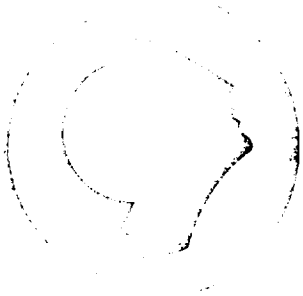
D. O. 123
NAS8-36955



Users Manual for Program SSFREQ

Intermediate Mode Stability Curves

Developed for Use on a PC Computer

Research Institute
The University of Alabama in Huntsville

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Wilbur C. Armstrong

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1.0 Introduction

The piping in a liquid rocket can assume complex configurations due to multiple tanks, multiple engines, and structures that must be piped around. The capability to handle some of these complex configurations have been incorporated into the SSFREQ code. The capability to modify the input on line has been implemented.

The configurations allowed include multiple tanks, multiple engines, the splitting of a pipe into unequal segments going to different (or the same) engines. This program will handle the following type elements

Straight pipes
Bends
Inline accumulators
Tuned stub accumulators
Helmholtz resonators
Parallel resonators
Pumps
Split pipes
Multiple tanks
Multiple engines

2.0 Input Description

SSFREQ uses the following files: ENG.RLN, LOX.RLN, FUEL.RLN, IMODE.RLN, and optionally uses IMODE.FRQ and IMODE.TAU. All files are in free format, therefore each of the following records will give the same results.

Record 1: 1.000000E-01 6219.000000 2.670000 2.330E-03 -315.0000

Record 2: 0.1 6219.0 2.67 0.00233 -315.0

Record 3:
```
1.E-01
6219.0
2.67
2.33E-3
-315.0
```

The file assignments are given in the following table:

Unit	File Name	File Type	Description
9	ENG.RLN	Input	Engine data
10	LOX.RLN	Input	LOX tanks & lines data
11	FUEL.RLN	Input	Fuel tanks & lines data
12	IMODE.RLN	Input	Chamber data
13	SURF.ERR	Output	Convergence error information
14	IMODE.OUT	Output	n-tau values
15	(LOX)	Work	Temporary file with LOX data
16	(FUEL)	Work	Temporary file with fuel data
17	(RESULT)	Work	Temporary file for results
18	IMODE.TAU	Input	tau's to be used
19	IMODE.FRQ	Input	Frequencies to be used
20	(IMODE)	Work	Temporary file for chamber data

2.1 Description of file ENG.RLN

```
Card # 1
   number of engines
 Card # 2
    total flow in engine (lbm/sec),
    chamber pressure (lbf/ft^2),
    pressure drop across orifice (lbf/ft^2)
 Read card # 2 "number of engines" times
```

2.2 Description of files LOX.RLN or FUEL.RLN

```
Card # 1
   title
Card # 2
   number of tanks
```

type	name	PIPE1	PIPE2	PIPE3	PIPE4	PIPE5
0	bend	radius	angle	diameter	end len.	
1	straight	length	diameter			
2	inline	length	diameter			
3	tuned	length	diameter			
4	Helmholtz	length	diameter	volume		
5	parallel	length	diameter	volume		
6	pump	length	diameter	$dp/d\mathring{m}$	L	C
7	manifold	volume	bulk mod.			

Dimensions:

radius, length, diameter, end length	- ft
angle	- deg
volume	- ft^3
$dp/d\mathring{m}$ (non-dimensionalized by $\bar{\dot{m}}/\bar{p}_C$)	- non-dimensional
L	- sec
C	- sec
bulk modulus	- lbf/ft^2

2.3 Description of file IMODE.RLN

Card # 1
  title
Card # 2
  number of x stations
Card # 3
  x - location (ft)
  pressure (lbf/ft^2)
  temperature (°R)
Read card # 3 "number of x stations" times
Card # 4
  invariant time lag (sec)
  mixture ratio interaction index
  damping part of frequency
Card # 5
  chamber diameter (ft)
  throat diameter (ft)
  length of combustion chamber (ft)
Card # 6
  ratio of specific heats
  gas constant ((ft/sec)^2/°R)
  maximum overpressure (lbf/ft^2)
  mixture ratio

Card # 7
dc*/dr (ft/sec)
dh/dr ((ft/sec)^2)
mass of liquid per unit chamber volume (lbm/ft^3)
axial component of liquid velocity (ft/sec)
Read card # 2-7 "number of engines" times

2.4 Description of file IMODE.FRQ

Card # 1
number of frequencies
Card # 2
frequency (rad/sec or Hertz)
Read card # 2 "number of frequencies" times

2.5 Description of file IMODE.TAU

Card # 1
number of taus (sensitive time lags)
Card # 2
tau (sec)
Read card # 2 "number of taus" times

3.0 Output Description

3.1 Output Files

Output from the program is a file (IMODE.OUT) which may be printed and various graphs under the control of the user. The print file contains the following:

CAREA=
TAREA=
ASTAR=
CSTARD=
RHOBAR=
UBARD=
RHOBAR=
UBARD=

Title, time, and date

Engine No.

DIMENSIONAL VARIABLES

NVAL=
XBAR=
UBAR=
DTAU = NR = CDIAM =
TDIAM = XLC = GAMMA =

RGAS = P00 = MBAR =
RBAR = DCSDR = DHLDR =
RHOLO = ULO = PCHMB =
TCHMB =

NON-DIMENSIONAL VARIABLES

NVAL=
XBAR=
UBAR=
DTAU= NR= RBAR=
MBAR= GAMMA= P00=
DHLDR= CSTAR= DCSDR=
RHOLO= ULO=
RFA= RFC=

the above for each engine

FREQUENCY =

Eng. No. tau-sec n FUNB(R) FUNB(I)
one entry for each engine and each tau requested
the above for each frequency requested.

Also, if a split pipe is analyzed, a file (SURF.ERR) is created if any point fails to converge within the specified number of iterations. This file contains:

Title, time, and date

jw = after iterations has error of % in line
I= J= |G|= |GOLD|=

3.2 Graphs Available

The graphs available are

1. Plot of the n-tau curve for a given frequency and engine upon request.
2. Plot of the n-tau curves for each engine. All frequencies for an engine are plotted on one graph.

4.0 Sample Run

The sample run consists of two lox tanks and four engines, two of the engines and lines going to them are identical. The total mass flow from each tank is the same, however the line from the first tank is split with half the mass flow going to engine # 2 and the other half split into two identical engines # 1.

4.1 Input for Sample Run

Sample ENG.RLN file:

```
3
853.5       4.502040E+05      1.610532E+06
1707.0      4.502040E+05      1.610532E+06
3414.0      4.502040E+05      1.610532E+06
```

Sample LOX.RLN file:

```
Sample Run
2
1.956300E+04   2928.0   1.185883E+07   71.4
1.956300E+04   2928.0   1.185883E+07   71.4
2
1 0
13 2
1   15.0      1.416    0.0      0.0    0.0
0   35.0      45.0     1.416    0.0    0.0
1   30.0      1.416    0.0      0.0    0.0
0   3.5       135.0    1.416    0.0    0.0
1   15.0      1.416    0.0      0.0    0.0
1   20.641    1.416    0.0      0.0    0.0
1   20.558    1.416    0.0      0.0    0.0
1   20.558    1.416    0.0      0.0    0.0
1   8.541     1.416    0.0      0.0    0.0
1   6.383     1.416    0.0      0.0    0.0
0   4.25      90.0     1.416    0.0    0.0
1   9.33      1.416    0.0      0.0    0.0
0   3.33      80.0     1.416    0.0    0.0
5   1  1
1   3.53      0.708    0.0      0.0    0.0
1   12.2      0.708    0.0      0.0    0.0
0   1.28      35.0     0.708    0.0    0.0
1   12.2      0.708    0.0      0.0    0.0
7   13.5   1.183346E+07 0.0      0.0    0.0
5   1 2
1   3.53      1.00126  0.0      0.0    0.0
1   12.2      1.00126  0.0      0.0    0.0
0   1.28      35.0     1.00126  0.0    0.0
1   12.2      1.00126  0.0      0.0    0.0
7   13.5   1.183346E+07 0.0      0.0    0.0
2 3
18 0
1   15.0      1.416    0.0      0.0    0.0
0   35.0      45.0     1.416    0.0    0.0
1   30.0      1.416    0.0      0.0    0.0
0   3.5       135.0    1.416    0.0    0.0
1   15.0      1.416    0.0      0.0    0.0
1   20.641    1.416    0.0      0.0    0.0
1   20.558    1.416    0.0      0.0    0.0
1   20.558    1.416    0.0      0.0    0.0
```

```
1   8.541     1.416    0.0      0.0    0.0
1   6.383     1.416    0.0      0.0    0.0
0   4.25      90.0     1.416    0.0    0.0
1   9.33      1.416    0.0      0.0    0.0
0   3.33      80.0     1.416    0.0    0.0
1   3.53      1.416    0.0      0.0    0.0
1   12.2      1.416    0.0      0.0    0.0
0   1.28      35.0     1.416    0.0    0.0
1   12.2      1.416    0.0      0.0    0.0
7   13.5   1.183346E+07 0.0     0.0    0.0
```

Sample FUEL.RLN file:

```
FUEL Split: 3-1,1-0
2
4.055000E+03    486.0    1.185883E+07    72.13
4.055000E+03    486.0    1.185883E+07    72.13
2
1 0
8 2
1   17.97     1.04154 0.0      0.0    0.0
0   1.2785    75.0    1.04154  0.0    0.0
1   8.138     1.04154 0.0      0.0    0.0
0   1.2785   -75.0    1.04154  0.0    0.0
1   32.51     1.04154 0.0      0.0    0.0
0   1.2785    75.0    1.04154  0.0    0.0
1   8.65      1.04154 0.0      0.0    0.0
0   1.2785   -75.0    1.04154  0.0    0.0
2 1 1
1   6.2       0.52077 0.0      0.0    0.0
7   4.5    1.183346E+07 0.0     0.0    0.0
2 1 2
1   6.2       0.73648 0.0      0.0    0.0
7   4.5    1.183346E+07 0.0     0.0    0.0
2 3
10 0
1   17.97     1.04154 0.0      0.0    0.0
0   1.2785    75.0    1.04154  0.0    0.0
1   8.138     1.04154 0.0      0.0    0.0
0   1.2785   -75.0    1.04154  0.0    0.0
1   32.51     1.04154 0.0      0.0    0.0
0   1.2785    75.0    1.04154  0.0    0.0
1   8.65      1.04154 0.0      0.0    0.0
0   1.2785   -75.0    1.04154  0.0    0.0
1   6.2       1.04154 0.0      0.0    0.0
7   4.5    1.183346E+07 0.0     0.0    0.0
```

Sample IMODE.RLN file:

```
  Check Case for SSFREQ
2
0.000000       450204.00        4000.000
4.00000        450204.00        4000.000
```

```
0.000697        0.01            0.000000
3.214000        2.232000        4.000000
1.200000        1716.000        142500.0        2.670000
-315.0000        0.010000        0.440000        1965.000
2
0.000000        450204.00        4000.000
4.00000         450204.00        4000.000
0.000697        0.01             0.000000
3.214000        2.232000        4.000000
1.200000        1716.000        142500.0        2.670000
-315.0000        0.010000        0.440000        1965.000
2
0.000000        450204.00        4000.000
4.00000         450204.00        4000.000
0.000697        0.01             0.000000
3.214000        2.232000        4.000000
1.200000        1716.000        142500.0        2.670000
-315.0000        0.010000        0.440000        1965.000
```

Sample IMODE.FRQ file:

```
3
110 113 116
```

Sample IMODE.TAU file:

```
11
0.0005 0.0007 0.0009 0.0011 0.0013 0.0015
0.0017 0.0019 0.0021 0.0023 0.0025
```

4.2 Walkthrough of Sample Run

```
Welcome to SSFREQ - an Intermediate Mode Program

To send a plot to the printer

The computer MUST be in GRAPHICS mode

Hit PrScn to send the current plot to the printer
```

```
If you want frequency in rad/sec, hit enter.
If you want it in Hertz, enter "H". h
Is the engine data on file ENG.RLN? (Y/N) y
 Is fuel line data in a file? (Y/N) y
Is the file name FUEL.RLN? (Y/N) y
Max. no. of iterations is set at  20
Do you wish to change it? n
 Is lox line data in a file? (Y/N) y
```

```
Is the file name LOX.RLN? (Y/N) y
Max. no. of iterations is set at  20
Do you wish to change it? n

Are you are using IMODE.RLN for input data? y



                    Welcome to SSFREQ

            Intermediate Mode Rocket Stability Aide

  There are three types of input, rocket parameters,
  Oxidizer feed parameters, and fuel feed parameters,
   Each may be read from files or from the keyboard

          File Name                    Input

   IMODE.RLN or NAME read in   Rocket Parameters
         LOX.RLN               Oxidizer Parameters
         FUEL.RLN              Fuel Parameters

 If keyboard entry, you will be prompted for values

Is your rocket input on file? Y OR N y
Does the file need to be rewound? Y OR N n

          Sample Run                          12:35PM   12-12-91

Engine No.  1

                        DIMENSIONAL VARIABLES
  NVAL=    2
  XBAR=  0.00000E+00  4.00000E+00
  UBAR=  4.98522E+01  4.98522E+01
 DTAU =  6.97000E-04      NR =  1.00000E-02   CDIAM =  3.21400E+00
TDIAM =  2.23200E+00     XLC =  4.00000E+00   GAMMA =  1.20000E+00
 RGAS =  1.71600E+03     P00 =  1.42500E+05    MBAR =  8.53500E+02
 RBAR =  2.67000E+00   DCSDR = -3.15000E+02   DHLDR =  1.00000E-02
RHOLO =  4.40000E-01     ULO =  1.96500E+03   PCHMB =  4.50204E+05
TCHMB =  4.00000E+03
                    NON-DIMENSIONAL VARIABLES
  NVAL=    2
  XBAR=  0.00000E+00  1.00000E+00
  UBAR=  1.73702E-02  1.73702E-02
  DTAU=  5.00094E-01       NR=  1.00000E-02     RBAR=  2.67000E+00
  MBAR=  6.94809E-02    GAMMA=  1.20000E+00      P00=  3.16523E-01
 DHLDR=  1.00000E-02    CSTAR=  2.31372E+01    DCSDR= -1.09757E-01
 RHOLO=  2.08505E-01      ULO=  6.84673E-01
   RFA=  1.44752E-03  0.00000E+00          RFC=  0.00000E+00  0.00000E+00
Hit ENTER to continue
```

```
        Sample Run                          12:35PM   12-12-91

Engine No.  2

                        DIMENSIONAL VARIABLES
  NVAL=    2
  XBAR=  0.00000E+00  4.00000E+00
  UBAR=  9.97045E+01  9.97045E+01
 DTAU =  6.97000E-04      NR =  1.00000E-02   CDIAM =  3.21400E+00
TDIAM =  2.23200E+00     XLC =  4.00000E+00   GAMMA =  1.20000E+00
 RGAS =  1.71600E+03     P00 =  1.42500E+05    MBAR =  1.70700E+03
 RBAR =  2.67000E+00   DCSDR = -3.15000E+02   DHLDR =  1.00000E-02
RHOLO =  4.40000E-01     ULO =  1.96500E+03   PCHMB =  4.50204E+05
TCHMB =  4.00000E+03
                    NON-DIMENSIONAL VARIABLES
  NVAL=    2
  XBAR=  0.00000E+00  1.00000E+00
  UBAR=  3.47404E-02  3.47404E-02
  DTAU=  5.00094E-01       NR=  1.00000E-02     RBAR=  2.67000E+00
  MBAR=  1.38962E-01    GAMMA=  1.20000E+00      P00=  3.16523E-01
 DHLDR=  1.00000E-02    CSTAR=  1.15686E+01    DCSDR= -1.09757E-01
 RHOLO=  2.08505E-01      ULO=  6.84673E-01
   RFA=  2.89504E-03  0.00000E+00          RFC=  0.00000E+00  0.00000E+00
Hit ENTER to continue

        Sample Run                          12:35PM   12-12-91

Engine No.  3

                        DIMENSIONAL VARIABLES
  NVAL=    2
  XBAR=  0.00000E+00  4.00000E+00
  UBAR=  1.99409E+02  1.99409E+02
 DTAU =  6.97000E-04      NR =  1.00000E-02   CDIAM =  3.21400E+00
TDIAM =  2.23200E+00     XLC =  4.00000E+00   GAMMA =  1.20000E+00
 RGAS =  1.71600E+03     P00 =  1.42500E+05    MBAR =  3.41400E+03
 RBAR =  2.67000E+00   DCSDR = -3.15000E+02   DHLDR =  1.00000E-02
RHOLO =  4.40000E-01     ULO =  1.96500E+03   PCHMB =  4.50204E+05
TCHMB =  4.00000E+03
                    NON-DIMENSIONAL VARIABLES
  NVAL=    2
  XBAR=  0.00000E+00  1.00000E+00
  UBAR=  6.94809E-02  6.94809E-02
  DTAU=  5.00094E-01       NR=  1.00000E-02     RBAR=  2.67000E+00
  MBAR=  2.77924E-01    GAMMA=  1.20000E+00      P00=  3.16523E-01
 DHLDR=  1.00000E-02    CSTAR=  5.78429E+00    DCSDR= -1.09757E-01
 RHOLO=  2.08505E-01      ULO=  6.84673E-01
   RFA=  5.79008E-03  0.00000E+00          RFC=  0.00000E+00  0.00000E+00
Hit ENTER to continue

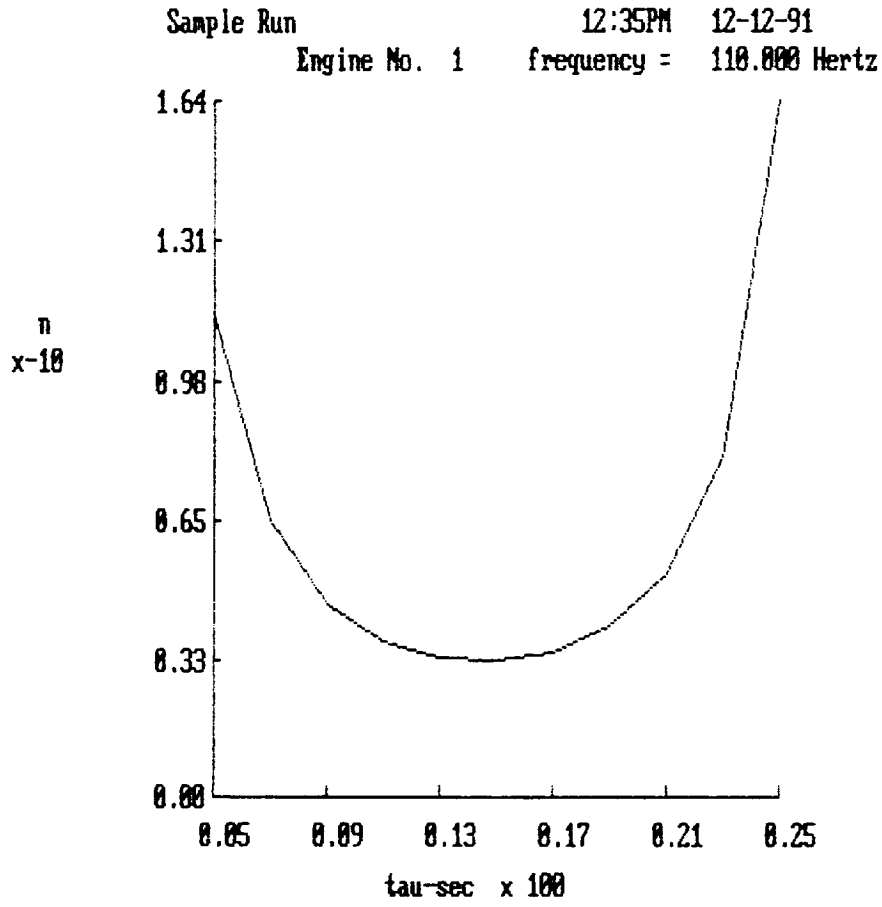
 Specify how frequency will be input -
   Enter R for a range of values
   Enter F for values in a file
```

```
    Enter K (end with -999) to enter values from keyboard
f
  Is the frequency on IMODE.FRQ?
       Enter Y or N y
  Specify how tau will be input -
    Enter R for a range of values
    Enter F for values in a file
    Enter K to enter values from keyboard
f
  Is tau on IMODE.TAU?
       Enter Y or N y

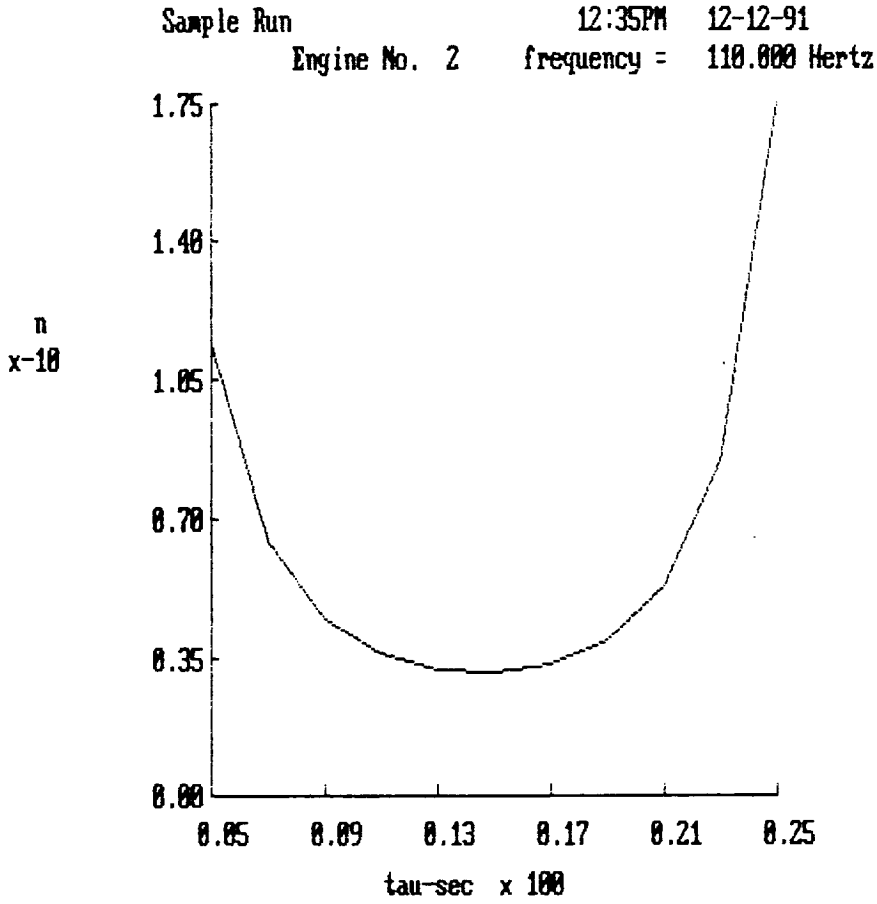
  FREQUENCY =  1.10000E+02 Hertz

 Eng. No.   tau-sec         n          FUNB(R)       FUNB(I)

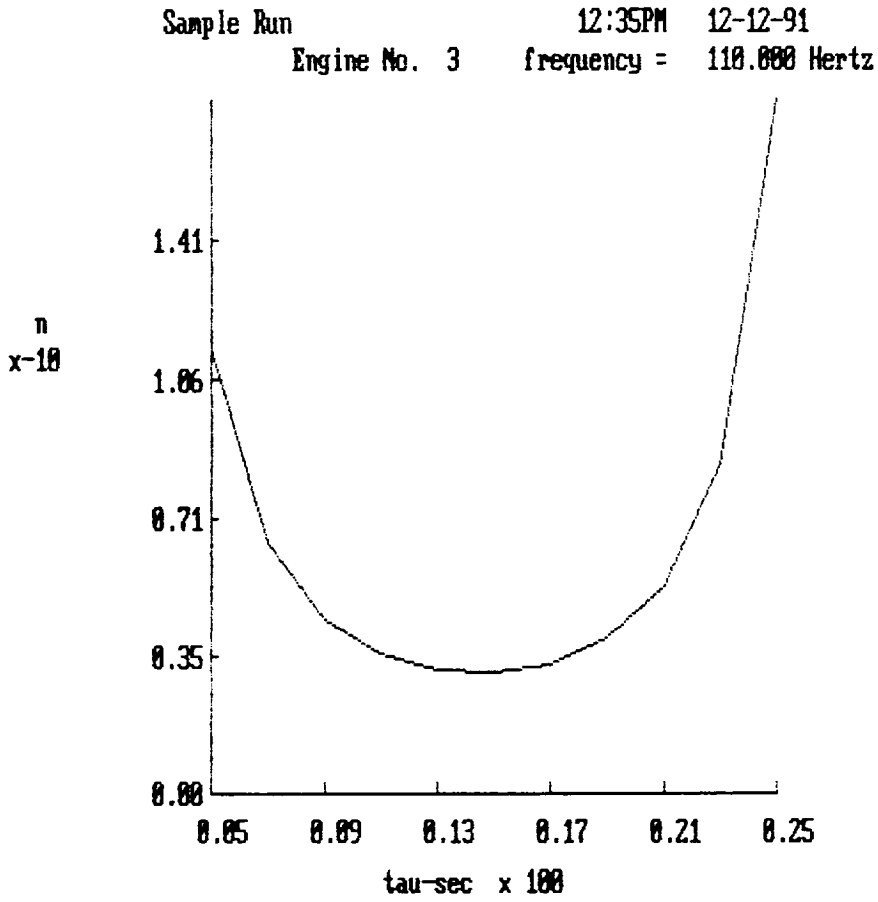
    1      5.00000E-04  1.14621E+01 -3.11896E-07 -4.67076E-01
    2      5.00000E-04  1.14841E+01 -3.03067E-07 -4.60113E-01
    3      5.00000E-04  1.14920E+01  3.88765E-07 -4.57809E-01
    1      7.00000E-04  6.55967E+00  8.66792E-07 -3.17231E-01
    2      7.00000E-04  6.48823E+00 -2.23960E-06 -3.05747E-01
    3      7.00000E-04  6.46472E+00 -1.18901E-06 -3.01928E-01
    1      9.00000E-04  4.62124E+00  2.49193E-07 -2.20846E-01
    2      9.00000E-04  4.50544E+00  6.42385E-07 -2.08742E-01
    3      9.00000E-04  4.46697E+00 -1.25355E-06 -2.04704E-01
    1      1.10000E-03  3.73689E+00 -2.28634E-07 -1.44484E-01
    2      1.10000E-03  3.59644E+00 -2.45890E-07 -1.35610E-01
    3      1.10000E-03  3.54970E+00 -7.22797E-07 -1.32642E-01
    1      1.30000E-03  3.35282E+00  1.55936E-07 -7.53268E-02
    2      1.30000E-03  3.20046E+00  1.72578E-07 -7.29305E-02
    3      1.30000E-03  3.14967E+00 -2.02976E-07 -7.21169E-02
    1      1.50000E-03  3.28318E+00 -4.40167E-08 -7.92099E-03
    2      1.50000E-03  3.13166E+00  5.27691E-08 -1.37797E-02
    3      1.50000E-03  3.08109E+00  5.24031E-08 -1.57178E-02
    1      1.70000E-03  3.49309E+00 -2.72676E-09  6.03049E-02
    2      1.70000E-03  3.36009E+00 -3.73278E-09  4.66884E-02
    3      1.70000E-03  3.31559E+00 -2.31758E-08  4.21583E-02
    1      1.90000E-03  4.06690E+00  2.46680E-08  1.31826E-01
    2      1.90000E-03  3.98268E+00  1.20805E-08  1.13762E-01
    3      1.90000E-03  3.95433E+00 -1.35946E-08  1.07738E-01
    1      2.10000E-03  5.30008E+00 -2.17681E-08  2.12487E-01
    2      2.10000E-03  5.32637E+00 -6.04931E-09  1.96344E-01
    3      2.10000E-03  5.33471E+00 -1.82410E-08  1.90944E-01
    1      2.30000E-03  8.12702E+00 -2.26766E-08  3.19093E-01
    2      2.30000E-03  8.41822E+00 -8.19192E-09  3.14610E-01
    3      2.30000E-03  8.51465E+00 -2.97111E-08  3.13079E-01
    1      2.50000E-03  1.64494E+01 -1.18208E-10  5.06763E-01
    2      2.50000E-03  1.75388E+01  3.19730E-08  5.29430E-01
    3      2.50000E-03  1.79009E+01  3.66275E-10  5.36935E-01
 Do you wish to see n vs tau for this frequency? y
 Specify which engine you wish to view
 Enter 1 -  3 or 0 to continue  1
```


