315

```
C       IS EQUITY SPECIFIED BY 'EQUFR' SUFFICIENT TO FULFILL  % REQUIRED
C       IF SO---USE IT.
        IF(QINV(J)*EQUFR(I).GT.QEQTY)
            QEQTY = QINV(J)*EQUFR(I)

C
```

Change 19 - Segment 'FLOW' - Subroutine ' CONSTR' - change
Approximate Line - FLOW#1340

```
C       CALCULATE AVERAGE OUTSTANDING LOAN BALANCE
        FBASE = FBASE/5.0
        IF(NDBG .GT. 2) WRITE(10,*) FBASE
C
C       CALCULATE FEE(NPASS).
        FEE(NPASS) = FBASE*FERT
C___________________________________
C
```

Change 20 - Segment 'FLOW' - Subroutine 'CASFLO' - change
Approximate Line - FLOW#1622

```
C       IF PROJECT IS A LIMITED PARTNERSHIP - NO TAX CREDITS.
        IF(NLONE .EQ. 1) GO TO 35

C
        IF(TXLIB     .LE. 0.0) GO TO 35
C
```

3.0 USER'S MANUAL CHANGES FOR BOTH V4.1 AND V5.0

The pages in this section are replacement pages for the User's Manual for GCFM Version 4.0 and 5.0. Please discard the equivalent pages in the original document.

These parameters remain constant throughout all of the sample runs. The only parameters which are varied are the Minimum Equity Fraction and the Annual Equity Fraction.

Figure 2-6 is the construction period output of a run using a minimum equity fraction of 0.0 and an annual equity fraction of 0.0. This run exhibits the model's preference for debt.

The only equity in this project is the 3 million dollars in sunk costs.* The annual investment, the interest and the DOE fees are all borrowed. Notice the equity fraction declines in each year and reaches 0.179 in year three.

Figure 2-7 shows what happens when the minimum equity fraction is changed to 0.25. Notice the first year the entire 6.0 million investment is borrowed and it is not until the second and third years that equity investments must be made to maintain the equity fraction at 0.25.

Figure 2-8 represents a run using a minimum equity fraction of 0.25 and annual equity fractions of 0.10. The values of the latter cause the debt preference of the model to be altered. The model will now require equity participation of at least 10% of each annual investment. This is useful when a developer has been given credit for a large amount of sunk costs, because it will prevent the model from assuming the use of 100% debt to cover early year investments.

*Sunk costs represent fixed investment by the borrower prior to application for guaranteed loan.

GLGP CASH FLOW MODEL
CONSTRUCTION PERIOD #F1.1

PROJECT NAME - TEST/V5.0 CONST
PROJECT TYPE - FIELD

FINANCIAL CASE NAME - TEST/V5.0
FINANCIAL STRUCTURE - NON-TAXABLE ENTITY

YEAR	CONSTRUCTION COST	ANNUAL INTEREST	ANNUAL DOE FEE	ANNUAL DEBT	ANNUAL EQUITY	CUMULATIVE DEBT	CUMULATIVE EQUITY	EQUITY FRACTION
SUNK COSTS	3000.0	0.0	0.0	0.0	3000.0	0.0	3000.0	1.000
1 - 1980	6000.0	398.0	31.8	6429.8	0.0	6429.8	3000.0	0.318
2 - 1981	3000.0	891.5	84.2	3975.7	0.0	10405.6	3000.0	0.224
3 - 1982	2000.0	1253.4	121.1	3374.5	0.0	13780.1	3000.0	0.179
TOTAL	14000.0	2543.0	237.1	13780.1	3000.0			

CONSTRUCTION BUDGET (K$/1980):

SUNK EQUITY COSTS	=	3000.0
PROJECT CAPITAL COST	=	11000.0
WORKING CAPITAL	=	0.0
TOTAL (LESS FINANCING)	=	14000.0
DOE FEE'S AND INTEREST	=	2780.1
TOTAL CAPITAL COST	=	16780.1

MINIMUM EQUITY FRACTION = 0.0
DOE FEE = 0.010

YEAR	INTEREST RATE	INVESTMENT BREAKDOWN	ANNUAL ** TAX LOSSES
1 - 1980	0.100	0.545	429.8
2 - 1981	0.100	0.273	975.7
3 - 1982	0.100	0.182	1374.5

** - ANNUAL TAX LOSSES INCLUDE CONSTRUCTION PERIOD DRY HOLE EXPENSES, EXPLORATION COSTS, INTANGIBLE DRILLING COSTS, DOE FEES , AND INTEREST.

FIGURE 2-6
CONSTRUCTION PERIOD OUTPUT WITH NO MINIMUM OR ANNUAL EQUITY FRACTIONS REQUIRED

GLGP CASH FLOW MODEL
CONSTRUCTION PERIOD #F1.1

PROJECT NAME - TEST/V5.0 CONST
PROJECT TYPE - FIELD

FINANCIAL CASE NAME - TEST/V5.0
FINANCIAL STRUCTURE - NON-TAXABLE ENTITY

YEAR	CONSTRUCTION COST	ANNUAL INTEREST	ANNUAL DOE FEE	ANNUAL DEBT	ANNUAL EQUITY	CUMULATIVE DEBT	CUMULATIVE EQUITY	EQUITY FRACTION
SUNK COSTS	3000.0	0.0	0.0	0.0	3000.0	0.0	3000.0	1.000
1 - 1980	6000.0	398.0	31.8	6429.8	0.0	6429.8	3000.0	0.318
2 - 1981	3000.0	879.9	83.3	3614.9	348.3	10044.8	3348.3	0.250
3 - 1982	2000.0	1159.6	112.9	2454.4	818.1	12499.1	4166.4	0.250
TOTAL	14000.0	2437.6	228.0	12499.1	4166.4			

CONSTRUCTION BUDGET (K$/1980):

SUNK EQUITY COSTS	=	3000.0
PROJECT CAPITAL COST	=	11000.0
WORKING CAPITAL	=	0.0
TOTAL (LESS FINANCING)	=	14000.0
DOE FEE'S AND INTEREST	=	2665.5
TOTAL CAPITAL COST	=	16665.5

MINIMUM EQUITY FRACTION = 0.250
DOE FEE = 0.010

YEAR	INTEREST RATE	INVESTMENT BREAKDOWN	ANNUAL ** TAX LOSSES
1 - 1980	0.100	0.545	429.8
2 - 1981	0.100	0.273	963.2
3 - 1982	0.100	0.182	1272.5

** - ANNUAL TAX LOSSES INCLUDE CONSTRUCTION PERIOD DRY HOLE EXPENSES, EXPLORATION COSTS, INTANGIBLE DRILLING COSTS, DOE FEES , AND INTEREST.

FIGURE 2-7
CONSTRUCTION PERIOD WITH MINIMUM TOTAL EQUITY FRACTION OF 0.25

GLGP CASH FLOW MODEL
CONSTRUCTION PERIOD #F1.1

PROJECT NAME - TEST/V5.0 CONST
PROJECT TYPE - FIELD

FINANCIAL CASE NAME - TEST/V5.0
FINANCIAL STRUCTURE - NON-TAXABLE ENTITY

YEAR	CONSTRUCTION COST	ANNUAL INTEREST	ANNUAL DOE FEE	ANNUAL DEBT	ANNUAL EQUITY	CUMULATIVE DEBT	CUMULATIVE EQUITY	EQUITY FRACTION
SUNK COSTS	3000.0	0.0	0.0	0.0	3000.0	0.0	3000.0	1.000
1 - 1980	6000.0	357.9	28.6	5783.7	602.9	5783.7	3602.9	0.384
2 - 1981	3000.0	801.2	75.7	3569.3	307.6	9353.0	3910.4	0.295
3 - 1982	2000.0	1125.5	108.7	3020.3	214.0	12373.3	4124.4	0.250
TOTAL	14000.0	2284.7	213.0	12373.3	4124.4			

CONSTRUCTION BUDGET (K$/1980):

SUNK EQUITY COSTS	=	3000.0
PROJECT CAPITAL COST	=	11000.0
WORKING CAPITAL	=	0.0
TOTAL (LESS FINANCING)	=	14000.0
DOE FEE'S AND INTEREST	=	2497.7
TOTAL CAPITAL COST	=	16497.7

MINIMUM EQUITY FRACTION = 0.250
DOE FEE = 0.010

YEAR	INTEREST RATE	INVESTMENT BREAKDOWN	ANNUAL ** TAX LOSSES
1 - 1980	0.100	0.545	386.5
2 - 1981	0.100	0.273	876.9
3 - 1982	0.100	0.182	1234.3

** - ANNUAL TAX LOSSES INCLUDE CONSTRUCTION PERIOD DRY HOLE EXPENSES, EXPLORATION COSTS, INTANGIBLE DRILLING COSTS, DOE FEES , AND INTEREST.

FIGURE 2-8
CONSTRUCTION PERIOD WITH MINIMUM TOTAL EQUITY FRACTION OF 0.25 AND ANNUAL EQUITY FRACTIONS OF 0.1

In the run represented by Figure 2-9, the annual equity investments are increased to 0.25. This causes the model to require equity investments to comprise 25% of each annual investment. Because of this requirement, coupled with the 100% equity sunk costs the minimum equity fraction is never approached.

2.4.9 Financial Case Initialization

There is a great deal of data entry involved in the creation of any new financial case. After entering several cases the user may discover that he is entering similar data values for many parameters. For this reason the model contains a feature which allows the user to set up a baseline set of values which may (at the users request) be used to initialize any subsequent financial cases. This allows the user to bypass the financial input routine and proceed to the change routine. In many cases this can save a great deal of time.

The mechanics of this feature are relatively simple. The user first creates a new financial case called "BASELINE" entering only those values which are to make up the initial data. From then on, any time a new financial case is created, the model will ask the user if the new case is to be initialized with the data in the "baseline case." If the user answers yes, the model performs the initialization and enters the change routine, bypassing the financial data entry routine. The user will then alter variables as needed for the new financial case.

GLGP CASH FLOW MODEL
CONSTRUCTION PERIOD #P1.1

PROJECT NAME - TEST/V5.0 CONST
PROJECT TYPE - FIELD

FINANCIAL CASE NAME - TEST/V5.0
FINANCIAL STRUCTURE - NON-TAXABLE ENTITY

YEAR	CONSTRUCTION COST	ANNUAL INTEREST	ANNUAL DOE FEE	ANNUAL DEBT	ANNUAL EQUITY	CUMULATIVE DEBT	CUMULATIVE EQUITY	EQUITY FRACTION
SUNK COSTS	3000.0	0.0	0.0	0.0	3000.0	0.0	3000.0	1.000
1 - 1980	6000.0	297.9	23.8	4815.7	1506.0	4815.7	4506.0	0.483
2 - 1981	3000.0	666.2	62.9	2963.4	765.7	7779.2	5271.7	0.404
3 - 1982	2000.0	935.0	90.4	2502.7	522.6	10281.9	5794.3	0.360
TOTAL	14000.0	1899.1	177.1	10281.9	5794.3			

CONSTRUCTION BUDGET (K$/1980):

SUNK EQUITY COSTS	=	3000.0
PROJECT CAPITAL COST	=	11000.0
WORKING CAPITAL	=	0.0
TOTAL (LESS FINANCING)	=	14000.0
DOE FEE'S AND INTEREST	=	2076.2
TOTAL CAPITAL COST	=	16076.2

MINIMUM EQUITY FRACTION = 0.250
DOE FEE = 0.010

YEAR	INTEREST RATE	INVESTMENT BREAKDOWN	ANNUAL ** TAX LOSSES
1 - 1980	0.100	0.545	321.7
2 - 1981	0.100	0.273	729.2
3 - 1982	0.100	0.182	1025.3

** - ANNUAL TAX LOSSES INCLUDE CONSTRUCTION PERIOD DRY HOLE EXPENSES, EXPLORATION COSTS, INTANGIBLE DRILLING COSTS, DOE FEES , AND INTEREST.

FIGURE 2-9
CONSTRUCTION PERIOD WITH MINIMUM TOTAL EQUITY FRACTION OF 0.25 AND ANNUAL EQUITY FRACTIONS OF 0.25

Revised June 22, 1981

Range of Values: 0-1.0, the total of all values must equal one. If not, the program will prorate those values given.

Number of Values: 1-9. A value must be given for each year of the construction period. Note, however, that any year may contain a zero value.

Units: Fraction

Defaults: As follows: (See Table 3-2)

Comments: As long as one of the values given are not zero, no defaults will be taken.

Example 1: If a three year construction period exists, and the values .25, .25, and .50 are given, then one quarter of the capital costs will be spent the first and second years, with the last half being spent the third year.

Example 2: If the user does not want any capital spent in the second construction year, he may use values such as .25, 0, 0.75. This would indicate that no work was performed during the second year of the construction period.

Example 3: Given a three year construction period, if the values 1,2, and 3 are entered, the program will correct them by prorating the values, One-sixth would be used for the first value, .33 for the second, and .50 for the third.

TABLE 3-2

DEFAULTS FOR CONSTRUCTION INVESTMENTS BREAKDOWN

NUMBER OF CONSTRUCTION YEARS	CONSTRUCTION YEAR 1	2	3	4	5	6	7	8	9
1	1.00	–	–	–	–	–	–	–	–
2	0.40	0.60	–	–	–	–	–	–	–
3	0.15	0.35	0.50	–	–	–	–	–	–
4	0.10	0.25	0.25	0.40	–	–	–	–	–
5	0.10	0.20	0.20	0.20	0.30	–	–	–	–
6	0.05	0.10	0.15	0.20	0.25	0.25	–	–	–
7	0.05	0.05	0.10	0.10	0.20	0.25	0.25	–	–
8	0.05	0.05	0.05	0.10	0.10	0.20	0.20	0.25	–
9	0.05	0.05	0.05	0.05	0.05	0.10	0.20	0.20	0.25

Range of Values: 0-1.0
Number of Values: One value is required for each year of the project life.
Units: Fraction
Default: 0.0 during construction years; 1.0 during entire operating life.
¡WARNING! The capacity factor must be zero during the construction period and should not be zero during the operating life.

9. Minimum Equity Fraction of Total Investment: The minimum portion of the capital cost of development which must be supplied by the developer in the form of equity.
Range of Values: 0-1.0
Number of Values: One
Units: Fraction
Default: .25
Comments: Note that this is not the same as the annual equity fractions. The minimum equity fraction represents an overall limitation on the amount of the borrower's risk capital (equity) during the construction period.

10. Annual Equity Fractions: A fraction representing the minimum required equity contribution to capital investment in any given construction year. Not to be confused with the minimum equity fraction of total investment.
Range of Values: 0-1.0
Number of Values: From one to nine values should be provided. One for each construction year.
Units: Fraction
Default: 0.0

11. Equity Rate of Return: The desired rate of return on equity which reflects the breakeven level of operation. The equity rate of return is used to calculate the annual breakeven prices in the breakeven price calculation.
Range of Values: 0-1.0
Number of Values: One for each year of the operating life of the project.
Units: Fraction
Default: 0.0

Comments: The equity rate of return is multiplied by the equity in the project to determine the cash flow required. This result is used to calculate the breakeven price. Equity Rate of Return values for construction years are ignored by the model.

12. Principal Payments on Debt: The annual debt retirement payments made during the project operating life.
Number of Values: One value for each year of the life of the loan.
Units: Thousands of dollars
Default: Equal principal payments for the length of time the power-on-line year and the end of the loan life.
Example: Consider a project whose base year is 1979 and power-on-line is 1982. The project life and loan life are assumed to be 33 and 30, respectively. The construction period therefore, is three years. The plant begins operating in 1982 and continues through 2012. Note that in 1982 the debt has twenty-seven years of life remaining while the plant has thirty years left. The default for each principal repayment will be 1/27th of the initial debt balance at power-on-line. Note that during the final three years the loan has been fully paid up and retired. Version 5.0 of the model has a constant payment debt amortization option (See 2.4.12).

13. Debt Interest Rate: Interest rate on the loan.
Range of Values: 0-1.0
Number of Values: One for each year of the life of the loan.
Units: Fraction
Default: 0.0

14. Department of Energy (DOE) Fee Rate: Portion of the annual average outstanding loan balance which must be paid to DOE to cover administration and build-up of reserve fund for coverage of defaults.
Range of Values: 0-1.0
Number of Values: One
Units: Fraction
Default: 0.01

15. Sinking Fund Deposits: The amount of money to be deposited in an account used to accumulate capital for replacement equipment. If no sinking fund is being used, this variable may be ignored.
Number of Values: One for each year of the operating life of the project.
Units: Thousands of dollars
Defaults: Defaults are calculated by financial module, and are intended to accumulate sufficient funds for all future replacements.

16. Sinking Fund Interest Rate: The before tax rate of return on the accumulated capital in the sinking fund.
Range of Values: 0-1.0
Number of Values: One
Units: Fraction
Default: .10

17. General Inflation Rate: The escalation rate for other operating costs and salvage values.
Range of Values: 0-1.0
Number of Values: One for each year of the project life.
Units: Fraction
Default: 0.0

18. Escalation Rate for Capital Costs: Rates reflecting the increase in the costs of capital accounts.
Range of Values: 0-10
Number of Values: One for each year of the project life for each capital account.
Units: Fraction
Default: 0.0
Comments: Each capital account has a separate annual escalation factor. See Capital Accounts Variables.

19. Escalation Rate for Market Price of Electricity: A rate which reflects the annual change in the market price of electricity.
Range of Values: 0-1.0
Number of Values: One for each year of the project life.
Units: Fraction
Default: 0.0
Comments: This value should be zero if a fixed price is assumed. Using zeroes during the construction years will result in the price of electricity not being escalated until the end of the first year of operation.

20. Escalation Rate for the Fluid Price: A rate which reflects the annual change in the market price of geothermal fluid.
Range of Values: 0-10
Number of Values: One for each year of the project life.
Units: Fraction
Default: 0.0
Comment: This value should be zero if a fixed price is assumed. Using zeroes during the construction years will result in the price of geothermal fluid not being escalated until the first year of operation.

21. Escalation Rate of Overhead and Maintenance (O&M) Costs: Rate which reflects the annual change in O&M cost.
Range of Values: 0-1.0
Number of Values: One for each year of the project life.
Units: Fraction
Default: 0.0

NOTE: The model calculates escalation at the end of the year.

