NASA Technical Memorandum 83234

Use of Interactive Graphics To Analyze QUICK-Geometry

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SUMMARY

The QUICK InterActive Graphics Analysis (QUIAGA) program and its advantages for displaying aircraft QUICK-geometry to aid in detection and analysis of errors are described. The QUICK-geometry system generates a completely analytical aircraft geometry description for use by finite-difference flow codes. The QUIAGA program was developed to exercise the QUICK-geometry subroutines to examine the analytic definition of a configuration by plotting cross sections and body lines on a graphics terminal. A number of options are available, including multiple cross-section views, hidden-line removal, and display of control point locations. Use of these options for the detection and analysis of errors in the QUICK-geometry definition can be of great assistance in speedily arriving at a correct analytical geometry description for flow-field computation. The QUIAGA program has been used in developing a QUICK-geometry model of the NASA Space Shuttle Orbiter, and examples from this experience are given to show some of the program's features. Details of program usage and an example session are given in the appendixes.

INTRODUCTION

The QUICK-geometry system (ref. 1) is a method for defining configuration shapes in completely analytical form. It was developed for use where the analytical definition of an aircraft geometry is advantageous or necessary for the solution of the flow around it. For example, a shock-fitting supersonic finite-difference marching method, known as the STEIN code (ref. 2), requires that a complete cross-sectional surface definition be available at any axial station where the marching step happens to fall. By using the QUICK-geometry system, the STEIN code has this information readily available. It also makes use of the analytic first and second derivatives of the surface geometry, provided by QUICK, so that these do not have to be generated by finite-difference methods.

While the QUICK-geometry system provides a convenient and flexible method for generating configurations with complete analytical definitions, experience in using it has uncovered some difficulties which arise, particularly when attempting to match a previously defined configuration. A set of interactive graphics computer programs developed by the National Aeronautics and Space Administration (ref. 3) aids in generating QUICK definitions of aircraft geometries. Other aids in using QUICK, generally limited to particular types of configurations, have also been reported (refs. 4 and 5). These aids alleviate the difficulties in defining a configuration but, as with manual preparation of inputs, do not guarantee a sufficiently accurate result. Even for only moderately complex configurations, such as the Space Shuttle described herein, a number of iterations may be required before the geometry is adequately represented. Each of these iterations requires examination of the QUICK-geometry attained and its comparison with the desired geometry. Since the QUICK-geometry system provides only a limited, batch-processed capability for geometry checking, a new plotting program, the QUick InterActive Graphics Analysis (QUIAGA) program, has been written to speed up the iterative process. The QUIAGA program uses the combination of a graphics terminal with interactive computer processing to exercise the QUICK-geometry subroutines in several modes and, thus, allows rapid detection and analysis of any errors which occurred in modeling. The program and its use in Space Shuttle modeling is described in this report.

This program can be considered a post-QUICK procedure and as such is complementary to pre-QUICK procedures such as references 3 through 5. It was written in FORTRAN IV for use on the Control Data computer systems and Tektronix 4014 Computer Display (storage-tube graphics) Terminal at Langley Research Center, but it should be readily adaptable to any system with similar capabilities. The complete program is available from Computer Software Management Information Center (COSMIC), 112 Barrow Hall, University of Georgia, Athens, Georgia 30602.

THE QUICK-GEOMETRY SYSTEM

The following is a brief discussion of the general concepts involved in the QUICK-geometry system. A more detailed description is given in reference 1, and a complete user's manual with examples is given in the appendixes in reference 2.

In the QUICK-geometry system the aircraft surface is enveloped by a set of body lines designated by user-defined names (fig. 1). Each of these body lines is a curve in space, defined mathematically in terms of its horizontal and vertical components. Each component consists of a sequence of linked curve segments. The set of curve shapes from which these segments are taken include straight lines, ellipses, parabolas, rotated parabolas, and cubics. Generally, each curve segment is defined by the user in terms of its beginning point, its ending point, and the slope at each end (fig. 1(b)). The body lines are then represented by QUICK as single-valued analytical functions of the axial coordinate; therefore, they define a unique set of points in any cross-sectional plane. These points in the plane are called control points in the QUICK-geometry system.

The aircraft surface is defined by arcs fitted to the control points in any cross-sectional plane (fig. 2). These arcs are segments of either straight lines or ellipses between designated control points and having the end slopes set by the other control points. The information supplied by the user, designating how the control points connect the arcs together into a complete cross section, forms a logical cross-section mode which applies over a range of the axial coordinate. As shown in figure 2(b), the physical cross section may vary a great deal within the range of a single logical cross-section model. (Note that some arcs may even be submerged below the rest of the model surface.) However, several cross-section models may be required to cover the complete range of cross-section shapes occurring from the nose to the tail of the aircraft.

The QUICK input consists of the required cross-section logical models defined in terms of the control-point names followed by the body-line mathematical models defined numerically. Figure 3 gives an abbreviated example of an input definition. (For a complete description, see ref. 2.)

The QUICK output is called the QUICK intermediate deck (fig. 4). It consists of the cross-section logical models and the body-line numerical models in a form directly usable by the SUBQUICK portion of the QUICK-geometry system. It is SUBQUICK which is incorporated into user programs, such as the STEIN shock-fitting, supersonic, finite-difference flow program (ref. 2), to interpret the aircraft surface geometry from the QUICK intermediate deck. SUBQUICK is used by the interactive graphics analysis program described in this report for this same purpose.

QUICK ANALYSIS PROGRAM

Experience with aircraft geometry definitions has shown that, even with the capabilities of the QUICK-geometry system backed up by such aids as the QUICK Interactive Input (ref. 3), there is frequently a need to make several iterations of geometry checks and corrections before a satisfactory geometry description is obtained. This need for checking was recognized in the development of the QUICK system with the provision of interrogation modes providing numerical output of the completed geometry. However, checking the numerical output can be done most effectively by plotting it; this was left to the user. Furthermore, the numerical output from a batch mode run of the QUICK program is often insufficient for complete analysis of the cause of any error in the geometry definition. The use of a graphics terminal along with interactive computing provides the capabilities for rapidly checking the QUICK geometry in detail, detecting errors in the surface definition, and analyzing the errors for cause and effective corrections. It was the need for these capabilities which prompted the development and evolution of the QUICK Interactive Graphics Analysis program. This program uses the SUBQUICK group of QUICK subroutines to insure that the geometry displayed is exactly the same as that of the other user programs incorporating QUICK geometry.

The interactive graphics program can produce several types of plots which are useful in different phases of the checking, error detection, and error analysis process. A general description of the plot types is given in the following material with the details of usage described in appendix A and an example of an interactive session given in appendix B.

There are two principal types of plots available: body-line plots and cross-section plots. The body-line plots are useful in determining that each body line is continuously and smoothly defined and in checking its position relative to the other body lines. The program allows the user to choose the axial range of the body-line plot, the distance between computed points, and the body-line components to be plotted. The program scales the plot and labels the body line (fig. 5).

The cross-section plots are useful for overall and detailed examination of the surface shape. A number of plotting options are available, including choices of a single or a series of cross sections, control points shown or omitted, and one-sided or symmetrical cross sections. A series of cross sections can be arranged as a front view or as an upper or lower pseudo-oblique view, and all lines can be drawn or hidden lines can be removed.

Figure 6 shows three examples of combinations of options for plots with many cross sections. Figure 7 shows two examples of combinations of options with one or a few cross sections.

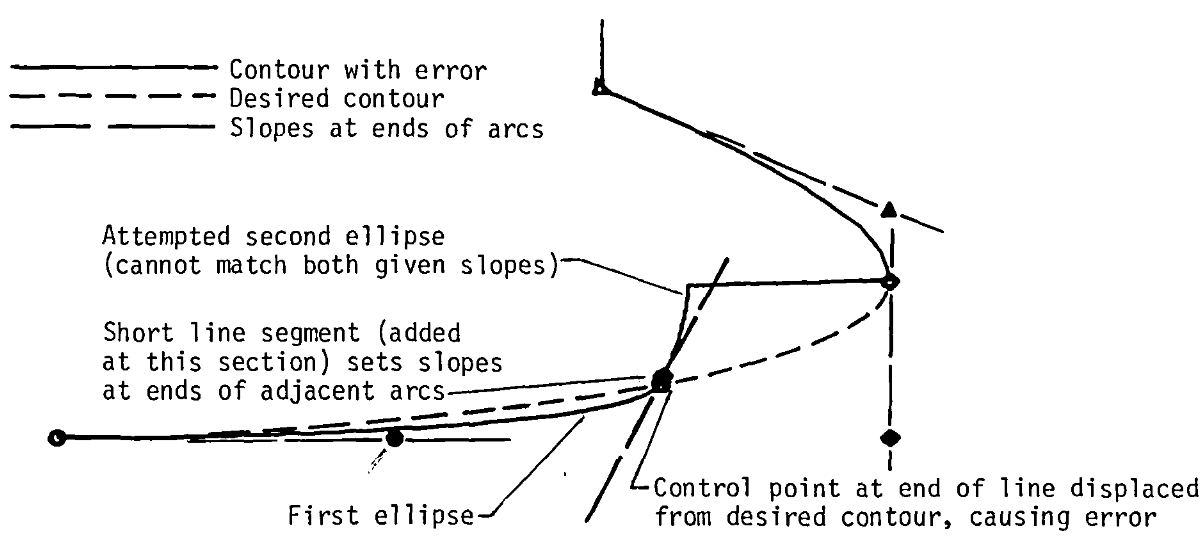
It should be noted that the pseudo-oblique views, while giving good overall impressions of the aircraft shape for an appropriate choice of scale factor, are not true rotated oblique views but only stacked cross sections. Similarly, the hidden-line removal algorithm uses an unsophisticated, vertical raster technique which serves well for most QUICK-geometries but does not always result in a true view. Since these two capabilities are adequate for checking the aircraft geometry for surface irregularities, more accurate (but also more complex) alternate methods have not been employed.

One additional cross-section option is available. If numerical values of points on the aircraft surface are on a file (as from digitized cross sections or cuts through aircraft geometry inputs as described in ref. 6 and commonly called Harris inputs), these data for any axial location can be plotted along with the QUICK-geometry cross section for evaluation of its accuracy. Figure 8 shows such a comparison plot with the QUICK control points also included so that changes in the control-point positions required to improve the accuracy can be estimated. (To change a control-point position would require a change in the corresponding body-line horizontal and/or vertical component over a range of axial locations.) Use of this option requires that the numerical data first be placed on a data base readable by the interactive graphics analysis program; this can be done by the associated program READATA described in appendix A.

EXPERIENCE WITH SPACE SHUTTLE ORBITER GEOMETRY

The QUICK InterActive Graphics Analysis (QUIAGA) program has been used extensively in developing a QUICK-geometry model of the NASA Space Shuttle Orbiter. Because this model was intended for use in computing the lower surface flow during reentry at supersonic speeds, the lower surface contours were modeled more carefully than the upper surfaces, and the canopy and orbital maneuvering system pods were omitted. In the course of checking, analyzing, and refining this Shuttle model the need for several of the options of the analysis program became evident and they were added.

Figure 9 shows two series of orbiter cross sections as originally modeled by using the QUICK Interactive Input program (ref. 3). These represent typical degrees of model checking which would be made by batch processing. No modeling errors are evident in this figure. Figure 10(a) shows how a closer check, using the Interactive Graphics Analysis program, revealed an error in the modeling of the wing lower surface at a single cross section. This error was immediately investigated by having the program plot an even closer series of cross sections in the region of the error (fig. 10(b)). Cross sections just before and in the error region were than chosen for analysis by having them plotted with the control-point locations (figs. 10(c) and 10(d)). The open symbols in this form of display represent the end points of the arcs making up the cross section; the filled symbols represent the control points used to define the slopes at the ends of the arcs. A different symbol shape is used for each arc. Figure 10(c) was at a station for which original data were available; therefore, this was also plotted for comparison. The analysis of the display in figure 10(d), as in the sketch below, shows that the displacement of a single control



point from its proper position caused the error. When the definition of the body line corresponding to this control point was corrected in the QUICK input and the resulting output was rechecked, the cross sections shown in figures 10(e) and 10(f) were displayed with the error evidently corrected.

Figure 11 shows a similar sequence of displays obtained in the course of correcting errors in modeling the nose. Part of the erroneous region and a single cross section for analysis are shown in figures 11(a) and 11(b). Figures 11(c) and 11(d) show top views of some of the body-line definitions, a few of which have obviously bad segments in that they go negative. (The bad body-line segments were caused by incompatible slopes at the beginning and end of the segments.) Figures 11(e) and 11(f) show the body lines with the segment corrected and the resulting cross sections. These are much improved but still require further iterations before they are completely satisfactory.

Figure 12 shows a front view and lower oblique view of the Shuttle after the corrections shown in figures 10 and 11 had been made. (The front view was made with an early version and the oblique view with a later version of the hidden-line removal algorithm.) In these views, deviations from actual Shuttle shape are discernible if not obvious in the regions of the corrections (arrows). In order to better judge the corrections needed to make a completely satisfactory model of the Orbiter, cross sections were compared with the original data digitized from engineering drawings (fig. 13). Both cross sections shown in figure 13 have significant deviations from the digitized data (plus marks).

Figure 14(a) shows nose-region cross sections after further corrections to the body lines, and figure 14(b) shows the corrected cross section compared with the same original data as in figure 13(b). A lower oblique view of the finally accepted Space Shuttle Orbiter QUICK-geometry model is shown in figure 15.

CONCLUDING REMARKS

The QUICK InterActive Graphics Analysis (QUIAGA) program exercises the QUICK-geometry model of an aircraft in several modes to plot overall and detailed views on the user's graphics terminal. QUICK-geometry is a system for modeling aircraft in completely analytic form so that surface coordinates and their first and second derivatives can be found easily at any axial location. The cross-section and body-line plots produced by the various modes of the QUIAGA program provide a means for rapidly detecting and analyzing any errors occurring in the QUICK-geometry model. Experience with the program in modeling the Space Shuttle Orbiter and other configurations has shown that it is of great assistance in arriving at a correct model description for flow-field computation.

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November 24, 1981

APPENDIX A

DESCRIPTION OF USAGE

Requirements and Availability

The QUICK InterActive Graphics Analysis (QUIAGA) program and its companion data reader (READATA) are coded in FORTRAN IV to run on the Control Data computer systems and Tektronix 4014 Computer Display (storage-tube graphics) Terminal at the Langley Research Center. The PLOT10 library is used for all graphics. Non-ANSI usages have been generally avoided in order to ease conversion to other systems with similar capabilities. The complete program is available from COSMIC (Computer Software Management and Information Center, 112 Barrow Hall, University of Georgia, Athens, GA 30602) as QUICK Interactive Graphics Analysis Program, LAR-12951. An essentially equivalent program, coded in FORTRAN 77 for Prime minicomputers, also is available through COSMIC as QUICK Interactive Graphics Analysis Program, LAR-12952.

The CDC Network Operating System is file oriented. In addition to the files for keyboard INPUT and the file for Graphics terminal screen OUTPUT, the program requires a file TAPE5 containing the QUICK intermediate deck (fig. 4). The optional capability to compare with original digitized data (as shown in fig. 13) requires an additional file TAPE9 containing the cross-section data written in mass storage format by the program READATA.

Usage of READATA

The program READATA, which runs in batch mode, takes numerical cross-section data from file TAPE2 and writes them in mass storage form on file TAPE9. The input data are in the same form as that used by the QUICK Interactive Input program (ref. 3). It can be generated by slightly modifying the output of a program for making cuts through aircraft numerical geometry data in the Harris input form (ref. 6). The input on TAPE2 for READATA consists of the following records:

Record	Format	Explanation	
1	I3	Number of cross sections to be given (≤120)	
2, 2a	7F10.5	Axial locations of the cross sections	
3	2I2	0 and 0	May be omitted
4	F10.5	Height of nose above reference plane	May be omitted
5	2I2	Component number, number of half-cross-section points for this component	Repeat for each additional component if necessary
6, 6a, etc.	7F10.5	Spanwise coordinates of cross-section points	Repeat for each additional component if necessary
7, 7a, etc.	7F10.5	Heights of cross-section points above reference plane	Repeat for each additional component if necessary
8	2I2	0 and 1	
9	4F10.5	Minimum and maximum spanwise coordinates and minimum and maximum heights for this cross section	

Repeat from record 5 or each additional cross section. The component numbers pertain to fuselage, wing, fins, and pods of the Harris inputs but have no significance to the present programs; they need only be nonzero. The total number of cross sections is limited to 120 and the total number of points per half cross section (all components) is limited to 30. The outputs from READATA is a list of the cross-section numbers and associated axial locations written to file OUTPUT (fig. 16) and the cross-section data in mass storage form written to file TAPE9.

Usage of QUIAGA

The QUICK InterActive Graphics Analysis (QUIAGA) program is run in the interactive mode. In this mode, the program pauses at a number of points to wait for a user response from the graphics terminal keyboard. Prompts are written on the terminal screen to aid the user in making an appropriate response. A flowchart of prompts and program actions is given in figure 17. As an example, before reading the QUICK intermediate data from file TAPE5, the program asks the user, "Do you need help?" If the response does not begin with an "N," the program lists the quantities which may be asked for in a session and appropriate responses (fig. 18). The following other prompts require numerical inputs; these are accepted in FORTRAN list-directed form, as shown in the figures. The rest of this section enlarges on this information; appendix B gives an example session.

BAUD RATE? 300/1200: This is the next question asked of the user. It is answered with the baud rate of the link between the graphics terminal and central computer.

Is Q2650 output on mass storage file TAPE9? Y/N: This question pertains to the availability of original numerical data for comparison plots such as those shown in figure 13. If a local file TAPE9 of such data, written in mass storage form by the companion program READATA, is available, answer "Y." The program will then list the X locations as in figure 19. If such data are not available, answer "N." (The program will continue running but comparison plots cannot be made.)

KEY: ITYPE, SCALE FACTOR: This prompt, which comes next, marks the beginning of the major program loop. After each series of plots is finished, the program will return to this point to begin a new series. The parameter ITYPE is a two-digit integer which determines the type of plots to be generated in the next series. If the first digit is zero, the plots will be single cross sections with original data for comparison (e.g., fig. 8); if it is 1, the one or more cross sections plotted will be aligned to form a front view (fig. 6(a)); if it is 2, the cross sections will be displaced in a row from upper left to lower right, somewhat like a lower oblique view (fig. 6(b)); if the first digit is 3, the cross sections will be a row from lower left to upper right, somewhat like an upper oblique view (fig. 6(c)). If the second digit is 1 or 3, only the right half of the cross sections will be plotted (e.g., fig. 6(b)); if it is 2 or 4, both halves will be plotted (figs. 6(a) and 7(b)); if the second digit is 5, body lines will be plotted instead of cross sections (fig. 5). If ITYPE is positive, all lines will be plotted (figs. 6(a) and 6(b)), but if ITYPE is negative, hidden lines will be omitted (fig. 6(c)). The SCALE FACTOR, entered after ITYPE and a comma, is the decimal multiplication factor required to convert from geometry units to inches on the graphics terminal screen. The best choice depends on the configuration and type of plot; it can be found most easily by making a few trials. For a new configuration, dividing 15 by the length should give a reasonable value. If 0.0 is used for SCALE FACTOR, the program will compute its own scale factor, which may be acceptable.

KEY: # PTS/SIDE, CONCENTR ANGL: This prompt appears next if the plots are to be of a cross-section type. The value of # PTS/SIDE is the integer number of points to be used in plotting each half cross section. The number must be between 3 and 180 (inclusive), chosen as a compromise between plotting speed and accuracy. The CONCENTR ANGL is a real number designating the angle about which there is to be a concentration of points around the cross section. The angle is measured from the horizontal through the QUICK map axis at each cross section. Concentrating near 0°, for example, helps to define the wing leading edge in plots such as those in figure 6. The range for concentrated points is from -90° to +90°. However, CONCENTR ANGL can be set outside this range (such as 99) to produce an even angular distribution of points.

