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Computer Program To Prepare Airfoil Characteristic Data for Use in Helicopter Performance Calculations

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SUMMARY

A computer program has been developed to prepare wind-tunnel-generated airfoil data for input into helicopter performance prediction programs. The program provides for numerically cross-plotting the data, plotting the data, and then tabulating and punching the tabulated result into computer cards for use in the government's rotorcraft flight simulation model.

INTRODUCTION

During the process of design and evaluation of rotors and rotor airfoils, it frequently becomes necessary to use experimentally derived airfoil characteristic data to predict helicopter performance. Performance predictions are usually accomplished through the use of helicopter performance programs such as the rotorcraft flight simulation model to calculate forward flight performance and the prescribed wake hover performance program to compute hover performance. (See refs. 1 and 2.) Generally, helicopter performance programs require airfoil characteristic data in a tabular format with angle of attack varying with Mach number. These programs generally require a uniform distribution of the coefficients at specified values of angle of attack and Mach number. This uniformity in distribution of data is rarely achievable in wind-tunnel testing; it is more efficient to test through a range of Mach number and angle of attack and then interpret the data at selected Mach numbers and angles of attack. This approach can result in a process of manually cross-plotting the data to prepare them for use in the performance programs.

The purpose of the current effort is to facilitate the preparation of the airfoil data from wind-tunnel experiments and to provide both plots of the data and punch card output for use in the performance programs. This purpose has been accomplished through the development of a computer program, entitled "PLTAERO," which is described in this report and is presented in the appendix.

SYMBOLS

c_d blade-element drag coefficient

c_l blade-element lift coefficient

c_m blade-element pitching-moment coefficient

c_n blade-element normal-force coefficient

M Mach number

R Reynolds number

α angle of attack, degrees

α_c angle of attack corrected for lift interference effects, degrees

ANALYSIS

The PLTAERO computer program provides for three functions: (1) numerically "cross-plotting" the wind-tunnel data to obtain values of c_l, c_d, and c_m at specified values of angle of attack and Mach number, (2) plotting the data as a function of both Mach number and angle of attack, and (3) tabulating and punching the data into computer cards for use in the performance programs. In accomplishing these functions, the computer program makes use of cubic-spline-under-tension subroutines for both the numerical cross-plotting and the data plots. References 3 and 4 give the theoretical background for these subroutines; the subroutines are unpublished but were written as part of the data-reduction computing package for the Langley V/STOL tunnel.

Numerical Cross-Plotting

The numerical cross-plotting is accomplished by four subroutines, each of which make use of the previously mentioned cubic-spline-under-tension technique to interpolate and extrapolate the input wind-tunnel data. The process requires three steps. The first step is to determine whether the wind-tunnel data fall within the minimum and maximum values of angle of attack and Mach number specified by PLTAERO and its input. The minimum angle of attack is required by the program to be -4°, and the maximum angle of attack is a function of Mach number and is specified by input. The second step in the numerical cross-plotting is to calculate the values of the airfoil characteristic data at the specified minimum and maximum angles of attack or Mach numbers. If the minimums and maximums fall within the range of the wind-tunnel data, a simple interpolation (using cubic splines under tension) is performed. If the minimums or the maximums fall outside the range of wind-tunnel data, then the cubic-spline-under-tension technique is used to calculate the slopes at the minimum and maximum points. After the slopes are calculated, a linear extrapolation of the curves is used to obtain values of the airfoil characteristic data at the specified "end" points. The third step in the process is an interpolation (using cubic splines under tension) to obtain the data at the specified angles of attack and Mach numbers.

The four subroutines applied are entitled "BOUND1," "BOUND2," "ADJUST1," and "ADJUST2." Subroutine BOUND1 calculates the airfoil characteristic data at the minimum and maximum angle of attack for each Mach number. Subroutine BOUND2 calculates the airfoil characteristic data at the minimum and maximum Mach numbers for each angle of attack. Subroutine ADJUST1 interpolates the data at specified angles of attack for each Mach number and subroutine ADJUST2 interpolates the data at specified Mach numbers for each angle of attack. The first and second steps of the cross-plotting take place in subroutines BOUND1 and BOUND2; the third step of the process takes place in subroutines ADJUST1 and ADJUST2.

Plotting of Data

The plotting of the coefficients takes place in two subroutines (P1 and P2). Plots are presented in two formats. The first format (produced by subroutine P1) presents the curves for c_l, c_d, and c_m as a function of Mach number for constant angle of attack as derived by BOUND1 and ADJUST1. Figures 1 to 4 are sample figures to illustrate the plotting formats of the computer program. They are all for a Wortmann FX69-H-098 airfoil with the data taken in the Langley 6- by 28-inch transonic tunnel. All the angles of attack are presented in one figure, as indicated by the example shown in figure 1. The second plotting format (produced by subroutine P2) presents the curves for c_l, c_d, and c_m as a function of angle of attack for constant Mach number. A separate curve for each Mach number is presented for the blade-element lift, drag, and pitching-moment coefficients as shown by the examples in figures 2, 3, and 4. Both subroutines make use of cubic splines under tension to fair the data. The data presented in figures 1, 2, 3, and 4 are based on the wind-tunnel data of reference 5.

Tabulating and Punching the Data

After the data have been plotted, they are presented in the format illustrated in table I. The information from table I is then "faired" into the internal table for an NACA 0012 airfoil of the rotorcraft flight simulation model (ref. 1). The table for the 0012 airfoil is included internal to PLTAERO. This inclusion is necessary because wind-tunnel tests do not generally include measurements at angles of attack from -180° to 180° (i.e., the range of values that might be experienced by a helicopter rotor blade as it travels around the hub).

The fairing is accomplished in the following manner: (1) Because values of c_l, c_d, and c_m at angles of attack less than -4° generally have little impact on performance, the coefficients in the reference tables at angles of attack less than -4° are left unchanged; (2) the values of c_l, c_d, and c_m for angles ranging from -4° to α_{max} (the maximum specified angle of attack at each specified Mach number) are replaced with corresponding values from table I; (3) values of c_l, c_d, and c_m for angles ranging from α_{max} to 21° are interpolated using TSPLINE; and (4) values of c_l, c_d, and c_m in the reference tables for angles of attack ranging from 21° to 180° are left unchanged. The resulting tables may be printed and punched in a format suitable for use with the rotorcraft flight simulation program. It is important to note that the plots generated by the PLTAERO program can be used to verify that the appropriate values have been inserted in the table. Any adjustments desired in the tabular data can be easily rectified by comparison with the plots.

RESULTS

Figure 5 is taken from reference 5 and shows the variation of c_n with angle of attack corrected for lift interference effects and c_d as a function of c_n. The blade-element lift coefficients used in the present report were calculated by using these normal-force coefficients with the corresponding drag coefficients of reference 5 to perform an axis rotation to define the lift coefficient. Comparison between these lift coefficients and the results of PLTAERO is presented in figure 6 as an example of program output. The card input guide is presented in table II.

CONCLUDING REMARKS

A computer program has been developed to facilitate the preparation of airfoil data for input into helicopter performance prediction programs. The program provides for numerically cross-plotting the data, plotting the data, and then tabulating and punching the tabulated results into computer cards for use in the government's rotorcraft flight simulation model.

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APPENDIX

COMPUTER PROGRAM TO PREPARE AIRFOIL DATA FOR USE IN HELICOPTER PERFORMANCE PROGRAMS

The computer program PLTAERO is written in the Langley FORTRAN Extended Version 4, or FTN 4, and has been used on the Control Data series 6000 and CYBER 175 computer systems under the NOS system. The subroutines and their uses are presented in table III. Figure 7 is a diagram of the program structure. Basic plotting subroutines, such as those for drawing axes and annotation, are supplied from the Langley graphics output system; similar routines are assumed to be available to the general programing community. PLTAERO requires 77400 octal storage locations and takes about 4 seconds to compile. Each case takes about 20 seconds to execute on the CYBER 175 computer.

Subroutine TSPLINE

Subroutine TSPLINE performs two functions in PLTAERO; it interpolates curves at specified values and it calculates the first derivatives of curves at specified values. Inputs to TSPLINE include the x- and y-coordinates of the curve (x must be strictly increasing), the number of input points, a tension parameter (set to 10 in PLTAERO), a computing option, the number of points to be interpolated, and the x values at which interpolated values are desired. Outputs from TSPLINE include the interpolated values along with their first and second derivatives and the area under the curve defined by the input x- and y-coordinates.

Computer Program

The computer program PLTAERO used to prepare airfoil data for use in helicopter performance programs is presented as follows.

```
      PROGRAM DECKPL(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,PUNCH)      MOD1       1
      COMMON /ONE/ XMN(30),PMN(30),AA(30,30),PAA(30),CL(30,30),CD(30,30)PLTAERO   2
     1,CPM(30,30),XTEMP(65),YTEMP(65),B(65),XI(65),YI(65),YP(65),YPP(65)MOD1     2
     2,XNA(30),XNMN(30),HEAD(30),BOTTOM(30),XNAT(30),XNMNT(30)          PLTAERO   4
     3,NAMAX,NMMAX                                                      MOD2      1
      COMMON/HLM/TENR,XINT,ST                                           PLTAERO   6
      DIMENSION XX(5)                                                   PLTAERO   7
      CALL PSEUDO                                                       PLTAERO   8
      CALL LEROY                                                        PLTAERO   9
      CALL CALPLT(0.,0.,-3)                                             PLTAERO  10
      ST=10.                                                            PLTAERO  14
      TENR=ST                                                           PLTAERO  15
      WRITE(6,900)                                                      MOD1      3
  900 FORMAT(29X,22HINPUT DATA CARD IMAGES)                             MOD1      4
      READ(5,107)NAMAX,NMMAX                                            MOD2      2
      WRITE(6,107)NAMAX,NMMAX                                           MOD2      3
      READ(5,107) KA,KB,KC                                              MOD2      4
      WRITE(6,107)KA,KB,KC                                              MOD2      5
      READ(5,107) LA,LB,LC                                              MOD2      6
      WRITE(6,107) LA,LB,LC                                             MOD2      7
      READ(5,107) MA,MB,MC                                              MOD2      8
      WRITE(6,107)MA,MB,MC                                              MOD2      9
  107 FORMAT(3I5)                                                       MOD2     10
      READ(5,100) (XNMN(I),I=1,NAMAX)                                   PLTAERO  18
      WRITE(6,207)(XNMN(I),I=1,NAMAX)                                   PLTAERO  19
      READ(5,100)(XNA(I),I=1,NMMAX)                                     MOD2     11
      WRITE(6,207)(XNA(I),I=1,NMMAX)                                    MOD2     12
      READ(5,100)(XNAT(I),I=1,NMMAX)                                    MOD2     13
      WRITE(6,207)(XNAT(I),I=1,NMMAX)                                   MOD2     14
      READ(5,100)(XMN(I),I=1,NMMAX)                                     MOD2     15
      WRITE(6,207)(XMN(I),I=1,NMMAX)                                    MOD2     16
      READ(5,100) (PMN(I),I=1,NMMAX)                                    MOD2     17
      WRITE(6,207)(PMN(I),I=1,NMMAX)                                    MOD2     18
      READ(5,100) (PAA(I),I=1,NAMAX)                                    MOD2     19
      WRITE(6,207)(PAA(I),I=1,NAMAX)                                    MOD2     20
      DO 200 I=1,NMMAX                                                  MOD2     21
      M=XNAT(I)                                                         PLTAERO  27
      READ(5,100)(AA(I,J),J=1,M)                                        PLTAERO  28
      WRITE(6,207)(AA(I,J),J=1,M)                                       PLTAERO  29
      READ(5,100)(CL(I,J),J=1,M)                                        PLTAERO  30
      WRITE(6,207)(CL(I,J),J=1,M)                                       PLTAERO  31
      READ(5,100)(CD(I,J),J=1,M)                                        PLTAERO  32
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      WRITE(6,207)(CD(I,J),J=1,M)                                       PLTAERO   33
      READ(5,100)(CPM(I,J),J=1,M)                                       PLTAERO   34
      WRITE(6,207)(CPM(I,J),J=1,M)                                      PLTAERO   35
  200 CONTINUE                                                          PLTAERO   36
      READ(5,103)(HEAD(J),J=1,3)                                        PLTAERO   37
      WRITE(6,103)(HEAD(J),J=1,3)                                       PLTAERO   38
      READ(5,103)(BOTTOM(J),J=1,3)                                      PLTAERO   39
      WRITE(6,103)(BOTTOM(J),J=1,3)                                     PLTAERO   40
      CALL BOUND1(CL)                                                   *******    1
      CALL BOUND1(CD)                                                   *******    2
      CALL BOUND1(CPM)                                                  *******    3
      CALL ADJUST1(CL)                                                  *******    4
      CALL ADJUST1(CD)                                                  *******    5
      CALL ADJUST1(CPM)                                                 *******    6
      CALL BOUND2(CL)                                                   *******    7
      CALL ADJUST2(CL)                                                  *******    8
      CALL BOUND2(CD)                                                   *******    9
      CALL ADJUST2(CD)                                                  *******   10
      CALL BOUND2(CPM)                                                  *******   11
      CALL ADJUST2(CPM)                                                 *******   12
      IF(KA.EQ.0)GO TO 400                                              MOD2      22
      CALL P1(CL,6.,24.,-.6,.1,16HLIFT COEFFICIENT,16,2.,1.,5.125,23.,  PLTAERO   53
     14.5,24.,5.625,23.5,4.875,22.5,4.875,22.,17.)                      PLTAERO   54
  400 CONTINUE                                                          MOD2      23
      IF(KB.EQ.0)GO TO 500                                              MOD2      24
      CALL P1(CD,0.,20.,0.,.01,16HDRAG COEFFICIENT,16,2.,1.,5.5,23.,5.25PLTAERO   55
     1,24.,6.,23.5,5.25,22.5,5.25,22.,19.)                              PLTAERO   56
  500 CONTINUE                                                          MOD2      25
      IF(KC.EQ.0)GO TO 600                                              MOD2      26
      CALL P1(CPM,10.,20.,-.2,.02,27HPITCHING MOMENT COEFFICIENT,27,1., PLTAERO   57
     1.5,4.875,23.,4.,24.,5.375,23.5,4.625,22.5,4.625,22.,9.)           PLTAERO   58
  600 CONTINUE                                                          MOD2      27
      IF(LA.EQ.0)GO TO 700                                              MOD2      28
      CALL P2(CL,.1,16HLIFT COEFFICIENT,16,0.,0.)                       PLTAERO   59
  700 CONTINUE                                                          MOD2      29
      IF(LB.EQ.0)GO TO 800                                              MOD2      30
      CALL P2(CD,.01,16HDRAG COEFFICIENT,16,0.,0.)                      PLTAERO   60
  800 CONTINUE                                                          MOD2      31
      IF(LC.EQ.0)GO TO 1000                                             MOD2      32
      CALL P2(CPM,.02,27HPITCHING MOMENT COEFFICIENT,27,10.,-.2)        PLTAERO   61
 1000 CONTINUE                                                          MOD2      33
      WRITE(6,141)                                                      PLTAERO   62
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      WRITE(6,142)(PMN(I),I=1,NMMAX)                            MOD2       34
      DO 143 J = 1,NAMAX                                        PLTAERO    64
      NNMN=XNMN(J)                                              PLTAERO    65
      WRITE(6,144)PAA(J),(CL(I,J),I=1,NNMN)                     PLTAERO    66
  143 CONTINUE                                                  PLTAERO    67
      WRITE(6,145)                                              PLTAERO    68
      WRITE(6,142)(PMN(I),I=1,NMMAX)                            MOD2       35
      DO 146 J = 1,NAMAX                                        PLTAERO    70
      NNMN=XNMN(J)                                              PLTAERO    71
      WRITE(6,144)PAA(J),(CD(I,J),I=1,NNMN)                     PLTAERO    72
  146 CONTINUE                                                  PLTAERO    73
      WRITE(6,147)                                              PLTAERO    74
      WRITE(6,142)(PMN(I),I=1,NMMAX)                            MOD2       36
      DO 148 J = 1,NAMAX                                        PLTAERO    76
      NNMN=XNMN(J)                                              PLTAERO    77
      WRITE(6,144)PAA(J),(CPM(I,J),I=1,NNMN)                    PLTAERO    78
  148 CONTINUE                                                  PLTAERO    79
      IF(MA.EQ.0)GO TO 1100                                     MOD2       37
      CALL C81(CL,-1)                                           PLTAERO    80
 1100 CONTINUE                                                  MOD2       38
      IF(MB.EQ.0)GO TO 1200                                     MOD2       39
      CALL C81(CD,0)                                            PLTAERO    81
 1200 CONTINUE                                                  MOD2       40
      IF(MC.EQ.0)GO TO 1300                                     MOD2       41
      CALL C81(CPM,1)                                           PLTAERO    82
 1300 CONTINUE                                                  MOD2       42
      CALL NFRAME(300.,0.)                                      PLTAERO    83
      CALL CALPLT(0.,0.,999)                                    PLTAERO    84
  100 FORMAT(8F10.0)                                            PLTAERO    85
  103 FORMAT(3A10)                                              PLTAERO    86
  142 FORMAT(9X,13F8.4)                                         PLTAERO    87
  144 FORMAT(14F8.4)                                            PLTAERO    88
  141 FORMAT(//,58X,16HLIFT COEFFICIENT)                        PLTAERO    89
  145 FORMAT(//,58X,16HDRAG COEFFICIENT)                        PLTAERO    90
  147 FORMAT(//,53X,27HPITCHING MOMENT COEFFICIENT)             PLTAERO    91
  207 FORMAT(8F10.4)                                            PLTAERO    92
      STOP                                                      PLTAERO    93
      END                                                       PLTAERO    94
```

```
      SUBROUTINE BOUND1(CX)                                             *******    13
      COMMON /ONE/ XMN(30),PMN(30),AA(30,30),PAA(30),CL(30,30),CD(30,30)PLTAERO    96
     1,CPM(30,30),XTEMP(65),YTEMP(65),B(65),XI(65),YI(65),YP(65),YPP(65)MOD1        8
     2,XNA(30),XNMN(30),HEAD(30),BOTTOM(30),XNAT(30),XMMNT(30)          PLTAERO    98
     3,NAMAX,NMMAX                                                      MOD2       43
      COMMON/HLM/TENR,XINT,ST                                           PLTAERO   100
      DIMENSION CX(30,30)                                               PLTAERO   101
      DO 100 I=1,NMMAX                                                  MOD2       44
      M = XNAT(I)                                                       PLTAERO   103
      M2 = XNA(I)                                                       PLTAERO   104
      DO 101 J=1,M                                                      PLTAERO   105
      XTEMP(J) = AA(I,J)                                                PLTAERO   106
      YTEMP(J) = CX(I,J)                                                PLTAERO   107
      XI(J) = AA(I,J)                                                   PLTAERO   108
C     WRITE(6,200)XTEMP(J),YTEMP(J),XI(J)                               PLTAERO   109
  101 CONTINUE                                                          PLTAERO   110
      CALL TSPLINE(XTEMP,YTEMP,M,B,ST,1,M,XI,YI,YP,YPP,XINT)            PLTAERO   111
      CX(I,1) = (PAA(1) - AA(I,1))*YP(1) + CX(I,1)                      PLTAERO   112
      CX(I,M) = (PAA(M2) - AA(I,M))*YP(M) + CX(I,M)                     PLTAERO   113
  100 CONTINUE                                                          PLTAERO   114
  200 FORMAT(3F10.4)                                                    PLTAERO   115
      RETURN                                                            PLTAERO   116
      END                                                               PLTAERO   117
```

```
      SUBROUTINE ADJUST1(CX)                                             *******      14
      COMMON /ONE/ XMN(30),PMN(30),AA(30,30),PAA(30),CL(30,30),CD(30,30)PLTAERO     119
     1,CPM(30,30),XTEMP(65),YTEMP(65),B(65),XI(65),YI(65),YP(65),YPP(65)MCD1          9
     2,XNA(30),XNMN(30),HEAD(30),BOTTIM(30),XMAT(30),XNMNT(30)           PLTAERO     121
     3,NAMAX,NMMAX                                                       MOD2         45
      COMMON/HLM/TENR,XINT,ST                                            PLTAERO     123
      DIMENSION CX(30,30)                                                PLTAERO     124
      DO 100 I=1,NMMAX                                                   MOD2         46
      M = XNAT(I)                                                        PLTAERO     126
      M2 = XNA(I)                                                        PLTAERO     127
      AA(I,1) = PAA(1)                                                   PLTAERO     128
      AA(I,M) = PAA(M2)                                                  PLTAERO     129
      DO 101 J=1,M                                                       PLTAERO     130
      XTEMP(J) = AA(I,J)                                                 PLTAERO     131
      YTEMP(J) = CX(I,J)                                                 PLTAERO     132
C     WRITE(6,200) XTEMP(J),YTEMP(J)                                     PLTAERO     133
  101 CONTINUE                                                           PLTAERO     134
      DO 103 K = 1,M2                                                    PLTAERO     135
      XI(K) = PAA(K)                                                     PLTAERO     136
  103 CONTINUE                                                           PLTAERO     137
      CALL TSPLINF(XTEMP,YTEMP,M,B,ST,1,M2,XI,YI,YP,YPP,XINT)            PLTAERO     138
      DO 102 J = 1,M2                                                    PLTAERO     139
      CX(I,J) = YI(J)                                                    PLTAERO     140
C     WRITE(6,200) XI(J),CX(I,J)                                         PLTAERO     141
  102 CONTINUE                                                           PLTAERO     142
  100 CONTINUE                                                           PLTAERO     143
  200 FORMAT(3F10.4)                                                     PLTAERO     144
      RETURN                                                             PLTAERO     145
      END                                                                PLTAERO     146
```

```
      SUBROUTINE P1(CX,YMS,LCS,VOCS,SFX,BCD,NC,TMAJ,TMIN,X1,Y1,X2,Y2,X3,PLTAERO     147
     1Y3,X4,Y4,X5,Y5,YXI)                                               PLTAERO     148
      COMMON /ONE/ XMN(30),PMN(30),AA(30,30),PAA(30),CL(30,30),CD(30,30)PLTAERO     149
     1,CPM(30,30),XTEMP(65),YTEMP(65),B(65),XI(65),YI(65),YP(65),YPP(65)MOD1         10
     2,XMA(30),XMMN(30),HEAD(30),BOTTOM(30),XNAT(30),XNMNT(30)          PLTAERO     151
     3,NAMAX,NMMAX                                                      MOD2         47
      COMMON/HLM/TENR,XINT,ST                                           PLTAERO     153
      DIMENSION CX(30,30),BCD(30),XX(5)                                 PLTAERO     154
      CALL AXES(0.,YMS,0.,10.,0.,.1,1.,0.,11HMACH NUMBER,.25,-11)       PLTAERO     155
      CALL AXES(0.,0.,90.,LCS,VOCS,SFX,TMAJ,TMIN,BCD(1),.25,NC)         PLTAERO     156
      CALL NOTATE(X1,Y1,.125,11HMACH NUMBER,0.,11)                      PLTAERO     157
      CALL NOTATE(X2,Y2,.125,BCD(1),0.,NC)                              PLTAERO     158
      CALL NOTATE(X3,Y3,.125,3HVS.,0.,3)                                PLTAERO     159
      CALL NOTATE(X4,Y4,.125,HEAD(1),0.,30)                             PLTAERO     160
      CALL NOTATE(X5,Y5,.125,BOTTOM(1),0.,30)                           PLTAERO     161
      CALL NOTATE(X4,21.5,.125,29HINTERPOLATED TO SELECTED MACH,0.,29)  PLTAERO     162
      CALL NOTATE(X4,21.,.125,28HNUMBERS AND ANGLES OF ATTACK,0.,28)    PLTAERO     163
      NO=1                                                              PLTAERO     164
      CALL CALPLT(0.,YMS,-3)                                            PLTAERO     165
      YX= YXI                                                           PLTAERO     166
      CALL NOTATE(10.,YX,.125,28,0.,-1)                                 PLTAERO     167
      CALL NOTATE(11.5,YX,.125,4HSYM.,0.,4)                             PLTAERO     168
      DO 100 J = 1,NAMAX                                                PLTAERO     169
      YX = YX -.25                                                      PLTAERO     170
      NMMN=XMMN(J)                                                      PLTAERO     171
      DO 200 I=1,NMMN                                                   PLTAERO     172
      XTEMP(I)=10.*PMN(I)                                               PLTAERO     173
      YTEMP(I) = CX(I,J)/SFX                                            PLTAERO     174
C     WRITE(6,300) XTEMP(I),YTEMP(I)                                    PLTAERO     175
  200 CONTINUE                                                          PLTAERO     176
      CALL CURPLT(XTEMP,YTEMP,NMMN,NO,1,2,J)                            PLTAERO     177
      CALL NUMBER(10.,YX,.125,PAA(J),0.,2)                              PLTAERO     178
      XY= YX-.0625                                                      PLTAERO     179
      CALL PNTPLT(11.5,YX,NO,1)                                         PLTAERO     180
      NO = NO + 1                                                       PLTAERO     181
  100 CONTINUE                                                          PLTAERO     182
  300 FORMAT(2F10.4)                                                    PLTAERO     183
      CALL NFRAME(25.,0.)                                               PLTAERO     184
      RETURN                                                            PLTAERO     185
      END                                                               PLTAERO     186
```

```
      SUBROUTINE BOUND2(CX)                                             *******       15
      COMMON /ONE/ XMN(30),PMN(30),AA(30,30),PAA(30),CL(30,30),CD(30,30)PLTAERO      188
     1,CPM(30,30),XTEMP(65),YTEMP(65),B(65),XI(65),YI(65),YP(65),YPP(65)MOD1          11
     2,XNA(30),XNMN(30),HEAD(30),BOTTOM(30),XNAT(30),XNMNT(30)          PLTAERO      190
     3,NAMAX,NMMAX                                                      MOD2          48
      COMMON/HLM/TENP,XINT,ST                                           PLTAERO      192
      DIMENSION CX(30,30),XX(5)                                         PLTAERO      193
      DO 100 J = 1,NAMAX                                                PLTAERO      194
      NNMN = XNMN(J)                                                    PLTAERO      195
      DO 200 I=1,NNMN                                                   PLTAERO      196
      XTEMP(I) = XMN(I)                                                 PLTAERO      197
      YTEMP(I) = CX(I,J)                                                PLTAERO      198
      XI(I) = XMN(I)                                                    PLTAERO      199
C     WRITE(6,300) XTEMP(I),YTEMP(I),XI(I)                              PLTAERO      200
  200 CONTINUE                                                          PLTAERO      201
      CALL TSPLINE(XTEMP,YTEMP,NNMN,B,ST,1,NNMN,XI,YI,YP,YPP,XINT)      PLTAERO      202
      CX(1,J) = (PMN(1) - XMN(1))*YP(1) + CX(1,J)                       PLTAERO      203
      CX(NNMN,J) =(PMN(NNMN) - XMN(NNMN))*YP(NNMN) + CX(NNMN,J)         PLTAERO      204
      XMN(1) = PMN(1)                                                   PLTAERO      205
      XMN(NNMN)= PMN(NNMN)                                              PLTAERO      206
  100 CONTINUE                                                          PLTAERO      207
  300 FORMAT(3F10.4)                                                    PLTAERO      208
      RETURN                                                            PLTAERO      209
      END                                                               PLTAERO      210
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      SUBROUTINE ADJUST2(CX)                                            *******      16
      COMMON /ONE/ XMN(30),PMN(30),AA(30,30),PAA(30),CL(30,30),CD(30,30)PLTAERO     212
     1,CPM(30,30),XTEMP(65),YTEMP(65),B(65),XI(65),YI(65),YP(65),YPP(65)MOD1         12
     2,XNA(30),XNMN(30),HEAD(30),BOTTOM(30),XNAT(30),XNMNT(30)          PLTAERO     214
     3,NAMAX,NMMAX                                                      MOD2         49
      COMMON/HLM/TENR,XINT,ST                                           PLTAERO     216
      DIMENSION CX(30,30),XX(5)                                         PLTAERO     217
      DO 100 J = 1,NAMAX                                                PLTAERO     218
      NNMN = XNMN(J)                                                    PLTAERO     219
      XMN(1) = PMN(1)                                                   PLTAERO     220
      XMN(NNMN) = PMN(NNMN)                                             PLTAERO     221
      DO 200 I=1,NNMN                                                   PLTAERO     222
      XTEMP(I) = XMN(I)                                                 PLTAERO     223
      YTEMP(I) = CX(I,J)                                                PLTAEPO     224
C     WRITE(6,300) XTEMP(I),YTEMP(I)                                    PLTAERO     225
  200 CONTINUE                                                          PLTAERO     226
      DO 203 I = 1,NNMN                                                 PLTAERO     227
      XI(I) = PMN(I)                                                    PLTAERO     223
C     WRITE(6,300) XI(I)                                                PLTAERO     229
  203 CONTINUE                                                          PLTAERO     230
      CALL TSPLINE(XTEMP,YTEMP,NNMN,B,ST,1,NNMN,XI,YI,YP,YPP,XINT)      PLTAERO     231
      DO 400 I = 1,NNMN                                                 PLTAERO     232
      CX(I,J) = YI(I)                                                   PLTAERO     233
  400 CONTINUE                                                          PLTAERO     234
  100 CONTINUE                                                          PLTAERO     235
  300 FORMAT(3F10.4)                                                    PLTAERO     236
      RETURN                                                            PLTAERO     237
      END                                                               PLTAERO     238
```

