PROGRAM ONX
ONX USER GUIDE

ON-DESIGN CYCLE ANALYSIS PROGRAM

The on-design cycle analysis program ONX is based on the equations developed in *Aircraft Engine Design* and can analyze the following seven different engine cycles (relevant section of textbook is shown within parentheses following cycle):

1. Turbojet without afterburner (Chapter 4 and Appendix E)
2. Turbojet with afterburner (Chapter 4 and Appendix E)
3. Turbofan with separate exhausts (convergent only exhaust nozzles) (Appendix G)
4. Turbofan with mixed exhaust and no afterburning (Chapter 4 and Appendix E)
5. Turbofan with mixed exhaust and afterburning (Chapter 4 and Appendix E)
6. Turboprop (convergent only exhaust nozzle) (Appendix H)
7. Ramjet (Appendix J)

This program is designed to be user friendly and uses multiple menus for program control and data input. When an error occurs in a menu selection or in the format of input data, the user is asked to enter the selection or value again. Multiple calculations for different values of one design variable are possible by selecting the iteration variable from a menu and then specifying its minimum, maximum, and incremental values. On-design input data files may be saved on disk for later use. Also, saved on-design input data files may be read from disk for current use. Program output may be directed to the screen only, the printer only, or both the screen and the printer. The reference data file required for input to the off-design cycle analysis program (OFFX) can only be made and saved on disk by performing a single design point calculation and then saving the required output data to a user-named reference data file.

A. MAIN MENU

When ONX is run, the first thing to appear on the screen is

```
*************************************************************************
*    ONX - ON-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.*
*                                                                         *
*  ONX 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
```

This logo identifies the name of the program and its version number. After the user inputs a carriage return (**<CR>**, also called a **RETURN** key and an **ENTER** key), the program displays the following screen for redirecting printed output to a disk file rather than the default printer **PRN**. If the

user answers the question **WANT TO CHANGE THE DEFAULT (Y=1)?** with anything other than **1**, the program uses the default name for the printer name. The example below shows responses for an output file named **OUTPUT1.PRN** on **Drive A:**. Note that responses are shown in bold letters.

```
*********************************************************
*    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)?   1

ENTER NAME OF PRINTER FILE (MAX OF 14 CHAR)   A:OUTPUT1.PRN
PRINTER FILE IS "A:OUTPUT1.PRN ", CORRECT (Y=1/N=0)?    1
```

The **MAIN MENU** screen is displayed after the printer redirection screen as follows:

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

          1 - ENGINE CYCLE SELECTION          (5)
          2 - CALC ITERATION VARIABLE         (4)
          3 - INPUT DATA
          4 - OUTPUT DEVICE                   (2)
          5 - PERFORM CALCULATIONS
          6 - EXIT PROGRAM

     ENTER YOUR SELECTION
```

Menu items **1** through **4** each have a corresponding sub-menu. Menu item **5** has no sub-menu and menu item **6** allows for an orderly exit from this program. The normal procedure is for a user to select menu items **1** through **4** before selecting item **5 - PERFORM CALCULATIONS**, unless the user wants to use the default values or data of sub-menus **1** through **4**. After a user has changed the selection of a sub-menu, this change is stored internally within the program and remains until changed or the program is ended. The current selection for main menu items **1**, **2**, and **4** is displayed within parentheses to the right of that menu item and initially will contain the default value set by the program. As indicated by this main menu, the default selections for main menu items **1**, **2**, and **4** are sub-menu selections **5**, **4**, and **2**, respectively.

B. CYCLE SELECTION MENU

The **CYCLE SELECTION MENU** is obtained when the user selects item **1 - ENGINE CYCLE SELECTION** from the **MAIN MENU**. The following menu is displayed on the screen:

```
*********************************************************
*             ON-DESIGN ENGINE ANALYSIS PROGRAM         *
*                                                       *
*                     CYCLE SELECTION MENU              *
*********************************************************
YOUR CURRENT SELECTION IS #5

      1 - TURBOJET
      2 - TURBOJET WITH AFTERBURNER
      3 - TURBOFAN WITH TWO EXHAUSTS (CONV. NOZZLE)
      4 - TURBOFAN WITH MIXED EXHAUST
      5 - TURBOFAN WITH MIXED EXHAUST AND AFTERBURNER
      6 - TURBOPROP (CONV. NOZZLE)
      7 - RAMJET
      0 - RETURN TO MAIN ON-DESIGN MENU

ENTER YOUR SELECTION
```

As indicated on the **MAIN MENU** and this menu, the default cycle selection is item number **5 - TURBOFAN WITH MIXED EXHAUST AND AFTERBURNER**. The user must select another item number to change the current cycle selection from this default value. After entry of a cycle selection, the program automatically returns to the **MAIN MENU** and the number of the current cycle is displayed within parentheses to the right of item **1 - ENGINE CYCLE SELECTION**. The user can only change the engine cycle to a new cycle by use of this **CYCLE SELECTION MENU**. To return to the **MAIN MENU**, enter the number zero.

C. ITERATION VALUE MENU

The **ITERATION VALUE MENU** is obtained when the user selects item **2 - CALC ITERATION VARIABLE** from the **MAIN MENU**. The following menu is displayed on the screen:

