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HP-9825A CALCULATOR PROGRAMS FOR PLOTTING ORBITER RCS JET DYNAMIC PRESSURE CONTOURS

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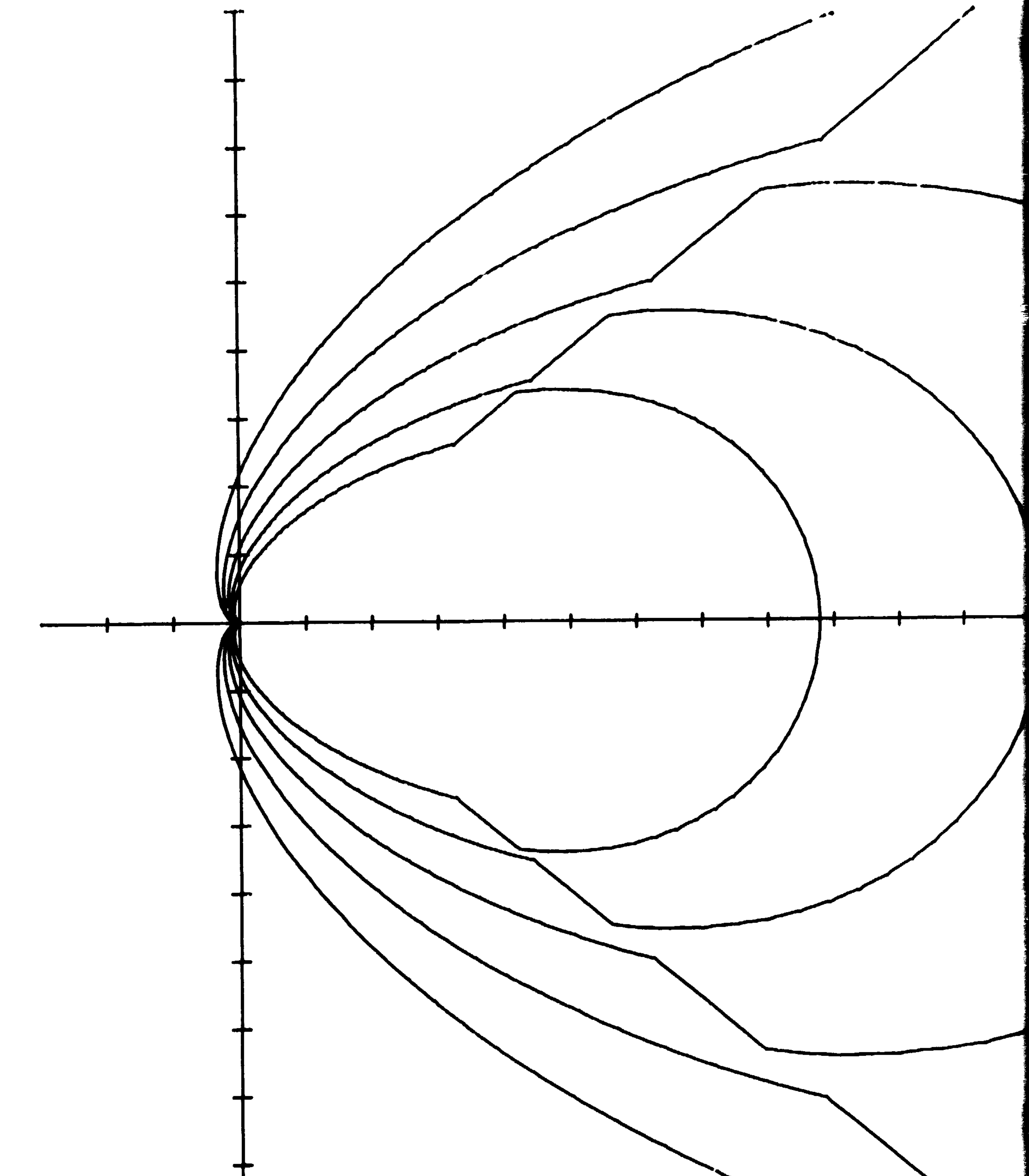
1. INTRODUCTION

The HP-9825A calculator programs to be described here provide the capability to generate displays, such as those shown in Figures 1 and 2, which depict the dynamic pressure fields generated by Orbiter RCS thruster firings. Figure 1 was generated by the Jet Contour Plotting Program (JCPP), which is a stand-alone program that can be used to generate dynamic contours for an isolated RCS jet. The Orbiter Profile/Jet Contour Plotting Program (OP/JCPP) provides the capability to superimpose the plume contours for specific jets or jet clusters on front and side views of the Orbiter profile. The code for the JCPP and the OP/JCPP resides in Files 0 and 1, respectively, of the program tape. The tape is enclosed in a standard HP-9825A data cartridge.

Both programs utilize the HP-9862A plotter and the HP-9866B thermal printer. The following four Read-Only Memory (ROM) blocks must be installed in the calculator before either program will load properly:

ROM	Part No.
String-Advanced Programming	98210A
Matrix	98211A
9885M Flexible Disk Drive	98217A
9862A Plotter - General I/O - Extended I/O	98214A



FOLDOUT FRAME

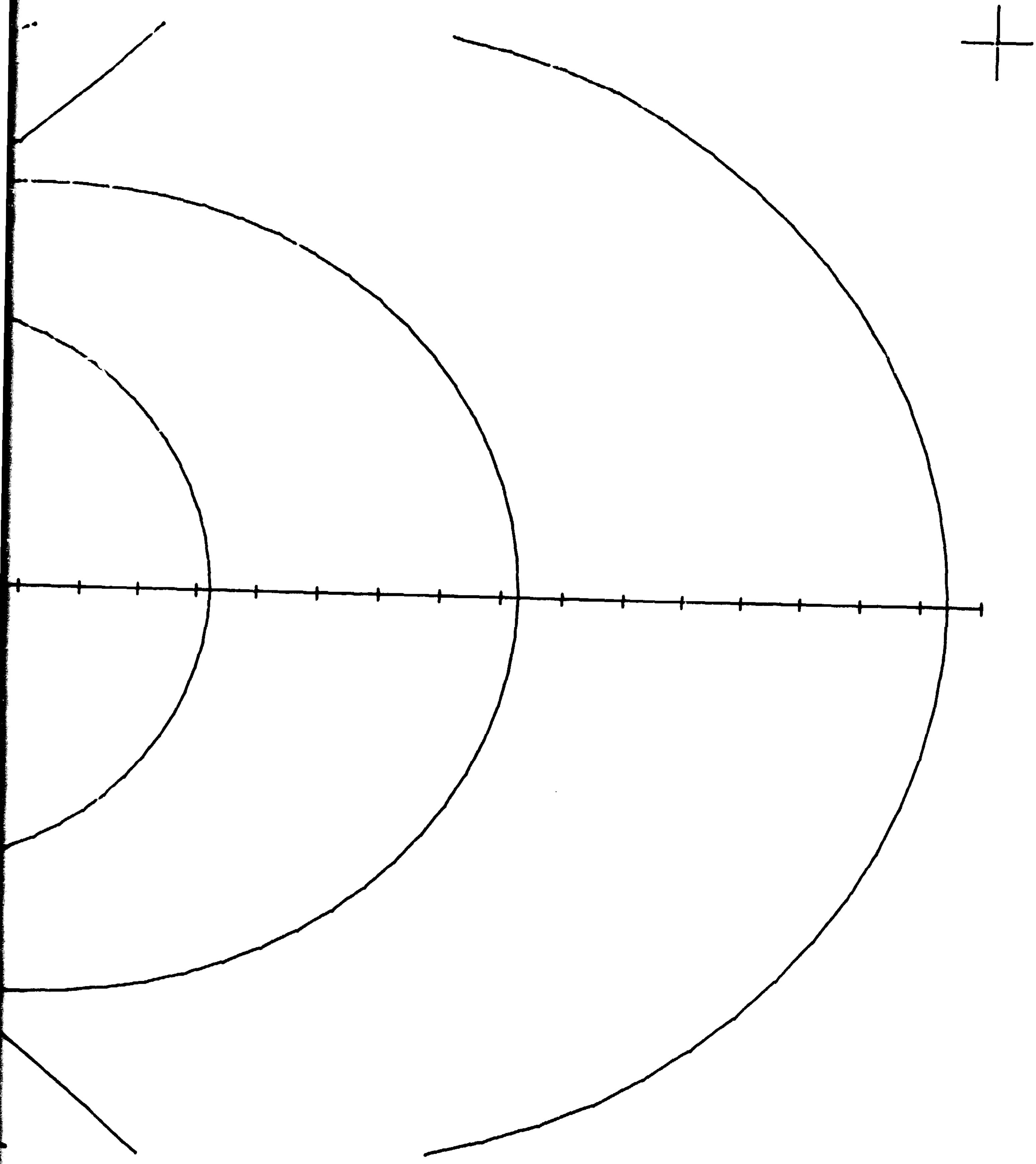
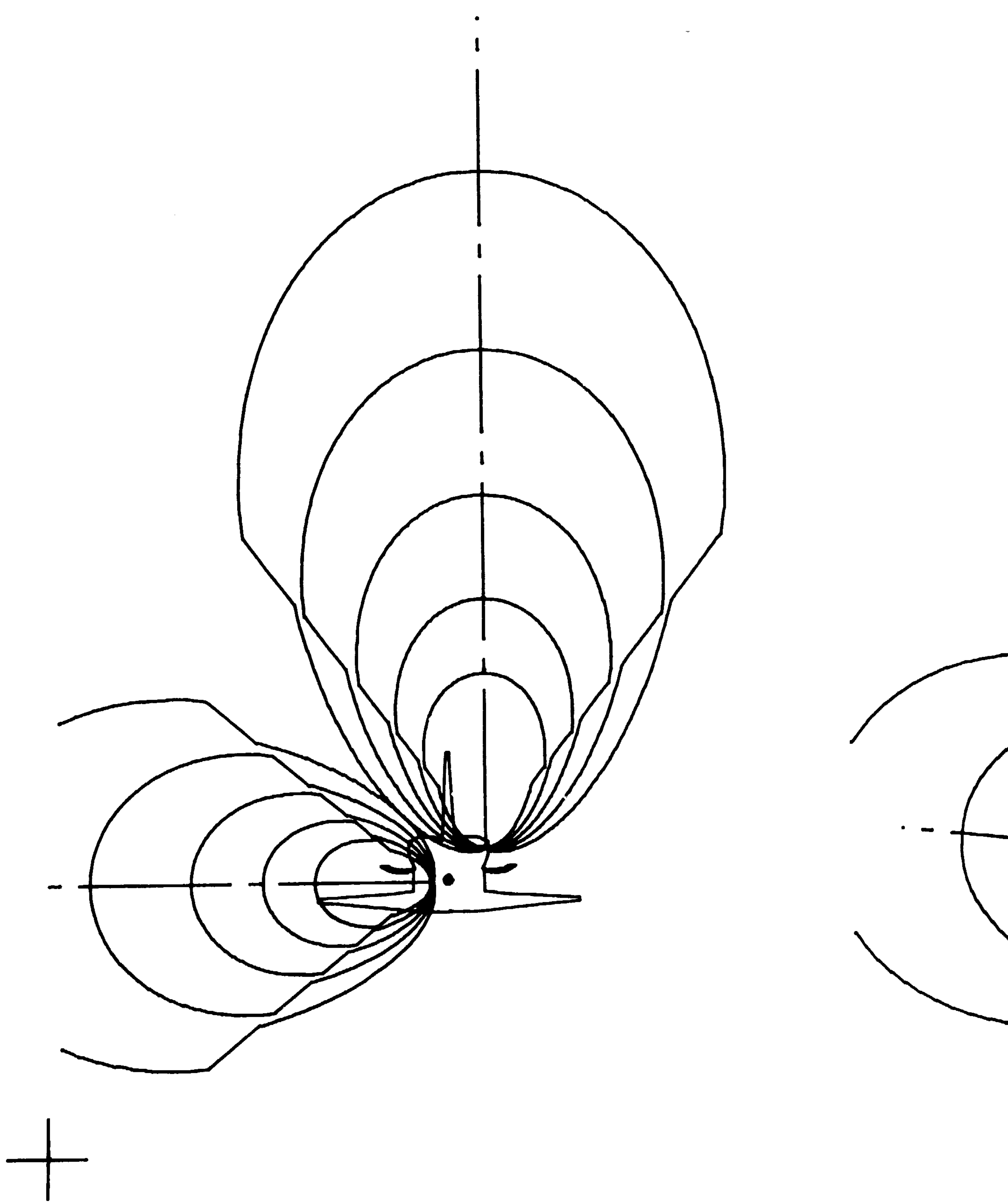


