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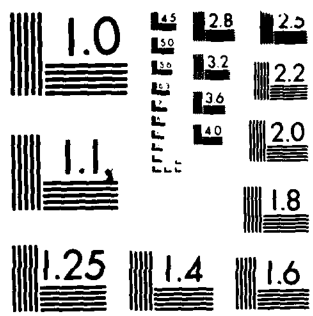

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MELBOURNE, VICTORIA

Systems Technical Memorandum 67

EXTENSIONS AND MODIFICATIONS TO THE ARL POINT-PERFORMANCE PROGRAM

V.A.E. ROUQUEIROL

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Systems Technical Memorandum 67

EXTENSIONS AND MODIFICATIONS TO THE ARL POINT-PERFORMANCE PROGRAM

by

V.A.E. ROUQUEIROL

SUMMARY

Several years of usage of the ARL point performance program described in ARL Technical Engineering Report 160 have indicated the desirability of certain improvements and extensions which have been incorporated. This document describes the purpose and nature of the various changes in sufficient detail to allow it to be used independently of the original report.

POSTAL ADDRESS: Director, Aeronautical Research Laboratories,
P.O. Box 4331, Melbourne, Victoria, 3001, Australia.

Page No.

NOTATION

Symbols	Definition	Unit or Value
C_D	Drag coefficient	
ΔC_{DS}	Store drag coefficient	-
C_L	Lift coefficient	-
C_{Lmax}	Maximum lift coefficient	-
D_{TOT}	Total aerodynamic drag	N(lb)
E	Total energy	J (ft lb)
E_s	Energy state	m (ft)
F_{EFFT}	Effective thrust vector	N(lb)
F_N	Engine net thrust	N(lb)
F_G	Engine gross thrust	N(lb)
g	Acceleration due to gravity	9.80665 m/s^2 (32.17405 ft/s^2)
h_p	Pressure altitude	m(ft)
L_{TOT}	Total lift force	N(lb)
ΔL	Jet induced lift loss	N(lb)
M	Mach number	-
n	Load factor normal to aircraft in plane of symmetry	-
P_s	Specific excess power, energy rate	m/s (ft/s)
q	Dynamic pressure	N/m^2 (lb/ft^2)
R_D	Intake momentum drag	N(ft)
S	Aircraft reference area	m^2 (ft^2)

Symbols	Definition	Unit or Value
t	Time	s
V	Velocity	m/s(ft/s)
W	Aircraft weight	N(lb)
w_f	Fuel flowrate	kg/s(lb/hr)

Greek Symbols		
α	Body incidence to flight path	rad(deg)
ζ	Load factor n or turn rate ω according to selected grid variable	rad(deg)
θ_i	Engine incidence angle	rad(deg)
θ_j	Nozzle deflection angle	rad(deg)
λ	Energy rate function	-
τ	Energy state E_s or pressure altitude h_p according to selected grid variable	m (ft)
ω	Turn rate	deg/s

LIST OF FIGURES

Note: In each chapter the relevant figures are grouped at the end of the chapter.

1. INTRODUCTION

Reference 1 described a suite of FORTRAN programs developed for the computation and presentation of data used in evaluating combat aircraft performance.

The suite of programs produces tabulated and plotted data describing aircraft combat performance in energy manoeuvrability terms. For each aircraft to be evaluated the user must supply subroutines which evaluate propulsion and aerodynamic characteristics.

After using the programs for several years some improvements and extensions have appeared necessary and have now been incorporated in the suite of programs.

This present document describes the purpose and nature of the various changes in sufficient detail to allow it to be used independently of Reference 1.

Chapter 2 presents an overview of the suite of programs and a description of the available options and capabilities.

Chapter 3 describes the modifications to the mathematical equations.

Chapters 4, 5 and 6 present a self contained and updated user's guide with instructions on how to operate the three modified programs.

Chapters 7, 8 and 9 describe the three modified programs; details of the modifications and the part of the programs they affect are contained in Appendix A.

Chapter 10 shows examples of the use of the various options.

2. OVERVIEW AND CAPABILITIES OF THE SUITE OF PROGRAMS

The object of the suite of programs is to produce tabular and plotted data for accurate assessment of the performance and manoeuvrability of any aircraft operating in a wide range of weapon/store configurations.

The suite consists of three main programs whose interrelations are shown in Figure 2.1.

ACRAFT is the generic name given to the family of programs which represents a particular aircraft; it includes user defined routines which calculate propulsion and aerodynamic parameters using engine and drag data files. The program uses input data describing the aircraft configuration to perform basic calculations and produces tabular output for line printer listing as well as a data file for input to program P2V2.

P2V2, the second program in the suite, processes the data provided by program ACRAFT. For some requirements, (options 4B, 4C, 4Z) plotter files (P2.PLT) are produced for plotting directly on the off line plotter; for other requirements, (4A, 4D, 4G) program P2V2 selects and rearranges the data arrays for further processing by P4V2.

Program P4V2 is a contour plotting program which processes the data provided by program P2V2 and produces plotter files (P4.PLT) for submission to the off line plotter queue.

An overview of all the options available is shown in Figure 2.2.

2.1 Program ACRAFT

Program ACRAFT produces two types of output:

(1) Unoptimised grid calculations:
χ and ζ' tabulated over an unoptimised grid of (τ, M, ζ)

(2) Optimised grid calculations:
χ_{opt} and ζ'_{opt} tabulated over an optimised grid of (E_s, ζ)

where the symbols can represent the following alternative parameters

τ is energy state E_s or pressure altitude h_p.

M is Mach number.

ζ is turn rate ω or load factor n.

ζ' is load factor if ζ is turn rate.
or turn rate if ζ is load factor.

χ is P_s, P_s/w_f, P_sV/w_f or P_s/V.

χ_{opt} is the maximum value of χ over the permissable range of M.

ζ'_{opt} is the ζ' corresponding to χ_{opt}

The selection of the alternative options for χ, τ and ζ is made through the conversational dialogue when running the program.

In addition ACRAFT provides for each Mach number M and energy state τ the values of the load factor and turn rate corresponding to the lift limit boundary.

2.2 Program P2V2

The input to the program P2V2 consist of data files prepared for particular aircraft by program ACRAFT. The user selects by terminal input the operations to be performed on the data. The user can choose the following options for presenting the data:

(1) Option 4A: Contours of χ on a (M,τ) grid for selected ζ values.

(2) Option 4B: Plots of χ versus ζ for lines of constant M with selected τ values.

(3) Option 4C: Plots of χ_{opt} versus E_s for lines of constant ζ. For this option the second type of output produced by ACRAFT is necessa (see paragraph 2.1).

(4) Option 4D: Differential contours of χ (between two aircraft) on a (M,τ) grid for selected ζ values.

(5) Option 4E: Differential 4C plots. This option is not currently available.

(6) Option 4G: Contours of χ on a (M,ζ) grid for selected values of τ.

(7) Option 4Z: Plots of χ versus M and ζ' versus M for lines of constant ζ with selected τ values.
Note: Now that option 4G has been added to the program, option 4Z, (which was previously used to create manually the contours of 4G), is not very meaningful.

When selecting option 4B, 4C or 4Z, the output from the program is a plotter file P2.PLT which can be submitted to the off line plotter. The outputs produced when selecting the other options need to be further processed by the contour plotting program P4V2.

2.3 Program P4V2

Program P4V2 processes files created by program P2V2 (with the extension .CON) when selecting options 4A, 4D and 4G and produces a plotter file P4.PLT to be submitted for off line plotting. The contour plots on file P4.PLT are of two types:

(1) Contours of energy rate (or other energy parameter) on a Mach number, altitude (or energy state) grid. (Option 4A and 4D)

(2) Contours of energy rate (or other energy parameter) on a Mach number, turn rate (or load factor) grid. (Option 4G)

A conversational dialogue allows the user to define the range of contours required and the scales to be used on the x and y axes.

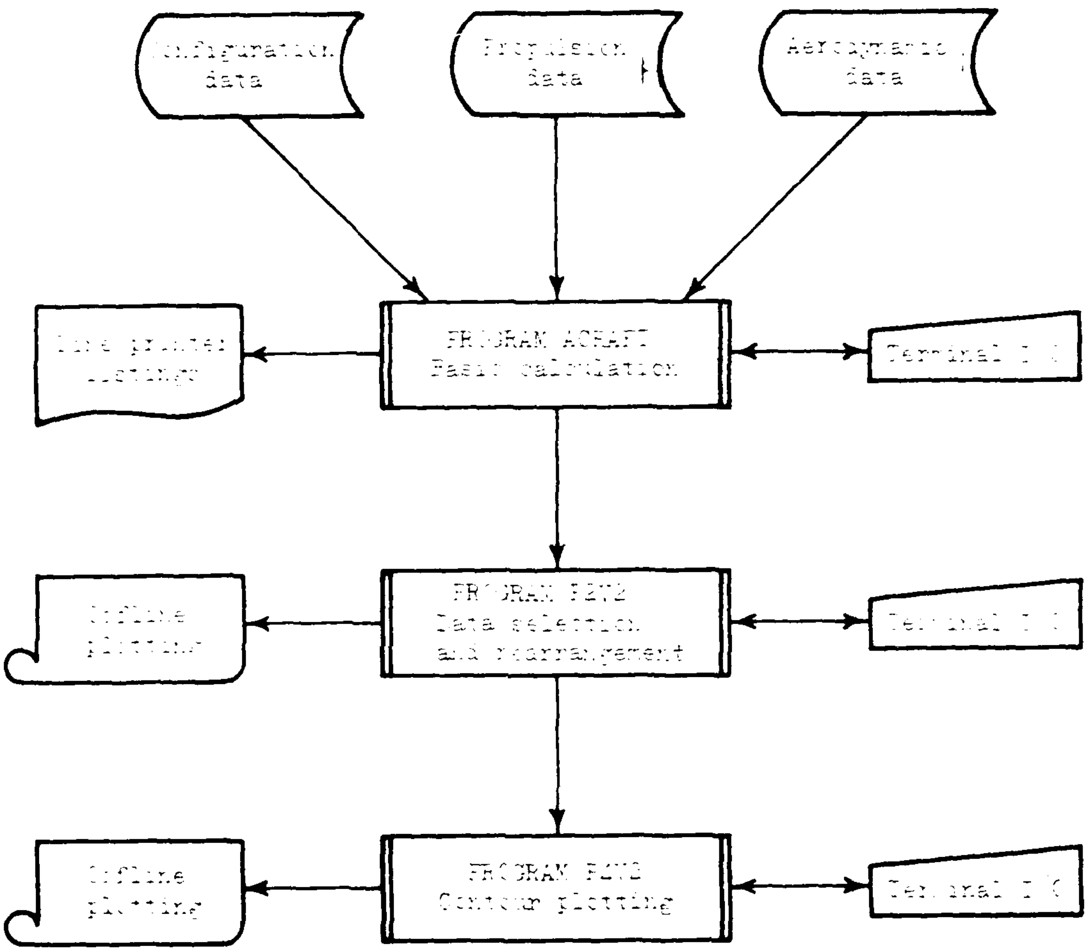

FIG. 2.1 Information flow between the three programs

τ	MMD	ζ		OPTION	
h_p	not asked if $\tau = h_p$	n	4A	contour of χ on a (M,h_p) grid. One page per selected n	1
			4B	χ versus ω for lines of constant M. One page per selected h_p	2
			4D	differential 4A	3
			4G	contours of χ on a (M,n) grid. One page per selected h_p	4
			4Z	χ versus M, ω versus M } for lines of constant n. One page per selected h_p	5
		ω	4A	contours of χ on a (M,h_p) grid. One page per selected ω	6
			4B	χ versus n for lines of constant M. One page per selected h_p	7
			4D	differential of 4A	8
			4G	contours of χ on a (M,ω) grid. One page per selected h_p	9
			4Z	χ versus M, n versus M } for lines of constant ω. One page per selected h_p	10
E_s	yes	n	4C	χ opt versus E_s for lines of constant n	11
			4E	differential of 4C - Not available	12
		ω	4C	χ opt versus E_s for line of constant ω	13
			4E	differential of 4C - Not available	14
	no	n	4A	contours of χ on a (M,E_s) grid. One page per selected n	15
			4B	χ versus ω for lines of constant M. One page per selected E_s	16
			4D	differential 4A	17
			4G	contours of χ on a (M,n) grid. One page per selected E_s	18
			4Z	χ versus M, ω versus M } for lines of constant n. One page per selected E_s	19
		ω	4A	contours of χ on a (M,E_s) grid. One page per selected ω	20
			4B	χ versus n for lines of constant M. One page per selected E_s	21
			4D	differential of 4A	22
			4G	contours of χ on a (M,ω) grid. One page per selected E_s	23
			4Z	χ versus M, n versus M } for lines of constant ω. One page per selected E_s	24

Note: τ is energy state E_s or pressure altitude h_p
ζ is load factor n or turn rate ω
χ is energy parameter P_s or P_s/w_f or $P_s\ V/w_f$ or P_s/V

FIG. 2.2: Overview of Options Available

3. ALTERATIONS TO EQUATIONS

The equations of motion contained in Chapter 2 of Reference 1 were approximate in that net thrust F_N was used instead of gross thrust F_G and a ram drag term was not included. In addition the effects of vectoring the thrust (as occurs in STOVL aircraft) had not been accounted for; this involves the inclusion of the nozzle deflection angle Θ_j and a term ΔL to allow for jet induced lift loss.

The equations have now been modified; the aerodynamic and propulsive forces acting on the aircraft have been resolved into three vectors (see Figure 3.1):

- A total lift vector which is perpendicular to the flight path:

$$L_{TOT} = qSC_L + (F_N + R_D) \sin (\alpha + \Theta_i + \Theta_j) - \Delta L$$

- An effective thrust vector which is the component of thrust acting along the flight path (including a propulsive drag term):

$$F_{EFFT} = (F_N + R_D) \cos (\alpha + \Theta_i + \Theta_j) - R_D$$

- A drag vector which lies along the flight path:

$$D_{TOT} = qSC_D + q \Sigma \Delta C_{DS}$$

where F_N = Engine net propulsive force

R_D = Ram drag (Intake momentum drag)

F_G = $F_N + R_D$ = Engine total gross thrust

α = Angle of attack (deg)

Θ_i = Engine incidence angle (deg)

Θ_j = Nozzle deflection angle (deg)

q = Dynamic pressure

ΔL = Jet induced lift loss

C_L = Lift coefficient

C_D = Drag coefficient

We can then write as with conventional aircraft (see Reference 1)

$$P_S = \frac{dE_s}{dt} = (F_{EFFT} - D_{TOT}) \frac{V}{W}$$

$$n = \frac{L_{TOT}}{W}$$

$$\omega = \frac{g}{V} \sqrt{n^2 - 1}$$

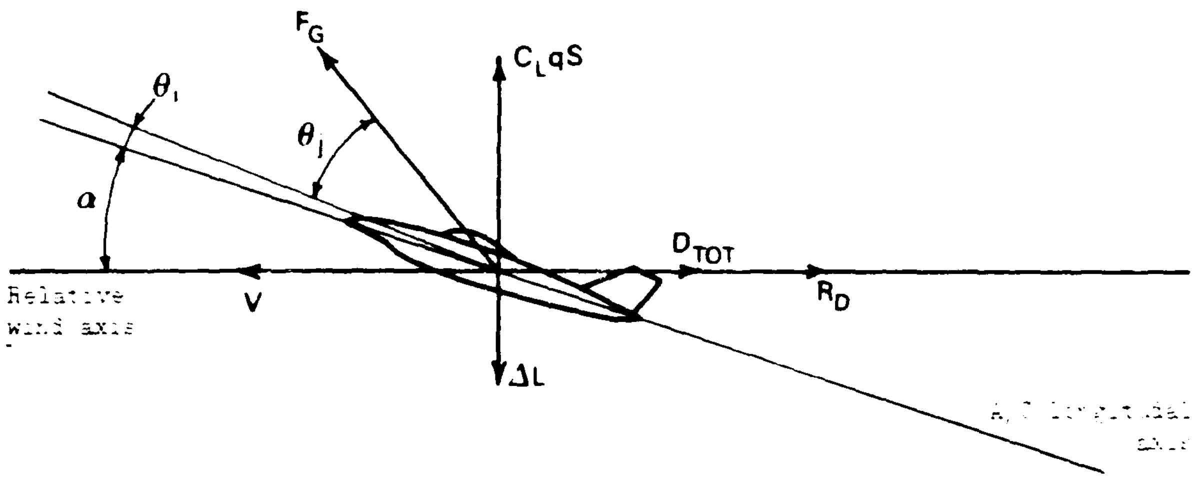

FIG. 3.1 Aerodynamic and propulsive forces

4. PROGRAM ACRAFT USER'S GUIDE

The conversational input to the program is best described with reference to a typical run. Examples of dialogue are shown in Chapter 10.

Care must be taken for the replies to questions on selecting grid variables to be compatible with the format of the plots required from the subsequent programs; the various options available are listed in Figure 2.2.

Although only some of the questions have been modified from the ones described in Reference 1, for completeness all replies have been described in this updated user's guide.

Question 1 : IMPERIAL (0) or SI(1) UNITS

Replies of 0 or 1 indicate that output quantities from ACRAFT are to be in Imperial or SI units respectively. Any other reply results in an error message and the question is repeated.

Note: All internal calculations are in imperial units.

Question 2 : AIRCRAFT DATA FILENAME

Reply with the name (up to 10 characters) of the disk file containing the required data. A typical example of a store file is given in Figure 4.1. The contents and format of the file are as follows.

Line	Format	Description
1	2A5	Aircraft name (up to 10 characters)
2	3G	Wing reference area (ft^2 or m^2), Store file unit flag (0 for Imperial units, 1 for SI units) Data type flag (0 for binary spline data, 1 for PACAM tabular data)
3	3G	Gross weight (lb or kg) c.g. position (% MAC) Structural load factor limit of aircraft
4	14A5	Configuration description (up to 70 characters)
5	2A5	Engine data file name if spline data or PACAM input file name if tabular data (up to 10 characters)
6	2A5	Aerodynamic data file name if spline data and blank if PACAM tabular data (up to 10 characters).
7	G	Number of points in store drag table
8	10G	Mach Number list in store drag table *
9	10G	Drag count list in store drag table *

* 10 items per line; carry on to next line if more than 10 entries on any line. Not needed if 0 points indicated at line 7.

Question 3 : PS, PS/WF, PS*V/WF OR PS/V (1,2,3 or 4)

Reply	Meaning
1	Calculate P_s as dependent variable, i.e. $\chi = P_s$
2	Calculate P_s/w_f as dependent variable, i.e. $\chi = P_s/w_f$
3	Calculate $P_sV/1000w_f$ as dependent variable, i.e. $\chi = P_sV/w_f$
4	Calculate $1000P_s/V$ as dependent variable, i.e. $\chi = P_s/V$

Values of 1,2,3 and 4 are valid as input. Any other value produces an error message and the question is repeated.

Question 4 : IS HP THE HEIGHT VARIABLE

A reply "Y" (yes) indicates that pressure altitude is to be used as the height grid variable (i.e. τ is pressure altitude h_p). Any other reply will result in energy state being used as the height variable (i.e. τ is E_s).

If energy state is selected as the height variable (τ is E_s) the following question is asked.

Question 4a : MAXIMUM MANOEUVRE?

A reply "Y" will cause χ optimum to be calculated for a maximum manoeuvre diagram (MMD).

Any other reply causes the performance variable χ to be calculated for an unoptimised grid.

Question 5 : PRESET GRID (Y,N or C/R)

A Carriage return (C/R) reply results in the preset grid values being typed on the user's terminal. The values for the preset grid are:

	start value	increment	final value
τ (Imperial)	0	4000	68000
τ (SI)	0	1000	20000
M (Military Power)	0	.05	1.5
M (After Burner)	0	0.05	2.0
ζ is load factor	1	2	9

A reply "Y" results in the preset grid values to be used in the run. The next question then being question 10.

Any other reply will result in the following questions

Question 6 : HP ,HP STEP, NO OF STEPS (if τ is h_p)
or ES ,ES STEP, NO OF STEPS (if τ is E_s)

Reply with . an initial value for τ (must be $\geq$ 0)
. an increment for τ (must be >0)
. number of points, including first and last. (must be >0 and $\leq$ 50)

These three parameters, defining the height grid, should be typed on one line separated by commas or blanks.

Question 7 : MACH, MACH STEP, NO OF STEPS

Reply in a similar way to question 6 so as to specify the Mach number grid.

If an optimized grid (MMD) has been requested in question 4a, question 7 is not asked.

Question 8 : GRID FOR LOAD FACTOR (0) OR TURN RATE (1)

A reply of 0, requests a constant increment grid of load factor (ζ is load factor)

A reply of 1, indicates a request for a constant increment grid of turn rate (ζ is turn rate).

Question 9 : TR, TR STEP, NO OF STEPS (if ζ is turn rate)
or GNO, GN STEP, NO OF STEPS (if ζ is load factor)

Reply in a similar fashion to question 6 so as to specify the ζ (turn rate or load factor) grid.

Note: Turnrate is expressed in deg/s and if ζ is load factor the initial value must be greater or equal to 1.

Question 10 : POWER (MIL=100, MAX=200)

Military power is indicated by a value of 100, and maximum augmented power by a value of 200. Tens and units digits indicate a percent of the maximum of that range. A valid reply is 0 $\leq$ Power $\leq$ 200. Any other reply causes an error message to be typed on the terminal and the question is repeated.

Note: The power setting requested must be consistent with the propulsion characteristics specified in the user defined subroutine THRUST.

Question 11 : WING SWEEP (IF VARIABLE)

Supply wing sweep in degrees if aerodynamic data includes wing sweep effects. Otherwise reply with a carriage return.

A nominal valid reply is 0 $\leq$ Wing sweep $\leq$ 80°. Any other reply causes an error message to be typed on the terminal and the question is repeated.