Sample Run
12:35PM 12-12-91
Engine No. 1
frequency = 110.000 Hertz
1.64
1.31
n
x-10
0.98
0.65
0.33
0.00
0.05
0.09
0.13
0.17
0.21
0.25
tau-sec x 100

Specify which engine you wish to view
Enter 1 - 3 or 0 to continue 2


Sample Run
12:35PM 12-12-91
Engine No. 2
frequency = 110.000 Hertz
n
x-10
1.75
1.40
1.05
0.70
0.35
0.00
0.05
0.09
0.13
0.17
0.21
0.25
tau-sec x 100

```
Specify which engine you wish to view
Enter 1 -  3 or 0 to continue  3
```


Sample Run
12:35PM 12-12-91
Engine No. 3
frequency = 110.000 Hertz
n
x-10
1.41
1.06
0.71
0.35
0.00
0.05
0.09
0.13
0.17
0.21
0.25
tau-sec x 100

```
Specify which engine you wish to view
Enter 1 -  3 or 0 to continue  4
 Invalid engine number, try again!
Specify which engine you wish to view
Enter 1 -  3 or 0 to continue  0

 FREQUENCY =  1.13000E+02 Hertz

Eng. No.    tau-sec          n           FUNB(R)       FUNB(I)

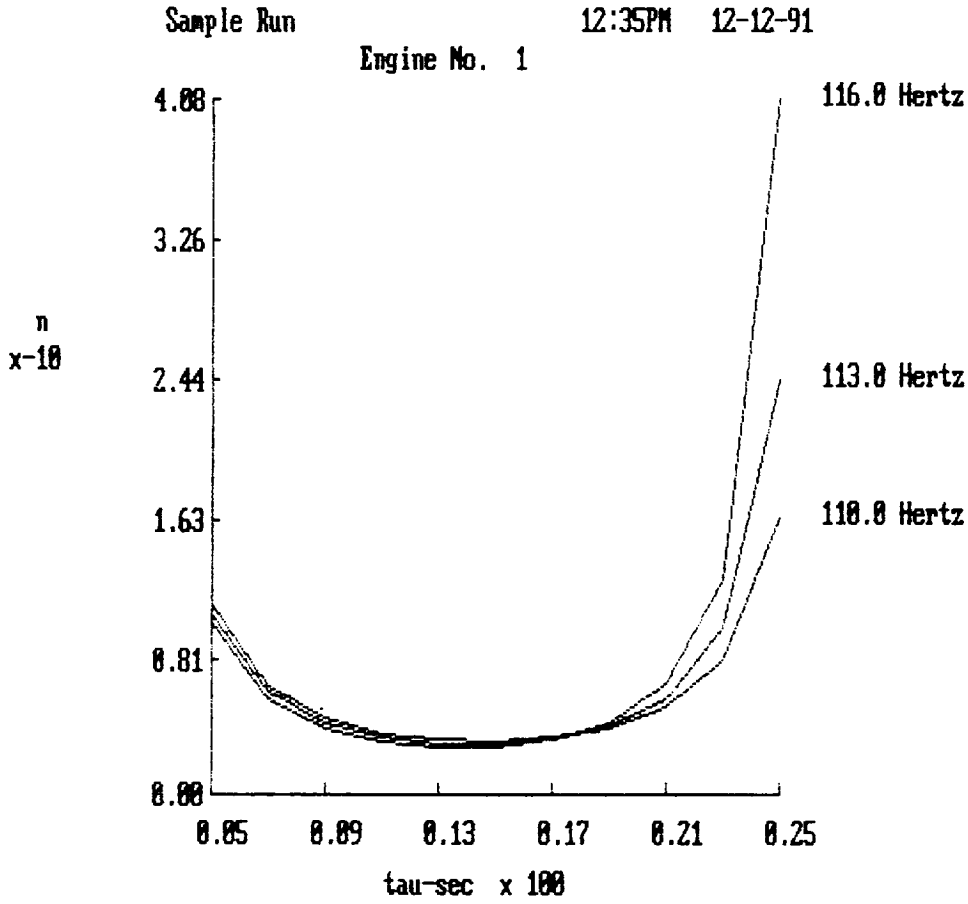
   1      5.00000E-04  1.08414E+01  4.69661E-07 -4.35565E-01
   2      5.00000E-04  1.08143E+01  5.71385E-09 -4.32209E-01
   3      5.00000E-04  1.08053E+01 -1.54009E-06 -4.31091E-01
   1      7.00000E-04  6.16340E+00 -1.62474E-06 -2.79945E-01
   2      7.00000E-04  6.12335E+00 -7.68963E-07 -2.76068E-01
   3      7.00000E-04  6.11010E+00  1.38288E-06 -2.74779E-01
   1      9.00000E-04  4.31322E+00  6.75733E-07 -1.80939E-01
   2      9.00000E-04  4.26871E+00  1.11379E-06 -1.77752E-01
   3      9.00000E-04  4.25390E+00  5.02842E-07 -1.76687E-01
   1      1.10000E-03  3.47502E+00 -2.45920E-07 -1.05288E-01
   2      1.10000E-03  3.43012E+00  8.45579E-08 -1.03835E-01
   3      1.10000E-03  3.41516E+00  4.99280E-07 -1.03347E-01
   1      1.30000E-03  3.12737E+00 -1.32093E-07 -3.97969E-02
   2      1.30000E-03  3.08554E+00  1.74440E-07 -4.07200E-02
   3      1.30000E-03  3.07158E+00  3.38107E-09 -4.10231E-02
   1      1.50000E-03  3.10466E+00  3.06501E-08  2.23420E-02
   2      1.50000E-03  3.07029E+00  1.45587E-08  1.90551E-02
   3      1.50000E-03  3.05879E+00 -2.11063E-08  1.79628E-02
   1      1.70000E-03  3.39810E+00  3.86204E-08  8.61902E-02
   2      1.70000E-03  3.37799E+00  5.28391E-10  8.13690E-02
   3      1.70000E-03  3.37122E+00  2.30528E-08  7.97620E-02
   1      1.90000E-03  4.14782E+00 -7.43721E-09  1.58042E-01
   2      1.90000E-03  4.15420E+00  2.49500E-08  1.53366E-01
   3      1.90000E-03  4.15623E+00  4.26392E-09  1.51804E-01
   1      2.10000E-03  5.81071E+00  6.40742E-09  2.49788E-01
   2      2.10000E-03  5.86935E+00  5.01835E-09  2.47722E-01
   3      2.10000E-03  5.88877E+00 -1.84221E-09  2.47025E-01
   1      2.30000E-03  9.95287E+00 -5.58452E-09  3.91053E-01
   2      2.30000E-03  1.01320E+01 -3.96782E-08  3.94885E-01
   3      2.30000E-03  1.01916E+01  1.64012E-08  3.96150E-01
   1      2.50000E-03  2.45212E+01  5.32486E-08  6.85143E-01
   2      2.50000E-03  2.50927E+01 -2.75042E-08  7.00201E-01
   3      2.50000E-03  2.52830E+01 -1.21638E-08  7.05209E-01
Do you wish to see n vs tau for this frequency? n

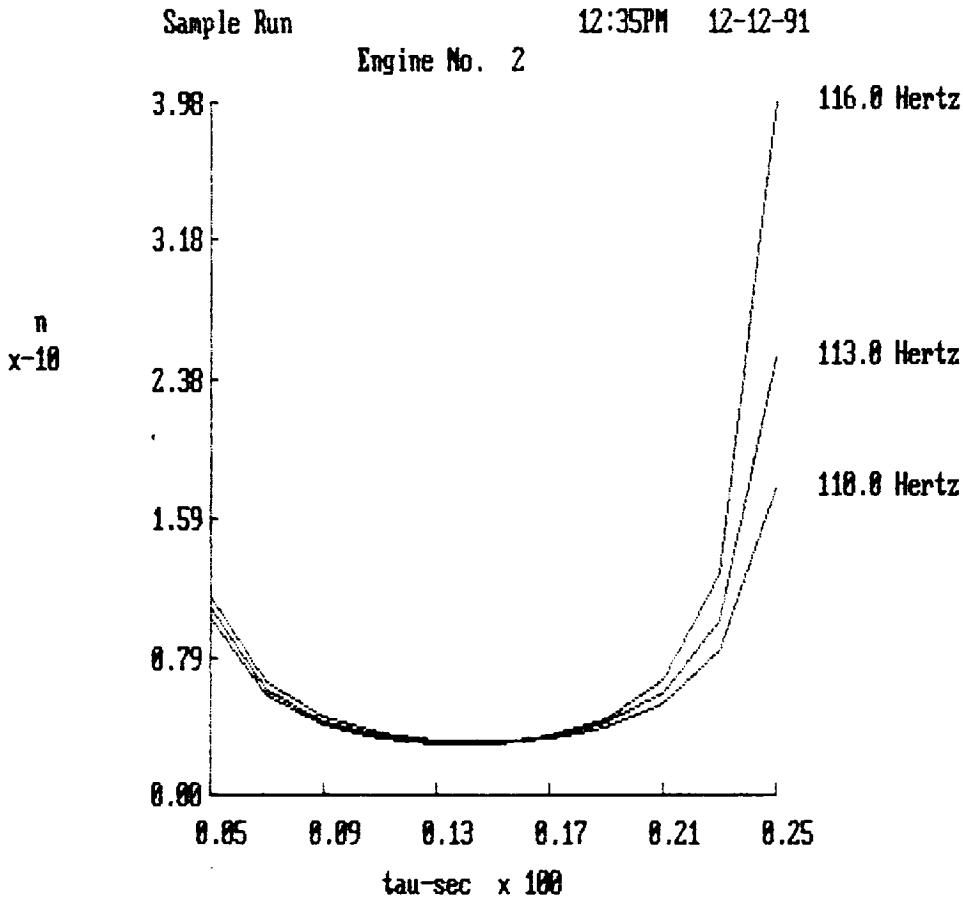
 FREQUENCY =  1.16000E+02 Hertz

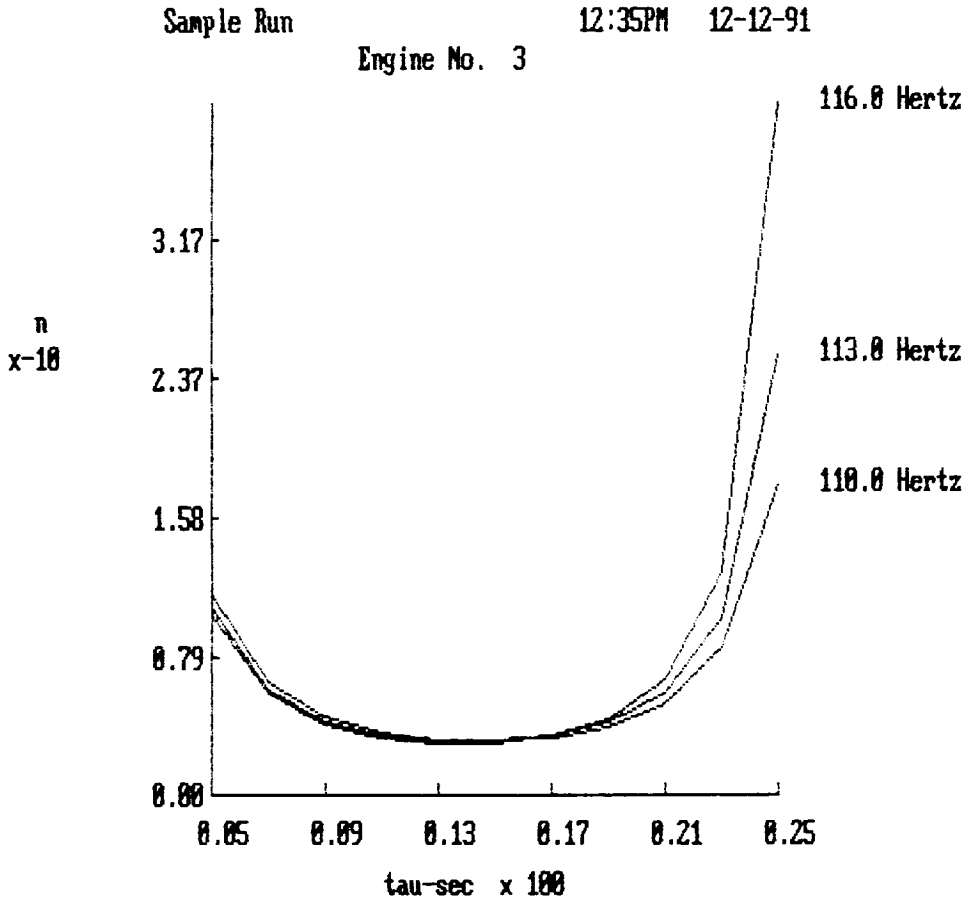
Eng. No.    tau-sec          n           FUNB(R)       FUNB(I)

   1      5.00000E-04  1.02991E+01 -5.12383E-06 -4.01431E-01
   2      5.00000E-04  1.02566E+01 -7.26954E-07 -4.02968E-01
   3      5.00000E-04  1.02423E+01  2.17450E-06 -4.03475E-01
   1      7.00000E-04  5.81341E+00  5.80983E-08 -2.41305E-01
```

```
2       7.00000E-04  5.82060E+00  5.68050E-07 -2.45578E-01
3       7.00000E-04  5.82285E+00 -8.08546E-07 -2.46997E-01
1       9.00000E-04  4.04158E+00  1.28387E-06 -1.41208E-01
2       9.00000E-04  4.07478E+00 -5.29651E-07 -1.46441E-01
3       9.00000E-04  4.08578E+00 -4.13673E-07 -1.48185E-01
1       1.10000E-03  3.24865E+00 -5.17933E-08 -6.79342E-02
2       1.10000E-03  3.29868E+00  3.70957E-07 -7.22060E-02
3       1.10000E-03  3.31530E+00  2.70439E-07 -7.36336E-02
1       1.30000E-03  2.94248E+00  6.76098E-07 -7.44052E-03
2       1.30000E-03  3.00384E+00 -3.21188E-08 -8.97935E-03
3       1.30000E-03  3.02428E+00  1.41335E-07 -9.49907E-03
1       1.50000E-03  2.97883E+00 -4.58275E-08  4.91058E-02
2       1.50000E-03  3.04639E+00 -2.01901E-09  5.14330E-02
3       1.50000E-03  3.06893E+00  3.29763E-08  5.22016E-02
1       1.70000E-03  3.38149E+00  1.35664E-08  1.10026E-01
2       1.70000E-03  3.44778E+00  2.08757E-09  1.16225E-01
3       1.70000E-03  3.46994E+00 -9.54488E-09  1.18287E-01
1       1.90000E-03  4.36821E+00 -3.11257E-09  1.86303E-01
2       1.90000E-03  4.41867E+00 -1.24407E-08  1.94871E-01
3       1.90000E-03  4.43563E+00  1.78421E-09  1.97729E-01
1       2.10000E-03  6.64360E+00 -5.92199E-09  2.97441E-01
2       2.10000E-03  6.64246E+00  1.34157E-08  3.05073E-01
3       2.10000E-03  6.64233E+00  2.06930E-08  3.07628E-01
1       2.30000E-03  1.28961E+01  2.52306E-08  4.92079E-01
2       2.30000E-03  1.27256E+01  1.19181E-08  4.93000E-01
3       2.30000E-03  1.26692E+01 -3.55738E-08  4.93328E-01
1       2.50000E-03  4.07941E+01 -6.08384E-08  9.70344E-01
2       2.50000E-03  3.97816E+01 -7.47497E-08  9.51817E-01
3       2.50000E-03  3.94452E+01 -1.56099E-08  9.45674E-01
Do you wish to see n vs tau for this frequency? n
```


Sample Run
12:35PM 12-12-91
Engine No. 1
4.88
3.26
2.44
1.63
0.81
0.00
n
x-10
116.0 Hertz
113.0 Hertz
110.0 Hertz
0.05
0.09
0.13
0.17
0.21
0.25
tau-sec x 100


Sample Run
12:35PM 12-12-91
Engine No. 2
116.0 Hertz
113.0 Hertz
110.0 Hertz
n
x-10
3.98
3.18
2.38
1.59
0.79
0.00
0.05
0.09
0.13
0.17
0.21
0.25
tau-sec x 100


Sample Run
12:35PM 12-12-91
Engine No. 3
116.0 Hertz
113.0 Hertz
110.0 Hertz
n
x-10
3.17
2.37
1.58
0.79
0.00
0.05
0.09
0.13
0.17
0.21
0.25
tau-sec x 100

Do you want to run another case? Enter Y or N **n**

4.3 Output for Sample Run

IMODE.OUT File

```
   CAREA=       8.113004
   TAREA=       3.912716
   ASTAR=    2869.983000
  CSTARD=   66403.230000
  RHOBAR=       2.110266
   UBARD=      49.852240
  RHOBAR=       2.110266
   UBARD=      49.852240

          Sample Run                          12:35PM   12-12-91

 Engine No.  1

                        DIMENSIONAL VARIABLES
   NVAL=    2
   XBAR=  0.00000E+00  4.00000E+00
   UBAR=  4.98522E+01  4.98522E+01
   DTAU =  6.97000E-04      NR =  1.00000E-02   CDIAM =  3.21400E+00
  TDIAM =  2.23200E+00     XLC =  4.00000E+00   GAMMA =  1.20000E+00
   RGAS =  1.71600E+03     P00 =  1.42500E+05    MBAR =  8.53500E+02
   RBAR =  2.67000E+00   DCSDR = -3.15000E+02   DHLDR =  1.00000E-02
  RHOLO =  4.40000E-01     ULO =  1.96500E+03   PCHMB =  4.50204E+05
  TCHMB =  4.00000E+03

                    NON-DIMENSIONAL VARIABLES
   NVAL=    2
   XBAR=  0.00000E+00  1.00000E+00
   UBAR=  1.73702E-02  1.73702E-02
   DTAU=  5.00094E-01       NR=  1.00000E-02     RBAR=  2.67000E+00
   MBAR=  6.94809E-02    GAMMA=  1.20000E+00      P00=  3.16523E-01
  DHLDR=  1.00000E-02    CSTAR=  2.31372E+01    DCSDR= -1.09757E-01
  RHOLO=  2.08505E-01      ULO=  6.84673E-01
    RFA=  1.44752E-03  0.00000E+00          RFC=  0.00000E+00  0.00000E+00
```

```
 CAREA=       8.113004
 TAREA=       3.912716
 ASTAR=    2869.983000
CSTARD=   33201.620000
RHOBAR=       2.110266
 UBARD=      99.704480
RHOBAR=       2.110266
 UBARD=      99.704480
```

Sample Run 12:35PM 12-12-91

Engine No. 2

DIMENSIONAL VARIABLES

```
 NVAL=    2
 XBAR=  0.00000E+00  4.00000E+00
 UBAR=  9.97045E+01  9.97045E+01
 DTAU =  6.97000E-04      NR =  1.00000E-02   CDIAM =  3.21400E+00
TDIAM =  2.23200E+00     XLC =  4.00000E+00   GAMMA =  1.20000E+00
 RGAS =  1.71600E+03     P00 =  1.42500E+05    MBAR =  1.70700E+03
 RBAR =  2.67000E+00   DCSDR = -3.15000E+02   DHLDR =  1.00000E-02
RHOLO =  4.40000E-01     ULO =  1.96500E+03   PCHMB =  4.50204E+05
TCHMB =  4.00000E+03
```

NON-DIMENSIONAL VARIABLES

```
 NVAL=    2
 XBAR=  0.00000E+00  1.00000E+00
 UBAR=  3.47404E-02  3.47404E-02
 DTAU=  5.00094E-01       NR=  1.00000E-02     RBAR=  2.67000E+00
 MBAR=  1.38962E-01    GAMMA=  1.20000E+00      P00=  3.16523E-01
DHLDR=  1.00000E-02    CSTAR=  1.15686E+01    DCSDR= -1.09757E-01
RHOLO=  2.08505E-01      ULO=  6.84673E-01
  RFA=  2.89504E-03  0.00000E+00         RFC=  0.00000E+00  0.00000E+00
```

```
 CAREA=       8.113004
 TAREA=       3.912716
 ASTAR=    2869.983000
CSTARD=   16600.810000
RHOBAR=       2.110266
 UBARD=     199.409000
RHOBAR=       2.110266
 UBARD=     199.409000
```

Sample Run 12:35PM 12-12-91

Engine No. 3

DIMENSIONAL VARIABLES

```
 NVAL=    2
 XBAR=  0.00000E+00  4.00000E+00
 UBAR=  1.99409E+02  1.99409E+02
 DTAU =  6.97000E-04      NR =  1.00000E-02   CDIAM =  3.21400E+00
TDIAM =  2.23200E+00     XLC =  4.00000E+00   GAMMA =  1.20000E+00
 RGAS =  1.71600E+03     P00 =  1.42500E+05    MBAR =  3.41400E+03
 RBAR =  2.67000E+00   DCSDR = -3.15000E+02   DHLDR =  1.00000E-02
RHOLO =  4.40000E-01     ULO =  1.96500E+03   PCHMB =  4.50204E+05
TCHMB =  4.00000E+03
```

NON-DIMENSIONAL VARIABLES

```
 NVAL=    2
 XBAR=  0.00000E+00  1.00000E+00
 UBAR=  6.94809E-02  6.94809E-02
 DTAU=  5.00094E-01      NR=  1.00000E-02     RBAR=  2.67000E+00
 MBAR=  2.77924E-01   GAMMA=  1.20000E+00      P00=  3.16523E-01
DHLDR=  1.00000E-02   CSTAR=  5.78429E+00    DCSDR= -1.09757E-01
RHOLO=  2.08505E-01     ULO=  6.84673E-01
  RFA=  5.79008E-03  0.00000E+00          RFC=  0.00000E+00  0.00000E+00
```