KEY: X LOCATION # (0 TO END): If the type of plot is a single cross section with comparison data, this prompt appears next. This is the integer corresponding to the desired axial location of the plot as listed after the yes response to the question "Is Q2650 output on mass storage file TAPE9?" (fig. 19). The program will then plot the original cross-section data for the indicated axial location and the QUICK geometry cross section of the type indicated by the second digit of ITYPE (fig. 8). The program returns to this same prompt after plotting; a response of zero when no more plots of this type are desired sends the program on to the last prompt of the main loop.

KEY: XMIN, XMAX, DELX: For all other types of plot this prompt appears next. Respond with the decimal axial locations for the first cross section to be plotted or the beginning of the body lines and for the last cross section to be plotted or the end of the body lines, and with the increment in axial location for the cross sections or for the body line points to be plotted. (For a single cross section give the axial location followed by a slash.) If cross sections are requested, the program will plot them according to the value of ITYPE. After completing the plot the program moves on to the last prompt.

KEY: # OF BL'S AND BL #'S: If body-line plots were requested (ITYPE = 5), the program prompts with this after requesting the axial locations. Respond with the number of body-line models to be plotted (up to a total of 20) and their model numbers. These numbers are found in parentheses in the "Body Line Coordinate Index" printed as part of the QUICK output when the geometry model is generated. See figure 20 for an example. The program will then plot the requested body lines between the given beginning and ending axial locations with points computed at the specified increments. The lines will be labeled with their model numbers.

MORE BL'S? (Y/N): This prompt appears after the plot. A response of "Y" sends the program back to the prompt of the previous paragraph. An "N" response sends the program on to the last prompt.

HIT 0 TO STOP, 1 TO CHANGE PLOT TYPE, 2 FOR NEW X STATIONS: This is the last prompt of the main program loop. A response of 0 ends the program, 1 returns the program to the beginning of the major program loop (at the prompt "KEY: ITYPE, SCALE FACTOR"), and 2 returns the program to the request for new axial locations (at the prompt "KEY: XMIN, XMAX, DELX"). If the response is 2, the ensuing plots will be of the same type and scale factor as the plots just completed, and if they are cross-section plots the same number of points per cross section and the same concentration angle will be used. The program will continue cycling and producing plots as requested until the user responds with a zero to this last prompt.

HIT <CR> TO CONTINUE: The program pauses after each plot is completed. A carriage return <CR> signals the program to clear the screen and continue when the user is ready.

APPENDIX B

EXAMPLE SESSION

This appendix gives an example of a short session using the QUICK Interactive Graphics Analysis program. The accompanying figures, taken from the graphics terminal screen, illustrate some of the types of plots available. For the sake of clarity, larger than normal characters were used for these plots and the user inputs have been marked by underlining.

The procedure files used on the Langley Research Center computer system to compile, load, and run the program are shown in figure 21. Note that in addition to the program, this procedure gets and loads the library of QUICK subroutines LIBQSUB. This is the same group of subroutines, called SUBQUICK, which is used whenever the QUICK-geometry system is invoked, for example, by the finite-difference flow-field program STEIN (ref. 2). The other library loaded is the PLOT10 graphics library. Note also that the procedure gets the QUICK intermediate data as local file TAPE5 and the original comparison data (previously put into mass storage form by the program READATA) as local file TAPE9.

Figure 22 is the series of screen images generated during the example interactive session. Notations have been added to point out significant features.

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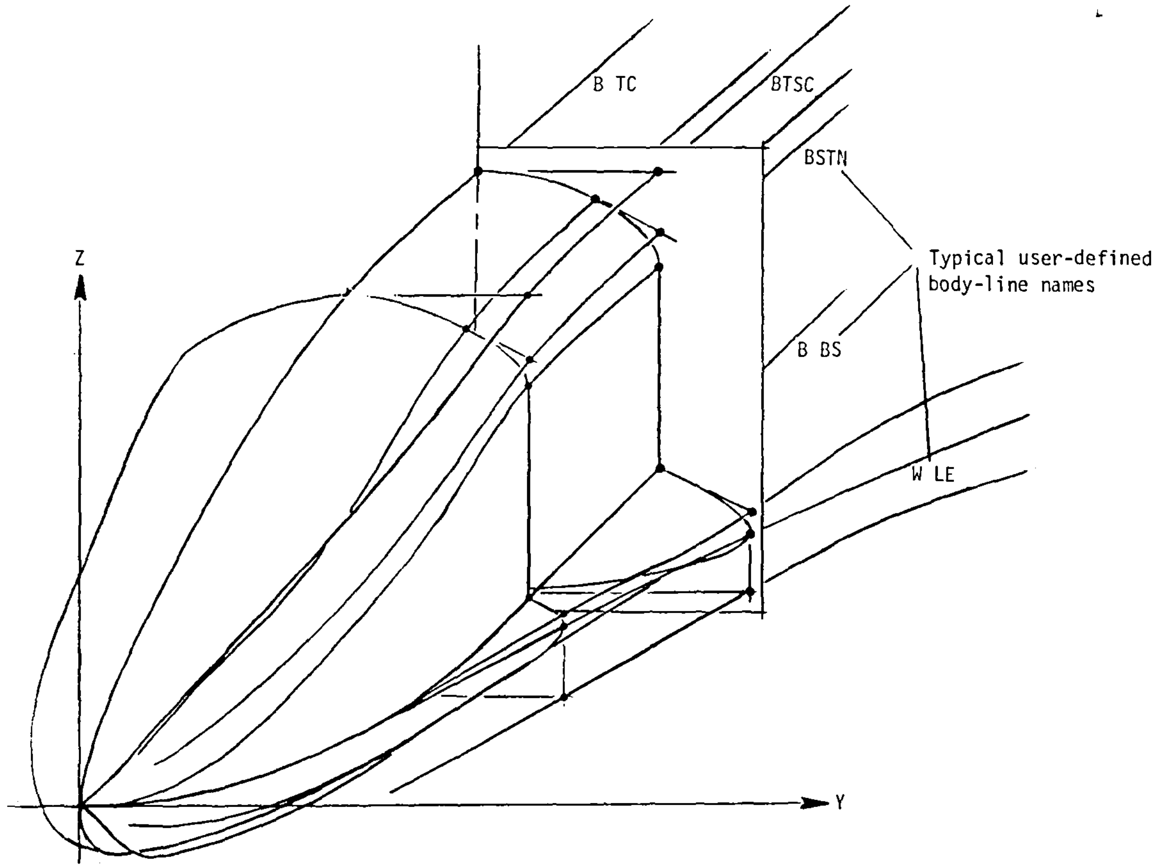
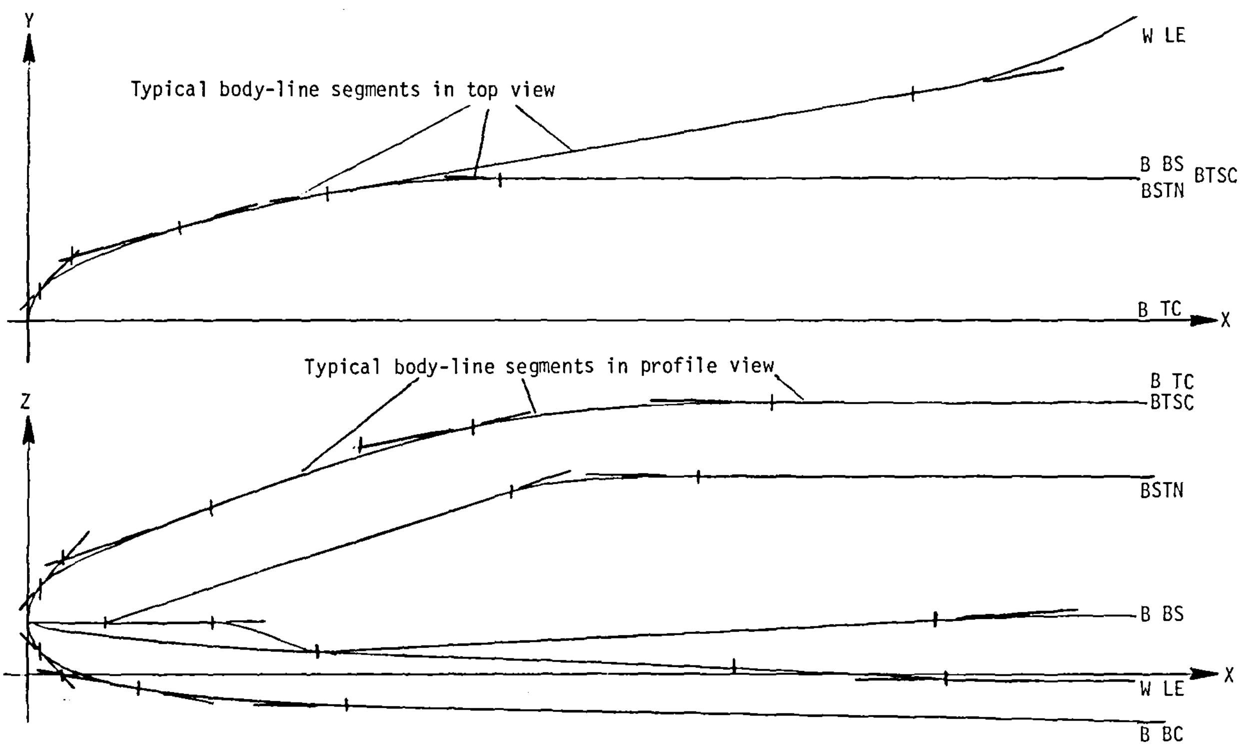
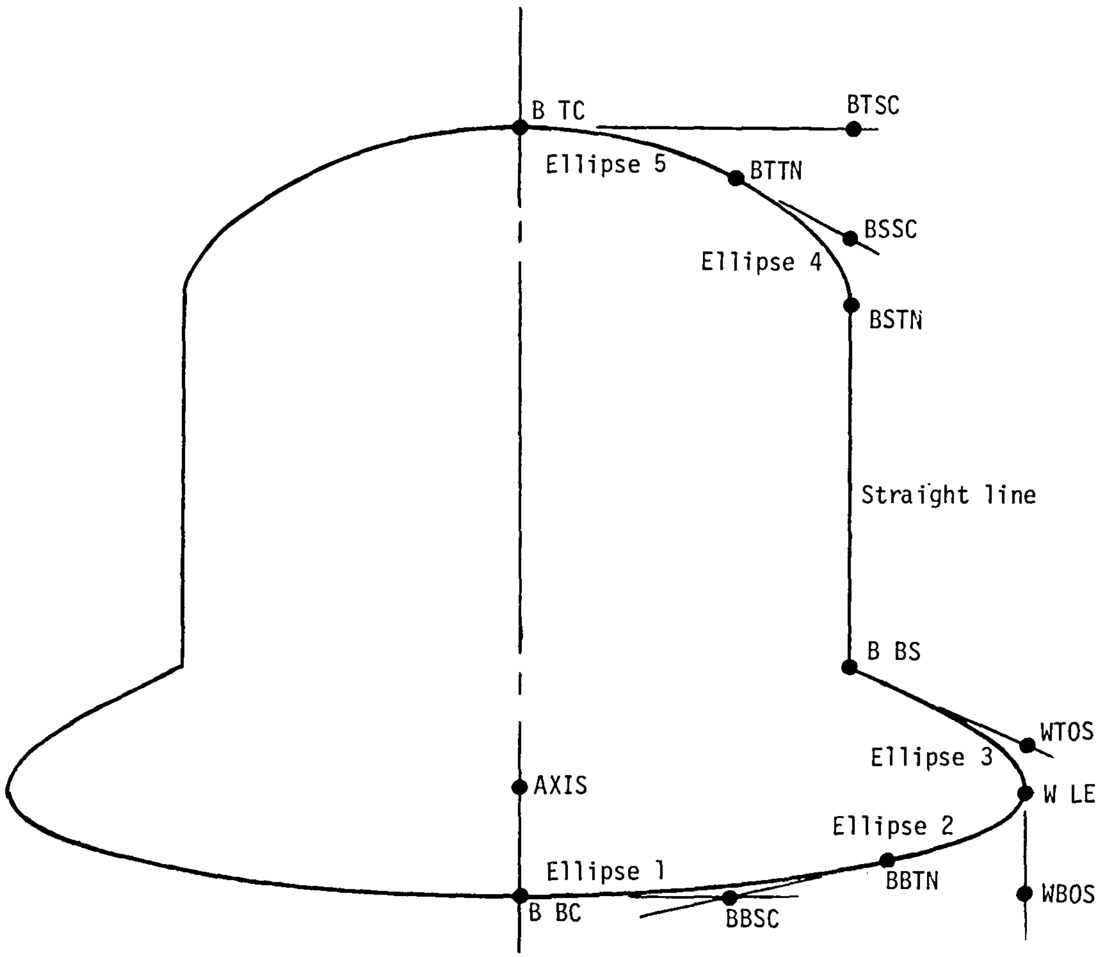


(a) Body-lines enveloping configuration.

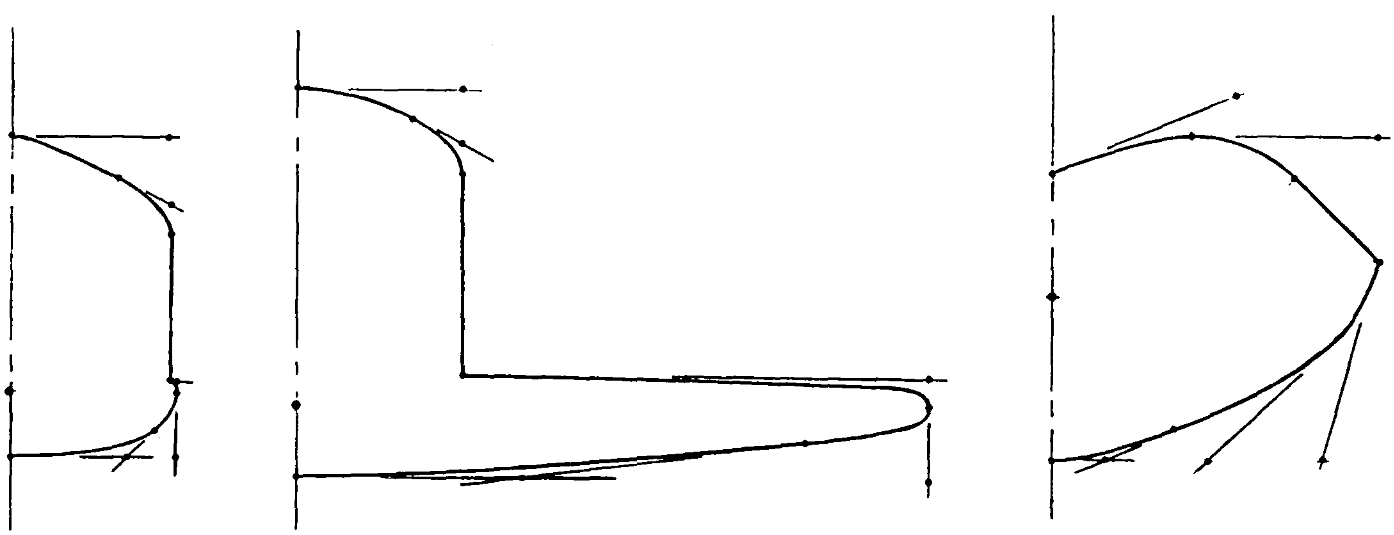


(b) Top and profile views of typical body lines with slopes specified by user.

Figure 1.- Example of body lines in QUICK-geometry definition.



(a) Example of cross-section logical definition. (Control points correspond to body lines in fig. 1.)



(b) Some other possible cross sections using same logical definition but changed control-point locations.

Figure 2.- Control points and cross-section arcs in QUICK-geometry definition.

```
 QUICK GEOMETRY INPUT
2
2 5          3FLL
ARC1     1ELLI  PIEC     B BC      BBTN      BBSC
ARC3     3ELLI  PATC     BBTN      B BS
ARC2     2LINE  PIEC     B BS      BSTN
ARC4     4ELLI  ALIN     BSTN      BTTN      BSSC
ARC5     5ELLI  ALIN     BTTN      B TC      BTSC
4 7          FSID
ARC2     2ELLI  FLIN     B BC      BBTN      BBSC
ARC1     1LINE  PIEC     BBTN      W BM
ARC3     3ELLI  ALIN     W BM      W LE      WBOS
ARC4     4ELLI  ALIN     W LE      B BS      WTOS
ARC5     5LINE  PIEC     B BS      BSTN
ARC6     6ELLI  ALIN     BSTN      BTTN      BSSC
ARC7     7ELLI  ALIN     BTTN      B TC      BTSC
2          AXIS
1 1          0.0000  222.0000
2 2        222.0000 1212.0000
ZB BC
2 ELLX    PIEC   KVO
 2.        23.49500  83.74463 -10.2190   13.8048    0.19619
1 ELLX    FLIN   KVO
 0.        38.49500  2.        2.        0.        30.
4 LINE    PIEC   KV5
241.67340 -23.631561071.92725 -40.9716    0.0000    0.0000
3 ELLX    PATC   KVO
 2.0000    2.0000    4.0000    4.0000    0.0000    0.0000
5 ELLX    ALIN   KVO
 4.0000    4.0000 1212.       -32.8324 1076.4395  -42.62299
-1
YBBTN
           PIEC   KVO
             60660  83.74463  52.0234    6.        26.

 4.                            16.5      83.7446   70.93103
-1
YAXIS                                                0.0000
1 LINE    PIEC   KV5
 0.        0.      1212.       0.
-1
ZAXIS
1 LINE    PIEC   KV5
 0.        38.49500 135.63550  38.4950    0.0000    0.0000
3 ELLX    PIEC   KVO
222.       16.38242 683.87390  -4.8312  523.6890    5.16437
5 LINE    PIEC   KV5
821.49744  -4.903111076.43945   6.6745    0.0000    0.0000
4 ELLX    PATC   KVO
 3.0000    3.0000    5.0000    5.0000    0.0000    0.0000
2 CUBI    PATC   KVO
 1.0000    1.0000    3.0000    3.0000    0.0000    0.0000
6 LINE    PIEC   KV5
1076.43945  6.674491212.       2.8632    0.0000    0.0000
-1
YB BC      YAXIS
ZBBSC      ZB BC
YBSTN      YB BS
           YB BS


YB
ZBBSC1     ZB
ZBSSC1     ZB TC
```

Identification

Cross-section model logical descriptions

Ranges for cross-section models

Body-line model numerical descriptions

Body-line model equivalences (QUICK "aliases")