Question 12 : NOZZLE DEFLECTION (IF VARIABLE)

Supply the nozzle deflection in degrees if the aircraft is a vectored thrust aircraft; otherwise reply with a carriage return.

A nominal valid reply is 0 $\leq$ nozzle angle $\leq$ 110°. Any other reply causes an error message to be typed on the terminal and the question is repeated.

Question 13 : ATMOSPHERE, DEVIATION

This input is provided if the user-defined subroutine THRUST (from ACRAFT) has been written to handle alternative atmospheres. Valid replies are:

ICAO,X }
ARDU,X } FORMAT (A4,G)

Where X is a deviation from the nominated atmosphere in degrees Celsius. It may be omitted if X is zero.

If an invalid reply is made a warning message is typed to the terminal and ICAO atmosphere is assumed.

Question 14 : OUTPUT (1=TEXT, 2=NOS, 3=BOTH)

Reply	Meaning
1	Formatted output with full ASCII text and headings is requested (on logical unit 6).
2	Numerical data output is required (on logical unit 8) for input to program P2V2.
3	Both types of output are required.

Any other reply causes an error message to be typed and the question is repeated.

Question 15 : O/P FILE NAME FOR UNIT m

Supply a 10-character filename for output as requested; m = 6 is the logical unit number for full format output; m = 8 is the logical unit number for numerical output.

Formatted output should be printed with /P/B switches to produce listings suitable for permanent retention.

Numerical output may be printed if required.

```
AIRCRAFT
230.,0,0
25000.,00.,7.0
 AIR SUPERIORITY : 2 AIM9 + 50% FUEL
ENGINE.BIN
AERO.BIN
5
.6,.7,.8,.9,1.0
120,146,191,304,370
```

FIG. 4.1 Typical Example of a Store File

5. PROGRAM P2V2 USER'S GUIDE

The inputs to program P2V2 consist of the data files created by the program ACRAFT.

The data is then manipulated by P2V2 according to commands supplied at the users terminal during the execution of the program.

Question 1 : OPTION OR (CR) FOR HELP:

Reply with the appropriate option code. A carriage return is interpreted as a request for help and a one line description of each option together with the name of the output file produced, is typed on the terminal.

Reply	Option
4A	χ contours on a (M, τ) grid for selected ζ values.
4B	χ versus ζ' for lines of constant M for selected τ values.
4C	χ_{opt} versus E_s for constant ζ values.
4D	differential χ contours on a (M,τ) grid for selected ζ values.
4E	differential χ_{opt} versus E_s for constant ζ values. Not implemented in this version.
4F	Maximum Manoeuvre Persistence interactive aid. Not available in this version.
4G	χ contours on a (M,ζ) grid for selected τ values.
4Z	χ versus M for lines of constant ζ as well as ζ' versus M for lines of constant ζ for selected τ values.
-	any other reply will cause a help message to be typed to the terminal and question 1 to be repeated.

Where χ is P_s or P_s/w_f or P_sV/wf or P_s/V.

τ is E_s or pressure height h_p.

ζ is turn rate or load factor.

ζ' is load factor if ζ is turn rate or vice versa.

5. PROGRAM P2V2 USER'S GUIDE

The inputs to program P2V2 consist of the data files created by the program ACRAFT.

The data is then manipulated by P2V2 according to commands supplied at the users terminal during the execution of the program.

Question 1 : OPTION OR (CR) FOR HELP:

Reply with the appropriate option code. A carriage return is interpreted as a request for help and a one line description of each option together with the name of the output file produced, is typed on the terminal.

Reply	Option
4A	χ contours on a (M, τ) grid for selected ζ values.
4B	χ versus ζ' for lines of constant M for selected τ values.
4C	χ_{opt} versus E_s for constant ζ values.
4D	differential χ contours on a (M, τ) grid for selected ζ values.
4E	differential χ_{opt} versus E_s for constant ζ values. Not implemented in this version.
4F	Maximum Manoeuvre Persistence interactive aid. Not available in this version.
4G	χ contours on a (M, ζ) grid for selected τ values.
4Z	χ versus M for lines of constant ζ as well as ζ' versus M for lines of constant ζ for selected τ values.
-	any other reply will cause a help message to be typed to the terminal and question 1 to be repeated.

Where χ is P_s or P_s/w_f or P_sV/wf or P_s/V.

τ is E_s or pressure height h_p.

ζ is turn rate or load factor.

ζ' is load factor if ζ is turn rate or vice versa.

5.1 Option 4A

This option produces χ contour data on a Mach number (x axis), τ (y axis) grid, at selected values of ζ (turn rate or load factor). The output is written on file P24A1.CON which will have to be processed by P4V2.

Examples of dialogues running this option are shown in Figures 10.1 and 10.4.

Question A1 : DATA BASE FILENAME :

Reply with the name (up to 10 characters) of the appropriate numerical output (logical unit 8) file from P1V2. After reading the header on the file program P2V2 echoes on the user terminal.

```
*** DATA ARE IN U UNITS, ENERGY PARAMETER IS χ ***
*** CONSTANT INC. OF ζ ***
```

U is IMPERIAL or SI, χ is PS, PS/WF, PS.V/WF or PS/V as appropriate and ζ is TURNRATE or LOAD FACTOR as appropriate.

Question A2 : REPLY "YES", "NO", "ALL" OR "END"
OUTPUT DATA FOR $\zeta = \zeta_i$?

Reply of 'Y', 'N', 'A' or 'E' indicates as follows:

Reply	Meaning
Y	Output data for contour plot at $\zeta = \zeta_i$ required.
N	No output data required for $\zeta = \zeta_i$.
A	Output data required for all ζ_i.
E	Exit from output data loop and do not output data for $\zeta = \zeta_i$ or any following ζ_i.
-	Any other reply is interpreted as a 'N'.

Question A2 is repeated for all values of ζ selected unless the loop is exited.

Output is written onto file P24A1.CON, for input to program P4V2. File P24A1.CON may be renamed if desired before running P4V2. P24A1.CON is an ASCII file and may be printed, although it is not easy to read but is suitable for debugging purposes.

5.2 Option 4B

This option creates plots of χ versus ζ' for selected values of Mach number. One page of plots is produced for each requested altitude (or energy state). The output is written onto the plot file P2.PLT which can be submitted to the plotter queue.

An example of dialogue running this option is shown in Figure 10.7.

Question B1 : DATA BASE FILENAME:

Reply with the name (up to 10 characters) of the appropriate numerical output (logical unit = 8) file from P1V2. Program P2V2 will echo on the terminal:

```
*** DATA ARE IN U UNITS, ENERGY PARAMETER IS χ ***
*** CONSTANT INCREMENT OF ζ     ***
```

where (as appropriate)

U is IMPERIAL or SI
is PS, PS/WF, PS.V/WF or PS/V
is TURN RATE or LOAD FACTOR

Question B2 : SCALES IN UNITS/INCH OF PLOT
TURNRATE/LOAD FACTOR, ENERGY VARIABLE:

Reply with the amount of physical quantity which one inch of plot would represent on each axis where the x axis represents ζ' (turnrate or load factor) and the y axis represents the energy variable χ. (As a rough guide use 500 ft/s/inch for P_s and 4 deg/sec/inch for the turn rate).

Question B3 : MAXIMUM FOR ENERGY AXIS:

Reply with the approximate maximum χ value of interest on the y axis (in the order of 1000 ft/s for P_s).

Question B4 : ENERGY AXIS LENGTH:

Reply with the appropriate length in inches of the y axis (7 inches is representative for trimming to A4 size).

Question B5 : REPLY "YES", "NO", "ALL" OR "END":
HEIGHT = τ_i ?

One page of curves is plotted for each height selected.
Replies and significance of questions are listed below.

Reply	Meaning
Y (Yes)	Plotting is required for τ_i value. Mach numbers to be plotted will now be listed.
N (No)	Do not produce the plot for this value of τ_i.
A (All)	Plot all the data given for τ_i. Use this when the Mach number values are known and plots for all τ_i are to be produced.
E (End)	Exit from height plotting and hence from program.

Question B6 : MACH = M_j ?

This question is asked only if the reply to Question B5 was 'Y'.

Reply	Meaning
Y (Yes)	Plot a curve for this Mach number.
N (No)	Skip this Mach number.
A (All)	Plot curves for all remaining Mach numbers for current τ_i.
E (End)	Skip remaining Mach numbers and go to the next τ_i.

The output file P2.PLT contains the requested plots and is submitted to the off line plot queue.

5.3 Option 4C

This option produces plots of λ_{opt} versus energy state E_s for contant ζ values. The output is written onto the plot file P2.PLT which can be submitted to the plot queue.

Examples of dialogues running this option are shown in Figures 10.9 and 10.12.

Question C1 : DATA BASE FILENAME:

Reply with the name (up to 10 characters) of the numerical output file from P1V2. Program P2V2 will echo the following message on the terminal:

*** DATA ARE IN U UNITS, ENERGY PARAMETERS IS λ ***
*** CONSTANT INC. OF ζ ****

where U is IMPERIAL or SI
λ is PS or PS/WF or PS.V/WF or PS/V
ζ is TURN RATE or LOAD FACTOR

Question C2 : SCALE IN UNIT/INCH OF PLOT
ES, PS :

Reply with the amount of physical quantity which one inch of plot would represent on each axis. E_s is plotted along the x axis and λ is plotted along the y axis.

Question C3 : PS MIN VALUE, PS AXIS LENGTH (INS) :

Reply with the approximate minimum λ value of interest and the length of the y axis (in inches).

Question C4 : REPLY "YES", "NO", "ALL" OR "END"
$\zeta = \zeta_i$?

Where ζ is TURN RATE or LOAD FACTOR as appropriate.

Replies and meanings are indicated below.

Reply	Meaning
Y (Yes)	Plot a curve of (E_s, λ) points for this ζ_i.
N (No)	Do not plot a curve and try next ζ_i .
A (All)	Plot curves for this and subsequent ζ_i .
E (End)	Skip the remaining ζ_i and hence exit from program.

The output file for option 4C is P2.PLT, a plot file which must be submitted to the off-line plot queue.

5.4 Option 4D

This option produces differential γ contour data on a Mach number, T grid at selected values of ζ (turn rate or load factor). The versions of ACRAFT appropriate to the two different aircraft are run using their respective data files with identical altitude, Mach number and load factor (or turn rate) grids as in option 4A, and then subtracting the data at the grid points when running P2V2. The output is written on three files P24A1.CON, P24A2.CON and P24DIF.CON which will have to be processed by P4V2.

An example of dialogue running this option is shown in Figure 10.15.

Question D1 : DATA BASE FILENAME:

Reply with the name (up to 10 characters) of the appropriate numerical output file (logical unit 8) created by P1V2 for the first aircraft. After reading the header on the file program P2V2 echoes, as in option 4A, details of the options selected when running P1V2.

Question D2 : REPLY "YES", "NO", "ALL" OR "END"
OUTPUT DATA FOR $\zeta = \zeta_i$?

Reply to this question is the same as for option 4A. The load factor (or turn rate) selection applies both to the base file and to the comparison file considered. This question is repeated for all values of selected when the loop is exited.

Question D3 : COMPARISON FILENAME:

Reply with the name of the output file (logical unit 8) created by P1V2 for the second aircraft (comparison aircraft) to be compared with the first aircraft (base aircraft). Data files are considered to be valid for comparison if when running ACRAFT the grid points selected are identical, and the type of energy parameter and units chosen are the same; other parameters such as power setting, wing sweeps, nozzle deflection and atmosphere type are not checked.

Output for this option is in ASCII mode on three files P24A1.CON, P24A2.CON, P24DIF.CON which can be used as input for processing by P4V2. P24A1.CON is the same as would be produced by running option 4A with the same replies using the base aircraft data file as input. P24A2.CON is the same as would be produced by running option 4A using the comparison aircraft data file as input. P24DIF.CON is the file used when running P4V2 to generate the differential contour plots.

5.5 Option 4E

In Reference 1 this option produced differential MMD plots. This option was not implemented when the programs were restructured and extended as it was felt the amount of programming effort required was not in proportion to the usefulness of the plots presented. The code used in Reference 1 is still available and this option could be implemented if required at a later date.

5.6 Option 4F

In Reference 1 this option provided an interactive aid for maximum manoeuvre persistence where the user provided data obtained from the output file of option 4C to calculate the number of turns an aircraft could make before running out of fuel. This option was removed because it was felt those calculations were better handled off line with a calculator.

5.7 Option 4G

This option creates a file P24G.CON which can then be processed by program P4V2 to produce contours of λ on a Mach number (x axis), ζ (y axis) grid at selected values of τ.

An example of dialogue running this option is shown in Figure 10.17.

Question G1 : DATA BASE FILENAME :

Reply with the name (up to 10 characters) of the appropriate numerical output file from P1V2. After reading the header on the file, program P2V2 will echo the following:

*** DATA ARE IN U UNITS, ENERGY PARAMETER IS λ ***
*** CONSTANT INC. OF ζ ***

where U is IMPERIAL or SI
λ is PS or PS/WF or PS.V/WF or PS/V
ζ is TURN RATE or LOAD FACTOR

Question G2 : REPLY "YES", "NO", "ALL" OR "END"
OUTPUT DATA FOR $\tau = \tau_i$?

Reply of 'Y', 'N', 'A', or 'E' indicates as follows

Reply	Meaning
Y (yes)	Output data for contour plot at $\tau = \tau_i$ is required.
N (no)	No output data required for $\tau = \tau_i$.
A (all)	Output data required for all τ_i.
E (end)	Exit from loop and program P2V2. Do not output data for or any subsequent τ_i .

Question G2 is repeated for all values of τ selected unless the loop is exited.

The output is written onto the file P24G.CON for input to program P4V2. P24G.CON is an ASCII file and maybe printed, although it is not easy to read but suitable for debugging purposes.

5.8 Option 4Z

This option creates a plot file P2.PLT for plotting the energy parameter λ versus Mach number for lines of constant [illegible] as well as ζ' versus Mach number for lines of constant ζ. One page of plots is produced for each requested τ.

An example of dialogue, running this option is shown in Figure 10.21.

Question Z1 : DATA BASE FILENAME:

Reply with the name of the appropriate numerical output file from P1V2. Program P2V2 echoes the following message on the terminal:

```
*** DATA ARE IN U UNITS, ENERGY PARAMETER IS [illegible] ***
*** CONSTANT INC. OF [illegible] ***
```

where U, λ and [illegible] are appropriately defined as for option 4B.

Question Z2 : REPLY "YES", "NO", "ALL" OR "END"
HEIGHT = τ_i ?

One page of curves is plotted for each height selected. Reply as for question B5

Question Z3 : $\zeta = \zeta_1$?

This question is asked only if the answer to question Z2 is yes.

Reply as for question B6 with Mach number being appropriately replaced by [illegible] in the discussion.

The output file for option 4Z is P2.PLT, a plot file which must be submitted to the off line plot queue. The scales for this option are fixed.

6. PROGRAM P4V2 USER'S GUIDE

The inputs to program P4V2 consist of data files created by program P2V2 when choosing options 4A, 4D and 4G.

A selection is made when running P4V2 using terminal inputs of data to be plotted. Numerous examples are shown in Chapter 10.

The sole output of the program P4V2 is the plotter file P4.PLT.

6.1 Option 4A

Examples of dialogues running this option are shown in Figures 10.1 and 10.4.

Question 1 : INPUT FILENAME

Reply with the name (up to 10 characters) of the appropriate file generated by option 4A in program P2V2. The file P24A1.CON created by P2V2 may be renamed before running P4V2, (P4V2 will still know which option produced it) P4V2 will then echo on the users terminal the following options selected in P1V2:

*** DATA ARE IN U UNITS, ENERGY PARAMETER IS λ ***
*** CONSTANT INC. FOR ζ ***

Where (as appropriate)
U is IMPERIAL or SI
λ is PS, PS/WF, PS.V/WF or PS/V
ζ is LOAD FACTOR or TURN RATE

Question 2 : SCALES IN UNITS/IN OF PLOT - MACH, ALT:

Reply with the amount of physical quantity which one inch of plot should represent on each axis, where the x axis represents Mach number and the y axis represents pressure altitude or energy state. (As a rough guide use .2 to .4 units/inch for the Mach number and 10000 ft/inch for the altitude).

Question 3 : SMOOTHED AND TEXTURED CONTOURS:

Reply with "Y" for the contour points to be joined by a cubic spline, meaning contours will have continuous 1st and 2nd derivatives.

Reply with "N" for the contour points to be joined by straight lines.

If the grid size is small there is little or no difference between smoothing and non-smoothing (So it is better to select non-smoothing as this will speed up execution time).

Question 4 : PLOT ES CONTOURS?

Reply with "Y" (yes) or "N" (no) where yes signifies that dashed lines of constant energy state will be superimposed on the requested plots.

Question 5 : CONTOUR LEVELS - START, STEP, NO:

This question is only asked if energy state contours are required.

Reply with the minimum E_s, the increment in E_s between contours and the number of E_s contours required.

These values should be in the appropriate units (as a rough guide use 5000ft for the start and step values and 20 for the number of steps).

Question 6 : PLOT $\zeta = \zeta_i$

ζ is either LOAD FACTOR or TURN RATE as appropriate.

Reply with "Y" (yes) or "N" (no) where yes signifies that a new page of plots be set up for the required ζ_i. If the reply is no, the question is repeated for the next ζ_i.

Question 7 : CONTOUR LEVELS - START, STEP, NO:

If the reply to question 6 was "yes" then this question is asked for the page of plot for each requested ζ_i.

Reply with the λ value of the lowest valued contour to be plotted, the increment between contours (must be positive) and the number of contours (>0 and $\leq$ 50).

These values should be in the appropriate units depending upon both U and λ. As load factor increases, more negative contours should be plotted.

After the last value of ζ is processed, an informative message "END OF DATA ON LOG5" is typed on the terminal, it does not indicate an error condition.

After question 7 is repeated for each ζ value for which data exists, P4V2 ceases execution and the output plot file P4.PLT may be placed on the off line plotter queue.

6.2 Option 4D

An example of dialogue running this option is shown in Figure 10.15.

Replies for this option are very similar to those of option 4A for one aircraft. The only difference is that requests for contour levels now refer to the difference between the two aircraft at each grid point. The aircraft referrred to by program P2V2 as the DATA BASE will be indicated by positive contours and that referred to as the COMPARISON will be indicated by negative contours. Full identification headers are included on the plotted output on file P4.PLT.

6.3 Option 4G

An example of dialogue using this option is shown in Figure 10.17.

Question 1 : INPUT FILENAME

The name of the file created by program P2V2 when using option 4G is P24G.CON but this file can be renamed before running P4V2. See Paragraph 6.1 for the meaning of the prompt message.

Question 2 : SCALES IN UNITS/IN OF PLOT - MACH, TR/LF:

Reply with the amount of physical quantity which one inch of plot should represent on each axis, where the x axis represents Mach number and the y axis represents either turn rate or load factor. (As a rough guide use .2 to .4 unit/inch for the Mach number, and 4 deg/sec/inch for the turn rate)

Question 3 : SMOOTHED AND TEXTURED CONTOURS:

Reply with 'Y' or 'N' as for question 3 of option 4A.

Question 4 : PLOT LOAD FAC. /TURN RAD. GRID ?

This question is only asked if ζ is turnrate.

Reply with 'Y' (yes) if a background grid of constant load factor lines and constant turn radius lines is desired for each page of plot. The grid is appropriately modified to suit the unit system selected.

Any other reply will be interpreted as no.

Question 5 : PLOT H = τ_i?

Reply with "Y" (yes) if a new page of contours is to be set up for the required height.

Any other reply is interpreted as no and the question is repeated for the next height value.

Question 6 : CONTOURS LEVELS - START, STEP, NO:

If the reply to question 5 was "yes" then this question is asked for the page of plot for each required height.

Reply as for question 7 of option 4A.

After question 6 is repeated for each height value for which data exists, P4V2 ceases execution and the output plot file P4.PLT can be placed on the off line plot queue.

7. PROGRAM ACRAFT DESCRIPTION

7.1 Loading of Program on DEC System-10

The commands for loading program ACRAFT and saving a core image on disk on DEC system-10 are:

- . LOAD ACRAFT, P1V2, P1LIB/SEARCH, PAC2IN/SEARCH
- . SAVE ACRAFT

The SAVE command on the DEC system-10 creates an executable version of the program.

The file ACRAFT contains all the user defined routines which are different for each aircraft, whereas the service routines in P1V2 are general and applicable to all aircraft. P1LIB includes routines for use with spline fitted data (Reference 3) whereas PAC2IN contains routines for use with the tabular format data of a PACAM2 aircraft data file (Reference 2).

The routines contained in each of these files are listed in the following table and described in this Chapter.

ACRAFT	MAIN BLOCK THRUST AEROMX GETALF AERO GETCD GETCDA GETCDCL XSPMIN XSPMAX YSPMIN YSPMAX
P1V2	P1IN BADINP TABLE ATMOS INTRP HEIGHT HTRUE IDENT P1OUT BININ ALTIT PARAMS MAXMAN SEP P1OUTA MONSEP
P1LIB	SURF CUBICS CHECKD SPDER3 ROMIN
PAC2IN	PAC2IN TABIN PACINT FIND DINTRP PACDER

7.2 File ACRAFT

7.2.1 ACRAFT MAIN Program

This is a small routine which calls P1IN for program input and TABLE to start calculation of aircraft performance parameters.

7.2.2 BLOCK DATA

Defines the data in the COMMON blocks. The data in COMMON C represents atmospheric profiles, text constants and other numeric constants; the data in COMMON USER is defined by the user for use in the aircraft dependent routines. The contents of all the COMMON blocks are listed in Appendix 6 of Reference 1.

7.2.3 THRUST Subroutine

THRUST is an aircraft dependent routine supplied by the user and is called by soubroutine TABLE or SEP (in P1V2).