Sample Run 12:35PM 12-12-91

FREQUENCY = 1.10000E+02 Hertz

Eng. No.	tau-sec	n	FUNB(R)	FUNB(I)
1	5.00000E-04	1.14621E+01	-3.11896E-07	-4.67076E-01
2	5.00000E-04	1.14841E+01	-3.03067E-07	-4.60113E-01
3	5.00000E-04	1.14920E+01	3.88765E-07	-4.57809E-01
1	7.00000E-04	6.55967E+00	8.66792E-07	-3.17231E-01
2	7.00000E-04	6.48823E+00	-2.23960E-06	-3.05747E-01
3	7.00000E-04	6.46472E+00	-1.18901E-06	-3.01928E-01
1	9.00000E-04	4.62124E+00	2.49193E-07	-2.20846E-01
2	9.00000E-04	4.50544E+00	6.42385E-07	-2.08742E-01
3	9.00000E-04	4.46697E+00	-1.25355E-06	-2.04704E-01
1	1.10000E-03	3.73689E+00	-2.28634E-07	-1.44484E-01
2	1.10000E-03	3.59644E+00	-2.45890E-07	-1.35610E-01
3	1.10000E-03	3.54970E+00	-7.22797E-07	-1.32642E-01
1	1.30000E-03	3.35282E+00	1.55936E-07	-7.53268E-02
2	1.30000E-03	3.20046E+00	1.72578E-07	-7.29305E-02
3	1.30000E-03	3.14967E+00	-2.02976E-07	-7.21169E-02
1	1.50000E-03	3.28318E+00	-4.40167E-08	-7.92099E-03
2	1.50000E-03	3.13166E+00	5.27691E-08	-1.37797E-02
3	1.50000E-03	3.08109E+00	5.24031E-08	-1.57178E-02
1	1.70000E-03	3.49309E+00	-2.72676E-09	6.03049E-02
2	1.70000E-03	3.36009E+00	-3.73278E-09	4.66884E-02
3	1.70000E-03	3.31559E+00	-2.31758E-08	4.21583E-02
1	1.90000E-03	4.06690E+00	2.46680E-08	1.31826E-01
2	1.90000E-03	3.98268E+00	1.20805E-08	1.13762E-01
3	1.90000E-03	3.95433E+00	-1.35946E-08	1.07738E-01
1	2.10000E-03	5.30008E+00	-2.17681E-08	2.12487E-01
2	2.10000E-03	5.32637E+00	-6.04931E-09	1.96344E-01
3	2.10000E-03	5.33471E+00	-1.82410E-08	1.90944E-01
1	2.30000E-03	8.12702E+00	-2.26766E-08	3.19093E-01
2	2.30000E-03	8.41822E+00	-8.19192E-09	3.14610E-01
3	2.30000E-03	8.51465E+00	-2.97111E-08	3.13079E-01
1	2.50000E-03	1.64494E+01	-1.18208E-10	5.06763E-01
2	2.50000E-03	1.75388E+01	3.19730E-08	5.29430E-01
3	2.50000E-03	1.79009E+01	3.66275E-10	5.36935E-01

Sample Run 12:35PM 12-12-91

FREQUENCY = 1.13000E+02 Hertz

Eng. No.	tau-sec	n	FUNB(R)	FUNB(I)
1	5.00000E-04	1.08414E+01	4.69661E-07	-4.35565E-01
2	5.00000E-04	1.08143E+01	5.71385E-09	-4.32209E-01
3	5.00000E-04	1.08053E+01	-1.54009E-06	-4.31091E-01
1	7.00000E-04	6.16340E+00	-1.62474E-06	-2.79945E-01
2	7.00000E-04	6.12335E+00	-7.68963E-07	-2.76068E-01
3	7.00000E-04	6.11010E+00	1.38288E-06	-2.74779E-01
1	9.00000E-04	4.31322E+00	6.75733E-07	-1.80939E-01
2	9.00000E-04	4.26871E+00	1.11379E-06	-1.77752E-01
3	9.00000E-04	4.25390E+00	5.02842E-07	-1.76687E-01
1	1.10000E-03	3.47502E+00	-2.45920E-07	-1.05288E-01
2	1.10000E-03	3.43012E+00	8.45579E-08	-1.03835E-01
3	1.10000E-03	3.41516E+00	4.99280E-07	-1.03347E-01
1	1.30000E-03	3.12737E+00	-1.32093E-07	-3.97969E-02
2	1.30000E-03	3.08554E+00	1.74440E-07	-4.07200E-02
3	1.30000E-03	3.07158E+00	3.38107E-09	-4.10231E-02
1	1.50000E-03	3.10466E+00	3.06501E-08	2.23420E-02
2	1.50000E-03	3.07029E+00	1.45587E-08	1.90551E-02
3	1.50000E-03	3.05879E+00	-2.11063E-08	1.79628E-02
1	1.70000E-03	3.39810E+00	3.86204E-08	8.61902E-02
2	1.70000E-03	3.37799E+00	5.28391E-10	8.13690E-02
3	1.70000E-03	3.37122E+00	2.30528E-08	7.97620E-02
1	1.90000E-03	4.14782E+00	-7.43721E-09	1.58042E-01
2	1.90000E-03	4.15420E+00	2.49500E-08	1.53366E-01
3	1.90000E-03	4.15623E+00	4.26392E-09	1.51804E-01
1	2.10000E-03	5.81071E+00	6.40742E-09	2.49788E-01
2	2.10000E-03	5.86935E+00	5.01835E-09	2.47722E-01
3	2.10000E-03	5.88877E+00	-1.84221E-09	2.47025E-01
1	2.30000E-03	9.95287E+00	-5.58452E-09	3.91053E-01
2	2.30000E-03	1.01320E+01	-3.96782E-08	3.94885E-01
3	2.30000E-03	1.01916E+01	1.64012E-08	3.96150E-01
1	2.50000E-03	2.45212E+01	5.32486E-08	6.85143E-01
2	2.50000E-03	2.50927E+01	-2.75042E-08	7.00201E-01
3	2.50000E-03	2.52830E+01	-1.21638E-08	7.05209E-01

Sample Run 12:35PM 12-12-91

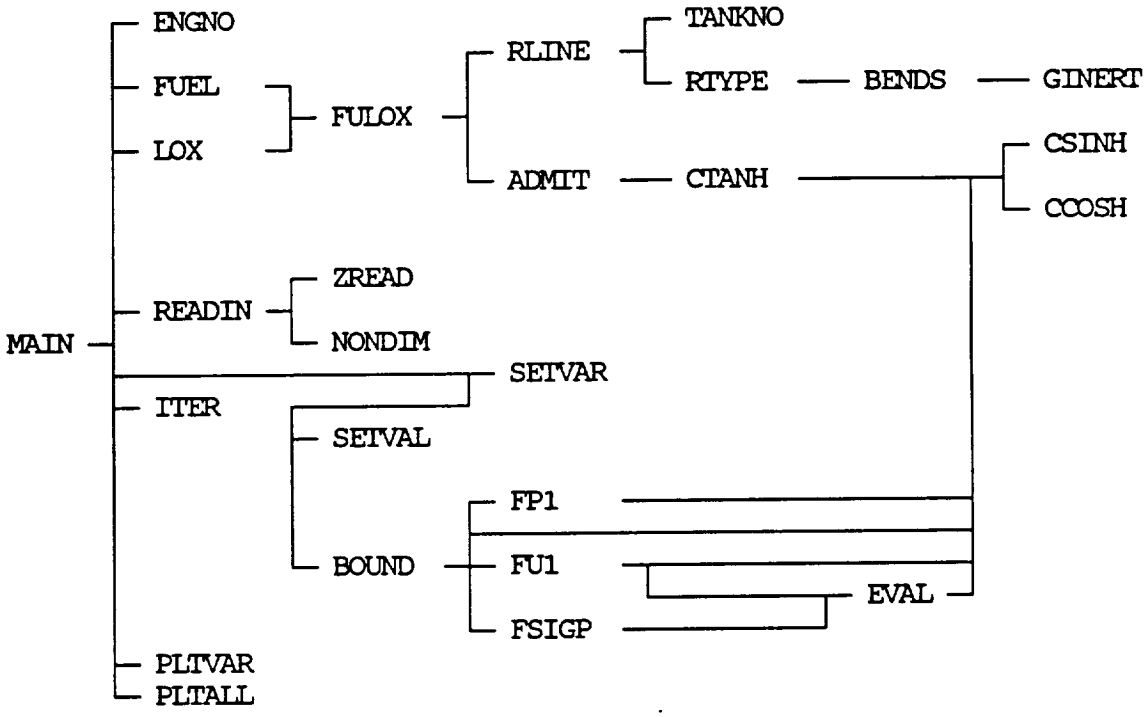
FREQUENCY = 1.16000E+02 Hertz

Eng. No.	tau-sec	n	FUNB(R)	FUNB(I)
1	5.00000E-04	1.02991E+01	-5.12383E-06	-4.01431E-01
2	5.00000E-04	1.02566E+01	-7.26954E-07	-4.02968E-01
3	5.00000E-04	1.02423E+01	2.17450E-06	-4.03475E-01
1	7.00000E-04	5.81341E+00	5.80983E-08	-2.41305E-01
2	7.00000E-04	5.82060E+00	5.68050E-07	-2.45578E-01
3	7.00000E-04	5.82285E+00	-8.08546E-07	-2.46997E-01
1	9.00000E-04	4.04158E+00	1.28387E-06	-1.41208E-01
2	9.00000E-04	4.07478E+00	-5.29651E-07	-1.46441E-01
3	9.00000E-04	4.08578E+00	-4.13673E-07	-1.48185E-01
1	1.10000E-03	3.24865E+00	-5.17933E-08	-6.79342E-02
2	1.10000E-03	3.29868E+00	3.70957E-07	-7.22060E-02
3	1.10000E-03	3.31530E+00	2.70439E-07	-7.36336E-02
1	1.30000E-03	2.94248E+00	6.76098E-07	-7.44052E-03
2	1.30000E-03	3.00384E+00	-3.21188E-08	-8.97935E-03
3	1.30000E-03	3.02428E+00	1.41335E-07	-9.49907E-03
1	1.50000E-03	2.97883E+00	-4.58275E-08	4.91058E-02
2	1.50000E-03	3.04639E+00	-2.01901E-09	5.14330E-02
3	1.50000E-03	3.06893E+00	3.29763E-08	5.22016E-02
1	1.70000E-03	3.38149E+00	1.35664E-08	1.10026E-01
2	1.70000E-03	3.44778E+00	2.08757E-09	1.16225E-01
3	1.70000E-03	3.46994E+00	-9.54488E-09	1.18287E-01
1	1.90000E-03	4.36821E+00	-3.11257E-09	1.86303E-01
2	1.90000E-03	4.41867E+00	-1.24407E-08	1.94871E-01
3	1.90000E-03	4.43563E+00	1.78421E-09	1.97729E-01
1	2.10000E-03	6.64360E+00	-5.92199E-09	2.97441E-01
2	2.10000E-03	6.64246E+00	1.34157E-08	3.05073E-01
3	2.10000E-03	6.64233E+00	2.06930E-08	3.07628E-01
1	2.30000E-03	1.28961E+01	2.52306E-08	4.92079E-01
2	2.30000E-03	1.27256E+01	1.19181E-08	4.93000E-01
3	2.30000E-03	1.26692E+01	-3.55738E-08	4.93328E-01
1	2.50000E-03	4.07941E+01	-6.08384E-08	9.70344E-01
2	2.50000E-03	3.97816E+01	-7.47497E-08	9.51817E-01
3	2.50000E-03	3.94452E+01	-1.56099E-08	9.45674E-01

SURF.ERR File

None created for this frequency range.

5.0 Flow Diagram



6.0 Variable Description

Variables in Commons

		/CMPVAL/
CVAR(17)	COMPLEX*8	equivalence(CVAR(1),X1)
X1	COMPLEX*8	first order term of x
Y1	COMPLEX*8	first order term of y
Z1	COMPLEX*8	first order term of z
W1	COMPLEX*8	first order term of w
M1	COMPLEX*8	first order term of m
P0	COMPLEX*8	zeroth order term of pressure
P1	COMPLEX*8	first order term of pressure
U0	COMPLEX*8	zeroth order term of velocity
U1	COMPLEX*8	first order term of velocity
RFH	COMPLEX*8	comb. response function for mixture ratio
RFK	COMPLEX*8	comb. response function for mass flow
RFP	COMPLEX*8	comb. response function for pressure
S	COMPLEX*8	lamda + mu I - perturbation oscillation
GF	COMPLEX*8	admittance of fuel line looking toward tank
GOX	COMPLEX*8	admittance of lox line looking toward tank
RFA	COMPLEX*8	nozzle pressure admittance coefficient
RFC	COMPLEX*8	nozzle entropy admittance coefficient
		/DIMVAL/
HOLDD(20)	REAL*4	equivalence(HOLDD(1),ND)
ND	REAL*4	pressure interaction index
TAUD	REAL*4	sensitive time lag (sec)
DTAUD	REAL*4	delta time lag (sec)
NRD	REAL*4	mixture ratio interaction index
LAMDAD	REAL*4	damping of perturbation
MUD	REAL*4	frequency of perturbation (rad/sec)
CDIAM	REAL*4	chamber diameter (ft)
TDIAM	REAL*4	throat diameter (ft)
XLCD	REAL*4	x location of chamber-nozzle interface (ft)
GAMMAD	REAL*4	ratio of specific heats
RGAS	REAL*4	gas constant (ft^2/sec^2/°R)
P0OD	REAL*4	maximum pressure at injection face (lbf/ft^2)
MBARD	REAL*4	mean comb. response function (lbm/sec)
RBARD	REAL*4	mean mixture ratio
DCSDRD	REAL*4	d(cstar)/d(mixture ratio) (ft/sec)
DHLDRD	REAL*4	d(enthalpy/d(mixture ratio) (ft^2/sec^2)
RHOLOD	REAL*4	mass of liquid per unit chamber vol (lbm/ft^3)
ULOD	REAL*4	axial component of liquid velocity (ft/sec)
PCHMB	REAL*4	chamber pressure (lbf/ft^2)
TCHMB	REAL*4	chamber temperature (°R)
XBARD(50)	REAL*4	x locations along axis (ft)
PBAR(50)	REAL*4	pressure along axis (lbf/ft^2)
TBAR(50)	REAL*4	temperature along axis (°R)

	/EPARAM/	
MENG	INTEGER*2	number of engines
TFLOW(25)	REAL*4	total flow rate of engine (lbm/sec)
PCHMB(25)	REAL*4	chamber pressure (lbf/ft^2)
DPROR(25)	REAL*4	pressure drop across orifices (lbf/ft^2)
PMRAT(25)	REAL*4	chamber pressure/total mass flow
	/FOPIPE/	
PIPE1(75,25)	REAL*4	first parameter of pipe description
PIPE2(75,25)	REAL*4	second parameter of pipe description
PIPE3(75,25)	REAL*4	third parameter of pipe description
PIPE4(75,25)	REAL*4	fourth parameter of pipe description
PIPE5(75,25)	REAL*4	fifth parameter of pipe description
	/FPARAM/	
MLINE	INTEGER*2	number of lines from tank
SPLIT(25)	REAL*4	number of unique lines from pipe split
A(25)	REAL*4	speed of sound in the fluid (ft/sec)
CMAN(25)	REAL*4	manifold capacitance
CTANK(25)	REAL*4	tank capacitance
DENS(25)	REAL*4	density of fluid (lbm/ft^3)
KMAN(25)	REAL*4	bulk modulus of manifold (lbf/ft^2)
KTANK(25)	REAL*4	bulk modulus of tank (lbf/ft^2)
LFLOW(25)	REAL*4	flow rate through pipe (lbm/sec)
VOL(25)	REAL*4	volume of tank (ft^3)
VOLMF(25)	REAL*4	volume of manifold (ft^3)
AREA(75,25)	REAL*4	area of pipe section (ft^2)
DIA(75,25)	REAL*4	diameter of pipe section (ft)
L(75,25)	REAL*4	length of pipe section (ft)
PIND(75,25)	REAL*4	inductance of pipe section
PCAP(75,25)	REAL*4	capacitance of pipe section
AVGK(25)	REAL*4	average bulk modulus
SEGMNF(25)	INTEGER*2	number of pipe sections
SECINF(75,25)	INTEGER*2	pipe section type
NOLINE(25)	INTEGER*2	number of identical lines
IENG(25)	INTEGER*2	engine number
ITANK(25)	INTEGER*2	tank number
LOPOLD(25)	INTEGER*2	previous maximum number of iterations
LOPEND(25)	INTEGER*2	maximum number of iterations for split pipe
	/INTVAL/	
NVAL	INTEGER*2	number of points along chamber
	/OPARAM/	
MLINE	INTEGER*2	number of lines from tank
SPLIT(25)	REAL*4	number of unique lines from pipe split
A(25)	REAL*4	speed of sound in the fluid (ft/sec)
CMAN(25)	REAL*4	manifold capacitance
CTANK(25)	REAL*4	tank capacitance
DENS(25)	REAL*4	density of fluid (lbm/ft^3)
KMAN(25)	REAL*4	bulk modulus of manifold (lbf/ft^2)
KTANK(25)	REAL*4	bulk modulus of tank (lbf/ft^2)
LFLOW(25)	REAL*4	flow rate through pipe (lbm/sec)

VOL(25)	REAL*4	volume of tank (ft^3)
VOLMF(25)	REAL*4	volume of manifold (ft^3)
AREA(75,25)	REAL*4	area of pipe section (ft^2)
DIA(75,25)	REAL*4	diameter of pipe section (ft)
L(75,25)	REAL*4	length of pipe section (ft)
PIND(75,25)	REAL*4	inductance of pipe section
PCAP(75,25)	REAL*4	capacitance of pipe section
AVGK(25)	REAL*4	average bulk modulus
SEGMNF(25)	INTEGER*2	number of pipe sections
SECTNF(75,25)	INTEGER*2	pipe section type
NOLINE(25)	INTEGER*2	number of identical lines
IENG(25)	INTEGER*2	engine number
ITANK(25)	INTEGER*2	tank number
LOPOLD(25)	INTEGER*2	previous maximum number of iterations
LOPEND(25)	INTEGER*2	maximum number of iterations for split pipe
	/PIPES/	
PFACE	REAL*4	pressure at injector face (lbf/ft^2)
TFACE	REAL*4	mean comb. response function (lbm/sec)
ASTAR	REAL*4	speed of sound at injector face (ft/sec)
	/RELVAL/	
RVAR(13)	REAL*4	equivalence(RVAR(1),N)
N	REAL*4	pressure interaction index
TAU	REAL*4	sensitive time lag
DTAU	REAL*4	delta time lag
NR	REAL*4	mixture ratio interaction index
RBAR	REAL*4	mean mixture ratio
MBAR	REAL*4	mean comb. response function
GAMMA	REAL*4	ratio of specific heats
P00	REAL*4	maximum pressure at injection face
DHLDR	REAL*4	d(enthalpy)/d(mixture ratio)
CSTAR	REAL*4	characteristic velocity at combustor exit
DCSDR	REAL*4	d(cstar)/d(mixture ratio)
RHOLO	REAL*4	mass of liquid per unit chamber volume
ULO	REAL*4	axial component of liquid velocity
LAMDA	REAL*4	damping of perturbation
MU	REAL*4	frequency of perturbation
TAUT	REAL*4	total time lag
UBAR(50)	REAL*4	velocity along axis
XBAR(50)	REAL*4	x locations along axis
XLC	REAL*4	x location of chamber-nozzle interface
	/RESULT/	
PP	COMPLEX*8	P' = P0 + P1
UP	COMPLEX*8	U' = U0 + U1
SIGP	COMPLEX*8	SIG' = SIG0 + SIG1
FUNB	COMPLEX*8	boundary function U' + RFA * P' + RFC * SIG'
	/SFACT/	
SFAC	REAL*4	factor for frequency

	/TITL/	
TITLE	CHAR*60	title for plots including date and time
TITLF	CHAR*40	input title
IHR	INTEGER*2	hour code run
IMIN	INTEGER*2	minute code run
AP	CHAR*2	AM or PM
IYR	INTEGER*2	yesr code run
IMON	INTEGER*2	month code run
IDAY	INTEGER*2	day code run
	/WCAOUT/	
NAMLIN(2)	CHAR*24	name of files containing pipe description
IUNITH	INTEGER*2	unit number of current file
	/WORK/	
YP(50,50)	REAL*4	n array
YP1(20,25)	REAL*4	work array
YP2(50,25)	REAL*4	work array
YP3(50,25)	REAL*4	work array
YPA(50,50)	REAL*4	n work array
YP4(50,25)	REAL*4	work array
YP5(30,25)	REAL*4	work array
	/WORK1/	
G(0:75,25)	COMPLEX*8	admittance looking toward tank
ZT(0:75,25)	COMPLEX*8	impedance looking toward tank
ZG(0:75,25)	COMPLEX*8	impedance looking toward engine
	/WORK2/	
ZO(75,25)	REAL*4	characteristic impedance

PROGRAM SSFREQ
Logic portion of code

Commons CMPVAL DIMVAL EPARAM INTVAL RELVAL RESULT SFACT
TITL WORK

Local Variables

AM	CHAR*2	'AM'
ANS	CHAR*1	response to question
DELF	REAL*4	intermediate variable
DELVAL	REAL*4	intermediate variable
FREQ(50)	REAL*4	array of frequencies
GFA(25)	COMPLEX*8	fuel line admittance
GOXA(25)	COMPLEX*8	lox line admittance
I	INTEGER*2	do loop index
IFREQ	INTEGER*2	flag denoting presence of frequency file
IGONE	INTEGER*2	flag for subroutine fuel or lox
ISEC	INTEGER*2	seconds at start
ITAU	INTEGER*2	flag denoting presence of tau file
I100	INTEGER*2	hundreds of seconds at start
J	INTEGER*2	do loop index
JUNIT	INTEGER*2	unit number of engine data file

K	INTEGER*2	do loop index
NA(25)	REAL*4	n for each engine
NAMENG	CHAR*24	name of engine file
NOF	INTEGER*2	maximum number of frequencies
NOT	INTEGER*2	maximum number of tau's
NPTF	INTEGER*2	number of frequencies
NPTS	INTEGER*2	number of tau's
PM	CHAR*2	'PM'
RADHER(2)	CHAR*8	labels
ROCIN	CHAR*24	input file name
ROCVAR	CHAR*24	file name for frequencies or tau's
STARTF	REAL*4	starting frequency
STARTV	REAL*4	starting tau
STOPF	REAL*4	ending frequency
STOPV	REAL*4	ending tau
TAULST(200)	REAL*4	array of tau's
TOL	REAL*4	convergence criteria
VARF	REAL*4	current frequency
VARP(3)	CHAR*8	labels
VART	REAL*4	current tau
VAR1	REAL*4	intermediate variable

SUBROUTINE ADMIT

Determines admittance looking toward tank

Commons FACTOR TITL WORK1 WORK2

Variables in Argument List

A	REAL*4	speed of sound in the fluid (ft/sec)
AREA(75,25)	REAL*4	area of pipe section (ft^2)
CMAN(25)	REAL*4	manifold capacitance
CTANK	REAL*4	tank capacitance
DPROR(25)	REAL*4	pressure drop across orifices (lbf/ft^2)
GADM(25)	COMPLEX*8	admittance looking toward tank
IENG(25)	INTEGER*2	engine number
IP	INTEGER*2	current pipe section
ITLIN	INTEGER*2	flag for fuel or lox
L(75,25)	REAL*4	length of pipe section (ft)
LFLOW	REAL*4	flow rate through pipe (lbm/sec)
LOPEND	INTEGER*2	maximum number of iterations for split pipe
NOLINE(25)	INTEGER*2	number of identical lines
PCAP(75,25)	REAL*4	capacitance of pipe section
PIND(75,25)	REAL*4	inductance of pipe section
PMRAT(25)	REAL*4	chamber pressure/total mass flow
S	COMPLEX*8	current frequency
SECIN(75,25)	INTEGER*2	pipe section type
SEGMN(25)	INTEGER*2	number of pipe sections
SPLIT	REAL*4	number of unique lines from pipe split
TFLOW(25)	REAL*4	total flow rate of engine (lbm/sec)

Local Variables

CAPM	COMPLEX*8	intermediate variable
CAPN	COMPLEX*8	intermediate variable
CFAC	COMPLEX*8	intermediate variable