Figure 3.- Abbreviated example of QUICK-geometry input.

```
 QUICK GEOMETRY OUTPUT          INTERMEDIATE DECK
 2 18
 5  2  5       0.0000   222.0000      3ELL
 2  1          1    3    1    0    2    7    8   -1   -1   -1   -1
 2  2          3    3    4    0    7    3    1   -1   -1   -1   -1
 2  3          2    1    1    0    3    9    1   -1   -1   -1   -1
 2  4          4    3    3    0    9   10   11   -1   -1   -1   -1
 2  5          5    3    3    0   10    5   12   -1   -1   -1   -1
 7  2  5     222.0000 1212.0000       FSID
 4  1          2    3    2    0    2    7    8   -1   -1   -1   -1
 4  2          1    1    1    0    7   16    1   -1   -1   -1   -1
 4  3          3    3    3    0   16   13   14   -1   -1   -1   -1
 4  4          4    3    3    0   13    3   15   -1   -1   -1   -1
 4  5          5    1    1    0    3    9    1   -1   -1   -1   -1
 4  6          6    3    3    0    9   10   11   -1   -1   -1   -1
 4  7          7    3    3    0   10    5   12   -1   -1   -1   -1
36
 1  0
 2  0
 3 18
 4  1
 5  4
    5

32 13
33 16
34  5
35 18
36 19
19
 1  5            0.0000       1212.0000
 1  1        0.0000    38.49500   2.0000    23.49500
 1  1 -3     -.16578982E+03 0.                    .26644911E+02
 1  2       2.0000    23.49500   83.74463 -10.21900
 1  2 -3     -.27023159E+02 -.13691815E+02  .91401023E-01
 1  3      83.74463 -10.21900 241.67340 -23.63156
 1  3 -3      .47240019E+04  .31722502E+05 -.12860324E+02
 1  4     241.67340 -23.631561071.92725 -40.97160
 1  4 -1     -.17340040E+02 -.83025385E+03 0.
 1  5    1071.92725 -40.971601212.0000  -32.83240
 1  5  3      .73974218E-01  .35419399E+01 -.53738476E-02
 2  6            2.0000       1212.0000
 2  1        2.0000    10.60660   83.74463   52.02340
 2  1  3     -.17290625E+02  .44929970E+01 -.73033173E-01
                  74463   52.02340 612.0000  116.50000
                                E+01  .26094227E+02 -.43921725E-02
17                                    .31262   87.0000
18  1                                               0.
18  1        0.0000
18  1  1     0.                    -.12
19  6            0.0000       1212.0000
19  1        0.0000    38.49500 135.63550   38.49500
19  1  1     0.                    -.13563550E+03 0.
19  2     135.63550   38.49500 222.0000    16.38242
19  2 -9     0.                    -.15706380E+05 -.13292793E+03
19  3     222.0000    16.38242 683.87390   -4.83120
19  3 -3      .33635131E+01  .90455553E+02 -.39679309E-03
19  4     683.87390   -4.83120 821.49744   -4.90311
19  4 -3     -.25858060E-01 -.41439065E+00  .18604347E-03
19  5     821.49744   -4.903111076.43945    6.67450
19  5  1      .11577610E+02 -.25494201E+03 0.
19  6    1076.43945    6.674491212.0000     2.86320
19  6 -1     -.38112900E+01 -.13556055E+03 0.
```

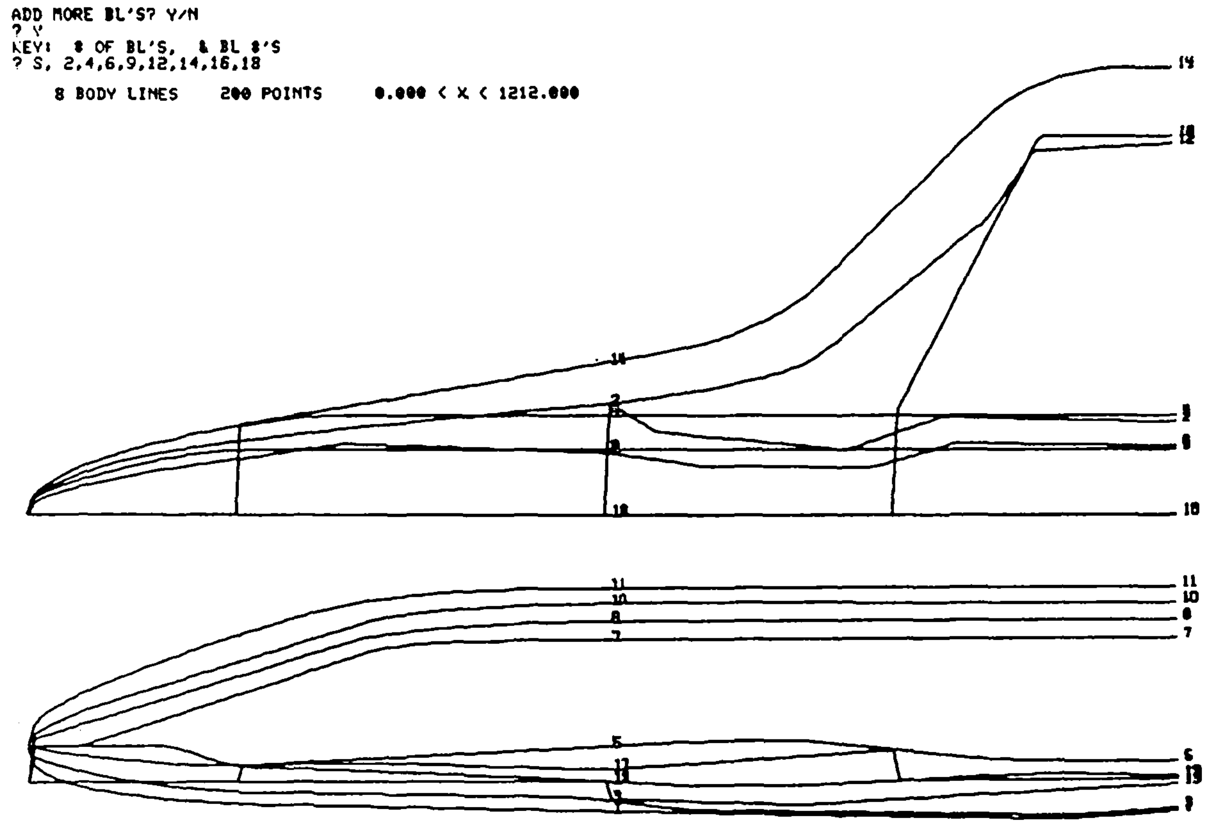
Identification

Cross-section model logical descriptions

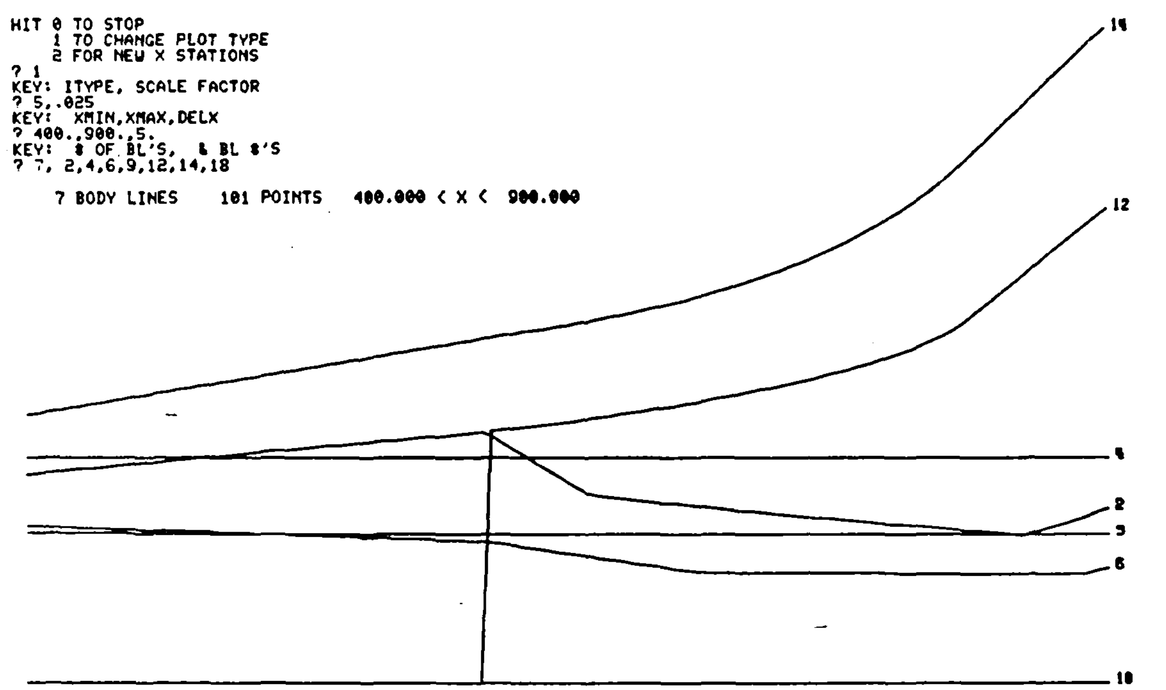
Correspondences between control points and body-line models

Body-line model numerical descriptions – beginning and ending points and coefficients of equations

Figure 4.- Abbreviated example of QUICK-geometry output.

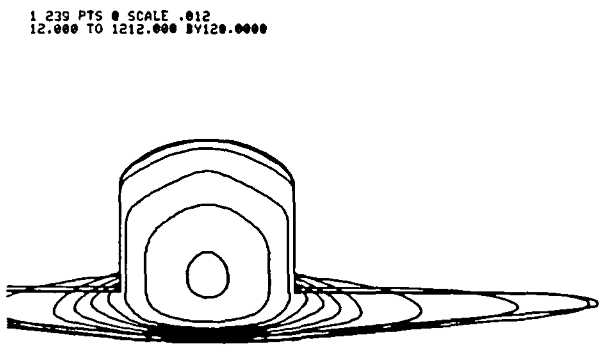


(a) Top view and side view body lines over whole modeled length.

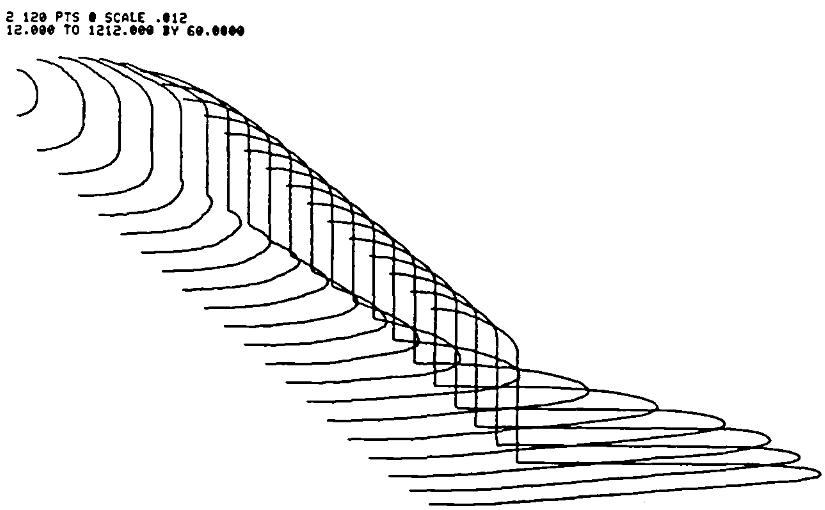


(b) Several top view body lines over shorter range.

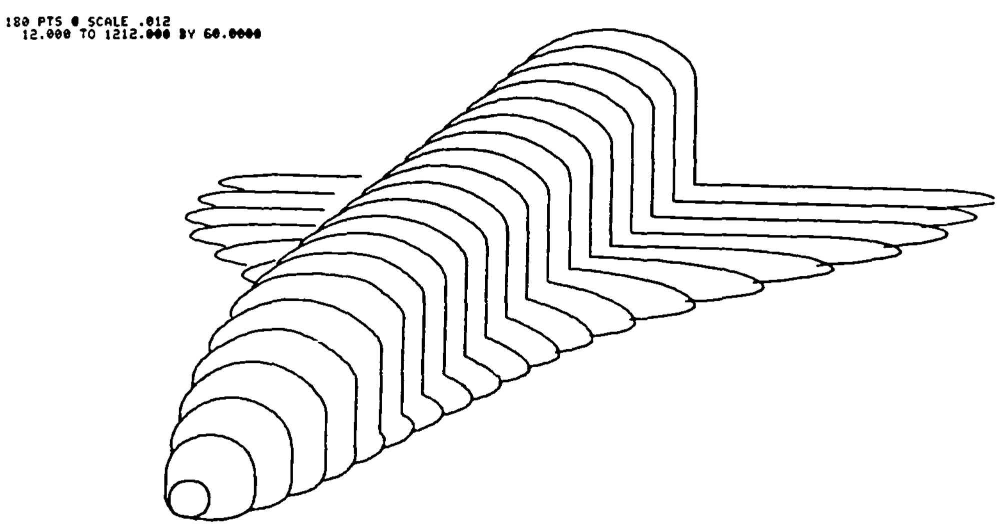
Figure 5.- Examples of body-line plots.



(a) Symmetric front view with all lines shown.

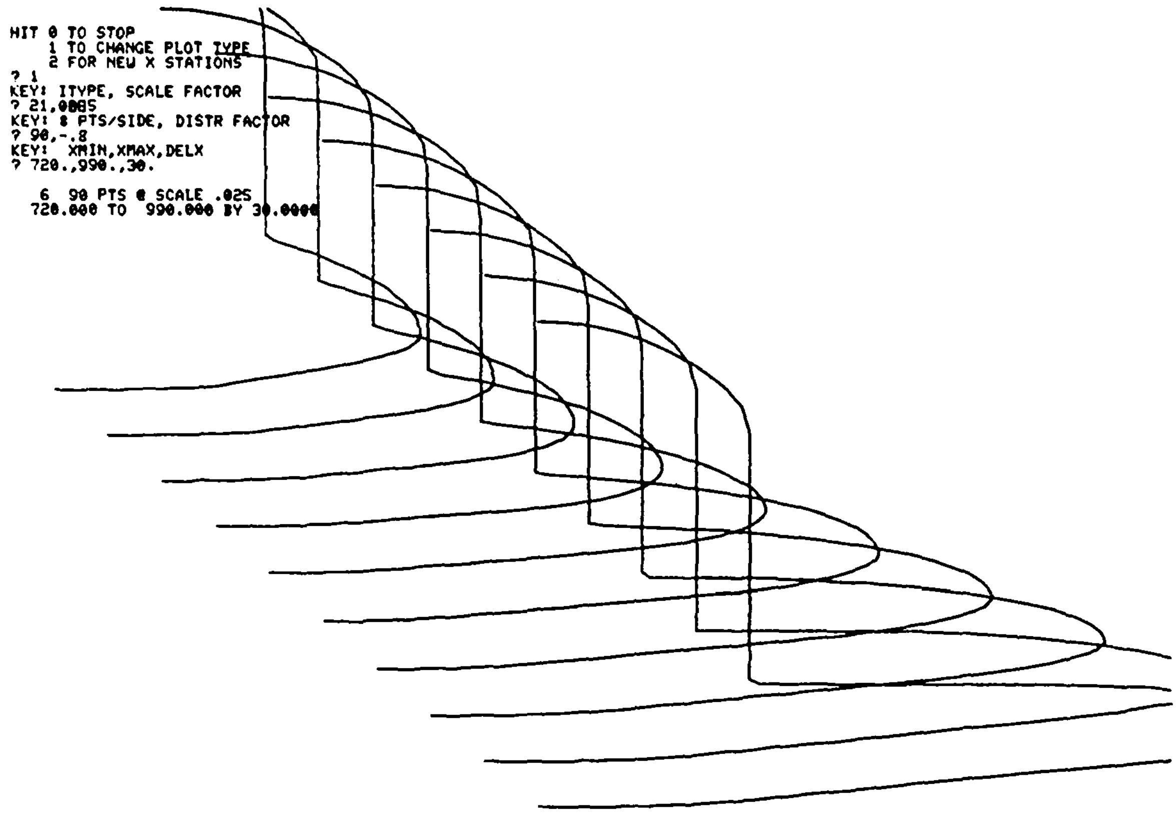


(b) One-sided lower pseudo-oblique view with all lines shown.

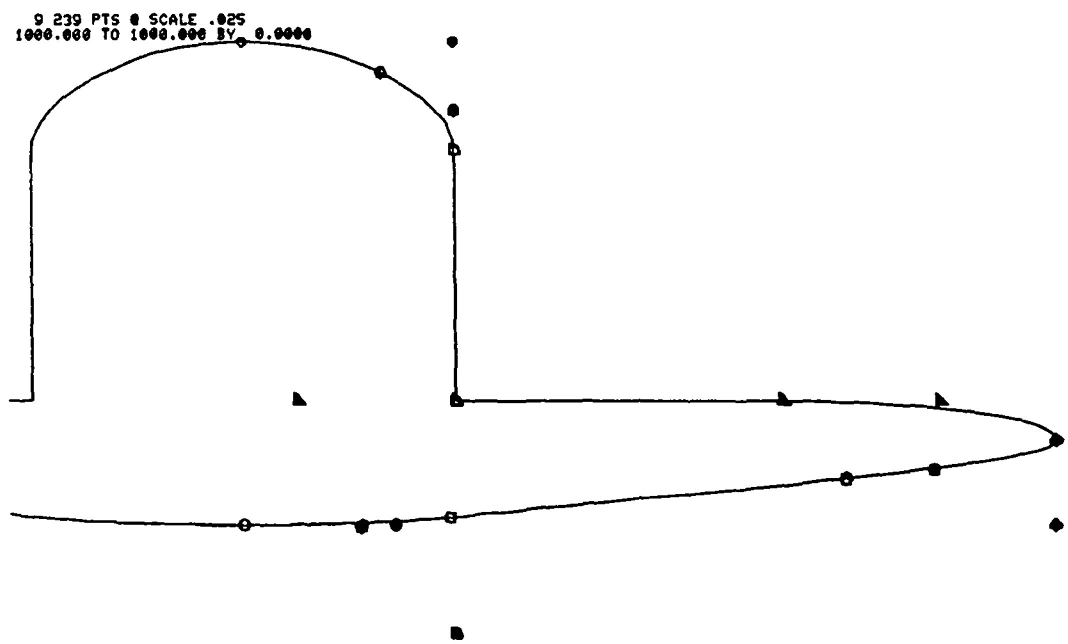


(c) Two-sided upper oblique view with hidden-line removal.

Figure 6.- Examples of overall views with many cross sections.



(a) Short series of one-sided cross sections with all lines shown.



(b) Symmetric single cross section with control-point locations indicated by symbols.

Figure 7.- Examples of plots with few cross sections.