In THRUST, values of gross thrust (and lift loss in the case of vectored thrust aircraft) are determined and transmitted through COMMON USER to the user defined subroutines AERO and AEROMX.

Fuel flow and maximum Mach number are also calculated in THRUST and supplied to P1V2 through COMMON B. Since THRUST is user defined its form will depend on the nature of the data available. The following three examples demonstrate the flexibility of this approach.

In example 1 (Figure 7.1) spline coefficients have been derived from original data for net thrust, ram drag and fuel flow expressed as dimensional functions of height and Mach number. The data was available for two power settings (intermediate and augmented) and an ICAO atmosphere. The spline coefficients were derived using program SPLFIT.EXE (see Reference 3) and stored in the binary file ENGIN.BIN which is then accessed in THRUST by calls to SURF.

In example 2 (Figure 7.2) spline fitting techniques were applied to tables of gross thrust, net thrust and fuel flow data, available in normalised form as functions of height and Mach number; an additional parameter, lift loss coefficient, was expressed as a function of jet velocity ratio and nozzle deflection angle.

Example 3 (Figure 7.3) illustrates the case where the data is accessed from an ASCII file with tabular format. Using the routines from PAC2IN, gross thrust, ram drag and fuel flow are linearly interpolated for the desired altitude, Mach number and power setting.

7.2.4 AEROMX Subroutine

AEROMX is a user defined routine called by subroutine TABLE or SEP.

For a given Mach number, AEROMX returns, to P1V2, through COMMON B, the maximum usable lift coefficient together with the corresponding angle of attack and total lift.

Other aerodynamic information dependent only on height and Mach number can also be determined in AEROMX (e.g. incremental store drag and other aerodynamic coefficients) and transmitted to the other user defined routines through COMMON USER. An example is shown in Figure 7.4.

7.2.5 GETALF Subroutine

GETALF is a user defined routine called by AEROMX.

For a given lift coefficient C_L passed through COMMON USER and a given Mach number M transmitted through COMMON B, subroutine GETALF will return the corresponding angle of attack α.

In the example of Figure 7.5 starting with an initial estimate of angle of attack a Newton Rahpson method is used to evaluate successive approximations of lift coefficient obtained from a call to SURF which returns $C_L(\alpha,M)$.

7.2.6 AERO Subroutine

AERO is a user dependent routine called by TABLE or SEP that returns through COMMON B, values of total drag and effective thrust.

In the example given in Figure 7.6 an initial estimate of the angle of attack is made and a Newtonian iteration is used to caluculate, for a given Mach number, altitude and load factor, the trimmed angle of attack and lift coefficient using the curve fitted data stored in array E. Effective thrust and total drag are then calculated.

7.2.7 GETCD Subroutine

GETCD is a routine called by AERO to determine the drag coefficient (including incremental store drag) for a given lift coefficient and Mach number. This can be done in various ways depending on the data available, as shown in Figures 7.7 and 7.8.

7.2.8 GETCDA Subroutine

The purpose of GETCDA is to return the drag coefficient and angle of attack, given Mach number and lift coefficient. This can simply be done by calling GETALF and GETCD as shown in Figure 7.9.

This routine is required if the user wishes to run program PC2P1 to use the spline fitted data created for P1V2 to make up an aircraft file for PACAM2.

7.2.9 GETCDCL Subroutine

For a given Mach number (passed through COMMON B) and a given angle of attack (passed through COMMON USER) GETCDCL determines the lift coefficient and then the drag coefficient.

In the example shown in Figure 7.10, C_L is determined by a call to SURF to access the first spline stored in array E representing $C_L(\alpha,M)$; C_D is then evaluated by a call to GETCD. Another example as shown in Figure 7.11.

7.2.10 XSPMIN and XSPMAX Functions

XSPMIN and XSPMAX are used in all the user defined functions; they respectively return the lower and upper bound of X, stored in the two dimensional spline. These functions are shown in Figure 7.12.

7.2.11 YSPMIN and YSPMAX Functions

Equivalent to 7.2.10 but for the Y variable.

7.3 File P1V2 (P1 Version 2)

7.3.1 P1IN Subroutine

P1IN controls all input data. All aircraft-independent parameters defining the type of calculations required are accepted in conversational mode, with validity checks where possible. Aircraft-dependent data is read from disk via a call to IDENT.

This subroutine has been slightly modified to allow for the additional options: turn rate variable and fourth energy parameter. The modifications are labelled K3, K4, K5 in the program listing.

7.3.2 BADINP Subroutine

BADINP types out an error message on the user's terminal. It is used to check input validity during conversational input operations.

This subroutine has not been changed.

7.3.3 TABLE Subroutine

TABLE controls the calculation and output of the unoptimised manoeuvrability grid using the following grid variables:

- ξ being energy state or pressure altitude depending on the input request.
- Mach number.
- ζ being load factor or turn rate depending on the input request.

The principal outputs are now:

- Energy parameter : P_s or P_s/w_f or P_sV/w_f or P_s/V.
- Turn rate (if ζ is load factor) or load factor (if ζ is turn rate).
- The load factor and turn rate corresponding to the maximum lift boundary.

The subroutine has been modified in Version 2 to allow for the additional options (turn rate grid variable and fourth energy parameter) and to calculate specific excess power P_s using gross thrust rather than net thrust (see Chapter 3 for more details). The modifications are labelled K2, K3, K4, K5 in the program listing.

7.3.4 ATMOS Subroutine

ATMOS calculates atmospheric parameters, giving temperature as a function of pressure height in either ICAO or ARDU Atmospheres.

This subroutine has not been changed.

7.3.5 INTRP Subroutine

INTRP is a linear interpolation, returning ordinate and gradient information.

This subroutine has not bee changed.

7.3.6 HEIGHT Subroutine

HEIGHT calculates the geopotential height corresponding to a given pressure height in the nominated atmosphere.

This subroutine has not been changed.

7.3.7 HTRUE Subroutine

HTRUE calculates the true height for given atmospheric parameters.

This subroutine has not been changed and is explained more fully in Reference 1.

7.3.8 IDENT Subroutine

IDENT is an input subroutine which reads the aircraft identification data file.

It has been modified to allow the option of either:

- calling BININ to read binary records from an engine data file into array F and an aerodynamic data file into array E.
- calling PAC2IN to read a PACAM2 ASCII data file (engine and aerodynamic tables) into arrays E and F. (See Paragraphs 7.1 and 7.5 for more details)

7.3.9 P1OUT Subroutine

P1OUT provides output control for unoptimized performance calculations. A text-formatted output file is produced for printing and an alphanumeric output file is produced for input to program P2V2.

This subroutine has been modified to print the lift limit boundaries, and to allow for the extra option of the energy parameter P_s/V and the alternative option of a turn rate grid. The modifications are labelled K2, K3, K4, K5 in the program listing.

7.3.10 BININ Subroutine

BININ reads data into a nominated storage area from a specified disk file. This file must consist of a sequence of binary records, with the first word in each record being the number of data items in that record.

This subroutine has not been changed.

7.3.11 ALTIT Subroutine

ALTIT performs a Newton iteration to determine pressure height h_p and other atmospheric quantities, when the independent variables are energy state E_s and Mach number.

This subroutine has not been changed and is described in detail in Reference 1.

7.3.12 PARAMS Subroutine

PARAMS calculates airspeed and pressure parameters.

The initial angle of attack estimate for each aircraft trim calculation has now been removed from this subroutine and added to the user defined subroutine AERO.

7.3.13 MAXMAN Subroutine

MAXMAN controls the calculation and output of the optimised manoeuvrability grid, using energy height E_s and load factor or turn rate as grid variables. Energy parameter (P_s, P_s/w_f, P_sV/w_f or P_s/V) is optimised by varying Mach number, and a simple Euler integration is performed at each energy state to estimate a climb time history.

This subroutine has been modified to allow for the additional option of the energy parameter P_s/V and the option of a turn rate grid variable. The modifications are labelled K5 and K8 in the program listing.

7.3.14 SEP Subroutine

SEP calculates the energy parameter (P_s, P_s/wf, P_sV/wf or P_s/V) for the optimised grid.

This subroutine has been largely rewritten. The calculation of P_s has been improved and the subroutine now allows for the additional options available. The modifications are labelled K3, K5, K8 in the listing.

7.3.15 PIOUTA Subroutine

PIOUTA provides output control for optimized performance calculations, in a like manner to subroutine PIOUT.

This subroutine has also been modified to allow for the additional options available. The modifications are labelled K3, K5, K8 in the program listing.

7.3.16 MONSEP Subroutine

MONSEP is a routine called by ROMIN to monitor the convergence of the energy parameter optimisation.

This routine has not been altered and is described in detail in Reference 1.

7.4 Subroutine Library PILIB

This subroutine library is exactly the same as described in Reference 1. It contains routines for curve fitting and optimisation which are explained in detail within the program listing and are described very briefly here for completeness.

7.4.1 SURF Subroutine

SURF takes spline fit information representing a surface stored in vector form and provides at the grid point (x,y) the function z = f(x,y) and, if requested, its 1st and 2nd order derivatives. The spline data represent knots and B-spline coefficents for least square curve fits of z against x for discrete values of y.

7.4.2 CUBICS Subroutine

CUBICS applies a least-squares cubic spline fit of B-splines to weighted data points with selected knots. In the present task, CUBICS is only required to fit a simple cubic to four points; hence the fit is exact, all weights are unity, and no external knots are required.

7.4.3 CHECKD Subroutine

CHECKD checks the validity of data supplied to subroutine CUBICS for curve fitting.

7.4.4 SPDER3 Subroutine

SPDER3 evaluates the cubic spline f(x) and its first derivative df(x)/dx, based on normalised B-spline coefficients and associated knot positions.

7.4.5 ROMIN Subroutine

ROMIN finds the local minimum of an unconstrained function of n variables.

7.5 Subroutine Library PAC2IN

This subroutine library contains utility routines for use when the data files provided are in ASCII tabular format.

7.5.1 PAC2IN Subroutine

PAC2IN is a new routine which has been added to read the relevant information of a PACAM2 aircraft data file which consists basically of values of military and after-burner thrust, fuel flow and ram drag stored in array form with Mach number and altitude as arguments. Aerodynamic data in the form of drag coefficients and angle of attack are also read in using Mach number and lift coefficient as arguments.

Hence PAC2IN first reads in the number of altitude, Mach number and lift coefficient arguments for which data will be read. The actual values of the altitudes, Mach number and lift coefficient arguments are then read followed by the maximum Mach number for each altitude argument and the maximum C_L for each Mach number argument. Tabulated values of military thrust, after-burner thrust, military fuel flow, after-burner fuel flow, and intake momentum drag are then read for the values of the altitude and Mach number arguments listed and entered into array F via calls to TABIN.

Finally values of drag coefficient and angle of attack for the listed values of the M and C_L arguments are entered into array E via calls to TABIN.

7.5.2 TABIN Subroutine

TABIN transfers data into a nominated internal storage area from a specified disk file. Although presently this file is in ASCII and has the format of a PACAM aircraft data file (doubly dimensioned table), the adaptation to a different tabulated format could be easily accomplished.

7.5.3 PACINT Subroutine

PACINT is a double linear interpolation routine. Given a variable (e.g. thrust) that is tabulated as a function of two independent arguments (e.g. Mach number and altitude), a value for this variable at any set of entries is determined by double linear interpolation between adjacent tabulated points.

7.5.4 FIND Subroutine

FIND will return the position, within a single dimensioned ordered array, of the tabular argument above the input variable.

7.5.5 DINTRP Subroutine

Given $z_{11} = f(x_1, y_1)$ $z_{12} = f(x_1, y_2)$
$z_{21} = f(x_2, y_1)$ $z_{22} = f(x_2, y_2)$

DINTRP will perform a double linear interpolation and return $z = f(x,y)$.

7.5.6 PACDER Subroutine

For a variable z that is tabulated as a function of two independent arguments x and y, PACDER determines a value for z and its derivatives with respect to x and y at any set of entries (x,y).

```
        SUBROUTINE THRUST

C WRITTEN BY VR ARL 1983.
C THRUST RETURNS FOR GIVEN HEIGHT /MACH NO. -
C       (1) WF   -FUEL CONSUMP. ( TO P1 THRU COMMON /B/ )
C       (2) XMLIM-MAX. MACH ALL.(  " "   "       "    "  )
C       (3) FN   -NET THRUST    ( ONLY TO AERO,AEROMX THRU COMMON /USER/)
C       (4) FG   -GROSS THRUST  (    "   "   "    "    "     "   "   )
C       (5) RD   -RAM DRAG      (    "   "   '    "    "     "   "   )
C MUST BE CALLED BEFORE EITHER AERO OR AEROMX ARE CALLED

        PARAMETER NUMENG=1
        COMMON /B/ B(200)
        COMMON /C/ C(200)
        COMMON /FDATA/ F(2000)
        COMMON /USER/ FN,FG,RD,CLT,CD,ALPHA,CDS
        EQUIVALENCE   (    XM,B(  3)),(    HP,B(  6)),(     V,B(  9)),
        1             (   PLA,B( 15)),
        1             (  SREF,B( 16)),(    WF,B( 42)),(   DIM,B(49 )),
        3             ( XMLIM,B( 61)),(  IERR,B( 75))
        EQUIVALENCE   (     G,C(39))

C ORDER OF SPLINES IN F IS ASSUMED TO BE -
C       (1)  NET THRUST-INT- (MACH,HEIGHT) [LBF]
C       (2)  ENGINE RAM DRAG-INT- (MACH,HEIGHT) [LBF]
C       (3)  FUEL CONS.-INT- (MACH,HEIGHT) [LBM/HR]
C       (4)  NET THRUST-A/B- (MACH,HEIGHT) [LBF]
C       (5)  ENGINE RAM DRAG-A/B- (MACH,HEIGHT) [LBF]
C       (6)  FUEL CONS.-A/B- (MACH,HEIGHT) [LBM/HR]


C CHECK IF A/B OR INTERMEDIATE POWER REQUEST -
C IF NOT STOP WITH APPROPRIATE MESSAGE
        NJ = 2
        IF(ABS(PLA-200.).LE..001) GOTO 10
        IF(ABS(PLA-100.).LE..001) GOTO 20
        TYPE 75 ,PLA
75      FORMAT(' CANNOT PROCESS ',F5.2,' % THRUST REQUEST YET')
        STOP

C A/B POWER SO READ THRU TO START OF A/B SPLINES
10      DO 11 I=1,3
                NJ = NJ + F(NJ-1) + .001
11      CONTINUE
C IF INTERMEDIATE POWER REQUEST ALREADY AT START OF INT SPLINES


C SET NOMINAL MACH NO. LIMIT
20      XMLIM = XSPMAX( F(NJ) )

C FIND NET THRUST,FN.
        CALL SURF(F(NJ),XM,HP,FN,D1,D2,D3,IERR)
        IF(IERR.NE.0) GOTO 900
        FN = FN*NUMENG

C FIND RAM DRAG,RD.
        NJ = NJ + F(NJ-1) + .001
        CALL SURF(F(NJ),XM,HP,RD,D1,D2,D3,IERR)
        IF(IERR.NE.0) GOTO 900
        RD = RD*NUMENG
        FG = FN + RD

C FIND FUEL CONSUMPTION,WF.
        NJ = NJ+F(NJ-1)+.001
        CALL SURF(F(NJ),XM,HP,WF,D1,D2,D3,IERR)
        IF(IERR.NE.0) GOTO 900
        WF = WF * NUMENG

900     CONTINUE
        RETURN
        END
```

FIG. 7.1   Example 1 of Subroutine THRUST

```
      SUBROUTINE THRUST
C WRITTEN BY VR ARL MARCH 1983
C THRUST RETURNS FOR GIVEN HEIGHT /MACH NO. -
C        (1) WF    -FUEL CONSUMP. ( TO P1 THRU COMMON /B/ )
C        (2) XMLIM-MAX. MACH ALL.(  " "   "        "    "  )
C        (3) FN    -NET THRUST     ( ONLY TO AERO,AEROMX THRU COMMON /USER/)
C        (4) FG    -GROSS THRUST   (  "    "   "    "      "    "     "   )
C        (5) DELTL-LIFT LOSS       (  "    "   "    "      "    "     "   )
C        (6) RD    -RAM DRAG       (  "    "   "    "      "    "     "   )
C MUST BE CALLED BEFORE EITHER AERO OR AEROMX ARE CALLED

      PARAMETER AJ = 6.38                    !NOZZLE AREA (FT**2)
      REAL JVR,LRR,K1,K2
      COMMON /B/ B(200)
      COMMON /FDATA/ F(2000)
      COMMON /USER/ FN,FG,RD,CLT,CD,ALPHA,DELTL,THETAE,
     1       CLO,DCLDA,K1,K2,CD0,CLCRIT,CDS
      EQUIVALENCE  (     XM,B(  3)),(      T,B(  4)),(     HP,B(  6)),
     1             (P      ,B(  7)),(    AJN,B( 13)),
     !             (  SREF,B( 16)),(     WF,B( 42)),(    DIM,B(49 )),
     3             ( XMLIM,B( 61)),(   IERR,B( 75))

C ORDER OF SPLINES IN F IS ASSUMED TO BE -
C        (1) [NORMALIZED] GROSS THRUST-COMBAT- (MACH,HEIGHT)
C        (2) [NORMALIZED] FUEL CONS.-COMBAT- (MACH,HEIGHT)
C        (3) [NORMALIZED] NET THRUST-COMBAT- (MACH,HEIGHT)
C        (4) LIFTLOSS/FG RATIO (JVR,ANG OF NOZZLE DEF)
C POWER LEVEL FOR  AIRCRAFT IS ASSUMED TO ALWAYS BE COMBAT.

C CALCULATE NORMALIZING FACTORS - PDPO = P/PO, TDTO = T/TO
      PDPO = P/2116.22
      TDTO = T/288.15

C SET NOMINAL MACH NO. LIMIT
      XMLIM = XSPMAX( F(2) )

C FIND GROSS THRUST FG FROM SPLINE THEN UN-NORMALISE
      NJ = 2
      CALL SURF(F(NJ),XM,HP,FG,D1,D2,D3,IERR)
      IF(IERR.NE.0) GOTO 900
      FG = FG*PDPO

C FIND FUEL CONSUPTION WF FROM SPLINE THEN UN-NORMALISE
      NJ = NJ+F(NJ-1)+.001
      CALL SURF(F(NJ),XM,HP,WF,D1,D2,D3,IERR)
      IF(IERR.NE.0) GOTO 900
      WF = WF*PDPO*SORT(TDTO)

C FIND NET THRUST FROM SPLINE THEN UN-NORMALISEFN.
      NJ = NJ+F(NJ-1)+.001
      CALL SURF(F(NJ),XM,HP,FN,D1,D2,D3,IERR)
      IF(IERR.NE.0) GOTO 900
      FN = FN*PDPO

C CALCULATE RAM DRAG RD
      RD = FG - FN

C FIND LIFT LOSS RATIO(LRR) & CALCULATE LIFT LOSS(DELTL)
      DELTL = 0.0
      IF(XM.LT. 1E-4) GOTO 900
      NJ = NJ + F(NJ-1) + .001
      JVR = SORT((FG*SREF)/(2.0*DIM*AJ))          !JET VEL. RATIO
      JVR = AMIN1(JVR,XSPMAX( F(NJ) ))
      AJN1=AMIN1(AJN,YSPMAX(F(NJ)))
      CALL SURF(F(NJ),JVR,AJN1,LRR,D1,D2,D3,IERR)
      IF(IERR.NE.0) GOTO 900
      DELTL = LRR * FG
900   CONTINUE
      RETURN
      END
```