22. <u>Discount Rate</u>: The rate at which cash flows are discounted to levelize the break-even prices and to determine the discounted cash flow rate of return at a given market price.
<u>Range of Values</u>: 0-1.0
<u>Number of Values</u>: One for each year of the project life.
<u>Units</u>: Fraction
<u>Defaults</u>: 0.0

23. <u>State Property Tax Rate</u>: The rate at which property taxes are assessed on the assets of the project. The property tax base is equal to the book value of the project. (i.e., undepreciated portion of all capital investments).
<u>Range of Values</u>: 0-1.0
<u>Number of Values</u>: One for each year of the project life.
<u>Units</u>: Fraction
<u>Default</u>: 0.0
<u>Comment</u>: No property taxes are assessed during the construction period. The values entered for these years will be ignored.

24. <u>Royalty Rate</u>: The portion of revenue paid as royalties.
<u>Range of Values</u>: 0-1.0
<u>Number of Values</u>: One for each year of the project life.
<u>Units</u>: Fraction
<u>Default</u>: 0.0
<u>Comments</u>: This applies to both power plant projects and field projects.

25. <u>Federal Income Tax Rate</u>: Rate of federal income tax paid on income earned by the project.
<u>Range of Values</u>: 0-1.0
<u>Number of Values</u>: One for eacy year of the project life.
<u>Units</u>: Fraction
<u>Default</u>: 0.0

26. <u>State Income Tax Rate</u>: Rate of state income taxes paid on income earned by the project.
<u>Range of Values</u>: 0-1.0
<u>Number of Values</u>: One for each year of the project life.
<u>Units</u>: Fraction
<u>Default</u>: 0.0

27. <u>Federal Tax Credit Rate</u>: Rates for each of the five capital accounts representing the fraction of any annual investments which may be taken as an investment tax credit.
<u>Range of Values</u>: 0-1.0
<u>Number of Values</u>: One value for each year of project life for each capital account.
<u>Units</u>: Fraction
<u>Defaults</u>: 0.0

28. <u>Depletion Allowance Rate</u>: The fraction of revenue that may be deducted from income taxes as an allowance for depletion of the geothermal resource.
<u>Range of Values</u>: 0-1.0
<u>Number of Values</u>: One for each year of the operating life of project.
<u>Units</u>: Fraction
<u>Defaults</u>: 0.0
<u>Comments</u>: This value is ignored when the project is a power plant.

GLGP CASH FLOW MODEL
CONSTRUCTION PERIOD #F1.1

PROJECT NAME - SAMPLE
PROJECT TYPE - POWER PLANT

FINANCIAL CASE NAME - SAMPLE
FINANCIAL STRUCTURE - TAXABLE ENTITY

YEAR	CONSTRUCTION COST	ANNUAL INTEREST	ANNUAL DOE FEE	ANNUAL DEBT	ANNUAL EQUITY	CUMULATIVE DEBT	CUMULATIVE EQUITY	EQUITY FRACTION
SUNK COSTS	4000.0	0.0	0.0	0.0	4000.0	0.0	4000.0	1.000
1 - 1980	11550.1	1294.1	57.5	11741.0	1160.8	11741.0	5160.8	0.305
2 - 1981	38111.9	9504.0	438.0	112239.3	36166.0	123980.2	41326.8	0.250
WORK CAP.*	5017.6							
TOTAL	58679.6	10798.1	495.6	123980.2	41326.8			

* - WORKING CAPITAL INVESTMENT MADE DURING THE FOURTH QUARTER OF THE FINAL CONSTRUCTION YEAR.

CONSTRUCTION BUDGET (K$/1980):

SUNK EQUITY COSTS	=	4000.0
PROJECT CAPITAL COST	=	49662.0
WORKING CAPITAL	=	5017.6
TOTAL (LESS FINANCING)	=	58679.6
DOE FEE'S AND INTEREST	=	11293.6
TOTAL CAPITAL COST	=	69973.2

MINIMUM EQUITY FRACTION = 0.250
DOE FEE = 0.010

YEAR	INTEREST RATE	INVESTMENT BREAKDOWN	ANNUAL ** TAX LOSSES
1 - 1980	0.180	0.250	1351.6
2 - 1981	0.180	0.750	9942.0

** - ANNUAL TAX LOSSES INCLUDE CONSTRUCTION PERIOD DRY HOLE EXPENSES, EXPLORATION COSTS, INTANGIBLE DRILLING COSTS, DOE FEES , AND INTEREST.

FIGURE 5-6
FIELD AND POWER PLANT DESIGNS, FINANCIAL CONSTRUCTION PERIOD REPORT

GLGE CASH FLOW MODEL
OPERATION PERIOD REPORT #P2.1

MARKET PRICE - REVENUE REPORT

PROJECT NAME - SAMPLE
PROJECT TYPE - POWER PLANT

FINANCIAL CASE NAME - SAMPLE
FINANCIAL STRUCTURE - TAXABLE ENTITY

YEAR	P.P. NET * (K-MWH)	X	PRICE** (MIL/KWH)	= SALES REVENUE	+	SALVAGE REVENUE	=	TOTAL REVENUE	-	OPERATING EXPENSES	=	BEFORE TAX INCOME/LOSS
3 - 1982	219.1		175.6	38486.2		0.0		38486.2		52362.2		-13876.0
4 - 1983	394.5		196.7	77588.1		0.0		77588.1		80772.6		-3184.5
5 - 1984	394.5		220.3	86898.7		0.0		86898.7		86747.8		150.9
6 - 1985	394.5		246.7	97326.5		0.0		97326.5		93918.6		3408.0
7 - 1986	394.5		276.3	109005.6		0.0		109005.6		102941.2		6064.5
8 - 1987	394.5		309.5	122086.2		0.0		122086.2		121152.1		934.2
9 - 1988	394.5		346.6	136736.6		0.0		136736.6		129428.7		7307.9
10 - 1989	394.5		388.2	153144.9		0.0		153144.9		142952.1		10192.9
11 - 1990	394.5		434.8	171522.2		0.0		171522.2		159101.0		12421.3
12 - 1991	394.5		487.0	192104.9		0.0		192104.9		178399.7		13705.3

* - THEORETICAL OUTPUT = 438.3 K-MWH/YEAR (ASSUMES A CAPACITY FACTOR OF 100%)
AVERAGE CAPACITY FACTOR = 86.0 %
AVERAGE OUTPUT = 376.9 K-MWH/YEAR

** - MARKET PRICE ESCALATED AT AVERAGE ANNUAL RATE OF 12.0 %

FIGURE 5-7
FIELD AND POWER PLANT DESIGNS
MARKET PRICE REVENUE REPORT

GLGP CASH FLOW MODEL
OPERATION PERIOD REPORT #F3.1

BREAKEVEN PRICE - REVENUE REPORT

PROJECT NAME - SAMPLE
PROJECT TYPE - POWER PLANT

FINANCIAL CASE NAME - SAMPLE
FINANCIAL STRUCTURE - TAXABLE ENTITY

YEAR	P.P. NET * (K-MWH)	X PRICE** (MIL/KWH)	= SALES REVENUE	+ SALVAGE REVENUE	= TOTAL REVENUE	- OPERATING EXPENSES	= BEFORE TAX INCOME/LOSS
3 - 1982	219.1	336.2	73668.1	0.0	73668.1	63359.4	10308.7
4 - 1983	394.5	321.3	126743.6	0.0	126743.6	78424.1	48319.6
5 - 1984	394.5	343.0	135313.1	0.0	135313.1	74404.6	60908.4
6 - 1985	394.5	356.9	140768.8	0.0	140768.8	70274.1	70494.7
7 - 1986	394.5	427.6	168683.9	0.0	168683.9	67995.2	100688.5
8 - 1987	394.5	338.4	133496.6	0.0	133496.6	73181.4	60315.2
9 - 1988	394.5	390.4	153987.7	0.0	153987.7	66257.1	87730.6
10 - 1989	394.5	400.0	157786.2	0.0	157786.2	61729.0	96057.2
11 - 1990	394.5	304.0	119904.2	0.0	119904.2	56299.9	63604.4
12 - 1991	394.5	295.8	116665.2	0.0	116665.2	54143.8	62521.4

LEVELIZED BREAKEVEN PRICE (CONSTANT-CURRENT DOLLARS) =351.6 MILLS/KWH

LEVELIZED BREAKEVEN PRICE (1980 DOLLARS) =178.0 MILLS/KWH
ASSUMES AN AVERAGE ANNUAL PRICE ESCALATION OF 12.0 % BEGINNING IN 1980

* - THEORETICAL OUTPUT = 438.3 K-MWH/YEAR (ASSUMES A CAPACITY FACTOR OF 100%)
AVERAGE CAPACITY FACTOR = 86.0 %
AVERAGE OUTPUT = 376.9 K-MWH/YEAR

FIGURE 5-8
FIELD AND POWER PLANT DESIGNS, FINANCIAL OPERATIONAL BREAKEVEN PRICE REVENUE REPORT

GLGP CASH FLOW MODEL
OPERATION PERIOD REPORT #F2.2

MARKET PRICE - INCOME TAX REPORT

PROJECT NAME - SAMPLE
PROJECT TYPE - POWER PLANT

FINANCIAL CASE NAME - SAMPLE
FINANCIAL STRUCTURE - TAXABLE ENTITY

YEAR	BEFORE TAX INCOME/LOSS	- TAX LOSS FORWARD =	TAXABLE INCOME **	INCOME TAX LIABILITY -	INCOME TAX CREDITS =	TAXES PAID **	BEFORE TAX INCOME/LOSS	- TAXES PAID =	AFTER TAX INCOME/LOSS
3 - 1982	-29442.6	0.0	-29442.6 **	0.0	0.0	0.0 **	-29442.6	0.0	-29442.6
4 - 1983	-16687.5	0.0	-16687.5 **	0.0	0.0	0.0 **	-16687.5	0.0	-16687.5
5 - 1984	-11280.9	0.0	-11280.9 **	0.0	0.0	0.0 **	-11280.9	0.0	-11280.9
6 - 1985	-5961.6	0.0	-5961.6 **	0.0	0.0	0.0 **	-5961.6	0.0	-5961.6
7 - 1986	-1441.0	0.0	-1441.0 **	0.0	0.0	0.0 **	-1441.0	0.0	-1441.0
8 - 1987	-7643.9	0.0	-7643.9 **	0.0	0.0	0.0 **	-7643.9	0.0	-7643.9
9 - 1988	903.0	903.0	0.0 **	0.0	0.0	0.0 **	903.0	0.0	903.0
10 - 1989	6024.6	6024.6	0.0 **	0.0	0.0	0.0 **	6024.6	0.0	6024.6
11 - 1990	9707.6	9707.6	0.0 **	0.0	0.0	0.0 **	9707.6	0.0	9707.6
12 - 1991	11521.5	11521.5	0.0 **	0.0	0.0	0.0 **	11521.5	0.0	11521.5

FIGURE 5-9
FIELD AND POWER PLANT DESIGNS
MARKET PRICE INCOME TAX REPORT

GLGP CASH FLOW MODEL
OPERATION PERIOD REPORT #F3.2

BREAKEVEN PRICE - INCOME TAX REPORT

PROJECT NAME - SAMPLE
PROJECT TYPE - POWER PLANT

FINANCIAL CASE NAME - SAMPLE
FINANCIAL STRUCTURE - TAXABLE ENTITY

YEAR	BEFORE TAX INCOME/LOSS	- TAX LOSS FORWARD =	TAXABLE ** INCOME **	INCOME TAX LIABILITY -	INCOME TAX CREDITS =	TAXES ** PAID **	BEFORE TAX INCOME/LOSS	- TAXES PAID =	AFTER TAX INCOME/LOSS
3 - 1982	10308.7	10308.7	0.0 **	0.0	0.0	0.0 **	10308.7	0.0	10308.7
4 - 1983	48319.6	985.0	47334.6 **	23951.3	0.0	23951.3 **	48319.6	23951.3	24368.3
5 - 1984	60908.4	0.0	60908.4 **	30819.6	0.0	30819.6 **	60908.4	30819.6	30088.8
6 - 1985	70494.7	0.0	70494.7 **	35670.3	0.0	35670.3 **	70494.7	35670.3	34824.4
7 - 1986	100688.5	0.0	100688.5 **	50948.4	0.0	50948.4 **	100688.5	50948.4	49740.1
8 - 1987	60315.2	0.0	60315.2 **	30519.5	6191.0	24328.5 **	60315.2	24328.5	35986.7
9 - 1988	87730.6	0.0	87730.6 **	44391.7	0.0	44391.7 **	87730.6	44391.7	43338.9
10 - 1989	96057.2	0.0	96057.2 **	48605.0	0.0	48605.0 **	96057.2	48605.0	47452.3
11 - 1990	63604.4	0.0	63604.4 **	32183.8	0.0	32183.8 **	63604.4	32183.8	31420.6
12 - 1991	62521.4	0.0	62521.4 **	31635.8	0.0	31635.8 **	62521.4	31635.8	30885.6

FIGURE 5-10
FIELD AND POWER PLANT DESIGNS, FINANCIAL OPERATIONAL BREAKEVEN PRICE INCOME TAX REPORT

GLGP CASH FLOW MODEL
OPERATION PERIOD REPORT #F2.3

MARKET PRICE - CASH FLOW REPORT

PROJECT NAME - SAMPLE
PROJECT TYPE - POWER PLANT

FINANCIAL CASE NAME - SAMPLE
FINANCIAL STRUCTURE - TAXABLE ENTITY

YEAR	AFTER TAX INCOME/LOSS	+ CASH * SOURCES	+ TAX LOSS FORWARD	- DEBT RETIREMENT	= GROSS CASH FLOW	- SINK. FUND DEPOSIT	- OTHER CAP.** INVESTMENTS	= NET CASH FLOW
3 - 1982	-29442.6	15962.7	0.0	15497.5	-28977.4	6148.7	0.0	-35126.1
4 - 1983	-16687.5	13763.0	0.0	15497.5	-18422.0	6148.7	0.0	-24570.7
5 - 1984	-11280.9	11563.3	0.0	15497.5	-15215.1	6148.7	0.0	-21363.8
6 - 1985	-5961.6	9363.7	0.0	15497.5	-12095.5	6148.7	0.0	-18244.2
7 - 1986	-1441.0	7164.0	0.0	15497.5	-9774.5	6148.7	0.0	-15923.3
8 - 1987	-7643.9	16275.6	0.0	15497.5	-6865.9	0.0	0.0	-6865.9
9 - 1988	903.0	10430.0	903.0	15497.5	-3261.5	0.0	0.0	-3261.5
10 - 1989	6024.6	7822.5	6024.6	15496.7	4374.9	0.0	0.0	4374.8
11 - 1990	9707.6	5215.0	9707.6	0.0	24630.3	0.0	0.0	24630.2
12 - 1991	11521.5	2607.5	11521.5	0.0	25650.5	0.0	0.0	25650.4

DISCOUNTED CASH FLOW RATE OF RETURN = -14.8 % (BASED ON NOMINAL CASH FLOWS)

= -26.6 % (BASED ON PRESENT VALUE OF CASH FLOWS IN 1980 DOLLARS)

* - CASH SOURCES INCLUDES ALL TAX DEPRECIATION, DEPLETION ALLOWANCES, INTANGIBLE DRILLING COSTS, AND DRY HOLE EXPENSES.

** - OTHER CAPITAL INVESTMENTS INCLUDE ANNUAL REPLACEMENT WELL INVESTMENTS, MAKE-UP WELL INVESTMENTS, AND FUNDS REQUIRED TO COVER ANY SINKING FUND SHORTFALLS.

FIGURE 5-11
FIELD AND POWER PLANT DESIGNS, FINANCIAL OPERATIONAL MARKET PRICE CASH FLOW REPORT

GLGP CASH FLOW MODEL
OPERATION PERIOD REPORT #P3.3

BREAKEVEN PRICE - CASH FLOW REPORT

PROJECT NAME - SAMPLE
PROJECT TYPE - POWER PLANT

FINANCIAL CASE NAME - SAMPLE
FINANCIAL STRUCTURE - TAXABLE ENTITY

YEAR	AFTER TAX INCOME/LOSS	CASH * + SOURCES	TAX LOSS + FORWARD -	DEBT RETIREMENT =	GROSS CASH FLOW -	SINK. FUND DEPOSIT -	OTHER CAP.** INVESTMENTS =	NET CASH FLOW
3 - 1982	10308.7	15962.7	10308.7	15497.5	21082.6	6148.7	0.0	14933.9
4 - 1983	24368.3	13763.0	985.0	15497.5	23618.7	6148.7	0.0	17470.0
5 - 1984	30088.8	11563.3	0.0	15497.5	26154.6	6148.7	0.0	20005.9
6 - 1985	34824.4	9363.7	0.0	15497.5	28690.5	6148.7	0.0	22541.8
7 - 1986	49740.1	7164.0	0.0	15497.5	41406.6	6148.7	0.0	35257.9
8 - 1987	35986.7	16275.6	0.0	15497.5	36764.8	0.0	0.0	36764.7
9 - 1988	43338.9	10430.0	0.0	15497.5	38271.4	0.0	0.0	38271.5
10 - 1989	47452.3	7822.5	0.0	15496.7	39778.1	0.0	0.0	39778.0
11 - 1990	31420.6	5215.0	0.0	0.0	36635.5	0.0	0.0	36635.6
12 - 1991	30885.6	2607.5	0.0	0.0	33493.1	0.0	0.0	33493.1

DISCOUNTED CASH FLOW RATE OF RETURN = 49.8 % (BASED ON NOMINAL CASH FLOWS)

= 28.5 % (BASED ON PRESENT VALUE OF CASH FLOWS IN 1980 DOLLARS)

* - CASH SOURCES INCLUDES ALL TAX DEPRECIATION, DEPLETION ALLOWANCES, INTANGIBLE DRILLING COSTS, AND DRY HOLE EXPENSES.

** - OTHER CAPITAL INVESTMENTS INCLUDE ANNUAL REPLACEMENT WELL INVESTMENTS, MAKE-UP WELL INVESTMENTS, AND FUNDS REQUIRED TO COVER ANY SINKING FUND SHORTFALLS.