```
************************************************************
*                    ITERATION VALUE MENU                  *
************************************************************
CURRENT ITERATION VARIABLE IS #4

MINIMUM VALUE =     16.00
MAXIMUM VALUE =     30.00
INCREMENT     =      1.00
     1 - SINGLE POINT CALCULATION
     2 - FLIGHT MACH NUMBER
     3 - MAX TEMPERATURE LEAVING MAIN BURNER (TT4)
     4 - COMPRESSOR PRESSURE RATIO
     5 - FAN PRESSURE RATIO
     6 - BYPASS RATIO
     0 - RETURN TO MAIN OFF-DESIGN MENU

ENTER SELECTION
```

As indicated on the **MAIN MENU** and this menu, the default selection is item number **4 - COMPRESSOR PRESSURE RATIO**. Also as indicated on this menu, the default values of minimum value, maximum value, and incremental value are **16**, **30**, and **1**, respectively. The user must select another item number to change the current calculation iteration selection from this default selection. If the user wants to change the minimum value, maximum value, and/or incremental value while either changing or retaining the current iteration variable, the desired iteration variable must be selected and the user will then be asked to input the minimum value, maximum value, and increment value. For example, if the user elects to change iteration variable **4 - COMPRESSOR PRESSURE RATIO** to a minimum value of **5**, maximum value of **40**, and incremental value of **1**, then one must enter selection **4** and the following interaction occurs.

```
************************************************************
*                    ITERATION VALUE MENU                  *
************************************************************
CURRENT ITERATION VARIABLE IS #4

MINIMUM VALUE =     16.00
MAXIMUM VALUE =     30.00
INCREMENT     =      1.00
     1 - SINGLE POINT CALCULATION
     2 - FLIGHT MACH NUMBER
     3 - MAX TEMPERATURE LEAVING MAIN BURNER (TT4)
     4 - COMPRESSOR PRESSURE RATIO
     5 - FAN PRESSURE RATIO
     6 - BYPASS RATIO
     0 - RETURN TO MAIN OFF-DESIGN MENU

ENTER SELECTION  4

MINIMUM VALUE =  5
MAXIMUM VALUE =  40
ITERATION INCREMENT =  1
```

```
MINIMUM VALUE =     5.00
MAXIMUM VALUE =    40.00
INCREMENT =         1.00

IS THIS CORRECT (Y=l/N=0) ?   1
```

After entry of an iteration variable and values, the program automatically returns to the **MAIN MENU** and the number of the current iteration variable is displayed within parentheses to the right of main menu item **2 - CALC ITERATION VARIABLE**. The user can only change the calculation iteration variable to a new variable by use of this menu. To return to the **MAIN MENU**, enter the number zero. The minimum value of the iteration variable is stored in this variable's data file and will be displayed (and can be changed) when the user displays the current input data file by selecting item **3 - CHANGE/VIEW CURRENT DATA FILE** on the **INPUT DATA MENU**. Maximum and incremental values of the iteration variable are stored within the program and only displayed when the **ITERATION VALUE MENU** is selected. Selection of menu item **1 - SINGLE POINT CALCULATION** will not be followed by request for input of minimum, maximum, and iteration values. After this selection, the program will return automatically to the **MAIN MENU** and the current data file is used for calculation. (Note: This is the only way to generate a reference data file for input to the off-design cycle analysis program, OFFX.)

D. INPUT DATA MENU

The **INPUT DATA MENU** is obtained when the user selects item **3 - INPUT DATA** from the **MAIN MENU**. The following menu is displayed on the screen:

```
************************************************************
*                ON-DESIGN INPUT DATA MENU                 *
************************************************************

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

ENTER YOUR SELECTION
```

A default input data file is loaded into temporary memory when this program is run and can be viewed and/or changed by initially selecting item **3 - CHANGE/VIEW CURRENT DATA FILE**. After this data file has been changed, the changed data is stored in temporary memory. An input data file can be copied and stored on disk by selecting item **2 - WRITE ON-DESIGN DATA FILE TO DISK** as shown below.