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      SUBROUTINE P2(CX,SFX,BCD,NC,YHS,VO)                              PLTAERO   239
      COMMON /ONE/ XMN(30),PMN(30),AA(30,30),PAA(30),CL(30,30),CD(30,30)PLTAERO   240
     1,CPM(30,30),XTEMP(65),YTEMP(65),B(65),XI(65),YI(65),YP(65),YPP(65)MOD1       13
     2,XNA(30),XNMN(30),HEAD(30),BOTTOM(30),XNAT(30),XNMNT(30)         PLTAERO   242
     3,NAMAX,NMMAX                                                     MOD2       50
      COMMON/HLM/TENR,XINT,ST                                          PLTAERO   244
      DIMENSION CX(30,30),BCD(NC)                                      PLTAERO   245
      NO = 1                                                           PLTAERO   246
      DO 100 I=1,NMMAX                                                 MOD2       51
      M = XNA(I)                                                       PLTAERO   248
      CALL NFRAME(25.,0.)                                              PLTAERO   249
      CALL AXES(4.,0.,90.,20.,VO,SFX,2.,1.,BCD(1),.25,NC)              PLTAERO   250
      CALL AXES(0.,YHS,0.,20.,-4.,1.,2.,1.,15HANGLE OF ATTACK,.25,-15) PLTAERO   251
      CALL NOTATE(7.75,24.,.125,BCD(1),0.,NC)                          PLTAERO   252
      CALL NOTATE(8.25,23.5,.125,3HVS.,0.,3)                           PLTAERO   253
      CALL NOTATE(7.625,23.,.125,15HANGLE OF ATTACK,0.,15)             PLTAERO   254
      CALL NOTATE(7.825,22.5,.125,HEAD(1),0.,30)                       PLTAERO   255
      CALL NOTATE(7.825,22.,.125,BOTTOM(1),0.,30)                      PLTAERO   256
      CALL NOTATE(7.825,20.5,.125,29HINTERPOLATED TO SELECTED MACH,0.,29PLTAERO   257
     1)                                                                PLTAERO   258
      CALL NOTATE(7.825,20.,.125,28HNUMBERS AND ANGLES OF ATTACK,0.,28) PLTAERO   259
      CALL NOTATE(7.825,19.5,.125,13HMACH NUMBER =,0.,13)              PLTAERO   260
      CALL NUMBER(9.625,19.0,.125,PMN(I),0.,3)                         PLTAERO   261
      DO 200 J=1,M                                                     PLTAERO   262
      XTEMP(J) = PAA(J) + 4.                                           PLTAERO   263
      YTEMP(J) = (CX(I,J)/SFX) + YHS                                   PLTAERO   264
C     WRITE(6,300) XTEMP(J),YTEMP(J)                                   PLTAERO   265
  200 CONTINUE                                                         PLTAERO   266
      CALL CURPLT(XTEMP,YTEMP,M,NO,1,2,I)                              PLTAERO   267
      NO = NO + 1                                                      PLTAERO   268
  100 CONTINUE                                                         PLTAERO   269
  300 FORMAT(2F10.4)                                                   PLTAERO   270
      PAA(1) = -4.                                                     PLTAERO   271
      RETURN                                                           PLTAERO   272
      END                                                              PLTAERO   273
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      SUBROUTINE C81(CX,JXP)                                          PLTAERO    274
      COMMON /ONE/ XMN(30),PMN(30),AA(30,30),PAA(30),CL(30,30),CD(30,30)PLTAERO  275
     1,CPM(30,30),XTEMP(65),YTEMP(65),B(65),XI(65),YI(65),YP(65),YPP(65)MOD1      14
     2,XNA(30),XNMN(30),HEAD(30),BOTTOM(30),XNAT(30),XNMT(30)         PLTAERO    277
     3,NAMAX,NMMAX                                                    MOD2        52
      DIMENSION  CX(30,30),CXL(11,39),CXD(11,65),CXP(9,47) ,ALL(39),ALD(PLTAERO  279
     165),ALP(47),XML(11),XMD(11),XMP(9),DUM(65)                      PLTAERO    280
      DATA ALL/-180.,-172.5,-161.,-147.,-129.,-49.,-39.,-21.,-16.5,-15.,PLTAERO  281
     1-14.,-13.,-12.,-11.,-10.,-8.,-6.,-4.,-2.,0.,2.,4.,6.,8.,10.,11.,12PLTAERO  282
     2.,13.,14.,15.,16.5,21.,39.,49.,129.,147.,161.,172.5,180./       PLTAERO    283
      DATA ALD/-180.,-175.,-170.,-165.,-160.,-140.,-120.,-110.,-100.,-90PLTAERO  284
     1.,-80.,-70.,-60.,-50.,-30.,-21.,-16.,-15.,-14.,-13.,-12.,-11.,-10.PLTAERO  285
     2,-9.,-8.,-7.,-6.,-5.,-4.,-3.,-2.,-1.,0.,1.,2.,3.,4.,5.,6.,7.,8.,9.PLTAERO  286
     3,10.,11.,12.,13.,14.,15.,16.,21.,30.,50.,60.,70.,80.,90.,100.,110.PLTAERO  287
     4,120.,140.,160.,165.,170.,175.,180./                            PLTAERO    288
      DATA ALP/-180.,-170.,-165.,-160.,-135.,-90.,-30.,23.,-16.,-15.,-14PLTAERO  289
     1.,-13.,-12.,-11.,-10.,-9.,-8.,-7.,-6.,-4.,-3.,-2.,-1.,0.,1.,2.,3.,PLTAERO  290
     24.,6.,7.,8.,9.,10.,11.,12.,13.,14.,15.,16.,23.,30.,90.,135.,160., PLTAERO  291
     3165.,170.,180./                                                 PLTAERO    292
      DATA XML/0.,.2,.3,.4,.5,.6,.7,.75,.8,.9,1./                     PLTAERO    293
      DATA XMD/0.,.2,.3,.4,.5,.6,.7,.75,.8,.9,1./                     PLTAERO    294
      DATA XMP/.2,.3,.4,.5,.6,.7,.75,.8,.9/                           PLTAERO    295
      DATA((CXL(I,J),J=1,39),I=1,6)/0.,.78,.62,1.,1.,-1.18,-1.18,-.8, MOD1        15
     S-1.007,-1.19,-1.333,                                            PLTAERO    297
     1-1.334,-1.225,-1.161,-1.055,-.844,-.633,-.422,-.211,0.,.211,.422, PLTAERO  298
     2.633,.844,1.055,1.161,1.255,1.334,1.333,1.19,1.007,.8,1.18,1.18,  PLTAERO  299
     3-1.,-1.,-.62,-.78,0.,0.,.78,.62,1.,1.,-1.18,-1.18,-.8,-1.007,-1.19PLTAERO  300
     4,-1.333,-1.334,-1.255,-1.161,-1.055,-.844,-.633,-.422,-.211,0.,   PLTAERO  301
     5.211,.422,.633,.844,1.055,1.161,1.255,1.334,1.333,1.19,1.007,.8,  PLTAERO  302
     61.18,1.18,-1.,-1.,-.62,-.78,0.,0.,.78,.62,1.,1.,-1.18,-1.18,-.81, PLTAERO  303
     7-.944,-1.09,-1.22,-1.28,-1.26,-1.19,-1.01,-.88,-.66,-.44,-.22,0., PLTAERO  304
     8.22,.44,.66,.88,1.1,1.19,1.26,1.28,1.22,1.09,.944,.81,1.18,1.18,  PLTAERO  305
     9-1.,-1.,-.62,-.78,0.,0.,.78,.62,1.,1.,-1.18,-1.18,-.83,-.93,      PLTAERO  306
     S-1.055,                                                         PLTAERO    307
     A-1.096,-1.12,-1.13,-1.12,-1.082,-.907,-.684,-.456,-.228,0.,.228,  PLTAERO  308
     B.456,.684,.907,1.082,1.12,1.13,1.12,1.096,1.055,.96,.83,1.18,1.18,PLTAERO  309
     C-1.,-1.,-.62,-.78,0.,0.,.78,.62,1.,1.,-1.18,-1.18,-.85,-.965,-.99,PLTAERO  310
     D-1.,-1.,-1.,-.994,-.985,-.922,-.741,-.494,-.247,0.,.247,.494,.741,PLTAERO  311
     E.922,.985,.994,1.,1.,1.,.99,.965,.85,1.18,1.18,-1.,-1.,-.62,-.78, PLTAERO  312
     F0.,0.,.78,.62,1.,1.,-1.18,-1.18,-.85,-.965,-.98,-.97,-.96,-.947,  PLTAERO  313
     G-.93,-.91,-.87,-.77,-.544,-.272,0.,.272,.544,.77,.87,.91,.93,.947,PLTAERO  314
     H.96,.97,.98,.965,.85,1.18,1.18,-1.,-1.,-.62,-.78,0./            PLTAERO    315
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      DATA((CXL(I,J),J=1,39),I=7,11)/0.,.78,.62,1.,                     MOD1        16
     I1.,-1.18,-1.18,-.85,-.965,-.98,-.97,-.96,-.94,-.923,-.9,-.84,-.75,PLTAERO    317
     J-.578,-.313,0.,.313,.578,.75,.84,.9,.923,.94,.96,.97,.98,.965,.85,PLTAERO    318
     K1.18,1.18,-1.,-1.,-.62,-.78,0.,0.,.78,.62,1.,1.,-1.18,-1.18,-.71, PLTAERO    319
     L-.795,-.83,-.84,-.85,-.85,-.85,-.845,-.82,-.77,-.627,-.35,0.,.35, PLTAERO    320
     M.627,.77,.82,.845,.85,.85,.85,.84,.83,.795,.71,1.18,1.18,-1.,-1., PLTAERO    321
     N-.62,-.78,0.,0.,.78,.62,1.,1.,-1.18,-1.18,-.68,-.76,-.79,-.805,   PLTAERO    322
     O-.815,-.82,-.81,-.805,-.77,-.72,-.603,-.395,0.,.395,.603,.72,.77, PLTAERO    323
     P.805,.81,.82,.815,.805,.79,.76,.68,1.18,1.18,-1.,-1.,-.62,-.78,0.,PLTAERO    324
     Q0.,.78,.62,1.,1.,-1.18,-1.18,-.64,-.7,-.72,-.73,-.735,-.74,-.74,  PLTAERO    325
     R-.73,-.695,-.593,-.396,-.2,0.,.2,.396,.593,.695,.73,.74,.74,.735, PLTAERO    326
     S.73,.72,.7,.64,1.18,1.18,-1.,-1.,-.62,-.78,0.,0.,.78,.62,1.,1.,   PLTAERO    327
     T-1.18,-1.18,-.64,-.7,-.72,-.73,-.735,-.74,-.74,-.73,-.695,-.593,  PLTAERO    328
     U-.396,-.2,0.,.2,.396,.593,.695,.73,.74,.74,.735,.73,.72,.7,.64,   PLTAERO    329
     V1.18,1.18,-1.,-1.,-.62,-.78,0./                                   PLTAERO    330
      DATA((CXD(I,J),J=1,65),I=1,3)/.022,.062,.132,.242,.302,1.042,     MOD1        17
     S1.652,1.852,2.022,2.022,                                          PLTAERO    332
     11.962,1.842,1.662,1.392,.562,.332,.155,.102,.038,.0264,.022,.0196,PLTAERO    333
     2.0174,.0154,.0138,.0122,.011,.01,.0093,.0088,.0085,.0083,.008,    PLTAERO    334
     3.0083,.0085,.0088,.0093,.01,.011,.0122,.0138,.0154,.0174,.0196,   PLTAERO    335
     4.022,.0264,.038,.102,.155,.332,.562,1.392,1.662,1.842,1.962,2.022,PLTAERO    336
     52.022,1.852,1.652,1.042,.302,.242,.132,.062,.022,.022,.062,.132,  PLTAERO    337
     6.242,.302,1.042,1.652,1.852,2.022,2.022,1.962,1.842,1.662,1.392,  PLTAERO    338
     7.562,.332,.155,.102,.038,.0264,.022,.0196,.0174,.0154,.0138,.0122,PLTAERO    339
     8.011,.01,.0093,.0088,.0085,.0083,.008,.0083,.0085,.0088,.0093,.01,PLTAERO    340
     9.011,.0122,.0138,.0154,.0174,.0196,.022,.0264,.038,.102,.155,.332,PLTAERO    341
     1.562,1.392,1.662,1.842,1.962,2.002,2.002,1.852,1.652,1.042,.302,  PLTAERO    342
     A.242,.132,.062,.022,.022,.062,.132,.242,.302,1.042,1.652,1.852,   PLTAERO    343
     B2.022,2.022,1.962,1.842,1.662,1.392,.562,.332,.181,.148,.099,.0455PLTAERO    344
     C,.03,.0232,.0189,.0159,.0138,.0122,.011,.01,.0093,.0088,.0085,    PLTAERO    345
     D.0083,.008,.0083,.0085,.0088,.0093,.01,.011,.0122,.0138,.0159,    PLTAERO    346
     E.0189,.0232,.03,.0455,.099,.148,.181,.332,.562,1.392,1.662,1.842, PLTAERO    347
     F1.962,2.022,2.022,1.852,1.652,1.042,.302,.242,.132,.062,.022/     PLTAERO    348
      DATA((CXD(I,J),J=1,65),I=4,6)/.022,                               MOD1        18
     G.062,.132,.242,.302,1.042,1.652,1.852,2.022,2.022,1.962,1.842,    PLTAERO    350
     H1.662,1.392,.562,.332,.207,.181,.146,.094,.06,.038,.0259,.0187,   PLTAERO    351
     I.0147,.0123,.011,.01,.0093,.0088,.0085,.0083,.008,.0083,.0085,    PLTAERO    352
     J.0088,.0093,.01,.011,.0123,.0147,.0187,.0259,.038,.06,.094,.146,  PLTAERO    353
     K .181,.207,.332,.562,1.392,1.662,1.842,1.962,2.022,2.022,1.852,   PLTAERO    354
     L1.652,1.042,.302,.242,.132,.062,.022,.022,.062,.132,.242,.302,    PLTAERO    355
     M1.042,1.652,1.852,2.022,2.022,1.962,1.842,1.662,1.392,.562,.332,  PLTAERO    356
     N.235,.209,.18,.148,.111,.078,.053,.0351,.022,.0141,.011,.01,.0093,PLTAERO    357
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      D.0068,.0085,.0083,.008,.0083,.0085,.0088,.0093,.01,.011,.0141,.022PLTAERO   358
      P,.0351,.053,.078,.111,.148,.18,.209,.235,.332,.562,1.392,1.662,   PLTAERO   359
      Q1.842,1.962,2.022,2.022,1.852,1.652,1.042,.302,.242,.132,.062,.022PLTAERO   360
      R,.022,.062,.132,.242,.302,1.042,1.652,1.852,2.022,2.022,1.962,    PLTAERO   361
      S1.842,1.662,1.392,.562,.332,.257,.233,.212,.191,.164,.135,.105,   PLTAERO   362
      T.077,.053,.035,.0212,.0132,.01,.009,.0085,.0083,.008,.0083,.0085, PLTAERO   363
      U.009,.01,.0132,.0212,.035,.053,.077,.105,.135,.164,.191,.212,.233,PLTAERO   364
      V.257,.332,.562,1.392,1.662,1.842,1.962,2.022,2.022,1.852,1.652,   PLTAERO   365
      W1.042,.302,.242,.132,.062,.022/                                   PLTAERO   366
       DATA((CXD(I,J),J=1,65),I=7,9)/.022,.062,.132,.242,.302,1.042,     MOD1       19
      X1.652,1.852,2.022,2.022,1.962,1.842,1.662,1.392,.562,.332,.274,   PLTAERO   368
      Y.252,.233,.216,.198,.17,.145,.122,.101,.082,.0615,.038,.0167,.0102PLTAERO   369
      Z,.0086,.0083,.008,.0083,.0086,.0102,.0167,.038,.0615,.082,.101,   PLTAERO   370
      1.122,.145,.17,.198,.216,.233,.252,.274,.332,.562,1.392,1.662,1.842PLTAERO   371
      2,1.962,2.022,2.022,1.852,1.652,1.042,.302,.242,.132,.062,.022,.022PLTAERO   372
      3,.062,.132,.242,.302,1.042,1.652,1.852,2.022,2.022,1.962,1.842,   PLTAERO   373
      41.662,1.392,.562,.332,.292,.271,.249,.231,.211,.192,.176,.159,.14,PLTAERO   374
      5.111,.082,.054,.030,.0175,.0117,.0091,.008,.0091,.0117,.0175,.03, PLTAERO   375
      6.054,.082,.111,.14,.159,.176,.192,.211,.231,.249,.271,.292,.332,  PLTAERO   376
      7.562,1.392,1.662,1.842,1.962,2.022,2.022,1.852,1.652,1.042,.302,  PLTAERO   377
      8.242,.132,.062,.022,.022,.062,.132,.242,.302,1.042,1.652,1.852,   PLTAERO   378
      92.022,2.022,1.962,1.842,1.662,1.392,.562,.332,.305,.282,.26,.239, PLTAERO   379
      A.22,.202,.186,.172,.155,.139,.12,.048,.0575,.0355,.024,.0175,.0137PLTAERO   380
      B,.0175,.024,.0355,.0575,.048,.12,.139,.155,.172,.186,.202,.22,.239PLTAERO   381
      C,.26,.282,.305,.332,.562,1.392,1.662,1.842,1.962,2.022,2.022,1.852PLTAERO   382
      D,1.652,1.042,.302,.242,.132,.062,.022/                            PLTAERO   383
       DATA((CXD(I,J),J=1,65),I=10,11)/.022,.062,.132,.242,.302,         MOD1       20
      E1.042,1.652,1.852,2.022,2.022,1.962,1.842,1.662,1.392,.562,.332,  PLTAERO   385
      F.342,.298,.293,.272,.252,.232,.213,.199,.183,.169,.14,.111,.095,  PLTAERO   386
      G.086,.081,.078,.078,.078,.081,.086,.095,.111,.14,.169,.183,.199,  PLTAERO   387
      H.213,.232,.252,.272,.293,.298,.342,.332,.562,1.392,1.662,1.842,   PLTAERO   388
      I1.962,2.022,2.022,1.852,1.652,1.042,.302,.242,.132,.062,.022,.022,PLTAERO   389
      J.062,.132,.242,.302,1.042,1.652,1.852,2.022,2.022,1.962,1.842,    PLTAERO   390
      K1.662,1.392,.562,.332,.342,.298,.293,.292,.291,.275,.254,.232,.214PLTAERO   391
      L,.192,.17,.14,.112,.102,.098,.096,.095,.096,.098,.102,.112,.14,.17PLTAERO   392
      M,.192,.214,.232,.254,.275,.291,.292,.293,.298,.342,.332,.562,1.392PLTAERO   393
      N,1.662,1.842,1.962,2.022,2.022,1.852,1.652,1.042, 302,.242,.132,  PLTAERO   394
      O.062,.022/                                                        PLTAERO   395
       DATA((CXP(I,J),J=1,47),I=1,6)/0.,.4,.3,.3,.5,.5,.174,.112,.073,   MOD1       21
      S.054,0.,0.,0.,0.,0.,0.,                                           PLTAERO   397
      10.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,         PLTAERO   398
      2-.054,-.073,-.112,-.174,-.5,-.5,-.3,-.3,-.4,0.,0.,.4,.3,.3,.5,.5, PLTAERO   399
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     3.184,.118,.078,.065,.027,.0015,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.PLTAERO    400
     4,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,-.0015,-.027,-.065,-.078,-.118, PLTAERO    401
     5-.184,-.5,-.5,-.3,-.3,-.4,0.,0.,.4,.3,.3,.5,.5,.196,.128,.086,.073PLTAERO    402
     6,.054,.025,.002,-.003,-.0015,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0., PLTAERO    403
     70.,0.,0.,0.,0.,.0015,.003,-.002,-.025,-.054,-.073,-.086,-.128,    PLTAERO    404
     8-.196,-.5,-.5,-.3,-.3,-.4,0.,0.,.4,.3,.3,.5,.5,.214,.144,.097,.084PLTAERO    405
     9,.068,.05,.03,.014,.002,-.003,-.004,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,PLTAERO    406
     A0.,0.,0.,.004,.003,-.002,-.014,-.03,-.05,-.068,-.084,-.097,-.144, PLTAERO    407
     B-.214,-.5,-.5,-.3,-.3,-.4,0.,0.,.4,.3,.3,.5,.5,.235,.157,.108,.097PLTAERO    408
     C,.086,.074,.06,.046,.032,.016,.005,-.004,-.063,0.,0.,0.,0.,0.,0.,0PLTAERO    409
     D.,0.,0.,.003,.004,-.005,-.016,-.032,-.046,-.06,-.074,-.086,-.097, PLTAERO    410
     E-.108,-.157,-.235,-.5,-.5,-.3,-.3,-.4,0.,0.,.4,.3,.3,.5,.5,.25,.17PLTAERO    411
     F1,.113,.111,.103,.093,.083,.074,.065,.054,.041,.0275,.016,.005,.00PLTAERO    412
     G25,0.,0.,0.,0.,0.,.0025,-.005,-.016,-.0275,-.041,-.054,-.065,-.074PLTAERO    413
     H,-.0183,-.093,-.103,-.111,-.117,-.171,-.25,-.5,-.5,-.3,-.3,-.4,0./PLTAERO    414
      DATA((CXP(I,J),J=1,47),I=7,9)/0.,.4,.3,.3,.5,.5,.264,.183,.137,   MOD1        22
     S.133,.127,.122,.116,.108,.1,.089,                                 PLTAERO    415
     J.082,.072,.0625,.04,.026,.013,.0035,0.,-.0035,-.013,-.026,-.04,   PLTAERO    417
     K-.0625,-.072,-.082,-.089,-.1,-.108,-.116,-.122,-.127,-.133,-.137, PLTAERO    418
     L-.183,-.264,-.5,-.5,-.3,-.3,-.4,0.,0.,.4,.3,.3,.5,.5,.277,.206,   PLTAERO    419
     M.176,.173,.167,.163,.157,.149,.142,.132,.123,.1125,.1,.076,.0665, PLTAERO    420
     N.053,.033,0.,-.033,-.053,-.0665,-.076,-.1,-.1125,-.123,-.132,-.142PLTAERO    421
     O,-.149,-.157,-.163,-.167,-.173,-.176,-.206,-.277,-.5,-.5,-.3,-.3, PLTAERO    422
     P-.4,0.,0.,.4,.3,.3,.5,.5,.298,.232,.2,.195,.189,.184,.176,.17,.163PLTAERO    423
     Q,.154,.145,.136,.125,.102,.087,.07,.045,0.,-.045,-.07,-.087,-.102,PLTAERO    424
     R-.125,-.136,-.145,-.154,-.163,-.17,-.176,-.184,-.189,-.195,-.2,   PLTAERO    425
     S-.232,-.298,-.5,-.5,-.3,-.3,-.4,0./                               PLTAERO    426
      IF(JXP) 107,108,109                                               MOD1        23
  107 WRITE(6,110)                                                      MOD1        24
      GO TO 113                                                         MOD1        25
  108 WRITE(6,111)                                                      MOD1        26
      GO TO 113                                                         MOD1        27
  109 WRITE(6,112)                                                      MOD1        28
  113 CONTINUE                                                          MOD1        29
  110 FORMAT(33X,14HC81 LIFT TABLE)                                     MOD1        30
  111 FORMAT(33X,14HC81 DRAG TABLE)                                     MOD1        31
  112 FORMAT(31X,16HC81 MOMENT TABLE)                                   MOD1        32
  977 FORMAT(////)                                                      MOD1        33
      IF(JXP)100,200,300                                                MOD1        34
  100 CONTINUE                                                          PLTAERO    428
      CALL C82(3,11,39,2,17,8,32,ALL,XML,CXL,CX,JXP)                    MOD1        35
      WRITE(6,120)                                                      MOD1        36
```