Figure 1. Typical JCPP Output



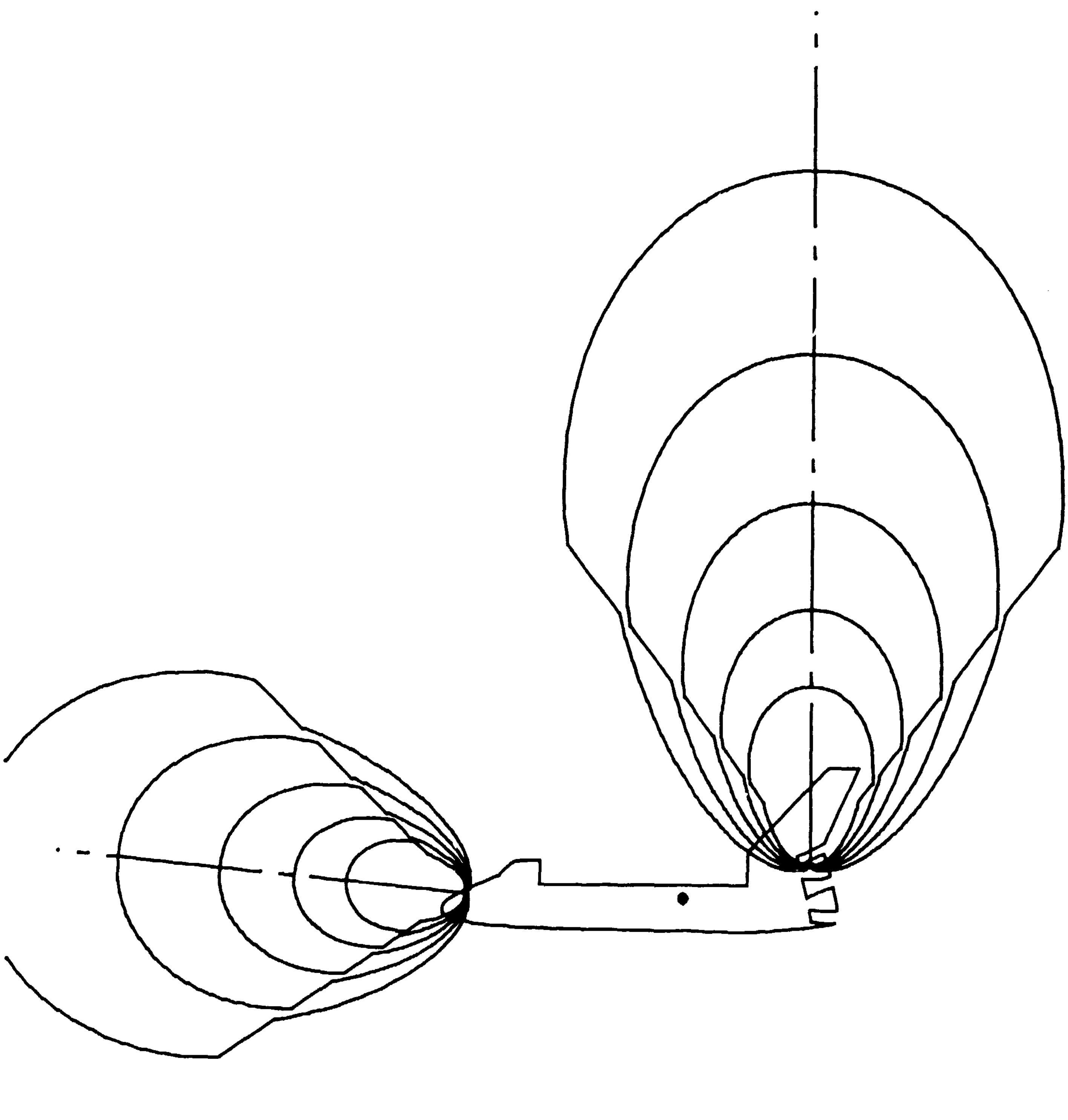


Figure 2. Typical OP/JCPP Output

2. PLUME MODELS

Three plume modeling options are provided in the JCPP and the OP/JCPP. They are described separately in Sections 2.1 through 2.3. All of the models are axisymmetric and define dynamic pressure ($q = 1/2\ \rho v^2$) as a function of a radial distance r and an angle θ measured in a coordinate system which is illustrated in Figure 3. The X axis is coincident with the jet thrust line, and the origin of the system lies at the center of the nozzle exit plane. In the equations which follow, all distances are measured in feet, angles in degrees, velocities in feet per second, densities in slugs per cubic foot, and pressure in pounds per square foot.

2.1 MD/ECL MODEL

This model (Reference 1) represents a curve fit of data published in Reference 2. Empirical equations for effluent density (ρ) and velocity (v) are defined separately for the continuum and the free-molecular flow regimes. In each flow regime, the flowfield is divided into two regions ($|\theta| \leq 38.6°$ and $|\theta| \geq 38.6°$). As illustrated in Figure 4, the entire flowfield is thus divided into four areas, each having a particular set of density and velocity equations. These equations are shown in Table 1.

To draw the contour line for a given value of q, arbitrary values are assigned to θ and the appropriate equations in Table 1 are solved to find r. The solution is explicit in the free-molecular regime where v and W are functions of θ only. In the continuum regime, v is a function of r, and an iterative solution is required.

