

(NASA-TM-102454) GRID2D/3D: A COMPUTER PROGRAM FOR GENERATING GRID SYSTEMS IN COMPLEX-SHAPED TWO- AND THREE-DIMENSIONAL SPATIAL DOMAINS. PART 2: USER'S MANUAL AND PROGRAM LISTING (NASA) 73 p
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GRID2D/3D—A Computer Program for Generating
Grid Systems in Complex-Shaped Two- and
Three-Dimensional Spatial Domains
Part 2: User's Manual and Program Listing

NASA Technical Memorandum 102454

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**GRID2D/3D — A COMPUTER PROGRAM FOR GENERATING GRID SYSTEMS
IN COMPLEX-SHAPED TWO- AND THREE-DIMENSIONAL SPATIAL DOMAINS**

Part 2: User's Manual and Program Listing

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1.0 INTRODUCTION

A computer program has been written which utilizes the algebraic grid generation techniques described in Part 1 of this technical memorandum. This FORTRAN 77 program is known as GRID2D/3D and can be used to generate grid systems within both two- and three- dimensional (2-D and 3-D) spatial domains. The program was developed for use on an IBM PC, XT, or AT compatible computer but can be easily modified for use on a workstation or mainframe computer. This part of the technical memorandum (Part 2) is a user's manual for GRID2D/3D. A complete listing of the program is also provided.

1.1 Methods Used in GRID2D/3D

For a complete description of the grid generation techniques used in GRID2D/3D, the reader is encouraged to read Part 1 of this technical memorandum. Here, we mention only a few brief facts concerning the inner workings of the program. GRID2D/3D uses either the Two- or Four-Boundary Method to generate grid systems. The Six-Boundary Method is not yet a part of GRID2D/3D but may be included in future versions. Boundary curves are described parametrically by using tension spline interpolation, while boundary surfaces are described by using three-dimensional bidirectional Hermite interpolation.

1.2 Programs in GRID2D/3D

GRID2D/3D is actually made up of two programs — GRID2D and GRID3D. As the names imply, GRID2D generates grid systems for 2-D spatial domains, while GRID3D does the same for 3-D ones. The programs are quite similar, but each has its own distinctive features which will be described in Section 2.0. Two related programs, 3DSURF and PRGRID, deal with the viewing of grids once they have been generated. These programs will be discussed in Section 3.0

2.0 USING GRID2D/3D TO GENERATE GRID SYSTEMS

In this section, a description of how to generate grid systems for 2-D and 3-D spatial domains is presented. Instructions are given in the context of using GRID2D/3D on an IBM PC compatible computer; however, use of the program on a

workstation or mainframe computer follows the same general procedure with only minor changes in file handling.

2.1 How to Generate Grid Systems in Two-Dimensional Spatial Domains

GRID2D/3D can be used to generate grids for 2-D spatial domains which meet the following criteria:

1. The domain of interest is a 2-D region with two or four specified boundary curves.
2. Each boundary curve is described by a set of discrete points which lie along the curve.

If these criteria have been met, the user must then answer the following questions:

1. Should the Two-Boundary Method or the Four-Boundary Method be used?
2. How many grid points are desired in the ξ and η directions?
3. Is any clustering of grid points needed?
4. What "K factors" (mentioned in Part 1 of this technical memorandum) should be used?

Once these questions have been answered, an input file should be constructed according to the format shown in figures 2-1 and 2-2. A guide to the grid control parameters mentioned in these figures is given in table 2-1.

The numbering of boundary curves is an important part of the input file, and the user should consult figure 2-3 to see how the numbered curves are mapped to the "transformed" domain. Figures 2-4 and 2-5 present sample 2-D grid input files for GRID2D/3D.

When running GRID2D/3D on a PC using MS-DOS, the user should first specify the input and output files using the DOS SET command. This is accomplished by typing

```
set 7=input.dat
set 8=output.dat
```

at the DOS prompt. The user should substitute the appropriate names for the input and output files. After this, the program can be run by typing

```
grid2d
```

at the DOS prompt.

The 2-D grid output files created by GRID2D/3D are printed out using the following algorithm (listed in pseudocode):

```
PrintOnOneLine (IL) (# of grid points in the  $\xi$  "direction")
PrintOnOneLine (JL) (# of grid points in the  $\eta$  "direction")
for i=1 to IL
  for j=1 to JL
    PrintOnOneLine (x(i, j) y(i, j) 1.0)
  end for j
end for i
```

The user should notice that a 1.0 has been tacked onto the end of each (x, y) grid point ordered pair. This was done to facilitate the use of the 3DSURF graphics program which is described in Section 3.0.

2.2 How to Generate Grid Systems in Three-Dimensional Spatial Domains

GRID2D/3D can be used to generate grids for 3-D spatial domains which meet the following criteria:

1. The domain of interest is a 3-D region with two or four specified boundary surfaces.

2. All boundary surfaces are four-sided with each side having four edge curves.
Each of these edge curves is described by a set of discrete points which lie along the curve.

If these criteria have been met, the user must then answer the following questions:

1. Should the Two-Surface Method or the Four-Surface Method be used?
2. How many grid points are desired in the ξ , η , and ζ directions?
3. Is any clustering of grid points needed?
4. What "K factors" (mentioned in Part 1 of this technical memorandum) should be used?

Once these questions have been answered, an input file should be constructed according to the format shown in figure 2-6. Note that a 3-D grid input file for GRID2D/3D contains information about only one grid. This is different from a 2-D grid input file in which more than one grid can be specified. A guide to the grid control parameters in figure 2-6 was given previously in table 2-1.

The numbering of boundary curves is an important part of the input file, and the user should consult figure 2-7 to see how the numbered curves are mapped to the "transformed" domain. It should be noted that the boundary surfaces are formed from their edge curves as follows:

surface 1 - formed from curves 1 - 4
surface 2 - formed from curves 5 - 8
surface 3 - formed from curves 9 - 12
surface 4 - formed from curves 13 - 16

It should be further noted that some of the curves are identical. Thus, curves 1 and 9 are the same, as are curves 2 and 13, curves 5 and 10, and curves 6 and 14. The reason for this is that the authors felt that it was simpler to have the user repeat the necessary curves in the input file to preserve a logical structure (i.e., surface 1 possesses edge curves 1 through 4, surface 2 possesses edge curves 5 through 8, and so on).

Figure 2-8 presents a sample 3-D grid input file for GRID2D/3D.

When running the program on a PC using MS-DOS, the user should first specify the input and output files using the DOS SET command. This is accomplished by typing

```
set 7=input.dat
set 8=output.dat
```

at the DOS prompt. The user should substitute the appropriate names for the input and output files. After this, the program can be run by typing

```
grid3d
```

at the DOS prompt.

The 3-D grid output files created by GRID2D/3D are printed out using the following algorithm (listed in pseudocode):

```
PrintOnOneLine (IL) (# of grid points in the  $\xi$  "direction")
PrintOnOneLine (JL) (# of grid points in the  $\eta$  "direction")
PrintOnOneLine (KL) (# of grid points in the  $\zeta$  "direction")
for i=1 to IL
  for j=1 to JL
    for k=1 to KL
      PrintOnOneLine (x(i, j) y(i, j) z(i, j, k))
    end for k
  end for j
end for i.
```

3.0 HOW TO VIEW THE TWO- AND THREE-DIMENSIONAL GRID SYSTEMS GENERATED

Two additional programs have been written to accompany GRID2D/3D. These two programs allow the user to see the grid which GRID2D/3D has produced as a graphics image on the computer screen and as hardcopy output from a Hewlett Packard HP-7470A pen plotter. The program which yields the graphics image/plotter output is called 3DSURF and is written in Turbo Pascal.