ERRP	REAL*4	convergence error
GDIF	REAL*4	maximum difference in admittance
GOLD(0:75,25)	COMPLEX*8	previous addmittance
GRAV	REAL*4	gravitational constant (lbm-ft/lbf-sec^2)
I	INTEGER*2	do loop index
IE	INTEGER*2	current engine number
IEE	INTEGER*2	engine number
IOPEN	INTEGER*2	flag indicating if SURF.ERR is open
IWG	INTEGER*2	first index of maximum error
J	INTEGER*2	do loop index
JWG	INTEGER*2	second index of maximum error
K	INTEGER*2	do loop index
KLOOP	INTEGER*2	do loop index
LOPHI	INTEGER*2	intermediate variable
RATPM	REAL*4	intermediate variable
RHS	COMPLEX*8	intermediate variable
TCOUNT	REAL*4	intermediate variable
TL	REAL*4	length/speed of sound
TMASS	REAL*4	intermediate variable
TYPEL(2)	CHAR*13	intermediate array
WG	REAL*4	intermediate variable
WGOLD	REAL*4	intermediate variable
ZGEFF	COMPLEX*8	effective impedance for calculations
ZLP	REAL*4	intermediate variable
ZOEFF	REAL*4	effective ZO for calculations
ZOR(25)	REAL*4	intermediate variable
ZTEFF	COMPLEX*8	effective Zt for calculations
ZTOP	REAL*4	intermediate variable

SUBROUTINE BENDS

Computes effective straight pipe for bend

Variables in Argument List

DIME	REAL*4	effective diameter (ft)
PIPE1	REAL*4	radius of bend (ft)
PIPE2	REAL*4	angle of bend (degrees)
PIPE3	REAL*4	diameter of bend (ft)
PIPE4	REAL*4	length of end straight segments (ft)
VALUE	REAL*4	effective length (ft)

Local Variables

GAMMA	REAL*4	intermediate variable
LBEND	REAL*4	intermediate variable
RATIO	REAL*4	intermediate variable
Y	REAL*4	intermediate variable

SUBROUTINE BOUND

Evaluates the boundary function

Commons CMPVAL INTVAL RELVAL

Variables in Argument List

FUNB	COMPLEX*8	boundary function U' + RFA * P' + RFC * SIG'

PP	COMPLEX*8	P' = P0 + P1
SIGP	COMPLEX*8	SIG' = SIG0 + SIG1
UP	COMPLEX*8	U' = U0 + U1

COMPLEX FUNCTION CCOSH
Evaluates the complex hyperbolic cosine

Variables in Argument List

S	COMPLEX*8	current frequency

Local Variables

COSHI	REAL*4	intermediate variable
COSHR	REAL*4	intermediate variable
LAMDA	REAL*4	real part of complex frequency
MU	REAL*4	complex part of complex frequency

COMPLEX FUNCTION CSINH
Evaluates the complex hyperbolic sine

Variables in Argument List

S	COMPLEX*8	current frequency

Local Variables

LAMDA	REAL*4	real part of complex frequency
MU	REAL*4	complex part of complex frequency
SINHI	REAL*4	intermediate variable
SINHR	REAL*4	intermediate variable

COMPLEX FUNCTION CTANH
Evaluates the complex hyperbolic tangent

Variables in Argument List

S	COMPLEX*8	current frequency

Local Variables

CTAND	COMPLEX*8	intermediate variable
CTANN	COMPLEX*8	intermediate variable

SUBROUTINE ENGNO
Reads engine parameters

Commons EPARAM

Variables in Argument List

IUNIT	INTEGER*2	unit number of engine file

Local Variables

I	INTEGER*2	do loop index

SUBROUTINE EVAL
Evaluates parameters at a given x location

Commons CMPVAL INTVAL RELVAL

```
                Variables in Argument List
X               REAL*4      current x station
                Local Variables
FAC             REAL*4      intermediate variable
I               INTEGER*2   do loop index
UB              REAL*4      intermediate variable
```

COMPLEX FUNCTION FP1
Evaluates P1

```
Commons CMPVAL  INTVAL  RELVAL
                Variables in Argument List
XL              REAL*4      length of chamber
                Local Variables
DX              REAL*4      integration increment
I               INTEGER*2   do loop variable
VINT            COMPLEX*8   intermediate variable
X               REAL*4      current x location
```

COMPLEX FUNCTION FSIGP
Evaluates SIG'

```
Commons CMPVAL  INTVAL  RELVAL
                Variables in Argument List
XL              REAL*4      length of chamber
                Local Variables
DX              REAL*4      integration increment
FA              REAL*4      intermediate variable
FCON            COMPLEX*8   intermediate variable
FSIG2           COMPLEX*8   intermediate variable
I               INTEGER*2   do loop index
II              INTEGER*2   do loop index
J               INTEGER*2   do loop index
UB(51)          REAL*4      intermediate array
VINT(51)        COMPLEX*8   intermediate array
VVINT(51)       COMPLEX*8   intermediate array
X               REAL*4      current x location
```

SUBROUTINE FUEL
Handles fuel piping logic

```
Commons EPARAM  FOPIPE  FPARAM  WCAOUT
                Variables in Argument List
GF(25)          COMPLEX*8   admittance looking toward tank
IGONE           INTEGER*2   flag for subroutine fuel or lox
IUNIT           INTEGER*2   unit number of fuel data file
IUNITP          INTEGER*2   unit number of fuel work file
S               COMPLEX*8   current frequency
                Local Variables
ANS             CHAR*1      response to question
```

FUELIN	CHAR*24	name of fuel data file

SUBROUTINE FULOX
Handles read, modify, and admittance calls for fuel and lox

Commons EPARAM

Variables in Argument List

A(25)	REAL*4	speed of sound in the fluid (ft/sec)
AREA(75,25)	REAL*4	area of pipe section (ft^2)
AVGK(25)	REAL*4	average bulk modulus
CMAN(25)	REAL*4	manifold capacitance
CTANK(25)	REAL*4	tank capacitance
DENS(25)	REAL*4	density of fluid (lbm/ft^3)
DIA(75,25)	REAL*4	diameter of pipe section (ft)
GF(25)	COMPLEX*8	admittance looking toward tank
IENG(25)	INTEGER*2	engine number
IGONE	INTEGER*2	flag for subroutine fuel or lox
ITANK(25)	INTEGER*2	tank number
ITLIN	INTEGER*2	flag indication fuel or lox
IUNIT	INTEGER*2	unit number of piping data file
IUNITP	INTEGER*2	unit number of working file
KMAN(25)	REAL*4	bulk modulus of manifold (lbf/ft^2)
KTANK(25)	REAL*4	bulk modulus of tank (lbf/ft^2)
L(75,25)	REAL*4	length of pipe section (ft)
LFLOW(25)	REAL*4	flow rate through pipe (lbm/sec)
LOPEND(25)	INTEGER*2	maximum number of iterations for split pipe
LOPOLD(25)	INTEGER*2	previous maximum number of iterations
MLINE	INTEGER*2	number of lines from tank
NOLINE(25)	INTEGER*2	number of identical lines
PCAP(75,25)	REAL*4	capacitance of pipe section
PIND(75,25)	REAL*4	inductance of pipe section
PIPE1(75,25)	REAL*4	first parameter of pipe description
PIPE2(75,25)	REAL*4	second parameter of pipe description
PIPE3(75,25)	REAL*4	third parameter of pipe description
PIPE4(75,25)	REAL*4	fourth parameter of pipe description
PIPE5(75,25)	REAL*4	fifth parameter of pipe description
S	COMPLEX*8	current frequency
SECTN(75,25)	INTEGER*2	pipe section type
SEGMN(25)	INTEGER*2	number of pipe sections
SPLIT(25)	REAL*4	number of unique lines from pipe split
VOL(25)	REAL*4	volume of tank (ft^3)
VOLMF(25)	REAL*4	volume of manifold (ft^3)

Local Variables

ANS	CHAR*1	response to question
I	INTEGER*2	do loop index
IP	INTEGER*2	current segment number
IT	INTEGER*2	current tank number
QUEST3(2)	CHAR*40	question array
TITL	CHAR*20	title from data file

COMPLEX FUNCTION FU1
    Evaluates U1

Commons CMPVAL INTVAL RELVAL

	Variables in Argument List	
XL	REAL*4	length of chamber
	Local Variables	
DX	REAL*4	integration increment
I	INTEGER*2	do loop index
VINT	COMPLEX*8	intermediate variable
X	REAL*4	current x location

SUBROUTINE GINERT
    Evaluates curve fit of inertance of bends

	Variables in Argument List	
BEND	REAL*4	angle of bend (degrees)
X	REAL*4	ratio of inner to outer radius
Y	REAL*4	inertance
	Local Variables	
A	REAL*4	intermediate variable
B(3)	REAL*4	coefficient array for inertance fit

SUBROUTINE ITER
    Iterates for dependent variable

Commons CMPVAL INTVAL RELVAL RESULT

	Variables in Argument List	
ID	INTEGER*2	flag for dependent variable
TOL	REAL*4	convergence criteria
	Local Variables	
FUN	REAL*4	intermediate variable
FUN1	REAL*4	intermediate variable
FUN2	REAL*4	intermediate variable
I	INTEGER*2	do loop index
VAL	REAL*4	intermediate variable
VAL1	REAL*4	intermediate variable
VAL2	REAL*4	intermediate variable

SUBROUTINE LOX
    Handles lox piping logic

Commons EPARAM FOPIPE OPARAM WCAOUT

	Variables in Argument List	
GOX(25)	COMPLEX*8	admittance looking toward tank
IGONE	INTEGER*2	flag for subroutine fuel or lox
IUNIT	INTEGER*2	unit number of lox data file
IUNITP	INTEGER*2	unit number of lox work file
S	COMPLEX*8	current frequency
	Local Variables	

ANS	CHAR*1	response to question
LOXIN	CHAR*24	name of lox data file

SUBROUTINE NONDIM

Nondimensionalizes variables

Commons CMPVAL DIMVAL INTVAL PIPES RELVAL TITL

Variables in Argument List

HOLD(20)	REAL*4	array for transferring variables
K	INTEGER*2	engine number

Local Variables

CAREA	REAL*4	area of chamber
CSTARD	REAL*4	intermediate variable
FAC	REAL*4	intermediate variable
GC	REAL*4	gravitational constant (lbm-ft/lbf-sec^2)
I	INTEGER*2	do loop index
PEXIT	REAL*4	exit pressure
PI	REAL*4	mathematical constant
RFAR	REAL*4	intermediate variable
RHOBAR(50)	REAL*4	intermediate variable array
TAREA	REAL*4	throat area
UBARD(50)	REAL*4	intermediate variable array
VAR(13)	CHAR*8	names of nondimensional variables
VARD(20)	CHAR*8	names of dimensional variables

SUBROUTINE PLTALL

Plots n vs τ for all frequencies

Commons SFACT TITL

Variables in Argument List

FREQ(NOF)	REAL*4	frequency array
LABLX	CHAR*8	label for x axis
LABLY	CHAR*8	label for y axis
M	INTEGER*2	number of frequencies
N	INTEGER*2	number of tau's
NENG	INTEGER*2	engine number
NOF	INTEGER*2	maximum number of frequencies
NOT	INTEGER*2	maximum number of tau's
X(NOT)	REAL*4	tau array
Y(NOT,NOF)	REAL*4	n array

Local Variables

ASPECT	REAL*4	intermediate variable
ETITL	CHAR*13	plot title
FREQL	CHAR*16	label for frequency
I	INTEGER*2	do loop index
IBOARD	INTEGER*2	flag for type of graphics board used
ICOLR	INTEGER*2	color flag
IEXTEN	INTEGER*2	extension of key hit
IFIL	INTEGER*2	color flag
IKEY	INTEGER*2	code of key hit
ILIN	INTEGER*2	color flag

IOPT	INTEGER*2	intermediate variable
IXLAB	INTEGER*2	intermediate variable
IXPIX	INTEGER*2	intermediate variable
IYLAB	INTEGER*2	intermediate variable
IYPIX	INTEGER*2	intermediate variable
J	INTEGER*2	do loop index
JCOL1	INTEGER*2	starting plot column
JCOL2	INTEGER*2	ending plot column
JROW1	INTEGER*2	starting plot row
JROW2	INTEGER*2	ending plot row
LABFAC(7)	CHAR*8	labels
MODE	INTEGER*2	graphics mode
MODET	INTEGER*2	text mode
NCOLT	INTEGER*2	number oc text columns
RADHER(2)	CHAR*8	labels
XFAC	REAL*4	intermediate variable
XLABL(2)	CHAR*8	label
XMAJC	REAL*4	intermediate variable
XMAX	REAL*4	maximum x value for plot
XMIN	REAL*4	minimum x value for plot
XORG	REAL*4	plot x origin
YFAC	REAL*4	intermediate variable
YLABL(2)	CHAR*8	label
YMAJ	REAL*4	intermediate variable
YMAX	REAL*4	maximum y value for plot
YMIN	REAL*4	minimum y value for plot
YORG	REAL*4	plot y origin
YOVERX	REAL*4	intermediate variable

SUBROUTINE PLTVAR

Plots n vs τ for a single frequency

Commons SFACT	TITL	
	Variables in Argument List	
FREQ	REAL*4	frequency
LABLX	CHAR*8	label for x axis
LABLY	CHAR*8	label for y axis
N	INTEGER*2	number of tau's
NENG	INTEGER*2	engine number
X(N)	REAL*4	tau array
Y(N)	REAL*4	n array
	Local Variables	
ASPECT	REAL*4	intermediate variable
FREQL	CHAR*29	label for frequency
I	INTEGER*2	do loop index
IBOARD	INTEGER*2	flag for type of graphics board used
ICOLR	INTEGER*2	color flag
IEXTEN	INTEGER*2	extension of key hit
IFIL	INTEGER*2	color flag
IKEY	INTEGER*2	code of key hit
ILIN	INTEGER*2	color flag
IOPT	INTEGER*2	intermediate variable

IXLAB	INTEGER*2	intermediate variable
IYLAB	INTEGER*2	intermediate variable
JCOL1	INTEGER*2	starting plot column
JCOL2	INTEGER*2	ending plot column
JROW1	INTEGER*2	starting plot row
JROW2	INTEGER*2	ending plot row
LABFAC(7)	CHAR*8	labels
MODE	INTEGER*2	graphics mode
MODET	INTEGER*2	text mode
NCOLT	INTEGER*2	number oc text columns
RADHER(2)	CHAR*8	labels
XFAC	REAL*4	intermediate variable
XLABL(2)	CHAR*8	label
XMAJ	REAL*4	intermediate variable
XMAX	REAL*4	maximum x value for plot
XMIN	REAL*4	minimum x value for plot
XORG	REAL*4	plot x origin
YFAC	REAL*4	intermediate variable
YLABL(2)	CHAR*8	label
YMAJ	REAL*4	intermediate variable
YMAX	REAL*4	maximum y value for plot
YMIN	REAL*4	minimum y value for plot
YORG	REAL*4	plot y origin
YOVERX	REAL*4	intermediate variable

SUBROUTINE READIN
Reads input data

Commons CMPVAL DIMVAL EPARAM INTVAL RELVAL TITL WORK

Local Variables

ANS	CHAR*1	response to question
CDIAM	REAL*4	chamber diameter (ft)
DCSDRD	REAL*4	d(cstar)/d(mixture ratio) (ft/sec)
DHLDRD	REAL*4	d(enthalpy)/d(mixture ratio) (ft/sec)^2
DTAUD	REAL*4	delta time lag (sec)
GAMMAD	REAL*4	ratio of specific heats
HOLD(20)	REAL*4	equivalenced to dimensioned variables
I	INTEGER*2	do loop index
IDATA	INTEGER*2	data source flag
IGO	INTEGER*2	path flag
II	INTEGER*2	do loop index
J	INTEGER*2	do loop index
K	INTEGER*2	do loop index
LAMDAD	REAL*4	real part of complex frequency
MBARD	REAL*4	mean comb. response function (lbm/sec)
MUD	REAL*4	imaginary part of complex frequency
NAME	CHAR*8	name of input parameter
ND	REAL*4	pressure interaction index
NRD	REAL*4	mixture ratio interaction index
PCHMB	REAL*4	chamber pressure (lbf/ft^2)
POOD	REAL*4	maximum pressure at injection face
RBARD	REAL*4	mean mixture ratio

RGAS	REAL*4	gas constant (ft^2/sec^2/°R)
RHOLOD	REAL*4	mass of liquid per unit chamber vol (lbm/ft^3)
TAUD	REAL*4	sensitive time lag (sec)
TCHMB	REAL*4	chamber temperature (°R)
TDIAM	REAL*4	throat diameter (ft)
ULOD	REAL*4	axial component of liquid velocity (ft/sec)
VALUE	REAL*4	value of input parameter
VAR(20)	CHAR*8	names of variables for printout
VARL(20)	CHAR*8	names of variables (lower case)
VARP(20)	CHAR*8	names of variables (upper case)
XLCD	REAL*4	x location of chamber-nozzle interface (ft)

SUBROUTINE RLINE

Reads fuel or lox file.

Commons EPARAM

Variables in Argument List

A(25)	REAL*4	speed of sound in the fluid (ft/sec)
AREA(75,25)	REAL*4	area of pipe section (ft^2)
AVGK(25)	REAL*4	average bulk modulus
CMAN(25)	REAL*4	manifold capacitance
CTANK(25)	REAL*4	tank capacitance
DENS(25)	REAL*4	density of fluid (lbm/ft^3)
DIA(75,25)	REAL*4	diameter of pipe section (ft)
IENG(25)	INTEGER*2	engine number
ITANK(25)	INTEGER*2	tank number
IUNIT	INTEGER*2	unit number of fuel or lox file
KMAN(25)	REAL*4	bulk modulus of manifold (lbf/ft^2)
KTANK(25)	REAL*4	bulk modulus of tank (lbf/ft^2)
L(75,25)	REAL*4	length of pipe section (ft)
LFLOW(25)	REAL*4	flow rate through pipe (lbm/sec)
LOPEND(25)	INTEGER*2	maximum number of iterations for split pipe
LOPOLD(25)	INTEGER*2	previous maximum number of iterations
MLINE	INTEGER*2	number of lines from tank
NOLINE(25)	INTEGER*2	number of identical lines
PCAP(75,25)	REAL*4	capacitance of pipe section
PIND(75,25)	REAL*4	inductance of pipe section
PIPE1(75,25)	REAL*4	first parameter of pipe description
PIPE2(75,25)	REAL*4	second parameter of pipe description
PIPE3(75,25)	REAL*4	third parameter of pipe description
PIPE4(75,25)	REAL*4	fourth parameter of pipe description
PIPE5(75,25)	REAL*4	fifth parameter of pipe description
SECTN(75,25)	INTEGER*2	pipe section type
SEGMN(25)	INTEGER*2	number of pipe sections
SPLIT(25)	REAL*4	number of unique lines from pipe split
TITL	CHAR*20	title from input file
VOL(25)	REAL*4	volume of tank (ft^3)
VOLMF(25)	REAL*4	volume of manifold (ft^3)

Local Variables

ANS	CHAR*1	response to question
DIVAVG	REAL*4	intermediate variable
I	INTEGER*2	do loop index

IE	INTEGER*2	current engine number
IT	INTEGER*2	current tank number
J	INTEGER*2	do loop index
M	INTEGER*2	pointer
MM	INTEGER*2	do loop index
MTANK	INTEGER*2	number of tanks

SUBROUTINE RTYPE
Stores values for different types of piping

Variables in Argument List

AREA	REAL*4	area of pipe section (ft^2)
AVGK	REAL*4	average bulk modulus
CMAN	REAL*4	manifold capacitance
DENS	REAL*4	density of fluid (lbm/ft^3)
DIA	REAL*4	diameter of pipe section (ft)
KMAN	REAL*4	bulk modulus of manifold (lbf/ft^2)
L	REAL*4	length of pipe section (ft)
PCAP	REAL*4	capacitance of pipe section
PIND	REAL*4	inductance of pipe section
PIPE1	REAL*4	first parameter of pipe description
PIPE2	REAL*4	second parameter of pipe description
PIPE3	REAL*4	third parameter of pipe description
PIPE4	REAL*4	fourth parameter of pipe description
PIPE5	REAL*4	fifth parameter of pipe description
SECTN	INTEGER*2	pipe section type
VOLMF	REAL*4	volume of manifold (ft^3)

Local Variables

AREAB	REAL*4	area of pipe
DIME	REAL*4	diameter of pipe
GRAV	REAL*4	gravitational constant (lbm-ft/lbf-sec^2)
PI	REAL*4	mathematical constant
VALUE	REAL*4	length of pipe

SUBROUTINE SETVAL
Sets value from iterated variable

Commons DIMVAL

Variables in Argument List

ID	INTEGER*2	pointer to variable
VAL	REAL*4	value of variable

SUBROUTINE SETVAR
Sets iterated variable from value

Commons CMPVAL DIMVAL INTVAL RELVAL

Variables in Argument List

ID	INTEGER*2	pointer to variable
VAL	REAL*4	value of variable

Local Variables

ASTAR	REAL*4	speed of sound at injector face
PI	REAL*4	mathematical constant

SUBROUTINE TANKNO

Reads tank parameters

Variables in Argument List

A(25)	REAL*4	speed of sound in the fluid (ft/sec)
CTANK(25)	REAL*4	tank capacitance
DENS(25)	REAL*4	density of fluid (lbm/ft^3)
IUNIT	INTEGER*2	unit number of fuel or lox file
KTANK(25)	REAL*4	bulk modulus of tank (lbf/ft^2)
LFLOW(25)	REAL*4	flow rate through pipe (lbm/sec)
MTANK	INTEGER*2	number of tanks
VOL(25)	REAL*4	volume of tank (ft^3)

Local Variables

GRAV	REAL*4	gravitational constant (lbm-ft/lbf-sec^2)
I	INTEGER*2	do loop index

SUBROUTINE ZREAD

Reads input for input modification

Variables in Argument List

NAME(8)	CHAR*1	name of input variable
VALUE	REAL*4	value of input variable

Local Variables

BLK	CHAR*1	' '
CARD(80)	CHAR*1	card image
CEND(3)	CHAR*1	'E','N','D'
COMMA	CHAR*1	','
DCARD	CHAR*80	card image
E	CHAR*1	'E'
FRACT	REAL*4	fractional part of number
I	INTEGER*2	do loop index
ICOUNT	INTEGER*2	position counter
ID	INTEGER*2	position counter
II	INTEGER*2	position counter
J	INTEGER*2	do loop index
JJ	INTEGER*2	position counter
LE	CHAR*1	'e'
LEND(3)	CHAR*1	'e','n','d'
MINUS	CHAR*1	'-'
NUMBER(10)	CHAR*1	'0','1','2','3','4','5','6','7','8','9'
PERIOD	CHAR*1	'.'
PLUS	CHAR*1	'+'
POUND	CHAR*1	'#'
QUEST	CHAR*1	'?'
SIGN	REAL*4	sign of number or exponent
WHOLE	REAL*4	whole part of number

