As another example, consider that the user wants to find the full-throttle off-design performance of the engine defined by the reference data file **AAFAB.DAT** at sea level versus Mach number from static to Mach 2. Before performing calculations, the user would:

1. Read from disk the reference data file **AAFAB.DAT** using the **REFERENCE DATA ENTRY MENU**
2. Change the iteration variable to Mach number and enter minimum, maximum, and iteration values using the **ITERATION VALUE MENU** (see example on page 36)
3. Change the off-design flight condition to sea level conditions using the **OFF DESIGN CONDITION MENU**

Performing calculations results in the following output on the terminal screen:

```
 FILE: AAFAB.DAT          OFF-DESIGN CALCULATIONS              PAGE  1

          ***** FIXED AREA TURBINE - TURBOFAN ENGINE *****

 INPUT CONSTANTS
 PID MAX = .9700   CP C    = .2380   CP T    = .2950   CP AB   = .2950
 ETA B   = .9800   GAM C   =1.4000   GAM T   =1.3000   GAM AB  =1.3000
 ETA  AB = .9700   PI B    = .9700   PI AB   = .9600   PI N    = .9800
 ETA C   = .8684   ETA CH  = .8742   ETA MH  = .9800   ETA ML  = .9900
 PI TH   = .3900   TAU TH  = .8242   ETA TL  = .9173   ETA MP  = .9800
 BLEED   = 1.00 %  COOL #1 = 5.00 %  COOL #2 = 5.00 %  PTOL(KW)=  150.
 PIM MAX = .9700   TAU Ml  = .9686   TAU M2  = .9750   ETA MPH = .9800
 PIC MAX =   .00   PT3 MAX =    .0   TT3 MAX =    0.R  PTOH(KW)=    0.
 RPML MAX=    .0%  RPMH MAX=    .0%

M0  =    .01    ALT =       0. FT    T0  = 518.70 R
P0  =  14.6960 PSIA  P0/P9 = 1.0000  TT4 = 3200.0 R  TT7   = 3600.0 R

    M0 THRUST   AIR   FUEL   F/MDOT   TSFC  PI C Pl C'  ALPHA PT9/P9  V9/V0 L
       (LBF) (LB/S) (LB/H)
   .01 16555. 131.53  26867. 125.86 1.6229 28.12 4.828   .481   4.14 346.42 0
   .10 16210. 131.88  26931. 122.92 1.6614 27.98 4.809   .482   4.15  34.69 0
   .20 15916. 132.93  27125. 119.73 1.7043 27.56 4.753   .485   4.18  17.39 0
   .30 15724. 134.69  27452. 116.74 1.7459 26.89 4.662   .490   4.23  11.63 0
   .40 15631. 137.20  27916. 113.93 1.7860 26.00 4.539   .497   4.31   8.77 0
   .50 15636. 140.49  28523. 111.29 1.8242 24.91 4.391   .505   4.41   7.06 0
   .60 15739. 144.62  29281. 108.83 1.8605 23.68 4.222   .516   4.54   5.93 0
   .70 15941. 149.63  30200. 106.53 1.8945 22.35 4.039   .528   4.69   5.13 0
   .80 16245. 155.63  31293. 104.39 1.9263 20.96 3.846   .543   4.88   4.54 0
   .90 16657. 162.68  32574. 102.39 1.9556 19.54 3.649   .559   5.09   4.08 0
  1.00 17180. 170.92  34059. 100.52 1.9825 18.14 3.453   .576   5.35   3.71 0
  1.10 17743. 179.84  35648.  98.66 2.0091 16.77 3.262   .596   5.62   3.42 0
  1.20 18383. 189.79  37400.  96.86 2.0345 15.46 3.077   .617   5.93   3.17 0
  1.30 19121. 201.01  39357.  95.12 2.0583 14.22 2.903   .639   6.28   2.97 0
  1.40 19969. 213.68  41543.  93.45 2.0803 13.07 2.739   .663   6.67   2.79 0
  1.50 20938. 227.97  43983.  91.84 2.1007 12.01 2.588   .688   7.12   2.64 0
  1.60 22034. 244.06  46698.  90.28 2.1194 11.03 2.448   .713   7.62   2.51 0
  1.70 23266. 262.15  49711.  88.75 2.1366 10.14 2.321   .739   8.19   2.39 0
  1.80 24642. 282.44  53043.  87.25 2.1525  9.33 2.205   .766   8.84   2.29 0
  1.90 26169. 305.15  56716.  85.76 2.1673  8.60 2.101   .793   9.56   2.20 0
  2.00 27852. 330.52  60749.  84.27 2.1812  7.95 2.007   .820   10.38  2.12 0
```

NOTE: *The initial value of each off-design variable is printed above the results of the off-design calculations. Also note that the initial Mach number has been changed by the computer from zero to 0.01 so that static performance can be approximated using the same equations as are used for non-static conditions without the problem of division by zero.*