```
************************************************************
*                ON-DESIGN INPUT DATA MENU                 *
************************************************************

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

ENTER YOUR SELECTION   2
ENTER NAME OF DATA FILE + ".DAT" (MAX OF 14 CHARACTERS)    ONAB.DAT
YOUR INPUT IS "ONAB.DAT      "     IS THIS CORRECT  (Y=l/N=0)?    1
IS THIS A NEW FILE NAME (Y=l/N=0)?   1
```

An input data file that was saved to disk by this program can be loaded from disk to the program temporary memory by selecting item **1 - READ ON-DESIGN DATA FILE FROM DISK** as shown below. You can use menu item **4 - PAUSE PROGRAM and USE DOS** to enter DOS and check on

file names that are already used. After selecting item **4**, enter the word **COMMAND**; enter the word **EXIT** to leave DOS and return to the program.

```
*********************************************************
*                ON-DESIGN INPUT DATA MENU               *
*********************************************************

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

ENTER YOUR SELECTION  1
 LAST ON-DESIGN DATA FILE ACCESSED WAS NAMED: ONAB.DAT

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

NOTE: *When saving a data file to disk, the user will need to write down the name given to this data file (filename) and some notes about the data file's content for later use when reading this data file back into this program. However, menu item* **4 - PAUSE PROGRAM and USE DOS** *can be used to temporarily use DOS.*

The data file currently in temporary memory will be displayed on the screen by selecting item **3 - CHANGE/VIEW CURRENT DATA FILE**. The following pages show the three pages of the default data file as they would appear on the screen for the default engine cycle (turbofan with mixed exhaust and afterburning). Note that pages 2 and 3 do not show input data variables **25**, **38**, **39**, or **43** since these input data variables are not used for this engine cycle but are reserved for other engine cycles. The default input data files for other engine cycles are shown in Section J of this user guide. Each input data variable can be individually changed by the user.

```
*********************************************************
*                  DATA  SET   1 , PAGE 1                *
*********************************************************
 1 - MACH NUMBER - - - - - - - - - - - - =  1.6000
 2 - ALTITUDE  - - - - - - - - - - - - - = 30000.0 FT
     AMBIENT:
 3 -   TEMPERATURE - - - - - - - - - - - =  411.90 R
 4 -   PRESSURE  - - - - - - - - - - - - =  4.3730 PSIA
 5 -   DENSITY - - - - - - - - - - - - - =.0008907 SLUG/CUFT
 6 - CP C  - - - - - - - - - - - - - - - =   .2380 BTU/LBM-R
 7 - GAMMA C - - - - - - - - - - - - - - =   1.400
 8 - CP T  - - - - - - - - - - - - - - - =   .2950 BTU/LBM-R
 9 - GAMMA T - - - - - - - - - - - - - - =   1.300
10 - FUEL HEATING VALUE  - - - - - - - - = 18000.0 BTU/LBM
11 - MAX TEMP (TT4) LVG COMBUSTOR  - - - =  3200.0 R
12 - MAX TEMP (TT7) LVG AFTERBURNER  - - =  3600.0 R
13 - CP A/B  - - - - - - - - - - - - - - =   .2950 BTU/LBM-R
14 - GAMMA A/B   - - - - - - - - - - - - =   1.300
15 - BLEED AIR FLOW (PERCENT)  - - - - - =     1.0 %
16 - COOLING AIR FLOW #1 - - - - - - - - =     5.0 %
17 - COOLING AIR FLOW #2 - - - - - - - - =     5.0 %
18 - POWER TAKE-OFF LOW  (CTOL)  - - - - =    .010
19 - POWER TAKE-OFF HIGH (CTOH)  - - - - =    .000

# OF VARIABLE YOU WISH TO CHANGE (0=NONE)
```

Since the program uses a standard atmosphere, the ambient temperature, pressure, and density (items **3**, **4**, and **5**) will be changed automatically when item **2 - ALTITUDE** on page 1 is changed. Thus if item **2** and item(s) **3**, **4**, and/or **5** are to be changed, data entry is reduced by changing item **2** first.

Power takeoff from the high pressure spool has been added to the programs. This adds two additional inputs to the input data file: the dimensionless power takeoff coefficient for the high pressure spool (CTOH - Item #19 on Page 1 of Input Data) and the mechanical efficiency of the power