7.0 Program Listing

```
C
C      PROGRAM SSFREQ  03-24-92
C
C                 Intermediate Mode Oscillations
C                   Modified for n vs tau plots
C
C        This program will handle the following type elements
C
C               Straight pipes
C               Bends
C               Inline accumulators
C               Tuned stub accumulators
C               Helmholtz resonators
C               Parallel resonators
C               Pumps
C               Split pipes
C               Multiple tanks
C               Multiple engines
C
$LARGE
      COMPLEX S,X1,Y1,Z1,W1,M1,P0,P1,U0,U1,GF,GOX,RFH,RFK,RFP,RFA,RFC
      COMPLEX PP,UP,SIGP,FUNB,CVAR(17)
      COMPLEX GFA(25),GOXA(25)
      CHARACTER*1 ANS
      CHARACTER*2 AM,PM,AP
      CHARACTER*8 VARP(3),RADHER(2)
      CHARACTER*24 ROCIN,ROCVAR,NAMENG
      CHARACTER*40 TITLF
      CHARACTER*60 TITLE
      INTEGER*2 IHR,IMIN,ISEC,I100,IYR,IMON,IDAY
      REAL FREQ(50),TAULST(50),MBAR,N,NR,LAMDA,MU,RVAR(13),NA(25)
      COMMON /WORK/YP(50,50),YPA(50,50)
      COMMON /CMPVAL/X1,Y1,Z1,W1,M1,P0,P1,U0,U1,RFH,RFK,RFP,
     *               S,GF,GOX,RFA,RFC
      COMMON /RELVAL/N,TAU,DTAU,NR,RBAR,MBAR,GAMMA,P00,DHLDR,CSTAR,
     *        DCSDR,RHOLO,ULO,LAMDA,MU,TAUT,UBAR(50),XBAR(50),XLC
      COMMON /RESULT/PP,UP,SIGP,FUNB
      COMMON /INTVAL/NVAL
      COMMON /DIMVAL/HOLDD(20),XBARD(50),PBAR(50),TBAR(50)
      COMMON /TITL/TITLE,TITLF,IHR,IMIN,AP,IYR,IMON,IDAY
      COMMON /SFACT/SFAC
      COMMON /EPARAM/MENG,TFLOW(25),PCHMB(25),DPROR(25),PMRAT(25)
      EQUIVALENCE (N,RVAR(1)),(X1,CVAR(1))
      DATA RADHER/' rad/sec',' Hertz  '/
      DATA AM/'AM'/,PM/'PM'/
      DATA VARP/'    n   ','tau(sec)','   MU   '/
      DATA TOL/.0001/
      DATA NOT/50/,NOF/50/
      DATA IFREQ/0/,ITAU/0/
    1 FORMAT(/' Eng. No.',3X,A8,5X,A8,5X,' FUNB(R)',5X,' FUNB(I)'/)
```

```
2 FORMAT(3X,I2,4X,1P4E13.5)
3 FORMAT(/'  FREQUENCY =',1PE13.5,A)
  CALL GETTIM(IHR,IMIN,ISEC,I100)
  CALL GETDAT(IYR,IMON,IDAY)
  IYR=IYR-1900
  IF(IHR.LT.12)  THEN
   AP=AM
  ELSE
   AP=PM
   IF(IHR.GT.12)  IHR=IHR-12
  ENDIF
  CALL QCLEAR(0,7)
  WRITE(*,'(10X,A)')
 *'╔═══════════════════════════════════════════════════════════════════════╗'
  WRITE(*,'(10X,A)')
 *'║                                                                       ║'
  WRITE(*,'(10X,A)')
 *'║       Welcome to SSFREQ - an Intermediate Mode Program                ║'
  WRITE(*,'(10X,A)')
 *'║                                                                       ║'
  WRITE(*,'(10X,A)')
 *'║                    To send a plot to the printer                      ║'
  WRITE(*,'(10X,A)')
 *'║                                                                       ║'
  WRITE(*,'(10X,A)')
 *'║              The computer MUST be in GRAPHICS mode                    ║'
  WRITE(*,'(10X,A)')
 *'║                                                                       ║'
  WRITE(*,'(10X,A)')
 *'║      Hit PrScn to send the current plot to the printer                ║'
  WRITE(*,'(10X,A)')
 *'║                                                                       ║'
  WRITE(*,'(10X,A)')
 *'╚═══════════════════════════════════════════════════════════════════════╝'
  SFAC=1.0
  WRITE(*,*)' '
  WRITE(*,'(A)')' If you want frequency in rad/sec, hit enter.'
  WRITE(*,'(A\)')' If you want it in Hertz, enter "H". '
  READ(*,'(A)')ANS
  IF(ANS.EQ.'H'.OR.ANS.EQ.'h')  SFAC=6.283185
  OPEN(17,FORM='UNFORMATTED')
  OPEN(20,FORM='UNFORMATTED')
  WRITE(*,'(A\)')' Is the engine data on file ENG.RLN? (Y/N) '
  READ(*,'(A)')ANS
  IF(ANS.NE.'N'.AND.ANS.NE.'n')  THEN
   NAMENG='ENG.RLN'
  ELSE
   WRITE(*,'(A\)')'  Enter name of file with the engine data '
   READ(*,'(A)')NAMENG
  ENDIF
  OPEN(UNIT=9,FILE=NAMENG)
  JUNIT=9
  CALL ENGNO(JUNIT)
```

```
      IGONE=2
      CALL FUEL(S,GFA,11,16,IGONE)
      IGONE=2
      CALL LOX(S,GOXA,10,15,IGONE)
      IGONE=0
      WRITE(*,*)' '
      WRITE(*,'(A\)')' Are you are using IMODE.RLN for input data? '
      READ(*,'(A)')ANS
      IF(ANS.NE.'N'.AND.ANS.NE.'n')  THEN
       ROCIN='IMODE.RLN'
      ELSE
       WRITE(*,'(A\)')'  Enter name of file containing input '
       READ(*,'(A)')ROCIN
      ENDIF
      OPEN(12,FILE=ROCIN)
      OPEN(14,FILE='IMODE.OUT')
      XLC=1.0
      WRITE(*,*)' '
      WRITE(*,*)' '
      WRITE(*,*)' '
      WRITE(*,*)' '
      WRITE(*,*)' '
      WRITE(*,*)' '
      WRITE(*,*)'                    Welcome to SSFREQ'
      WRITE(*,*)' '
      WRITE(*,*)'          Intermediate Mode Rocket Stability Aide'
      WRITE(*,*)' '
      WRITE(*,*)'  There are three types of input, rocket parameters,'
      WRITE(*,*)'  Oxidizer feed parameters, and fuel feed parameters,'
      WRITE(*,*)'   Each may be read from files or from the keyboard'
      WRITE(*,*)' '
      WRITE(*,*)'          File Name                  Input'
      WRITE(*,*)' '
      WRITE(*,*)'    IMODE.RLN or NAME read in   Rocket Parameters  '
      WRITE(*,*)'          LOX.RLN               Oxidizer Parameters'
      WRITE(*,*)'          FUEL.RLN              Fuel Parameters    '
      WRITE(*,*)' '
      WRITE(*,*)' If keyboard entry, you will be prompted for values'
      GO TO 22
   21 CONTINUE
      WRITE(*,*)' '
      WRITE(*,'(A\)')' Do you want to run another case? Enter Y or N '
      READ(*,'(A)')ANS
      IF(ANS.EQ.'N'.OR.ANS.EQ.'n')  STOP
      WRITE(*,'(A\)')' Do you wish to rewind engine file? '
      READ(*,'(A)')ANS
      IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')  REWIND JUNIT
      CALL ENGNO(JUNIT)
      IGONE=1
      CALL FUEL(S,GFA,11,16,IGONE)
      IGONE=1
      CALL LOX(S,GOXA,10,15,IGONE)
      IGONE=0
```

```
      IF(IFREQ.NE.0)  THEN
       WRITE(*,'(A\)')' Do you wish to rewind frequency file? '
       READ(*,'(A)')ANS
       IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')  REWIND 19
      ENDIF
      IF(ITAU.NE.0)  THEN
       WRITE(*,'(A\)')' Do you wish to rewind tau file? '
       READ(*,'(A)')ANS
       IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')  REWIND 18
      ENDIF
   22 CONTINUE
      CALL READIN
      WRITE(*,*)' '
   23 CONTINUE
      WRITE(*,*)' Specify how frequency will be input -'
      WRITE(*,*)'   Enter R for a range of values'
      WRITE(*,*)'   Enter F for values in a file'
      WRITE(*,*)'   Enter K (end with -999) to enter values ',
     *          'from keyboard'
      READ(*,'(A)')ANS
      IF(ANS.EQ.'R'.OR.ANS.EQ.'r')  THEN
   24 CONTINUE
       IF(SFAC.EQ.1.0)  THEN
        WRITE(*,*)' Enter first and last values of frequency ',
     *          'in rad/sec and no. of points.'
       ELSE
        WRITE(*,*)' Enter first and last values of frequency ',
     *          'in hertz and no. of points.'
       ENDIF
       READ(*,*)STARTF,STOPF,NPTF
       IF(STARTF.EQ.0.0.AND.STOPF.EQ.0.0.AND.NPTF.EQ.0)  GO TO 21
       IF(NPTF.GT.NOF)  THEN
        WRITE(*,*)' No. of points must be <',NOF
        GO TO 24
       ENDIF
       IF(STOPF.EQ.0.0)  STOPF=STARTF
       IF(NPTF.EQ.0)  NPTF=1
       IF(NPTF.EQ.1) THEN
        DELF=0.0
       ELSE
        DELF=(STOPF-STARTF)/(NPTF-1)
       ENDIF
       DO 25 I=1,NPTF
       FREQ(I)=STARTF+DELF*(I-1)
   25  CONTINUE
       GO TO 27
      ENDIF
      IF(ANS.EQ.'F'.OR.ANS.EQ.'f')  THEN
       IFREQ=1
       WRITE(*,*)' Is the frequency on IMODE.FRQ?'
       WRITE(*,'(A\)')'        Enter Y or N '
       READ(*,'(A)')ANS
       IF(ANS.NE.'N'.AND.ANS.NE.'n')  THEN
```

```
      OPEN(19,FILE='IMODE.FRQ')
     ELSE
      WRITE(*,'(A\)')' Enter name of file for frequency '
      READ(*,'(A)')ROCVAR
      OPEN(19,FILE=ROCVAR)
     ENDIF
     READ(19,*)NPTF
     IF(NPTF.GT.NOF)  THEN
      WRITE(*,*)' Too many points for program'
      GO TO 23
     ENDIF
     READ(19,*)(FREQ(I),I=1,NPTF)
     GO TO 27
    ENDIF
    IF(ANS.EQ.'K'.OR.ANS.EQ.'k')  THEN
     NPTF=0
26   CONTINUE
     READ(*,*)VAR1
     IF(VAR1.EQ.-999)  GO TO 27
     NPTF=NPTF+1
     FREQ(NPTF)=VAR1
     IF(NPTF.EQ.NOF)  GO TO 27
     GO TO 26
    ELSE
     WRITE(*,*)'  R, F, or K not entered, try again!'
     GO TO 23
    ENDIF
27  CONTINUE
    WRITE(*,*)' Specify how tau will be input -'
    WRITE(*,*)'   Enter R for a range of values'
    WRITE(*,*)'   Enter F for values in a file'
    WRITE(*,*)'   Enter K to enter values from keyboard'
    READ(*,'(A)')ANS
    IF(ANS.EQ.'R'.OR.ANS.EQ.'r')  GO TO 28
    IF(ANS.EQ.'F'.OR.ANS.EQ.'f')  GO TO 30
    IF(ANS.EQ.'K'.OR.ANS.EQ.'k')  GO TO 31
    WRITE(*,*)'  R, F, or K not entered, try again!'
    GO TO 27
28  CONTINUE
    WRITE(*,*)' Enter first and last values of tau ',
   *          'and no. of points.'
    READ(*,*)STARTV,STOPV,NPTS
    IF(NPTS.GT.NOT)  THEN
     WRITE(*,*)' No. of points must be <',NOT
     GO TO 28
    ENDIF
    IF(STOPV.EQ.0.0)  STOPV=STARTV
    IF(NPTS.EQ.0)  NPTS=1
    IF(NPTS.EQ.1) THEN
     DELVAL=0.0
    ELSE
     DELVAL=(STOPV-STARTV)/(NPTS-1)
    ENDIF
```

```
      DO 29 I=1,NPTS
       TAULST(I)=STARTV+(I-1)*DELVAL
   29 CONTINUE
      GO TO 33
   30 CONTINUE
      ITAU=1
      WRITE(*,*)' Is tau on IMODE.TAU?'
      WRITE(*,'(A\)')'        Enter Y or N '
      READ(*,'(A)')ANS
      IF(ANS.NE.'N'.AND.ANS.NE.'n')  THEN
       OPEN(18,FILE='IMODE.TAU')
      ELSE
       WRITE(*,'(A\)')'  Enter name of file for tau '
       READ(*,'(A)')ROCVAR
       OPEN(18,FILE=ROCVAR)
      ENDIF
      READ(18,*)NPTS
      IF(NPTS.GT.NOT)  THEN
       WRITE(*,*)' Too many points for program'
       GO TO 27
      ENDIF
      READ(18,*)(TAULST(I),I=1,NPTS)
      GO TO 33
   31 CONTINUE
      NPTS=0
   32 CONTINUE
      WRITE(*,'(A\)')
     *  ' Enter new value for tau (-999 to stop) '
      READ(*,*,END=99)VAR1
      IF(VAR1.EQ.-999.0)  GO TO 33
      NPTS=NPTS+1
      TAULST(I)=VAR1
      IF(NPTS.EQ.NOT)  GO TO 33
      GO TO 32
   33 CONTINUE
      DO 34 K=1,MENG
       NA(K)=1.0
   34 CONTINUE
      REWIND 17
      DO 38 J=1,NPTF
      WRITE(14,'(1X,A)')TITLE
      IF(SFAC.EQ.1.0)  THEN
       WRITE(14,3)FREQ(J),RADHER(1)
       WRITE(*,3)FREQ(J),RADHER(1)
      ELSE
       WRITE(14,3)FREQ(J),RADHER(2)
       WRITE(*,3)FREQ(J),RADHER(2)
      ENDIF
      WRITE(14,1)VARP(2),VARP(1)
      WRITE(*,1)VARP(2),VARP(1)
       VARF=SFAC*FREQ(J)
       CALL SETVAR(VARF,6)
       CALL FUEL(S,GFA,11,16,IGONE)
```

```
      CALL LOX(S,GOXA,10,15,IGONE)
      DO 36 I=1,NPTS
       VART=TAULST(I)
       REWIND 20
       DO 35 K=1,MENG
        GF=GFA(K)
        GOX=GOXA(K)
        READ(20)HOLDD,XBARD,PBAR,TBAR
        CALL SETVAR(VARF,6)
        CALL SETVAR(VART,2)
        CALL SETVAR(NA(K),1)
        CALL ITER(1,TOL)
        NA(K)=HOLDD(1)
        YP(I,K)=HOLDD(1)
        WRITE(14,2)K,HOLDD(2),HOLDD(1),FUNB
        WRITE(*,2)K,HOLDD(2),HOLDD(1),FUNB
35     CONTINUE
36    CONTINUE
      WRITE(17)YP
      WRITE(*,'(A\)')
     *        ' Do you wish to see n vs tau for this frequency? '
      READ(*,'(A)')ANS
      IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')  THEN
       IF(MENG.EQ.1)  THEN
        CALL PLTVAR(TAULST,YP(1,1),NPTS,VARP(2),VARP(1),FREQ(J),1)
       ELSE
37      CONTINUE
        WRITE(*,'(A)')' Specify which engine you wish to view'
        WRITE(*,'(A,I3,A\)')' Enter 1 -',MENG,' or 0 to continue '
        READ(*,*)K
        IF(K.LT.0.OR.K.GT.MENG)  THEN
         WRITE(*,*)' Invalid engine number, try again!'
         GO TO 37
        ELSEIF(K.NE.0)  THEN
         CALL PLTVAR(TAULST,YP(1,K),NPTS,VARP(2),VARP(1),FREQ(J),K)
         GO TO 37
        ENDIF
       ENDIF
      ENDIF
38  CONTINUE
     DO 41 K=1,MENG
      REWIND 17
      DO 40 J=1,NPTF
       READ(17)YPA
       DO 39 I=1,NPTS
        YP(I,J)=YPA(I,K)
39     CONTINUE
40    CONTINUE
      CALL PLTALL(TAULST,YP,NOT,NOF,NPTS,NPTF,VARP(2),VARP(1),FREQ,K)
41  CONTINUE
     GO TO 21
99  CONTINUE
     STOP
```

```
      END
      SUBROUTINE ADMIT(S,GADM,A,AREA,CMAN,CTANK,DPROR,L,LFLOW,PMRAT,
     *                 SEGMN,SECTN,SPLIT,LOPEND,PCAP,PIND,IENG,TFLOW,
     *                 NOLINE,IP,ITLIN)
C       Determines admittance looking toward tank
      CHARACTER*40 TITLE
      CHARACTER*20 TITLF
      INTEGER*2 IHR,IMIN,IYR,IMON,IDAY
      CHARACTER*2 AP
      COMMON /WCATIT/TITLE,TITLF,IHR,IMIN,AP,IYR,IMON,IDAY
      INTEGER SEGMN(25),SECTN(75,25)
      INTEGER IENG(25),NOLINE(25)
      REAL AREA(75,25),PCAP(75,25),PIND(75,25),L(75,25),LFLOW,ZO(75,25),
     *     CMAN(25),DPROR(25),PMRAT(25),ZOR(25),TFLOW(25)
      COMPLEX G(0:75,25),ZT(0:75,25),ZG(0:75,25),GOLD(0:75,25),GADM(25),
     *        S,ZGEFF,ZTEFF
      COMMON /WORK1/G,ZT,ZG
      COMMON /WORK2/ZO
      COMMON /SFACT/SFAC
      COMPLEX CTANH,RHS,CFAC,CAPN,CAPM
      CHARACTER*13 TYPEL(2)
      DATA TYPEL/' in FUEL line',' in LOX  line'/
      DATA GRAV/32.2/
      DATA IOPEN/0/
      ZTOP=A/GRAV
        TMASS=0.0
        TCOUNT=0.0
      DO 22 J=IP,IP+SPLIT
       GOLD(0,J)=0.0
       SECTN(SEGMN(J)+1,J)=0
       DO 21 I=1,SEGMN(J)
        GOLD(I,J)=0.0
        ZO(I,J)=0.0
        IF(SECTN(I,J).LE.2)  THEN
         ZO(I,J)=ZTOP/AREA(I,J)
        ELSEIF(SECTN(I,J).EQ.7)  THEN
         ZO(I,J)=0.0
        ELSE
         ZO(I,J)=SQRT(PIND(I,J)/PCAP(I,J))
        ENDIF
   21  CONTINUE
       IF(IENG(J).NE.0)  THEN
        IE=IENG(J)
        ZOR(J)=2.0*DPROR(IE)/LFLOW
        IF(J.EQ.IP.AND.SPLIT.EQ.0.0)  THEN
         TMASS=TFLOW(IE)
        ELSEIF(J.NE.IP)  THEN
         TMASS=TMASS+NOLINE(J)*TFLOW(IE)
         TCOUNT=TCOUNT+NOLINE(J)
        ENDIF
       ENDIF
   22 CONTINUE
      IF(TCOUNT.EQ.0.0)  TCOUNT=1.0
```

```
      G(0,IP)=CTANK*S
      G(0,IP)=G(0,IP)/TCOUNT
      ZT(0,IP)=1.0/G(0,IP)
      DO 31 KLOOP=1,LOPEND
       DO 25 J=IP,IP+SPLIT
        IF(J.NE.IP)  THEN
         G(0,J)=G(SEGMN(IP),IP)
         ZT(0,J)=1.0/G(0,J)
        ENDIF
        DO 24 I=1,SEGMN(J)
         ZGEFF=G(I-1,J)
         IF(SECIN(I,J).LE.1)  THEN
C             bend in pipe or straight section
          TL=L(I,J)/A
          IF(KLOOP.NE.1.AND.SPLIT.NE.0.AND.J.NE.IP.AND.I.EQ.1)  THEN
           ZGEFF=0.0
           DO 23 K=IP+1,IP+SPLIT
            IE=IENG(K)
            IF(K.EQ.J)  THEN
             ZGEFF=ZGEFF+(NOLINE(K)-1.0)/ZG(0,K)
            ELSE
             ZGEFF=ZGEFF+NOLINE(K)/ZG(0,K)
            ENDIF
   23       CONTINUE
            ZGEFF=G(SEGMN(IP),IP)+ZGEFF
          ENDIF
          G(I,J)=(1.0+CTANH(S*TL)/(ZGEFF*ZO(I,J)))/(1.0+ZGEFF*
     *           ZO(I,J)*CTANH(S*TL))
         ELSEIF(SECIN(I,J).EQ.2)  THEN
C             inline resonator
          G(I,J)=1.0+PCAP(I,J)*S/ZGEFF
         ELSEIF(SECIN(I,J).EQ.3)  THEN
C             tuned stub
          G(I,J)=1.0+CTANH(S*SQRT(PIND(I,J)*PCAP(I,J)))/(ZO(I,J)*
     *           ZGEFF)
         ELSEIF(SECIN(I,J).EQ.4)  THEN
C             helmholtz resonator
          G(I,J)=1.0+S*PCAP(I,J)/(1.0+PIND(I,J)*PCAP(I,J)*S**2)/ZGEFF
         ELSEIF(SECIN(I,J).EQ.5)  THEN
C             parallel resonator
          G(I,J)=PIND(I,J)*PCAP(I,J)*S**2+1.0
          G(I,J)=G(I,J)/(G(I,J)+PIND(I,J)*S*ZGEFF)
         ELSEIF(SECIN(I,J).EQ.6)  THEN
C             pump
          G(I,J)=(1.0+PCAP(I,J)*S/ZGEFF)/(1.0+(PIND(I,J)*S+
     *            AREA(I,J))*(PCAP(I,J)*S+ZGEFF))
         ELSEIF(SECIN(I,J).EQ.7)  THEN
          G(SEGMN(J),J)=1.0+CMAN(J)*S/ZGEFF
         ENDIF
         G(I,J)=G(I,J)*ZGEFF
         ZT(I,J)=1.0/G(I,J)
   24   CONTINUE
        IF(SPLIT.NE.0.0.AND.J.EQ.IP)  GO TO 25
```

```
      G(SEGMN(J)+1,J)=1.0/(1.0+ZOR(J)*G(SEGMN(J),J))
      G(SEGMN(J)+1,J)=G(SEGMN(J)+1,J)*G(SEGMN(J),J)
25    CONTINUE
      IF(LOPEND.EQ.1.OR.SPLIT.EQ.0.0)  GO TO 31
      DO 28 J=IP+SPLIT,IP,-1
       IF(J.EQ.IP)  THEN
        LOPHI=SEGMN(J)
       ELSE
        ZG(SEGMN(J)-1,J)=ZOR(J)/(ZOR(J)*CMAN(J)*S+1.0)
        LOPHI=SEGMN(J)-2
       I=LOPHI+1
       ENDIF
       IF(LOPHI.NE.0)  THEN
        DO 27 I=LOPHI,1,-1
         IF(I.EQ.LOPHI.AND.J.EQ.IP)  THEN
          ZG(I,J)=0.0
          ZTEFF=ZT(I-1,J)
          DO 26 K=IP+1,IP+SPLIT
           ZGEFF=ZG(1,K)
           ZOEFF=ZO(1,K)
           ZLP=L(1,K)
           TL=(L(I,J)+ZLP)/A
           CAPN=(ZOEFF-ZTEFF)/(ZOEFF+ZTEFF)
           CAPM=(ZOEFF-ZGEFF)/(ZOEFF+ZGEFF)
           CFAC=CEXP(-2.0*S*TL)
           RHS=(ZOEFF+ZGEFF)*(1.0-CAPN*CAPM*CFAC)*CEXP(S*ZLP/A)
           CFAC=CAPN*CFAC*CEXP(2.0*S*ZLP/A)
           ZG(0,K)=(RHS-ZOEFF*(1.0-CFAC))/(1.0+CFAC)
           ZG(I,J)=ZG(I,J)+NOLINE(K)/ZG(0,K)
26        CONTINUE
          ZG(I,J)=1.0/ZG(I,J)
         ELSE
          ZGEFF=ZG(I+1,J)
          ZOEFF=ZO(I+1,J)
          ZLP=L(I+1,J)
          ZTEFF=ZT(I-1,J)
          IF(SECIN(I+1,J).LE.1)  THEN
C            bend in pipe or straight section
           TL=(L(I,J)+ZLP)/A
           CAPN=(ZOEFF-ZTEFF)/(ZOEFF+ZTEFF)
           CAPM=(ZOEFF-ZGEFF)/(ZOEFF+ZGEFF)
           CFAC=CEXP(-2.0*S*TL)
           RHS=(ZOEFF+ZGEFF)*(1.0-CAPN*CAPM*CFAC)*CEXP(S*ZLP/A)
           CFAC=CAPN*CFAC*CEXP(2.0*S*ZLP/A)
           ZG(I,J)=(RHS-ZOEFF*(1.0-CFAC))/(1.0+CFAC)
          ELSEIF(SECIN(I+1,J).EQ.2)  THEN
C            inline resonator
           ZG(I,J)=ZGEFF/(ZGEFF*PCAP(I+1,J)*S+1.0)
          ELSEIF(SECIN(I+1,J).EQ.3)  THEN
C            tuned stub
           ZG(I,J)=ZOEFF/CTANH(S*SQRT(PIND(I+1,J)*PCAP(I+1,J)))
           ZG(I,J)=(ZG(I,J)*ZGEFF)/(ZG(I,J)+ZGEFF)
          ELSEIF(SECIN(I+1,J).EQ.4)  THEN
```

```
C            helmholtz resonator
             ZG(I,J)=(1.0+PIND(I+1,J)*PCAP(I+1,J)*S**2)/(PCAP(I+1,J)*S)
             ZG(I,J)=(ZG(I,J)*ZGEFF)/(ZG(I,J)+ZGEFF)
            ELSEIF(SECIN(I+1,J).EQ.5)  THEN
C            parallel resonator
             ZG(I,J)=ZGEFF+PIND(I+1,J)*S/(PIND(I+1,J)*PCAP(I+1,J)*S**2+
     *              1.0)
            ELSEIF(SECIN(I+1,J).EQ.6)  THEN
C            pump
             ZG(I,J)=ZGEFF+PIND(I+1,J)*S-AREA(I+1,J)
             ZG(I,J)=ZG(I,J)/(1.0+ZG(I,J)*PCAP(I+1,J)*S)
            ENDIF
           ENDIF
   27     CONTINUE
         ENDIF
   28    CONTINUE
         ERRP=0.0
         DO 30 J=IP,IP+SPLIT
          DO 29 I=1,SEGMN(J)
           GDIF=CABS(GOLD(I,J))
           IF(GDIF.NE.0.0)  GDIF=ABS(GDIF-CABS(G(I,J)))/GDIF
           IF(GDIF.GT.ERRP)  THEN
            ERRP=GDIF
            WG=CABS(G(I,J))
            WGOLD=CABS(GOLD(I,J))
            IWG=I
            JWG=J
           ENDIF
           GOLD(I,J)=G(I,J)
   29     CONTINUE
   30    CONTINUE
         IF(KLOOP.GT.1.AND.ERRP.LT.0.001)  GO TO 32
   31  CONTINUE
         IF(LOPEND.EQ.1)  GO TO 32
         IF(IOPEN.EQ.0)  THEN
          OPEN(UNIT=13,FILE='SURF.ERR')
          WRITE(13,*)' '
          WRITE(13,*)' '
          WRITE(13,*)TITLE
          WRITE(13,*)' '
          IOPEN=1
         ENDIF
         WRITE(13,'('' jw ='',F8.1,''  after'',I3,'' iterations'',
     *            '' has error of'',F8.3,''% '',A)')
     *           AIMAG(S)/SFAC,LOPEND,100.0*ERRP,TYPEL(ITLIN)
        WRITE(13,'(10X,'' I='',I3,3X,''J='',I3,3X,''|G|='',1PE12.4,3X,
     *           ''|GOLD|='',E12.4)')IWG,JWG,WG,WGOLD
   32  CONTINUE
       DO 35 J=IP,IP+SPLIT
        IF(IENG(J).EQ.0)  THEN
         RATPM=0.0
         DO 33 I=IP+1,IP+SPLIT
          RATPM=RATPM+PMRAT(IENG(I))*NOLINE(I)
```

```
   33   CONTINUE
        RATPM=RATPM/TCOUNT
        LOPHI=SEGMN(J)
       ELSE
        RATPM=PMRAT(IENG(J))
        IF(NOLINE(J).NE.0) RATPM=RATPM*NOLINE(J)
        LOPHI=SEGMN(J)+1
       ENDIF
       DO 34 I=0,LOPHI
        G(I,J)=RATPM*G(I,J)
   34  CONTINUE
       IF(IENG(J).EQ.0)  GO TO 35
       IEE=IENG(J)
       GADM(IEE)=GADM(IEE)+G(LOPHI,J)
   35 CONTINUE
      RETURN
      END
      SUBROUTINE BENDS(PIPE1,PIPE2,PIPE3,PIPE4,VALUE,DIME)
C       Computes effective straight pipe for bend
      REAL LBEND
      LBEND=0.0174533*PIPE1*ABS(PIPE2)
      RATIO=(PIPE1-0.5*PIPE3)/(PIPE1+0.5*PIPE3)
      CALL GINERT(ABS(PIPE2),RATIO,Y)
      GAMMA=(LBEND+Y*PIPE3)/LBEND
      VALUE=GAMMA*(LBEND+2.0*PIPE4)
      DIME=PIPE3/(GAMMA)**0.25
      RETURN
      END
      SUBROUTINE BOUND(PP,UP,SIGP,FUNB)
C       Evaluates the boundary function
      COMMON /CMPVAL/X1,Y1,Z1,W1,M1,P0,P1,U0,U1,RFH,RFK,RFP,
     *               S,GF,GOX,RFA,RFC
      COMMON /RELVAL/N,TAU,DTAU,NR,RBAR,MBAR,GAMMA,P00,DHLDR,CSTAR,
     *        DCSDR,RHOLO,ULO,LAMDA,MU,TAUT,UBAR(50),XBAR(50),XLC
      COMMON /INTVAL/NVAL
      REAL MBAR,N,NR,LAMDA,MU
      COMPLEX S,X1,Y1,Z1,W1,M1,P0,P1,U0,GF,GOX,U1,RFH,RFK,RFP,RFA,RFC
      COMPLEX FP1,FU1,FSIGP,PP,UP,SIGP,FUNB,CSINH,CCOSH
      P1=FP1(XLC)
      U1=FU1(XLC)
      P0=P00*CCOSH(S*XLC)
      U0=-(1.0/GAMMA)*P00*CSINH(S*XLC)
      PP=P0+P1
      UP=U0+U1
      SIGP=FSIGP(XLC)
      FUNB=UP+RFA*PP+RFC*SIGP
      RETURN
      END
      COMPLEX FUNCTION CCOSH(S)
C       Evaluates the complex hyperbolic cosine
      COMPLEX S
      REAL LAMDA, MU
      LAMDA=REAL(S)
```

```
      MU=AIMAG(S)
      COSHR=COSH(LAMDA)*COS(MU)
      COSHI=SINH(LAMDA)*SIN(MU)
      CCOSH=CMPLX(COSHR,COSHI)
      RETURN
      END
      COMPLEX FUNCTION CSINH(S)
C       Evaluates the complex hyperbolic sine
      COMPLEX S
      REAL LAMDA, MU
      LAMDA=REAL(S)
      MU=AIMAG(S)
      SINHR=SINH(LAMDA)*COS(MU)
      SINHI=COSH(LAMDA)*SIN(MU)
      CSINH=CMPLX(SINHR,SINHI)
      RETURN
      END
      COMPLEX FUNCTION CTANH(S)
C       Evaluates the complex hyperbolic tangent
      COMPLEX S,CTANN,CTAND,CSINH,CCOSH
      CTANN=CSINH(S)
      CTAND=CCOSH(S)
      CTANH=(0.0,0.0)
      IF(CTAND.NE.0.0)  CTANH=CTANN/CTAND
      RETURN
      END
      SUBROUTINE ENGNO(IUNIT)
C       Reads engine parameters
      COMMON /EPARAM/MENG,TFLOW(25),PCHMB(25),DPROR(25),PMRAT(25)
      READ(IUNIT,*)MENG
      IF(MENG.GT.25)  THEN
       WRITE(*,*)'  Number of engines must be less than 25'
       STOP
      ENDIF
      IF(MENG.LE.0)  MENG=1
      DO 21 I=1,MENG
       READ(IUNIT,*)TFLOW(I),PCHMB(I),DPROR(I)
       PMRAT(I)=PCHMB(I)/TFLOW(I)
   21 CONTINUE
      RETURN
      END
      SUBROUTINE EVAL(X)
C       Evaluates parameters at a given x location
      COMMON /CMPVAL/X1,Y1,Z1,W1,M1,P0,P1,U0,U1,RFH,RFK,RFP,
     *               S,GF,GOX,RFA,RFC
      COMMON /RELVAL/N,TAU,DTAU,NR,RBAR,MBAR,GAMMA,P00,DHLDR,CSTAR,
     *        DCSDR,RHOLO,ULO,LAMDA,MU,TAUT,UBAR(50),XBAR(50),XLC
      COMMON /INTVAL/NVAL
      REAL MBAR,N,NR,LAMDA,MU
      COMPLEX S,X1,Y1,Z1,W1,M1,P0,P1,U0,U1,GF,GOX,RFH,RFK,RFP,RFA,RFC
      COMPLEX CSINH,CCOSH
      IF(NVAL.EQ.1)  THEN
       UB=UBAR(1)
```

```
      GO TO 23
     ENDIF
     DO 21 I=2,NVAL
      IF(X.LE.XBAR(I))  GO TO 22
   21 CONTINUE
     UB=UBAR(NVAL)
     GO TO 23
   22 CONTINUE
     FAC=(X-XBAR(I-1))/(XBAR(I)-XBAR(I-1))
     UB=UBAR(I-1)+FAC*(UBAR(I)-UBAR(I-1))
   23 CONTINUE
     RFH=(1.0+RBAR)*((RBAR/CSTAR)*DCSDR-NR*S*TAU)*(GOX
    *     -RBAR*GF)/RBAR
     RFK=(1.0+S*TAUT)*(GOX+GF)
     RFP=N*(1.0-CEXP(S*TAU))
     P0=P00*CCOSH(S*X)
     U0=-(1.0/GAMMA)*P00*CSINH(S*X)
     X1=(GAMMA-1.0)*UB*U0+(1.0+RBAR)*DHLDR*(MBAR/S)
    *    *CEXP(-S*TAUT)*(GOX-RBAR*GF)*P00
     Y1=-UB*P0
     Z1=(1.0/GAMMA)*UB*P0+RHOLO*ULO
     W1=2.0*UB*U0
     M1=MBAR*(CEXP(-S*TAUT)*(RFK+RFH)*P00-RFP*P0)
     RETURN
     END
     COMPLEX FUNCTION FP1(XL)
C      Evaluates P1
     COMMON /CMPVAL/X1,Y1,Z1,W1,M1,P0,P1,U0,U1,RFH,RFK,RFP,
    *               S,GF,GOX,RFA,RFC
     COMMON /RELVAL/N,TAU,DTAU,NR,RBAR,MBAR,GAMMA,P00,DHLDR,CSTAR,
    *        DCSDR,RHOLO,ULO,LAMDA,MU,TAUT,UBAR(50),XBAR(50),XLC
     COMMON /INTVAL/NVAL
     REAL MBAR,N,NR,LAMDA,MU
     COMPLEX S,X1,Y1,Z1,W1,M1,P0,P1,U0,U1,GF,GOX,RFH,RFK,RFP,RFA,RFC
     COMPLEX CSINH,CCOSH
     COMPLEX VINT
     DX=XL/50.0
     FP1=CMPLX(0.0,0.0)
     DO 21 I=1,51
      X=(I-1)*DX
      CALL EVAL(X)
      VINT=(S*(W1-X1)+M1)*CSINH(S*(XL-X))
    *      +S*(Y1+Z1)*CCOSH(S*(XL-X))
      IF(I.EQ.1.OR.I.EQ.51)  THEN
       FP1=FP1+0.5*VINT*DX
      ELSE
       FP1=FP1+VINT*DX
      ENDIF
   21 CONTINUE
     FP1=-GAMMA*(W1+FP1)
     RETURN
      END
     COMPLEX FUNCTION FSIGP(XL)
```

```
C       Evaluates SIG'
        COMMON /CMPVAL/X1,Y1,Z1,W1,M1,P0,P1,U0,U1,RFH,RFK,RFP,
       *                S,GF,GOX,RFA,RFC
        COMMON /RELVAL/N,TAU,DTAU,NR,RBAR,MBAR,GAMMA,P00,DHLDR,CSTAR,
       *        DCSDR,RHOLO,ULO,LAMDA,MU,TAUT,UBAR(50),XBAR(50),XLC
        COMMON /INTVAL/NVAL
        REAL MBAR,N,NR,LAMDA,MU
        COMPLEX S,X1,Y1,Z1,W1,M1,P0,P1,U0,U1,GF,GOX,RFH,RFK,RFP,RFA,RFC
        REAL UB(51)
        COMPLEX VINT(51),VVINT(51),FSIG2,FCON
        DX=XL/50.0
        DO 23 I=1,51
         X=(I-1)*DX
         IF(NVAL.EQ.1)  THEN
          UB(I)=UBAR(1)
          GO TO 23
         ENDIF
         DO 21 II=2,NVAL
          IF(X.LE.XBAR(II))  GO TO 22
   21   CONTINUE
         II=NVAL
   22   CONTINUE
         FAC=(X-XBAR(II-1))/(XBAR(II)-XBAR(II-1))
         UB(I)=UBAR(II-1)+FAC*(UBAR(II)-UBAR(II-1))
   23   CONTINUE
        DO 24 I=1,51
         X=(I-1)*DX
         CALL EVAL(X)
         VINT(I)=((GAMMA-1.0)/GAMMA)*P0
         VVINT(I)=1.0/UB(I)
   24   CONTINUE
        FCON=(1.0+RBAR)*DHLDR*(GOX-RBAR*GF)*P00
       *     *CEXP(-S*TAUT)
        DO 26 I=1,51
         FSIG2=CMPLX(0.0,0.0)
         DO 25 J=I,51
          IF(J.EQ.I.OR.J.EQ.51)  THEN
           FSIG2=FSIG2+0.5*VVINT(J)*DX
          ELSE
           FSIG2=FSIG2+VVINT(J)*DX
          ENDIF
   25   CONTINUE
         FSIG2=CEXP(-S*FSIG2)
         VINT(I)=(VINT(I)+FCON)*MBAR*FSIG2
   26   CONTINUE
        FSIGP=CMPLX(0.0,0.0)
        DO 27 I=1,51
         IF(I.EQ.1.OR.I.EQ.51)  THEN
          FSIGP=FSIGP+0.5*VINT(I)*DX
         ELSE
          FSIGP=FSIGP+VINT(I)*DX
         ENDIF
   27   CONTINUE
```

```
      FSIGP=-FSIGP/UB(51)
      RETURN
      END
      SUBROUTINE FUEL(S,GF,IUNIT,IUNITP,IGONE)
C       Handles fuel piping logic
      COMPLEX GF(25),S
      COMMON /EPARAM/MENG,TFLOW(25),PCHMB(25),DPROR(25),PMRAT(25)
      INTEGER SEGMN(25),SECTN(75,25),NOLINE(25),IENG(25),ITANK(25),
     *        LOPOLD(25),LOPEND(25)
      REAL KMAN(25),KTANK(25),LFLOW(25),L(75,25)
      COMMON /FPARAM/MLINE,SPLIT(25),A(25),CMAN(25),CTANK(25),
     *               DENS(25),KMAN,KTANK,LFLOW,VOL(25),VOLMF(25),
     *               AREA(75,25),DIA(75,25),L,PIND(75,25),
     *               PCAP(75,25),AVGK(25),
     *               SEGMN,SECTN,NOLINE,IENG,ITANK,LOPOLD,LOPEND
      COMMON /FOPIPE/PIPE1(75,25),PIPE2(75,25),PIPE3(75,25),
     *              PIPE4(75,25),PIPE5(75,25)
      CHARACTER*24 FUELIN,NAMLIN(2)
      COMMON /WCAOUT/NAMLIN,IUNITH
      CHARACTER*1 ANS
      IF(IGONE.EQ.2) THEN
       WRITE(*,'(A\)')'  Is fuel line data in a file? (Y/N) '
       READ(*,'(A)')ANS
       IF(ANS.NE.'N'.AND.ANS.NE.'n')  THEN
        WRITE(*,'(A\)')' Is the file name FUEL.RLN? (Y/N) '
        READ(*,'(A)')ANS
        IF(ANS.NE.'N'.AND.ANS.NE.'n')  THEN
         OPEN(UNIT=IUNIT,FILE='FUEL.RLN')
         NAMLIN(1)='FUEL.RLN'
        ELSE
         WRITE(*,'(A\)')'  Enter name of file with fuel line data '
         READ(*,'(A)')FUELIN
         OPEN(IUNIT,FILE=FUELIN)
         NAMLIN(1)=FUELIN
        ENDIF
       ENDIF
       OPEN(IUNITP,FORM='UNFORMATTED')
      ENDIF
      IUNITH=IUNIT
      CALL FULOX(S,GF,SEGMN,SECTN,PIPE1,PIPE2,PIPE3,PIPE4,PIPE5,
     *  A,AREA,AVGK,CMAN,CTANK,DENS,DIA,IENG,IGONE,ITANK,
     *  IUNIT,IUNITP,KMAN,KTANK,L,LOPEND,LOPOLD,LFLOW,MLINE,NOLINE,PCAP,
     *  PIND,SPLIT,VOL,VOLMF,1)
      RETURN
      END
      SUBROUTINE FULOX(S,GF,SEGMN,SECTN,PIPE1,PIPE2,PIPE3,PIPE4,PIPE5,
     *  A,AREA,AVGK,CMAN,CTANK,DENS,DIA,IENG,IGONE,ITANK,
     *  IUNIT,IUNITP,KMAN,KTANK,L,LOPEND,LOPOLD,LFLOW,MLINE,NOLINE,PCAP,
     *  PIND,SPLIT,VOL,VOLMF,ITLIN)
C       Handles read, modify, and admittance calls for fuel and lox
      COMMON /EPARAM/MENG,TFLOW(25),PCHMB(25),DPROR(25),PMRAT(25)
      INTEGER SEGMN(25),SECTN(75,25),NOLINE(25),IENG(25),ITANK(25),
     *        LOPOLD(25),LOPEND(25)
```

```
      REAL KMAN(25),KTANK(25),LFLOW(25),L(75,25)
      REAL SPLIT(25),A(25),CMAN(25),CTANK(25),
     *               DENS(25),VOL(25),VOLMF(25),
     *               AREA(75,25),DIA(75,25),PIND(75,25),
     *               PCAP(75,25),AVGK(25)
      REAL PIPE1(75,25),PIPE2(75,25),PIPE3(75,25),
     *     PIPE4(75,25),PIPE5(75,25)
      COMPLEX GF(25),S
      CHARACTER*20 TITL
      CHARACTER*1 ANS
      CHARACTER*40 QUEST3(2)
      DATA QUEST3/' Do you wish to rewind fuel line file?  ',
     *            ' Do you wish to rewind lox line file?   '/
      IF(IGONE.EQ.2)  THEN
       CALL RLINE(TITL,SEGMN,SECIN,PIPE1,PIPE2,PIPE3,
     *  PIPE4,PIPE5,L,AREA,DIA,PIND,PCAP,LOPEND,LOPOLD,SPLIT,IUNIT,
     *  A,CMAN,CTANK,DENS,KMAN,KTANK,LFLOW,VOL,VOLMF,NOLINE,IENG,ITANK,
     *  AVGK,MLINE)
       REWIND IUNITP
       WRITE(IUNITP)PIPE1,PIPE2,PIPE3,PIPE4,PIPE5
      ELSEIF(IGONE.EQ.0)  THEN
       DO 21 I=1,MENG
        GF(I)=0.0
   21  CONTINUE
       IP=1
       DO 22 I=1,MLINE
        IT=ITANK(I)
        CALL ADMIT(S,GF,A(IT),AREA,CMAN,CTANK(IT),DPROR,
     *             L,LFLOW(IT),PMRAT,SEGMN,SECIN,
     *             SPLIT(I),LOPEND(I),PCAP,PIND,IENG,TFLOW,
     *             NOLINE,IP,ITLIN)
        IP=IP+SPLIT(I)+1
   22  CONTINUE
       RETURN
      ELSEIF(IGONE .EQ. 1)  THEN
        WRITE(*,'(A\)')QUEST3(ITLIN)
        READ(*,'(A)')ANS
        IF(ANS .EQ. 'Y' .OR. ANS .EQ. 'y')  REWIND IUNIT
        CALL RLINE(TITL,SEGMN,SECIN,PIPE1,PIPE2,PIPE3,
     *  PIPE4,PIPE5,L,AREA,DIA,PIND,PCAP,LOPEND,LOPOLD,SPLIT,IUNIT,
     *  A,CMAN,CTANK,DENS,KMAN,KTANK,LFLOW,VOL,VOLMF,NOLINE,IENG,ITANK,
     *  AVGK,MLINE)
        REWIND IUNITP
        WRITE(IUNITP)PIPE1,PIPE2,PIPE3,PIPE4,PIPE5
       IGONE=0
      ENDIF
      RETURN
      END
      COMPLEX FUNCTION FU1(XL)
C       Evaluates U1
      COMMON /CMPVAL/X1,Y1,Z1,W1,M1,P0,P1,U0,U1,RFH,RFK,RFP,
     *               S,GF,GOX,RFA,RFC
      COMMON /RELVAL/N,TAU,DTAU,NR,RBAR,MBAR,GAMMA,P00,DHLDR,CSTAR,
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     *        DCSDR,RHOLO,ULO,LAMDA,MU,TAUT,UBAR(50),XBAR(50),XLC
      COMMON /INTVAL/NVAL
      REAL MBAR,N,NR,LAMDA,MU
      COMPLEX S,X1,Y1,Z1,W1,M1,P0,P1,U0,U1,GF,GOX,RFH,RFK,RFP,RFA,RFC
      COMPLEX CSINH,CCOSH
      COMPLEX VINT
      DX=XL/50.0
      FU1=CMPLX(0.0,0.0)
      DO 21 I=1,51
       X=(I-1)*DX
       CALL EVAL(X)
       VINT=(S*(W1-X1)+M1)*CCOSH(S*(XL-X))
     *      +S*(Y1+Z1)*CSINH(S*(XL-X))
       IF(I.EQ.1.OR.I.EQ.51)  THEN
        FU1=FU1+0.5*VINT*DX
       ELSE
        FU1=FU1+VINT*DX
       ENDIF
   21 CONTINUE
      FU1=Y1+FU1
      RETURN
      END
      SUBROUTINE GINERT(BEND,X,Y)
C       Evaluates curve fit of inertance of bends
      DIMENSION B(3)
      DATA B/0.0,0.7877014E-02,-0.2814679E-04/
      A=B(1)+(B(2)+B(3)*BEND)*BEND
      Y=A*(X-1.0)**2
      RETURN
      END
      SUBROUTINE ITER(ID,TOL)
C       Iterates for dependent variable
      COMMON /CMPVAL/X1,Y1,Z1,W1,M1,P0,P1,U0,U1,RFH,RFK,RFP,
     *               S,GF,GOX,RFA,RFC
      COMMON /RELVAL/N,TAU,DTAU,NR,RBAR,MBAR,GAMMA,P00,DHLDR,CSTAR,
     *        DCSDR,RHOLO,ULO,LAMDA,MU,TAUT,UBAR(50),XBAR(50),XLC
      COMMON /INTVAL/NVAL
      COMMON /RESULT/PP,UP,SIGP,FUNB
      REAL MBAR,N,NR,LAMDA,MU,RVAR(13)
      COMPLEX S,X1,Y1,Z1,W1,M1,P0,P1,U0,U1,GF,GOX,RFH,RFK,RFP,RFA,RFC
      COMPLEX PP,UP,SIGP,FUNB,CVAR(17)
      EQUIVALENCE (N,RVAR(1)),(X1,CVAR(1))
      CALL SETVAL(VAL1,ID)
      CALL BOUND(PP,UP,SIGP,FUNB)
      FUN1=REAL(FUNB)
      IF(ABS(FUN1).LE.TOL)  GO TO 22
      VAL2=1.01*VAL1
      IF(VAL1.EQ.0)  VAL2=0.01
      CALL SETVAR(VAL2,ID)
      CALL BOUND(PP,UP,SIGP,FUNB)
      FUN2=REAL(FUNB)
      IF(ABS(FUN2).LE.TOL)  GO TO 22
      IF(FUN1.EQ.FUN2)  THEN
```

```
       VAL=VAL1+VAL2
      ELSE
       VAL=VAL1-FUN1*(VAL2-VAL1)/(FUN2-FUN1)
      ENDIF
       IF(ABS(FUN2).LT.ABS(FUN1))  THEN
        FUN=FUN2
        FUN2=FUN1
        FUN1=FUN
        VAL=VAL2
        VAL2=VAL1
        VAL1=VAL
       ENDIF
      DO 21 I=1,20
       CALL SETVAR(VAL,ID)
       CALL BOUND(PP,UP,SIGP,FUNB)
       FUN=REAL(FUNB)
       IF(ABS(FUN).LE.TOL)  GO TO 22
       IF(ABS(FUN).LT.ABS(FUN1))  THEN
        FUN2=FUN1
        FUN1=FUN
        VAL2=VAL1
        VAL1=VAL
       ELSE
        FUN2=FUN
        VAL2=VAL
       ENDIF
       IF(FUN1.EQ.FUN2)  THEN
        IF(VAL1.EQ.VAL2)  THEN
         VAL=VAL1+VAL2
        ELSE
         VAL=0.5*(VAL1+VAL2)
        ENDIF
       ELSE
        VAL=VAL1-FUN1*(VAL2-VAL1)/(FUN2-FUN1)
       ENDIF
   21 CONTINUE
      WRITE(*,*)' FAILED TO CONVERGE after 20 iterations'
   22 CONTINUE
      RETURN
       END
      SUBROUTINE LOX(S,GOX,IUNIT,IUNITP,IGONE)
C       Handles fuel piping logic
      COMPLEX GOX(25),S
      COMMON /EPARAM/MENG,TFLOW(25),PCHMB(25),DPROR(25),PMRAT(25)
      INTEGER SEGMN(25),SECTN(75,25),NOLINE(25),IENG(25),ITANK(25),
     *        LOPOLD(25),LOPEND(25)
      REAL KMAN(25),KTANK(25),LFLOW(25),L(75,25)
      COMMON /OPARAM/MLINE,SPLIT(25),A(25),CMAN(25),CTANK(25),
     *               DENS(25),KMAN,KTANK,LFLOW,VOL(25),VOLMF(25),
     *               AREA(75,25),DIA(75,25),L,PIND(75,25),
     *               PCAP(75,25),AVGK(25),
     *               SEGMN,SECTN,NOLINE,IENG,ITANK,LOPOLD,LOPEND
      COMMON /FOPIPE/PIPE1(75,25),PIPE2(75,25),PIPE3(75,25),
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*              PIPE4(75,25),PIPE5(75,25)
      CHARACTER*24 LOXIN,NAMLIN(2)
      COMMON /WCAOUT/NAMLIN,IUNITH
      CHARACTER*1 ANS
      IF(IGONE.EQ.2) THEN
       WRITE(*,'(A\)')'  Is lox line data in a file? (Y/N) '
       READ(*,'(A)')ANS
       IF(ANS.NE.'N'.AND.ANS.NE.'n')  THEN
        WRITE(*,'(A\)')' Is the file name LOX.RLN? (Y/N) '
        READ(*,'(A)')ANS
        IF(ANS.NE.'N'.AND.ANS.NE.'n')  THEN
         OPEN(UNIT=IUNIT,FILE='LOX.RLN')
         NAMLIN(2)='LOX.RLN'
        ELSE
         WRITE(*,'(A\)')'  Enter name of file with lox line data '
         READ(*,'(A)')LOXIN
         OPEN(IUNIT,FILE=LOXIN)
         NAMLIN(2)=LOXIN
        ENDIF
       ENDIF
       OPEN(IUNITP,FORM='UNFORMATTED')
      ENDIF
      IUNITH=IUNIT
      CALL FULOX(S,GOX,SEGMN,SECIN,PIPE1,PIPE2,PIPE3,PIPE4,PIPE5,
     *  A,AREA,AVGK,CMAN,CTANK,DENS,DIA,IENG,IGONE,ITANK,
     *  IUNIT,IUNITP,KMAN,KTANK,L,LOPEND,LOPOLD,LFLOW,MLINE,NOLINE,PCAP,
     *  PIND,SPLIT,VOL,VOLMF,2)
      RETURN
      END
      SUBROUTINE NONDIM(HOLD,K)
C       Nondimensionalizes variables
      COMMON /CMPVAL/X1,Y1,Z1,W1,M1,P0,P1,U0,U1,RFH,RFK,RFP,
     *               S,GF,GOX,RFA,RFC
      COMMON /RELVAL/N,TAU,DTAU,NR,RBAR,MBAR,GAMMA,P00,DHLDR,CSTAR,
     *        DCSDR,RHOLO,ULO,LAMDA,MU,TAUT,UBAR(50),XBAR(50),XLC
      COMMON /INTVAL/NVAL
      COMMON /DIMVAL/HOLDD(20),XBARD(50),PBAR(50),TBAR(50)
      COMMON /PIPES/PFACE,TFACE,ASTAR
      INTEGER*2 IHR,IMIN,IYR,IMON,IDAY
      CHARACTER*2 AP
      CHARACTER*60 TITLE
      CHARACTER*40 TITLF
      COMMON /TITL/TITLE,TITLF,IHR,IMIN,AP,IYR,IMON,IDAY
      REAL MBAR,N,NR,LAMDA,MU,RVAR(15)
      REAL MBARD,ND,NRD,LAMDAD,MUD
      REAL HOLD(20),UBARD(50),RHOBAR(50)
      COMPLEX S,X1,Y1,Z1,W1,M1,P0,P1,U0,U1,GF,GOX,RFH,RFK,RFP,RFA,RFC
      COMPLEX CVAR(17)
      CHARACTER*8 VAR(13),VARD(20)
      EQUIVALENCE (N,RVAR(1)),(X1,CVAR(1))
      EQUIVALENCE
     *    (ND,HOLDD(1)),(TAUD,HOLDD(2)),(DTAUD,HOLDD(3)),
     *    (NRD,HOLDD(4)),(LAMDAD,HOLDD(5)),(MUD,HOLDD(6)),
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*     (CDIAM,HOLDD(7)),(TDIAM,HOLDD(8)),(XLCD,HOLDD(9)),
*     (GAMMAD,HOLDD(10)),(RGAS,HOLDD(11)),(P00D,HOLDD(12)),
*     (MBARD,HOLDD(13)),(RBARD,HOLDD(14)),(DCSDRD,HOLDD(15)),
*     (DHLDRD,HOLDD(16)),(RHOLOD,HOLDD(17)),(ULOD,HOLDD(18)),
*     (PCHMB,HOLDD(19)),(TCHMB,HOLDD(20))
      DATA VAR/'      N=',' TAU=',' DTAU=',' NR=',' RBAR=',
     *       ' MBAR=',' GAMMA=',' P00=',' DHLDR=',' CSTAR=',
     *       ' DCSDR=',' RHOLO=',' ULO='/
      DATA VARD/'     N =',' TAU =',' DTAU =',' NR =',' LAMDA =',
     *        ' MU =',' CDIAM =',' TDIAM =',' XLC =',' GAMMA =',
     *        ' RGAS =',' P00 =',' MBAR =',' RBAR =',' DCSDR =',
     *        ' DHLDR =',' RHOLO =',' ULO =',' PCHMB =',' TCHMB ='/
      DATA PI/3.141593/,GC/32.174/
    1 FORMAT(A8,1PE13.5,2X,A8,E13.5,2X,A8,E13.5)
    2 FORMAT(' ')
      DO 21 I=1,20
       HOLDD(I)=HOLD(I)
   21 CONTINUE
      IF(PCHMB.NE.PBAR(1))  THEN
       FAC=PCHMB/PBAR(1)
       DO 22 I=1,NVAL
        PBAR(I)=FAC*PBAR(I)
   22 CONTINUE
      ENDIF
      IF(TCHMB.NE.TBAR(1))  THEN
       FAC=TCHMB/TBAR(1)
       DO 23 I=1,NVAL
        TBAR(I)=FAC*TBAR(I)
   23 CONTINUE
      ENDIF
      CAREA=0.25*PI*CDIAM**2
      WRITE(14,2)
      WRITE(14,*)'  CAREA=',CAREA
      TAREA=0.25*PI*TDIAM**2
      WRITE(14,*)'  TAREA=',TAREA
      PFACE=PBAR(1)
      PEXIT=PBAR(NVAL)
      TFACE=MBARD
      ASTAR=SQRT(GAMMAD*RGAS*TBAR(1))
      WRITE(14,*)'  ASTAR=',ASTAR
      CSTARD=PEXIT*TAREA*GC/MBARD
      WRITE(14,*)' CSTARD=',CSTARD
      DO 24 I=1,NVAL
       RHOBAR(I)=PBAR(I)*GC/(RGAS*TBAR(I))
      WRITE(14,*)' RHOBAR=',RHOBAR(I)
       UBARD(I)=MBARD/(RHOBAR(I)*CAREA)
      WRITE(14,*)'  UBARD=',UBARD(I)
   24 CONTINUE
      N=ND
      TAU=TAUD*ASTAR/XLCD
      DTAU=DTAUD*ASTAR/XLCD
      TAUT=TAU+DTAU
      NR=NRD
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      RBAR=RBARD
      MBAR=MBARD/(RHOBAR(1)*ASTAR*CAREA/XLCD)
      GAMMA=GAMMAD
      P00=P00D/PBAR(1)
      DHLDR=DHLDRD
      CSTAR=CSTARD/ASTAR
      DCSDR=DCSDRD/ASTAR
      RHOLO=RHOLOD/RHOBAR(1)
      ULO=ULOD/ASTAR
      LAMDA=LAMDAD*XLCD/ASTAR
      MU=MUD*XLCD*PI/ASTAR
      XLC=1.0
      DO 25 I=1,NVAL
       XBAR(I)=XBARD(I)/XLCD
       UBAR(I)=UBARD(I)/ASTAR
   25 CONTINUE
      S=CMPLX(LAMDA,MU)
      RFAR=(GAMMA-1.0)*UBAR(1)/(2.0*GAMMA)
      RFA=CMPLX(RFAR,0.0)
      RFC=CMPLX(0.0,0.0)
      WRITE(*,*)' '
      WRITE(*,*)TITLE
      WRITE(*,'(/A,I2/)')' Engine No. ',K
      WRITE(*,*)'                              DIMENSIONAL VARIABLES'
      WRITE(*,'('' NVAL='',I5)')NVAL
      WRITE(*,'('' XBAR='',1P4E13.5/(8X,4E13.5))')(XBARD(I),I=1,NVAL)
      WRITE(*,'('' UBAR='',1P4E13.5/(8X,4E13.5))')(UBARD(I),I=1,NVAL)
      WRITE(*,1)VARD(3),HOLDD(3),VARD(4),HOLDD(4),(VARD(I),HOLDD(I),
     *          I=7,20)
      WRITE(14,2)
      WRITE(14,'(1X,A)')TITLE
      WRITE(14,'(/A,I2/)')' Engine No. ',K
      WRITE(14,*)'                              DIMENSIONAL VARIABLES'
      WRITE(14,'('' NVAL='',I5)')NVAL
      WRITE(14,'('' XBAR='',1P4E13.5/(8X,4E13.5))')(XBARD(I),I=1,NVAL)
      WRITE(14,'('' UBAR='',1P4E13.5/(8X,4E13.5))')(UBARD(I),I=1,NVAL)
      WRITE(14,1)VARD(3),HOLDD(3),VARD(4),HOLDD(4),(VARD(I),HOLDD(I),
     *          I=7,20)
      WRITE(*,*)'                          NON-DIMENSIONAL VARIABLES'
      WRITE(*,'('' NVAL='',I5)')NVAL
      WRITE(*,'('' XBAR='',1P4E13.5/(8X,4E13.5))')(XBAR(I),I=1,NVAL)
      WRITE(*,'('' UBAR='',1P4E13.5/(8X,4E13.5))')(UBAR(I),I=1,NVAL)
      WRITE(*,1)(VAR(I),RVAR(I),I=3,13)
      WRITE(*,'('' RFA='',1P2E13.5,5X,'' RFC='',2E13.5)')RFA,RFC
      WRITE(14,2)
      WRITE(14,*)'                          NON-DIMENSIONAL VARIABLES'
      WRITE(14,'('' NVAL='',I5)')NVAL
      WRITE(14,'('' XBAR='',1P4E13.5/(8X,4E13.5))')(XBAR(I),I=1,NVAL)
      WRITE(14,'('' UBAR='',1P4E13.5/(8X,4E13.5))')(UBAR(I),I=1,NVAL)
      WRITE(14,1)(VAR(I),RVAR(I),I=3,13)
      WRITE(14,'('' RFA='',1P2E13.5,5X,'' RFC='',2E13.5)')RFA,RFC
      WRITE(*,'(A\)')' Hit ENTER to continue '
      READ(*,*)
```