```
  120 FORMAT(32X,16HDATA CARD IMAGES)                          MOD1       37
      NXL = 11                                                 PLTAERO   459
      NZL = 39                                                 PLTAERO   460
      NXD = 11                                                 PLTAERO   461
      NZD = 65                                                 PLTAERO   462
      NXM = 9                                                  PLTAERO   463
      NZM = 47                                                 PLTAERO   464
      WRITE(6,905)(HEAD(J),J=1,3)                              MOD1       38
      PUNCH 905,(HEAD(J),J=1,3)                                MOD1       39
  905 FORMAT(1X,3A10)                                          MOD1       40
      WRITE(6,906)(BOTTOM(J),J=1,3),NXL,NZL,NXD,NZD,NXM,NZM    MOD1       41
      PUNCH 906,(BOTTOM(J),J=1,3),NXL,NZL,NXD,NZD,NXM,NZM      MOD1       42
  906 FORMAT(3A10,6I2)                                         PLTAERO   470
      WRITE(6,910) (XML(I),I=1,9)                              MOD1       43
      PUNCH910, (XML(I),I=1,9)                                 MOD1       44
      WRITE(6,911) (XML(I),I=10,11)                            MOD1       45
      PUNCH 911, (XML(I),I=10,11)                              MOD1       46
  907 FORMAT(F7.0,9F7.4)                                       MOD1       47
  908 FORMAT(7X,2F7.4)                                         MOD1       48
  910 FORMAT(7X,9F7.4)                                         MOD1       49
  911 FORMAT(7X,2F7.4)                                         MOD1       50
      DO 1000 J=1,39                                           PLTAERO   474
      WRITE(6,907) ALL(J),(CXL(I,J),I=1,9)                     MOD1       51
      WRITE(6,908) (CXL(I,J),I=10,11)                          MOD1       52
      PUNCH 907, ALL(J),(CXL(I,J),I=1,9)                       MOD1       53
      PUNCH 908, (CXL(I,J),I=10,11)                            MOD1       54
 1000 CONTINUE                                                 PLTAERO   477
      WRITE(6,977)                                             MOD1       55
      RETURN                                                   PLTAERO   478
  200 CONTINUE                                                 PLTAERO   479
      CALL C82(3,11,65,2,28,16,50,ALD,XMD,CXD,CX,JXP)          MOD1       56
      WRITE(6,120)                                             MOD1       57
      WRITE(6,910) (XMD(I),I=1,9)                              MOD1       58
      PUNCH910, (XMD(I),I=1,9)                                 MOD1       59
      WRITE(6,911) (XMD(I),I=10,11)                            MOD1       60
      PUNCH 911, (XMD(I),I=10,11)                              MOD1       61
      DO 1400 J=1,65                                           PLTAERO   512
      WRITE(6,907) ALD(J),(CXD(I,J),I=1,9)                     MOD1       62
      WRITE(6,908) (CXD(I,J),I=10,11)                          MOD1       63
      PUNCH 907, ALD(J),(CXD(I,J),I=1,9)                       MOD1       64
      PUNCH 908, (CXD(I,J),I=10,11)                            MOD1       65
 1400 CONTINUE                                                 PLTAERO   515
```

```
      WRITE(6,977)                                          MOD1        66
      RETURN                                                PLTAERO    516
  300 CONTINUE                                              PLTAERO    517
      CALL CB2(2,9,47,1,19,8,40,ALP,XMP,CXP,CX,JXP)        MOD1        67
      WRITE(6,120)                                          MOD1        68
      DO 1800 J=1,47                                        PLTAERO    549
      WRITE(6,910) (XMP(I),I=1,9)                           MOD1        69
      PUNCH910, (XMP(I),I=1,9)                              MOD1        70
      WRITE(6,907) ALP(J),(CXP(I,J),I=1,9)                  MOD1        71
      PUNCH 907, ALP(J),(CXP(I,J),I=1,9)                    MOD1        72
 1800 CONTINUE                                              PLTAERO    552
      WRITE(6,977)                                          MOD1        73
      RETURN                                                PLTAERO    553
      END                                                   PLTAERO    554
```

APPENDIX

```
      SUBROUTINE C82(IA,IB,IC,ID,IE,IF,IG,ALPHA,XMACH,CXX,CX,JXP)       MOD1      74
      COMMON /ONE/ XMN(30),PMN(30),AA(30,30),PAA(30),CL(30,30),CD(30,30)MOD1      75
     1,CPM(30,30),XTEMP(65),YTEMP(65),B(65),XI(65),YI(65),YP(65),YPP(65)MOD1      76
     2,XNA(30),XNMN(30),HEAD(30),BOTTOM(30),XNAT(30),XNMNT(30)          MOD1      77
     3,NAMAX,NMMAX                                                      MOD2      53
      COMMON /HLM/ TENR,XINT,ST                                         MOD1      79
      DIMENSION CX(30,30),CXX(IB,IC),XMACH(IB),DUM(11,65),ALPHA(IC)     MOD1      80
      DO 499 I = 1,IB                                                   MOD1      81
      DO 498 J = 1,IC                                                   MOD1      82
      DUM(I,J) = CXX(I,J)                                               MOD1      83
  498 CONTINUE                                                          MOD1      84
  499 CONTINUE                                                          MOD1      85
  101 FORMAT(12F10.4)                                                   MOD1      86
  102 FORMAT(////)                                                      MOD1      87
      DO 500 I = IA,IB                                                  MOD1      88
      DO 501 J = 1,IC                                                   MOD1      89
      DO 502 II=1,NMMAX                                                 MOD2      54
      NAT = XNA(II)                                                     MOD1      91
      DO 503 JJ = 1,NAT                                                 MOD1      92
      IF(PAA(JJ).EQ.ALPHA(J).AND.PMN(II).EQ.XMACH(I)) CXX(I,J)=CX(II,JJ)MOD1      93
      IF(PAA(JJ).EQ.ALPHA(J).AND.PMN(II).EQ.XMACH(I)) GO TO 501         MOD1      94
  503 CONTINUE                                                          MOD1      95
  502 CONTINUE                                                          MOD1      96
  501 CONTINUE                                                          MOD1      97
  500 CONTINUE                                                          MOD1      98
      DO 510 I = 1,ID                                                   MOD1      99
      NAT = XNA(I)                                                      MOD1     100
      JJOP = IE + 1                                                     MOD1     101
      DO 511 J = JJOP,IC                                                MOD1     102
      IF(ALPHA(J).GT.PAA(NAT)) GO TO 511                                MOD1     103
      CXX(I,J) = CXX(IA,J)                                              MOD1     104
  511 CONTINUE                                                          MOD1     105
  510 CONTINUE                                                          MOD1     106
      IF(JXP.EQ.1) GO TO 513                                            MOD1     107
      IF(PMN(NMMAX).LE..9) GO TO 513                                    MOD2      55
      NAT = XNA(NMMAX)                                                  MOD2      56
      DO 512 J = JJOP,IC                                                MOD1     110
      IF(ALPHA(J).GT.PAA(NAT)) GO TO 512                                MOD1     111
      CXX(I,J) = CXX(10,J)                                              MOD1     112
  512 CONTINUE                                                          MOD1     113
  513 CONTINUE                                                          MOD1     114
      DO 600 I = 1,IB                                                   MOD1     115
```