FIGURE 5-12
FIELD AND POWER PLANT DESIGNS, FINANCIAL OPERATIONAL BREAKEVEN PRICE CASH FLOW REPORT

GLGP CASH FLOW MODEL
OPERATION PERIOD REPORT #P2.4

MARKET PRICE - CASH FLOW PATTERN REPORT

PROJECT NAME - SAMPLE
PROJECT TYPE - POWER PLANT

FINANCIAL CASE NAME - SAMPLE
FINANCIAL STRUCTURE - TAXABLE ENTITY

YEAR	NET CASH FLOW	SUM OF NET CASH FLOWS	CASH FLOWS DISCOUNTED	SUM DISCOUNTED	UNUSED TAX BENEFITS TAX LOSSES	UNUSED TAX BENEFITS TAX CREDITS
1 - 1980	-5160.8	-5160.8	-5160.8	-5160.8	1351.6	0.0
2 - 1981	-36166.0	-41326.8	-31177.6	-36338.4	9039.0	0.0
3 - 1982	-35126.1	-76452.9	-26104.4	-62442.8	23418.1	6434.3
4 - 1983	-24570.7	-101023.6	-15741.4	-78184.2	6979.8	0.0
5 - 1984	-21363.8	-122387.4	-11799.0	-89983.2	0.0	0.0
6 - 1985	-18244.2	-140631.6	-8686.3	-98669.4	5720.9	0.0
7 - 1986	-15923.3	-156554.8	-6535.6	-105205.0	1441.0	0.0
8 - 1987	-6865.9	-163420.7	-2429.4	-107634.3	7643.9	6191.0
9 - 1988	-3261.5	-166682.2	-994.9	-108629.1	0.0	0.0
10 - 1989	4374.8	-162307.4	1150.4	-107478.7	0.0	0.0
11 - 1990	24630.2	-137677.1	5583.3	-101895.4	0.0	0.0
12 - 1991	25650.4	-112026.6	5012.5	-96882.9	0.0	0.0

FIGURE 5-13
FIELD AND POWER PLANT DESIGNS
MARKET PRICE CASH FLOW PATTERN REPORT
TAXABLE OWNERSHIP

GLGP CASH FLOW MODEL
OPERATION PERIOD REPORT #P2.4

MARKET PRICE - CASH FLOW PATTERN REPORT

PROJECT NAME - SAMPLE
PROJECT TYPE - POWER PLANT

FINANCIAL CASE NAME - SAMPLE
FINANCIAL STRUCTURE - NON-TAXABLE ENTITY

YEAR	NET CASH FLOW	SUM OF NET CASH FLOWS	CASH FLOWS DISCOUNTED	SUM DISCOUNTED	LIMITED PARTNERSHIP TAX BENEFITS INCOME	DPR/DPL/IDC	TAX CREDITS
1 - 1980	-5160.8	-5160.8	-5160.8	-5160.8	0.0	1351.6	0.0
2 - 1981	-36166.0	-41326.8	-31177.6	-36338.4	0.0	9942.0	0.0
3 - 1982	-34535.8	-75862.6	-25665.7	-62004.1	-13479.9	15962.7	6434.3
4 - 1983	-23980.4	-99842.9	-15363.2	-77367.2	-2924.5	13763.0	0.0
5 - 1984	-20773.5	-120616.4	-11473.0	-88840.2	282.4	11563.3	0.0
6 - 1985	-17653.9	-138270.2	-8405.2	-97245.4	3402.1	9363.7	0.0
7 - 1986	-15332.9	-153603.1	-6293.3	-103538.7	5723.0	7164.0	0.0
8 - 1987	-6865.9	-160469.1	-2429.4	-105968.0	8631.6	16275.6	6191.0
9 - 1988	-4164.6	-164633.6	-1270.3	-107238.2	11333.0	10430.0	0.0
10 - 1989	-1649.7	-166283.3	-433.8	-107672.0	13847.0	7822.5	0.0
11 - 1990	14922.6	-151360.7	3382.7	-104289.2	14922.6	5215.0	0.0
12 - 1991	14128.9	-137231.7	2761.0	-101528.2	14128.9	2607.5	0.0

FIGURE 5-14
FIELD AND POWER PLANT DESIGNS, FINANCIAL OPERATIONAL MARKET PRICE CASH FLOW PATTERN FOR TAX EXEMPT OWNERSHIPS

GLGP CASH FLOW MODEL
OPERATION PERIOD REPORT #F2.5

MARKET PRICE - OPERATING EXPENSE REPORT

PROJECT NAME - SAMPLE
PROJECT TYPE - POWER PLANT

FINANCIAL CASE NAME - SAMPLE
FINANCIAL STRUCTURE - TAXABLE ENTITY

YEAR	ROYALTIES+	O&M/OTHER COSTS +	FUEL COST +	INTEREST COST +	DOE FEE +	TAX DEPREC. +	PROPERTY TAXES +	IDC/DHE +	DEPLETION ALLOWANCE =	OPERATING EXPENSES
3 - 1982	1924.3	2769.7	27452.1	17725.3	1162.3	15962.7	932.4	0.0	0.0	67928.8
4 - 1983	3879.4	3102.1	56331.7	15400.6	1007.3	13763.0	791.5	0.0	0.0	94275.6
5 - 1984	4344.9	3474.4	64218.1	13076.0	852.4	11563.3	650.6	0.0	0.0	98179.5
6 - 1985	4866.3	3891.3	73208.6	10751.3	697.4	9363.7	509.7	0.0	0.0	103288.1
7 - 1986	5450.3	4358.2	83457.7	8426.7	542.4	7164.0	1047.5	0.0	0.0	110446.6
8 - 1987	6104.3	4881.2	95141.7	6102.0	387.4	16275.6	838.0	0.0	0.0	129730.2
9 - 1988	6836.8	5467.0	108461.5	3777.4	232.5	10430.0	628.5	0.0	0.0	135833.5
10 - 1989	7657.2	6123.0	123646.0	1452.8	0.0	7822.5	419.0	0.0	0.0	147120.4
11 - 1990	8576.1	6857.7	140956.4	0.0	0.0	5215.0	209.5	0.0	0.0	161814.6
12 - 1991	9605.2	7680.7	160690.1	0.0	0.0	2607.5	0.0	0.0	0.0	180583.4

FIGURE 5-15
FIELD AND POWER PLANT DESIGNS, FINANCIAL
OPERATIONAL MARKET PRICE OPERATING EXPENSE REPORT

GLGP CASH FLOW MODEL
OPERATION PERIOD REPORT #F2.6

MARKET PRICE - SINKING FUND ACTIVITY & INVESTMENT REPORT

PROJECT NAME - SAMPLE　　　FINANCIAL CASE NAME - SAMPLE
PROJECT TYPE - POWER PLANT　　　FINANCIAL STRUCTURE - TAXABLE ENTITY

YEAR	STARTING BALANCE +	SINK. FUND DEPOSITS +	SINK. FUND INTEREST -	SINK. FUND INCOME TAXES -	SINK. FUND WITHDRAWLS =	FINISHING BALANCE	** **	SINK. FUND INVESTMENT	OTHER CAP. +INVESTMENT	=TOTAL INVESTMENT
3 - 1982	0.0	6148.7	614.9	311.1	0.0	6452.4	**	0.0	0.0	0.0
4 - 1983	6452.4	6148.7	1260.1	637.6	0.0	13223.6	**	0.0	0.0	0.0
5 - 1984	13223.6	6148.7	1937.2	980.2	0.0	20329.3	**	0.0	0.0	0.0
6 - 1985	20329.3	6148.7	2647.8	1339.8	0.0	27786.0	**	0.0	0.0	0.0
7 - 1986	27786.0	6148.7	0.1	0.0	33933.9	0.9	**	33933.9	0.0	33933.9
8 - 1987	0.9	0.0	0.1	0.0	0.0	0.9	**	0.0	0.0	0.0
9 - 1988	0.9	0.0	0.1	0.0	0.0	0.9	**	0.0	0.0	0.0
10 - 1989	0.9	0.0	0.1	0.0	0.0	1.0	**	0.0	0.0	0.0
11 - 1990	1.0	0.0	0.1	0.0	0.0	1.0	**	0.0	0.0	0.0
12 - 1991	1.0	0.0	0.1	0.1	0.0	1.1	**	0.0	0.0	0.0

FIGURE 5-16
FIELD AND POWER PLANT DESIGNS, FINANCIAL OPERATIONAL MARKET PRICE SINKING FUND ACTIVITY AND INVESTMENT REPORT

```
                         GLGP CASH FLOW MODEL
                 FINANCIAL CASE INPUT DATA DUMP REPORT

                    FINANCIAL CASE NAME - SAMPLE

VARIABLE#  1 - BASE YEAR
        1980

VARIABLE#  2 - POWER-ON-LINE YEAR
        1982

VARIABLE#  3 - PROJECT LIFE
          12

VARIABLE#  4 - LOAN LIFE
          10

VARIABLE#  5 - WORKING CAPITAL - (K$)
    4000.000

VARIABLE#  6 - ELECTRICITY MARKET PRICE - (MILLS/KWH)
     140.000

VARIABLE#  7 - FLUID MARKET PRICE - (MILLS/KWH)
      70.000

VARIABLE#  8 - CAPACITY FACTOR
   CONSTRUCTION PERIOD -
      0.0         0.0

   OPERATING LIFE -
       0.500       0.900       0.900       0.900       0.900       0.900       0.900       0.900       0.900       0.900

VARIABLE#  9 - MINIMUM TOTAL EQUITY FRACTION
       0.250

VARIABLE# 10 - MINIMUM ANNUAL EQUITY FRACTION
       0.100       0.100

VARIABLE# 11 - EQUITY RATE OF RETURN
   CONSTRUCTION PERIOD -
      0.0         0.0

   OPERATING LIFE -
       0.300       0.300       0.300       0.300       0.300       0.300       0.300       0.300       0.300       0.300
```

FIGURE 5-17
DATA DUMP FROM FINANCIAL MODULE

GLGP CASH FLOW MODEL
FINANCIAL CASE INPUT DATA DUMP REPORT

FINANCIAL CASE NAME - SAMPLE

VARIABLE# 12 - PRINCIPAL PAYMENTS

CONSTRUCTION PERIOD -

0.0	0.0

OPERATING LIFE -

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

VARIABLE# 13 - DEBT INTEREST RATE

CONSTRUCTION PERIOD -

0.180	0.180

OPERATING LIFE -

0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150

VARIABLE# 14 - DOE USER FEE RATE

0.010

VARIABLE# 15 - SINKING FUND DEPOSITS

CONSTRUCTION PERIOD -

0.0	0.0

OPERATING LIFE -

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

VARIABLE# 16 - SINKING FUND INTEREST RATES

0.100

VARIABLE# 17 - ESCALATION RATE FOR OTHER COSTS

CONSTRUCTION PERIOD -

0.120	0.120

OPERATING LIFE -

0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120

FIGURE 5-17
DATA DUMP FROM FINANCIAL MODULE
(CONTINUED)

GLGP CASH FLOW MODEL
FINANCIAL CASE INPUT DATA DUMP REPORT

FINANCIAL CASE NAME - SAMPLE

VARIABLE# 18 - ESCALATION RATES FOR CAPITAL COSTS

CAPITAL CATEGORY # 1
CONSTRUCTION PERIOD -

0.160	0.160

OPERATING LIFE -

0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160

CAPITAL CATEGORY # 2
CONSTRUCTION PERIOD -

0.160	0.160

OPERATING LIFE -

0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160

CAPITAL CATEGORY # 3
CONSTRUCTION PERIOD -

0.110	0.110

OPERATING LIFE -

0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110

CAPITAL CATEGORY # 4
CONSTRUCTION PERIOD -

0.110	0.110

OPERATING LIFE -

0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110

CAPITAL CATEGORY # 5
CONSTRUCTION PERIOD -

0.0	0.0

OPERATING LIFE -

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

VARIABLE# 19 - ESCALATION RATE FOR ELECTRICITY MARKET PRICE
CONSTRUCTION PERIOD -

0.120	0.120

OPERATING LIFE -

0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120

FIGURE 5-17
DATA DUMP FROM FINANCIAL MODULE
(CONTINUED)

GCFM FINANCIAL ANALYSIS EQUATIONS

This appendix documents the major calculational approaches used in the Geothermal Loan Guaranty Cash Flow Model financial routines.

The subjects covered are:

I. Annual Accounts

- Ia. Annual Revenue
- Ib. Annual Operating Expenses
- Ic. Annual Taxable Income
- Id. Annual After Tax Income
- Ie. Annual Cash Flows

II. Breakeven Prices

- IIa. Annual Breakeven Price
- IIb. Levelized Breakeven Price

III. Discounted Cash Flow Rate of Return

IV. Sinking Fund Calculations

V. Salvage Value

Ia Annual Revenue

$$(A\text{-}1)\ R_i = P_i C_i Q\ (0.36525)\ (24) + S_i$$

Where:

P_i = annual sales price (mills/kwh)*

C_i = annual capacity factor

Q = sales output (MW_e),**

S_i = annual salvage revenue,

R_i = total revenue, and

i = current year.

*The annual sales price for the market price calculations is determined using the base year market price and a market price escalation factor. The annual prices in the breakeven price case are derived by reviewing the entire cash flow calculation.

**The factor (.36525) (24) converts MW_e into 10^3 MWh.

Revised June 29, 1981

Ib <u>Annual Operating Expenses</u>

(A-2) $OC_i = OM_i + F_i + PT_i + IDC_i + DF_i + INT_i + ROY_i + DPR_i + DPL_i$

Where:

OM_i = sum of the annual operations and maintenance costs, and other operating costs,

F_i = annual fuel cost,*

PT_i = annual property tax assessment,**

IDC_i = sum of the annual intangible drilling costs and the annual dry hole expenses,

DF_i = annual DOE user fee,

INT_i = annual interest costs,

ROY_i = annual royalty paid on revenues,

DPR_i = annual tax depreciation,***

DPL_i = annual depletion allowance,****

OC_i = total annual operating expenses, and

i = current year.

*The cost of fuel refers to either the power plant fluid costs or the field's electricity costs.

**Property taxes are calculated as a percentage of the book value of the project.

***Tax depreciation is accelerated using the sum of the years digits method.

****Depletion is calculated using the percentage depletion method.

Revised August 10, 1981

Ic <u>Annual Taxable Income</u>

$$\text{(A-3)}\quad TXI_i = R_i - OC_i$$

Where:

R_i = annual revenue,

OC_i = annual operating expenses,

TXI_i = annual taxable income (loss), and

i = current year.

If the resulting value TXI_i in equation (A-3) is greater than zero, the model determines whether tax losses exist for previous years. If they exist, they are carried forward reducing the current year's taxable income. (See Equation A-4). If the TXI_i value represents a loss (negative), the value is placed in the unused tax losses account and carried forward for up to seven years.

$$\text{(A-4)}\quad 0 \geq TXI_i - TLF_i$$

Where:

TXI_i = annual taxable income,

TLF_i = annual tax loss brought forward, and

i = current year.

The taxable income (Equation A-3) is restated to reflect the tax loss carry forward as follows:

$$\text{(A-5)}\quad TXI_i = R_i - OC_i - TLF_i \geq 0$$

Id Annual After Tax Income (Loss)

The annual taxable income (TXI_i) is greater than zero the model calculates a tax liability, otherwise, the tax liability is assumed to be zero.

(A-6) $ATI_i = TXI_i\ (1 - ET_i) + TC_i$

Where:

TXI_i = annual taxable income,

ET_i = annual effective tax rate,

TC_i = annual investment tax credit,

ATI_i = annual after tax income, and

i = current year.

(A-6a) $ET_i = FTR_i + STR_i - \left(FTR_i\right) \cdot \left(STR_i\right)$

Where:

ET_i = annual effective tax rate,

FTR_i = annual federal income tax rate,

STR_i = annual state income tax rate, and

i = the current year

Revised June 29, 1981

(A-6b) $TXL_i = TXI_i \, (ET_i)$

Where:

TXL_i = annual tax liability

TXI_i = annual taxable income

ET_i = annual effective tax rate, and

i = current year.

Tax Credits

In any tax year the model calculates the investment tax credit as the lesser of the income tax liability or $25,000 plus 50% of the tax liability in excess of $25,000. Any unused credit will be carried forward to the seven suceeding years or until it is used. If unused at the end of seven years the credits are lost.

(A-6c) $TXPD_i = TXL_i - TC_i$

Where:

$TXPD_i$ = annual taxes paid.

TXL_i = annual tax liability,

TC_i = annual tax credits, and*

i = current year.

*Tax Credits are computed as a percentage of each years capital investments. Note power plant computed costs include labor costs which are not tax creditable. Appropriate adjustments should be made.

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Ie Annual Cash Flows

(A-7) $CF_i = ATI_i + TCS_i + TLF_i - PMT_i - INV_i - SFD_i$

Where:

CF_i = annual net cash flow,

ATI_i = annual after tax income (loss),

TCS_i = annual total cash sources,**

TLF_i = annual tax loss carried forward,***

PMT_i = annual debt retirement payment (principle only),

SFD_i = annual sinking fund deposit,

INV_i = annual non sinking fund investment, and

i = current year.

*Cash Sources Values on output reports F2.3 and F3.3 are equal to the sum of depreciation, depletion, and intangible drilling costs.

**Tax depreciation is calculated using the sum of the years digits method.

***Tax losses are carried forward for up to seven years.

Cash Flow Patterns - Financial Reports F2.4 and F3.4 detail the annual cash flows, the sum of these cash flows, the present value of each annual cash flows in base year dollars and the sum of the present value of the cash flows in base year dollars.

IIa Annual Breakeven Price

The annual breakeven price in each year is defined as that price which will cover all operating expenses and yield the desired after tax return on equity. The model calculates a breakeven cash flow which equals the equity value of the project multipled by the equity rate of return. This annual breakeven cash flow is the after tax return from which each annual breakeven price is calculated.

Before making these calculations, we first define the initial equity value at the power-on-line date as the total capital cost minus the amount of debt financing. The subsequent annual equity values are calculated as follows:

$$E_i = E_{i-1} = BDP_i + INV_i + PMT_i \qquad \text{(A-8)}$$

Where:

E_i = annual equity value,

BDP_i = annual book depreciation

INV_i = annual capital investments (replacements),

PMT_i = annual debt retirement payments (principal only), and

i = current year.