As another example, consider that the user wants to find the off-design performance of the engine defined by the reference data file **AAFAB.DAT** at sea level static while producing 4000 lbf of thrust. Before performing calculations, the user would:

1. Read from disk the reference data file **AAFAB.DAT** using the **REFERENCE DATA ENTRY MENU**

2. Change the iteration variable to **2 - ENGINE THROTTLED FOR REQUIRED THRUST** and enter the required thrust as 4000 lbf using the **ITERATION VALUE MENU** (see example on page 34)
3. Change the off-design flight condition to sea level static conditions using the **OFF-DESIGN CONDITION MENU** (**Note**: Now that the iteration variable has been changed to item 2, the required thrust will be shown as item 10 on the **OFF-DESIGN CONDITION MENU** and can be changed from this menu without using the **ITERATION VALUE MENU**.)

Performing calculations results in the following output to a printer:

```
FILE: AAFAB.DAT          OFF-DESIGN CALCULATIONS              PAGE  2

         ***** FIXED AREA TURBINE - TURBOFAN ENGINE *****
         ENGINE THROTTLED FOR UNINSTALLED THRUST = 4000.LBF
INPUT CONSTANTS
PID MAX = .9700   CP C    = .2380   CP T    = .2950   CP AB   = .2950
ETA B   = .9800   GAM C   =1.4000   GAM T   =1.3000   GAM AB  =1.3000
ETA  AB = .9700   PI B    = .9700   PI AB   = .9600   PI N    = .9800
ETA C   = .8684   ETA CH  = .8742   ETA MH  = .9800   ETA ML  = .9900
PI TH   = .3900   TAU TH  = .8242   ETA TL  = .9173   ETA MP  = .9800
BLEED   = 1.00 %  COOL #1 = 5.00 %  COOL #2 = 5.00 %  PTOL(KW)=  150.
PIM MAX = .9700   TAU Ml  = .9686   TAU M2  = .9750   ETA MPH = .9800
PIC MAX =   .00   PT3 MAX =    .0   TT3 MAX =    0.R  PTOH(KW)=    0.
RPML MAX=    .0%  RPMH MAX=    .0%

PARAMETER                    REFERENCE            OFF-DESIGN
M0                                1.60                   .01
T0  (R)                          394.1                 518.7
P0  (PSIA)                         3.468               14.696
ALT (FT)                       35000.0                    .0
TT4 (R)                         3200.0                2244.1
TT7 (R)                         3600.0                1220.6
PI R  / TAU R             4.250/ 1.512          1.000/ 1.000
PI D                              .933                  .970
PI C  / TAU C            20.000/ 2.600         12.295/ 2.232
PI C` / TAU C`            3.700/ 1.522          2.601/ 1.362
PI CH / TAU CH            5.405/ 1.709          4.726/ 1.639
PI TL / TAU TL            .4537/ .8471          .4764/ .8558
LP SPOOL - % REF RPM            100.00                 77.67
HP SPOOL - % REF RPM            100.00                 83.80
M5 / M5P                  .4000/ .5104          .3794/ .6121
M6                                .4441                 .4439
GAMMA M                          1.329                 1.333
CP M                              .275                  .272
PO/P9                            1.000                 1.000
PT9/P9                          12.543                 2.069
Limit                                                   None
PI AB                             .960                  .980
PT5'/PT5                         1.078                 1.174
PT6/PT5                           .979                 1.002
TT6/TT5                           .827                  .817
ALPHA                             .550                  .665
MDOT (LBM/S)                     94.50                 77.21
MDOT CORR (LBM/S)               100.98                 77.21
AREA0  SQFT)                      2.56                 90.44
AREA0* SQFT)                      2.04                  1.56
F                                .0345                 .0228
F AB                             .0362                 .0000
FO (OVERALL)                     .0557                 .0122
T9/T0                           5.0959                1.9624
V9/VO                           3.1269              149.4381
M9/M0                           1.4367              109.3589
A9/A0                           1.7120                 .0132
A9/A8                           2.4338                1.0277
S (l/H)                         1.8181                 .8452
F/M (LBF/LBM/S)                110.38                 51.82
FUEL FLOW (LB/H)               18965.                 3382.
THRUST (LBF)                   10431.                 4001.
PROP EFF (%)                    49.27                  1.33
THERM EFF (%)                   44.82                 26.37
```