FIG. 7.2 Example 2 of Subroutine THRUST

```
      SUBROUTINE THRUST
C THRUST RETURNS FOR GIVEN HEIGHT /MACH NO. -
C       (1) WF    -FUEL CONSUMP. ( TO P1 THRU COMMON /B/ )
C       (2) XMLIM-MAX. MACH ALL.(  " "   "      "    "  )
C       (3) FN    -NET THRUST    ( ONLY TO AERO,AEROMX THRU COMMON /USER/)
C       (4) FG    -GROSS THRUST  (  "    "    "    "     "    "      "  )
C       (5) RD    -RAM DRAG
C       (6) IXM   -INDEX S.T.  VMARG(IXM-1) < XM <= VMARG(IXM)
C MUST BE CALLED BEFORE EITHER AERO OR AEROMX ARE CALLED

      COMMON /B/ B(200)
      COMMON /FDATA/ F(2000)
      COMMON /USER/ U(10)
      DIMENSION HARG(20), VMARG(20), VMTOP(20)
      EQUIVALENCE   (     XM,B(  3)),(      T,B(  4)),(     HP,B(  6)),
     1              (P      ,B(  7)),(    AJN,B( 13)),(    PLA,B( 15)),
     1              (   SREF,B( 16)),(     WF,B( 42)),(    DIM,B(49 )),
     3              ( XMLIM,B( 61)),(  IERR,B( 75))
      EQUIVALENCE     (   FN,U( 1)),(     FG,U( 2)),(     RD,U( 3)),
     1              (    IXM,U(10))
      EQUIVALENCE     (   NA,F(1 )),(     NM,F( 2)),(   HARG,F( 3)),
     1              ( VMARG,F(23)),( VMTOP,F(43))

      FINTRP(X,X1,Y1,X2,Y2)=Y1+(X-X1)*(Y2-Y1)/(X2-X1)

C ASSUMES A PACAM2 A/C DATA FILE.
C ASSUMES F CONTAINS -
C       (1) NA    -NO. OF ALTITUDE ARGS
C       (2) NM    -NO. OF MACH ARGS
C       (3) HARG  -ARRAY OF ALTITUDE ARGS
C       (4) VMARG -ARRAY OF MACH ARGS
C       (5) VMTOP -ARRAY OF MAX MACH( ALT)
C       (6) THRMP -TABLE OF MIL. THRUST(MACH,ALT)
C       (7) THRAB -TABLE OF A/B THRUST(MACH,ALT)
C       (8) DINM  -TABLE OF RAM DRAG(MACH,ALT)
C       (9) FCMP  -TABLE OF MIL. FUEL CONS.(MACH,ALT)
C       (10)FCAB  -TABLE OF A/B FUEL CONS.(MACH,ALT)

C FIND IXM,IHP
      CALL FIND(VMARG,NM,XM,IXM)
      CALL FIND(HARG,NA,HP,IHP)

C FIND MAX MACH NO. FOR THIS ALTITUDE
      XMLIM = FINTRP(HP,HARG(IHP-1),VMTOP(IHP-1),HARG(IHP),
     1        VMTOP(IHP))

C FIND GROSS THRUST :FG
      NJ = 63                       !POINTER TO CURRENT TABLE IN F
      FGMIL = PACINT(XM,HP,VMARG,HARG,F(NJ),IXM,IHP,NM,NA)
      NJ = NJ + NA*NM
      IF(PLA.GT.100.) GOTO 10
C INTERPOLATE FROM 0 TO MIL POWER RATING
      FG = FINTRP(PLA,0.,0.,100.,FGMIL)
      GOTO 20
C INTERPOLATE BETWEEN MIL POWER & A/B POWER
10    FGAB = PACINT(XM,HP,VMARG,HARG,F(NJ),IXM,IHP,NM,NA)
      FG = FINTRP(PLA,100.,FGMIL,200.,FGAB)

C FIND RAM DRAG - INTAKE MOMENTUM DRAG
20    NJ = NJ + NA*NM
      RD = PACINT(XM,HP,VMARG,HARG,F(NJ),IXM,IHP,NM,NA)

C CALCULATE NET THRUST :FN
      FN = FG - RD

C FIND FUEL CONSUMPTION :WF
      NJ = NJ + NA*NM
      WFMIL = PACINT(XM,HP,VMARG,HARG,F(NJ),IXM,IHP,NM,NA)
      IF(PLA.GT.100.) GOTO 50
C INTERPOLATE BETWEEN 0 & MIL POWER
      WF = FINTRP(PLA,0.,0.,100.,WFMIL)
      GOTO 100
C INTERPOLATE BETWEEN MIL POWER & A/B POWER
50    NJ = NJ + NA*NM
      WFAB = PACINT(XM,HP,VMARG,HARG,F(NJ),IXM,IHP,NM,NA)
      WF = FINTRP(PLA,100.,WFMIL,200.,WFAB)
C
100   RETURN
      END
```

FIG. 7.3   Example 3 of Subroutine THRUST

```
      SUBROUTINE AEROMX
C
C AEROMX FINDS FOR A GIVEN HEIGHT & MACH NO.
C       (1) CLMAX
C       (2) ALPMAX - ALPHA CORRESPONDING TO CLMAX
C       (3) TLMAX  -TOTAL LIFT CORRESPONDING TO CLMAX
C       (4) CDS    -STORE DRAG COEF.( PASSED THRU /USER/ TO AERO)
C AEROMX ASSUMES A CALL HAS BEEN MADE TO THRUST PRIOR TO ITS CALLING.
C AEROMX MUST BE CALLED BEFORE AERO IS CALLED FOR THAT PARTICULAR HEIGHT/
C MACH NO. COMBINATION.
C VR ARL APRIL 1983

C ASSUMES ORDER OF SPLINE FITS IN E IS -
C       (1) CL(ALPHA,MACH)
C       (2) CLMAX(MACH)
C       (3) CDL(CL,MACH)
C       (4) CDO(MACH)

      COMMON /B/ B(200)
      COMMON /C/ C(200)
      COMMON /EDATA/ E(2000)
      COMMON /USER/ FN,FG,RD,CLT,CD,ALPHA,CDO,CDS
      DIMENSION XMDCDS(20), DELCDS(20)
      EQUIVALENCE    (RADIAN,C( 40))
      EQUIVALENCE     (  GN,B(  2)),(    XM,B(  3)),( THETAI,B( 13)),
     1              (    W,B( 17)),(  EFFT,B(41)),
     1              (    D,B( 43)),( CLMAX,B( 44)),
     2              (ALPMAX,B( 45)),( TLMAX,B( 48)),(   DIM,B( 49)),
     3(  IERR,B( 75)),( NDCDS,B( 80)),(XMDCDS,B( 81)),(DELCDS,B(101))

      FINTRP(X,X1,Y1,X2,Y2) = Y1 + (X-X1) * (Y2-Y1) / (X2-X1)

C FIND CLMAX FROM 2ND SPLINE FIT IN E
      IERR = 0                                    !RESET IERR
      NJ = E(1)+2.0001                            !NJ POINTS TO 2ND SPLINE IN E
      X = AMAX1(XM,XSPMIN( E(NJ) ))
      Y = 0
      CALL SURF(E(NJ),X,Y,CLMAX,D1,D2,D3,IERR)         !GET CLMAX FOR MACH X
      IF(IERR.NE.0) GOTO 30

C FIND CDO FROM 4TH SPLINE IN E
      NJ=NJ+E(NJ-1)+.001
      NJ=NJ+E(NJ-1)+.001                          !NJ POINTS TO 4TH SPLINE IN E
      X=AMAX1(XM,XSPMIN(E(NJ)))
      Y=0
      CALL SURF(E(NJ),X,Y,CDO,D1,D2,D3,IERR)           !GET CDO FOR MACH X

C FIND ALPHA CORRESPONDING TO CLT = CLMAX
      CLT = CLMAX
      CALL GETALF
      ALPMAX = ALPHA

C CALCULATE TLMAX : LIFT CORRESPONDING TO CLMAX
      TLMAX = FG*SIND(ALPMAX) + CLMAX*DIM
30    CONTINUE

C FIND STORE DRAG
      CDS = 0.
      IF (NDCDS.EQ.0) GOTO 900
      IF (XM.LE.XMDCDS(1)) CDS = DELCDS(1)
      IF (XM.GE.XMDCDS(NDCDS)) CDS = DELCDS(NDCDS)
      IF (XM.LE.XMDCDS(1) .OR. XM.GE.XMDCDS(NDCDS)) GOTO 540
      DO 450 I=2,NDCDS
  450 IF (XM.LE.XMDCDS(I)) GOTO 500
      IERR = 104
      GOTO 900
  500 IM = I-1
      CDS = FINTRP (XM, XMDCDS(IM), DELCDS(IM), XMDCDS(I), DELCDS(I))
  540 CDS = CDS * 1.0E-04
  900 CONTINUE
      RETURN
      END
```

FIG. 7.4 Example of Subroutine AEROMX

```
      SUBROUTINE GETALF
C FINDS ALPHA FOR GIVEN CLT IN /USER/ AND XM IN /B/
C
      COMMON /EDATA/ E(2000)
      COMMON /B/ B(200)
      COMMON /USER/ FN,FG,RD,CLT,CD,ALPHA,CDO,CDS
      EQUIVALENCE     (XM  ,B(  3)),(  IERR,B( 75))

C USE N/R TO FIND FROM CL(ALPHA,MACH) -THE 1ST SPLINE FIT IN E -
C THE ALPHA CORRESPONDING TO CLT.
      ALPHA = CLT /.09                !EMP. DET BEST 1ST ESTIMATE
      NJ = 2                          !NJ POINTS TO 1ST SPLINE IN E
      ASPMAX=XSPMAX(E(NJ))
      YM = AMAX1(XM,YSPMIN( E(NJ) ))
      DO 20 I=1,20
            IERR = -1                       !DERIVATIVES REQUIRED
            A = AMIN1(ASPMAX,ALPHA)
            CALL SURF(E(NJ),A,YM,CL,DCDA,D2,D3,IERR)
            IF(IERR.NE.0) GOTO 21
            CL = CL+(ALPHA-A)*DCDA          !EXTRAPOLATE OUTSIDE RANGE
            FA = CL-CLT
            IF(ABS(FA).LT.1E-4) GOTO 25     !EXIT AS CLOSE ENOUGH
            ALPHA = ALPHA - FA/DCDA
20    CONTINUE
21    IERR = 102                            !DID NOT CONVERGE IN 20 ITER.
25    RETURN
      END
```

FIG. 7.5 Example of Subroutine GETALF

```
      SUBROUTINE AERO

C AERO ROUTINE RETURNS FOR GIVEN LOAD FACTOR /HEIGHT /MACH NO. -
C       (1) D    - DRAG
C       (2) EFFT - EFFECTIVE THRUST
C AERO ASSUMES AEROMX HAS PREVIOUSLY BEEN CALLED TO SET UP VARIABLES DEPENDING ONLY ON
C GIVEN HEIGHT/MACH NO.
C SIMILAIRLY IT ASSUMES THRUST HAS SET UP PROPULSION ASSOCIATTED VAR FOR THE
C GIVEN HEIGHT /MACH NO.

C ASSUMES ORDER OF SPLINE FITS IN E IS -
C       (1) CL(ALPHA,MACH)

      COMMON /B/ B(200)
      COMMON /C/ C(200)
      COMMON /EDATA/ E(2000)
      COMMON /USER/ FN,FG,RD,CLT,CD,ALPHA,CD0,CDS
      DIMENSION XMDCDS(20), DELCDS(20)
      EQUIVALENCE   (RADIAN,C( 40))
      EQUIVALENCE     (   GN,B(  2)),(     XM,B(  3)),(THETAI,B( 13)),
     1               (    W,B( 17)),(  EFFT,B( 41)),
     1               (    D,B(43 )),( CLMAX,B( 44)),
     2               ( TLMAX,B( 48)),(   DIM,B( 49)),(  IERR,B( 75)),
     3               ( NDCDS,B( 80)),(XMDCDS,B( 81)),(DELCDS,B(101))

      FINTRP(X,X1,Y1,X2,Y2) = Y1 + (X-X1) * (Y2-Y1) / (X2-X1)

C FIND TRIMMED ANGLE OF ATTACK & CL FOR GIVEN HIEGHT,MACH & LOAD FACTOR.

C FIND CL TRIM (CLT) & ALPHA USING N/R ,ITERATING ON ALPHA
      T1 = GN*W                                     !TEMP. VAR TO SAVE CALC.
      IF(XM.GE.0.0) GOTO 110
      IERR = 103
      GOTO 900
110   NJ = 2                                        !POINTS TO IST SPLINE
      DCLDA = 0.09                                  !ESTIMATE FROM GRAPH
      ALPHA = T1 / ( FG/RADIAN + DIM*DCLDA )        !INITIAL EST.
      ASPMAX = XSPMAX( E(NJ) )
      DO 120 I=1,10
            IERR = -1                               !REQUIRE SPLINE DERIVS
            A = AMIN1(ASPMAX,ALPHA)
            CALL SURF(E(NJ),A,XM,CLT,DCLDA,D2,D3,IERR)
            IF(IERR.NE.0) GOTO 900
            CLT = CLT+(ALPHA-A)*DCLDA               !LINEAR EXTRAPOLATION
            DFDA = DIM*DCLDA + FG*COSD(ALPHA)/RADIAN
            F = FG*SIND(ALPHA) + CLT*DIM - T1
            DALF = F/DFDA
            IF(ABS(DALF).LT.0.001) GOTO 200         !EXIT AS CLOSE ENOUGH
            ALPHA = ALPHA - DALF
120   CONTINUE
      IERR = 102                                    !MORE THAN 20 ITERATIONS
      GOTO 900

C CALCULATE EFFT - EFFECTIVE THRUST
200   EFFT = FG*COSD(ALPHA)-RD

C CALCULATE CD & THEN D
      CALL GETCD
      D = CD * DIM
900   CONTINUE
      RETURN                                        ! RETURN NORMALLY
      END
```

FIG. 7.6   Example of Subroutine AERO.

```
      SUBROUTINE GETCD

C ROUTINE TO CALCULATE CD GIVEN CLT & XM AND A PRIOR CALL TO AEROMX.

      COMMON /USER/ FN,FG,RD,CLT,CD,ALPHA,DELTL,THETAE,
     1        CL0,DCLDA,K1,K2,CD0,CLCRIT,CDS
      REAL K1,K2

C CALCULATE DRAG COEFF
      IF(CLT.LE.CLCRIT) CDL = (CD0+K1*CLT*CLT)
      IF(CLT.GT.CLCRIT) CDL = (CD0+(K1-K2)*CLCRIT*CLCRIT
     1                        +K2*CLT*CLT)

C CALCULATE TOTAL DRAG
      CD = CDL + CDS
      CONTINUE
      RETURN
      END
```

FIG. 7.7 Example 1 of Subroutine GETCD

```
      SUBROUTINE GETCD

C CALCULATES CD (=CDL+CD0+CDS) FOR GIVEN CLT & MACH.
C ASSUMES CDL(CL,MACH) IS THE 3RD SPLINE IN E

      COMMON /EDATA/ E(2000)
      COMMON /B/ B(200)
      COMMON /USER/ FN,FG,RD,CLT,CD,ALPHA,CD0,CDS
      EQUIVALENCE (    XM,B(   3)),(   IERR,B( 75))

      NJ = E(1) + 2.001
      NJ = NJ + E(NJ-1) + .001                 !PTS TO 3RD SPLINE IN E
      XCLT = AMIN1(CLT,XSPMAX(E(NJ)))
      YM = AMAX1(XM,YSPMIN( E(NJ) ))
      IERR = -1                                !DERIVATIVE REQUIRED
      CALL SURF(E(NJ),XCLT,YM,CDL,DCDDCL,D2,D3,IERR)
      IF(IERR.NE.0) GOTO 900
      CDL = CDL+(CLT-XCLT)*DCDDCL              !LINEAR EXTRAPOLATION
      CD = CD0 + CDL + CDS

900   CONTINUE
      RETURN
      END
```

FIG. 7.8 Example 2 of Subroutine GETCD

```
      SUBROUTINE GETCDA
C
C RETURNS CD & ALPHA FOR GIVEN XM & CL.
C
      CALL GETALF
      CALL GETCD
      RETURN
      END
```

FIG. 7.9 Example of Subroutine GETCDA

```
      SUBROUTINE GETCDCL

C RETURNS CD & CL FOR GIVEN MACH & ALPHA.

      COMMON /EDATA/ E(2000)
      COMMON /B/ B(200)
      COMMON /USER/ FN,FG,RD,CLT,CD,ALPHA,DELTL,THETAE,CDDIFF,CDS
      EQUIVALENCE (    XM,B(  3)),(  IERR,B( 75))

      NJ = 2
      YM = AMAX1(XM,YSPMIN( E(NJ)) )
      CALL SURF(E(NJ),ALPHA,YM,CLT,D1,D2,D3,IERR)
      IF(IERR.NE.0) RETURN

      CALL GETCD

      RETURN
      END
```

FIG. 7.10 Example 1 of Subroutine GETCDCL

```
      SUBROUTINE GETCDCL

C RETURNS CLT & CD FOR GIVEN VALUES OF MACH & ALPHA.
C ASSUMES PRIOR CALL TO AEROMX.

      COMMON /USER/ FN,FG,RD,CLT,CD,ALPHA,DELTL,THETAE,
     1      CL0,DCLDA,K1,K2,CD0,CLCRIT,CDS
      REAL K1,K2

C CALCULATE TRIMMED CL
      CLT = DCLDA*ALPHA + CL0
C CALCULATE CD
      CALL GETCD
      RETURN
      END
```

FIG. 7.11 Example 2 of Subroutine GETCDCL

```
      FUNCTION XSPMIN(SPL)
C
C RETURNS LOWER BOUND OF SPLINE FIT SPL 'S X RANGE
      DIMENSION SPL(1)

      NC = SPL(2) + .001
      XSPMIN = SPL(NC+3)
      RETURN
      END

      FUNCTION XSPMAX(SPL)
C
C RETURNS UPPER BOUND OF SPLINE FIT SPL'S X RANGE.
      DIMENSION SPL(1)

      NC = SPL(2) + .001
      XSPMAX = SPL(NC+4)
      RETURN
      END

      FUNCTION YSPMIN(SPL)
C
C RETURNS LOWER BOUND OF SPLINE FIT SPL'S Y RANGE.
      DIMENSION SPL(1)

      YSPMIN = SPL(3)
      RETURN
      END

      FUNCTION YSPMAX(SPL)
C
C RETURNS UPPER BOUND OF SPLINE FIT SPL'S Y RANGE.
      DIMENSION SPL(1)

      NC = SPL(2) + .001
      YSPMAX = SPL(NC+2)
      RETURN
      END
```

FIG. 7.12 Useful Functions used in ACRAFT

8. PROGRAM P2V2 DESCRIPTION

8.1 Loading of Program on DEC System-10

The commands for loading program P2V2 and saving a core image on disk on DEC system-10 are:

. LOAD P2V2, P24LIB/SEARCH
. SAVE P2V2

The routines contained in each of these files are listed in the following table and described briefly in this chapter.

P2V2	MAIN P2IN INMMD PSCON PDSIFF RATE1 SEPCON RATE2 MMP GRID
P24LIB	INTRP BADINP INLAB PLTLAB UNITS WRLAB

8.2 File P2V2 (P2 Version 2)

Most subroutines contained in this file have been extensively rewritten. Their purpose is described here and further details are available in the source program listing which is extensively documented.

8.2.1 P2 MAIN Program

P2V2 processes data files prepared for a particular aircraft by program ACRAFT and produces either plotter files ready for submission to the off line plot queue or output files to be further processed by the contour plotting program P4V2.

Plotter files (named P2.PLT) are produced by options 4B, 4C and 4Z. The output file P24A1.CON is produced by option 4A and the output files P24A1.CON, P24A2.CON and P24DIF.CON are created by option 4D. Option 4G creates the file P24G.CON. All these output files (.CON) are used as input files to the contour plotting program P4V2.

The main program has been modified mainly to cater for the additional option 4G. The Modifications are labelled K1 and K4 in the source program listing.

8.2.2 P2IN Subroutine

P2IN is called by the main program to process the aircraft identification header on the input file and requests an option code for the type of run. An error halt is forced if the 8000 words allocated for vector WORK are insufficient to accommodate the data required by the input grid. It is the user's responsibility to ensure that the option requested is consistent with the purpose for which program ACRAFT produced the data.

This subroutine has been modified to allow for the additional option 4G which plots contours of the energy parameter on a Mach number, turn rate (or load factor) grid.

8.2.3 INMMD Subroutine

Subroutine INMMD is called by subroutine P2IN. It performs a conversational dialogue with the user to accept text, grid data and configuration parameters for on-line provision of maximum manoeuvre diagram data.

It is still in its original condition as described in Reference 1.

8.2.4 PSCON Subroutine

Subroutine PSCON is called from the main program when IOPT=1 (Option 4A). PSCON reads data files produced by program ACRAFT, expressed on a load factor (or turn rate), Mach number grid for each pressure height requested, and prepares a disk file P24A1.CON where the energy parameter is expressed on a (Mach number, altitude) grid for each of the requested load factor or turn rate grid points. P24A1.CON will then be used as the input file when running P4V2 to produce contour plots.

In addition this subroutine now calculates the lift limit boundary by working out for each Mach number the height at which the load factor (or turnrate) corresponding to the maximum lift coefficient is equal to the requested load factor (or turn rate).

This subroutine has been largely rewritten. The modifications are labelled K2,K4 in the program listing.

8.2.5 PSDIFF Subroutine

Subroutine PSDIFF is called from the main program when IOPT=4(Option 4D). PSDIFF performs the functions of PSCON with two separate files produced by ACRAFT. Subroutine PSDIFF produces three data files, P24A1.CON, P24A2.CON and P24DIF.CON (one for each aircraft and the differential data) any of which can then be processed by program P4V2.

This subroutine has only been slightly changed and is described in Reference 1. The modifications are labelled K2,K4 in the program listing.

8.2.6 RATE1 Subroutine

Subroutine RATE1 is called from the main program when IOPT=2(option 4B). RATE1 reads data produced by program ACRAFT expressed as energy parameter versus turn rate (or load factor) for a range of altitudes (pressure height or energy height) and Mach numbers, and prepares a plotter file P2.PLT ready for plotting. A separate plotter page is produced for each value of the altitude variable.

This subroutine has been slightly changed to allow for the choice of load factor as the x axis. The modifications are labelled K4 in the program listing.

8.2.7 SEPCON Subroutine

Subroutine SEPCON is called from the main program when IOPT=8(option 4G). SEPCON reads data files produced by program ACRAFT, expressed on a turn rate (or load factor), Mach number grid for each pressure heights requested and prepares a file P24G.CON where the energy parameter is expressed on a Mach number, turn rate (or load factor) grid for each of the requested heights. P24G.CON will then be input to program P4V2 to produce contour plots.

In addition this subroutine also transmits to P24G.CON the lift limit boundaries calculated in program ACRAFT.

This subroutine was entirely rewritten for Version 2.

8.2.8 RATE2 Subroutine

Subroutine RATE2 is called from the main program when IOPT=3(option 4C).

RATE2 reads data produced by program ACRAFT representing the optimum energy parameter and corresponding turn rate (or load factor) for a range of energy states and load factors (or turn rates). RATE2 then prepares the plotter file P2.PLT ready for plotting.

This subroutine has been entirely rewritten for Version 2. Previously (Version 1) it was necessary to run P4 to obtain these plots. It is now possible (and more accurate) to create the plotter file directly from P2V2 because of the alternative turn rate grid variable.

8.2.9 MMP Subroutine

Subroutine MMP is called by the main program when IOPT=6 (Option 4F).

MMP is a conversational routine to assist in calculating data for the Maximum Manoeuvre Persistance Diagram. Fuel available for optimum manoeuvres at discrete range intervals, together with energy state, maximum sustained turn rate and fuel flow, are requested as terminal input, and the number of sustained turns at each range is provided as terminal output.

This subroutine has not been modified in Version 2 and is described fully in Reference 1.

8.2.10 GRID Subroutine

Subroutine GRID is called by the main program when IOPT = 7 (Option 4E).