```
      IJ = 0                                                            MOD1   116
      DO 601 J = 1,IC                                                   MOD1   117
      IF(CXX(I,J).NE.DUM(I,J)) IJ = IJ+1                                MOD1   118
  601 CONTINUE                                                          MOD1   119
      IJJ = IE + IJ                                                     MOD1   120
      DO 602 J = 1,IJJ                                                  MOD1   121
      XTEMP(J) = ALPHA(J)                                               MOD1   122
      YTEMP(J) = CXX(I,J)                                               MOD1   123
  602 CONTINUE                                                          MOD1   124
      IJJP = IJJ + 1                                                    MOD1   125
      IJJQ = IJJ + IF                                                   MOD1   126
  107 FORMAT(11I5)                                                      MOD1   127
      DO 603 J = IJJP,IJJQ                                              MOD1   128
      JXJ = (J-IJJP) + IG                                               MOD1   129
      XTEMP(J) = ALPHA(JXJ)                                             MOD1   130
      YTEMP(J) = CXX(I,JXJ)                                             MOD1   131
  603 CONTINUE                                                          MOD1   132
      CALL TSPLINE(XTEMP,YTEMP,IJJQ,B,ST,1,IC,ALPHA,YI,YP,YPP,XINT)     MOD1   133
      DO 604 J = 1,IC                                                   MOD1   134
      CXX(I,J) = YI(J)                                                  MOD1   135
  604 CONTINUE                                                          MOD1   136
  600 CONTINUE                                                          MOD1   137
      DO 700 J = 1,IC                                                   MOD1   138
      WRITE(6,101) ALPHA(J),(CXX(I,J),I=1,IB)                           MOD1   139
  100 FORMAT(11F10.4)                                                   MOD1   140
  700 CONTINUE                                                          MOD1   141
      WRITE(6,102)                                                      MOD1   142
      RETURN                                                            MOD1   143
      END                                                               MOD1   144
```

```
      SUBROUTINE SYMBS(NO,IS,X,Y,T)                                     PLTAERO  555
C        NO  -  SYMBOL NUMBER                                           PLTAERO  556
C        IS  -  SYMBOL SIZE    1-SMALL    2-MEDIUM    3-LARGE           PLTAERO  557
C        X AND Y  -  INTERCEPT OF SYMBOL AND RADIAL DRAWN FROM SYMBOL   PLTAERO  558
C                    CENTER AT ANGLE T.                                 PLTAERO  559
      DIMENSION SCALE(3)                                                PLTAERO  560
      DATA RAD/57.2957795131/,PI/3.141592654/                           PLTAERO  561
      DATA DA/1.4142135624/,R/1.7320508076/,SCALE/.13,.16,.19/          PLTAERO  562
      DATA T1/213.6900675260/,T2/326.3099324740/,T3/116.5650511771/,T4/3PLTAERO  563
     133.4349488229/,T7/11.3099324740/,T8/168.6900675260/,T9/218.6598082PLTAERO  564
     2541/,S1/321.3401917459/,S2/185.7105931375/,S3/354.2894068625/,S4/1PLTAERO  565
     31.3099324740/,S5/168.6900675260/,S6/218.6598082541/,S7/321.3401917PLTAERO  566
     4459/                                                              PLTAERO  567
      IF ((NO.EQ.1).OR.(NO.EQ.11)) GO TO 1                              PLTAERO  568
      IF ((NO.EQ.2).OR.(NO.EQ.12)) GO TO 2                              PLTAERO  569
      IF ((NO.EQ.3).OR.(NO.EQ.13)) GO TO 8                              PLTAERO  570
      IF ((NO.EQ.4).OR.(NO.EQ.14)) GO TO 13                             PLTAERO  571
      IF ((NO.EQ.5).OR.(NO.EQ.15)) GO TO 17                             PLTAERO  572
      IF ((NO.EQ.6).OR.(NO.EQ.16)) GO TO 21                             PLTAERO  573
      IF ((NO.EQ.7).OR.(NO.EQ.17)) GO TO 26                             PLTAERO  574
      IF ((NO.EQ.8).OR.(NO.EQ.18)) GO TO 31                             PLTAERO  575
      IF ((NO.EQ.9).OR.(NO.EQ.19)) GO TO 35                             PLTAERO  576
      IF ((NO.EQ.10).OR.(NO.EQ.20)) GO TO 40                            PLTAERO  577
      IF ((NO.EQ.21).OR.(NO.EQ.22)) GO TO 45                            PLTAERO  578
      IF (NO.GT.22) RETURN                                              PLTAERO  579
C        SYMBOL NUMBER 1 OR 11                                          PLTAERO  580
    1 X=SCALE(IS)*.5525*COS(T/RAD)                                      PLTAERO  581
      Y=SCALE(IS)*.5525*SIN(T/RAD)                                      PLTAERO  582
      RETURN                                                            PLTAERO  583
C        SYMBOL NUMBER 2 OR 12                                          PLTAERO  584
    2 IF ((T.GE.0.).AND.(T.LT.45.)) GO TO 3                             PLTAERO  585
      IF ((T.GE.45.0).AND.(T.LT.135.)) GO TO 4                          PLTAERO  586
      IF ((T.GE.135.).AND.(T.LT.225.)) GO TO 5                          PLTAERO  587
      IF ((T.GE.225.).AND.(T.LT.315.)) GO TO 6                          PLTAERO  588
      IF ((T.GE.315.).AND.(T.LE.360.)) GO TO 7                          PLTAERO  589
    3 X=SCALE(IS)/2.                                                    PLTAERO  590
      Y=X*TAN(T/RAD)                                                    PLTAERO  591
      RETURN                                                            PLTAERO  592
    4 Y=SCALE(IS)/2.                                                    PLTAERO  593
      IF (T.EQ.90.) X=0.0                                               PLTAERO  594
      IF (T.NE.90.) X=Y/TAN(T/RAD)                                      PLTAERO  595
      RETURN                                                            PLTAERO  596
```

```
 5    X=-SCALE(IS)/2.                                          PLTAERO  597
      Y=X*TAN(T/RAD)                                           PLTAERO  598
      RETURN                                                   PLTAERO  599
 6    Y=-SCALE(IS)/2.                                          PLTAERO  600
      IF (T.EQ.270.) X=0.0                                     PLTAERO  601
      IF (T.NE.270.) X=Y/TAN(T/RAD)                            PLTAERO  602
      RETURN                                                   PLTAERO  603
 7    X=SCALE(IS)/2.                                           PLTAERO  604
      Y=X*TAN(T/RAD)                                           PLTAERO  605
      RETURN                                                   PLTAERO  606
C        SYMBOL NUMBER 3 OR 13                                 PLTAERO  607
 8    IF ((T.GE.0.).AND.(T.LT.90.)) GO TO 9                    PLTAERO  608
      IF ((T.GE.90.).AND.(T.LT.180.)) GO TO 10                 PLTAERO  609
      IF ((T.GE.180.).AND.(T.LT.270.)) GO TO 11                PLTAERO  610
      IF ((T.GE.270.).AND.(T.LE.360.)) GO TO 12                PLTAERO  611
 9    X=SCALE(IS)*DA/2./(TAN(T/RAD)+1.)                        PLTAERO  612
      Y=-X+SCALE(IS)*DA/2.                                     PLTAERO  613
      RETURN                                                   PLTAERO  614
10    IF (T.EQ.90.) X=0.0                                      PLTAERO  615
      IF (T.NE.90.) X=SCALE(IS)*DA/2./(TAN(T/RAD)-1.)          PLTAERO  616
      Y=X+SCALE(IS)*DA/2.                                      PLTAERO  617
      RETURN                                                   PLTAERO  618
11    X=-SCALE(IS)*DA/2./(TAN(T/RAD)+1.)                       PLTAERO  619
      Y=-X-SCALE(IS)*DA/2.                                     PLTAERO  620
      RETURN                                                   PLTAERO  621
12    IF (T.EQ.270.) X=0.0                                     PLTAERO  622
      IF (T.NE.270.) X=-SCALE(IS)*DA/2./(TAN(T/RAD)-1.)        PLTAERO  623
      Y=X-SCALE(IS)*DA/2.                                      PLTAERO  624
      RETURN                                                   PLTAERO  625
C        SYMBOL NUMBER 4 OR 14                                 PLTAERO  626
13    IF ((T.GE.0.).AND.(T.LT.90.)) GO TO 14                   PLTAERO  627
      IF ((T.GE.90.).AND.(T.LT.T1)) GO TO 15                   PLTAERO  628
      IF ((T.GE.T1).AND.(T.LT.T2)) GO TO 16                    PLTAERO  629
      IF ((T.GE.T2).AND.(T.LE.360.)) GO TO 14                  PLTAERO  630
14    X=(2./3.)*SCALE(IS)*1.105/(TAN(T/RAD)+2.)                PLTAERO  631
      Y=-2.*X+2.*SCALE(IS)*1.105/3.                            PLTAERO  632
      RETURN                                                   PLTAERO  633
15    IF (T.EQ.90.) X=0.0                                      PLTAERO  634
      IF (T.NE.90.) X=(2./3.)*SCALE(IS)*1.105/(TAN(T/RAD)-2.)  PLTAERO  635
      Y=2.*X+2.*SCALE(IS)*1.105/3.                             PLTAERO  636
      RETURN                                                   PLTAERO  637
16    Y=-SCALE(IS)*1.105/3.                                    PLTAERO  638
```

```
      IF (T.NE.270.) X=0.0
      IF (T.NE.270.) X=Y/TAN(T/RAD)
      RETURN
C        SYMBOL NUMBER 5 OR 15
17    IF ((T.GE.0.).AND.(T.LT.T3)) GO TO 18
      IF ((T.GE.T3).AND.(T.LT.225.)) GO TO 19
      IF ((T.GE.225.).AND.(T.LT.T4)) GO TO 20
      IF ((T.GE.T4).AND.(T.LE.360.)) GO TO 18
18    IF (T.EQ.90.) X=0.0
      IF (T.NE.90.) X=SCALE(IS)*1.22222/3./(TAN(T/RAD)+1.)
      Y=-X+SCALE(IS)*1.22222/3.
      RETURN
19    X=-SCALE(IS)*1.22222/3.
      Y=X*TAN(T/RAD)
      RETURN
20    Y=-SCALE(IS)*1.22222/3.
      IF (T.EQ.270.) X=0.0
      IF (T.NE.270.) X=Y/TAN(T/RAD)
      RETURN
C        SYMBOL NUMBER 6 OR 16
21    A=4.*SCALE(IS)*1.22222/(3.*PI)
      B=SCALE(IS)*1.22222-A
      T5=ATAN(A/B)*RAD
      T6=360.-T5
      T5=90.+T5
      IF ((T.GE.0.).AND.(T.LT.T5)) GO TO 22
      IF ((T.GE.T5).AND.(T.LT.225.)) GO TO 24
      IF ((T.GE.225.).AND.(T.LT.T6)) GO TO 25
      IF ((T.GE.T6).AND.(T.LE.360.)) GO TO 22
22    IF (T.EQ.90.) GO TO 23
      BB=-2.*A*(1.+TAN(T/RAD))
      AA=TAN(T/RAD)**2+1.
      CC=2.*A*A-(SCALE(IS)*1.22222)**2
      X=SQRT(BB*BB-4.*AA*CC)/(2.*AA)
      IF ((T.GE.0.).AND.(T.LT.90.)) X=X+BB/(2.*AA)
      IF ((T.GE.90.).AND.(T.LT.180.)) X=-X+BB/(2.*AA)
      IF ((T.GE.270.).AND.(T.LE.360.)) X=X+BB/(2.*AA)
      Y=X*TAN(T/RAD)
      RETURN
23    X=0.0
      Y=-A+SQRT((SCALE(IS)*1.22222)**2-A*A)
      RETURN
```

```
24    X=-A                                                                  PLTAERO    681
      Y=X*TAN(T/RAD)                                                        PLTAERO    682
      RETURN                                                                PLTAERO    683
25    Y=-A                                                                  PLTAERO    684
      IF (T.EQ.270.) X=0.0                                                  PLTAERO    685
      IF (T.NE.270.) X=Y/TAN(T/RAD)                                         PLTAERO    686
      RETURN                                                                PLTAERO    687
C        SYMBOL NUMBER 7 OR 17                                              PLTAERO    688
26    IF ((T.GE.0.0).AND.(T.LT.T7)) GO TO 27                                PLTAERO    689
      IF ((T.GE.T7).AND.(T.LT.T8)) GO TO 28                                 PLTAERO    690
      IF ((T.GE.T8).AND.(T.LT.T9)) GO TO 29                                 PLTAERO    691
      IF ((T.GE.T9).AND.(T.LT.S1)) GO TO 30                                 PLTAERO    692
      IF ((T.GE.S1).AND.(T.LE.360.)) GO TO 27                               PLTAERO    693
27    X=SCALE(IS)/2.                                                        PLTAERO    694
      Y=X*TAN(T/RAD)                                                        PLTAERO    695
      RETURN                                                                PLTAERO    696
28    X=SCALE(IS)*.1*SIN(T/RAD)*COS(T/RAD)+SCALE(IS)*COS(T/RAD)*SQRT(.25PLTAERO    697
     1-(.1*COS(T/RAD))**2)                                                  PLTAERO    698
      Y=X*TAN(T/RAD)                                                        PLTAERO    699
      RETURN                                                                PLTAERO    700
29    X=-SCALE(IS)/2.                                                       PLTAERO    701
      Y=X*TAN(T/RAD)                                                        PLTAERO    702
      RETURN                                                                PLTAERO    703
30    Y=-SCALE(IS)*.4                                                       PLTAERO    704
      IF (T.EQ.270.) X=0.0                                                  PLTAERO    705
      IF (T.NE.270.) X=Y/TAN(T/RAD)                                         PLTAERO    706
      RETURN                                                                PLTAERO    707
C        SYMBOL NUMBER 8 OR 18                                              PLTAERO    708
31    IF ((T.GE.0.0).AND.(T.LT.S2)) GO TO 32                                PLTAERO    709
      IF ((T.GE.S2).AND.(T.LE.270.)) GO TO 33                               PLTAERO    710
      IF ((T.GT.270.).AND.(T.LE.S3)) GO TO 34                               PLTAERO    711
      IF ((T.GT.S3).AND.(T.LE.360.)) GO TO 32                               PLTAERO    712
32    X=-.05*SCALE(IS)*SIN(T/RAD)*COS(T/RAD)+SCALE(IS)*COS(T/RAD)*SQRT(.PLTAERO    713
     125-(.05*COS(T/RAD))**2)                                               PLTAERO    714
      Y=X*TAN(T/RAD)                                                        PLTAERO    715
      RETURN                                                                PLTAERO    716
33    IF (T.EQ.270.) X=0.0                                                  PLTAERO    717
      IF (T.EQ.270.) Y=-SCALE(IS)*.55                                       PLTAERO    718
      IF (T.NE.270.) X=-SCALE(IS)*.55/(TAN(T/RAD)+1.)                       PLTAERO    719
      IF (T.NE.270.) Y=X*TAN(T/RAD)                                         PLTAERO    720
      RETURN                                                                PLTAERO    721
34    X=-SCALE(IS)*.55/(TAN(T/RAD)-1.)                                      PLTAERO    722
```

```
      Y=X*TAN(T/RAD)                                                    PLTAERO  723
      RETURN                                                            PLTAERO  724
C        SYMBOL NUMBER 9 OR 19                                          PLTAERO  725
   35 IF ((T.GE.0.0).AND.(T.LT.90.)) GO TO 36                           PLTAERO  726
      IF ((T.GE.90.).AND.(T.LT.180.)) GO TO 37                          PLTAERO  727
      IF ((T.GE.180.).AND.(T.LT.270.)) GO TO 38                         PLTAERO  728
      IF ((T.GE.270.).AND.(T.LE.360.)) GO TO 39                         PLTAERO  729
   36 X=SCALE(IS)*R/2./(TAN(T/RAD)+R)                                   PLTAERO  730
      Y=X*TAN(T/RAD)                                                    PLTAERO  731
      RETURN                                                            PLTAERO  732
   37 IF (T.EQ.90.) X=0.0                                               PLTAERO  733
      IF (T.NE.90.) X=SCALE(IS)*R/2./(TAN(T/RAD)-R)                     PLTAERO  734
      IF (T.EQ.90.) Y=SCALE(IS)*R/2.                                    PLTAERO  735
      IF (T.NE.90.) Y=X*TAN(T/RAD)                                      PLTAERO  736
      RETURN                                                            PLTAERO  737
   38 X=-SCALE(IS)*R/2./(TAN(T/RAD)+R)                                  PLTAERO  738
      Y=X*TAN(T/RAD)                                                    PLTAERO  739
      RETURN                                                            PLTAERO  740
   39 IF (T.EQ.270.) X=0.0                                              PLTAERO  741
      IF (T.EQ.270.) Y=-SCALE(IS)*R/2.                                  PLTAERO  742
      IF (T.NE.270.) X=-SCALE(IS)*R/2./(TAN(T/RAD)-R)                   PLTAERO  743
      IF (T.NE.270.) Y=X*TAN(T/RAD)                                     PLTAERO  744
      RETURN                                                            PLTAERO  745
C        SYMBOL NUMBER 10 OR 20                                         PLTAERO  746
   40 IF ((T.GE.0.0).AND.(T.LT.S4)) GO TO 41                            PLTAERO  747
      IF ((T.GE.S4).AND.(T.LT.S5)) GO TO 42                             PLTAERO  748
      IF ((T.GE.S5).AND.(T.LT.S6)) GO TO 43                             PLTAERO  749
      IF ((T.GE.S6).AND.(T.LT.S7)) GO TO 44                             PLTAERO  750
      IF ((T.GE.S7).AND.(T.LE.360.)) GO TO 41                           PLTAERO  751
   41 X=SCALE(IS)/2.                                                    PLTAERO  752
      Y=X*TAN(T/RAD)                                                    PLTAERO  753
      RETURN                                                            PLTAERO  754
   42 IF (T.LT.90.) X=SCALE(IS)*.6/(TAN(T/RAD)+1.)                      PLTAERO  755
      IF (T.EQ.90.) X=0.0                                               PLTAERO  756
      IF (T.GT.90.) X=SCALE(IS)*.6/(TAN(T/RAD)-1.)                      PLTAERO  757
      IF (T.EQ.90.) Y=SCALE(IS)*.6                                      PLTAERO  758
      IF (T.NE.90.) Y=X*TAN(T/RAD)                                      PLTAERO  759
      RETURN                                                            PLTAERO  760
   43 X=-SCALE(IS)/2.                                                   PLTAERO  761
      Y=X*TAN(T/RAD)                                                    PLTAERO  762
      RETURN                                                            PLTAERO  763
   44 Y=-SCALE(IS)*.4                                                   PLTAERO  764
```