Output on the terminal screen consists of the above output plus the throttle iteration as the program converges on the required thrust value. This throttle iteration is printed on the screen between the input constants and resulting performance and, for this example, would appear as

```
THRUST =   16554.63LBF, TT4 = 3200.00R, TT7 = 3600.00R
THRUST =   16285.27LBF, TT4 = 3200.00R, TT7 = 3500.00R
THRUST =   14906.08LBF, TT4 = 3200.00R, TT7 = 3000.00R
THRUST =   13456.55LBF, TT4 = 3200.00R, TT7 = 2500.00R
THRUST =   11905.17LBF, TT4 = 3200.00R, TT7 = 2000.00R
THRUST =   11162.39LBF, TT4 = 3200.00R
THRUST =   10172.90LBF, TT4 = 3100.00R
THRUST =    7479.90LBF, TT4 = 2788.08R
THRUST =    6027.20LBF, TT4 = 2586.54R
THRUST =    5132.48LBF, TT4 = 2445.93R
THRUST =    4612.59LBF, TT4 = 2356.93R
THRUST =    4322.08LBF, TT4 = 2304.50R
THRUST =    4165.92LBF, TT4 = 2275.44R
THRUST =    4084.34LBF, TT4 = 2260.00R
THRUST =    4042.54LBF, TT4 = 2252.02R
THRUST =    4021.36LBF, TT4 = 2247.96R
THRUST =    4010.73LBF, TT4 = 2245.91R
THRUST =    4005.34LBF, TT4 = 2244.88R
THRUST =    4002.70LBF, TT4 = 2244.36R
THRUST =    4001.32LBF, TT4 = 2244.10R
```

G. EXIT PROGRAM

To exit this program, the user must select item **6 - EXIT PROGRAM** from the **MAIN MENU**. A warning is then printed at the terminal and the user must enter "X" (capital x) to exit the program.

```
        ************************************************************
        *                                                          *
        *            OFF-DESIGN ENGINE ANALYSIS PROGRAM            *
        *                                                          *
        *                        MAIN MENU                         *
        *                                                          *
        ************************************************************

             1 - READ/SAVE REFERENCE DATA   (CYCLE 5)
             2 - INPUT OFF-DESIGN CONDITION
             3 - ITERATION VARIABLE               (1)
             4 - OUTPUT DEVICE                    (2)
             5 - PERFORM CALCULATIONS
             6 - EXIT PROGRAM

         ENTER YOUR SELECTION   6
       YOU ARE ABOUT TO EXIT THIS PROGRAM - ENTER A "X" TO EXIT
       OR ANY OTHER CHARACTER TO GET THE MAIN MENU.    X
Stop - Program terminated.

A>
```

H. EXAMPLE INTERACTION

Consider that a user wants to determine the variation of static thrust of the engine in data file **AAFAB.DAT** as follows:

(1) with altitude at maximum power from sea level to 7,000 ft in increments of 500 ft.

(2) with partial throttle at sea level from military power (TT4=3200 R) to minimum thrust in increments of 50 R. When the exit nozzle unchokes, the nozzle throat area is to remain constant.