GRID reads the data files produced by program ACRAFT, expressed on a Mach number, load factor (or turn rate) grid for each height requested and prepares a disk file P2.PLT for plotting. Turn rate (or load factor) and energy parameter are plotted against Mach number for each load factor (or turn rate) requested. A separate page of plots is produced for each value of the height variable (energy height or pressure height).
These plots are intended as an overview of the data grid and are produced with a predetermined scale.

This subroutine has been modified to allow for the additional option of selecting load factor or turn rate as one of the grid variables. The modifications are labelled F4 in the program listing.

8.3 Subroutine Library P24LIB

P24LIB contains a number of small utility subroutines. Most of these subroutines have been slightly modified in Version 2 mainly to cater for the extra information being presented. The modifications are labelled K3 and K5 in the program listing.

8.3.1 INTRP and BADINP Subroutines

Routine INTRP (numerical interpolation) and routine BADINP (input error text) are obtained from the file P1V2 and are described in Chapter 7.

8.3.2 INLAB Subroutine

INLAB is called from subroutine PSDIFF to read an alphanumeric identifying header from an input disk file produced by program ACRAFT.

8.3.3 PLTLAB Subroutine

PLTLAB outputs the identifying header read by INLAB to a plotter file.

8.3.4 UNITS Subroutine

UNITS is called by P2IN to allocate text strings to variables for use in terminal dialogue and plotter axis labelling, dependent on the unit system and the energy variable selected.

8.3.5 WRLAB Subroutine

WRLAB writes the descriptive header read by INLAB onto an output disk file to be used as input program P4V2.

9. PROGRAM P4V2 DESCRIPTION

9.1 Loading of Program on DEC System-10

The commands for loading program P4V2 and saving a core image on disk on DEC system-10 are:

. LOAD P4V2, P4LIB/SEARCH, P24LIB/SEARCH
. SAVE P4V2

The routine contained in these files are listed in the following table and described in this chapter.

P4V2	MAIN P4PS4A P4PS4G PCON PES OUTXT PLOTD GRIDC BOUND ETSEND
P4LIB	CONT DIAG SMOOTH PROMPT REALIN DASH
P24LIB	INTRP BADINP INLAB PLTLAB UNITS

9.2 File P4V2

Most routines contained in this file have been restructured and rewritten. Their purpose is described here and further details are available in the source program listing which is extensively documented.

9.2.1 P4 MAIN Program

The program P4V2 processes data files produced by program P2V2 and produces contour plots for off line plotting. The contour plots on file P4.PLT are of two types:

(1) Contours of energy parameter on a Mach number, altitude (or energy state) grid for selected load factors (option 4A and 4D).

(2) Contours of energy parameter on a Mach number, turnrate (or load factor) grid for selected heights (Option 4G).

The brief main program performs preliminary input operations and calls routine P4PS4A if option 4A (or 4D) is selected and routine P4PS4G if option 4G is selected.

9.2.2 P4PS4A Subroutine

Subroutine P4PS4A is called from the main program when options 4A or 4D are selected. It uses the input data filename to differentiate between requests for single aircraft or comparison plots.

P4PS4A controls the conversational dialogue which allows the user to vary several features of the plots: scale of plots, number and level of contours, selection of load factors (or turn rate), smoothness of plots, inclusion of energy state contours.

P4PS4A also controls the setting up and plotting of identifying text and axes, the reading of grid data and boundary points from file P24A.CON, the plotting of energy rate contours together with the lift limit boundary and the plotting of the superimposed energy state contours

9.2.3 P4PS4G Subroutine

Subroutine P4PS4G is called from the main program when option 4G is chosen.

P4PS4G controls the conversational dialogue which allows the user to vary several features of the plots: scale of plots, number and level of contours, selection of heights (or energy states), smoothness of plots, inclusion of load factor and turn radius grid (if the grid selected is turn rate).

P4PS4G also controls the reading of grid data and boundary points from file P24G.CON, the plotting of energy rate contours together with the lift limit boundary, and the plotting of the superimposed constant load factor lines and structural load factor boundary when turn rate has been selected as a grid variable. Only the points within the lift limit boundary are plotted whereas contours outside the structural limit boundaries are drawn with a dashed line.

9.2.4 BOUND Subroutine

Subroutine BOUND is called by subroutine P4PS4A or P4PS4G to plot the lift limit boundary line and label the end of the line.

9.2.5 ETSBND Subroutine

Subroutine ETSBND is called by subroutine P4PS4G to plot and label the line corresponding to the structural load factor limit on a (Mach number, turn rate) grid.

9.2.6 GRIDC Subroutine

Subroutine GRIDC is called by subroutine P4PS4G. It controls the plotting of lines of constant load factor and lines of constant turn radius on a (Mach number, turn rate) grid.

9.2.7 PCON Subroutine

Subroutine PCON is called by subroutines P4PS4A or P4PS4G to control calls to the software routine PLOT. Plotting is achieved by calls to PLOTD (P4V2) for straight lines between points or calls to SMOOTH (P4LIB) for cubic arcs between points.

9.2.8 PES Subroutine

Subroutine PES is called by subroutine P4PS4A to control the plotting of E_s contours by calling either PLOTD or SMOOTH for straight line or smoothed plots, respectively.

9.2.9 PLOTD Subroutine

PLOTD is a interface routine for the CALCOMP software routine PLOT. This routine has been transfered from Version 1.

9.2.10 OUTXT Subroutine

Subroutine OUTXT is called by PCON at the start of a contour line to output the contour level on the plotter.

This subroutine was derived from Version 1.

9.3 Subroutine Library P4LIB

Most subroutines put together in P4LIB were taken from a set of general purpose library routines available to all ARL staff. These routines are outlined briefly below but more details are available in Reference 1.

9.3.1 CONT Subroutine

Subroutine CONT is called by P4PS4A or P4PS4G to draw contour lines for a variable stored in a two dimensional array (i.e. $P_s(M,H)$).

9.3.2 DIAG Subroutine

DIAG is a routine called by CONT to interpolate along a mesh diagonal using a simple biquadratic representation of the mesh.

9.3.3 SMOOTH Subroutine

SMOOTH is a routine which smooths the contour plots by joining successive points on the contour with cubic arcs having tangential coincidence at their common points (knots). The tangential slope is set equal to the mean of the slopes of the straight lines that would otherwise join points on either side of the knot. When smoothing is selected, an additional call to SMOOTH is required to complete the current contour before proceeding to the next contour request.

9.3.4 PROMPT Subroutine

PROMPT is a routine called by SMOOTH and REALIN which writes a text on the user's terminal.

9.3.5 REALIN Subroutine

REALIN is a routine called by SMOOTH to accept real numerical data from the user's terminal.

9.3.6 DASH Subroutine

DASH is a new subroutine called by subroutine PLOTD (P4V2) to plot a dashed line between two points.

9.4 Subroutine Library P24LIB

This library has been described in Paragraph 8.3.

10. EXAMPLES

The previous chapters have discussed the three programs in the suite. This chapter presents examples of the interactive dialogue used when running the programs, and of the tabular outputs and plots produced when using the programs in a co-ordinated fashion. Any given aircraft is represented by files of propulsion, aerodynamic and configuration data, together with the source and core image of the FORTRAN programs. A suitable naming convention is required to provide efficient housekeeping of these files. These files can be stored on DEC tape, since changes to one or more files will be needed as data banks and programs are developed.

10.1 Option 4A

This option corresponds to the options 1, 6, 15 and 20 in the overview on Figure 2.2.

Figure 10.1 shows a sample dialogue when running the three programs ACRAFT, P2V2, P4V2 to produce a set of SEP (P_s) contours plots for specified load factors (option 1 in Figure 2.2). Program ACRAFT produces a file (EXAMPL.TXT) for printing and a file (EXAMPL.NUM) for input to program P2V2.

Figure 10.2 shows a portion of the file EXAMPL.TXT and illustrates the main features of the listed output. The header page identifies the run and echoes the configuration data supplied in the configuration file. In the subsequent pages energy rate and turn rate data are tabulated at each grid point. Also listed for each Mach number are the turn rate and load factor corresponding to the lift limit boundary. Energy rate values outside the lift limited envelope are flagged with the values of -9999.99.

The 1g load factor SEP contour plot produced using the dialogue in Figure 10.1 is shown in Figure 10.3. Contours are labelled with a number indicating the value of the parameter plotted, as shown on the right hand side of the plot. The zero SEP contour is emphasised by a dashed line. Superimposed on the plot are contours of constant energy state.

Figure 10.4 illustrates a similar dialogue to obtain contours of P_sV/w_f for specified turn rates (option 6 in Figure 2.2) with an extract of the corresponding output shown in Figure 10.5 and a typical plot shown on Figure 10.6.

10.2 Option 4B

This option corresponds to the options 2, 7, 16, 21 in the overview of Figure 2.2.

Figure 10.7 shows a typical dialogue for producing plots of SEP versus turn rate for lines of constant Mach number using the two programs ACRAFT and P2V2 (option 2 in Figure 2.2). A load factor increment of 0.5 was chosen to provide a smooth curve when the values are plotted. The Mach number and altitude selected for the plots are nominated when running P2V2.

Figure 10.8 shows an example of such a plot where each curve plotted is identified with Mach number and energy state annotation.

10.3 Option 4C

This option corresponds to the options 11 and 13 in the overview of Figure 2.2.

Figure 10.9 shows a typical dialogue when running the two programs ACRAFT and P2V2 for producing a maximum manoeuvre diagram where P_s is optimised with respect to Mach number and plotted against energy state E_s for selected values of load factor.

An extract of the output file produced is shown in Figure 10.10 and the corresponding plot in Figure 10.11. To understand the meaning of the data produced a summary of the theory used may be useful.

By definition $P_s = \frac{dE_s}{dt}$

therefore the time to climb from one energy state E_{s1} to another E_{s2} is:

$$t = \int_{E_{s1}}^{E_{s2}} \frac{1}{P_s} \, dE_s$$

If we look at a 1g P_s contour plots (Figure 10.3) it can be shown theoretically (Reference 4) that the optimum climb for minimum time will be the locus of the points at which the lines of constant E_s and the lines of constant P_s have common tangents. On the output file shown in Figure 10.10 the 1g load factor points provide the profile for a minimum time climb which could be drawn on Figure 10.3. The output file also provides for each energy state and load factor the fuel flow corresponding to the Mach number and altitude which optimises P_s. The right hand side load factor column provides optimum sustained turn conditions which are used in maximum manoeuvre persistence calculations. Also indicated at each energy state are the time to climb, fuel used in the climb and range obtained by integration from the initial energy state. (More details are available in Reference 1).

Figures 10.12, 10.13 and 10.14 show a similar run but with lines of constant turn rate. In a similar fashion the amount of fuel used to climb from energy state E_{s1} to another E_{s2} is:

$$\int w_f \, dt = \int \frac{w_f}{P_s} \, dE_s$$

and option 4C can be run with P_s/w_f as the energy parameter to provide the optimum climb for minimum fuel used, which can then be used in conjunction with 1g contours of P_s/w_f plotted using option 4A.

Similarly option 4C can be run with the two other energy parameters P_sV/w_f and P_s/V to provide optimum climb for maximum range per unit mass of fuel and maximum range respectively.

10.4 Option 4D

This option corresponds to the options 3, 8, 17 and 22 in the overview of Figure 2.2.

Figure 10.15 shows part of the dialogue used when running P2V2 and P4V2 for producing 1g SEP differential contours. First the program ACRAFT written for the first aircraft was run using data from the store file AC1.STR generating AC1.NUM for input to P2V2. In a similar manner AC2.NUM was created for the second aircraft. This part of the dialogue was omitted as it is the same as for option 4A.

Figure 10.16 shows the plot obtained using the dialogue above. On this plot the lift limit boundaries for both aircraft have been plotted by P4V2 together with the differential P_s contours.

10.5 Option 4G

This option corresponds to the options 4, 9, 18, 23 in the overview of Figure 2.2.

Figure 10.17 shows a typical dialogue used when running the three programs ACRAFT, P2V2 and P4V2 to produce a set of SEP contour plots at a constant altitude on a Mach number, turn rate grid.

Program ACRAFT produces a file EXAMPL.NUM for input to program P4V2 and a file EXAMPL.TXT ready for printing and shown in Figure 10.18 which is similar to the one described in Paragraph 10.2.

A plot produced using the dialogue above is shown in Figure 10.19. Contours are labelled at their start with a level number which is identified at the right hand side of the plot. Superimposed are the lines of constant load factor and turn radius. The lift limit and structural load factor boundaries are also generated by P4V2 with the contours outside the structural limit drawn with a dashed line and the points outside the lift limit boundary ignored.

Figure 10.20 shows SEP contour plots at a constant altitude but on a Mach number, load factor grid; the presentation is slightly different but the lift limit has again been generated by P4V2.

10.6 Option 4Z

This option corresponds to the options 5, 10, 19, 24 in the overview of Figure 2.2.

Fig 10.21 shows a typical dialogue for producing a plot of SEP versus Mach number for several load factors at a given altitude using the two programs ACRAFT and P2V2; the plot generated is shown in Figure 10.22.

Plots on this format were previously used (Reference 1) to obtain contours of P_s on a Mach number, turn rate grid at a specified height; this is now done using option 4G and this format does not present much interest any more.

```
.RUN ACRAFT


MANEUVERABILITY GRID CALCULATION

IMPERIAL (0) OR S.I. (1) UNITS    ? 0

AIRCRAFT DATA FILENAME            ? EXAMPL.STR

AIRCRAFT  EXAMPLE    DATE 21-Jun-83   TIME 13:58 23.7
 2 AIM-9 + GUNS + 50% FUEL

PS, PS/WF, PS*V/WF OR PS/V  (1, 2, 3 OR 4) ? 1

IS HP THE HEIGHT VARIABLE         ? Y

PRESET GRID (Y, N OR C/R)         ? N

HP0 , HP STEP (FT), NO. OF STEPS ? 0,5000,13

MACH0, MACH STEP  , NO. OF STEPS ? 0,.05,21

GRID FOR LOAD FACTOR (0), OR TURNRATE (1) ?0

G0    , G STEP      , NO. OF STEPS ? 1,2,3

POWER (MIL=100,MAX=200)           ? 100

WING SWEEP (IF VARIABLE)          ? 0

NOZZLE DEFLECTION (IF VARIABLE)   ? 0

ATMOSPHERE , DEVIATION            ? ICAO,0

OUTPUT (1=TEXT,2=NOS.,3=BOTH)     ? 3

O/P FILENAME FOR UNIT 6           ? EXAMPL.TXT

O/P FILENAME FOR UNIT 3           ? EXAMPL.NUM

CALCULATION :

         ALTITUDE HP =       0.0 FT
         ALTITUDE HP =    5000.0 FT
         ALTITUDE HP =   10000.0 FT
         ALTITUDE HP =   15000.0 FT
         ALTITUDE HP =   20000.0 FT
         ALTITUDE HP =   25000.0 FT
         ALTITUDE HP =   30000.0 FT
         ALTITUDE HP =   35000.0 FT
         ALTITUDE HP =   40000.0 FT
         ALTITUDE HP =   45000.0 FT
         ALTITUDE HP =   50000.0 FT
         ALTITUDE HP =   55000.0 FT
         ALTITUDE HP =   60000.0 FT
STOP

END OF EXECUTION
CPU TIME: 19.05 ELAPSED TIME: 2:40.30
EXIT
```

FIG. 10.1(a) Sample Dialogue for Option 4A
(Load factor grid, P_s as energy parameter)

```
.RUN P2V2


COMBAT PERFORMANCE PROCESSING

OPTION OR (CR) FOR HELP : 4A

4A  PS CONTOURS ON ALT VS MACH GRID          (P24A1.CON)
DATA BASE  FILENAME        : EXAMPL.NUM

*** DATA ARE IN IMPERIAL UNITS. ENERGY PARAMETER IS PS          ***
***     CONITANT INC. OF LOAD FACTOR      ***
REPLY "YES", "NO", "ALL" OR "END" :
OUTPUT DATA FOR  N =    1.00 ? ALL

END OF EXECUTION
CPU TIME: 6.05  ELAPSED TIME: 51.60
EXIT

.RUN P4V2


INPUT FILENAME : P24A1.CON

*** DATA ARE IN IMPERIAL UNITS. ENERGY PARAMETER IS PS          ***
*** CONSTANT INC. FOR LOAD FACTOR     ***
CONTOUR PLOTTING

SCALES IN UNITS/IN OF PLOT - MACH, ALT : .1,10000

SMOOTHED AND TEXTURED CONTOURS      ? N

PLOT ES CONTOURS ? Y

CONTOUR LEVELS - START, STEP, NO. : 3000,500,15

PLOT  G =    1.00  ? Y

CONTOUR LEVELS - START, STEP, NO. : -200,50,9

PLOT  G =    2.00  ? N

PLOT  G =    3.00  ? N

STOP

END OF EXECUTION
CPU TIME: 7.96  ELAPSED TIME: 2:9.44
EXIT
```

FIG. 10.1(b) Sample Dialogue for Option 4A (cont)

```
                    AIRCRAFT MANEUVERABILITY TABLE FOR  AIRCRAFT  EXAMPLE

                    ROLE :  2 AIM-9 + GUNS + 50% FUEL

        NOMINAL ARGUMENTS :   13    ALTITUDES FROM      0. TO  60000. IN INCREMENTS OF  5000. FT
                              21 MACH NUMBERS FROM    0.000 TO   1.000 IN INCREMENTS OF  0.050 MACH
                               3 LOAD FACTR FROM     1.00 TO    5.00 IN INCREMENTS OF   2.00 G

          WING REFERENCE AREA  260.00 FT**2        EXTERNAL DRAG TABLE HAS  0 DATA POINTS

ICAO ATMOSPHERE + (  0.0)C  CG  0.00%MAC  WT 14974.LB   ETA STRUCT.  5.3 G 100.0% MIL POWER   WING SWEEP  0.00 DEG   NOZZLE DEF. 0.00DEG
DATE 10-Oct-83    TIME 11:49 35.6
```

FIG. 10.2(a) Sample Output Listing of Program ACRAFT: Header Page (Load factor grid, P_s as energy parameter)

ALTITUDE HP = 0.0 FT

MAX MACH = 1.0

TABULATED VALUES : PS - FT/S
TURNRATE - DEG/S

I	MACH NO	TAS KT	ES FT	H FT	WF LB/HR	TRMAX DEG/S	EMAX G UNITS	LOAD FACTR 1.00	3.00	5.00
2	.050	33.1	48.	0.	7418.	0.00	0.22	-48.5	-9999.9	-9999.9
								0.00	93.40	161.78
3	.100	66.1	194.	0.	7479.	0.00	0.43	1.8	-870.3	-3204.0
								0.00	46.70	80.89
4	.150	99.2	436.	0.	7541.	0.00	0.77	40.4	-412.7	-1486.8
								0.00	31.13	53.93
5	.200	132.3	775.	0.	7603.	6.28	1.26	80.2	-286.4	-1046.8
								0.00	23.35	40.45
6	.250	165.4	1211.	0.	7664.	10.52	1.88	117.5	-189.6	-814.9
								0.00	18.68	32.36
7	.300	198.4	1743.	0.	7727.	13.47	2.64	142.1	-107.1	-642.1
								0.00	15.57	26.96
8	.350	231.5	2373.	0.	7795.	16.05	3.55	162.7	-33.5	-500.7
								0.00	13.34	23.11
9	.400	264.6	3099.	0.	7870.	18.48	4.59	179.1	34.8	-379.5
								0.00	11.68	20.22
10	.450	297.7	3923.	0.	7953.	20.84	5.77	191.3	83.7	-271.4
								0.00	10.38	17.98
11	.500	330.7	4843.	0.	8044.	23.17	7.09	198.8	101.5	-171.7
								0.00	9.34	16.18
12	.550	363.8	5860.	0.	8139.	25.48	8.55	200.9	112.1	-77.9
								0.00	8.49	14.71
13	.600	396.9	6973.	0.	8236.	27.78	10.14	196.7	115.1	-48.3
								0.00	7.78	13.48
14	.650	430.0	8184.	0.	8333.	30.07	11.88	185.0	109.2	-42.6
								0.00	7.18	12.44
15	.700	463.0	9491.	0.	8422.	32.36	13.75	160.0	97.6	-57.2
								0.00	6.67	11.56
16	.750	496.1	10896.	0.	8496.	34.64	15.77	120.9	50.8	-89.3
								0.00	6.23	10.79
17	.800	529.2	12397.	0.	8549.	36.93	17.92	63.4	-5.5	-143.3
								0.00	5.84	10.11
18	.850	562.3	13995.	0.	8576.	39.21	20.21	-38.4	-109.9	-252.9
								0.00	5.49	9.52
19	.900	595.3	15690.	0.	8580.	41.50	22.64	-219.9	-299.2	-457.7
								0.00	5.19	8.99
20	.950	628.4	17482.	0.	8569.	43.78	25.21	-546.8	-641.1	-829.8
								0.00	4.92	8.51
21	1.000	661.5	19370.	0.	8550.	46.07	27.92	-979.7	-1088.9	-1307.2
								0.00	4.67	8.09

FIG. 10.2(b) Sample Output Listing of Program ACRAFT: Extract (Load factor grid, P_S as energy parameter)