```
                 IF (T.EQ.270.) X=0.0                              PLTAERO  765
                 IF (T.NE.270.) X=Y/TAN(T/RAD)                     PLTAERO  766
                 RETUPN                                            PLTAERO  767
           C        SYMBOL NUMBER 21 OR 22                         PLTAERO  768
215        45    X=.1*SCALE(IS)*COS(T/RAD)                         PLTAERO  769
                 Y=.1*SCALE(IS)*SIN(T/RAD)                         PLTAERO  770
                 RETURN                                            PLTAERO  771
                 END                                               PLTAERO  772
```

```
      SUBROUTINE CURPLT (X,Y,N,NO,IS,IOP,IRUN)                          PLTAERO  773
C        X AND Y  ARE COORDINATES OF POINTS TO BE PLOTTED               PLTAERO  774
C        N  IS NUMBER OF POINTS                                         PLTAERO  775
C        NO  IS SYMBOL IDENTIFICATION NUMBER                            PLTAERO  776
C        IS  IS SYMBOL SIZE IDENTIFICATION                              PLTAERO  777
C        IOP  IS PLOT OPTION    IOP=1 PLOT SYMBOLS ONLY                 PLTAERO  778
C                               IOP=2 PLOT CURVE AND SYMBOL             PLTAERO  779
C                                                                       PLTAERO  780
      DIMENSION X(N), Y(N)                                              PLTAERO  781
      DIMENSION DS1(105), DS2(105), DUMX(105), DUMY(105), DELTH(3)      PLTAERO  782
      REAL M(50)                                                        PLTAERO  783
      DATA RAD/57.2957795131/,NH/101/,XNT/100./,DIFF/0.0001/,NTA/100/,DEPLTAERO  784
     1LTH/.02,.03,.04/                                                  PLTAERO  785
      IF (IOP.EQ.1) GO TO 1                                             PLTAERO  786
      IF (IOP.EQ.2) GO TO 3                                             PLTAERO  787
    1 DO 2 I=1,N                                                        PLTAERO  788
    2 CALL PNTPLT (X(I),Y(I),NO,IS)                                     PLTAERO  789
      RETURN                                                            PLTAERO  790
C        CHECK TO SEE IF X IS STRICTLY INCREASING                       PLTAERO  791
    3 DO 4 I=2,N                                                        PLTAERO  792
      IF (X(I).LT.X(I-1)) GO TO 5                                       PLTAERO  793
    4 CONTINUE                                                          PLTAERO  794
      GO TO 7                                                           PLTAERO  795
    5 PRINT 21, IRUN                                                    PLTAERO  796
      PRINT 22, (X(I),Y(I),I=1,N)                                       PLTAERO  797
      DO 6 I=1,N                                                        PLTAERO  798
    6 CALL PNTPLT (X(I),Y(I),NO,IS)                                     PLTAERO  799
      RETURN                                                            PLTAERO  800
    7 CALL CUBSPL (X,Y,N,M)                                             PLTAERO  801
C        PLOT FIRST POINT                                               PLTAERO  802
      CALL PNTPLT (X(1),Y(1),NO,IS)                                     PLTAERO  803
C        PLOT REMAINING POINTS                                          PLTAERO  804
      NN=N-1                                                            PLTAERO  805
      DO 20 I=1,NN                                                      PLTAERO  806
C        COMPUTE STRAIGHT LINE DISTANCE BETWEEN TWO POINTS. IF DISTANCE PLTAERO  807
C        LESS THAN SYMBOL DIAMETER, PLOT POINTS ONLY.                   PLTAERO  808
      X1=X(I+1)-X(I)                                                    PLTAERO  809
      Y1=Y(I+1)-Y(I)                                                    PLTAERO  810
      DS=SQRT(X1*X1+Y1*Y1)                                              PLTAERO  811
      T1=ATANH(Y1,X1)                                                   PLTAERO  812
      CALL SYMBS (NO,IS,XS1,YS1,T1)                                     PLTAERO  813
      DSS1=SQRT(XS1*XS1+YS1*YS1)                                        PLTAERO  814
```

```
      X1=-X1                                                              PLTAERO   815
      Y1=-Y1                                                              PLTAERO   816
      T1=ATANH(Y1,X1)                                                     PLTAERO   817
      CALL SYMBS (NO,IS,XS2,YS2,T1)                                       PLTAERO   818
      DSS2=SQRT(XS2*XS2+YS2*YS2)                                          PLTAERO   819
      IF ((DSS1+DSS2).GE.DS) GO TO 19                                     PLTAERO   820
C        COMPUTE DISTANCE ALONG CURVE AS A FUNCTION OF X BETWEEN POINT    PLTAERO   821
C        I AND I+1                                                        PLTAERO   822
      NT=IFIX(XNT*(X(I+1)-X(I)))+1                                        PLTAERO   823
      IF (NT.LT.3) NT=3                                                   PLTAERO   824
      IF (NT.GT.NH) NT=NH                                                 PLTAERO   825
      DELTA=(X(I+1)-X(I))/FLOAT(NT-1)                                     PLTAERO   826
      DUMX(1)=X(I)                                                        PLTAERO   827
      DUMY(1)=Y(I)                                                        PLTAERO   828
      DS1(1)=0.0                                                          PLTAERO   829
      XA=X(I)                                                             PLTAERO   830
      DO 8 J=2,NT                                                         PLTAERO   831
      XA=XA+DELTA                                                         PLTAERO   832
      DUMX(J)=XA                                                          PLTAERO   833
      DUMY(J)=FUNC(XA,X(I),X(I+1),Y(I),Y(I+1),M(I),M(I+1))                PLTAERO   834
    8 DS1(J)=SQRT((DUMX(J)-X(I))**2+(DUMY(J)-Y(I))**2)                    PLTAERO   835
      DO 9 J=1,NT                                                         PLTAERO   836
      K=NT+1-J                                                            PLTAERO   837
    9 DS2(J)=SQRT((DUMX(K)-X(I+1))**2+(DUMY(K)-Y(I+1))**2)                PLTAERO   838
C        FIND X AND Y LOCATION WHERE SYMBOL AND CURVE INTERSECT           PLTAERO   839
      DELTA=DELTH(IS)                                                     PLTAERO   840
      XA=X(I)                                                             PLTAERO   841
      DO 11 J=2,NTA                                                       PLTAERO   842
      XA=XA+DELTA                                                         PLTAERO   843
      IF (XA.GE.X(I+1)) GO TO 12                                          PLTAERO   844
      X1=XA-X(I)                                                          PLTAERO   845
      Y1=FUNC(XA,X(I),X(I+1),Y(I),Y(I+1),M(I),M(I+1))-Y(I)                PLTAERO   846
      DS=SQRT(X1*X1+Y1*Y1)                                                PLTAERO   847
      T1=ATANH(Y1,X1)                                                     PLTAERO   848
      CALL SYMBS (NO,IS,XS1,YS1,T1)                                       PLTAERO   849
      DSS1=SQRT(XS1*XS1+YS1*YS1)                                          PLTAERO   850
      IF (ABS(DS-DSS1).LE.DIFF) GO TO 12                                  PLTAERO   851
      IF (DS.GT.DSS1) GO TO 10                                            PLTAERO   852
      GO TO 11                                                            PLTAERO   853
   10 XA=XA-DELTA                                                         PLTAERO   854
      DELTA=DELTA/2.                                                      PLTAERO   855
   11 CONTINUE                                                            PLTAERO   856
```

```
12    XS1=XS1+X(I)                                                      PLTAERO  857
      YS1=YS1+Y(I)                                                      PLTAERO  858
      DELTA=DELTH(IS)                                                   PLTAERO  859
      XA=X(I+1)                                                         PLTAERO  860
      DO 14 J=2,NTA                                                     PLTAERO  861
      XA=XA-DELTA                                                       PLTAERO  862
      IF (XA.LE.X(I)) GO TO 15                                          PLTAERO  863
      X1=XA-X(I+1)                                                      PLTAERO  864
      Y1=FUNC(XA,X(I),X(I+1),Y(I),Y(I+1),M(I),M(I+1))-Y(I+1)            PLTAERO  865
      DS=SQRT(X1*X1+Y1*Y1)                                              PLTAERO  866
      T1=ATANH(Y1,X1)                                                   PLTAERO  867
      CALL SYMBS (NO,IS,XS2,YS2,T1)                                     PLTAERO  868
      DSS2=SQRT(XS2*XS2+YS2*YS2)                                        PLTAERO  869
      IF (ABS(DS-DSS2).LE.DIFF) GO TO 15                                PLTAERO  870
      IF (DS.GT.DSS2) GO TO 13                                          PLTAERO  871
      GO TO 14                                                          PLTAERO  872
13    XA=XA+DELTA                                                       PLTAERO  873
      DELTA=DELTA/2.                                                    PLTAERO  874
14    CONTINUE                                                          PLTAERO  875
15    XS2=XS2+X(I+1)                                                    PLTAERO  876
      YS2=YS2+Y(I+1)                                                    PLTAERO  877
      NP=1                                                              PLTAERO  878
      NDS1=0                                                            PLTAERO  879
      DO 16 J=2,NT                                                      PLTAERO  880
      IF ((DS1(J).LT.DSS1).AND.(NDS1.EQ.0)) GO TO 16                    PLTAERO  881
      IF ((DS1(J).GE.DSS1).AND.(NDS1.EQ.0)) NDS1=1                      PLTAERO  882
      NP=NP+1                                                           PLTAERO  883
      DUMX(NP)=DUMX(J)                                                  PLTAERO  884
      DUMY(NP)=DUMY(J)                                                  PLTAERO  885
16    CONTINUE                                                          PLTAERO  886
      DUMX(1)=XS1                                                       PLTAERO  887
      DUMY(1)=YS1                                                       PLTAERO  888
      DO 17 J=1,NT                                                      PLTAERO  889
      IF (DS2(J).LE.DSS2) GO TO 17                                      PLTAERO  890
      GO TO 18                                                          PLTAERO  891
17    NP=NP-1                                                           PLTAERO  892
18    NP=NP+1                                                           PLTAERO  893
      DUMX(NP)=XS2                                                      PLTAERO  894
      DUMY(NP)=YS2                                                      PLTAERO  895
C        PLOT CURVE BETWEEN POINTS                                      PLTAERO  896
      DUMX(NP+1)=DUMY(NP+1)=0.0                                         PLTAERO  897
      DUMX(NP+2)=DUMY(NP+2)=1.0                                         PLTAERO  898
```

```
         CALL LINE (DUMX,DUMY,NP,1,0,0,0)                                     PLTAERO  899
   19    CALL PNTPLT (X(I+1),Y(I+1),NO,IS)                                    PLTAERO  900
   20    CONTINUE                                                             PLTAERO  901
         RETURN                                                               PLTAERO  902
C                                                                             PLTAERO  903
   21    FORMAT (1H1//5X,36HX IS NOT STRICTLY INCREASING FOR RUN,I7/16X,1HXPLTAERO  904
        1,13X,1HY/)                                                           PLTAERO  905
   22    FORMAT (5X,2F15.4)                                                   PLTAERO  906
         END                                                                  PLTAERO  907
```

```
      SUBROUTINE CUBSPL (X,Y,N,B)                                         PLTAERO   908
      DIMENSION X(N), Y(N), B(N)                                          PLTAERO   909
C        DIMENSION A(10*N)                                                PLTAERO   910
      DIMENSION A(500)                                                    PLTAERO   911
      COMMON/HLM/TENR,XINT,ST                                             PLTAERO   912
      COMMON/TENS/T                                                       PLTAERO   913
C        CUBIC SPLINE CURVE FIT PROGRAM                                   PLTAERO   914
      M=N-1                                                               PLTAERO   915
      N1=M+1                                                              PLTAERO   916
      N2=N1+N                                                             PLTAERO   917
      N3=N2+N                                                             PLTAERO   918
      N4=N3+N                                                             PLTAERO   919
      N5=N4+N                                                             PLTAERO   920
      N6=N5+N                                                             PLTAERO   921
      N7=N6+N                                                             PLTAERO   922
      N8=N7+N                                                             PLTAERO   923
      N9=N8+N                                                             PLTAERO   924
C        LOAD MATRIX ROWS 2 THRU N-1                                      PLTAERO   925
      T=TENR*FLOAT(N-1)/(X(N)-X(1))                                       PLTAERO   926
      DO 1 I=1,M                                                          PLTAERO   927
      H2=X(I+1)-X(I)                                                      PLTAERO   928
      A(I)=(1./H2-T/SINH(T*H2))/(T*T)                                     PLTAERO   929
      K=2*N+I                                                             PLTAERO   930
      A(K)=A(I)                                                           PLTAERO   931
      IF(I.EQ.1) GO TO 1                                                  PLTAERO   932
      K=K+N                                                               PLTAERO   933
      H1=X(I)-X(I-1)                                                      PLTAERO   934
      A(K)=(T*COSH(T*H1)/SINH(T*H1)-1./H1+T*COSH(T*H2)/SINH(T*H2)-1./H2)PLTAERO   935
     1/(T*T)                                                              PLTAERO   936
      K=K+N                                                               PLTAERO   937
      A(K)=(Y(I+1)-Y(I))/(X(I+1)-X(I))-(Y(I)-Y(I-1))/(X(I)-X(I-1))        PLTAERO   938
    1 CONTINUE                                                            PLTAERO   939
C        LOAD MATRIX ROWS 1 AND N                                         PLTAERO   940
      A(N3)=1.0                                                           PLTAERO   941
      A(N4-1)=1.0                                                         PLTAERO   942
      A(N2)=-.5                                                           PLTAERO   943
      A(M)=-.5                                                            PLTAERO   944
      A(N4)=0.0                                                           PLTAERO   945
      A(N5-1)=0.0                                                         PLTAERO   946
C        SOLVE TRIDIAGONAL MATRIX                                         PLTAERO   947
      A(N7)=A(N3)                                                         PLTAERO   948
      A(N8)=A(N4)/A(N3)                                                   PLTAERO   949
```

```
      A(N9)=A(N2)/A(N3)                                                 PLTAERO  950
C                                                                       PLTAERO  951
      DO 4 I=2,N                                                        PLTAERO  952
      I1=I-1                                                            PLTAERO  953
      I2=I-2                                                            PLTAERO  954
      A(N7+I1)=A(N3+I1)-A(I1)*A(N9+I2)                                  PLTAERO  955
      IF (I.EQ.N) GO TO 4                                               PLTAERO  956
      A(N9+I1)=A(N2+I1)/A(N7+I1)                                        PLTAERO  957
    4 A(N8+I1)=(A(N4+I1)-A(I1)*A(N8+I2))/A(N7+I1)                       PLTAERO  958
C                                                                       PLTAERO  959
      A(N6-1)=A(N9-1)                                                   PLTAERO  960
      DO 5 I=1,M                                                        PLTAERO  961
      I1=N6-1-I                                                         PLTAERO  962
      I2=N-I                                                            PLTAERO  963
      I3=I2-1                                                           PLTAERO  964
    5 A(I1)=A(N8+I3)-A(N9+I3)*A(I1+1)                                   PLTAERO  965
C                                                                       PLTAERO  966
      K=0                                                               PLTAERO  967
      DO 6 I=1,N                                                        PLTAERO  968
      I1=I-1                                                            PLTAERO  969
      A(N6+K)=A(N5+I1)                                                  PLTAERO  970
    6 K=K+1                                                             PLTAERO  971
      A(M)=A(N3-2)                                                      PLTAERO  972
C        LOAD SOLUTION INTO B VECTOR                                    PLTAERO  973
      DO 7 I=1,N                                                        PLTAERO  974
      I1=N6+I-1                                                         PLTAERO  975
    7 B(I)=A(I1)                                                        PLTAERO  976
C                                                                       PLTAERO  977
      XINT=0.0                                                          PLTAERO  978
      DO 11 I=2,N                                                       PLTAERO  979
      H = X(I) - X(I-1)                                                 PLTAERO  980
   11 XINT=XINT+(Y(I)+Y(I-1))*(X(I)-X(I-1))/2.                          PLTAERO  981
     1 - (B(I)+B(I-1))*((1.-COSH(T*H))/(T**3*SINH(T*H))+H/(2.*T*T))     PLTAERO  982
      RETURN                                                            PLTAERO  983
      END                                                               PLTAERO  984
```

APPENDIX

```
      FUNCTION FUNC(X,X1,X2,Y1,Y2,M1,M2)                               PLTAERO   985
      COMMON/TENS/T                                                    PLTAERO   986
      REAL M1,M2                                                       PLTAERO   987
C        SPLINE FUNCTION UNDER TENSION (T)                             PLTAERO   988
      DX1=X-X1                                                         PLTAERO   989
      DX2=X2-X                                                         PLTAERO   990
      H=X2-X1                                                          PLTAERO   991
      F1=M1/(T*T)                                                      PLTAERO   992
      F2=M2/(T*T)                                                      PLTAERO   993
      FUNC=(F1*SINH(T*DX2)+F2*SINH(T*DX1))/SINH(T*H)+((Y1-F1)*DX2+(Y2-F2PLTAERO   994
     1)*DX1)/H                                                         PLTAERO   995
      RETURN                                                           PLTAERO   996
      END                                                              PLTAERO   997
```

```
      FUNCTION ATANH (DY,DX)                                           PLTAERO   998
      IF (DX.EQ.0.0) GO TO 1                                           PLTAERO   999
      ATANH=ABS(DY/DX)                                                 PLTAERO  1000
      ATANH=ATAN(ATANH)*57.2957795131                                  PLTAERO  1001
      IF ((DX.GT.0.0).AND.(DY.LT.0.0)) ATANH=360.-ATANH                PLTAERO  1002
      IF ((DX.LT.0.0).AND.(DY.GT.0.0)) ATANH=180.-ATANH                PLTAERO  1003
      IF ((DX.LT.0.0).AND.(DY.LT.0.0)) ATANH=180.+ATANH                PLTAERO  1004
      RETURN                                                           PLTAERO  1005
    1 IF (DY.LT.0.0) ATANH=270.                                        PLTAERO  1006
      IF (DY.GE.0.0) ATANH=90.                                         PLTAERO  1007
      RETURN                                                           PLTAERO  1008
      END                                                              PLTAERO  1009
```