3DSURF is intended for use on an IBM PC, XT, or AT compatible computer and supports both CGA and EGA graphics. This program takes a 2-D grid file created by GRID2D/3D and draws the resulting grid on the CRT and the pen plotter (if desired); however, 3-D grid files created by GRID2D/3D are not suitable as input for 3DSURF. For this reason, another program, PRGRID, has been written. PRGRID uses a 3-D grid file created by GRID2D/3D to generate an output file suitable for use as input to 3DSURF. This section is intended to show how 3DSURF and PRGRID can be used.

3.1 How to Use 3DSURF

3DSURF allows the user to plot surface grids on the computer screen. Two-dimensional grid output files from GRID2D/3D are already in the proper format for use with 3DSURF. Three-dimensional grid output files from GRID2D/3D must be used as input for PRGRID as detailed in the next subsection to create files suitable for use with 3DSURF.

An input file for 3DSURF consists of a list of the grid point locations for one or more grid surfaces together with the number of grid points for each surface. The 2-D grid output files from GRID2D/3D have been "padded" in the sense that a z-coordinate of 1.0 has been assigned to all grid points generated by GRID2D/3D. Output files from PRGRID naturally have z-coordinates since they represent 3-D grids. The user should look at a 2-D grid output file from GRID2D/3D or an output file from PRGRID using an editor to see what these files actually look like.

Assuming the user has a suitable input file for 3DSURF (i.e., a 2-D grid output file from GRID2D/3D or an output file from PRGRID), 3DSURF can be invoked by typing

```
3dsurf
```

at the DOS prompt. The program will begin by asking the user for the input file name which the user should type in (including the appropriate drive information). The program will then inform the user how many surface grids are in the specified input file and ask how many of these surfaces the user actually wants to see. After the user responds, the program will ask for a list of the numbers of each surface to be displayed. The user should enter these numbers as a list on one line, each number separated from the next by a space. As an example, suppose that the user has just indicated that he or she wishes to view three surfaces out of a possible twelve in some file. If the surfaces that he or she wants to see are the third, fifth, and ninth in the file, then he or she should type

3 5 9

when asked for the surface numbers. Having been informed which surfaces are to be displayed, the program will prompt the user for what is referred to as the View Reference Point (VRP). This point represents the location of the user's eye as he or she views the surface or surfaces. For 2-D grids, an appropriate VRP is

0.0 0.0 1.0.

The VRP coordinates should be entered exactly as just described (i.e., as an ordered triple of real numbers separated by spaces, representing the x, y, and z locations of the VRP). A scale factor will also be requested. Numbers between 0.0 and 1.0 will reduce the image, while a value of 1.0 allows the program to automatically scale the image to fill the screen. Finally, the program will ask the user whether he or she wishes to generate pen plotter output. This is possible only if the PC is connected to a Hewlett Packard HP-7470A pen plotter (baud rate = 4800). The appropriate responses are "y" for yes and "n" for no. Having received a response, the program will generate a view of the grid as if the user were looking at it from the VRP. Parallel projection is used (i.e., no perspective), and no effort is made to hide lines or surfaces which should be

hidden from view. Once a grid has been displayed, the user only needs to hit <RETURN> to produce a menu asking whether he or she wishes to continue.

3.2 How to Use PRGRID

Once a 3-D grid output file has been generated with GRID2D/3D, the user is often interested in evaluating the resulting grid visually using 3DSURF. As mentioned previously, 3-D grid output files from GRID2D/3D are not suitable as input files for 3DSURF. For this reason, the FORTRAN 77 program PRGRID has been written. PRGRID reads 3-D grid files created by GRID2D/3D and produces output files which can be used as input files for 3DSURF.

When running PRGRID, the user should first specify the input and output files using the DOS SET command. This is accomplished by typing

```
set 7=input.dat  
set 8=output.dat
```

at the DOS prompt. The user should substitute the appropriate names for the input and output files. After this, the program can be run by typing

```
prgrid
```

at the DOS prompt. The user will be informed of the number of grid points in the ξ , η and ζ "directions" (IL, JL, and KL, respectively) and will be asked for three new numbers. These numbers are referred to as IL1, JL1, and KL1, and they represent the grid point numbers where an internal "chunk" will be removed from the grid to allow the user to see the "inside" of the 3-D grid (fig. 3-1). The output files created by PRGRID contain information about the 12 surfaces shown in figure 3-1. Since plotting the entire 3-D grid without hiding appropriate lines and surfaces would be confusing, PRGRID basically filters out all of the other grid points not contained in surfaces 1

through 12. As a consequence, its output files provide 3DSURF with information about only the outside “shell” of the 3-D grid with a “chunk” taken out to show the grid’s interior features. Usually, the first nine surfaces are sufficient, but sometimes the other three (10–12) prove visually helpful. Here, we note that if the user specifies that $IL1=IL$, $JL1=JL$, and $KL1=KL$, then the output file from PRGRID will contain only the six surfaces which correspond to the six faces of the cube-shaped “transformed” domain.

4.0 EXAMPLES

In this section, we provide two sample input files for GRID2D/3D, together with the grids that were generated using these files. By examining these input files and the resulting grids, it is hoped that the user may become more familiar with the use of GRID2D/3D. The first file will be referred to as INLET.DAT and is a GRID2D/3D input file for generating a two-zone grid for a 2-D supersonic inlet. INLET.DAT is listed in figure 4-1, and the corresponding grid is shown in figure 4-2. The geometry of the inlet dictates the use of a zonal approach due to the separation of the interior and exterior flows. Clustering in the η “direction” was used to place more grid points near the solid surfaces in anticipation of complex boundary layer flow there. Other zonal configurations could be used to better resolve the physics of the flow (e.g., to facilitate shock capturing during the solution if the flow is supersonic).

The second example input file for GRID2D/3D will be referred to as STATOR.DAT and is actually four separate files—ZONE1.DAT, ZONE2.DAT, ZONE3.DAT, and ZONE4.DAT, listed in figures 4-3 through 4-6, respectively. These files create a four-zone grid between the blades of a 3-D axial turbine stator. The resulting grid is shown in figure 4-7. A single-zone grid was found to be unsatisfactory, so four zones were chosen to minimize grid skewness while maintaining (to as high a

degree as possible) grid line orthogonality at the boundaries. Even with a judicious choice of zones, it was still necessary to smooth the ζ grid lines along the zonal interfaces. Such smoothing is often necessary in cases where the geometry contains sharp corners in the boundaries. A method for smoothing was given previously in Section 4.1 of Part 1 of this technical memorandum.

5.0 SUMMARY

Part 2 of this technical memorandum has presented a user's manual for GRID2D/3D — a versatile and efficient computer program for generating grid systems inside complex-shaped 2-D and 3-D spatial domains. The structures of the input and output files for GRID2D/3D have been discussed, and the details necessary to use GRID2D/3D for generating grid systems have been given. Two related programs, 3DSURF and PRGRID, have also been described. These programs are used to view the grid systems generated by GRID2D/3D on the CRT and may also be used to generate a hardcopy output of a grid on a Hewlett Packard HP-7470A pen plotter. Two example grids were presented showing both the input files and the resulting grids. Finally, a complete listing of GRID2D/3D is given in the Appendixes.