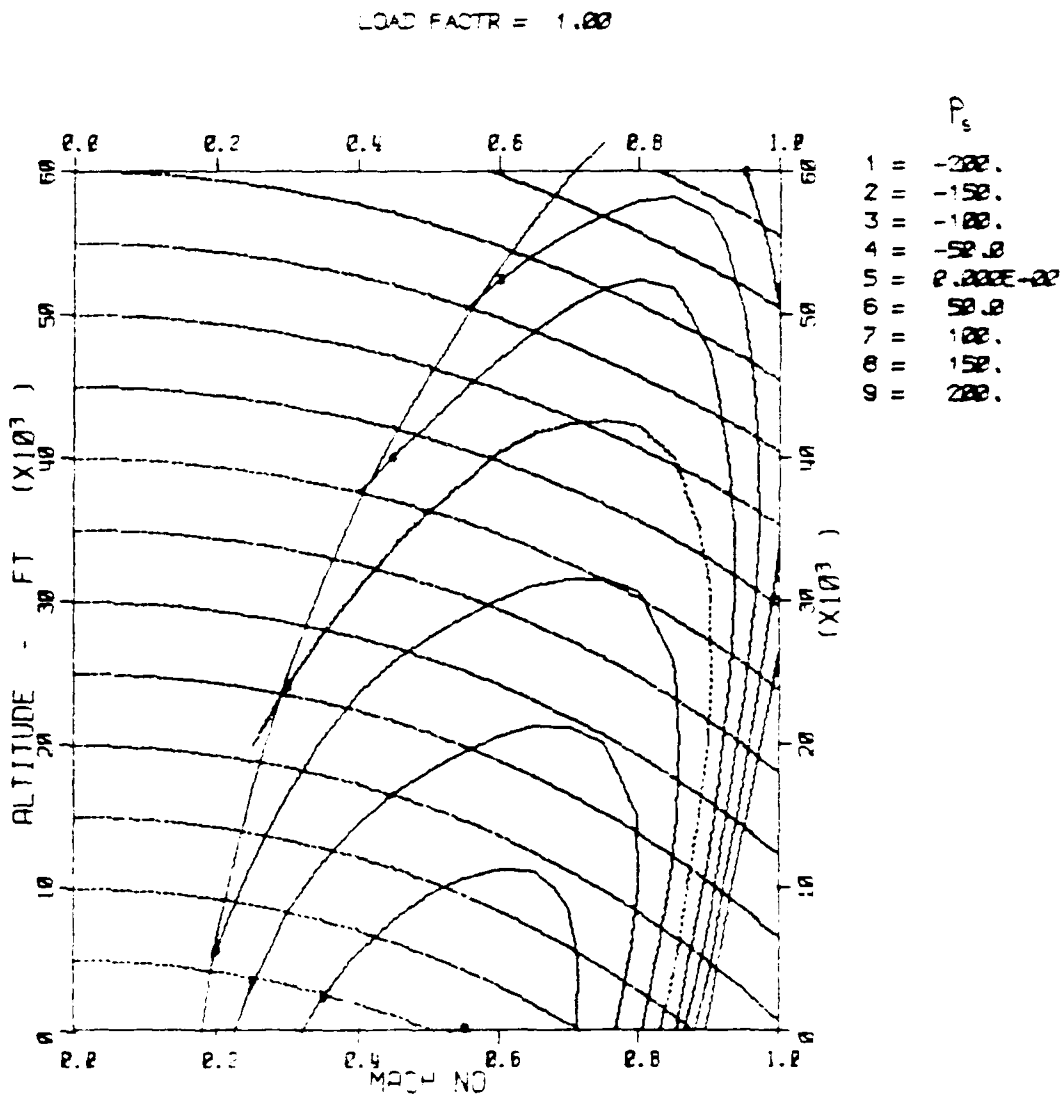

FIG. 10.3 Sample SEP Contours plots at a Constant Load Factor

```
.RUN ACRAFT


MANEUVERABILITY GRID CALCULATION

IMPERIAL (0) OR S.I. (1) UNITS    ? 0

AIRCRAFT DATA FILENAME            ? EXAMPL.STR

AIRCRAFT  EXAMPLE    DATE 11-Oct-83   TIME 15:27 08.4
 2 AIM-9 + GUNS + 50% FUEL

PS, PS/WF, PS*V/WF OR PS/V  (1, 2, 3 OR 4) ? 3

IS HP THE HEIGHT VARIABLE         ? Y

PRESET GRID (Y, N OR C/R)         ? N

HPO , HP STEP (FT), NO. OF STEPS ? 0,5000,13

MACHO, MACH STEP  , NO. OF STEPS ? 0,.025,41

GRID FOR LOAD FACTOR (0), OR TURNRATE (1) ?1

RO   ,TR STEP     , NO. OF STEPS ? 0,4,3

POWER (MIL=100,MAX=200)           ? 100

WING SWEEP (IF VARIABLE)          ? 0

NOZZLE DEFLECTION (IF VARIABLE)   ? 0

ATMOSPHERE , DEVIATION            ? ICAO,0

OUTPUT (1=TEXT,2=NOS.,3=BOTH)     ? 3

O/P FILENAME FOR UNIT 6           ? EXAMPL.TXT

O/P FILENAME FOR UNIT 8           ? EXAMPL.NUM

CALCULATION :

         ALTITUDE HP =       0.0 FT
         ALTITUDE HP =    5000.0 FT
         ALTITUDE HP =   10000.0 FT
         ALTITUDE HP =   15000.0 FT
         ALTITUDE HP =   20000.0 FT
         ALTITUDE HP =   25000.0 FT
         ALTITUDE HP =   30000.0 FT
         ALTITUDE HP =   35000.0 FT
         ALTITUDE HP =   40000.0 FT
         ALTITUDE HP =   45000.0 FT
         ALTITUDE HP =   50000.0 FT
         ALTITUDE HP =   55000.0 FT
         ALTITUDE HP =   60000.0 FT
STOP

END OF EXECUTION
CPU TIME: 40.12 ELAPSED TIME: 6:37.32
EXIT
```

FIG. 10.4(a) Sample Dialogue for Option 4A
(Turn rate grid, $P_s V/w_f$ as energy parameter)

```
.RUN P2V2


COMBAT PERFORMANCE PROCESSING

OPTION OR (CR) FOR HELP : 4A

4A  PS CONTOURS ON ALT VS MACH GRID          (P24A1.CON)
DATA BASE  FILENAME       : EXAMPL.NUM

*** DATA ARE IN IMPERIAL UNITS. ENERGY PARAMETER IS PSV/1000WF ***
***     CONSTANT INC. OF TURN RATE        ***
REPLY "YES", "NO", "ALL" OR "END" :
OUTPUT DATA FOR TR =     0.00 ? ALL

END OF EXECUTION
CPU TIME: 12.78 ELAPSED TIME: 3:3.36
EXIT

.RUN P4V2


INPUT FILENAME : P24A1.CON

*** DATA ARE IN IMPERIAL UNITS. ENERGY PARAMETER IS PSV/1000WF ***
*** CONSTANT INC. FOR TURN RATE        ***
CONTOUR PLOTTING

SCALES IN UNITS/IN OF PLOT - MACH, ALT : .2,10000

SMOOTHED AND TEXTURED CONTOURS     ? N

PLOT ES CONTOURS ? Y

CONTOUR LEVELS - START, STEP, NO. : 5000,5000,15

PLOT TR =    0.00   ? N

PLOT TR =    4.00   ? Y

CONTOUR LEVELS - START, STEP, NO. : -300,50,13

PLOT TR =    5.00   ? N

STOP

END OF EXECUTION
CPU TIME: 11.89 ELAPSED TIME: 2:4.82
EXIT
```

FIG. 10.4(b) Sample Dialogue for Option 4A (cont)

ALTITUDE HP = 10000.0 FT

MAX MACH = 1.0

TABULATED VALUES : PS*V/WF - FT**2/LB.S/1000
LOAD FACTR - G

I	MACH NO	TAS KT	ES FT	H FT	WF LB/HR	TRMAX DEG/S	G	EMAX UNITS	TURNRATE 0.00	4.00	8.00
4	.075	47.9	10101.	10000.	5543.	0.00		0.21	-3.7	-4.0	-4.8
									1.00	1.02	1.06
5	.100	63.8	10180.	10000.	5575.	0.00		0.30	-3.0	-3.4	-4.5
									1.00	1.03	1.10
6	.125	79.8	10282.	10000.	5609.	0.00		0.41	-2.2	-2.8	-4.7
									1.00	1.04	1.16
7	.150	95.7	10406.	10000.	5643.	0.00		0.54	-0.8	-1.8	-4.7
									1.00	1.06	1.22
8	.175	111.7	10552.	10000.	5679.	0.00		0.69	1.1	-0.3	-4.4
									1.00	1.08	1.29
9	.200	127.7	10722.	10000.	5716.	0.00		0.87	3.6	1.7	-3.9
									1.00	1.10	1.37
10	.225	143.6	10913.	10000.	5755.	2.98		1.07	6.5	4.1	-3.2
									1.00	1.13	1.45
11	.250	159.6	11127.	10000.	5795.	5.70		1.30	10.0	6.9	-2.3
									1.00	1.16	1.54
12	.275	175.5	11364.	10000.	5836.	7.39		1.55	13.9	10.2	-1.1
									1.00	1.19	1.63
13	.300	191.5	11623.	10000.	5879.	8.72		1.83	18.0	13.8	0.2
									1.00	1.22	1.72
14	.325	207.5	11905.	10000.	5923.	9.88		2.13	21.4	17.8	1.9
									1.00	1.26	1.82
15	.350	223.4	12210.	10000.	5969.	10.92		2.45	24.9	21.3	3.7
									1.00	1.29	1.92
16	.375	239.4	12537.	10000.	6017.	11.91		2.79	28.5	24.3	5.9
									1.00	1.33	2.02
17	.400	255.3	12886.	10000.	6066.	12.85		3.17	32.0	27.3	8.3
									1.00	1.37	2.12
18	.425	271.3	13258.	10000.	6117.	13.75		3.56	35.6	30.3	11.1
									1.00	1.41	2.22
19	.450	287.2	13653.	10000.	6170.	14.64		3.98	39.0	33.2	14.2
									1.00	1.45	2.33
20	.475	303.2	14070.	10000.	6224.	15.51		4.42	42.4	35.9	16.3
									1.00	1.49	2.44
21	.500	319.2	14510.	10000.	6280.	16.37		4.89	45.6	38.4	16.9
									1.00	1.54	2.54
22	.525	335.1	14972.	10000.	6338.	17.21		5.38	48.6	40.7	17.2
									1.00	1.58	2.65
23	.550	351.1	15457.	10000.	6398.	18.06		5.89	51.4	42.8	17.1
									1.00	1.63	2.76
24	.575	367.0	15964.	10000.	6459.	18.89		6.43	53.9	44.6	16.7
									1.00	1.68	2.87
25	.600	383.0	16494.	10000.	6523.	19.73		6.99	56.0	46.0	15.9
									1.00	1.72	2.98
26	.625	399.0	17046.	10000.	6588.	20.56		7.57	57.9	47.1	14.8
									1.00	1.77	3.09
27	.650	414.9	17621.	10000.	6654.	21.38		8.18	59.0	47.4	12.5

FIG. 10.5 Sample Output Listing of Program ACRAFT (Turn rate grid, $P_s V/w_f$ as energy parameter)

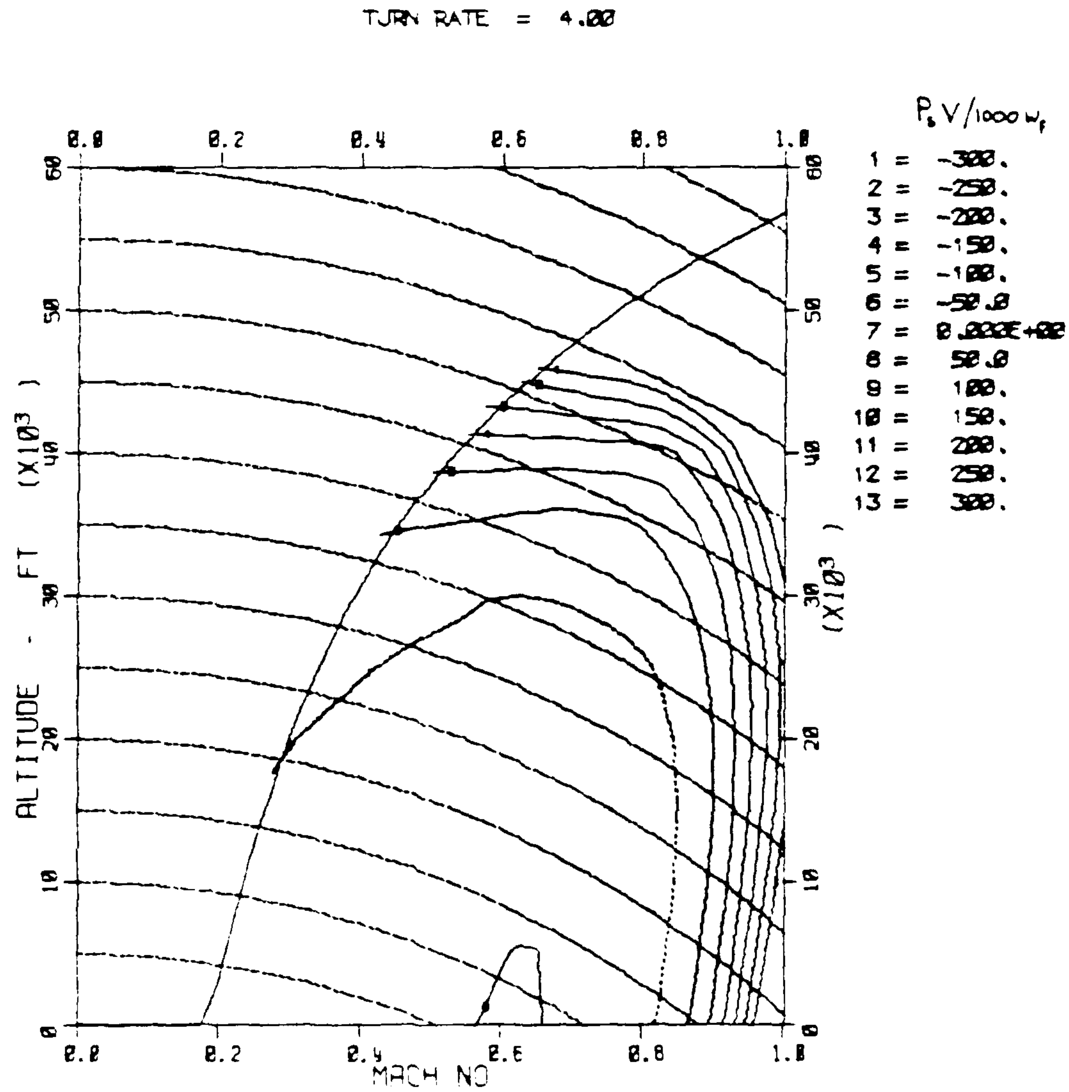

FIG. 10.6 Sample P_s V/1000w_f Contour Plots at a Constant Turn Rate

```
.RUN ACRAFT


MANEUVERABILITY GRID CALCULATION

IMPERIAL (0) OR S.I. (1) UNITS   ? 0

AIRCRAFT DATA FILENAME           ? DUMMY.STR

AIRCRAFT EXAMPLE      DATE 11-Oct-83   TIME 16:05 56.9
AIR SUPERIORITY : 2 AIM9 + 50% FUEL

PS, PS/WF, PS*V/WF OR PS/V  (1, 2, 3 OR 4) ? 1

IS HP THE HEIGHT VARIABLE        ? Y

PRESET GRID (Y, N OR C/R)        ? N

HP0 , HP STEP (FT), NO. OF STEPS ? 0,10000,2

MACH0, MACH STEP  , NO. OF STEPS ? .4,.2,6

GRID FOR LOAD FACTOR (0), OR TURNRATE (1) ?0

G0    , G STEP     , NO. OF STEPS ? 1,.5,15

POWER (MIL=100,MAX=200)          ? 200

WING SWEEP (IF VARIABLE)         ? 0

NOZZLE DEFLECTION (IF VARIABLE)  ? 0

ATMOSPHERE , DEVIATION           ? ICAO,0

OUTPUT (1=TEXT,2=NOS.,3=BOTH)    ? 3

O/P FILENAME FOR UNIT 6          ? EXAMPL.TXT

O/P FILENAME FOR UNIT 8          ? EXAMPL.NUM

CALCULATION :

         ALTITUDE HP =       0.0 FT
         ALTITUDE HP =   10000.0 FT
STOP

END OF EXECUTION
CPU TIME: 4.43  ELAPSED TIME: 3:7.56
EXIT

.RUN P2V2


COMBAT PERFORMANCE PROCESSING

OPTION OR (CR) FOR HELP : 4B

4B  PS VS OMEGA/ETA FOR GIVEN HEIGHT.          (P2.PLT)
DATA BASE  FILENAME      : EXAMPL.NUM

*** DATA ARE IN IMPERIAL UNITS, ENERGY PARAMETER IS PS          ***
***     CONSTANT INC. OF LOAD FACTOR     ***
SCALES IN UNITS/INCH OF PLOT
TURN RATE/LOAD FACTOR , ENERGY VARIABLE : 4,200

MAXIMUM FOR ENERGY AXIS : 400

ENERGY AXIS LENGTH (IN) : 7

REPLY "YES", "NO", "ALL" OR "END" :
HEIGHT =       0.0 FT     ? N

HEIGHT =  10000.0 FT     ? Y

  MACH =  .400 ? N

  MACH =  .600 ? N

  MACH =  .800 ? Y

  MACH = 1.000 ? Y

  MACH = 1.200 ? E

END OF EXECUTION
CPU TIME: 4.63  ELAPSED TIME: 2:26.90
EXIT
```

FIG. 10.7   Sample Dialogue for Option 4B

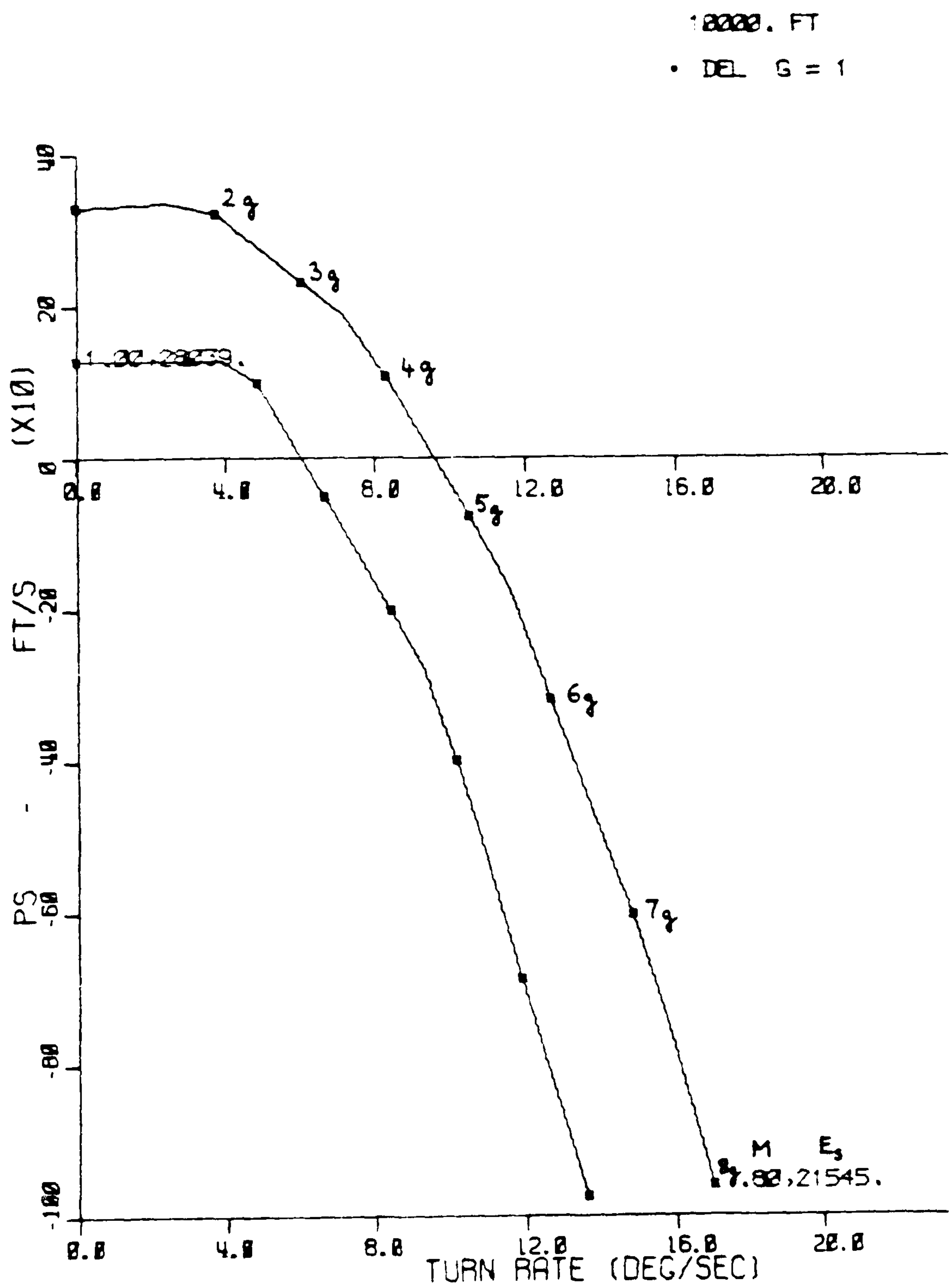

FIG. 10.8 Sample SEP Versus Turn Rate Plot

```
.RUN ACRAFT


MANEUVERABILITY GRID CALCULATION

IMPERIAL (0) OR S.I. (1) UNITS    ? 0

AIRCRAFT DATA FILENAME              ? EXAMPL.STR

AIRCRAFT  EXAMPLE     DATE 10-Oct-83    TIME 10:34 40.1
 2 AIM-9 + GUNS + 50% FUEL

PS, PS/WF, PS*V/WF OR PS/V  (1, 2, 3 OR 4) ? 1

IS HP THE HEIGHT VARIABLE           ? N

MAXIMUM MANEUVER                    ? Y

ES0 , ES STEP (FT), NO. OF STEPS ? 5000,5000,13

GRID FOR LOAD FACTOR (0), OR TURNRATE (1) ?0

G0    , G STEP      , NO. OF STEPS ? 1,1,5

POWER (MIL=100,MAX=200)             ? 100

WING SWEEP (IF VARIABLE)            ? 0

NOZZLE DEFLECTION (IF VARIABLE)   ? 0

ATMOSPHERE , DEVIATION              ? ICAO,0

OUTPUT (1=TEXT,2=NOS.,3=BOTH)       ? 3

O/P FILENAME FOR UNIT 6             ? EXAOPT.TXT

O/P FILENAME FOR UNIT 3             ? EXAOPT.NUM

CALCULATION :

ENERGY STATE ES =      5000.0 FT
ENERGY STATE ES =     10000.0 FT
ENERGY STATE ES =     15000.0 FT
ENERGY STATE ES =     20000.0 FT
ENERGY STATE ES =     25000.0 FT
ENERGY STATE ES =     30000.0 FT
ENERGY STATE ES =     35000.0 FT
ENERGY STATE ES =     40000.0 FT
ENERGY STATE ES =     45000.0 FT
ENERGY STATE ES =     50000.0 FT
ENERGY STATE ES =     55000.0 FT
ENERGY STATE ES =     60000.0 FT
ENERGY STATE ES =     65000.0 FT
STOP

END OF EXECUTION
CPU TIME: 43.39 ELAPSED TIME: 5:14.50
EXIT

.RUN PSV2


COMBAT PERFORMANCE PROCESSING

OPTION OR (CR) FOR HELP : 4C

4C  MAXIMUM MANEUVER DIAGRAM - MMD.              (PS.PLT)
DATA BASE  FILENAME       : EXAOPT.NUM

*** DATA ARE IN IMPERIAL UNITS, ENERGY PARAMETER IS PS          ***
***     CONSTANT INC. OF LOAD FACTOR     ***
SCALE IN UNIT/INCH OF PLOT
ES ,PS : 10000,200

PS MIN VALUE, PS AXIS LENGTH( INS) : -700,5

REPLY "YES", "NO", "ALL" OR "END" :
   G =  1.00 ? ALL

END OF EXECUTION
CPU TIME: 3.73  ELAPSED TIME: 1:13.10
EXIT
```