```
      SUBROUTINE TSPLINE(X,Y,N,B,ST,IOP,NP,XI,YI,YP,YPP,XINT)          PLTAERO   1010
C                                                                      PLTAERO   1011
C        TENSION AND CUBIC SPLINE CURVE FIT PROGRAM                    PLTAERO   1012
C                                                                      PLTAERO   1013
C        X AND Y - INPUT TABLE.                                        PLTAERO   1014
C        N       - NUMBER OF INPUT VALUES OF X AND Y.                  PLTAERO   1015
C        B       - SOLUTION VECTOR (SECOND DERIVATIVE AT INPUT VALUES OFPLTAERO   1016
C                  X AND Y.                                            PLTAERO   1017
C        ST      - TENSION PARAMETER.                                  PLTAERO   1018
C        IOP     - COMPUTING OPTION.                                   PLTAERO   1019
C                  =0  COMPUTE YI,YP,AND YPP AT NP EQUALLY SPACED VALUESPLTAERO   1020
C                      OF XI BETWEEN X(1) AND X(N)                     PLTAERO   1021
C                  =1  COMPUTE YI,YP,AND YPP AT NP INPUT VALUES OF XI  PLTAERO   1022
C        NP      - NUMBER OF INPUT VALUES OF XI.                       PLTAERO   1023
C        XI      - INPUT TABLE OF INTERPOLATION VALUES OF X BETWEEN X(1)PLTAERO   1024
C                  AND X(N).                                           PLTAERO   1025
C        YI      - INTERPOLATED TABLE OF Y VALUES.                     PLTAERO   1026
C        YP      - INTERPOLATED TABLE OF FIRST DERIVATIVE VALUES.      PLTAERO   1027
C        YPP     - INTERPOLATED TABLE OF SECOND DERIVATIVE VALUES.     PLTAERO   1028
C        XINT    - VALUE OF INTEGRAL OF Y BETWEEN X(1) AND X(N).       PLTAERO   1029
C                                                                      PLTAERO   1030
      DIMENSION X(N),Y(N),B(65),XI(65),YI(65),YP(65),YPP(65)           MOD1       145
C        A IS DUMMY STORAGE VECTOR. DIMENSION A(10*N).                 PLTAERO   1032
      DIMENSION A(650)                                                 MOD1       146
C                                                                      PLTAERO   1034
      M=N-1                                                            PLTAERO   1035
      N1=N+1                                                           PLTAERO   1036
      N2=N1+N                                                          PLTAERO   1037
      N3=N2+N                                                          PLTAERO   1038
      N4=N3+N                                                          PLTAERO   1039
      N5=N4+N                                                          PLTAERO   1040
      N6=N5+N                                                          PLTAERO   1041
      N7=N6+N                                                          PLTAERO   1042
      N8=N7+N                                                          PLTAERO   1043
      N9=N8+N                                                          PLTAERO   1044
      T=ST*FLOAT(N-1)/(X(N)-X(1))                                      PLTAERO   1045
C        LOAD MATRIX ROWS 2 THRU N-1.                                  PLTAERO   1046
      DO 1 I=1,M                                                       PLTAERO   1047
      H2=X(I+1)-X(I)                                                   PLTAERO   1048
      IF(ST.EQ.0.0) A(I)=H2/6.                                         PLTAERO   1049
      IF(ST.NE.0.0) A(I)=(1./H2-T/SINH(T*H2))/(T*T)                    PLTAERO   1050
      K=2*N+I                                                          PLTAERO   1051
```

```
      A(K)=A(I)                                                         PLTAERO   1052
      IF(I.EQ.1) GO TO 1                                                PLTAERO   1053
      K=K+N                                                             PLTAERO   1054
      H1=X(I)-X(I-1)                                                    PLTAERO   1055
      IF(ST.EQ.0.0) A(K)=(H2+H1)/3.                                     PLTAERO   1056
      IF(ST.NE.0.0) A(K)=(T*COSH(T*H1)/SINH(T*H1)-1./H1+T*COSH(T*H2)/SINPLTAERO   1057
     1H(T*H2)-1./H2)/(T*T)                                              PLTAERO   1058
      K=K+N                                                             PLTAERO   1059
      A(K)=(Y(I+1)-Y(I))/H2-(Y(I)-Y(I-1))/H1                            PLTAERO   1060
    1 CONTINUE                                                          PLTAERO   1061
C        LOAD MATRIX ROWS 1 AND N.                                      PLTAERO   1062
      A(M)=-.5                                                          PLTAERO   1063
      A(N2)=-.5                                                         PLTAERO   1064
      A(N3)=1.0                                                         PLTAERO   1065
      A(N4-1)=1.0                                                       PLTAERO   1066
      A(N4)=0.0                                                         PLTAERO   1067
      A(N5-1)=0.0                                                       PLTAERO   1068
C        SOLVE TRIDIAGONAL MATRIX.                                      PLTAERO   1069
      A(N7)=A(N3)                                                       PLTAERO   1070
      A(N8)=A(N4)/A(N3)                                                 PLTAERO   1071
      A(N9)=A(N2)/A(N3)                                                 PLTAERO   1072
      DO 4 I=2,N                                                        PLTAERO   1073
      I1=I-1                                                            PLTAERO   1074
      I2=I-2                                                            PLTAERO   1075
      A(N7+I1)=A(N3+I1)-A(I1)*A(N9+I2)                                  PLTAERO   1076
      IF(I.EQ.N) GO TO 4                                                PLTAERO   1077
      A(N9+I1)=A(N2+I1)/A(N7+I1)                                        PLTAERO   1078
    4 A(N8+I1)=(A(N4+I1)-A(I1)*A(N8+I2))/A(N7+I1)                       PLTAERO   1079
      A(N6-1)=A(N9-1)                                                   PLTAERO   1080
      DO 5 I=1,M                                                        PLTAERO   1081
      I1=N6-1-I                                                         PLTAERO   1082
      I2=N-I                                                            PLTAERO   1083
      I3=I2-1                                                           PLTAERO   1084
    5 A(I1)=A(N8+I3)-A(N9+I3)*A(I1+1)                                   PLTAERO   1085
      K=0                                                               PLTAERO   1086
      DO 6 I=1,N                                                        PLTAERO   1087
      I1=I-1                                                            PLTAERO   1088
      A(N6+K)=A(N5+I1)                                                  PLTAERO   1089
    6 K=K+1                                                             PLTAERO   1090
      A(M)=A(N3-2)                                                      PLTAERO   1091
C        LOAD SOLUTION INTO VECTOR B.                                   PLTAERO   1092
      DO 7 I=1,N                                                        PLTAERO   1093
```

```
      I1=N6+I-1                                                         PLTAERO 1094
    7 B(I)=A(I1)                                                        PLTAERO 1095
C        COMPUTE  Y,YP,YPP AT DESIRED X VALUES                          PLTAERO 1096
      IF(NP.LE.0) RETURN                                                PLTAERO 1097
      IF(IOP.EQ.0) GO TO 13                                             PLTAERO 1098
      GO TO 14                                                          PLTAERO 1099
   13 DELTAX=(X(N)-X(1))/FLOAT(NP-1)                                    PLTAERO 1100
      XI(1)=X(1)                                                        PLTAERO 1101
      DO 15 I=2,NP                                                      PLTAERO 1102
   15 XI(I)=XI(I-1)+DELTAX                                              PLTAERO 1103
   14 CONTINUE                                                          PLTAERO 1104
      DO 8 I=1,NP                                                       PLTAERO 1105
      P=XI(I)                                                           PLTAERO 1106
      DO 9 K=2,N                                                        PLTAERO 1107
      K1=K-1                                                            PLTAERO 1108
      IF((P.GE.X(K1)).AND.(P.LE.X(K))) GO TO 10                         PLTAERO 1109
      GO TO 9                                                           PLTAERO 1110
   10 J1=K1                                                             PLTAERO 1111
      J2=K                                                              PLTAERO 1112
    9 CONTINUE                                                          PLTAERO 1113
      H=X(J2)-X(J1)                                                     PLTAERO 1114
      IF(ST.EQ.0.0) GO TO 11                                            PLTAERO 1115
      SINHT=SINH(T*H)                                                   PLTAERO 1116
      YI(I)=B(J1)*(SINH(T*(X(J2)-P))/(T*T*SINHT)-(X(J2)-P)/(H*T*T))+B(J2PLTAERO 1117
     1)*(SINH(T*(P-X(J1)))/(T*T*SINHT)-(P-X(J1))/(H*T*T))+(Y(J1)*(X(J2)-PLTAERO 1118
     2P)+Y(J2)*(P-X(J1)))/H                                             PLTAERO 1119
      YP(I)=B(J1)*(1./(H*T*T)-COSH(T*(X(J2)-P))/(T*SINHT))+B(J2)*(COSH(TPLTAERO 1120
     1*(P-X(J1)))/(T*SINHT)-1./(H*T*T))+(Y(J2)-Y(J1))/H                 PLTAERO 1121
      YPP(I)=B(J1)*SINH(T*(X(J2)-P))/SINHT+B(J2)*SINH(T*(P-X(J1)))/SINHTPLTAERO 1122
      GO TO 8                                                           PLTAERO 1123
   11 YI(I)=B(J1)*((X(J2)-P)**3/(6.*H)-(X(J2)-P)*H/6.)+B(J2)*((P-X(J1))*PLTAERO 1124
     1*3/(6.*H)-(P-X(J1))*H/6.)+(Y(J1)*(X(J2)-P)+Y(J2)*(P-X(J1)))/H     PLTAERO 1125
      YP(I)=B(J1)*(H/6.-(X(J2)-P)**2/(2.*H))+B(J2)*((P-X(J1))**2/(2.*H)-PLTAERO 1126
     1H/6.)+(Y(J2)-Y(J1))/H                                             PLTAERO 1127
      YPP(I)=B(J1)*(X(J2)-P)/H+B(J2)*(P-X(J1))/H                        PLTAERO 1128
    8 CONTINUE                                                          PLTAERO 1129
C        COMPUTE INTEGRAL OF Y BETWEEN X(1) AND X(N).                   PLTAERO 1130
      XINT=0.0                                                          PLTAERO 1131
      DO 12 I=2,N                                                       PLTAERO 1132
      H=X(I)-X(I-1)                                                     PLTAERO 1133
      XINT=XINT+(Y(I)+Y(I-1))*H/2.                                      PLTAERO 1134
      IF(ST.EQ.0.0)XINT=XINT-(B(I)+B(I-1))*H**3/24.                     PLTAERO 1135
```