APPENDIXES – LISTING OF PROGRAM GRID2D/3D

A.1 Listing of GRID2D

PROGRAM Grid2D

C This program generates a two-dimensional algebraic grid system using
 C transfinite Hermite interpolation. The geometric configuration of the
 C grid is determined by information provided by the user at run-time via
 C an input file. The user selects either the “two-boundary technique” or
 C the “four-boundary technique” depending on whether two or four
 C boundaries of the spatial domain need to be mapped correctly. Boundary
 C curves are formed from sets of discrete data points using tension splines.

PARAMETER (MxBCvs = 4, MxBPts = 50, MxGSiz = 51)

INTEGER Tech, CrvNum, GrdNum, NBCrvs, NGrids, StrXi, StrEt,
 \$ IL, JL, i, j, NDPts(MxBCvs)

REAL EtStep, XiStep, S1XiRa, S2XiRa, S3EtRa, S4EtRa,
 \$ k1, k2, k3, k4, BetaXi, BetaEt,
 \$ Right(MxBPts), Diag(MxBPts), OfDiag(MxBPts),
 \$ h1(MxGSiz), h2(MxGSiz), h3(MxGSiz),
 \$ h4(MxGSiz), h5(MxGSiz), h6(MxGSiz),
 \$ h7(MxGSiz), h8(MxGSiz), X1(MxGSiz), X2(MxGSiz),
 \$ X3(MxGSiz), X4(MxGSiz), Y1(MxGSiz), Y2(MxGSiz),
 \$ Y3(MxGSiz), Y4(MxGSiz),
 \$ PX1PEt(MxGSiz), PX2PEt(MxGSiz),
 \$ PY1PEt(MxGSiz), PY2PEt(MxGSiz),
 \$ PX3PXi(MxGSiz), PY3PXi(MxGSiz),
 \$ PX4PXi(MxGSiz), PY4PXi(MxGSiz),
 \$ Tensn(MxBCvs), x(MxBCvs,MxBPts),
 \$ y(MxBCvs,MxBPts), s(MxBCvs,MxBPts),
 \$ zx(MxBCvs,MxBPts), zy(MxBCvs,MxBPts),
 \$ XMid(MxGSiz,MxGSiz), YMid(MxGSiz,MxGSiz)

READ(7,*) NGrids
 WRITE(8,*) NGrids

DO 20 GrdNum=1,NGrids

READ(7,*) Tech
 NBCrvs=Tech

C Form the boundary curves by splining.

DO 10 CrvNum=1,NBCrvs
 CALL RdGrIn(x,y,NDPts,CrvNum,Tensn,MxBCvs,MxBPts)
 CALL PTSpln(x,y,s,zx,zy,NDPts(CrvNum),CrvNum,Tensn(CrvNum),
 \$ Right,Diag,OfDiag,MxBCvs,MxBPts)
 10 CONTINUE

C Calculate the grid point locations.

```
CALL RdRgIn(IL,JL,StrXi,StrEt,Tech,NDPts,k1,k2,k3,k4,  
$ BetaXi,BetaEt,S1XiRa,S2XiRa,S3EtRa,S4EtRa,  
$ s, XiStep, EtStep, MxBCvs, MxBPts)
```

```
CALL TwoBnd(XMid, YMid, IL, JL, k1, k2, BetaXi, BetaEt,  
$ S1XiRa, S2XiRa, XiStep, EtStep, h1, h2, h3, h4,  
$ X1, X2, Y1, Y2, PX1PEt, PX2PEt, PY1PEt, PY2PEt,  
$ x, y, s, zx, zy, NDPts, StrXi, StrEt, Tensn, MxBCvs,  
$ MxBPts, MxGSiz)
```

ENDIF

IF (Tech.EQ.4) THEN

```
CALL FourBd(XMid, YMid, IL, JL, k3, k4, BetaXi, BetaEt,  
$ S3EtRa, S4EtRa, XiStep, EtStep, h1, h2, h3, h4,  
$ X1, X2, Y1, Y2, PX1PEt, PX2PEt, PY1PEt, PY2PEt,  
$ x, y, s, zx, zy, NDPts, StrXi, StrEt, Tensn,  
$ h5, h6, h7, h8, X3, X4, Y3, Y4, PX3PXi, PX4PXi,  
$ PY3PXi, PY4PXi, MxBCvs, MxBPts, MxGSiz)
```

ENDIF

```
CALL PrGrid(XMid, YMid, IL, JL, MxBCvs, MxBPts, MxGSiz)
```

20 CONTINUE

END

C=====C

```
SUBROUTINE RdGrIn (x,y,NPts,CrvNum,Tensn,MxBCvs,MxBPts)
```

C This procedure reads in the information concerning discrete points on
C the boundaries. The information is used for generating spline-fitted
C boundary approximation curves.

```
INTEGER CrvNum, i, NPts(MxBCvs)
```

```
REAL x(MxBCvs,MxBPts), y(MxBCvs,MxBPts),  
$ Tensn(MxBCvs)
```

```
READ(7,*) Tensn(CrvNum)  
READ(7,*) NPts(CrvNum)
```

```
DO 10 i=1,NPts(CrvNum)  
  READ(7,*) x(CrvNum,i), y(CrvNum,i)  
10 CONTINUE
```

```
RETURN  
END
```

C=====C

```
SUBROUTINE CalcS (x,y,s,NPts,CrvNum,MxBCvs,MxBPts)
```

C This procedure calculates the spline parameter, s, as an approximate arc length.

```
INTEGER CrvNum, NPts, i

REAL x(MxBCvs,MxBPts), y(MxBCvs,MxBPts),
$   s(MxBCvs,MxBPts)

s(CrvNum,1)=0.0

DO 10 i=2,NPts
  s(CrvNum,i)=s(CrvNum,i-1)
$       +SQRT( (x(CrvNum,i)-x(CrvNum,i-1))**2
$             +(y(CrvNum,i)-y(CrvNum,i-1))**2)
10 CONTINUE

RETURN
END
```

C=====C

```
SUBROUTINE SplMat (Diag,OfDiag,Right,w,s,NPts,T,CrvNum,
$   MxBCvs,MxBPts)
```

C This procedure forms the parametric tension spline matrix for a
C particular boundary curve data set.

```
INTEGER CrvNum, NPts, i

REAL Diag(MxBPts), OfDiag(MxBPts), Right(MxBPts),
$   w(MxBCvs,MxBPts), s(MxBCvs,MxBPts), T, h, hm

Diag(1)=1.0
OfDiag(1)=0.0
Right(1)=0.0

DO 10 i=2,NPts-1
  h=s(CrvNum,i+1)-s(CrvNum,i)
  hm=s(CrvNum,i)-s(CrvNum,i-1)
  Diag(i)=(T*COSH(T*hm)/SINH(T*hm)-1/hm+T*COSH(T*h)/SINH(T*h)
$   -1/h)/T**2
  OfDiag(i)=(1/h-T/SINH(T*h))/T**2
  Right(i)=(w(CrvNum,i+1)-w(CrvNum,i))/h
$   -(w(CrvNum,i)-w(CrvNum,i-1))/hm
10 CONTINUE

Diag(NPts)=1.0
OfDiag(NPts-1)=0.0
Right(NPts)=0.0

RETURN
END
```