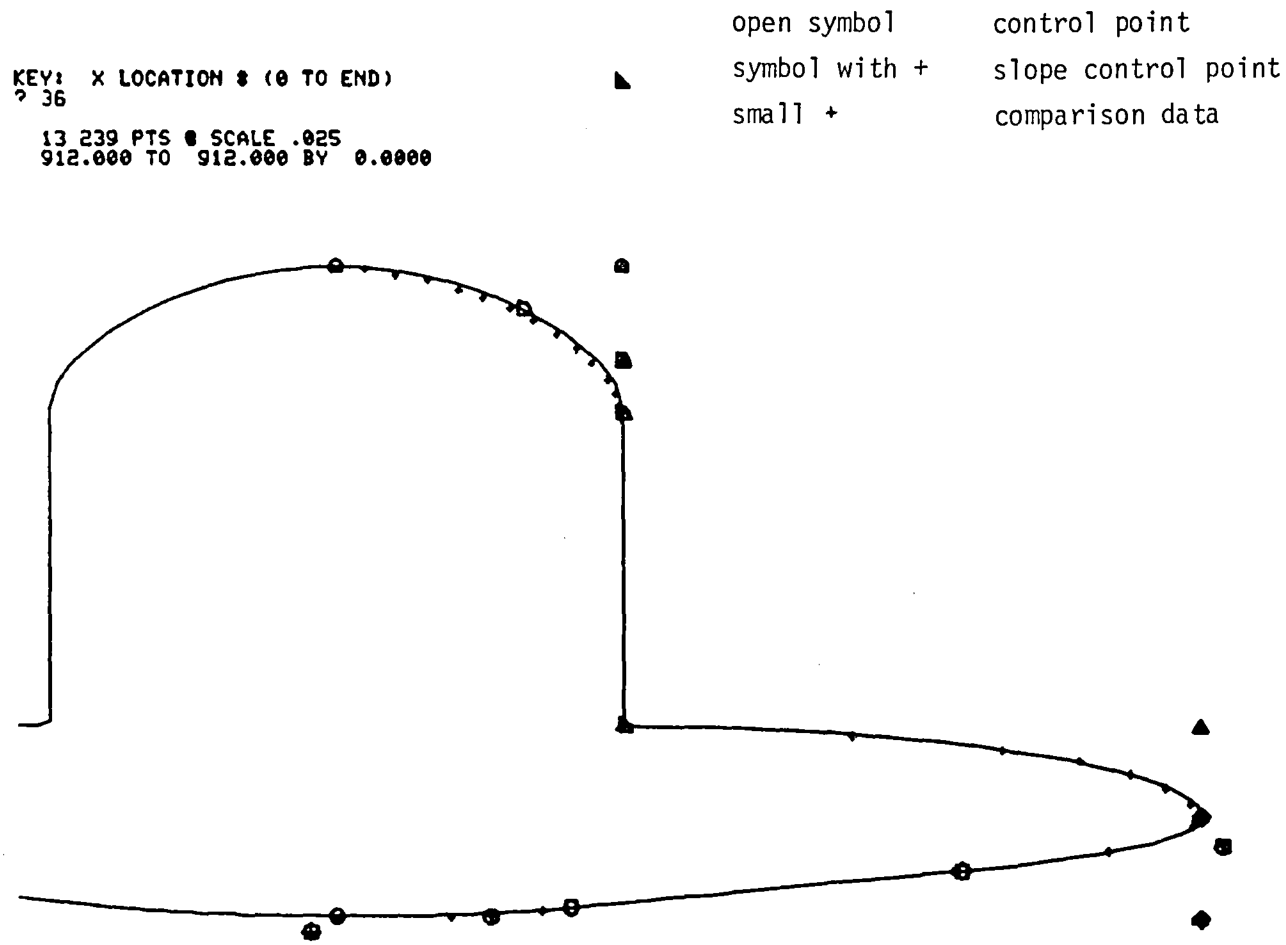
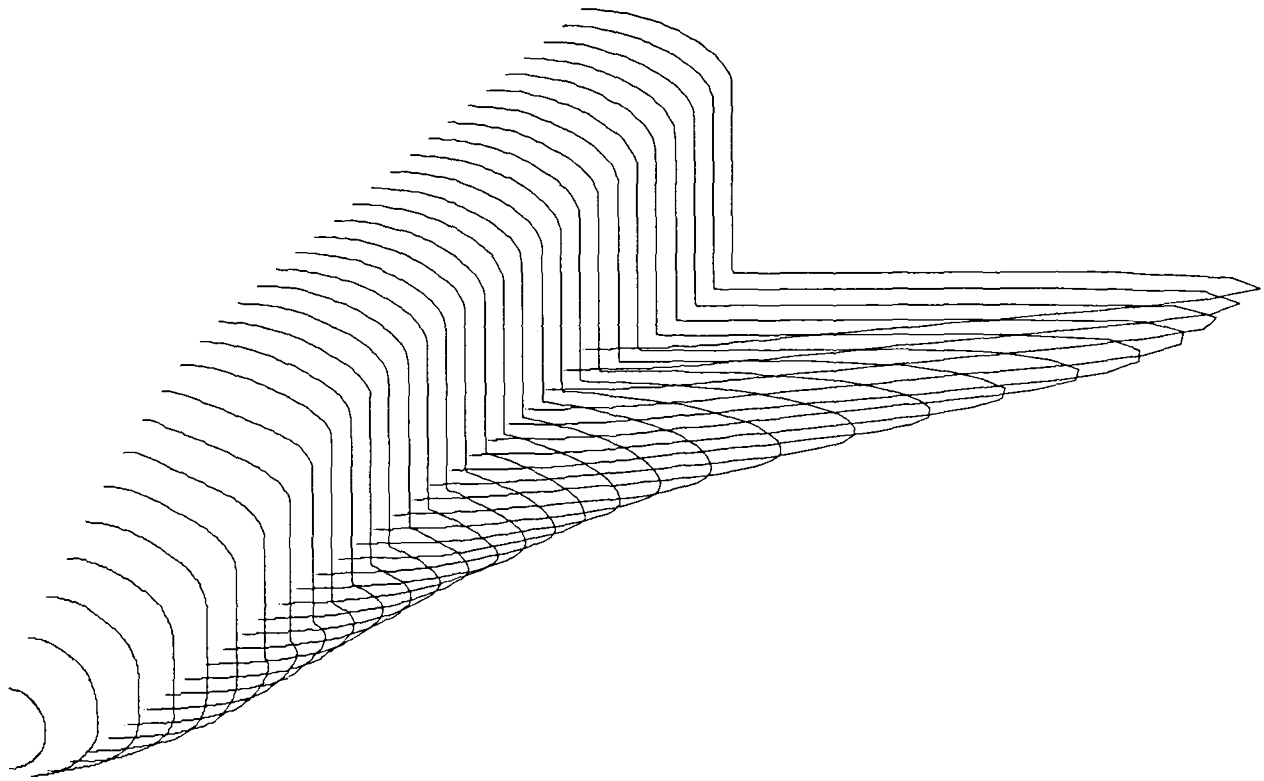
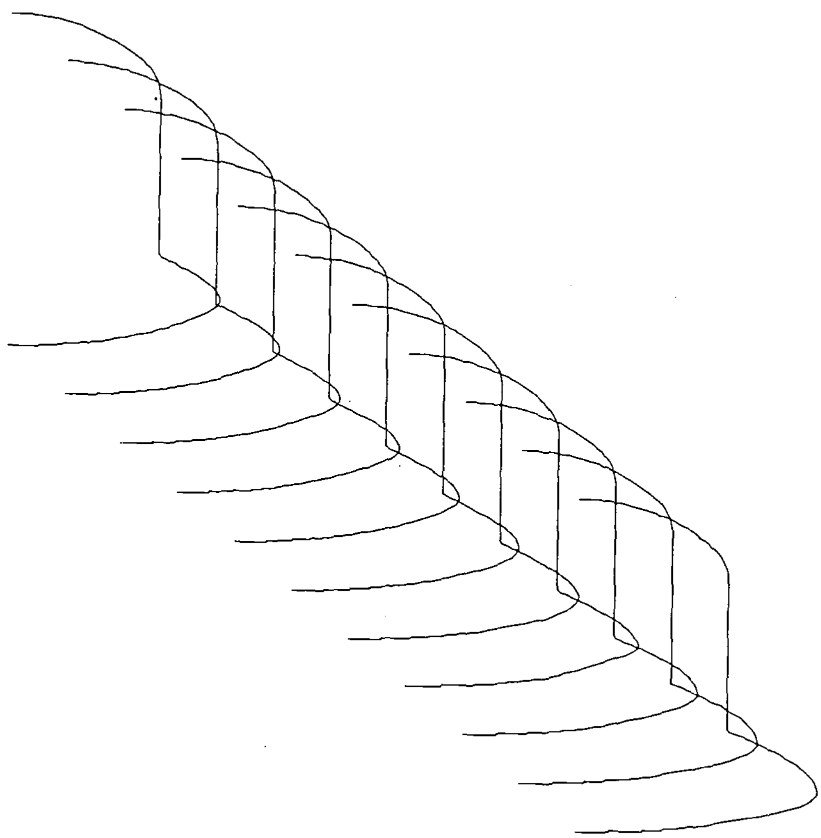


Figure 8.- Comparison of QUICK cross-section model including control points with original data digitized from drawing.

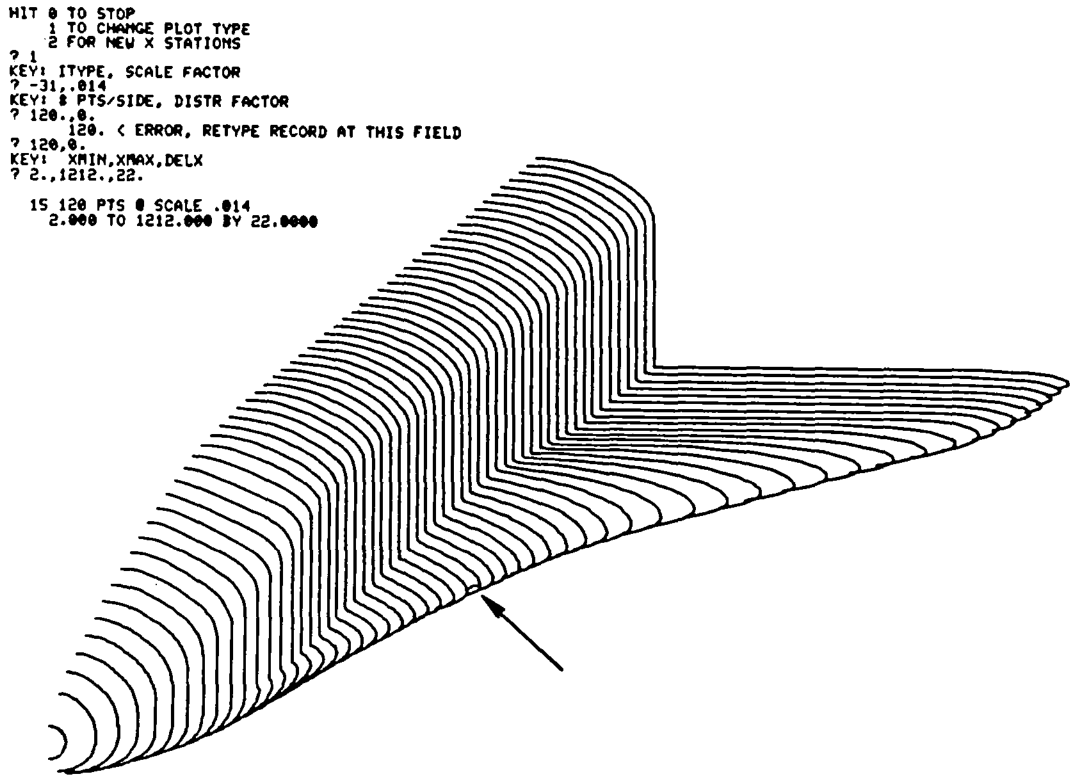


(a) Sequence of cross sections over length of body.

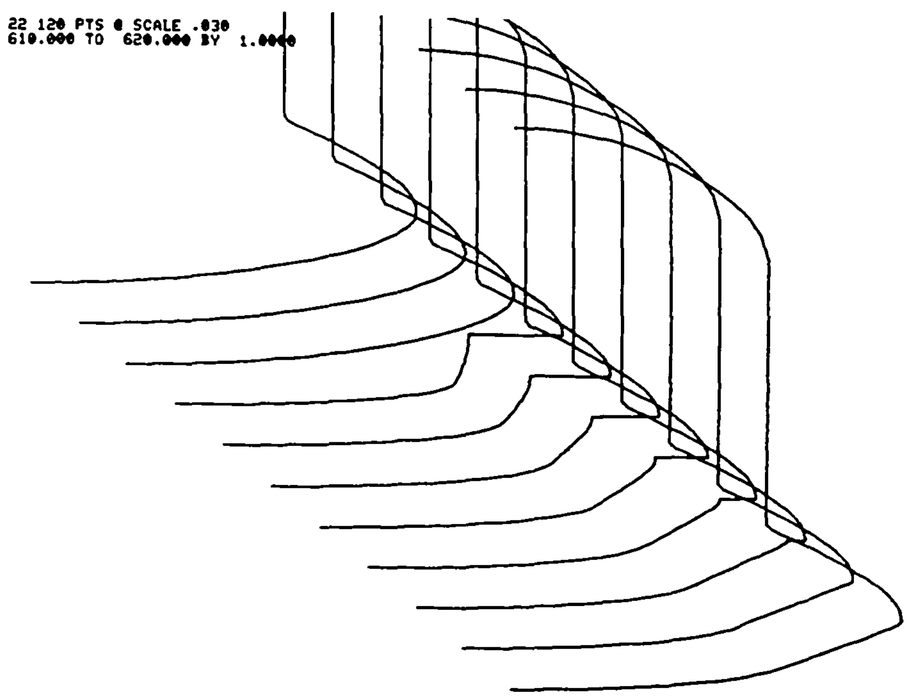


(b) Closely spaced cross sections over a short section.

Figure 9.- Two batch-processed plots of Space Shuttle Orbiter as originally modeled.

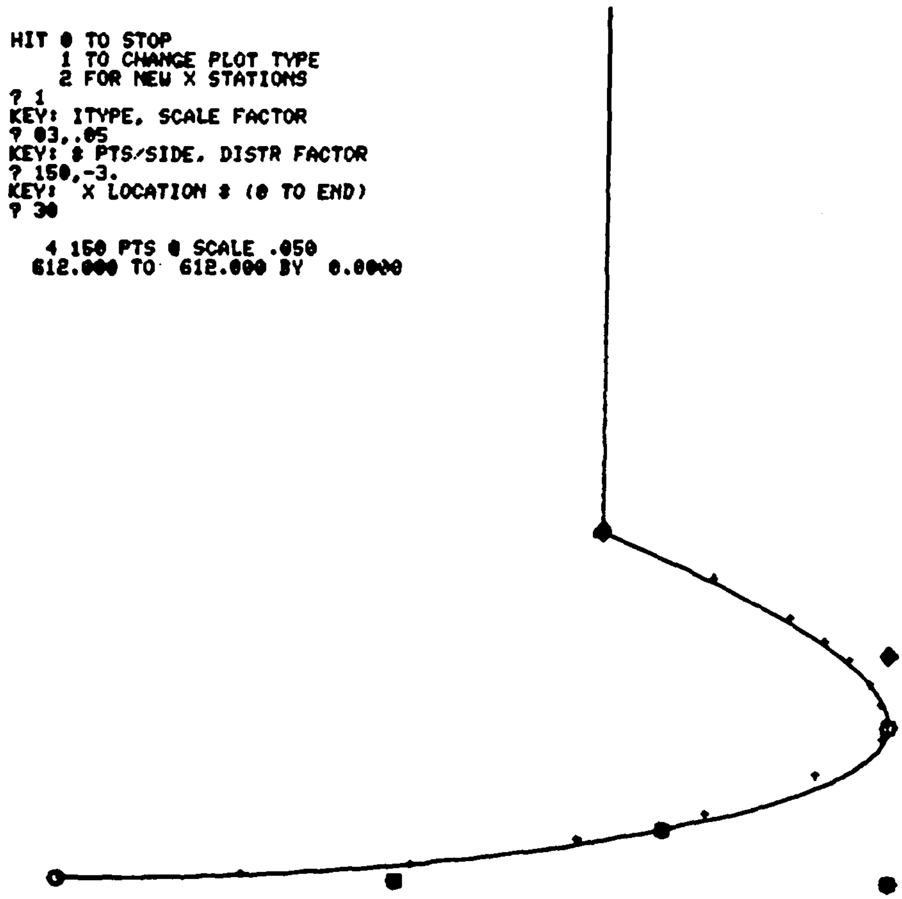


(a) Detection of error at single cross section (arrow).

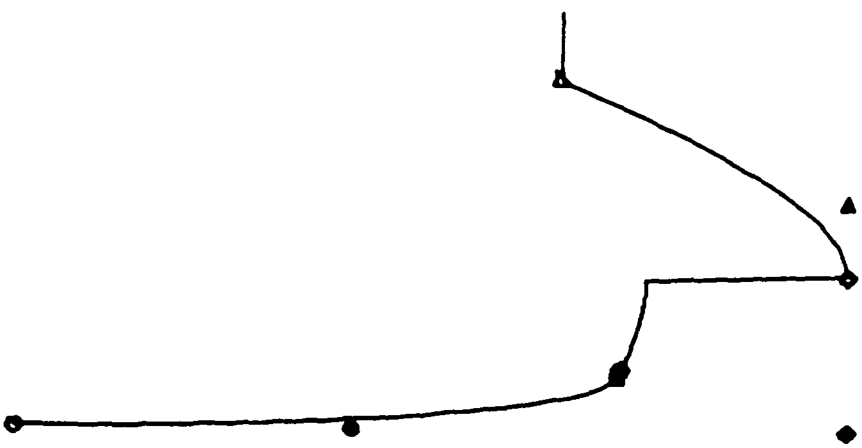


(b) Region of modeling error expanded to show location and extent.

Figure 10.- Error in modeling detected and analyzed with QUIAGA program.

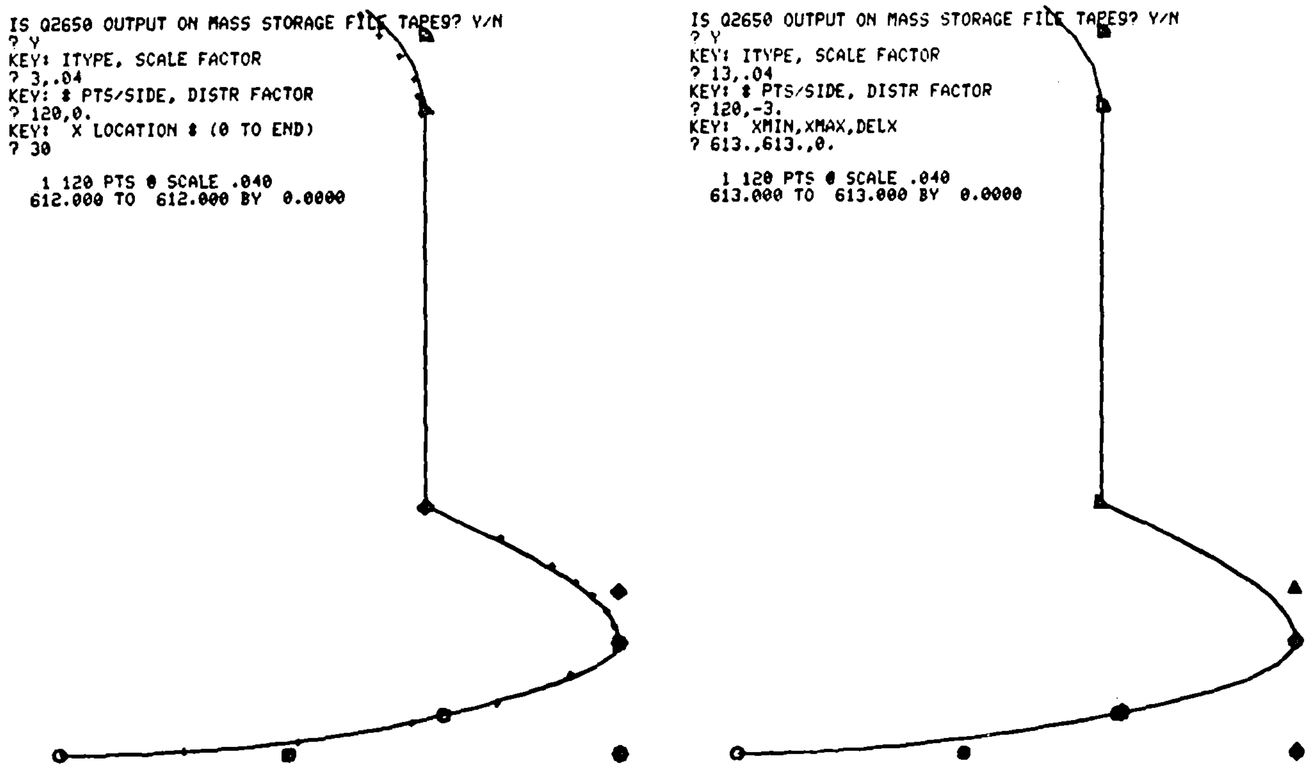


(c) Cross section just ahead of error compared with original data.