In the computational procedure, free-molecular flow is assumed initially, and the explicit solution

$$r = (Wv^2/2q)^{1/2}$$

is calculated. The density is then calculated from

$$\rho = W/r^2 .$$

If $\rho \leq 1.91885 \times 10^{-10}$, the solution is complete. Otherwise, the value of r obtained from the free-molecular solution becomes the first guess in a Newton-Raphson iteration which uses the analytic derivative

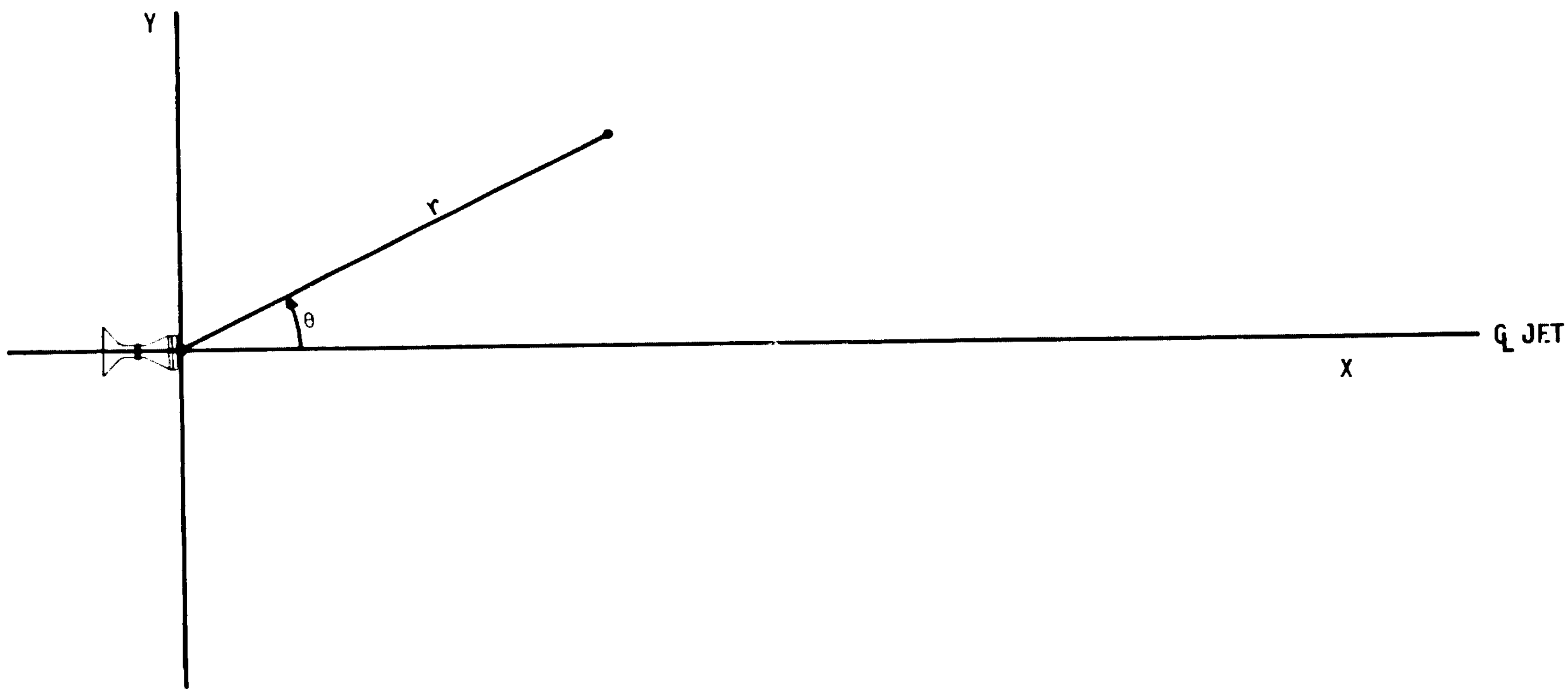


Figure 3. Flowfield Coordinate System

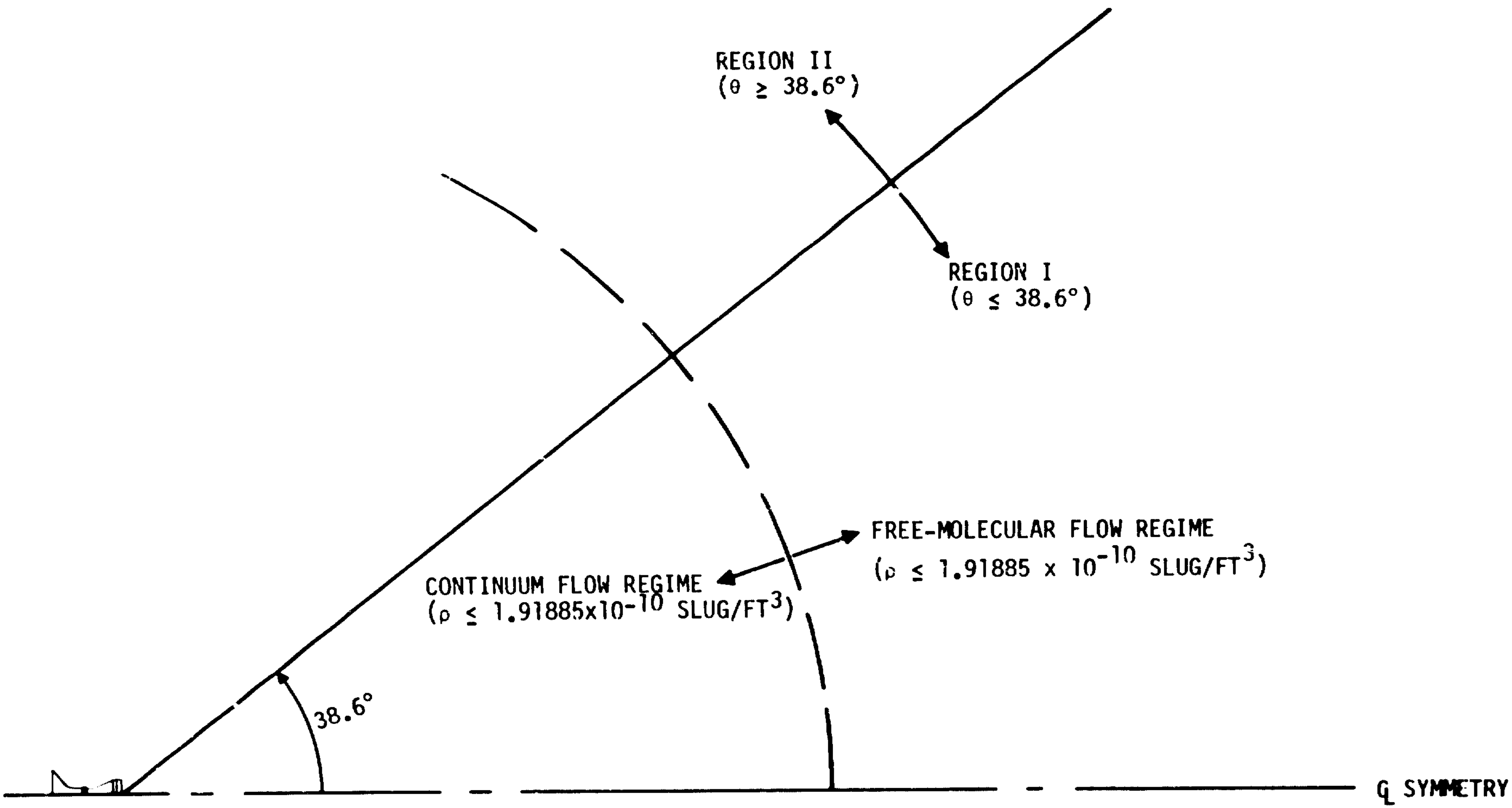


Figure 4. MD/ECL Flow Regimes and Regions

Table 1. Equations for MD/ECL RCS Jet Plume Model

	CONTINUUM FLOW ($\rho > 1.91885\times10^{-10}$)	FREE-MOLECULAR FLOW ($\rho \leq 1.91885\times10^{-10}$)
REGION II ($\theta \geq 38.6$)	$v = 12600 - 0.0012 \lvert(110-r)^3\rvert$ $\rho = W/r^2$ $W = \dfrac{1.40679\times10^{-6}}{\exp[0.07564(\theta - 38.6)]}$	$v = 11400 + 865 \cos\theta$ $\rho = W/r^2$ $W = \dfrac{1.40679 \times 10^{-6}}{\exp[0.07564(\theta - 38.6)]}$
REGION I ($\theta \leq 38.6$)	$v = 12600 - 0.0012 \lvert(110-r)^3\rvert$ $\rho = W/r^2$ $W = 6.5712\times10^{-6} \cos^{5.1} (90\theta/98.6)$	$v = 11400 + 865 \cos\theta$ $\rho = W/r^2$ $W = 6.356\times10^{-6} \cos^{5.1} (90\theta/98.6)$

$$\frac{dq}{dr} = \left[.0036(110-r)^2 - \frac{v}{r}\right]\left(\frac{Wv}{r^2}\right)$$

for calculating corrections to r in the continuum regime.

2.2 E&D MODEL

In this model (Reference 3), the radial distance for given values of q and θ is computed directly from the equation

$$r = [546\ f(\theta)/q]^{1/2}$$

where

$$f(\theta) = \cos^{7.14}(90\theta/98.6) \text{ if } \theta \leq 55.05$$

and

$$f(\theta) = \frac{0.04105}{\exp\left[0.139934\ (\theta - 55.05)\right]} \text{ if } \theta > 55.05.$$

The constants in the above equations result from assigning the following values to the parameters delineated in Reference 3:

$$A = 1.1911$$

$$\gamma = 1.28$$

$$P_o = 22032$$

$$r_e = 0.4$$

$$A_e/A^* = 22.$$

2.3 MD/QLDP MODEL

This plume model is the one used in the MDAC Quick Look Disturbance Program (Reference 4). For given values of q and θ, the radial distance is computed from the equation

$$r = \left\{\left[625\ \cos^{8.47}(90\theta/145)\right]/q\right\}^{1/2}.$$

For this model, the magnitude of the angle θ is limited to 145 degrees.