takeoff shaft (Item #35 on Page 2 of Input Data). The dimensionless power takeoff coefficient is defined for either the low pressure or high pressure spool by Eq. 4.19b in the text.

```
************************************************************
*                  DATA  SET   1 , PAGE 2                  *
************************************************************
20 - PI DIFFUSER (MAX)   - - - - - - - - =  .970
21 - PI BURNER   - - - - - - - - - - - - =  .970
22 - PI AFTERBURNER  - - - - - - - - - - =  .960
23 - PI MIXER (MAX)  - - - - - - - - - - =  .970
24 - PI NOZZLE   - - - - - - - - - - - - =  .980
     POLYTROPIC EFFICIENCIES
26 -   LP COMPRESSOR [FAN]  (EC`)  - - - =  .890
27 -   HP COMPRESSOR (ECH) - - - - - - - =  .900
28 -   HP TURBINE (ETH)  - - - - - - - - =  .890
29 -   LP TURBINE (ETL)  - - - - - - - - =  .910
     COMPONENT EFFICIENCIES
30 -   BURNER  - - - - - - - - - - - - - =  .980
31 -   AFTERBURNER   - - - - - - - - - - =  .970
32 -   MECHANICAL (HIGH PRESS SPOOL) - - =  .980
33 -   MECHANICAL (LOW PRESS SPOOL)  - - =  .990
34 -   MECHANICAL (POWER TAKE-OFF LOW) - =  .980
35 -   MECHANICAL (POWER TAKE-OFF HIGH)  =  .980
36 -   P0/P9   - - - - - - - - - - - - - = 1.000
37 -   MACH NUMBER AT STATION #5 - - - - =  .400

# OF VARIABLE YOU WISH TO CHANGE (0=NONE)

************************************************************
*                  DATA  SET   1 , PAGE 3                  *
************************************************************
     DESIGN CONDITIONS
40 -   PI C  - - - - - - - - - - - - - - = 16.000
41 -   PI C PRIME  - - - - - - - - - - - =  3.500
42 -   ALPHA   - - - - - - - - - - - - - =   .300

# OF VARIABLE YOU WISH TO CHANGE (0=NONE)
```

NOTE: *The minimum value of the iteration variable is stored in the data set displayed above. For example, if the iteration variable is the compressor pressure ratio, item* **40** *displays the minimum value and this value can be changed. However, the maximum and increment of the iteration variable can only be changed from the* **ITERATION VALUE MENU**. *See Page 22 for computer solution of optimum design values for engine cycles 3 and 6.*

Bypass Ratio for Matching Total Pressures - Engine Cycles 4 and 5

For ONX engine cycles 4 and 5, the computer program can calculate the engine bypass ratio that matches the total pressures at stations 5 and 5' by entering a minus one (-1) for Item #42 - ALPHA of the INPUT DATA FILE (see below). NOTE: ALPHA can not be the iteration variable.

```
************************************************************
*                  DATA  SET   1 , PAGE 3                  *
************************************************************
     DESIGN CONDITIONS
40 -   PI C  - - - - - - - - - - - - - - = 16.000
41 -   PI C PRIME  - - - - - - - - - - - =  3.500
42 -   ALPHA   - - - - - - - - - - - - - =   .300

# OF VARIABLE YOU WISH TO CHANGE (0=NONE)   42
ENTER NEW VALUE OF VARIABLE #42   -1

************************************************************
*                  DATA  SET   1 , PAGE 3                  *
************************************************************
     DESIGN CONDITIONS
40 -   PI C  - - - - - - - - - - - - - - = 16.000
41 -   PI C PRIME  - - - - - - - - - - - =  3.500
42 -   ALPHA   - - - - - - - - - - - - - = -1.000

# OF VARIABLE YOU WISH TO CHANGE (0=NONE)   0
```

The output results for the DEFAULT Data File with a value of -1 for Item #42 - ALPHA are given on the page 10.

Fan Pressure Ratio for Matching Total Pressures - Engine Cycles 4 and 5

For ONX engine cycles 4 and 5, the computer program can calculate the fan pressure ratio that matches the total pressures at stations 5 and 5' by entering a minus one (-1) for Item #41 - PI C PRIME of the INPUT DATA FILE (see below). NOTE: PI C PRIME can not be the iteration variable.

```
************************************************************
*                  DATA  SET   1 , PAGE 3                  *
************************************************************
     DESIGN CONDITIONS
40 -   PI C  - - - - - - - - - - - - - - = 16.000
41 -   PI C PRIME  - - - - - - - - - - - =  3.500
42 -   ALPHA   - - - - - - - - - - - - - =   .300

# OF VARIABLE YOU WISH TO CHANGE (0=NONE)   41
ENTER NEW VALUE OF VARIABLE #42   -1

************************************************************
*                  DATA  SET   1 , PAGE 3                  *
************************************************************
     DESIGN CONDITIONS
40 -   PI C  - - - - - - - - - - - - - - = 16.000
41 -   PI C PRIME  - - - - - - - - - - - = -1.000
42 -   ALPHA   - - - - - - - - - - - - - =   .300

# OF VARIABLE YOU WISH TO CHANGE (0=NONE)   0
```

The output results for the DEFAULT Data File with a value of -1 for Item #41 - PI C PRIME are given on page 11.