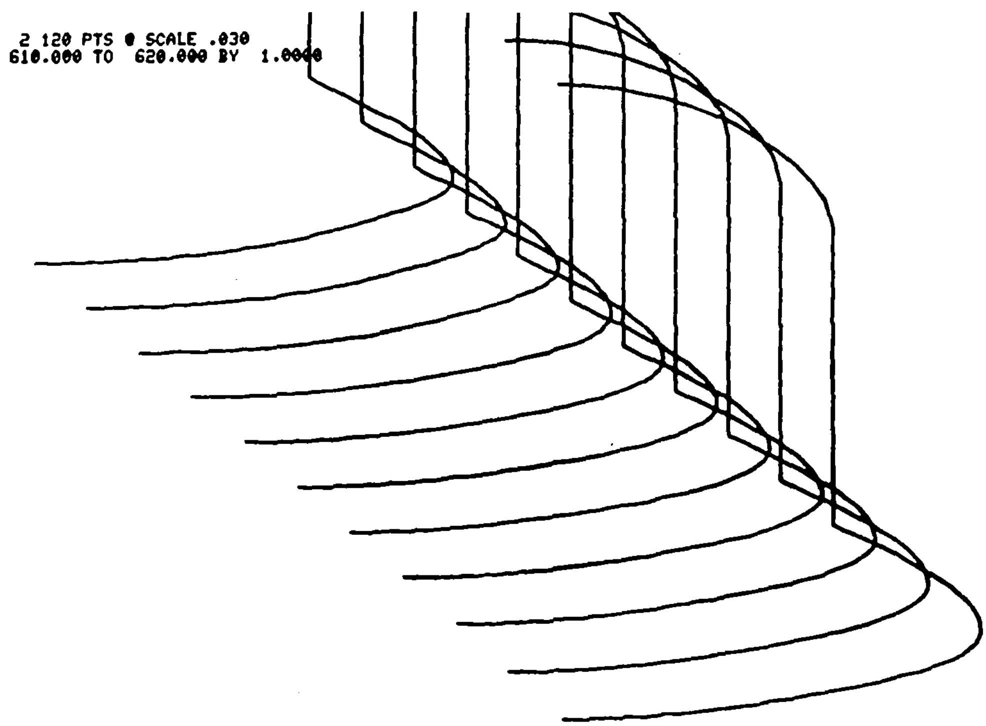


(d) Partial cross section with error, showing control-point locations.

Figure 10.- Continued.

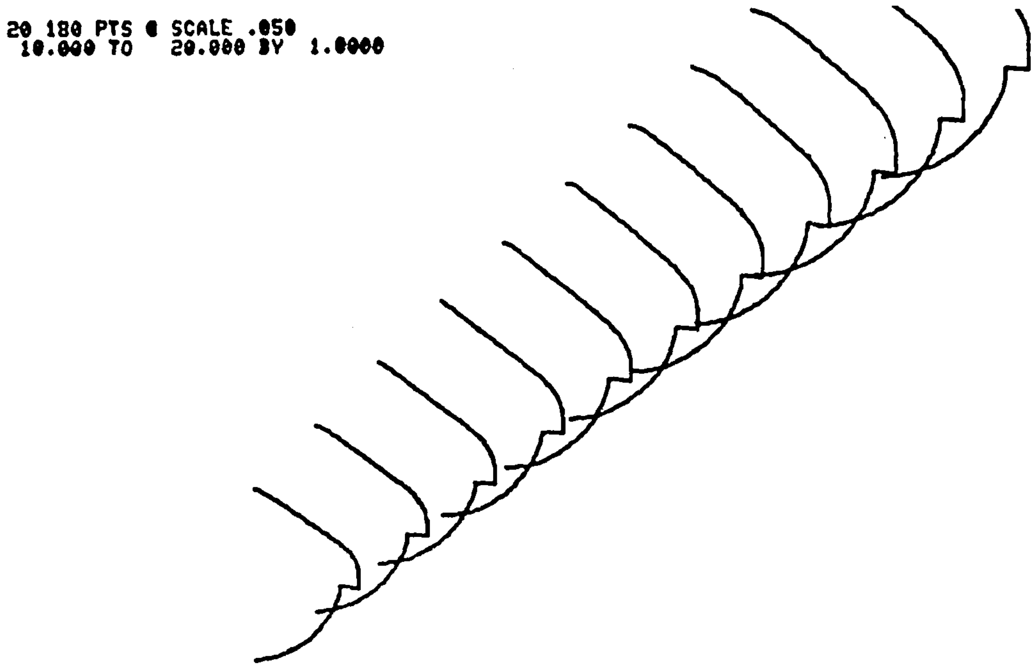


(e) Cross sections after correction. (Compare with figs. 10(c) and 10(d).)

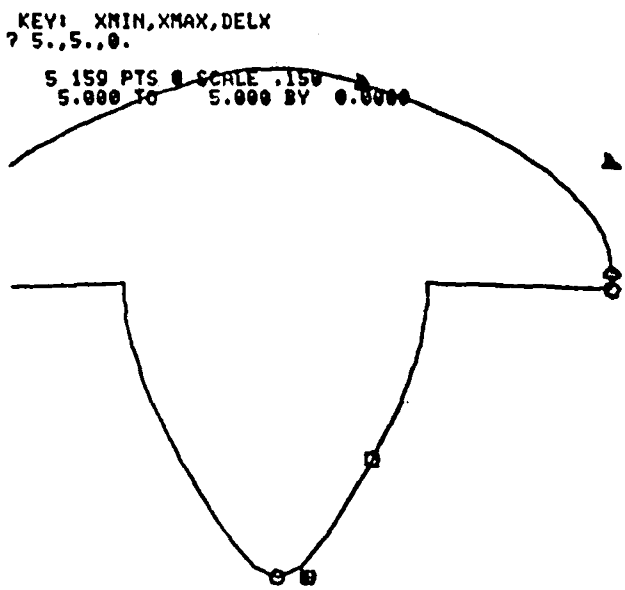


(f) Series of cross section (same as fig. 10(b)) showing error corrected.

Figure 10.- Concluded.

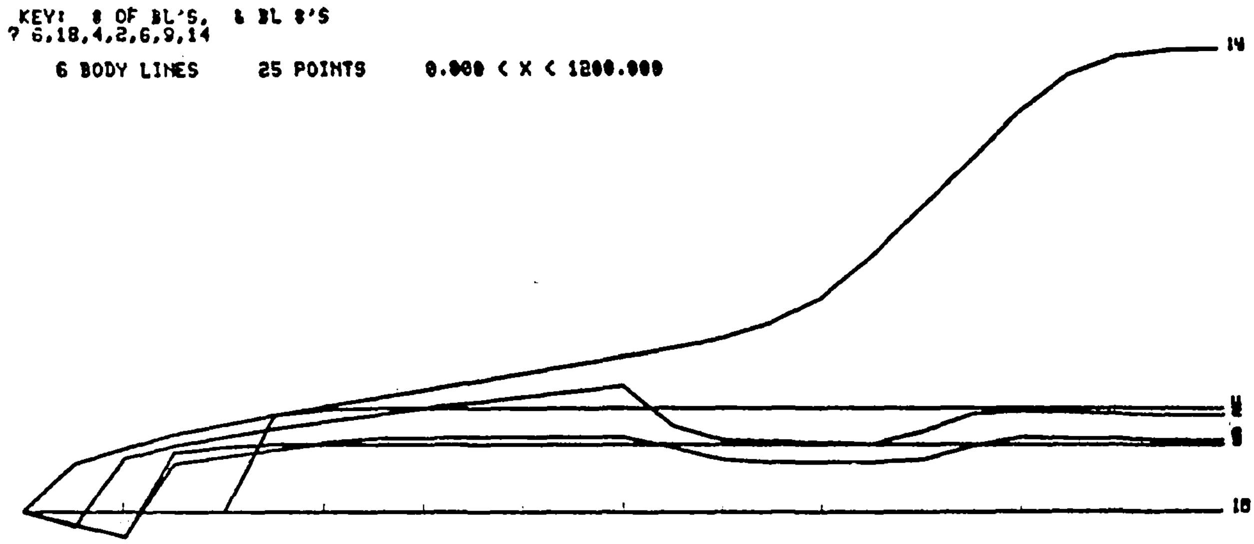


(a) Unsatisfactory cross sections in nose region.

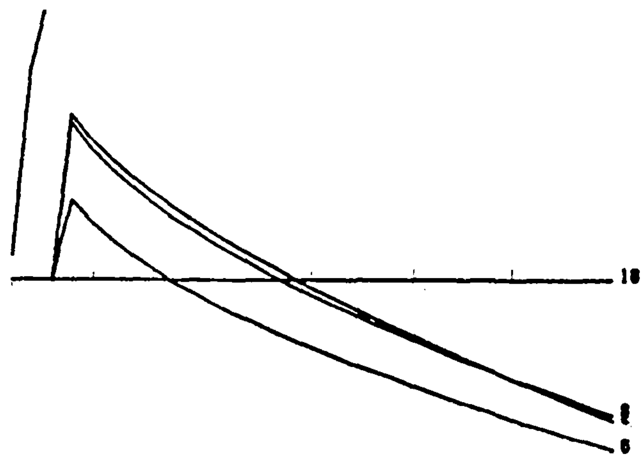


(b) Cross section near nose with control points.

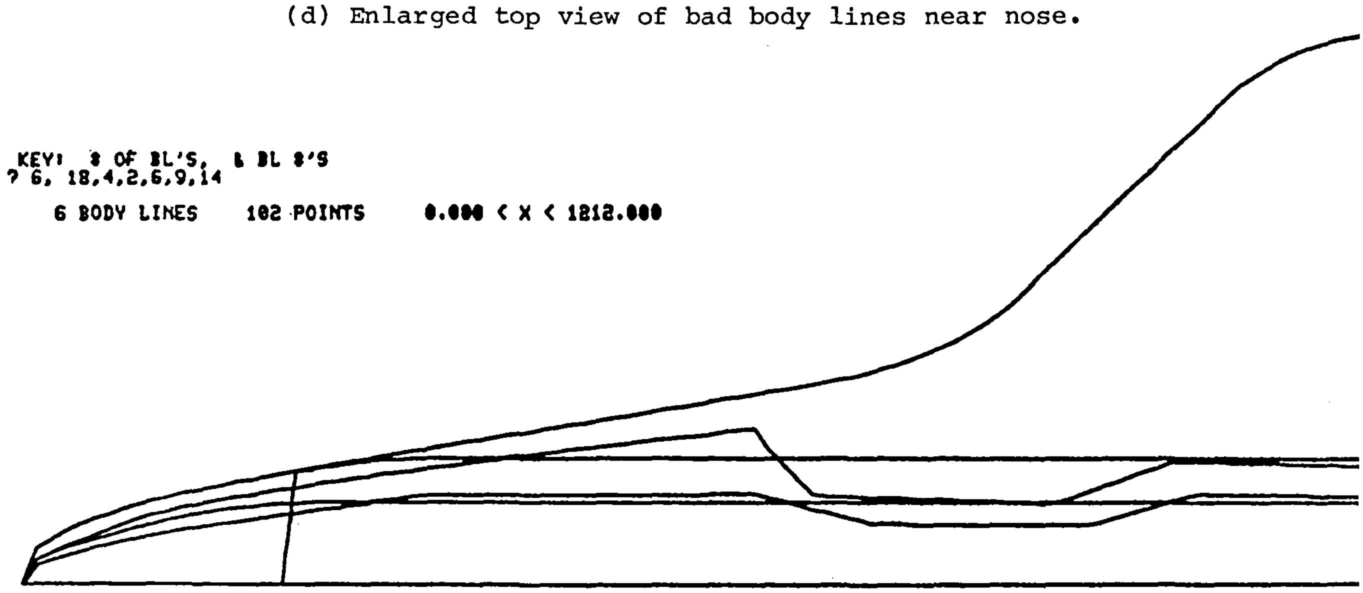
Figure 11.- Sequence of displays obtained in analyzing error in nose modeling.



(c) Top view of several body lines, showing error near nose.

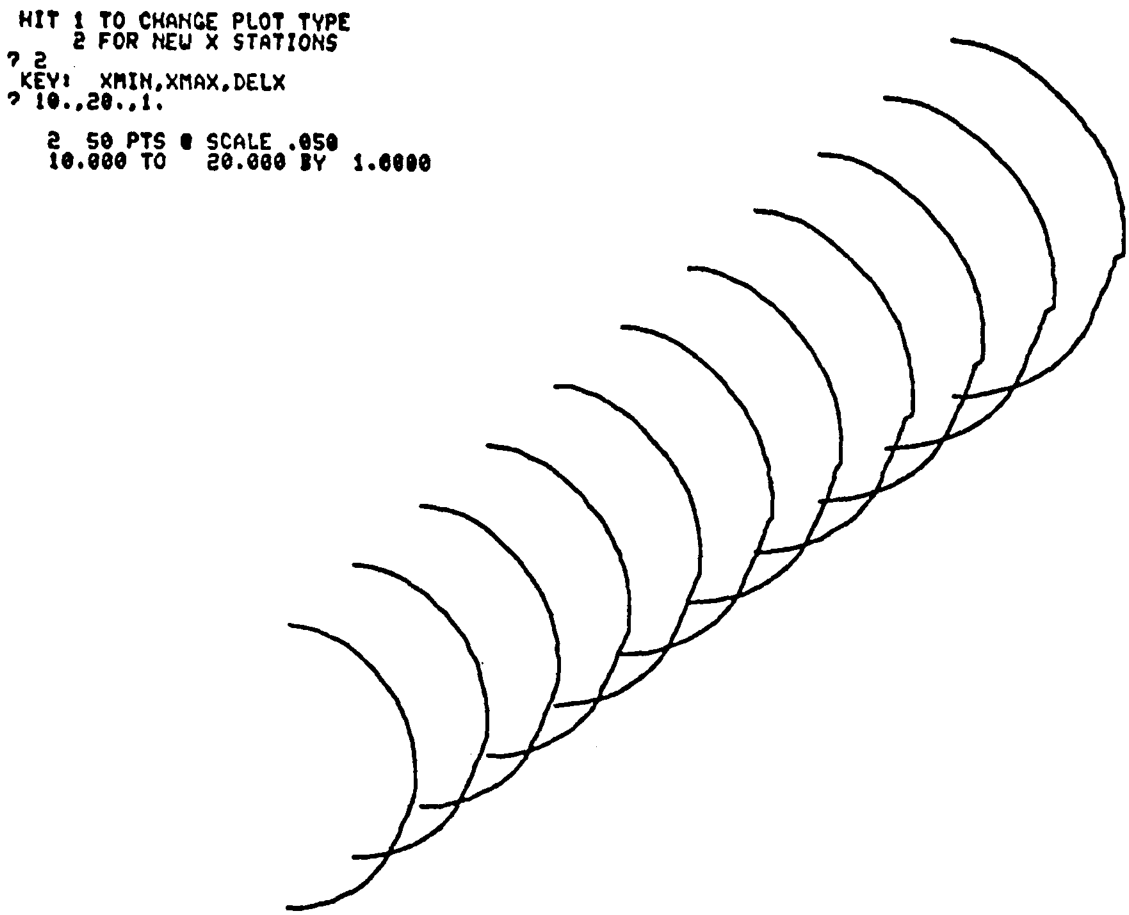


(d) Enlarged top view of bad body lines near nose.



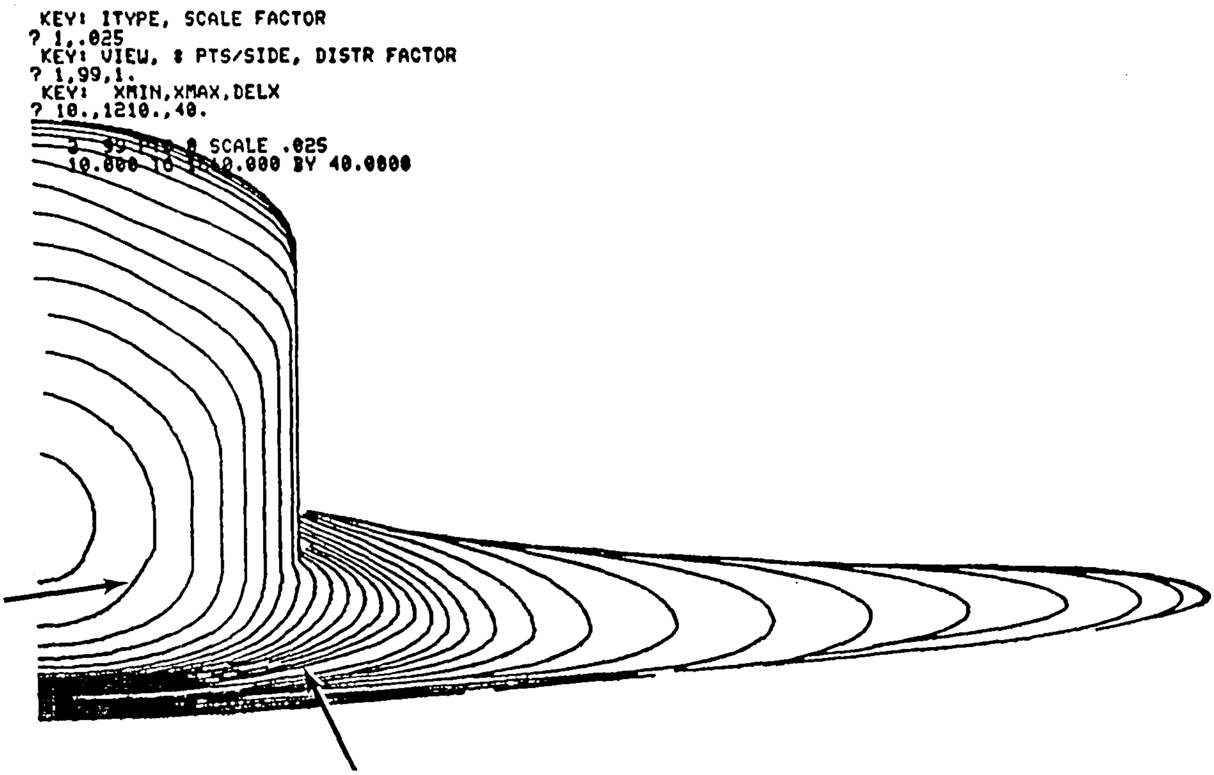
(e) Top view of body lines with segment corrected.

Figure 11.- Continued.

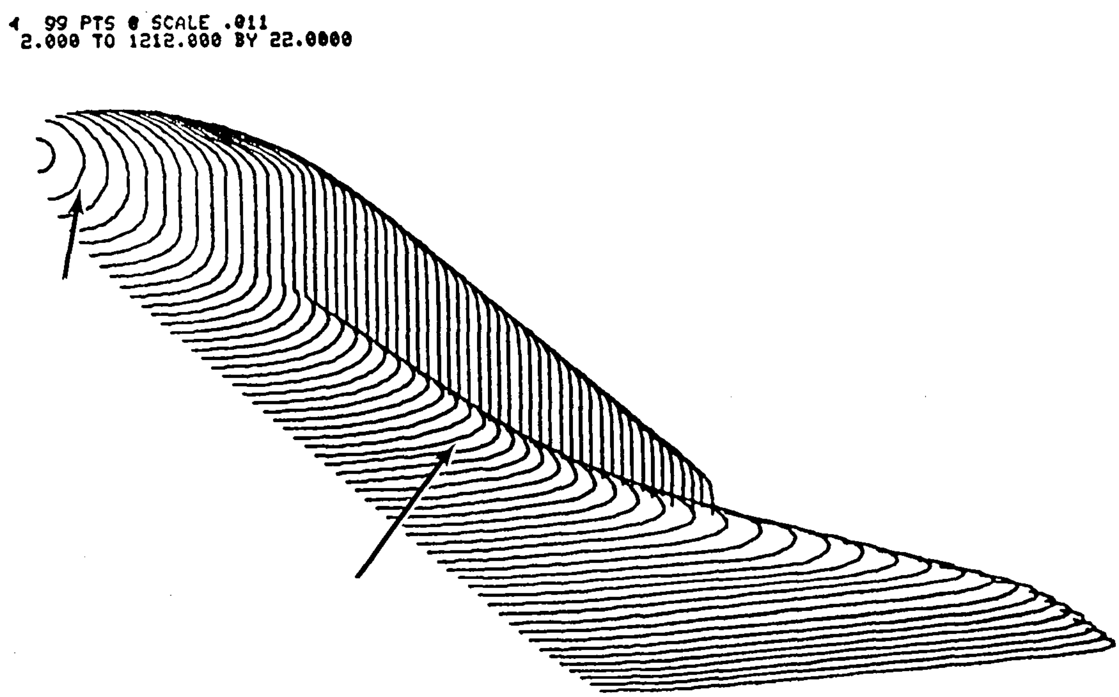


(f) Improved cross sections in nose region (same locations as fig. 11(a)).