3. SETTING PHYSICAL PLOT BOUNDARIES

The HP-9862A plotting board is a rectangle whose dimensions are approximately 17 inches by 12 inches. The plotter $\underline{X}$ axis is parallel to the longer side and the $\underline{Y}$ axis is parallel to the shorter side. The maximum area accessible to the plotter's inking pen is a smaller rectangle whose dimensions are 15 inches by 10 inches. A plot can be drawn on any sheet of paper small enough to fit on the plotting board. The paper is held in place by electrostatic force that is controlled by the CHART HOLD button on the plotter control panel. As indicated in Figure 5, a small sheet of paper can be located at an arbitrary position on the board, and the plotting area can be bounded on the paper by a simple procedure that is described in the next paragraph.

For convenience, fiducial marks should be inscribed on the sheet of plotting paper at the lower left and upper right corners of the desired plotting area before it is placed on the plotting board. After the paper has been secured by pressing the CHART HOLD button, the user presses the PEN UP and then the LOWER LEFT buttons on the plotter control panel. After the pen comes to rest, its position is adjusted to coincide with the lower left corner of the desired plotting area by rotating two knobs adjacent to the LOWER LEFT button. These two knobs move the pen parallel to the plotter $\underline{X}$ and $\underline{Y}$ axes independently. After the pen point has been positioned over the lower left fiducial mark as closely as the eye can judge, the PEN DOWN and PEN UP buttons can be pressed in sequence to mark the exact pen position on the paper. If necessary, fine adjustments of the pen position can then be made. After the user has adjusted the pen position at the lower left corner to his satisfaction, he presses the UPPER RIGHT button and positions the pen over the upper right fiducial mark by using the adjacent control knobs. Again, the exact position of the pen can be determined by pressing the PEN DOWN and PEN UP buttons in succession to produce a dot of ink on the paper.

The sequence of operations described in the preceding paragraph is important. The adjustment of the lower left corner must always be made first. If for any reason a readjustment is made at the lower left corner, it must be followed by a readjustment at the upper right corner.

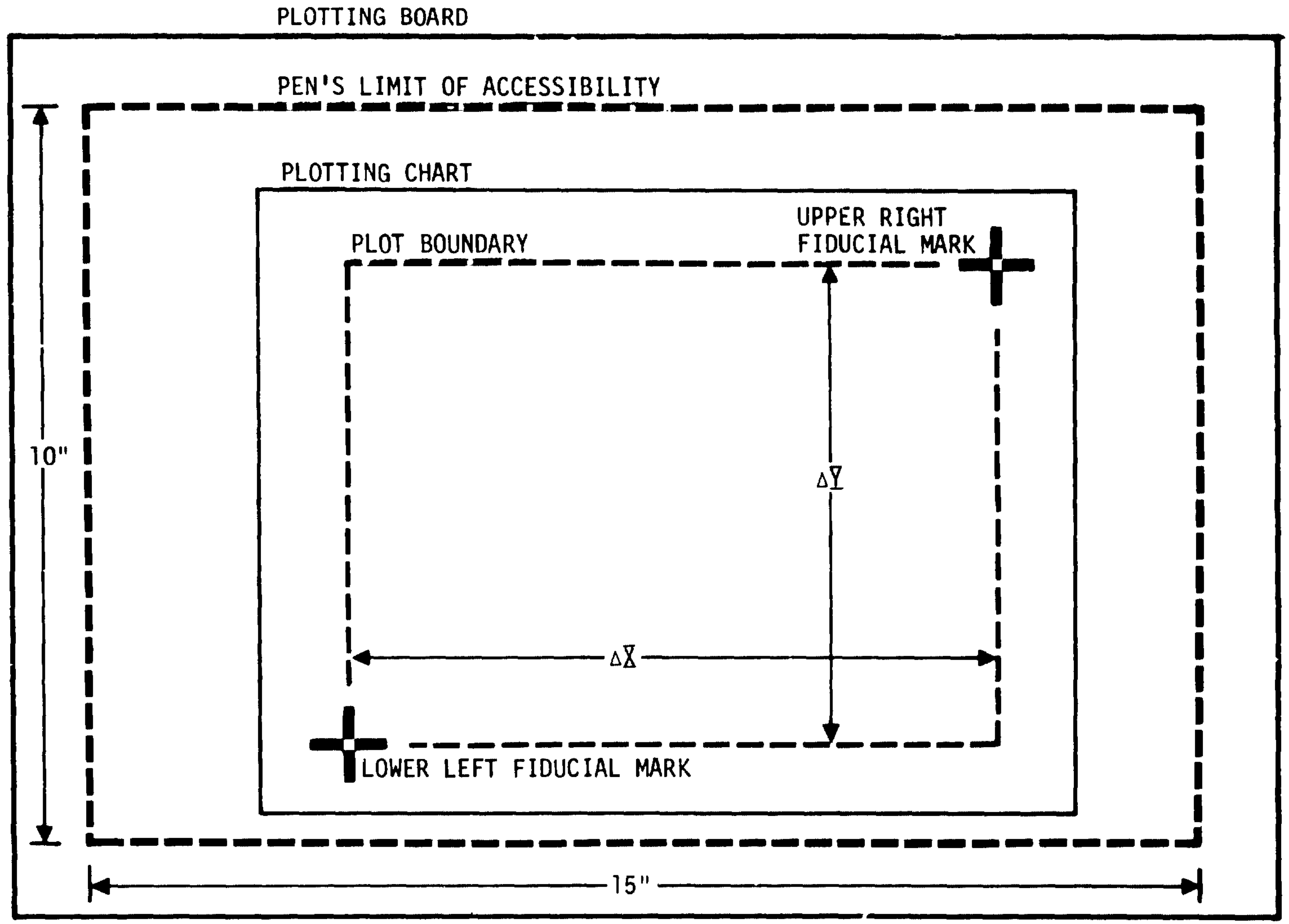


Figure 5. Physical Plot Boundaries

4. JCPP PROGRAM

4.1 OPERATING INSTRUCTIONS

1. Turn on power switches on the HP-9825A calculator, the HP-9862 plotter, and the HP-9866B printer.

2. Insert data cartridge containing program tape into the slot to the left of the display window on the HP-9825A calculator.

3. Press REWIND*.

4. Type in the instruction "ldmØ"† (load memory from tape file Ø). Verify that the instruction appears correctly in the calculator display window, then press EXECUTE . This will cause the program instructions and the standard input data base to be loaded into memory.

5. When the lazy T ("⊢") character appears in the display window, press REWIND . The data cartridge may be removed when the amber tape activity light below the cartridge slot ceases to glow.

6. Place a sheet of paper on the HP-9862A plotting board and adjust the physical bounds of the plotting area as explained in Section 3.

7. Press CONTINUE . The calculator will respond by listing the current contents of the input data base (see Section 4.2) on the HP-9866B printer.

8. The query "WHAT REGISTER?" should now appear in the display window. If no (further) changes to the input data base are desired, press CONTINUE and skip ahead to Step 11. Otherwise, go to Step 9.

---

* Individual keys on the calculator keyboard are designated by circumscribing the characters appearing on the key (e.g., EXECUTE).

† Instructions or messages appearing in the calculator display window are enclosed in quotation marks.

9. Enter the number of the data register (whose contents are to be changed) into the display, and then press CONTINUE . The calculator will respond by printing the current contents of the specified register* on the HP-9866B printer.

10. The query "NEW VALUE?" should now appear in the display window. Enter the desired value† into the display and press CONTINUE . The calculator will print the new value on the HP-9866B. Go back to Step 8.

11. The program will now begin automatic execution and will continue plotting until all of the specified dynamic pressure contours have been drawn. If any input parameters were changed, the revised input data base will be listed in its entirety before plotting begins.

12. When plotting is complete, the calculator will issue a beep sound and display the message "FINIS" in the display window. If a new set of contours is to be drawn on the same sheet of paper, go back to Step 7. Otherwise go to Step 13.

13. Press the CHART HOLD button on the plotter control panel to release the electrostatic force and then remove the completed chart. If a new chart is to be prepared, go back to Step 6. Otherwise, go to Step 14.

14. Turn off the power switches on the HP-9825A calculator, the HP-9862A plotter, and the HP-9866B printer.

---

* If the operator's entry was not a valid input data register number, nothing will be printed. In such a case, go back to Step 8.

† The entry may be a number or any valid expression. If an expression is entered, the calculator will evaluate it and store the result in the specified input data register. If no entry is made, the contents of the input data register will not be changed.

4.2 INPUT DATA

The standard input data base which resides on the program tape is shown in Table 2. The operator may change any or all of the input values at the beginning of a run by use of the editing logic described in Section 4.1. If another run is initiated without reloading memory from the program tape, the previously-edited data base becomes the starting point for the new run. Individual input parameters are explained in Sections 4.2.1 through 4.2.5.