E. DATA OUTPUT DEVICE(S)

The menu entitled **DATA OUTPUT DEVICE(S)** is obtained when the user selects item **4 - OUTPUT DEVICE** from the **MAIN MENU**. The following menu is displayed on the screen.

```
************************************************************
*            ON-DESIGN ENGINE ANALYSIS PROGRAM             *
*                                                          *
*                   DATA OUTPUT DEVICE(S)                  *
************************************************************
CURRENT SELECTION IS ITEM #2

     1 - OUTPUT TO PRINTER ONLY
     2 - OUTPUT TO TERMINAL SCREEN ONLY
     3 - OUTPUT TO BOTH PRINTER AND TERMINAL SCREEN
     0 - RETURN TO MAIN MENU

ENTER YOUR SELECTION
```

As indicated on the **MAIN MENU** and this menu, the default output device is item number **2 - OUTPUT TO TERMINAL SCREEN ONLY**. The user must select another item number to change the current cycle selection from this default value. After entry of an output device selection, the program automatically returns to the **MAIN MENU** and the number of the current output device is displayed within parentheses to the right of item **4 - OUTPUT DEVICE**. The user can only change the output device(s) to another selection by use of this menu. To return to the **MAIN MENU**, enter the number zero.

F. CALCULATIONS

The user-specified on-design cycle calculations are performed after the user selects item **5 - PERFORM CALCULATIONS** from the **MAIN MENU**. The program will ensure that the input data correspond to the engine cycle selected before performing the calculations (e.g. make the bypass ratio zero for a turbojet engine). Below is displayed the screen output obtained when all the default values

are used for menu selections and input data (i.e. selection of item **5 - PERFORM CALCULATIONS** without changing anything). Since multiple iterations are to be performed, the user is given the opportunity to save results in files that can be imported into other software for graphical presentation (see page 52 for file formats).

```
      ************************************************************
      *                                                          *
      *          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: DEFAULT           ON-DESIGN CALCULATIONS                 PAGE  1

                TURBOFAN ENGINE WITH MIXED EXHAUST

*********************      INPUT DATA      **********************
      MACH NO   =  1.600              ALPHA      =   .300
      ALT (FT)  = 30000.              PI C`      =  3.500
      T0 (R)    = 411.90              PI D (MAX) =   .97
      P0 (PSIA) = 4.3730              PI B       =   .97
      DENSITY   =.00089066            PI N       =   .98
      (SLUG/CUFT)                   EFFICIENCY
      CP C =  .238 BTU/LBM-R          BURNER     =   .98
      CP T =  .295 BTU/LBM-R          MECH HI PR =   .98
      GAMMA C = 1.400                 MECH LO PR =   .99
      GAMMA T = 1.300                 LP COMPR (FAN) =   .89 (EC`)
      TT4 MAX = 3200. (R)             HP COMPR       =   .90 (ECH)
      H - FUEL (BTU/LBM) = 18000.     HP TURBINE     =   .89 (ETH)
      CTO LOW         = .0100         LP TURBINE     =   .91 (ETL)
      CTO HIGH        = .0000         PWR MECH EFF L =   .98
      COOLING AIR #1  =  5.00 %       PWR MECH EFF H =   .98
      COOLING AIR #2  =  5.00 %       BLEED AIR      =  1.00 %
      P0/P9 =  1.00
                        ** AFTERBURNER **
      TT7 MAX   = 3600. (R)           PI AB      =   .96
      CP A/B =  .295 BTU/LBM-R        ETTA A/B   =   .97
      GAMMA A/B =  1.30
      *** MIXER ***                   PI MIXER MAX =   .97
************************    RESULTS    *************************
      TAU R =  1.512                  A0 =  994.8 FT/SEC
      PI R  =  4.250                  V0 = 1591.7 FT/SEC
      PI D  =   .933                  TAU L =   9.629

  PI C F/MDOT    S     M5   M5P TAUTL  M6   PT9/P9  V9/V0  T EFF  P EFF
 16.00 109.21  1.8252 .400 .382 .8724 .411  12.627   3.06  44.87  50.06
 17.00 109.37  1.8230 .400 .367 .8712 .408  12.712   3.06  44.96  50.02
 18.00 109.48  1.8215 .400 .355 .8701 .406  12.775   3.07  45.02  49.99
 19.00 109.57  1.8205 .400 .346 .8690 .404  12.821   3.07  45.07  49.97
 20.00 109.62  1.8200 .400 .341 .8680 .402  12.850   3.07  45.09  49.96
 21.00 109.65  1.8199 .400 .338 .8669 .401  12.865   3.07  45.10  49.95
 22.00 109.65  1.8202 .400 .337 .8659 .401  12.867   3.07  45.09  49.95
 23.00 109.64  1.8208 .400 .339 .8649 .401  12.858   3.07  45.07  49.96
 24.00 109.61  1.8217 .400 .343 .8639 .402  12.839   3.07  45.04  49.97
 25.00 109.56  1.8228 .400 .349 .8629 .403  12.811   3.07  45.00  49.98
 26.00 109.49  1.8242 .400 .357 .8619 .404  12.773   3.07  44.95  49.99
 27.00 109.41  1.8258 .400 .365 .8609 .406  12.729   3.07  44.90  50.01
 28.00 109.32  1.8277 .400 .375 .8600 .408  12.677   3.06  44.83  50.04
 29.00 109.22  1.8297 .400 .386 .8590 .410  12.618   3.06  44.76  50.06
 30.00 109.10  1.8320 .400 .397 .8581 .412  12.554   3.06  44.68  50.09
 DATA SET  1 CALCULATED. ENTER ANY SINGLE CHARACTER TO CONTINUE.    <CR>
```