```
      IF(ST.NE.0.0)XINT=XINT-(B(I)+B(I-1))*((1.-COSH(T*H))/(T**3*SINH(T*PLTAERO 1136
     1H))+H/(2.*T*T))                                                  PLTAERO 1137
130   12 CONTINUE                                                      PLTAERO 1138
C                                                                      PLTAERO 1139
      RETURN                                                           PLTAERO 1140
      END                                                              PLTAERO 1141
```

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1. Davis, John M.: Rotorcraft Flight Simulation With Aeroelastic Rotor and Improved Aerodynamic Representation. Volume II - User's Manual. USAAMRDL-TR-74-10B, U.S. Army, June 1974. (Available from DDC as AD 782 756.)

2. Landgrebe, Anton J.: An Analytical and Experimental Investigation of Helicopter Rotor Hover Performance and Wake Geometry Characteristics. USAAMRDL Tech. Rep. 71-24, U.S. Army, June 1971. (Available from DDC as AD 728 835.)

3. Cline, A. K.: Scalar- and Planar-Valued Curve Fitting Using Splines Under Tension. Commun. ACM, vol. 17, no. 4, Apr. 1974, pp. 218-220.

4. Cline, A. K.: Algorithm 476 - Six Subprograms for Curve Fitting Using Splines Under Tension [E2]. Commun. ACM, vol. 17, no. 4, Apr. 1974, pp. 220-223.

5. Noonan, Kevin W.; and Bingham, Gene J.: Two-Dimensional Aerodynamic Characteristics of Several Rotorcraft Airfoils at Mach Numbers From 0.35 to 0.90. NASA TM X-73990, 1977.

TABLE I.- COMPUTER PRINTOUT OF INTERPOLATED DATA

LIFT COEFFICIENT

	.3000	.3500	.4000	.4500	.5000	.5500	.6000	.6500	.7000	.7500	.8000	.8500	.9000
-4.0000	-.3137	-.3137	-.3156	-.3267	-.3409	-.3364	-.3392	-.3592	-.4059	-.4958	-.5654	-.5720	-.2865
-3.0000	-.1984	-.1983	-.2056	-.2055	-.2156	-.2105	-.2138	-.2302	-.2553	-.3028	-.3562	-.3801	-.2224
-2.0000	-.0832	-.0829	-.0948	-.0842	-.0904	-.0844	-.0873	-.1006	-.1043	-.1119	-.1478	-.1894	-.1657
-1.0000	.0321	.0323	.0254	.0373	.0347	.0429	.0487	.0446	.0493	.0567	.0535	.0017	-.1091
0.0000	.1463	.1463	.1457	.1563	.1607	.1704	.1827	.1898	.1986	.2184	.2381	.1939	-.0524
1.0000	.2574	.2575	.2568	.2698	.2895	.2982	.3079	.3255	.3375	.3786	.3926		
2.0000	.3683	.3683	.3693	.3834	.4122	.4242	.4365	.4620	.4849	.4859	.4599		
3.0000	.4759	.4765	.4902	.4971	.5301	.5484	.5675	.5930	.6371	.5676	.4750		
4.0000	.5848	.5844	.5990	.6148	.6535	.6720	.6934	.7166	.7048				
5.0000	.7024	.7024	.7054	.7370	.7658	.7926	.8060	.8217	.7614				
6.0000	.8394	.8401	.8150	.8664	.8465	.9067	.8891	.8706	.7904				
7.0000	.9465	.9468	.9342	.9776	.9224	.9769	.9437						
8.0000	1.0127	1.0115	1.0596	1.0719	.9940	1.0048	.9920						
9.0000	1.0763	1.0758	1.0952	1.0950	1.0334	1.0355							
10.0000	1.1375	1.1397	1.0922	1.0973	1.0468	1.0590							
11.0000	1.1502	1.1515	1.1016	1.0972	1.0621	1.0764							
12.0000	1.1431	1.1438	1.1175	1.0958	1.0789	1.0873							

DRAG COEFFICIENT

	.3000	.3500	.4000	.4500	.5000	.5500	.6000	.6500	.7000	.7500	.8000	.8500	.9000
-4.0000	.0073	.0073	.0076	.0080	.0078	.0089	.0114	.0137	.0178	.0274	.0470	.0240	.0406
-3.0000	.0076	.0076	.0075	.0077	.0079	.0081	.0094	.0104	.0124	.0183	.0283	.0222	.0383
-2.0000	.0078	.0078	.0074	.0075	.0080	.0074	.0077	.0073	.0077	.0098	.0112	.0208	.0363
-1.0000	.0074	.0074	.0070	.0077	.0082	.0071	.0074	.0070	.0069	.0081	.0098	.0225	.0374
0.0000	.0071	.0071	.0068	.0078	.0084	.0070	.0076	.0073	.0065	.0099	.0156	.0253	.0397
1.0000	.0077	.0077	.0072	.0079	.0081	.0072	.0078	.0077	.0063	.0149	.0281		
2.0000	.0082	.0082	.0074	.0077	.0078	.0076	.0078	.0085	.0101	.0252	.0329		
3.0000	.0084	.0084	.0071	.0073	.0078	.0082	.0079	.0098	.0218	.0371	.0330		
4.0000	.0079	.0079	.0076	.0071	.0084	.0085	.0093	.0150	.0340				
5.0000	.0077	.0077	.0083	.0072	.0091	.0097	.0117	.0230	.0480				
6.0000	.0089	.0089	.0090	.0076	.0101	.0129	.0157	.0378	.0659				
7.0000	.0095	.0095	.0099	.0092	.0108	.0146	.0203						
8.0000	.0092	.0092	.0111	.0115	.0113	.0149	.0251						
9.0000	.0102	.0101	.0126	.0140	.0133	.0152							
10.0000	.0118	.0118	.0146	.0168	.0165	.0158							
11.0000	.0184	.0182	.0258	.0281	.0248	.0265							
12.0000	.0269	.0265	.0417	.0440	.0367	.0441							

TABLE I.- Concluded

PITCHING-MOMENT COEFFICIENT

	.3000	.3500	.4000	.4500	.5000	.5500	.6000	.6500	.7000	.7500	.8000	.3500	.9000
-4.0000	-.0155	-.0155	-.0157	-.0195	-.0221	-.0252	-.0181	-.0388	-.0442	-.0492	-.0370	-.0291	-.0424
-3.0000	-.0148	-.0148	-.0162	-.0182	-.0202	-.0219	-.0163	-.0314	-.0352	-.0397	-.0365	-.0310	-.0350
-2.0000	-.0141	-.0141	-.0157	-.0171	-.0184	-.0188	-.0144	-.0243	-.0267	-.0304	-.0355	-.0330	-.0275
-1.0000	-.0138	-.0138	-.0146	-.0160	-.0169	-.0173	-.0120	-.0207	-.0219	-.0240	-.0299	-.0352	-.0200
0.0000	-.0133	-.0133	-.0148	-.0149	-.0156	-.0160	-.0063	-.0180	-.0176	-.0196	-.0269	-.0373	-.0126