Figure 11.- Concluded.

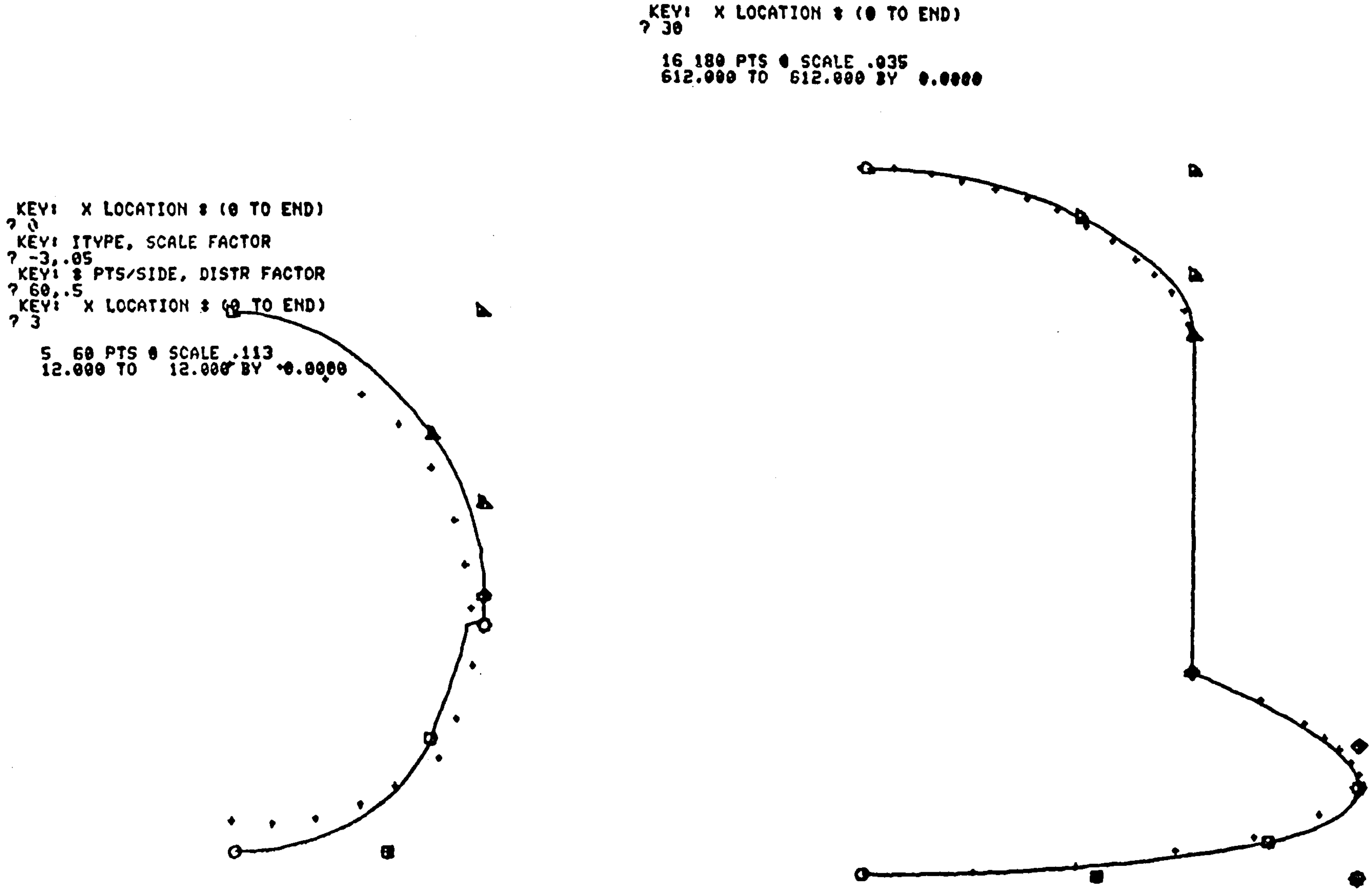


(a) Front view.



(b) Lower oblique view.

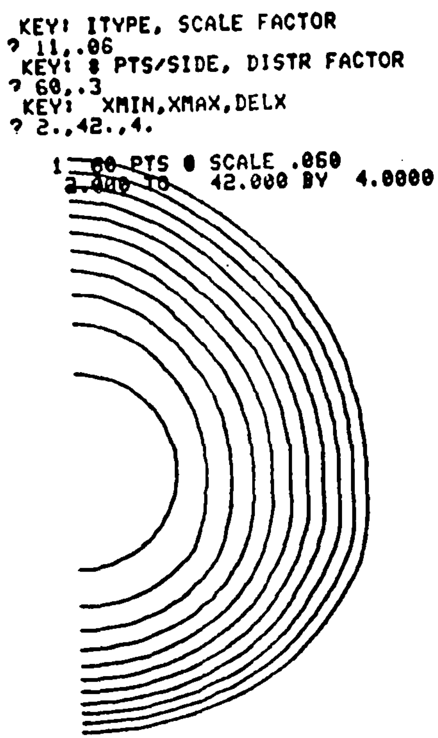
Figure 12.- Two views of improved Shuttle cross sections.



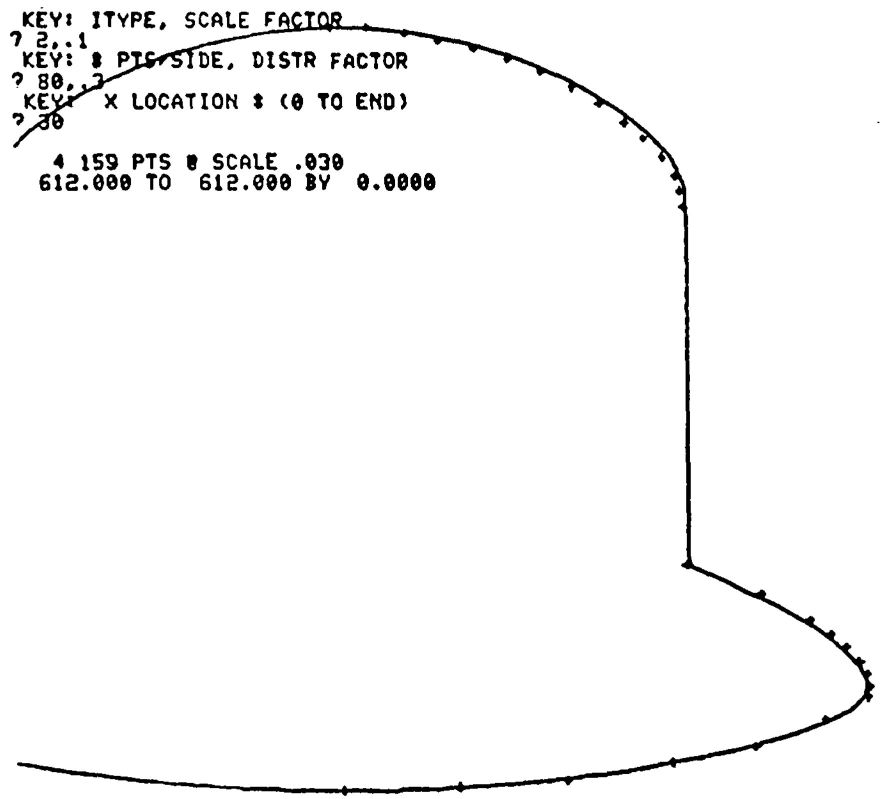
(a) Cross section in nose region.

(b) Cross section with beginning of wing.

Figure 13.- Comparison of cross sections with original data.



(a) Nose region.



(b) Comparison with same original data as figure 13(b).

Figure 14.- Cross sections after further correction.

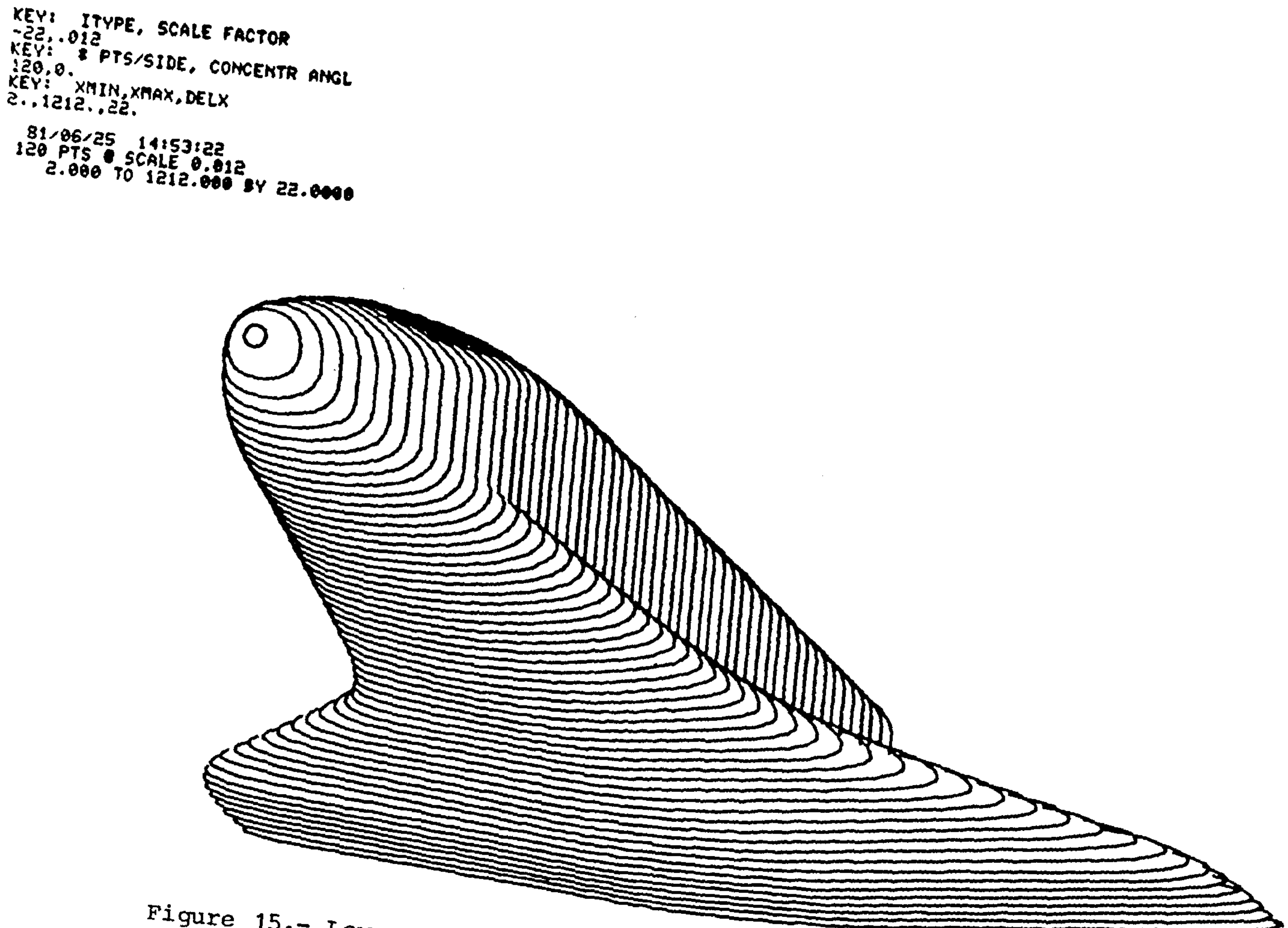


Figure 15.- Lower oblique view of final QUICK-geometry model of Space Shuttle Orbiter.

#	X LOCATION	#	X LOCATION
1	0.00000	2	2.00000
3	12.00000	4	22.00000
5	32.00000	6	42.00000
7	52.00000	8	62.00000
9	62.00000	10	87.00000
11	112.00000	12	137.00000
13	162.00000	14	182.00000
15	187.00000	16	202.00000
17	222.00000	18	242.00000
19	262.00000	20	282.00000
21	302.00000	22	322.00000
23	342.00000	24	362.00000
25	402.00000	26	432.00000
27	462.00000	28	512.00000
29	562.00000	30	612.00000
31	662.00000	32	712.00000
33	762.00000	34	812.00000
35	862.00000	36	912.00000
37	962.00000	38	1012.00000
39	1012.00000	40	1062.00000
41	1073.00000	42	1082.00000
43	1112.00000	44	1162.00000
45	1212.00000	46	1237.00000
47	1262.00000		

Figure 16.- Sample output list from READATA giving numbers and locations of cross-section data written in mass storage form on file TAPES.

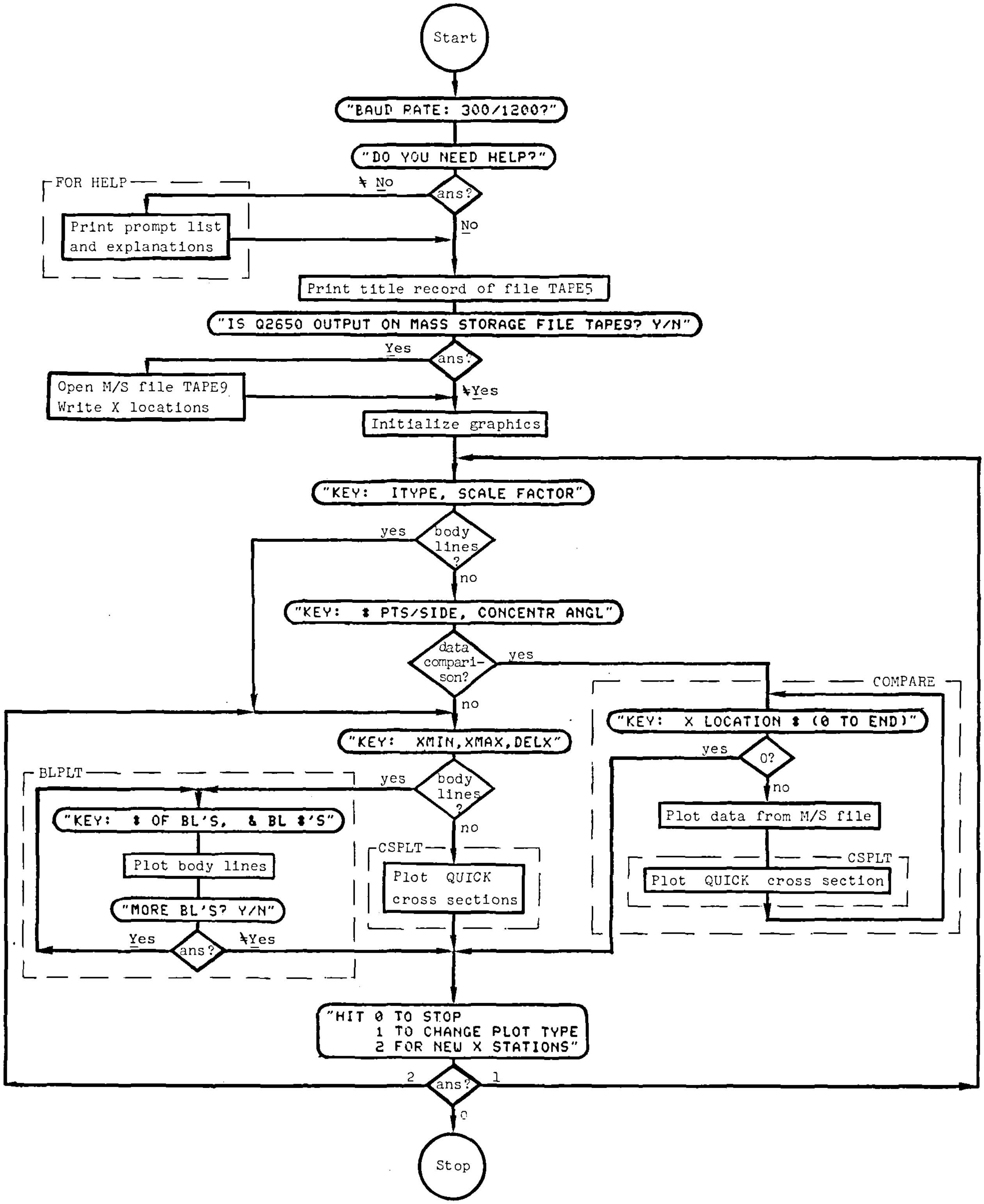


Figure 17.- Simplified flowchart of QUIAGA program. Items in quotes are prompts requiring keyboard response; dashed outlines denote subroutines.

```
              QUICK  INTERACTIVE GRAPHICS ANALYSIS
         HELPS YOU CHECK  QUICK  OUTPUT (ON LOCAL FILE TAPE5)

WHEN ASKED FOR:    GIVE A:      EXPLANATION:


ITYPE          2-DIGIT INTEGER <0  HIDDEN LINES OUT
                               >0  ALL LINES

                    1ST DIGIT = 0  COMPARISON W/ ORIGINAL DATA (TAPE9)
                                1  FRONT VIEW
                                2  BOTTOM OBLIQUE
                                3  TOP      "

                    2ND DIGIT = 1  HALF CROSS SECTIONS
                                2  WHOLE  "      "
                                3  HALF   "      "    WITH CONTROL POINTS
                                4  WHOLE  "      "     "     "     "
                                5  BODY LINES

SCALE FACTOR        REAL         SCREEN INCH/MODEL INCH (AUTO IF 0.)

# PTS/SIDE          INTEGER      NUMBER OF POINTS AROUND HALF CROSS SECTIONS(<=180)
CONCENTR ANGL       REAL         ANGLE FOR CONCENTRATED POINTS  (-90. TO 90.)
                                 EVEN ANGULAR DISTRIBUTION IF NOT IN RANGE

# OF BL'S           INTEGER      NUMBER OF  BODY LINES TO PLOT  (NBLS<=10)
BL #'S          NBLS INTEGERS    BODY LINE COORDINATE INDEX NUMBERS FROM  QUICK


XMIN                REAL         BEGIN AT THIS AXIAL STATION
XMAX                REAL         END   "   "    "     "
DELX                REAL         INCREMENT IN   "     "

X LOCATION #        INTEGER      NUMBER FROM LOCATION LIST
```

Figure 18.- Help output from QUICK Interactive Graphics Analysis program.