Revised June 29, 1981

The derivation of Equation (A-8) is as follows. The total capital value is the sum of the debt and equity values. From this we obtain Equation A-9.

(A-9) $$C_i = D_i + E_i$$

The annual change in capital value of the project is determined by depreciation and investments. This yields Equation A-10.

(A-10) $$C_i = C_{i-1} - BDP_i + INV_i$$

The annual change in the outstanding debt is determined by the annual debt repayment. This yields Equation A-11.

(A-11) $$D_i = D_{i-1} - PMT_i$$

The combination of Equations A-9 and A-10 yields Equation A-12.

(A-12) $$D_i + E_i = D_{i-1} + E_{i-1} - BDP_i + INV_i$$

which is equivalent to A-13 and the original equation A-5

(A-13) $$E_i = E_{i-1} - BDP_1 + INV_i + PMT_i$$

Where:

C_i = annual total capitalization,

D_i = annual debt balance,

E_i = annual equity balance,

BDP_i = annual book depreciation,

INV_i = annual capital investments,

PMT_i = annual debt retirement payment, and

i = current year.

Building upon this definition of equity, we can then derive the breakeven cash flow and the rate of return in equity as follows:

(A-14) $BCF_i = E_i (ROR_i)$

Where:

BCF_i = annual breakeven cash flow,

E_i = annual equity value,

ROR_i = annual after tax return on equity, and

i = current year.

Finally, drawing from Equation A-2, A-7 and A-14, and consolidating variables, the annual breakeven price is calculated as follows:

(A-15) $ABR_i = BCF_i - NTD_i + OPE_i - S_i$

Where:

ABR_i = annual breakeven revenue

NTD_i = non-cash tax deductions [intangible drilling costs (IDC_i), tax loss carried forward (TLF_i), and annual tax depreciation (DPR_i)]

OPE_i = out-of-pocket expenses

S_i = annual salvage revenue, and

i = current year.

(A-15a) $$ABP_i = \frac{ABR_i}{C_i(0.36525)\ (24.0)\ Q}$$

Where:

ABP_i = annual breakeven price,

ABR_i = annual breakeven revenue,

C_i = annual capacity factor,

Q = net sales output, and

i = current year.

(A-15b) $$OPE_i = OM_i + F_i + PT_i + DF_i + ROY_i + TXP_i + PMT_i + SFD_i$$

Where:

OPE_i = annual out of pocket expenses,

OM_i = annual operations and maintenance,

F_i = annual fuel cost,

PT_i = annual property taxes,

DF_i = annual DOE user fee,

ROY_i = annual royalties paid,

TXP_i = annual taxes paid,

PMT_i = annual principal payment,

SFD_i = annual sinking fund deposits,

i = current year.

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IIb Levelized Breakeven Price

As discussed previously, GCFM solves for two distinct levelized breakeven prices as well as the annual breakeven price. Figure A-1 presents a comparison of the two levelized breakeven prices with the annual breakeven price which is derived from Equation A-15. All solid lines in this figure represent nominal or current dollar values. BP_1 is the levelized price adopted by EPRI (EPRI, 1979) and commonly used by the electric utility industry. BP_1 appears in Figure A-1 as a horizontal line which bisects the upward sloping annual breakeven price. By definition, the sum of the present worth of the annual breakeven price stream. Mathematically, this is expressed as:

$$\text{(A-16)} \quad \text{Net Present Value of Revenue Stream} = \sum_{i=1}^{N} \frac{P_i\ (Q_i)}{(1+a)^{i-1}} = \sum_{i=1}^{N} \frac{BP_1\ (Q_i)}{(1+a)^{i-1}}$$

Where:

P_i = annual breakeven price,

Q_i = annual output (10^3 MWh)

a_1 = discount rate,

BP_1 = levelized breakeven price (in current dollars),

i = current year, and

N = project life.

For the early years of a project (up to the point where the annual breakeven price line crosses BP_1), the current dollar price of BP_1 will be greater than the actual breakeven price required in those years. During the later years, however, the price of

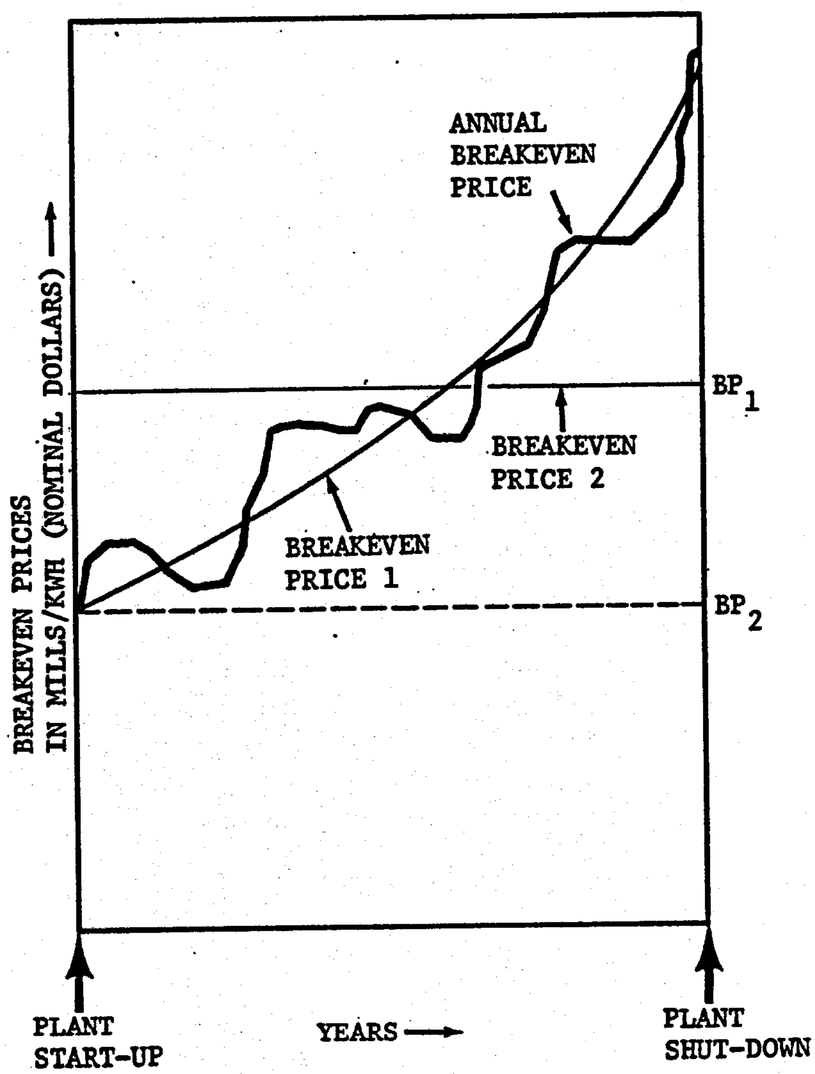

FIGURE A-1
BREAKEVEN PRICES

BP_1 will be lower than the annual breakeven price. The definition of BP_1 implies that the present value of the resulting revenue stream declines over time.

An alternative way of expressing levelized cost is to develop a smooth curve that approximates the irregular slope of the annual breakeven price curve. For this reason, BP_2 has been developed and used for comparative purposes (MITRE, 1977 and MITRE, 1978) to express a levelized price which escalates at fixed rate but is expressed in constant rather than current dollars. The mathematical expression for this approach is as follows:

(A-17) $$\text{New Present Value of Revenue Stream} = \sum_{i=1}^{N} \frac{P_i\,(Q_i)}{(1+a)^{i-1}} = \sum_{i=1}^{N} \frac{BP_2(Q_i)(1+e)^{i-1}}{(1+a)^{i-1}}$$

Where:

P_i = annual breakeven price,

Q_i = annual output (10^3 MWh)

a = discount rate,

e = electricity price escalation factor,

BP_2 = levelized breakeven price (in constant dollars),

i = current year, and

N = project life.

The definition of BP_2 implies that when BP_2 is escalated by the rate e, the present value of the resulting revenue stream remains constant.

Although BP_1 is always greater than BP_2, the differences are entirely conceptual and interpretive in nature.

Despite the different approaches, both methods would result in exactly the same ordering of projects by economic preference. There are philosophical arguments which can be made for using each levelizing technique, depending upon one's frame of reference and the desired assumptions about future price escalations. For the purposes of this model, both levelized prices are provided to enable the user to determine his own preferred approach.

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III DCFROR

To aid in the comparison of various cases both the market price calculations and the breakeven price calculations include calculations at discounted cash flow rates of return (DCFROR). Mathematically, this is the same technique for calculating an internal rate of return (IRR), in which the rate of return solved for is the one which makes the net present value of the project equal to zero. Two such calculations are performed by the model.

$DCFROR_1$ is a strict textbook calculation. The cash flows (Fig. A-2) are to be discounted at an unknown rate r such that the resulting present value of the cash flow stream is zero. Equation A-18 represents this calculation.

$$\text{(A-18)} \qquad 0 = \sum_{i=1}^{N} \frac{CF_i}{(1+R_1)^{i-1}}$$

where

i = current year,

N = project life,

CF_i = annual cash flow, and

R_i = $DCFROR_1$.

This represents a nominal (including inflation) rate of return.

$DCFROR_2$ is a discounted cash flow calculation for the incremental rate of return above a minimum acceptable rate, say the historical average return on investment. This calculation method is similar to that of the $DCFROR_1$, except that the cash flows are discounted twice; first by a typical discount rate which incorporates a real average return on investment (say 2 to 3 percent) plus inflation; and second, by the incremental rate (R_2) which, when solved for, represents the additional return above an assumed average return earned on venture capital. Equation A-19 represents this calculation.

$$(A\text{-}19) \qquad 0 = \sum_{i=1}^{N} \left(\frac{CF_i}{(1+a)^{i-1}}\right) \left(\frac{1}{(1+R_2)^{i-1}}\right)$$

where

i = current year,

n = project life,

CF_i = annual cash flow,

a = discount rate accounting for the time value of money for an average or minimally acceptable investment, including inflation, and

R_2 = $DCFROR_2$ or incremental rate of return.

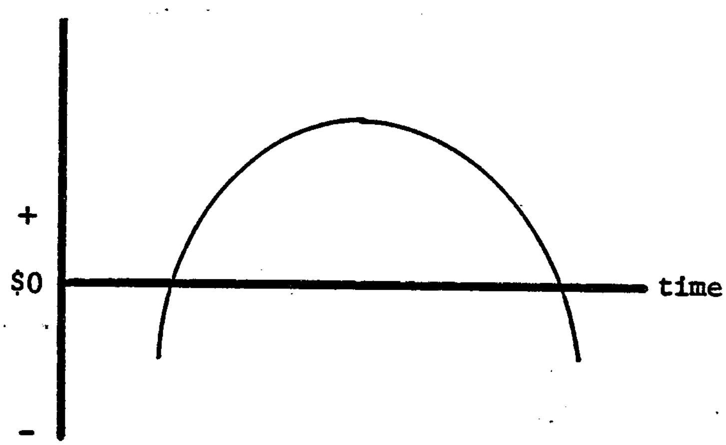

Figure A-2

Cash Flow Vs Time (Positive rate of return)

In the event that a stream of cash flows is negative (Fig. A.3), the project will have a negative rate of return. Such a stream might look like this:

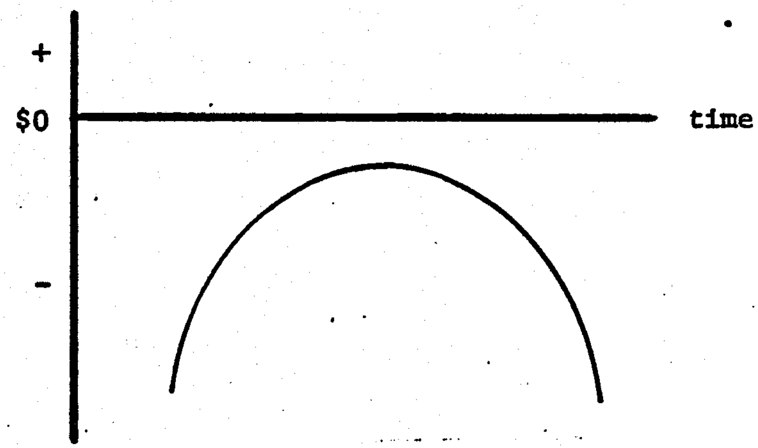

Figure A-3

Cash Flow Vs Time
(Negative Rate of Return)

The cash flow stream must be positive for part of the project duration for the rate of return to be positive.

IV Sinking Fund Calculations

The sinking fund operations are made in the following order:

1) Deposits made and investments removed

2) Interest calculated

3) Taxes calculated

4) Year end balance recalculated to reflect interest and taxes.

(A-20) $SF_i = SF_{i-1} + SD_i - SW_i$

(A-21) $SI_i = SF_i \cdot SFR$

Recalculate year end balance

(A-22) $SF_i = SF_{i-1} + SD_i - SW_i + SI_i - ST_i$

Where:

SF_i = annual sinking fund balance,

SD_i = annual sinking fund deposit,

SW_i = annual sinking fund withdrawal,

SI_i = annual interest earned in sinking fund,

SFR = sinking fund interest rate,

ST_i = sinking fund income taxes paid, and

i = current year.

The Sinking Fund Deposits default calculates a deposit amount sufficient to cover future capital investments associated with equipment replacement. A factor is used to calculate these deposits as a fraction of the replacement cost of an asset.

(A-23)

(A-23) $$FTR = \frac{SFR(1-ATX)}{[(SFR(1-ATX) + 1]^{LF} - 1)}$$

Where:

FTR = sinking fund deposit factor for asset,

ATX = average effective income tax rate,

SFR = sinking fund interest rate, and

LF = book life of the asset.

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4.0 USER'S MANUAL CHANGES FOR V4.1 ONLY

The pages in this section are replacement pages for the User's Manual for GCFM Version 4.1. They do not apply to Version 5.0, and should be discarded if you are updating MITRE Technical Report MTR-80W160 for use with Version 5.0.

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TECHNICAL NOTES

NOTE 1: Memory Size Required

GCFM requires virtual memory size of 750K bytes on an IBM VM/370 system.

NOTE 2: GCFM Subroutines

The names and general functions of the GCFM main program, subroutines, and segments are presented in Table C-1. This table is included for the reader who wishes to study the model in depth.

NOTE 3: Segmentation

The model code is divided into seven code segments. This segmentation is required by the HP 3000 for the purposes of paging. The segment configuration is intended to reduce the amount of paging required to run the program.

NOTE 4: GCFM Debugging Outputs

GCFM contains options that produce output of a great many values of intermediate calculations. These options were built into the code for debugging during the development of the model, but they could be of interest to programmer/analysts who wish to examine intermediate variables in order to further understand or verify the accuracy of the model.

WARNING: Avoid using these options unless you are very familiar with Fortran and the GCFM model. The options produce copious amounts of partially documented output, in some cases will inhibit normal use of certain features of the model, and will at times deliver unlabelled outputs to the terminal screen.

To perform a run with the debugging option turned on, the user must enter the number 10883 instead of 1,2, or 3 when GCFM asks which module is to be used.

GCFM will then print:

ENTER DEBUGGING CODE.

The user then enters one of the following codes to select an option:

TABLE C-1

DESCRIPTION OF GCFM SUBROUTINES

CODE SEGMENT	SUBROUTINE NAME	OTHER SUBROUTINES CALLED	PURPOSE OF SUBROUTINE
MAIN	MAIN PROGRAM	UTILTY, PRODCR, FINANC	GCFM driver program
MAIN	CHANGE	ICHG, RCHG, CHGERR	Generic change routine for all three modules
MAIN	ICHG		Accepts change I/O for integer variables.
MAIN	RCHG		Accepts change I/O for real variables.
MAIN	CHGERR		Perform validity check on critical variables.
MAIN	DDUMP	IPRT, RPRT	Generic database to printer dump routine for three modules
MAIN	IPRT		Output of integer variables on data dump report.
MAIN	RPRT		Output of real variables on data dump report.
ENTR	FININ	SVECT SVECTD DVECT	Data entry routine for financial module.
ENTR	PRODIN	SVECT SVECTD	Data entry routine for field module.
ENTR	UTILIN	SVECT	Data entry routine for power plant module.
ENTR	SVECT		Generic 50 element array input routine - one default
ENTR	SVECTD		Generic 50 element array input routine - two defaults
ENTR	SVECTD		Generic 5 X 50 element matrix input routine
UTIL	UTILTY	PLNTIO UTICAL UTIPRT UTILIN CHANGE (MAIN segment) STDES BTDES STCST BTCST (UDES segment) FINANC (FLOW segment)	Power plant module driver and database manager.
UTIL	PLNTIO	HEAD	Power plant cycle design program I/O routine
UTIL	HEAD		Power plant cycle I/O routine header routine
UTIL	UTICAL		Power plant module cost and design routine
UTIL	UTIPRT	DDUMP (MAIN segment)	Power plant module cost and design print routine

UDES	STDES	various functions	Power plant steam cycle calculation program.
UDES	BTDES	various functions	Power plant supercritical binary cycle calculation program.
UDES	STCST	various functions	Power plant steam cycle capital cost program. (GEOCST,77)
UDES	BTCST	various functions	Power plant binary cycle capital cost program. (GEOCST,77)
UDES	WHL		Function: H(sat.wat.liq) = f(P)
UDES	WHG		Function: H(sat.wat.vap) = f(P)
UDES	WPT		Function: P(sat.wat.vap) = f(T)
UDES	WSL		Function: S(sat.wat.liq) = f(T)
UDES	WSG		Function: S(sat.wat.vap) = f(T)
UDES	WSV		Function: V(sat.wat.vap) = f(P)
UDES	WDH		Function: H(sup.wat.vap) = f(P,T)
UDES	WDS		Function: S(sup.wat.vap) = f(P,T)
UDES	BPT		Function: P(sat.iso.vap) = f(T)
UDES	BHG		Function: H(sat.iso.vap) = f(P)
UDES	BHL		Function: H(sat.iso.liq) = f(P)
UDES	BSG		Function: S(sat.iso.vap) = f(P)
UDES	BSL		Function: S(sat.iso.liq) = f(P)
UDES	BDH		Function: H(sup.iso.vap) = f(P,T)
UDES	BDS		Function: S(sup.iso.vap) = f(P,T)
UDES	BHS		Function: H(sup.iso.vap) = f(P,S)
UDES	BSV		Function: V(sup.iso.vap) = f(P,T)
UDES	BTP		Function: T(sat.iso.vap) = f(P)
UDES	BDT		Function: T(sat.iso.vap) = f(P,S)
PROD	PRODCR	PRODES PROPRT PRODIN CHANGE (MAIN segment) FINANC (FLOW segment)	Field module driver and database manager.
PROD	PRODES	PLNTIO UTICAL UTIPRT	Field design and capital cost routine.
PROD	PROPRT	DDUMP (MAIN segment)	Field design and capital cost print routine.
FLOW	FINANC	FINCHK CASH FININ CHANGE (MAIN segment)	Financial routine driver and database manager
FLOW	FINCHK		Checks validity of project time framework
FLOW	CASH	PWORTH CASFLO CONSTR AMORT FULCST (FSUB segment) LEVEL FINPRT FINPR2 (FSUB segment) DDUMP (MAIN segment)	Financial analysis main routine
FLOW	PWORTH		Calculates present value of a series of cash flows
FLOW	CASFLO		Calculates net cash flows, income taxes, tax credit carryforwards, tax loss carryforwards, royalties and depletion allowance.
FSUB	CONSTR		Calculates debt/equity, interest and doe fees during const.
FSUB	LEVEL		Calculates levelization of breakeven prices.
FSUB	AMORT		Calculates debt amortization during operating life.
FSUB	FULCST		Calculates fuel costs
FSUB	FINPRT		Financial output routine for market price calculations
FSUB	FINPR2		Financial output routine for breakeven price calculations

CODE	OPTION
1	Turn on debug output for power plant module only.
2	Turn on debug output for field module only.
3	Turn on debug output for financial module only.
4	Turn on debug output for all three modules. Under this option, the display of all change menus at the user's terminal is inhibited.

