ELES-1984

December 1984

EXPANDED LIQUID ENGINE SIMULATION COMPUTER PROGRAM

PROGRAMMERS MANUAL

Prepared By:

Charles E.Taylor

Aerojet TechSystems Company
P.O. Box 13222
Sacramento, California 95813

RPT/AA0145

ACKNOWLEDGEMENTS

The mathematical models used in ELES-1984 are the result of many analysts committing their knowledge and experience to the task of producing simplified, preliminary-design algorithms. The following is a list of contributors:

Roger Anderson
Ed Barth (AFRPL)
Randy Bickford
Kirk Christensen
Don Culver
Jack Dever
Al Epes
Fred Fischietto
Keith Hamlyn (MMDA)
Ross Hewitt
John Hidahl
Bob Holman (SEA)
Jack Ito
Joe Jellison
Craig Judd
Tom Lee
Don Lemke
Bruce Lindley
Barbara Loch/Bicknell (MMDA)
Rich Matlock (AFRPL)
Gregg Meagher
Joe Mellish
Gary Nickerson (SEA)
Charles O'Brien
Dave Perkins (AFRPL)
Bob Schwantes
Adam Siebenhaar
Jim Smith
Charles Taylor
Vic Viteri
Dick Walker

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

The ELES-1984 computer code is a landmark development in the preliminary systems analysis of liquid rocket vehicles. It is capable of revealing subsystem interactions and design choice impacts on total vehicle performance. Its use enables very rapid determinations of optimum vehicle designs.

The liquid propulsion system models in ELES have been developed by Aerojet TechSystems Company under the auspices of AFRPL during the past few years (1980-1984). The main purpose of ELES is to find optimum vehicle designs for specified mission requirements. Toward that end it is capable of evaluating the size, weight, and performance of system components over a range of design configurations, materials of construction, and operating points. These capabilities allow the code to act as an excellent propulsion system preliminary design training tool.

The objective of this manual is to explain the internal structure of the ELES-1984 computer code. Main topics to be covered are the logic flowchart, internal variable definitions, data files, and numerical techniques used.

The non-liquid portions of ELES (solid stage design, trajectory simulation, method of multipliers optimization, etc.) are documented by other sources available through AFRPL.

There are four manuals which describe the operation of the ELES-1984 Computer Program.

Taylor, C. E.
Expanded Liquid Engine Simulation Computer Program
New Users Guide, Aerojet TechSystems Company, 1984

Taylor, C. E.
Expanded Liquid Engine Simulation Computer Program
Technical Information Manual, Aerojet TechSystems Company, 1984

Taylor, C. E.
Expanded Liquid Engine Simulation Computer Program
Programmers Manual, Aerojet TechSystems Company, 1984

Taylor, C. E.
Expanded Liquid Engine Simulation Computer Program
Advanced Users Manual, Aerojet TechSystems Company, 1984

Both users guides are concerned with proper formulation and input of a problem statement. The new users guide does so in a more basic manner than the advanced users guide. The technical information manual describes the mathematical algorithms used in ELES to model the various propulsion subsystems. The programmers manual deals with the internal structure of the FORTRAN code, its file structure, and internal communication.

For more information regarding the ELES-1984 computer program contact

Charles E. Taylor
Aerojet TechSystems Company
P.O. Box 13222
Sacramento, CA 95813
(916) 355-2773

2.0 LIQUID STAGE DESIGN PROCEDURE

The general procedure used for calculating the size/weight/performance of liquid stages is described in Figure 2.1. It begins with the initialization of propellant feed circuit parameters (temperature, pressure, flowrate). The remainder of the procedure refines those initial estimates.

Refinements to the feed schedules include calculating the engine's barrier mixture ratio, engine performance, regenerative cooling jacket properties, turbo pump assembly (TPA) design, propellant tank pressurization requirements, and tankage heat transfer. Iterative procedures are used for some of the parameters.

When the propellant feed schedules are finalized, the final calculations of size, weight, and performance of the TPA, engine, and tankage can take place. A stage summary of those parameters and related parameters can then be made.

1) Initialize temperature schedule
2) Calculate engine barrier mixture ratio
3) Initialize flowrate schedule (using some rough estimates)
    3.1) Estimate tank sizes
        3.1.1 Estimate tank heat transfer
        3.1.2 Estimate pressurization requirements
4) Calculate feed system pressure schedule
    4.1) Calculate engine performance
    4.2) Perform regen cooling analysis (if required)
5) Perform non-conventional nozzle modifications
6) Calculate flowrate schedule (using improved estimates)
    6.1) Calculate tank sizes
        6.1.1) Calculate tank heat transfer
        6.1.2) Calculate pressurization requirements.
7) Design TPA (if required)
    (iterate, if not power balanced)
8) Update propellant temperature schedule
    (iterate on temperature schedule, if required)
9) Calculate TPA size/weight (if required)
10) Calculate engine size/weight
11) Calculate tankage size/weight
12) Calculate stage summary size/weight/performance

Figure 2.1. Liquid Stage Design Procedure

3.0 ELES FLOW CHART

The overall flowchart of ELES is shown in Figure 3.1. The main program is named MODEC. The column to the right of MODEC shows each subroutine called by MODEC. The column below and to the right of each subroutine shows the subroutines which it calls.

In the intertest of reducing the overall length of the flowchart, some entries have been abbreviated (FLUCON, FLUCP, FLUDEN, FLUPRO, FLUVIS, and RUNIT). The fluid property routines are abbreviated in all instances. The major subroutine RUNIT is abbreviated where it is called by the optimizer. The flowchart indicates abbreviated listings by parentheses following the subroutine name.

A brief description of each subroutine in ELES appears in Figure 3.2. The flowchart and subroutine description list should be used together.

```
Main
Program
MODEC
  .     FILOPN
  .     NEWNLP
  .       :     READ3
  .       :       !     NLPIN
  .     FILCLS
  .     INITLQ
  .       :     MAKCAS
  .       :     PROLIB
  .       :     HXLIB
  .       :     INPROP
  .       :       !     FLUCON(conductivity)
  .       :       !     LVPRES
  .       :       !     FLUCP(heat capacity)
  .       :       !     FLUDEN(density)
  .       :       !     FLUVIS(viscosity)
  .       :     INTSAT
  .       :       !     LVPRES
  .       :     LVPRES
  .       :     INITER
  .       :       !     MAKODE
  .       :       !       "     DBINT
  .       :       !     MAKCSR
  .       :       !       "     DBINT
  .     INTERM
  .       :     FILCLS
  .     THRUST
  .       :     NOZZEX
  .     CFVAC
  .     PARSEL
  .     RUNIT
  .       :     PARSEL
  .       :     SSTAGE
  .       :       !     GRAPH
  .       :       !       "     PARCOE
  .       :       !     CFVAC
  .       :     LSTAGE
  .       :       !     INITMP
  .       :       !       "     MAKODE
  .       :       !       "       .     DBINT
  .       :       !     BARMIX
  .       :       !       "     ERISP
  .       :       !       "       .     MAKODE
  .       :       !       "       .       :     DBINT
  .       :       !       "     ERCSR
  .       :       !       "       .     MAKCSR
  .       :       !       "       .       :     DBINT
  .       :       !       "     MAKODE
  .       :       !       "       .     DBINT
  .       :       !       "     MAKCSR
  .       :       !       "       .     DBINT
  .       :       !       "     TBVSMR
  .       :       !       "       .     ERISP
  .       :       !       "       .       :     MAKODE
  .       :       !       "       .       :       !     DBINT
  .       :       !       "       .     MAKODE
  .       :       !       "       .       :     DBINT
                                                        .
                                                        :
                                                        .
```

Figure 3.1. ELES Flowchart (Sheet 1 of 10)

```
:       !       "       CMBGPR
:       !       "       GASH
        !       "       RADENG
        !       "               QUART
        !       "       .       :       CUBROT
        !       "       MACH
        !       INITWD
        !       "       ERISP
        !       "       .       MAKODE
        !       "               :       DBINT
        !       "       MAKODE
        !       "       .       DBINT
        !       "       LVPRES
        !       "       FLUDEN(density)
        !       "       WSCHED
        !       "       .       TNKEST
        !       "       .       :       THWALL
        !       "       .       :       !       MPROP
        !       "       .       :       TNDVOL
        !       "       .       :       !       FLUPRO(fluid properties)
        !       "       .       :       !       ACQUID
        !       "       .       :       !         "     BLADR
        !       "       .       :       !         "     .       GOTOER
        !       "       .       :       !         "     BLADWT
        !       "       .       :       !       TSAT
        !       "       .       :       !       HVAPVT
        !       "       .       .       !       FLUCP(heat capacity)
        !       "       .       :       !       TANKHX
        !       "       .       :       !         "     MPROP
        !       "       .       :       !         "     COMPHX
        !       "       .       :       !         "     CNSTBT
        !       "       .       :       !         "     .       FLUPRO(fluid properties)
        !       "       .       :       !         "     .       FLUDEN(density)
        !       "       .       :       !         "     .       FLUCP(heat capacity)
        !       "       .       :       !         "     .       FREECN
        !       "       .       :       !         "     .       CALCON
        !       "       .       :       !         "     .       COMPHX
        !       "       .       :       !         "     ORBHX
        !       "       .       :       !         "     PSYCHO
        !       "       .       :       !         "     .       DBINT
        !       "       .       :       !       PRESS
        !       "       .       :       !         "     AUTOGN
        !       "       .       :       !         "     .       TSAT
        !       "       .       :       !         "     .       FLUDEN(density)
        !       "       .       :       !         "     .       FLUPRO(fluid properties)
        !       "       .       :       !         "     .       FLUCP(heat capacity)
        !       "       .       :       !         "     .       FREECN
:       !       "       .       :       !         "     .       MPROP
:       !       "       .       :       !         "     .       EPSTN
        !       "       .       :       !         "     SOLGG
        !       "       .       :       !         "     CGPRES
        !       "       .       :       !         "     TSAT
        !       "       .       :       !         "     MPROP
        !       "       .       :       !         "     HEDATA
        !       "       .       :       !         "     .       DBINT
        !       "       .       :       !         "     FREECN
        !       "       .       :       !         "     EPSTN
        .       "       .       :       NCTVOL
        !       "       .       :       !       FLUPRO(fluid properties)
        !       "       .       :       !       ACQUID
                                        .
                                        .
                                        .
```

Figure 3.1. ELES Flowchart (Sheet 2 of 10)

```
!     "          :     !     "     BLADR
!     "          :     !     "           GOTOER
!     "                !     "     BLADWT
!     "                !  TSAT
!     "          :     !  HVAPVT
!     "          :     !  FLUCP(heat capacity)
!     "          :     !  SAT4HX
!     "          :     !     "     MPROP
!     "          :     !  TANKHX
!     "          :     !     "     MPROP
!     "          :     !     "     COMPHX
!     "          :     !     "     CNSTBT
!     "          :     !     "           FLUPRO(fluid properties)
!     "          :     !     "           FLUDEN(density)
!     "          :     !     "           FLUCP(heat capacity)
!     "          :     !     "           FREECN
!     "          :     !     "           CALCON
!     "          :     !     "           COMPHX
!     "          :     !     "     ORBHX
!     "          :     !     "     PSYCHO
!     "          :     !     "           DBINT
!     "          :     !  PRESS
!     "          :     !     "     AUTOGN
!     "          :     !     "           TSAT
!     "          :     !     "           FLUDEN(density)
!     "          :     !     "           FLUPRO(fluid properties)
!     "          :     !     "           FLUCP(heat capacity)
!     "          :     !     "           FREECN
!     "          :     !     "           MPROP
!     "          :     !     "           EPSTN
!     "          :     !     "     SOLGG
!     "          :     !     "     CGPRES
!     "          :     !     "     TSAT
!     "          :     !     "     MPROP
!     "          :     !     "     HEDATA
!     "          :     !     "           DBINT
!     "          :     !     "     FREECN
!     "          :     !     "     EPSTN
!  PSCHED
!     "     LPERF
!     "          ANNEPS
!     "          :     MAKODE
!     "          :     !  DBINT
!     "          :     MAKCSR
!     "          :     !  DBINT
!     "          :     ERISP
!     "          :     !  MAKODE
!     "          :     !     "     DBINT
!     "          :     ERCSR
!     "          :     !  MAKCSR
!     "          :     !     "     DBINT
!     "          :     RADCON
!     "          ERISP
!     "          :     MAKODE
!     "          :     !  DBINT
!     "          MAKODE
!     "          :     DBINT
!     "          MAKCSR
!     "          :     DBINT
!     "          ERCSR
```

.
.
.

Figure 3.1. ELES Flowchart (Sheet 3 of 10)

```
!    "     .     :     MAKCSR
!    "           :     !     DBINT
!    "           VAPCON
!    "     .     .     FLUPRO(fluid properties)
!    "     .     .     SURTEN
!    "     .     .     !     LVPRES
!    "     .     DBINT
!    "     .     GOTOER
!    "           MAKODK
!    "           :     DBINT
!    "     CMBGPR
!    "     REGEN
!    "     .     MACH
!    "     .     GASH
!    "           FLUCP(heat capacity)
!    "           FLUCON(conductivity)
!    "     .     TRANSP
!    "           FLUPRO(fluid properties)
!    "           TSAT
!    "           FFACTR
!    "           HXHCV
!    "           .     FLUPRO(fluid properties)
!    "     .     :     FLUCP(heat capacity)
!    "     LVPRES
!  PLUG
!    "     TLTANG
!    "           NOZZEX
!    "     NOZZEX
!  ANULAR
!    "     NOZZEX
!  WSCHED
!    "     TNKEST
!    "     .     THWALL
!    "           :     MPROP
!    "     .     TNDVOL
!    "           :     FLUPRO(fluid properties)
!    "     .     :     ACQUID
!    "           :     !     BLADR
!    "     .     :     !     "     GOTOER
!    "     .     :     !     BLADWT
!    "     .     :     TSAT
!    "     .     :     HVAPVT
!    "     .     :     FLUCP(heat capacity)
!    "           .     TANKHX
!    "     .     .     !     MPROP
!    "           :     !     COMPHX
!    "           .     !     CNSTBT
!    "     .     :     !     "     FLUPRO(fluid properties)
!    "     .     .     !     "     FLUDEN(density)
!    "           .     !     "     FLUCP(heat capacity)
!    "           :     !     "     FREECN
!    "           :     !     "     CALCON
!    "     .     .     !     "     COMPHX
!    "           :     !     ORBHX
!    "     .     :     !     PSYCHO
!    "           :     !     "     DBINT
!    "           :     PRESS
!    "           .     !     AUTOGN
!    "     .     :     !     "     TSAT
!    "     .     :     !     "     FLUDEN(density)
```

Figure 3.1. ELES Flowchart (Sheet 4 of 10)

```
!       "             :        !        "      FLUPRO(fluid properties)
!       "             :        !        "      FLUCP(heat capacity)
!       "             :        !        "      FREECN
!       "             :        !        "      MPROP
!       "             :        !        "      EPSTN
!       "             :        !     SOLGG
!       "             :        !     CGPRES
!       "             :        !     TSAT
!       "             :        !     MPROP
!       "             :        !     HEDATA
!       "             :        !        "      DBINT
!       "             :        !     FREECN
!       "             :        !     EPSTN
!       "          NCTVOL
!       "             :     FLUPRO(fluid properties)
!       "             :     ACQUID
!       "             :        !     BLADR
!       "             :        !        "      GOTOER
!       "             :        !     BLADWT
!       "             :     TSAT
!       "             :     HVAPVT
!       "             :     FLUCP(heat capacity)
!       "             :     SAT4HX
!       "             :        !     MPROP
!       "             :     TANKHX
!       "             :        !     MPROP
!       "             :        !     COMPHX
!       "             :        !     CNSTBT
!       "             :        !        "      FLUPRO(fluid properties)
!       "             :        !        "      FLUDEN(density)
!       "             :        !        "      FLUCP(heat capacity)
!       "             :        !        "      FREECN
!       "             :        !        "      CALCON
!       "             :        !        "      COMPHX
!       "             :        !     ORBHX
!       "             :        !     PSYCHO
!       "             :        !        "      DBINT
!       "             :     PRESS
!       "             :        !     AUTOGN
!       "             :        !        "      TSAT
!       "             :        !        "      FLUDEN(density)
!       "             :        !        "      FLUPRO(fluid properties)
!       "             :        !        "      FLUCP(heat capacity)
!       "             :        !        "      FREECN
!       "             :        !        "      MPROP
!       "             :        !        "      EPSTN
!       "             :        !     SOLGG
!       "             :        !     CGPRES
!       "             :        !     TSAT
!       "             :        !     MPROP
!       "             :        !     HEDATA
!       "             :        !        "      DBINT
!       "             :        !     FREECN
!       "             :        !     EPSTN
!    TSCHED
!       "    FLUCP(heat capacity)
!       "    FLUPRO(fluid properties)
!       "    MAKODE
!       "           DBINT
!    TPASYS
```

Figure 3.1. ELES Flowchart (Sheet 5 of 10)

```
  :         !         "     LVPRES
  :         !         "     FLUPRO(fluid properties)
  :         !         "     TPAGG
  :         !         "            PUMP
  :         !         "              :     HEADCO
  :         !         "              :     PMPEFF
  :         !         "              :     BPHDCO
  :         !         "              :     BPEFF
  :         !         "            TRBEFF
  :         !         "            SPOUT
  :         !         "            TURBIN
  :         !         "            BLADE
  :         !         "            PARTAD
            !         "              :     TRBEFF
            !         "            ALLOW
            !         "            MAXRPM
            !         "              :     TURBIN
            !         "              :     BLADE
            !         "              :     PARTAD
            !         "              :       !     TRBEFF
            !         "              :     PUMP
            !         "              :       !     HEADCO
            !         "              :       !     PMPEFF
            !         "              :       !     BPHDCO
            !         "              :       !     BPEFF
            !         "     TPAOTH
            !         "            PUMP
            !         "              :     HEADCO
            !         "              :     PMPEFF
            !         "              :     BPHDCO
            !         "              :     BPEFF
            !         "            HEADCO
            !         "            PMPEFF
            !         "            TRBEFF
            !         "            SPOUT
            !         "            TURBIN
            !         "            BLADE
            !         "            PARTAD
            !         "              :     TRBEFF
            !         "            ALLOW
            !         "            MAXRPM
            !         "              :     TURBIN
            !         "              :     BLADE
            !         "              :     PARTAD
            !         "              :       !     TRBEFF
            !         "              :     PUMP
            !         "              :       !     HEADCO
            !         "              :       !     PMPEFF
            !         "              :       !     BPHDCO
            !         "              :       !     BPEFF
            !         "     MAKODE
            !         "            DBINT
            !     WTPA
  :         !         "     FLUDEN(density)
  :         !         "     MAKODE
            !         "            DBINT
            :         "     MAKCSR
            :         "            DBINT
  :         :         "     FLUCP(heat capacity)
  :         !         "     TSAT
```

Figure 3.1. ELES Flowchart (Sheet 6 of 10)

```
!    "    HVAPVT
!  BURNTM
!    "    BTINT
!    "           LINI
!    "           MAKCSR
!    "             :     DBINT
!    "           ERCSR
!    "             :     MAKCSR
!    "             :       !     DBINT
!    "    THROTT
!    "           LINI
!    "    MAKODE
!    "           DBINT
!    "    MAKCSR
!    "           DBINT
!    "    ERISP
!    "           MAKODE
!    "             :     DBINT
!    "    ERCSR
!    "           MAKCSR
!    "             :     DBINT
!  WTTCA
!    "    FLUPRO(fluid properties)
!    "    WTRANZ
!    "           RADCON
!    "    FLUDEN(density)
!  TNKAGE
!    "    LQTANK
!    "           FLUPRO(fluid properties)
!    "           MPROP
!    "           THWALL
!    "             :     MPROP
!    "           TNDVOL
!    "             :     FLUPRO(fluid properties)
!    "             :     ACQUID
!    "             :       !     BLADR
!    "             :       !       "     GOTOER
!    "             :       !     BLADWT
!    "                   TSAT
!    "                   HVAPVT
!    "             :     FLUCP(heat capacity)
!    "             :     TANKHX
!    "             :       !     MPROP
!    "             :       !     COMPHX
!    "             :       !     CNSTBT
!    "             :       !       "     FLUPRO(fluid properties)
!    "             :       !       "     FLUDEN(density)
!    "             :       !       "     FLUCP(heat capacity)
!    "             :       !       "     FREECN
!    "             :       !       "     CALCON
!    "             :       !       "     COMPHX
!    "             :       !     ORBHX
!    "             :       !     PSYCHO
!    "             :       !       "     DBINT
!    "             :     PRESS
!    "             :       !     AUTOGN
!    "             :       !       "     TSAT
!    "             :       !       "     FLUDEN(density)
!    "             :       !       "     FLUPRO(fluid properties)
!    "             :       !       "     FLUCP(heat capacity)
```

Figure 3.1. ELES Flowchart (Sheet 7 of 10)

```
:    !    "    .    :    !    "    FREECN
     !    "    .    :    !    "    MPROP
     !    "    .    :    !    "    EPSTN
     !    "         :    !    SOLGG
:    !    "    .    :    !    CGPRES
:    !    "    .    :    !    TSAT
     !    "    .    :    !    MPROP
     !    "    .    :    !    HEDATA
     !    "    .    :    !    "    DBINT
     !    "    .    :    !    FREECN
     !    "    .    :    !    EPSTN
     !    "    .    GOTOER
     !    "    .    BLADR
     !    "    .    :    GOTOER
     !    "         BLADWT
     !    "         LAYERV
:    !    "    MPROP
:    !    "    SHRTLD
     !    "         NCTVOL
     !    "    .    :    FLUPRO(fluid properties)
     !    "    .    :    ACQUID
     !    "    .    :    !    BLADR
     !    "    .    :    !    "    GOTOER
:    !    "    .    :    !    BLADWT
     !    "    .    :    TSAT
     !    "         :    HVAPVT
     !    "    .    :    FLUCP(heat capacity)
     !    "    .    :    SAT4HX
     !    "    .    :    !    MPROP
     !    "    .    :    TANKHX
     !    "    .    :    !    MPROP
     !    "    .    :    !    COMPHX
     !    "    .    :    !    CNSTBT
     !    "    .    :    !    "    FLUPRO(fluid properties)
     !    "    .    :    !    "    FLUDEN(density)
     !    "    .    :    !    "    FLUCP(heat capacity)
     !    "    .    :    !    "    FREECN
     !    "    .    :    !    "    CALCON
     !    "    .    :    !    "    COMPHX
     !    "         :    !    ORBHX
     !    "    .    :    !    PSYCHO
     !    "    .    :    !    "    DBINT
     !    "    .    :    PRESS
     !    "         :    !    AUTOGN
     !    "         :    !    "    TSAT
     !    "    .    :    !    "    FLUDEN(density)
     !    "    .    :    !    "    FLUPRO(fluid properties)
     !    "    .    :    !    "    FLUCP(heat capacity)
     !    "    .    :    !    "    FREECN
     !    "    .    :    !    "    MPROP
     !    "         :    !    "    EPSTN
     !    "         :    !    SOLGG
     !    "    .    :    !    CGPRES
     !    "    .    :    !    TSAT
     !    "         :    !    MPROP
     !    "    .    :    !    HEDATA
     !    "    .    :    !    "    DBINT
     !    "         :    !    FREECN
     !    "         :    !    EPSTN
     !    "    .    CSETNK
```

.
.
.

Figure 3.1. ELES Flowchart (Sheet 8 of 10)

```
      !       "            :    MPROP
      !       "            :    ACQUID
      !       "            :      !     BLADR
      !       "            :      !       "     GOTOER
      !       "            :      !     BLADWT
      !       "          TORUS
      !       "            :    ACQUID
      !       "            :      !     BLADR
      !       "            :      !       "     GOTOER
      !       "            :      !     BLADWT
      !       "            :    MPROP
      !       "          ELLELL
      !       "            :    QUART
      !       "            :      !     CUBROT
      !       "          TORPNT
      !       "          CONELL
      !       "          NCTLIN
      !       "            :    FLUPRO(fluid properties)
      !       "            :    MPROP
      !       "            :    LINDIA
      !       "            :      !     FFACTR
    FLYPAR
    INTEG
      !     ATMOSD
      !     THRUST
      !       "     NOZZEX
      !     GUIDE
      !       "     GOTOER
      !       "     AEROF
      !     AEROF
      !     GOTOER
      !     TRJPRN
      !       "     GOTOER
      !     KEPLER
    SPRINT
    LQWARN
    TNDSUM
      !     MPROP
    PICTND
      !     INITT
      !       "     ERASE
      !     DWINDO
      !     TEKCHR
      !     MOVEA
      !     DRAWA
      !     CAVHOR
      !       "     MOVEA
      !       "     DRAWA
      !     DRAWR
      !       "     DRAWA
      !     HDCOPY
    VEHSUM
      !     CHRSIZ
      !     ERASE
      !     RESET
      !     MPROP
      !     LINFIX
      !     FINITT
    NCTPAR
    PICVEH
```

Figure 3.1. ELES Flowchart (Sheet 9 of 10)

```
  :         !     INITT
  .         !       "     ERASE
            !     DWINDO
            !     TEKAXS
  :         !     TEKCHR
  :         !     MOVEA
  :         !     DRAWR
  :         !       "     DRAWA
  :         !     DRAWA
  :         !     CAVEDN
  :         !       "     MOVEA
  :         !       "     DRAWA
  :         !     CAVEUP
  :         !       "     MOVEA
            !       "     DRAWA
            !     HDCOPY
            !     ERASE
            !     RESET
          PROSUM
            !     FLUPRO(fluid properties)
            !     LVPRES
          ENGSUM
  .       REGSUM
  :       TPWSUM
  :         !     TSAT
  :       TPASUM
          WTSUM
          VPRINT
NLPPEN
  :       RUNIT(repeat all design and trajectory)
          FUNC
            !     SCALE
            !       "     RUNIT(repeat all design and trajectory)
            !       "     GOTOER
            !     GOTOER
  :       RINIT
            !     GOTOER
          SELOPT
            !     GOTOER
            !     VA10A
            !       "     FUNCT
            !       "               FUNC
            !       "                 :     SCALE
            !       "                 :       !     RUNIT(repeat all design and trajectory)
            !       "                 :       !     GOTOER
  :         !       "                 :     GOTOER
  :         !       "     GOTOER
  :         !       "     CARDS
            !       "               GOTOER
          PENSET
            !     GOTOER
            !     FUNC
            !       "     SCALE
            !       "               RUNIT(repeat all design and trajectory)
            !       "               GOTOER
            !       "     GOTOER
            !     SIMEQ
          CARDS
            !     GOTOER
 SECOND




          CTIM
```

Figure 3.1. ELES Flowchart (Sheet 10 of 10)

1) ACQUID - calculates the displacement volume and weight of propellant acquisition devices and propellant residual volumes in tanks.

2) AEROF - computes axial and normal aerodynamic forces acting on missile as a function of mach number, altitude and angle of attack.

3) ALLOW - calculates the design blade root centrifugal stress limit for turbine blades assuming 20% overspeed, 5% centrifugal bending stress, and 10% gas bending stress.

4) ANNEPS - calculates the area ratio of annular engines based on engine combustion performance, geometry, and thrust requirement.

5) ANULAR - calculates the performance of an annular engine. Detailed performance analysis in subroutine LPERF is required prior to this routine.

6) ATMOSD - computes ambient atmospheric pressure and speed of sound for a given altitude based on 1962 standard atmosphere.

7) AUTOGN - calculates propellant tank autogenous pressurization requirements. Assumes pressurant properties of pure oxidizer or pure fuel when pressurizing the oxidizer or fuel tank respectively.

8) BARMIX - calculates the combustion chamber barrier mixture ratio required for the cooling option under consideration.

9) BLADE - calculates the turbine blade height based on flowrate, velocity, and turbine exhaust gas density.

10) BLADR - calculates the positive expulsion bladder pressure differential, expulsion efficiency, and (for some configurations) thickness.

Figure 3.2. ELES Subroutine List (Sheet 1 of 15)

11) BLADWT - calculates the weight of positive expulsion bladders.

12) BPEFF - calculates the efficiency of boost pumps based on specific speed and impeller diameter.

13) BPHDCO - calculates boost pump head coefficient based on specific speed.

14) BTINT - called by subroutine BURNTM to set up time intervals in the array TBRN for interfacing liquid vehicles with the trajectory routines.

15) BURNTM - sets up the arrays FT, WDOT, and TBRN for interfacing liquid vehicles with the trajectory routines.

16) CALCON - calculates thermal conductivities of spray on foam insulation (SOFI) and multi layer insulation (MLI) under various operating conditions.

17) CARDS - saves intermediate values of optimization run.

18) CAVE - draws elliptical tank heads to the pseudo-Tektronix screen for vertical tank axes.

19) CAVHOR - draws elliptical tank heads to the pseudo-Tektronix screen for horizontal tank axes.

20) CETSQR - error trapping routine for negative square root calls.

21) CFVAC - computes theoretical vacuum thrust coefficient from nozzle expansion ratio and effective propellant ratio of specific heats.

22) CGPRES - calculates the helium pressurant requirements for a storable propellant tank.

Figure 3.2. ELES Subroutine List (Sheet 2 of 15)

23) CHRSIZ - a Tektronix graphics command. Has no function in the line-printer pseudo-Tektronix mode of ELES.

24) CMBGPR - returns combustion gas properties for combustion chamber cooling routines. (At present it provides only a fixed set of default values. This routine is targeted for future improvement).

25) CNSTBT - calculates temperatures at all tank wall interfaces and the heat flux for a constant temperature external boundary on the propellant tank.

26) COMPHX - calculates interface temperatures in a composite one dimensional heat transfer problem.

27) CONELL - used to calculate geometry of non-conventional tankage. Calculates the vertical difference in positions of an interfering conical frostrum and ellipse. (Returns zero if frustrum and ellipse do not touch.)

28) CSETNK - calculates the size and weight of a cylindrical-spherical-elliptical tank.

29) CUBROT - solves for the real roots of a cubic equation.

30) DBINT - double interpolates a two dimensional array of data.

31) DRAWA - simulates the Tektronix DRAWA command for making plots on line printer.

32) DRAWR - simulates the Tektronix DRAWR command for making plots on line printer.

33) DWINDO - simulates the Tektronix DWINDO command for making plots on line printer.

Figure 3.2. ELES Subroutine List (Sheet 3 of 15)

34) ELLELL - used to calculate geometry of non-conventional tankage. Calculates the difference in vertical positions of two interfering ellipses. (Returns zero if they do not touch.)

35) ENGSUM - prints a page of engine size/weight/performance summary data.

36) EPSTN - calculates the pressurant requirements for a cryogenic propellant tank using the Epstein equation.

37) ERASE - simulates the Tektronix ERASE command for making plots on line printer.

38) ERCSR - approximates the C* of a user defined propellant using the equivalence ratio method.

39) ERISP - approximates the Isp of a user defined propellant using the equivalence ratio method.

40) EXTRAZ - calculates the compressibility factor of supercritical fluids.

41) FFACTR - calculates the Weisbach-Darcy friction factor as a function of Reynolds number, absolute surface roughness, and hydraulic dimater.

42) FILCLS - closes all open files prior to a normal termination of program execution.

43) FILOPN - opens many of the files used during program execution.

44) FINITT - simulates the Tektronix FINITT command. (Performs no function in the line-printer mode.)

45) FLUCON - calculates the thermal conductivity of a fluid at any given temperature and pressure.

Figure 3.2. ELES Subroutine List (Sheet 4 of 15)

46) FLUCP - calculates the heat capacity of a fluid at a given temperature and pressure based on the Webb-Rubin equation of state.

47) FLUDEN - calculates the density of a fluid at a given temperature and pressure.

48) FLUPRO - calculates fluid density, viscosity, and thermal conductivity at a given temperature and pressure. (Calls routines FLUDEN, FLUVIS, and FLUCON.)

49) FLUVIS - calculates fluid viscosity at a given temperature and pressure.

50) FLYPAR - adjusts the thrust, burn time, and flowrate arrays in order to allow for parallel burns of integrated stages.

51) FREECN - calculates the fluid heat transfer coefficient due to free convection.

52) FUNC - evaluates the method of multipliers augmented Lagrangian function.

53) FUNCT - manipulates the internal arrays related to optimization.

54) GASDCP - calculates the difference in heat capacity between a real gas and an ideal gas.

55) GASH - calculates combustion chamber gas side heat transfer coefficient using Bartz correlation.

56) GASZ - calculates the compressibility factor of subcritical gases. (Called by FLUDEN.)

57) GENTRP - general interpolator for bivariate data.

58) GOTOER - an error trapping routine related to computed GO TO statements.

59) GRAPH - used by subroutine SSTAGE to design solid stage.

Figure 3.2. ELES Subroutine List (Sheet 5 of 15)

60) GUIDE - checks input flight profiles and exercises the corresponding guidance laws for trajectory calculations.

61) H2DATA - calculates density, thermal conductivity, viscosity, and heat capacity for para-hydrogen.

62) HDCOPY - simulates the Tektronix HDCOPY command for making plots on the line-printer.

63) HEADCO - calculates main pump head coefficient based on specific speed.

64) HEDATA - calculates density, thermal conductivity, viscosity, and heat capacity for helium.

65) HVAPVT - calculates liquid heat of vaporization vs. temperature.

66) HXHCV - for regenerative cooling model this routine calculates the coolant heat transfer coefficient if given velocity or velocity if given coolant heat transfer coefficient.

67) HXLIB - library of liquid propellant heat transfer data.

68) INITER - initialization routine for the equivalence ratio method of calculating performance of user defined propellants.

69) INITLQ - initialization routine for liquid stages. Provides fluid property constants and restructures input data structure.

70) INITMP - initializes the propellant temperature schedule throughout the feed system. Temperature estimates are improved as analysis continues.

71) INITT - simulates the Tektronix INITT command for making plots on the line-printer. (Performs form feed and erases the printing screen.)

Figure 3.2. ELES Subroutine List (Sheet 6 of 15)

72) INITWD - initializes the propellant flow rate schedule throughout the feed system. Flowrate estimates are improved as analysis continues.

73) INPROP - initializes propellant critical properties based on reference data and the method of corresponding states.

74) INTEG - integrates missile trajectory using either a 4th order Runge-Kutta or a 4th order Adams-Moulton predictor corrector procedure.

75) INTERM - checks for fatal input errors and terminates execution if discovered.

76) INTSAT - initializes the data arrays used in subroutine TSAT which calculates fluid saturation temperature.

77) KEPLER - examines orbital injection conditions, burnout radius, burnout flight path angle, and burnout velocity in order to calculate the orbital parameters described by that energy state.

78) LAYERV - calculates volumes of concentric cylindrical volumes with elliptical ends (i.e., insulation layers on a propellant tank).

79) LINDIA - calculates diameter of fluid feed lines with various bends, valves, etc.

80) LINFIX - used to format lines in the non-conventional tank summary output page.

81) LINI - linear interpolation routine.

82) LIQDCP - calculates the difference in heat capacity of a real liquid and an ideal gas.

83) LIQZ - Calculates the compressibility factor of a liquid at a given temperature and pressure.

Figure 3.2. ELES Subroutine List (Sheet 7 of 15)

84) LPERF - calculates the delivered performance of a liquid rocket engine.

85) LQTANK - calculates the size and weight of tandem tankage.

86) LQWARN - prints a listing of warning messages for the liquid stage under consideration. Messages relate to inputs outside of normal design range, components critical design constraints, and designs with potential problems.

87) LSTAGE - supervisory routine for calculating the size, weight, and performance of liquid stages.

88) LVPRES - calculates liquid vapor pressure based on the Riedel-Plank-Miller vapor pressure correlation.

89) MACH - calculates mach number in a combustion chamber in both the subsonic and supersonic regimes.

90) MAKCAS - loads internal data arrays for propellant combination performance. Reads values for specific impulse, characteristic velocity, and combustion temperature from the file "PROPLIB".

91) MAKCSR - interpolates characteristic velocity at a given chamber pressure and mixture ratio from the data arrays read by MAKCAS.

92) MAKODE - interpolates equilibrium specific impulse at a given chamber pressure, mixture ratio, and area ratio from the data arrays read by MAKCAS.

93) MAKODK - interpolates kinetic specific impulse at a given chamber pressure, mixture ratio, area ratio, and throat radius from the data arrays read by MAKCAS.

94) MAXRPM - checks the turbine blade root stress and if necessary causes the turbopump assembly.

Figure 3.2. ELES Subroutine List (Sheet 8 of 15)

95) MODEC - the overall executive program. Initializes variables, sets namelist definitions, etc.

96) MOVEA - simulates the Tektronix MOVEA command for making plots on line printer.

97) MPROP - the material properties library. Provides yield strength, modulus of elasticity, density, minimum gauge, heat capacity, and thermal conductivity.

98) NCTLIN - calculates propellant feed line weights for non-conventional tankage designs.

99) NCTPAR - prints a summary page of non-conventional tankage parameters.

100) NCTVOL - calculates tank volumes and pressures for non-conventional tankage designs.

101) NEWNLP - supervisory routine for the optimizer.

102) NLPIN - performs namelist input and input error checking for the optimizer routines.

103) NLPPEN - driver routine for the optimizer. Directs control of individual elements of the algorithm.

104) NOZZEX - calculates the pressure ratio, exit mach number, and Prandtl-Meyer angle of a nozzle.

105) ORBHX - calculates the external boundary temperature of an orbiting tank exposed to radiant heat flux.

106) PARCOE - gives coefficients for a parabolic curve fit.

Figure 3.2. ELES Subroutine List (Sheet 9 of 15)

107) PARSEL - selects approrpriate parameters to be placed into the optimization list.

108) PARTAD - changes turbine design to partial admission if turbine blades become too small.

109) PENSET - updates the Lagrange multipliers and penalty constants between uncontrained function minimizations.

110) PICTND - creates a scaled schematic drawing of a tandem tank design on the line printer.

111) PICVEH - creates a scaled schematic drawing at a non-conventional tank design on the line printer.

112) PLUG - calculates the size and performance of a plug cluster engine.

113) PMPEFF - calculates the efficiency of a main pump using specific speed and impeller diameter.

114) PRESS - administrates the calculation of propellant tank pressurization requirements for storable or cryogenic propellants.

115) PROLIB - holds propellant properties data for library propellants.

116) PROSUM - prints a page of propellant property data over the operating temperature range of each propellant.

117) PSCHED - calculates the majority of the propellant feed pressure schedule.

118) PSYCHO - from a psychrometric chart this routine looks up the molar concentration of water in air as a function of relative humidity and ambient temperature.

Figure 3.2. ELES Subroutine List (Sheet 10 of 15)

119) PUMP - designs pumps for diameter, efficiency, number of stages, specific speed, and horse power requirements.

120) PVTFNC - checks the Benedict-Webb-Rubin equation of state to see if it is satisfied with input values of reduced temperature, reduced pressure, and reduced volume.

121) QUART - solves for the real roots of a quartic equation.

122) RADENG - calculates the gas side temperature required to maintain a radiation cooled TCA at the maximum allowable material temperature.

123) RAOCON - approximates the contour of a Rao nozzle with hyperbolic curve fits of Rao data.

124) READ3 - sets up position pointers prior to reading optimizer input namelist.

125) REGEN - calculates the pressure drop and temperature rise across a regenerative cooling jacket.

126) REGSUM - prints a one page summary of the regenerative cooling jacket analysis.

127) RESET - simulates the Tektronix RESET command for making plots on line printer. (Issues form feed for line printer.)

128) RINIT - initializes penalty constants for both equality and inequality constraints prior to start of Methods of Multipliers optimization algorithm.

129) RUNIT - administrates calls to solid and liquid stage design and trajectory model.

130) SAT4HX - calculates the surface area and average wall thickness of propellant tanks for use in heat transfer calculations.

Figure 3.2. ELES Subroutine List (Sheet 11 of 15)

131) SCALE - performs all the scaling and unscaling of control variables, objective function, and constraints for the optimizer.

132) SECOND - system specific routine used to determine run-time violations.

133) SELOPT - driver to select the method of unconstrained function minimization for the optimizer.

134) SHRTLD - computes the size, position, and weight of non-conventional tankage designs.

135) SIMEQ - solves a set of simultaneous linear equations.

136) SOLGG - calculates the solid gas generator pressurization requirements of a storable propellant tank including condensibles.

137) SPOUT - calculates the isentropic spouting velocity of a turbine configuration.

138) SPRINT - prints a summary of solid stage designs.

139) SSTAGE - calculates the size, weight, and performance of a solid stage.

140) SUPDCP - calculates the difference in heat capacity of a real fluid and an ideal fluid at supercritical pressures.

141) SUPERZ - calculates the compressibility factor of supercritical fluids.

142) SURTEN - calculates surface tension based on the Hakim equation.

143) TANKHX - calculates propellant tank heat flux for several different heat flux scenarios.

Figure 3.2. ELES Subroutine List (Sheet 12 of 15)

144 TBVSMR - calculates a propellant mixture ratio which corresponds to a desired combustion temperature.

145) TEKAXS - labels the plotting axes for the line-printer output plots.

146) TEKCHR - selects the character to be plotted on the line printer output.

147) THROTT - calculates the throttled chamber pressure and throttling efficiencies for liquid rocket engines.

148) THRUST - computes and integrates delivered thrust and propellant flow rate as a function of burn time.

149) THWALL - calculates the thickness of propellant tank walls for tandem tank designs.

150) TLTANG - calculates the required tilt angle for plug cluster modules.

151) TNDSUM - prints a one page summary of the tankage in a tandem design.

152) TNDVOL - calculates the volumes and pressures for tandem tank routines.

153) TNKAGE - administrates routines for the tankage design routines.

154) TNKEST - administrates routines which estimate the tank volumes for preliminary calculations.

155) TORPNT - used in non-conventional tankage geometry calculations to find the point on a torus to use as an effective ellipse in subroutine ELLELL.

156) TORUS - calculates the geometry of a toroidal tank and its associated weight.

Figure 3.2. ELES Subroutine List (Sheet 13 of 15)

157) TPAGG - designs the turbopump assesmbly (TPA) for gas generator bleed power cycles.

158) TPAOTH - designs the turbopump assembly (TPA) for staged combustion, staged reaction, and expander power cycles.

159) TPASUM - prints a one page summary of the turbopump assembly design.

160) TPASYS - administrates the turbopump assembly system design for all power cycles.

161) TPWSUM - prints a one page summary of the propellant feed system temperature, pressure, and flowrate schedules.

162) TRANSP - calculates the required mass flux of coolant required by a transpiration cooled chamber section.

163) TRBEFF - calculates the efficiency of a single stage turbine over a range of admission fractions.

164) TRJPRN - prints trajectory information at designated time steps.

165) TSAT - calculates fluid saturation temperature at a given pressure.

166) TSCHED - calculates the propellant feed system temperature schedule.

167) TURBIN - sizes the turbine and stages if required.

168) VA1ØA - performs unconstrained function minimization by a quasi-Newton variable-metric technique.

Figure 3.2. ELES Subroutine List (Sheet 14 of 15)

169) VAPCON - calculates propellant vaporization constants which are used in the performance routine (LPERF) to determine the vaporization efficiency of the engine.

170) VEHSUM - prints a summary of non-conventional tankage.

171) VPRINT - prints a one page summary of the vehicle (one to four stages).

172) WSCHED - calculates the flowrate schedule for the propellant feed system.

173) WTPA - calculates the weight of the turbopump assembly (TPA) and related hardware.

174) WTRANZ - calculates the weight of spring actuated translating nozzles and gas deployed skirts.

175) WTSUM - prints a one page summary of the weight items of a stage.

176) WTTCA - calculates the weight of a liquid thrust chamber assembly (TCA)

Figure 3.2. ELES Subroutine List (Sheet 15 of 15)

4.0 NUMERICAL TECHNIQUES

There are a number of different numerical techniques used within ELES-1984. The choice of technique is based on accuracy requirements, implementation effort, code complexity, applicability, and impact on other components of ELES. Small weight items, for example, can tolerate high degrees of error in their weight calculations without appreciably affecting stage or vehicle weight. A simple curve fit would suffice in those instances. When high accuracy is required, an iteration scheme can sometimes work well. If it terminates based on an accuracy criteria, however, it can adversely affect derivative calculations made in the optimizer.

One of the most preferred techniques for use in ELES-1984 is physical modeling. When a component's dimensions, thicknesses, etc. can be calculated, the weights calculated from those dimensions tend to be more accurate and to scale more accurately. Examples of physical modeling in ELES include the thrust chamber, positive expulsion bladder, translating nozzles, and tank weights.

Another method for insuring the accuracy of a model over a wide range of applicability is the use of mechanistic models. These models represent major mechanisms of a process. The engine performance model, for example, starts with ideal performance and mechanistically approaches each loss component by calculating injector characteristics, propellant drop sizes, vaporization rates, element type, stream tube geometry, etc. Other models which utilize a mechanistic approach are the ablative thickness model, regenerative cooling, and transpiration cooling models.

Analytical solutions are another preferred approach. A typical problem with analytical solutions is that a number of simplifying assumptions are required. These assumptions can reduce the accuracy and applicability of the model. When these assumptions are reasonable, ELES employs analytical solutions. Examples include radiation cooling model, heat transfer through tank insulation, physical interference of non-conventional tankage, and solutions of cubic and quartic equations.

When physical modeling is too complex, a physically based scaling approach can be taken. Using only the major dimensions of a component, scaling equations can still reflect a great deal of reality and do not tend to "blow up" outside a narrow range of applicability. Some component weights are calculated by this approach such as the pumps, turbines, valves, and injectors.

Another reliable method for obtaining good accuracy over a wide range of application is table look-up. For example, the ideal performance of the library propellant combinations, fluid properties of both hydrogen and helium, and the efficiencies of both pumps and turbines are looked up in tables. Potential draw-backs to this approach are that the generation of tabular data can be time consuming, erroneous table entries can be easily overlooked, tables take up a lot of computer memory, and table look-ups can take a lot of computer time (especially bivariate or trivariate data).

Curve fits are an extremely common method of representing the variation of a parameter. Depending on the form of the curve fit and the behavior of the data as the independent variables go to extreme values, curve fits can be very accurate and very well behaved. Because the reverse can also be true, extreme care must be taken with the use of curve fits. ELES uses curve fit methods to calculate gimbal system weight, thrust mount weight, expulsion efficiency, heat transfer through tank lines, cryogenic pressurization requirements, nozzle contours, non-optimum tank weight factors, heat transfer coefficients, bladder pressure differentials, fluid properties, and many other parameters.

A less common numerical technique used in ELES is scaling by analogy. Scaling by analogy involves using a model, which is normally used to calculate a parameter, as a way of scaling a known data point. The method of corresponding states, for example, is a method for predicting fluid properties based on critical temperatures and pressures, normal boiling points, molecular weights, etc. ELES uses this method to scale known reference values of those properties. (The accuracy of the predictive method is increased by its use as a scaling procedure.)

Another less common technique is inverse interpolation from curve fits. ELES uses this approach to calculate fluid saturation temperatures as a function of pressure. The method consists of an initialization phase and a subsequent usage phase. During initialization, ELES generates a data table of temperature vs. vapor pressure using the Riedel-Plank-Miller equation for vapor pressure.

$$\ln(P_{vr}) = \frac{G}{T_r}\left[1 - T_r^2 + K\,(3 + T_r)\,(1 - T_r)^3\right]$$

During the usage phase ELES interpolates the data table to obtain saturation temperature as a function of pressure. The interpolation is made using the form of a Clapeyron vapor pressure equation in order to enhance interpolation accuracy.

$$\ln(P_v) = A - B/T$$

In general, inverse interpolation from curve fits is used to provide more execution speed than an iterative solution can provide. The more calls there are to the routine the faster it is compared to iteration. This approach will also provide a better derivative than iterative methods especially if care is taken in the interpolation.

As implied above, iteration is a common method of obtaining the solution of a variable with a non-linear relationship to other known variables. There are a number of different methods of iteration, each of which has its advantages and disadvantages in the areas of convergence speed, convergence assurance, convergence detection, and ease of implementation.

For finding the mixture ratio of a propellant combination which corresponds to a desired combustion temperature, ELES uses the "brute force" halving the interval method. Although this method converges slowly, convergence is guaranteed and an iteration limit assures a known accuracy. Newton-Raphson and secant type methods were avoided in order to assure good program behavior even when the optimizer drives the program into regimes where non-convergence is more likely.

Some of the other iterations in ELES use a Gauss-Siedel or modified Gauss-Siedel technique. The overall area ratio of an annular engine is one of the simpler examples of this. The overall area ratio is a function of the Isp, and the Isp is a function of the overall area ratio. By starting with an initial guess of area ratio and calculating Isp, one can use this Isp value to calculate a better value of area ratio, from which a better value of Isp can be obtained, and so on. A typical termination criteria is an accuracy criteria. However, ELES uses a constant number of iterations in an attempt to provide a more reliable derivative.

Some of the more complicated Gauss-Siedel iterations include the overall propellant feed system temperature schedule and the TPA power balance routine. Due to the numerous computations involved in even a single iteration for both of those solutions, the termination criteria is for $\pm 3\%$ accuracy.

A final numerical technique, which is actually more of a programmer's technique, is the implementation of dummy routines to provide required data. The routine in ELES which provides combustion gas fluid properties, for example, merely returns a constant value for each of its outputs. Its function is to hold a place in the code and allow for future improvements in a modular manner. A second example is the material properties library, which currently has several materials in it but could easily be enlarged to incorporate many other materials.

4.1 WARNING FLAGS

There are many possible inputs to ELES which would create unreasonable designs or designs contrary to good engineering judgement. Because the optimizer may pass through such a design while searching for an optimum, ELES can not halt operation when this happens but must output information which the user and the optimizer can both use. The mechanism which informs the user is warning flags. The mechanism which informs the optimizer is constraint parameters.

The subroutine LQWARN (see flowchart in Figure 3.1) checks all warning flags at output time and issues appropriate messages to the user. Warning flags are set in the various design routines of ELES at the point where the potential error is detected. The format for setting the warning flag (IWARN) is:

```
IWARN (NS, I) = 0
If (condition) IWARN (NS, I) = 1
```

where: NS = stage number
I = identification number of warning
condition = condition under which warning should occur

The warning flag is first set to zero (no error) and then checked for the error condition so that only the last pass through that portion of code can set the warning flag. If the optimizer strays into a "bad" area, warnings will only occur if it does not return to a more accepted design before program termination.

A list of the current warning flags in ELES-1984 is listed in "Expanded Liquid Engine Simulation Computer Program Technical Information Manual", Aerojet TechSystems Company, 1984, section 13.0.