4.2.1 Logical Plot Boundaries (Registers 0 - 3)

```
FT          -6.00000000E 01     0:  X MIN
FT           5.00000000E 02     1:  X MAX
FT          -1.80000000E 02     2:  Y MIN
FT           1.80000000E 02     3:  Y MAX
```

The logical boundaries of the plotting area are defined in terms of the Cartesian flowfield coordinates $X = r \cos \theta$ and $Y = r \sin \theta$ (see Figure 3). The logical coordinates $\left(X_{min}, Y_{min}\right)$ correspond to the lower left corner of the physical boundary described in Section 3. The logical coordinates $\left(X_{max}, Y_{max}\right)$ correspond to the upper right corner of the physical boundary.

The logical and physical boundaries can be adjusted to plot any portion of the flowfield at any desired scale. However, the equation

$$\frac{\Delta \underline{Y}}{\Delta \underline{X}} = \frac{\left|Y_{max} - Y_{min}\right|}{\left|X_{max} - X_{min}\right|}$$

must be satisfied if distortions are to be avoided, where $\Delta\underline{Y}$ and $\Delta\underline{X}$ are as defined in Figure 5. The standard input values for registers 0 - 3 yield a scale of 1" = 40' when $\Delta\underline{X}$ = 14" and $\Delta\underline{Y}$ = 9".

4.2.2 Tic Interval (Register 4)

```
FT           2.00000000E 01     4:  TIC INTERVAL
```

If register 4 contains a number greater than zero, the flowfield coordinate axes will be drawn on the display, with tic marks at the specified interval. If register 4 contains a zero or a negative number, the coordinate axes will not be drawn.

Table 2. JCPP Standard Input Data Base

JET CONTOUR PLOTTING PROGRAM INPUT

UNITS	VALUE	REG:	DESCRIPTION
FT	-6.00000000E 01	0:	X MIN
FT	5.00000000E 02	1:	X MAX
FT	-1.80000000E 02	2:	Y MIN
FT	1.80000000E 02	3:	Y MAX
FT	2.00000000E 01	4:	TIC INTERVAL
--	0	5:	PLUME MODEL (0=MD/ECL,1=E&D,2=MD/QL)
LB/FT↑2	1.00000000E-05	6:	Q MIN
--	1.00000000E 01	7:	Q RATIO BETWEEN CONTOURS
--	6	8:	NO. CONTOURS
--	1	9:	NO. JETS

Register 4 should not be assigned a positive value if the logical plot boundaries (Section 4.2.1) are defined such that the origin of the flowfield coordinate system lies outside the plotting area. If a positive value is assigned in such a case, an error condition will result when the plotter attempts to draw the axes.

4.2.3 Plume Model (Register 5)

```
--                    0     5:  PLUME MODEL (0=MD/ECL,1=E&D,2=MD/QL..
```

Any of the plume models described in Section 2 can be utilized by loading the appropriate value into register 5.

4.2.4 Contour Specifications (Registers 6 - 8)

```
LB/FT↑2      1.00000000E-05     6:  Q MIN
--           1.00000000E 01     7:  Q RATIO BETWEEN CONTOURS
--                        6     8:  NO. CONTOURS
```

The value assigned to register 6 defines the dynamic pressure for the outermost flowfield contour. For each succeeding contour, the dynamic pressure is multiplied by the contents of register 7. Register 8 defines the total number of contour lines to be drawn.

4.2.5 Jet Multiplier (Register 9)

```
--                    1     9:  NO. JETS
```

Provisions are made for approximating the flowfield of clustered jets firing simultaneously. When this option is used, the number of jets is entered in register 9. It is assumed that the dynamic pressure in an N-jet flowfield is N times greater at every point than the dynamic pressure produced by a single jet. No representations are made as to the validity of the assumption; certainly it is not accurate at short distances from the jet exit(s). It is left to the user to determine how much credence should be given to multi-jet data generated in this manner.

5. OP/JCPP PROGRAM

5.1 OPERATING INSTRUCTIONS

1. Turn on power switches on the HP-9825A calculator, the HP-9862A plotter, and the HP-9866B printer.

2. Insert data cartridge containing program tape into the slot to the left of the display window on the HP-9825A calculator.

3. Press REWIND*.

4. Type in the instruction "ldm1"† (load memory from tape file 1). Verify that the instruction appears correctly in the calculator display window, then press EXECUTE. This will cause the program instructions, program constants, and the standard input data base to be loaded into memory.

5. When the lazy T ("⊢") character appears in the display window, press REWIND. The data cartridge may be removed when the amber tape activity light below the cartridge slot ceases to glow.

6. Place a sheet of paper on the HP-9862A plotting board and adjust the physical bounds of the plotting area as explained in Section 3.

7. Press CONTINUE. The calculator will respond by listing the current contents of the input data base (see Section 5.2) on the HP-9866B printer.

8. The query "WHAT REGISTER?" should now appear in the display window. If no (further) changes to the input data base are desired, press CONTINUE and skip ahead to Step 11. Otherwise, go to Step 9.

---

* Individual keys on the calculator keyboard are designated by circumscribing the characters appearing on the key (e.g., EXECUTE).

† Instructions or messages appearing in the calculator display window are enclosed in quotation marks.

9. Enter the number of the data register (whose contents are to be changed) into the display, and then press CONTINUE . The calculator will respond by printing the current contents of the specified register* on the HP-9866B printer.

10. The query "NEW VALUE?" should now appear in the display window. Enter the desired value† into the display and press CONTINUE . The calculator will print the new value on the HP-9866B. Go back to Step 8.

11. If any input parameters have been changed, the program will list the revised input data base in its entirety.

12. The query "OV PROFILE?" should now appear in the display window. If it is <u>not</u> desired to have the plotter draw the profile view(s) of the Orbiter vehicle, load a zero ("Ø") into the display and then press CONTINUE . Otherwise, press CONTINUE without making any entry, or else load any non-zero value into the display and then press CONTINUE .

13. The program will now begin automatic execution and will continue plotting until all of the specified dynamic pressure contours have been drawn. If no entry was made in Step 12, or if a non-zero value was entered, the profile view(s) of the Orbiter will be drawn before the dynamic pressure contours are plotted.

14. When plotting is complete, the calculator will issue a beep sound and display the message "FINIS" in the display window. If a new set of contours is to be drawn on the same sheet of paper, go back to Step 7. Otherwise, go to Step 15.

---

* If the operator's entry was not a valid input data register number, nothing will be printed. In such a case, go back to Step 8.

† The entry may be a number or any valid expression. If an expression is entered, the calculator will evaluate it and store the result in the specified input data register. If no entry is made, the contents of the input data register will not be changed.

15. Press the CHART HOLD button on the plotter control panel to release the electrostatic force and remove the completed chart. If a new chart is to be prepared, go back to Step 6. Otherwise, go to Step 16.

16. Turn off the power switches on the HP-9825A calculator, the HP-9862A plotter, and the HP-9866B printer.

5.2 INPUT DATA

The standard input data base which resides on the program tape is shown in Table 3. The operator may change any or all of the input values at the beginning of a run by use of the editing logic described in Section 5.1. If another run is initiated without reloading memory from the program tape, the previously-edited data base becomes the starting point for the new run. Individual input parameters are explained in Sections 5.2.1 through 5.2.5.

5.2.1 Logical Plot Boundaries (Registers 0 - 5)

```
FT     -1.20000000E 02     0:  XOB MIN
FT      2.00000000E 02     1:  XOB MAX
FT     -1.20000000E 02     2:  YOB MIN
FT      1.20000000E 02     3:  YOB MAX
FT     -2.80000000E 02     4:  ZOB MIN
FT      8.00000000E 01     5:  ZOB MAX
```

The logical plotting boundaries are defined in terms of Orbiter body axes (OB) coordinates. This coordinate system is described in Figure 12 of Reference 5.

Figure 6 shows the relationship between the logical plot boundaries and the physical boundaries established by the procedure explained in Section 3. As indicated, the plotting area is partitioned to provide a side view and a front view of the Orbiter. The location of the partition and the scale of the plotted figures can be adjusted by changing the values in registers 0 - 5. The front view can be suppressed by setting $Y_{OBmax} = Y_{OBmin}$, or the side view can be suppressed by setting $X_{OBmax} = X_{OBmin}$. In any event, the equation

$$\frac{\Delta \underline{Y}}{\Delta \underline{X}} = \frac{|Z_{OBmax} - Z_{OBmin}|}{|(Y_{OBmax} - Y_{OBmin}) + (X_{OBmax} - X_{OBmin})|}$$