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      RETURN
       END
      SUBROUTINE PLTALL(X,Y,NOT,NOF,N,M,LABLX,LABLY,FREQ,NENG)
C       Plots n vs τ for all frequencies
      DIMENSION X(NOT),Y(NOT,NOF),FREQ(NOF)
      CHARACTER*8 LABLX,LABLY,LABFAX(8),LABFAY(8)
      CHARACTER*8 XLABL(2),YLABL(2)
      CHARACTER*16 FREQL
      COMMON /TITL/TITLE,TITLF,IHR,IMIN,AP,IYR,IMON,IDAY
      INTEGER*2 IHR,IMIN,IYR,IMON,IDAY
      CHARACTER*2 AP
      CHARACTER*13 ETITL
      CHARACTER*60 TITLE
      CHARACTER*40 TITLF
      COMMON /SFACT/SFAC
      CHARACTER*8 RADHER(2)
      DATA RADHER/' rad/sec',' Hertz  '/
      DATA LABFAY/'        ',' x 10 ',' x 100 ',' x 1000 ',
     *            ' x 10000',' x-10 ',' x-100 ',' x-1000 '/
      DATA LABFAX/'        ',' x 10  ',' x 100  ',' x 1000 ',
     *            ' x 10000',' x-10  ',' x-100  ',' x-1000 '/
      DATA ASPECT/1.35/
    1 FORMAT(F8.1,A)
    2 FORMAT('Engine No. ',I2)
      WRITE(ETITL,2)NENG
      CALL QRMODE(MODET,NCOLT)
      CALL QVIDBD(IBOARD)
      IF(IBOARD.LT.1.OR.IBOARD.GT.3)  THEN
       WRITE(*,*)' Graphics board not installed!'
       RETURN
      ENDIF
      IF(IBOARD.EQ.1)  MODE=6
      IF(IBOARD.EQ.2)  MODE=16
      IF(IBOARD.EQ.3)  MODE=18
      YMIN=Y(1,1)
      YMAX=Y(N,1)
      XMIN=X(1)
      XMAX=X(N)
      DO 21 I=1,N
       IF(XMIN.GT.X(I))  XMIN=X(I)
       IF(XMAX.LT.X(I))  XMAX=X(I)
      DO 21 J=1,M
       IF(YMIN.GT.Y(I,J))  YMIN=Y(I,J)
       IF(YMAX.LT.Y(I,J))  YMAX=Y(I,J)
   21 CONTINUE
      IF(YMIN.GT.0.0)  YMIN=0.0
      IXLAB=1
      IF(XMAX.LT.1.0)  IXLAB=2
      IF(XMAX.LT.0.10)  IXLAB=3
      IF(XMAX.LT.0.010)  IXLAB=4
      IF(XMAX.LT.0.001)  IXLAB=5
      IF(XMAX.GT.10.0)  IXLAB=6
      IF(XMAX.GT.100.0)  IXLAB=7
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      IF(XMAX.GT.1000.0)  IXLAB=8
      IYLAB=1
      IF(YMAX.LT.1.0)  IYLAB=2
      IF(YMAX.LT.0.10)  IYLAB=3
      IF(YMAX.LT.0.010)  IYLAB=4
      IF(YMAX.LT.0.001)  IYLAB=5
      IF(YMAX.GT.10.0)  IYLAB=6
      IF(YMAX.GT.100.0)  IYLAB=7
      IF(YMAX.GT.1000.0)  IYLAB=8
      IF(IXLAB.NE.1)  THEN
       IF(IXLAB.EQ.2)  XFAC=10.0
       IF(IXLAB.EQ.3)  XFAC=100.0
       IF(IXLAB.EQ.4)  XFAC=1000.0
       IF(IXLAB.EQ.5)  XFAC=10000.0
       IF(IXLAB.EQ.6)  XFAC=0.1
       IF(IXLAB.EQ.7)  XFAC=0.01
       IF(IXLAB.EQ.8)  XFAC=0.001
       XMIN=XMIN*XFAC
       XMAX=XMAX*XFAC
       DO 22 I=1,N
        X(I)=X(I)*XFAC
   22 CONTINUE
      ENDIF
      IF(IYLAB.NE.1)  THEN
       IF(IYLAB.EQ.2)  YFAC=10.0
       IF(IYLAB.EQ.3)  YFAC=100.0
       IF(IYLAB.EQ.4)  YFAC=1000.0
       IF(IYLAB.EQ.5)  YFAC=10000.0
       IF(IYLAB.EQ.6)  YFAC=0.1
       IF(IYLAB.EQ.7)  YFAC=0.01
       IF(IYLAB.EQ.8)  YFAC=0.001
       YMIN=YMIN*YFAC
       YMAX=YMAX*YFAC
       DO 23 J=1,M
       DO 23 I=1,N
        Y(I,J)=Y(I,J)*YFAC
   23 CONTINUE
      ENDIF
      XLABL(1)=LABLX
      XLABL(2)=LABFAX(IXLAB)
      YLABL(1)=LABLY
      YLABL(2)=LABFAY(IYLAB)
      XMAJ=0.2*(XMAX-XMIN)
      YMAJ=0.2*(YMAX-YMIN)
      ICOLR=4
      IFIL=3
      ILIN=1
      CALL QSMODE(MODE)
      IF(IBOARD.NE.1)  THEN
       CALL QPREG(0,ICOLR)
      ENDIF
      JCOL1=150
      JCOL2=500
```