C=====C

```

SUBROUTINE SplSlv (Diag,OfDiag,Right,Deriv2,NPts,CrvNum,
$                 MxBCvs,MxBPts)

```

C This procedure solves the diagonally dominant parametric tension
C spline matrix for a given data set using the Gauss-Seidel iteration.
C Convergence is assumed after 20 iterations.

```

INTEGER NPts, CrvNum, i, j

```

```

REAL Diag(MxBPts), OfDiag(MxBPts), Right(MxBPts),
$   Deriv2(MxBCvs,MxBPts)

```

C Initialize the second derivative matrix to all zeroes.

```

DO 10 i=1,NPts
    Deriv2(CrvNum,i)=0.0
10 CONTINUE

```

C Calculate the second derivative values using 20 iterations of
C the Gauss-Seidel method.

```

DO 30 j=1,20
    DO 20 i=2,NPts-1
        Deriv2(CrvNum,i)=(Right(i)-OfDiag(i)*Deriv2(CrvNum,i+1)
$                               -OfDiag(i-1)*Deriv2(CrvNum,i-1))
$                               /Diag(i)
20 CONTINUE
30 CONTINUE

```

```

RETURN
END

```

C=====C

```

FUNCTION SplVal (s,w,Deriv2,sval,T,n,CrvNum,MxBCvs,MxBPts)

```

C This real function finds the w-value (x-value or y-value) corresponding
C to a specified s-value using the parametric tension spline curve
C generated for a particular boundary curve data set.

```

INTEGER n, CrvNum

```

```

REAL s(MxBCvs,MxBPts), w(MxBCvs,MxBPts),
$   Deriv2(MxBCvs,MxBPts), sval, T, h, Interim,
$   Temp1, Temp2

```

```

Temp1=sval-s(CrvNum,n)

```

```

h=s(CrvNum,n+1)-s(CrvNum,n)

```

```

Temp2=s(CrvNum,n+1)-sval

```

```

Interim=Deriv2(CrvNum,n)/T**2*SINH(T*Temp2)/SINH(T*h)
$   +(w(CrvNum,n)-Deriv2(CrvNum,n)/T**2)*Temp2/h

```

```

SplVal=Interim+Deriv2(CrvNum,n+1)/T**2*SINH(T*Temp1)

```

```

$          /SINH(T*h)+(w(CrvNum,n+1)
$          -Deriv2(CrvNum,n+1)/T**2)*Temp1/h

```

```

RETURN
END

```

C=====C

```

SUBROUTINE PTSpln (x,y,s,XDeriv2,YDeriv2,NPts,CrvNum,Tensn,
$          Right,Diag,OfDiag,MxBCvs,MxBPts)

```

C This procedure forms the main routine for the parametric tension
C spline process.

```

INTEGER NPts, CrvNum

```

```

REAL Tensn, x(MxBCvs,MxBPts), y(MxBCvs,MxBPts),
$   s(MxBCvs,MxBPts), XDeriv2(MxBCvs,MxBPts),
$   YDeriv2(MxBCvs,MxBPts), Diag(MxBPts),
$   OfDiag(MxBPts), Right(MxBPts)

```

```

CALL CalcS(x,y,s,NPts,CrvNum,MxBCvs,MxBPts)

```

```

CALL SplMat (Diag,OfDiag,Right,x,s,NPts,Tensn,CrvNum,
$   MxBCvs,MxBPts)

```

```

CALL SplSlv (Diag,OfDiag,Right,XDeriv2,NPts,CrvNum,
$   MxBCvs,MxBPts)

```

```

CALL SplMat (Diag,OfDiag,Right,y,s,NPts,Tensn,CrvNum,
$   MxBCvs,MxBPts)

```

```

CALL SplSlv (Diag,OfDiag,Right,YDeriv2,NPts,CrvNum,
$   MxBCvs,MxBPts)

```

```

RETURN
END

```

C=====C

```

SUBROUTINE FindHs (h1,h2,h3,h4,n)

```

C This procedure computes the h factors used in Hermite interpolation.

```

REAL h1, h2, h3, h4, n

```

```

h1= 2*n**3-3*n**2+1

```

```

h2=-2*n**3+3*n**2

```

```

h3= n**3-2*n**2+n

```

```

h4= n**3-n**2

```

```

RETURN
END

```

C=====C

```

SUBROUTINE SplInt (n,s,SValue,NDPts,CurCrv,MxBCvs,MxBPts)

```

C This procedure finds the proper interval in which a point on a specified
 C boundary lies. The interval indicates which initial data points the
 C point in question lies between and thus which spline coefficients to
 C use.

INTEGER i, n, CurCrv, NDPts(MxBCvs)

REAL Temp, SValue, s(MxBCvs,MxBPts)

n=1

i=NDPts(CurCrv)

10 IF ((n.EQ.1).AND.(i.GT.1)) THEN

i=i-1

Temp=SValue-s(CurCrv,i)

IF (Temp.GT.0.0) THEN

n=i

ENDIF

GOTO 10

ENDIF

RETURN

END

C=====C

SUBROUTINE FAInew (AlNew,Alpha,B,Str)

C This procedure computes the new Alpha value after stretching as
 C AlNew. Alpha is a dummy variable representing either Xi or Eta.

INTEGER Str

REAL AlNew, Alpha, B, Temp1, Temp2, B2

AlNew=Alpha

Temp1=(B+1)/(B-1)

IF (Str.EQ.1) THEN

Temp2=Temp1**(1-Alpha)

AlNew=((B+1)-(B-1)*Temp2)/(Temp2+1)*1

ENDIF

IF (Str.EQ.2) THEN

B2=0

Temp2=Temp1**((Alpha-B2)/(1-B2))

AlNew=((B+2*B2)*Temp2-B+2*B2)/((2*B2+1)*(1+Temp2))

ENDIF

IF (Str.EQ.3) THEN

```

      B2=0.5
      Temp2=Temp1**((Alpha-B2)/(1-B2))
      AlNew=((B+2*B2)*Temp2-B+2*B2)/((2*B2+1)*(1+Temp2))
    ENDIF

```

```

    RETURN
  END

```

C=====C

```

    SUBROUTINE TwoBnd (XMid,YMid,IL,JL,k1,k2,BetaXi,BetaEt,S1XiRa,
    $                 S2XiRa,XiStep,EtStep,h1,h2,h3,h4,X1,X2,Y1,Y2,
    $                 PX1PEt,PX2PEt,PY1PEt,PY2PEt,x,y,s,zx,zy,
    $                 NDPts,StrXi,StrEt,Tensn,MxBCvs,MxBPts,MxGSiz)

```

C This procedure calculates the grid point locations between two specified
C boundaries (1 and 2) using the "two-boundary technique".

```

    INTEGER  XCnt, YCnt, n1, n2, IL, JL, StrXi, StrEt, NDPts(MxBCvs)

```

```

    REAL  Xi, Eta, XiNew, EtaNew, XiStep, EtStep,
    $     S1XiRa, S2XiRa, S1, S2, k1, k2,
    $     BetaXi, BetaEt, PY1PXi, PX1PXi, PY2PXi, PX2PXi,
    $     x(MxBCvs,MxBPts), y(MxBCvs,MxBPts),
    $     s(MxBCvs,MxBPts), Tensn(MxBCvs),
    $     zx(MxBCvs,MxBPts), zy(MxBCvs,MxBPts),
    $     h1(MxGSiz), h2(MxGSiz), h3(MxGSiz), h4(MxGSiz),
    $     X1(MxGSiz), X2(MxGSiz), Y1(MxGSiz), Y2(MxGSiz),
    $     PX1PEt(MxGSiz), PX2PEt(MxGSiz),
    $     PY1PEt(MxGSiz), PY2PEt(MxGSiz),
    $     XMid(MxGSiz,MxGSiz), YMid(MxGSiz,MxGSiz)