5.0 COMMON BLOCK VARIABLES

All of the variables which appear in common blocks are presented in Figure 5.1. The variables are given in alphabetical order and include a definition, the engineering units of the variable, its default value, the namelist in which it appears (if any), and the name of the labeled common block in which it appears. See the key at the top of the figure to interpret the format of the information.

```
C
CIIIIIIIIIIIIIIIIIII  ELES COMMON BLOCK VARIABLES  IIIIIIIIIIIIIIIIIIIII
CI                                                                       I
CI                   ( UNITS DEFAULT $NAMELIST /COMMON/ )                I
CI                                                                       I
CI      AAA        ENEC WEIGHT                                           I
CI                 ( LBM --- $--- /SSCOM/   )                            I
CI      AATT       NO AVAILABLE DEFINITION    ( /SSCOM/ )                I
CI      ABAPGG     MAXIMUM BURN AREA TO THROAT AREA RATIO                I
CI                 ( --- --- $--- /GASGEN/   )                           I
CI      ABATGG     BURN TO THROAT AREA RATIO IN SOLID GG                 I
CI                 ( --- --- $--- /GASGEN/   )                           I
CI      ACAMAX     MAXIMUM ALLOWABLE AXIAL ACCELERATION DURING FLIGHT    I
CI                 ( G'S 50 $INTRAJ /MOTOR/   )                          I
CI      ACLAPF     CORRELATION COEFFICIENT USED IN CALCULATING FUEL      I
CI                 SATURATION TEMPERATURE                                I
CI                 ( --- --- $--- /CLAP/   )                             I
CI      ACLAPO     CORRELATION COEFFICIENT USED IN CALCULATING OX        I
CI                 SATURATION TEMPERATURE                                I
CI                 ( --- --- $--- /CLAP/   )                             I
CI      ADHPFL     NO AVAILABLE DEFINITION    ( /TPOUT2/ )               I
CI      ADHPOX     NO AVAILABLE DEFINITION    ( /TPOUT2/ )               I
CI      AE         FIBER AREA                                            I
CI                 ( IN**2/END 0.000135 $FILMNT /MOTOR/   )              I
CI      AEPLUG     EXIT AREA OF PLUG CLUSTER                             I
CI                 ( IN**2 --- $--- /PLUGCL/   )                         I
CI      AESSR      CROSS SECTIONAL AREA OF ENGINE SHROUD STIFFENING      I
CI                 RING                                                  I
CI                 ( IN**2 0.152 $LTANK /TANKS/   )                      I
CI      AEXIT      EXIT AREA OF NOZZLE                                   I
CI                 ( IN**2 1.0 $THVST /PERF/   )                         I
CI      AFL        FUEL FLOW AREA IN INJECTOR FACE                       I
CI                 ( IN**2 --- $--- /LIQUID/   )                         I
CI      AFSSR      CROSS SECTIONAL AREA OF FORWARD SHROUD STIFFENING     I
CI                 RING                                                  I
CI                 ( IN**2 0.25 $LTANK /TANKS/   )                       I
CI      ALFDIV     EFFECTIVE HALF ANGLE                                  I
CI                 ( DEG --- $--- /SSCOM/   )                            I
CI      ALFMIX     BARRIER MIXING ANGLE IN CHAMBER                       I
CI                 ( DEG 0.286 $INJECT /LIQUID/   )                      I
CI      ALFNOZ     NOZZLE DIVERGENCE ANGLE OF CONICAL NOZZLES OR EXIT    I
CI                 ANGLE OF CONTOURED NOZZLES                            I
CI                 ( DEG 15. $NOZZLE ///EQ///   )                        I
CI      ALFPRT     EXIT HALF ANGLE                                       I
CI                 ( DEG --- $--- /SSCOM/   )                            I
CI      ALFSTG     NO AVAILABLE DEFINITION    ( /AERO/ )                 I
CI      ALFTB      TURN BACK ANGLE                                       I
CI                 ( DEG --- $--- /SSCOM/   )                            I
CI      ALFTRN     INITIAL FLOW TURNING ANGLE FOR CONTOURED NOZZLES      I
CI                 (FOR BELL(1) = 1 ONLY)                                I
CI                 ( DEG 27 $MATER /MOTOR/   )                           I
CI      ALPH       ANGLE OF ATTACKS FOR WHICH AERODYNAMIC                I
CI                 COEFFICIENTS ARE INPUT                                I
CI                 ( DEG 0. $AEROD /AERO/   )                            I
CI      ALPHA      INITIAL ANGLE OF ATTACK                               I
CI                 ( DEG 0. $INTRAJ ///EQ///   )                         I
CI      ALPHAC     COMMANDED CONSTANT ANGLE OF ATTACK; INPUT FOR         I
CI                 TRAJECTORY GUIDANCE SECTIONS UTILIZING GUIDANCE       I
CI                 OPTION 1                                              I
CI                 ( DEG 0 $GUIDA ///EQ///   )                           I
```

Figure 5.1. Common Block Variables (Sheet 1 of 46)

C

```
CI      ALPMAX    NO AVAILABLE DEFINITION    ( /TRAJ/ )                      I
CI      ALPMLD    ANGLE OF ATTACKS PRODUCING MAXIMUM LIFT-TO-DRAG             I
CI                INPUT AS A FUNCTION OF MACH NUMBER FOR TRAJEC-              I
CI                TORIES UTILIZING GUIDANCE OPTION 9                          I
CI                ( DEG 0. $GUIDA /AERO/  )                                   I
CI      ALPTOL    CONVERGENCE TOLERANCE FOR LC-RHA ITERATION FOR              I
CI                ANGLE OF ATTACK, ALPHA                                      I
CI                ( --- .000001 $AEROD /TRAJ/  )                              I
CI      ALT       NO AVAILABLE DEFINITION    ( /TRAJ/ )                       I
CI      ALTBOM    NO AVAILABLE DEFINITION    ( /TRAJ/ )                       I
CI      ALTI      INITIAL MISSILE ALTITUDE                                    I
CI                ( FT 0.0 $INTRAJ ///EQ///  )                                I
CI      ALTRE     ALTITUDE TO BEGIN RE-ENTRY CALCULATIONS                     I
CI                ( FT 3.E5 $INTRAJ /TRAJ/  )                                 I
CI      ALTSF     ALTITUDES FOR WHICH SKIN FRICTION COEFFICIENTS              I
CI                ARE INPUT                                                   I
CI                ( FT 0. $AEROD /AERO/  )                                    I
CI      ALTSTG    NO AVAILABLE DEFINITION    ( /TRAJ/ )                       I
CI      ALTTGT    ALTITUDE OF TARGET                                          I
CI                ( FT 0.0 $INTRAJ /TRAJ/  )                                  I
CI      AMACH     MACH NUMBERS FOR WHICH AERODYNAMIC COEFFICIENTS             I
CI                ARE INPUT                                                   I
CI                ( --- 0. $AEROD /AERO/  )                                   I
CI      ANOZZ     NOZZLE LENGTH RATIO                                         I
CI                ( --- --- $--- /SSCOM/  )                                   I
CI      AOB       NO AVAILABLE DEFINITION    ( /SSCOM/ )                      I
CI      AOX       OXIDIZER FLOW AREA IN INJECTOR FACE                         I
CI                ( IN**2 --- $--- /LIQUID/  )                                I
CI      APARK     SEMIMAJOR AXIS OF PARKING ORBIT                             I
CI                ( FT 0.0 $ORB ///EQ///  )                                   I
CI      APATAV    NO AVAILABLE DEFINITION    ( ///EQ/// )                     I
CI      APATGG    MINIMUM PORT TO THROAT AREA RATIO                           I
CI                ( --- 3.0 $SOLDGG /GASGEN/  )                               I
CI      APOGEE    NO AVAILABLE DEFINITION    ( ///EQ/// )                     I
CI      AREA      NO AVAILABLE DEFINITION    ( /AERO/ )                       I
CI      AREF      MISSILE AERODYNAMIC REFERENCE AREA INPUT FOR EACH           I
CI                STAGE                                                       I
CI                ( FT**2 0.0 $THVST /AERO/  )                                I
CI      ARFPAY    NO AVAILABLE DEFINITION    ( /AERO/ )                       I
CI      ARGN      CORRELATION COEFFICIENT USED IN CALCULATING                 I
CI                REGEN COOLANT SATURATION TEMPERATURE                        I
CI                ( --- --- $--- /CLAP/  )                                    I
CI      ASTGMX    NO AVAILABLE DEFINITION    ( /AERO/ )                       I
CI      AT        NOMINAL THROAT AREA FOR EACH STAGE                          I
CI                ( IN**2 100. $INPGEN ///EQ///  )                            I
CI      ATILT     NO AVAILABLE DEFINITION    ( /PLUGCL/ )                     I
CI      AUTWTF    TOTAL FUEL AUTOGENOUS PRESSURANT WEIGHT                     I
CI                ( LB --- $--- /TANKS2/  )                                   I
CI      AUTWTO    TOTAL OXIDIZER AUTOGENOUS PRESSURANT WEIGHT                 I
CI                ( LB --- $--- /TANKS2/  )                                   I
CI      B         NO AVAILABLE DEFINITION    ( /SSCOM/ )                      I
CI      BALPAR    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                     I
CI      BCLAPF    CORRELATION COEFFICIENT USED IN CALCULATING FUEL            I
CI                SATURATION TEMPERATURE                                      I
CI                ( --- --- $--- /CLAP/  )                                    I
CI      BCLAPO    CORRELATION COEFFICIENT USED IN CALCULATING OX              I
CI                SATURATION TEMPERATURE                                      I
CI                ( --- --- $--- /CLAP/  )                                    I
CI      BETA      TOLERANCE TO TEST FOR PENALTY CONSTANT INCREASE             I
CI                ( --- 0.25 $NLP /WARN/  )                                   I
```

Figure 5.1. Common Block Variables (Sheet 2 of 46)

C

```
CI        BHPBPF      NO AVAILABLE DEFINITION    ( /TPAOUT/ )
CI        BHPBPO      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                    I
CI        BHPFL       FUEL PUMP BRAKE HORSE POWER                                I
CI                    ( HP --- $--- /TPAOUT/  )                                  I
CI        BHPOX       OXIDIZER PUMP BRAKE HORSE POWER                            I
CI                    ( HP --- $--- /TPAOUT/  )                                  I
CI        BLSPCA      SPACE BETWEEN TRANSVERSE BLADDER AND AFT TANK              I
CI                    WALL (KBLAT = 1)                                           I
CI                    ( IN 0.01 $--- /TANKS/  )                                  I
CI        BLSPCF      SPACE BETWEEN TRANSVERSE BLADDER AND FORWARD TANK          I
CI                    WALL (KBLFT = 1)                                           I
CI                    ( IN 0.01 $--- /TANKS/  )                                  I
CI        BLSPFL      FUEL TANK TRANSVERSE COLLAPSING BLADDER SPACE              I
CI                    ( IN .01 $BLADER /TANKS2/  )                               I
CI        BLSPOX      OXIDIZER TANK TRANSVERSE COLLAPSING BLADDER SPACE          I
CI                    ( IN .01 $BLADER /TANKS2/  )                               I
CI        BPFRFL      FUEL BOOST PUMP FRACTION OF TOTAL HEAD RISE                I
CI                    ( --- 0.0464 $PUMP /PRESCH/  )                             I
CI        BPFROX      OXIDIZER BOOST PUMP FRACTION OF TOTAL HEAD RISE            I
CI                    ( --- 0.0464 $PUMP /PRESCH/  )                             I
CI        BRGN        CORRELATION COEFFICIENT USED IN CALCULATING                I
CI                    REGEN COOLANT SATURATION TEMPERATURE                       I
CI                    ( --- --- $--- /CLAP/  )                                   I
CI        BRRGG       RATIO OF MAXIMUM TO MINIMUM BURN RATE IN SOLID GG          I
CI                    ( --- --- $--- /GASGEN/  )                                 I
CI        BTEQGG      RATIO OF EQUILIBRIUM TEMPERATURE IN PROPELLANT             I
CI                    TANK TO MINIMUM OPERATING TEMPERATURE (TMIN)               I
CI                    ( --- 1.5 $SOLDGG /GASGEN/  )                              I
CI        BULK        COMPOSITE MOTOR CASE MATERIAL BULK FACTOR FOR              I
CI                    EACH STAGE                                                 I
CI                    ( --- 1. $MATER /MOTOR/  )                                 I
CI        BURNRA      GRAIN BURN RATE FOR START CARTRIDGE (ISTART=3)             I
CI                    ( IN/SEC 0.14 $PUMP /TPAIN/  )                             I
CI        BYPREG      REGEN JACKET BYPASS FLOW FRACTION                          I
CI                    ( --- 0.0 $INREGN /SCHEDW/  )                              I
CI        BYPTUR      TURBINE BYPASS FLOW FRACTION                               I
CI                    ( --- 0.0 $INREGN /SCHEDW/  )                              I
CI        C           NO AVAILABLE DEFINITION    ( /ATMOS/ )                     I
CI        CA          AERODYNAMIC AXIAL FORCE COEFFICIENTS INPUT AS              I
CI                    FUNCTIONS OF MACH NUMBER AND ANGLE OF ATTACK               I
CI                    CA(I,J) CORRESPONDS TO AMACH(I)                            I
CI                    ( --- --- $AEROD /AERO/  )                                 I
CI        CAB         BASE DRAG CORRECTION FACTOR; DECREASE IN CA FOR            I
CI                    POWER-ON                                                   I
CI                    ( --- 0. $AEROD /AERO/  )                                  I
CI        CALPH       NO AVAILABLE DEFINITION    ( /TRAJ/ )                      I
CI        CBM         CRITICAL BENDING MOMENT                                    I
CI                    ( IN/LBF 0.0 $LTANK /TANKS/  )                             I
CI        CBMLT       BASE PRESSURE THRUST MULTIPLIER ON PLUG CLUSTER            I
CI                    AND ANNULAR ENGINES                                        I
CI                    ( --- 0.7 $NOZZLE /PLUGCL/  )                              I
CI        CBRGG       BURN RATE COEFFICIENT OF SOLID GRAIN                       I
CI                    ( IN/SEC 0.095 $SOLDGG /GASGEN/  )                         I
CI        CCHIP       NO AVAILABLE DEFINITION    ( /TRAJ/ )                      I
CI        CCHIR       NO AVAILABLE DEFINITION    ( /TRAJ/ )                      I
CI        CCLEN       CHAMBER LENGTH                                             I
CI                    ( IN --- $--- ///EQ///  )                                  I
CI        CCRIT       CRITICAL THERMAL CONDUCTIVITY OF REGEN COOLANT             I
CI                    ( BTU/IN**2/SEC/DEGR/IN --- $--- /COOLNT/  )               I
CI        CCRITF      FUEL CRITICAL THERMAL CONDUCTIVITY                         I
```

Figure 5.1. Common Block Variables (Sheet 3 of 46)

C

```
CI                ( BTU/IN/SEC/DEGR --- $--- /PROPRO/  )                          I
CI    CCRITO      OX CRITICAL THERMAL CONDUCTIVITY                                I
CI                ( BTU/IN/SEC/DEGR --- $--- /PROPRO/  )                          I
CI    CDESGG      DESIGN COMPLEXITY MULTIPLIER ON GAS GENERATOR                   I
CI                ( --- 1.25 $SOLDGG /GASGEN/  )                                  I
CI    CDIFL       FUEL INJECTOR DISCHARGE COEFFICIENT                             I
CI                ( --- 0.77 $INJECT /LIQUID/  )                                  I
CI    CDIOX       OXIDIZER INJECTOR DISCHARGE COEFFICIENT                         I
CI                ( --- 0.72 $INJECT /LIQUID/  )                                  I
CI    CDVLVF      NO AVAILABLE DEFINITION    ( /TCA/ )                            I
CI    CDVLVO      NO AVAILABLE DEFINITION    ( /TCA/ )                            I
CI    CFTCAB      ABLATIVE THICKNESS COEFFICIENT FOR CHAMBER                      I
CI                ( --- 0. $ABLATE /TCA/  )                                       I
CI    CFTNAB      ABLATIVE THICKNESS COEFFICIENT FOR NOZZLE                       I
CI                ( --- 0. $ABLATE /TCA/  )                                       I
CI    CFTTAB      ABLATIVE THICKNESS COEFFICIENT FOR THROAT                       I
CI                ( --- 0. $ABLATE /TCA/  )                                       I
CI    CFVLS       NO AVAILABLE DEFINITION    ( /SSCOM/ )                          I
CI    CGAMA       NO AVAILABLE DEFINITION    ( /TRAJ/ )                           I
CI    CHIDOT      COMMAND CONSTANT INERTIAL PITCH RATE; INPUT FOR                 I
CI                TRAJECTORY GUIDANCE SECTIONS UTILIZING GUIDANCE                 I
CI                OPTION 5                                                        I
CI                ( DEG/SEC --- $GUIDA ///EQ///  )                                I
CI    CHIP        NO AVAILABLE DEFINITION    ( /TRAJ/ )                           I
CI    CHIPO       INITIAL VALUE OF INERTIAL ATTITUDE                              I
CI                ( DEG --- $INTRAJ /TRAJ/  )                                     I
CI    CHIPC       COMMANDED CONSTANT INERTIAL ATTITUDE; INPUT FOR                 I
CI                TRAJECTORY GUIDANCE SECTIONS UTILIZING GUIDANCE                 I
CI                OPTION 2                                                        I
CI                ( DEG --- $GUIDA ///EQ///  )                                    I
CI    CHIR        NO AVAILABLE DEFINITION    ( /TRAJ/ )                           I
CI    CHMULT      COOLING CHANNEL MULTIPLIER IN REGEN COOLING LOGIC               I
CI                ( --- 1.0 $INREGN /WTREGN/  )                                   I
CI    CHPOPC      NO AVAILABLE DEFINITION    ( /LIQUID/ )                         I
CI    CHRPIX      CHARACTERS PER INCH OUTPUT BY THE LINE PRINTER                  I
CI                IN THE HORIZONTAL DIRECTION                                     I
CI                (USED BY PSEUDO-TEKTRONIX ROUTINES)                             I
CI                ( CHAR/IN 10 $NCTINP /PSUTEK/  )                                I
CI    CHRPIY      CHARACTERS PER INCH IN THE Y DIRECTION OUTPUT                   I
CI                BY THE LINE PRINTER (FOR PSEUDO-TEKTRONIX ROUTINE)              I
CI                ( CHAR/IN 6 $NCTINP /PSUTEK/  )                                 I
CI    CLOVOL      CLOSEOUT VOLUME OF REGENERATIVELY COOLED CHAMBER                I
CI                ( IN**3 --- $--- /WTREGN/  )                                    I
CI    CLRAF       SPACE BETWEEN AFT AND FORWARD TANK HEADS                        I
CI                ( IN 0.0 $LTANK /TANKS/  )                                      I
CI    CLRFP       SPACE BETWEEN FORWARD TANK HEAD AND PRESSURE TANK               I
CI                HEAD                                                            I
CI                ( IN 0.0 $LTANK /TANKS/  )                                      I
CI    CLRNOZ       (NOT USED)                                                     I
CI                ( IN 0.0 $NOZZLE ///EQ///  )                                    I
CI    CLRTNK      CLEARANCE BETWEEN NON-CONVENTIONAL TANKS WHEN                   I
CI                LOADING THEM INTO STAGE ENVELOPE                                I
CI                ( IN 2.0 $NCTINP /NCTIN/  )                                     I
CI    CM          MOTOR EFFICIENCY FOR EACH STAGE; AFFECTS THRUST                 I
CI                ONLY                                                            I
CI                ( --- 0.9 $PROPEL /MOTOR/  )                                    I
CI    CMMAX       MAXIMUM CARRY MOMENT                                            I
CI                ( IN/LBF 0.0 $LTANK /TANKS/  )                                  I
CI    CN          AERODYNAMIC NORMAL FORCE COEFFICIENTS INPUT AS                  I
CI                FUNCTIONS OF MACH NUMBER AND ANGLE OF ATTACK.                   I
```

Figure 5.1. Common Block Variables (Sheet 4 of 46)

C

```
CI            CN(I,J) CORRESPONDS TO AMACH(I) AND ALPH(J)                    I
CI            ( --- --- $AEROD /AERO/  )                                     I
CI    CNMLI   EFFECTIVE THERMAL CONDUCTIVITY OF MULTILAYER                   I
CI            INSULATION (MLI)                                               I
CI            ( BTU/IN-SEC-DEGR 4.E-9 $TANKHX /INSLHX/  )                    I
CI    CNSOFI  EFFECTIVE THERMAL CONDUCTIVITY OF SPRAY ON FOAM                I
CI            INSULATION (SOFI)                                              I
CI            ( BTU/IN-SEC-DEGR 3.5E-7 $TANKHX /INSLHX/  )                   I
CI    CNSTRN  VALUE OF CONSTRAINT                                            I
CI            ( --- --- $INPOPT /OPTIM/  )                                   I
CI    CNW     NO AVAILABLE DEFINITION   ( /MOTOR/ )                          I
CI    CONDCT  MATERIAL THERMAL CONDUCTIVITY TABLE                            I
CI            ( BTU/IN-SEC-DEGR .00023,.0001,8*0 $LIQMAT /MTPROP             I
CI    CONDGG  CONDENSATION LOSS MULTIPLIER FOR SOLID GG                      I
CI            ( --- --- $--- /GASGEN/  )                                     I
CI    CONDNZ  NOZZLE EXTENSION THERMAL CONDUCTIVITY AT TNENOM                I
CI            ( BTU/IN/SEC/DEGR .000555 $LIQENG /COOLNT/  )                  I
CI    CONREF  PRODUCT OF EQUIVALENCE RATIO AND MIXTURE RATIO                 I
CI            FOR USER DEFINED PROPELLANT (IPROP=0)                          I
CI            ( --- 2.249 $LPROP /EQUIVR/  )                                 I
CI    CONSIM  PRODUCT OF EQUIVALENCE RATIO AND MIXTURE RATIO                 I
CI            FOR THE LIBRARY PROPELLANT                                     I
CI            ( --- --- $--- /EQUIVR/  )                                     I
CI    CONTOL  TOLERANCE FOR CONSTRAINT                                       I
CI            ( --- --- $INPOPT /OPTIM/  )                                   I
CI    CPCNAF  CONSTANT IN EQUATION OF IDEAL GAS HEAT CAPACITY                I
CI            FOR FUEL                                                       I
CI            ( --- --- $LFUEL /PROPRO/  )                                   I
CI    CPCNAO  CONSTANT IN EQUATION OF IDEAL GAS HEAT CAPACITY                I
CI            FOR OX                                                         I
CI            ( --- --- $LOXID /PROPRO/  )                                   I
CI    CPCNBF  CONSTANT IN EQUATION OF IDEAL GAS HEAT CAPACITY                I
CI            FOR FUEL                                                       I
CI            ( --- --- $LFUEL /PROPRO/  )                                   I
CI    CPCNBO  CONSTANT IN EQUATION OF IDEAL GAS HEAT CAPACITY                I
CI            FOR OX                                                         I
CI            ( --- --- $LOXID /PROPRO/  )                                   I
CI    CPCNCF  CONSTANT IN EQUATION OF IDEAL GAS HEAT CAPACITY                I
CI            FOR FUEL                                                       I
CI            ( --- --- $LFUEL /PROPRO/  )                                   I
CI    CPCNCO  CONSTANT IN EQUATION OF IDEAL GAS HEAT CAPACITY                I
CI            FOR OX                                                         I
CI            ( --- --- $LOXID /PROPRO/  )                                   I
CI    CPCNDF  CONSTANT IN EQUATION OF IDEAL GAS HEAT CAPACITY                I
CI            FOR FUEL                                                       I
CI            ( --- --- $LFUEL /PROPRO/  )                                   I
CI    CPCNDO  CONSTANT IN EQUATION OF IDEAL GAS HEAT CAPACITY                I
CI            FOR OX                                                         I
CI            ( --- --- $LOXID /PROPRO/  )                                   I
CI    CPCONA  IDEAL HEAT CAPACITY CONSTANT                                   I
CI            ( --- 3.89 $LPROP /COOLNT/  )                                  I
CI    CPCONB  IDEAL HEAT CAPACITY CONSTANT                                   I
CI            ( --- 23.2 $LPROP /COOLNT/  )                                  I
CI    CPCONC  IDEAL HEAT CAPACITY CONSTANT                                   I
CI            ( --- -9.818 $LPROP /COOLNT/  )                                I
CI    CPCOND  IDEAL HEAT CAPACITY CONSTANT                                   I
CI            ( --- 1.666 $LPROP /COOLNT/  )                                 I
CI    CPFACT  HEAT CAPACITY CORRECTION FACTOR TO REFERENCE                   I
CI            HEAT CAPACITY (CPREF)                                          I
CI            ( --- --- $--- /COOLNT/  )                                     I
```

Figure 5.1. Common Block Variables (Sheet 5 of 46)

C

```
CI     CPFCTF     NO AVAILABLE DEFINITION    ( /PROPRO/ )                    I
CI     CPFCTO     NO AVAILABLE DEFINITION    ( /PROPRO/ )                    I
CI     CPGGPB     HEAT CAPACITY OF GAS GENERATOR/PREBURNER                     I
CI                COMBUSTION GAS                                               I
CI                ( BTU/LB/DEGR .721 $PUMP /TPAIN/  )                          I
CI     CPLINF     FRACTION OF FACE P ACROSS FUEL LINE                          I
CI                ( --- 0 172 $LIQUID /LIQUID/  )                              I
CI     CPLINO     FRACTION OF FACE P ACROSS OXIDIZER LINE                      I
CI                ( --- 0.207 $LIQUID /LIQUID/  )                              I
CI     CPREF      REFERENC HEAT CAPACITY FOR COOLANT                           I
CI                ( BTU/LBM/DEGR 0.725 $LPROP /COOLNT/  )                      I
CI     CPREFF     FUEL REFERENCE HEAT CAPACITY                                 I
CI                ( BTU/LB/DEGR --- $LFUEL /PROPRO/  )                         I
CI     CPREFO     OX REFERENCE HEAT CAPACITY                                   I
CI                ( BTU/LB/DEGR --- $LOXID /PROPRO/  )                         I
CI     CPVLVF     FRACTION OF FACE P ACROSS FUEL VALVE                         I
CI                ( --- 0.409 $LIQUID /LIQUID/  )                              I
CI     CPVLVO     FRACTION OF FACE P ACROSS OXIDIZER VALVE                     I
CI                ( --- 0.28 $LIQUID /LIQUID/  )                               I
CI     CR         CONTRACTION RATIO OF LIQUID ENGINE                           I
CI                ( --- 2.54 $LIQENG ///EQ///  )                               I
CI     CREF       REFERENCE THERMAL CONDUCTIVITY FOR COOLANT                   I
CI                ( BTU/IN/SEC/DEGR 3.85E-6 $LPROP /COOLNT/  )                 I
CI     CREFFL     FUEL REFERENCE THERMAL CONDUCTIVITY                          I
CI                ( BTU/IN/SEC/DEGR --- $LFUEL /PROPRO/  )                     I
CI     CREFOX     OX REFERENCE THERMAL CONDUCTIVITY                            I
CI                ( BTU/IN/SEC/DEGR --- $LOXID /PROPRO/  )                     I
CI     CSGG       SOLID GRAIN CHARACTERISTIC VELOCITY                          I
CI                ( FT/SEC 3932. $SOLDGG /GASGEN/  )                           I
CI     CSREFF     CSTAR EFFICIENCY                                             I
CI                ( --- --- $--- /LIQUID/  )                                   I
CI     CSRMX      CSTAR FOR USER PROPELLANT AT PC=500 AND OFRMX                I
CI                ( FT/SEC 5689. $LPROP /EQUIVR/  )                            I
CI     CSRODE     IDEAL ONE DIMENSIONAL EQUILIBRIUM CSTAR                      I
CI                ( FT/SEC --- $--- /LIQUID/  )                                I
CI     CSSMMX     CSTAR OF LIBRARY PROPELLANT AT MAX ISP FOR                   I
CI                PC=500  E=20                                                 I
CI                ( FT/SEC --- $--- /EQUIVR/  )                                I
CI     CSTAR      PROPELLANT CHARACTERISTIC VELOCITY INPUT AS A                I
CI                FUNCTION OF CHAMBER PRESSURE; CSTAR(J,I) CORRES-             I
CI                PONDS TO PCR(J) FOR THE I-TH STAGE                           I
CI                ( FT/SEC 0. $PROPEL /MOTOR/  )                               I
CI     CSTARL     DELIVERED CSTAR FOR TCA  (KPERF=0)                           I
CI                ( FT/SEC 5523  $LQPERF /LIQUID/  )                           I
CI     CSTODE     IDEAL CHARACTERISTIC VELOCITY TABLES                         I
CI                ( FT/SEC --- $--- /OPCOND/  )                                I
CI     CTMLT      MULTIPLIER ON THRUST COEFFICIENT FOR PLUG CLUSTER            I
CI                AND ANNULAR ENGINES                                          I
CI                ( --- 0.99 $NOZZLE /PLUGCL/  )                               I
CI     CTOL       NO AVAILABLE DEFINITION    ( /CUT/ )                         I
CI     CV         START VALVE COMPLEXITY MULTIPLIER                            I
CI                ( --- 1.0 $PUMP /TPAIN/  )                                   I
CI     CVACUM     ACCUMULATOR VALVE COMPLEXITY MULTIPLIER (ISTART=2)           I
CI                ( --- 1.0 $PUMP /TPAIN/  )                                   I
CI     CVMAX      MAXIMUM VALUES FOR CONTROL VECTOR (IOPT) ELEMENTS            I
CI                ( --- --- $INPOPT /CVBOND/  )                                I
CI     CVMIN      MINIMUM VALUES FOR CONTROL VECTOR (IOPT) ELEMENTS            I
CI                ( --- --- $INPOPT /CVBOND/  )                                I
CI     CVMLTF     CONTROL VALVE PRESSURE DROP MULTIPLIER USED TO               I
CI                CALCULATE PRESSURE DROP FROM PUMP DISCHARGE TO               I
```

Figure 5.1. Common Block Variables (Sheet 6 of 46)

C

```
CI                GAS GENERATOR/PRE-BURNER INJECTOR INLET                      I
CI                ( --- 0.65 $PUMP /PRESCH/  )                                 I
CI       CXHTCF   HEAT TRANSFER COEFFICIENT MULTIPLIER FOR HEAT                I
CI                EXCHANGER ON FUEL SIDE                                       I
CI                ( --- .38073 $--- /TPAIN/  )                                 I
CI       CXHTCO   HEAT TRANSFER COEFFICIENT MULTIPLIER FOR HEAT                I
CI                EXCHANGER ON OXIDIZER SIDE                                   I
CI                ( --- 0.23439 $--- /TPAIN/  )                                I
CI       CXINJ    INJECTOR COMPLEXITY MULTIPLIER                               I
CI                ( --- 1. $CXWMLT /TCA/  )                                    I
CI       CXVALV   VALVE COMPLEXITY MULTIPLIER                                  I
CI                ( --- 1. $CXWMLT /TCA/  )                                    I
CI       CXWATL   AFT TANK LINE WEIGHT MULTIPLIER                              I
CI                ( --- 1. $CXWMLT /MULT/  )                                   I
CI       CXWATN   AFT TANK WEIGHT MULTIPLIER                                   I
CI                ( --- 1. $--- /TWTMLT/  )                                    I
CI       CXWCHM   CHAMBER WEIGHT MULTIPLIER                                    I
CI                ( --- 1. $CXWMLT /TCA/  )                                    I
CI       CXWDUC   HOT GAS DUCT WEIGHT MULTIPLIER                               I
CI                ( --- 2.5 $PUMP /TPAIN/  )                                   I
CI       CXWENG   ENGINE WEIGHT MULTIPLIER                                     I
CI                ( --- 1.05 $CXWMLT /TCA/  )                                  I
CI       CXWFLT   FUEL TANK WEIGHT MULTIPLIER                                  I
CI                ( --- 1. $CXWMLT /TWTMLT/  )                                 I
CI       CXWFTL   FORWARD TANK LINE WEIGHT MULTIPLIER                          I
CI                ( --- 1. $CXWMLT /MULT/  )                                   I
CI       CXWFTN   FORWARD TANK WEIGHT MULTIPLIER                               I
CI                ( --- 1. $--- /TWTMLT/  )                                    I
CI       CXWGIM   WEIGHT MULTIPLIER ON ENGINE GIMBALING SYSTEM                 I
CI                ( --- 1.0 $CXWMLT /TWTMLT/  )                                I
CI       CXWIGG   GAS GENERATOR OR PRE-BURNER INJECTOR WEIGHT                  I
CI                MULTIPLIER                                                   I
CI                ( --- 1.0 $PUMP /TPAIN/  )                                   I
CI       CXWLIN   ENGINE BAY PROPELLANT LINE WEIGHT MULTIPLIER                 I
CI                ( --- 2.5 $PUMP /TPAIN/  )                                   I
CI       CXWNCT   NO AVAILABLE DEFINITION   ( /NCTIN/ )                        I
CI       CXWNZE   NOZZLE EXTENSION WEIGHT MULTIPLIER                           I
CI                ( --- 1.1 $CXWMLT /TCA/  )                                   I
CI       CXWOXT   OXIDIZER TANK WEIGHT MULTIPLIER                              I
CI                ( --- 1. $CXWMLT /TWTMLT/  )                                 I
CI       CXWPCH   PRESSURANT CONTROL HARDWARE WEIGHT MULTIPLIER                I
CI                ( --- 1. $CXWMLT /MULT/  )                                   I
CI       CXWPTL   PRESSURE TANK LINE WEIGHT MULTIPLIER                         I
CI                ( --- 1. $CXWMLT /MULT/  )                                   I
CI       CXWPTN   PRESSURE TANK WEIGHT MULTIPLIER                              I
CI                ( --- 1. $CXWMLT /TWTMLT/  )                                 I
CI       CXWSTR   STRUCTURAL WALL WEIGHT MULTIPLIER                            I
CI                ( --- 1. $CXWMLT /MULT/  )                                   I
CI       CXWTHM   WEIGHT MULTIPLIER ON ENGINE THRUST MOUNT                     I
CI                ( --- 1.0 $CXWMLT /TWTMLT/  )                                I
CI       CXWTNK   TANK WEIGHT MULTIPLIER                                       I
CI                 (FOR BOTH TANDEM AND NON-CONVENTIONAL)                      I
CI                ( --- 1. $CXWMLT /MULT/  )                                   I
CI       CXWTPA   TURBOPUMP ASSEMBLY WEIGHT MULTIPLIER                         I
CI                ( --- 1. $CXWMLT /TPAIN/  )                                  I
CI       CYLLAT   CYLINDRICAL LENGTH OF AFT TANK                               I
CI                ( IN -- $--- /TANKS/  )                                      I
CI       CYLLFT   CYLINDRICAL LENGTH OF FORWARD TANK                           I
CI                ( IN --- $--- /TANKS/  )                                     I
CI       CYLLPT   CYLINDRICAL LENGTH OF PRESSURE TANK                          I
```

Figure 5.1. Common Block Variables (Sheet 7 of 46)

C

```
CI                 ( IN --- $--- /TANKS/   )                          I
CI      CYLTNK    NO AVAILABLE DEFINITION    ( /NCTOUT/ )             I
CI      CZERFL    NO AVAILABLE DEFINITION    ( /TPAOUT/ )             I
CI      CZERO     NO AVAILABLE DEFINITION    ( /TPAOUT/ )             I
CI      CZEROX    NO AVAILABLE DEFINITION    ( /TPAOUT/ )             I
CI      DACCFL    NO AVAILABLE DEFINITION    ( /TPOUT2/ )             I
CI      DACCOX    NO AVAILABLE DEFINITION    ( /TPOUT2/ )             I
CI      DACQFL    FUEL TANK ACQUISITION DEVICE DENSITY (KACQFL=6)     I
CI                ( LB/IN**3 0.1 $LTANK /TANKS2/   )                  I
CI      DACQOX    OXIDIZER TANK ACQUISITION DEVICE DENSITY(KACQOX=6)  I
CI                ( LB/IN**3 0.1 $LTANK /TANKS2/   )                  I
CI      DANBAS    DIAMETER OF BASE OF ANNULAR ENGINE                  I
CI                ( IN --- $--- /PLUGCL/   )                          I
CI      DANEX     DIAMETER OF ANNULAR THROAT OF ANNULAR ENGINE        I
CI                ( IN 48 $NOZZLE /PLUGCL/   )                        I
CI      DBEXPA    EXPONENT ON REYNOLDS NUMBER IN LIQUID HEAT TRANS-   I
CI                FER COEFFICIENT CALCULATION                         I
CI                ( --- 0.95 $LPROP /COOLNT/   )                      I
CI      DBEXPB    EXPONENT ON PRANDTL NUMBER IN LIQUID HEAT TRANS-    I
CI                FER COEFFICIENT CALCULATION                         I
CI                ( --- 0.4 $LPROP /COOLNT/   )                       I
CI      DBMLTK    MULTIPLYING FACTOR IN LIQUID HEAT TRANSFER          I
CI                COEFFICIENT CALCULATION                             I
CI                ( --- 0.005 $LPROP /COOLNT/   )                     I
CI      DBNDFL    FUEL TANK BOND DENSITY                              I
CI                ( LB/IN**3 .04 $BLADER /TANKS2/   )                 I
CI      DBNDOX    OXIDIZER TANK BOND DENSITY                          I
CI                ( LB/IN**3 .04 $BLADER /TANKS2/   )                 I
CI      DBOTFL    NO AVAILABLE DEFINITION    ( /TPOUT2/ )             I
CI      DBOTOX    NO AVAILABLE DEFINITION    ( /TPOUT2/ )             I
CI      DBPFL     NO AVAILABLE DEFINITION    ( /TPAOUT/ )             I
CI      DBPOX     NO AVAILABLE DEFINITION    ( /TPAOUT/ )             I
CI      DBRCS     NO AVAILABLE DEFINITION    ( /TPAOUT/ )             I
CI      DCBAT     CENTER BODY DIAMETER IN AFT TANK                    I
CI                ( IN --- $--- /TANKS/   )                           I
CI      DCBFT     CENTER BODY DIAMETER IN FORWARD TANK                I
CI                ( IN --- $--- /TANKS/   )                           I
CI      DCHAM     CHAMBER INSIDE DIAMETER                             I
CI                ( IN --- $--- /LIQUID/   )                          I
CI      DCHARC    REFERENCE CHAR DEPTH IN CHAMBER                     I
CI                ( IN 1.02 $ABLATE /TCA/   )                         I
CI      DCHARN    NOZZLE REFERENCE CHAR DEPTH                         I
CI                ( IN 0.087 $ABLATE /TCA/   )                        I
CI      DCHART    REFERENCE CHAR DEPTH IN THROAT                      I
CI                ( IN 1.33 $ABLATE /TCA/   )                         I
CI      DCRIT     CRITICAL DENSITY OF REGEN COOLANT                   I
CI                ( LBM/IN**3 --- $--- /COOLNT/   )                   I
CI      DCRITF    FUEL CRITICAL DENSITY                               I
CI                ( LB/IN**3 --- $--- /PROPRO/   )                    I
CI      DCRITO    OX CRITICAL DENSITY                                 I
CI                ( LB/IN**3 --- $--- /PROPRO/   )                    I
CI      DDUCBF    NO AVAILABLE DEFINITION    ( /TPOUT2/ )             I
CI      DDUCFL    NO AVAILABLE DEFINITION    ( /TPOUT2/ )             I
CI      DDUCOX    NO AVAILABLE DEFINITION    ( /TPOUT2/ )             I
CI      DDUCT     NO AVAILABLE DEFINITION    ( /TPOUT2/ )             I
CI      DDUCTI    NO AVAILABLE DEFINITION    ( /TPOUT2/ )             I
CI      DEEXIT    EXIT DIAMETER                                       I
CI                ( IN --- $--- /SSCOM/   )                           I
CI      DEL       INITIAL OPTIMIZATION STEP SIZE                      I
CI                ( --- 5 $INPOPT /OPTIM/   )                         I
```

Figure 5.1. Common Block Variables (Sheet 8 of 46)

C

```
CI        DELCHK      NO AVAILABLE DEFINITION    ( ///EQ/// )                I
CI        DELINC      INCLINATION CHANGE                                     I
CI                    ( DEG 0.0 $ORB ///EQ///  )                             I
CI        DELMIN      MINIMUM OPTIMIZATION STEP SIZE FOR CONVERGENCE         I
CI                    ( --- --- $INPOPT /OPTIM/  )                           I
CI        DELT        TRAJECTORY INTEGRATION TIME STEP INTERVAL              I
CI                    (CONSTANT DURING FLIGHT)                               I
CI                    ( SEC 1 $INTRAJ /TRAJ/  )                              I
CI        DELT24      NO AVAILABLE DEFINITION    ( /TRAJ/ )                  I
CI        DELTAP      TOTAL DELTA P ACROSS REGEN JACKET                      I
CI                    ( PSI --- $--- /COOLNT/  )                             I
CI        DELTAT      TOTAL DELTA T ACROSS REGEN JACKET                      I
CI                    ( DEGR --- $--- /COOLNT/  )                            I
CI        DELTAV      NO AVAILABLE DEFINITION    ( ///EQ/// )                I
CI        DELTEE      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                I
CI        DELTFL      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                I
CI        DELTOX      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                I
CI        DEXIT       NOZZLE EXIT DIAMETER                                   I
CI                    ( IN --- $--- /LSCOM/  )                               I
CI        DFL         FUEL PUMP DIAMETER                                     I
CI                    ( IN --- $--- /TPAOUT/  )                              I
CI        DFL2        NO AVAILABLE DEFINITION    ( /TPOUT2/ )                I
CI        DFLJ        FUEL INJECTOR ORIFICE DIAMETER                         I
CI                    ( IN --- $--- /LIQUID/  )                              I
CI        DGGPB       NO AVAILABLE DEFINITION    ( /TPOUT2/ )                I
CI        DGPRD       NO AVAILABLE DEFINITION    ( /CONST/ )                 I
CI        DHVAPF      FUEL HEAT OF VAPORIZATION AT NORMAL BOILING POINT      I
CI                    ( BTU/LB --- $LFUEL /PROPRO/  )                        I
CI        DHVAPO      OX HEAT OF VAPORIZATION AT NORMAL BOILING POINT        I
CI                    ( BTU/LB --- $LOXID /PROPRO/  )                        I
CI        DIFTBF      USED TO CALCULATE BARRIER TEMPERATURE FOR REGEN        I
CI                    COOLED CHAMBERS AND TRANS-REGEN CHAMBERS USING         I
CI                      TBARRIER = DIFTBF * (TCORE - TGWNOM) + TGWNOM        I
CI                    ( --- 1.0 $INREGN ///EQ///  )                          I
CI        DLAFT       AFT LINE DIAMETER                                      I
CI                    ( IN --- $--- /TANKS/  )                               I
CI        DLBPFL      NO AVAILABLE DEFINITION    ( /TPOUT2/ )                I
CI        DLBPOX      NO AVAILABLE DEFINITION    ( /TPOUT2/ )                I
CI        DLFWD       FORWARD LINE DIAMETER                                  I
CI                    ( IN --- $--- /TANKS/  )                               I
CI        DLMPFL      NO AVAILABLE DEFINITION    ( /TPOUT2/ )                I
CI        DLMPOX      NO AVAILABLE DEFINITION    ( /TPOUT2/ )                I
CI        DMINSG      MINIMUM ALLOWABLE SOLID GRAIN DIAMETER                 I
CI                    ( IN 3.0 $SOLDGG /TANKS/  )                            I
CI        DMOTOR      MOTOR OUTSIDE DIAMETER INCLUDING EXTERNAL              I
CI                    INSULATION                                             I
CI                    ( IN 66. $INPGEN ///EQ///  )                           I
CI        DNMLI       MULTILAYER INSULATION (MLI) DENSITY                    I
CI                    ( LBM/IN**3 .002 $TANKHX /TANKS2/  )                   I
CI        DNSOFI      SPRAY ON FOAM INSULATION (SOFI) DENSITY                I
CI                    ( LBM/IN**3 .00127 $TANKHX /TANKS2/  )                 I
CI        DOX         OXIDIZER PUMP DIAMETER                                 I
CI                    ( IN --- $--- /TPAOUT/  )                              I
CI        DOX2        NO AVAILABLE DEFINITION    ( /TPOUT2/ )                I
CI        DOXJ        OXIDIZER INJECTOR ORIFICE DIAMETER                     I
CI                    ( IN --- $--- /LIQUID/  )                              I
CI        DPBLDA      AFT BLADDER DELTA P                                    I
CI                    ( PSI --- $--- /TANKS/  )                              I
CI        DPBLDF      FORWARD BLADDER DELTA P                                I
CI                    ( PSI --- $--- /TANKS/  )                              I
```

Figure 5.1. Common Block Variables (Sheet 9 of 46)

C

```
CI       DPBLFL     FUEL BLADDER DELTA P                                        I
CI                  ( PSI --- $--- /PRESCH/  )                                  I
CI       DPBLOX     OXIDIZER BLADDER DELTA P                                    I
CI                  ( PSI --- $--- /PRESCH/  )                                  I
CI       DPBPFL     DELTA P BETWEEN FUEL IN TANK AND BOOST PUMP INLET           I
CI                  ( PSIA --- $--- /PRESCH/  )                                 I
CI       DPBPOX     DELTA P BETWEEN OX IN TANK AND BOOST PUMP INLET             I
CI                  ( PSIA --- $--- /PRESCH/  )                                 I
CI       DPGPBF     FUEL DELTA P ACROSS GAS GENERATOR/PREBURNER                 I
CI                  INJECTOR                                                    I
CI                  ( PSIA --- $--- /PRESCH/  )                                 I
CI       DPGPBO     OX DELTA P ACROSS GAS GENERATOR/PREBURNER INJECTOR          I
CI                  ( PSIA --- $--- /PRESCH/  )                                 I
CI       DPIJFL     FUEL INJECTOR DELTA P                                       I
CI                  ( PSI --- $--- /LIQUID/  )                                  I
CI       DPIJOX     OXIDIZER INJECTOR DELTA P                                   I
CI                  ( PSI --- $--- /LIQUID/  )                                  I
CI       DPLNFL     FUEL LINE DELTA P                                           I
CI                  ( PSI --- $--- /LIQUID/  )                                  I
CI       DPLNOX     OXIDIZER LINE DELTA P                                       I
CI                  ( PSI --- $--- /LIQUID/  )                                  I
CI       DPPMPF     DELTA P ACROSS FUEL PUMP                                    I
CI                  ( PSIA --- $--- /PRESCH/  )                                 I
CI       DPPMPO     DELTA P ACROSS OX PUMP                                      I
CI                  ( PSIA --- $--- /PRESCH/  )                                 I
CI       DPREGF     FUEL DELTA P ACROSS REGEN JACKET                            I
CI                  ( PSIA --- $--- /PRESCH/  )                                 I
CI       DPREGO     OX DELTA P ACROSS REGEN JACKET                              I
CI                  ( PSIA --- $--- /PRESCH/  )                                 I
CI       DPSYSF     FUEL FEED SYSTEM DELTA P                                    I
CI                  ( PSI --- $--- /LIQUID/  )                                  I
CI       DPSYSO     OXIDIZER FEED SYSTEM DELTA P                                I
CI                  ( PSI --- $--- /LIQUID/  )                                  I
CI       DPTURB     DELTA P ACROSS TURBINE                                      I
CI                  ( PSIA --- $--- /PRESCH/  )                                 I
CI       DPVLVF     FUEL VALVE DELTA P                                          I
CI                  ( PSI --- $--- /LIQUID/  )                                  I
CI       DPVLVO     OXIDIZER VALVE DELTA P                                      I
CI                  ( PSI --- $--- /LIQUID/  )                                  I
CI       DREF       REFERENCE VALUE OF DENSITY FOR COOLANT                      I
CI                  ( LBM/IN**3 0.0327 $LPROP /COOLNT/  )                       I
CI       DREFFL     FUEL REFERENCE DENSITY                                      I
CI                  ( LB/IN**3 --- $LFUEL /PROPRO/  )                           I
CI       DREFOX     OX REFERENCE DENSITY                                        I
CI                  ( LB/IN**3 --- $LOXID /PROPRO/  )                           I
CI       DRGL       NO AVAILABLE DEFINITION    ( /TRAJ/ )                       I
CI       DRGLOS     IDEAL VELOCITY LOSSES DUE TO AERODYNAMIC DRAG               I
CI                  ( FT/SEC 0 $INTRAJ /TRAJ/  )                                I
CI       DSPH       NO AVAILABLE DEFINITION    ( /TPOUT2/ )                     I
CI       DTBPFL     FUEL DELTA T ACROSS BOOST PUMP                              I
CI                  ( DEGR --- $--- /TEMSCH/  )                                 I
CI       DTBPOX     OX DELTA T ACROSS BOOST PUMP                                I
CI                  ( DEGR --- $--- /TEMSCH/  )                                 I
CI       DTHRT      INITIAL THROAT DIAMETER                                     I
CI                  ( IN --- $--- /LSCOM/  )                                    I
CI       DTIJFL     FUEL DELTA T ACROSS TCA INJECTOR                            I
CI                  ( DEGR --- $--- /TEMSCH/  )                                 I
CI       DTIJOX     OX DELTA T ACROSS TCA INJECTOR                              I
CI                  ( DEGR --- $--- /TEMSCH/  )                                 I
CI       DTLNFL     FUEL DELTA T ACROSS FEED LINE                               I
```

Figure 5.1. Common Block Variables (Sheet 10 of 46)

C

```
CI                   ( DEGR --- $--- /TEMSCH/  )                                  I
CI       DTLNOX      OX DELTA T ACROSS FEED LINE                                  I
CI                   ( DEGR --- $--- /TEMSCH/  )                                  I
CI       DTPA        NO AVAILABLE DEFINITION    ( /TPOUT2/ )                      I
CI       DTPABF      NO AVAILABLE DEFINITION    ( /TPOUT2/ )                      I
CI       DTPABO      NO AVAILABLE DEFINITION    ( /TPOUT2/ )                      I
CI       DTPAFL      NO AVAILABLE DEFINITION    ( /TPOUT2/ )                      I
CI       DTPAOX      NO AVAILABLE DEFINITION    ( /TPOUT2/ )                      I
CI       DTPMPF      FUEL DELTA T ACROSS MAIN PUMP                                I
CI                   ( DEGR --- $--- /TEMSCH/  )                                  I
CI       DTPMPO      OX DELTA T ACROSS MAIN PUMP                                  I
CI                   ( DEGR --- $--- /TEMSCH/  )                                  I
CI       DTREGF      FUEL DELTA T ACROSS REGEN JACKET                             I
CI                   ( DEGR --- $--- /TEMSCH/  )                                  I
CI       DTREGO      OX DELTA T ACROSS REGEN JACKET                               I
CI                   ( DEGR --- $--- /TEMSCH/  )                                  I
CI       DTTURB      TEMPERATURE DROP ACROSS TURBINE                              I
CI                   ( DEGR --- $--- /TEMSCH/  )                                  I
CI       DTURB       TURBINE DIAMETER                                             I
CI                   ( IN --- $--- /TPAOUT/  )                                    I
CI       DTURBF      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                      I
CI       DTURBO      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                      I
CI       DTVLVF      FUEL DELTA T ACROSS BIPROP VALVE                             I
CI                   ( DEGR --- $--- /TEMSCH/  )                                  I
CI       DTVLVO      OX DELTA T ACROSS BIPROP VALVE                               I
CI                   ( DEGR --- $--- /TEMSCH/  )                                  I
CI       DVREQ       NO AVAILABLE DEFINITION    ( /MOTOR/ )                       I
CI       E           REGEN STATION LOCAL AREA RATIO                               I
CI                   ( --- --- $--- /RGNSUM/  )                                   I
CI       EAFSKT      MODULUS OF ELASTICITY OF STAGE AFT SKIRT                     I
CI                   ( LBF/IN**2 29.E6 $INTSTG /MOTOR/  )                         I
CI       EARIR       EARTH INFRA-RED HEAT FLUX (KHXOPT=2)                         I
CI                   ( BTU/SEC-IN**2 1.35E-4 $TANKHX /INSLHX/  )                  I
CI       EARREF      EARTH REFLECTANCE (ALBEDO) (KHXOPT=2)                        I
CI                   ( --- 0.39 $TANKHX /INSLHX/  )                               I
CI       EBRGG       BURN RATE EXPONENT OF SOLID GRAIN                            I
CI                   ( --- 0.64 $SOLDGG /GASGEN/  )                               I
CI       ECASE       MODULUS OF ELASTICITY OF CASE MATERIAL                       I
CI                   ( LBF/IN**2 29.E6 $MATER /MOTOR/  )                          I
CI       ECCEN       NO AVAILABLE DEFINITION    ( ///EQ/// )                      I
CI       ECFTHR      TABLE OF NOZZLE EFFICIENCIES FOR THROTTLED                   I
CI                   PRESSURE FRACTIONS                                           I
CI                   ( --- --- $THROT /THREFF/  )                                 I
CI       ECSVAP      CSTAR VAPORIZATION EFFICIENCY                                I
CI                   ( --- --- $--- /LIQUID/  )                                   I
CI       EDES        ECCENTRICITY OF DESTINATION ORBIT                            I
CI                   ( --- 0.0 $ORB ///EQ///  )                                   I
CI       EECRAT      EXTENDABLE EXIT CONE EXPANSION RATIO                         I
CI                   ( --- 1.5 $NOZZLE ///EQ///  )                                I
CI       EINSTG      MODULUS OF ELASTICITY OF INTERSTAGE MATERIAL AT              I
CI                   THE TOP OF EACH LOWER STAGE                                  I
CI                   ( LBF/IN**2 1.8E6 $INTSTG /MOTOR/  )                         I
CI       ELDENS      INJECTOR ELEMENT DENSITY                                     I
CI                   ( ELEMENTS/IN**2 3.1 $INJECT ///EQ///  )                     I
CI       ELDOME      ELLIPSE RATIO FOR THE CASE/TANK DOMES                        I
CI                   ( --- 1. $INPGEN ///EQ///  )                                 I
CI       ELLCHM      NO AVAILABLE DEFINITION    ( /NCTIN/ )                       I
CI       ELLTNK      NO AVAILABLE DEFINITION    ( /NCTIN/ )                       I
CI       ELPRIM      NO AVAILABLE DEFINITION    ( /NCTIN/ )                       I
CI       ELRP        PRESSURE TANK ELLIPSE RATIO                                  I
```

Figure 5.1. Common Block Variables (Sheet 11 of 46)

C

```
CI                 ( --- 1.0 $LTANK ///EQ/// )                          I
CI      EMISTC     THRUST CHAMBER EMMISIVITY FOR TCA RADIATION           I
CI                 COOLING MODEL                                         I
CI                 ( --- 0.9 $LIQENG /COOLNT/ )                          I
CI      EMISVE     VEHICLE EMMISIVITY IN ENGINE BAY FOR TCA              I
CI                 RADIATION COOLING MODEL                               I
CI                 ( --- 0.5 $LIQENG /COOLNT/ )                          I
CI      ENDROV     NUMBER OF ENDS PER ROVING                             I
CI                 ( --- 4.0 $FILMNT /MOTOR/ )                           I
CI      ENDVAL     NO AVAILABLE DEFINITION    ( ///EQ/// )               I
CI      ENDVLG     VALUE OF ENDING PARAMETER AT WHICH GUIDANCE           I
CI                 SECTION IS TO BE TERMINATED                           I
CI                 ( --- --- $GUIDA ///EQ/// )                           I
CI      ENDVLM     VALUE OF MOTOR ENDING PARAMETER AT WHICH MOTOR        I
CI                 SECTION IS TO BE TERMINATED                           I
CI                 ( --- --- $GUIDA ///EQ/// )                           I
CI      ENGANG     NO AVAILABLE DEFINITION    ( /NCTIN/ )                I
CI      ENGRAD     NO AVAILABLE DEFINITION    ( /NCTIN/ )                I
CI      ENGSPC     MINIMUM SPACE BETWEEN NOZZLE EXITS IN NON-CONVEN-     I
CI                 TIONAL TANK DESIGN                                    I
CI                 ( IN 2.0 $NCTINP /NCTIN/ )                            I
CI      EPARK      ECCENTRICITY OF PARKING ORBIT                         I
CI                 ( --- 0.0 $ORB ///EQ/// )                             I
CI      EPIPE      ABSOLUTE SURFACE ROUGHNESS OF COOLING CHANNELS        I
CI                 ( IN 0.00008 $INREGN /COOLNT/ )                       I
CI      EPS        NOMINAL EXPANSION RATIO FOR EACH STAGE                I
CI                 ( --- 10. $INPGEN ///EQ/// )                          I
CI      EPSATT     EXPANSION RATIO AT THE NOZZLE-DOME ATTACH POINT       I
CI                 FOR SOLID STAGES.  EXPANSION RATIO WHERE RADIATION    I
CI                 COOLED NOZZLE IS ATTACHED FOR LIQUID STAGES           I
CI                 ( --- 1. $INPGEN ///EQ/// )                           I
CI      EPSEEC     AVERAGE EXPANSION RATIO                               I
CI                 ( --- --- $--- ///EQ/// )                             I
CI      EPSGGB     AREA RATIO OF BLEED NOZZLE                            I
CI                 ( --- 2.0 $PUMP /TPAIN/ )                             I
CI      EPSPLG     PLUG CLUSTER OVERALL AREA RATIO                       I
CI                 ( --- --- $--- /PLUGCL/ )                             I
CI      EPSR       REFERENCE EXPANSION RATIO AT WHICH PROPELLANT         I
CI                 BALLISTIC PERFORMANCE DATA IS INPUT: SHOULD           I
CI                 APPROXIMATE FINAL DESIGN EXPANSION RATIO              I
CI                 ( --- 10. $PROPEL /MOTOR/ )                           I
CI      EPSTH      HOOP FIBER ULTIMATE STRAIN                            I
CI                 ( % 0.015 $FILMNT /MOTOR/ )                           I
CI      EPSTRD     DOWNSTREAM AREA RATIO FOR TRANSPIRATION COOLING       I
CI                 ( --- 1.2 $INREGN /TRANCO/ )                          I
CI      EPSTRU     UPSTREAM AREA RATIO FOR TRANSPIRATION COOLING         I
CI                 ( --- 2 $INREGN /TRANCO/ )                            I
CI      EPTRAT     ATTACH AREA RATIO OF TRANSLATING NOZZLE               I
CI                 ( --- 50 $LIQENG /TRANOZ/ )                           I
CI      EREMIX     MIXING EFFICIENCY                                     I
CI                 ( --- --- $--- /LIQUID/ )                             I
CI      EREMRD     MIXTURE RATIO MALDISTRIBUTION LOSS MULTIPLIER         I
CI                 ( --- --- $--- /LIQUID/ )                             I
CI      ERETHR     TABLE OF CHAMBER EFFICIENCIES FOR THROTTLED           I
CI                 PRESSURE FRACTIONS                                    I
CI                 ( --- --- $THROT /THREFF/ )                           I
CI      EREVAP     VAPORIZATION EFFICIENCY                               I
CI                 ( --- --- $--- /LIQUID/ )                             I
CI      ERFCHR     REFERENCE AREA RATIO FOR DCHARN                       I
CI                 ( --- 7.5 $ABLATE /TCA/ )                             I
```