```
      DO 27 J=1,M
      DO 27 I=1,N
       Y(I,J)=Y(I,J)/YFAC
   27 CONTINUE
      ENDIF
      RETURN
      END
      SUBROUTINE PLTVAR(X,Y,N,LABLX,LABLY,FREQ,NENG)
C       Plots n vs τ for a single frequency
      DIMENSION X(N),Y(N)
      CHARACTER*8 LABLX,LABLY,LABFAX(8),LABFAY(8)
      CHARACTER*8 XLABL(2),YLABL(2)
      COMMON /TITL/TITLE,TITLF,IHR,IMIN,AP,IYR,IMON,IDAY
      COMMON /SFACT/SFAC
      INTEGER*2 IHR,IMIN,IYR,IMON,IDAY
      CHARACTER*2 AP
      CHARACTER*60 TITLE
      CHARACTER*40 TITLF
      CHARACTER*47 FREQL
      CHARACTER*8 RADHER(2)
      DATA RADHER/' rad/sec',' Hertz  '/
      DATA LABFAY/'        ',' x 10 ',' x 100 ',' x 1000 ',
     *            ' x 10000',' x-10 ',' x-100 ',' x-1000 '/
      DATA LABFAX/'        ',' x 10  ',' x 100  ',' x 1000 ',
     *            ' x 10000',' x-10  ',' x-100  ',' x-1000 '/
      DATA ASPECT/1.35/
    1 FORMAT('Engine No. ',I2,5X,'frequency =',F10.3,A)
      CALL QRMODE(MODET,NCOLT)
      CALL QVIDBD(IBOARD)
      IF(IBOARD.LT.1.OR.IBOARD.GT.3)  THEN
       WRITE(*,*)' Graphics board not installed!'
       RETURN
      ENDIF
      IF(IBOARD.EQ.1)  MODE=6
      IF(IBOARD.EQ.2)  MODE=16
      IF(IBOARD.EQ.3)  MODE=18
      XMIN=X(1)
      XMAX=X(N)
      YMIN=Y(1)
      YMAX=Y(N)
      DO 21 I=1,N
       IF(XMIN.GT.X(I))  XMIN=X(I)
       IF(XMAX.LT.X(I))  XMAX=X(I)
       IF(YMIN.GT.Y(I))  YMIN=Y(I)
       IF(YMAX.LT.Y(I))  YMAX=Y(I)
   21 CONTINUE
      IF(YMIN.GT.0.0)  YMIN=0.0
      IXLAB=1
      IF(XMAX.LT.1.0)  IXLAB=2
      IF(XMAX.LT.0.10)  IXLAB=3
      IF(XMAX.LT.0.010)  IXLAB=4
      IF(XMAX.LT.0.001)  IXLAB=5
      IF(XMAX.GT.10.0)  IXLAB=6
```

```
      IF(XMAX.GT.100.0)  IXLAB=7
      IF(XMAX.GT.1000.0)  IXLAB=8
      IYLAB=1
      IF(YMAX.LT.1.0)  IYLAB=2
      IF(YMAX.LT.0.10)  IYLAB=3
      IF(YMAX.LT.0.010)  IYLAB=4
      IF(YMAX.LT.0.001)  IYLAB=5
      IF(YMAX.GT.10.0)  IYLAB=6
      IF(YMAX.GT.100.0)  IYLAB=7
      IF(YMAX.GT.1000.0)  IYLAB=8
      IF(IXLAB.NE.1)  THEN
       IF(IXLAB.EQ.2)  XFAC=10.0
       IF(IXLAB.EQ.3)  XFAC=100.0
       IF(IXLAB.EQ.4)  XFAC=1000.0
       IF(IXLAB.EQ.5)  XFAC=10000.0
       IF(IXLAB.EQ.6)  XFAC=0.1
       IF(IXLAB.EQ.7)  XFAC=0.01
       IF(IXLAB.EQ.8)  XFAC=0.001
       XMIN=XMIN*XFAC
       XMAX=XMAX*XFAC
       DO 22 I=1,N
        X(I)=X(I)*XFAC
   22 CONTINUE
      ENDIF
      IF(IYLAB.NE.1)  THEN
       IF(IYLAB.EQ.2)  YFAC=10.0
       IF(IYLAB.EQ.3)  YFAC=100.0
       IF(IYLAB.EQ.4)  YFAC=1000.0
       IF(IYLAB.EQ.5)  YFAC=10000.0
       IF(IYLAB.EQ.6)  YFAC=0.1
       IF(IYLAB.EQ.7)  YFAC=0.01
       IF(IYLAB.EQ.8)  YFAC=0.001
       YMIN=YMIN*YFAC
       YMAX=YMAX*YFAC
       DO 23 I=1,N
        Y(I)=Y(I)*YFAC
   23 CONTINUE
      ENDIF
      XLABL(1)=LABLX
      XLABL(2)=LABFAX(IXLAB)
      YLABL(1)=LABLY
      YLABL(2)=LABFAY(IYLAB)
      XMAJ=0.2*(XMAX-XMIN)
      YMAJ=0.2*(YMAX-YMIN)
      ICOLR=4
      IFIL=3
      ILIN=1
      CALL QSMODE(MODE)
      IF(IBOARD.NE.1)  THEN
       CALL QPREG(0,ICOLR)
      ENDIF
      JCOL1=150
      JCOL2=500
```

```
      JROW1=40
      IF(MODE.EQ.6)  JROW1=60
      JROW2=149
      IF(MODE.EQ.16)  JROW2=299
      IF(MODE.EQ.18)  JROW2=419
      XORG=XMIN
      YORG=YMIN
      YOVERX=1.0
      IOPT=0
      IF(SFAC.EQ.1.0)  THEN
       WRITE(FREQL,1)NENG,FREQ,RADHER(1)
      ELSE
       WRITE(FREQL,1)NENG,FREQ,RADHER(2)
      ENDIF
      IF(MODE.NE.18)  THEN
       CALL QPTXT(60,TITLE,7,5,23)
       CALL QPTXT(47,FREQL,7,25,22)
      ELSE
       CALL QPTXT(60,TITLE,7,5,29)
       CALL QPTXT(47,FREQL,7,25,28)
      ENDIF
      CALL QPTXT(8,YLABL(1),7,2,15)
      CALL QPTXT(8,YLABL(2),7,2,14)
      CALL QPLOT(JCOL1,JCOL2,JROW1,JROW2,XMIN,XMAX,YMIN,YMAX,
     *           XORG,YORG,IOPT,YOVERX,ASPECT)
      CALL QSETUP(0,ILIN,-2,IFIL)
      CALL QXAXIS(XMIN,XMAX,0.0,0,0,0)
      CALL QPTXTA(16,XLABL,7)
      CALL QXAXIS(XMIN,XMAX,XMAJ,0,-1,2)
      CALL QYAXIS(YMIN,YMAX,YMAJ,0,-1,2)
      CALL QTABL(1,N,X,Y)
   24 CONTINUE
      CALL QONKEY(IKEY)
      IF(IKEY.EQ.0)  GO TO 24
      CALL QINKEY(IEXTEN,IKEY)
      CALL QSMODE(MODET)
   25 CONTINUE
      IF(IXLAB.NE.1)  THEN
       DO 26 I=1,N
        X(I)=X(I)/XFAC
   26 CONTINUE
      ENDIF
      IF(IYLAB.NE.1)  THEN
       DO 27 I=1,N
        Y(I)=Y(I)/YFAC
   27 CONTINUE
      ENDIF
      RETURN
       END
      SUBROUTINE READIN
C       Reads input data
      COMMON /CMPVAL/X1,Y1,Z1,W1,M1,P0,P1,U0,U1,RFH,RFK,RFP,
     *               S,GF,GOX,RFA,RFC
```

```
      COMMON /RELVAL/N,TAU,DTAU,NR,RBAR,MBAR,GAMMA,P00,DHLDR,CSTAR,
     *        DCSDR,RHOLO,ULO,LAMDA,MU,TAUT,UBAR(50),XBAR(50),XLC
      COMMON /INTVAL/NVAL
      COMMON /DIMVAL/HOLDD(20),XBARD(50),PBAR(50),TBAR(50)
      COMMON /TITL/TITLE,TITLF,IHR,IMIN,AP,IYR,IMON,IDAY
      INTEGER*2 IHR,IMIN,IYR,IMON,IDAY
      CHARACTER*2 AP
      CHARACTER*60 TITLE
      CHARACTER*40 TITLF
      REAL MBAR,N,NR,LAMDA,MU,RVAR(15)
      REAL MBARD,ND,NRD,LAMDAD,MUD,HOLD(20)
      COMPLEX S,X1,Y1,Z1,W1,M1,P0,P1,U0,U1,GF,GOX,RFH,RFK,RFP,RFA,RFC
      COMPLEX CVAR(17)
      EQUIVALENCE (N,RVAR(1)),(X1,CVAR(1))
      EQUIVALENCE (ND,HOLD(1)),(TAUD,HOLD(2)),(DTAUD,HOLD(3)),
     *            (NRD,HOLD(4)),(LAMDAD,HOLD(5)),(MUD,HOLD(6)),
     *            (CDIAM,HOLD(7)),(TDIAM,HOLD(8)),(XLCD,HOLD(9)),
     *            (GAMMAD,HOLD(10)),(RGAS,HOLD(11)),(P00D,HOLD(12)),
     *            (MBARD,HOLD(13)),(RBARD,HOLD(14)),(DCSDRD,HOLD(15)),
     *            (DHLDRD,HOLD(16)),(RHOLOD,HOLD(17)),(ULOD,HOLD(18)),
     *            (PCHMB,HOLD(19)),(TCHMB,HOLD(20))
      CHARACTER*8 VAR(20),VARP(20),VARL(20),NAME
      CHARACTER*1 ANS
      COMMON /EPARAM/MENG,TFLOW(25),PCHMBX(25),DPROR(25),PMRAT(25)
      COMMON /WORK/YP1(20,25),YP2(50,25),YP3(50,25),YP4(50,25),
     *             YP5(30,25)
      DATA IGO/0/
      DATA VAR /'    ND =','  TAUD =',' DTAUD =','   NRD =','LAMDAD =',
     *          '   MUD =',' CDIAM =',' TDIAM =','  XLCD =','GAMMAD =',
     *          '  RGAS =','  P00D =',' MBARD =',' RBARD =','DCSDRD =',
     *          'DHLDRD =','RHOLOD =','  ULOD =',' PCHMB =',' TCHMB =' /
      DATA VARP/'ND      ','TAUD    ','DTAUD   ','NRD     ','LAMDAD  ',
     *          'MUD     ','CDIAM   ','TDIAM   ','XLCD    ','GAMMAD  ',
     *          'RGAS    ','P00D    ','MBARD   ','RBARD   ','DCSDRD  ',
     *          'DHLDRD  ','RHOLOD  ','ULOD    ','PCHMB   ','TCHMB   '/
      DATA VARL/'nd      ','taud    ','dtaud   ','nrd     ','lamdad  ',
     *          'mud     ','cdiam   ','tdiam   ','xlcd    ','gammad  ',
     *          'rgas    ','p00d    ','mbard   ','rbard   ','dcsdrd  ',
     *          'dhldrd  ','rholod  ','ulod    ','pchmb   ','tchmb   '/
    1 FORMAT(16I5)
    2 FORMAT(' Enter X (ft), P (lbf/ft^2), and T (°R) for point ',
     *       I3,'  ')
    3 FORMAT(1P4E15.6)
    4 FORMAT(2X,A8,1PE13.5,2X,A8,E13.5,2X,A8,E13.5)
    5 FORMAT(1P3E15.6)
    6 FORMAT(A40,2X,I2.2,':',I2.2,A2,3X,I2.2,'-',I2.2,'-',I2.2)
      IF(IGO.EQ.1)  THEN
       WRITE(*,'(A\)')' Do you wish to use old data with or without chan
     *ges? Y or N '
       READ(*,'(A)')ANS
       IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')  GO TO 24
      ENDIF
      IGO=1
```