Table 3. OP/JCPP Standard Input Data Base

OV PROFILE / JET CONTOUR PLOTTING PROGRAM INPUT

UNITS	VALUE	REG:	DESCRIPTION
FT	-1.20000000E 02	0:	XOB MIN
FT	2.00000000E 02	1:	XOB MAX
FT	-1.20000000E 02	2:	YOB MIN
FT	1.20000000E 02	3:	YOB MAX
FT	-2.80000000E 02	4:	ZOB MIN
FT	8.00000000E 01	5:	ZOB MAX
IN	1.07670000E 03	6:	OV CG STA
IN	0.00000000E 00	7:	OV CG BL
IN	3.74100000E 02	8:	OV CG WL
--	0	9:	PLUME MODEL (0=MD/ECL,1=E&D,2=MD/QL)
LB/FT↑2	2.50000000E-02	10:	Q MIN
--	2.00000000E 00	11:	Q RATIO BETWEEN CONTOURS
--	5	12:	NO. CONTOURS
--	0	13:	NO. FWD -X JETS (0,1,2,3)
--	0	14:	NO. FWD +Y JETS (0,1,2)
--	0	15:	NO. FWD -Y JETS (0,1,2)
--	0	16:	NO. FWD +Z JETS (0,1,2,3)
--	0	17:	NO. AFT LH +X JETS (0,1,2)
--	0	18:	NO. AFT RH +X JETS (0,1,2)
--	0	19:	NO. AFT +Y JETS (0,1,2,3,4)
--	0	20:	NO. AFT -Y JETS (0,1,2,3,4)
--	0	21:	NO. AFT LH +Z JETS (0,1,2,3)
--	0	22:	NO. AFT RH +Z JETS (0,1,2,3)

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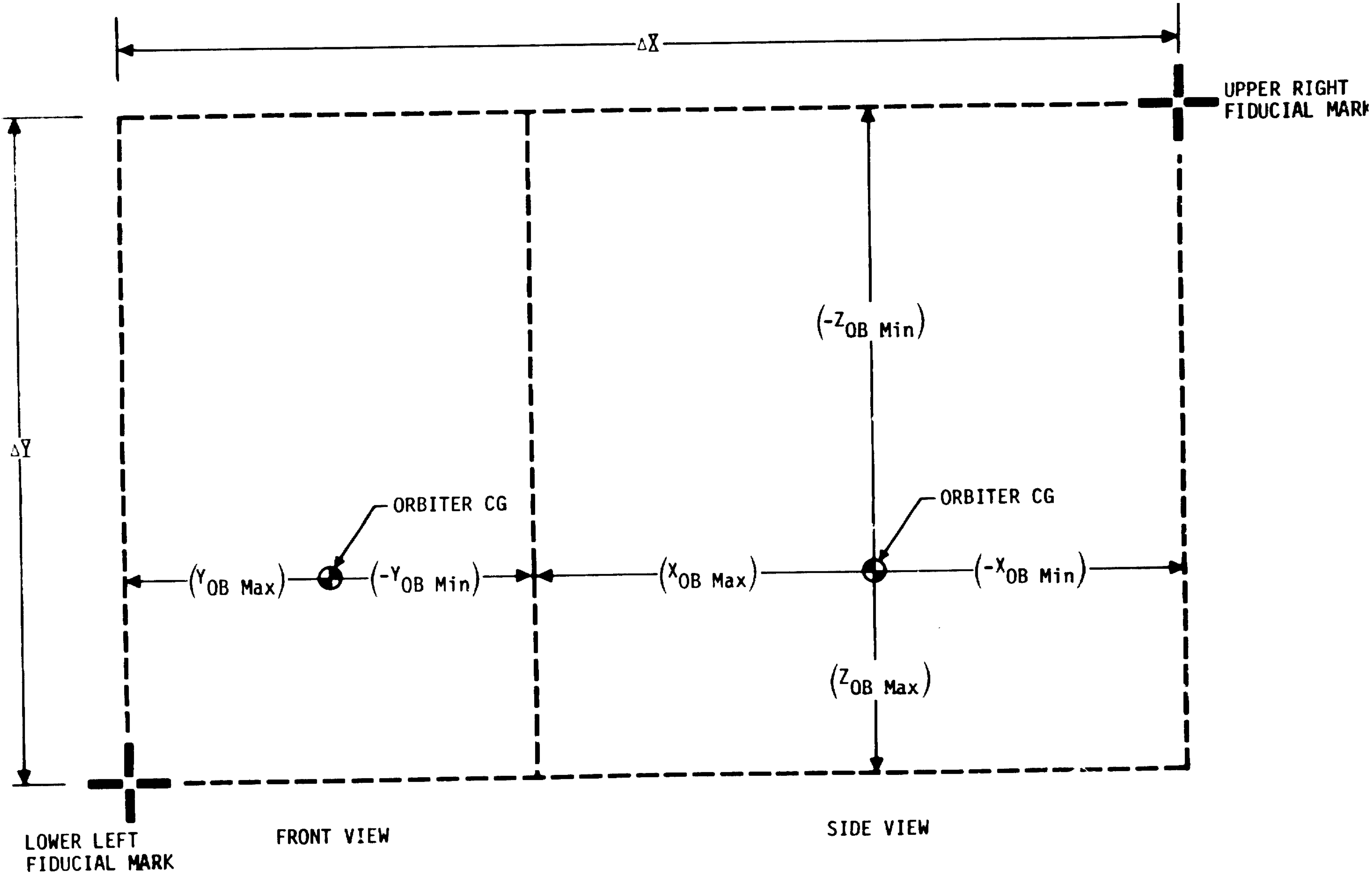

Figure 6. OP/JCPP Logical Plot Boundaries

must be satisfied if distortions are to be avoided. The standard input values for registers 0 - 5 yield a scale of 1" = 40' when $\Delta\underline{\overline{X}}$ = 14" and $\Delta\underline{\overline{Y}}$ = 9".

5.2.2 Orbiter CG Location (Registers 6 - 8)

```
IN        1.07670000E 03     6:  OV CG STA
IN        0.00000000E 00     7:  OV CG BL
IN        3.74100000E 02     8:  OV CG WL
```

The Orbiter center of gravity (CG) location, which is the origin of the OB coordinate system, is defined in terms of Orbiter structural body coordinates. The structural body coordinate system is defined in Figure 23 of Reference 5. In OP/JCPP, the X, Y, and Z structural body coordinates are designated, respectively, as the station (STA), buttock line (BL), and water line (WL).

5.2.3 Plume Model (Register 9)

```
--                        0     9:  PLUME MODEL (0=MD/ECL,1=E&D,2=MD/QL)
```

Any of the plume models described in Section 2 can be utilized by loading the appropriate value into register 9.

5.2.4 Contour Specifications (Registers 10 - 12)

```
LB/FT↑2   2.50000000E-02    10:  Q MIN
--        2.00000000E 00    11:  Q RATIO BETWEEN CONTOURS
--                     5    12:  NO. CONTOURS
```

The value assigned to register 10 defines the dynamic pressure for the outermost flowfield contour. For each succeeding contour, the dynamic pressure is multiplied by the contents of register 11. Register 12 defines the total number of contour lines to be drawn for each active jet or jet cluster.

5.2.5 Jet Multipliers (Registers 13 - 22)

```
--                        0    13:  NO. FWD -X JETS     (0,1,2,3)
--                        0    14:  NO. FWD +Y JETS     (0,1,2)
--                        0    15:  NO. FWD -Y JETS     (0,1,2)
--                        0    16:  NO. FWD +Z JETS     (0,1,2,3)
--                        0    17:  NO. AFT LH +X JETS  (0,1,2)
--                        0    18:  NO. AFT RH +X JETS  (0,1,2)
--                        0    19:  NO. AFT +Y JETS     (0,1,2,3,4)
--                        0    20:  NO. AFT -Y JETS     (0,1,2,3,4)
--                        0    21:  NO. AFT LH +Z JETS  (0,1,2,3)
--                        0    22:  NO. AFT RH +Z JETS  (0,1,2,3)
```

Registers 13 - 22 contain the number of active jets in each of 10 RCS jet clusters. Each cluster is identified in terms of its location (e.g., AFT LH) and the general direction of the force it exerts on the Orbiter (e.g., +X), as measured in the Orbiter body axes coordinate system. The direction of the jet effluent is opposite to the direction of the force it produces on the Orbiter. Downward-firing (-Z) jets are not modeled in the OP/JCPP.

A value of zero in one of the jet multiplier registers signifies that all the jets in the appropriate cluster are inactive, and that no contours are to be drawn for that cluster. For the purpose of generating the contours for any particular cluster, it is assumed that the dynamic pressure in an N-jet flowfield is N times greater at every point than the dynamic pressure produced by a single jet. The possibility of interactions between the flowfields produced by different jet clusters is ignored. The effect of Orbiter structure on the flowfields is also ignored. No representations are made as to the validity of these assumptions and simplifications; it is left to the user to determine how much credence should be given to the flowfield data thus generated.

The origin of each flowfield is taken to be at the mean location of the centers of the exit planes for the individual jets in the appropriate cluster. The origin and orientation of each flowfield is defined in Table 4. The information given there is based on data obtained from Reference 6.

Table 4. RCS Jet Cluster Flowfield Data

CLUSTER DESIGNATION	PLUME DIRECTION	NUMBER OF JETS IN CLUSTER	FLOWFIELD ORIGIN (STRUCTURAL BODY COORDINATES)			ANGLE BETWEEN $-Z_{OB}$ AXIS & PLUME ℄ (DEG)	
			STA (IN.)	BL (IN.)	WL (IN.)	FRONT VIEW	SIDE VIEW
FWD -X	FWD	3	314	0	394	*	84.4†
FWD +Y	L	2	364	- 65	364	90	*
FWD -Y	R	2	364	65	364	90	*
FWD +Z	UP	3	351	0	415	0	1.06†
AFT LH +X	AFT	2	1571	-131	476	*	80
AFT RH +X	AFT	2	1571	131	476	*	80
AFT +Y	L	4	1536	-149	459	90	*
AFT -Y	R	4	1536	149	459	90	*
AFT LH +Z	UP	3	1529	-132	494	0	0
AFT RH -Z	UP	3	1529	132	494	0	0

* PLUME NOT SHOWN IN THIS VIEW.