Figure 5.1. Common Block Variables (Sheet 12 of 46)

C

```
CI        ERMR      PRODUCT OF EQUIVALENCE RATIO AND MIXTURE RATIO                I
CI                  ( --- --- $--- /LIQUID/  )                                    I
CI        ERRMX     EQUIVALENCE RATIO OF USER PROPELLANT AT REFERENCE             I
CI                  MIXTURE RATIO (OFRMX)                                         I
CI                  ( --- --- $--- /EQUIVR/  )                                    I
CI        ERSMMX    EQUIVALENCE RATIO OF LIBRARY PROPELLANT AT MAX                I
CI                  ISP FOR PC=500 E=20                                           I
CI                  ( --- --- $--- /EQUIVR/  )                                    I
CI        ETABAR    LOSS MULTIPLIER ON BARRIER PERFORMANCE                        I
CI                  ( --- 0.9 $LQPERF /LIQUID/  )                                 I
CI        ETABL     BOUNDARY LAYER LOSS MULTIPLIER                                I
CI                  ( --- --- $--- /LIQUID/  )                                    I
CI        ETACF     NOZZLE PERFORMANCE EFFICIENCY                                 I
CI                  ( --- --- $--- /LIQUID/  )                                    I
CI        ETADIV    DIVERGENCE LOSS MULTIPLIER                                    I
CI                  ( --- --- $--- /LIQUID/  )                                    I
CI        ETAERE    CHAMBER ENERGY RELEASE EFFICIENCY                             I
CI                  ( --- --- $--- /LIQUID/  )                                    I
CI        ETAGGB    GAS GENERATOR BLEED PERFORMANCE LOSS MULTIPLIER               I
CI                  ( --- --- $--- /TPAOUT/  )                                    I
CI        ETAKE     KINETIC LOSS EFFICIENCY                                       I
CI                  ( --- --- $--- /LIQUID/  )                                    I
CI        ETASUB    NO AVAILABLE DEFINITION    ( /SSCOM/ )                        I
CI        ETATP     TWO PHASE FLOW LOSS MULTIPLIER                                I
CI                  ( --- --- $--- /LIQUID/  )                                    I
CI        EXPLFL    FUEL TANK EXPULSION EFFICIENCY                                I
CI                  ( --- .995 $LTANK /TANKS/  )                                  I
CI        EXPLOX    OXIDIZER TANK EXPULSION EFFICIENCY                            I
CI                  ( --- .995 $LTANK /TANKS/  )                                  I
CI        EXPULA    EXPULSION EFFICIENCY OF AFT TANK                              I
CI                  ( --- 0.99 $--- /TANKS/  )                                    I
CI        EXPULF    EXPULSION EFFICIENCY OF FORWARD TANK                          I
CI                  ( --- 0.99 $--- /TANKS/  )                                    I
CI        F         NO AVAILABLE DEFINITION    ( /PERF/ )                         I
CI        FAA       NO AVAILABLE DEFINITION    ( /TRAJ/ )                         I
CI        FADFL     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                       I
CI        FADMIS    TURBINE ADMISSION FRACTION                                    I
CI                  ( --- --- $--- /TPAOUT/  )                                    I
CI        FADOX     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                       I
CI        FALFAF    ALLOWABLE HELICAL FIBER STRESS                                I
CI                  ( LBF/IN**2 270000. $FILMNT /MOTOR/  )                        I
CI        FANBAS    NO AVAILABLE DEFINITION    ( /PLUGCL/ )                       I
CI        FANMOT    FRACTION OF MOTOR DIAMETER USED FOR CALCULATING               I
CI                  EXIT DIAMETER (DANEX) OF ANNULAR ENGINE                       I
CI                  ( --- 0.8 $NOZZLE /PLUGCL/  )                                 I
CI        FASKTL    AFT SKIRT FRACTIONAL LENGTH OF ENGINE BAY LENGTH              I
CI                  (FOR NON-CONVENTIONAL TANKS IT IS THE AFT SKIRT               I
CI                   FRACTIONAL LENGTH OF STAGE LENGTH)                           I
CI                  ( --- 0.067 $LIQUID /TANKS/  )                                I
CI        FCHGFL    FRACTION OF INJECTOR FACE PRESSURE FOR FUEL                   I
CI                  DELTA P ACROSS INJECTOR                                       I
CI                  ( --- 0.15 $LIQUID ///EQ///  )                                I
CI        FCHGOX    FRACTION OF INFECTOR FACE PRESSURE FOR OX DELTA P             I
CI                  ACROSS INJECTOR                                               I
CI                  ( --- 0.15 $LIQUID ///EQ///  )                                I
CI        FEEDK     INTERNAL CONSTANT USED TO OPTIMIZE PROPELLANT                 I
CI                  PRESSURE SCHEDULE                                             I
CI                  ( --- 1.0 $--- ///EQ///  )                                    I
CI        FFFC      FUEL FILM COOLING FRACTION                                    I
CI                  ( --- --- $--- /LIQUID/  )                                    I
```

Figure 5.1. Common Block Variables (Sheet 13 of 46)

C

```
CI        FFLV      FRACTION OF FUEL WHICH IS VAPORIZED
CI                  ( --- --- $--- /LIQUID/  )                              I
CI        FFSKTL    FORWARD SKIRT FRACTIONAL LENGTH OF FORWARD DOME         I
CI                  HEIGHT (FOR NON-CONVENTIONAL TANKS IT IS THE            I
CI                  FORWARD SKIRT FRACTIONAL LENGTH OF STAGE                I
CI                  DIAMETER)                                               I
CI                  ( --- 0.3 $LIQUID /TANKS/  )                            I
CI        FH2OGG    MOLAR FRACTION OF WATER IN COMBUSTION PRODUCTS          I
CI                  OF GAS GENERATOR                                        I
CI                  ( --- 0.2662 $SOLDGG /GASGEN/  )                        I
CI        FLKFCT    NUMBER OF VELOCITY HEADS LOST IN FUEL FEED LINE         I
CI                  DUE TO BENDS, VALVES, ETC.                              I
CI                  ( VEL-HEADS 5. $LTANK /TANKS2/  )                       I
CI        FLNPSH    FUEL PUMP NET POSITIVE SUCTION HEAD                     I
CI                  ( FT --- $--- /TPAOUT/  )                               I
CI        FLNPSP    FUEL NET POSITIVE SUCTION PRESSURE IN TANK              I
CI                  ( PSIA 10. $PUMP /PRESCH/  )                            I
CI        FLOPEL    NUMBER OF FUEL ORIFICES/ELEMENT                         I
CI                  ( --- 2.0 $INJECT /ELEMEN/  )                           I
CI        FLTTIM    STAGE ACTION TIME (USED IN TANK HEAT LOSS )             I
CI                  ( SEC 100. $TANKHX /INSLHX/  )                          I
CI        FNA       NO AVAILABLE DEFINITION    ( /TRAJ/ )                   I
CI        FOXV      FRACTION OF OXIDIZER WHICH IS VAPORIZED                 I
CI                  ( --- --- $--- /LIQUID/  )                              I
CI        FPGGMR    FRACTION OF MAXIMUM GAS GENERATOR OPERATING             I
CI                  PRESSURE LOST ACROSS GAS GENERATOR'S INJECTOR           I
CI                  ( --- 0.65 $PUMP ///EQ///  )                            I
CI        FPLUGV    PLUG CLUSTER VACUUM DELIVERED THRUST                    I
CI                  ( LBF --- $--- /PLUGCL/  )                              I
CI        FPULCG    MULTIPLYING FACTOR ON ULLAGE PRESSURE TO CALCULATE      I
CI                  MINIMUM GAS BOTTLE BLOWDOWN PRESSURE                    I
CI                  ( --- 0.8 $COLDG /COLDGP/  )                            I
CI        FPULGG    MULTIPLYING FACTOR ON ULLAGE PRESSURE TO CALCULATE      I
CI                  MINIMUM OPERATING GAS GENERATOR PRESSURE                I
CI                  ( --- 1.1 $SOLDGG /GASGEN/  )                           I
CI        FRACYL    RATIO OF CHAMBER CYLINDRICAL LENGTH TO TOTAL            I
CI                  CHAMBER LENGTH                                          I
CI                  ( --- --- $--- /LIQUID/  )                              I
CI        FT        THRUST VALUES INPUT FOR SPECIFYING MOTOR PERFORM-       I
CI                  ANCE;  USED IN VARIABLE THRUST-TIME TABLE WHERE         I
CI                  FT(J,I) CORRESPONDS TO TBRN(J) FOR THE ITH STAGE        I
CI                  ( LBF 0.0 $THVST /PERF/  )                              I
CI        FTHF      ALLOWABLE HOOP FIBER STRESS                             I
CI                  ( LBF/IN**2 300000. $FILMNT /MOTOR/  )                  I
CI        FTPNMI    NO AVAILABLE DEFINITION    ( /CONST/ )                  I
CI        FVAC      VACUUM THRUST PER LIQUID THRUST CHAMBER                 I
CI                  ( LBF 0.0 $LIQUID ///EQ///  )                           I
CI        FVACD     VACUUM DELIVERED THRUST                                 I
CI                  ( LBF --- $--- /PERF/  )                                I
CI        FVENTF    FRACTION OF FUEL TANK NOMINAL ULLAGE PRESSURE AT        I
CI                  WHICH VENT OCCURS                                       I
CI                  ( --- 1.1 $TANKHX /INSLHX/  )                           I
CI        FVENTO    FRACTION OF OX TANK NOMINAL ULLAGE PRESSURE AT          I
CI                  WHICH VENT OCCURS                                       I
CI                  ( --- 1.1 $TANKHX /INSLHX/  )                           I
CI        FWEB      WEB FRACTION                                            I
CI                  ( --- 0.85 $--- /MOTOR/  )                              I
CI        G         NO AVAILABLE DEFINITION    ( /TRAJ/ )                   I
CI        GO        GRAVITIONAL CONSTANT                                    I
CI                  ( FT/SEC**2 32.174 $--- /CONST/  )                      I
```

Figure 5.1. Common Block Variables (Sheet 14 of 46)

C

```
CI        GA        NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GAGE      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                               I
CI        GAGEFL    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                               I
CI        GAGEOX    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                               I
CI        GAMABO    NO AVAILABLE DEFINITION    ( ///EQ/// )                               I
CI        GAMAX     NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GAMDOT    COMMANDED RATE OF CHANGE OF FLIGHT PATH ANGLE;                        I
CI                  INPUT FOR TRAJECTORY GUIDANCE SECTIONS                                I
CI                  ( DEG/SEC 0. $GUIDA ///EQ/// )                                        I
CI        GAMGG     GAS GENERATOR COMBUSTION PRODUCTS SPECIFIC HEAT                       I
CI                  RATIO                                                                 I
CI                  ( --- 1.27 $SOLDGG /GASGEN/ )                                         I
CI        GAMGPB    RATIO OF SPECIFIC HEATS OF GAS GENERATOR/PREBURNER                    I
CI                  COMBUSTION GAS                                                        I
CI                  ( --- 1.25 $PUMP /TPAIN/ )                                            I
CI        GAMICG    COLD GAS ISENTROPIC RATIO OF SPECIFIC HEAT                            I
CI                  ( --- 1.66 $COLDG /COLDGP/ )                                          I
CI        GAMM      NO AVAILABLE DEFINITION    ( /SSCOM/ )                                I
CI        GAMMA     NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GAMMAO    NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GAMMAC    COMMANDED CONSTANT FLIGHT PATH ANGLE; INPUT FOR                       I
CI                  GUIDANCE SECTIONS UTILIZING GUIDANCE OPTION 3                         I
CI                  ( DEG -1.E20 $GUIDA ///EQ/// )                                        I
CI        GAMMAI    INITIAL MISSILE FLIGHT PATH ANGLE                                     I
CI                  ( DEG 90. $INTRAJ ///EQ/// )                                          I
CI        GAMMAL    APPROXIMATION OF LIQUID COMBUSTION PRODUCTS RATIO                     I
CI                  OF SPECIFIC HEATS                                                     I
CI                  ( --- --- $--- /LIQUID/ )                                             I
CI        GAMPCG    COLD GAS POLYTROPIC GAMMA AT INFINITE TIME                            I
CI                  ( --- 1. $COLDG /COLDGP/ )                                            I
CI        GAMRED    NO AVAILABLE DEFINITION    ( ///EQ/// )                               I
CI        GAMSTG    NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GASMW     MOLECULAR WEIGHT OF PRESSURIZATION GAS (ISTART=2)                     I
CI                  ( LBM/LB-MOLE 28 $PUMP /TPAIN/ )                                      I
CI        GG        NO AVAILABLE DEFINITION    ( /GSTOR/ )                                I
CI        GGCR      GAS GENERATOR OR PRE-BURNER CONTRACTIN RATIO                          I
CI                  ( --- 12 $PUMP /TPAIN/ )                                              I
CI        GIMINT    INTERFERENCE GIMBAL ANGLE OF ADJACENT NOZZLES                         I
CI                  ( DEG --- $--- /GIMBAL/ )                                             I
CI        GMAX      NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GMBANG    MAXIMUM ANGLE TO WHICH NOZZLES GIMBAL                                 I
CI                  ( DEG 6.0 $LIQUID /GIMBAL/ )                                          I
CI        GN        NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GNMAX     NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GNW       NO AVAILABLE DEFINITION    ( /MOTOR/ )                                I
CI        GPC       NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GPOLY     COLD GAS POLYTROPIC RATIO OF SPECIFIC HEATS                           I
CI                  ( --- --- $--- /COLDGP/ )                                             I
CI        GRAVL     NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GREMAX    NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GREMIN    NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GREMN1    NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GRVLOS    IDEAL VELOCITY LOSSES DUE TO GRAVITY FORCES                           I
CI                  ( FT/SEC 0 $INTRAJ /TRAJ/ )                                           I
CI        GTOT      NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GTPARM    NO AVAILABLE DEFINITION    ( /TRAJ/ )                                 I
CI        GTURN     COMMANDED TOTAL ACCELERATION DURING MISSILE TURN;                     I
CI                  INPUT FOR GUIDANCE SECTIONS USING GUIDANCE OPT 6                      I
CI                  ( DEG 0. $GUIDA ///EQ/// )                                            I
CI        GUIPAR    NO AVAILABLE DEFINITION    ( ///EQ/// )                               I
```

Figure 5.1. Common Block Variables (Sheet 15 of 46)

C

```
CI        GUIPAR    NO AVAILABLE DEFINITION    ( /TRAJ/ )                            I
CI        GWMING    MINIMUM GUAGE OF CHAMBER GAS WALL                                I
CI                  ( IN 0.025 $INREGN /WTREGN/   )                                  I
CI        GWVOL     GAS WALL MATERIAL VOLUME IN REGEN CHAMBER                        I
CI                  ( IN**3 --- $--- /WTREGN/   )                                    I
CI        H         AN APPROXIMATION OF HESSIAN USED IN THE QUASI-                   I
CI                  NEWTON UNCONSTRAINED FUNCTION MINIMIZATION                       I
CI                  ( --- --- $NLP /RGNSUM/   )                                      I
CI        HAFPI     NO AVAILABLE DEFINITION    ( /CONST/ )                           I
CI        HBFL      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HBLADE    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HBOX      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HBPFL     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HBPOX     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HC        REGEN STATION LOCAL COOLANT SIDE HEAT TRANSFER                   I
CI                  COEFFICIENT                                                      I
CI                  ( BTU/IN**2/SEC/DEGR --- $--- /RGNSUM/   )                       I
CI        HCBPFL    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HCBPOX    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HCFL      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HCFL2     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HCONI     NO AVAILABLE DEFINITION    ( /MOTOR/ )                           I
CI        HCOX      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HCOX2     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HFL       HEAD RISE OF FUEL PUMP                                           I
CI                  ( FT --- $--- /TPAOUT/   )                                       I
CI        HFL2      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HG        REGEN STATION LOCAL GAS SIDE HEAT TRANSFER COEFF                 I
CI                  ( BTU/IN**2/SEC/DEGR --- $--- /RGNSUM/   )                       I
CI        HH        NO AVAILABLE DEFINITION    ( /HSTOR/ )                           I
CI        HLDTIM    STAGE HOLD TIME (USED IN TANK HEAT LOSS)                         I
CI                  ( SEC 100. $TANKHX /INSLHX/   )                                  I
CI        HOWMAX    MAXIMUM DEPTH TO WIDTH RATIO IN COOLING CHANNELS                 I
CI                  ( --- 5.0 $INREGN /COOLNT/   )                                   I
CI        HOX       HEAD RISE OF OXIDIZER PUMP                                       I
CI                  ( FT --- $--- /TPAOUT/   )                                       I
CI        HOX2      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                          I
CI        HTRNOZ    HEIGHT OF TRANSLATING PORTION OF NOZZLE                          I
CI                  ( IN --- $--- /TRANOZ/   )                                       I
CI        HTURB     NO AVAILABLE DEFINITION    ( /TPOUT2/ )                          I
CI        HTURBF    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                          I
CI        HTURBO    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                          I
CI        HXALT     AVERAGE ORBITAL ALTITUDE FROM EARTH SURFACE                      I
CI                  (KHXOPT=2)                                                       I
CI                  ( MILES 125. $TANKHX /INSLHX/   )                                I
CI        IAM4      FLAG SPECIFYING TRAJECTORY METHOD                                I
CI                  -1 = 4TH ORDER RUNGE-KUTTA INTEGRATION THROUGHOUT                I
CI                   0 = 4TH ORDER RUNGE-KUTTA DURING MOTOR BURN                     I
CI                       4TH ORDER ADAMS-MOULTON AFTER BURNOUT                       I
CI                  +1 = 4TH ORDER ADAMS-MOULTON THROUGHOUT FLIGHT                   I
CI                  ( --- 0 $INTRAJ /TRAJ/   )                                       I
CI        IBELL     FLAG INDICATING NOZZLE TYPE                                      I
CI                  0 = CONICAL NOZZLE                                               I
CI                  1 = CONTOURED NOZZLE (CIRCULAR ARC)                              I
CI                  2 = ELLIPSOIDAL OR HYPERBOLIC NOZZLE                             I
CI                  ( --- 0 $NOZZLE /MOTOR/   )                                      I
CI        ICOAST    NO AVAILABLE DEFINITION    ( /PERF/ )                            I
CI        ICOMPS    COMPOSITE CASE INDICATOR                                         I
CI                  0 = METAL CASE                                                   I
CI                  1 = COMPOSIT CASE                                                I
```

Figure 5.1. Common Block Variables (Sheet 16 of 46)

C

```
CI                ( --- 0 $MATER /MOTOR/  )
CI      ICON      (I,1) - REFERENCE NUMBER OF VARIABLE TO BE              I
CI                        CONSTRAINED                                     I
CI                (I,2) - CONSTRAINT TYPE                                 I
CI                  -1 = LESS THAN OR EQUAL                               I
CI                   0 = EQUAL TO                                         I
CI                  +1 = GREATER THAN OR EQUAL                            I
CI                ( --- --- $INPOPT /OPTIM/  )                            I
CI      ICPFAG    WARNING FLAG FOR HEAT CAPACITY ROUTINE CALLED WITH      I
CI                OUT OF RANGE INPUT                                      I
CI                ( --- 0 $--- /WARN/  )                                  I
CI      ICPFLG    WARNING FLAG FOR HEAT CAPACITY ROUTINE CALL WITH        I
CI                OUT OF RANGE INPUTS                                     I
CI                ( --- 0 $--- /WARN/  )                                  I
CI      ICRYFL    FUEL CRYOGENIC FLAG (0=STORABLE, 1=CRYOGENIC)           I
CI                ( --- 0 $LFLAG /LIQUID/  )                              I
CI      ICRYOX    OXIDIZER CRYOGENIC FLAG (0=STORABLE, 1=CRYOGENIC)       I
CI                ( --- 0 $LFLAG /LIQUID/  )                              I
CI      ICRYTM    NO AVAILABLE DEFINITION    ( /TEMSCH/ )                 I
CI      ICS       ICS = 1 - PREPREG WINDING                               I
CI                    = 1 - WET WIND                                      I
CI                ( --- 0 $FILMNT /MOTOR/  )                              I
CI      IDRAW     NON-CONVENTIONAL TANK DRAW FLAG (1=DRAW THREE           I
CI                VIEWS ON ONE PAGE, 2=DRAW EACH VIEW ON A SEPARATE       I
CI                PAGE)                                                   I
CI                ( --- 2 $NCTINP /NCTIN/  )                              I
CI      IDTRAN    TRANSPIRATION COOLING CRITERIA FLAG (1=USE QMAXTR       I
CI                TO CALCULATE EPSTRD AND EPSTRU, 2=USE THE INPUT         I
CI                VALUES FOR EPSTRD AND EPSTRU)                           I
CI                ( --- 2 $INREGN /TRANCO/  )                             I
CI      IELDEN    INJECTOR ELEMENT DENSITY FLAG                           I
CI                0 = INPUT NUMBER OF ORIFICES                            I
CI                1 = INPUT ELEMENT DENSITY                               I
CI                ( --- 0 $INJECT /ELEMEN/  )                             I
CI      IENDPG    NO AVAILABLE DEFINITION    ( ///EQ/// )                 I
CI      IENDPM    NO AVAILABLE DEFINITION    ( ///EQ/// )                 I
CI      IENDPR    NO AVAILABLE DEFINITION    ( ///EQ/// )                 I
CI      IENDPR    NO AVAILABLE DEFINITION    ( /TRAJ/ )                   I
CI      IENEC     FLAG INDICATING EXTENDABLE EXIT CONE                    I
CI                0 = NONE                                                I
CI                1 = SEGMENT CONE                                        I
CI                2 = GAS DEPLOYED SKIRT                                  I
CI                ( --- 0 $NOZZLE /MOTOR/  )                              I
CI      IERRMD    NO AVAILABLE DEFINITION    ( /CVBOND/ )                 I
CI      IFREGN    REGEN COOLING FLUID FLAG                                I
CI                0 = OXIDIZER IS COOLANT                                 I
CI                1 = FUEL IS COOLANT                                     I
CI                ( --- 1 $INREGN /COOLNT/  )                             I
CI      IFUEL     NO AVAILABLE DEFINITION    ( /TPAIN/ )                  I
CI      IGPHSE    NO AVAILABLE DEFINITION    ( /TRAJ/ )                   I
CI      IGUID     NO AVAILABLE DEFINITION    ( /TRAJ/ )                   I
CI      IGUISC    NO AVAILABLE DEFINITION    ( /TRAJ/ )                   I
CI      IHYPER    HYPERGOLIC PROPELLANT FLAG (REQUIRED FOR NON-           I
CI                LIBRARY PROPELLANTS (IPROP=0))                          I
CI                0 = NOT HYPERGOLIC    1 = HYPERGOLIC                    I
CI                ( --- 1 $LFLAG /LIQUID/  )                              I
CI      ILIFT     NO AVAILABLE DEFINITION    ( /AERO/ )                   I
CI      IMMAN     NO AVAILABLE DEFINITION    ( /MOTOR/ )                  I
CI      INDES     DESIGN LOOP INDICATOR                                   I
CI                +1 = MOTOR IS SIMULATED, NO TRAJECTORY INTEGRATION      I
```

Figure 5.1. Common Block Variables (Sheet 17 of 46)

```
CI                    0 = TRAJECTORY INTEGRATION
CI                    -1 = TRAJECTORY INTEGRATION PLUS DELTA V CALC       I
CI                    -2 = TRAJECTORY USING THRUST-TIME TRACE, NO         I
CI                         MOTOR SIMULATION                               I
CI                    ( --- --- $INPOPT /TRAJ/  )                         I
CI         INPEXF     INPUT FUEL TANK EXPULSION EFFICIENCY FLAG (0=       I
CI                    CALCULATE EXPULSION EFFICIENCY, 1=USE VALUE INPUT   I
CI                    FOR EXPLFL)                                         I
CI                    ( --- 0 $LFLAG /TANKS/  )                           I
CI         INPEXO     INPUT OXIDIZER TANK EXPULSION EFFICIENCY FLAG       I
CI                    (0=CALCULATE EXPULSION EFFICIENCY, 1=USE VALUE      I
CI                    INPUT FOR EXPLOX)                                   I
CI                    ( --- 0 $LFLAG /TANKS2/  )                          I
CI         INTANK     NO AVAILABLE DEFINITION   ( /NCTIN/ )               I
CI         IOBJF      INDEX SPECIFYING THE OPTIMIZATION OBJECTIVE FUNC    I
CI                    ( --- --- $INPOPT /OPTIM/  )                        I
CI         IOPFLG     NO AVAILABLE DEFINITION   ( /PRINT/ )               I
CI         IOPT       PARAMETER OPTIMIZATION SWITCHES (SEE METHOD OF      I
CI                    MULTIPLIERS DOCUMENTATION)                          I
CI                    ( --- 0 $INPOPT /OPTIM/  )                          I
CI         IOPTRJ     NO AVAILABLE DEFINITION   ( /OPTIM/ )               I
CI         IORBIT     NO AVAILABLE DEFINITION   ( /TRAJ/ )                I
CI         IPAR       NO AVAILABLE DEFINITION   ( /OPTIM/ )               I
CI         IPHASE     TWO PHASE FLOW WARNING FLAG                         I
CI                    ( --- --- $--- /COOLNT/  )                          I
CI         IPLOT      INDEX FLAG FOR PLOT DATA (GENERATES TAPE 4 FOR RFL  I
CI                    CALCOMP PLOT ROUTINES).  THE OPTIMIZER SHOULD BE    I
CI                    OFF FOR THIS FEATURE.                               I
CI                    0 = NO PLOT                                         I
CI                    1 = PLOT                                            I
CI                    ( --- 0 $INPOPT /TRAJ/  )                           I
CI         IPLUG      PLUG CLUSTER FLAG                                   I
CI                    0 = NO PLUG CLUSTER                                 I
CI                    1 = PLUG CLUSTER                                    I
CI                    2 = ANNULAR ENGINE                                  I
CI                    ( --- 0 $LIQUID /PLUGCL/  )                         I
CI         IPRINT     OUTPUT PRINT INDICATOR                              I
CI                    IPRINT(1) - INPUT DATA FILE                         I
CI                    0 = NO PRINTOUT                                     I
CI                    1= PRINT INPUT                                      I
CI                    IPRINT(2) - INITIAL GUESS DESIGN                    I
CI                    0 = NO PRINTOUT                                     I
CI                    1 = PRINT MOTOR SUMMARY                             I
CI                    2 = PRINT MOTOR SUMMARY AND TRAJECTORY PROFILE      I
CI                    IPRINT(3) - NOT USED                                I
CI                    IPRINT(4) - FINAL DESIGN                            I
CI                    0 = NO PRINTOUT                                     I
CI                    1 = PRINT MOTOR SUMMARY                             I
CI                    2 = PRINT MOTOR SUMMARY AND TRAJECTORY PROFILE      I
CI                    IPRINT(5) - NUMBER OF FINAL DESIGN SUMMARIES        I
CI                    ALSO                                                I
CI                    A VARIABLE OF THE SAME NAME IS USED IN $NLP AS A    I
CI                    FLAG USED TO CONTROL INTERMEDIATE ITERATION         I
CI                    PRINTOUT. VALUES RANGE FROM 0 TO 11. THE GREATER    I
CI                    THE VALUE THE GREATER THE INTERMEDIATE OUTPUT       I
CI                    ( --- 1 $INPOPT /OPTIM/  )                          I
CI         IPROP      PROPELLANT SELECTION FLAG                           I
CI                    0 = NON-LIBRARY PROPELLANT                          I
CI                    1 = N2O4/MMH                                        I
CI                    2 = MON-25/MHF-3                                    I
```

Figure 5.1. Common Block Variables (Sheet 18 of 46)

C

```
CI                3 = CLF5/MHF-3                                                I
CI                4 = MON-25/60%MHF-3 + 40% AL                                  I
CI                5 = LO2/LH2                                                   I
CI                6 = LO2/RP-1                                                  I
CI                7 = LO2/CH4                                                   I
CI                8 = LF2/LH2                                                   I
CI                9 = LF2/N2H4                                                  I
CI                ( --- 0 $LFLAG /LIQUID/  )                                    I
CI      IPRSIM    PROPELLANT SIMILARITY FLAG ( IPROP = 0 )                      I
CI                ( --- 1 $LPROP /LIQUID/  )                                    I
CI      IPRTFL    NO AVAILABLE DEFINITION   ( /PRINT/ )                         I
CI      IPUTMP    NO AVAILABLE DEFINITION   ( /TEMSCH/ )                        I
CI      IRPRNT    REGENERATIVE COOLING PRINT FLAG                               I
CI                0 = NO PRINTOUT OF REGEN SUMMARY                              I
CI                1 = PRINT REGEN SUMMARY                                       I
CI                ( --- 0 $INREGN /COOLNT/  )                                   I
CI      ISET      NO AVAILABLE DEFINITION   ( /ATMOS/ )                         I
CI      ISF       NO AVAILABLE DEFINITION   ( /AERO/ )                          I
CI      ISTART    TPA START SYSTEM FLAG                                         I
CI                0=TANK HEAD   1=COLD GAS SPIN   2=START TANKS                 I
CI                3=SOLID CARTRIDGE                                             I
CI                ( --- 0 $PUMP /TPAIN/  )                                      I
CI      ISTG      NO AVAILABLE DEFINITION   ( /PERF/ )                          I
CI      ITARGE    NO AVAILABLE DEFINITION   ( /TRAJ/ )                          I
CI      ITB       BURN TIME INTERPOLATION INDEX                                 I
CI                ( --- 1 $--- /PERF/  )                                        I
CI      ITER      NO AVAILABLE DEFINITION   ( /PERF/ )                          I
CI      ITERAT    NO AVAILABLE DEFINITION   ( /TPAOUT/ )                        I
CI      ITLIM     OPTIMIZER ITERATION LIMIT (BASE POINT)                        I
CI                ( --- 500 $INPOPT /OPTIM/  )                                  I
CI      ITRMAX    NO AVAILABLE DEFINITION   ( /CUT/ )                           I
CI      IVEH      VEHICLE SCHEMATIC ARRAY                                       I
CI                ( --- --- $--- /LPRVLI/  )                                    I
CI      IWARN     ARRAY OF WARNING MESSAGE FLAGS                                I
CI                ( --- 0 $--- /WARN/  )                                        I
CI      IWDFIX    NO AVAILABLE DEFINITION   ( /FIXFLG/ )                        I
CI      JBPFL     FUEL BOOST PUMP SELECTION FLAG                                I
CI                0 = NO BOOST PUMP FOR FUEL                                    I
CI                1 = BOOST PUMP                                                I
CI                ( --- 0 $PUMP /TPAIN/  )                                      I
CI      JBPOX     OXIDIZER BOOST PUMP SELECTION FLAG                            I
CI                0 = NO BOOST PUMP FOR OXIDIZER                                I
CI                1 = BOOST PUMP                                                I
CI                ( --- 0 $PUMP /TPAIN/  )                                      I
CI      JCNFIG    TPA CONFIGURATION FLAG                                        I
CI                1=GEARBOX   2=SINGLE SHAFT TPA   3=TWIN TPA IN                I
CI                SERIES   4=PARALLEL TPAS                                      I
CI                ( --- 2 $PUMP /TPAIN/  )                                      I
CI      K         NO AVAILABLE DEFINITION   ( /SSCOM/ )                         I
CI      KACQFL    KIND OF FUEL ACQUISITION DEVICE (0=NO ACQUISITION             I
CI                DEVICE, 1=TRANSVERSE COLLAPSING ALUMINUM BLADDER,             I
CI                2=FULL BONDED ROLLING DIAPHRAM(AL), 3=HALF BRD (AL)           I
CI                4=FULL BRD (SS), 5=HALF BRD (SS), 6=SURFACE                   I
CI                TENSION ACQUISITION DEVICE)                                   I
CI                ( --- 0 $LFLAG /TANKS/  )                                     I
CI      KACQOX    KIND OF OXIDIZER ACQUISITION DEVICE (SEE KACQFL)              I
CI                ( --- 0 $LFLAG /TANKS/  )                                     I
CI      KALCON    CALCULATE TANK INSULATION THERMAL CONDUCTIVITIES              I
CI                FLAG  (0=USE INPUT, 1=CALCULATE)                              I
CI                ( --- 1 $TANKHX /INSLHX/  )                                   I
```

Figure 5.1. Common Block Variables (Sheet 19 of 46)

C

```
CI        KALMOD    FLAG DETERMINES CALCULATION MODE FOR NON-CONVEN-      I
CI                  TIONAL TANKS (0=USE DIMENSIONLESS INPUT , 1= USE      I
CI                  MAJOR TANK DIMENSION (RMAJ))                          I
CI                  ( --- 0 $NCTINP /NCTIN/  )                            I
CI        KBLAT     AFT TANK BLADDER FLAG                                 I
CI                  0 = NO BLADDER                                        I
CI                  1 = TRANSVERSE COLLAPSING ALUMINUM BLADDER            I
CI                  2 = FULL BONDED ROLLING DIAPHRAM (ALUMINUM)           I
CI                  3 = HALF BONDED ROLLING DIAPHRAM (ALUMINUM)           I
CI                  4 = FULL BONDED ROLLING DIAPHRAM (STAINLESS STEEL)    I
CI                  5 = HALF BONDED ROLLING DIAPHRAM (STAINLESS STEEL)    I
CI                  ( --- 0 $--- /TANKS/  )                               I
CI        KBLFT     FORWARD TANK BLADDER FLAG (SEE KBLAT)                 I
CI                  ( --- 0 $--- /TANKS/  )                               I
CI        KCYCLE    0 = PRESSURE FED                                      I
CI                  1 = PUMP FED (GG BLEED)                               I
CI                  2 = STAGED COMBUSTION (FUEL RICH PREBURNER)           I
CI                  3 = EXPANDER CYCLE (HYDROGEN FUEL)                    I
CI                  4 = STAGED REACTION (MONOPROPELLANT FUEL)             I
CI                  ( --- 0 $LFLAG /TPAIN/  )                             I
CI        KDOME     COMMON DOME FLAG FOR AFT AND FORWARD TANKS            I
CI                  0 = SEPARATE HEADS                                    I
CI                  1 = COMMON DOME                                       I
CI                  ( --- 1 $TNKGEO /TANKS/  )                            I
CI        KEXNOZ    NOZZLE EXTENSION FLAG                                 I
CI                  0 = NO EXTENSION                                      I
CI                  1 = NOZZLE EXTENSION                                  I
CI                  ( --- 1 $LIQENG /MAITCA/  )                           I
CI        KGAS      PROPELLAT TANK PRESSURIZATION FLAG                    I
CI                  1 = SOLID GAS GENERATOR                               I
CI                  2 = COLD GAS PRESSURIZATION                           I
CI                  (USED IF OX AND FUEL TANKS DO NOT USE                 I
CI                   AUTOGENOUS PRESSURIZATION)                           I
CI                  ( --- 2 $LFLAG /TANKS/  )                             I
CI        KGASFL    FUEL TANK AUTOGENOUS PRESSURIZATION FLAG              I
CI                  (0=USE KGAS TYPE PRESSURIZATION, 1=AUTOGENOUS)        I
CI                  ( --- 0 $LFLAG /TANKS/  )                             I
CI        KGASOX    OX TANK AUTOGENOUS PRESSURIZATION FLAG                I
CI                  (0=USE KGAS TYPE PRESSURIZATION, 1=AUTOGENOUS)        I
CI                  ( --- 0 $LFLAG /TANKS/  )                             I
CI        KGIMB     MODE OF GIMBALING FLAG FOR MULTIPLE TCA'S             I
CI                  (NOT USED AT PRESENT)                                 I
CI                  ( --- 2 $LIQUID /GIMBAL/  )                           I
CI        KGPOWR    FLAG WHICH DETERMINES LOCATION OF GIMBALING           I
CI                  POWER SUPPLY                                          I
CI                  0 = NOT ON STAGE                                      I
CI                  1 = ON STAGE                                          I
CI                  ( --- 0 $LIQUID /GIMBAL/  )                           I
CI        KHXOPT    TANK HEAT TRANSFER OPTION (0=IGNORE TANK HEAT         I
CI                  TRANSFER, 1=EXTERNAL BOUNDARY EXPOSED TO              I
CI                  CONDUCTIVE SOURCE, 2=WORST CASE SOLAR RADIATION,      I
CI                  3=CONDUCTIVE AND CONVECTIVE SOURCE WITH GROUND-       I
CI                  HOLD LAYER OF ICE)                                    I
CI                  ( --- 0 $LFLAG /INSLHX/  )                            I
CI        KLINEA    FEED LINE FLAG                                        I
CI                  0 = EXTERNAL FEED LINE                                I
CI                  1 = INTERNAL FEED LINE                                I
CI                  ( --- 1 $TNKGEO /TANKS/  )                            I
CI        KNEST     ENGINE NESTING FLAG FOR NON-CONVENTIONAL TANKS        I
CI                  (0=NO NESTING, 1=NEST EACH ENGINE INDEPENDENTLY,      I
```

Figure 5.1. Common Block Variables (Sheet 20 of 46)

C

```
CI                     2=NEST ENGINES TO SAME EXIT PLANE, 3=NEST ENGINES      I
CI                     TO EXIT PLANE AT END OF TANKAGE + XMOUNT)              I
CI                     ( --- 2 $NCTINP /NCTIN/  )                             I
CI        KNOZ         NOZZLE TYPE FLAG                                       I
CI                     1 = CONICAL                                            I
CI                     2 = RAO                                                I
CI                     ( --- 1 $LIQENG /LIQUID/  )                            I
CI        KOOLNZ       NOZZLE COOLING METHOD FLAG (1=ABLATIVE, 2=REGEN.       I
CI                     3=TRANS-REGEN, 4=RADIATION, 5=FILM)                    I
CI                     ( --- 1 $LFLAG /COOLNT/  )                             I
CI        KOOLTC       THRUST CHAMBER COOLING METHOD FLAG (1=ABLATIVE,        I
CI                     2=REGEN, 3=TRANS-REGEN, 4=RADIATION)                   I
CI                     ( --- 1 $LFLAG /COOLNT/  )                             I
CI        KORBOR       NO AVAILABLE DEFINITION   ( /INSLHX/ )                 I
CI        KPERF        ENGINE PERFORMANCE FLAG                                I
CI                     0 = INPUT PERFORMANCE (DO NOT CALCULATE)               I
CI                     1 = CALCULATE ENGINE PERFORMANCE                       I
CI                     ( --- 1 $LFLAG /MAILPE/  )                             I
CI        KPRESS       PRESSURE TANK LOCATION FLAG                            I
CI                     0 = SPHERICAL IN ENGINE BAY                            I
CI                     1 = SUSPENDED FORWARD OF FORWARD TANK                  I
CI                     2 = MONOCOQUE SEPARATE DOME                            I
CI                     3 = MONOCOQUE COMMON DOME                              I
CI                     4 = CYLINDRICAL IN FORWARD TANK                        I
CI                     ( --- 0 $TNKGEO /TANKS/  )                             I
CI        KPRPA        PROPELLANT LOCATION FLAG                               I
CI                     1 = FUEL IN AFT TANK                                   I
CI                     2 = OXIDIZER IN AFT TANK                               I
CI                     ( --- 2 $TNKGEO /TANKS/  )                             I
CI        KPUMP        1 = 1 TPA ASSEMBLY PER STAGE                           I
CI                     2 = 1 TPA ASSEMBLY PER ENGINE                          I
CI                     ( --- 1 $PUMP /TPAIN/  )                               I
CI        KREG         THROAT REGRESSION FLAG                                 I
CI                     0 = NO REGRESSION                                      I
CI                     1 = (NOT USED)                                         I
CI                     2 = INPUT THROAT REGRESSION COEFFICIENTS               I
CI                     ( --- 1 $LFLAG /LIQUID/  )                             I
CI        KSTAGE       FLAG INDICATING STAGE TYPE                             I
CI                     1 = SOLID STAGE                                        I
CI                     2 = LIQUID STAGE                                       I
CI                     3 = LIQUID STAGE INTEGRATED WITH LOWER STAGE           I
CI                         (MUST USE NON-CONVENTIONAL TANKAGE)                I
CI                     ( --- 1 $INPGEN /STAGE/  )                             I
CI        KTANKS       NO AVAILABLE DEFINITION   ( /NCTIN/ )                  I
CI        KTHICK       NO AVAILABLE DEFINITION   ( /NCTIN/ )                  I
CI        KTRNOZ       KIND OF TRANSLATING NOZZLE FLAG (0=NONE, 1=SPRING      I
CI                     ACTUATED, 2=GAS DEPLOYED)                              I
CI                     ( --- 0 $LIQENG /TRANOZ/  )                            I
CI        KWTMOD       ENGINE WEIGHT MODEL FLAG                               I
CI                     -1 = INPUT ENGINE WEIGHT                               I
CI                      0 = SIMPLIFIED ABLATIVE ENGINE WEIGHT MODEL           I
CI                      1 = PHYSICAL MODEL                                    I
CI                     ( --- 0 $LFLAG /TCA/  )                                I
CI        KXATAH       AFT TANK AFT HEAD CONVEXITY FLAG                       I
CI                     -1 = CONVEX FORWARD                                    I
CI                      1 = CONVEX AFT                                        I
CI                     ( --- 1 $TNKGEO /TANKS/  )                             I
CI        KXATFH       AFT TANK FORWARD HEAD CONVEXITY FLAG                   I
CI                     -1 = CONVEX FORWARD                                    I
CI                      1 = CONVEX AFT                                        I
```

Figure 5.1. Common Block Variables (Sheet 21 of 46)

C

```
CI              ( --- -1 $TNKGEO /TANKS/  )                                  I
CI     KXFTAH   FORWARD TANK AFT HEAD CONVEXITY FLAG                         I
CI              -1 = CONVEX FORWARD                                          I
CI               1 = CONVEX AFT                                              I
CI              ( --- -1 $TNKGEO /TANKS/  )                                  I
CI     KXFTFH   FORWARD TANK FORWARD HEAD CONVEXITY FLAG                     I
CI              -1 = CONVEX FORWARD                                          I
CI               1 = CONVEX AFT                                              I
CI              ( --- -1 $TNKGEO /TANKS/  )                                  I
CI     LABEL    NO AVAILABLE DEFINITION   ( /PLABEL/ )                       I
CI     LNFULL   LINES FULL AT BURNOUT FLAG(0=EMPTY, 1=FULL)                  I
CI              ( --- 1 $LFLAG /TANKS2/  )                                   I
CI     LOOP     ITERATION LOOP COUNTER IN ROUTINE MAXRPM                     I
CI              ( --- --- $--- /TPAOUT/  )                                   I
CI     LOOPFL   ITERATION LOOP COUNTER IN ROUTINE MAXRPM                     I
CI              ( --- --- $--- /TPOUT2/  )                                   I
CI     LOOPOX   ITERATION LOOP COUNTER IN ROUTINE MAXRPM                     I
CI              ( --- --- $--- /TPOUT2/  )                                   I
CI     LTHRTL   THROTTLING FLAG                                              I
CI              ( LOGICAL --- $--- /THRLOG/  )                               I
CI     LTPABF   NO AVAILABLE DEFINITION   ( /TPOUT2/ )                       I
CI     LTPABO   NO AVAILABLE DEFINITION   ( /TPOUT2/ )                       I
CI     LTURFD   TURBINE FEED LOCATION FLAG                                   I
CI              0 = FEED TURBINE FROM REGEN OUTLET                           I
CI              1 = FEED TURBINE FROM UPSTREAM OF REGEN JACKET               I
CI                  USING REGEN BYPASS FLOW SET BY THE VARIABLE              I
CI                  BYPREG.                                                  I
CI              ( --- 0 $LFLAG /SCHEDW/  )                                   I
CI     LUSEP    PROPELLANT USE FLAG                                          I
CI              TRUE = ALL PROPELLANT IS TO BE BURNED                        I
CI              FALSE = THRUST TERMINATES AT THE END OF THE LAST             I
CI                      TIME INTERVAL IN TIMTHR FOR THAT STAGE               I
CI              ( LOGICAL .TRUE. $THROT /THRLOG/  )                          I
CI     MANDEG   METHOD OF ANNULAR ENGINE EXIT DIAMETER CALCULATION           I
CI              (0=INPUT DANEX, 1=CALCULATE DANEX AS DMOTOR*FANMOT           I
CI              ( --- 1 $NOZZLE /PLUGCL/  )                                  I
CI     MATAT    MATERIAL FLAG FOR AFT TANK (IN ARRAYS RHO, SIGMAX            I
CI              , AND YMOD)                                                  I
CI              ( --- 1 $--- /TANKS/  )                                      I
CI     MATATL   MATERIAL FLAG FOR AFT TANK LINE                              I
CI              ( --- 1 $--- /TANKS/  )                                      I
CI     MATFT    MATERIAL FLAG FOR FORWARD TANK                               I
CI              ( --- 1 $--- /TANKS/  )                                      I
CI     MATFTL   MATERIAL FLAG FOR FORWARD TANK LINE                          I
CI              ( --- 1 $--- /TANKS/  )                                      I
CI     MATNKS   NO AVAILABLE DEFINITION   ( /NCTIN/ )                        I
CI     MATPT    MATERIAL FLAG FOR PRESSURE TANK                              I
CI              ( --- 2 $LIQMAT /TANKS/  )                                   I
CI     MATPTL   MATERIAL FLAG FOR PRESSURE TANK LINES                        I
CI              ( IN ARRAYS RHO, SIGMAX, AND YMOD)                           I
CI              ( --- 1 $LIQMAT /TANKS/  )                                   I
CI     MATSTR   MATERIAL FOR STRUCTURAL WALL                                 I
CI              ( --- 1 $LIQMAT /TANKS/  )                                   I
CI     METHOD   NO AVAILABLE DEFINITION   ( /OPTIM/ )                        I
CI     MG       NO AVAILABLE DEFINITION   ( /GSTOR/ )                        I
CI     MH       NO AVAILABLE DEFINITION   ( /HSTOR/ )                        I
CI     MLIENV   MULTILAYER INSULATION (MLI) ENVIRONMENT FLAG                 I
CI              (1=GROUND HOLD WITH N2 PURGE, 2=GROUND HOLD WITH             I
CI              HE PURGE, 3=SPACE HOLD WITH N2 PURGE AT PRGMLI               I
CI              PSIA, 4=SPACE HOLD WITH HE AT PRGMLI PSIA)                   I
```

Figure 5.1. Common Block Variables (Sheet 22 of 46)

C

```
CI                     ( --- 1 $TANKHX /INSLHX/  )                          I
CI       MNCQA         AFT TANK MONOCOQUE FLAG                              I
CI                     0 = SUSPENDED TANK                                   I
CI                     1 = MONOCOQUE TANK                                   I
CI                     ( --- 1 $TNKGEO /TANKS/  )                           I
CI       MNCQF         FORWARD TANK MONOCOQUE FLAG                          I
CI                     0 = SUSPENDED TANK                                   I
CI                     1 = MONOCOQUE TANK                                   I
CI                     ( --- 1 $TNKGEO /TANKS/  )                           I
CI       MPHSE         NO AVAILABLE DEFINITION   ( /TRAJ/ )                 I
CI       MTNKFL        MATERIAL FLAG FOR FUEL TANK AND                      I
CI                     FUEL LINES                                           I
CI                     ( --- 1 $LIQMAT /TANKS2/  )                          I
CI       MTNKOX        MATERIAL FLAG FOR OXIDIZER TANK AND                  I
CI                     OXIDIZER LINES                                       I
CI                     ( --- 1 $LIQMAT /TANKS2/  )                          I
CI       MX            NO AVAILABLE DEFINITION   ( /XSTOR/ )                I
CI       N             NO AVAILABLE DEFINITION   ( /OPTIM/ )                I
CI       NALPHA        NO AVAILABLE DEFINITION   ( /AERO/ )                 I
CI       NALTSF        NO AVAILABLE DEFINITION   ( /AERO/ )                 I
CI       NAME          NO AVAILABLE DEFINITION   ( /OPNAME/ )               I
CI       NAMEP         PROPELLANT NAME                                      I
CI                     ( CHARACTER --- $--- /PROPN/  )                      I
CI       NBPT          NO AVAILABLE DEFINITION   ( /THRLOG/ )               I
CI       NCON          NUMBER OF SEGMENTS IN CONVERGENT CHAMBER SECTION     I
CI                     FOR HEAT TRANSFER ANALYSIS                           I
CI                     ( --- 5 $INREGN /COOLNT/  )                          I
CI       NCRYOG        NUMBER OF CRYOGENIC PROPELLANTS ON BOARD THE STAGE   I
CI                     (VALUES OF 0-2 FOR BI-PROPELLANT STAGE)(ONLY         I
CI                     REQUIRED FOR NON-LIBRARY PROPELLANTS (IPROP=0))      I
CI                     ( --- 0 $--- /LIQUID/  )                             I
CI       NCTNK         NONCONVENTIONAL TANK SELECTION FLAG (0=TANDEM,       I
CI                     1= NON-CONVENTIONAL)                                 I
CI                     ( --- 0 $LFLAG /NCTIN/  )                            I
CI       NCYL          NUMBER OF SEGMENTS IN CYLINDRICAL CHAMBER SECTION    I
CI                     FOR HEAT TRANSFER ANALYSIS                           I
CI                     ( --- 5 $INREGN /COOLNT/  )                          I
CI       NELEM         NUMBER OF INJECTOR ELEMENTS                          I
CI                     ( --- 336 $INJECT /LIQUID/  )                        I
CI       NFLORF        NUMBER OF FUEL INJECTOR ORIFICES                     I
CI                     ( --- 672 $INJECT /LIQUID/  )                        I
CI       NGIMB         NUMBER OF GIMBALING NOZZLES                          I
CI                     ( --- 1 $LIQUID /GIMBAL/  )                          I
CI       NITHX         NUMBER OF ITERATIONS IN SUBROUTINE TANKHX WHICH      I
CI                     CONTROLS THE ACCURACY OF TANK HEAT TRANSFER CALCS    I
CI                     ( --- 8 $TANKHX /INSLHX/  )                          I
CI       NMACH         NO AVAILABLE DEFINITION   ( /AERO/ )                 I
CI       NNOZ          NUMBER OF SOLID MOTOR NOZZLES PER STAGE              I
CI                     ( --- 1 $NOZZLE /GENRL/  )                           I
CI       NNZL          NUMBER OF NOZZLE SEGMENTS USED IN HEAT TRANSFER      I
CI                     ANALYSIS                                             I
CI                     ( --- 5 $INREGN /COOLNT/  )                          I
CI       NODEAR        NUMBER OF ENTRIES IN AREA RATIO ARRAY ODEEPS         I
CI                     ( --- --- $--- /OPCOND/  )                           I
CI       NODEMR        NUMBER OF ENTRIES IN MIXTURE RATIO ARRAY ODEMR       I
CI                     ( --- --- $--- /OPCOND/  )                           I
CI       NODEPC        NUMBER OF ENTRIES IN CHAMBER PRESSURE ARRAY ODEPC    I
CI                     ( --- --- $--- /OPCOND/  )                           I
CI       NODKAR        NUMBER OF ENTRIES IN AREA RATIO ARRAY ODKEPS         I
CI                     ( --- --- $--- /OPCOND/  )                           I
```

Figure 5.1. Common Block Variables (Sheet 23 of 46)