The following is the interaction to accomplish the above as it would appear on the terminal screen. User inputs are shown in bold type.

```
*************************************************************************
*   OFFX - OFF-DESIGN AIRCRAFT ENGINE CYCLE ANALYSIS PROGRAM - VERSION 2.2  *
*                  Copyright (C) by Dr. Jack D. Mattingly                 *
*                      May 1996.  All rights reserved.                    *
*                                                                         *
*  AIAA has exclusive license to promote and sell this copyrighted soft-  *
*  ware.  This program is provided "AS IS" without warranty of any kind.  *
*  Jack D. Mattingly and AIAA do not warrant or guarantee the use, or the *
*  results of the use, of this software or accompanying user guide in     *
*  terms of correctness, accuracy, reliability, currentness, or otherwise.*
*  The entire risk and performance of the software is assumed by the user.*
*                                                                         *
*  OFFX was written for use with the AIAA Education Series textbook AIRCRAFT*
*  ENGINE DESIGN and is based on the engine models contained therein.  It *
*  is intended for educational use only and not as a replacement for the  *
*  more complex and highly accurate aircraft engine cycle decks used in the *
*  industry.  This program gives accurate performance trends within the   *
*  limitations of the models and user input data.                         *
*                                                                         *
*  The purchaser is granted the right to use one copy of this software    *
*  program on a single terminal connected to a single computer (i.e., with *
*  a single CPU).  You may NOT network this software program or otherwise *
*  use it on more than one computer or computer terminal at the same time.*
*************************************************************************
             Press "Return" (Enter) key to continue    <CR>


     ********************************************************
     *    The default printer name is "PRN", the standard for   *
     *    MS-DOS.  At this point in the program, this can be    *
     *    changed to a disk file, e.g. "A:OUTNAME.PRN".         *
     ********************************************************
          WANT TO CHANGE THE DEFAULT (Y=1)?   <CR>


         ************************************************************
         *                                                          *
         *            OFF-DESIGN ENGINE ANALYSIS PROGRAM            *
         *                                                          *
         *                        MAIN MENU                         *
         *                                                          *
         ************************************************************

              1 - READ/SAVE REFERENCE DATA   (CYCLE 5)
              2 - INPUT OFF-DESIGN CONDITION
              3 - ITERATION VARIABLE              (1)
              4 - OUTPUT DEVICE                   (2)
              5 - PERFORM CALCULATIONS
              6 - EXIT PROGRAM

         ENTER YOUR SELECTION  1
```

```
*************************************************************
*            OFF-DESIGN ENGINE ANALYSIS PROGRAM             *
*                                                           *
*               REFERENCE DATA ENTRY MENU                   *
*************************************************************

     1 - READ OFF-DESIGN REFERENCE DATA FILE FROM DISK
     2 - WRITE OFF-DESIGN REFERENCE DATA FILE TO DISK
     3 - CHANGE/VIEW OFF-DESIGN REFERENCE DATA FILE
     4 - PAUSE PROGRAM and USE DOS
     0 - RETURN TO MAIN ON-DESIGN MENU

ENTER YOUR SELECTION   1

ENTER NAME OF DATA FILE + ".DAT" (MAX OF 14 CHARACTERS)    AAFAB.DAT
YOUR INPUT IS "AAFAB.DAT     "     IS THIS CORRECT  (Y=l/N=0)?    1


 *************************************************************
 *                                                           *
 *            OFF-DESIGN ENGINE ANALYSIS PROGRAM             *
 *                                                           *
 *                        MAIN MENU                          *
 *                                                           *
 *************************************************************

     1 - READ/SAVE REFERENCE DATA   (CYCLE 5)
     2 - INPUT OFF-DESIGN CONDITION
     3 - ITERATION VARIABLE              (1)
     4 - OUTPUT DEVICE                   (2)
     5 - PERFORM CALCULATIONS
     6 - EXIT PROGRAM

 ENTER YOUR SELECTION   3


  *************************************************************
  *            OFF-DESIGN ENGINE ANALYSIS PROGRAM             *
  *                                                           *
  *                   ITERATION VALUE MENU                    *
  *************************************************************
  CURRENT ITERATION VARIABLE IS #1

  SINGLE OFF-DESIGN POINT CALCULATION:
       1 - FIXED THROTTLE (TT4)
       2 - ENGINE THROTTLED FOR REQUIRED THRUST
  MULTIPLE OFF-DESIGN POINT CALCULATIONS:
       3 - MACH NUMBER
       4 - AMBIENT TEMP (R)
       5 - AMBIENT PRESSURE (PSIA)
       6 - ALTITUDE (FEET)
       7 - TOTAL TEMP (TT4) LVG COMBUSTOR (R)
       8 - TOTAL TEMP (TT7) LVG AFTERBURNER (R)
       9 - EXHAUST PRE SURE RATIO (P0/P9)
       0 - RETURN TO MAIN OFF-DESIGN MENU

  ENTER SELECTION   6

  MINIMUM VALUE = ?   0
  MAXIMUM VALUE = ?   7000
  ITERATION INCREMENT = ?    500

  MINIMUM VALUE =       .00
  MAXIMUM VALUE =   7000.00
  INCREMENT     =    500.00
  IS THIS CORRECT (Y=1/N=0) ?    1