The user should then enter 1,2 or 3 to select a module in the normal manner. That module will then be operated with the selected debug option in effect.

The debugging option is turned off the next time a module is selected.

The reader should note that most of the additional outputs generated by these options will not be interpretable unless the FORTRAN source code is examined in detail.

5.0 USER'S MANUAL CHANGES FOR V5.0 ONLY

The pages in this section are replacement pages for the User's manual for GCFM Version 5.0. They do not apply to Version 4.0, and should be discarded if you are updating MITRE Technical Report MTR-80W160 for use with Version 4.1.

2.4.6 Modes of Calculation

The Financial Modules generates two sets of reports, each representing a different type of calculation. The major difference betwee them is in the method in which the revenue stream is calculated. The first uses the annual escalated market price to generate the revenue steam from which the profitability of a given project may be calculated. Thus for the market price report, GCFM begins with an assumed series of selling prices, and from the resulting cash flows (the difference between revenues and costs after taxes), assessed the ability of a given project to meet its financial obligations on a year-to-year basis.

The second calculation more closely resembles the typical revenue requirements approach used in utility financing. This method calculates a required revenue stream necessary to achieve a desired return on equity. This is called the annual breakeven price. Since this annual price differs from year to year, it is difficult to compare the relative merits of different projects. Through the process of levelization. used throughout the electric utility industry, the required selling price for a given project can be expressed as a single number. Such a number may be considered as the average cost of power, including required return to all parties, over the lifetime of the project. However, there are different ways of levelizing a cash flow stream, depending upon whether the required selling price is to be expressed in current or constant dollars. The GCFM calculates two such levelized prices for use at the user's discretion. Appendix A provides a detailed description of the various modes of calculation employed by the model.

2.4.7 Variable Allocation of Investments

No two projects develop at the same pace. The portion of the project which is undertaken during any given year depends on situation-specific factors. The model incorporates a feature which allows the user to specify a variable investment structure during the construction period. The contrast is most obvious in the case of field versus power plant projects. Many field development expenses will occur long before the power plant construction even begins.

Both the power plant and the field modules have an input variable entitled, "Capital Investment Breakdown" which consists of a series of fractions that determine the investment schedule throughout the construction period. For example, suppose over a five year period both a power plant and a field are being developed at a given site. The investment/construction for the power plant need not begin until some time after the wells have been proven. Table 2-2 is illustrative of how this can be treated.

The model assumes that within each construction year there will be a constant rate of investment. With this in mind, the model calculates four equal quarterly investments. This is important to note because interest expenses during the construction period are compounded quarterly on the outstanding loan balance in that quarter.

2.4.8 Debt/Equity Structure During Construction

The model allows a great deal of flexibility in the allocation of expenses between debt and equity during the construction period. The debt/equitv ratio is very important because often loan agreements require a minimum level of equitv* participation. It is

---

*The minimum desired level as determined under the rules of the DOE Geothermal Loan Guarantee Program is 25 percent equity participation (or 10 percent for municipal or cooperative borrowers).

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2.4.10 <u>Tax Vs. No. Tax</u>

The model has the option to omit the payment of income taxes and receipt of tax benefits on any project. The purpose of this option is to examine the economic viability of operating a geothermal field or plant as a tax-exempt entity such as a limited partnership (in which the tax liabilities and benefits are passed directly from the project to the limited partners) or a municipality as compared to the viability of a corporation. Of course, the corporate tax rate may itself be adjusted to assess the relative economics of operation under different size companies. In the interactive session, the model asks the user: "DOES THE PROJECT PAY INCOME TAXES? (Y or N)." The user then simply enters Y or N for Yes or No.

2.4.11 <u>Sinking Fund Vs. No Sinking Fund</u>

Similar to the tax question, the model allows the user the option of having or not having a sinking fund. The purpose of this option is to provide a set-aside fund to meet equipment replacement obligations. Replacement occurs when the user specified book life of one or more of the five capital accounts is less than the operating life. Without such a fund, the cash flow requirements tend to exhibit major fluctuations in years when such replacements occur.

In the interactive session, the model asks the user: "DO YOU WITH TO CREATE A SINKING FUND? (Y or N)." The user simply enters Y or N for yes or no.

Revised August 10. 1981

2.4.12 Constant Payment Debt Amortization

The latest version of the model (Version 5.0) allows the user a new option with respect to the selection of a projects debt amortization schedule. The model asks the user at execution time whether a constant payment (interest + principle) amortization schedule is to be used. A response of yes will cause any other user supplied schedule to be overriden, while a response of no will cause the model to use either a user supplied schedule or the constant principle payment default.

2.4.13 Principle Payments Grace Period

Version 5.0 contains a run time option which allows the user to specify a number of operation years as a loan payment grace period. During these years only interest payments will be made. A response of 1 will result in principle payments of zero in the first year of project operation.

2.4.14 Field Revenue/Power Plant Fuel Cost Pass Thru

Version 5.0 contains a facility to allow the user the option of passing revenues from field project financial runs to power plant project financial runs where they may be used as power plant fuel costs. This facility requires the execution of a field project financial run to initialize the field revenue buffer. Once this buffer is initialized, both the field breakeven price and the field market price revenues are available to the power plant for use as fuel costs. The user will select a fuel cost option for each of the power plant breakeven analysis and the power plant market price analysis. (See interactive sessions pages 4-40 and 4-40.1).

When the on-line year and project life of the revenue streams in the field revenue buffer are different from the corresponding power plant variables the model will allow the run to proceed but will print a warning message.

2.5 Statement of Extent of Testing

Testing a computer program of the complexity of the GLGP Cash Flow Model is an extremely difficult task. The nature of software packages is that testing must be performed under operating conditions. The model has been tested and refined to a level at which the error frequency has become very low, but as of September 1980, we cannot guarantee that the model is error-free.

2.5.1 Cycle Design Routine

The power plant cycle design and costing routine has been given extensive testing and found to give results generally close to a set of generic designs and costs estimated by J. R. Schilling for MITRE in 1976, (Schilling, 1976). The nature of the steam and isobutane thermodynamic equations used in GCFM is such that a 3-5% error in equipment size may be introduced when selecting the cycle design points.

The cycle design routine does not optimize the power plant cycle. The default values used by the cycle design routine are intended to prevent the model from not working due to a lack of data, and as such they do not represent optimum values at any site. The design routine is intended to provide a "best guess" when little or no power plant data exists.

2.5.2 Power Plant Module

The power plant module is relatively straight forward. Aside from the cycle design routine this module only monitors a database

Figure 4-12 shows the execution of the field module when an existing financial case is used without changes.

4.5 Data Change Procedure

Each of the three modules contains a change routine to facilitate alteration of the input parameters. The cycle design routine contains its own change routine which is slightly different from the main change routines. Figure 4-13 shows an example of a change being made. The other three change routines are of the same format, as shown in Figure 4-14, for the field module.

4.6 Case Deletion Procedure

If the user selects the name of an existing project, he will be given the option of deleting it. Figure 4-15 shows the steps taken for deleting an existing power plant, field or financial case. As a precaution the user must verify any deletion request by answering a second question. This prevents the user from accidentally deleting an important project.

4.7 Warning Messages

GCFM does not supply default values for all required input variables. In those cases the user must enter a value if the program is to run properly. The program is designed to display error messages when needed as shown in Figure 4-16. It is not possible, however, to verify all data entries, so there are still many ways the user can cause errors with the use of improper data.

```
ENTER FINANCIAL CASE NAME (UP TO 20 CHARACTERS).

sample
 A FINANCIAL CASE ALREADY EXISTS UNDER THAT NAME.

 DO YOU WISH TO DELETE IT?  (Y OR N)

n
 DO YOU WISH TO CHANGE THE FINANCIAL INPUT PARAMETERS?  (Y OR N)

n
 DO YOU WISH TO PERFORM A FINANCIAL ANALYSIS? (Y OR N).

y
 DO YOU WISH TO CREATE A SINKING FUND? (Y OR N)

y
 DOES THE PROJECT PAY INCOME TAXES? (Y OR N)

y
 DO YOU WISH TO USE A CONSTANT PAYMENT DEBT AMORTIZATION
                                        SCHEDULE?  (Y OR N).
y
 ENTER PRINCIPLE PAYMENTS GRACE PERIOD.
 DEFAULT = 0


0
ENTER FINANCIAL CASE NAME (UP TO 20 CHARACTERS).


ENTER FIELD NAME (UP TO 20 CHARACTERS).


WELCOME TO THE GEOTHERMAL LOAN GUARANTY CASH FLOW MODEL.
MODULES AVAILABLE
 1 = POWER PLANT DESIGN MODULE
 2 = FIELD DESIGN MODULE
 3 = FINANCIAL MODULE
 ENTER NUMBER OF MODULE DESIRED?
```

FIGURE 4-12
EXECUTION OF FINANCIAL ROUTINE

```
DO YOU WISH TO PERFORM A FINANCIAL ANALYSIS? (Y OR N).

Y
REVENUE STREAMS FROM THE LAST RUN OF TLE IMPERIAL-X
FIELD PROJECT MAY BE USED AS THE.FUEL COSTS FOR THE
FINANCIAL ANALYSIS OF THE IMPERIAL-X          POWER PLANT PROJECT.

FUEL COST OPTIONS:
   1 - USER SUPPLIED VIA FINANCIAL CASE(DEFAULT).
   2 - BREAKEVEN PRICE REVENUES FROM FIELD PROJECT.
   3 - MARKET PRICE REVENUES FROM FIELD PROJECT.
ENTER OPTION NUMBER FOR BREAKEVEN PRICE ANALYSIS AND MARKET PRICE ANALYSIS

2 3
```

FIGURE 4-12.1

EXECUTION OF FINANCIAL MODULE
FIELD REVENUE/POWER PLANT FUEL COST
PASSTHRU OPTIONS

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```
WELCOME TO THE GEOTHERMAL LOAN GUARANTY CASH FLOW MODEL.
MODULES AVAILABLE
 1 = POWER PLANT DESIGN MODULE
 2 = FIELD DESIGN MODULE
 3 = FINANCIAL MODULE
 ENTER NUMBER OF MODULE DESIRED?

?
3
CURRENT FINANCIAL CASE NAMES:
 BASELINE
 DEMO
 KEN
 TEST1
 GELCOM
 NEW
 SAMPLE
 MARK
 BRAW
 TESTOR
 GEYSER
 TPC-GEYSER
 IMPERIAL-X
ENTER FINANCIAL CASE NAME (UP TO 20 CHARACTERS).

ken
A FINANCIAL CASE ALREADY EXISTS UNDER THAT NAME.

DO YOU WISH TO DELETE IT?  (Y OR N)

Y
VERIFICATION OF FINANCIAL CASE DELETION REQUEST - DELETE? (Y OR N)

Y
ENTER FINANCIAL CASE NAME (UP TO 20 CHARACTERS).
```

FIGURE 4-15
DELETION OF AN EXISTING CASE

```
 ENTER BASE YEAR AND COST INDEX (1979=100). (2)
 DEFAULT - BASE YEAR = 1979
         - COST INDEX = 100.0

?
1980
?

 ENTER PROJECT LIFE AND POWER-ON-LINE YEAR. (2)
 *** NO DEFAULTS ***

?

 *** ERROR ***

 FIELD LIFE LESS THAN 1 YEAR---RESET TO 50 YEARS
 *** ERROR ***

 THE POWER-ON-LINE YEAR IS LESS THAN THE BASE YEAR---RESET TO 1981



 DO YOU WISH TO PERFORM A FINANCIAL ANALYSIS? (Y OR N).

Y
 THE PROJECT POWER-ON-LINE YEAR =1982
 THE FINANCIAL CASE POWER-ON-LINE YEAR =1983
 THESE VALUES ARE NOT EQUAL - FATAL ERROR - MODEL WILL NOT RUN

 THE PROJECT LIFE = 5
 FINANCIAL CASE LIFE =34
 THESE VALUES ARE NOT EQUAL - FATAL ERROR - MODEL WILL NOT RUN

 THE PROJECT BASE YEAR =1980
 FINANCIAL CASE BASE YEAR =1979
 THESE VALUES ARE NOT EQUAL - FATAL ERROR - MODEL WILL NOT RUN

 ENTER FINANCIAL CASE NAME (UP TO 20 CHARACTERS).
```

FIGURE 4-16

EXAMPLES OF MODEL ERROR MESSAGES

TECHNICAL NOTES

NOTE 1: Memory Size Required

GCFM requires virtual memory size of 750K bytes on an IBM VM/370 system.

NOTE 2: GCFM Subroutines

The names and general functions of the GCFM main program, subroutines, and segments are presented in Table C-1. This table is included for the reader who wishes to study the model in depth.

NOTE 3: Segmentation

The model code is divided into seven code segments. This segmentation is required by the HP 3000 for the purposes of paging. The segment configuration is intended to reduce the amount of paging required to run the program.

NOTE 4: GCFM Debugging Outputs

GCFM contains options that produce output of a great many values of intermediate calculations. These options were built into the code for debugging during the development of the model, but they could be of interest to programmer/analysts who wish to examine intermediate variables in order to further understand or verify the accuracy of the model.

WARNING: Avoid using these options unless you are very familiar with Fortran and the GCFM model. The options produce copious amounts of partially documented output, in some cases will inhibit normal use of certain features of the model, and will at times deliver unlabelled outputs to the terminal screen.

To perform a run with the debugging option turned on, the user must enter the number 10883 instead of 1,2, or 3 when GCFM asks which module is to be used.

GCFM will then print!

ENTER DEBUGGING CODE.

The user then enters one of the following codes to select an option:

TABLE C-1

DESCRIPTION OF GCPM SUBROUTINES

CODE SEGMENT	SUBROUTINE NAME	OTHER SUBROUTINES CALLED	PURPOSE OF SUBROUTINE
MAIN	MAIN PROGRAM	UTILTY, PRODCR, FINANC	GCPM driver program
MAIN	CHANGE	ICHG, RCHG, CHGERR	Generic change routine for all three modules
MAIN	ICHG		Accepts change I/O for integer variables.
MAIN	RCHG		Accepts change I/O for real variables.
MAIN	CHGERR		Perform validity check on critical variables.
MAIN	DDUMP	IPRT, RPRT	Generic database to printer dump routine for three modules
MAIN	IPRT		Output of integer variables on data dump report.
MAIN	RPRT		Output of real variables on data dump report.
ENTR	FININ	SVECT SVECTD DVECT	Data entry routine for financial module.
ENTR	PRODIN	SVECT SVECTD	Data entry routine for field module.
ENTR	UTILIN	SVECT	Data entry routine for power plant module.
ENTR	SVECT		Generic 50 element array input routine - one default
ENTR	SVECTD		Generic 50 element array input routine - two defaults
ENTR	DVECT		Generic 5 X 50 element matrix input routine
UTIL	UTILTY	PLNTIO UTICAL UTIPRT UTILIN CHANGE (MAIN segment) STDES BTDES STCST BTCST (UDES segment) FINANC (FLOW segment)	Power plant module driver and database manager.
UTIL	PLNTIO	HEAD	Power plant cycle design program I/O routine
UTIL	HEAD		Power plant cycle I/O routine header routine
UTIL	UTICAL		Power plant module cost and design routine
UTIL	UTIPRT	DDUMP (MAIN segment)	Power plant module cost and design print routine

UDES	STDES	various functions	Power plant steam cycle calculation program.
UDES	BTDES	various functions	Power plant supercritical binary cycle calculation program.
UDES	STCST	various functions	Power plant steam cycle capital cost program. (GEOCST,77)
UDES	BTCST	various functions	Power plant binary cycle capital cost program. (GEOCST,77)
UDES	WHL		Function: H(sat.wat.liq) = f(P)
UDES	WHG		Function: H(sat.wat.vap) = f(P)
UDES	WPT		Function: P(sat.wat.vap) = f(T)
UDES	WSL		Function: S(sat.wat.liq) = f(T)
UDES	WSG		Function: S(sat.wat.vap) = f(T)
UDES	WSV		Function: V(sat.wat.vap) = f(P)
UDES	WDH		Function: H(sup.wat.vap) = f(P,T)
UDES	WDS		Function: S(sup.wat.vap) = f(P,T)
UDES	BPT		Function: P(sat.iso.vap) = f(T)
UDES	BHG		Function: H(sat.iso.vap) = f(P)
UDES	BHL		Function: H(sat.iso.liq) = f(P)
UDES	BSG		Function: S(sat.iso.vap) = f(P)
UDES	BSL		Function: S(sat.iso.liq) = f(P)
UDES	BDH		Function: H(sup.iso.vap) = f(P,T)
UDES	BDS		Function: S(sup.iso.vap) = f(P,T)
UDES	BHS		Function: H(sup.iso.vap) = f(P,S)
UDES	BSV		Function: V(sup.iso.vap) = f(P,T)
UDES	BTP		Function: T(sat.iso.vap) = f(P)
UDES	BDT		Function: T(sat.iso.vap) = f(P,S)
PROD	PRODCR	PRODES PROPRT PRODIN CHANGE (MAIN segment) FINANC (FLOW segment)	Field module driver and database manager.
PROD	PRODES	PLTIO UTICAL UTIPRT	Field design and capital cost routine.
PROD	PROPRT	DDUMP (MAIN segment)	Field design and capital cost print routine.
FLOW	FINANC	FINCHK CASH FININ CHANGE (MAIN segment)	Financial routine driver and database manager
FLOW	FINCHK		Checks validity of project time framework
FLOW	CASH	PWORTH CASFLO CONSTR AMORT FULCST (FSUB segment) LEVEL FINPRT FINPR2 (FSUB segment) DDUMP (MAIN segment)	Financial analysis main routine
FLOW	PWORTH		Calculates present value of a series of cash flows
FLOW	CASFLO		Calculates net cash flows, income taxes, tax credit carryforwards, tax loss carryforwards, royalties and depletion allowance.
FSUB	CONSTR		Calculates debt/equity, interest and doe fees during const.
FSUB	LEVEL		Calculates levelization of breakeven prices.
FSUB	AMORT		Calculates debt amortization during operating life.
FSUB	FULCST		Calculates fuel costs
FSUB	FINPRT		Financial output routine for market price calculations
FSUB	FINPR2		Financial output routine for breakeven price calculations

CODE	OPTION
1	Turn on debug output for power plant module only.
2	Turn on debug output for field module only.
3	Turn on debug output for financial module only.
4	Turn on debug output for all three modules. Under this option, all change menus are prevented from being displayed to the user's terminal.

The user should then enter 1,2 or 3 to select a module in the normal manner. That module will then be operated with the selected debug option in effect.

The debugging option is turned off the next time a module is selected.

The reader should note that most of the additional outputs generated by these options will not be interpretable unless the FORTRAN source code is examined in detail.

6.0 INSTALLATION GUIDE FOR GCFM VERSION 5.0

The GCFM data tape for Version 5.0 consists of seven FORTRAN source code files, two data files and an EXEC file. The tape format has the following attributes:

Labels	- NONE
Data Format	- EBCDIC
Density	- 1600 bpi
Tracks	- 9
Record Length	- 80 bytes
Blocking Factor	- 200 records per block

The only exception is the 10th (last) file whose blocking factor is 17 (blksize=1360).

The files are on the tape in the following sequence with one end-of-file mark after each file:

IBM FILE NAME	HP FILE NAME	BLOCKS	APPROX RECORDS
ENTR FORTRAN	ENTRSC	7	1294
FLOW FORTRAN	FLOWSC	8	1529
FSUB FORTRAN	FSUBSC	9	1603
MAIN FORTRAN	MAINSC	7	1321
PROD FORTRAN	PRODSC	7	1240
UDES FORTRAN	UDESSC	9	1760
UTIL FORTRAN	UTILSC	7	1337
CHGINIT DATA	CHGINIT	2	210
INITIAL DATA	INITIAL	2	213
GCFM EXEC	Not Used	1	17

The model was written on an IBM 370 Virtual Memory (VM) Conversational Monitor System. The EXEC listed as follows defines the datafiles and executes the model under this system. The model required 750K of virtual memory in this environment.