C

```
CI      NODKMR    NUMBER OF ENTRIES IN ARRAY ODKMR                    I
CI                ( --- --- $--- /OPCOND/ )                           I
CI      NODKPC    NUMBER OF ENTRIES IN ARRAY ODKPC                    I
CI                ( --- --- $--- /OPCOND/ )                           I
CI      NOXORF    NUMBER OF OXIDIZER ORIFICES IN INJECTOR FACE        I
CI                ( --- 500 $INJECT /LIQUID/ )                        I
CI      NPCR      NUMBER OF REFERENCE CHAMBER PRESSURES               I
CI                ( --- 1 $PROPEL /MOTOR/ )                           I
CI      NPHSE     NO AVAILABLE DEFINITION   ( /TRAJ/ )                I
CI      NPOINT    NUMBER OF HEAT TRANSFER ANALYSIS POINTS ALONG       I
CI                REGENERATIVELY COOLED CHAMBER                       I
CI                ( --- --- $--- /RGNSUM/ )                           I
CI      NPRB      NUMBER OF PRESSURE BOTTLES IN ENGINE BAY            I
CI                (KPRESS = 0)                                        I
CI                ( --- 1 $TNKGEO /TANKS/ )                           I
CI      NR        NUMBER OF ENGINE RESTARTS (USED TO SIZE START       I
CI                SYSTEM)                                             I
CI                ( --- 1 $PUMP /TPAIN/ )                             I
CI      NRUNIT    NO AVAILABLE DEFINITION   ( /OPTIM/ )               I
CI      NSTGES    NUMBER OF STAGES                                    I
CI                ( --- 3 $INPGEN /PERF/ )                            I
CI      NTANKS    TOTAL NUMBER OF NON-CONVENTIONAL TANKS ON STAGE     I
CI                ( --- 3 $NCTINP /NCTIN/ )                           I
CI      NTB       NUMBER OF POINTS DESCRIBING THRUST PROFILE          I
CI                ( --- --- $--- /PERF/ )                             I
CI      NTBL      NUMBER OF POINTS DESCRIBING THRUST PROFILE          I
CI                ( --- --- $--- /LIQUID/ )                           I
CI      NTC       NUMBER OF LIQUID THRUST CHAMBERS OR PLUG MODULES    I
CI                ( --- 1 $LIQENG /LIQUID/ )                          I
CI      NTHEFF    NUMBER OF ENTRIES IN TABLES THRPC, ECFTHR, AND      I
CI                ERETHR FOR EACH STAGE                               I
CI                ( --- 7 $THROT /THREFF/ )                           I
CI      NTHINT    NUMBER OF THROTTLING INTERVALS                      I
CI                ( --- --- $--- /THRLOG/ )                           I
CI      NTINT     NO AVAILABLE DEFINITION   ( /THRLOG/ )              I
CI      NTMPIT    NUMBER OF INTERATIONS ON TEMPERATURE SCHEDULE IN    I
CI                SUBROUTINE LSTAGE.  ALSO CONTROLS NUMBER OF         I
CI                ITERATIONS ON FLOWRATE SCHEDULE                     I
CI                ( --- 1 $LIQUID /TEMSCH/ )                          I
CI      OBJSCL    SCALING FACTOR FOR OBJECTIVE FUNCTION               I
CI                ( --- --- $INPOPT /OPTIM/ )                         I
CI      ODEEPS    ARRAY OF AREA RATIOES CORRESPONDING TO ODE          I
CI                PERFORMANCE IN ARRAYS  ODEST                        I
CI                ( --- --- $--- /OPCOND/ )                           I
CI      ODEMR     ARRAY OF MIXTURE RATIOES CORRESPONDING TO ODE       I
CI                PERFORMANCE IN ARRAYS ODEST                         I
CI                ( --- --- $--- /OPCOND/ )                           I
CI      ODEPC     ARRAY OF CHAMBER PRESSURE CORRESPONDING TO ODE      I
CI                PERFORMANCE IN ARRAYS  ODEST                        I
CI                ( --- --- $--- /OPCOND/ )                           I
CI      ODEST1    IDEAL ONE DIMENSIONAL EQUILIBRIUM ISP DATA ARRAY    I
CI                ( --- --- $--- /OPCOND/ )                           I
CI      ODEST2    IDEAL ONE DIMENSIONAL EQUILIBRIUM ISP DATA ARRAY    I
CI                ( --- --- $--- /OPCOND/ )                           I
CI      ODEST3    IDEAL ONE DIMENSIONAL EQUILIBRIUM ISP DATA ARRAY    I
CI                ( --- --- $--- /OPCOND/ )                           I
CI      ODEST4    IDEAL ONE DIMENSIONAL EQUILIBRIUM ISP DATA ARRAY    I
CI                ( --- --- $--- /OPCOND/ )                           I
CI      ODKEPS    NO AVAILABLE DEFINITION   ( /OPCOND/ )              I
CI      ODKMR     ARRAY OF MIXTURE RATIOES CORRESPONDING TO ODK       I
```

Figure 5.1. Common Block Variables (Sheet 24 of 46)

C

```
CI                  PERFORMANCE DATA IN ODKST                                  I
CI                  ( --- --- $--- /OPCOND/  )                                 I
CI        ODKPC     ARRAY OF CHAMBER PRESSURE CORRESPONDING TO ODK             I
CI                  PERFORMANCE DATA IN ODKST                                  I
CI                  ( --- --- $--- /OPCOND/  )                                 I
CI        ODKST1    IDEAL ONE DIMENSIONAL KINETIC ISP DATA ARRAY               I
CI                  ( --- --- $--- /OPCOND/  )                                 I
CI        ODKST2    IDEAL ONE DIMENSIONAL KINETIC ISP DATA ARRAY               I
CI                  ( --- --- $--- /OPCOND/  )                                 I
CI        ODKST3    IDEAL ONE DIMENSIONAL KINETIC ISP DATA ARRAY               I
CI                  ( --- --- $--- /OPCOND/  )                                 I
CI        ODKST4    IDEAL ONE DIMENSIONAL KINETIC ISP DATA ARRAY               I
CI                  ( --- --- $--- /OPCOND/  )                                 I
CI        OFBARR    MIXTURE RATIO OF BARRIER                                   I
CI                  ( --- 1.0 $--- ///EQ///  )                                 I
CI        OFCORE    MIXTURE OF GAS CORE IN LIQUID COMBUSTION CHAMBER           I
CI                  ( --- 1.9 $LQPERF ///EQ///  )                              I
CI        OFGGPB    MIXTURE RATIO OF GAS GENERATOR/PREBURNER                   I
CI                  ( --- 0.1 $PUMP /TPAIN/  )                                 I
CI        OFMTC     OVERALL ENGINE MIXTURE RATIO  (KPERF=0)                    I
CI                  ( --- 1.782 $LQPERF /LIQUID/  )                            I
CI        OFRMX     MIXTURE RATIO ON USER PROPELLANT AT MAX ISP,               I
CI                  PC=500  (IPROP=0)                                          I
CI                  ( --- 2.03 $LPROP /EQUIVR/  )                              I
CI        OMEGA     ACENTRIC FACTOR OF REGEN COOLANT                           I
CI                  ( --- --- $--- /COOLNT/  )                                 I
CI        OMEGAF    FUEL ACENTRIC FACTOR                                       I
CI                  ( --- --- $--- /PROPRO/  )                                 I
CI        OMEGAO    OX ACENTRIC FACTOR                                         I
CI                  ( --- --- $--- /PROPRO/  )                                 I
CI        ORBANG    ANGLE BETWEEN THE EARTH-SUN VECTOR AND VEHICLE             I
CI                  ORBITAL PLANE (KHXOPT=2)                                   I
CI                  ( DEG 0.0 $TANKHX /INSLHX/  )                              I
CI        OXKFCT    NUMBER OF VELOCITY HEADS LOST IN OXIDIZER FEED             I
CI                  LINE DUE TO BENDS, VALVES, ETC.                            I
CI                  ( VEL-HEADS 5. $LTANK /TANKS2/  )                          I
CI        OXNPSH    OXIDIZER PUMP NET POSITIVE SUCTION HEAD                    I
CI                  ( FT --- $--- /TPAOUT/  )                                  I
CI        OXNPSP    OX NET POSITIVE SUCTION PRESSURE IN TANK                   I
CI                  ( PSIA 10. $PUMP /PRESCH/  )                               I
CI        OXOPEL    NUMBER OF OXIDIZER ORIFICES/ELEMENT                        I
CI                  ( --- 1.5 $INJECT /ELEMEN/  )                              I
CI        P         REGEN STATION LOCAL PRESSURE                               I
CI                  ( PSIA --- $--- /RGNSUM/  )                                I
CI        P1000N    NO AVAILABLE DEFINITION    ( /MOTOR/ )                     I
CI        PA        NO AVAILABLE DEFINITION    ( /PERF/ )                      I
CI        PAMB      AMBIENT PRESSURE CORRECTION FOR VARIABLE THRUST-           I
CI                  TIME TRACE                                                 I
CI                  ( PSIA 0.0 $THVST /PERF/  )                                I
CI        PARAM     NO AVAILABLE DEFINITION    ( ///EQ/// )                    I
CI        PARAM     NO AVAILABLE DEFINITION    ( /PURAM/ )                     I
CI        PARAML    NO AVAILABLE DEFINITION    ( ///EQ/// )                    I
CI        PBASE     NO AVAILABLE DEFINITION    ( /PLUGCL/ )                    I
CI        PBINJF    FUEL PRESSURE AT PREBURNER INJECTOR INLET                  I
CI                  ( PSIA --- $--- /PRESCH/  )                                I
CI        PBINJO    OX PRESSURE AT PREBURNER INJECTOR INLET                    I
CI                  ( PSIA --- $--- /PRESCH/  )                                I
CI        PBPFLO    FUEL BOOST PUMP INLET PRESSURE                             I
CI                  ( PSIA --- $--- /PRESCH/  )                                I
CI        PBPOXO    OX BOOST PUMP INLET PRESSURE                               I
```

Figure 5.1. Common Block Variables (Sheet 25 of 46)

```
CI                   ( PSIA --- $--- /PRESCH/  )                            I
CI       PBPRF       FUEL PRESSURE RATIO ACROSS PREBURNER INJECTOR          I
CI                   ( PSIA 1.2 $PUMP /PRESCH/  )                           I
CI       PBPRO       OX PRESSURE RATIO ACROSS PREBURNER INJECTOR            I
CI                   ( PSIA 1.2 $PUMP /PRESCH/  )                           I
CI       PBURST      MINIMUM EXPECTED BURST PRESSURE                        I
CI                   ( LBF/IN**2 1200. $FILMNT /MOTOR/  )                   I
CI       PC          NOMINAL OPERATING CHAMBER PRESSURE                     I
CI                   ( LBF/IN**2 600. $INPGEN ///EQ///  )                   I
CI       PCAV        NO AVAILABLE DEFINITION   ( /MOTOR/ )                  I
CI       PCFACE      INJECTOR FACE PRESSURE                                 I
CI                   ( PSIA --- $--- /LIQUID/  )                            I
CI       PCISP1      INTERMEDIATE CHAMBER PRESSURE ARRAY IN PERFORMANCE     I
CI                   ROUTINES                                               I
CI                   ( --- --- $--- /OPCOND/  )                             I
CI       PCR         REFERENCE CHAMBER PRESSURES AT WHICH CSTAR AND         I
CI                   SPECIFIC IMPULSE DATA IS INPUT                         I
CI                   ( LBF/IN**2 600. $PROPEL /MOTOR/  )                    I
CI       PCRIT       CRITICAL PRESSURE OF COOLANT                           I
CI                   ( PSIA 1731. $LPROP /COOLNT/  )                        I
CI       PCRITF      FUEL CRITICAL PRESSURE                                 I
CI                   ( PSIA --- $LFUEL /PROPRO/  )                          I
CI       PCRITO      OX CRITICAL PRESSURE                                   I
CI                   ( PSIA --- $LOXID /PROPRO/  )                          I
CI       PCTHRT      CHAMBER PRESSURE FRACTIONS FOR THROTTLED OPERATION     I
CI                   ( --- 1. $THROT /THROTL/  )                            I
CI       PEFBPF      NO AVAILABLE DEFINITION   ( /TPAOUT/ )                 I
CI       PEFBPO      NO AVAILABLE DEFINITION   ( /TPAOUT/ )                 I
CI       PEFFFL      FUEL PUMP EFFICIENCY                                   I
CI                   ( --- --- $--- /TPAOUT/  )                             I
CI       PEFFL2      NO AVAILABLE DEFINITION   ( /TPOUT2/ )                 I
CI       PEFFOX      OXIDIZER PUMP EFFICIENCY                               I
CI                   ( --- --- $--- /TPAOUT/  )                             I
CI       PEFOX2      NO AVAILABLE DEFINITION   ( /TPOUT2/ )                 I
CI       PERIGE      NO AVAILABLE DEFINITION   ( ///EQ/// )                 I
CI       PFLPIN      FUEL PUMP INLET PRESSURE                               I
CI                   ( PSIA --- $--- /TPAOUT/  )                            I
CI       PGAS        NO AVAILABLE DEFINITION   ( /TANKS/ )                  I
CI       PGMAX       PRESSURANT TANK MAXIMUM PRESSURE                       I
CI                   ( PSIA --- $--- /TANKS/  )                             I
CI       PI          NO AVAILABLE DEFINITION   ( /CONST/ )                  I
CI       PICG        MAX INITIAL PRESSURE OF COLD GAS BOTTLE                I
CI                   ( PSIA 4365. $COLDG ///EQ///  )                        I
CI       PINJFL      FUEL INJECTOR INLET PRESSURE                           I
CI                   ( PSIA --- $--- /LIQUID/  )                            I
CI       PINJOX      OXIDIZER INJECTOR INLET PRESSURE                       I
CI                   ( PSIA --- $--- /LIQUID/  )                            I
CI       PIO3        NO AVAILABLE DEFINITION   ( /CONST/ )                  I
CI       PIO4        NO AVAILABLE DEFINITION   ( /CONST/ )                  I
CI       PIPKGG      TEMPERATURE SENSITIVITY OF GAS GENERATOR               I
CI                   OPERATING PRESSURE                                     I
CI                   ( 1/DEGR 0.0036 $SOLDGG /GASGEN/  )                    I
CI       PLF         VOLUMETRIC LOADING FRACTION FOR EACH STAGE BASED       I
CI                   ON THE VOLUME INSIDE THE LINER, AND REDUCED BY THE     I
CI                   SUBMERGED SECTION OF THE NOZZLE                        I
CI                   ( --- .85 $PROPEL ///EQ///  )                          I
CI       PLGODE      PLUG CLUSTER IDEAL ODE ISP                             I
CI                   ( SEC --- $--- /PLUGCL/  )                             I
CI       PMFRAC      STAGE PROPELLANT MASS FRACTION                         I
CI                   ( --- --- $--- ///EQ///  )                             I
```

Figure 5.1. Common Block Variables (Sheet 26 of 46)

C

```
CI        PNZREF    REFERENCE NOZZLE CHAMBER PRESSURE                          I
CI                  ( PSIA 125.  $LIQENG /TCA/   )                             I
CI        POWRAT    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                    I
CI        POXPIN    OXIDIZER PUMP INLET PRESSURE                               I
CI                  ( PSIA --- $--- /TPAOUT/   )                               I
CI        PPOWFL    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                    I
CI        PPOWOX    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                    I
CI        PPRPFL    FUEL PRESSURE IN TANK                                      I
CI                  ( PSIA --- $--- /LIQUID/   )                               I
CI        PPRPOX    OXIDIZER PRESSURE IN TANK                                  I
CI                  ( PSIA --- $--- /LIQUID/   )                               I
CI        PRATP     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                    I
CI        PREF      PRESSURE AT WHICH REFERENCE PROPERTIES APPLY               I
CI                  ( PSIA 14.7 $LPROP /COOLNT/   )                            I
CI        PREFFL    FUEL REFERENCE PRESSURE FOR REFERENCE PROPERTIES           I
CI                  ( PSIA --- $LFUEL /PROPRO/   )                             I
CI        PREFOX    OX REFERENCE PRESSURE FOR REFERENCE PROPERTIES             I
CI                  ( PSIA --- $LOXID /PROPRO/   )                             I
CI        PREGFO    FUEL PRESSURE AT REGEN JACKET OUTLET                       I
CI                  ( PSIA --- $--- /PRESCH/   )                               I
CI        PREGOO    OX PRESSURE AT REGEN JACKET OUTLET                         I
CI                  ( PSIA --- $--- /PRESCH/   )                               I
CI        PREL      NO AVAILABLE DEFINITION    ( /TRAJ/ )                      I
CI        PRELOS    IDEAL VELOCITY LOSSES DUE TO PRESSURE FORCES               I
CI                  ( FT/SEC 0 $INTRAJ /TRAJ/   )                              I
CI        PRFCHM    REFERENCE CHAMBER PRESSURE FOR CHAMBER STRESS              I
CI                  ( PSIA 125.  $LIQENG /TCA/   )                             I
CI        PRFCHR    REFERENCE CHAMBER PRESSURE FOR CHAR DEPTH                  I
CI                  ( PSIA 125.  $ABLATE /TCA/   )                             I
CI        PRGMLI    MLI PURGE GAS PRESSURE AT SPACE HOLD CONDITIONS            I
CI                  ( PSIA 2.0E-7 $TANKHX /INSLHX/   )                         I
CI        PSTAGF    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        PSTAGO    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        PTANKS    NO AVAILABLE DEFINITION    ( /NCTIN/ )                     I
CI        PTEFL1    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        PTEOX1    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        PTURBI    TURBINE INLET PRESSURE                                     I
CI                  ( PSIA --- $--- /PRESCH/   )                               I
CI        PTURBO    TURBINE OUTLET PRESSURE                                    I
CI                  ( PSIA --- $PUMP /PRESCH/   )                              I
CI        PULLFL    FUEL TANK ULLAGE PRESSURE                                  I
CI                  ( PSIA --- $--- /PRESCH/   )                               I
CI        PULLOX    OX TANK ULLAGE PRESSURE                                    I
CI                  ( PSIA --- $--- /PRESCH/   )                               I
CI        PUMPHP    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                    I
CI        PVENTF    FUEL TANK VENT PRESSURE                                    I
CI                  ( PSIA --- $--- /INSLHX/   )                               I
CI        PVENTO    OXIDIZER TANK VENT PRESSURE                                I
CI                  ( PSIA --- $--- /INSLHX/   )                               I
CI        PVLVFL    FUEL VALVE INLET PRESSURE                                  I
CI                  ( PSIA --- $--- /LIQUID/   )                               I
CI        PVLVFO    FUEL PRESSURE AT BIPROP VALVE OUTLET                       I
CI                  ( PSIA --- $--- /PRESCH/   )                               I
CI        PVLVOO    OX PRESSURE AT BIPROP VALVE OUTLET                         I
CI                  ( PSIA --- $--- /PRESCH/   )                               I
CI        PVLVOX    OXIDIZER VALVE INLET PRESSURE                              I
CI                  ( PSIA --- $--- /LIQUID/   )                               I
CI        PVMAXF    VAPOR PRESSURE OF FUEL AT TMAX                             I
CI                  ( PSIA 3.6 $LPROP /LIQUID/   )                             I
CI        PVMAXO    VAPOR PRESSURE OF OXIDIZER ST TMAX                         I
```

Figure 5.1. Common Block Variables (Sheet 27 of 46)

C

```
CI                  ( PSIA 2.4 $LPROP /LIQUID/  )                              I
CI        PVPLN     NATURAL LOGARITHM OF VAPOR PRESSURE ARRAY USED IN          I
CI                  CALCULATING SATURATION TEMPERATURE OF COOLANT IN           I
CI                  A REGENERATIVELY COOLED CHAMBER                            I
CI                  ( --- --- $--- /CLAP/  )                                   I
CI        PVPLNF    NATURAL LOGARITHM OF VAPOR PRESSURE ARRAY USED IN          I
CI                  CALCULATING SATURATION TEMPERATURE OF FUEL                 I
CI                  ( --- --- $--- /CLAP/  )                                   I
CI        PVPLNO    NATURAL LOGARITHM OF VAPOR PRESSURE ARRAY USED IN          I
CI                  CALCULATING SATURATION TEMPERATURE OF OX                   I
CI                  ( --- --- $--- /CLAP/  )                                   I
CI        Q         NO AVAILABLE DEFINITION   ( /TRAJ/ )                       I
CI        QALPMX    NO AVAILABLE DEFINITION   ( /AERO/ )                       I
CI        QFL       FUEL PUMP VOLUMETRIC FLOW RATE                             I
CI                  ( GPM --- $--- /TPAOUT/  )                                 I
CI        QFL2      NO AVAILABLE DEFINITION   ( /TPAOUT/ )                     I
CI        QMAXTR    MAXIMUM HEAT FLUX COOLED BY REGEN JACKET BEFORE            I
CI                  TRANSPIRATION COOLING IS USED                              I
CI                  ( BTU/IN**2/SEC 1.0 $INREGN /TRANCO/  )                    I
CI        QOX       OXIDIZER PUMP VOLUMETRIC FLOW RATE                         I
CI                  ( GPM --- $--- /TPAOUT/  )                                 I
CI        QOX2      NO AVAILABLE DEFINITION   ( /TPAOUT/ )                     I
CI        QRGN      REGEN STATION LOCAL HEAT FLUX                              I
CI                  ( BTU/IN**2/SEC --- $--- /RGNSUM/  )                       I
CI        QSTG      NO AVAILABLE DEFINITION   ( ///EQ/// )                     I
CI        QTANKF    HEAT FLUX INTO FUEL TANK(S)                                I
CI                  ( BTU/SEC --- $--- /INSLHX/  )                             I
CI        QTANKO    HEAT FLUX INTO OXIDIZER TANK(S)                            I
CI                  ( BTU/SEC --- $--- /INSLHX/  )                             I
CI        QTURB     NO AVAILABLE DEFINITION   ( /TPOUT2/ )                     I
CI        QTURBF    NO AVAILABLE DEFINITION   ( /TPOUT2/ )                     I
CI        QTURBO    NO AVAILABLE DEFINITION   ( /TPOUT2/ )                     I
CI        QULTC1    CONSTANT IN NUCLEATE BOILING ULTIMATE HEAT FLUX            I
CI                  EQUATION                                                   I
CI                  ( BTU/IN**2/SEC 4.55 $LPROP /COOLNT/  )                    I
CI        QULTC2    MULTIPLYING CONSTANT IN NUCLEATE BOILING HEAT              I
CI                  FLUX EQUATION                                              I
CI                  ( BTU/IN**3/SEC 0.00686 $LPROP /COOLNT/  )                 I
CI        RA        NO AVAILABLE DEFINITION   ( /SSCOM/ )                      I
CI        RADLOC    NO AVAILABLE DEFINITION   ( /NCTIN/ )                      I
CI        RADPIN    RADIATION SHIELDS PER INCH IN MULTILAYER INSULA-           I
CI                  TION (MLI)                                                 I
CI                  ( #/IN 40. $TANKHX /INSLHX/  )                             I
CI        RANGE     NO AVAILABLE DEFINITION   ( /TRAJ/ )                       I
CI        RATANK    NO AVAILABLE DEFINITION   ( /NCTIN/ )                      I
CI        RATE      BURN RATE (MOTOR COND)                                     I
CI                  ( IN/SEC --- $--- /MOTOR/  )                               I
CI        RATMLR    RATIO OF NOZZLE LENGTH TO THAT OF A MINIMUM LENGTH         I
CI                  RAO NOZZLE                                                 I
CI                  ( --- 1.177 $LIQENG ///EQ///  )                            I
CI        RATTCH    NO AVAILABLE DEFINITION   ( /SSCOM/ )                      I
CI        RB1000    NO AVAILABLE DEFINITION   ( ///EQ/// )                     I
CI        RBO       NO AVAILABLE DEFINITION   ( ///EQ/// )                     I
CI        RCHAM     NO AVAILABLE DEFINITION   ( /NCTIN/ )                      I
CI        RCNOW     NO AVAILABLE DEFINITION   ( /MOTOR/ )                      I
CI        RCONI     NO AVAILABLE DEFINITION   ( /MOTOR/ )                      I
CI        RCRT      RATIO OF THROAT RADIUS OF CURVATURE TO THROAT              I
CI                  RADIUS                                                     I
CI                  ( --- 1.2 $NOZZLE /MOTOR/  )                               I
CI        RDIM      NO AVAILABLE DEFINITION   ( /NCTIN/ )                      I
```

Figure 5.1. Common Block Variables (Sheet 28 of 46)

C

```
CI        RDPDG     NO AVAILABLE DEFINITION    ( /CONST/ )                       I
CI        REARTH    NO AVAILABLE DEFINITION    ( /CONST/ )                       I
CI        REEXIT    NO AVAILABLE DEFINITION    ( ///EQ/// )                      I
CI        REFNWT    REFERENCE NOZZLE WEIGHT                                      I
CI                  ( LBM 1000. $PROPEL /MOTOR/  )                               I
CI        REFSTF    FUEL REFERENCE SURFACE TENSION                               I
CI                  ( LB/IN --- $LFUEL /PROPRO/  )                               I
CI        REFSTO    OX REFERENCE SURFACE TENSION                                 I
CI                  ( LB/IN --- $LOXID /PROPRO/  )                               I
CI        REFWDT    REFERENCE NOZZLE FLOW RATE                                   I
CI                  ( LBM/SEC 100. $PROPEL /MOTOR/  )                            I
CI        REGA      THROAT REGRESSION COEFFICIENT                                I
CI                  ( --- 0.002798 $ABLATE /LIQUID/  )                           I
CI        REGB      THROAT REGRESSION COEFFICIENT                                I
CI                  ( --- 0.0005995 $ABLATE /LIQUID/  )                          I
CI        REGC      THROAT REGRESSION COEFFICIENT                                I
CI                  ( --- 0.4246 $ABLATE /LIQUID/  )                             I
CI        RELHUM    RELATIVE HUMIDITY OF AMBIENT ATMOSPHERE FOR USE              I
CI                  WITH KHXOPT=3                                                I
CI                  ( --- 50. $TANKHX /INSLHX/  )                                I
CI        REPLUG    PLUG CLUSTER EXIT RADIUS                                     I
CI                  ( IN --- $--- /PLUGCL/  )                                    I
CI        RESIDA    AFT TANK RESIDUAL PROPELLANT WEIGHT                          I
CI                  ( LBM --- $--- /TANKS/  )                                    I
CI        RESIDF    FORWARD TANK RESIDUAL PROPELLANT WEIGHT                      I
CI                  ( LBM --- $--- /TANKS/  )                                    I
CI        REXIT     NOZZLE EXIT RADIUS                                           I
CI                  ( IN --- $--- ///EQ///  )                                    I
CI        RF        RADIUS OF FORWARD DOME POLAR BOSS OPENING                    I
CI                  ( IN 2. $FILMNT /MOTOR/  )                                   I
CI        RGIMB     NO AVAILABLE DEFINITION    ( /GIMBAL/ )                      I
CI        RHBNDA    DENSITY OF AFT BLADDER BOND MATERIAL                         I
CI                  ( LBM/IN**3 0.04 $--- /TANKS/  )                             I
CI        RHBNDF    DENSITY OF FORWARD BLADDER BOND MATERIAL                     I
CI                  ( LBM/IN**3 0.04 $--- /TANKS/  )                             I
CI        RHCABL    DENSITY OF CHAMBER ABLATIVE MATERIAL                         I
CI                  ( LBM/IN**3 0.0632 $LIQMAT /TCA/  )                          I
CI        RHCSTR    DENSITY OF CHAMBER STRUCTURAL MATERIAL                       I
CI                  ( LBM/IN**3 0.0632 $LIQMAT /TCA/  )                          I
CI        RHO       MATERIAL DENSITY TABLE                                       I
CI                  ( LBM/IN**3 0.29,0.16,8*0.0 $LIQMAT /MTPROP/  )              I
CI        RHOABP    BAND DENSITY                                                 I
CI                  ( ENDS/IN/PLY 35. $FILMNT /MOTOR/  )                         I
CI        RHOALF    DENSITY OF HELICAL WINDINGS                                  I
CI                  ( LBM/IN**3 0.042 $FILMNT /MOTOR/  )                         I
CI        RHOATM    NO AVAILABLE DEFINITION    ( /ATMOS/ )                       I
CI        RHOBOT    START BOTTLE MATERIAL DENSITY (ISTART=2)                     I
CI                  ( LBM/IN**3 0.16 $PUMP /TPAIN/  )                            I
CI        RHOCAS    CASE MATERIAL DENSITY                                        I
CI                  ( LBM/IN**3 .282 $MATER /MOTOR/  )                           I
CI        RHOCLS    REGEN CHAMBER CLOSEOUT MATERIAL DENSITY                      I
CI                  ( LBM/IN**3 0.322 $LIQMAT /WTREGN/  )                        I
CI        RHOCYL    START CYLINDER MATERIAL DENSITY (ISTART=2)                   I
CI                  ( LBM/IN**3 0.3 $PUMP /TPAIN/  )                             I
CI        RHOEXF    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                      I
CI        RHOEXH    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                      I
CI        RHOEXO    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                      I
CI        RHOEXT    DENSITY OF EXTERNAL INSULATION                               I
CI                  ( LBM/IN**3 .06 $MATER /MOTOR/  )                            I
CI        RHOGG     SOLID GRAIN DENSITY                                          I
```

Figure 5.1. Common Block Variables (Sheet 29 of 46)

C

```
CI                     ( LB/IN**3 0.056 $SOLDGG /GASGEN/   )                  I
CI        RHOGW        REGEN CHAMBER GAS WALL MATERIAL DENSITY                I
CI                     ( LBM/IN**3 0.28 $LIQMAT /WTREGN/   )                  I
CI        RHOINJ       INJECTOR MATERIAL DENSITY                              I
CI                     ( LBM/IN**3 0.098 $LIQMAT /TCA/   )                    I
CI        RHOINS       DENSITY OF INTERNAL INSULATION                         I
CI                     ( LBM/IN**3 .0414 $MATER /MOTOR/   )                   I
CI        RHOINT       DENSITY OF INTERSTAGE MATERIAL                         I
CI                     ( LBM/IN**3 .101 $INTSTG /MOTOR/   )                   I
CI        RHOLNR       LINER DENSITY                                          I
CI                     ( LBM/IN**3 .0414 $MATER /MOTOR/   )                   I
CI        RHONOZ       DENSITY OF NOZZLE EXIT CONE                            I
CI                     ( LBM/IN**3 .06 $NOZZLE /GENRL/   )                    I
CI        RHONZE       NO AVAILABLE DEFINITION    ( /TCA/ )                   I
CI        RHOP         PROPELLANT DENSITY FOR EACH STAGE                      I
CI                     ( LBM/IN**3 0.  $PROPEL /MOTOR/   )                    I
CI        RHOPLB       PLUG CLUSTER BASE DENSITY ( IPLUG = 1 )                I
CI                     ( LBM/IN**3 0.06 $LIQMAT /PLGBAS/   )                  I
CI        RHOSPH       START SYSTEM SPHERE MATERIAL DENSITY (ISTART=1)        I
CI                     ( LB/IN**3 0.1 $PUMP /TPAIN/   )                       I
CI        RHOTFL       FUEL TURBINE BLADE MATERIAL DENSITY(JCNFIG=3 OR 4)     I
CI                     ( LBM/IN**3 0.3 $PUMP /TPAIN/   )                      I
CI        RHOTH        DENSITY OF HOOP WINDINGS                               I
CI                     ( LBM/IN**3 0.042 $FILMNT /MOTOR/   )                  I
CI        RHOTOX       OX TURBINE BLADE MATERIAL DENSITY(JCNFIG=3 OR 4)       I
CI                     ( LBM/IN**3 0.3 $PUMP /TPAIN/   )                      I
CI        RHOTPA       TPA EFFECTIVE DENSITY                                  I
CI                     ( LBM/IN**3 0.3 $PUMP /TPAIN/   )                      I
CI        RHOTUR       TURBINE BLADE MATERIAL DENSITY (JCNFIG=1 OR 2)         I
CI                     ( LBM/IN**3 0.3 $PUMP /TPAIN/   )                      I
CI        RHOVLV       VALVE MATERIAL DENSITY                                 I
CI                     ( LBM/IN**3 0.098 $LIQMAT /TCA/   )                    I
CI        RHPTIN       DENSITY OF TANK INSULATION                             I
CI                     ( LBM/IN**3 0.04 $LIQMAT /TANKS/   )                   I
CI        RHTRIN       MATERIAL DENSITY OF TRANSPIRATION COOLING THROAT       I
CI                     INSERT                                                 I
CI                     ( LBM/IN**3 0.28 $LIQMAT /TRANCO/   )                  I
CI        RINTNK       NO AVAILABLE DEFINITION    ( /NCTOUT/ )                I
CI        RLNRI2       NO AVAILABLE DEFINITION    ( /MOTOR/ )                 I
CI        RMFFL        FUEL DROPLET RADIUS CORRECTION FACTOR                  I
CI                     ( --- 0.33 $LQPERF /LIQUID/   )                        I
CI        RMFOX        OXIDIZER DROPLET RADIUS CORRECTION FACTOR              I
CI                     ( --- 0.33 $LQPERF /LIQUID/   )                        I
CI        RMOTOR       NO AVAILABLE DEFINITION    ( /NCTIN/ )                 I
CI        RNGBO        NO AVAILABLE DEFINITION    ( ///EQ/// )                I
CI        RNGIMP       NO AVAILABLE DEFINITION    ( ///EQ/// )                I
CI        RNGNM        NO AVAILABLE DEFINITION    ( ///EQ/// )                I
CI        RNGRE        NO AVAILABLE DEFINITION    ( ///EQ/// )                I
CI        RNGSTG       NO AVAILABLE DEFINITION    ( /TRAJ/ )                  I
CI        RNZEXT       NO AVAILABLE DEFINITION    ( /NCTIN/ )                 I
CI        RNZREF       REFERENCE NOZZLE THROAT RADIUS                         I
CI                     ( IN 3.74 $LIQENG /TCA/   )                            I
CI        ROACVL       ACCUMULATOR VALVE MATERIAL DENSITY (ISTART=2)          I
CI                     ( LB/IN**3 0.3 $PUMP /TPAIN/   )                       I
CI        ROCART       START CARTRIDGE MATERIAL DENSITY (ISTART=3)            I
CI                     ( LBM/IN**3 0.3 $PUMP /TPAIN/   )                      I
CI        ROGRAN       START CARTRIDGE GRAIN DENSITY (ISTART=3)               I
CI                     ( LBM/IN**3 0.07 $PUMP /TPAIN/   )                     I
CI        ROINGG       GAS GENERATOR OR PRE-BURNER INJECTOR MATERIAL          I
CI                     DENSITY                                                I
```

Figure 5.1. Common Block Variables (Sheet 30 of 46)

C

```
CI                 ( LBM/IN**3 0.3 $PUMP /TPAIN/   )                                 I
CI      ROLINE     PROPELLANT LINE MATERIAL DENSITY(ENGINE BAY LINES)               I
CI                 ( LB/IN**3 0.3 $PUMP /TPAIN/   )                                  I
CI      ROOTNZ     NO AVAILABLE DEFINITION    ( /MOTOR/ )                            I
CI      ROSPVL     DENSITY OF COLD GAS VALVE MATERIAL (ISTART=1)                     I
CI                 ( LBM/IN**3 0.3 $PUMP /TPAIN/   )                                 I
CI      ROSTAK     HOT GAS DUCT MATERIAL DENSITY                                     I
CI                 ( LBM/IN**3 0.3 $PUMP /TPAIN/   )                                 I
CI      ROTRNZ     DENSITY OF TRANSLATING NOZZLE MATERIAL                            I
CI                 ( LB/IN**3 0.28 $LIQMAT /TRANOZ/   )                              I
CI      ROUTNK     NO AVAILABLE DEFINITION    ( /NCTOUT/ )                           I
CI      RPM        SINGLE SHAFT TPA SPEED OF ROTATION                                I
CI                 ( RPM --- $--- /TPAOUT/   )                                       I
CI      RPMBPF     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                           I
CI      RPMBPO     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                           I
CI      RPMBRS     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                           I
CI      RPMFL      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                           I
CI      RPMOX      NO AVAILABLE DEFINITION    ( /TPAOUT/ )                           I
CI      RPMSFL     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                           I
CI      RPMSOX     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                           I
CI      RPMTFL     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                           I
CI      RPMTOX     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                           I
CI      RPMTUR     NO AVAILABLE DEFINITION    ( /TPAOUT/ )                           I
CI      RRFCHM     REFERENCE CHAMBER RADIUS FOR TCA WEIGHT                           I
CI                 ( IN 5.95 $LIQENG /TCA/   )                                       I
CI      RTCORR     KINETIC LOSS THROAT CORRECTION FACTOR                             I
CI                 ( --- --- $--- /OPCOND/   )                                       I
CI      RTHRT      CHAMBER THROAT RADIUS                                             I
CI                 ( IN --- $--- ///EQ///   )                                        I
CI      RTOT       NO AVAILABLE DEFINITION    ( /TRAJ/ )                             I
CI      RTRATT     RADIUS OF NOZZLE AT ATTACH POINT OF TRANSLATING                   I
CI                 NOZZLE                                                            I
CI                 ( IN --- $--- /TRANOZ/   )                                        I
CI      RUFFFL     ABSOLUTE SURFACE ROUGHNESS OF FUEL FEED LINE                      I
CI                 ( IN .0001 $LTANK /TANKS2/   )                                    I
CI      RUFFOX     ABSOLUTE SURFACE ROUGHNESS OF OXIDIZER FEED LINE                  I
CI                 ( IN .0001 $LTANK /TANKS2/   )                                    I
CI      SABSOR     STAGE ABSORBTIVITY (KHXOPT=2)                                     I
CI                 ( --- 0.2 $TANKHX /INSLHX/   )                                    I
CI      SACCEL     AVERAGE STAGE ACCELERATION (FOR TANK HEAT LOSS)                   I
CI                 ( G'S 2.0 $TANKHX /INSLHX/   )                                    I
CI      SAFACT     CASE DESIGN SAFETY FACTOR                                         I
CI                 ( --- 1.5 $MATER /MOTOR/   )                                      I
CI      SALFT      NO AVAILABLE DEFINITION    ( /MOTOR/ )                            I
CI      SALPH      NO AVAILABLE DEFINITION    ( /TRAJ/ )                             I
CI      SAMULT     SURFACE AREA MULTIPLIER ON REGEN COOLED ENGINE                    I
CI                 ( --- 1.0 $INREGN /WTREGN/   )                                    I
CI      SCASE      DESIGN STRENGTH OF CASE MATERIAL (HOOP)                           I
CI                 ( LBF/IN**2 220000. $MATER /MOTOR/   )                            I
CI      SCHIP      NO AVAILABLE DEFINITION    ( /TRAJ/ )                             I
CI      SCHIR      NO AVAILABLE DEFINITION    ( /TRAJ/ )                             I
CI      SCREEN     NO AVAILABLE DEFINITION    ( /PSUTK2/ )                           I
CI      SDOMEH     DOME HOOP DESIGN STRENGTH                                         I
CI                 ( LBF/IN**2 220000. $MATER /MOTOR/   )                            I
CI      SDOMEM     DOME MERIDIONAL STRENGTH                                          I
CI                 ( LBF/IN**2 220000. $MATER /MOTOR/   )                            I
CI      SEMISI     STAGE EMMISIVITY (KHXOPT=2)                                       I
CI                 ( --- 0.9 $TANKHX /INSLHX/   )                                    I
CI      SEPRNG     NO AVAILABLE DEFINITION    ( ///EQ/// )                           I
CI      SFABL      ABLATIVE THICKNESS SAFETY FACTOR                                  I
```

Figure 5.1. Common Block Variables (Sheet 31 of 46)

C

```
CI                    ( --- 1.  $ABLATE /TCA/  )                                I
CI        SFC         AERODYNAMIC SKIN FRICTION COEFFICIENTS INPUT AS           I
CI                    FUNCTIONS OF MACH NUMBER AND ALTITUDE;  SFC(I,J)          I
CI                    CORRESPONDS TO AMACH(I) AND ALTSF(J)                      I
CI                    ( --- 0.  $AEROD /AERO/  )                                I
CI        SFCHM       CHAMBER STRUCTURAL SAFETY FACTOR                          I
CI                    ( --- 1.  $LIQENG /TCA/  )                                I
CI        SFFLTK      SAFETY FACTOR FOR FUEL TANK                               I
CI                    ( --- 1.25 $LIQMAT /TWTMLT/  )                            I
CI        SFINST      DESIGN SAFETY FACTOR FOR INTERSTAGE THICKNESS             I
CI                    SIZING                                                    I
CI                    ( --- 1.5 $INTSTG /MOTOR/  )                              I
CI        SFLINE      SAFETY FACTOR FOR PROPELLANT AND PRESSURIZATION           I
CI                    LINES                                                     I
CI                    ( --- 2.0 $LIQMAT /TWTMLT/  )                             I
CI        SFOXTK      SAFETY FACTOR FOR OXIDIZER TANK                           I
CI                    ( --- 1.25 $LIQMAT /TWTMLT/  )                            I
CI        SFPRTK      SAFETY FACTOR FOR PRESSURE TANK                           I
CI                    ( --- 1.5 $LIQMAT /TWTMLT/  )                             I
CI        SFSTRC      SAFETY FACTOR FOR STRUCTURAL WALL OF STAGE                I
CI                    ( --- 1.25 $LIQMAT /TWTMLT/  )                            I
CI        SFTNKS      NO AVAILABLE DEFINITION   ( /NCTIN/ )                     I
CI        SGAMA       NO AVAILABLE DEFINITION   ( /TRAJ/ )                      I
CI        SIGCHM      HOT CHAMBER DESIGN STRENGTH                               I
CI                    ( PSI 25000.  $LIQMAT /TCA/  )                            I
CI        SIGCLS      DESIGN STRESS OF REGEN JACKET CLOSEOUT MATERIAL           I
CI                    ( PSIA 25000 $LIQMAT /TCA/  )                             I
CI        SIGGG       BURN RATE TEMPERATURE SENSITIVITY OF SOLID GRAIN          I
CI                    ( 1/DEGR 0.0013 $SOLDGG /GASGEN/  )                       I
CI        SIGINJ      INJECTOR MATERIAL DESIGN STRESS                           I
CI                    ( PSI 25000.  $LIQMAT /TCA/  )                            I
CI        SIGMAX      MATERIAL DESIGN STRESS TABLE                              I
CI                    ( NOT INCLUDING SAFETY FACTORS )                          I
CI                    ( PSI 112300.,130000.,8*0.  $LIQMAT /MTPROP/  )           I
CI        SIGNZE      DESIGN STRESS OF NOZZLE EXTENSION MATERIAL                I
CI                    ( PSIA 25000 $LIQMAT /TCA/  )                             I
CI        SINST       DESIGN STRENGTH OF INTERSTAGE MATERIAL                    I
CI                    ( LBF/IN**2 220000.  $INTSTG /MOTOR/  )                   I
CI        SMASS       STAGE MASS RATIO                                          I
CI                    ( --- --- $--- /SSCOM/  )                                 I
CI        SOFIA       CONSTANT IN SOFI THERMAL CONDUCTIVITY EQUATION            I
CI                    K = SOFIA + SOFIB * TEMPERATURE                           I
CI                    ( BTU/IN-SEC-DEGR 3.935E-8 $TANKHX /INSLHX/  )            I
CI        SOFIB       CONSTANT IN SOFI THERMAL CONDUCTIVITY EQUATION            I
CI                    K = SOFIA + SOFIB * TEMPERATURE                           I
CI                    ( BTU/IN-SEC-DEGR**2 5.676E-10 $TANKHX /INSLHX/  )        I
CI        SOLCON      SOLAR HEAT FLUX (KHXOPT=2)                                I
CI                    ( BTU/SEC-IN**2 8.28E-4 $TANKHX /INSLHX/  )               I
CI        SPCNOZ      SPACE BETWEEN ADJACENT NOZZLES                            I
CI                    ( IN 1.0 $LIQENG /GIMBAL/  )                              I
CI        SPHEAT      MATERIAL SPECIFIC HEAT TABLE                              I
CI                    ( BTU/LB-DEGR .12,.13,8*0.  $LIQMAT /MTPROP/  )           I
CI        SPRMX       MAXIMUM ISP FOR USER PROPELLANT AT PC=500                 I
CI                    AREA RATIO=20   (IPROP=0)                                 I
CI                    ( SEC 328.8 $LPROP /EQUIVR/  )                            I
CI        SPSMMX      ISP OF LIBRARY PROPELLANT AT MAX ISP FOR PC=500           I
CI                    AND E=20                                                  I
CI                    ( --- --- $--- /EQUIVR/  )                                I
CI        SSBPFL      NO AVAILABLE DEFINITION   ( /TPAOUT/ )                    I
CI        SSBPOX      NO AVAILABLE DEFINITION   ( /TPAOUT/ )                    I
```

Figure 5.1. Common Block Variables (Sheet 32 of 46)

C

```
CI        SSFL       FUEL PUMP SPECIFIC SPEED                              I
CI                   ( --- --- $--- /TPAOUT/  )                            I
CI        SSFL2      NO AVAILABLE DEFINITION    ( /TPAOUT/ )               I
CI        SSHEAR     NO AVAILABLE DEFINITION    ( /MOTOR/ )                I
CI        SSMIN      MINIMUM SPECIFIC SPEED ALLOWED IN PUMPS               I
CI                   ( --- 800. $PUMP ///EQ///  )                          I
CI        SSOX       OXIDIZER PUMP SPECIFIC SPEED                          I
CI                   ( --- --- $--- /TPAOUT/  )                            I
CI        SSOX2      NO AVAILABLE DEFINITION    ( /TPAOUT/ )               I
CI        SSSBPF     MAXIMUM SUCTION SPECIFIC SPEED OF FUEL BOOST PUMP     I
CI                   ( RPM-GPM-FT 30000-OR-40000 $PUMP /TPAIN/  )          I
CI        SSSBPO     MAXIMUM SUCTION SPECIFIC SPEED OF OX BOOST PUMP       I
CI                   ( RPM-GPM-FT 30000 $PUMP /TPAIN/  )                   I
CI        SSSFL      MAXIMUM SUCTION SPECIFIC SPEED OF FUEL PUMP           I
CI                   ( RPM-GPM-FT 20000 $PUMP /TPAIN/  )                   I
CI        SSSMAX     MAXIMUM SUCTION SPECIFIC SPEED ALLOWED IN PUMPS       I
CI                   ( --- 20000. $PUMP ///EQ///  )                        I
CI        SSSOX      MAXIMUM SUCTION SPECIFIC SPEED OF OXIDIZER PUMP       I
CI                   ( RPM-GPM-FT 20000 $PUMP /TPAIN/  )                   I
CI        SSTRFL     NO AVAILABLE DEFINITION    ( /TPOUT2/ )               I
CI        SSTROX     NO AVAILABLE DEFINITION    ( /TPOUT2/ )               I
CI        SSTURB     NO AVAILABLE DEFINITION    ( /TPOUT2/ )               I
CI        STGIMP     NO AVAILABLE DEFINITION    ( ///EQ/// )               I
CI        SYBOT      START BOTTLE YIELD STRENGTH (ISTART=2)                I
CI                   ( PSI 75000 $PUMP /TPAIN/  )                          I
CI        SYCART     YIELD STRENGTH FOR START CARTRIDGE (ISTART=3)         I
CI                   ( PSI 100000 $PUMP /TPAIN/  )                         I
CI        SYCYL      START CYLINDER YIELD STRENGTH (ISTART=2)              I
CI                   ( PSI 30000 $PUMP /TPAIN/  )                          I
CI        SYDUCT     HOT GAS DUCT MATERIAL YEILD STRENGTH                  I
CI                   ( PSI 30000 $PUMP /TPAIN/  )                          I
CI        SYINGG     GAS GENERATOR OR PRE-BURNER INJECTOR YIELD            I
CI                   STRENGTH                                              I
CI                   ( PSI 30000 $PUMP /TPAIN/  )                          I
CI        SYLIN      PROPELLANT LINE YIELD STRENGTH (ENGINE BAY LINES)     I
CI                   ( PSI 30000 $PUMP /TPAIN/  )                          I
CI        SYSPH      START SYSTEM SPHERE YIELD STRENGTH (ISTART=1)         I
CI                   ( PSI 47000 $PUMP /TPAIN/  )                          I
CI        TALFT      NO AVAILABLE DEFINITION    ( /MOTOR/ )                I
CI        TALFT2     NO AVAILABLE DEFINITION    ( /MOTOR/ )                I
CI        TAMICE     AMBIENT TEMPERATURE FOR GROUND HOLD ICE HEAT          I
CI                   TRANSFER CALCULATION (KHXOPT=3)                       I
CI                   ( DEGR 560 $TANKHX /INSLHX/  )                        I
CI        TAMRAD     AMBIENT TEMPERATURE FOR TCA RADIATION COOLING         I
CI                   ( DEGR 560 $LIQENG /COOLNT/  )                        I
CI        TANGLE     NO AVAILABLE DEFINITION    ( /NCTIN/ )                I
CI        TAUWEB     WEB INSULATION THICKNESS                              I
CI                   ( IN --- $--- ///EQ///  )                             I
CI        TB         CHAMBER BARRIER TEMPERATURE                           I
CI                   ( DEGR --- $--- /LIQUID/  )                           I
CI        TBKCS      NO AVAILABLE DEFINITION    ( /MOTOR/ )                I
CI        TBKIST     NO AVAILABLE DEFINITION    ( /MOTOR/ )                I
CI        TBLDFL     FUEL TANK BLADDER THICKNESS                           I
CI                   ( IN .025 $BLADER /TANKS2/  )                         I
CI        TBLDOX     OXIDIZER TANK BLADDER THICKNESS                       I
CI                   ( IN .025 $BLADER /TANKS2/  )                         I
CI        TBNDFL     FUEL TANK BOND THICKNESS                              I
CI                   ( IN .04 $BLADER /TANKS2/  )                          I
CI        TBNDOX     OXIDIZER TANK BOND THICKNESS                          I
CI                   ( IN .04 $BLADER /TANKS2/  )                          I
```

Figure 5.1. Common Block Variables (Sheet 33 of 46)

C

```
CI         TBOGAS      START BOTTLE GAS TEMPERATURE (ISTART=2)                 I
CI                     ( DEGR 530 $PUMP /TPAIN/   )                            I
CI         TBOGG       TEMPERATURE OF SOLID GAS GENERATOR PRESSURANT           I
CI                     AT BURNOUT                                              I
CI                     ( DEGF --- $--- /GASGEN/   )                            I
CI         TBOIL       NORMAL BOILING POINT OF COOLANT                         I
CI                     ( DEGR 618. $LPROP /COOLNT/   )                         I
CI         TBOILF      FUEL NORMAL BOILING POINT                               I
CI                     ( DEGR --- $LFUEL /PROPRO/   )                          I
CI         TBOILO      OX NORMAL BOILING POINT                                 I
CI                     ( DEGR --- $LOXID /PROPRO/   )                          I
CI         TBONDA      THICKNESS OF AFT TANK BOND MATERIAL (KBLAT=2-5)         I
CI                     ( IN 0.04 $--- /TANKS/   )                              I
CI         TBONDF      THICKNESS OF FORWARD TANK BOND MATERIAL                 I
CI                     (KBLFT = 2-5)                                           I
CI                     ( IN 0.04 $--- /TANKS/   )                              I
CI         TBPFLO      FUEL TEMPERATURE AT BOOST PUMP OUTLET                   I
CI                     ( DEGR --- $--- /TEMSCH/   )                            I
CI         TBPOXO      OX TEMPERATURE AT BOOST PUMP OUTLET                     I
CI                     ( DEGR --- $--- /TEMSCH/   )                            I
CI         TBR         REGEN STATION COOLANT BULK TEMPERATURE                  I
CI                     ( DEGR --- $--- /RGNSUM/   )                            I
CI         TBRCHR      REFERENCE BURN TIME FOR CHAR DEPTH                      I
CI                     ( SEC 500. $ABLATE /TCA/   )                            I
CI         TBRN        TABLE OF MOTOR BURN TIMES;  INPUT FOR EACH STAGE        I
CI                     ( SEC 0.0 $THVST /PERF/   )                             I
CI         TBUCKL      NO AVAILABLE DEFINITION    ( /SSCOM/ )                  I
CI         TBURN       STAGE BURN TIME                                         I
CI                     ( SEC --- $--- /LSCOM/   )                              I
CI         TC          CHAMBER CORE COMBUSTION TEMPERATURE                     I
CI                     ( DEGR --- $--- /LIQUID/   )                            I
CI         TCASE       CASE THICKNESS                                          I
CI                     ( IN --- $--- /MOTOR/   )                               I
CI         TCHAM       IDEAL EQUILIBRIUM CHAMBER TEMPERATURE DATA ARRAY        I
CI                     ( --- --- $--- /OPCOND/   )                             I
CI         TCHMAB      ABLATIVE THICKNESS IN CHAMBER                           I
CI                     ( IN --- $--- /TCA/   )                                 I
CI         TCHMST      CHAMBER STRUCTURAL THICKNESS                            I
CI                     ( IN --- $--- /TCA/   )                                 I
CI         TCMBGG      GAS GENERATOR COMBUSTION TEMPERATURE                    I
CI                     ( DEGR 2130. $SOLDGG /GASGEN/   )                       I
CI         TCONE       THICKNESS OF NOZZLE EXIT CONE                           I
CI                     ( IN 0.0 $NOZZLE /MOTOR/   )                            I
CI         TCRIT       CRITICAL TEMPERATURE OF COOLANT                         I
CI                     ( DEGR 1093. $LPROP /COOLNT/   )                        I
CI         TCRITF      FUEL CRITICAL TEMPERATURE                               I
CI                     ( DEGR --- $LFUEL /PROPRO/   )                          I
CI         TCRITO      OX CRITICAL TEMPERATURE                                 I
CI                     ( DEGR --- $LOXID /PROPRO/   )                          I
CI         TCW         REGEN STATION LOCAL COOLANT WALL TEMPERATURE            I
CI                     ( DEGR --- $--- /RGNSUM/   )                            I
CI         TDCYGG      TEMPERATURE DECAY TIME CONSTANT                         I
CI                     ( SEC 100. $SOLDGG /GASGEN/   )                         I
CI         TDESTR      DESIGN TEMPERATURE OF TRANSPIRATION COOLED WALL         I
CI                     MATERIAL                                                I
CI                     ( DEGR 2000 $INREGN /TRANCO/   )                        I
CI         TDOME       DOME THICKNESS                                          I
CI                     ( IN --- $--- /MOTOR/   )                               I
CI         TEKCH       NO AVAILABLE DEFINITION    ( /PSUTK2/ )                 I
CI         TEKXMN      NO AVAILABLE DEFINITION    ( /PSUTEK/ )                 I
```

Figure 5.1. Common Block Variables (Sheet 34 of 46)