```

C Calculate the grid point locations along boundaries 1 and 2.

```

      Xi=0.0

```

```

    DO 10 XCnt=1,IL
      CALL FAlNew(XiNew,Xi,BetaXi,StrXi)
      S1=XiNew*S1XiRa
      S2=XiNew*S2XiRa
      CALL SplInt(n1,s,S1,NDPts,1,MxBCvs,MxBPts)
      CALL SplInt(n2,s,S2,NDPts,2,MxBCvs,MxBPts)
      X1(XCnt)=SplVal(s,x,zx,S1,Tensn(1),n1,1,MxBCvs,MxBPts)
      X2(XCnt)=SplVal(s,x,zx,S2,Tensn(2),n2,2,MxBCvs,MxBPts)
      Y1(XCnt)=SplVal(s,y,zy,S1,Tensn(1),n1,1,MxBCvs,MxBPts)
      Y2(XCnt)=SplVal(s,y,zy,S2,Tensn(2),n2,2,MxBCvs,MxBPts)
      Xi=Xi+XiStep
    10 CONTINUE

```

C Calculate the h factors for the boundary 1-2 Hermite connecting
C curves.

```

      Eta=0.0

```

```

    DO 20 YCnt=1,JL

```

```

CALL FAINew(EtaNew,Eta,BetaEt,StrEt)
CALL FindHs(h1(YCnt),h2(YCnt),h3(YCnt),h4(YCnt),EtaNew)
Eta=Eta+EtStep
20 CONTINUE

```

C Calculate the derivative values for forcing grid line orthogonality
C along boundaries 1 and 2.

```

PX1PXi=(X1(2)-X1(1))/XiStep
PX2PXi=(X2(2)-X2(1))/XiStep
PY1PXi=(Y1(2)-Y1(1))/XiStep
PY2PXi=(Y2(2)-Y2(1))/XiStep
PX1PEt(1)=-k1*PY1PXi
PX2PEt(1)=-k2*PY2PXi
PY1PEt(1)= k1*PX1PXi
PY2PEt(1)= k2*PX2PXi

```

```

PX1PXi=(X1(IL)-X1(IL-1))/XiStep
PX2PXi=(X2(IL)-X2(IL-1))/XiStep
PY1PXi=(Y1(IL)-Y1(IL-1))/XiStep
PY2PXi=(Y2(IL)-Y2(IL-1))/XiStep
PX1PEt(IL)=-k1*PY1PXi
PX2PEt(IL)=-k2*PY2PXi
PY1PEt(IL)= k1*PX1PXi
PY2PEt(IL)= k2*PX2PXi

```

```

DO 30 XCnt=2,IL-1
PX1PXi=(X1(XCnt+1)-X1(XCnt-1))/2/XiStep
PX2PXi=(X2(XCnt+1)-X2(XCnt-1))/2/XiStep
PY1PXi=(Y1(XCnt+1)-Y1(XCnt-1))/2/XiStep
PY2PXi=(Y2(XCnt+1)-Y2(XCnt-1))/2/XiStep
PX1PEt(XCnt)=-k1*PY1PXi
PX2PEt(XCnt)=-k2*PY2PXi
PY1PEt(XCnt)= k1*PX1PXi
PY2PEt(XCnt)= k2*PX2PXi

```

30 CONTINUE

C Calculate the interior grid point locations.

```

DO 50 XCnt=1,IL
DO 40 YCnt=1,JL
XMid(XCnt,YCnt)= h1(YCnt)*X1(XCnt)
$ +h2(YCnt)*X2(XCnt)
$ +h3(YCnt)*PX1PEt(XCnt)
$ +h4(YCnt)*PX2PEt(XCnt)
YMid(XCnt,YCnt)= h1(YCnt)*Y1(XCnt)
$ +h2(YCnt)*Y2(XCnt)
$ +h3(YCnt)*PY1PEt(XCnt)
$ +h4(YCnt)*PY2PEt(XCnt)
40 CONTINUE
50 CONTINUE

```

```

RETURN
END

```

C=====C

```
      SUBROUTINE FourBd (XMid,YMid,IL,JL,k3,k4,BetaXi,BetaEt,  
      $                 S3EtRa,S4EtRa,xiStep,EtStep,h1,h2,h3,h4,  
      $                 X1,X2,Y1,Y2,PX1PEt,PX2PEt,PY1PEt,PY2PEt,  
      $                 x,y,s,zx,zy,NDPts,StrXi,StrEt,Tensn,  
      $                 h5,h6,h7,h8,X3,X4,Y3,Y4,PX3PXi,PX4PXi,  
      $                 PY3PXi,PY4PXi,MxBCvs,MxBPts,MxGSiz)
```

C This procedure adjusts the grid so that the other two boundaries (3 and 4)
C are mapped correctly using the "four-boundary technique".

```
      INTEGER XCnt, YCnt, i, j, n3, n4, IL, JL, StrXi, StrEt,  
      $       NDPts(MxBCvs)
```

```
      REAL Xi, Eta, XiNew, EtaNew, XiStep, EtStep, S3EtRa, S4EtRa,  
      $    S3, S4, k3, k4, BetaXi, BetaEt,  
      $    x(MxBCvs,MxBPts), y(MxBCvs,MxBPts), s(MxBCvs,MxBPts),  
      $    zx(MxBCvs,MxBPts), zy(MxBCvs,MxBPts), Tensn(MxBCvs),  
      $    h1(MxGSiz), h2(MxGSiz), h3(MxGSiz), h4(MxGSiz),  
      $    h5(MxGSiz), h6(MxGSiz), h7(MxGSiz), h8(MxGSiz),  
      $    X1(MxGSiz), X2(MxGSiz), Y1(MxGSiz), Y2(MxGSiz),  
      $    X3(MxGSiz), X4(MxGSiz), Y3(MxGSiz), Y4(MxGSiz),  
      $    PY3PEt, PX3PEt, PY4PEt, PX4PEt,  
      $    P2Y00, P2Y01, P2Y10, P2Y11, P2X00, P2X01, P2X10, P2X11,  
      $    PX3PXi(MxGSiz), PY3PXi(MxGSiz),  
      $    PX4PXi(MxGSiz), PY4PXi(MxGSiz),  
      $    PX1PEt(MxGSiz), PX2PEt(MxGSiz),  
      $    PY1PEt(MxGSiz), PY2PEt(MxGSiz),  
      $    XMid(MxGSiz,MxGSiz), YMid(MxGSiz,MxGSiz)
```

C Calculate the grid point locations along boundaries 3 and 4.