1.0000	-.0126	-.0124	-.0189	-.0135	-.0145	-.0144	.0066	-.0158	-.0140	-.0177	-.0306		
2.0000	-.0118	-.0115	-.0211	-.0124	-.0133	-.0128	.0141	-.0132	-.0103	-.0201	-.0335		
3.0000	-.0115	-.0114	-.0126	-.0115	-.0117	-.0110	.0148	-.0087	-.0072	-.0244	-.0358		
4.0000	-.0103	-.0103	-.0099	-.0100	-.0090	-.0080	-.0132	-.0032	-.0083				
5.0000	-.0101	-.0101	-.0097	-.0079	-.0056	-.0041	-.0302	.0001	-.0130				
6.0000	-.0130	-.0131	-.0063	-.0049	-.0004	.0008	-.0234	-.0028	-.0254				
7.0000	-.0115	-.0117	-.0040	-.0013	.0045	.0037	-.0191						
8.0000	-.0041	-.0041	-.0017	.0029	.0093	.0047	-.0172						
9.0000	.0004	.0004	.0038	.0079	.0127	.0056							
10.0000	.0032	.0031	.0103	.0127	.0148	.0065							
11.0000	-.0048	-.0051	.0056	.0015	.0042	.0043							
12.0000	-.0173	-.0177	-.0048	-.0187	-.0151	.0002							

TABLE II.- CARD INPUT GUIDE

Card	Variable	Format	Description
1	NAMAX	I5	Maximum number of angles of attack
	NMMAX	I5	Maximum number of Mach numbers
2	KA, KB, KC	3I5	Control plotting of c_l, c_d, and c_m, respectively, in P1 subroutine; e.g., if KA = 0, c_l plots are suppressed, etc.
3	LA, LB, LC	3I5	Control plotting of c_l, c_d, and c_m, respectively, in P2 subroutine; e.g., if LA = 0, c_l plots are suppressed, etc.
4	MA, MB, MC	3I5	Control ılculation and punching of tables for performance program, e.g.; if MA = 0, c_l tables are suppressed, etc.
5	PMN(I)	8F10.0	Desired Mach numbers (extend lowest Mach number data back through 0.3, 0.2, to M = 0, NMMAX values required)
6	XNMN(I)	8F10.0	Number of desired Mach numbers at each desired angle of attack (NAMAX values required)
7	PAA(I)	8F10.0	Desired angles of attack, using 1° intervals starting at -4° (NMMAX values required)
8	XNA(I)	8F10.0	Number of desired angles of attack at each desired Mach number (NMMAX values required)
9	XMN(I)	8F10.0	Measured Mach numbers (extend lowest Mach number data back through 0.3, 0.2, to M = 0, NMMAX values)
10	XNAT(I)	8F10.0	Number of measured angles of attack at each measured Mach number (NMMAX values required)
11	AA(I,J)	8F10.0	Measured angles of attack at Ith Mach number (XNAT(I) values)
12	CL(I,J)	8F10.0	Measured lift coefficients at Ith Mach number (XNAT(I) values)
13	CD(I,J)	8F10.0	Measured drag coefficients at Ith Mach number (XNAT(I) values)
14	CM(I,J)	8F10.0	Measured pitching-moment coefficients at Ith Mach number (XNAT(I) values)
(a)			
15	Title	3A10	Heading for plots (first line)
16	Title	3A10	Heading for plots (second line)

[a]Cards 11, 12, 13, and 14 should be repeated NMMAX times.

TABLE III.- SUBROUTINES USED IN PLTAERO

Subroutine	Use
DECKPL	Input/output and control
BOUND1	Numerical cross-plotting
ADJUST1	Numerical cross-plotting
P1	Plot control
BOUND2	Numerical cross-plotting
ADJUST2	Numerical cross-plotting
P2	Plot control
C81	Punch control
C82	Numerical fairing of performance tables
SYMBS	Draws standards, NASA symbol for cubic spline
CURPLT	Plots and fairs a cubic spline under tension through a set of points
CUBSPL	Calculates cubic spline for CURPLT
FUNC (function)	Auxiliary to CUBSPL
ATANH (function)	Auxiliary to CUBSPL
TSPLINE	Tension and cubic-spline interpolating subroutine

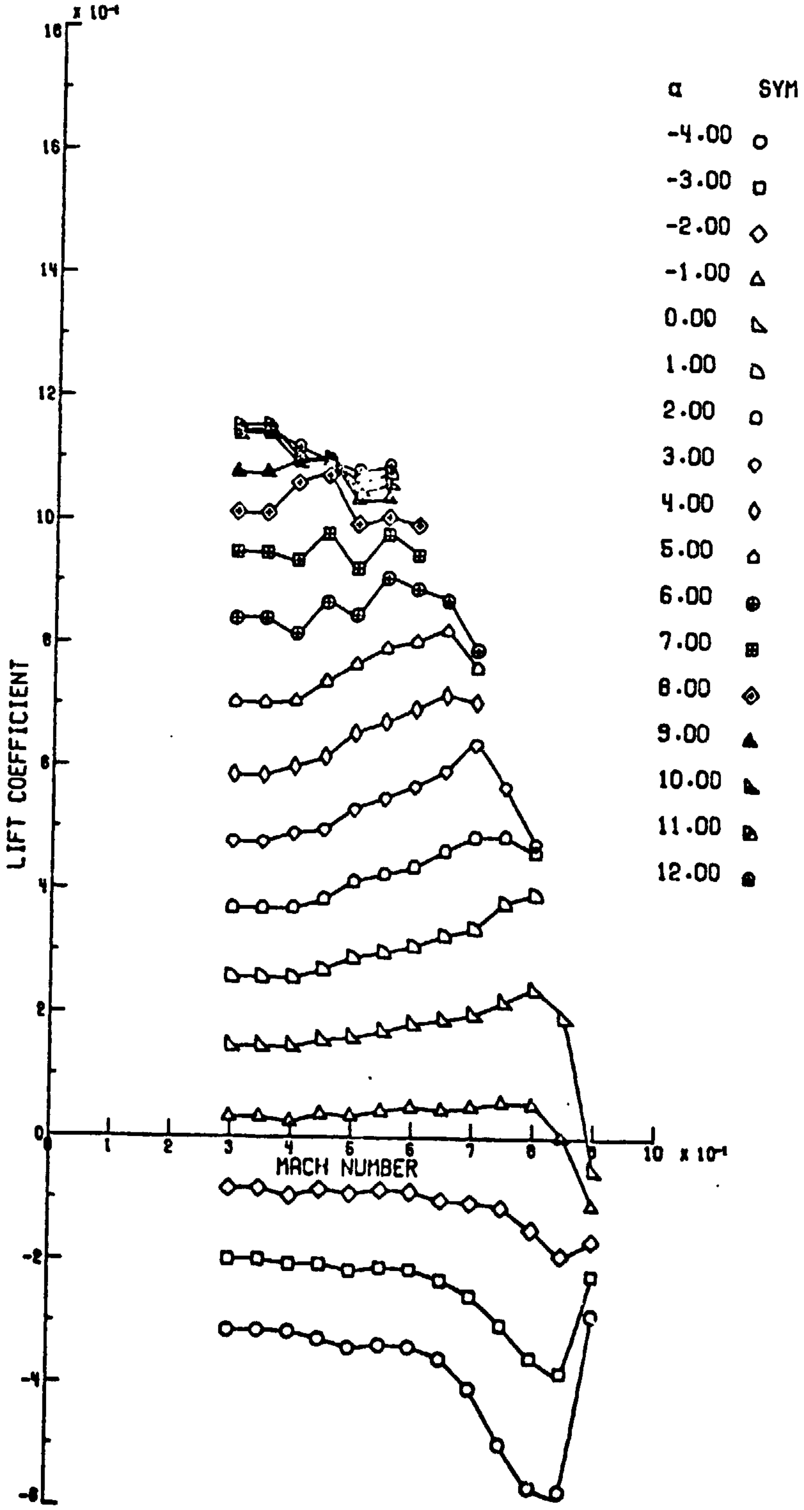


Figure 1.- Blade-element lift coefficient plotted against Mach number for FX69-H-098 airfoil, generated by subroutine P1.

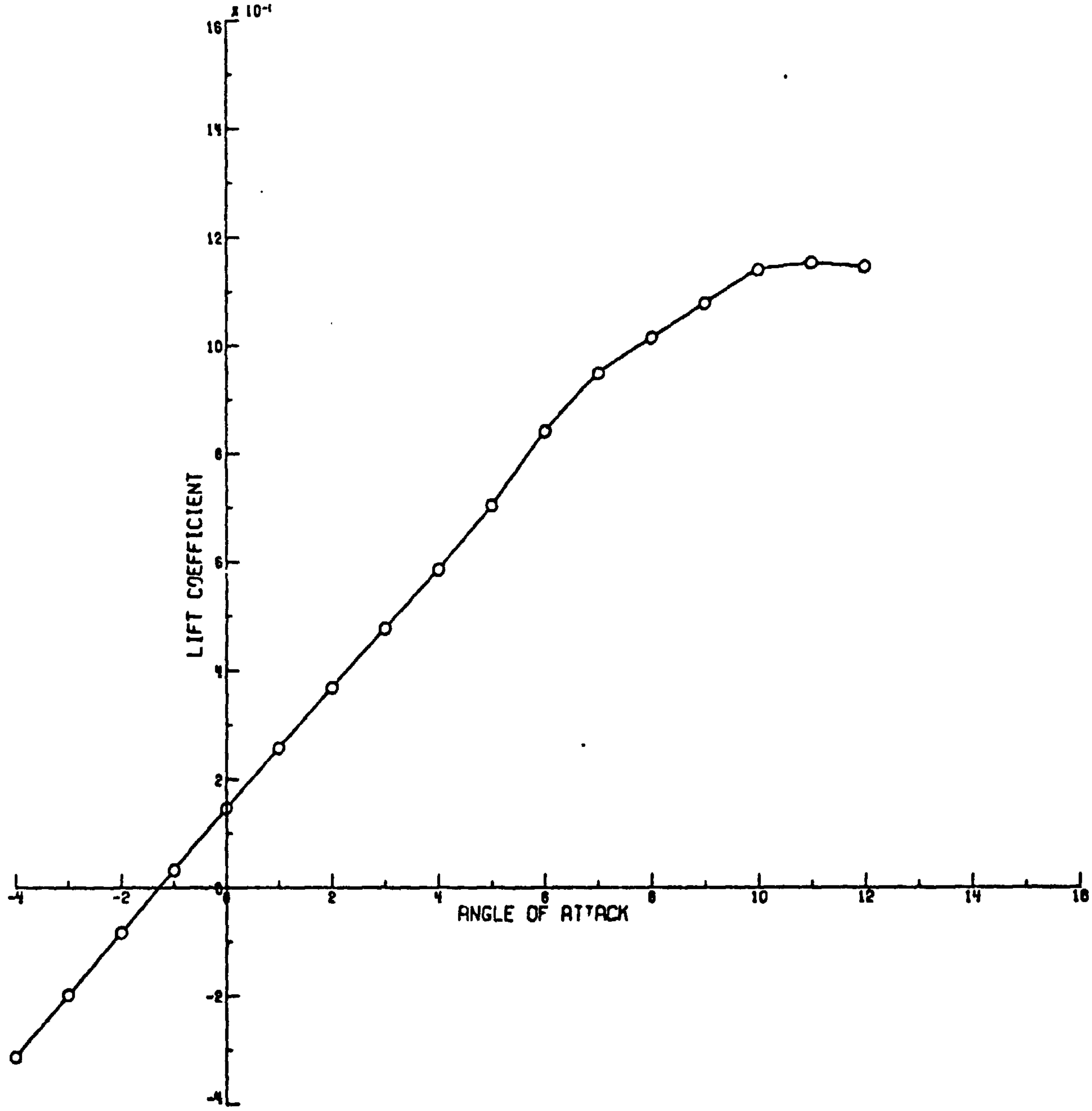


Figure 2.- Blade-element lift coefficient plotted against angle of attack at M = 0.30 for FX69-H-098 airfoil, generated by subroutine P2.

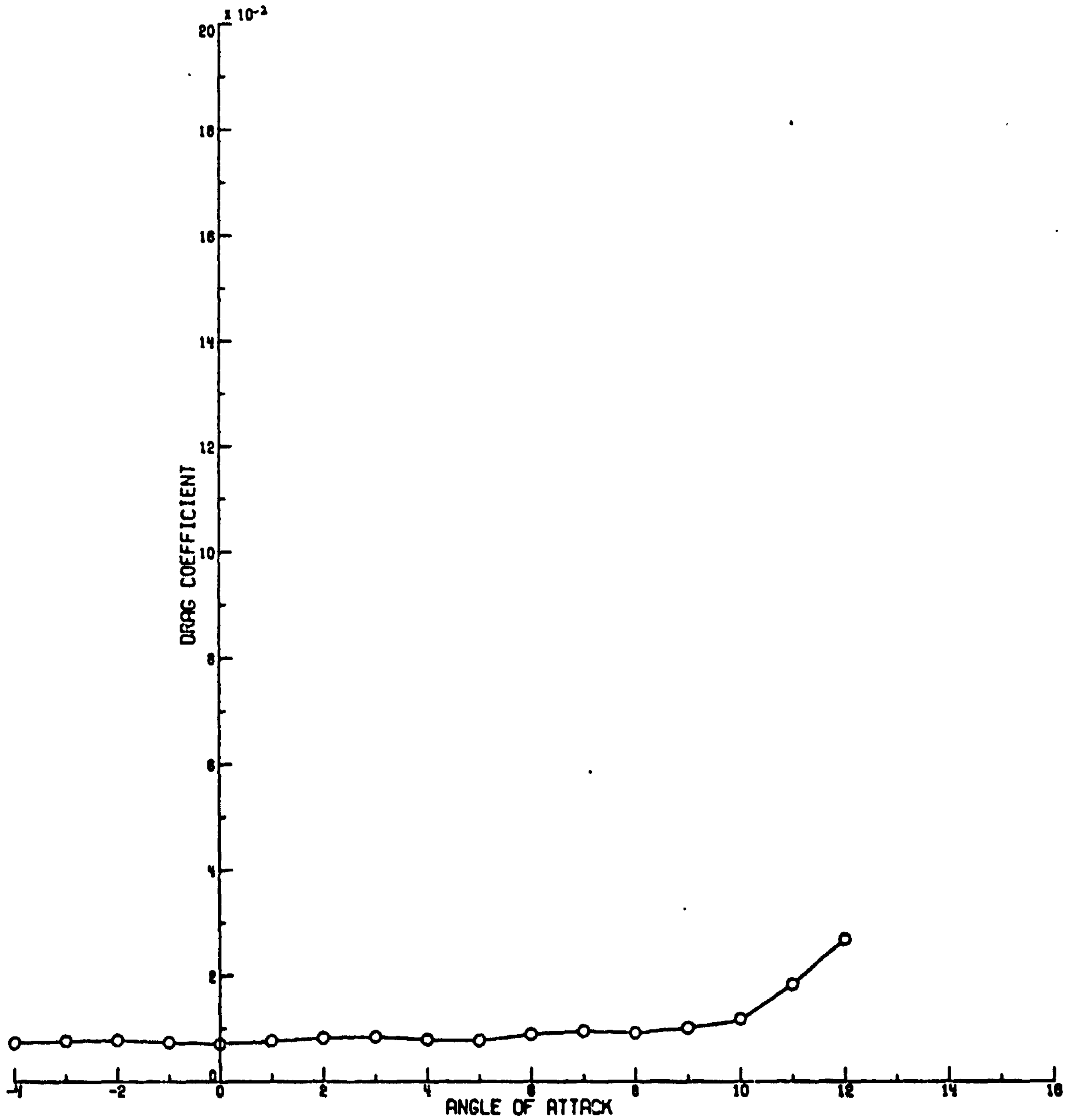


Figure 3.- Blade-element drag coefficient plotted against angle of attack at M = 0.30 for FX69-H-098 airfoil, generated by subroutine P2.

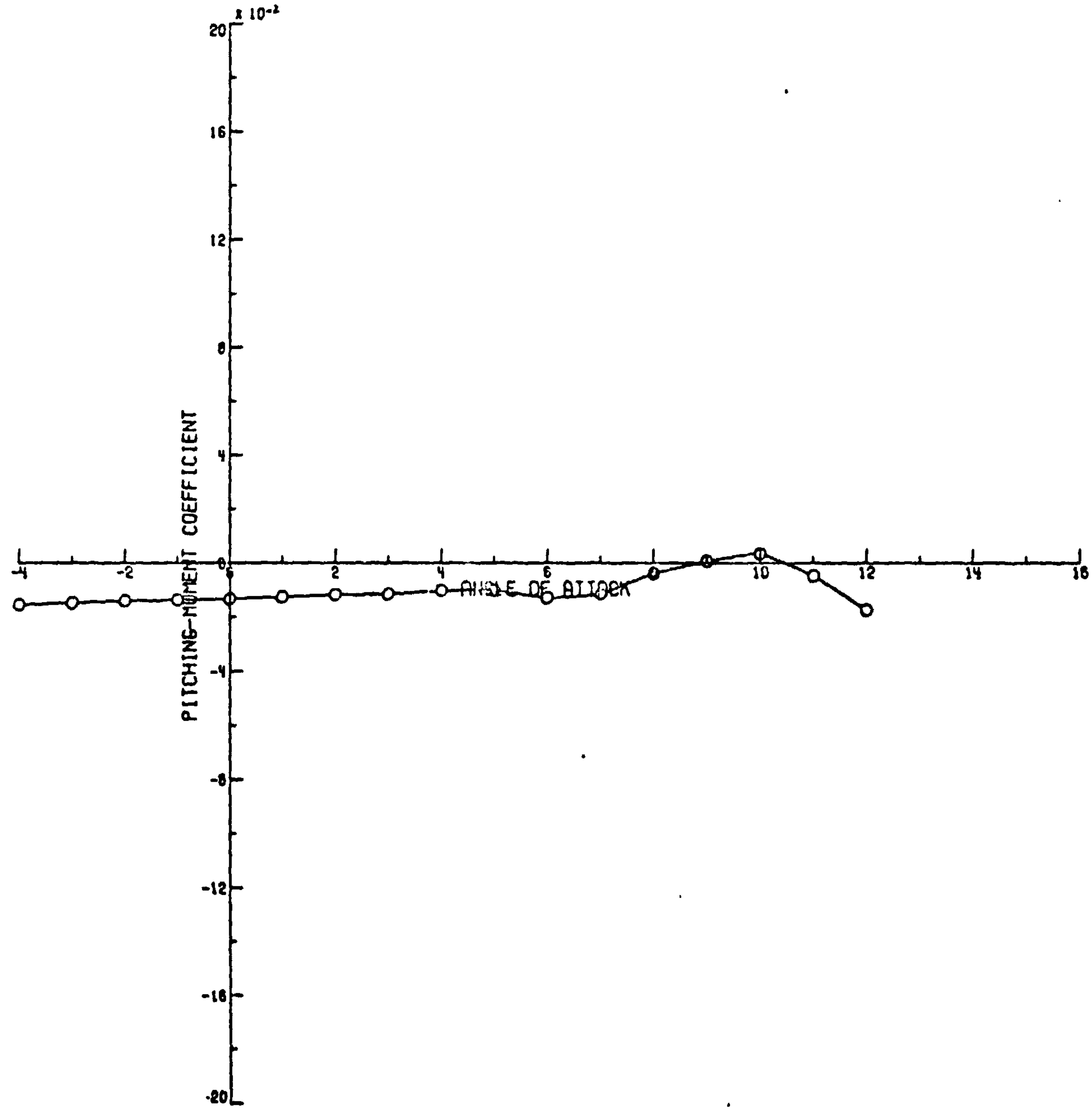
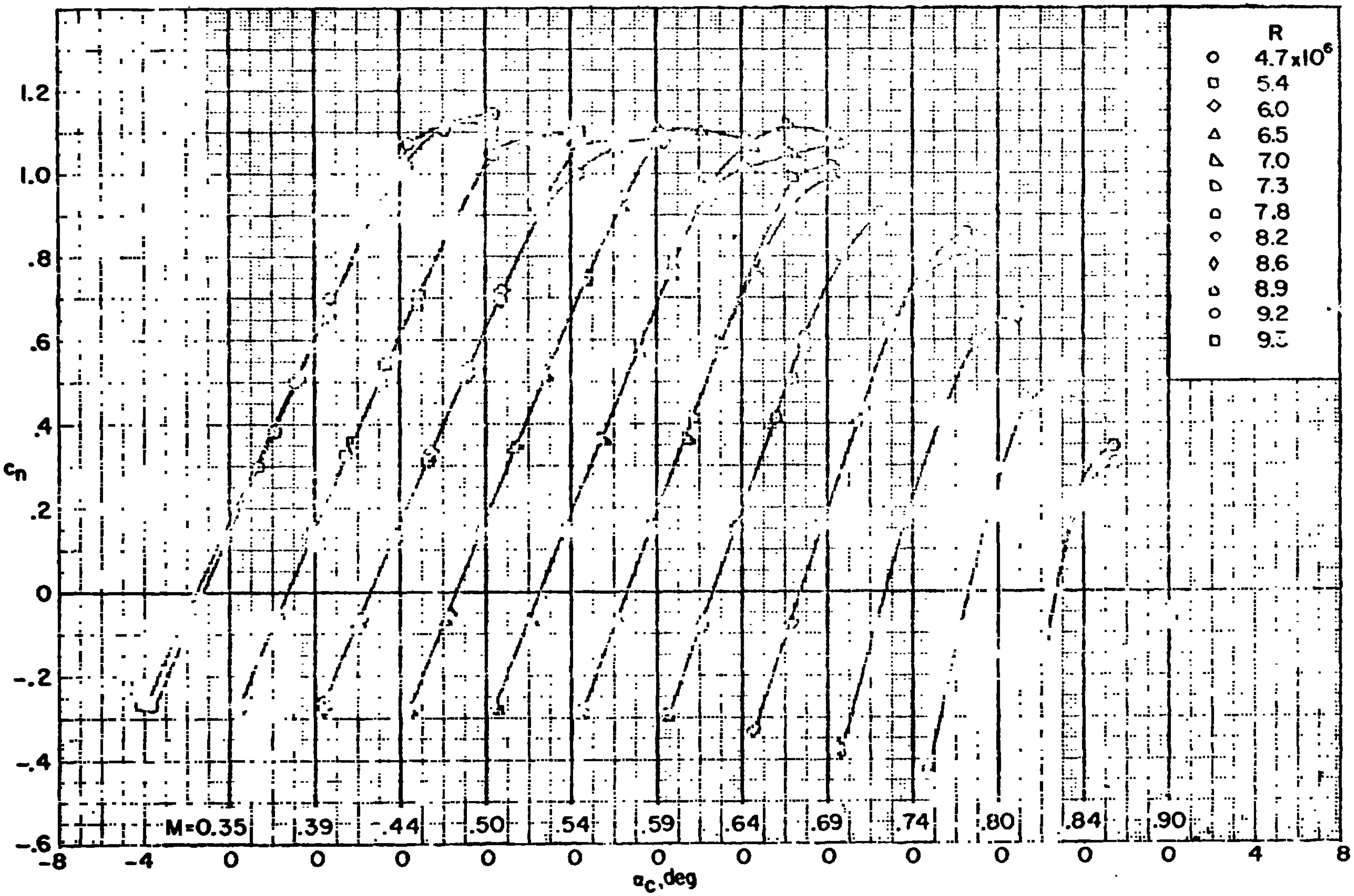
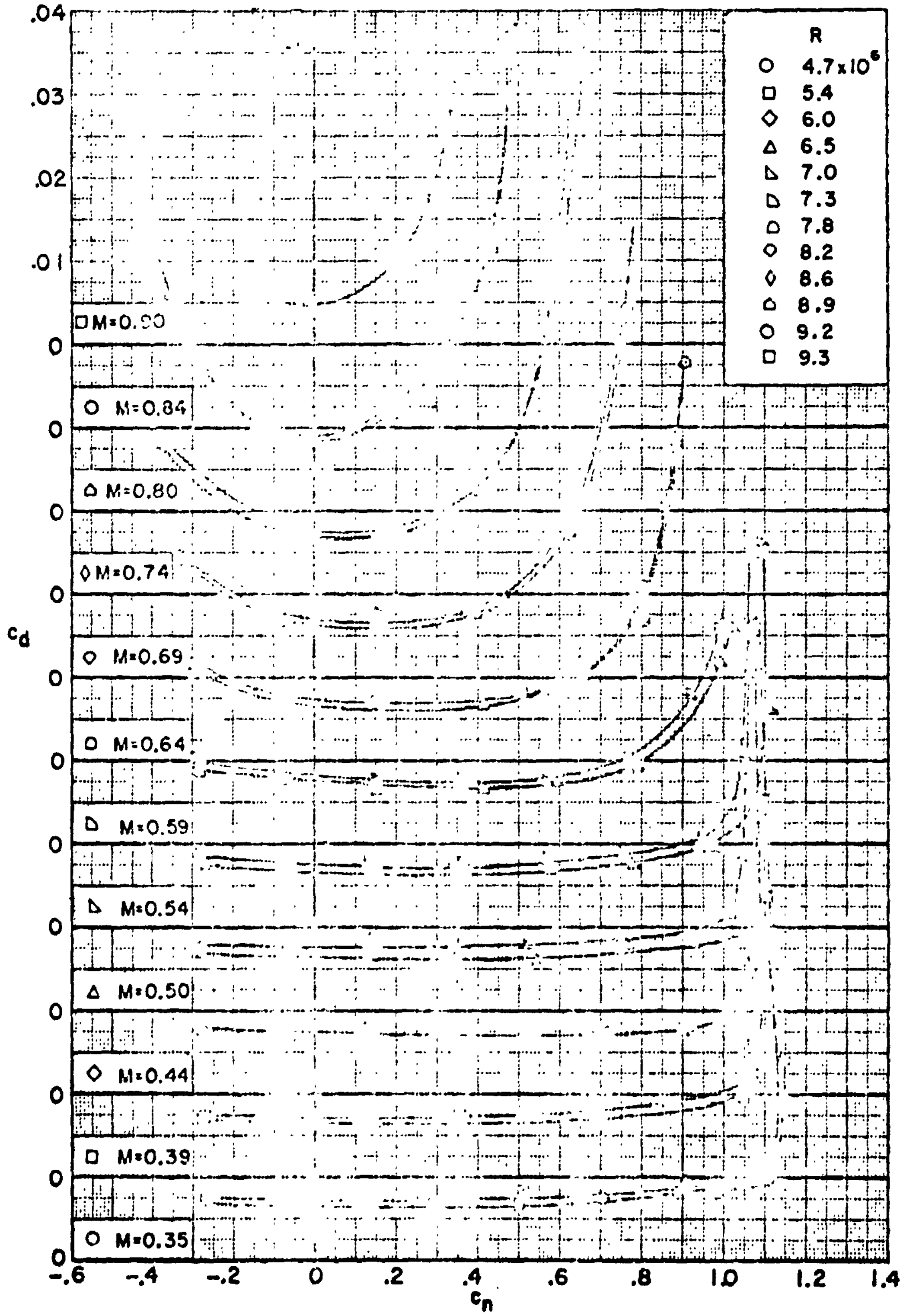


Figure 4.- Blade-element pitching-moment coefficient plotted against angle of attack at M = 0.30 for FX69-H-098 airfoil, generated by subroutine P2.



(a) Normal-force coefficients.

Figure 5.- Section coefficients for FX69-H-098 airfoil in the Langley 6- by 28-inch transonic tunnel. (From ref. 5.) Plain symbols indicate model smooth; symbols with +, transition fixed.



(b) Drag coefficients.

Figure 5.- Concluded.

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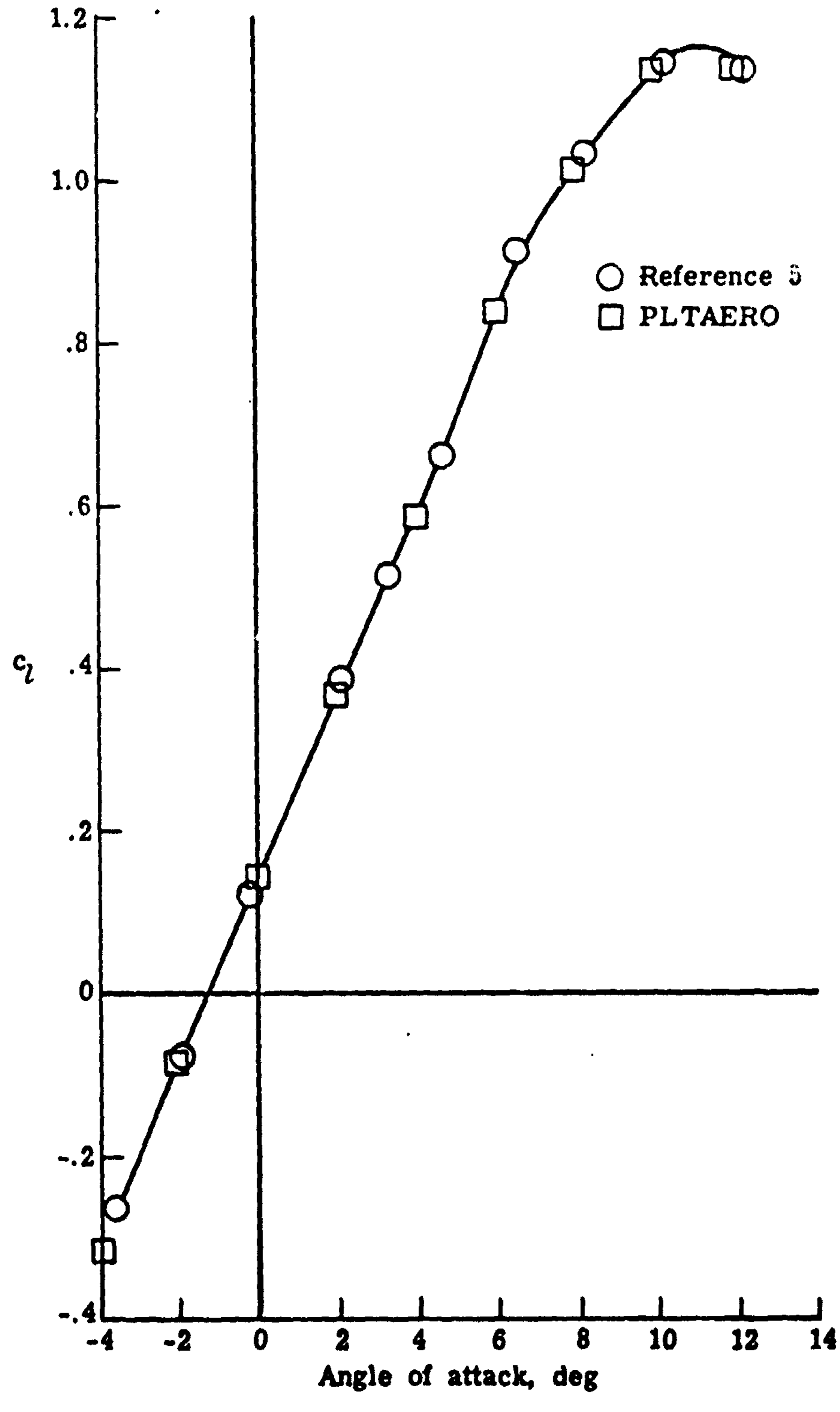
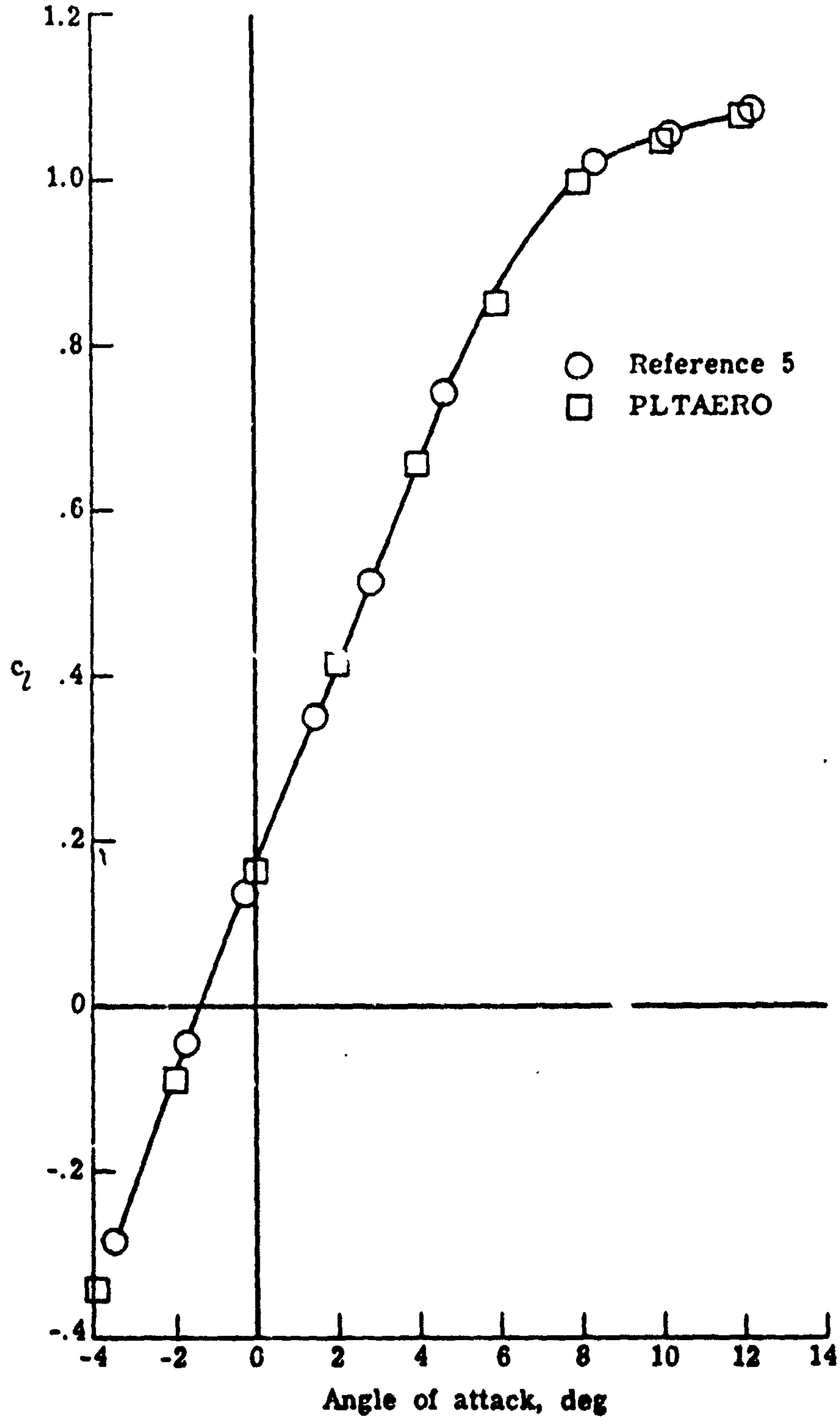


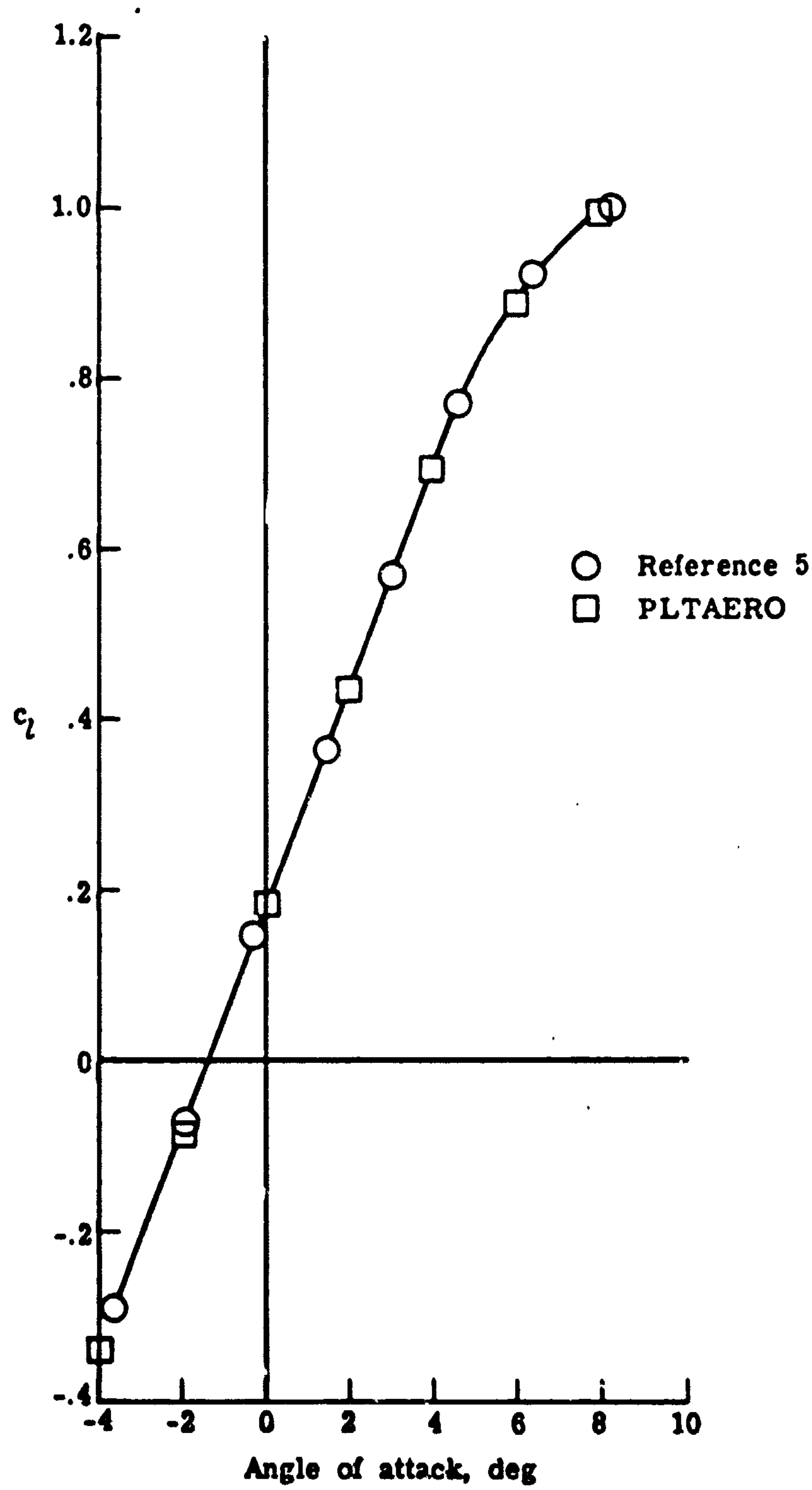
(a) M = 0.35.

Figure 6.- Comparison of section lift coefficients calculated by PLTAERO and section lift coefficients generated from reference 5 for FX69-H-098 airfoil.



(b) M = 0.5.

Figure 6.- Continued.



(c) M = 0.6.

Figure 6.- Concluded.

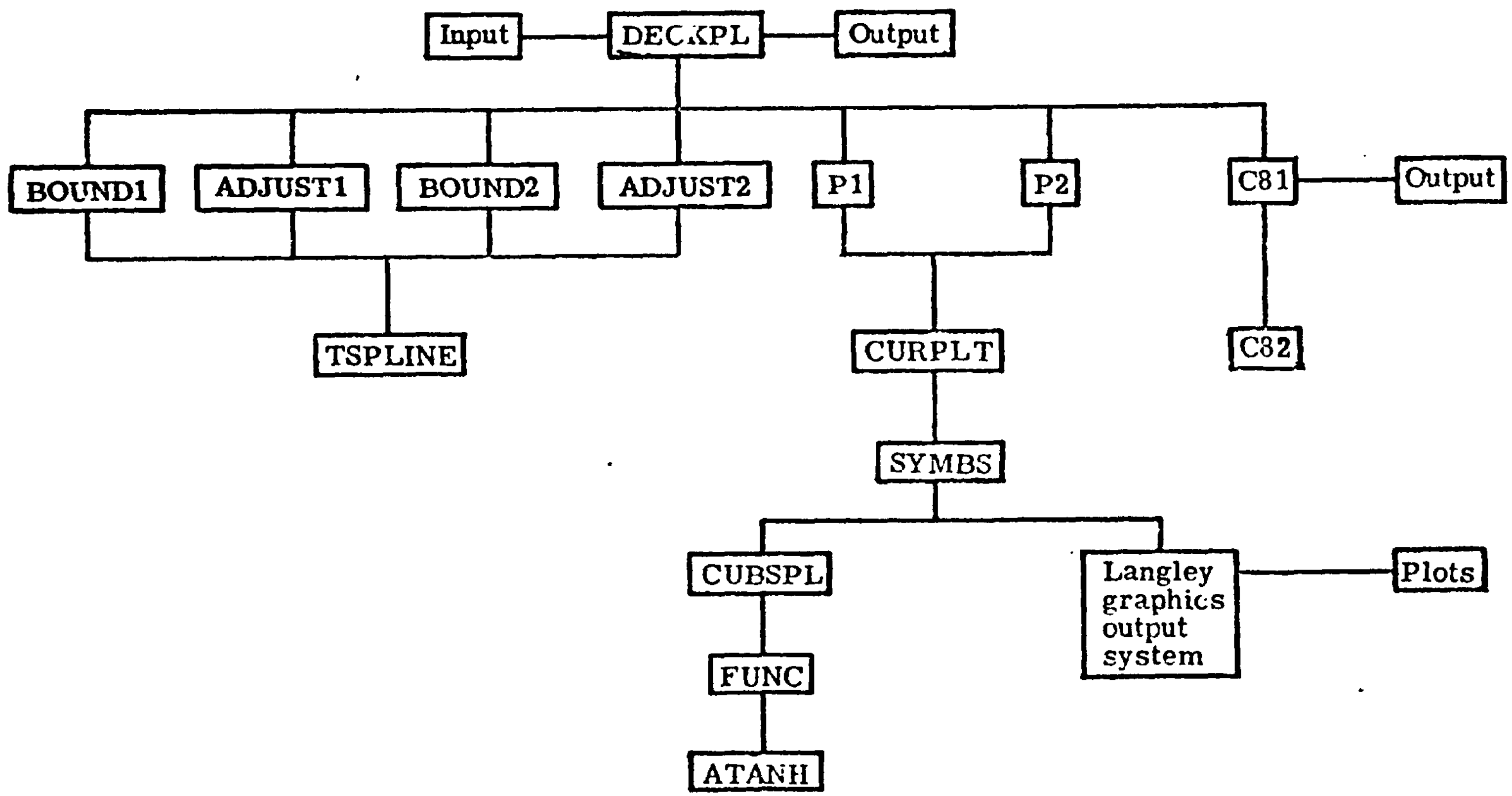


Figure 7.- Program structure.