C

```
CI        TEKXMX     NO AVAILABLE DEFINITION    ( /PSUTEK/ )                        I
CI        TEKXP      NO AVAILABLE DEFINITION    ( /PSUTEK/ )                        I
CI        TEKYMN     NO AVAILABLE DEFINITION    ( /PSUTEK/ )                        I
CI        TEKYMX     NO AVAILABLE DEFINITION    ( /PSUTEK/ )                        I
CI        TEKYP      NO AVAILABLE DEFINITION    ( /PSUTEK/ )                        I
CI        TENTTR     AVERAGE TEMPERATURE RISE OF TRANSPIRATION COOLANT              I
CI                   UP TO THE INJECTION POINT                                      I
CI                   ( DEGR --- $--- /TRANCO/  )                                    I
CI        TEXBOU     EXTERNAL BOUNDARY TEMPERATURE (KHXOPT=1)                       I
CI                   ( DEGR 560. $TANKHX /INSLHX/  )                                I
CI        TF1        TEMPERATURE OF COLD GAS PRESSURANT IN TANK 1                   I
CI                   AFTER EXPANSION                                                I
CI                   ( DEGF --- $--- /COLDGP/  )                                    I
CI        TF2        TEMPERATURE OF COLD GAS PRESSURANT IN TANK 2                   I
CI                   AFTER EXPANSION                                                I
CI                   ( DEGF --- $--- /COLDGP/  )                                    I
CI        TFACFL     FUEL TEMPERATURE AT TCA INJECTOR FACE                          I
CI                   ( DEGR --- $--- /TEMSCH/  )                                    I
CI        TFACOX     OX TEMPERATURE AT TCA INJECTOR FACE                            I
CI                   ( DEGR --- $--- /TEMSCH/  )                                    I
CI        TFB        TEMPERATURE OF COLD GAS PRESSURANT IN PRESSURE                 I
CI                   TANK AFTER EXPANSION INTO PROPELLANT TANKS                     I
CI                   ( DEGF --- $--- /COLDGP/  )                                    I
CI        TFLPIN     FUEL TEMPERATURE AT PUMP INLET                                 I
CI                   ( DEGR --- $--- /TEMSCH/  )                                    I
CI        TGAS       REGEN STATION LOCAL COMBUSTION GAS TEMPERATURE                 I
CI                   ( DEGR --- $--- /RGNSUM/  )                                    I
CI        TGEOH      PLATELET THICKNESS OF TRANSPIRATION COOLED SECTION             I
CI                   ( IN .08 $INREGN /TRANCO/  )                                   I
CI        TGEOL      PLATELET LAND THICKNESS OF TRANSPIRATION COOLED                I
CI                   SECTION                                                        I
CI                   ( IN .1 $INREGN /TRANCO/  )                                    I
CI        TGEOS      SEPARATOR PLATELET THICKNESS IN TRANSPIRATION                  I
CI                   COOLED SECTION                                                 I
CI                   ( IN .04 $INREGN /TRANCO/  )                                   I
CI        TGEOW      PLATELET FLOW PASSAGE WIDTHS IN TRANSPIRATION                  I
CI                   COOLED SECTION                                                 I
CI                   ( IN .14 $INREGN /TRANCO/  )                                   I
CI        TGW        REGEN STATION LOCAL GAS WALL TEMPERATURE                       I
CI                   ( DEGR --- $--- /RGNSUM/  )                                    I
CI        TGWNOM     NOMINAL GAS WALL TEMPERATURE (NOT TO BE EXCEEDED)              I
CI                   ( DEGR 2000. $INREGN /COOLNT/  )                               I
CI        THATHD     AFT TANK DOME THICKNESS                                        I
CI                   ( IN --- $--- /TANKS/  )                                       I
CI        THFTHD     FORWARD TANK DOME THICKNESS                                    I
CI                   ( IN --- $--- /TANKS/  )                                       I
CI        THIKNS     NO AVAILABLE DEFINITION    ( /SSCOM/ )                         I
CI        THKBLA     AFT BLADDER MATERIAL THICKNESS (KBLAT = 1)                     I
CI                   ( IN 0.025 $--- /TANKS/  )                                     I
CI        THKBLF     FORWARD BLADDER MATERIAL THICKNESS (KBLFT = 1)                 I
CI                   ( IN 0.025 $--- /TANKS/  )                                     I
CI        THKCYL     NO AVAILABLE DEFINITION    ( /NCTOUT/ )                        I
CI        THKEND     NO AVAILABLE DEFINITION    ( /NCTOUT/ )                        I
CI        THPTCH     PRESSURE TANK COMMON HEAD THICKNESS                            I
CI                   ( IN --- $--- /TANKS/  )                                       I
CI        THPTHD     PRESSURE TANK DOME THICKNESS                                   I
CI                   ( IN --- $--- /TANKS/  )                                       I
CI        THRPC      TABLE OF CHAMBER PRESSURE FRACTIONS FOR CORRES-                I
CI                   PONDING VALUES OF ERETHR AND ECFTHR                            I
CI                   ( --- --- $THROT /THREFF/  )                                   I
```

Figure 5.1. Common Block Variables (Sheet 35 of 46)

C

```
CI      TEKXMX    NO AVAILABLE DEFINITION    ( /PSUTEK/ )                          I
CI      TEKXP     NO AVAILABLE DEFINITION    ( /PSUTEK/ )                          I
CI      TEKYMN    NO AVAILABLE DEFINITION    ( /PSUTEK/ )                          I
CI      TEKYMX    NO AVAILABLE DEFINITION    ( /PSUTEK/ )                          I
CI      TEKYP     NO AVAILABLE DEFINITION    ( /PSUTEK/ )                          I
CI      TENTTR    AVERAGE TEMPERATURE RISE OF TRANSPIRATION COOLANT                I
CI                UP TO THE INJECTION POINT                                        I
CI                ( DEGR --- $--- /TRANCO/   )                                     I
CI      TEXBOU    EXTERNAL BOUNDARY TEMPERATURE (KHXOPT=1)                         I
CI                ( DEGR 560.  $TANKHX /INSLHX/   )                                I
CI      TF1       TEMPERATURE OF COLD GAS PRESSURANT IN TANK 1                     I
CI                AFTER EXPANSION                                                  I
CI                ( DEGF --- $--- /COLDGP/   )                                     I
CI      TF2       TEMPERATURE OF COLD GAS PRESSURANT IN TANK 2                     I
CI                AFTER EXPANSION                                                  I
CI                ( DEGF --- $--- /COLDGP/   )                                     I
CI      TFACFL    FUEL TEMPERATURE AT TCA INJECTOR FACE                            I
CI                ( DEGR --- $--- /TEMSCH/   )                                     I
CI      TFACOX    OX TEMPERATURE AT TCA INJECTOR FACE                              I
CI                ( DEGR --- $--- /TEMSCH/   )                                     I
CI      TFB       TEMPERATURE OF COLD GAS PRESSURANT IN PRESSURE                   I
CI                TANK AFTER EXPANSION INTO PROPELLANT TANKS                       I
CI                ( DEGF --- $--- /COLDGP/   )                                     I
CI      TFLPIN    FUEL TEMPERATURE AT PUMP INLET                                   I
CI                ( DEGR --- $--- /TEMSCH/   )                                     I
CI      TGAS      REGEN STATION LOCAL COMBUSTION GAS TEMPERATURE                   I
CI                ( DEGR --- $--- /RGNSUM/   )                                     I
CI      TGEOH     PLATELET THICKNESS OF TRANSPIRATION COOLED SECTION               I
CI                ( IN .08 $INREGN /TRANCO/   )                                    I
CI      TGEOL     PLATELET LAND THICKNESS OF TRANSPIRATION COOLED                  I
CI                SECTION                                                          I
CI                ( IN .1 $INREGN /TRANCO/   )                                     I
CI      TGEOS     SEPARATOR PLATELET THICKNESS IN TRANSPIRATION                    I
CI                COOLED SECTION                                                   I
CI                ( IN .04 $INREGN /TRANCO/   )                                    I
CI      TGEOW     PLATELET FLOW PASSAGE WIDTHS IN TRANSPIRATION                    I
CI                COOLED SECTION                                                   I
CI                ( IN .14 $INREGN /TRANCO/   )                                    I
CI      TGW       REGEN STATION LOCAL GAS WALL TEMPERATURE                         I
CI                ( DEGR --- $--- /RGNSUM/   )                                     I
CI      TGWNOM    NOMINAL GAS WALL TEMPERATURE (NOT TO BE EXCEEDED)                I
CI                ( DEGR 2000.  $INREGN /COOLNT/   )                               I
CI      THATHD    AFT TANK DOME THICKNESS                                          I
CI                ( IN --- $--- /TANKS/   )                                        I
CI      THFTHD    FORWARD TANK DOME THICKNESS                                      I
CI                ( IN --- $--- /TANKS/   )                                        I
CI      THIKNS    NO AVAILABLE DEFINITION    ( /SSCOM/ )                           I
CI      THKBLA    AFT BLADDER MATERIAL THICKNESS (KBLAT = 1)                       I
CI                ( IN 0.025 $--- /TANKS/   )                                      I
CI      THKBLF    FORWARD BLADDER MATERIAL THICKNESS (KBLFT = 1)                   I
CI                ( IN 0.025 $--- /TANKS/   )                                      I
CI      THKCYL    NO AVAILABLE DEFINITION    ( /NCTOUT/ )                          I
CI      THKEND    NO AVAILABLE DEFINITION    ( /NCTOUT/ )                          I
CI      THPTCH    PRESSURE TANK COMMON HEAD THICKNESS                              I
CI                ( IN --- $--- /TANKS/   )                                        I
CI      THPTHD    PRESSURE TANK DOME THICKNESS                                     I
CI                ( IN --- $--- /TANKS/   )                                        I
CI      THRPC     TABLE OF CHAMBER PRESSURE FRACTIONS FOR CORRES-                  I
CI                PONDING VALUES OF ERETHR AND ECFTHR                              I
CI                ( --- --- $THROT /THREFF/   )                                    I
```

Figure 5.1. Common Block Variables (Sheet 35 of 46)

C

```
CI      THRVAC    VACUUM DELIVERED THRUST                              I
CI                ( LBF --- $--- /SSCOM/  )                            I
CI      TIMPCG    TIME AT WHICH POLYTROPIC GAMMA EQUALS 1.1            I
CI                ( SEC 240. $COLDG /COLDGP/  )                        I
CI      TIMTHR    TIME INTERVALS FOR ENGINE THROTTLING                 I
CI                ( SEC 0.0 $THROT /THROTL/  )                         I
CI      TINADM    INSULATION THICKNESS IN AFT DOME SECTION             I
CI                ( IN 0. $MATER /MOTOR/  )                            I
CI      TINFDM    INSULATION THICKNESS IN FORWARD DOME SECTION         I
CI                ( IN 0. $MATER /MOTOR/  )                            I
CI      TINJFL    FUEL TEMPERATURE AT TCA INJECTOR INLET               I
CI                ( DEGR --- $--- /TEMSCH/  )                          I
CI      TINJOX    OX TEMPERATURE AT TCA INJECTOR INLET                 I
CI                ( DEGR --- $--- /TEMSCH/  )                          I
CI      TINSCS    INSULATION THICKNESS IN CYLINDRICAL SECTION OF THE   I
CI                MOTOR CASE (LC)                                      I
CI                ( IN .1 $MATER /MOTOR/  )                            I
CI      TINSTG    NO AVAILABLE DEFINITION   ( /LSCOM/ )                I
CI      TINSUL    INSULATION THICKNESS FOR PRESSURE TANK               I
CI                ( IN 0.0 $LIQMAT /TANKS/  )                          I
CI      TISEFF    GAS GENERATOR BLEED TURBINE EXHAUST ISP EFFICIENCY   I
CI                ( --- --- $--- /TPAOUT/  )                           I
CI      TKOAL     TANK OVERALL LENGTH                                  I
CI                ( IN --- $--- /TANKS/  )                             I
CI      TKRCHM    REFERENCE CHAMBER THICKNESS OF ABLATIVE              I
CI                ( IN 0.22 $ABLATE /TCA/  )                           I
CI      TLIMIT    MAXIMUM RUN TIME IN C.P. SECONDS                     I
CI                ( SEC 4000 $INPOPT /OPTIM/  )                        I
CI      TLNADM    THICKNESS OF LINER IN AFT DOME SECTION               I
CI                ( IN 0. $MATER /MOTOR/  )                            I
CI      TLNFDM    LINER THICKNESS (FORWARD DOME)                       I
CI                ( IN --- $MATER /MOTOR/  )                           I
CI      TLNRCS    THICKNESS OF LINER IN CYLINDRICAL SECTION            I
CI                ( IN 0. $MATER /MOTOR/  )                            I
CI      TMAX      MAXIMUM VEHICLE OPERATING TEMPERATURE                I
CI                ( DEGF 90.0 $LIQUID /TEMPS/  )                       I
CI      TMIN      MINIMUM VEHICLE OPERATING TEMPERATURE                I
CI                ( DEGF 60.0 $LIQUID /TEMPS/  )                       I
CI      TMING     MINIMUM GUAGE THICKNESS OF TANKS                     I
CI                ( IN 0.035 $LIQMAT /TANKS/  )                        I
CI      TMINGL    MINIMUM GUAGE THICKNESS OF LINES                     I
CI                ( IN 0.065 $LIQMAT /TANKS/  )                        I
CI      TMINGS    MINIMUM GUAGE THICKNESS OF STRUCTURAL WALL           I
CI                ( IN 0.035 $LIQMAT /TANKS/  )                        I
CI      TMLIF     MULTILAYER INSULATION (MLI) THICKNESS FOR FUEL       I
CI                TANK(S)                                              I
CI                ( IN 0. $TANKHX /INSLHX/  )                          I
CI      TMLIO     MULTILAYER INSULATION (MLI) THICKNESS FOR OXIDIZER   I
CI                TANK(S)                                              I
CI                ( IN 0. $TANKHX /INSLHX/  )                          I
CI      TMNTNK    NO AVAILABLE DEFINITION   ( /NCTOUT/ )               I
CI      TMPCHF    FUEL TEMPERATURE USED IN VAPORIZATION CALCULATION    I
CI                ( DEGR --- $--- /TEMSCH/  )                          I
CI      TMPCHO    OX TEMPERATURE USED IN VAPORIZATION CALCULATION      I
CI                ( DEGR --- $--- /TEMSCH/  )                          I
CI      TMPRA     NO AVAILABLE DEFINITION   ( /MOTOR/ )                I
CI      TNENOM    NOZZLE EXTENSION DESIGN TEMPERATURE                  I
CI                ( DEGR 2000 $LIQENG /COOLNT/  )                      I
CI      TNKODA    AFT TANK OUTSIDE DIAMETER                            I
CI                ( IN --- $--- /TANKS/  )                             I
```

Figure 5.1. Common Block Variables (Sheet 36 of 46)

C

```
CI        TNKODF    FORWARD TANK OUTSIDE DIAMETER                        I
CI                  ( IN --- $--- /TANKS/  )                             I
CI        TNKODP    PRESSURE TANK OUTSIDE DIAMETER                       I
CI                  ( IN --- $--- /TANKS/  )                             I
CI        TNOZAB    NOZZLE AVERAGE ABLATIVE THICKNESS                    I
CI                  ( IN 0.  $--- /TCA/  )                               I
CI        TNOZZL    NOZZLE EXTENSION MATERIAL THICKNESS                  I
CI                  ( IN --- $--- /TCA/  )                               I
CI        TNZMIN    MINIMUM NOZZLE EXTENSION THICKNESS                   I
CI                  ( IN 0.01 $LIQENG /TCA/  )                           I
CI        TNZREF    REFERENCE NOZZLE EXTENSION THICKNESS                 I
CI                  ( IN 0.019 $LIQENG /TCA/  )                          I
CI        TOP       NOMINAL VEHICLE OPERATING TEMPERATURE                I
CI                  ( DEGF 75.0 $LIQUID /TEMPS/  )                       I
CI        TOXPIN    OX TEMPERATURE AT MAIN PUMP INLET                    I
CI                  ( DEGR --- $--- /TEMSCH/  )                          I
CI        TP        PERIOD OF DESTINATION ORBIT                          I
CI                  ( SEC 0.0 $ORB ///EQ///  )                           I
CI        TPARAM    NO AVAILABLE DEFINITION   ( ///EQ/// )               I
CI        TPARAM    NO AVAILABLE DEFINITION   ( /TRAJ/ )                 I
CI        TPAWT     TPA WEIGHT                                           I
CI                  ( LBM --- $--- /TPOUT2/  )                           I
CI        TPHSE     NO AVAILABLE DEFINITION   ( /TRAJ/ )                 I
CI        TPLGBS    PLUG CLUSTER BASE THICKNESS                          I
CI                  ( IN 0.5 $LIQUID /PLGBAS/  )                         I
CI        TPMAXF    MAX FUEL TEMPERATURE IN TANK                         I
CI                  ( DEGR --- $LFUEL /TEMSCH/  )                        I
CI        TPMAXO    MAX OX TEMPERATURE IN TANK                           I
CI                  ( DEGR --- $LOXID /TEMSCH/  )                        I
CI        TPMINF    MIN FUEL TEMPERATURE IN TANK                         I
CI                  ( DEGR --- $LFUEL /TEMSCH/  )                        I
CI        TPMINO    MIN OX TEMPERATURE IN TANK                           I
CI                  ( DEGR --- $LOXID /TEMSCH/  )                        I
CI        TPNOMF    NOMINAL FUEL TEMPERATURE IN TANK                     I
CI                  ( DEGR --- $LFUEL /TEMSCH/  )                        I
CI        TPNOMO    NOMINAL OX TEMPERATURE IN TANK                       I
CI                  ( DEGR --- $LOXID /TEMSCH/  )                        I
CI        TRANKM    PLATELET MATERIAL THERMAL CONDUCTIVITY IN            I
CI                  TRANSPIRATION COOLED SECTION                         I
CI                  ( BTU/IN/SEC/DEGR .0004 $INREGN /TRANCO/  )          I
CI        TREF      TEMPERATURE AT WHICH REFERENCE PROPERTIES APPLY      I
CI                  ( DEGR 530.  $LPROP /COOLNT/  )                      I
CI        TREFFL    FUEL REFERENCE TEMPERATURE FOR REFERENCE PROPERTIE   I
CI                  ( DEGR --- $LFUEL /PROPRO/  )                        I
CI        TREFGG    REFERENCE TEMPERATURE FOR BURN RATE COEFFICIENT      I
CI                  OF GAS GENERATOR'S SOLID GRAIN                       I
CI                  ( DEGF 80.  $SOLDGG /GASGEN/  )                      I
CI        TREFOX    OX REFERENCE TEMPERATURE FOR REFERENCE PROPERTIES    I
CI                  ( DEGR --- $LOXID /PROPRO/  )                        I
CI        TREGFO    FUEL TEMPERATURE AT REGEN JACKET OUTLET              I
CI                  ( DEGR --- $--- /TEMSCH/  )                          I
CI        TREGOO    OX TEMPERATURE AT REGEN JACKET OUTLET                I
CI                  ( DEGR --- $--- /TEMSCH/  )                          I
CI        TRINST    THICKNESS OF TRANSPIRATION COOLING THROAT INSERT     I
CI                  ( IN 0.3 $LIQMAT /TRANCO/  )                         I
CI        TRMX      CHAMBER TEMPERATURE OF NEW PROPELLANT AT PC=500      I
CI                   AND OFRMX   (IPROP = 0)                             I
CI                  ( DEGR 5934. $LPROP /EQUIVR/  )                      I
CI        TSH       THERMODYNAMIC SUPPRESSION HEAD (NON-ZERO FOR         I
CI                  HYDROGEN) (IE EFFECTIVE NPSH FOR PUMP)               I
```

Figure 5.1. Common Block Variabiles (Sheet 37 of 46)

C

```
CI                ( FT O-OR-90 $--- /TPAIN/  )                               I
CI      TSIDE     NO AVAILABLE DEFINITION    ( /NCTOUT/ )                    I
CI      TSMMX     COMBUSTION TEMP OF LIBRARY PROPELLANT AT MAX ISP           I
CI                FOR PC=500 E=20                                            I
CI                ( DEGR --- $--- /EQUIVR/  )                                I
CI      TSOFIF    SPRAY ON FOAM INSULATION (SOFI) THICKNESS FOR              I
CI                FUEL TANK(S)                                               I
CI                ( IN O.  $TANKHX /INSLHX/  )                               I
CI      TSOFIO    SPRAY ON FOAM INSULATION (SOFI) THICKNESS FOR              I
CI                OXIDIZER TANK(S)                                           I
CI                ( IN O.  $TANKHX /INSLHX/  )                               I
CI      TSPCA     SPACE BETWEEN AFT TANK AND VEHICLE SKIN                    I
CI                ( IN O.O $LTANK /TANKS/  )                                 I
CI      TSPCF     SPACE BETWEEN FORWARD TAN AND VEHICLE SKIN                 I
CI                ( IN O.O $LTANK /TANKS/  )                                 I
CI      TSPCP     SPACE BETWEEN PRESSURE TANK AND VEHICLE SKIN                I
CI                ( IN O.O $LTANK /TANKS/  )                                 I
CI      TSPEED    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI      TSPH      START SYSTEM SPHERE TEMPERATURE (ISTART=1)                 I
CI                ( DEGR 210.  $PUMP /TPAIN/  )                              I
CI      TSTAG1    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI      TSTAG2    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI      TSTAG3    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI      TSTAG4    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI      TSTAG5    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI      TSTAGE    NO AVAILABLE DEFINITION    ( /PERF/ )                      I
CI      TSTRC     STRUCTURAL WALL THICKNESS                                  I
CI                ( IN --- $LIQUID /TANKS/  )                                I
CI      TTEFL1    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI      TTEOX1    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI      TTHRAB    ABLATIVE THICKNESS AT THROAT                               I
CI                ( IN --- $--- /TCA/  )                                     I
CI      TTOFL     NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI      TTOOX     NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI      TTOP      NO AVAILABLE DEFINITION    ( /NCTOUT/ )                    I
CI      TTORMN    NO AVAILABLE DEFINITION    ( /NCTOUT/ )                    I
CI      TTORMX    NO AVAILABLE DEFINITION    ( /NCTOUT/ )                    I
CI      TTOTP     NO AVAILABLE DEFINITION    ( /MOTOR/ )                     I
CI      TTURBI    GAS TEMPERATURE AT TURBINE INLET                           I
CI                ( DEGR --- $PUMP /TEMSCH/  )                               I
CI      TTURBO    GAS TEMPERATURE AT TURBINE OUTLET                          I
CI                ( DEGR --- $--- /TEMSCH/  )                                I
CI      TTWAFT    THICKNESS OF AFT TANK WALL                                 I
CI                ( IN --- $--- /TANKS/  )                                   I
CI      TTWFWD    THICKNESS OF FORWARD TANK WALL                             I
CI                ( IN --- $--- /TANKS/  )                                   I
CI      TTWPRS    THICKNESS OF PRESSURE TANK WALL                            I
CI                ( IN --- $--- /TANKS/  )                                   I
CI      TULLFL    NO AVAILABLE DEFINITION    ( /TEMSCH/ )                    I
CI      TULLOX    NO AVAILABLE DEFINITION    ( /TEMSCH/ )                    I
CI      TURBHP    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                    I
CI      TURBPR    TURBINE PRESSURE RATIO                                     I
CI                ( --- 2 $PUMP /PRESCH/  )                                  I
CI      TUREFF    TURBINE EFFICIENCY                                         I
CI                ( --- --- $--- /TPAOUT/  )                                 I
CI      TUREFO    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                    I
CI      TUREFU    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                    I
CI      TURHPF    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                    I
CI      TURHPO    NO AVAILABLE DEFINITION    ( /TPAOUT/ )                    I
CI      TVLVFL    FUEL TEMPERATURE AT BIPROP VALVE INLET                     I
```

Figure 5.1. Common Block Variables (Sheet 38 of 46)

C

```
CI                     ( DEGR --- $--- /TEMSCH/  )                              I
CI        TVLVFO       FUEL TEMPERATURE AT BIPROP VALVE OUTLET                  I
CI                     ( DEGR --- $--- /TEMSCH/  )                              I
CI        TVLVOO       OX TEMPERATURE AT BIPROP VALVE OUTLET                    I
CI                     ( DEGR --- $--- /TEMSCH/  )                              I
CI        TVLVOX       OX TEMPERATURE AT BIPROP VALVE INLET                     I
CI                     ( DEGR --- $--- /TEMSCH/  )                              I
CI        TWDOTF       TOTAL FUEL FLOWRATE                                      I
CI                     ( LBM/SEC --- $--- /LFLOW/  )                            I
CI        TWDOTL       TOTAL FLOWRATE                                           I
CI                     ( LBM/SEC --- $--- /LFLOW/  )                            I
CI        TWDOTO       TOTAL OXIDIZER FLOWRATE                                  I
CI                     ( LBM/SEC --- $--- /LFLOW/  )                            I
CI        TWOPI        NO AVAILABLE DEFINITION   ( /CONST/ )                    I
CI        TXINS        THICKNESS OF EXTERNAL ENSULATION                         I
CI                     ( IN 0. $MATER /MOTOR/  )                                I
CI        ULFRHA       ULLAGE FRACTION OF AFT TANK AT TMAX                      I
CI                     ( --- 0.045 $--- /TANKS/  )                              I
CI        ULFRHF       ULLAGE FRACTION OF FORWARD TANK AT TMAX                  I
CI                     ( --- 0.045 $--- /TANKS/  )                              I
CI        ULLFFL       FUEL TANK ULLAGE FRACTION                                I
CI                     ( --- 0.02 $LTANK /TANKS2/  )                            I
CI        ULLFOX       OXIDIZER TANK ULLAGE FRACTION                            I
CI                     ( --- 0.02 $LTANK /TANKS2/  )                            I
CI        UOVCFL       NO AVAILABLE DEFINITION   ( /TPAOUT/ )                   I
CI        UOVCOX       NO AVAILABLE DEFINITION   ( /TPAOUT/ )                   I
CI        UOVERC       TURBINE PITCH LINE VELOCITY DIVIDED BY ISENTROPIC        I
CI                     SPOUTING VELOCITY                                        I
CI                     ( --- 0.4 $PUMP /TPAIN/  )                               I
CI        US           TURBINE BLADE ULTIMATE STRENGTH                          I
CI                     ( PSI 127000 $PUMP /TPAIN/  )                            I
CI        V            REGEN STATION LOCAL COOLANT VELOCITY                     I
CI                     ( IN/SEC --- $--- /RGNSUM/  )                            I
CI        V65          VISCOSITY OF REGEN COOLANT AT TR=0.65 PR=1.0             I
CI                     ( LB*SEC/IN**2 --- $--- /COOLNT/  )                      I
CI        V65FL        NO AVAILABLE DEFINITION   ( /PROPRO/ )                   I
CI        V65OX        NO AVAILABLE DEFINITION   ( /PROPRO/ )                   I
CI        VACQFL       FUEL ACQUISITION SYSTEM VOLUME                           I
CI                     ( IN**3 --- $--- /TANKS2/  )                             I
CI        VACQOX       OXIDIZER ACQUISITION SYSTEM VOLUME                       I
CI                     ( IN**3 --- $--- /TANKS2/  )                             I
CI        VBAR         NO AVAILABLE DEFINITION   ( ///EQ/// )                   I
CI        VBO          NO AVAILABLE DEFINITION   ( ///EQ/// )                   I
CI        VCONE        NO AVAILABLE DEFINITION   ( /SSCOM/ )                    I
CI        VCRIT        CRITICAL VISCOSITY OF REGEN COOLANT                      I
CI                     ( LB*SEC/IN**2 --- $--- /COOLNT/  )                      I
CI        VCRITF       FUEL CRITICAL VISCOSITY                                  I
CI                     ( LB*SEC/IN**2 --- $--- /PROPRO/  )                      I
CI        VCRITO       OX CRITICAL VISCOSITY                                    I
CI                     ( LB*SEC/IN**2 --- $--- /PROPRO/  )                      I
CI        VELI         INITIAL VELOCITY AT IGNITION                             I
CI                     ( FT/SEC 0 $INTRAJ ///EQ///  )                           I
CI        VFL          VELOCITY OF FUEL THROUGH INJECTOR ORIFICES               I
CI                     ( IN/SEC --- $--- /LIQUID/  )                            I
CI        VFLTNK       FUEL TANK VOLUME                                         I
CI                     ( IN**3 --- $--- /TANKS2/  )                             I
CI        VGAS         VISCOSITY OF CHAMBER COMBUSTION PRODUCTS                 I
CI                     ( LB*SEC/IN**2 --- $--- /TANKS/  )                       I
CI        VINSTG       NO AVAILABLE DEFINITION   ( /LSCOM/ )                    I
CI        VLNGTH       NO AVAILABLE DEFINITION   ( /NCTOUT/ )                   I
```

Figure 5.1. Common Block Variables (Sheet 39 of 46)

C

```
CI       VOLAND    TOTAL MATERIAL VOLUME OF THE LANDS BETWEEN COOLING   I
CI                 CHANNELS IN THE REGEN CHAMBER                        I
CI                 ( IN**3 --- $--- /WTREGN/  )                         I
CI       VOX       VELOCITY OF OXIDIZER THROUGH INJECTOR ORIFICES       I
CI                 ( IN/SEC --- $--- /LIQUID/  )                        I
CI       VOXTNK    OXIDIZER TANK VOLUME                                 I
CI                 ( IN**3 --- $--- /TANKS2/  )                         I
CI       VPRTNK    NO AVAILABLE DEFINITION   ( /TANKS2/ )               I
CI       VRE       NO AVAILABLE DEFINITION   ( ///EQ/// )               I
CI       VRE1      NO AVAILABLE DEFINITION   ( /TRAJ/ )                 I
CI       VRE3      NO AVAILABLE DEFINITION   ( /TRAJ/ )                 I
CI       VRE4      NO AVAILABLE DEFINITION   ( /TRAJ/ )                 I
CI       VREF      REFERENCE VALUE OF VISCOSITY FOR COOLANT             I
CI                 ( LBM/IN/SEC 5.17E-5 $LPROP /COOLNT/  )              I
CI       VREFFL    FUEL REFERENCE VISCOSITY                             I
CI                 ( LB*SEC/IN**2 --- $LFUEL /PROPRO/  )                I
CI       VREFOX    OX REFERENCE VISCOSITY                               I
CI                 ( LB*SEC/IN**2 --- $LOXID /PROPRO/  )                I
CI       VS        NO AVAILABLE DEFINITION   ( /MOTOR/ )                I
CI       VSTG      NO AVAILABLE DEFINITION   ( /TRAJ/ )                 I
CI       VTANKS    NO AVAILABLE DEFINITION   ( /NCTIN/ )                I
CI       VTERM     NO AVAILABLE DEFINITION   ( ///EQ/// )               I
CI       VTOT      NO AVAILABLE DEFINITION   ( /TRAJ/ )                 I
CI       VULLA     ULLAGE VOLUME OF AFT TANK                            I
CI                 ( IN**3 --- $--- /TANKS/  )                          I
CI       VULLF     ULLAGE VOLUME OF FORWARD TANK                        I
CI                 ( IN**3 --- $--- /TANKS/  )                          I
CI       VX        NO AVAILABLE DEFINITION   ( /TRAJ/ )                 I
CI       VXACFT    HORIZONTAL VELOCITY OF LAUNCH AIRCRAFT (ASSUMED      I
CI                 CONSTANT AND USED FOR COMPUTING MISSILE SEPARA-      I
CI                 TION RANGE)                                          I
CI                 ( FT/SEC 0 $INTRAJ /TRAJ/  )                         I
CI       VY        NO AVAILABLE DEFINITION   ( /TRAJ/ )                 I
CI       W         REGEN STATION LOCAL CHANNEL WIDTH                    I
CI                 ( IN --- $--- /RGNSUM/  )                            I
CI       WACQFL    FUEL ACQUISITION SYSTEM WEIGHT                       I
CI                 ( LB --- $--- /TANKS2/  )                            I
CI       WACQOX    OXIDIZER ACQUISITION SYSTEM WEIGHT                   I
CI                 ( LB --- $--- /TANKS2/  )                            I
CI       WAFCSK    AFT SKIRT WEIGHT                                     I
CI                 ( LBM --- $--- /SSCOM/  )                            I
CI       WAFDOM    DOME WEIGHT (AFT)                                    I
CI                 ( LBM --- $--- /SSCOM/  )                            I
CI       WAINST    NO AVAILABLE DEFINITION   ( /MOTOR/ )                I
CI       WALLK     THERMAL CONDUCTIVITY OF CHAMBER WALL MATERIAL        I
CI                 (AT AVERAGE WALL OPERATING TEMPERATURE)              I
CI                 ( BTU/IN/SEC/DEGR 0.00039 $INREGN /COOLNT/  )        I
CI       WALLTH    CHAMBER WALL THICKNESS                               I
CI                 ( IN 0.025 $--- /COOLNT/  )                          I
CI       WATL      AFT TANK LINES WEIGHT                                I
CI                 ( LBM --- $--- /TANKS/  )                            I
CI       WBNOUT    GROSS BURNOUT WEIGHT                                 I
CI                 ( LBM --- $--- /LSCOM/  )                            I
CI       WBOILF    NO AVAILABLE DEFINITION   ( /TANKS2/ )               I
CI       WBOILO    NO AVAILABLE DEFINITION   ( /TANKS2/ )               I
CI       WCASE     NO AVAILABLE DEFINITION   ( /SSCOM/ )                I
CI       WCAT      MISCELLANEOUS CASE WEIGHT                            I
CI                 ( LBM --- $--- /MOTOR/  )                            I
CI       WCCYL     CYLINDRICAL CASE WEIGHT                              I
CI                 ( LBM --- $--- /SSCOM/  )                            I
```

Figure 5.1. Common Block Variables (Sheet 40 of 46)

```
C
```

```
CI        WCONE     NO AVAILABLE DEFINITION    ( /SSCOM/ )                  I
CI        WDAUTF    FUEL TANK AUTOGENOUS PRESSURANT FLOWRATE                I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDAUTO    OX TANK AUTOGENOUS PRESSURANT FLOWRATE                  I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDBLNZ    GAS GENERATOR BLEED NOZZLE FLOWRATE                     I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDBYPF    FUEL TURBINE BYPASS FLOWRATE                            I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDBYPO    OX TURBINE BYPASS FLOWRATE                              I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDBYRF    FUEL REGEN JACKET BYPASS FLOWRATE                       I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDBYRO    OX REGEN JACKET BYPASS FLOWRATE                         I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDINJF    FUEL FLOWRATE THROUGH TCA INJECTOR                      I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDINJO    OX FLOWRATE THROUGH TCA INJECTOR                        I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDOT      TABLE OF WEIGHT FLOW RATE FOR VARIABLE THRUST-          I
CI                  TIME TRACE                                              I
CI                  ( LBF/SEC 0.0 $THVST /PERF/  )                          I
CI        WDOTF     FUEL FLOWRATE THROUGH A SINGLE TCA                      I
CI                  ( LB/SEC --- $--- /LIQUID/  )                           I
CI        WDOTL     PROPELLANT FLOW RATE                                    I
CI                  ( LBM/SEC --- $--- /LIQUID/  )                          I
CI        WDOTO     OXIDIZER FLOWRATE THROUGH A SINGLE TCA                  I
CI                  ( LB/SEC --- $--- /LIQUID/  )                           I
CI        WDOTTR    TOTAL TRANSPIRATION COOLANT FLOWRATE                    I
CI                  ( LB/SEC --- $--- /TRANCO/  )                           I
CI        WDPMPF    FUEL FLOWRATE THROUGH MAIN PUMP                         I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDPMPO    OX FLOWRATE THROUGH MAIN PUMP                           I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDREGF    FUEL FLOWRATE THROUGH REGEN JACKET                      I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDREGO    OX FLOWRATE THROUGH REGEN JACKET                        I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDRGN     FLOW RATE EXITING REGEN JACKET (IE. MINUS THE           I
CI                  TRANSPIRATION COOLANT FLOWRATE )                        I
CI                  ( LB/SEC --- $--- /RGNSUM/  )                           I
CI        WDTANF    FUEL TRANSPIRATION COOLING FLOWRATE                     I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDTANO    OX TRANSPIRATION COOLING FLOWRATE                       I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDTEXP    NO AVAILABLE DEFINITION    ( /LSCOM/ )                  I
CI        WDTKOF    FUEL FLOWRATE OUT OF TANK                               I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDTKOO    OX FLOWRATE OUT OF TANK                                 I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDTRIF    FUEL FLOWRATE INTO PREBURNER                            I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDTRIO    OX FLOWRATE INTO PREBURNER                              I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDTROF    NO AVAILABLE DEFINITION    ( /SCHEDW/ )                 I
CI        WDTROO    NO AVAILABLE DEFINITION    ( /SCHEDW/ )                 I
CI        WDTURB    TURBINE FLOWRATE                                        I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
CI        WDVLVF    FUEL FLOWRATE THROUGH BIPROP VALVE                      I
CI                  ( LB/SEC --- $--- /SCHEDW/  )                           I
```

Figure 5.1. Common Block Variables (Sheet 41 of 46)

C

```
CI          WDVLVO     OX FLOWRATE THROUGH BIPROP VALVE                           I
CI                     ( LB/SEC --- $--- /SCHEDW/  )                              I
CI          WEXPND     WEIGHT OF EXPENDABLE INERTS FOR EACH STAGE                 I
CI                     (EXPENDED LINERLY WITH BURN TIME)                          I
CI                     ( LBM 0.0 $INPGEN /GENRL/  )                               I
CI          WFINST     NO AVAILABLE DEFINITION   ( /MOTOR/ )                      I
CI          WFTL       FORWARD TANK LINES WEIGHT                                  I
CI                     ( LBM --- $--- /TANKS/  )                                  I
CI          WFUEL      PROPELLANT WEIGHT                                          I
CI                     ( LBM --- $--- /GENRL/  )                                  I
CI          WFUELR     NO AVAILABLE DEFINITION   ( /SSCOM/ )                      I
CI          WFWCSK     FORWARD SKIRT WEIGHT                                       I
CI                     ( LBM --- $--- /SSCOM/  )                                  I
CI          WFWDOM     DOME WEIGHT (FORWARD)                                      I
CI                     ( LBM --- $--- /SSCOM/  )                                  I
CI          WGAS       PRESSURANT WEIGHT                                          I
CI                     ( LBM --- $--- /TANKS/  )                                  I
CI          WGGPB      NO AVAILABLE DEFINITION   ( /TPOUT2/ )                     I
CI          WGL        GAS LINES WEIGHT                                           I
CI                     ( LBM --- $--- /TANKS/  )                                  I
CI          WGRES      WEIGHT OF RESIDUAL GAS IN PRESSURANT TANK                  I
CI                     ( LBM --- $--- /COLDGP/  )                                 I
CI          WHGMF      NO AVAILABLE DEFINITION   ( /TPOUT2/ )                     I
CI          WIGN       STAGE IGNITION WEIGHT                                      I
CI                     ( LBM --- $--- /GENRL/  )                                  I
CI          WIGNIT     NO AVAILABLE DEFINITION   ( /TPOUT2/ )                     I
CI          WINERT     INTERSTAGE WEIGHT                                          I
CI                     ( LBM --- $--- /GENRL/  )                                  I
CI          WINSFL     FUEL TANK INSULATION WEIGHT                                I
CI                     ( LB --- $--- /INSLHX/  )                                  I
CI          WINSOX     OXIDIZER TANK INSULATION WEIGHT                            I
CI                     ( LB --- $--- /INSLHX/  )                                  I
CI          WINSTG     NO AVAILABLE DEFINITION   ( /LSCOM/ )                      I
CI          WINSUL     INTERNAL INSULATION WEIGHT                                 I
CI                     ( LBM --- $--- /LSCOM/  )                                  I
CI          WLINER     LINER WEIGHT                                               I
CI                     ( LBM --- $--- /SSCOM/  )                                  I
CI          WLTHR      LAND WIDTH BETWEEN COOLANT CHANNELS AT THROAT              I
CI                     ( IN 0.03 $INREGN /COOLNT/  )                              I
CI          WM1        NO AVAILABLE DEFINITION   ( /PERF/ )                       I
CI          WMGGPB     MOLECULAR WEIGHT OF GAS GENERATOR/PREBURNER                I
CI                     COMBUSTION GAS                                             I
CI                     ( --- 14 $PUMP /TPAIN/  )                                  I
CI          WMI        NO AVAILABLE DEFINITION   ( /PERF/ )                       I
CI          WMISC      MISCELLANEOUS WEIGHT PER STAGE EXCLUDING PAYLOAD           I
CI                     ( LBM 0 $INPGEN /GENRL/  )                                 I
CI          WMISFL     MISCELLANEOUS FUEL ADDED TO STAGE (REMAINS ON              I
CI                     STAGE AT BURNOUT)                                          I
CI                     ( LBM 0 $INPGEN /GENRL/  )                                 I
CI          WMISOX     MISCELLANEOUS OXIDIZER ADDED TO STAGE (REMAINS ON          I
CI                     STAGE AT BURNOUT)                                          I
CI                     ( LBM 0 $INPGEN /GENRL/  )                                 I
CI          WMOUNT     THRUST MOUNT WEIGHT                                        I
CI                     ( LBM --- $--- /TCA/  )                                    I
CI          WNCTLN     NO AVAILABLE DEFINITION   ( /NCTOUT/ )                     I
CI          WNDMPH     WIND VELOCITY AROUND VEHICLE FOR HEAT TRANSFER             I
CI                     OPTION (KHXOPT=3)                                          I
CI                     ( MPH 10 $TANKHX /INSLHX/  )                               I
CI          WNOZ       NOZZLE ASSEMBLY WEIGHT                                     I
CI                     ( LBM --- $--- /SSCOM/  )                                  I
```

Figure 5.1. Common Block Variables (Sheet 42 of 46)

C

```
CI        WPAY      NO AVAILABLE DEFINITION    ( /GENRL/ )                           I
CI        WPAYLD    PAYLOAD WEIGHT FORWARD OF THE FINAL PROPULSIVE                   I
CI                  STAGE                                                            I
CI                  ( LBM 0 $INPGEN ///EQ///   )                                     I
CI        WPAYR     NO AVAILABLE DEFINITION    ( /SSCOM/ )                           I
CI        WPBOGG    WEIGHT OF PRESSURANT IN PROPELLANT TANKS                         I
CI                  ( LBM --- $--- /GASGEN/   )                                      I
CI        WPCH      PRESSURANT CONTROL HARDWARE WEIGHT                               I
CI                  ( LBM --- $--- /TANKS/   )                                       I
CI        WPDOT     PROPELLANT FLOW RATE                                             I
CI                  ( LBM/SEC --- $--- /PERF/   )                                    I
CI        WPERC     PERCENT STAGE WEIGHT USED AS MISC                                I
CI                  ( --- 0. $INPGEN /MOTOR/   )                                     I
CI        WPEXPL    NO AVAILABLE DEFINITION    ( /PERF/ )                            I
CI        WPLEFT    NO AVAILABLE DEFINITION    ( /PERF/ )                            I
CI        WPLGBS    PLUG CLUSTER BASE WEIGHT                                         I
CI                  ( LBM --- $--- /PLGBAS/   )                                      I
CI        WPROP     WEIGHT OF STAGE PROPELLANT (THRUST-TIME OPTION)                  I
CI                  ( LBM 0.0 $THVST ///EQ///   )                                    I
CI        WRESFL    NO AVAILABLE DEFINITION    ( /TANKS2/ )                          I
CI        WRESOX    NO AVAILABLE DEFINITION    ( /TANKS2/ )                          I
CI        WSHTNK    NO AVAILABLE DEFINITION    ( /NCTOUT/ )                          I
CI        WSTART    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                          I
CI        WSUPHD    THRUST CHAMBER ASSY SUPPORT HARDWARE WEIGHT                      I
CI                  ( LBM --- $--- /TCA/   )                                         I
CI        WTANKS    TOTAL STAGE TANK WEIGHT                                          I
CI                  ( LBM --- $--- /TANKS/   )                                       I
CI        WTATJT    WEIGHT OF AFT TANK JOINTS                                        I
CI                  ( LBM --- $--- /LQTLPR/   )                                      I
CI        WTATNK    AFT TANK WEIGHT                                                  I
CI                  ( LBM --- $--- /LQTLPR/   )                                      I
CI        WTBLDA    AFT BLADDER WEIGHT                                               I
CI                  ( LBM --- $--- /TANKS/   )                                       I
CI        WTBLDF    FORWARD BLADDER WEIGHT                                           I
CI                  ( LBM --- $--- /TANKS/   )                                       I
CI        WTBNDA    AFT BOND WEIGHT                                                  I
CI                  ( LBM --- $--- /TANKS/   )                                       I
CI        WTBNDF    FORWARD BOND WEIGHT                                              I
CI                  ( LBM --- $--- /TANKS/   )                                       I
CI        WTCHAM    CHAMBER WEIGHT                                                   I
CI                  ( LBM --- $--- /TCA/   )                                         I
CI        WTFTJT    WEIGHT OF FORWARD TANK JOINTS                                    I
CI                  ( LBM --- $--- /LQTLPR/   )                                      I
CI        WTFTNK    FORWARD TANK WEIGHT                                              I
CI                  ( LBM --- $--- /LQTLPR/   )                                      I
CI        WTGIMB    GIMBAL SYSTEM WEIGHT                                             I
CI                  ( LBM --- $--- /GIMBAL/   )                                      I
CI        WTHR      COOLANT CHANNEL WIDTH AT CHAMBER THROAT                          I
CI                  ( IN 0.03 $INREGN /COOLNT/   )                                   I
CI        WTHTX     AUTOGENOUS PRESSURIZATION HEAT EXCHANGER WEIGHT                  I
CI                  ( LBM --- $--- /TPOUT2/   )                                      I
CI        WTINJ     INJECTOR WEIGHT                                                  I
CI                  ( LBM --- $--- /TCA/   )                                         I
CI        WTJET     AMOUNT OF INERT WEIGHT JETTISONED DURING THE                     I
CI                  CURRENT MOTOR SECTION                                            I
CI                  ( LBM 0. $GUIDA /PERF/   )                                       I
CI        WTKMNT    TANK MOUNT WEIGHT                                                I
CI                  ( LBM --- $--- /TANKS/   )                                       I
CI        WTLPRP    WEIGHT OF BURNED LIQUID PROPELLANT                               I
CI                  ( LBM 13250. $LIQUID ///EQ///   )                                I
```

Figure 5.1. Common Block Variables (Sheet 43 of 46)

C

```
CI    WTLTCA    WEIGHT OF LIQUID TCA (KWTMOD = -1)                               I
CI              ( LBM 184.1 $LIQENG /TCA/  )                                     I
CI    WTM       WEIGHT OF TOTAL MISSILE SYSTEM                                   I
CI              ( LBM --- $THVST /PERF/  )                                       I
CI    WTMCG     MOLECULAR WEIGHT OF COLD GAS PRESSURANT                          I
CI              ( LB/LBMOLE 4. $COLDG /COLDGP/  )                                I
CI    WTMGG     MOLECULAR WEIGHT OF GAS GENERATOR PRESSURANT                     I
CI              ( LB/LBMOLE 19.0 $SOLDGG /GASGEN/  )                             I
CI              ( MOLECULAR WEIGHT OF COOLANT $LPROP /COOLNT/  )                 I
CI    WTMOLF    FUEL MOLECULAR WEIGHT                                            I
CI              ( LB/LBMOLE --- $LFUEL /PROPRO/  )                               I
CI    WTMOLO    OX MOLECULAR WEIGHT                                              I
CI              ( LB/LBMOLE --- $LOXID /PROPRO/  )                               I
CI    WTMOUT    NO AVAILABLE DEFINITION   ( ///EQ/// )                           I
CI    WTNZEX    NOZZLE EXTENSION WEIGHT                                          I
CI              ( LBM --- $--- /TCA/  )                                          I
CI    WTPLIN    NO AVAILABLE DEFINITION   ( /TPOUT2/ )                           I
CI    WTPOW     GIMBAL POWER SUPPLY WEIGHT                                       I
CI              ( LBM 0. $--- /GIMBAL/  )                                        I
CI    WTPTJT    WEIGHT OF PRESSURANT TANK JOINTS                                 I
CI              ( LBM --- $--- /LQTLPR/  )                                       I
CI    WTPTNK    PRESSURE TANK WEIGHT                                             I
CI              ( LBM --- $--- /LQTLPR/  )                                       I
CI    WTRHSA    AFT TANK REVERSE HEAD STIFFENER WEIGHT                           I
CI              ( LBM --- $--- /LQTLPR/  )                                       I
CI    WTRHSF    FORWARD TANK REVERSE HEAD STIFFENER WEIGHT                       I
CI              ( LBM --- $--- /LQTLPR/  )                                       I
CI    WTRNOZ    WEIGHT OF TRANSLATING NOZZLE                                     I
CI              ( LBM --- $--- /TRANOZ/  )                                       I
CI    WTSKTA    AFT SKIRT WEIGHT                                                 I
CI              ( LBM --- $--- /TANKS/  )                                        I
CI    WTSKTF    FORWARD SKIRT WEIGHT                                             I
CI              ( LBM --- $--- /TANKS/  )                                        I
CI    WTSTAG    TOTAL INERT WEIGHT OF THE STAGE                                  I
CI              ( LBM 0.0 $THVST /PERF/  )                                       I
CI    WTSTW     STRUCTURAL WALL WEIGHT                                           I
CI              ( LBM --- $--- /TANKS/  )                                        I
CI    WTURBF    NO AVAILABLE DEFINITION   ( /TPAOUT/ )                           I
CI    WTURBO    NO AVAILABLE DEFINITION   ( /TPAOUT/ )                           I
CI    WTVLVS    VALVE WEIGHT                                                     I
CI              ( LBM --- $--- /TCA/  )                                          I
CI              ( LBM EXTERNAL INSULATION WEIGHT $--- /SSCOM/  )                 I
CI    WZERO     GROSS IGNITION WEIGHT                                            I
CI              ( LBM --- $--- /LSCOM/  )                                        I
CI    WZEROS    TOTAL STAGE WEIGHT                                               I
CI              ( LBM --- $--- /LSCOM/  )                                        I
CI    XA        NO AVAILABLE DEFINITION   ( /SSCOM/ )                            I
CI    XACCFL    NO AVAILABLE DEFINITION   ( /TPOUT2/ )                           I
CI    XACCOX    NO AVAILABLE DEFINITION   ( /TPOUT2/ )                           I
CI    XAFSKT    LENGTH OF AFT SKIRT                                              I
CI              ( IN 0.0 $INTSTG ///EQ///  )                                     I
CI    XCYL      LENGTH OF CYLINDRICAL SECTION OF MOTOR CASE                      I
CI              ( IN 10. $INPGEN ///EQ///  )                                     I
CI    XDOME     NO AVAILABLE DEFINITION   ( /SSCOM/ )                            I
CI    XE        NO AVAILABLE DEFINITION   ( /SSCOM/ )                            I
CI    XENG      NO AVAILABLE DEFINITION   ( /NCTOUT/ )                           I
CI    XFWSKT    LENGTH OF FWD SKIRT                                              I
CI              ( IN 0.0 $INTSTG ///EQ///  )                                     I
CI    XINJFF    LENGTH FROM INJECTOR FACE TO ENGINE GIMBAL POINT                 I
CI              ( IN --- $--- /LIQUID/  )                                        I
```

Figure 5.1. Common Block Variables (Sheet 44 of 46)

C

```
CI        XINSTG    INTERSTAGE LENGTH                                          I
CI                  ( IN --- $--- /LSCOM/  )                                   I
CI        XISODE    IDEAL ONE DIMENSIONAL EQUILIBRIUM ISP (VACUUM)             I
CI                  ( SEC --- $--- /LIQUID/  )                                 I
CI        XISP      DELIVERED VACUUM SPECIFIC IMPULSE  (KPERF=0)               I
CI                  ( SEC 314.1 $LQPERF /LIQUID/  )                            I
CI        XISPR     REFERENCE SPECIFIC IMPULSE: INPUT AS A FUNCTION OF         I
CI                  REFERENCE CHAMBER PRESSURE                                 I
CI                  ( SEC 265.  $PROPEL /MOTOR/  )                             I
CI        XISVAC    VACUUM DELIVERED ISP                                       I
CI                  ( SEC --- $--- /SSCOM/  )                                  I
CI        XITOT     INPUT TOTAL IMPULSE CORRECTION FACTOR FOR VARIABLE         I
CI                  THRUST-TIME TRACE                                          I
CI                  ( LBF/SEC 0.0 $THVST ///EQ///  )                           I
CI        XITVAC    NO AVAILABLE DEFINITION    ( /SSCOM/ )                     I
CI        XKALFA    HELICAL BULK FACTOR                                        I
CI                  ( --- 1.9 $FILMNT /MOTOR/  )                               I
CI        XKN       NO AVAILABLE DEFINITION    ( /MOTOR/ )                     I
CI        XKTH      HOOP BULK FACTOR                                           I
CI                  ( --- 1.6 $FILMNT /MOTOR/  )                               I
CI        XLC       AXIAL CHAMBER CYLINDRICAL LENGTH                           I
CI                  ( IN 0.0 $LIQENG /LIQUID/  )                               I
CI        XLDOME    NO AVAILABLE DEFINITION    ( /MOTOR/ )                     I
CI        XLDUCB    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLDUCF    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLDUCI    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLDUCO    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLDUCT    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLEEXP    ENEC-NOZZLE LENGTH RATIO                                   I
CI                  ( --- --- $--- /MOTOR/  )                                  I
CI        XLFL      BARRIER LIQUID FILM LENGTH                                 I
CI                  ( IN 1.0 $LQPERF ///EQ///  )                               I
CI        XLGGPB    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLLBPF    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLLBPO    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLLMPF    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLLMPO    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLN       AXIAL CHAMBER CONVERGENT LENGTH                            I
CI                  ( IN 18.7 $LIQENG /LIQUID/  )                              I
CI        XLNEXP    NOZZLE EXPOSED LENGTH                                      I
CI                  ( IN --- $--- ///EQ///  )                                  I
CI        XLNOZ     LENGTH OF NOZZLE FROM THROAT TO EXIT PLANE                 I
CI                  (KWTMOD = -1)                                              I
CI                  ( IN 76.04 $LIQENG /LSCOM/  )                              I
CI        XLSTG     STAGE LENGTH                                               I
CI                  ( IN --- $--- ///EQ///  )                                  I
CI        XLSUB     NOZZLE SUBMERGED LENGTH                                    I
CI                  ( IN --- $--- ///EQ///  )                                  I
CI        XLTOTL    TOTAL VEHICLE LENGTH                                       I
CI                  ( IN --- $--- ///EQ///  )                                  I
CI        XLTPA     NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLTPAF    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLTPAO    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XLTUBE    NO AVAILABLE DEFINITION    ( /TPOUT2/ )                    I
CI        XM        NO AVAILABLE DEFINITION    ( /MOTOR/ )                     I
CI        XMACH     NO AVAILABLE DEFINITION    ( /TRAJ/ )                      I
CI        XMOUNT    LENGTH FROM TANK TO ENGINE GIMBAL POINT                    I
CI                  ( IN 2.  $LIQENG /LIQUID/  )                               I
CI        XMU       NO AVAILABLE DEFINITION    ( /CONST/ )                     I
CI        XNORO     NUMBER OF ROVINGS                                          I
```

Figure 5.1. Common Block Variables (Sheet 45 of 46)

C

```
CI                      ( --- 8.0 $FILMNT /MOTOR/  )                           I
CI        XNOZ          NO AVAILABLE DEFINITION    ( /NCTIN/ )                 I
CI        XNRATE        PROPELLANT BURNING RATE PRESSURE EXPONENT IN THE       I
CI                      ST. ROGERTS BURNING RATE LAW                           I
CI                      ( --- 40 $PROPEL /MOTOR/  )                            I
CI        XNUASK        POISSON'S RATIO OF STAGE AFT SKIRT                     I
CI                      ( --- .25 $INTSTG /MOTOR/  )                           I
CI        XNUCSE        POISSON'S RATIO FOR THE CASE MATERIAL                  I
CI                      ( --- .25 $MATER /MOTOR/  )                            I
CI        XNUINS        POISSIN'S RATIO FOR THE INTERSTAGE MATERIAL            I
CI                      ( --- .25 $INTSTG /MOTOR/  )                           I
CI        XREGCN        NO AVAILABLE DEFINITION    ( /REGOUT/ )                I
CI        XREGCY        NO AVAILABLE DEFINITION    ( /REGOUT/ )                I
CI        XREGNZ        NO AVAILABLE DEFINITION    ( /REGOUT/ )                I
CI        XSHTNK        NO AVAILABLE DEFINITION    ( /NCTOUT/ )                I
CI        XTAR          INTERMEDIATE AREA RATIO ARRAY IN PERFORMANCE           I
CI                      ROUTINES                                               I
CI                      ( --- --- $--- /OPCOND/  )                             I
CI        XTNK          NO AVAILABLE DEFINITION    ( /NCTOUT/ )                I
CI        XTPC          INTERMEDIATE CHAMBER PRESSURE ARRAY IN PERFORMANCE     I
CI                      ROUTINES                                               I
CI                      ( --- --- $--- /OPCOND/  )                             I
CI        XX            NO AVAILABLE DEFINITION    ( /XSTOR/ )                 I
CI        Y1            AXIAL LENGTH FROM AFT DOME TANGENT POINT TO NOZZLE     I
CI                      ATTACH POINT                                           I
CI                      ( IN --- $--- /GENRL/  )                               I
CI        Y2            AXIAL LENGTH FROM FORWARD DOME TANGENT POINT TO A      I
CI                      POINT ON THE DOME IMMEDIATELY AFT OF THE NEXT          I
CI                      UPPER STAGE NOZZLE EXIT (FINAL STAGE USES DOME         I
CI                      AXIAL LENGTH PLUS 1.0 INCH)                            I
CI                      ( IN --- $--- /GENRL/  )                               I
CI        YENG          NO AVAILABLE DEFINITION    ( /NCTOUT/ )                I
CI        YHITNK        NO AVAILABLE DEFINITION    ( /NCTOUT/ )                I
CI        YLOTNK        NO AVAILABLE DEFINITION    ( /NCTOUT/ )                I
CI        YMOD          MATERIAL ELASTIC MODULUS TABLE                         I
CI                      ( PSI 29E6,17E6,8*0 $LIQMAT /MTPROP/  )                I
CI        YS            TURBINE BLADE YIELD STRENGTH                           I
CI                      ( PSI 104000 $PUMP /TPAIN/  )                          I
CI        YVMR          INTERMEDIATE MIXTURE RATIO ARRAY IN PERFORMANCE        I
CI                      ROUTINES                                               I
CI                      ( --- --- $--- /OPCOND/  )                             I
CI        ZENG          NO AVAILABLE DEFINITION    ( /NCTOUT/ )                I
CI        ZTNK          NO AVAILABLE DEFINITION    ( /NCTOUT/ )                I
CI        ZTTC          INTERMEDIATE CHAMBER TEMPERATURE ARRAY IN              I
CI                      PERFORMANCE ROUTINES                                   I
CI                      ( --- --- $--- /OPCOND/  )                             I
CI        ZTVAR         INTERMEDIATE VALUE ARRAY IN PERFORMANCE ROUTINES       I
CI                      ( --- --- $--- /OPCOND/  )                             I
CIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
C
```

Figure 5.1. Common Block Variables (Sheet 46 of 46)

6.0 PROPELLANT LIBRARY

The calculation of liquid engine performance begins with the ideal one dimensional equilibrium performance. The ideal performance is provided to ELES through internal data arrays for specific impulse, characteristic velocity, and combustion temperature. A part of the ELES initialization procedure is the loading of those data arrays from the direct access file called PROPLIB.