When item **1 - SINGLE POINT CALCULATION** is selected on the **ITERATION VALUE MENU** and then item **5 - PERFORM CALCULATIONS** is selected on the **MAIN MENU**, the screen output will be similar to that shown below. After the user enters a carriage return (**<CR>**) following the output, the user then enters the area of the program that allows engine sizing and writing the resulting reference output data file to disk for use by the OFFX program.

```
 FILE: DEFAULT          ON-DESIGN CALCULATIONS                PAGE  1

                TURBOFAN ENGINE WITH MIXED EXHAUST

**********************      INPUT DATA      **********************
      MACH NO   =  1.600              ALPHA      =   .300
      ALT (FT)  = 30000.              PI C`      =  3.500
      T0 (R)    = 411.90              PI D (MAX) =   .97
      P0 (PSIA) = 4.3730              PI B       =   .97
      DENSITY   =.00089066            PI N       =   .98
      (SLUG/CUFT)                   EFFICIENCY
      CP C =  .238 BTU/LBM-R          BURNER     =   .98
      CP T =  .295 BTU/LBM-R          MECH HI PR =   .98
      GAMMA C = 1.400                 MECH LO PR =   .99
      GAMMA T = 1.300                 LP COMPR (FAN) =   .89 (EC`)
      TT4 MAX = 3200. (R)             HP COMPR       =   .90 (ECH)
      H - FUEL (BTU/LBM) = 18000.     HP TURBINE     =   .89 (ETH)
      CTO LOW         = .0100         LP TURBINE     =   .91 (ETL)
      CTO HIGH        = .0000         PWR MECH EFF L =   .98
      COOLING AIR #1  =  5.00 %       PWR MECH EFF H =   .98
      COOLING AIR #2  =  5.00 %       BLEED AIR      =  1.00 %
      P0/P9 =  1.00
                        ** AFTERBURNER **
      TT7 MAX   = 3600. (R)           PI AB      =   .96
      CP A/B =  .295 BTU/LBM-R        ETTA A/B   =   .97
      GAMMA A/B =  1.30
      *** MIXER ***                   PI MIXER MAX =   .97
************************    RESULTS    ************************
      TAU R =  1.512                  A0 =  994.8 FT/SEC
      PI R  =  4.250                  V0 = 1591.7 FT/SEC
      PI D  =   .933                  MASS FLOW  =     200.00 LBM/SEC
      TAU L =  9.629                  AREA ZERO  =      4.385 SQFT
      PTO LO= 206.87 KW               AREA ZERO* =      3.507 SQFT
      PTO HI=    .00 KW
      PT5`/P0 = 13.887                TT5`/T0 =  2.261
      PT5 /P0 = 13.914                TT5 /T0 =  5.380
      PI C   = 16.00                  TAU M1  =  .9681
      PI C`  = 3.500                  TAU M2  =  .9739
      TAU C` = 1.495                  TAU M   =  .8889
      ETA C` = .8693                  PI M    =  .9647
      PI CH  = 4.571                  M5      =  .4000
      TAU CH = 1.620                  M5`     =  .3823
      ETA CH = .8769                  M6      =  .4113
      PI TH  = .4329                  A5`/A5 =  .1914
      TAU TH = .8420                  GAMMA M= 1.3180
      ETA TH = .8992                  CP M    =  .2821
      PI TL  = .5219                  ETA TL =  .9160
      TAU TL = .8724
    WITHOUT AB                      WITH AB
      PT9/P0 = 12.8903                PT9/P0 = 12.6272
      F      =   .0350                F      =   .0350
                                      FAB    =   .0316
                                      FO     =   .0554
      F/M    =  64.030 LBF/LBM/S      F/M    = 109.211 LBF/LBM/S
      S      =  1.3486 1/H            S      =  1.8252 1/H
      T9/T0  =  2.5808                T9/T0  =  4.8681
      V9/V0  =    2.26                V9/V0  =    3.06
      M9/M0  =    1.45                M9/M0  =    1.44
      A9/A0  =  1.1629                A9/A0  =  1.6678
      A9/A8  =  2.4364                A9/A8  =  2.4440
      THRUST =  12806. LBF            THRUST =  21842. LBF
 DATA SET  2 CALCULATED. ENTER ANY SINGLE CHARACTER TO CONTINUE.    <CR>
```

```
*************************************************************
*            ON-DESIGN ENGINE ANALYSIS PROGRAM              *
*                                                           *
*                       ENGINE SIZE                         *
*************************************************************

SPECIFIC THRUST           =  109.2110 LBF/LBM/SEC
SPECIFIC FUEL CONSUMPTION =    1.8252 1/HR
MASS FLOW RATE OF AIR     =  200.0000 LBM/SEC
MASS FLOW RATE OF FUEL    =  39866.48 LBM/HR
ENGINE THRUST AT DESIGN   =  21842.19 LBF

WANT TO CHANGE ENGINE THRUST (Y=1/N=0)?   0

WANT TO CHANGE MASS FLOW OF AIR (Y=1/N=0)?   0

DO YOU WANT TO SAVE THESE RESULTS AS A REFERENCE DATA FILE
THAT BECOMES THE INPUT TO THE OFF-DESIGN PROGRAM  (Y=l/N=0)?    1
ENTER NAME OF DATA FILE + ".DAT" (MAX OF 14 CHAR)    OFFAB.DAT
YOUR INPUT IS "OFFAB.DAT     ", IS THIS CORRECT  (Y=l/N=0)?    1
```