```
      IDATA=1
      WRITE(*,*)' '
      WRITE(*,'(A\)')' Is your rocket input on file? Y OR N '
      READ(*,'(A)')ANS
      IF(ANS.NE.'N'.AND.ANS.NE.'n')  THEN
       WRITE(*,'(A\)')' Does the file need to be rewound? Y OR N '
       READ(*,'(A)')ANS
       IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')  REWIND 12
       READ(12,'(A)',END=99)TITLF
       WRITE(TITLE,6)TITLF,IHR,IMIN,AP,IMON,IDAY,IYR
       IDATA=0
      ELSE
       WRITE(*,*)' Enter Title'
       READ(*,'(A)')TITLF
       WRITE(TITLE,6)TITLF,IHR,IMIN,AP,IMON,IDAY,IYR
       WRITE(12,'(A)')TITLF
      ENDIF
      REWIND 20
      DO 23 K=1,MENG
       IF(IDATA.EQ.0)  THEN
        READ(12,*,END=99)NVAL
        IF(NVAL.EQ.0)  GO TO 99
        DO 21 I=1,NVAL
         READ(12,*)XBARD(I),PBAR(I),TBAR(I)
21      CONTINUE
        READ(12,*)DTAUD,NRD,LAMDAD
        READ(12,*)CDIAM,TDIAM,XLCD
        READ(12,*)GAMMAD,RGAS,P00D,RBARD
        READ(12,*)DCSDRD,DHLDRD,RHOLOD,ULOD
        MBARD=TFLOW(K)
       ELSE
        WRITE(*,'(A\)')' How many points along centerline? '
        READ(*,*,END=99)NVAL
        IF(NVAL.EQ.0)  GO TO 99
        DO 22 I=1,NVAL
         WRITE(*,1)I
         READ(*,*)XBARD(I),PBAR(I),TBAR(I)
22      CONTINUE
        WRITE(*,*)' Enter NR (mixture ratio interaction index)'
        READ(*,*)NR
        WRITE(*,*)' Enter DTAU (invarient time lag - sec)'
        READ(*,*)DTAUD
        WRITE(*,*)' Enter LAMDA (real part of frequency'
        READ(*,*)LAMDAD
        WRITE(*,*)' Enter XLCD (length of combustion chamber - ft)'
        READ(*,*)XLCD
        WRITE(*,*)' Enter CDIAM (chamber diameter - ft) and TDIAM',
     *            ' (throat diameter - ft)'
        READ(*,*)CDIAM,TDIAM
        WRITE(*,*)' Enter GAMMA (ratio of specific heats), RGAS',
     *            ' (gas constant - ft^2/sec^2/°R)'
        READ(*,*)GAMMAD,RGAS
        WRITE(*,*)' Enter P00 (maximum overpressure - lbf/ft^2)'
```

```
      READ(*,*)P00D
      WRITE(*,*)' Enter RBAR (mean mixture ratio)'
      READ(*,*)RBARD
      WRITE(*,*)' Enter DCSDR (dc*/dr - ft/sec) and DHLDR',
     *          ' (dh/dr - ft^2/sec^2)'
      READ(*,*)DCSDRD,DHLDRD
      WRITE(*,*)' Enter RHOLO (mass of liquid/unit chamber vol -',
     *          'lbm/ft^3)'
      WRITE(*,*)'   and ULO (axial component of liquid velocity',
     *          ' - ft/sec)'
      READ(*,*)RHOLOD,ULOD
      MBARD=TFLOW(K)
      WRITE(12,1)NVAL
      WRITE(12,5)(XBARD(I),PBAR(I),TBAR(I),I=1,NVAL)
      WRITE(12,3)DTAUD,NR,LAMDAD
      WRITE(12,3)CDIAM,TDIAM,XLCD
      WRITE(12,3)GAMMAD,RGAS,P00D,RBARD
      WRITE(12,3)DCSDRD,DHLDRD,RHOLOD,ULOD
     ENDIF
     PCHMB=PCHMBX(K)
     TCHMB=TBAR(1)
     CALL NONDIM(HOLD,K)
     WRITE(20)HOLDD,XBARD,PBAR,TBAR
23 CONTINUE
   RETURN
24 CONTINUE
   WRITE(*,'(A\)')'  are there any changes? Y or N '
   READ(*,'(A)')ANS
   IF(ANS.NE.'Y'.AND.ANS.NE.'y')  RETURN
   WRITE(*,'(A\)')'  Do you wish to change title? Y or N '
   READ(*,'(A)')ANS
   IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')  THEN
    WRITE(*,*)' Enter Title'
    READ(*,'(A)')TITLF
    WRITE(TITLE,6)TITLF,IHR,IMIN,AP,IMON,IDAY,IYR
   ENDIF
   REWIND 20
   DO 33 K=1,MENG
    READ(20)HOLDD,XBARD,PBAR,TBAR
    WRITE(*,'(A,I2,A\)')'  are there any changes for engine no. ',
     *                  K,' ? '
    READ(*,'(A)')ANS
    IF(ANS.NE.'Y'.AND.ANS.NE.'y')  GO TO 31
    GO TO 27
25  CONTINUE
    WRITE(*,*)'   VARIABLE NAMES AND DESCRIPTIONS'
    WRITE(*,*)' '
    WRITE(*,*)' DTAUD  - invarient time lag                    sec'
    WRITE(*,*)' NRD    - mixture ratio interaction index'
    WRITE(*,*)' LAMDAD - damping of perturbation'
    WRITE(*,*)' CDIAM  - chamber diameter                      ft'
    WRITE(*,*)' TDIAM  - throat diameter                       ft'
    WRITE(*,*)' XLCD   - length of combustion chamber          ft'
```

```
      WRITE(*,*)' GAMMAD - ratio of specific heats'
      WRITE(*,*)' RGAS   - gas constant                              ',
     *          '(ft/sec)^2/°R'
      WRITE(*,*)' POOD   - maximum pressure                          ',
     *          'lbf/ft^2'
      WRITE(*,*)' RBARD  - mean mixture ratio'
      WRITE(*,*)' DCSDRD - d(c*)/d(mixture ratio)                    ',
     *          'ft/sec'
      WRITE(*,*)' DHLDRD - d(enthalpy)/d(mixture ratio)              ',
     *          'ft^2/sec^2'
      WRITE(*,*)' RHOLOD - mass of liquid/unit chamber volume        ',
     *          'lbm/ft^3'
      WRITE(*,*)' ULOD   - axial component of liquid velocity        ',
     *          'ft/sec'
      WRITE(*,*)' TCHMB  - chamber temperature                       °R'
      WRITE(*,*)' '
      GO TO 28
   26 CONTINUE
      WRITE(*,*)'   VARIABLE NAMES AND VALUES'
      WRITE(*,*)' '
      WRITE(*,4)(VAR(I),HOLD(I),I=3,5),(VAR(I),HOLD(I),I=7,12),
     *          (VAR(I),HOLD(I),I=14,18),VAR(20),HOLD(20)
   27 CONTINUE
      WRITE(*,*)' '
      WRITE(*,*)' Enter ? to print variable names & descriptions'
      WRITE(*,*)'       # to print variable names & values'
      WRITE(*,*)'       END when all changes have been made'
      WRITE(*,*)' '
   28 CONTINUE
      WRITE(*,'(A\)')'   Enter variable name and new value, END, ?, or
     * # '
      CALL ZREAD(NAME,VALUE)
      IF(NAME.EQ.'?')  GO TO 25
      IF(NAME.EQ.'#')  GO TO 26
      IF(NAME.EQ.'END'.OR.NAME.EQ.'end')  THEN
       CALL NONDIM(HOLD,K)
       GO TO 31
       RETURN
      ENDIF
      DO 29 II=3,20
       IF(II.EQ.6.OR.II.EQ.13.OR.II.EQ.19)  GO TO 29
       I=II
       IF(NAME.EQ.VARP(I).OR.NAME.EQ.VARL(I))  GO TO 30
   29 CONTINUE
      WRITE(*,*)'     Invalid name, try again'
      GO TO 25
   30 CONTINUE
      HOLD(I)=VALUE
      GO TO 28
   31 CONTINUE
      DO 32 J=1,50
       IF(J.LE.20)  YP1(J,K)=HOLDD(J)
       YP2(J,K)=XBARD(J)
```

```
      AVGK(MM)=0.0
      DIVAVG=0.0
      READ(IUNIT,*)SEGMN(M),SPLIT(MM)
      DO 21 I=1,SEGMN(M)
       READ(IUNIT,*)SECTN(I,M),PIPE1(I,M),PIPE2(I,M),PIPE3(I,M),
     *              PIPE4(I,M),PIPE5(I,M)
       IF(SECTN(I,M).NE.7)  GO TO 21
       AVGK(MM)=AVGK(MM)+PIPE2(I,M)
       DIVAVG=DIVAVG+1
   21 CONTINUE
      IF(SPLIT(MM).EQ.0)  THEN
       AVGK(MM)=KTANK(IT)
       GO TO 24
      ENDIF
C           split pipe
      DO 23 J=1,SPLIT(MM)
       M=M+1
       READ(IUNIT,*)SEGMN(M),NOLINE(M),IENG(M)
       IF(IENG(M).GT.MENG)  THEN
        WRITE(*,*)'  Invalid engine number.'
        STOP
       ENDIF
       IE=IENG(M)
       IF(NOLINE(M).EQ.0)  NOLINE(M)=1
       DO 22 I=1,SEGMN(M)
        READ(IUNIT,*)SECTN(I,M),PIPE1(I,M),PIPE2(I,M),PIPE3(I,M),
     *               PIPE4(I,M),PIPE5(I,M)
        IF(SECTN(I,M).NE.7)  GO TO 22
        AVGK(MM)=AVGK(MM)+PIPE2(I,M)*NOLINE(M)
        DIVAVG=DIVAVG+NOLINE(M)
   22   CONTINUE
   23  CONTINUE
      WRITE(*,'(A,I3)')' Max. no. of iterations is set at ',
     *                 LOPOLD(MM)
      WRITE(*,'(A\)')' Do you wish to change it? '
      READ(*,'(A)')ANS
      IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')  THEN
       WRITE(*,'(A\)')' Enter maximum no. of iterations '
       READ(*,*)LOPOLD(MM)
      ENDIF
      LOPEND(MM)=LOPOLD(MM)
      IF(DIVAVG.LE.0.0)  DIVAVG=1.0
      AVGK(MM)=KTANK(IT)+AVGK(MM)/DIVAVG
   24 CONTINUE
      M=0
      DO 28 MM=1,MLINE
       M=M+1
       IT=ITANK(MM)
       IE=IENG(M)
       DO 25 I=1,SEGMN(M)
        CALL RTYPE(SECTN(I,M),PIPE1(I,M),PIPE2(I,M),
     *             PIPE3(I,M),PIPE4(I,M),PIPE5(I,M),L(I,M),AREA(I,M),
     *             DIA(I,M),PIND(I,M),PCAP(I,M),AVGK(MM),DENS(IT),
```

```
     *             CMAN(M),KMAN(M),VOLMF(M))
  25 CONTINUE
      IF(SPLIT(MM).EQ.0)  GO TO 28
      DO 27 J=1,SPLIT(MM)
       M=M+1
       IE=IENG(M)
       DO 26 I=1,SEGMN(M)
        CALL RTYPE(SECIN(I,M),PIPE1(I,M),PIPE2(I,M),
     *             PIPE3(I,M),PIPE4(I,M),PIPE5(I,M),L(I,M),AREA(I,M),
     *             DIA(I,M),PIND(I,M),PCAP(I,M),AVGK(MM),DENS(IT),
     *             CMAN(M),KMAN(M),VOLMF(M))
  26 CONTINUE
  27 CONTINUE
  28 CONTINUE
     RETURN
     END
     SUBROUTINE RTYPE(SECIN,PIPE1,PIPE2,PIPE3,PIPE4,PIPE5,L,
     *                AREA,DIA,PIND,PCAP,AVGK,DENS,CMAN,KMAN,
     *                VOLMF)
C       Stores values for different types of piping
     INTEGER SECIN
     REAL L,KMAN
     DATA GRAV/32.2/,PI/3.141593/
     IF(SECIN.EQ.0)  THEN
      CALL BENDS(PIPE1,PIPE2,PIPE3,PIPE4,VALUE,DIME)
       AREAB=0.785398*DIME**2
       L=VALUE
       AREA=AREAB
       DIA=DIME
      ELSEIF(SECIN.EQ.1)  THEN
C           straight section
       VALUE=PIPE1
       DIME=PIPE2
       AREAB=0.785398*DIME**2
       L=VALUE
       AREA=AREAB
       DIA=DIME
      ELSEIF(SECIN.EQ.2)  THEN
C           inline accumulator
C         PIPE1 - LEN
C         PIPE2 - DIA
C         PIPE3 - DEN
C         PIPE4 - K
       L=PIPE1
       DIA=PIPE2
       AREA=0.25*PI*PIPE2**2
       IF(PIPE3.EQ.0.0)  PIPE3=DENS
       IF(PIPE4.EQ.0.0)  PIPE4=AVGK
       PCAP=PIPE3*L*AREA/PIPE4
      ELSEIF(SECIN.EQ.3)  THEN
C           tuned stub - suppresses omega = (PI/2)/(L*SQRT(PIND*PCAP))
C         PIPE1 - LEN
C         PIPE2 - DIA
```

```
C          PIPE3 - DEN
C          PIPE4 - K
           L=PIPE1
           DIA=PIPE2
           AREA=0.25*PI*DIA**2
           IF(PIPE3.EQ.0.0)  PIPE3=DENS
           IF(PIPE4.EQ.0.0)  PIPE4=AVGK
           PCAP=PIPE3*L*AREA/PIPE4
           PIND=L/(AREA*GRAV)
          ELSEIF(SECTN.EQ.4.OR.SECTN.EQ.5)  THEN
C               helmholtz resonator or parallel resonator
C                 suppresses omega = 1/SQRT(PIND*PCAP)
C            PIPE1 - LEN
C            PIPE2 - DIA
C            PIPE3 - VOL
C            PIPE4 - DEN
C            PIPE5 - K
           L=PIPE1
           DIA=PIPE2
           AREA=PIPE3
           IF(PIPE4.EQ.0.0)  PIPE4=DENS
           IF(PIPE5.EQ.0.0)  PIPE5=AVGK
           PCAP=PIPE4*AREA/PIPE5
           PIND=L/(0.25*PI*DIA**2*GRAV)
          ELSEIF(SECTN.EQ.6)  THEN
C               pump
C            PIPE1 - LEN
C            PIPE2 - DIA
C            PIPE3 - DP/DM
C            PIPE4 - IND
C            PIPE5 - CAP
           L=PIPE1
           DIA=PIPE2
           AREA=PIPE3
           PCAP=PIPE4
           PIND=PIPE5
          ELSEIF(SECTN.EQ.7)  THEN
C               manifold
C            PIPE1 - VOLMF
C            PIPE2 - KMAN
           VOLMF=PIPE1
           KMAN=PIPE2
           CMAN=DENS*VOLMF/KMAN
           L=VOLMF
           DIA=CMAN
          ENDIF
         RETURN
         END
         SUBROUTINE SETVAL(VAL,ID)
C          Sets value from iterated variable
         COMMON /DIMVAL/HOLDD(20),XBARD(50),PBAR(50),TBAR(50)
         VAL=HOLDD(ID)
         RETURN
```

```
      END
      SUBROUTINE SETVAR(VAL,ID)
C       Sets iterated variable from value
      COMMON /CMPVAL/X1,Y1,Z1,W1,M1,P0,P1,U0,U1,RFH,RFK,RFP,
     *               S,GF,GOX,RFA,RFC
      COMMON /RELVAL/N,TAU,DTAU,NR,RBAR,MBAR,GAMMA,P00,DHLDR,CSTAR,
     *        DCSDR,RHOLO,ULO,LAMDA,MU,TAUT,UBAR(50),XBAR(50),XLC
      COMMON /INTVAL/NVAL
      COMMON /DIMVAL/HOLDD(20),XBARD(50),PBAR(50),TBAR(50)
      REAL MBAR,N,NR,LAMDA,MU,RVAR(13)
      REAL MBARD,ND,NRD,LAMDAD,MUD
      COMPLEX S,X1,Y1,Z1,W1,M1,P0,P1,U0,U1,GF,GOX,RFH,RFK,RFP,RFA,RFC
      COMPLEX CVAR(17)
      EQUIVALENCE (N,RVAR(1)),(X1,CVAR(1))
      EQUIVALENCE
     *    (ND,HOLDD(1)),(TAUD,HOLDD(2)),(DTAUD,HOLDD(3)),
     *    (NRD,HOLDD(4)),(LAMDAD,HOLDD(5)),(MUD,HOLDD(6)),
     *    (CDIAM,HOLDD(7)),(TDIAM,HOLDD(8)),(XLCD,HOLDD(9)),
     *    (GAMMAD,HOLDD(10)),(RGAS,HOLDD(11)),(P00D,HOLDD(12)),
     *    (MBARD,HOLDD(13)),(RBARD,HOLDD(14)),(DCSDRD,HOLDD(15)),
     *    (DHLDRD,HOLDD(16)),(RHOLOD,HOLDD(17)),(ULOD,HOLDD(18)),
     *    (PCHMB,HOLDD(19)),(TCHMB,HOLDD(20))
      DATA PI/3.141593/
      HOLDD(ID)=VAL
      IF(ID.EQ.1)  THEN
C                          ND
       N=ND
       RETURN
      ENDIF
      IF(ID.EQ.2)  THEN
C                          TAUD
       ASTAR=SQRT(GAMMAD*RGAS*TBAR(1))
       TAU=TAUD*ASTAR/XLCD
       TAUT=TAU+DTAU
       RETURN
      ENDIF
      IF(ID.EQ.6)  THEN
C                          MUD
       ASTAR=SQRT(GAMMAD*RGAS*TBAR(1))
       MU=MUD*XLCD*PI/ASTAR
       S=CMPLX(LAMDA,MU)
       RETURN
      ENDIF
      RETURN
      END
      SUBROUTINE TANKNO(MTANK,VOL,LFLOW,KTANK,DENS,A,CTANK,IUNIT)
C       Reads tank parameters
      REAL VOL(25),LFLOW(25),KTANK(25),DENS(25),A(25),CTANK(25)
      DATA GRAV/32.2/
      READ(IUNIT,*)MTANK
      IF(MTANK.GT.25)  THEN
       WRITE(*,*)' Number of tanks must be less than 25'
       STOP
```

```
      ENDIF
      IF(MTANK.LE.0)  MTANK=1
      DO 21 I=1,MTANK
      READ(IUNIT,*)VOL(I),LFLOW(I),KTANK(I),DENS(I)
      A(I)=SQRT(GRAV*KTANK(I)/DENS(I))
      CTANK(I)=DENS(I)*VOL(I)/KTANK(I)
   21 CONTINUE
      RETURN
      END
      SUBROUTINE ZREAD(NAME,VALUE)
C       Reads input for input modification
      CHARACTER*1 NAME(8)
      CHARACTER*1 CARD(80),PLUS,MINUS,PERIOD,LE,E,NUMBER(10)
      CHARACTER*1 LEND(3),CEND(3),POUND,QUEST,BLK,COMMA
      CHARACTER*80 DCARD
      EQUIVALENCE (CARD(1),DCARD)
      DATA PLUS/'+'/,MINUS/'-'/,PERIOD/'.'/,LE/'e'/,E/'E'/,BLK/' '/
      DATA NUMBER/'0','1','2','3','4','5','6','7','8','9'/,COMMA/','/
      DATA LEND/'e','n','d'/,CEND/'E','N','D'/,POUND/'#'/,QUEST/'?'/
    1 FORMAT(A)
      DO 21 I=1,8
       NAME(I)=BLK
   21 CONTINUE
      READ(*,1)DCARD
      IF(CARD(1).EQ.POUND)  THEN
       NAME(1)=POUND
       RETURN
      ENDIF
      IF(CARD(1).EQ.QUEST)  THEN
       NAME(1)=QUEST
       RETURN
      ENDIF
      DO 22 I=1,3
       IF(CARD(I).NE.LEND(I).AND.CARD(I).NE.CEND(I))  GO TO 23
       NAME(I)=CEND(I)
   22 CONTINUE
      RETURN
   23 CONTINUE
      DO 24 I=1,8
       II=I
       IF(CARD(I).EQ.BLK.OR.CARD(I).EQ.COMMA)  GO TO 25
       NAME(I)=CARD(I)
   24 CONTINUE
   25 CONTINUE
      DO 26 I=II,80
       ID=I
       IF(CARD(I).NE.BLK.AND.CARD(I).NE.COMMA)  GO TO 27
   26 CONTINUE
      VALUE=0.0
      WRITE(*,*)'   No value given, ZERO assumed'
      RETURN
   27 CONTINUE
      SIGN=1.0
```

```
      IF(CARD(ID).EQ.MINUS)  THEN
       SIGN=-1.0
       ID=ID+1
      ELSEIF(CARD(ID).EQ.PLUS)  THEN
       ID=ID+1
      ENDIF
      WHOLE=0.0
      DO 30 I=ID,80
       II=I
       IF(CARD(I).EQ.PERIOD)  GO TO 31
       IF(CARD(I).EQ.PLUS)  GO TO 36
       IF(CARD(I).EQ.MINUS)  GO TO 36
       IF(CARD(I).EQ.E.OR.CARD(I).EQ.LE)  GO TO 35
       DO 28 J=1,10
        JJ=J-1
        IF(CARD(I).EQ.NUMBER(J))  GO TO 29
   28 CONTINUE
       VALUE=SIGN*WHOLE
       IF(CARD(I).EQ.BLK)  RETURN
       WRITE(*,*)'  Input error, value set to ZERO'
       VALUE=0.0
       RETURN
   29 CONTINUE
       WHOLE=WHOLE*10.0+JJ
   30 CONTINUE
      VALUE=SIGN*WHOLE
      RETURN
   31 CONTINUE
      ID=II+1
      FRACT=0.0
      ICOUNT=0
      DO 34 I=ID,80
       ICOUNT=ICOUNT+1
       II=I
       IF(CARD(I).EQ.PERIOD)  THEN
        WRITE(*,*)'  Input error, value set to ZERO'
        VALUE=0.0
        RETURN
       ENDIF
       IF(CARD(I).EQ.PLUS)  GO TO 36
       IF(CARD(I).EQ.MINUS)  GO TO 36
       IF(CARD(I).EQ.E.OR.CARD(I).EQ.LE)  GO TO 35
       DO 32 J=1,10
        JJ=J-1
        IF(CARD(I).EQ.NUMBER(J))  GO TO 33
    32 CONTINUE
       VALUE=SIGN*(WHOLE+FRACT)
       IF(CARD(I).EQ.BLK)  RETURN
       WRITE(*,*)'  Input error, value set to ZERO'
       VALUE=0.0
       RETURN
    33 CONTINUE
       FRACT=FRACT+JJ/10.0**ICOUNT
```

```
34 CONTINUE
   VALUE=SIGN*(WHOLE+FRACT)
   RETURN
35 CONTINUE
   II=II+1
36 CONTINUE
   VALUE=SIGN*(WHOLE+FRACT)
   SIGN=1.0
   IF(CARD(II).EQ.MINUS)  THEN
    SIGN=-1.0
    II=II+1
   ELSEIF(CARD(II).EQ.PLUS)  THEN
    II=II+1
   ENDIF
   WHOLE=0.0
   DO 39 I=II,80
    DO 37 J=1,10
     JJ=J-1
     IF(CARD(I).EQ.NUMBER(J))  GO TO 37
37 CONTINUE
    VALUE=VALUE*10.0**(SIGN*WHOLE)
    IF(CARD(I).EQ.BLK)  RETURN
    WRITE(*,*)'  Input error, value set to ZERO'
    VALUE=0.0
    RETURN
38 CONTINUE
    WHOLE=WHOLE*10.0+JJ
39 CONTINUE
   VALUE=VALUE*10.0**(SIGN*WHOLE)
   RETURN
   END
```