In PROPLIB the first block of information lists the propellant combinations for which data exists in the file, the corresponding propellant flag (IPROP) value, and the line location where the data begins. As new propellant combinations are added to the file, the first blank card after the propellant list must be replaced with a card that identifies the propellant data location (See Figure 6.1). The line numbers along the left hand margin of Figure 6.1 are for convenience only. They are not a part of the file.

Notice that on line 6 of Figure 6.1 the flag IPROP=1 corresponds to the propellant combination $N_2 0_4$/MMH, and that line 31 is where the data for $N_2 0_4$/MMH begins. Looking at line 31, there is a header for the propellant combination, followed by comment cards, and finally the beginning of the data itself.

The structure of the propellant data is shown in Figure 6.2. It is read into ELES by the subroutine MAKCAS. MAKCAS opens the data file PROPLIB and reads the performance data. The subroutine locates the proper data block and loads the data into the appropriate data array. These data arrays are passed to the appropriate subroutines via COMMON blocks. The arrays have been sized to hold data for a maximum of 4 stages, 8 chamber pressures, 10 mixture ratios, and 17 area ratios.

MAKCAS reads all the comment cards looking for the key identifier that proceeds each data group. If the key identifier is not found, MAKCAS will print an error message identifying which data was not found, and then terminate execution.

When the data is required by some design routine within ELES, it is accessed through the routines MAKODE, MAKODK, and MAKCSR. MAKODE finds the ODE specific impulse and combustion temperature. MAKODK calculates the kinetic specific

```
 1) C
 2) C  PROPELLANT COMBINATIONS AND DATA LOCATION
 3) C
 4) C
 5)    FLAG             PROPELLANTS              LINE
 6)  IPROP=1             N204/MMH                  31
 7)  IPROP=2           MON-25/MHF-3               431
 8)  IPROP=3           CLF5/MHF-3                 831
 9)  IPROP=4       MON-25/60%MHF-3+40%AL         1231
10)  IPROP=5             LOX/LH2                 1631
11)  IPROP=6             LOX/RP-1                2031
12)  IPROP=7             LOX/CH4                 2431
13)  IPROP=8             LF2/LH2                 2831
14)  IPROP=9             LF2/N2H4                3231
15) C
16) C
17) C
18) C
19) C
20) CC
21) C
22) C
23) C
24) C
25) C
26) C
27) C
28) C
29) C
30) C
31) C  PROPELLANTS:            N204/MMH
32) C
33) C  ASSUMPTIONS                 ENTHALPY         TEMP     STATE
34) C                   N204
35) C                   MMH
36) C
37) C
38) C
39) C                 C-STAR & CHAMBER TEMP DATA EVALUATED AT ODE PC & ODE MR VALUESC
40) C
41) C
42) C
43)   SIZE OF VARIOUS DATA ARRAYS
44)   ODE PC     ODE MR     ODE EPS    ODK PC     ODK MR     ODK EPS
45)      4          7         10          0          0          0
46) C
47)   ODE MIXTURE RATIO VALUES
48)   MR=   0.0     0.5     1.0     1.5     2.0     2.3     2.8
49) C
50)  EPS    CHAMBER PRESSURE =    50.0    ODE SPECIFIC IMPULSE
51)    1.   155.8  175.2  208.9  218.0  214.8  210.8  203.9
52)    2    184.4  206.2  244.1  257.8  256.4  251.9  243.7
53)    4.   202.9  226.6  264.8  282.1  283.7  279.6  270.5
54)   10.   221.3  247.2  283.4  304.4  310.0  307.4  297.4
55)   20.   232.2  259.8  293.8  316.6  324.7  323.9  313.5
56)   40    240.4  270.6  302.6  326.3  336.3  337.1  326.6
57)   70    245.6  278.2  308.9  332.6  344.0  345.9  335.3
58)  100    248.4  282.6  312.7  336.2  348.2  350.7  340.2
59)  150    251.4  287.2  316.6  339.7  352.5  355.7  345.0
60)  200.   253.3  290.3  319.3  342.0  355.2  358.8  348.2
```

Figure 6.1. Beginning of Propellant Library (PROPLIB)

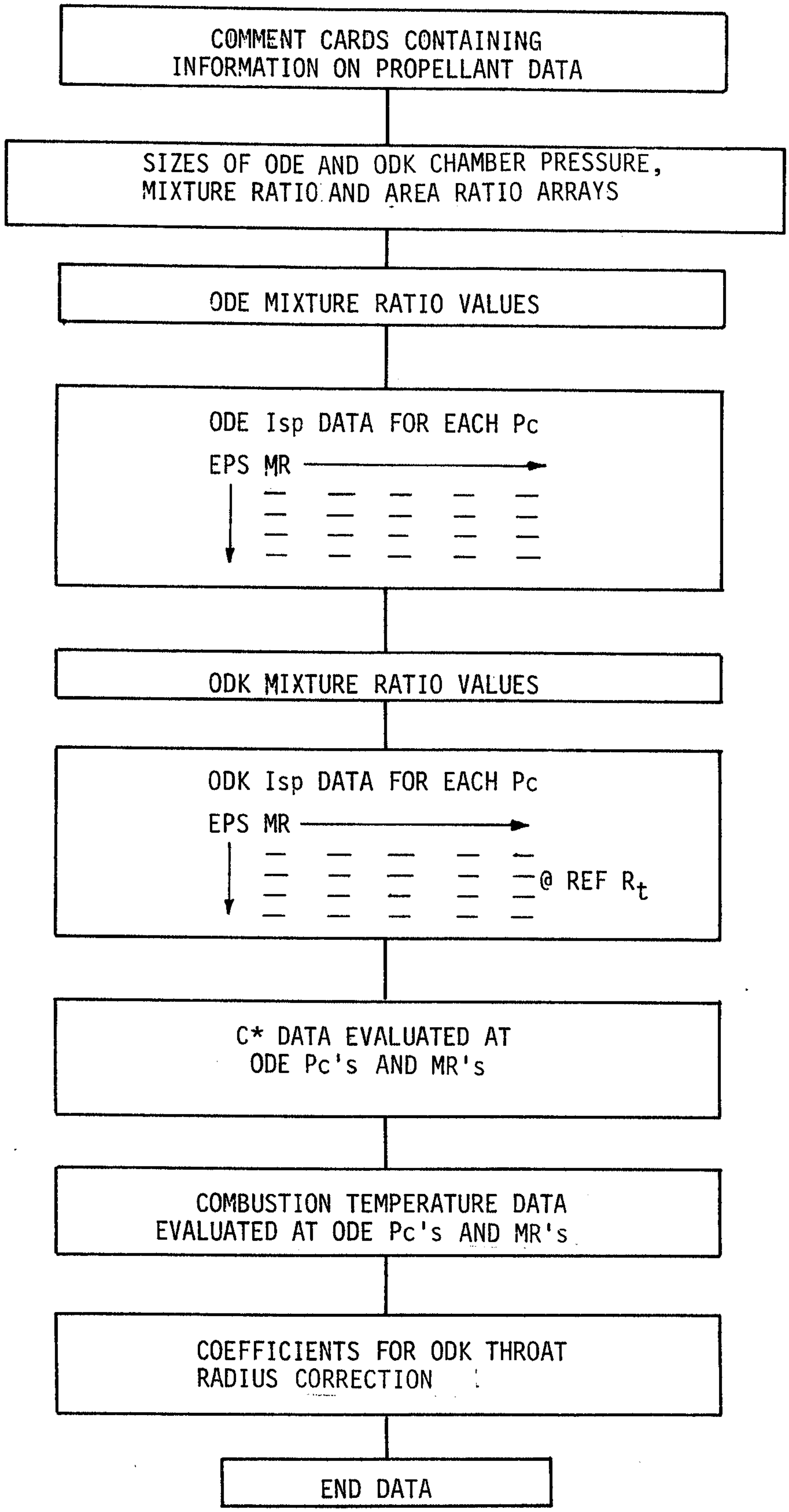

Figure 6.2. Propellant Data Structure

impulse for the desired operating point. MAKCSR calculates the characteristic velocity for a desired chamber pressure and mixture ratio.

These routines use standardized double (DBTINT) and single (GENTRP) interpolation routines that have been used at Aerojet for several years. The interpolation order can be varied from 1 to 5 in these routines. Experience has shown a second order interpolation to provide the most accurate results and therefore is selected for use in these subroutines. If any of the specified operating points are outside the range of the data provided, a linear extrapolation will be performed using the two closest data points.

Figure 6.3 is a complete listing of the propellant library.

```
C
C  PROPELLANT COMBINATIONS AND DATA LOCATION
C
C
   FLAG             PROPELLANTS               LINE
  IPROP=1            N204/MMH                   31
  IPROP=2          MON-25/MHF-3                431
  IPROP=3           CLF5/MHF-3                 831
  IPROP=4      MON-25/60%MHF-3+40%AL          1231
  IPROP=5            LOX/LH2                  1631
  IPROP=6            LOX/RP-1                 2031
  IPROP=7            LOX/CH4                  2431
  IPROP=8            LF2/LH2                  2831
  IPROP=9            LF2/N2H4                 3231
C
C
C
C
C
CC
C
C
C
C
C
C
C
C
C
C
C  PROPELLANTS:            N204/MMH
C
C  ASSUMPTIONS                   ENTHALPY          TEMP     STATE
C                   N204
C                   MMH
C
C
C
C                 C-STAR & CHAMBER TEMP DATA EVALUATED AT ODE PC & ODE MR VALUES
C
C
C
  SIZE OF VARIOUS DATA ARRAYS
  ODE PC     ODE MR     ODE EPS    ODK PC     ODK MR     ODK EPS
     4          7          10         0          0          0
C
  ODE MIXTURE RATIO VALUES
  MR=    0.0     0.5     1.0     1.5     2.0     2.3     2.8
C
 EPS    CHAMBER PRESSURE =    50.0     ODE SPECIFIC IMPULSE
   1.   [illegible] 175.2   208.9   218.0   214.8   210.8   203.9
   2.   184.4   206.2   244.1   257.8   256.4   251.9   243.7
   4.   202.9   226.6   264.8   282.1   283.7   279.6   270.5
  10.   221.3   247.2   283.4   304.4   310.0   307.4   297.4
  20.   232.2   259.8   293.8   316.6   324.7   323.9   313.5
  40.   240.4   270.6   302.6   326.3   336.3   337.1   326.6
  70.   245.6   278.2   308.9   332.6   344.0   345.9   335.3
 100.   248.4   282.8   312.7   336.2   348.2   350.7   340.2
 150.   251.4   287.2   316.6   339.7   352.5   355.7   345.0
 200.   253.3   290.3   319.3   342.0   355.2   358.8   348.2
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 1 of 32)

```
C
 EPS    CHAMBER PRESSURE =  500.0     ODE SPECIFIC IMPULSE
    1.   161.5   180.3   209.1   220.5   219.9   216.2   208.9
    2.   190.9   212.4   244.2   259.6   261.6   257.9   249.2
    4.   209.8   233.3   264.9   283.5   288.2   285.5   275.9
   10.   227.5   254.2   283.6   305.3   313.3   312.6   302.3
   20.   236.9   266.9   294.6   317.3   327.3   328.2   317.7
   40.   244.3   277.6   304.0   326.8   338.4   340.6   330.0
   70.   249.2   285.2   310.7   333.1   345.7   348.8   338.2
  100.   252.1   289.5   314.6   336.6   349.8   353.4   342.8
  150.   255.0   294.1   318.7   340.3   353.9   358.0   347.3
  200.   257.0   297.2   321.5   342.6   356.5   360.9   350.3
C
 EPS    CHAMBER PRESSURE = 1000.0     ODE SPECIFIC IMPULSE
    1.   162.2   181.2   209.1   220.7   220.6   217.0   209.6
    2.   191.7   213.5   244.2   259.7   262.2   258.7   250.0
    4.   210.5   234.5   264.9   283.6   288.7   286.3   276.6
   10.   228.0   255.4   283.8   305.3   313.6   313.2   302.9
   20.   237.4   268.1   294.9   317.4   327.5   328.7   318.2
   40.   244.7   278.8   304.3   326.9   338.6   341.0   330.4
   70.   249.7   286.3   311.1   333.2   345.9   349.1   338.6
  100.   252.5   290.7   315.0   336.7   349.9   353.7   343.1
  150.   255.5   295.3   319.2   340.4   354.0   358.2   347.6
  200.   257.5   298.3   322.0   342.8   356.6   361.2   350.5
C
 EPS    CHAMBER PRESSURE = 3000.0     ODE SPECIFIC IMPULSE
    1.   165.1   185.1   209.2   221.4   223.1   220.0   212.4
    2.   195.[illegible]   218.1   244.2   260.3   264.5   261.9   252.9
    4.   213.3   239.2   265.0   283.9   290.6   289.3   279.4
   10.   229.9   260.2   284.4   305.6   314.9   315.6   305.3
   20.   239.1   272.8   295.9   317.6   328.6   330.6   320.1
   40.   246.5   283.5   305.8   327.0   339.4   342.5   332.0
   70.   251.5   291.0   312.7   333.4   346.6   350.4   339.9
  100.   254.4   295.3   316.8   337.0   350.6   354.8   344.2
  150.   257.4   299.9   321.1   340.8   354.6   359.3   348.6
  200.   259.4   302.8   323.9   343.3   357.1   362.1   351.5
C
  ODK MIXTURE RATIOS
C  THERE IS NO ODK DATA.  SIMPLIFIED METHOD USED
C
  MR=     0.0     0.5     1.0     1.5     2.0     2.3     2.8
  PC           CHARACTERISTIC VELOCITY   (FT/SEC)
  50.   4140.   4502.   5381.   5670.   5612.   5509.   5330.
 500.   4185.   4659.   5380.   5714.   5734.   5644.   5454.
1000.   4234.   4676.   5380.   5717.   5748.   5662.   5471.
3000.   4280.   4779.   5379.   5728.   5805.   5735.   5538.
C
  MR=     0.0     0.5     1.0     1.5     2.0     2.3     2.8
  PC         COMBUSTION TEMPERATURE  (DEG - R)
  50.   1787.   2386.   4224.   5215.   5513.   5529.   5463.
 500.   2058.   2569.   4255.   5456.   5940.   5983.   5893.
1000.   2105.   2619.   4257.   5479.   6090.   6051.   5957.
3000.   2295.   2819.   4265.   5572.   6239.   6325.   6214.
C
C
   END DATA
C
C
C
C
```

Figure 6.3. Propellant Library (PROPLIB) Sheet 2 of 32)

C
C
C
C PROPELLANTS: MON-25/MHF-3
C
C ASSUMPTIONS ENTHALPY TEMP STATE
C MON-25
C MHF-3
C
C
C C-STAR & CHAMBER TEMP DATA EVALUATED AT ODE PC & ODE MR VALUES
C
C
C

SIZE OF VARIOUS DATA ARRAYS

ODE PC	ODE MR	ODE EPS	ODK PC	ODK MR	ODK EPS
4	7	10	0	0	0

C

ODE MIXTURE RATIO VALUES

MR= 0.0 0.5 1.0 1.5 2.0 2.3 2.8

C

EPS	CHAMBER PRESSURE =	50.0		ODE SPECIFIC	IMPULSE		
1.	157.8	179.8	212.2	219.8	216.4	212.5	206.0
2.	186.6	210.4	248.1	260.1	258.2	253.9	246.2
4.	205.2	230.5	269.2	284.8	285.8	281.7	273.1
10.	223.1	250.9	288.2	307.4	312.2	309.6	300.2
20.	232.5	263.3	298.6	319.8	327.1	326.2	316.4
40.	239.6	274.0	307.3	329.5	338.8	339.5	329.5
70.	244.4	281.5	313.4	335.9	346.5	348.3	338.3
100.	247.2	285.8	317.0	339.4	350.7	353.1	343.1
150.	250.1	290.4	320.9	343.0	355.0	358.0	348.0
200.	252.0	293.4	323.4	345.3	357.7	361.1	351.1

C

EPS	CHAMBER PRESSURE =	500.0		ODE SPECIFIC	IMPULSE		
1.	163.6	183.5	212.5	222.6	221.6	218.0	211.1
2.	193.2	215.8	248.2	262.2	263.6	260.0	251.8
4.	211.3	236.6	269.4	286.4	290.5	287.7	278.7
10.	227.3	257.4	288.3	308.5	315.7	315.0	305.2
20.	236.0	270.0	299.2	320.6	329.8	330.6	320.7
40.	243.1	280.6	308.4	330.2	341.0	343.0	333.0
70.	248.0	288.1	314.9	336.5	348.3	351.2	341.2
100.	250.8	292.5	318.7	339.9	352.4	355.8	345.8
150.	253.7	297.0	322.8	343.5	356.4	360.3	350.3
200.	255.7	300.0	325.5	345.9	359.1	363.3	353.2

C

EPS	CHAMBER PRESSURE =	1000.0		ODE SPECIFIC	IMPULSE		
1.	164.2	184.4	212.5	222.8	222.3	218.8	211.9
2.	193.7	216.9	248.2	262.4	264.2	260.8	252.5
4.	211.6	237.8	269.4	286.5	291.0	288.5	279.4
10.	227.6	258.6	288.4	308.5	316.1	315.6	305.8
20.	236.4	271.2	299.4	320.7	330.1	331.1	321.2
40.	243.5	281.8	308.7	330.2	341.2	343.4	333.4
70.	248.4	289.3	315.3	336.5	348.5	351.6	341.6

Figure 6.3. Propellant Library (PROBLIB) (Sheet 3 of 32)

```
C

 100.   [illegible]  293.6  319.1  340.0  352.5  356.0  346.0
 150.   [illegible]  298.2  323.2  343.6  356.6  360.6  350.6
 200.   286.2  301.2  325.9  346.0  359.2  363.5  353.4
C
 EPS    CHAMBER PRESSURE = 3000.0    ODE SPECIFIC IMPULSE
    1.  166.6  188.0  212.6  223.7  224.9  221.9  214.7
    2.  [illegible]  221.3  248.3  263.0  266.6  264.0  255.5
    4.  213.0  242.5  269.4  287.0  292.9  291.6  282.3
   10.  228.9  263.4  288.8  308.9  317.5  318.1  308.2
   20.  237.8  276.0  300.2  320.9  331.2  333.0  323.1
   40.  245.1  286.6  309.9  330.4  342.1  345.0  335.0
   70.  250.2  294.0  316.7  336.7  349.2  352.9  342.9
  100.  [illegible]  298.3  320.7  340.3  353.2  357.2  347.2
  150.  256.2  302.8  324.9  344.0  357.2  361.6  351.6
  200.  [illegible]  305.7  327.7  346.5  359.7  364.4  354.4
C
  ODK MIXTURE RATIOS
C  THERE IS NO ODK DATA.  SIMPLIFIED METHOD USED
C
  MR=    [illegible]    0.5    1.0    1.5    2.0    2.3    2.8
  PC          CHARACTERISTIC VELOCITY   (FT/SEC)
  50.  [illegible]  [illegible]  5470.  5719.  5651.  5553.  5384.
 500.  4237.  4724.  5470.  5772.  5777.  5690.  5511.
1000.  4250.  4749.  5470.  5775.  5792.  5709.  5528.
3000.  4304.  4849.  5470.  5789.  5852.  5783.  5596.
C
  MR=    [illegible]    0.5    1.0    1.5    2.0    2.3    2.8
  PC        COMBUSTION TEMPERATURE  (DEG - R)
  50.  1799.  2554.  4365.  5274.  5546.  5564.  5509.
 500.  2071.  2651.  4409.  5540.  5984.  6026.  5949.
1000.  2119.  2696.  4412.  5566.  6045.  6095.  6015.
3000.  2711.  2875.  4423.  5673.  6293.  6374.  6279.
C
C
  END DATA
C
C
C
C
C
C
C  PROPELLANTS:     CLF5/MHF-3
C
C  ASSUMPTIONS               ENTHALPY          TEMP     STATE
C                CLF5
C                MHF-3
C
C
C                C-STAR & CHAMBER TEMP DATA EVALUATED AT ODE PC & ODE MR VALUE
C
C

C
C
C
C
C
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 4 of 32)

```
C
  SIZE OF VARIOUS DATA ARRAYS
  ODE PC     ODE MR     ODE EPS     ODK PC     ODK MR     ODK EPS
     4          5          10          0          0          0
C
  ODE MIXTURE RATIO VALUES
  MR=    0.0     1.0     2.0     3.0     4.0     5.0
C
 EPS    CHAMBER PRESSURE =    50.0     ODE SPECIFIC IMPULSE
   1.   157.8   217.5   223.9   223.3   213.9   201.4
   2.   186.6   256.5   266.9   267.0   253.8   239.3
   4.   205.2   279.7   294.6   295.7   279.1   264.7
  10.   223.1   300.2   320.7   323.0   304.4   290.4
  20.   232.5   311.1   334.8   338.0   319.4   306.1
  40.   239.6   319.4   345.6   349.5   331.7   319.3
  70.   244.4   324.6   352.4   357.2   340.1   328.4
 100.   247.2   327.8   356.0   361.5   345.0   333.5
 150.   250.1   331.0   359.5   366.0   350.0   338.9
 200.   252.0   333.2   361.7   368.9   353.4   342.4
C
 EPS    CHAMBER PRESSURE =   500.0     ODE SPECIFIC IMPULSE
   1.   183.6   218.4   227.8   228.4   217.7   207.5
   2.   193.2   257.1   271.0   272.6   258.0   246.6
   4.   211.3   280.1   298.3   301.1   283.9   272.4
  10.   227.3   300.6   323.4   327.2   309.3   298.1
  20.   236.0   311.5   336.9   341.4   324.3   313.5
  40.   243.1   320.0   347.1   352.7   336.6   326.2
  70.   248.0   325.7   353.6   360.3   345.0   335.0
 100.   250.8   329.0   357.1   364.5   349.9   340.0
 150.   253.7   332.4   360.5   368.7   354.9   345.3
 200.   255.7   334.6   362.6   371.4   358.2   348.7
C
 EPS    CHAMBER PRESSURE = 1000.0     ODE SPECIFIC IMPULSE
   1.   184.2   218.4   228.3   229.1   218.2   208.6
   2.   193.7   257.1   271.4   273.3   258.6   247.8
   4.   211.6   280.2   298.6   301.7   284.6   273.7
  10.   227.6   300.6   323.6   327.7   310.1   299.3
  20.   236.4   311.6   337.1   341.8   325.1   314.6
  40.   243.5   320.1   347.3   353.1   337.3   327.3
  70.   248.4   325.9   353.7   360.7   345.8   336.1
 100.   251.2   329.2   357.2   364.8   350.6   341.0
 150.   254.2   332.7   360.5   369.0   355.6   346.3
 200.   256.2   334.9   362.7   371.6   358.9   349.7
C
 EPS    CHAMBER PRESSURE = 3000.0     ODE SPECIFIC IMPULSE
   1.   186.6   218.6   230.0   231.8   220.2   212.9
   2.   195.5   257.2   273.1   276.2   261.1   252.6
   4.   213.0   280.3   300.0   304.2   287.4   278.6
  10.   228.9   300.8   324.6   329.5   313.0   304.2
  20.   237.8   311.9   337.8   343.6   328.1   319.2
  40.   245.1   320.8   347.8   354.9   340.4   331.7
  70.   250.2   326.8   354.2   362.3   348.8   340.3
 100.   253.1   330.2   357.6   366.3   353.5   345.1
 150.   256.2   333.8   360.9   370.3   358.4   350.2
 200.   258.2   336.1   363.0   372.8   361.6   353.4
C
  ODK MIXTURE RATIOS
C  THERE IS NO ODK DATA.  SIMPLIFIED METHOD USED
C
  MR=    0.0     1.0     2.0     3.0     4.0     5.0
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 5 of 32)

```
C
C
C
C

  PC          CHARACTERISTIC VELOCITY    (FT/SEC)
   50.   4088.   5652.   5852.   5848.   5584.   5231.
  500.   4237.   5668.   5948.   5976.   5675.   5394.
 1000.   4250.   5669.   5958.   5993.   5683.   5421.
 3000.   4304.   5671.   5998.   6060.   5713.   5531.
C
  MR=     0.0     1.0     2.0     3.0     4.0     5.0
  PC         COMBUSTION TEMPERATURE  (DEG - R)
   50.   1799.   4756.   5861.   6275.   6137.   5773.
  500.   2071.   4838.   6226.   6738.   6578.   6251.
 1000.   2119.   4845.   6273.   6808.   6663.   6353.
 3000.   2311.   4872.   6459.   7088.   7004.   6762.
C
C
  END DATA
C
C
C
C
C
C  PROPELLANTS:      MON-25/60%MHF-3+40%AL
C
C  ASSUMPTIONS                 ENTHALPY          TEMP     STATE
                MON-25
               MHF-3
                 AL
C
C
C              C-STAR & CHAMBER TEMP DATA EVALUATED AT ODE PC & ODE MR VALUES(
C
C
C
  SIZE OF VARIOUS DATA ARRAYS
  ODE PC    ODE MR    ODE EPS    ODK PC    ODK MR    ODK EPS
     4         8        10          0         0          0
C
  ODE MIXTURE RATIO VALUES
  MR=     0.1     0.4     0.6     0.8     1.0     1.2     1.6     2.0
C
 EPS   CHAMBER PRESSURE =   50.0    ODE SPECIFIC IMPULSE
   1.   193.2   199.9   201.5   216.0   216.2   213.7   208.0   202.6
   2.   230.3   240.1   242.1   258.2   258.4   255.7   249.0   242.6
   4.   264.1   267.3   270.4   286.3   286.7   283.9   276.8   269.7
  10.   277.5   293.7   299.6   315.1   315.1   312.5   305.3   297.6
  20.   292.3   308.8   317.6   333.1   333.2   330.2   323.1   315.0
  40.   306.1   322.2   332.5   347.9   348.7   345.9   338.5   330.2
  70.   314.2   331.9   342.4   358.3   359.4   357.0   349.9   341.5
 100.   319.4   337.7   348.1   364.1   365.5   363.3   356.6   348.1
 150.   324.9   344.0   354.3   370.0   371.7   370.0   363.7   355.2
 200.   328.4   348.2   358.4   373.9   375.7   374.3   368.5   360.0
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 6 of 32)

```
 EPS    CHAMBER PRESSURE =  500.0     ODE SPECIFIC IMPULSE
   1.   194.5   206.2   208.6   220.5   221.3   219.3   213.9   208.3
   2.   231.3   246.4   249.9   262.9   264.0   261.8   255.7   249.1
   4.   255.1   272.9   278.0   290.9   292.2   290.1   283.8   276.6
  10.   279.6   298.1   307.2   319.1   320.2   318.5   312.5   304.8
  20.   294.7   313.8   324.3   336.8   337.8   335.7   330.1   322.2
  40.   307.6   327.5   338.1   351.4   352.9   351.0   345.2   337.3
  70.   316.5   337.5   347.9   361.3   363.1   361.7   356.2   348.2
 100.   321.6   343.4   353.8   366.9   368.8   367.7   362.8   354.8
 150.   326.8   349.7   360.1   372.7   374.7   374.0   369.7   361.9
 200.   330.2   354.0   364.3   376.5   378.6   378.0   374.2   366.6
C
 EPS    CHAMBER PRESSURE = 1000.0     ODE SPECIFIC IMPULSE
   1.   194.5   206.9   209.6   221.1   222.0   220.0   214.7   209.1
   2.   231.3   247.0   251.1   263.5   264.7   262.5   256.6   250.0
   4.   255.7   273.4   279.0   291.4   292.9   290.8   284.8   277.6
  10.   279.9   298.7   308.1   319.5   320.8   319.2   313.4   305.7
  20.   295.1   314.5   325.0   337.2   338.3   336.3   331.0   323.2
  40.   307.9   328.3   338.8   351.8   353.3   351.5   346.0   338.3
  70.   316.8   338.3   348.7   361.6   363.5   362.1   357.0   349.1
 100.   321.9   344.2   354.6   367.2   369.2   368.2   363.6   355.7
 150.   327.1   350.5   360.9   373.0   375.0   374.4   370.4   362.8
 200.   330.5   354.8   365.2   376.7   378.8   378.4   374.9   367.5
C
 EPS    CHAMBER PRESSURE = 3000.0     ODE SPECIFIC IMPULSE
   1.   194.4   209.9   213.8   223.2   224.5   222.8   218.0   212.4
   2.   231.2   249.5   255.6   265.7   267.3   265.6   260.2   253.6
   4.   256.0   275.4   283.3   293.4   295.3   293.8   288.5   281.4
  10.   281.1   301.1   311.6   321.2   322.9   321.8   317.1   309.7
  20.   296.4   317.3   327.9   338.9   340.2   338.7   334.5   327.1
  40.   309.2   331.4   341.8   353.3   355.0   353.7   349.3   342.1
  70.   317.9   341.5   351.9   363.0   364.9   364.1   360.1   352.9
 100.   322.9   347.5   357.9   368.5   370.5   369.9   366.5   359.3
 150.   328.0   353.8   364.3   374.2   376.2   376.0   373.1   366.3
 200.   331.4   358.1   368.6   377.8   379.9   379.9   377.4   371.0
C
  ODK MIXTURE RATIOS
C  THERE IS NO ODK DATA.  SIMPLIFIED METHOD USED
C
  MR=      0.1     0.4     0.6     0.8     1.0     1.2     1.6     2.0
  PC          CHARACTERISTIC VELOCITY    (FT/SEC)
  50.   5053.   5240.   5264.   5648.   5653.   5591.   5442.   5301.
 500.   5078.   5395.   5462.   5757.   5780.   5729.   5591.   5446.
1000.   5077.   5412.   5488.   5770.   5795.   5746.   5611.   5466.
3000.   5075.   5480.   5592.   5820.   5855.   5814.   5693.   5547.
C
  MR=      0.1     0.4     0.6     0.8     1.0     1.2     1.6     2.0
  PC        COMBUSTION TEMPERATURE   (DEG - R)
  50.   4372.   4484.   4705.   5790.   6106.   6227.   6271.   6206.
 500.   4542.   4944.   5084.   6224.   6655.   6836.   6932.   6852.
1000.   4554.   5019.   5176.   6283.   6733.   6926.   7037.   6956.
3000.   4598.   5317.   5545.   6519.   7044.   7286.   7457.   7370.
C
C
C
  END DATA
C
C
C
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 7 of 32)

```
C
C
C
C
C
      PROPELLANTS  LIQUID OXYGEN - LIQUID HYDROGEN
      ASSUMPTIONS:
C                   TEMP         ENTHALPY
C              LOX  90.18 K   -3093. CAL/MOL
C              LH2  20.27 K   -2154. CAL/MOL
C
C         ODK VALUES CORRESPOND TO THROAT RADIUS=2.289 IN.
C          C-STAR & CHAMBER TEMP DATA EVALUATED AT ODE PC & ODE MR VALUES
C
C
C
C
C
C
   SIZE OF VARIOUS DATA ARRAYS
   ODE PC     ODE MR     ODE EPS    ODK PC     ODK MR     ODK EPS
      7         10         14          7         10         14
C
   ODE MIXTURE RATIO VALUES
C  MR:    0.1    2.     3.     4.     5.     6.     7.     8.     9.     10.
C
  EPS    CHAMBER PRESSURE = 20.0       ODE SPECIFIC IMPULSE
    1.   104.6  302.1, 307.6, 301.0, 289.9, 278.1, 267.0, 257.0, 248.3, 240.7,
    2.   119.7  351.4, 360.7, 356.7, 345.8, 332.7, 319.7, 306.8, 295.0, 284.0,
    4.   127.5  379.4, 392.3, 391.3, 382.2, 369.3, 355.4, 342.0, 329.0, 318.2,
   10.   133.9  403.3, 420.0, 422.7, 417.1, 406.0, 392.0, 377.9, 364.9, 353.4,
   20.   137.0  415.5, 434.6, 439.7, 436.5, 427.7, 414.6, 399.9, 386.1, 373.7,
   40.   139.3  424.4, 445.4, 452.6, 451.7, 445.2, 433.8, 418.9, 404.3, 391.0,
  100.   141.1  432.7, 455.7, 465.2, 466.9, 463.1, 454.5, 440.5, 424.7, 410.0,
  200.   142.2  437.2, 461.3, 472.1, 475.5, 473.6, 467.0, 454.4, 437.5, 421.6,
  300.   142.6  439.2, 463.9, 475.4, 479.7, 478.7, 473.3, 461.5, 442.0, 427.2,
  400.   142.8  440.4, 465.5, 477.5, 482.3, 482.0, 477.3, 466.5, 448.2, 431.2,
  600.   143.2  442.0, 467.5, 480.0, 485.5, 486.1, 482.4, 472.7, 453.6, 436.0,
  800.   143.5  442.8, 468.3, 481.5, 487.5, 488.6, 485.6, 476.7, 457.0, 439.0,
 1000.   143.6  443.4, 469.1, 482.6, 488.9, 490.5, 488.0, 479.6, 459.5, 441.2,
 3000.   144.1  445.9, 472.1, 486.9, 494.4, 497.7, 497.4, 491.8, 470.8, 449.5
C
  EPS    CHAMBER PRESSURE = 40.0       ODE SPECIFIC IMPULSE
    1.   104.6  302.2, 307.9, 302.4, 292.0, 280.5, 269.4, 258.0, 250.5, 243.0,
    2.   119.7  351.4, 361.0, 357.9, 347.9, 335.3, 322.5, 309.0, 298.0, 288.5,
    4.   127.5  379.4, 392.4, 392.1, 384.1, 372.0, 358.3, 344.0, 332.0, 320.5,
   10.   133.9  403.3, 420.1, 423.3, 418.5, 408.4, 394.9, 380.5, 367.0, 355.0,
   20.   137.0  415.5, 434.7, 440.1, 437.6, 429.7, 417.4, 402.5, 388.6, 375.8,
   40.   139.3  424.4, 445.5, 452.9, 452.6, 446.8, 436.3, 421.6, 406.6, 393.0,
  100.   141.1  432.7, 455.7, 465.4, 467.5, 464.3, 456.5, 443.0, 426.8, 411.8,
  200.   142.2  437.3, 461.3, 472.3, 476.0, 474.6, 468.7, 456.2, 439.3, 423.0,
  300.   142.6  439.2, 463.9, 475.6, 480.1, 479.6, 474.7, 463.5, 445.2, 428.8,
  400.   142.8  440.4, 465.5, 477.6, 482.6, 482.8, 478.6, 468.3, 449.7, 432.3,
  600.   143.2  442.0, 467.5, 480.1, 485.8, 486.7, 483.6, 474.5, 454.8, 437.0,
  800.   143.5  442.8, 468.5, 481.6, 487.8, 489.3, 486.7, 478.5, 458.0, 440.0,
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 8 of 32)

1000.	143.6	443.4,	469.4,	482.7,	489.2,	491.1,	489.0,	481.2,	460.6,	442.0,
3000.	144.1	445.9,	472.1,	486.9,	494.6,	498.1,	498.1,	493.5,	471.8,	450.4

C

EPS CHAMBER PRESSURE = 100.0 ODE SPECIFIC IMPULSE

1.	104.6	302.2	308.3	304.0	294.6	283.6	272.7	261.0	253.0	245.0
2.	119.7	351.4	361.2	359.2	350.5	338.7	326.1	312.0	300.5	290.5
4.	127.5	379.4	392.6	393.1	386.3	375.2	362.1	347.0	335.0	322.6
10.	133.9	403.3	420.2	423.9	420.1	411.2	398.6	383.9	370.0	358.5
20.	137.0	425.5	434.7	440.6	438.9	432.0	420.8	406.2	391.8	378.7
40.	139.3	424.4	445.5	453.3	453.6	448.7	439.3	425.2	409.7	395.7
100.	141.1	432.7	455.7	465.7	468.2	465.7	458.9	446.2	429.6	414.0
200.	142.2	437.2	461.3	472.5	476.6	475.7	470.6	459.6	441.5	424.8
300.	142.6	439.2	463.9	475.7	480.6	480.6	476.5	466.4	447.7	430.2
400.	142.8	440.4	465.5	477.7	483.1	483.7	480.2	470.8	451.4	433.9
600.	143.2	442.0	467.5	480.2	486.2	487.5	485.0	476.2	456.5	438.2
800.	143.5	442.8	468.5	481.8	488.1	490.0	488.9	480.0	459.3	441.0
1000.	143.6	443.4	469.5	482.8	489.5	491.7	490.2	483.0	462.0	443.2
3000.	144.1	445.9	472.2	487.0	494.8	498.6	498.9	494.5	472.4	451.2

C

EPS CHAMBER PRESSURE = 300.0 ODE SPECIFIC IMPULSE

1.	104.6	302.2	308.5	305.4	297.3	287.1	276.4	264.0	256.0	247.0
2.	119.7	351.4	361.3	360.3	353.0	342.4	328.0	313.0	303.0	293.0
4.	127.5	379.4	392.7	393.9	388.5	378.7	365.	350.0	337.5	326.0
10.	133.9	403.3	420.3	424.4	421.6	414.1	402.5	387.7	373.4	361.0
20.	137.0	415.5	434.8	441.0	440.1	434.4	424.3	410.4	395.6	382.0
40.	139.3	424.4	445.5	453.6	454.5	450.6	442.5	429.2	413.4	398.7
100.	141.1	432.7	455.8	465.9	468.9	467.1	461.4	449.9	432.4	416.2
200.	142.2	437.2	461.3	472.7	477.1	476.8	472.6	462.8	444.0	426.8
300.	142.6	439.2	463.9	475.9	481.0	481.6	478.2	469.2	449.8	431.8
400.	142.8	440.4	465.5	477.9	483.5	484.6	481.9	473.6	453.6	435.4
600.	143.2	441.8	467.5	480.3	486.5	488.3	486.4	479.1	458.4	439.7
800.	143.5	442.7	468.7	481.9	488.4	490.7	489.3	482.6	461.5	442.5
1000.	143.6	443.3	469.5	482.9	489.8	492.4	491.4	485.2	463.7	444.4
3000.	144.1	445.1	472.0	487.1	495.0	499.0	499.8	496.1	473.0	452.5

C

EPS CHAMBER PRESSURE = 500.0 ODE SPECIFIC IMPULSE

1.	104.6	302.2	308.6	305.9	298.4	288.6	278.1	265.0	257.1	248.3
2.	119.7	351.4	361.4	360.7	354.0	343.9	331.0	313.7	303.5	294.2
4.	127.5	379.4	392.7	394.1	389.3	380.2	366.3	351.3	339.5	327.3
10.	133.9	403.3	420.3	424.6	422.2	415.3	404.4	389.4	374.9	362.8
20.	137.0	415.5	434.8	441.1	440.5	435.3	425.8	412.2	397.2	383.4
40.	139.3	424.4	445.6	453.7	454.9	451.3	443.8	431.0	414.9	399.9
100.	141.1	432.7	455.8	466.0	469.2	467.7	462.4	451.4	433.6	417.1
200.	142.2	437.2	461.3	472.7	477.3	477.3	473.5	464.1	445.0	427.5
300.	142.6	439.3	463.9	475.9	481.2	482.0	478.8	470.5	450.5	432.8
400.	142.8	440.5	465.5	477.9	483.6	484.9	482.5	474.7	454.4	436.0
600.	143.2	441 9	467.5	480.4	486.7	488.6	487.0	480.1	459.1	440.2
800.	143.5	442.8	468.7	481.9	488.6	491.0	489.9	483.5	462.2	443.0
1000.	143.6	443.4	469.5	483.0	489.9	492.6	491.9	486.0	464.3	444.9
3000.	144.1	445.2	471.9	487.1	495.1	499.2	499.9	496.2	473.6	452.7

C

EPS CHAMBER PRESSURE = 1000.0 ODE SPECIFIC IMPULSE

1.	104.6	302.2	308.7	306.5	299.7	290.5	280.3	266.5	258.9	249.4
2.	119.7	351.4	361.4	361.3	355.2	345.7	332.6	314.4	304.4	295.4
4.	127.5	379.4	392.7	394.2	390.2	382.2	367.7	353.0	341.4	329.0
10.	133.9	403.3	420.3	424.7	422.8	416.6	406.6	391.4	376.9	364.5
20.	137.0	415.5	434.8	441.2	441.1	436.4	427.7	414.6	399.2	385.1
40.	139.3	424.4	445.6	453.9	455.3	452.2	445.4	433.2	416.7	401.3
100.	141.1	432.7	455.8	466.0	469.5	468.4	463.6	453.2	435.0	418.2
200.	142.2	437.2	461.3	472.8	477.5	477.8	474.5	465.7	446.2	428.4

Figure 6.3. Propellant Library (PROPLIB) (Sheet 9 of 32)

```
 300.   142.6   439.3   463.9   476.0   481.4   482.4   479.9   472.0   451.8   433.5
 400.   142.8   440.5   465.5   478.0   483.8   485.3   483.3   476.0   455.4   436.8
 600.   143.2   441.9   467.5   480.4   486.8   489.0   487.7   481.0   460.0   440.9
 800.   143.5   442.8   468.7   481.9   488.7   491.3   490.5   484.6   463.0   443.6
1000.   143.6   443.4   469.5   483.0   490.0   492.9   492.5   487.0   465.1   445.5
3000.   144.1   445.2   471.9   487.2   495.2   499.4   500.6   497.0   473.7   453.1
 EPS    CHAMBER PRESSURE = 5000.0        ODE SPECIFIC IMPULSE
   1.   104.6   302.2   308.7   308.0   302.4   295.0   284.3   269.0   261.5   251.3
   2.   119.7   351.4   361.4   362.4   357.4   350.5   336.4   315.0   306.0   297.7
   4.   127.5   379.4   392.7   394.4   391.8   386.4   370.5   356.7   345.3   333.8
  10.   133.9   403.3   420.3   425.0   424.2   418.4   410.5   395.6   380.5   368.2
  20.   137.0   415.5   434.8   441.4   441.9   438.4   431.6   419.7   403.5   388.6
  40.   139.3   424.4   445.6   454.0   455.9   453.7   448.3   437.6   420.1   404.1
 100.   141.1   432.7   455.8   466.0   469.9   469.5   465.8   456.9   437.8   420.4
 200.   142.2   437.2   461.3   473.1   477.9   478.7   476.3   468.8   448.5   430.2
 300.   142.6   439.3   463.9   476.2   481.1   482.5   480.6   473.8   452.8   434.3
 400.   142.8   440.5   465.5   478.1   484.1   486.1   484.8   478.6   457.3   438.2
 600.   143.2   441.9   467.5   480.7   487.1   489.6   489.1   483.5   461.7   442.2
 800.   143.5   442.8   468.7   482.1   488.9   491.6   491.8   486.7   464.5   444.7
1000.   143.6   443.4   469.5   483.0   490.2   493.5   493.7   489.0   466.5   446.6
3000.   144.1   445.2   471.9   487.1   495.2   499.7   501.3   498.3   474.4   453.9
C
  ODK MIXTURE RATIOS
C   MR      .1       2.      3.      4.      5.      6.      7.      8.      9.     10.
C
 EPS    CHAMBER PRESSURE = 20.0        ODK SPECIFIC IMPULSE
   1.   104.6   302.0   305.8   299.3   287.9   276.6   265.7   255.9   247.2   239.6
   2.   119.7   351.2   357.8   343.5   334.5   321.5   308.0   298.5   288.5   279.0
   4.   127.5   379.2   388.6   378.8   370.0   356.5   342.5   332.0   320.2   300.0
  10.   133.9   403.1   415.7   406.0   401.2   388.7   375.0   361.8   349.6   338.6
  20.   137.0   415.3   429.9   421.0   417.4   405.3   391.5   377.8   365.2   353.6
  40.   139.3   424.2   440.4   438.5   429.8   418.2   404.5   390.6   377.5   365.6
 100.   141.1   432.5   450.3   449.3   441.9   431.1   417.5   403.4   389.9   377.6
 200.   142.2   436.9   455.7   455.4   448.7   438.3   424.9   410.7   397.1   384.5
 300.   142.6   438.9   458.2   457.9   451.9   441.7   428.4   414.1   400.2   387.5
 400.   142.8   440.1   459.8   459.4   453.8   443.9   430.6   416.4   402.6   389.9
 600.   143.2   441.6   461.7   461.5   456.3   446.5   433.3   419.1   405.3   392.4
 800.   143.5   442.4   462.8   462.9   457.8   448.1   435.0   420.8   406.9   394.0
1000.   143.6   443.0   463.6   463.7   458.8   449.3   436.2   422.0   408.1   395.2
3000.   144.1   445.4   466.6   467.3   463.0   453.4   440.6   426.9   413.4   399.5
C
 EPS    CHAMBER PRESSURE = 40.0        ODK SPECIFIC IMPULSE
   1.   104.6   302.1   306.8   301.9   290.9   279.7   268.6   258.7   250.0   242.4
   2.   119.7   351.3   359.0   346.7   337.8   325.0   312.0   301.4   291.2   281.3
   4.   127.5   379.3   390.0   382.0   374.5   361.3   348.4   336.1   324.3   306.0
  10.   133.9   403.2   417.2   410.0   405.4   394.5   383.0   367.5   355.0   343.7
  20.   137.0   415.3   431.5   426.2   423.3   412.5   399.2   387.0   374.0   362.0
  40.   139.3   424.2   442.1   444.7   440.0   432.0   420.0   404.7   390.3   377.6
 100.   141.1   432.6   452.1   456.0   453.0   446.2   435.0   419.0   404.3   391.0
 200.   142.2   437.0   457.5   462.8   460.8   457.2   444.0   428.0   413.4   399.5
 300.   142.6   439.0   460.1   465.6   464.5   460.8   448.4   432.6   417.3   403.7
 400.   142.8   440.2   461.7   467.6   466.6   462.3   452.0   434.7   419.6   406.0
 600.   143.2   441.6   463.5   469.7   469.7   466.4   457.0   438.2   423.2   409.0
 800.   143.5   442.5   464.7   471.1   471.4   468.2   457.3   440.8   425.7   411.4
1000.   143.6   443.1   465.6   471.7   472.6   470.1   458.0   441.8   427.6   413.0
3000.   144.1   445.5   468.3   475.6   477.0   475.6   466.3   448.8   433.2   418.8
C
 EPS    CHAMBER PRESSURE = 100.0        ODK SPECIFIC IMPULSE
   1.   104.6   302.1   307.7   304.4   294.1   283.2   272.2   262.3   253.3   245.6
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 10 of 32)

2.	119.7	351.3	360.2	350.6	342.0	329.6	312.2	305.0	294.7	284.7
4.	127.5	379.4	391.4	386.1	379.8	367.4	355.7	341.6	329.4	313.4
10.	133.9	403.2	418.8	416.0	412.0	402.	390.3	375.0	361.7	350.2
20.	137.0	415.4	433.2	432.3	430.0	421.3	408.5	396.0	382.2	360.0
40.	139.3	424.3	433.8	450.0	447.2	441.2	430.5	415.3	400.2	387.0
100.	141.1	432.6	454.0	461.6	460.8	456.0	446.0	431.0	415.4	401.0
200.	142.2	437.0	459.5	469.0	468.9	466.7	456.0	440.3	425.0	410.2
300.	142.6	439.0	462.0	471.8	472.7	470.7	460.4	445.3	429.1	414.5
400.	142.8	440.2	463.6	473.8	475.0	472.3	464.0	447.7	431.7	417.2
600.	143.2	441.7	465.5	476.0	478.1	476.5	468.5	451.5	435.6	420.3
800.	143.5	442.5	466.8	477.4	479.7	478.3	469.7	454.1	438.1	423.0
1000.	143.6	443.1	467.6	478.2	481.0	480.2	470.7	455.5	440.1	424.5
3000.	144.1	445.6	470.6	482.0	485.6	486.0	479.0	462.8	446.3	430.6

C

EPS CHAMBER PRESSURE = 300.0 ODK SPECIFIC IMPULSE

1.	104.6	302.1	308.4	306.0	297.3	287.1	276.4	266.2	257.0	248.8
2.	119.7	351.3	361.0	353.8	345.8	334.5	322.0	309.0	299.0	288.0
4.	127.5	379.4	392.3	389.8	385.4	373.8	363.0	347.0	335.0	321.0
10.	133.9	403.2	419.8	421.2	419.0	411.0	397.5	381.0	368.0	355.0
20.	137.0	415.4	434.3	437.	437.8	430.8	418.8	403.8	389.7	376.6
40.	139.3	424.3	445.0	453.6	452.2	447.1	437.0	422.6	407.5	393.3
100.	141.1	432.7	455.2	465.3	466.2	462.9	454.5	439.5	423.6	408.6
200.	142.2	437.1	460.7	468.0	474.2	472.0	464.0	449.6	433.3	417.7
300.	142.6	439.1	463.3	475.8	478.0	476.5	469.0	454.6	438.1	422.2
400.	142.8	440.3	464.9	477.8	480.3	479.3	472.2	457.8	441.1	425.1
600.	143.2	441.7	466.9	480.1	483.3	482.9	476.2	461.9	445.0	428.7
800.	143.5	442.6	468.1	481.5	485.1	485.1	478.7	464.5	447.5	431.1
1000.	143.6	443.2	468.9	482.4	486.4	486.6	480.5	466.3	449.3	432.7
3000.	144.1	445.0	471.4	486.2	491.5	492.8	487.7	473.7	456.3	439.3

C

EPS CHAMBER PRESSURE = 500.0 ODK SPECIFIC IMPULSE

1.	104.6	302.1	308.5	307.5	298.3	288.6	278.1	267.9	258.6	250.3
2.	119.7	351.4	361.2	357.	348.0	337.0	325.0	311.0	301.0	290.0
4.	127.5	379.4	392.5	392.2	388.0	376.5	366.0	349.8	337.0	324.5
10.	133.9	403.3	420.1	425.	421.0	413.0	400.0	385.0	370.8	358.5
20.	137.0	415.4	434.5	441.5	439.3	433.1	422.4	407.5	393.1	379.7
40.	139.3	424.3	445.3	454.5	453.6	449.3	440.4	426.3	410.8	396.2
100.	141.1	432.7	455.5	466.7	467.7	465.3	457.7	443.7	427.3	411.8
200.	142.2	437.1	461.0	474.0	475.7	474.5	468.1	454.2	437.3	421.2
300.	142.6	439.1	463.6	477.2	479.5	479.1	473.2	459.4	442.3	425.8
400.	142.8	440.3	465.2	478.9	481.9	481.9	476.5	462.7	445.4	428.8
600.	143.2	441.7	467.2	480.9	484.9	485.5	480.6	467.0	449.5	432.6
800.	143.5	442.6	468.4	482.3	486.8	487.8	483.3	469.7	452.1	435.0
1000.	143.6	443.2	469.2	483.4	488.1	489.4	485.1	471.6	453.9	436.7
3000.	144.1	445.0	471.6	487.2	493.1	495.6	492.6	479.4	461.3	443.5

C

EPS CHAMBER PRESSURE = 1000.0 ODK SPECIFIC IMPULSE

1.	104.6	302.1	308.7	308.1	299.7	290.5	280.3	270.1	260.6	252.1
2.	119.7	351.4	361.4	358.2	351.5	340.0	330.0	314.5	304.0	293.0
4.	127.5	379.4	392.7	395.	390.5	380.0	369.0	352.5	340.5	328.6
10.	133.9	403.3	420.2	426.6	423.5	415.5	406.0	391.0	376.8	364.0
20.	137.0	415.4	434.7	443.	440.5	435.6	426.1	411.8	396.8	383.0
40.	139.3	424.4	445.5	455.3	454.7	451.4	443.8	430.4	414.3	399.2
100.	141.1	432.7	455.7	467.5	468.9	467.3	461.4	448.3	431.3	415.2
200.	142.2	437.1	461.2	474.3	476.9	476.6	472.0	459.2	441.6	424.7
300.	142.6	439.1	463.8	477.3	480.7	481.2	477.2	464.6	446.7	429.5
400.	142.8	440.3	465.4	479.8	483.1	484.0	480.6	468.1	450.0	432.6
600.	143.2	441.7	467.4	482.2	486.1	487.6	484.8	472.6	454.2	436.4
800.	143.5	442.6	468.6	483.8	488.0	489.9	487.5	475.4	456.9	438.9
1000.	143.6	443.2	469.4	484.7	489.3	491.5	489.4	477.5	458.8	440.7

Figure 6.3. Propellant Library (PROPLIB) (Sheet 11 of 32)