```

```
*************************************************************
*                                                           *
*            OFF-DESIGN ENGINE ANALYSIS PROGRAM             *
*                                                           *
*                        MAIN MENU                          *
*                                                           *
*************************************************************

     1 - READ/SAVE REFERENCE DATA   (CYCLE 5)
     2 - INPUT OFF-DESIGN CONDITION
     3 - ITERATION VARIABLE              (1)
     4 - OUTPUT DEVICE                   (2)
     5 - PERFORM CALCULATIONS
     6 - EXIT PROGRAM

ENTER YOUR SELECTION   5


 ************************************************************
 *                                                          *
 *          You can save multiple iteration results         *
 *          as disk file(s) for later plotting in           *
 *          one of two file formats:                        *
 *                                                          *
 ************************************************************

      1 - SINGLE DISK FILE        (LOTUS or TWIN)
      2 - MULTIPLE DISK FILES     (GRAPHER)

 ENTER YOUR SELECTION (<CR>=DO NOT SAVE)    <CR>


 FILE: AAFAB.DAT          OFF-DESIGN CALCULATIONS              PAGE  1

          ***** FIXED AREA TURBINE - TURBOFAN ENGINE *****

 INPUT CONSTANTS
 PID MAX = .9700   CP C    = .2380   CP T    = .2950   CP AB   = .2950
 ETA B  = .9800    GAM C   =1.4000   GAM T   =1.3000   GAM AB  =1.3000
 ETA AB = .9700    PI B    = .9700   PI AB   = .9600   PI N    = .9800
 ETA C' = .8684    ETA CH  = .8742   ETA MH  = .9800   ETA ML  = .9900
 PI TH  = .3900    TAU TH  = .8242   ETA TL  = .9173   ETA MP  = .9800
 BLEED   = 1.00 %  COOL #1 = 5.00 %  COOL #2 = 5.00 %  PTOL(KW)=  150.
 PIM MAX = .9700   TAU Ml  = .9686   TAU M2  = .9750   ETA MPH = .9800
 PIC MAX =   .00   PT3 MAX =    .0   TT3 MAX =    0.R  PTOH(KW)=    0.
 RPML MAX=    .0%  RPMH MAX=    .0%

M0  =    .01    ALT =       O. FT    T0  = 518.70 R
P0  =  14.6960 PSIA  P0/P9 = 1.0000  TT4 = 3200.0 R  TT7   = 3600.0 R

  ALT   THRUST   AIR   FUEL   F/MDOT   TSFC  PI C PI C`  ALPHA PT9/P9  V9/V0 L
        (LBF) (LB/S) (LB/H)
    .00 16555. 131.53  26867. 125.86 1.6229 28.12 4.828    .481  4.14 346.42 0
 500.00 16421. 130.17  26600. 126.15 1.6199 28.36 4.861    .480  4.17 347.81 0
1000.00 16283. 128.78  26328. 126.44 1.6169 28.61 4.895    .478  4.20 349.21 0
1500.00 16146. 127.41  26059. 126.72 1.6140 28.85 4.928    .476  4.23 350.57 0
2000.00 16005. 126.02  25785. 127.00 1.6111 29.10 4.961    .475  4.26 351.94 0
2500.00 15873. 124.70  25525. 127.29 1.6081 29.36 4.996    .473  4.30 353.36 0
3000.00 15738. 123.35  25261. 127.58 1.6051 29.62 5.031    .471  4.33 354.79 0
3500.00 15608. 122.06  25007. 127.88 1.6021 29.89 5.067    .469  4.37 356.22 0
4000.00 15475. 120.74  24747. 128.17 1.5992 30.16 5.103    .468  4.40 357.66 0
4500.00 15342. 119.44  24491. 128.45 1.5963 30.42 5.139    .466  4.44 359.07 0
5000.00 15205. 118.11  24229. 128.74 1.5934 30.69 5.175    .464  4.47 360.48 0
5500.00 15079. 116.86  23983. 129.03 1.5905 30.97 5.213    .463  4.51 361.94 0
6000.00 14949. 115.59  23732. 129.32 1.5876 31.26 5.251    .461  4.54 363.41 0
6500.00 14823. 114.36  23490. 129.62 1.5846 31.55 5.290    .459  4.58 364.89 0
7000.00 14694. 113.11  23242. 129.91 1.5817 31.84 5.329    .458  4.62 366.38 0
  DATA SET  1 CALCULATED. ENTER ANY SINGLE CHARACTER TO CONTINUE.    <CR>
```

```
************************************************************
*                                                          *
*            OFF-DESIGN ENGINE ANALYSIS PROGRAM            *
*                                                          *
*                        MAIN MENU                         *
*                                                          *
************************************************************

     1 - READ/SAVE REFERENCE DATA   (CYCLE 5)
     2 - INPUT OFF-DESIGN CONDITION
     3 - ITERATION VARIABLE              (6)
     4 - OUTPUT DEVICE                   (2)
     5 - PERFORM CALCULATIONS
     6 - EXIT PROGRAM

ENTER YOUR SELECTION   3


 ************************************************************
 *            OFF-DESIGN ENGINE ANALYSIS PROGRAM            *
 *                                                          *
 *                  ITERATION VALUE MENU                    *
 ************************************************************
 CURRENT ITERATION VARIABLE IS #6
 MINIMUM VALUE =       .00
 MAXIMUM VALUE =   7000.00
 INCREMENT     =    500.00

 SINGLE OFF-DESIGN POINT CALCULATION:
      1 - FIXED THROTTLE (TT4)
      2 - ENGINE THROTTLED FOR REQUIRED THRUST
 MULTIPLE OFF-DESIGN POINT CALCULATIONS:
      3 - MACH NUMBER
      4 - AMBIENT TEMP (R)
      5 - AMBIENT PRESSURE (PSIA)
      6 - ALTITUDE (FEET)
      7 - TOTAL TEMP (TT4) LVG COMBUSTOR (R)
      8 - TOTAL TEMP (TT7) LVG AFTERBURNER (R)
      9 - EXHAUST PRE SURE RATIO (P0/P9)
      0 - RETURN TO MAIN OFF-DESIGN MENU

 ENTER SELECTION  7

 MINIMUM VALUE = ?  2000
 MAXIMUM VALUE = ?  3200
 ITERATION INCREMENT = ?   50

 MINIMUM VALUE =   2000.00
 MAXIMUM VALUE =   32000.00
 INCREMENT     =     50.00
 IS THIS CORRECT (Y=1/N=0) ?   1


************************************************************
*                                                          *
*            OFF-DESIGN ENGINE ANALYSIS PROGRAM            *
*                                                          *
*                        MAIN MENU                         *
*                                                          *