† PLUME ℄ ROTATED FORWARD FROM $-Z_{OB}$ AXIS; INCLUDES NOZZLE SCARFING EFFECT.

REFERENCES

1. E. C. Lineberry, unpublished data, 17 February 1977.

2. R. J. Rader, "Space Shuttle RCS Plume Definition (Short Side Scarf of the -X Engine)," MDAC Memorandum No. 03-202-AANO-76-167, 20 December 1976.

3. B. G. Jackson, "Update to Plume Impingement Model Transmitted to EJ4 for Use in Rendezvous Simulations," NASA/JSC Memorandum No. EX32/7702-24, 3 February 1977.

4. D. J. Pearson, "QLDP User's Guide," MDAC Memorandum No. 1.4-MAB-102, 7 January 1977.

5. L. D. Davis, "Coordinate Systems for the Space Shuttle Program," NASA TM X-58153, October 1974.

6. D. L. Sweitzer, "Presimulation Report, On-Orbit FCS Evaluation," Lockheed Report No. LEC-6666, August 1975.

APPENDIX A

JCPP CODE

```
0: "JET CONTOUR PLOTTING PROGRAM":deg;gto "LOAD"
1: "DIST":
2: if r5=2;gto "MDQL"
3: if r5=1;gto "E&D"
4: "MDAC":11400+865cos(P)→V
5: jmp L
6: 6.356e-6cos(90P/98.6)↑5.1→W;gto +2
7: 1.40679e-6/exp(.07564(P-38.6))→W
8: WVV/20→U;√U→R
9: if W/U<1.91885e-10;ret
10: if L=1;6.5712W/6.356→W
11: 12600-.0012abs((110-R)↑3)→V
12: Q-WVV/2RR→U
13: (.0036(110-R)↑2-V/R)(WV/RR)→Y
14: U/Y→X
15: if abs(X)<1e-4B;ret
16: R+X→R;gto -5
17: "E&D":if P>55.05;gto +2
18: cos(90P/98.6)↑7.14→W;gto +2
19: .04105/exp(.139934(P-55.05))→W
20: √(546W/Q)→R;ret
21: "MDQL":if P>=145;0→R;ret
22: cos(90P/145)↑8.47→W
23: √(625W/Q)→R;ret
24: "HDG":fmt 5/,"JET CONTOUR PLOTTING PROGRAM INPUT";wrt 6
25: fmt 2/,"UNITS",14x,"VALUE",6x,"REG:",2x,"DESCRIPTION",2/;wrt 6;ret
26: "LOAD":
27: cfg 1;cfg 2;0→I;gsb "HDG"
28: fmt "FT",8x,e17.8,f6.0,":  X MIN";gto +10
29: fmt "FT",8x,e17.8,f6.0,":  X MAX";gto +9
30: fmt "FT",8x,e17.8,f6.0,":  Y MIN";gto +8
31: fmt "FT",8x,e17.8,f6.0,":  Y MAX";gto +7
32: fmt "FT",8x,e17.8,f6.0,":  TIC INTERVAL";gto +6
33: fmt "--",8x,f17.0,f6.0,":  PLUME MODEL (0=MD/ECL,1=E&D,2=MD/QL)";gto +5
34: fmt "LB/FT↑2",3x,e17.8,f6.0,":  Q MIN";gto +4
35: fmt "--",8x,e17.8,f6.0,":  Q RATIO BETWEEN CONTOURS";gto +3
36: fmt "--",8x,f17.0,f6.0,":  NO. CONTOURS";gto +2
37: fmt "--",8x,f17.0,f6.0,":  NO. JETS"
38: wrt 6,rI,I;if flg1=0;gto +3
39: fmt ;wrt 6;beep;ent "NEW VALUE ?",rI;cfg 13
```

```
40: fmt 10x,e17.8,/;wrt 6,rI;gto +3
41: I+1→I;if I<=9;gto +9
42: fmt 2/;wrt 6;if flg2;gto +9
43: sfg 1;beep;ent "WHAT REGISTER ?",I
44: if flg13=0;sfg 2;gto +4
45: cfg 13;if flg2=0;gto +6
46: cfg 1;0→I;gsb "HDG"
47: gto +3
48: if I>=0;if I<=9;gto +2
49: gto -6
50: jmp I-22
51: scl r0,r1,r2,r3
52: r1-r0→B
53: if r4>0;axe 0,0,r4,r4
54: 0→N;r6/r9→Q
55: 1→S
56: pen;0→P;1→L
57: gsb "DIST"
58: SP→E
59: Rcos(E)→X;Rsin(E)→Y;plt X,Y
60: if L=2;gto +4
61: if P=38.6;2→L;gto -4
62: P+1.93→P;if P>38;38.6→P
63: gto -6
64: P+2→P;if P>170;gto +2
65: gto -8
66: if S<0;gto +2
67: -1→S;gto -11
68: N+1→N;if N<r8;Qr7→Q;gto -13
69: pen;plt r0,r2
70: pen;beep;dsp "FINIS"
71: stp ;end
*6659
```

APPENDIX B

OP/JCPP CODE

APPENDIX B

OP/JCPP CODE

```
0: "OV PROFILE / JET CONTOUR PLOTTING PROGRAM":deg;gto "LOAD"
1: if flg4;gto +3
2: if r6-12r1>X;pen;ret
3: plt X,Y;ret
4: if 12r2>X;pen;ret
5: plt r6+r7+12(r2-r1)-X,Y;ret
6: "CIRC":A→E
7: H+Rcos(E)→X;K+Rsin(E)→Y;gsb 1
8: if E=B;ret
9: E+C→E;if E>B;B→E
10: gto -3
11: "CTRL":1→I;0→R;sin(A)→F;cos(A)→G;pen
12: H+RG→X;K+RF→Y;gsb 1
13: if R=B;pen;ret
14: jmp I
15: R+.75C→R;gto +4
16: R+.1C→R;pen;gto +3
17: R+.05C→R;gto +2
18: R+.1C→R;pen
19: if R>B;B→R
20: I+1→I;if I>4;1→I
21: gto -9
22: "DIST":
23: if r9=2;gto "MDQL"
24: if r9=1;gto "E&D"
25: "MDAC":11400+865cos(P)→V
26: jmp L
27: 6.356e-6cos(90P/98.6)↑5.1→W;gto +2
28: 1.40679e-6/exp(.07564(P-38.6))→W
29: WVV/2Q→U;rU→R
30: if W/U<1.91885e-10;ret
31: if L=1;6.5712W/6.356→W
32: 12600-.0012abs((110-R)↑3)→V
33: Q-WVV/2RR→U
34: if abs(U)<1e-20;ret
35: (.0036(110-R)↑2-V/R)(WV/RR)→Y
36: U/Y→X
37: if abs(X)<1e-4B;ret
38: R+X→R;gto -6
39: "E&D":if P>55.05;gto +2
```