```
&CONTROL ERROR
FILE 10 PRINTER  (LRECL 133 BLOCK 133 RECFM FA
FILE 11 TERMINAL
FILE 03 DISK CHGINIT DATA B (LRECL 80 BLOCK 800 RECFM FB XTENT 213
FILE 04 DISK INITIAL DATA B (LRECL 80 BLOCK 800 RECFM FB XTENT 21
FILE 01 DISK PLANT   DATA B (LRECL 80 BLOCK 800 RECFM FB XTENT 220
FILE 02 TERMINAL
FILE 07 DISK GLOBCOM DATA B (LRECL 3800 BLOCK 7608 RECFM FB XTENT 20
FILE 08 DISK PRODCOM DATA B (LRECL 400  BLOCK 4040 RECFM FB XTENT 10
FILE 09 DISK FINCOM  DATA B (LRECL 6000 BLOCK 12008 RECFM FB XTENT 15
FILE 15 DISK PLANT   INDEX B (LRECL 20 BLOCK 200 RECFM FB XTENT 10
FILE 12 DISK GLOBCOM INDEX B (LRECL 24 BLOCK 240 RECFM FB XTENT 20
FILE 13 DISK PRODCOM INDEX B (LRECL 20 BLOCK 200 RECFM FB XTENT 10
FILE 14 DISK FINCOM  INDEX B (LRECL 20 BLOCK 200 RECFM FB XTENT 15

LOAN MAIN PROD FLOW UDES UNTIL ENTR FSUB
START
```

NOTES:
1 - XTENT 210 means that the file contains 210 records
2 - FILE = FILEDEF
3 - numbers to right of file are FORTRAN file reference numbers(FTN's)
4 - the LOAD command creates an executable load module which mav be saved and/or executed.

The load module requires 750K of virtual memory on the VM/370 computer system. The DATA files and the INDEX files must be created before the model is run for the first time. (See Table 6-1). Each record of the four INDEX files (FTN12, FTN13, FTN14, and FTN16) must be inialized to it's 'empty' state. These files are 'empty' when each contains the appropriate number of lines each containing 20 asterisks (*).

```
PLANT INDEX     ********************     10 lines

PRODCOM INDEX   ********************     10 lines

GLOBCOM INDEX   ********************     20 lines

FINCOM INDEX    ********************     15 lines
```

TABLE 6-1

GCFM DATABASE DESCRIPTION

FORTRAN FILE #	IBM FILE NAME	HP3000 FILE NAME	LRECL	RECORDS
01	PLANT DATA B	PLANTS (MGR.MITRE)*	80	220
02	TERMINAL (input)	Not Used	80	213
03	CHGINIT DATA B	CHGINIT	80	213
04	INITIAL DATA B	INITIAL	80	210
05	Not Used	TERMINAL($STDIN)	-	-
07	GLOBCOM DATA B	BLOBCOM	3800	20
08	PRODCOM DATA B	PRODCOM	400	10
09	FINCOM DATA B	FINCOM	6000	15
10	PRINTER	PRINTER	133	-
11	TERMINAL(output)	TERMINAL($STDLST)	-	-
12	GLOBCOM INDEX B	GLINDEX	24	20
13	PRODCOM INDEX B	PRINDEX	20	10
14	FINCOM INDEX B	FINDEX	20	15
15	PLANT INDEX B	PINDEX	20	10

*PLANTS,MGR.,MITRE is filename, however, the use of the MGR.MITRE account implies this.

In addition to the MITRE computer, the model is currently being run on an HP3000 Series III computer at the DOE San Francisco operations office. The additional FORTRAN statements required for use on the HP3000 have been included in the FORTRAN source code but are commented out. The attached listing contains the XEDIT commands which are used to convert the code for use on the HP3000. Please note that the changes do not necessarily apply to all code segments for more information see Appendix A of users guide.

7.0 REVISION OF POWER PLANT DESIGN ROUTINE AND THERMODYNAMIC PROPERTY CALCULATIONS

7.1 Revision of Power Plant Design Routine

The power plant design routine has been revised to increase its accuracy. The following changes were made at the suggestion of T.L. Lawford of EG&G (see attached letter).

7.1.1 Inlet Pressure Trottling Loss

A pressure drop of 10% of the absolute pressure in the flash tank has been included to represent the pressure drop between the flash tank and the turbine blading.

7.1.2 Moisture Correction for Turbine Efficiency

An iterative routine has been added which reduces the turbine efficiency from a base of 85% by 1/2% for each 1% moisture in the steam at the blading exit.

7.1.3 Leaving Loss

A 10 Btu/lb leaving loss has been added to account for the loss at the last stage of the turbine and in the exhaust hood.

7.1.4 Flash Tank Temperature Corrections

The flash tank temperatures are calculated in degrees Rankine (^{o}R) instead of degrees Farenheit (^{o}F).

7.2 Revision of Thermodynamic Functions

Five thermodynamic functions were modified for increased accuracy. The following functions were changed:

WPT - Pressure as a function of temperature along the saturation line for water

WHL - Enthalpy of saturated water

WHG - Enthalpy of saturated steam

WSL - Entropy of saturated water

WSG - Entropy of saturated steam

In general, the changes are a result of a more accurate curve fit to the thermodynamic property in question. The increased accuracy is due to increasing the number of data points used for the fit and by breaking the curve into two or more regions.

7.3 FORTRAN Source Code Listings

Listings of the sections of source code which were modified follow. The changes in the power plant design routine are marked with an asterisk (*). These changes have been made to GCFM 5.0 and should be made to GCFM 4.1 to bring it up to date.

The five thermodynamic functions were rewritten and complete copies are provided.

```
0001           SUBROUTINE STDES
          C---$CONTROL MAP,CROSSREF,LABEL,LOCATION,USLINIT,SEGMENT=UDES
          C***  SUBROUTINE STDES
          C
          C     GCPM - VERSION 5.0     15 JULY 1981
          C###########
          C########### TURBINE PRESSURE LOSS,P TO R, TURBINE EFFICIENCY CALC.
          C########### 9/21/81:JCB
          C###########
          C
          C     THIS COMPUTER PROGRAM AND ASSOCIATED DATA WERE PREPARED AS AN
          C  ACCOUNT OF WORK SPONSORED BY THE UNITED STATES GOVERNMENT. NEITHER
          C  THE UNITED STATES NOR THE UNITED STATES DEPARTMENT OF ENERGY, NOR
          C  ANY OF THEIR EMPLOYEES OR CONTRACTORS, MAKES ANY WARRANTY, EXPRESS
          C  OR IMPLIED, OR ASSUMES ANY LEGAL LIABILITY OR RESPONSIBILITY FOR
          C  THE ACCURACY, COMPLETENESS, OR USEFULNESS OF THIS COMPUTER PROGRAM
          C  OR ANY INFORMATION, APPARATUS, PRODUCT, OR PROCESS DISCLOSED, OR
          C  REPRESENTS THAT ITS USE WOULD NOT INFRINGE ON PRIVATELY OWNED
          C  RIGHTS.  THE VIEWS AND OPINIONS OF THE AUTHORS PERTAINING TO THIS
          C  COMPUTER PROGRAM OR ASSOCIATED DATA DO NOT NECESSARILY STATE OR
          C  REFLECT THOSE OF THE UNITED STATES GOVERNMENT OR ANY AGENCY THEREOF.
          C  RESULTS OBTAINED FROM THE USE OF THIS PROGRAM AND ASSOCIATED DATA
          C  WILL NOT NECESSARILY MEET WITH ACCEPTANCE BY OR ON BEHALF OF THE
          C  UNITED STATES GOVERNMENT OR ANY AGENCY THEROF.
          C
          C
          C    THIS PROGRAM WAS DESIGNED BY THE MITRE CORPORATION FOR THE
          C  DEPARTMENT OF ENERGY UNDER CONTRACT NUMBER DE-AC03-79SF10494.
          C
          C THIS PROGRAM WAS DESIGNED, WRITTEN AND DEBUGGED BY MARK A. KEINIG.
          C  SPECIAL THANKS TO J. RENE BARRIOS FOR THE DESIGN AND WRITING OF THE
          C  POWER PLANT CYCLE DESIGN PROGRAM.
          C
          C
          C
          C
          C
          C
0002           COMMON /PGMCTL/ NCHGTP,NPTYPE,PTITLE(5),FTITLE(5),NDBG,IX3,IX4,
             1 IXFIN,IXPDCR,IXUTIL,IXGLBL,IX5,IX7,IX8,IX9,IX15,IX17,IX18,IX19
          C
0003           COMMON /IGLOBL/ IUSE,IX,LTWR,NTPMP,NDPMP,NTWR
          C
0004           COMMON /RGLOBL/ BFLOW,CE,CI,CWP,FAN,GEFF,HT,
             1 PLANT,PT,P1,P2,P3,P4,P5,RIP,T1,T2,T3,T4,T5,T6,TWB,
             3 UNITS,WATER,C(25),STOT(10),TITLE(10),
             S CDP,EHP,ELP,GAS,SFHP,SFLP,SOL,WHP,WLP,
             B ACD,AHE,CBP,P6,P7,P8,P9,RPRES,TEFF,T7,T8,T9,UCD,UHE,WFLOW,WFP
```

```
                    C                                                                   UDE00490
                    C                                                                   UDE00500
 0005                     COMMON /GLODES/ NCODE,LPTXU(5),LPTXP(5),NYEAR,CST(5),POWER,   UDE00510
                         1  SALVU(5),OMPRU(5),COSTS(25),CINDEX,RXTRA2(36)               UDE00520
                    C                                                                   UDE00530
 0006                     EQUIVALENCE (STOT(8),HEAT)                                    UDE00540
                    C     **************************************************************UDE00550
 0007                     EMOT   = 0.92                                                 UDE00560
 0008                     POWER  = PLANT                                                UDE00570
 0009                     HUND   = 100.0                                                UDE00580
 0010                     GEFF   = GEFF/HUND                                            UDE00590
 0011                     ELP    = ELP/HUND                                             UDE00600
 0012                     EHP    = EHP/HUND                                             UDE00610
                    C     **************************************************************UDE00620
                    C                                                                   UDE00630
                    C     THIS PROGRAM DOES THE CYCLE CALCULATIONS FOR  SINGLE FLASHED, UDE00640
                    C     DOUBLE FLASHED AND DRY STEAM GEOTHERMAL POWER PLANTS.         UDE00650
                    C                                                                   UDE00660
                    C                                                                   UDE00670
                    C         VARIABLE NAMES                                            UDE00680
                    C     THE VARIABLES OF THE FORM  P1,T2, & S2 ARE NAMED AS FOLLOWS   UDE00690
                    C        THE SINGLE LETTERS INDICATE THE TYPE OF VALUE WHICH THE    UDE00700
                    C        VARIABLE REPRESENTS.                                       UDE00710
                    C            T.........TEMPERATURE  (DEG. F.)                       UDE00720
                    C            P.........PRESSURE   (PSI)                             UDE00730
                    C            H.........ENTHALPY (BTU/LB)                            UDE00740
                    C            S.........ENTROPY  (BTU/LB DEG)                        UDE00750
                    C                                                                   UDE00760
                    C        THE SINGLE DIGIT INDICATES THAT VALUES LOCATION IN THE POWER UDE00770
                    C        CYCLE                                                      UDE00780
                    C            1.........RESERVOIR CONDITION                          UDE00790
                    C            2.........CONDITION OF STEAM-TURBINE INLET-L.P.        UDE00800
                    C            3.........CONDITION OF STEAM-TURBINE INLET-H.P.        UDE00810
                    C            4.........CONDITION OF STEAM-TURBINE OUTLET            UDE00820
                    C            5.........CONDITION OF STEAM-CONDENSER OUTLET          UDE00830
                    C            6.........COOLING WOTER TEMP-CONDENSER INLET           UDE00840
                    C                                                                   UDE00850
                    C     OTHER VARIABLE NAMES.                                         UDE00860
                    C            PLANT....PLANT NET OUTPUT  (MW)                        UDE00870
                    C            PT.......PLANT GROSS OUTPUT (MW)                       UDE00880
                    C            GEFF.....GENERATOR EFFICIENCY                          UDE00890
                    C          ONLY DUAL STAGE FLASH PLANTS HAVE TWO STAGES.  ALL OTHERS UDE00900
                    C           USE ONLY L. P. STAGE CALCULATIONS.                      UDE00910
                    C            EHP......H. P. TURBINE EFFICIENCY                      UDE00920
                    C            ELP......L. P. TURBINE EFFICIENCY                      UDE00930
                    C            DHP......WORK DONE ON H. P. TURBINE (BTU/LB)           UDE00940
                    C            DLP......WORK DONE ON L. P. TURBINE (BTU/LB)           UDE00950
                    C            WHP......PLANT GROSS OUTPUT H. P. STAGE (M W)          UDE00960
```