************************************************************

     1 - READ/SAVE REFERENCE DATA   (CYCLE 5)
     2 - INPUT OFF-DESIGN CONDITION
     3 - ITERATION VARIABLE              (7)
     4 - OUTPUT DEVICE                   (2)
     5 - PERFORM CALCULATIONS
     6 - EXIT PROGRAM

ENTER YOUR SELECTION   5
```

```
        ************************************************************
        *                                                          *
        *          You can save multiple iteration results         *
        *          as disk file(s) for later plotting in           *
        *          one of two file formats:                        *
        *                                                          *
        ************************************************************

             1 - SINGLE DISK FILE        (LOTUS or TWIN)
             2 - MULTIPLE DISK FILES     (GRAPHER)

        ENTER YOUR SELECTION (<CR>=DO NOT SAVE)    <CR>

  FILE: AAFAB.DAT          OFF-DESIGN CALCULATIONS              PAGE  1

           ***** FIXED AREA TURBINE - TURBOFAN ENGINE *****

  INPUT CONSTANTS
  PID MAX = .9700   CP C    = .2380   CP T    = .2950   CP AB   = .2950
  ETA B  = .9800    GAM C   =1.4000   GAM T   =1.3000   GAM AB  =1.3000
  ETA AB = .9700    PI B    = .9700   PI AB   = .9600   PI N    = .9800
  ETA C' = .8684    ETA CH  = .8742   ETA MH  = .9800   ETA ML  = .9900
  PI TH  = .3900    TAU TH  = .8242   ETA TL  = .9173   ETA MP  = .9800
  BLEED   = 1.00 %  COOL #1 = 5.00 %  COOL #2 = 5.00 %  PTOL(KW)=  150.
  PIM MAX = .9700   TAU Ml  = .9686   TAU M2  = .9750   ETA MPH = .9800
  PIC MAX =   .00   PT3 MAX =    .0   TT3 MAX =    0.R  PTOH(KW)=    0.
  RPML MAX=    .0%  RPMH MAX=    .0%

 M0  =    .01    ALT =       O. FT    T0  = 518.70 R
 P0  =  14.6960 PSIA  P0/P9 = 1.0000  TT4 = 3200.0 R  TT7   = 3600.0 R

  TT4   THRUST   AIR   FUEL   F/MDOT   TSFC  PI C PI C`  ALPHA PT9/P9  V9/V0 L
        (LBF) (LB/S) (LB/H)
3200.00 11162. 131.53  10002.  84.86  .8960 28.12 4.828    .481  4.22 242.11 0
3150.00 10660. 128.04   9510.  83.25  .8912 27.02 4.678    .488  4.08 237.63 0
3100.00 10173. 124.62   9036.  81.63  .8883 25.96 4.532    .496  3.94 233.13 0
3050.00  9702. 121.28   8581.  80.00  .8845 24.94 4.390    .503  3.80 228.59 0
3000.00  9247. 118.01   8144.  78.35  .8807 23.94 4.251    .511  3.66 224.01 0
2950.00  8806. 114.82   7724.  76.70  .8771 22.97 4.117    .519  3.53 219.39 0
2900.00  8381. 111.70   7321.  75.03  .8735 22.04 3.987    .528  3.41 214.74 0
2850.00  7970. 108.65   6934.  73.35  .8701 21.13 3.860    .536  3.28 210.05 0
2800.00  7573. 105.68   6564.  71.66  .8668 20.25 3.737    .545  3.17 205.31 0
2750.00  7189. l02.77   6208.  69.95  .8636 19.41 3.618    .554  3.05 200.53 0
2700.00  6819.  99.94   5868.  68.23  .8605 18.59 3.502    .564  2.94 195.71 0
2650.00  6462.  97.18   5542.  66.50  .8577 17.79 3.389    .574  2.83 190.85 0
2600.00  6118.  94.48   5231.  64.75  .8550 17.03 3.281    .584  2.72 185.93 0
2550.00  5786.  91.85   4933.  62.99  .8526 16.29 3.175    .594  2.62 180.97 0
2500.00  5466.  89.29   4648.  61.21  .8504 15.57 3.073    .605  2.52 175.96 0
2450.00  5157.  86.80   4376.  59.41  .8485 14.88 2.974    .616  2.43 170.90 0
2400.00  4860.  84.37   4116.  57.60  .8470 14.22 2.879    .627  2.34 165.78 0
2350.00  4573.  82.01   3869.  55.77  .8459 13.58 2.787    .639  2.25 160.61 0
2300.00  4298.  79.71   3633.  53.92  .8453 12.96 2.697    .651  2.16 155.37 0
2250.00  4032.  77.47   3408.  52.05  .8452 12.36 2.611    .664  2.08 150.07 0
2200.00  3776.  75.30   3194.  50.15  .8458 11.79 2.528    .676  2.00 144.69 0
2150.00  3530.  73.18   2990.  48.23  .8472 11.24 2.448    .690  1.92 139.25 0
 ************************ EXIT NOZZLE IS UNCHOKED ************************
   EXIT MACH NUMBER IS .9973
   ENTER DESIRED THROAT AREA IN TERMS OF ITS REFERENCE AREA (A8/A8R)
   A8/A8R =  1
   YOUR SELECTED A8/A8R IS 1.0000 (Y=1/N=0)?   1
2100.00  3292.  71.13   2796.  46.28  .8494 10.71 2.371    .703  1.85 133.71 0
 ************************ EXIT NOZZLE IS UNCHOKED ************************
   EXIT MACH NUMBER IS .9656
   ENTER DESIRED THROAT AREA IN TERMS OF ITS REFERENCE AREA (A8/A8R)
   A8/A8R =  1
   YOUR SELECTED A8/A8R IS 1.0000 (Y=1/N=0)?   1
2050.00  3063.  69.13   2612.  44.31  .8529 10.20 2.296    .717  1.77 128.09 0
 ************************ EXIT NOZZLE IS UNCHOKED ************************
   EXIT MACH NUMBER IS .9293
   ENTER DESIRED THROAT AREA IN TERMS OF ITS REFERENCE AREA (A8/A8R)
   A8/A8R =  1
   YOUR SELECTED A8/A8R IS 1.0000 (Y=1/N=0)?   1
2000.00  2842.  67.20   2438.  42.29  .8577  9.71 2.225    .732  1.70 122.37 0
  DATA SET  1 CALCULATED. ENTER ANY SINGLE CHARACTER TO CONTINUE.    <CR>
```

```
      ************************************************************
      *                                                          *
      *            OFF-DESIGN ENGINE ANALYSIS PROGRAM            *
      *                                                          *
      *                        MAIN MENU                         *
      *                                                          *
      ************************************************************

           1 - READ/SAVE REFERENCE DATA   (CYCLE 5)
           2 - INPUT OFF-DESIGN CONDITION
           3 - ITERATION VARIABLE              (7)
           4 - OUTPUT DEVICE                   (2)
           5 - PERFORM CALCULATIONS
           6 - EXIT PROGRAM

      ENTER YOUR SELECTION   6
      YOU ARE ABOUT TO EXIT THIS PROGRAM - ENTER A "X" TO EXIT
      OR ANY OTHER CHARACTER TO GET THE MAIN MENU.    X
Stop - Program terminated.

A>
```