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```
40: cos(90P/98.6)↑7.14→W;gto +2
41: .04105/exp(.139934(P-55.05))→W
42: r(546W/Q)→R;ret
43: "MDQL":if P>=145;0→R;ret
44: cos(90P/145)↑8.47→W
45: r(625W/Q)→R;ret
46: "PLTM":0→N;r10/r(13+M)→Q
47: 1→S
48: pen;0→P;1→L
49: gsb "DIST"
50: A+SP→E
51: H+12Rcos(E)→X;K+12Rsin(E)→Y;gsb 1
52: if L=2;gto +4
53: if P=38.6;2→L;gto -4
54: P+1.93→P;if P>38;38.6→P
55: gto -6
56: P+2→P;if P>170;gto +2
57: gto -8
58: if S<0;gto +2
59: -1→S;gto -11
60: N+1→N;if N<r12;Qr11→Q;gto -13
61: ret
62: "HDG":fmt 5/,"OV PROFILE / JET CONTOUR PLOTTING PROGRAM INPUT";wrt 6
63: fmt 2/,"UNITS",14x,"VALUE",6x,"REG:",2x,"DESCRIPTION",2/;wrt 6;ret
64: "LOAD":
65: cfg 1;cfg 2;0→I;gsb "HDG"
66: fmt "FT",8x,e17.8,f6.0,":  XOB MIN";gto +23
67: fmt "FT",8x,e17.8,f6.0,":  XOB MAX";gto +22
68: fmt "FT",8x,e17.8,f6.0,":  YOB MIN";gto +21
69: fmt "FT",8x,e17.8,f6.0,":  YOB MAX";gto +20
70: fmt "FT",8x,e17.8,f6.0,":  ZOB MIN";gto +19
71: fmt "FT",8x,e17.8,f6.0,":  ZOB MAX";gto +18
72: fmt "IN",8x,e17.8,f6.0,":  OV CG STA";gto +17
73: fmt "IN",8x,e17.8,f6.0,":  OV CG BL";gto +16
74: fmt "IN",8x,e17.8,f6.0,":  OV CG WL";gto +15
75: fmt "--",8x,f17.0,f6.0,":  PLUME MODEL (0=MD/ECL,1=E&D,2=MD/QL)";gto +14
76: fmt "LB/FT↑2",3x,e17.8,f6.0,":  Q MIN";gto +13
77: fmt "--",8x,e17.8,f6.0,":  Q RATIO BETWEEN CONTOURS";gto +12
78: fmt "--",8x,f17.0,f6.0,":  NO. CONTOURS";gto +11
79: fmt "--",8x,f17.0,f6.0,":  NO. FWD -X JETS    (0,1,2,3)";gto +10
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80: fmt "--",8x,f17.0,f6.0,":  NO. FWD +Y JETS     (0,1,2)";gto +9
81: fmt "--",8x,f17.0,f6.0,":  NO. FWD -Y JETS     (0,1,2)";gto +8
82: fmt "--",8x,f17.0,f6.0,":  NO. FWD +Z JETS     (0,1,2,3)";gto +7
83: fmt "--",8x,f17.0,f6.0,":  NO. AFT LH +X JETS (0,1,2)";gto +6
84: fmt "--",8x,f17.0,f6.0,":  NO. AFT RH +X JETS (0,1,2)";gto +5
85: fmt "--",8x,f17.0,f6.0,":  NO. AFT +Y JETS     (0,1,2,3,4)";gto +4
86: fmt "--",8x,f17.0,f6.0,":  NO. AFT -Y JETS     (0,1,2,3,4)";gto +3
87: fmt "--",8x,f17.0,f6.0,":  NO. AFT LH +Z JETS (0,1,2,3)";gto +2
88: fmt "--",8x,f17.0,f6.0,":  NO. AFT RH +Z JETS (0,1,2,3)"
89: wrt 6,rI,I;if flg1=0;gto +3
90: fmt ;wrt 6;beep;ent "NEW VALUE ?",rI;cfg 13
91: fmt 10x,e17.8,/;wrt 6,rI;gto +3
92: I+1→I;if I<=22;gto +9
93: fmt 2/;wrt 6;if flg2;gto +9
94: sfg 1;beep;ent "WHAT REGISTER ?",I
95: if flg13=0;sfg 2;gto +4
96: cfg 13;if flg2=0;gto +6
97: cfg 1;0→I;gsb "HDG"
98: gto +3
99: if I>=0;if I<=22;gto +2
100: gto -6
101: jmp I-35
102: 12max(r1-r0,r5-r4)→r101
103: 12max(r3-r2,r5-r4)→r100
104: scl r6-12(r1+r3-r2),r6-12r0,r8-12r5,r8-12r4
105: 1→I;beep;ent "OV PROFILE ?",I;cfg 13
106: if I=0;gto "PLUM"
107: if r3=r2;gto "SIDE"
108: sfg 4;-1→S
109: pen;0→X;261→Y;gsb 1
110: 50S→X;262→Y;gsb 1
111: 100S→X;263→Y;gsb 1
112: 468S→X;300→Y;gsb 1
113: 312→Y;gsb 1
114: 200S→X;327→Y;gsb 1
115: 130S→X;336→Y;gsb 1
116: 125S→X;403→Y;gsb 1
117: 150S→X;399→Y;gsb 1
118: 175S→X;gsb 1
119: 200S→X;403→Y;gsb 1
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120: 220S→X;412→Y;gsb 1
121: 241S→X;424→Y;gsb 1
122: 232S→X;gsb 1
123: 220S→X;422→Y;gsb 1
124: 200S→X;413→Y;gsb 1
125: 175S→X;409→Y;gsb 1
126: 150S→X;gsb 1
127: 125S→X;413→Y;gsb 1
128: 120S→X;415→Y;gsb 1
129: 130S→X;430→Y;gsb 1
130: 139S→X;450→Y;gsb 1
131: 143S→X;462→Y;gsb 1
132: 145S→X;475→Y;gsb 1
133: 144S→X;490→Y;gsb 1
134: 140S→X;509→Y;gsb 1
135: 130S→X;515→Y;gsb 1
136: 115S→X;524→Y;gsb 1
137: 100S→X;526→Y;gsb 1
138: 80S→X;gsb 1
139: 60S→X;524→Y;gsb 1
140: 40S→X;518→Y;gsb 1
141: 30S→X;512→Y;gsb 1
142: 20S→X;513→Y;gsb 1
143: 4S→X;816→Y;gsb 1
144: if S<=0;1→S;gto -35
145: -4S→X;gsb 1
146: pen;r7→X;r8-16→Y;gsb 1
147: r8+16→Y;gsb 1
148: pen;r7+16→X;r8→Y;gsb 1
149: r7-16→X;gsb 1
150: r7→H;r8→K;16→R;0→A;360→B;15→C;gsb "CIRC"
151: "SIDE":cfg 4;if r1=r0;gto "PLUM"
152: pen
153: 1613→X;291→Y;gsb 1
154: 1534→X;298→Y;gsb 1
155: 1526→X;336→Y;gsb 1
156: 1550→X;335→Y;gsb 1
157: 1575→X;334→Y;gsb 1
158: 1600→X;gsb 1
159: 1623→X;336→Y;gsb 1
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160: 1609→X;412→Y;gsb 1
161: 1600→X;410→Y;gsb 1
162: 1575→X;402→Y;gsb 1
163: 1550→X;392→Y;gsb 1
164: 1525→X;382→Y;gsb 1
165: 1517→X;376→Y;gsb 1
166: 1502→X;441→Y;gsb 1
167: 1525→X;gsb 1
168: 1550→X;442→Y;gsb 1
169: 1575→X;445→Y;gsb 1
170: 1598→X;453→Y;gsb 1
171: 1578→X;526→Y;gsb 1
172: 1550→X;517→Y;gsb 1
173: 1525→X;506→Y;gsb 1
174: 1500→X;489→Y;gsb 1
175: 1492→X;483→Y;gsb 1
176: 1482→X;519→Y;gsb 1
177: 1576→X;562→Y;gsb 1
178: 1700→X;816→Y;gsb 1
179: 1593→X;gsb 1
180: 1325→X;548→Y;gsb 1
181: 1317→X;540→Y;gsb 1
182: 1311→X;533→Y;gsb 1
183: 1308→X;524→Y;gsb 1
184: 1307→X;516→Y;gsb 1
185: 420→Y;gsb 1
186: 576→X;gsb 1
187: 500→Y;gsb 1
188: 500→X;gsb 1
189: 491→X;499→Y;gsb 1
190: 480→X;493→Y;gsb 1
191: 472→X;489→Y;gsb 1
192: 434→X;450→Y;gsb 1
193: 300→X;394→Y;gsb 1
194: 283→X;385→Y;gsb 1
195: 270→X;378→Y;gsb 1
196: 259→X;372→Y;gsb 1
197: 250→X;364→Y;gsb 1
198: 262.5→H;338→K;27.5→R;135→A;237→B;10→C;gsb "CIRC"
199: 263→X;308→Y;gsb 1
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200: 286→X;300→Y;gsb 1
201: 312→X;294→Y;gsb 1
202: 337→X;289→Y;gsb 1
203: 362→X;286→Y;gsb 1
204: 387→X;283→Y;gsb 1
205: 414→X;280→Y;gsb 1
206: 450→X;278→Y;gsb 1
207: 492→X;275→Y;gsb 1
208: 535→X;273→Y;gsb 1
209: 575→X;272→Y;gsb 1
210: 625→X;271→Y;gsb 1
211: 675→X;269→Y;gsb 1
212: 725→X;268→Y;gsb 1
213: 775→X;267→Y;gsb 1
214: 900→X;265→Y;gsb 1
215: 1000→X;264→Y;gsb 1
216: 1100→X;263→Y;gsb 1
217: 1150→X;262→Y;gsb 1
218: 1250→X;261→Y;gsb 1
219: 1300→X;gsb 1
220: 1350→X;264→Y;gsb 1
221: 1400→X;267→Y;gsb 1
222: 1450→X;271→Y;gsb 1
223: 1500→X;275→Y;gsb 1
224: 1550→X;281→Y;gsb 1
225: 1600→X;288→Y;gsb 1
226: 1613→X;290→Y;gsb 1
227: pen;r6→X;r8-16→Y;gsb 1
228: r8+16→Y;gsb 1
229: pen;r6-16→X;r8→Y;gsb 1
230: r6+16→X;gsb 1
231: r6→H;r8→K;16→R;0→A;360→B;15→C;gsb "CIRC"
232: "PLUM":0→M
233: if r(13+M)=0;gto +11
234: if r3=r2;gto "JPSV"
235: if r(40+M)#1;if r(40+M)#3;gto "JPSV"
236: sfg 4;r100→B;B/6→C
237: r(80+M)→A;r(60+M)→H;r(70+M)→K;gsb "CTRL"
238: gsb "PLTM"
239: "JPSV":if r1=r0;gto +5
```

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240: if r(40+M)#2;if r(40+M)#3;gto +4
241: cfg 4;r101→B;B/6→C
242: r(90+M)→A;r(50+M)→H;r(70+M)→K;gsb "CTRL"
243: gsb "PLTM"
244: M+1→M;if M<10;gto -11
245: pen;plt r6-12(r1+r3-r2),r8-12r5
246: pen;beep;dsp "FINIS"
247: stp ;end
*29061
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