```
C
3000.   144.1   445.0   471.8   488.6   494.4   497.8   497.1   485.7   466.6   447.8
C
 EPS    CHAMBER PRESSURE = 5000.0       ODK SPECIFIC IMPULSE
   1.   104.6   302.1   308.7   308.6   302.9   295.5   286.1   276.1   266.1   255.9
   2.   119.7   351.4   361.4   359.0   351.5   343.5   331.0   318.0   307.0   296.0
   4.   127.5   379.4   392.7   396.5   393.5   383.0   370.0   356.0   343.0   331.0
  10.   133.9   403.3   420.2   428.5   423.5   419.0   410.0   396.0   381.0   367.0
  20.   137.0   415.4   434.7   443.7   441.4   437.6   431.0   418.9   402.9   388.0
  40.   139.3   424.4   445.3   456.0   455.4   453.0   447.7   436.5   419.3   403.4
 100.   141.1   432.7   455.7   468.6   469.5   468.8   465.2   455.1   436.6   419.4
 200.   142.2   437.1   461.2   476.0   477.5   478.1   475.6   466.4   447.1   429.1
 300.   142.6   439.1   463.8   478.8   481.4   482.6   481.0   472.0   452.2   434.0
 400.   142.8   440.3   463.8   480.3   483.7   485.4   484.2   475.7   455.7   437.0
 600.   143.2   441.7   467.4   482.5   486.6   489.0   488.4   480.4   460.0   440.9
 800.   143.5   442.6   468.6   484.0   488.5   491.2   491.1   483.5   462.8   443.4
1000.   143.6   443.2   469.4   485.2   489.8   492.8   493.0   485.6   464.8   445.2
3000.   144.1   445.0   471.8   488.9   495.2   499.8   502.5   494.0   473.5   452.3
C
C MR:     .1      2.      3.      4.      5.      6.      7.      8.      9.      10.
  PC        CHARACTERISTIC VELOCITY (FT/SEC)
  20.   2641.   7752.   7955.   7837.   7572.   7274.   6986.   6728.   6499.   6300.
  40.   2641.   7752.   7958.   7867.   7622.   7334.   7048.   6788.   6555.   6349.
 100.   2641.   7752.   7960.   7898.   7683.   7410.   7129.   6867.   6630.   6420.
 300.   2641.   7752.   7961.   7925.   7745.   7495.   7222.   6958.   6717.   6502.
 500.   2641.   7752.   7962.   7934.   7769.   7532.   7264.   6999.   6756.   6538.
1000.   2641.   7752.   7762.   7943.   7798.   7578.   7318.   7054.   6806.   6584.
5000.   2641.   7752.   7962.   7955.   7845.   7665.   7433.   7171.   6914.   6680.0
C
C MR =   0.0      2.      3.      4.      5.      6.      7.      8.      9.      10.
  PC      COMBUSTION   TEMPERATURE
  20.   149.    3235.   4325.   4955.   5291.   5457.   5520.   5531.   5511.   5475.
  40.   149.    3236.   4354.   5039.   5417.   5605.   5678.   5689.   5668.   5626.
 100.   149.    3237.   4383.   5140.   5578.   5804.   5894.   5909.   5880.   5830.
 300.   149.    3238.   4407.   5240.   5759.   6042.   6161.   6179.   6143.   6080.
 500.   149.    3238.   4415.   5279.   5838.   6151.   6285.   6307.   6267.   6197.
1000.   149.    3238.   4424.   5325.   5936.   6296.   6454.   6482.   6436.   6354.
5000.   149.    3238.   4435.   5398.   6120.   6600.   6842.   6887.   6819.   6705.
C
C  COEFFICIENTS FOR THROAT RAIUS CORRECTION CORRELATION
C   (DELTA KL/DELTA RT) = A + B * LN(KL REF)
      A = -0.2791    B = 1.2005       RTEF =    2.289
C
 END DATA
C
C  PROPELLANTS:    LIQUID OXYGEN - RP1
C
C
C
C
C
C     ASSUMPTIONS:
C      LOX TEMP= 90.18 DEGREES KELVIN
C      RP-1 TEMP= 298.15 DEGREES KELVIN
C      LOX ENTHALPY= -3093. CAL/MOL
C
C
C
C
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 12 of 32)

```
C       RP-1 ENTHALPY= -6200. CAL/MOL
C
C       ODK DATA CORRESPONDS TO THROAT RADIUS OF 2.289 IN.
C
C
C
C
C
C
C
C
C
C
   SIZE OF VARIOUS DATA ARRAYS
   ODE PC     ODE MR     ODE EPS    ODK PC     ODK MR     ODK EPS
     8          10         17          5         10          8
C
  ODE MIXTURE RATIO VALUES
C MR    0.22    1.0    2.0    2.4    2.6    2.8    3.0    3.2    3.5    10.0
C
 EPS    CHAMBER PRESSURE = 20.0           ODE SPECIFIC IMPULSE
    1.  122.9  168.8  219.9  216.8  215.0  212.6  210.3  208.0  204.3  166.7
    2.  146.9  198.6  261.6  259.3  257.4  254.6  251.8  249.1  245.4  198.1
    4.  162.8  215.5  288.3  287.7  286.1  283.2  280.2  277.2  273.2  218.0
   10.  179.0  238.9  313.2  314.0  315.5  312.6  309.4  306.2  301.7  236.5
   20.  189.0  251.6  327.1  334.2  333.5  330.9  327.7  324.4  319.6  246.7
   40.  197.4  262.7  338.1  348.9  348.7  346.7  343.6  340.2  335.0  254.8
  100.  207.0  275.6  349.6  363.2  364.9  364.4  361.8  358.5  353.3  262.9
  200.  213.3  284.2  356.7  371.8  374.7  375.5  373.8  370.6  365.0  267.6
  300.  216.7  288.8  360.3  375.7  379.7  381.2  380.1  377.2  371.5  269.8
  400.  219.0  292.0  362.6  378.6  382.9  384.9  384.3  381.6  375.9  271.1
  500.  220.6  294.3  364.3  380.6  385.2  387.5  387.3  384.8  379.1  272.2
  600.  222.0  296.2  365.7  382.3  387.1  389.6  389.8  387.5  381.8  273.0
  800.  224.0  299.1  367.7  384.9  389.8  392.7  393.3  391.4  385.8  274.1
 1000.  225.5  301.2  369.3  386.8  391.8  395.0  395.9  394.4  390.4  274.9
 1500.  228.2  305.0  371.9  389.5  394.9  398.5  399.9  399.1  394.8  276.2
 2000.  230.0  307.6  373.8  391.5  397.2  401.0  402.8  402.3  397.9  277.0
 3000.  232.4  311.1  376.4  394.2  400.3  404.5  406.8  407.0  402.3  277.9
C
 EPS    CHAMBER PESSURE =  40.            ODE SPECIFIC IMPULSE
    1.  123.3  169.6  221.4  214.2  217.1  214.7  212.3  210.0  206.7  167.5
    2.  147.3  199.9  263.1  261.7  259.7  257.0  254.2  251.5  247.6  198.8
    4.  163.3  220.0  289.5  290.3  288.5  285.6  282.6  279.7  275.4  218.5
   10.  179.5  240.6  314.0  319.0  317.8  315.1  312.0  308.8  304.1  236.8
   20.  189.5  253.4  327.8  336.0  335.7  333.4  330.2  326.9  322.0  247.0
   40.  198.0  264.6  338.7  350.0  350.6  349.1  346.1  342.8  337.7  255.0
  100.  207.6  277.5  350.1  363.8  366.4  366.5  364.3  361.0  355.7  263.1
  200.  213.9  286.1  357.0  372.1  376.0  377.3  376.1  373.1  367.7  267.7
  300.  217.3  290.7  360.6  376.5  380.9  382.8  382.3  379.6  374.1  269.9
  400.  219.6  293.9  362.9  379.3  384.0  386.4  386.3  384.0  378.5  271.3
  500.  221.2  296.2  364.6  381.3  386.3  388.9  389.2  387.2  381.7  272.3
  600.  222.6  298.1  366.0  383.0  388.1  391.0  391.6  389.8  384.3  273.1
  800.  224.6  301.0  368.1  385.5  390.8  394.0  395.0  393.7  388.3  274.2
 1000.  226.1  303.2  369.6  387.1  392.7  396.2  397.5  396.5  391.3  275.0
 1500.  228.8  306.9  372.3  389.9  395.8  399.6  401.4  401.0  396.2  276.2
 2000.  230.6  309.5  374.1  392.0  397.9  402.0  404.1  404.2  399.6  277.0
 3000.  233.0  312.9  376.8  394.8  401.0  405.4  408.0  408.7  404.5  278.0
C
 EPS    CHAMBER PRESSURE =  100.          ODE SPECIFIC IMPULSE
    1.  124.4  171.0  223.3  221.4  219.7  217.4  215.0  212.7  209.3  168.3
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 13 of 32)

2.	148.6	201.8	264.8	264.5	262.7	260.0	257.3	254.5	250.6	199.6
4.	164.7	222.3	290.8	293.0	291.6	288.9	285.9	282.9	278.5	219.1
10.	181.1	243.1	315.0	321.4	320.8	318.4	315.3	312.1	307.3	237.3
20.	191.1	256.0	328.5	337.4	338.4	336.6	333.6	330.3	325.3	247.3
40.	199.7	267.2	339.3	350.7	353.0	352.1	349.4	346.1	341.0	255.3
100.	209.4	280.2	350.5	364.6	368.3	369.0	367.4	364.3	358.9	263.2
200.	215.7	288.8	357.4	373.2	377.5	379.4	378.9	376.3	370.9	267.8
300.	219.1	293.4	361.0	377.4	382.2	384.7	384.9	382.7	377.3	270.1
400.	221.3	296.6	363.3	380.1	385.3	388.1	388.8	387.0	381.6	271.5
500.	223.0	298.9	365.0	382.1	387.5	390.6	391.6	390.1	384.8	272.4
600.	224.3	300.8	366.4	383.7	389.3	392.6	393.8	392.7	387.4	273.2
800.	226.4	303.7	368.5	386.1	391.9	395.5	397.1	396.4	391.3	274.3
1000.	227.9	305.8	370.1	387.8	393.7	397.6	399.5	399.1	394.2	275.1
1500.	230.5	309.5	372.8	390.7	396.7	400.9	403.2	403.4	398.9	276.3
2000.	232.3	312.1	374.7	392.7	398.8	403.2	405.9	406.4	402.3	277.1
3000.	234.7	315.5	377.4	395.6	401.8	406.5	409.6	410.7	407.0	278.0

C

EPS CHAMBER PRESSURE = 300. ODE SPECIFIC IMPULSE

1.	125.5	173.1	225.1	224.8	222.9	220.6	218.2	215.9	212.5	169.2
2.	149.9	204.5	266.3	267.6	266.1	263.8	260.8	258.0	254.0	200.3
4.	166.3	225.3	291.9	295.8	295.0	292.6	289.7	286.6	282.3	219.7
10.	182.8	246.3	315.7	324.4	324.0	322.1	319.2	315.9	311.1	237.6
20.	192.9	259.3	329.2	340.4	342.0	341.0	337.5	334.1	329.2	247.6
40.	201.6	270.6	339.8	352.9	355.4	355.4	353.2	350.1	344.8	255.5
100.	211.3	283.6	351.0	366.3	370.2	371.7	370.9	368.1	362.7	263.4
200.	217.6	292.2	357.8	374.4	379.1	381.7	382.0	379.9	374.6	268.0
300.	221.0	296.8	361.3	378.5	383.7	386.7	387.6	386.2	380.9	270.2
400.	223.3	299.9	363.6	381.2	386.6	390.0	391.3	390.3	385.2	271.6
500.	225.0	302.3	365.3	383.1	388.7	392.4	393.9	393.3	388.3	272.5
600.	226.3	304.1	366.6	384.7	390.5	394.3	396.1	395.8	390.8	273.3
800.	228.3	307.0	368.5	387.0	393.0	397.1	399.2	399.3	394.7	274.4
1000.	229.8	309.1	370.0	388.8	394.9	399.2	401.8	402.0	397.9	275.1
1500.	232.5	312.8	372.4	391.8	398.1	402.7	405.5	405.7	401.9	276.4
2000.	234.2	315.3	374.2	393.8	400.3	405.3	408.1	408.4	404.7	277.1
3000.	236.6	318.7	376.6	396.8	403.5	408.8	411.8	412.1	408.7	278.1

C

EPS CHAMBER PRESSURE = 500. ODE SPECIFIC IMPULSE

1.	125.9	174.2	225.9	226.1	224.3	222.1	219.7	217.3	213.9	169.6
2.	150.5	205.9	266.7	269.0	267.7	265.4	262.5	259.6	255.7	200.6
4.	166.8	226.8	292.3	297.3	296.6	294.3	291.4	288.4	284.0	219.9
10.	183.5	247.9	316.0	324.8	325.5	323.0	321.1	317.7	313.0	237.8
20.	193.7	260.9	329.5	340.8	342.5	342.6	339.4	336.5	331.0	247.7
40.	202.3	272.3	340.0	353.6	356.4	356.8	354.9	351.8	346.6	255.6
100.	212.1	285.2	351.1	366.8	370.9	372.8	372.3	369.8	364.4	263.5
200.	218.5	293.8	357.9	374.8	379.8	382.6	383.2	381.5	376.2	268.0
300.	221.8	298.4	361.4	378.9	384.3	387.6	388.8	387.7	382.5	270.2
400.	224.1	301.5	363.7	381.6	387.2	390.8	392.4	391.8	386.7	271.6
500.	225.8	303.9	365.4	383.5	389.3	393.1	395.0	394.7	389.8	272.6
600.	227.1	305.7	366.7	385.1	391.0	395.0	397.1	397.1	392.4	273.3
800.	229.2	308.5	368.6	387.3	393.4	397.7	400.1	400.5	396.1	274.4
1000.	230.7	310.7	370.0	388.8	395.0	399.2	402.6	403.4	398.9	275.2
1500.	233.3	314.4	372.5	391.4	397.7	402.2	406.3	407.9	403.2	276.4
2000.	235.1	316.8	374.2	393.2	399.7	404.2	408.9	411.2	406.2	277.2
3000.	237.4	320.2	376.7	395.8	402.4	407.2	412.6	415.7	410.5	278.1

C

EPS CHAMBER PRESSURE = 1000. ODE SPECIFIC IMPULSE

1.	126.5	175.8	226.7	227.8	226.2	224.1	221.7	219.3	215.9	170.0
2.	151.2	207.8	267.4	270.6	269.8	267.5	264.8	262.0	257.9	200.9
4.	167.7	228.8	292.9	298.6	298.7	296.6	293.8	290.8	286.3	220.1
10.	184.4	250.1	316.3	326.0	327.3	326.0	323.4	320.2	315.4	237.9

Figure 6.3. Propellant Library (PROPLIB) (Sheet 14 of 32)

```
   20.   194.6   263.2   329.8   341.5   344.1   343.7   341.6   338.4   333.4   247.9
   40.   203.3   274.5   340.3   354.4   357.6   358.5   357.1   354.2   349.0   255.7
  100.   213.1   287.4   351.3   367.4   371.9   374.2   374.2   372.0   366.7   263.6
  200.   219.5   296.0   358.1   375.3   380.6   383.7   384.8   383.6   378.4   268.1
  300.   222.9   300.6   361.6   379.4   385.0   388.6   390.2   389.3   384.6   270.3
  400.   225.2   303.7   363.8   382.0   387.8   391.8   393.7   393.6   388.8   271.6
  500.   226.8   306.0   365.5   383.9   389.9   394.1   396.2   396.2   391.8   272.6
  600.   228.2   307.9   366.8   385.5   391.6   395.9   398.3   398.3   394.3   273.4
  800.   230.1   310.7   368.7   387.7   394.0   398.5   401.3   401.6   398.0   274.4
 1000.   231.7   312.8   370.2   389.2   395.8   400.5   403.4   404.5   400.7   275.2
 1500.   234.3   316.4   372.6   391.9   398.6   403.6   406.8   408.3   404.9   276.4
 2000.   236.1   318.9   374.2   393.7   400.7   405.7   409.2   411.1   408.0   277.2
 3000.   238.4   322.4   376.6   396.4   403.5   408.8   412.6   414.9   412.2   278.1
C
 EPS    CHAMBER PRESSURE =  2000.                ODE SPECIFIC IMPULSE
    1.   126.9   177.4   227.9   230.3   229.1   227.1   224.7   222.3   218.9   170.3
    2.   151.7   209.7   268.4   273.1   273.0   270.7   268.3   265.6   261.2   201.1
    4.   168.3   230.9   293.8   300.6   301.8   300.1   297.4   294.4   289.8   220.3
   10.   185.1   252.2   316.8   327.8   330.0   330.4   326.9   324.0   319.0   238.1
   20.   195.4   265.4   330.2   342.6   346.5   347.5   344.9   341.5   337.0   248.0
   40.   204.2   276.7   340.7   355.6   359.4   361.0   360.4   357.8   352.6   255.8
  100.   214.0   289.6   351.6   368.3   373.4   376.3   377.0   375.3   370.2   263.6
  200.   220.4   298.2   358.4   376.0   381.8   385.4   387.2   386.7   381.7   268.1
  300.   223.8   302.8   361.9   380.1   386.0   390.1   392.3   391.8   387.8   270.3
  400.   226.1   305.9   363.9   382.6   388.7   393.3   395.7   396.3   392.0   271.7
  500.   227.8   308.2   365.6   384.5   390.8   395.5   398.1   398.4   394.8   272.7
  600.   229.1   310.0   366.9   386.1   392.5   397.2   400.1   400.2   397.2   273.4
  800.   231.1   312.8   368.8   388.3   394.9   399.7   403.1   403.4   400.9   274.5
 1000.   232.7   314.9   370.5   389.8   396.9   402.4   404.6   406.2   403.4   275.2
 1500.   235.3   318.5   372.7   392.6   399.9   405.6   407.7   409.1   407.6   276.4
 2000.   237.0   321.0   374.3   394.5   402.1   407.9   409.8   411.2   410.6   277.2
 3000.   239.3   324.3   376.5   397.3   405.1   411.1   412.8   414.1   414.9   278.2
C
 EPS    CHAMBER PRESSURE =  5000.                ODE SPECIFIC IMPULSE
    1.   127.3   179.5   228.1   231.2   230.2   228.4   226.1   223.8   220.2   170.7
    2.   152.3   212.2   268.8   274.5   274.1   272.4   269.8   267.0   262.8   201.4
    4.   169.0   233.6   293.9   302.3   302.8   301.5   299.0   296.1   291.5   220.5
   10.   186.0   255.0   317.1   328.6   330.7   330.5   328.5   325.6   320.6   238.2
   20.   196.3   268.2   330.2   343.7   346.8   347.7   346.5   343.7   338.6   248.1
   40.   205.2   279.6   340.6   355.8   359.9   361.8   361.6   359.3   354.1   255.9
  100.   215.1   292.5   351.6   368.5   373.7   376.8   377.9   376.8   371.7   263.7
  200.   221.5   301.0   358.3   376.3   382.0   385.9   387.9   387.8   383.1   268.2
  300.   224.9   305.6   361.8   380.2   386.3   390.5   393.0   393.4   389.1   270.4
  400.   227.2   308.7   364.0   382.8   389.1   393.6   396.3   397.1   393.2   271.7
  500.   228.9   310.9   365.7   384.7   391.1   395.7   398.7   399.7   396.1   272.7
  600.   230.2   312.8   367.0   386.2   392.7   397.5   400.7   401.9   398.4   273.4
  800.   232.2   315.5   368.9   388.4   395.1   400.1   403.5   405.1   401.9   274.5
 1000.   233.7   317.6   370.5   390.0   396.8   402.0   405.5   407.4   404.5   275.2
 1500.   236.3   321.1   372.9   392.7   399.7   405.1   409.0   411.2   409.0   276.5
 2000.   238.0   323.7   374.6   394.6   401.8   407.3   411.5   413.8   412.3   277.2
 3000.   240.3   326.9   377.0   397.3   404.7   410.4   415.0   417.6   416.8   278.2
C
  ODK MIXTURE RATIOS
C MR     0.22    1.0     2.0     2.6     2.8     2.9     3.0     3.2     3.4     10.
C
 EPS    CHAMBER PRESSURE =  20.                  ODK SPECIFIC IMPULSE
   40.   131.8   233.3   321.8   323.0   320.4   319.0   317.5   314.3   311.2   250.1
  100.   138.2   234.3   330.5   333.3   330.9   329.4   327.9   324.8   321.6   257.7
  200.   142.4   241.6   335.4   339.2   336.8   335.5   334.0   330.8   327.6   262.1
  300.   144.6   245.5   337.6   342.0   339.7   338.4   336.9   333.8   330.5   264.2
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 15 of 32)

```
 400.   146.2   248.2   339.0   343.8   341.6   340.2   338.7   335.6   332.4   265.5
 500.   147.2   250.2   340.0   345.0   342.8   341.5   340.0   336.9   333.7   266.5
 600.   148.2   251.8   340.8   346.0   343.8   342.5   341.0   337.9   334.7   267.2
 800.   149.5   254.2   341.8   347.3   345.2   343.9   342.5   339.4   336.2   268.2
C
 EPS    CHAMBER PRESSURE =  300.                    ODK SPECIFIC IMPULSE
  40.   134.6   230.0   337.1   350.3   348.9   347.7   346.3   343.0   339.5   255.1
 100.   141.0   241.1   347.0   363.7   362.8   361.6   360.3   357.0   353.4   263.0
 200.   145.2   248.4   352.5   371.6   371.1   370.1   368.8   365.5   361.9   267.7
 300.   147.2   252.3   355.1   375.6   375.3   374.3   373.0   369.8   366.2   269.8
 400.   149.1   254.9   356.8   378.1   378.0   377.1   375.8   372.6   368.9   271.2
 500.   150.2   257.0   357.9   379.9   379.9   379.0   377.8   374.6   370.9   272.1
 600.   151.1   258.5   358.8   381.3   381.4   380.5   379.3   376.1   372.5   272.9
 800.   152.4   261.0   360.1   383.3   383.6   382.8   381.6   378.4   374.7   273.9
C
 EPS    CHAMBER PRESSURE =  500.                    ODK SPECIFIC IMPULSE
  40.   135.0   231.5   338.1   353.3   352.4   351.3   350.0   346.8   343.3   255.4
 100.   141.6   242.4   347.9   366.9   366.7   365.8   364.5   361.3   357.7   263.3
 200.   145.8   249.7   353.5   375.1   375.4   374.6   373.4   370.2   366.6   267.8
 300.   148.1   253.6   356.1   379.1   379.7   379.0   377.9   374.7   371.1   270.0
 400.   149.6   256.3   357.8   381.7   382.5   381.9   380.8   377.7   374.0   271.4
 500.   150.6   258.3   359.0   383.6   384.5   383.9   382.8   379.8   376.1   272.3
 600.   151.6   259.8   359.8   385.0   386.1   385.5   384.5   381.4   377.7   273.1
 800.   153.0   262.2   361.1   387.1   388.4   387.9   386.9   383.9   380.2   272.2
C
 EPS    CHAMBER PRESSURE =  1000.                   ODK SPECIFIC IMPULSE
  40.   135.7   233.3   338.2   356.2   356.2   355.4   354.2   351.1   347.6   255.6
 100.   142.2   244.3   348.6   370.0   370.9   370.4   369.3   366.3   362.8   263.4
 200.   146.5   251.6   354.2   378.3   379.9   379.6   378.6   375.7   372.1   268.0
 300.   148.8   255.5   356.8   382.4   384.4   384.2   383.4   380.5   376.9   270.2
 400.   150.2   258.1   358.5   385.0   387.3   387.2   386.4   383.6   380.0   271.5
 500.   151.4   260.1   359.6   386.9   389.4   389.4   388.6   385.9   382.2   272.5
 600.   152.3   261.7   360.5   388.4   391.1   391.1   390.4   387.6   384.0   273.3
 800.   153.7   264.1   361.9   390.5   393.5   393.6   392.9   390.2   386.6   274.3
C
 EPS    CHAMBER PRESSURE =  5000.                   ODK SPECIFIC IMPULSE
  40.   137.0   237.7   339.3   359.5   361.3   361.3   360.8   358.3   354.9   255.8
 100.   143.6   248.6   349.1   373.1   376.1   376.8   376.7   374.7   371.3   263.7
 200.   147.9   255.9   354.6   381.2   385.2   386.2   386.5   384.9   381.6   268.2
 300.   150.1   259.8   357.2   385.3   389.7   391.0   391.5   390.2   386.8   270.3
 400.   151.7   262.4   358.9   387.9   392.7   394.1   394.8   393.6   390.2   271.7
 500.   152.8   264.3   360.0   389.7   394.8   396.4   397.1   396.1   392.8   272.7
 600.   153.7   265.9   360.9   391.2   396.4   398.1   399.0   398.0   394.7   273.4
 800.   155.0   268.2   362.2   393.3   398.9   400.7   401.7   400.5   397.6   274.5
C
C    MR  0.22    1.0     2.0     2.4     2.6     2.8     3.0     3.2     3.5     10.
  PC           CHARACTERISTIC VELOCITY (FT/SEC)
  20.   2150.   4336.   5736.   5668.   5625.   5564.   5502.   5443.   5359.   4348.
  40.   2150.   4363.   5771.   5721.   5676.   5615.   5554.   5494.   5409.   4365.
 100.   2150.   4408.   5812.   5788.   5743.   5684.   5622.   5562.   5475.   4383.
 300.   2150.   4471.   5853.   5868.   5822.   5764.   5703.   5642.   5554.   4401.
 500.   2150.   4502.   5868.   5900.   5857.   5801.   5740.   5679.   5591.   4407.
1000.   2150.   4545.   5884.   5940.   5904.   5850.   5790.   5729.   5639.   4415.
2000.   2150.   4588.   5909.   5977.   5940.   5887.   5832.   5765.   5677.   4588.
5000.   2150.   4645.   5910.   6020.   6002.   5958.   5902.   5841.   5749.   4427.
C
C MR =  .22     1.      2.      2.4     2.6     2.8     3.      3.2     3.5     10.
  PC        COMBUSTION TEMPERATURE
  20.   2140.   2505.   5374.   5594.   5632.   5646.   5646.   5639.   5619.   4736.
  40.   2140.   2524.   5495.   5752.   5795.   5812.   5813.   5806.   5785.   4808.
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 16 of 32)

```
C

 100.  2140.  2566.  5651.  5965.  6019.  6040.  6044.  6037.  6011.  4896.
 300.  2140.  2652.  5826.  6224.  6297.  6328.  6334.  6326.  6298.  4990.
 500.  2140.  2706.  5899.  6344.  6428.  6464.  6473.  6466.  6434.  5028.
1000.  2140.  2793.  5989.  6506.  6608.  6653.  6666.  6659.  6625.  5075.
2000.  2140.  2895.  6067.  6663.  6785.  6843.  6861.  6856.  6822.  5116.
5000.  2140.  3050.  6150.  6859.  7019.  7098.  7124.  7122.  7086.  5162.
C
C  COEFFICEINTS FOR THROAT RADIUS CORRECTION CORRELATION
   (DELTA KL/DELTA RT) = A + B * LN(KL REF)
      A = -1.1543    B =  1.7378      RTREF =     2.289
C
C
C
  END DATA
C
C
C
C   PROPELLANTS:    LIQUID OXYGEN - METHANE
C
C
C
C
C
C     ASSUMPTIONS:
C
C                   TEMP       ENTHALPY
C              LOX    90.18 K    -3090. CAL/MOL
C              CH4   111.64 K   -21370. CAL/MOL
C
C     ODK VALUES CORRESPOND TO THROAT RADIUS = 7.07 IN
C
C
C
C
 SIZE OF VARIOUS DATA ARRAYS
 ODE PC     ODE MR     ODE EPS    ODK PC     ODK MR     ODK EPS
    7         10         17         7          10         17
C
C
 ODE MIXTURE RATIO VALUES
C  MR    0.6   2.0,   2.5,   3.0,  3.4,   3.5,   3.6,   3.8,   4.0,   4.5
C
 EPS    CHAMBER PRESSURE =  20.0          ODE SPECIFIC IMPULSE
   1.   149.8  222.5  228.4  225.0  220.5  219.3  218.2  216.0  213.8  208.8
   2.   178.7  261.4  271.7  269.2  264.1  262.7  261.4  258.7  256.2  250.1
   4.   198.0  285.0  299.4  298.9  293.7  292.3  290.8  287.9  285.1  278.3
  10.   217.3  306.6  325.4  328.6  324.2  322.7  321.1  318.0  314.9  307.4
C
C
C
C
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 17 of 32)

20.	229.0	318.7	339.7	346.1	343.0	341.6	340.0	336.8	333.5	325.6
40.	239.1	328.5	351.2	360.2	359.1	357.8	356.4	353.1	349.7	341.3
100.	250.3	339.0	363.3	375.0	376.6	375.9	374.8	371.8	368.3	359.3
200.	257.7	345.5	370.7	383.9	387.3	387.2	386.6	384.1	380.6	371.1
[illegible]00.	261.6	348.8	374.5	388.4	392.7	392.9	392.6	390.6	387.2	377.3
[illegible]0.	264.2	351.0	377.0	391.3	396.2	396.6	396.5	395.0	391.6	381.4
[illegible]00.	266.2	352.5	378.8	393.4	398.7	399.2	399.3	398.1	394.8	384.3
600.	267.8	353.7	380.2	395.1	400.8	401.3	401.5	400.6	397.5	386.7
800.	270.1	355.5	382.2	397.6	403.7	404.4	404.8	404.2	401.5	390.2
1000.	271.9	356.8	383.8	399.4	405.9	406.7	407.2	406.9	404.4	392.7
1500.	275.0	358.9	386.3	402.2	409.2	410.2	410.9	411.0	409.0	396.6
2000.	277.0	360.3	388.0	404.4	411.6	412.7	413.4	414.0	412.3	399.5
3000.	279.8	361.9	390.0	406.9	414.9	416.2	417.1	418.1	416.9	403.4

C

EPS CHAMBER PRESSURE = 40.0 ODE SPECIFIC IMPULSE

1.	151.2	222.8	229.8	227.0	222.5	221.4	220.2	217.9	215.8	210.8
2.	180.3	261.6	273.0	271.5	266.4	265.1	263.7	261.0	258.4	252.2
4.	199.7	285.1	300.4	301.3	296.1	294.7	293.2	290.3	287.4	280.5
10.	219.2	306.7	325.9	331.0	326.6	325.1	323.6	320.5	317.3	309.7
20.	230.9	318.7	340.2	348.4	345.3	344.0	342.5	339.2	335.9	327.9
40.	241.0	328.6	351.7	362.3	361.2	360.0	358.7	355.6	352.1	343.6
100.	252.3	339.1	363.7	376.7	378.3	377.8	377.0	374.2	370.7	361.6
200.	259.6	345.5	371.0	385.3	388.7	388.8	388.4	386.3	382.9	373.3
300.	263.5	348.9	374.8	389.7	394.0	394.3	394.2	392.7	389.4	379.4
400.	266.1	351.0	377.2	392.5	397.4	397.9	398.0	396.9	393.8	383.5
500.	268.1	352.6	379.0	394.5	399.9	400.5	400.7	399.9	397.0	386.4
600.	269.7	353.8	380.4	396.2	401.9	402.6	402.9	402.4	399.6	388.7
800.	272.0	355.6	382.5	398.6	404.7	405.6	406.1	405.9	403.4	392.0
1000.	273.8	356.8	384.0	400.3	406.8	407.8	408.4	408.5	406.3	394.5
1500.	276.9	359.0	386.5	403.0	410.0	411.2	412.0	412.5	410.8	398.3
2000.	278.9	360.3	388.1	404.9	412.4	413.6	414.5	415.3	414.0	401.1
[illegible]00.	281.6	361.9	390.2	407.6	415.6	417.0	418.1	419.3	418.5	404.9

EPS CHAMBER PRESSURE = 100. ODE SPECIFIC IMPULSE

1.	153.0	223.1	231.5	229.4	225.1	224.0	222.8	220.6	218.3	213.1
2.	182.4	261.8	274.5	274.0	269.3	268.0	266.6	264.0	261.3	255.1
4.	202.0	285.2	301.5	303.6	299.2	297.8	296.2	293.4	290.5	283.6
10.	221.6	306.7	326.7	332.6	329.6	328.3	327.3	323.7	320.5	312.8
20.	233.4	318.9	340.9	349.4	348.2	347.0	345.9	342.4	339.1	330.9
40.	243.5	328.6	352.2	362.9	363.8	362.9	361.8	358.7	355.3	346.6
100.	254.7	339.1	364.1	377.1	380.3	380.2	379.6	377.2	373.7	364.2
200.	262.2	345.6	371.4	385.6	390.4	390.7	390.6	389.1	385.8	375.6
300.	266.1	348.9	375.1	390.0	395.5	396.1	396.2	395.3	392.2	381.5
400.	268.7	351.0	377.5	392.8	398.9	399.5	399.9	399.3	396.5	385.3
500.	270.6	352.6	379.3	394.8	401.2	402.0	402.5	402.2	399.6	388.1
600.	272.2	353.8	380.7	396.4	403.1	404.0	404.6	404.5	402.2	390.3
800.	274.5	355.6	382.7	398.8	405.9	406.9	407.6	407.9	405.9	393.6
1000.	276.3	356.9	384.2	400.6	408.0	409.1	409.9	410.4	408.6	395.9
1500.	279.3	359.0	386.7	403.3	411.1	412.4	413.3	414.2	412.9	399.6
2000.	281.3	360.3	388.3	405.1	413.4	414.7	415.8	417.0	416.0	402.1
3000.	284.0	362.0	390.3	407.8	416.5	418.0	419.2	420.8	420.3	405.8

C

EPS CHAMBER PRESSURE = 300.0 ODE SPECIFIC IMPULSE

1.	155.1	223.4	233.1	232.9	228.2	227.1	226.0	223.7	221.4	216.2
2.	184.9	262.0	275.8	278.1	272.8	271.5	270.2	267.5	264.8	258.5
4.	204.6	285.3	302.6	308.2	302.8	301.4	300.0	297.1	294.2	287.2
10.	224.4	306.8	327.4	334.9	333.1	331.9	330.5	327.4	324.2	316.5
20.	236.3	318.9	341.5	351.2	351.4	350.4	349.2	346.2	342.8	334.7
[illegible]0.	246.5	328.7	352.7	364.4	366.5	366.0	365.1	362.3	358.9	350.3
[illegible]0.	257.8	339.1	364.5	378.2	382.5	382.6	382.3	380.5	377.2	367.3

Figure 6.3. Propellant Library (PROPLIB) (Sheet 18 of 32)

```
  200.   265.1   345.6   371.7   386.6   392.2   392.7   392.9   392.0   389.1   378.3
  300.   269.0   348.9   375.4   390.8   397.1   397.9   398.3   398.0   395.3   383.9
  400.   271.6   351.1   377.8   393.6   400.3   401.2   401.8   401.8   399.5   387.6
  500.   273.5   352.6   379.5   395.6   402.6   403.6   404.3   404.6   402.5   390.3
  600.   275.0   353.8   380.9   397.2   404.5   405.6   406.3   406.8   404.9   392.4
  800.   277.3   355.6   383.0   399.5   407.2   408.4   409.3   410.0   408.5   395.5
 1000.   279.1   356.9   384.4   401.2   409.1   410.4   411.4   412.4   411.2   397.7
 1500.   282.0   359.0   386.9   404.1   412.2   413.6   414.7   416.1   415.3   401.5
 2000.   284.0   360.3   388.5   405.9   414.3   415.9   417.1   418.6   418.1   404.0
 3000.   286.6   362.0   390.5   408.3   417.4   419.0   420.4   422.3   422.2   407.1
C
 EPS    CHAMBER PRESSURE =  500.0                  ODE SPECIFIC IMPULSE
    1.   156.0   223.4   233.8   233.5   229.6   228.5   227.4   225.1   222.8   217.4
    2.   185.9   262.0   276.3   279.4   274.3   273.0   271.8   269.1   266.4   260.4
    4.   205.8   285.4   302.9   309.7   304.3   303.6   301.8   298.8   295.8   288.7
   10.   225.6   306.8   327.7   339.1   334.6   333.8   332.3   329.1   325.9   318.1
   20.   237.6   318.9   341.7   351.9   352.7   351.9   351.2   347.8   344.5   335.9
   40.   247.8   328.7   352.8   365.0   367.6   367.2   366.5   363.9   360.5   351.4
  100.   259.1   339.2   364.6   378.6   383.3   383.6   383.5   381.9   378.7   368.6
  200.   266.4   345.6   371.8   386.9   392.9   393.6   393.5   393.3   390.5   379.4
  300.   270.3   348.9   375.5   391.2   397.8   398.7   399.2   399.1   396.7   385.0
  400.   272.9   351.1   377.9   393.9   400.9   402.0   402.6   402.8   400.8   388.6
  500.   274.8   352.6   379.6   395.8   403.2   404.3   405.1   405.5   403.7   391.2
  600.   276.3   353.8   381.0   397.4   405.0   406.2   407.1   407.7   406.1   393.3
  800.   278.6   355.6   383.0   399.8   407.7   409.0   409.9   410.9   409.7   396.3
 1000.   280.3   356.9   384.5   401.5   409.6   411.0   412.0   413.2   412.2   398.5
 1500.   283.2   359.0   387.0   404.2   412.6   415.1   415.3   416.8   416.2   402.5
 2000.   285.2   360.3   385.5   406.0   414.7   418.1   417.6   419.3   419.0   405.4
 3000.   287.7   362.0   390.5   408.7   417.7   419.5   420.9   422.9   423.0   409.4
C
 EPS    CHAMBER PRESSURE =  1000.                  ODE SPECIFIC IMPULSE
    1.   157.2   223.5   234.4   236.2   231.5   230.4   229.3   227.0   224.7   219.4
    2.   187.3   262.1   276.9   281.7   276.4   275.2   273.9   271.2   268.5   262.1
    4.   207.3   285.4   303.3   311.8   306.4   305.3   304.0   301.0   298.0   290.9
   10.   227.2   306.9   328.0   341.1   336.5   335.7   334.6   331.3   328.1   320.3
   20.   239.3   318.9   341.9   352.8   354.3   353.3   352.2   350.0   346.7   338.5
   40.   249.4   328.7   353.0   365.7   368.9   368.8   368.3   366.0   362.7   354.0
  100.   260.8   339.2   364.7   379.2   384.4   384.8   384.9   383.8   380.7   371.4
  200.   268.1   345.6   371.9   387.4   393.8   394.6   395.1   394.8   392.3   382.5
  300.   271.9   348.9   375.6   391.6   398.6   399.6   400.3   400.5   398.4   388.2
  400.   274.5   351.1   378.0   394.3   401.7   402.8   403.6   404.1   402.4   391.9
  500.   276.4   352.6   379.7   396.3   403.9   405.1   406.1   406.7   405.3   394.4
  600.   277.9   353.8   381.1   397.8   405.7   407.0   408.1   408.9   407.6   396.5
  800.   280.2   355.6   383.1   400.1   408.3   409.7   410.8   412.0   411.1   399.5
 1000.   281.8   356.9   384.6   401.7   410.2   411.6   412.8   414.0   413.6   401.6
 1500.   284.7   359.0   387.0   404.5   413.2   414.7   416.0   417.6   417.5   404.8
 2000.   286.6   360.3   388.6   405.2   415.2   416.9   418.3   420.1   420.2   407.2
 3000.   289.2   362.0   390.6   410.1   418.2   420.0   421.5   423.7   424.1   410.4
C
 EPS    CHAMBER PRESSURE =  5000.                  ODE SPECIFIC IMPULSE
    1.   159.6   224.0   235.4   238.1   235.4   234.5   233.4   231.1   228.8   223.1
    2.   190.2   262.6   286.9   284.9   281.6   280.6   279.3   276.7   274.0   267.2
    4.   210.4   285.9   304.3   316.3   312.6   311.5   310.3   307.7   304.5   297.3
   10.   230.6   307.4   329.0   336.4   339.5   339.2   337.8   334.9   331.8   323.1
   20.   242.7   319.4   342.9   354.3   357.4   357.3   356.4   354.2   351.4   342.2
   40.   253.0   329.2   354.0   366.9   371.6   371.8   371.3   369.7   367.2   357.2
  100.   264.3   339.7   365.7   380.1   386.5   387.2   387.4   386.8   384.8   373.5
  200.   271.6   346.1   372.9   388.2   395.6   396.6   397.5   397.7   396.1   383.6
  300.   275.4   349.4   376.6   392.3   400.3   401.4   402.6   403.3   401.9   388.8
  400.   277.9   351.6   379.0   394.9   403.3   404.5   405.9   407.0   405.7   392.1
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 19 of 32)

500.	280.1	353.1	380.7	396.8	405.4	406.7	408.3	409.6	408.4	394.5
600.	281.2	354.3	382.1	398.4	407.1	408.5	410.2	411.7	410.6	396.5
800.	283.4	356.1	384.1	400.6	409.6	411.1	413.1	414.9	413.9	399.3
1000.	285.0	357.4	385.6	402.3	411.5	413.0	415.1	417.1	416.2	401.3
1500.	287.7	359.5	388.0	405.0	415.4	417.2	419.4	421.5	420.6	405.0
00.	289.5	360.8	389.6	406.8	418.2	420.1	422.4	424.6	423.7	407.5
00.	291.9	362.5	391.6	409.5	422.2	424.3	426.7	429.1	428.1	411.2

C

ODK MIXTURE RATIOS

C MR	0.6	2.0	2.5	3.0	3.4	3.5	3.6	3.8	4.0	4.5

C

EPS CHAMBER PRESSURE = 20.0 ODK SPECIFIC IMPULSE

EPS										
1.	104.9	222.3	228.4	225.2	220.8	219.7	218.5	216.3	214.1	209.0
2.	125.1	260.8	271.5	266.1	261.3	260.0	258.7	256.1	253.5	247.5
4.	138.6	283.8	298.5	291.7	287.1	285.4	284.1	281.8	278.5	272.0
10.	152.1	304.3	323.5	317.5	312.8	311.4	309.9	306.9	303.9	296.5
20.	160.3	315.1	337.2	333.3	326.5	325.3	323.6	320.6	317.7	310.2
40.	167.4	323.3	347.9	342.8	338.6	337.1	335.6	332.5	329.3	321.3
100.	175.2	331.1	358.5	354.1	350.3	348.9	347.4	344.2	340.9	332.6
200.	180.4	335.3	364.5	360.5	356.6	355.8	353.9	351.0	347.9	339.3
300.	183.1	337.3	367.4	363.7	360.0	359.1	357.3	354.4	351.2	342.6
400.	184.9	338.5	369.1	365.7	362.6	361.2	359.7	356.6	353.2	344.6
500.	186.2	339.4	370.4	367.1	363.6	362.8	361.1	357.9	354.6	346.0
600.	187.5	340.0	371.4	368.1	365.0	363.9	362.4	359.1	355.7	347.1
800.	189.1	341.0	372.7	369.7	366.8	365.5	364.1	360.9	357.5	348.9
1000.	190.3	341.6	373.7	370.8	368.0	366.7	365.2	362.1	358.7	350.0
1500.	192.5	342.6	375.3	372.6	369.9	368.6	367.2	364.0	360.7	351.9
2000.	193.9	343.3	376.3	373.7	371.1	369.8	368.4	365.2	361.9	353.1
3000.	195.9	344.0	377.5	374.5	372.6	371.3	369.9	366.8	363.4	354.6

C

EPS CHAMBER PRESSURE = 40.0 ODK SPECIFIC IMPULSE

EPS										
1.	105.8	222.7	229.8	227.6	223.2	222.1	220.9	218.7	216.5	211.3
2.	126.3	261.3	272.9	269.7	265.0	263.7	262.4	259.7	257.1	251.0
4.	139.8	284.3	300.0	297.0	292.5	290.9	289.5	286.4	284.0	276.9
10.	153.4	304.8	325.0	323.5	319.2	317.8	316.3	313.3	310.2	302.6
20.	161.6	315.7	338.8	339.8	334.0	332.6	331.1	327.9	325.1	316.7
40.	168.7	323.9	349.5	350.1	346.6	345.2	343.7	340.5	337.2	328.9
100.	176.6	331.7	360.2	362.2	359.3	358.0	356.5	353.3	349.8	341.2
200.	181.7	336.0	366.2	368.9	366.9	365.6	364.1	360.8	357.3	348.5
300.	184.5	338.0	369.1	372.4	370.4	369.2	367.9	364.6	361.2	352.1
400.	186.3	339.2	370.9	374.8	372.8	371.6	370.1	366.9	363.4	354.4
500.	187.7	340.1	372.2	376.4	374.4	373.1	371.8	368.5	365.1	356.0
600.	188.8	340.7	373.1	377.6	375.6	374.4	373.0	369.7	366.4	357.2
800.	190.4	341.7	374.5	379.2	377.6	376.4	375.0	371.8	368.3	359.2
1000.	273.8	342.3	375.5	380.4	379.0	377.7	376.3	373.1	369.6	360.5
1500.	193.6	343.4	377.1	382.4	381.1	379.9	378.5	375.4	371.9	362.6
2000.	195.2	344.0	378.1	383.6	382.5	381.3	379.9	376.8	373.3	364.0
3000.	197.1	344.8	379.3	385.1	384.2	383.0	381.7	378.5	375.0	365.7

C

EPS CHAMBER PRESSURE = 100.0 ODK SPECIFIC IMPULSE

EPS										
1.	107.1	223.1	231.5	230.3	226.1	224.9	223.8	221.5	219.3	214.0
2.	127.7	261.6	274.5	273.5	268.9	267.6	266.3	263.6	261.0	254.7
4.	141.4	284.6	301.4	302.1	297.9	296.6	295.7	292.1	289.3	282.0
10.	155.1	305.2	326.2	329.5	326.0	324.7	323.2	320.1	317.0	309.2
20.	163.4	316.1	340.0	346.9	342.3	341.0	339.4	336.2	332.7	324.6
40.	170.5	324.3	350.7	357.6	355.5	354.2	352.7	349.5	346.1	337.5
100.	178.4	332.1	361.3	370.4	369.3	368.0	366.6	363.4	359.9	350.9
200.	183.5	336.4	367.3	377.7	377.6	376.3	374.8	371.7	368.0	358.9
300.	186.3	338.4	370.2	381.5	381.8	380.7	378.9	376.0	372.2	363.0
0.	188.1	339.6	372.0	383.9	384.2	383.2	381.8	378.6	375.0	365.5

Figure 6.3. Propellant Library (PROPLIB) (Sheet 20 of 32)