```
                C           WLP......PLANT GROSS OUTPUT L. P. STAGE (M W)              UDE00970
                C           SPHP.....STEAM FLOW H. P. STAGE(M LB/HR)                   UDE00980
                C           SPLP.....STEAM FLOW L. P. STAGE(M LB/HR)                   UDE00990
                C                                                                      UDE01000
                C           GAS......NON-CONDENSABLE GAS CONTENT(%)                    UDE01010
                C           SOL......DISSOLVED SOLIDS(PPM)                             UDE01020
                C           BFLOW....BRINE FLOW (DOES NOT APPLY TO DRY STEAM)          UDE01030
                C           HEAT.....HEAT TO BE REJECTED BY TOWER (M BTU/HR)           UDE01040
                C           WATER....WATER FLOW THROUGH CONDENSER (M LB/HR)            UDE01050
                C           CONST....PUMP HORSEPOWER CONVERSION CONSTANT               UDE01060
                C           RIP......RE-INJECTION PUMP (H. P.)                         UDE01070
                C           CDP......CONDENSATE PUMP (H. P.)                           UDE01080
                C           CWP......COOLING WATER PUMP (H. P.)                        UDE01090
                C           HT.......HEIGHT OF COOLING TOWER (FT)                      UDE01100
                C           FAN......COOLING TOWER FAN (H. P.)                         UDE01110
                C           AUX......POWER REQUIREMENTS OF AUXILARIES (AUX)            UDE01120
                C     *************************************************************UDE01130
                C     *************************************************************UDE01140
                C     USE DEFAULT VALUES IF NECESSARY                                  UDE01150
                C                                                                      UDE01160
 0013                 IF(T1 .EQ. 0.0)   T1 = 400.0                                     UDE01170
 0014                 IF(IUSE .EQ. 1  .AND.  TWB .EQ. 0.0) TWB = 65.0                  UDE01180
 0015                 IF(IUSE .NE. 1  .AND.  TWB .EQ. 0.0) TWB = 79.0                  UDE01190
 0016                 IF(T6 .EQ. 0.0) T6 = TWB + 10.0                                  UDE01200
 0017                 IF(T5 .EQ. 0.0) T5 = T6 + 20.0                                   UDE01210
 0018                 IF(T4 .EQ. 0.0) T4 = T5 + 10.0                                   UDE01220
 0019                 IF(PLANT .EQ. 0.0) PLANT = 50.0                                  UDE01230
 0020                 IF(GEFF .EQ. 0.0) GEFF = 0.98                                    UDE01240
 0021                 IF(EHP .EQ. 0.0)  EHP = 0.73                                     UDE01250
 0022                 IF(ELP .EQ. 0.0)  ELP = 0.67                                     UDE01260
 0023                 IF(HT .EQ. 0.0)   HT = 40.0                                      UDE01270
 0024                 IF(MTPMP .EQ. 0)  MTPMP = 1                                      UDE01280
 0025                 IF(MDPMP .EQ. 0)  MDPMP = 1                                      UDE01290
 0026                 IF(LTWR .EQ. 0)   LTWR = 1                                       UDE01300
 0027                 IF(MTWR .EQ. 0)   MTWR = 1                                       UDE01310
 0028                 IF(GAS .EQ. 0.0)  GAS = 0.0                                      UDE01320
 0029                 IF(SOL .EQ. 0.0)  SOL = 0.0                                      UDE01330
                C     *************************************************************UDE01340
                C     *************************************************************UDE01350
 0030                 IF(IUSE .NE. 1) GO TO 15                                         UDE01360
                C                                                                      UDE01370
                C     DRY STEAM POWER PLANT DESIGN ROUTINE.                            UDE01380
                C                                                                      UDE01390
                C                                                                      UDE01400
                C     IF RESERVOIR PRESSURE NOT GIVEN THEN ASSUME THE STEAM IS         UDE01410
                C     SATURATED VAPOR - P1 = PSAT                                      UDE01420
 0031                 IF(P1 .EQ. 0.0) GO TO 5                                          UDE01430
 0032                 H1  = WDH(P1,T1)                                                 UDE01440
```

```
0033              P1 = .9*P1                                                 UDE01450*
0034              S1  = WDS(P1,T1)                                           UDE01460
0035              GO TO 10                                                   UDE01470
           C                                                                 UDE01480
0036       5      CONTINUE                                                   UDE01490
0037              P1  = WPT(T1)                                              UDE01500
0038              H1  = WHG(P1)                                              UDE01510
0039              P1 = .9*P1                                                 UDE01520*
0040              S1  = WSG(P1)                                              UDE01530
           C                                                                 UDE01540
0041       10     CONTINUE                                                   UDE01550
0042              P2  = P1                                                   UDE01560
0043              P4  = WPT(T4)                                              UDE01570
0044              P5  = P4                                                   UDE01580
0045              P3  = P4                                                   UDE01590
0046              SL4 = WSL(P4)                                              UDE01600
0047              SG4 = WSG(P4)                                              UDE01610
           C      COMPUTE ISENTROPIC TURBINE WORK (DLP) ACCROSS TURBINE.     UDE01620
0048              X4  = (S1-SL4)/(SG4-SL4)                                   UDE01630
0049              HL4 = WHL(P4)                                              UDE01640
0050              HG4 = WHG(P4)                                              UDE01650
0051              H4  = HL4+X4*(HG4-HL4)                                     UDE01660
           C  THE ITERATIVE PROCEDURE BELOW FOR CALCULATING TURBINE EFFICIENCY  UDE01670*
           C  WAS SUPPLIED BY T.W.LAWFORD OF E.G.&G.                         UDE01680*
0052              IF(ELP.NE. 0.0) GO TO 1001                                 UDE01690*
0053              ELP = .80                                                  UDE01700*
0054              DO 1000 I = 1,20                                           UDE01710*
0055              RLP = (H1-H4)*ELP                                          UDE01720*
0056              XH = H1-RLP                                                UDE01730*
0057              X4 = (XH-HL4)/(HG4-HL4)                                    UDE01740*
0058              ELP = .85*(1.-((1.-X4)/2.))                                UDE01750*
0059        1000  CONTINUE                                                   UDE01760*
0060        1001  CONTINUE                                                   UDE01770*
0061              DLP = H1-H4                                                UDE01780
0062              DHP = 0.0                                                  UDE01790
0063              EHP = 0.0                                                  UDE01800
0064              W1  = 1.0                                                  UDE01810
0065              W2  = 0.0                                                  UDE01820
0066              R   = 0.0                                                  UDE01830
           C      PREPARE  FOR CONDENSER CALCULATIONS.                       UDE01840
0067              H2 = H1                                                    UDE01850
           C      ***************************************************************UDE01860
           C      END OF DRY STEAM CYCLE CALCULATIONS.                       UDE01870
0068              GO TO 25                                                   UDE01880
           C                                                                 UDE01890
0069          15  CONTINUE                                                   UDE01900
0070              IF(IUSE .NE. 2) GO TO 20                                   UDE01910
           C      ***************************************************************UDE01920
```

```
                C                                                                        UDE01930
                C     SINGLE STAGE FLASHED STEAM POWER PLANT DESIGN ROUTINE.             UDE01940
                C                                                                        UDE01950
                C                                                                        UDE01960
 0071                 IF(T2 .EQ. 0.0) T2 = (SQRT((T1+460.)*(T4+460.)))-460.              UDE01970*
 0072                 P1   = WPT(T1)                                                     UDE01980
 0073                 P2   = WPT(T2)                                                     UDE01990
 0074                 IF(P2 .LT. 14.7) P2 = 14.7                                         UDE02000
 0075                 P3   = P2                                                          UDE02010
 0076                 P4   = WPT(T4)                                                     UDE02020
 0077                 P5   = P4                                                          UDE02030
 0078                 HL1 = WHL(P1)                                                      UDE02040
 0079                 HL2 = WHL(P2)                                                      UDE02050
 0080                 HG2 = WHG(P2)                                                      UDE02060
 0081                 H2   = HG2                                                         UDE02070
 0082                 HL4 = WHL(P4)                                                      UDE02080
 0083                 HG4 = WHG(P4)                                                      UDE02090
 0084                 X2   = (HL1-HL2)/(HG2-HL2)                                         UDE02100
 0085                 PX2 = .9*P2                                                        UDE02110*
 0086                 SG2 = WSG(PX2)                                                     UDE02120*
 0087                 SL4 = WSL(P4)                                                      UDE02130
 0088                 SG4 = WSG(P4)                                                      UDE02140
                C     COMPUTE ISENTROPIC TURBINE WORK (DLP) ACCROSS TURBINE.             UDE02150
 0089                 X4   = (SG2-SL4)/(SG4-SL4)                                         UDE02160
 0090                 H4   = HL4+X4*(HG4-HL4)                                            UDE02170
                C  THE ITERATIVE PROCEDURE BELOW FOR CALCULATING TURBINE EFFICIENCY      UDE02180*
                C  WAS SUPPLIED BY T.W.LAWFORD OF E.G.&G.                                UDE02190*
 0091                 IF(ELP.NE. 0.0) GO TO 2001                                         UDE02200*
 0092                 ELP = .80                                                          UDE02210*
 0093                 DO 2000 I = 1,20                                                   UDE02220*
 0094                 RLP = (H2-H4)*ELP                                                  UDE02230*
 0095                 XH = H2-RLP                                                        UDE02240*
 0096                 X4 = (XH-HL4)/(HG4-HL4)                                            UDE02250*
 0097                 ELP = .85*(1.-((1.-X4)/2.))                                        UDE02260*
 0098            2000 CONTINUE                                                           UDE02270*
 0099            2001 CONTINUE                                                           UDE02280*
 0100                 DLP = H2-H4                                                        UDE02290
 0101                 DHP = 0.0                                                          UDE02300
 0102                 EHP = 0.0                                                          UDE02310
 0103                 W1   = 0.0                                                         UDE02320
 0104                 W2   = X2                                                          UDE02330
 0105                 R    = 0.0                                                         UDE02340
                C     ********************************************************************UDE02350
                C     END OF SINGLE STAGE FLASH CYCLE CALCULATIONS                       UDE02360
 0106                 GO TO 25                                                           UDE02370
                C                                                                        UDE02380
 0107           20    CONTINUE                                                           UDE02390
                C     ********************************************************************UDE02400
```

```
                C                                                                         UDE02410
                C      DUAL STAGE FLASHED STEAM POWER PLANT DESIGN ROUTINE.               UDE02420
                C                                                                         UDE02430
                C                                                                         UDE02440
 0108                  IF(T2 .EQ. 0.0) T2=(((T1+460.)*(T1+460.)*(T4+460.))**0.33333)-460.UDE02450*
 0109                  IF(T3 .EQ. 0.0) T3 = (SQRT((T2+460.)*(T4+460.)))-460.              UDE02460*
 0110                  P1  = WPT(T1)                                                      UDE02470
 0111                  P2  = WPT(T2)                                                      UDE02480
 0112                  P3  = WPT(T3)                                                      UDE02490
 0113                  IF(P3 .LT. 14.7) P3 = 14.7                                         UDE02500
 0114                  P4  = WPT(T4)                                                      UDE02510
 0115                  P5  = P4                                                           UDE02520
                C                                                                         UDE02530
 0116                  HL1 = WHL(P1)                                                      UDE02540
 0117                  HL2 = WHL(P2)                                                      UDE02550
 0118                  HG2 = WHG(P2)                                                      UDE02560
                C      COMPUTE STEAM FLASHED BY ADIBATIC EXPANSION IN FIRST FLASH TANK.   UDE02570
 0119                  X2  = (HL1-HL2)/(HG2-HL2)                                          UDE02580
                C                                                                         UDE02590
 0120                  HL3 = WHL(P3)                                                      UDE02600
 0121                  HG3 = WHG(P3)                                                      UDE02610
 0122                  HL4 = WHL(P4)                                                      UDE02620
 0123                  HG4 = WHG(P4)                                                      UDE02630
                C      COMPUTE STEAM FLASHED BY ADIBATIC EXPANSION IN SECOND FLASH TANK.  UDE02640
 0124                  X3 = (HL2-HL3)/(HG3-HL3)                                           UDE02650
                C                                                                         UDE02660
 0125                  PX  = .9*P2                                                        UDE02670*
 0126                  SG2 = WSG(PX)                                                      UDE02680*
 0127                  SL3 = WSL(P3)                                                      UDE02690
 0128                  SG3 = WSG(P3)                                                      UDE02700
 0129                  SL4 = WSL(P4)                                                      UDE02710
 0130                  SG4 = WSG(P4)                                                      UDE02720
                C                                                                         UDE02730
                C      COMPUTE ISENTROPIC OUTLET ENTHALPY (H3) FOR H.P. TURBINE, ACTUAL   UDE02740
                C      OUTLET ENTHALPY (HX3) AND OUTLET QUALITY (XHP).                    UDE02750
 0131                  XHP = (SG2-SL3)/(SG3-SL3)                                          UDE02760
 0132                  H3  = HL3+XHP*(HG3-HL3)                                            UDE02770
                C  THE ITERATIVE PROCEDURE BELOW FOR CALCULATING TURBINE EFFICIENCY       UDE02780*
                C  WAS SUPPLIED BY T.W.LAWFORD OF E.G.&G.                                 UDE02790*
 0133                  IF(EHP.NE. 0.0) GO TO 3001                                         UDE02800*
 0134                  EHP = .80                                                          UDE02810*
 0135                  DO 3000 I = 1,20                                                   UDE02820*
 0136                  RHP = (HG2-H3)*EHP                                                 UDE02830*
 0137                  XH = HG2-RHP                                                       UDE02840*
 0138                  XHP = (XH-HL3)/(HG3-HL3)                                           UDE02850*
 0139                  EHP = .85*(1.-((1.-XHP)/2.))                                       UDE02860*
 0140            3000  CONTINUE                                                           UDE02870*
 0141            3001  CONTINUE                                                           UDE02880*
```

```
0142              DHX =  (HG2 - H3) * EHP                                             UDE02890
0143              H3X = HG2 - DHX                                                     UDE02900
0144              XHP = (H3X - HL3)/(HG3 - HL3)                                       UDE02910
            C                                                                         UDE02920
            C     COMPUTE  NET STEAM FRACTION (XLP), AND ACTUAL STEAM PROPERTIES      UDE02930
            C     HM3 AND SM3 ENTERING L.P. TURBINE.                                  UDE02940
0145              W1  = X2                                                            UDE02950
0146              W2  = (1.0-X2)*X3                                                   UDE02960
0147              PH  = .9*P3                                                         UDE02970*
0148              HXG3 = WHG(PH)                                                      UDE02980*
0149              XLP = (W1*XHP+W2)/(W1+W2)                                           UDE02990
0150              HM3 = HL3+XLP*(HG3-HL3)                                             UDE03000
0151              IF(HM3 .GT. HXG3) GO TO 5000                                        UDE03010*
0152              HL3 = WHL(PH)                                                       UDE03020*
0153              XLP = (HM3-HL3)/(HXG3-HL3)                                          UDE03030*
0154              SG3 = WSG(PH)                                                       UDE03040*
0155              SL3 = WSL(PH)                                                       UDE03050*
0156              SM3 = SL3+XLP*(SG3-SL3)                                             UDE03060*
0157              GO TO 5001                                                          UDE03070*
0158         5000 CONTINUE                                                            UDE03080*
0159              SM3 = WSG(PH)                                                       UDE03090*
0160         5001 CONTINUE                                                            UDE03100*
            C                                                                         UDE03110
0161              X4  = (SM3-SL4)/(SG4-SL4)                                           UDE03120
            C                                                                         UDE03130
0162              H4  = HL4+X4*(HG4-HL4)                                              UDE03140
            C THE ITERATIVE PROCEDURE BELOW FOR CALCULATING TURBINE EFFICIENCY        UDE03150
            C WAS SUPPLIED BY T.W.LAWFORD OF E.G.&G.                                  UDE03160
0163              IF(ELP.NE. 0.0) GO TO 4001                                          UDE03170
0164              ELP = .80                                                           UDE03180
0165              DO 4000 I = 1,20                                                    UDE03190
0166              RLP = (HM3-H4)*ELP                                                  UDE03200
0167              XH = HM3-RLP                                                        UDE03210
0168              X4 = (XH-HL4)/(HG4-HL4)                                             UDE03220
0169              ELP = .85*(1.-(((1.-XLP)+(1.-X4))/2.))                              UDE03230
0170         4000 CONTINUE                                                            UDE03240
0171         4001 CONTINUE                                                            UDE03250
0172              R   = W1/(W1+W2)                                                    UDE03260
            C     COMPUTE ISENTROPIC WORK FROM H.P. AND L.P. TURBINES (DHP & DLP).    UDE03270
0173              DHP = HG2-H3                                                        UDE03280
0174              DLP = HM3-H4                                                        UDE03290
            C     PREPARE FOR CONDENSER CALCULATION.                                  UDE03300
0175              H2  = HM3                                                           UDE03310
            C     **************************************************************UDE03320
            C     END OF DUAL STAGE FLASH CYCLE CALCULATIONS.                         UDE03330
            C                                                                         UDE03340
0176        25    CONTINUE                                                            UDE03350
            C     **************************************************************UDE03360
```

```
                C
0177                  IF(NDBG .NE. 1 .AND. NDBG .NE. 4) GO TO 26
0178                  WRITE(10,277)
0179              277 FORMAT('1')
0180                  DUMX = 0.0
0181                  WRITE(10,*) T1,P1,H1,DUMX,DUMX,S1,DUMX,DUMX
0182                  WRITE(10,*) T2,P2,H2,HG2,HL2,DUMX,SG2,DUMX
0183                  WRITE(10,*) T3,P3,H3,HG3,HL3,DUMX,SG3,SL3
0184                  WRITE(10,*) T4,P4,H4,HG4,HL4,DUMX,SG4,SL4
0185                  WRITE(10,*) T5,P5,H5,DUMX,DUMX,DUMX,DUMX,DUMX
0186                  WRITE(10,*) T6,P6,DUMX,DUMX,DUMX,DUMX,DUMX,DUMX
0187                  WRITE(10,*) ELP,DLP,WLP,EHP,DHP,WHP,DUMX,X2,X3,X4
0188              555 FORMAT(10F10.5)
0189               26 CONTINUE
                C     GENERAL PLANT CALCULATIONS COMMON TO ALL THREE TYPES OF PLANTS.
                C
                C     ************************************************
                C     ***   CYCLE CALCULATION & EQUIPMENT SIZING   ***
                C     ************************************************
                C
                C     FIRST CUT TURBINE SIZING
0190                  PG    = PLANT/GEFF
0191                  PT    = PG
                C
                C
0192                  TDS   = 1.0/(1.024 - 1.724E-06*SOL)
                C
                C     ITERATION TO COMPUTE AUXILIARIES
                C
0193                  DO 30 I=1,2
                C
                C     ACTUAL WORK DONE BY TURBINE
0194                  WLP   = PT
0195                  IF(IUSE .EQ. 3) WLP  = PT/(1.0+R*(EHP*DHP-10.)/(ELP*DLP-10.))
0196                  WHP   = PT-WLP
                C
                C     CALCULATE STEAM FLOW THROUGH TURBINE USING ACTUAL TURBINE WORK
                C      (EHP*DHP) AND (ELP*DLP).
0197                  SFLP  = 3.413*WLP/(ELP*DLP-10.)
0198                  IF(IUSE .EQ. 3) SFHP = 3.413*WHP/(EHP*DHP-10.)
                C
                C     CALCULATE PUMP UNIT CONVERSION CONSTANT
                C     CONST = (HR/60MIN)*(2.307FT/PSI)*(E06)/(33000FT-LB/HP)
0199                  CONST = 1.165/EMOT
                C
                C     ENTHALPY IN HOTWELL.
0200                  H5    = WHL(P4)-(T4-T5)
                C     HEAT REJECTED VIA CONDENSER, ACCOUNTING FOR NON-ISENTROPIC
```