FIG. 10.9 Sample Dialogue for Option 4C
(Load factor grid)

*** ENERGY STATE ES = 5000.0 FT ***

G		1.00	2.00	3.00	4.00	5.00	4.11
PS	FT/S	199.54	163.60	103.70	19.85	-156.25	0.00
OMEGA	DEG/S	0.000	5.629	9.192	12.587	15.921	12.963
MACH		0.508	0.508	0.508	0.508	0.508	0.508
TAS	KT	336.044	336.060	336.064	336.069	336.070	336.069
HP	FT	1.	0.	0.	0.	0.	0.
WF	LB/HR	8059.	8059.	8059.	8059.	8059.	8059.
TIME	S	0.00					
FUEL	LB	0.					
RANGE	N.M.	0.000					

*** ENERGY STATE ES = 10000.0 FT ***

G		1.00	2.00	3.00	4.00	5.00	4.35
PS	FT/S	186.91	154.16	101.55	30.60	-57.48	0.00
OMEGA	DEG/S	0.000	4.654	7.373	9.794	12.046	10.577
MACH		0.608	0.620	0.638	0.657	0.674	0.663
TAS	KT	398.166	406.518	419.010	431.908	444.179	436.171
HP	FT	2982.	2684.	2228.	1742.	1266.	1576.
WF	LB/HR	7779.	7854.	7966.	8081.	8189.	8118.
TIME	S	25.88					
FUEL	LB	57.					
RANGE	N.M.	2.591					

*** ENERGY STATE ES = 15000.0 FT ***

G		1.00	2.00	3.00	4.00	5.00	3.90
PS	FT/S	167.19	130.52	71.45	-8.17	-106.97	0.00
OMEGA	DEG/S	0.000	4.507	7.097	9.463	11.578	9.220
MACH		0.633	0.651	0.674	0.691	0.712	0.689
TAS	KT	407.431	419.731	435.265	447.023	462.126	445.817
HP	FT	7651.	7201.	6613.	6153.	5546.	6201.
WF	LB/HR	7030.	7155.	7314.	7434.	7589.	7422.
TIME	S	54.12					
FUEL	LB	115.					
RANGE	N.M.	5.654					

FIG. 10.10 Extract of Sample MMD with a Load Factor Grid

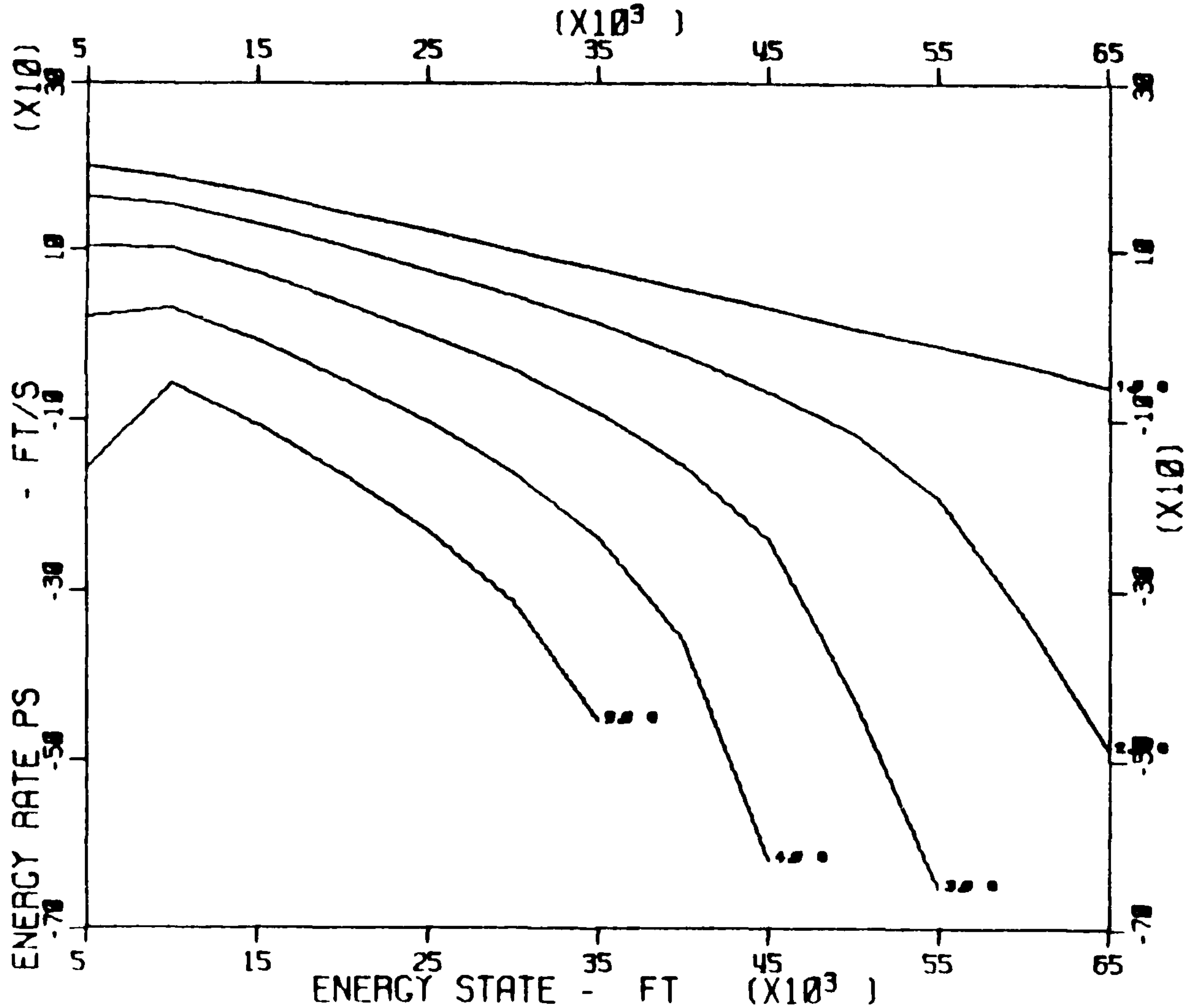

FIG. 10.11 Sample Maximum Manoeuvre Diagram for Specified Load Factors

```
.RUN ACRAFT


MANEUVERABILITY GRID CALCULATION

IMPERIAL (0) OR S.I. (1) UNITS   ? 0

AIRCRAFT DATA FILENAME           ? EXAMPL.STR

AIRCRAFT  EXAMPLE    DATE 11-Oct-83   TIME 15:12 21.8
 2 AIM-9 + GUNS + 50% FUEL

PS, PS/WF, PS*V/WF OR PS/V  (1, 2, 3 OR 4) ? 1

IS HP THE HEIGHT VARIABLE        ? N

MAXIMUM MANEUVER                 ? Y

ESO , ES STEP (FT), NO. OF STEPS ? 0,10000,8

GRID FOR LOAD FACTOR (0), OR TURNRATE (1) ?1

RO   ,TR STEP    , NO. OF STEPS ? 0,4,4

POWER (MIL=100,MAX=200)          ? 100

WING SWEEP (IF VARIABLE)         ? 0

NOZZLE DEFLECTION (IF VARIABLE)  ? 0

ATMOSPHERE , DEVIATION           ? ICAO,0

OUTPUT (1=TEXT,2=NOS.,3=BOTH)    ? 3

O/P FILENAME FOR UNIT 6          ? EXAMPL.TXT

O/P FILENAME FOR UNIT 8          ? EXAMPL.NUM

CALCULATION :

ENERGY STATE ES =       0.0 FT
ENERGY STATE ES =   10000.0 FT
ENERGY STATE ES =   20000.0 FT
ENERGY STATE ES =   30000.0 FT
ENERGY STATE ES =   40000.0 FT
ENERGY STATE ES =   50000.0 FT
ENERGY STATE ES =   60000.0 FT
ENERGY STATE ES =   70000.0 FT
STOP

END OF EXECUTION
CPU TIME: 25.67 ELAPSED TIME: 8:3.72
EXIT

.RUN P2V2


COMBAT PERFORMANCE PROCESSING

OPTION OR (CR) FOR HELP : 4C

4C  MAXIMUM MANEUVER DIAGRAM - MMD.          (P2.PLT)
DATA BASE  FILENAME      : EXAMPL.NUM

*** DATA ARE IN IMPERIAL UNITS. ENERGY PARAMETER IS PS          ***
***    CONSTANT INC. OF TURN RATE       ***
SCALE IN UNIT/INCH OF PLOT
ES ,PS : 10000,200

PS MIN VALUE, PS AXIS LENGTH( INS) : -800,6

REPLY "YES", "NO", "ALL" OR "END" :
  TR =  0.00 ? ALL

END OF EXECUTION
CPU TIME: 5.05  ELAPSED TIME: 1:0.88
EXIT
```

10.12

FIG. 10.12   Sample Dialogue for Option 4C
(Turn rate grid)

*** ENERGY STATE ES = 10000.0 FT ***

OMEGA	DEG/S	0.000	4.000	8.000	12.000	11.468
PS	FT/S	186.91	163.44	94.94	-14.57	0.00
G		1.00	1.73	2.87	4.01	3.86
MACH		0.608	0.591	0.563	0.543	0.545
TAS	KT	398.166	386.357	367.269	353.352	355.204
HP	FT	2982.	3392.	4029.	4473.	4413.
WF	LB/HR	7779.	7675.	7507.	7386.	7402.
TIME	S	0.00				
FUEL	LB	0.				
RANGE	N.M.	0.000				

*** ENERGY STATE ES = 20000.0 FT ***

OMEGA	DEG/S	0.000	4.000	8.000	12.000	8.315
PS	FT/S	144.88	111.62	14.34	-167.73	0.00
G		1.00	1.81	3.05	4.91	3.20
MACH		0.666	0.654	0.624	0.689	0.629
TAS	KT	421.725	413.425	393.545	437.415	396.999
HP	FT	12126.	12433.	13144.	11530.	13016.
WF	LB/HR	6316.	6225.	6011.	6491.	6049.
TIME	S	60.28				
FUEL	LB	118.				
RANGE	N.M.	6.693				

*** ENERGY STATE ES = 30000.0 FT ***

OMEGA	DEG/S	0.000	4.000	8.000	12.000	5.356
PS	FT/S	97.78	48.50	-94.59	-490.06	0.00
G		1.00	1.87	3.26	5.54	2.34
MACH		0.748	0.705	0.696	0.805	0.702
TAS	KT	458.125	430.260	424.194	496.000	428.204
HP	FT	20709.	21805.	22034.	19109.	21882.
WF	LB/HR	5080.	4767.	4702.	5541.	4745.
TIME	S	142.70				
FUEL	LB	248.				
RANGE	N.M.	16.659				

FIG. 10.13 Extract of Sample MMD with Turn Rate Grid

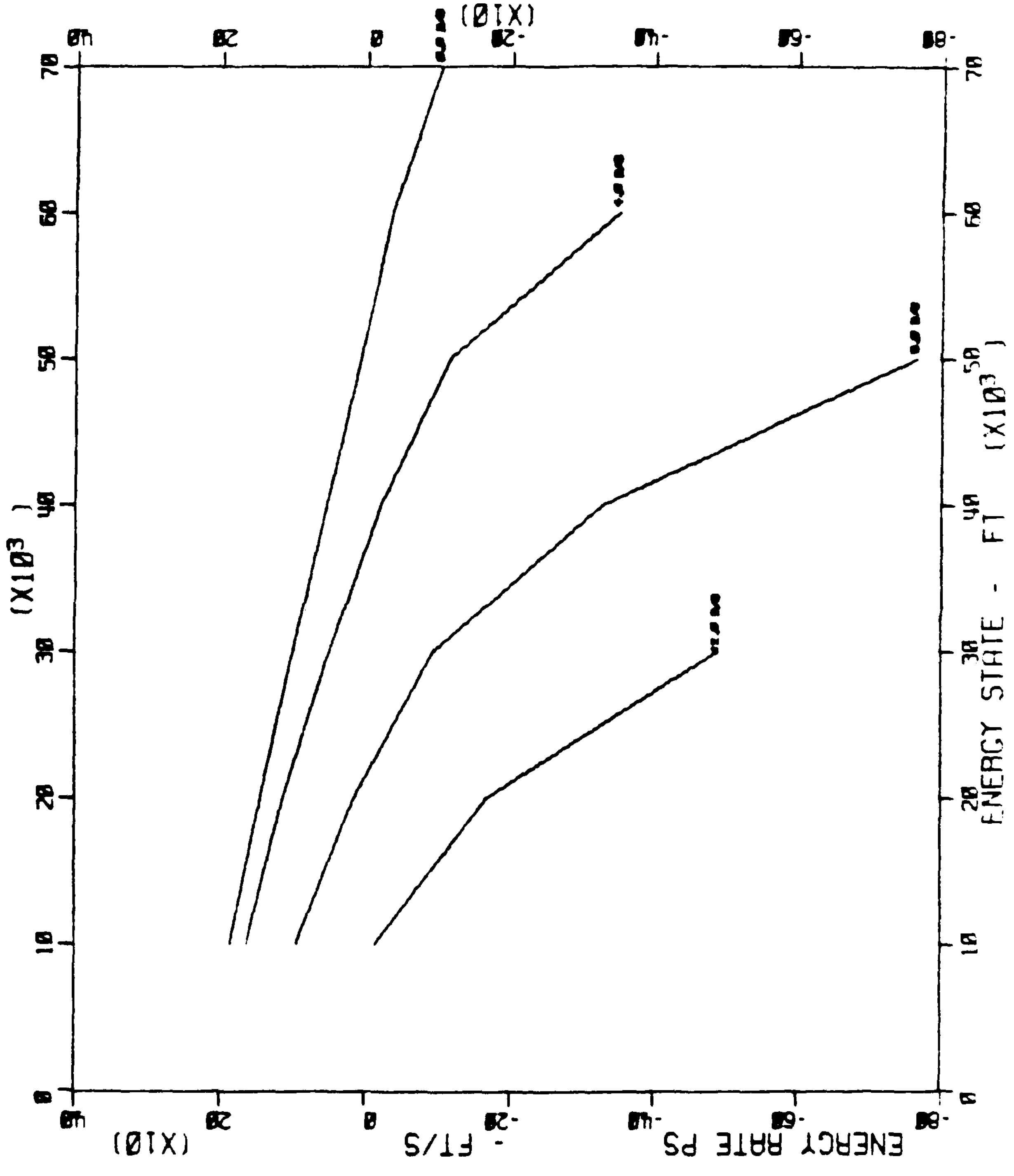

FIG. 10.14 Sample Maximum Manoeuvre Diagram for Specified Turn Rate

```
.RUN P2V2


COMBAT PERFORMANCE PROCESSING

OPTION OR (CR) FOR HELP : 4D

4D  PS DIFFERENT. PLOT(P24A1.CON,P24A2.CON,P24DIF.CON)
DATA BASE  FILENAME      : AC1.NUM

*** DATA ARE IN IMPERIAL UNITS, ENERGY PARAMETER IS PS          ***
***     CONSTANT INC. OF LOAD FACTOR     ***
REPLY "YES", "NO", "ALL" OR "END" :
OUTPUT DATA FOR  N =    1.00 ? Y

COMPARISON FILENAME      : AC2.NUM

END OF EXECUTION
CPU TIME: 13.19 ELAPSED TIME: 1:47.32
EXIT

.RUN P4V2


INPUT FILENAME : P24DIF.CON

*** DATA ARE IN IMPERIAL UNITS, ENERGY PARAMETER IS PS          ***
*** CONSTANT INC. FOR LOAD FACTOR     ***
CONTOUR PLOTTING

SCALES IN UNITS/IN OF PLOT - MACH, ALT : .2,10000

SMOOTHED AND TEXTURED CONTOURS     ? N

PLOT ES CONTOURS ? N

PLOT  G =   1.00   ? Y

CONTOUR LEVELS - START, STEP, NO. : -100,25,9

STOP

END OF EXECUTION
CPU TIME: 0.39  ELAPSED TIME: 1:55.80
EXIT
```

FIG. 10.15 Sample Dialogue for Option 4D

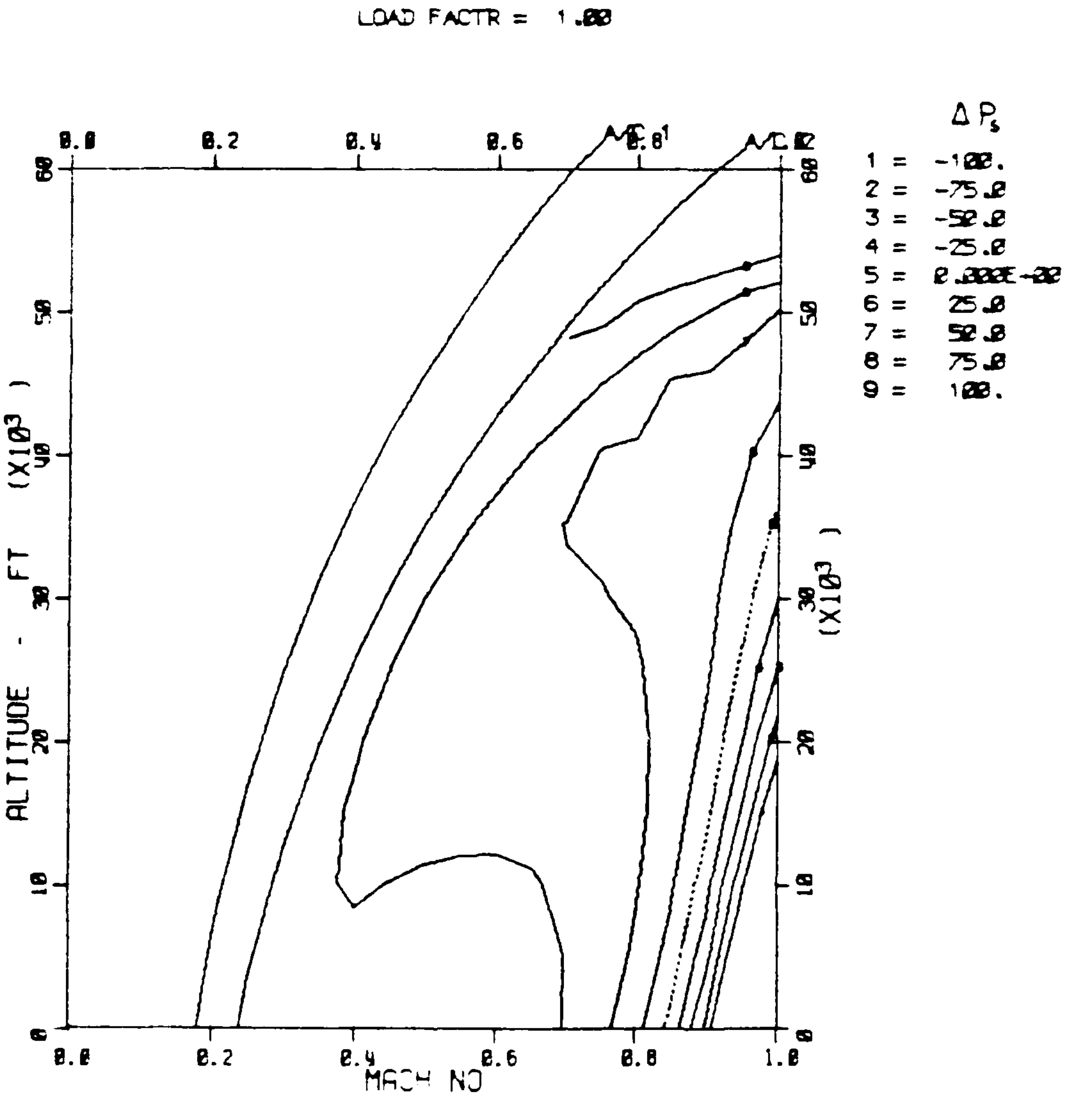

FIG. 10.16 Sample 1g Differential SEP Contour Plot

```
.RUN ACRAFT


MANEUVERABILITY GRID CALCULATION

IMPERIAL (O) OR S.I. (1) UNITS   ? 0

AIRCRAFT DATA FILENAME            ? EXAMPL.STR

AIRCRAFT  EXAMPLE    DATE 12-Oct-83   TIME 14:52 09.1
 2 AIM-9 + GUNS + 50% FUEL

PS, PS/WF, PS*V/WF OR PS/V  (1, 2, 3 OR 4) ? 1

IS HP THE HEIGHT VARIABLE         ? Y

PRESET GRID (Y, N OR C/R)         ? N

HPO , HP STEP (FT), NO. OF STEPS ? 0,10000,2

MACHO, MACH STEP  , NO. OF STEPS ? 0,.025,41

GRID FOR LOAD FACTOR (0), OR TURNRATE (1) ?1

RO   ,TR STEP     , NO. OF STEPS ? 0,.5,41

POWER (MIL=100,MAX=200)           ? 100

WING SWEEP (IF VARIABLE)          ? 0

NOZZLE DEFLECTION (IF VARIABLE)   ? 0

ATMOSPHERE , DEVIATION            ? ICAO,0

OUTPUT (1=TEXT,2=NOS.,3=BOTH)     ? 3

O/P FILENAME FOR UNIT 6           ? EXAMPL.TXT

O/P FILENAME FOR UNIT 8           ? EXAMPL.NUM

CALCULATION :

         ALTITUDE HP =        0.0 FT
         ALTITUDE HP =    10000.0 FT
STOP

END OF EXECUTION
CPU TIME: 25.49 ELAPSED TIME: 3:47.10
EXIT
```