```
  500.   189.4   340.5   373.3   385.6   386.2   385.3   383.7   380.4   376.8   367.5
  600.   190.5   341.1   374.2   386.9   387.7   386.7   385.2   381.9   378.2   368.8
  800.   192.2   342.1   375.6   388.7   389.7   388.7   387.4   384.2   380.6   370.9
 1000.   193.4   342.7   376.7   390.1   391.2   390.2   388.9   385.8   382.2   372.5
 1500.   195.5   343.7   378.2   392.2   393.7   392.8   391.5   388.4   384.8   375.0
 2000.   196.9   344.4   379.2   393.6   395.3   394.4   393.1   390.0   386.4   376.5
 3000.   198.8   345.2   380.4   395.3   397.3   396.4   395.2   392.1   388.5   378.6
C
 EPS     CHAMBER PRESSURE =  300.               ODK SPECIFIC IMPULSE
    1.   108.6   223.3   233.1   233.2   229.2   228.1   226.9   224.6   222.4   217.0
    2.   129.4   261.8   275.8   276.9   272.7   271.4   270.1   267.4   264.7   258.3
    4.   143.2   284.8   302.5   306.0   303.5   301.6   300.9   297.7   294.7   287.2
   10.   157.1   305.3   327.1   334.0   331.9   330.6   329.2   326.2   323.0   315.0
   20.   165.4   316.3   340.7   351.2   348.7   347.6   346.4   343.4   340.2   331.6
   40.   172.6   324.4   351.3   362.7   363.0   362.0   360.8   357.7   354.3   345.3
  100.   179.3   332.3   361.9   375.9   377.8   377.0   375.8   372.8   369.2   359.7
  200.   185.6   336.5   367.9   383.2   387.1   385.8   384.7   382.4   378.5   368.5
  300.   188.3   338.5   370.7   387.2   391.9   390.4   389.5   386.7   383.0   373.1
  400.   190.1   339.8   372.5   389.9   394.0   393.5   392.5   389.6   386.0   375.9
  500.   191.5   340.6   373.8   391.4   395.9   395.6   394.5   391.7   388.2   377.9
  600.   192.5   341.3   374.7   392.7   397.6   397.1   396.2   393.3   389.8   379.5
  800.   194.1   342.2   376.1   394.9   400.0   399.7   398.8   395.9   392.3   382.0
 1000.   195.4   342.9   377.1   396.2   401.7   401.4   400.5   397.7   394.1   383.7
 1500.   197.4   343.9   378.7   398.5   404.5   404.3   403.5   400.7   397.1   386.5
 2000.   198.8   344.6   379.6   399.9   406.3   406.1   405.3   402.6   399.0   389.8
 3000.   200.6   345.3   380.8   401.7   408.5   408.4   407.7   405.0   401.4   390.7
C
 EPS     CHAMBER PRESSURE =  500.0              ODK SPECIFIC IMPULSE
    1.   109.2   223.4   233.7   235.0   233.0   232.2   231.1   228.8   226.6   221.3
    2.   130.1   261.9   276.3   278.0   275.6   274.7   273.4   270.9   268.4   262.1
    4.   144.1   284.9   302.9   304.9   302.3   301.3   300.0   297.4   294.8   287.9
   10.   157.9   305.4   327.4   336.6   336.5   335.8   334.3   331.2   328.0   319.8
   20.   166.5   316.3   341.0   351.1   351.0   350.3   348.9   345.9   342.7   334.1
   40.   173.5   324.5   351.6   363.9   365.2   364.7   363.3   360.4   357.2   348.1
  100.   181.4   332.3   362.0   377.1   380.2   380.0   378.7   375.9   372.7   363.0
  200.   186.5   336.6   368.0   384.9   389.3   389.3   388.1   385.4   382.2   372.1
  300.   189.2   338.6   370.9   388.7   393.9   394.0   392.9   390.2   387.0   376.7
  400.   191.0   339.8   372.6   391.1   396.8   397.0   395.9   393.3   390.1   379.7
  500.   192.4   340.7   373.9   392.8   398.9   399.1   398.1   395.5   392.3   381.8
  600.   193.4   341.3   374.8   394.2   400.6   400.9   399.8   397.3   394.1   383.5
  800.   195.0   342.3   376.2   396.1   403.1   403.4   402.4   399.9   396.7   386.0
 1000.   196.2   342.9   377.2   397.5   404.8   405.2   404.2   401.7   398.6   387.8
 1500.   198.2   344.0   378.8   399.4   406.9   407.4   406.4   404.0   400.8   390.0
 2000.   199.6   344.6   379.6   400.7   408.5   408.9   408.0   405.5   402.4   391.5
 3000.   201.4   345.4   381.0   402.6   410.6   411.1   410.2   407.7   404.6   393.7
C
 EPS     CHAMBER PRESSURE =  1000.              ODK SPECIFIC IMPULSE
    1.   110.0   223.5   234.4   235.6   234.1   233.4   232.4   230.2   228.1   222.6
    2.   131.1   261.9   276.9   278.7   276.9   276.2   275.0   272.6   270.2   263.7
    4.   145.1   284.5   303.3   305.7   304.3   303.5   302.2   299.5   296.8   289.6
   10.   159.0   305.4   327.7   337.4   336.8   337.6   342.3   347.5   347.1   321.8
   20.   167.5   316.3   341.2   352.0   352.7   352.2   350.9   348.1   345.0   336.2
   40.   174.6   324.5   351.7   364.7   367.0   366.8   365.5   362.8   359.7   350.5
  100.   182.6   332.4   362.2   377.8   382.1   382.2   381.1   378.7   375.7   365.7
  200.   187.7   336.6   368.1   385.6   391.3   391.6   390.7   388.4   385.5   375.0
  300.   190.3   338.6   371.0   389.4   395.9   396.3   395.5   393.3   390.4   379.8
  400.   192.2   339.9   372.8   391.8   398.9   399.4   398.6   396.5   393.6   382.9
  500.   193.2   340.7   374.0   393.5   401.0   401.5   400.8   398.8   395.9   385.0
  600.   194.5   341.4   375.0   394.8   402.7   403.3   402.6   400.6   397.8   386.8
  800.   196.1   342.3   376.3   396.7   405.2   405.8   405.2   403.3   400.5   389.4
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 21 of 32)

```
1000.  197.3  343.0  377.0  398.1  406.9  407.6  407.0  405.2  402.4  391.2
1500.  199.3  344.0  378.9  400.0  409.0  409.8  409.3  407.5  404.7  393.5
2000.  200.6  344.7  379.8  401.3  410.6  411.3  410.9  409.0  406.3  395.0
3000.  202.4  345.4  381.1  403.2  412.7  413.5  413.1  411.3  408.5  397.2
S      CHAMBER PRESSURE =  5000.          ODK SPECIFIC IMPULSE
   1.  111.7  224.0  235.4  236.8  236.7  236.3  235.6  233.9  232.0  226.1
   2.  133.2  262.4  277.9  280.2  280.1  279.6  278.8  277.0  274.8  267.8
   4.  147.3  285.4  304.3  307.3  307.1  306.6  305.9  304.1  301.9  294.2
  10.  161.4  305.9  328.7  339.1  342.1  342.0  341.0  338.6  335.8  327.0
  20.  169.9  316.8  342.2  353.7  356.8  356.7  355.8  353.6  350.8  341.6
  40.  177.2  325.0  352.7  366.2  371.0  371.2  370.6  368.9  366.3  356.3
 100.  185.0  332.9  362.2  379.1  386.0  386.6  386.5  385.4  383.1  372.2
 200.  190.1  337.1  369.1  386.7  395.0  395.9  396.2  395.6  393.6  382.0
 300.  192.8  339.1  372.0  390.4  399.5  400.6  401.1  400.8  398.9  387.0
 400.  194.5  340.4  373.8  392.8  402.5  403.7  404.3  404.2  402.4  390.3
 500.  196.1  341.2  375.0  394.5  404.6  405.8  406.6  406.6  404.9  392.6
 600.  196.8  341.9  376.0  395.8  406.2  407.6  408.4  408.6  406.9  394.4
 800.  198.1  342.8  377.6  397.7  408.6  410.1  411.0  411.4  409.8  397.2
1000.  199.5  343.5  378.0  399.1  410.4  411.9  412.9  413.4  411.9  399.1
1500.  201.4  344.5  379.9  401.0  412.5  414.1  415.2  415.7  414.2  401.4
2000.  202.7  345.2  380.8  402.3  414.1  415.7  416.8  417.4  415.9  402.9
3000.  204.3  345.9  382.1  404.2  416.2  417.9  419.0  419.7  418.2  405.2
C
C  MR:    0.6   2.0,   2.5,   3.0,   3.4,    3.5,    3.6,    3.8,    4.0,    4.5
  PC        CHARACTERISTIC VELOCITY (FT/SEC)
  20.  3911.  5759.  5960.  5886.  5771.  5741.  5711.  5653.  5597.  5465.
  40.  3946.  5762.  5989.  5933.  5821.  5791.  5761.  5703.  5646.  5512.
 100.  3992.  5766.  6027.  5995.  5887.  5858.  5828.  5769.  5711.  5575.
 300.  4090.  5768.  6082.  6117.  6030.  6002.  5974.  5915.  5855.  5720.
 500.  4069.  5768.  6073.  6092.  5999.  5971.  5942.  5882.  5823.  5683.
  _0.  4109.  5768.  6086.  6129.  6045.  6017.  5989.  5930.  5870.  5737.
  _00. 4163.  5768.  6085.  6200.  6140.  6119.  6090.  6032.  5974.  5825.
C
C MR = 0.6    2.0    2.5    3.0    3.4    3.5    3.6    3.8    4.0    4.5
  PC             COMBUSTION TEMPERATURE (DEG - R)
  20. 1627.  4484.  5199.  5441.  5495.  5500.  5502.  5500.  5493.  5463.
  40. 1665.  4501.  5259.  5526.  5586.  5591.  5594.  5592.  5584.  5552.
 100. 1780.  4553.  5440.  5779.  5857.  5865.  5868.  5867.  5858.  5819.
 300. 1867.  4573.  5541.  5949.  6048.  6058.  6061.  6062.  6053.  6007.
 500. 1953.  4593.  5642.  6118.  6238.  6250.  6254.  6256.  6247.  6195.
1000. 2033.  4603.  5712.  6260.  6404.  6418.  6425.  6429.  6418.  6361.
5000. 2227.  4618.  5835.  6562.  6789.  6814.  6827.  6836.  6826.  6752.
C
C  COEFFICEINTS FOR THROAT RADIUS CORRECTION CORRELATION
   (DELTA KL/DELTA RT) = A + B * LN(KL REF)
       A = -1.1576    B =  1.7368     RTREF =     7.07
C
C
C
  END DATA
C
C
C
C
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 22 of 32)

```
C
C
C
C  PROPELLANTS:      LIQUID FLORINE - LIQUID HYDROGEN
C
C  ASSUMPTIONS                  ENTHALPY           TEMP     STATE
C                    F2     -3056. CAL/MOLE     84.7  K    LIQ
C                    H2     -2154. CAL/MOLE     20.27 K    LIQ
C
C           ODK VALUES FOR THROAT RADIUS = 2.289 INCH
C
C              C-STAR & CHAMBER TEMP DATA EVALUATED AT ODE PC & ODE MR VALUESC
C
C
C
  SIZE OF VARIOUS DATA ARRAYS
  ODE PC     ODE MR     ODE EPS    ODK PC     ODK MR     ODK EPS
     6          10         16         6          10         16
C
  ODE MIXTURE RATIO VALUES
  MR=   0.0    2.0    4.0    6.0    8.0    10.0   12.0   14.0   16.0   20.0
C
```

EPS CHAMBER PRESSURE = 40.0 ODE SPECIFIC IMPULSE

EPS	0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	20.0
1.	102.3	306.5	324.0	317.4	310.2	305.2	301.7	298.0	293.5	284.0
2.	117.0	353.9	378.8	375.6	368.1	362.4	358.5	354.7	349.9	338.7
4.	124.6	380.0	409.9	411.5	405.3	399.6	395.5	391.9	387.4	375.3
10.	130.9	401.7	436.1	442.8	440.5	435.8	431.8	428.5	424.7	412.3
20.	133.9	412.5	449.2	458.7	459.2	456.5	453.2	450.1	446.8	434.7
40.	136.0	420.3	458.6	470.2	473.0	472.3	470.3	467.9	465.1	453.3
70.	137.2	425.0	464.4	477.2	481.4	482.0	481.2	479.6	477.4	465.3
100.	137.9	427.4	467.4	480.8	485.8	487.1	486.9	485.9	484.2	471.7
150.	138.5	429.8	470.3	484.3	490.0	492.0	492.5	492.0	490.8	477.8
200.	138.9	431.2	472.0	486.5	492.5	495.0	495.9	495.8	495.0	481.5
300.	139.4	432.9	474.2	489.1	495.6	498.7	500.0	500.4	500.0	486.1
400.	139.6	434.0	475.5	490.6	497.5	500.9	502.5	503.2	503.1	489.0
600.	139.9	435.2	477.0	492.6	499.9	503.6	505.6	506.6	506.9	492.4
800.	140.1	436.0	478.0	493.8	501.3	505.3	507.5	508.8	509.2	494.5
1000.	140.2	436.5	478.7	494.6	502.3	506.4	508.8	510.2	510.9	496.0
3000.	140.4	438.5	481.2	497.7	506.0	510.8	513.8	515.7	517.0	502.5

C

EPS CHAMBER PRESSURE = 100.0 ODE SPECIFIC IMPULSE

EPS	0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	20.0
1.	102.3	306.5	325.2	320.7	314.3	309.6	306.1	302.5	298.1	288.6
2.	117.0	354.0	379.6	378.7	372.3	367.1	363.2	359.6	355.0	343.9
4.	124.6	380.0	410.4	413.9	409.3	404.2	400.3	396.8	392.5	380.6
10.	130.9	401.7	436.4	444.3	443.4	439.9	436.4	433.2	429.6	417.5
20.	133.9	412.5	449.4	459.8	461.4	459.8	457.2	454.5	451.5	439.7
40.	136.0	420.3	458.8	471.0	474.6	474.8	473.5	471.6	469.3	457.5
70.	137.2	425.0	464.5	477.8	482.7	484.0	483.7	482.7	481.0	486.6
100.	137.9	427.4	467.5	481.4	486.8	488.8	489.1	488.6	487.3	474.5
150.	138.5	429.8	470.4	484.8	490.9	493.4	494.3	494.3	493.6	480.2
200.	138.9	431.2	472.1	486.9	493.3	496.3	497.5	497.8	497.4	483.7
300.	139.4	432.9	474.2	489.4	496.3	499.7	501.4	502.1	502.1	487.9
400.	139.6	434.0	475.5	490.9	498.1	501.8	503.8	504.7	504.9	490.5

Figure 6.3. Propellant Library (PROPLIB) (Sheet 23 of 32)

600.	139.9	435.2	477.1	492.8	500.4	504.4	506.7	507.9	508.5	493.8
800.	140.1	436.0	478.1	494.0	501.7	506.0	508.4	509.9	510.6	495.8
1000.	140.2	436.5	478.7	494.8	502.7	507.1	509.7	511.3	512.1	497.3
3000.	140.4	438.5	481.2	497.8	506.3	511.2	514.3	516.4	517.8	503.5

[illegible]S CHAMBER PRESSURE = 300.0 ODE SPECIFIC IMPULSE

1.	102.3	306.5	326.3	324.2	318.9	314.6	311.3	307.8	303.6	294.2
2.	117.0	354.0	380.3	381.8	377.0	372.5	368.8	365.4	361.0	350.1
4.	124.6	380.0	410.9	416.2	413.5	409.4	405.8	402.1	398.6	387.0
10.	130.9	401.7	436.6	445.8	446.4	444.2	441.4	438.6	435.4	423.7
20.	133.9	412.5	449.6	460.8	463.6	463.2	461.5	459.3	456.7	445.2
40.	136.0	420.3	458.9	471.8	476.2	477.3	476.8	475.6	473.8	461.7
70.	137.2	425.0	464.6	478.4	483.9	485.9	486.4	485.9	484.8	472.0
100.	137.9	427.4	467.6	481.9	487.9	490.5	491.4	491.4	490.6	477.4
150.	138.5	429.8	470.4	485.2	491.8	494.9	496.2	496.6	496.3	482.6
200.	138.9	431.2	472.2	487.2	494.1	497.5	499.2	499.9	499.9	485.8
300.	139.4	432.9	474.3	489.7	497.0	500.8	502.8	503.9	504.2	489.8
400.	139.6	434.0	475.6	491.2	498.7	502.8	505.0	506.3	506.8	492.2
600.	139.9	435.2	477.1	493.1	500.9	505.2	507.7	509.2	510.0	495.3
800.	140.1	436.0	478.1	494.2	502.2	506.7	509.4	511.1	512.0	497.3
1000.	140.2	436.5	478.8	495.0	503.1	507.7	510.5	512.3	513.4	498.7
3000.	140.4	438.1	481.2	497.9	506.5	511.6	514.9	517.1	518.6	504.6

C

EPS CHAMBER PRESSURE = 500.0 ODE SPECIFIC IMPULSE

1.	102.3	306.5	326.7	325.7	320.9	316.9	313.6	310.3	306.2	296.9
2.	117.0	354.0	380.5	383.0	379.0	374.8	371.4	368.0	363.8	353.0
4.	124.6	380.0	411.0	417.0	415.2	411.6	408.3	405.2	401.4	389.9
10.	130.9	401.7	436.7	446.3	447.6	446.0	443.5	441.0	437.9	426.4
20.	133.9	412.5	449.7	461.3	464.5	464.5	463.2	461.4	459.0	447.5
40.	136.0	420.3	459.0	472.1	476.9	478.3	478.1	477.2	475.6	463.4
70.	137.2	425.0	464.7	478.7	484.1	486.7	487.4	487.2	486.3	473.3
[illegible]0.	137.9	427.4	467.6	482.1	488.4	491.2	492.3	492.5	492.0	478.6
[illegible]0.	138.5	429.8	470.5	485.4	492.1	495.4	497.0	497.6	497.5	483.6
200.	138.9	431.2	472.2	487.4	494.4	498.0	499.9	500.7	500.9	486.7
300.	139.4	432.9	474.3	489.8	497.3	501.2	503.4	504.6	505.0	490.5
400.	139.6	434.0	475.6	491.3	499.0	503.1	505.5	506.9	507.6	492.5
600.	139.9	435.2	477.2	493.2	501.1	505.5	508.2	509.8	510.7	495.9
800.	140.1	436.0	478.1	494.3	502.4	506.9	509.8	511.5	512.6	497.9
1000.	140.2	436.5	478.8	495.1	503.2	508.0	510.9	512.7	513.9	499.3
3000.	140.4	438.5	481.3	498.0	506.6	511.8	515.1	517.3	518.9	505.0

C

EPS CHAMBER PRESSURE = 1000.0 ODE SPECIFIC IMPULSE

1.	102.3	306.5	327.1	327.4	323.5	319.9	316.8	313.6	309.7	300.4
2.	117.0	354.0	380.7	384.5	381.5	377.9	374.7	371.5	367.5	356.8
4.	124.6	380.0	411.2	418.1	417.5	414.4	411.5	408.6	405.0	393.7
10.	130.9	401.7	436.8	447.0	449.0	448.1	446.2	444.0	441.3	429.9
20.	133.9	412.5	449.7	461.7	465.5	466.1	465.4	463.9	461.9	450.3
40.	136.0	420.3	459.0	472.4	477.6	479.5	479.8	479.2	478.0	465.6
70.	137.2	425.0	464.7	478.9	485.0	487.7	488.7	488.8	488.2	475.0
100.	137.9	427.4	467.6	482.3	488.9	492.0	493.4	493.8	493.6	480.0
150.	138.5	429.8	470.5	485.6	492.6	496.1	497.9	498.7	498.8	484.8
200.	138.9	431.2	472.2	487.6	494.8	498.6	500.7	501.8	502.1	487.8
300.	139.4	432.9	474.3	490.0	497.6	501.7	504.1	505.4	506.0	491.5
400.	139.6	434.0	475.6	491.5	499.3	503.6	506.1	507.7	508.5	493.8
600.	139.9	435.2	477.2	493.3	501.3	505.9	508.7	510.4	511.4	496.8
800.	140.1	436.0	478.1	494.4	502.6	507.3	510.2	512.1	513.2	498.7
1000.	140.2	436.5	478.8	495.1	503.4	508.3	511.3	513.3	514.5	500.1
3000.	140.4	438.5	481.3	498.0	506.7	512.0	515.3	517.7	519.3	505.6

[illegible]S CHAMBER PRESSURE = 5000.0 ODE SPECIFIC IMPULSE

Figure 6.3. Propellant Library (PROPLIB) (Sheet 24 of 32)

```
    1.   102.3   306.5   327.7   330.6   328.6   326.1   323.6   320.8   317.4   308.4
    2.   117.0   354.0   381.1   386.9   386.3   384.1   381.7   379.1   375.8   365.4
    4.   124.6   380.0   411.4   419.8   421.0   419.8   418.0   415.8   413.0   402.2
   10.   130.9   401.7   437.0   448.0   451.5   452.1   451.4   450.1   448.1   437.0
   20.   133.9   412.5   449.8   462.5   467.4   469.1   469.3   468.8   467.6   455.7
   40.   136.0   420.3   459.1   473.0   479.0   481.6   482.7   482.9   482.4   469.6
   70.   137.2   425.0   464.8   479.4   486.1   489.4   491.0   491.7   491.7   478.2
  100.   137.9   427.4   467.7   482.7   489.8   493.4   495.4   496.4   496.6   482.8
  150.   138.5   429.8   470.5   485.9   493.3   497.4   499.6   500.9   501.4   487.2
  200.   138.9   431.2   472.3   487.8   495.5   497.3   502.2   503.7   504.4   490.0
  300.   139.4   432.9   474.4   490.2   498.1   499.7   505.3   507.0   508.0   493.5
  400.   139.6   434.0   475.6   491.7   499.7   504.4   507.3   509.1   510.2   495.7
  600.   139.9   435.2   477.2   493.4   501.7   506.6   509.6   511.6   512.9   498.6
  800.   140.1   436.0   478.1   494.5   502.9   507.9   511.0   513.2   514.5   500.4
 1000.   140.2   436.5   478.8   495.3   503.8   508.8   512.0   514.2   515.7   501.7
 3000.   140.4   438.5   481.3   498.1   507.0   512.3   515.8   518.3   520.0   506.6
C
  ODK MIXTURE RATIOS
C MR=     0.0     2.0     4.0     6.0     8.0    10.0    12.0    14.0    16.0    20.0
C
 EPS   CHAMBER PRESSURE = 40.0    ODK SPECIFIC IMPULSE
    1.   102.3   306.4   320.4   314.4   308.3   304.0   300.8   297.2   292.8   283.2
    2.   117.0   353.9   372.1   366.3   360.3   356.2   353.5   350.5   345.6   333.8
    4.   124.6   380.0   401.3   395.9   390.1   386.3   384.2   382.2   377.3   363.6
   10.   130.9   401.6   425.8   420.9   415.4   411.8   410.3   409.7   404.5   388.8
   20.   133.9   412.4   438.0   433.4   428.0   424.6   423.4   423.5   418.3   401.5
   40.   136.0   420.2   446.8   442.4   437.1   433.7   432.7   433.4   428.1   410.5
   70.   137.2   424.9   452.2   447.8   442.5   439.2   438.3   439.3   434.0   415.8
  100.   137.9   427.3   455.0   450.6   445.3   442.0   441.1   442.3   437.0   418.6
  150.   138.5   429.6   457.6   453.3   448.0   444.6   443.8   445.2   439.8   421.2
  200.   138.9   430.9   459.3   454.9   449.6   446.3   445.4   446.9   441.5   422.7
  300.   139.4   432.5   461.2   456.9   451.5   448.2   447.4   449.0   443.6   424.6
  400.   139.6   433.4   462.4   458.1   452.7   449.4   448.6   450.2   444.8   425.7
  600.   139.9   434.5   463.9   459.6   454.2   450.8   450.0   451.7   446.3   427.1
  800.   140.1   435.1   464.8   460.5   455.1   451.7   450.9   452.6   447.2   427.9
 1000.   140.2   435.5   465.4   461.1   455.7   452.3   451.5   453.2   447.8   428.5
 3000.   140.4   437.0   467.7   463.4   457.9   454.5   453.7   455.6   450.1   430.6
     C
 EPS   CHAMBER PRESSURE = 100.0   ODK SPECIFIC IMPULSE
    1.   102.3   306.4   323.4   319.5   313.6   309.2   305.8   302.2   297.9   288.4
    2.   117.0   353.9   375.9   373.6   368.5   364.4   361.3   358.1   353.6   342.3
    4.   124.6   380.0   405.7   404.8   400.7   397.2   394.7   392.3   388.3   375.6
   10.   130.9   401.6   430.7   431.4   428.2   425.4   423.6   422.3   419.2   404.7
   20.   133.9   412.4   443.3   444.8   442.2   439.8   438.3   437.7   435.4   419.6
   40.   136.0   420.2   452.3   454.5   452.3   450.2   449.0   448.9   447.2   430.4
   70.   137.2   424.9   457.8   460.3   458.4   456.4   455.4   455.5   454.3   437.0
  100.   137.9   427.3   460.7   463.3   461.5   459.7   458.7   459.0   458.0   440.3
  150.   138.5   429.6   463.4   466.2   464.5   462.8   461.9   462.3   461.5   443.5
  200.   138.9   430.9   465.1   468.0   466.4   464.6   463.8   464.3   463.6   445.4
  300.   139.4   432.5   467.1   470.2   468.6   466.9   466.1   466.7   466.2   447.7
  400.   139.6   433.4   468.4   471.5   470.0   468.3   467.5   468.2   467.7   449.2
  600.   139.9   434.5   469.9   473.1   471.6   469.9   469.2   469.9   469.6   450.8
  800.   140.1   435.1   470.8   474.1   472.6   417.0   470.2   471.0   470.7   451.8
 1000.   140.2   435.6   471.4   474.7   473.3   471.7   470.9   471.7   471.5   452.6
 3000.   140.4   437.0   473.8   477.3   475.9   474.3   473.6   474.5   474.4   455.2
C
 EPS   CHAMBER PRESSURE = 300.   ODK SPECIFIC IMPULSE
    1.   102.3   306.4   325.7   323.9   318.7   314.5   311.2   307.8   303.6   294.2
    2.   117.0   353.9   379.0   380.0   375.9   371.7   368.4   365.0   360.8   349.8
    4.   124.6   380.0   409.2   412.5   410.0   406.7   403.9   401.1   397.4   385.6
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 25 of 32)

```
  10.   130.9  401.6  434.6  440.5  439.7  437.5  435.4  433.5  431.0  418.3
  20.   133.9  412.5  447.4  454.8  454.9  453.4  451.8  450.5  448.9  435.5
  40.   136.0  420.3  456.7  465.1  466.0  465.0  463.8  463.0  462.2  448.2
  70.   137.2  424.9  462.3  471.3  472.8  472.1  471.2  470.6  470.3  456.1
 100.   137.9  427.4  465.2  474.6  476.3  475.8  475.0  474.6  474.6  460.1
 150.   138.5  429.6  468.0  477.7  479.6  479.3  478.7  478.4  478.7  464.0
 200.   138.9  431.0  469.7  479.6  481.7  481.5  480.9  480.7  481.1  466.4
 300.   139.4  432.5  471.8  481.9  484.2  484.1  483.6  483.5  484.1  469.3
 400.   139.6  433.4  473.1  483.3  485.7  485.7  485.2  485.2  485.9  471.0
 600.   139.9  434.5  474.6  485.0  487.6  487.6  487.2  487.3  488.2  473.1
 800.   140.1  435.2  475.5  486.1  488.7  488.8  488.5  488.6  489.5  474.4
1000.   140.2  435.6  476.2  486.8  489.5  489.6  489.3  489.4  490.4  475.3
3000.   140.4  437.0  478.6  489.6  492.4  492.7  492.4  492.7  493.9  478.6
C
 EPS    CHAMBER PRESSURE = 500.0   CDK SPECIFIC IMPULSE
   1.   102.3  306.4  326.3  325.5  320.9  316.9  313.6  310.3  306.2  296.9
   2.   117.0  353.9  379.8  382.0  378.4  374.5  371.2  367.9  363.7  352.8
   4.   124.6  380.0  410.1  414.9  413.1  410.0  407.2  404.4  400.8  389.1
  10.   130.9  401.6  435.6  443.2  443.3  441.5  439.5  437.6  435.1  423.0
  20.   133.9  412.5  448.5  457.7  458.9  457.9  456.5  455.1  453.5  441.1
  40.   136.0  420.3  457.7  468.1  470.3  470.0  469.0  468.1  467.2  454.5
  70.   137.2  425.0  463.4  474.5  477.3  477.3  476.7  476.1  475.6  462.8
 100.   137.9  427.4  466.3  477.8  480.9  481.2  480.7  480.3  480.0  467.2
 150.   138.5  429.6  469.1  481.0  484.4  484.8  484.5  484.3  484.3  471.4
 200.   138.9  431.0  470.8  482.9  486.5  487.1  486.9  486.7  486.9  473.9
 300.   139.4  432.5  472.9  485.3  489.0  489.8  489.7  489.7  490.0  477.0
 400.   139.6  433.5  474.2  486.7  490.6  491.5  491.5  491.5  492.0  478.9
 600.   139.9  434.5  475.8  488.5  492.5  493.5  493.6  493.7  494.3  481.2
 800.   140.1  435.2  476.7  489.5  493.7  494.7  494.8  495.0  495.7  482.6
1000.   140.2  435.6  477.4  490.3  494.5  495.6  495.7  495.9  496.7  483.5
3000.   140.4  437.0  479.8  493.1  497.6  498.8  499.1  499.4  500.4  487.1

 EPS    CHAMBER PRESSURE = 1000.0   ODK SPECIFIC IMPULSE
   1.   102.3  306.4  327.0  327.4  323.4  319.9  316.8  313.6  309.6  300.4
   2.   117.0  353.9  380.4  384.1  381.3  377.8  374.6  371.5  367.5  356.8
   4.   124.6  380.0  410.8  417.2  416.3  413.7  411.0  408.3  404.8  393.5
  10.   130.9  401.6  436.4  445.6  446.9  445.7  444.0  442.2  439.8  428.3
  20.   133.9  412.5  449.3  460.2  462.8  462.5  461.5  460.2  458.6  447.1
  40.   136.0  420.3  458.5  470.7  474.4  474.9  474.5  473.7  472.7  461.2
  70.   137.2  425.0  464.2  477.1  481.5  482.5  482.5  482.0  481.5  470.0
 100.   137.9  427.4  467.1  480.4  485.1  486.5  486.6  486.4  486.1  474.7
 150.   138.5  429.6  469.9  483.6  488.7  490.3  490.7  490.6  490.5  479.1
 200.   138.9  431.0  471.7  485.6  490.9  492.7  493.1  493.2  493.2  481.9
 300.   139.4  432.5  473.8  488.0  493.5  495.5  496.1  496.3  496.6  485.2
 400.   139.6  433.5  475.1  489.4  495.1  497.2  497.9  498.2  498.6  487.2
 600.   139.9  434.5  476.6  491.2  497.1  499.3  500.1  500.5  501.0  489.7
 800.   140.1  435.2  477.6  492.3  498.3  500.6  501.5  502.0  502.5  491.2
1000.   140.2  435.6  478.2  493.1  499.1  501.5  502.5  502.9  503.6  492.2
3000.   140.4  437.1  480.7  495.9  502.3  504.9  506.0  506.7  507.5  496.1
C
 EPS    CHAMBER PRESSURE = 5000.0   ODK SPECIFIC IMPULSE
   1.   102.3  306.5  327.7  330.5  329.0  326.1  323.6  320.9  317.4  308.4
   2.   117.0  354.0  381.0  386.9  386.2  384.0  381.7  379.1  375.7  365.4
   4.   124.6  380.0  411.3  419.7  420.9  419.7  417.9  415.8  412.9  402.1
  10.   130.9  401.7  436.9  447.9  451.2  451.7  451.0  449.7  447.8  436.9
  20.   133.9  412.5  449.8  462.3  467.0  468.5  468.6  468.0  466.8  455.5
  40.   136.0  420.3  459.1  472.8  478.5  480.9  481.7  481.7  481.1  469.5
  70.   137.2  425.0  464.7  479.2  485.6  488.6  489.9  490.3  490.1  478.1
 100.   137.9  427.4  467.6  482.5  489.3  492.6  494.1  494.8  494.8  482.7
 150.   138.5  429.8  470.5  485.7  492.8  496.4  498.3  499.1  499.5  487.1
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 26 of 32)

```
 200.  138.9  431.2  472.2  487.6  495.0  498.8  500.8  501.8  502.3  485.8
 300.  139.4  432.9  474.3  490.0  497.6  501.6  503.9  505.1  505.7  493.1
 400.  139.6  434.0  475.6  491.4  499.2  503.4  505.7  507.1  507.8  495.1
 600.  139.9  435.2  477.1  493.2  501.2  505.5  508.0  509.5  510.4  497.5
 800.  140.1  436.0  478.1  494.3  502.4  506.8  509.4  511.0  512.0  499.0
1000.  140.2  436.5  478.7  495.1  503.2  507.8  510.4  512.0  513.1  500.1
3000.  140.4  438.5  481.2  497.9  506.4  511.2  514.1  515.9  517.2  504.0
C
C MR =  0.1    2.0    4.0    6.0    8.0   10.0   12.0   14.0   16.0   20.0
  PC          CHAPACTERISTIC VELOCITY   (FT/SEC)
  40.  2583.  7820.  8372.  8247.  8067.  7941.  7854.  7758.  7657.  7410.
 100.  2583.  7820.  8390.  8322.  8165.  8046.  7962.  7877.  7770.  7525.
 300.  2583.  7820.  8402.  8400.  8275.  8169.  8088.  8008.  7906.  7663.
 500.  2583.  7820.  8406.  8431.  8322.  8223.  8146.  8067.  7969.  7727.
1000.  2583.  7820.  8409.  8468.  8381.  8293.  8221.  8147.  8053.  7814.
5000.  2583.  7820.  8412.  8527.  8495.  8438.  8382.  8321.  8240.  8008.
C
C MR =  0.1    2.0    4.0    6.0    8.0   10.0   12.0   14.0   16.0   20.0
  PC       COMBUSTION TEMPERATURE  (DEG - R)
  40.   142.  3063.  4916.  5732.  6246.  6662.  7013.  7266.  7417.  7527.
 100.   142.  3063.  5002.  5927.  6503.  6955.  7327.  7597.  7763.  7883.
 300.   142.  3063.  5086.  6151.  6815.  7321.  7725.  8021.  8206.  8339.
 500.   142.  3063.  5118.  6250.  6960.  7494.  7918.  8227.  8423.  8563.
1000.   142.  3063.  5154.  6376.  7153.  7732.  8184.  8515.  8727.  8877.
5000.   142.  3064.  5210.  6623.  7571.  8272.  8811.  9207.  9467.  9646.
C
C  COEFFICIENTS FOR ODK THROAT RADIUS CORRECTION CORRELATION
C    (DELTA KL/DELTA RT) = A + B * LN(REF KL)
      A = -0.2791    B = 1.2005         RTREF = 2.289
C
  END DATA
C
C
C
C
C
C
C
C
C
C
C
C
C
C  PROPELLANT:  LIQUID FLORINE - LIQUID HYDRAZINE
C
C  ASSUMPTIONS:             ENTHAPLY           TEMP     STATE
C                   F2     -3056. CAL MOLE   84.7 K     LIQ
C                   N2H4   12054. CAL MOLE  298.16K     LIQ
C
C
C
C  MONO-PROPELLANT, MR=0.0, DATA FROM TRAM 72 RUNS
C     ODK VALUES CORRESPOND TO A THROAT RADIUS OF 2.289 INCHES
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 27 of 32)

```
C
C
C
C
C
 SIZE OF VARIOUS DATA ARRAYS
 ODE PC     ODE MR     ODE EPS    ODK PC     ODK MR     ODK EPS
    6          9         16          6          9         16
C
 ODE MIXTURE RATIO VALUES
C MR      0.0     1.0     1.4     1.8     2.0     2.2     2.4     3.0     5.0
C
 EPS    CHAMBER PRESSURE =  40.0             ODE SPECIFIC IMPULSE
    1.  201.5   260.1   265.4   268.3   268.1   267.1   265.6   259.5   213.6
    2.  232.4   307.8   314.7   318.8   319.2   318.3   316.6   308.7   245.2
    4.  250.5   337.4   346.3   351.5   352.7   352.3   350.5   340.0   263.0
   10.  268.0   363.6   376.2   383.1   385.1   385.8   384.4   367.1   280.1
   20.  278.5   377.1   392.4   401.0   403.7   405.3   404.6   380.7   290.5
   40.  287.5   387.0   404.4   414.8   418.2   420.6   420.6   390.6   299.5
   70.  293.9   393.1   411.8   423.4   427.4   430.3   430.6   396.7   306.0
  100.  297.6   396.2   415.7   427.9   432.2   435.4   435.9   400.2   309.8
  150.  301.8   399.3   419.4   432.3   436.9   440.5   441.1   403.7   313.8
  200.  304.3   401.1   421.7   435.0   439.8   443.6   444.3   406.1   316.6
  300.  308.0   403.4   424.5   438.2   443.3   447.3   448.2   409.2   320.2
  400.  310.2   404.8   426.2   440.2   445.4   449.6   450.6   411.3   322.6
  600.  313.4   406.5   428.3   442.7   448.1   452.5   453.5   414.1   325.9
  800.  315.6   407.5   429.6   444.2   449.7   454.2   455.3   415.9   328.1
 1000.  317.2   408.2   430.5   445.2   450.8   455.4   456.6   417.3   329.7
 3000.  324.5   410.9   433.8   449.2   455.0   460.0   461.5   422.9   336.9
C
 EPS    CHAMBER PRESSURE =  100.0            ODE SPECIFIC IMPULSE
    1.  201.7   262.9   268.8   271.9   271.9   271.0   269.5   263.2   213.6
    2.  232.9   310.4   318.2   322.7   323.3   322.6   321.0   312.5   245.4
    4.  251.5   339.5   349.6   355.3   356.6   356.5   354.9   343.0   263.6
   10.  269.5   365.0   378.7   386.4   388.7   389.7   388.6   368.9   281.2
   20.  280.3   378.1   394.3   403.7   406.7   408.6   408.3   382.0   291.9
   40.  289.5   387.8   405.8   416.8   420.6   432.2   432.4   391.6   301.1
   70.  296.0   393.7   412.9   425.0   429.2   432.4   432.9   397.7   307.7
  100.  299.8   396.7   416.7   429.3   433.8   437.3   437.9   401.1   311.5
  150.  304.1   399.7   420.3   433.4   438.2   442.0   442.8   404.7   315.6
  200.  306.6   401.5   422.5   436.0   441.0   444.9   445.8   407.1   318.3
  300.  310.3   403.7   425.1   439.1   444.3   448.5   449.4   410.3   322.0
  400.  312.6   405.0   426.8   441.0   446.3   450.7   451.7   412.4   324.4
  600.  315.8   406.7   428.8   443.3   448.8   453.4   454.4   415.1   327.7
  800.  318.0   407.7   430.0   444.8   450.4   455.0   456.2   417.0   329.9
 1000.  319.6   408.4   430.8   445.8   451.4   456.1   457.4   418.3   331.5
 3000.  327.0   411.0   434.1   449.5   455.4   460.4   462.0   423.6   338.5
C
 EPS    CHAMBER PRESSURE =  300.0            ODE SPECIFIC IMPULSE
    1.  202.1   265.8   272.5   276.1   276.4   275.7   274.3   267.6   213.7
    2.  233.9   313.1   322.0   327.1   328.0   327.6   326.1   316.7   245.7
    4.  253.2   341.5   353.0   359.5   361.2   361.5   360.1   346.0   264.6
   10.  271.9   366.3   381.3   389.9   392.5   394.0   393.3   370.8   282.8
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 28 of 32)

20.	283.0	379.1	396.2	406.4	409.8	412.1	412.1	383.4	293.8
40.	292.4	388.5	407.2	418.9	422.9	426.0	426.3	392.7	303.2
70.	299.0	394.2	414.1	426.6	431.1	434.6	435.2	398.8	309.9
100.	302.9	397.2	417.6	430.7	435.4	439.2	439.9	402.3	313.8
150.	307.2	400.1	421.1	434.6	439.6	443.6	444.5	405.9	317.9
200.	309.7	401.9	423.2	437.0	442.2	446.4	447.3	408.3	320.7
300.	313.5	404.0	425.7	440.0	445.3	449.7	450.7	411.5	324.3
400.	315.8	405.3	427.3	441.8	447.3	451.8	452.8	413.6	326.7
600.	319.0	406.9	429.2	444.0	449.6	454.3	455.4	416.3	330.0
800.	321.2	407.9	430.4	445.4	451.0	455.8	457.1	418.1	332.1
1000.	322.8	408.6	431.2	446.3	452.0	456.9	458.2	419.4	333.7
3000.	331.7	411.1	434.3	449.8	455.8	460.9	462.6	424.3	340.2

C

EPS CHAMBER PRESSURE = 500.0 ODE SPECIFIC IMPULSE

1.	202.5	267.0	274.2	278.0	278.4	277.8	276.5	269.5	213.8
2.	234.7	314.1	323.7	329.0	330.1	329.9	328.5	318.4	246.0
4.	254.3	342.3	354.5	361.3	363.2	363.7	362.4	347.1	265.1
10.	273.2	366.8	382.3	391.3	394.2	395.8	395.3	371.5	283.7
20.	284.4	379.5	397.0	407.5	411.1	413.6	413.7	383.9	294.8
40.	293.9	388.8	407.8	419.7	423.9	427.1	427.5	393.2	304.3
70.	300.6	394.4	414.5	427.3	431.9	435.5	436.2	399.3	311.0
100.	304.4	397.4	418.0	431.3	436.1	439.9	440.7	402.8	314.9
150.	308.7	400.2	421.7	435.1	440.2	444.3	445.2	406.5	319.1
200.	311.3	402.0	423.4	437.5	442.7	446.9	447.9	408.9	321.8
300.	315.1	404.1	426.0	440.4	445.8	450.2	451.2	412.1	325.4
400.	317.4	405.4	427.5	442.1	447.6	452.2	453.3	414.1	327.9
600.	320.6	407.0	429.4	444.3	449.9	454.6	455.9	416.9	331.1
800.	322.4	408.0	430.5	445.6	451.3	456.1	457.5	418.6	333.2
1000.	324.4	408.6	431.3	446.5	452.3	457.2	458.6	419.8	334.7
3000.	331.7	411.2	434.4	450.0	456.0	461.1	462.8	424.6	341.0

C

EPS CHAMBER PRESSURE = 1000.0 ODE SPECIFIC IMPULSE

1.	203.2	268.5	276.3	280.5	281.1	280.6	279.4	271.9	213.9
2.	235.9	315.4	325.8	331.6	332.9	332.9	331.6	320.4	246.6
4.	255.9	343.2	356.2	363.6	365.7	366.5	365.4	348.5	266.1
10.	275.1	367.4	383.5	393.1	396.2	398.1	397.8	372.3	285.0
20.	286.5	379.9	397.9	408.9	412.7	415.4	415.7	384.6	296.3
40.	296.1	389.1	408.5	420.7	425.1	428.4	429.0	393.8	305.9
70.	302.8	394.7	415.0	428.1	432.8	436.6	437.3	400.0	312.6
100.	306.7	397.6	418.4	431.9	436.9	440.9	441.7	403.5	316.6
150.	311.0	400.4	421.8	435.7	440.9	445.1	446.0	407.2	320.7
200.	313.6	402.1	423.8	438.0	443.3	447.7	448.6	409.6	323.4
300.	317.3	404.2	426.2	440.8	446.3	450.8	451.9	412.8	327.0
400.	319.6	405.5	427.8	442.5	448.1	452.7	453.9	414.9	329.4
600.	322.9	407.1	429.6	444.6	450.3	455.1	456.4	417.5	332.5
800.	325.1	408.1	430.7	445.9	451.7	456.5	457.9	419.2	334.6
1000.	326.7	408.7	431.5	446.8	452.6	457.5	459.0	420.4	336.1
3000.	333.9	411.2	434.5	450.1	456.2	461.3	463.0	425.0	342.0

C

EPS CHAMBER PRESSURE = 5000.0 ODE SPECIFIC IMPULSE

1.	206.1	271.1	280.6	285.7	286.8	286.8	285.8	276.6	214.9
2.	240.0	317.4	329.7	336.7	338.7	339.3	338.2	323.8	248.7
4.	260.7	344.7	359.4	368.1	370.8	372.3	371.6	350.7	269.1
10.	280.5	368.3	385.7	396.3	400.0	402.6	402.7	373.8	288.7
20.	292.1	380.6	399.4	411.4	415.6	418.8	419.3	385.8	300.3
40.	301.8	389.6	409.6	422.6	427.3	431.0	431.8	395.1	310.0
70.	308.6	395.1	415.9	429.5	434.6	438.6	439.5	401.4	316.8
100.	312.5	397.9	419.2	433.2	438.4	442.7	443.6	405.0	320.6
150.	316.8	400.7	422.4	436.8	442.1	446.6	447.6	408.8	324.7
200.	319.3	402.4	424.4	438.9	444.4	449.0	450.1	411.2	327.4

Figure 6.3. Propellant Library (PROPLIB) (Sheet 29 of 32)

```
 300.  323.1  404.5  426.7  441.6  447.2  451.9  453.1  414.3  330.8
 400.  325.4  405.7  428.2  443.2  448.9  453.7  455.0  416.4  333.1
 600.  328.6  407.3  430.0  445.2  451.0  455.9  457.4  418.9  335.9
 800.  330.7  408.2  431.1  446.4  452.3  457.3  458.8  420.4  337.7
1000.  332.3  408.8  431.8  447.3  453.2  458.2  459.8  421.5  339.0
3000.  339.3  411.3  434.7  450.5  456.6  461.8  463.5  425.7  343.9
C
  ODK MIXTURE RATIOS
C MR      0.0    1.0    1.4    1.8    2.0    2.2    2.4    3.0    5.0
C
 EPS   CHAMBER PRESSURE =  40.0             ODK SPECIFIC IMPULSE
   1.  201.5  257.9  264.0  267.2  267.1  266.0  264.4  258.2  213.4
   2.  232.4  300.8  308.8  314.0  314.2  313.0  310.9  302.4  245.2
   4.  250.5  325.3  334.6  341.5  342.0  340.6  338.1  327.8  262.0
  10.  268.0  346.3  356.7  365.3  366.1  364.3  361.4  349.3  275.3
  20.  278.5  357.0  367.9  377.4  378.4  376.4  373.3  360.0  281.6
  40.  287.5  364.7  376.0  386.1  387.3  385.2  381.8  367.7  286.0
  70.  293.9  369.3  380.8  391.3  392.6  390.4  387.0  372.3  288.5
 100.  297.6  371.7  383.3  394.1  395.4  393.1  389.6  374.7  289.8
 150.  301.8  374.0  385.7  396.6  398.0  395.7  392.1  376.9  291.0
 200.  304.3  375.4  387.2  398.2  399.6  397.3  393.7  378.3  291.7
 300.  308.0  377.1  388.9  400.1  401.5  399.2  395.5  379.9  292.6
 400.  310.2  378.1  390.0  401.2  402.7  400.3  396.6  380.9  293.1
 600.  313.4  379.4  391.3  402.6  404.1  401.7  398.0  382.1  293.7
 800.  315.6  380.1  392.1  403.5  404.9  402.5  398.8  382.8  294.1
1000.  317.2  380.7  392.6  404.0  405.5  403.1  399.3  383.3  294.4
3000.  324.5  382.6  354.7  406.2  407.7  405.3  401.4  385.1  295.3
C
 EPS   CHAMBER PRESSURE =  100.0            ODKSPECIFIC IMPULSE
   1.  201.7  262.0  268.3  271.5  271.6  270.7  269.2  262.8  213.6
   2.  232.9  306.5  315.2  320.5  321.3  320.5  318.8  309.9  245.3
   4.  251.5  332.4  342.8  349.8  351.4  350.9  348.8  337.6  262.5
  10.  269.5  354.6  366.7  375.3  378.1  377.6  375.1  361.3  276.4
  20.  280.3  366.0  378.9  388.5  392.0  391.4  388.7  373.3  283.0
  40.  289.5  374.3  387.8  398.1  402.2  401.6  398.7  382.1  287.6
  70.  296.0  379.3  393.3  403.9  408.4  407.8  404.7  387.3  290.3
 100.  299.8  381.9  396.1  406.9  411.7  411.0  407.9  390.0  291.7
 150.  304.1  384.4  398.8  406.8  414.8  414.0  410.9  392.6  292.9
 200.  306.6  385.9  400.4  411.6  416.6  415.9  412.7  394.2  293.7
 300.  310.3  387.8  402.4  413.7  418.9  418.2  414.9  396.0  294.6
 400.  312.6  388.9  403.6  415.0  420.3  419.5  416.2  397.2  295.2
 600.  315.8  390.3  405.0  416.6  422.0  421.2  417.9  398.5  295.8
 800.  318.0  391.1  405.9  417.5  423.0  422.2  418.9  399.4  296.2
1000.  319.6  391.7  406.6  418.2  423.7  422.9  419.5  400.0  296.5
3000.  327.0  393.9  408.9  420.7  426.3  425.5  422.1  402.1  297.5
C
 EPS   CHAMBER PRESSURE =  300.0            ODK SPECIFIC IMPULSE
   1.  202.1  265.5  272.4  276.0  276.3  275.6  274.2  267.4  213.7
   2.  233.9  311.6  321.1  326.4  327.5  327.1  325.6  316.0  245.7
   4.  253.2  338.6  350.3  357.3  359.3  359.6  358.0  344.9  264.0
  10.  271.9  362.0  375.8  384.5  387.5  388.8  387.1  369.6  280.0
  20.  283.0  374.0  369.0  398.7  402.4  404.3  402.4  382.3  288.0
  40.  292.4  382.8  398.7  409.2  413.3  415.8  413.8  391.4  293.6
  70.  299.0  388.2  404.7  415.6  420.1  423.0  420.8  397.0  296.9
 100.  302.9  391.0  407.8  419.0  423.6  426.7  424.5  399.9  298.6
 150.  307.2  393.7  410.8  422.2  427.0  430.3  428.0  402.6  300.2
 200.  309.7  395.3  412.6  424.2  429.1  432.5  430.2  404.3  301.1
 300.  313.5  397.3  414.8  426.6  431.6  435.1  432.8  406.3  302.3
 400.  315.8  398.6  416.2  428.0  433.1  436.8  434.4  407.5  303.0
 600.  319.0  400.0  417.8  429.8  435.0  438.8  436.4  409.0  303.8
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 30 of 32)

```
 800.   321.2  400.9  418.9  430.9  436.1  440.0  437.6  409.8  304.3
1000.   322.6  401.6  419.5  431.6  436.9  440.8  438.4  410.5  304.6
3000.   330.1  403.9  422.2  434.5  439.9  443.9  441.5  412.8  305.8
C
 EPS    CHAMBER PRESSURE =  500.0            ODK SPECIFIC IMPULSE
   1.   202.5  266.9  274.1  277.9  278.3  277.8  276.4  269.4  213.8
   2.   234.7  313.3  323.2  328.7  329.8  329.6  328.2  318.1  246.0
   4.   254.3  340.6  352.8  359.9  362.0  362.6  361.2  346.7  264.9
  10.   273.2  364.2  378.7  387.7  390.8  392.4  391.2  371.1  282.1
  20.   284.4  376.4  392.2  402.2  405.9  408.4  407.1  383.5  291.0
  40.   293.9  385.4  402.2  413.0  417.1  420.3  418.9  392.5  297.3
  70.   300.6  390.8  408.4  419.6  424.0  427.7  426.3  398.0  301.1
 100.   304.4  393.7  411.6  423.1  427.7  431.6  430.2  400.8  303.0
 150.   308.7  396.4  414.6  426.4  431.2  435.3  433.9  403.5  304.9
 200.   311.3  398.1  416.5  428.5  433.3  437.6  436.2  405.1  306.0
 300.   315.1  400.1  418.8  431.0  435.9  440.4  439.0  407.1  307.3
 400.   317.4  401.4  420.2  432.5  437.5  442.1  440.7  408.3  308.1
 600.   320.6  402.9  421.9  434.3  439.5  444.2  442.8  409.7  309.0
 800.   322.8  403.8  423.0  435.5  440.7  445.4  444.0  410.6  309.6
1000.   324.4  404.5  423.7  436.2  441.5  446.3  444.9  411.2  310.0
3000.    331.7  406.9  426.4  439.2  444.6  449.6  448.2  413.5  311.4
C
 EPS    CHAMBER PRESSURE =  1000.            ODK SPECIFIC IMPULSE
   1.   203.2  268.4  276.3  280.4  281.0  280.6  279.3  271.9  213.9
   2.   235.9  315.0  325.6  331.4  332.8  332.8  331.4  320.3  246.6
   4.   255.9  342.4  355.4  362.9  365.1  366.0  364.8  348.3  266.0
  10.   275.1  366.2  361.7  391.0  394.3  396.3  395.6  372.1  284.4
  20.   286.5  378.5  395.4  405.9  409.6  412.4  412.0  384.3  294.5
  40.   296.1  387.5  405.6  416.9  421.1  424.5  424.3  393.1  301.9
  70.   302.8  393.1  411.8  423.7  428.2  432.0  432.0  398.5  306.4
 100.   306.7  395.9  415.1  427.3  432.0  436.0  436.1  401.3  308.7
 150.   311.0  398.7  418.3  430.8  435.6  439.8  440.0  403.9  310.9
 200.   313.6  400.4  420.2  432.9  437.8  442.2  442.4  405.5  312.3
 300.   317.3  402.4  422.5  435.5  440.5  445.0  445.4  407.4  313.9
 400.   319.6  403.7  424.0  437.0  442.2  446.8  447.2  408.6  314.9
 600.   322.9  405.2  425.7  439.0  444.2  448.9  449.4  410.0  316.0
 800.   325.1  406.2  426.8  440.1  445.4  450.2  450.7  410.9  316.7
1000.   326.7  406.8  427.6  440.9  446.3  451.1  451.7  411.5  317.2
3000.   333.9  409.3  430.4  444.0  449.5  454.5  455.2  413.8  319.0
C
 EPS    CHAMBER PRESSURE =  5000.            ODK SPECIFIC IMPULSE
   1.   206.1  271.1  280.6  285.7  286.8  286.8  285.8  276.6  214.9
   2.   240.0  317.4  329.7  336.7  338.6  339.3  338.2  323.7  248.7
   4.   260.7  344.6  359.3  368.0  370.7  372.2  371.6  350.6  269.1
  10.   280.5  368.2  385.4  396.0  399.7  402.2  402.4  373.7  288.7
  20.   292.1  380.4  399.1  410.8  415.0  418.2  418.9  385.6  300.1
  40.   301.8  389.4  409.2  421.9  426.5  430.2  431.3  394.5  309.4
  70.   308.6  394.9  415.5  428.7  433.7  437.7  439.1  400.0  315.3
 100.   312.5  397.7  418.8  432.4  437.4  441.7  443.2  402.8  318.5
 150.   316.8  400.5  421.9  435.9  441.1  445.5  447.2  405.6  321.6
 200.   319.3  402.2  423.9  438.0  443.4  447.9  449.6  407.2  323.5
 300.   323.1  404.2  426.2  440.6  446.1  450.7  452.6  409.3  325.8
 400.   325.4  405.5  427.7  442.2  447.8  452.5  454.4  410.5  327.2
 600.   328.6  407.0  429.4  444.2  449.8  454.7  456.7  412.0  328.9
 800.   330.7  408.0  430.5  445.4  451.1  456.0  458.1  412.9  329.9
1000.   332.3  408.6  431.2  446.2  452.0  456.9  459.0  413.5  330.7
3000.   339.3  411.1  434.1  449.4  455.3  460.4  462.6  415.9  333.4
C
C MR =   .001    1.0    1.4    1.8    2.0    2.2    2.4    3.0    5.0
  PC        CHARACTERISTIC VELOCITY (FT/SEC)
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 31 of 32)

```
C

   40.   5125.   6756.   6900.   6988.   6990.   6966.   6927.   6764.   5419.
  100.   5310.   6819.   6980.   7075.   7082.   7063.   7025.   6854.   5420.
  300.   5146.   6865.   7070.   7176.   7190.   7176.   7141.   6956.   5422.
  500.   5159.   6911.   7109.   7221.   7239.   7228.   7194.   7000.   5425.
 1000.   5183.   6942.   7158.   7280.   7303.   7296.   7265.   7055.   5430.
 5000.   5272.   6994.   7252.   7401.   7438.   7444.   7418.   7153.   5465.
C
   PC          COMBUSTION TEMPERATURE (DEG - R)
   40.   1767.   5988.   6618.   7081.   7216.   7299.   7344.   7335.   5644.
  100.   1771.   6193.   6879.   7374.   7523.   7616.   7666.   7645.   5648.
  300.   1789.   6431.   7197.   7740.   7910.   8017.   8074.   8032.   5653.
  500.   1787.   6536.   7344.   7915.   8095.   8210.   8271.   8215.   5657.
 1000.   1805.   6670.   7542.   8153.   8351.   8477.   8543.   8462.   5666.
 5000.   1895.   6935.   7973.   8701.   8946.   9107.   9188.   9013.   5726.
C
C  COEFFICIENTS FOR CDK THROAT CORRECTION CORRELATION
C    (DELTA KL/DELTA RT) = A + B * LN(REF KL)
       A = -1.1543    B =  1.7378       RTREF =    2.289
C
C
  END DATA
C
C
C
C
C
C
C
C
C
C
C
C
C
```

Figure 6.3. Propellant Library (PROPLIB) (Sheet 32 of 32)