I. ERROR AND OTHER MESSAGES

Sometimes during iterative calculations the exit total pressure of the exhaust stream is less than that required for flow to exist. The program first discovers this when trying to calculate the exit Mach number and the following message is displayed/printed.

EXIT MACH IS IMAGINARY

Off-design analysis assumes that the inlet nozzle to the low pressure turbine remain choked. At some off-design conditions, this assumption may not be true and this depends on both the pressure ratio of the low pressure turbine and this turbine's design. The following is printed on the terminal screen

LOW PRESSURE TURBINE NOZZLE MIGHT BE UNCHOKED

when calculation shows that the current value of the low pressure turbine pressure ratio can not have the inlet nozzles choked for a perfect turbine with zero degree of reaction.

Sometimes during iterative calculations for a mixed flow turbofan engine (see Fig. 5.12) a solution can not be reached within a certain number of iteration and one of the following four messages is displayed/printed.

1. If the mixer solution can not be obtained within 200 iterations, the following message is displayed/ printed.

XXXXXXX.XX SOLUTION FOR MIXER WILL NOT CONVERGE FOR M5 = X.XXX, M5P = X.XXX

2. If a solution for Tau tL can not be obtained within 100 iterations, the following message is displayed/ printed .

XXXXXXX.XX SOLUTION FOR TAUTL WILL NOT CONVERGE, TAUTL = .XXXX, ERRT = .XXXX

3. If a solution for the bypass ratio can not be obtained within 50 iterations, the following message is displayed/printed.

XXXXXXX.XX SOLUTION FOR ALPHA WILL NOT CONVERGE, ERRA = .XXXX

4. If a solution for the engine mass flow can not be obtained within 25 iterations, the following message is displayed/printed.

XXXXXXX.XX SOLUTION FOR MASS FLOW WILL NOT CONVERGE, ERRM = .XXXX

Sometimes during iterative calculations for a separate flow turbofan engine with convergent nozzles a solution can not be reached within a certain number of iteration and one of the following two messages is displayed/printed.

1. If the solution for Tau c` can not be obtained within 100 iterations, the following message is displayed/ printed.

```
UNABLE TO CONVERGE ON A SOLUTION FOR TAU C`
```

2. If a solution for the engine mass flow can not be obtained within 50 iterations, the following message is displayed/printed.

```
UNABLE TO CONVERGE ON A SOLUTION FOR MASS FLOW
```

Sometimes during iterative calculations for a turboprop engine with convergent nozzle a solution for Tau tL can not be obtained within 100 iterations, the following message is displayed/printed.

```
UNABLE TO CONVERGE ON A SOLUTION FOR PI TL
```

When iteration variable **2 - ENGINE THROTTLED FOR REQUIRED THRUST** is selected and a solution can not be obtained within 500 iterations, the following message is displayed on the terminal screen.

```
***** THROTTLE ITERATION WILL NOT CONVERGE *****
      LAST VALUE FOR TT4 = XXXXX.XX
      LAST VALUE FOR TT7 = XXXXX.XX
      THROTTLED THRUST = XXXXXXXXX.
```