Calculations - Bypass Ratio for Matching Total Pressures - Engine Cycles 4 and 5 (see page 6)

```
FILE: DEFAULT           ON-DESIGN CALCULATIONS                 PAGE  1

               TURBOFAN ENGINE WITH MIXED EXHAUST

*********************      INPUT DATA      **********************
      MACH NO   =  1.600              ALPHA      = -1.000
      ALT (FT)  = 30000.              PI C`      =  3.500
      T0 (R)    = 411.90              PI D (MAX) =   .97
      P0 (PSIA) = 4.3730              PI B       =   .97
      DENSITY   =.00089066            PI N       =   .98
      (SLUG/CUFT)                   EFFICIENCY
      CP C =  .238 BTU/LBM-R          BURNER     =   .98
      CP T =  .295 BTU/LBM-R          MECH HI PR =   .98
      GAMMA C = 1.400                 MECH LO PR =   .99
      GAMMA T = 1.300                 LP COMPR (FAN) =   .89 (EC`)
      TT4 MAX = 3200. (R)             HP COMPR       =   .90 (ECH)
      H - FUEL (BTU/LBM) = 18000.     HP TURBINE     =   .89 (ETH)
      CTO LOW         = .0100         LP TURBINE     =   .91 (ETL)
      CTO HIGH        = .0000         PWR MECH EFF L =   .98
      COOLING AIR #1  =  5.00 %       PWR MECH EFF H =   .98
      COOLING AIR #2  =  5.00 %       BLEED AIR      =  1.00 %
      P0/P9 =  1.00
                      ** AFTERBURNER **
      TT7 MAX   = 3600. (R)           PI AB      =   .96
      CP A/B =  .295 BTU/LBM-R        ETTA A/B   =   .97
      GAMMA A/B =  1.30
      *** MIXER ***                   PI MIXER MAX =   .97
************************    RESULTS    ************************
      TAU R =  1.512                  A0 =  994.8 FT/SEC
      PI R  =  4.250                  V0 = 1591.7 FT/SEC
      PI D  =   .933                  TAU L =   9.629

  PI C F/MDOT    S     M5   M5P TAUTL ALPHA PT9/P9  V9/V0  T EFF  P EFF
 16.00 109.18  1.8258 .400 .386 .8720  .304 12.606   3.06  44.85  50.07
 17.00 109.19  1.8262 .400 .386 .8695  .318 12.605   3.06  44.84  50.07
 18.00 109.20  1.8265 .400 .386 .8673  .328 12.605   3.06  44.83  50.07
 19.00 109.21  1.8269 .400 .386 .8654  .336 12.605   3.06  44.82  50.07
 20.00 109.22  1.8272 .400 .386 .8639  .340 12.605   3.06  44.81  50.07
 21.00 109.22  1.8275 .400 .386 .8626  .342 12.606   3.06  44.81  50.07
 22.00 109.22  1.8278 .400 .386 .8615  .342 12.607   3.06  44.80  50.07
 23.00 109.22  1.8281 .400 .386 .8607  .340 12.608   3.06  44.79  50.07
 24.00 109.23  1.8283 .400 .386 .8600  .337 12.609   3.06  44.79  50.07
 25.00 109.23  1.8286 .400 .386 .8595  .332 12.611   3.06  44.78  50.07
 26.00 109.22  1.8289 .400 .386 .8592  .325 12.612   3.06  44.77  50.07
 27.00 109.22  1.8292 .400 .386 .8590  .318 12.614   3.06  44.77  50.07
 28.00 109.22  1.8295 .400 .386 .8589  .310 12.615   3.06  44.76  50.07
 29.00 109.21  1.8298 .400 .386 .8590  .300 12.617   3.06  44.76  50.06
 30.00 109.21  1.8301 .400 .386 .8592  .290 12.619   3.06  44.75  50.06
```

NOTE: For matched total pressures at stations 5 and 5', the Mach numbers at stations 5 and 5' are nearly equal and the performance of this afterburning turbofan engine does not appreciably vary with engine pressure ratio.