CROSS SECTION DATA READ FROM TAPE9

LOCATION #	X	LOCATION #	X	LOCATION #	X
1	0.0000	18	242.0000	35	862.0000
2	2.0000	19	262.0000	36	912.0000
3	12.0000	20	282.0000	37	962.0000
4	22.0000	21	302.0000	38	1012.0000
5	32.0000	22	322.0000	39	1012.0000
6	42.0000	23	342.0000	40	1062.0000
7	52.0000	24	362.0000	41	1073.0000
8	62.0000	25	402.0000	42	1082.0000
9	62.0000	26	432.0000	43	1112.0000
10	87.0000	27	462.0000	44	1162.0000
11	112.0000	28	512.0000	45	1212.0000
12	137.0000	29	562.0000	46	1237.0000
13	162.0000	30	612.0000	47	1262.0000
14	182.0000	31	662.0000	48	1262.0000
15	187.0000	32	712.0000	49	1282.0000
16	202.0000	33	762.0000	50	-I
17	222.0000	34	812.0000	51	-I

Figure 19.- Listing of X location numbers and corresponding axial locations in confirmation that data base file has been opened and read.

```
QUICK GEOMETRY INPUTS (FULL SHUTTLE 4/15/81)

 CHECK BODY LINE DEFINITION

BODY LINE COORDINATE INDEX
 1  Y              ( 0)
 2  Z              ( 0)
 3  Y  B  BC       (18)
 4  Z  B  BC       ( 1)
 5  Y  B  BS       ( 4)
 6  Z  B  BS       ( 5)
 7  Y  BBSC1       ( 4)
 8  Z  BBSC1       ( 1)
 9  Y  B  TC       (18)
10  Z  B  TC       (11)
11  Y  BSSC1       ( 4)
12  Z  BSSC1       (11)
13  Y  BBTN        ( 2)
14  Z  BBTN        ( 3)
15  Y  BBSC        ( 6)
16  Z  BBSC        ( 1)
17  Y  BSTN        ( 4)
18  Z  BSTN        ( 7)
19  Y  BTTN        ( 9)        Body-line model numbers
20  Z  BTTN        (10)
21  Y  BSSC        ( 4)
22  Z  BSSC        ( 8)
23  Y  BTSC        ( 4)
24  Z  BTSC        (11)
25  Y  W  LE       (14)
26  Z  W  LE       (15)
27  Y  WBOS        (14)
28  Z  WBOS        ( 1)
29  Y  WTOS        (14)
30  Z  WTOS        (17)
31  Y  W  BM       (12)
32  Z  W  BM       (13)
33  Y  W  TM       (16)
34  Z  W  TM       ( 5)
35  Y  AXIS        (18)
36  Z  AXIS        (19)
```

Figure 20.- Example of body-line Coordinate Index from QUICK output.

```
*   QUIAGA PROCEDURE FILES FOR  NOS
*
 PROC,GENRDAT
 *GENERATE RELOCATABLE BINARY
GET,READATA
FTN(I-READATA,B-BREADAT,OPT-2)
RETURN,READATA
SAVE,BREADAT
GET,TAPE2-QINP
LDSET(PRESETA-NGINF,MAP-SBEX)
BREADAT
SAVE,TAPE9-DATQTP9
EXIT.
REPLACE,TAPE9-Q9999
*
 PROC,GENQPLT
 *GENERATE RELOCATABLE BINARY
GET,QUIAGA
FTN(I-QUIAGA,B-BQUIAGA,OPT-2)
RETURN,QUIAGA
GET,QUIKSUB
FTN(I-QUIKSUB,B-BQKSUB,OPT-2)
LIBGEN(BQKSUB,LIBQSUB)
SAVE,BQUIAGA,LIBQSUB
RETURN,QUIKSUB,BQKSUB
GET,TAPE9-DATQTP9
GET,TAPE5-QOUTPUT
ATTACH,LIBFTEK/UN-LIBRARY
LDSET(LIB-LIBQSUB/LIBFTEK,PRESETA-NGINF,MAP-SBEX/MAPQX)
LOAD(BQUIAGA)
NOGO(QPLOT)
REPLACE,QPLOT
QPLOT
EXIT
REPLACE,MAPQX
```

Figure 21.- Procedure files to compile, load, and run programs READATA and QUIAGA.

```
/GET,QPLOT/UN=894900N.
/GET,TAPE5=QOTPTC.
/GET,TAPE9=DATQTP9.
/QPLOT.
```

NOS control statements to access absolute binary of QUIAGA (generated by procedure file of fig. 21), to access QUICK intermediate output file and original data file, and to begin execution.

```
BAUD RATE: 300/1200?
? 1200


DO YOU NEED HELP?
? NO
```

If response does not begin with N, screen clears and HELP list is printed. (see fig. 18)

```
SHUTTLE GEOMETRY INPUTS (FULL SHUTTLE 7/19/81)
```

Identification from TAPE5

```
IS Q2650 OUTPUT ON MASS STORAGE FILE TAPE9? Y/N
? YES
```

Response beginning N would skip this list and not allow comparisons with original data.

CROSS SECTION DATA READ FROM TAPE9

LOCATION #	X	LOCATION #	X	LOCATION #	X
1	0.0000	18	242.0000	35	862.0000
2	2.0000	19	262.0000	36	912.0000
3	12.0000	20	282.0000	37	962.0000
4	22.0000	21	302.0000	38	1012.0000
5	32.0000	22	322.0000	39	1012.0000
6	42.0000	23	342.0000	40	1062.0000
7	52.0000	24	362.0000	41	1073.0000
8	62.0000	25	402.0000	42	[illegible]
9	62.0000	26	[illegible]		
10	[illegible]				

Etc., see fig. 19.

(a) Initialization.

Figure 22.- Example interactive session using QUIAGA.

```
 <HIT  <CR>  TO CONTINUE
KEY: ITYPE, SCALE FACTOR
? 11,.02
KEY: # PTS/SIDE, CONCENTR ANGL
? 120,0.
KEY:  XMIN,XMAX,DELX
? 12.,1212.,44.
```

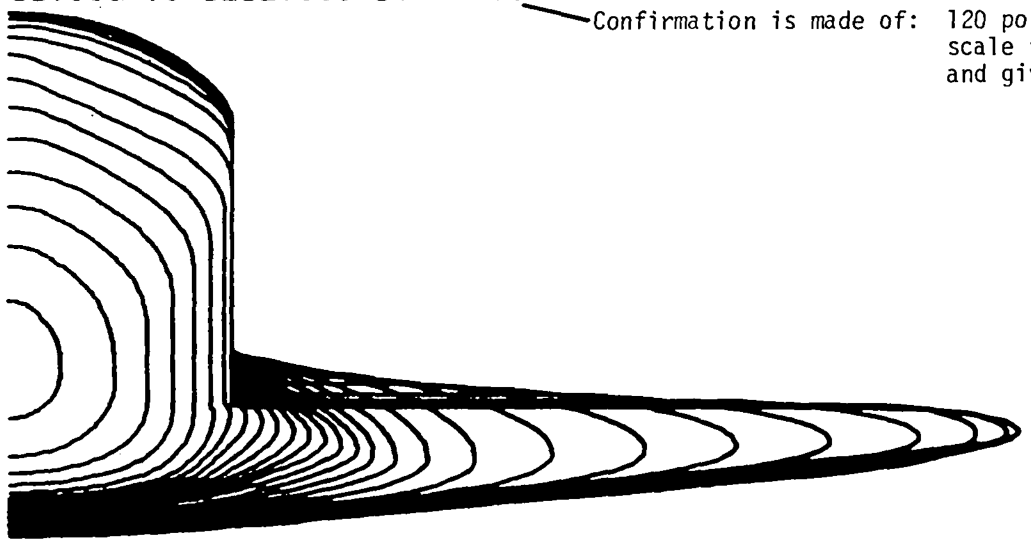
ITYPE 11 is one-sided front view with all lines shown.

Concentration angle of 0° corresponds to wing leading-edge region.

This asks for cross section beginning at X = 12., ending at X = 1212., and at intervals of 44.

```
   1 120 PTS @ SCALE .020
   12.000 TO 1212.000 BY 44.0000
```

Confirmation is made of: 120 points per cross section, scale factor of 0.020, and given X locations.



(b) First plot: front view.

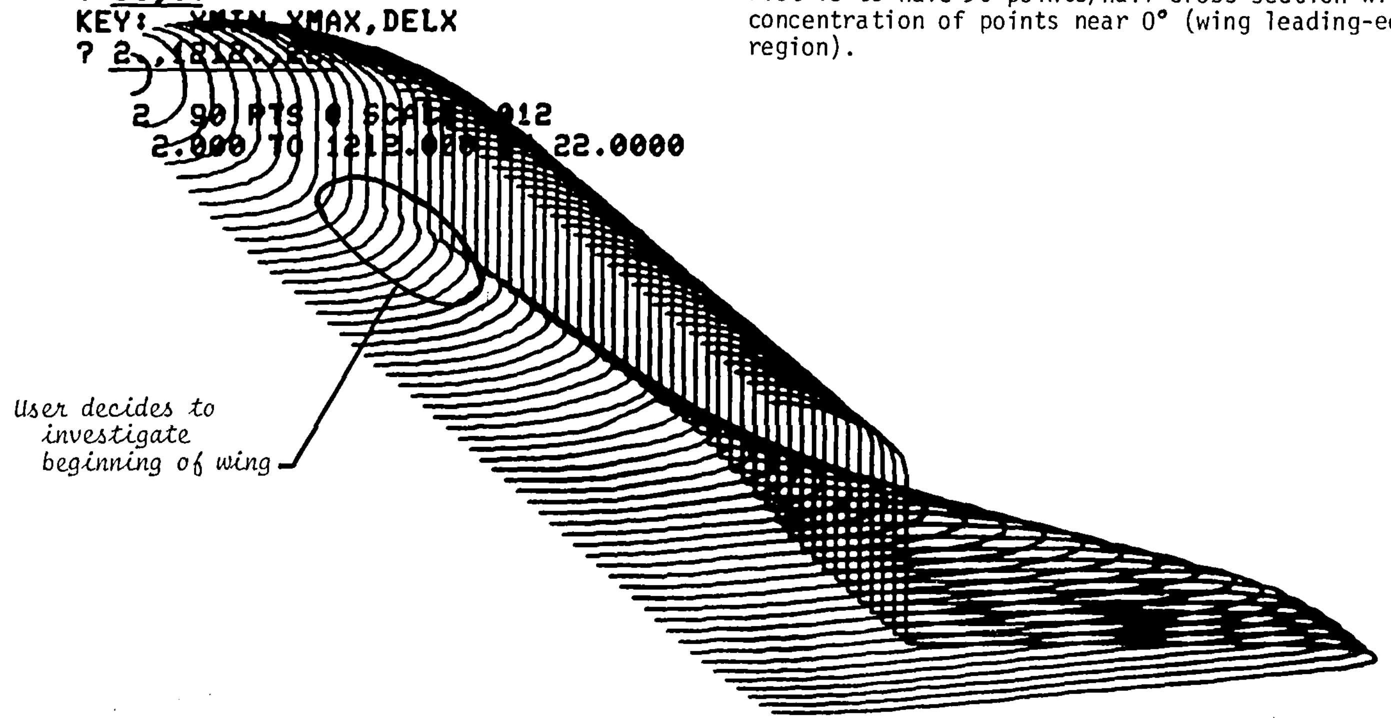
Figure 22.- Continued.

```
<HIT  <CR>  TO CONTINUE

HIT 0 TO STOP
    1 TO CHANGE PLOT TYPE
    2 FOR NEW X STATIONS
? 1
KEY: ITYPE, SCALE FACTOR
? 21,.012
KEY: # PTS/SIDE, CONCENTR ANGL
? 90,0.
KEY: XMIN XMAX,DELX
? 2.,1218.,22.

  2  90 PTS @ SCALE  .012
   2.000 TO 1218.000 BY 22.0000
```

Plot is to be of a different type

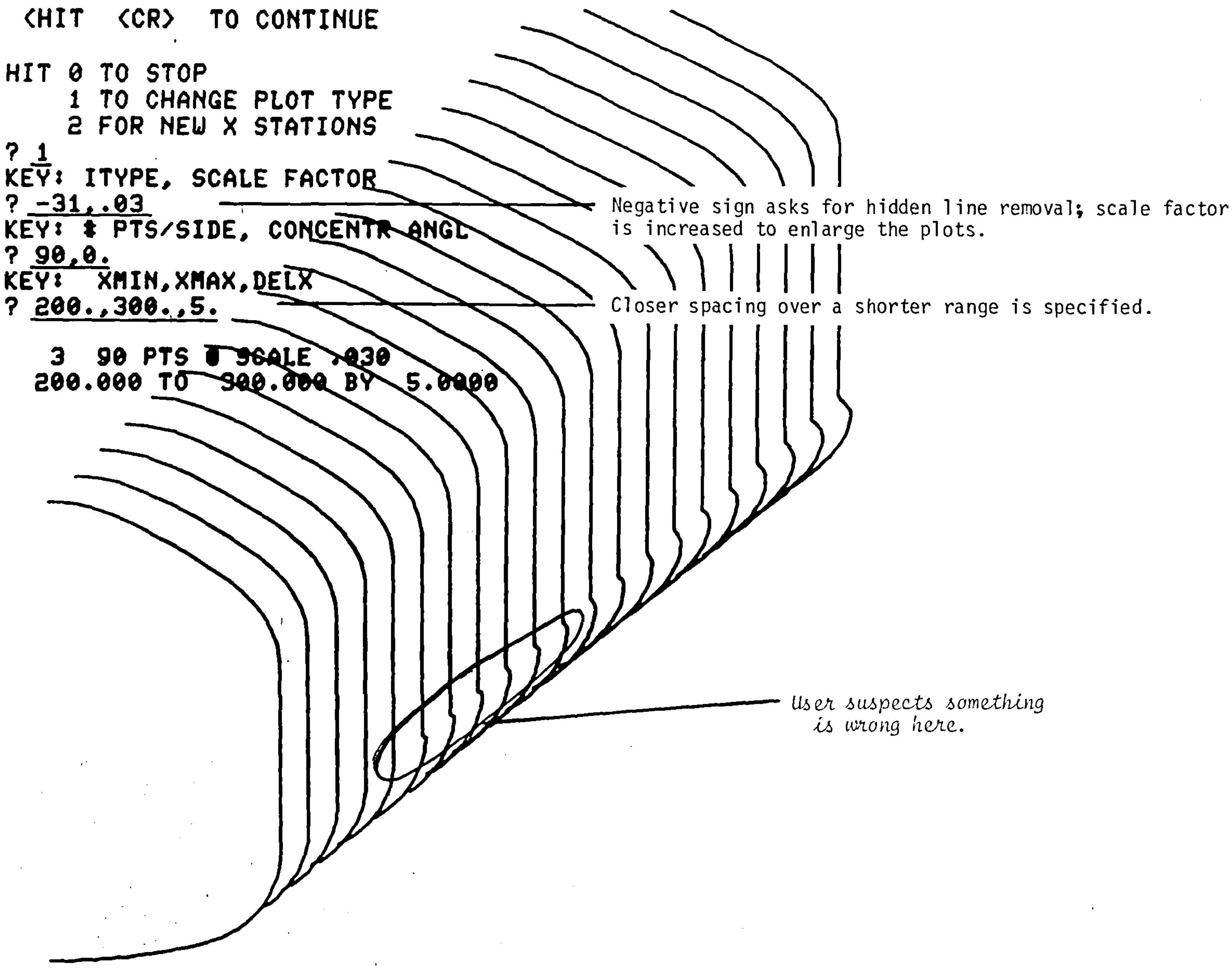
ITYPE 21 is one-sided lower oblique with all lines drawn.

Plot is to have 90 points/half cross section with concentration of points near 0° (wing leading-edge region).



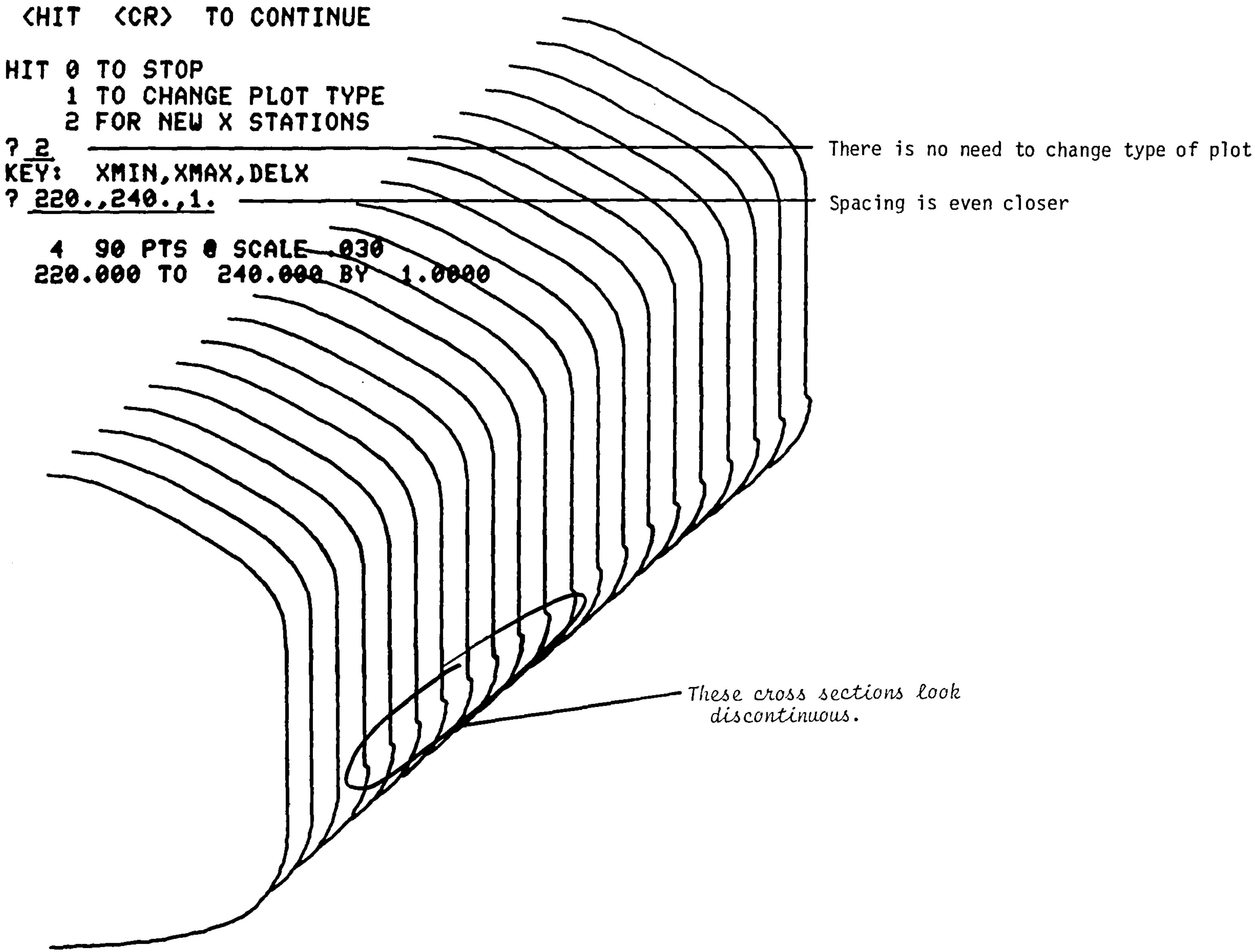
(c) Second plot: lower oblique view.

Figure 22.- Continued.



(d) Third plot: upper oblique near start of wing.

Figure 22.- Continued.



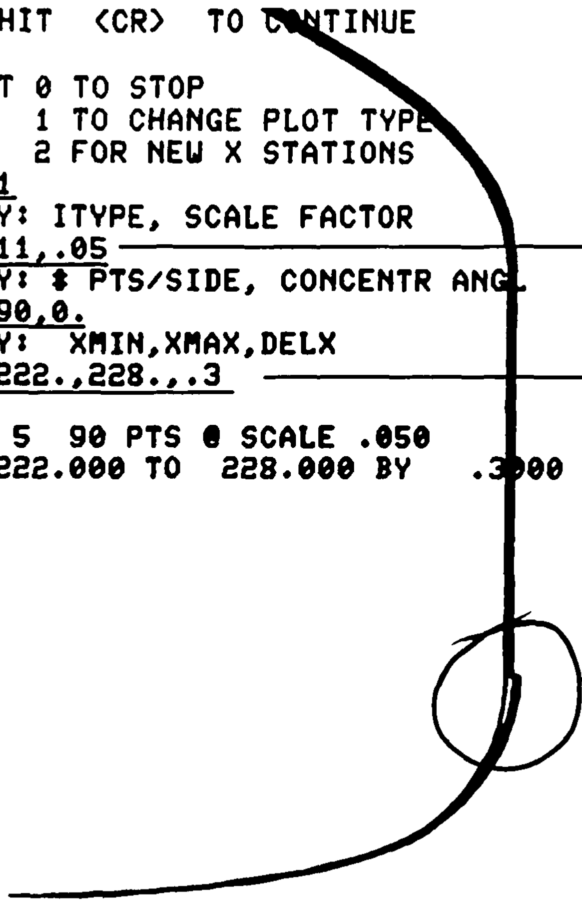
(e) Fourth plot: same as third, but closer spacing.