Eta=0.0

```
      DO 10 YCnt=1,JL  
        CALL FAlNew(EtaNew,Eta,BetaEt,StrEt)  
        S3=EtaNew*S3EtRa  
        S4=EtaNew*S4EtRa  
        CALL SplInt(n3,s,S3,NDPts,3,MxBCvs,MxBPts)  
        CALL SplInt(n4,s,S4,NDPts,4,MxBCvs,MxBPts)  
        X3(YCnt)=SplVal(s,x,zx,S3,Tensn(3),n3,3,MxBCvs,MxBPts)  
        X4(YCnt)=SplVal(s,x,zx,S4,Tensn(4),n4,4,MxBCvs,MxBPts)  
        Y3(YCnt)=SplVal(s,y,zy,S3,Tensn(3),n3,3,MxBCvs,MxBPts)  
        Y4(YCnt)=SplVal(s,y,zy,S4,Tensn(4),n4,4,MxBCvs,MxBPts)  
        Eta=Eta+EtStep  
10  CONTINUE
```

C Calculate the h factors for the boundary 3-4 Hermite adjusting
C curves.

Xi=0.0

```
      DO 20 XCnt=1,IL
```



```

      CALL FALNew(XiNew,Xi,BetaXi,StrXi)
      CALL FindHs(h5(XCnt),h6(XCnt),h7(XCnt),h8(XCnt),XiNew)
      Xi=Xi+XiStep
20  CONTINUE

```

C Calculate the derivative values for forcing grid line orthogonality
C along boundaries 3 and 4.

```

PX3PEt=(X3(2)-X3(1))/EtStep
PX4PEt=(X4(2)-X4(1))/EtStep
PY3PEt=(Y3(2)-Y3(1))/EtStep
PY4PEt=(Y4(2)-Y4(1))/EtStep
PX3PXi(1)= k3*PY3PEt
PX4PXi(1)= k4*PY4PEt
PY3PXi(1)=-k3*PX3PEt
PY4PXi(1)=-k4*PX4PEt

```

```

PX3PEt=(X3(JL)-X3(JL-1))/EtStep
PX4PEt=(X4(JL)-X4(JL-1))/EtStep
PY3PEt=(Y3(JL)-Y3(JL-1))/EtStep
PY4PEt=(Y4(JL)-Y4(JL-1))/EtStep
PX3PXi(JL)= k3*PY3PEt
PX4PXi(JL)= k4*PY4PEt
PY3PXi(JL)=-k3*PX3PEt
PY4PXi(JL)=-k4*PX4PEt

```

```

DO 30 YCnt=2,JL-1
  PX3PEt=(X3(YCnt+1)-X3(YCnt-1))/2/EtStep
  PX4PEt=(X4(YCnt+1)-X4(YCnt-1))/2/EtStep
  PY3PEt=(Y3(YCnt+1)-Y3(YCnt-1))/2/EtStep
  PY4PEt=(Y4(YCnt+1)-Y4(YCnt-1))/2/EtStep
  PX3PXi(YCnt)= k3*PY3PEt
  PX4PXi(YCnt)= k4*PY4PEt
  PY3PXi(YCnt)=-k3*PX3PEt
  PY4PXi(YCnt)=-k4*PX4PEt
30  CONTINUE

```

C Set the corner cross derivative terms to zero.

```

P2X00=0.0
P2X10=0.0
P2X01=0.0
P2X11=0.0
P2Y00=0.0
P2Y10=0.0
P2Y01=0.0
P2Y11=0.0

```

C Calculate the grid point locations everywhere.

```

DO 50 i=1,IL
  DO 40 j=1,JL
    XMid(i,j)=XMid(i,j)
$      +(X3(j)-h1(j)*X1(1)
$      -h2(j)*X2(1)

```

```

$          -h3(j)*PX1PEt(1)
$          -h4(j)*PX2PEt(1))*h5(i)
$          +(X4(j)-h1(j)*X1(IL)
$          -h2(j)*X2(IL)
$          -h3(j)*PX1PEt(IL)
$          -h4(j)*PX2PEt(IL))*h6(i)
$          +(PX3PXi(j)-( h1(j)*PX3PXi(1)
$          +h2(j)*PX3PXi(JL)
$          +h3(j)*P2X00+h4(j)*P2X01))*h7(i)
$          +(PX4PXi(j)-( h1(j)*PX4PXi(1)
$          +h2(j)*PX4PXi(JL)
$          +h3(j)*P2X10+h4(j)*P2X11))*h8(i)
$          YMid(i,j)=YMid(i,j)
$          +(Y3(j)-h1(j)*Y1(1)
$          -h2(j)*Y2(1)
$          -h3(j)*PY1PEt(1)
$          -h4(j)*PY2PEt(1))*h5(i)
$          +(Y4(j)-h1(j)*Y1(IL)
$          -h2(j)*Y2(IL)
$          -h3(j)*PY1PEt(IL)
$          -h4(j)*PY2PEt(IL))*h6(i)
$          +(PY3PXi(j)-( h1(j)*PY3PXi(1)
$          +h2(j)*PY3PXi(JL)
$          +h3(j)*P2Y00+h4(j)*P2Y01))*h7(i)
$          +(PY4PXi(j)-( h1(j)*PY4PXi(1)
$          +h2(j)*PY4PXi(JL)
$          +h3(j)*P2Y10+h4(j)*P2Y11))*h8(i)
40  CONTINUE
50  CONTINUE

      RETURN
      END

```

C=====C

SUBROUTINE PrGrid (XMid,YMid,IL,JL,MxBCvs,MxBPts,MxGSiz)

C This procedure prints (to output) the grid point x and y coordinates
C as ordered pairs.

```

      INTEGER i, j, IL, JL

      REAL XMid(MxGSiz,MxGSiz), YMid(MxGSiz,MxGSiz)

      WRITE(8,*) IL
      WRITE(8,*) JL

      DO 20 i=1,IL
        DO 10 j=1,JL
          WRITE(8,35) XMid(i,j),YMid(i,j),1.0
10      CONTINUE
20      CONTINUE

35  FORMAT(1X,F10.6,3X,F10.6,3X,F3.1)

```

```
RETURN
END
```

C=====C

```
      SUBROUTINE RdRgIn (IL,JL,StrXi,StrEt,Tech,NDPts,k1,k2,k3,k4,
$           BetaXi,BetaEt,S1XiRa,S2XiRa,S3EtRa,S4EtRa,
$           s,XiStep,EtStep,MxBCvs,MxBPts)
```

C This procedure reads in the grid control information.

```
      INTEGER Tech, IL, JL, StrXi, StrEt, NDPts(MxBCvs)
```

```
      REAL k1, k2, k3, k4, BetaXi, BetaEt, XiStep, EtStep,
$      S1XiRa, S2XiRa, S3EtRa, S4EtRa, s(MxBCvs,MxBPts)
```

```
      READ(7,*) IL
      READ(7,*) JL
```

```
      READ(7,*) StrXi
      READ(7,*) StrEt
```

```
      READ(7,*) k1
      READ(7,*) k2
```

```
      IF (Tech.EQ.4) THEN
        READ(7,*) k3
        READ(7,*) k4
      ENDIF
```

```
      READ(7,*) BetaXi
      READ(7,*) BetaEt
```

```
      S1XiRa=s(1,NDPts(1))
      S2XiRa=s(2,NDPts(2))
```

```
      IF (Tech.EQ.4) THEN
        S3EtRa=s(3,NDPts(3))
        S4EtRa=s(4,NDPts(4))
      ENDIF
```

```
      XiStep=1.0/(IL-1)
      EtStep=1.0/(JL-1)
```

```
      RETURN
      END
```