```
            C      EXPANSION THROUGH L.P. TURBINE.                                       UDE03850
0201               HEAT  = SFLP*(H2-ELP*DLP-H5)                                          UDE03860
0202               WATER = HEAT/(T5-T6)                                                  UDE03870
            C                                                                            UDE03880
            C      TOWER EQUATION FROM HYDROCARBON PROCESSING NOV. 1978**                UDE03890
            C                                                                            UDE03900
            C      RANGE & APPROACH OF COOLING TOWER.                                    UDE03910
0203               RG    = T5-T6                                                         UDE03920
0204               AP    = T6-TWB                                                        UDE03930
0205               RT    = RG/AP                                                         UDE03940
            C                                                                            UDE03950
            C      COOLING TOWER FAN                                                     UDE03960
0206               FAN   = EXP(1.43668+0.73536*ALOG(RT))                                 UDE03970
0207               FAN   = FAN*WATER*4.538/EMOT                                          UDE03980
            C                                                                            UDE03990
            C      EFFECT OF GAS EJECTION ON STEAM FLOW                                  UDE04000
0208               IF(GAS .GE. 1.0) SFLP = SFLP*(1.0+0.04*GAS)                           UDE04010
            C                                                                            UDE04020
            C      CALCULATE BRINE FLOW TAKING INTO ACCOUNT TOTAL DISOLVED SOLIDS        UDE04030
0209               BFLOW = SFLP/(W1+W2)*TDS                                              UDE04040
            C                                                                            UDE04050
            C      SIZE OF VARIOUS PUMPS - PUMP SIZES ARE BASED ON THE ASSUMPTION        UDE04060
            C        THAT AN AMOUNT OF SPENT BRINE AND CONDENSATE EQUAL TO THE AMOUNTUDE04070
            C        OF BRINE WITHDRAWN FROM THE RESERVOIR IS RE-INJECTED AT A           UDE04080
            C        PRESSURE EQUAL TO THE RESERVOIR PRESSURE.                           UDE04090
0210               CWP   = WATER*(HT/2.307-P5)*CONST                                     UDE04100
0211               CDP   = SFLP*(P3-P4)*CONST                                            UDE04110
0212               RIP   = BFLOW*(P1-P3)*CONST                                           UDE04120
0213               AUX   = (CWP+CDP+RIP+FAN)*0.7457E-03                                  UDE04130
            C                                                                            UDE04140
            C      SPECIFIC NET ENERGY VS SOLIDS BASED ON HEBER PLANT DESIGN             UDE04150
            C                                                                            UDE04160
0214               SNE   = PT/SFLP                                                       UDE04170
0215               PT    = PG+AUX/GEFF                                                   UDE04180
0216         30    CONTINUE                                                              UDE04190
0217               IF(NDPMP .EQ. 2) PT = PT - (CWP+CDP+RIP)*0.7457E-03/GEFF              UDE04200
0218               WLP  = PT                                                             UDE04210
0219               IF(IUSE .EQ. 3) WLP  = PT/(1.0+(W1/(W1+W2))*EHP*DHP/(ELP*DLP))        UDE04220
0220               WHP  = PT-WLP                                                         UDE04230
            C                                                                            UDE04240
            C      COOLING TOWER CALCULATIONS - COOLING TOWER LOSSES IN TERMS OF         UDE04250
            C         PLUMES AND  BLOWDOWN IS ASSUMED TO BE REPLACED BY AN EQUAL         UDE04260
            C         AMOUNT OF FRESH MAKE-UP WATER.  ESTIMATION OF THE AMOUNT OF        UDE04270
            C         FRESH MAKE-UP WATER IS NOT INCLUDED BUT AMMOUNTS TO ROUGHLY        UDE04280
            C         15% OF THE CIRCULATING COOLING WATER REQUIREMENT.                  UDE04290
            C      RG = RANGE OF TOWER                                                   UDE04300
            C      AP = APPROACH                                                         UDE04310
            C                                                                            UDE04320
```

```
      RF = 3.76-0.0524*TWB+0.1347*RG-0.1725*AP
      RF = RF+0.00019*TWB*TWB-0.00081*RG*RG
      RF = RF+0.00196*AP*AP-0.00073*TWB*RG
      RF = RF+0.00107*TWB*AP-0.0013*RG*AP
      UNITS = RF*WATER*1E+06/506.4
      IF(LTWR .EQ. 2) UNITS = HEAT
      GEFF=GEFF*HUND
      ELP=ELP*HUND
      EHP=EHP*HUND
      RETURN
      END
```

FUNCTION TO CALCULATE PRESSURE AS A FUNCTION OF TEMPERATURE

```
FORTRAN IV G1   RELEASE 2.0          WPT              DATE = 81294        10/54/20

0001              FUNCTION WPT(XX)
0002              IMPLICIT REAL*8 (A-Z)
           C***   END
           C---$CONTROL MAP,CROSSREF,LABEL,LOCATION,SEGMENT=UDES
           C***   FUNCTION WPT(XX)
           C      MODIFIED 21OCT81 BY FITTING CURVE OVER TWO REGIONS.JCB.
           C
           C      WATER - PRESSURE OF SATURATED VAPOR
           C        P = F(T)
           C
0003              DATA
                 1 A0/ 0.324378E+01/,  A1/ 0.586826E-02/,
                 2 A2/ 0.117024E-07/,  A3/ 0.218785E-02/
0004              DATA
                 1 B0/ 0.334631E+01/,  B1/ 0.414113E-01/,
                 2 B2/ 0.751548E-08/,  B3/ 0.656444E-10/,
                 3 B4/ 0.137945E-01/
           C
0005              TK = (5./9.)*(XX-32.0)+273.16
0006              X = 647.27 - TK
0007              T1 = X/TK
0008               IF(XX.GE. 200.0) GO TO 100
0009              T2 = 1. + A3*X
0010              T3 = T1/T2
0011              Y = T3*((A2*X*X+A1)*X+A0)
0012              GO TO 101
0013          100 T2 = 1. + B4*X
0014              T3 = T1/T2
0015              Y = T3*(((B3*X+B2)*X*X+B1)*X+B0)
0016         101  WPT=3206.1822*10.**(-Y)
0017              RETURN
0018              END
```

FUNCTION TO CALCULATE ENTHALPY OF SATURATED WATER

```
FORTRAN IV G1  RELEASE 2.0            WHL                 DATE = 81294          10/53/02

0001                FUNCTION WHL(XX)                                                  WHL00010
              C***  END                                                               WHL00020
              C---$CONTROL MAP,CROSSREF,LABEL,LOCATION,SEGMENT=UDES                   WHL00030
              C***  FUNCTION WHL(XX)                                                  WHL00040
              C                                                                       WHL00050
              C     WATER - ENTHALPY OF SATURATED LIQUID                              WHL00060
              C       H = F(P)                                                        WHL00070
              C     MODIFIED 21OCT81 BY FITTING CURVE OVER TWO REGIONS.JCB.           WHL00080
0002                DATA                                                              WHL00090
                   1 A0/ 0.424250E+01/,  A1/ 0.471044E+00/,                           WHL00100
                   2 A2/-0.670478E-01/,  A3/ 0.419248E-01/,                           WHL00110
                   3 A4/-0.324539E-01/,  A5/-0.873229E-02/,                           WHL00120
                   4 A6/ 0.131376E-01/,  A7/ 0.231567E-02/,                           WHL00130
                   5 A8/-0.252983E-02/,  A9/ 0.000000E-06/,                           WHL00140
                   6 AA/ 0.000000E-07/                                                WHL00150
              C    CMSSQ = 0.146764E-04                                               WHL00160
0003                DATA                                                              WHL00170
                   1 B0/ 0.422868E+01/,  B1/ 0.418488E+00/,                           WHL00180
                   2 B2/ 0.690782E-02/,  B3/-0.155874E-01/,                           WHL00190
                   3 B4/ 0.818569E-03/,  B5/ 0.524740E-03/,                           WHL00200
                   4 B6/-0.719860E-05/,  B7/-0.149404E-04/,                           WHL00210
                   5 B8/-0.181923E-06/,  B9/ 0.340726E-06/,                           WHL00220
                   6 BA/-0.219136E-07/                                                WHL00230
              C                                                                       WHL00240
              C                                                                       WHL00250
0004                X=ALOG(XX)                                                        WHL00260
0005                 IF(XX .GE. 3.0) GO TO 100                                        WHL00270
0006                Y = ((( ((( (((                                                   WHL00280
                   1 AA*X+A9)*X+A8)*X+A7) *X+A6)*X+A5)*X+A4) *X+A3)*X+A2)*X+A1)*X+A0  WHL00290
0007                GO TO 101                                                         WHL00300
0008           100  Y = ((( ((( (((                                                   WHL00310
                   1 BA*X+B9)*X+B8)*X+B7) *X+B6)*X+B5)*X+B4) *X+B3)*X+B2)*X+B1)*X+B0  WHL00320
0009           101  WHL=EXP(Y)                                                        WHL00330
0010                RETURN                                                            WHL00340
0011                END                                                               WHL00350
```

FUNCTION TO CALCULATE ENTHALPY OF SATURATED STEAM

```
FORTRAN IV G1  RELEASE 2.0             WHG                DATE = 81294          10/53/20

0001                 FUNCTION WHG(XX)
               C***  END
               C---$CONTROL MAP,CROSSREF,LABEL,LOCATION,SEGMENT=UDES
               C***  FUNCTION WHG(XX)
               C
               C     WATER - ENTHALPY OF SATURATED VAPOR
               C       H = F(P)
               C     MODIFIED 21OCT81 BY FITTING CURVE OVER TWO REGIONS.JCB.
0002                 DATA
                    1 A0/ 0.700832E+01/,  A1/ 0.130056E-01/,
                    2 A2/ 0.649011E-03/,  A3/ 0.000000E-02/,
                    3 A4/ 0.000000E-02/,  A5/ 0.000000E-02/,
                    4 A6/ 0.000000E-03/,  A7/ 0.000000E-06/,
                    5 A8/ 0.000000E-06/,  A9/ 0.000000E-07/,
                    6 AA/ 0.000000E-07/
0003                 DATA
                    1 B0/ 0.708881E+01/,  B1/-0.834852E-01/,
                    2 B2/ 0.380562E-01/,  B3/-0.376460E-02/,
                    3 B4/-0.913026E-03/,  B5/ 0.237223E-03/,
                    4 B6/-0.152369E-04/,  B7/ 0.000000E-06/,
                    5 B8/ 0.000000E-06/,  B9/ 0.000000E-07/,
                    6 BA/ 0.000000E-07/
               C
0004                 X=ALOG(XX)
0005                  IF(XX .GE. 5.0) GO TO 100
0006                 Y = ((( ((( (((
                    1 AA*X+A9)*X+A8)*X+A7) *X+A6)*X+A5)*X+A4) *X+A3)*X+A2)*X+A1)*X+A0
0007                 GO TO 101
0008             100 Y = ((( ((( (((
                    1 BA*X+B9)*X+B8)*X+B7) *X+B6)*X+B5)*X+B4) *X+B3)*X+B2)*X+B1)*X+B0
0009             101 WHG=EXP(Y)
0010                 RETURN
0011                 END
```

FUNCTION TO CALCULATE ENTROPY OF SATURATED WATER

```
FORTRAN IV G1  RELEASE 2.0           WSL                 DATE = 81294          10/53/36

0001                 FUNCTION WSL(XX)
             C***    END
             C---$CONTROL MAP,CROSSREF,LABEL,LOCATION,SEGMENT=UDES
             C***    FUNCTION WSL(XX)
             C
             C       MODIFIED 21OCT81 BY FITTING CURVE OVER TWO REGIONS.JCB.
             C       WATER - ENTROPY OF SATURATED VAPOR
             C         S = F(P)
0002                 DATA
                    1 A0/-0.202218E+01/,  A1/ 0.435140E 00/,
                    2 A2/-0.797689E-01/,  A3/ 0.485220E-01/,
                    3 A4/-0.113432E-01/,  A5/-0.810410E-02/,
                    4 A6/ 0.114638E-02/,  A7/-0.336488E-03/,
                    5 A8/-0.146272E-03/,  A9/ 0.403614E-03/,
                    6 AA/-0.112411E-03/
             C
             C      CMSSQ= 0.173936E-04
             C
0003                 DATA
                    1 B0/-0.194085E+01/,  B1/ 0.329339E+00/,
                    2 B2/-0.108023E-01/,  B3/-0.323546E-02/,
                    3 B4/ 0.761815E-03/,  B5/-0.721715E-04/,
                    4 B6/ 0.324272E-05/,  B7/ 0.000000E-07/,
                    5 B8/ 0.000000E-07/,  B9/ 0.000000E-07/,
                    6 BA/ 0.000000E-08/
             C
             C      CMSSQ= 0.348307E-05
             C
0004                 X=ALOG(XX)
0005                  IF(XX .GE. 5.0) GO TO 100
0006                 Y = ((( ((( (((
                    1 AA*X+A9)*X+A8)*X+A7) *X+A6)*X+A5)*X+A4) *X+A3)*X+A2)*X+A1)*X+A0
0007                 GO TO 101
0008            100  Y = ((( ((( (((
                    1 BA*X+B9)*X+B8)*X+B7) *X+B6)*X+B5)*X+B4) *X+B3)*X+B2)*X+B1)*X+B0
0009            101  WSL=EXP(Y)
0010                 RETURN
0011                 END
```

FUNCTION TO CALCULATE ENTROPY OF SATURATED STEAM

```
FORTRAN IV G1  RELEASE 2.0              WSG                 DATE = 81294          10/54/03

0001                 FUNCTION WSG(XX)
               C***  END
               C---$CONTROL MAP,CROSSREF,LABEL,LOCATION,SEGMENT=UDES
               C***  FUNCTION WSG(XX)
               C
               C     MODIFIED 21OCT81 BY FITTING CURVE OVER TWO REGIONS.JCB.
               C     WATER - ENTROPY OF SATURATED VAPOR
               C        S = F(P)
0002                 DATA
                    1 A0/ 0.682130E+00/,  A1/-0.426375E-01/,
                    2 A2/-0.441297E-03/,  A3/-0.750950E-04/,
                    3 A4/-0.337103E-04/,  A5/ 0.291020E-04/,
                    4 A6/ 0.378325E-05/,  A7/-0.339029E-05/,
                    5 A8/ 0.000000E-02/,  A9/ 0.000000E-06/,
                    6 AA/ 0.000000E-07/
               C    CMSSQ= 0.895527E-09
0003                 DATA
                    1 B0/ 0.709889E+00/,  B1/-0.686143E-01/,
                    2 B2/ 0.464198E-02/,  B3/ 0.100798E-02/,
                    3 B4/-0.392016E-03/,  B5/ 0.262748E-04/,
                    4 B6/ 0.831162E-06/,  B7/-0.431737E-07/,
                    5 B8/-0.826707E-07/,  B9/ 0.234882E-07/,
                    6 BA/-0.181887E-08/
               C
               C    CMSSQ= 0.138593E-05
               C
0004                 X=ALOG(XX)
0005                  IF(XX .GE. 5.0) GO TO 100
0006                 Y = ((( ((( (((
                    1 AA*X+A9)*X+A8)*X+A7) *X+A6)*X+A5)*X+A4) *X+A3)*X+A2)*X+A1)*X+A0
0007                 GO TO 101
0008           100   Y = ((( ((( (((
                    1 BA*X+B9)*X+B8)*X+B7) *X+B6)*X+B5)*X+B4) *X+B3)*X+B2)*X+B1)*X+B0
0009           101   WSG=EXP(Y)
0010                 RETURN
0011                 END
```

EG&G Idaho, Inc.
P.O. BOX 1625, IDAHO FALLS, IDAHO 83415

Received 10/23/81
D Entingh

October 20, 1981

Dr. D. Entingh
Advanced Energy and Resource System
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The Mitre Corporation/Metrek Division
1820 Dolly Madison Blvd.
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TURBINE EFFICIENCY FACTORS USED FOR RECOMMENDED GCFM MODIFICATIONS - TWL-17-81

Dear Dan:

Although most of the turbine efficiency factors used in the recommended GCFM modifications have come from personal experience with turbines of the size and type used for geothermal applications and proprietary references accumulated during this work, similar values can be found in the open literature. I reference "Steam Turbines" by Edwin F. Church, Jr., Third Edition, McGraw-Hill Book Company, Inc., 1950, as providing similar values. Discussion of individual factors of turbine performance with sections from the above referene follow below.

Inlet Pressure Throttling Loss - INEL recommended using a pressure drop of 10% of the absolute pressure in the flash tank to represent the total pressure drop between the flash tank and the turbine blading. This drop includes moisture removal screens in the flash tank, piping between the flash and the turbine inlet, turbine inlet screens, and turbine governor valve drops. Church, in Section 13.3, recommends 5% for just the turbine inlet screen and governor valve pressure drops.

85% Blading Base Efficiency, Moisture Correction 1/2% for Each 1% Moisture at Blading Exit - Church, Section 7.16, Figure 7-29 shows peak theoretical efficiencies for both impulse and reaction blading to be 87%. The recommended value of .85 allows for operation off peak efficiency of 1% plus stage leakage of 1%. In Section 14.4, Church references 1% to 1.15% moisture losses for each 1% average moisture in each stage. For turbine inlet conditions near the saturation line, the average moisture in the turbine is approximately 1/2 of the blade exit moisture.

Dr. D. Entingh
TWL-17-81
October 20, 1981
Page 2

10 Btu/lb Leaving Loss - Church, Section 13.7, Figure 13.18 shows a GE exhaust loss curve with a minimum of 4 Btu/lb. Similar proprietary W curves show minimums of about 6 Btu/lb. However, finite designs of blading and exhaust hoods mean that the exhaust loss for a specific application is seldom at the minimum. The recommended 10 Btu/lb allows for off-optimum operation.

I hope that these references suffice for the final description of the GCFM modifications.

Very truly yours,

T. W. Lawford, Manager
Federal Program Support

jd

cc: W. Holman, DOE/SAN

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