Figure 22.- Continued.

```
 <HIT  <CR>  TO CONTINUE

HIT 0 TO STOP
    1 TO CHANGE PLOT TYPE
    2 FOR NEW X STATIONS
? 1
KEY: ITYPE, SCALE FACTOR
? 11,.05
KEY: # PTS/SIDE, CONCENTR ANGL
? 90,0.
KEY:  XMIN,XMAX,DELX
? 222.,228.,.3

   5  90 PTS @ SCALE .050
  222.000 TO  228.000 BY   .3000
```

Change ITYPE back to front view; further increase the scale factor.

Very close spacing is specified.



A discontinuity here is obvious. Now look for the cause.

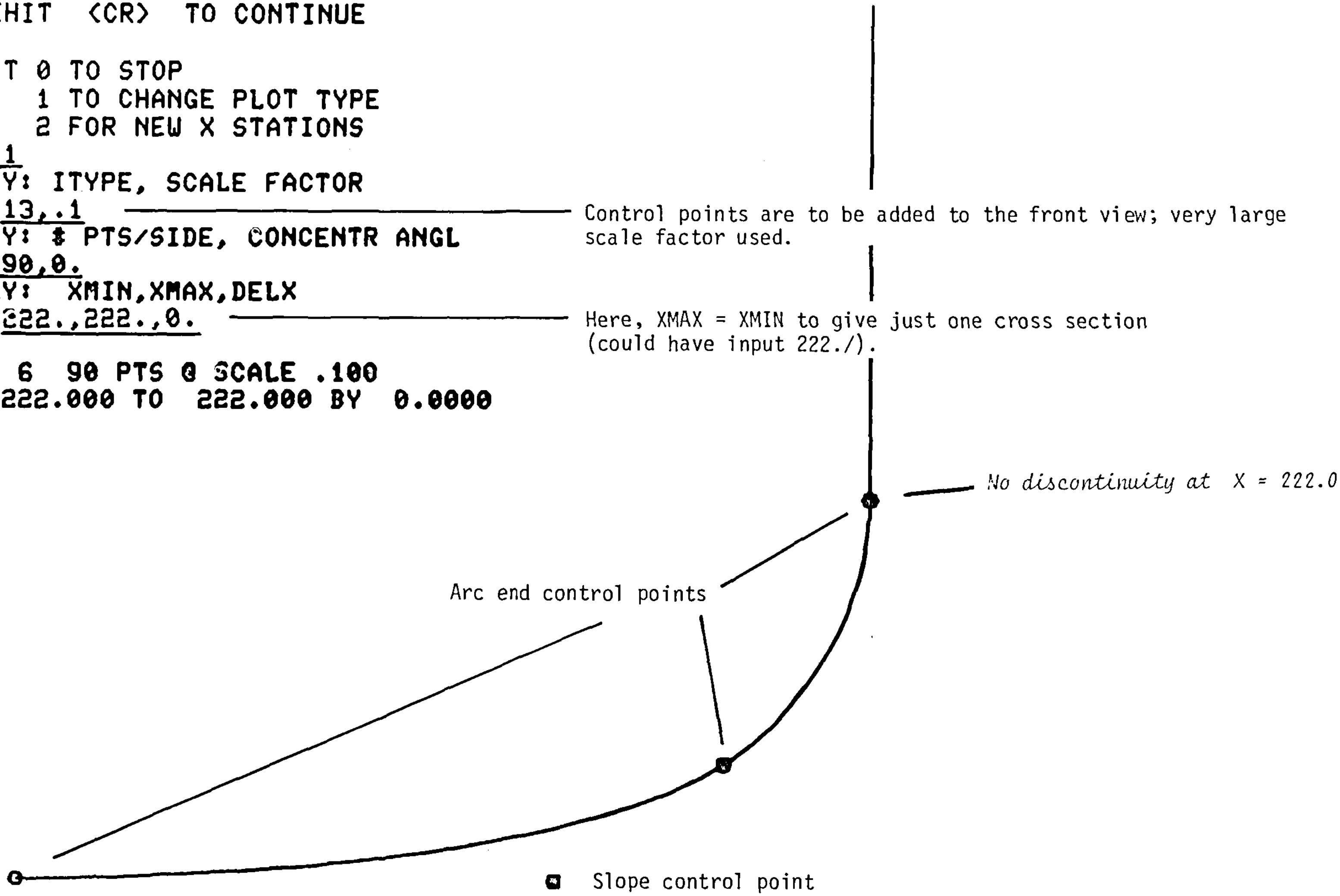
(f) Fifth plot: front view at start of wing.

Figure 22.- Continued.

```
 <HIT  <CR>  TO CONTINUE

HIT 0 TO STOP
    1 TO CHANGE PLOT TYPE
    2 FOR NEW X STATIONS
? 1
KEY: ITYPE, SCALE FACTOR
? 13,.1
KEY: # PTS/SIDE, CONCENTR ANGL
? 90,0.
KEY:  XMIN,XMAX,DELX
? 222.,222.,0.

   6  90 PTS @ SCALE .100
  222.000 TO  222.000 BY  0.0000
```

Control points are to be added to the front view; very large scale factor used.

Here, XMAX = XMIN to give just one cross section (could have input 222./).

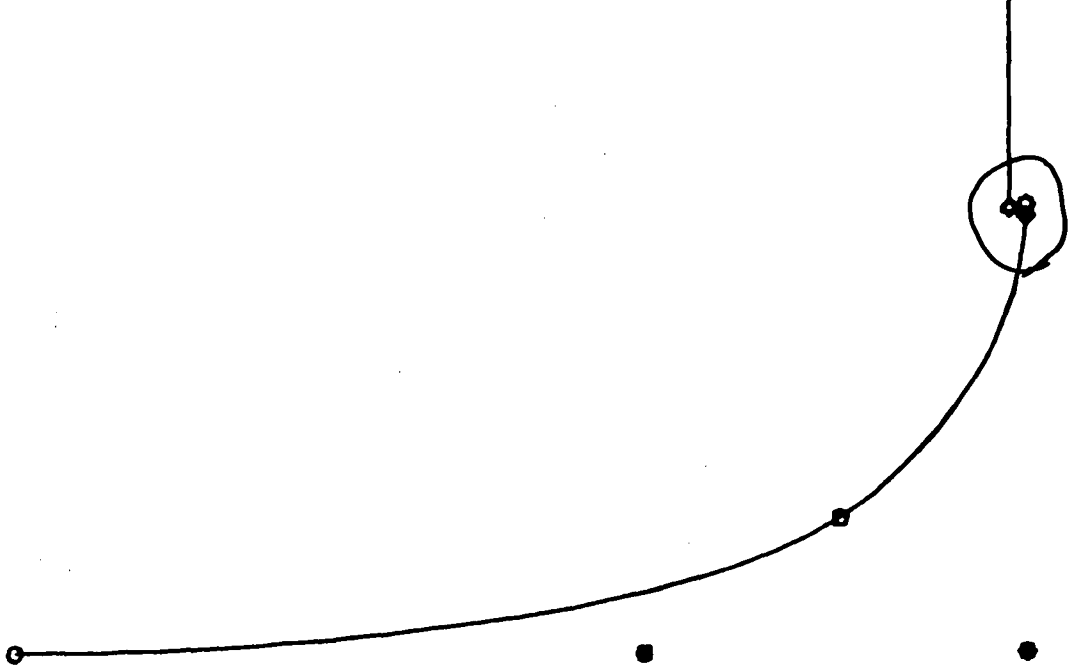


(g) Sixth plot: control points just before start of wing.

Figure 22.- Continued.

```
<HIT  <CR>  TO CONTINUE

HIT 0 TO STOP
    1 TO CHANGE PLOT TYPE
    2 FOR NEW X STATIONS
? 2
KEY:  XMIN,XMAX,DELX
? 223.,223.,0.

   7  90 PTS @ SCALE .100
  223.000 TO  223.000 BY  0.0000
```

Only the X station is to be changed.



These 3 points define a new arc beginning at X = 222., but one end point is misplaced. Which one is it?

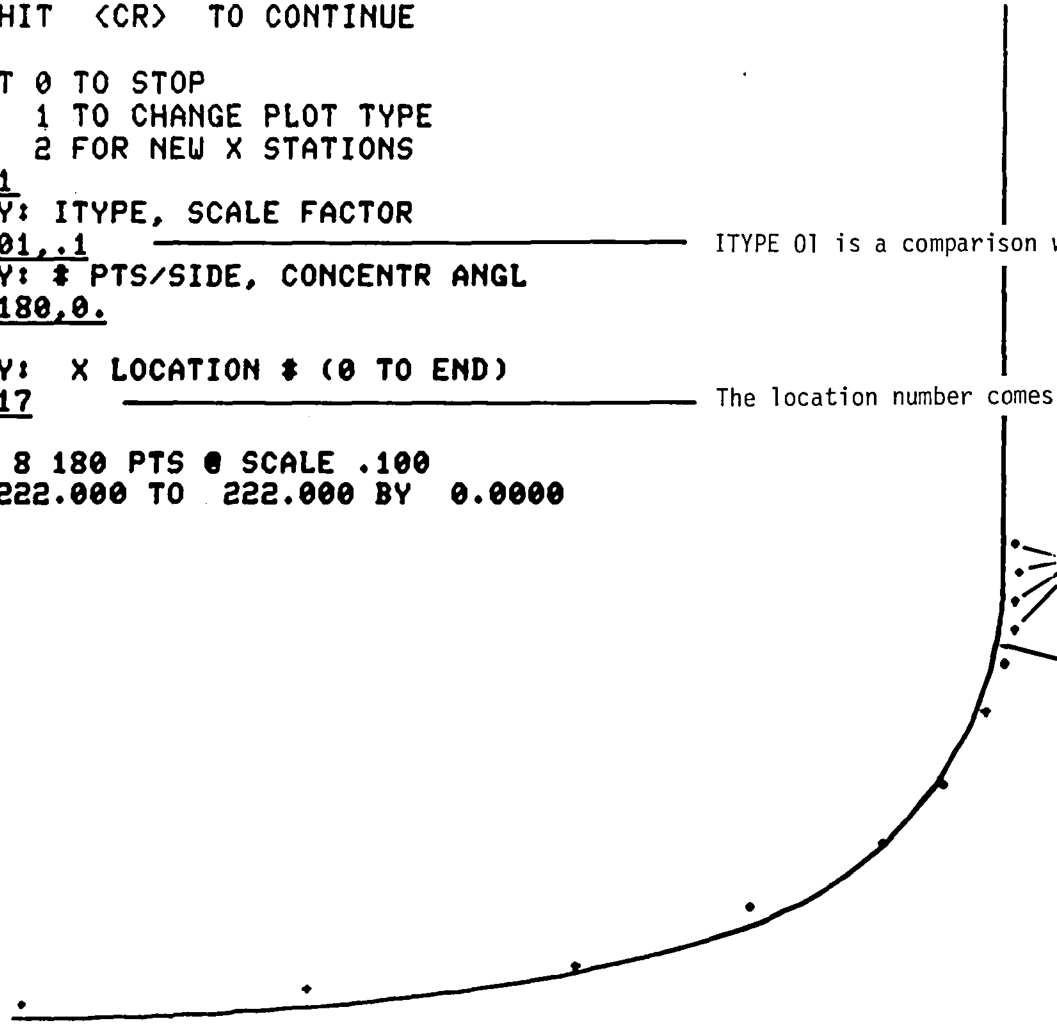
(h) Seventh plot: control points just after start of wing.

Figure 22.- Continued.

```
 <HIT  <CR>  TO CONTINUE

HIT 0 TO STOP
    1 TO CHANGE PLOT TYPE
    2 FOR NEW X STATIONS
? 1
KEY: ITYPE, SCALE FACTOR
? 01,.1
KEY: # PTS/SIDE, CONCENTR ANGL
? 180,0.

KEY:  X LOCATION # (0 TO END)
? 17

   8 180 PTS @ SCALE .100
  222.000 TO  222.000 BY  0.0000
```

ITYPE 01 is a comparison with original data.

The location number comes from the table in figure 19.



Data points.

Cross section is drawn inside the data points; therefore control point beginning the side (vertical line) in figure 22(h) needs to be moved outward.

(i) Eighth plot: comparison with data just before start of wing.

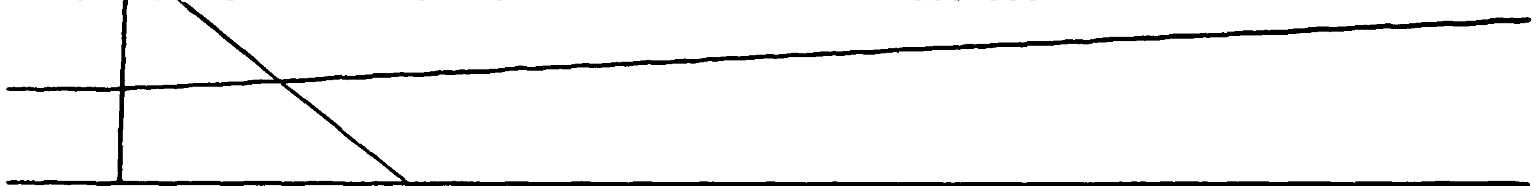
Figure 22.- Continued.

```
<HIT  <CR>  TO CONTINUE

KEY:  X LOCATION # (0 TO END)
? 0
```

No more comparisons with data are needed.

```
HIT 0 TO STOP
    1 TO CHANGE PLOT TYPE
    2 FOR NEW X STATIONS
? 1
KEY: ITYPE, SCALE FACTOR
? 5
? .05
KEY:  XMIN,XMAX,DELX
? 200.,500.,3.
KEY:  # OF BL'S,  & BL #'S
? 3, 5,14,18

    3 BODY LINES    101 POINTS   200.000 < X <  500.000
```

ITYPE 5 specifies body-line plots.
(Note that list-directed read asks again for scale factor.)

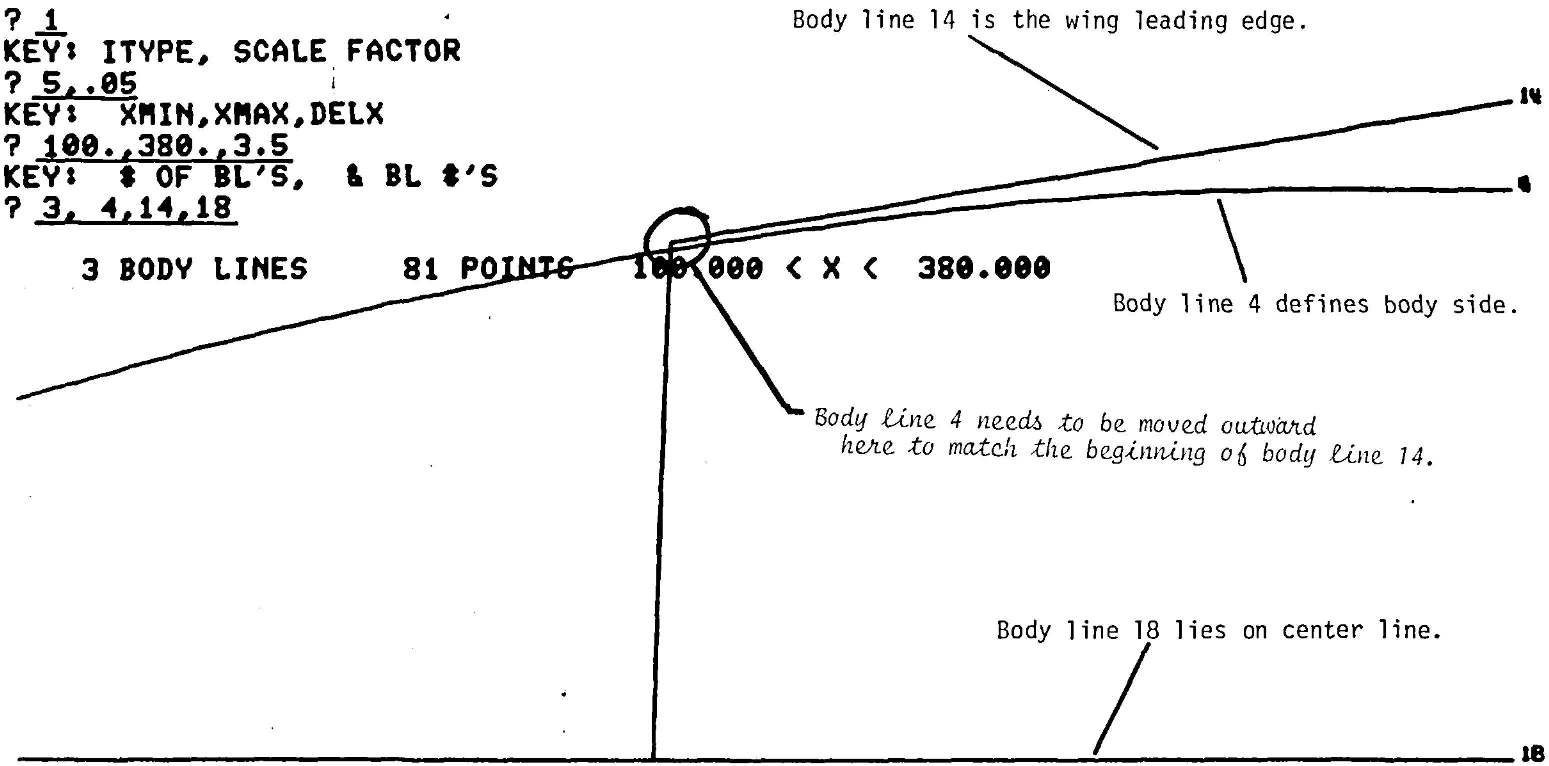


Asked for wrong body line and too large a region; will try again.

(j) Ninth plot: body lines near start of wing.

Figure 22.- Continued.

```
 <HIT  <CR>  TO CONTINUE

ADD MORE BL'S? Y/N
? N

HIT 0 TO STOP
    1 TO CHANGE PLOT TYPE
    2 FOR NEW X STATIONS
? 1
KEY: ITYPE, SCALE FACTOR
? 5,.05
KEY:  XMIN,XMAX,DELX
? 100.,380.,3.5
KEY:  # OF BL'S,  & BL #'S
? 3, 4,14,18
```



(k) Tenth plot: body-line error at start of wing.

Figure 22.- Continued.

```
<HIT  <CR>  TO CONTINUE

ADD MORE BL'S? Y/N
? N

HIT 0 TO STOP
    1 TO CHANGE PLOT TYPE
    2 FOR NEW X STATIONS
? 0
```

Session is complete.
User will revise QUICK input file to change location of body line 4.
After rerunning QUICK, the results can be checked by another session
with this QUICK Interactive Graphics Analysis program.

```
EXIT.
```

(1) End of session.

Figure 22.- Concluded.

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15. Supplementary Notes

16. Abstract

The advantages of using interactive computer graphics to display aircraft geometry to aid in detection and analysis of errors are described. The QUICK-geometry system is reviewed and the QUICK InterActive Graphics Analysis (QUIAGA) program is described. This QUIAGA program was developed to exercise the QUICK-geometry subroutines to examine the analytic definition of a configuration by plotting overall and detailed views in several modes on a graphics terminal. Its use in the detection and analysis of errors in the QUICK-geometry definition can be of great assistance in speedily arriving at a correct analytical geometry description for flow-field computation. Experience with the program in developing a QUICK-geometry model of the NASA Space Shuttle Orbiter is used to show some of its features. Appendixes giving details of program usage and an example session are included.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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