A.2 Listing of GRID3D

```

PROGRAM Grid3d

PARAMETER (MxSrfS = 4, MxBPts = 23, MxGSiz = 23)

INTEGER CrvNum, SrfNum, NSurfs,
$       StrXi, StrEt, StrZt, StrAA, StrBB, IL, JL, KL, AL, BL,
$       i, j, k, NDPts(4)

REAL EtStep, XiStep, ZtStep, AAStep, BBStep,
$   k1, k2, k3, k4, kXi1, kXi2, kEta1, kEta2, kZeta1, kZeta2,
$   BetaXi, BetaEt, BetaZt, BetaAA, BetaBB,
$   h1(MxGSiz), h2(MxGSiz), h3(MxGSiz), h4(MxGSiz),
$   h5(MxGSiz), h6(MxGSiz), h7(MxGSiz), h8(MxGSiz),
$   X1(MxGSiz), X2(MxGSiz), X3(MxGSiz), X4(MxGSiz),
$   Y1(MxGSiz), Y2(MxGSiz), Y3(MxGSiz), Y4(MxGSiz),
$   Z1(MxGSiz), Z2(MxGSiz), Z3(MxGSiz), Z4(MxGSiz),
$   PXS1PE(MxGSiz,MxGSiz), PXS2PE(MxGSiz,MxGSiz),
$   PYS1PE(MxGSiz,MxGSiz), PYS2PE(MxGSiz,MxGSiz),
$   PZS1PE(MxGSiz,MxGSiz), PZS2PE(MxGSiz,MxGSiz),
$   PXS3Zt(MxGSiz,MxGSiz), PXS4Zt(MxGSiz,MxGSiz),
$   PYS3Zt(MxGSiz,MxGSiz), PYS4Zt(MxGSiz,MxGSiz),
$   PZS3Zt(MxGSiz,MxGSiz), PZS4Zt(MxGSiz,MxGSiz)
REAL Tensn(4),
$   Diag(MxBPts), OfDiag(MxBPts), Right(MxBPts),
$   XDeriv2(4,MxBPts), YDeriv2(4,MxBPts),
$   ZDeriv2(4,MxBPts),
$   x(4,MxBPts), y(4,MxBPts),
$   z(4,MxBPts), s(4,MxBPts),
$   zx(4,MxBPts), zy(4,MxBPts),
$   zz(4,MxBPts)
REAL PX1PBB(MxGSiz), PX2PBB(MxGSiz),
$   PY1PBB(MxGSiz), PY2PBB(MxGSiz),
$   PZ1PBB(MxGSiz), PZ2PBB(MxGSiz),
$   PX1PAA(MxGSiz), PX2PAA(MxGSiz),
$   PY1PAA(MxGSiz), PY2PAA(MxGSiz),
$   PZ1PAA(MxGSiz), PZ2PAA(MxGSiz),
$   PX3PBB(MxGSiz), PX4PBB(MxGSiz),
$   PY3PBB(MxGSiz), PY4PBB(MxGSiz),
$   PZ3PBB(MxGSiz), PZ4PBB(MxGSiz),
$   PX3PAA(MxGSiz), PX4PAA(MxGSiz),
$   PY3PAA(MxGSiz), PY4PAA(MxGSiz),
$   PZ3PAA(MxGSiz), PZ4PAA(MxGSiz),
$   XS(MxSrfS,MxGsiz,MxGsiz),
$   YS(MxSrfS,MxGsiz,MxGsiz),
$   ZS(MxSrfS,MxGsiz,MxGsiz),
$   XPnt(MxGSiz,MxGSiz,MxGSiz),
$   YPnt(MxGSiz,MxGSiz,MxGSiz),
$   ZPnt(MxGSiz,MxGSiz,MxGSiz)

```

C Read in the grid control information.

```
CALL RdGrIn(IL,JL,KL,StrXi,StrEt,StrZt,NSurfs,kXi1,kXi2,  
$      kEta1,kEta2,kZeta1,kZeta2,BetaXi,BetaEt,BetaZt,  
$      XiStep,EtStep,ZtStep)
```

C Calculate the boundary surface grid point locations.

```
DO 20 SrfNum=1,NSurfs
```

C Form the boundary surface edge curves by splining.

```
DO 10 CrvNum=1,4  
  CALL RdCvIn(x,y,z,NDPts,CrvNum,Tensn,MxBPts)  
  CALL PTSpln(x,y,z,s,zx,zy,zz,Diag,OfDiag,Right,NDPts,  
$      Tensn(CrvNum),CrvNum,MxBPts)  
10 CONTINUE
```

```
IF (SrfNum.LE.2) THEN
```

```
  AASStep=ZtStep  
  BBStep=XiStep  
  StrAA=StrZt  
  StrBB=StrXi  
  BetaAA=BetaZt  
  BetaBB=BetaXi  
  k1=kXi1  
  k2=kXi2  
  k3=kZeta1  
  k4=kZeta2  
  AL=KL  
  BL=IL
```

```
ELSE
```

```
  AASStep=XiStep  
  BBStep=EtStep  
  StrAA=StrXi  
  StrBB=StrEt  
  BetaAA=BetaXi  
  BetaBB=BetaEt  
  k1=kEta1  
  k2=kEta2  
  k3=kXi1  
  k4=kXi2  
  AL=IL  
  BL=JL
```

```
ENDIF
```

C Calculate the boundary surface edge grid point locations.

```
CALL EdgPts(X1,X2,X3,X4,Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,AL,BL,  
$      AASStep,BBStep,x,y,z,s,zx,zy,zz,NDPts,Tensn,  
$      StrAA,StrBB,BetaAA,BetaBB,MxBPts,MxGSiz)
```

C Calculate the boundary surface edge derivative values.

```

CALL EdgDer(PX1PAA,PX2PAA,PY1PAA,PY2PAA,PZ1PAA,PZ2PAA,
$          PX3PBB,PX4PBB,PY3PBB,PY4PBB,PZ3PBB,PZ4PBB,
$          X1,X2,X3,X4,Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,AL,BL,
$          AASStep,BBStep,MxGSiz)

```

C Calculate the boundary surface grid point locations.

```

CALL TwoBnd(XS,YS,ZS,SrfNum,AL,BL,k1,k2,BetaAA,BetaBB,
$          AASStep,BBStep,h1,h2,h3,h4,X1,X2,X3,X4,
$          Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,PX1PBB,PX2PBB,
$          PY1PBB,PY2PBB,PZ1PBB,PZ2PBB,PX1PAA,PX2PAA,
$          PY1PAA,PY2PAA,PZ1PAA,PZ2PAA,PX3PBB,PX4PBB,
$          PY3PBB,PY4PBB,PZ3PBB,PZ4PBB,StrAA,StrBB,
$          MxGSiz,MxSrfs)

```

```

CALL ForBnd(XS,YS,ZS,SrfNum,AL,BL,k3,k4,BetaAA,BetaBB,
$          AASStep,BBStep,h1,h2,h3,h4,h5,h6,h7,h8,
$          X1,X2,X3,X4,Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,
$          PX1PBB,PX2PBB,PY1PBB,PY2PBB,PZ1PBB,PZ2PBB,
$          PX1PAA,PX2PAA,PY1PAA,PY2PAA,PZ1PAA,PZ2PAA,
$          PX3PBB,PX4PBB,PY3PBB,PY4PBB,PZ3PBB,PZ4PBB,
$          PX3PAA,PX4PAA,PY3PAA,PY4PAA,PZ3PAA,PZ4PAA,
$          StrAA,StrBB,MxGSiz,MxSrfs)