FIG. 10.17(a) Sample Dialogue for Option 4G (Turn rate grid, P_s as energy parameter)

```
.RUN P2V2


COMBAT PERFORMANCE PROCESSING

OPTION OR (CR) FOR HELP : 4G

4G  PS CONTOURS ON OMEGA/LF VS MACH GRID    (P24G.CON)
DATA BASE  FILENAME       : EXAMPL.NUM

*** DATA ARE IN IMPERIAL UNITS. ENERGY PARAMETER IS PS          ***
***    CONSTANT INC. OF TURN RATE        ***
REPLY "YES","NO","ALL" OR "END" :
OUTPUT DATA FOR H =      0.?ALL

END OF EXECUTION
CPU TIME: 12.17 ELAPSED TIME: 1:0.24
EXIT

.RUN P4V2


INPUT FILENAME : P24G.CON

*** DATA ARE IN IMPERIAL UNITS. ENERGY PARAMETER IS PS          ***
*** CONSTANT INC. FOR TURN RATE        ***
CONTOUR PLOTTING

SCALES IN UNITS/IN OF PLOT - MACH,TR/LF : .2,4

SMOOTHED AND TEXTURED CONTOURS     ? N

PLOT LOAD FAC./TURN RAD.GRID ? Y

PLOT H =        0.   ? Y

CONTOUR LEVELS - START, STEP, NO. : -200,50,9

PLOT H =  10000.   ? N

STOP

END OF EXECUTION
CPU TIME: 17.36 ELAPSED TIME: 1:43.04
EXIT
```

FIG. 10.17(b) Sample Dialogue for Option 4G (cont)

ALTITUDE HP = 0.0 FT

MAX MACH = 1.0

TABULATED VALUES : PS - FT/S
LOAD FACTR - G

I	MACH NO	TAS KT	ES FT	H FT	WF LB/HR	TRMAX DEG/S	EMAX G UNITS	TURNRATE									
								0.00	0.50	1.00	1.50	2.00	2.50	3.00	[illegible].50	4.00	4.50
								5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50
								10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50
								15.00	15.50	16.00	16.50	17.00	17.50	18.00	18.50	19.00	19.50
								20.00									
2	.025	16.5	12.	0.	7389.	0.00	0.17	-139.5	-139.5	-139.4	-139.4	-139.4	-139.3	-139.3	-139.2	-139.2	-139.1
								1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
								-139.0	-138.9	-138.8	-138.7	-138.5	-138.4	-138.3	-138.1	-137.9	-137.8
								1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01
								-137.6	-96.2	-96.4	-9999.9	-9999.9	-9999.9	-9999.9	-9999.9	-9999.9	-9999.9
								1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.02	1.02
3	.050	33.1	48.	0.	7418.	0.00	0.22	-48.5	-48.5	-48.7	-49.0	-49.4	-49.9	-50.5	-51.4	-52.3	-53.5
								1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01
								-54.9	-56.5	-58.6	-61.2	-64.7	-71.8	-9999.9	-9999.9	-9999.9	-9999.9
								1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04
4	.075	49.6	109.	0.	7449.	0.00	0.30	-16.0	-16.0	-16.1	-16.3	-16.6	-16.9	-17.3	-17.8	-18.3	-19.0
								1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.02	1.02
								-19.7	-20.5	-21.3	-22.3	-23.3	-24.4	-25.6	-26.9	-28.2	-29.7
								1.03	1.03	1.04	1.04	1.05	1.06	1.06	1.07	1.08	1.09
								-31.2	-32.9	-34.6	-36.4	-38.3	-40.3	-42.4	-44.6	-46.9	-49.3
								1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.19	1.20
								-51.9	-54.5	-57.3	-60.2	-63.2	-66.4	-69.7	-73.2	-76.8	-80.6
								1.21	1.22	1.24	1.25	1.26	1.28	1.29	1.31	1.32	1.34
								-84.5									
								1.35									
5	.100	66.1	194.	0.	7479.	0.00	0.43	1.8	1.7	1.5	1.2	0.8	0.3	-0.3	-1.1	-2.0	-3.0
								1.00	1.00	1.00	1.00	1.01	1.01	1.02	1.02	1.03	1.04
								-4.1	-5.3	-6.6	-8.1	-9.7	-11.4	-13.2	-15.2	-17.3	-19.5
								1.04	1.05	1.06	1.07	1.09	1.10	1.11	1.12	1.14	1.15

FIG. 10.18 Sample Output Listing of Program ACRAFT: Extract (Turn rate grid, P_s as energy parameter)

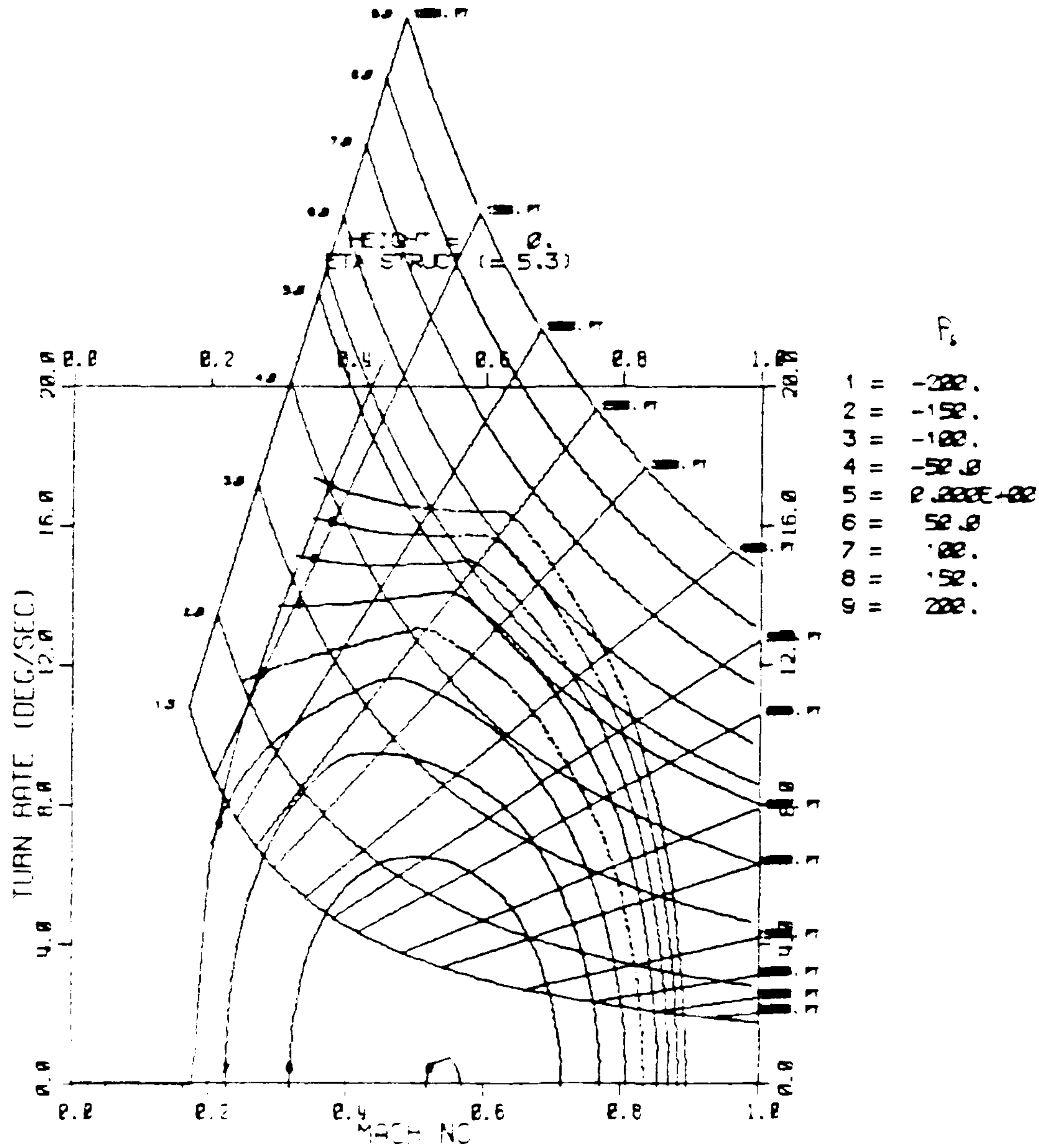

FIG. 10.19 Sample SEP Contour Plots on a Mach Number Turn Rate Grid for a Specified Altitude

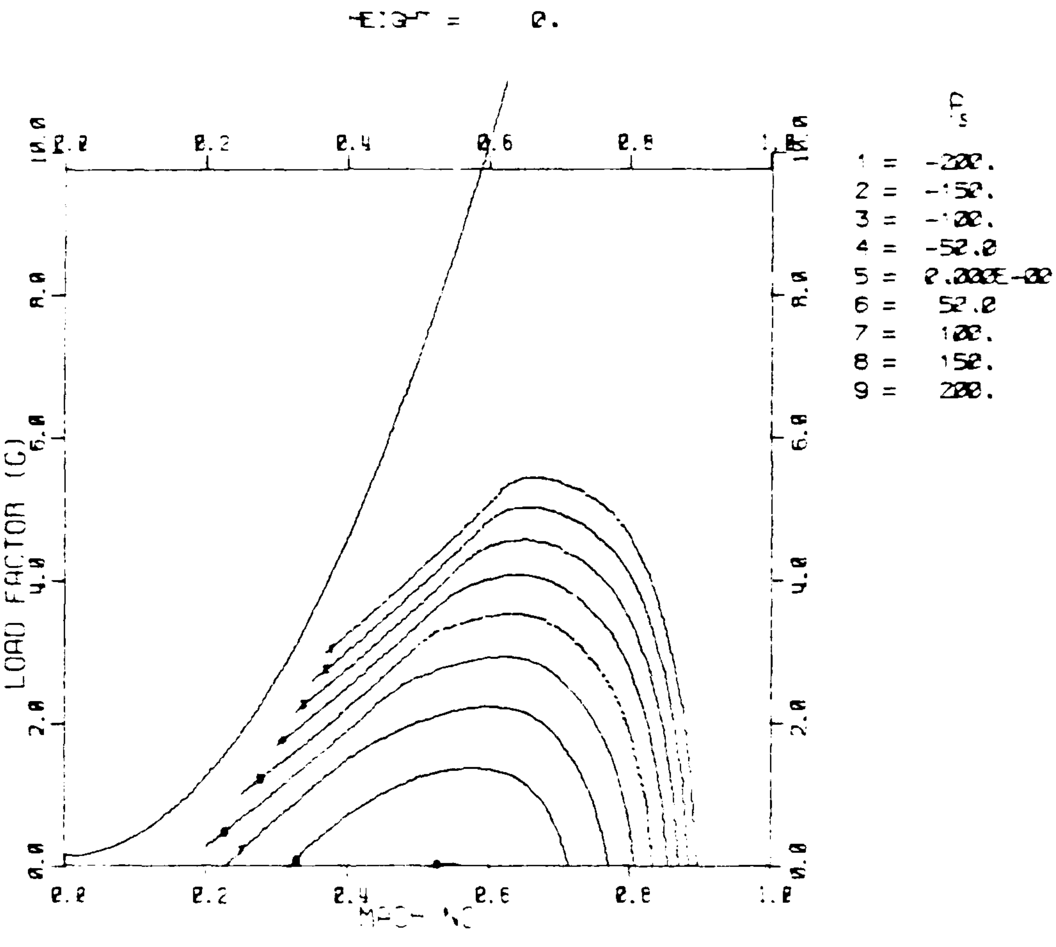

FIG. 10.20 Sample SEP Contour Plots on a Mach Number/Load Factor Grid for a Specified Altitude

```
.RUN ACRAFT


MANEUVERABILITY GRID CALCULATION

IMPERIAL (0) OR S.I. (1) UNITS   ? 0

AIRCRAFT DATA FILENAME           ? DUMMY.STR

AIRCRAFT EXAMPLE     DATE 11-Oct-83   TIME 16:00:06.3
AIR SUPERIORITY : 2 AIM9 + 50% FUEL

PS, PS/WF, PS*V/WF OR PS/V  (1, 2, 3 OR 4) ? 1

IS HP THE HEIGHT VARIABLE        ? Y

PRESET GRID (Y, N OR C/R)        ? N

HPO , HP STEP (FT), NO. OF STEPS ? 0,10000,2

MACHO, MACH STEP  , NO. OF STEPS ? 0,.05,40

GRID FOR LOAD FACTOR (0), OR TURNRATE (1) ?0

GO   , G STEP     , NO. OF STEPS ? 1,2,4

POWER (MIL=100,MAX=200)          ? 200

WING SWEEP (IF VARIABLE)         ? 0

NOZZLE DEFLECTION (IF VARIABLE)  ? 0

ATMOSPHERE , DEVIATION           ? ICAO,0

OUTPUT (1=TEXT,2=NOS.,3=BOTH)    ? 3

O/P FILENAME FOR UNIT 6          ? EXAMPL.TXT

O/P FILENAME FOR UNIT 8          ? EXAMPL.NUM

CALCULATION :

        ALTITUDE HP =       0.0 FT
        ALTITUDE HP =   10000.0 FT
STOP

END OF EXECUTION
CPU TIME: 7.02  ELAPSED TIME: 2:34.34
EXIT

.RUN P2V2


COMBAT PERFORMANCE PROCESSING

OPTION OR (CR) FOR HELP : 4Z

4Z  OMEGA/ETA, PS VS MACH FOR GIVEN HEIGHT.   (P2.PLT)
DATA BASE  FILENAME      : EXAMPL.NUM

*** DATA ARE IN IMPERIAL UNITS, ENERGY PARAMETER IS PS          ***
***    CONSTANT INC. OF LOAD FACTOR    ***
REPLY "YES", "NO", "ALL" OR "END" :
HEIGHT =          0.0 FT  ? N

HEIGHT =      10000.0 FT  ? ALL

END OF EXECUTION                                               10.21
CPU TIME: 5.09  ELAPSED TIME: 58.04
EXIT
```

FIG. 10.21   Sample Dialogue for Option 4Z

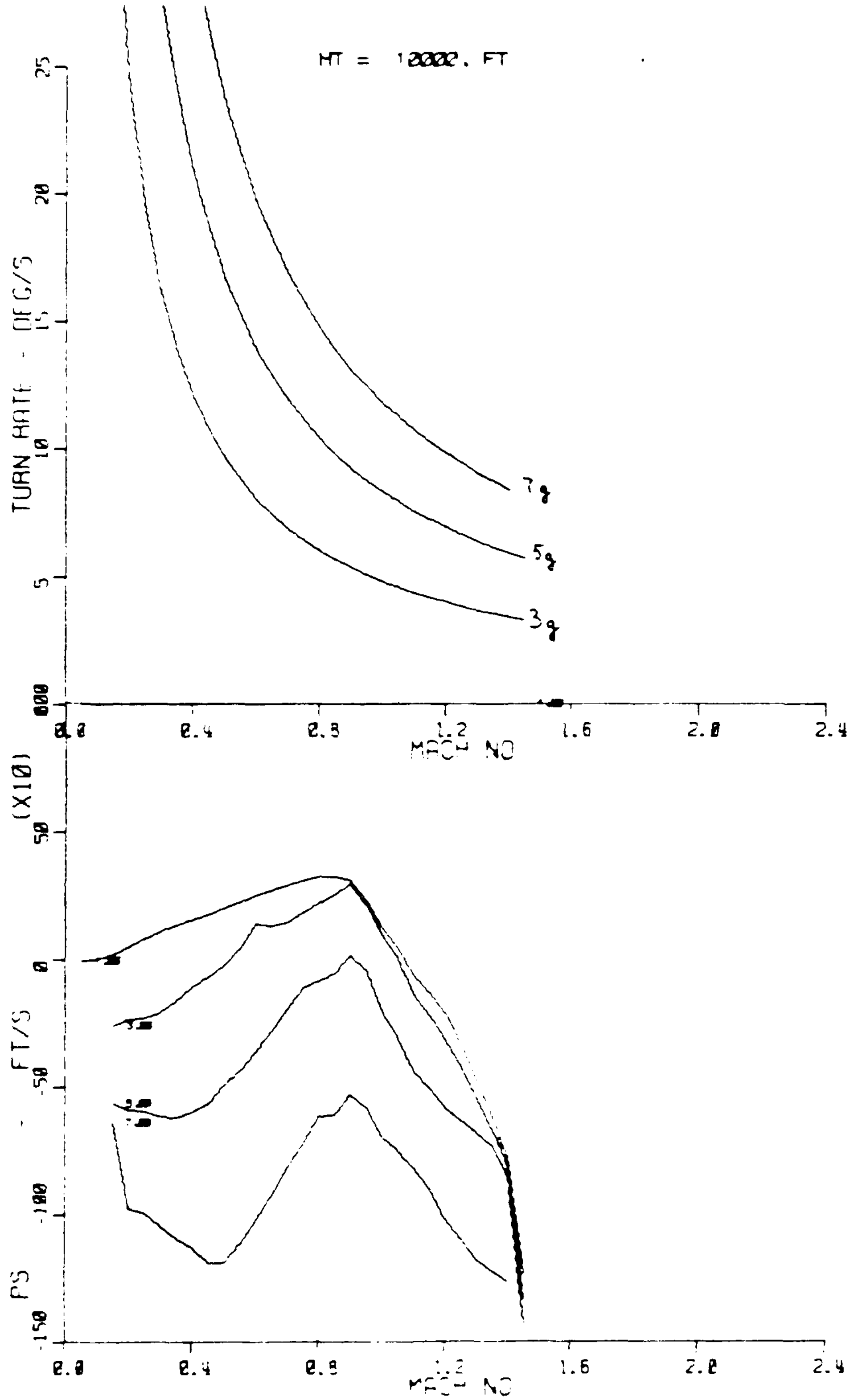

FIG. 10.22 Sample SEP Versus Mach Number Plot

11. ACKNOWLEDGEMENT

The author acknowledges the help and co-operation provided by Mr. K. Marriott was employed at the time as a part-time temporary Computer Science Officer with the group.

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APPENDIX A

SUMMARY OF MODIFICATIONS

The modifications incorporated are labelled K1, K2,......K8 in the program listing and are as follows:

1. MODIFICATION K1

Addition of an option (4G) in program P2V2 to plot contours of the energy parameter χ on a Mach number, turn rate (or load factor) grid; one page of plots being produced for each pressure height (or energy state).

This involved some modifications to the routines in P2V2 and two new subroutines GRIDC and P4PS4G in P4V2.

2. MODIFICATION K2

Calculation and plotting of the boundaries corresponding to the lift limit and structural limit in the options 4A and 4G available in P2V2.

This involved some modifications in P1V2 to calculate and print the boundary points, and in P2V2 to calculate the points on the boundary plot for option 4A. In addition two new subroutines BOUND and ESTBOUND where provided in P4V2.

3. MODIFICATION K3

Restructuring of subprogram P1V2 and the user supplied routines to facilitate the programming of these user routines.

Also refers to modifications in P1V2 and P24LIB to allow for vectored thrust aircraft.

4. MODIFICATION K4

Provision of a turn rate grid as an additional option (as an alternative to the load factor grid) when running ACRAFT and hence the option of plotting either load factor or turn rate when using various plotting options available in P2V2.

5. MODIFICATION K5

The additional option of a fourth type of energy parameter $\chi_4 = F_s/V$ has involved modifications in P1V2 and in P24LIB.

6. MODIFICATION K6

Modifications to allow for a PACAM2 tabulated data file in ASCII to be used as input by the user defined routines THRUST and AERO as an alternative to the spline fitted information stored in binary.

7. MODIFICATION K7

Restructuring of P4V2 which was mostly rewritten. Subroutines PCON, PES, GRIDC, P4PS4A, P4PS4G are new and other modifications were made in P4V2 and P4LIB.

8. MODIFICATION K8

Following on from modification K4, P1V2 was modified and RATE2 (in P2V2) was rewritten in order to improve the accuracy of the results in option 4C.

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16. Abstract

Several years of usage of the ARL point performance program described in ARL Technical Engineering Report 160 have indicated the desirability of certain improvements and extensions which have been incorporated. This document describes the purpose and nature of the various changes in sufficient detail to allow it to be used independently of the original report.

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