Calculations - Fan Pressure Ratio for Matching Total Pressures - Engine Cycles 4 and 5 (see page 7)

```
FILE: DEFAULT           ON-DESIGN CALCULATIONS                  PAGE  1

                    TURBOFAN ENGINE WITH MIXED EXHAUST

**********************      INPUT DATA      **********************
      MACH NO   =  1.600              ALPHA      =   .300
      ALT (FT)  = 30000.              PI C`      = -1.000
      T0 (R)    = 411.90              PI D (MAX) =   .97
      P0 (PSIA) = 4.3730              PI B       =   .97
      DENSITY   =.00089066            PI N       =   .98
      (SLUG/CUFT)                   EFFICIENCY
      CP C =  .238 BTU/LBM-R          BURNER     =   .98
      CP T =  .295 BTU/LBM-R          MECH HI PR =   .98
      GAMMA C = 1.400                 MECH LO PR =   .99
      GAMMA T = 1.300                 LP COMPR (FAN) =   .89 (EC`)
      TT4 MAX = 3200. (R)             HP COMPR       =   .90 (ECH)
      H - FUEL (BTU/LBM) = 18000.     HP TURBINE     =   .89 (ETH)
      CTO LOW         = .0100         LP TURBINE     =   .91 (ETL)
      CTO HIGH        = .0000         PWR MECH EFF L =   .98
      COOLING AIR #1  =  5.00 %       PWR MECH EFF H =   .98
      COOLING AIR #2  =  5.00 %       BLEED AIR      =  1.00 %
      P0/P9 =  1.00
                      ** AFTERBURNER **
      TT7 MAX   = 3600. (R)           PI AB      =   .96
      CP A/B =  .295 BTU/LBM-R        ETTA A/B   =   .97
      GAMMA A/B =  1.30
      *** MIXER ***                   PI MIXER MAX =   .97
**********************    RESULTS    **********************
      TAU R =  1.512                  A0 =  994.8 FT/SEC
      PI R  =  4.250                  V0 = 1591.7 FT/SEC
      PI D  =   .933                  TAU L =   9.629

  PI C F/MDOT    S     M5   M5P TAUTL PIC P PT9/P9  V9/V0  T EFF  P EFF
 16.00 109.21  1.8252 .400 .386 .8722 3.506 12.628   3.06  44.88  50.06
 17.00 109.37  1.8229 .400 .386 .8703 3.530 12.716   3.06  44.97  50.02
 18.00 109.50  1.8213 .400 .386 .8686 3.548 12.783   3.07  45.03  49.99
 19.00 109.58  1.8202 .400 .386 .8671 3.561 12.830   3.07  45.08  49.97
 20.00 109.64  1.8197 .400 .386 .8657 3.569 12.861   3.07  45.10  49.95
 21.00 109.67  1.8196 .400 .386 .8645 3.574 12.877   3.07  45.11  49.95
 22.00 109.68  1.8198 .400 .386 .8635 3.574 12.880   3.07  45.11  49.95
 23.00 109.66  1.8204 .400 .386 .8625 3.571 12.870   3.07  45.09  49.95
 24.00 109.63  1.8213 .400 .386 .8617 3.565 12.849   3.07  45.06  49.96
 25.00 109.57  1.8225 .400 .386 .8610 3.557 12.819   3.07  45.01  49.97
 26.00 109.50  1.8240 .400 .386 .8604 3.546 12.780   3.07  44.96  49.99
 27.00 109.42  1.8257 .400 .386 .8598 3.532 12.733   3.07  44.90  50.01
 28.00 109.32  1.8276 .400 .386 .8594 3.517 12.679   3.06  44.83  50.04
 29.00 109.22  1.8297 .400 .386 .8590 3.500 12.618   3.06  44.76  50.06
 30.00 109.10  1.8320 .400 .386 .8587 3.482 12.552   3.06  44.67  50.09
```

NOTE: For matched total pressures at stations 5 and 5', the Mach numbers at stations 5 and 5' are nearly equal and the performance of this afterburning turbofan engine does not appreciably vary with engine pressure ratio.

G. EXIT PROGRAM

To exit this program, the user must select item **6 - EXIT PROGRAM** from the **MAIN MENU**. A warning is then printed on the screen and the user must enter "X" (capital x) to exit the program. An example is shown below. If the user does not enter "X" (capital x), then the program shows the screen for redirecting printed output to a disk file as shown on page 2.

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

           1 - ENGINE CYCLE SELECTION           (5)
           2 - CALC ITERATION VARIABLE          (4)
           3 - INPUT DATA
           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>
```