A feature permitting variable throat area of the exhaust nozzle is available for use with both the turbojet and mixed flow turbofan engine cycles (engine cycles 1, 2, 4, and 5) when the exhaust nozzle becomes unchoked. This is most likely to occur at partial throttle and the user is asked for a value of A_8/A_{8R} via the following message on the terminal screen (see example on page 49).

```
************************ EXIT NOZZLE IS UNCHOKED **********************
  EXIT MACH NUMBER IS  .XXXX
  ENTER DESIRED THROAT AREA IN TERMS OF ITS REFERENCE AREA (A8/A8R)
  A8/A8R = X.XXXX
  YOUR SELECTED A8/A8R IS X.XXXX (Y=l/N=0)?
```

and, if output to the printer has been requested, the following message is then printed .

```
EXIT NOZZLE UNCHOKED. EXIT MACH = .XXX, A8/A8R =X.XXX
```

PLOTTING OUTPUT

When calculations in ONX and OFFX are performed for different iteration values, the user can save the results in disk files for later plotting. When Item #**5 - PERFORM CALCULATIONS** is selected from the **MAIN MENU** (see below OFFX example), the user is asked tp specify a preference for saving results in disk file(s) for later plotting.

```
************************************************************
*                                                          *
*            OFF-DESIGN ENGINE ANALYSIS PROGRAM            *
*                                                          *
*                        MAIN MENU                         *
*                                                          *
************************************************************

     1 - READ/SAVE REFERENCE DATA   (CYCLE 5)
     2 - INPUT OFF-DESIGN CONDITIONS
     3 - ITERATION VARIABLE              (3)
     4 - OUTPUT DEVICE                   (3)
     5 - PERFORM CALCULATIONS
     6 - EXIT PROGRAM

ENTER YOUR SELECTION   5

************************************************************
*                                                          *
*          You can save multiple iteration results         *
*          as disk file(s) for later plotting in           *
*          one of two file formats:                        *
*                                                          *
************************************************************

     1 - SINGLE DISK FILE        (LOTUS or TWIN)
     2 - MULTIPLE DISK FILES     (GRAPHER)

ENTER YOUR SELECTION (<CR>=DO NOT SAVE)
```

If 1 or 2 is entered, a prompt for the disk file name(s) appears. This output data is stored in multiple column format with the name of the variable on top. User input other than 1 or 2 will bypass this saving option. A list of output variables for each engine cycle is included in the following section of this section. GRAPHER is a product of Golden Software, Golden, CO.

ONX and OFFX - Output Plotting File(s)

When the user selects to save either ONX output or OFFX output for multiple iteration calculations for later plotting, data file(s) are created in columnar format headed by the name of the variable.

```
Cycle                            NOTE: Format 2 is for the plotting
1 - Dry Turbojet                 program GRAPHER and stores files in
2 - Turbojet with AB             a format with a maximum of five
3 - High Bypass Turbofan         columns wide. ONX requires one to
4 - Dry Mixed Flow Turbofan      two file(s) and OFFX requires two
5 - Mixed Flow Turbofan with AB  to four files.
6 - Turboprop
7 - Ramjet
```

ONX PLOT FILE FORMATS

ONX Output Variable	Cycles	Format File	1 Col 1	2 Col 1	2 Col 2	ONX Iteration Variables
Iteration Variable	All		1	1	1	Mach 0
F/m	All		2	2		Tt4
S	All		3	3		PI C
T Eff	All		4	4		PI C'
P Eff	All		5	5		ALPHA
Alpha*	3+		6		2	
M5	4,5		6		2	
M5'	4,5		7		3	
M6	4,5		8		4	
Alpha	4,5+		8		4	
PIC P	4,5++		8		4	
TAUTL	4,5		9		5	
CC	6		6		2	
CProp	6		7		3	
CTotal	6		8		4	
TAUT	6		9		5	

\+ Input Data Item #42 Set = -1

++ Input Data Item #41 Set = -1

Col = Column

OFFX PLOT FILE FORMATS

OFFX Output Variable	Cycles	Format File	1 Col 1	2 Col 1	2 Col 2	2 Col 3	2 Col 4	OFFX Iteration Variables
Iteration Variable	All		1	1	1	1	1	Mach 0
Thrust	All		2	2				T0
S	All		3	3				P0
mdot	All		4	4				Alt
mdotc	All		5	5				Tt4
A0 or A0*	All		6		2			Tt7
Area 9	All		7		3			P9/P0
mdotc2	All		8		4			
PI C	1-6		9		5			
mdotc2	1-5		10			2		
PI C'	1-5		11			3		
mdotc3'	1-5		12			4		
PI CH	1-5		13			5		
mdotc4c	1-5		14				2	
PI TL	1-5		15				3	
Alpha	3-5		16				4	
mdotc4c	6		10			2		
PI TL	6		11			3		
Power	6		12			4		
PSFC	6		13			5		

Col = Column