```

20 CONTINUE

C Calculate the interior grid point locations.

```

CALL TwoSrf(XPnt,YPnt,ZPnt,IL,JL,KL,kEta1,kEta2,
$          BetaXi,BetaEt,BetaZt,
$          XiStep,EtStep,ZtStep,XS,YS,ZS,h1,h2,h3,h4,
$          PXS1PE,PXS2PE,PYS1PE,PYS2PE,PZS1PE,
$          PZS2PE,StrXi,StrEt,StrZt,MxGSiz,MxSrfs)

```

IF (NSurfs.EQ.4) THEN

```

CALL ForSrf(XPnt,YPnt,ZPnt,IL,JL,KL,kZeta1,kZeta2,
$          BetaXi,BetaEt,BetaZt,XS,YS,ZS,
$          XiStep,EtStep,ZtStep,
$          h1,h2,h3,h4,h5,h6,h7,h8,
$          PXS1PE,PXS2PE,PYS1PE,PYS2PE,PZS1PE,PZS2PE,
$          PXS3Zt,PXS4Zt,PYS3Zt,PYS4Zt,PZS3Zt,PZS4Zt,
$          StrXi,StrEt,StrZt,MxGSiz,MxSrfs)

```

ENDIF

```

CALL PrGrid(XPnt,YPnt,ZPnt,IL,JL,KL,MxGSiz)

```

END

C=====C

```

SUBROUTINE TwoSrf(XPnt,YPnt,ZPnt,IL,JL,KL,k1,k2,BetaXi,BetaEt,
$          BetaZt,XiStep,EtStep,ZtStep,XS,YS,ZS,
$          h1,h2,h3,h4,PXS1PE,PXS2PE,PYS1PE,PYS2PE,PZS1PE,
$          PZS2PE,StrXi,StrEt,StrZt,MxGSiz,MxSrfs)

```

C This procedure calculates the grid point locations between two specified
C surfaces using the "two-boundary technique".

```

INTEGER i, j, k, StrXi, StrEt, StrZt, IL, JL, KL

REAL Xi, Eta, Zeta, XiNew, EtaNew, ZtaNew,
$ PXS1Xi, PXS2Xi, PYS1Xi, PYS2Xi, PZS1Xi, PZS2Xi,
$ PXS1Zt, PXS2Zt, PYS1Zt, PYS2Zt, PZS1Zt, PZS2Zt,
$ k1, k2, BetaXi, BetaEt, BetaZt, XiStep, EtStep, ZtStep,
$ h1(MxGSiz), h2(MxGSiz), h3(MxGSiz), h4(MxGSiz),
$ PXS1PE(MxGSiz,MxGsiz), PXS2PE(MxGSiz,MxGsiz),
$ PYS1PE(MxGSiz,MxGsiz), PYS2PE(MxGSiz,MxGsiz),
$ PZS1PE(MxGSiz,MxGsiz), PZS2PE(MxGSiz,MxGsiz),
$ XS(MxSrfs,MxGsiz,MxGsiz),
$ YS(MxSrfs,MxGsiz,MxGsiz),
$ ZS(MxSrfs,MxGsiz,MxGsiz),
$ XPnt(MxGSiz,MxGsiz,MxGSiz),
$ YPnt(MxGSiz,MxGsiz,MxGSiz),
$ ZPnt(MxGSiz,MxGsiz,MxGSiz)

```

C Calculate the h factors for the boundary surface 1-2 Hermite
C connecting curves.

```

Eta=0.0

DO 50 j=1,JL
  CALL FAINew(EtaNew,Eta,BetaEt,StrEt)
  CALL FindHs(h1(j),h2(j),h3(j),h4(j),EtaNew)
  Eta=Eta+EtStep
50 CONTINUE

```

C Calculate the derivative values along the constant Xi/Zeta
C boundaries.

```

PXS1Xi=(XS(1,1,2)-XS(1,1,1))/XiStep
PXS2Xi=(XS(2,1,2)-XS(2,1,1))/XiStep
PYS1Xi=(YS(1,1,2)-YS(1,1,1))/XiStep
PYS2Xi=(YS(2,1,2)-YS(2,1,1))/XiStep
PZS1Xi=(ZS(1,1,2)-ZS(1,1,1))/XiStep
PZS2Xi=(ZS(2,1,2)-ZS(2,1,1))/XiStep
PXS1Zt=(XS(1,2,1)-XS(1,1,1))/ZtStep
PXS2Zt=(XS(2,2,1)-XS(2,1,1))/ZtStep
PYS1Zt=(YS(1,2,1)-YS(1,1,1))/ZtStep
PYS2Zt=(YS(2,2,1)-YS(2,1,1))/ZtStep
PZS1Zt=(ZS(1,2,1)-ZS(1,1,1))/ZtStep
PZS2Zt=(ZS(2,2,1)-ZS(2,1,1))/ZtStep
PXS1PE(1,1)=-k1*(PYS1Xi*PZS1Zt-PZS1Xi*PYS1Zt)
PXS2PE(1,1)=-k2*(PYS2Xi*PZS2Zt-PZS2Xi*PYS2Zt)
PYS1PE(1,1)= k1*(PXS1Xi*PZS1Zt-PZS1Xi*PXS1Zt)
PYS2PE(1,1)= k2*(PXS2Xi*PZS2Zt-PZS2Xi*PXS2Zt)
PZS1PE(1,1)=-k1*(PXS1Xi*PYS1Zt-PYS1Xi*PXS1Zt)
PZS2PE(1,1)=-k2*(PXS2Xi*PYS2Zt-PYS2Xi*PXS2Zt)

PXS1Xi=(XS(1,1,IL)-XS(1,1,IL-1))/XiStep
PXS2Xi=(XS(2,1,IL)-XS(2,1,IL-1))/XiStep

```

$PYS1Xi = (YS(1,1,IL) - YS(1,1,IL-1)) / XiStep$
 $PYS2Xi = (YS(2,1,IL) - YS(2,1,IL-1)) / XiStep$
 $PZS1Xi = (ZS(1,1,IL) - ZS(1,1,IL-1)) / XiStep$
 $PZS2Xi = (ZS(2,1,IL) - ZS(2,1,IL-1)) / XiStep$
 $PXS1Zt = (XS(1,2,IL) - XS(1,1,IL)) / ZtStep$
 $PXS2Zt = (XS(2,2,IL) - XS(2,1,IL)) / ZtStep$
 $PYS1Zt = (YS(1,2,IL) - YS(1,1,IL)) / ZtStep$
 $PYS2Zt = (YS(2,2,IL) - YS(2,1,IL)) / ZtStep$
 $PZS1Zt = (ZS(1,2,IL) - ZS(1,1,IL)) / ZtStep$
 $PZS2Zt = (ZS(2,2,IL) - ZS(2,1,IL)) / ZtStep$
 $PXS1PE(IL,1) = -k1 * (PYS1Xi * PZS1Zt - PZS1Xi * PYS1Zt)$
 $PXS2PE(IL,1) = -k2 * (PYS2Xi * PZS2Zt - PZS2Xi * PYS2Zt)$
 $PYS1PE(IL,1) = k1 * (PXS1Xi * PZS1Zt - PZS1Xi * PXS1Zt)$
 $PYS2PE(IL,1) = k2 * (PXS2Xi * PZS2Zt - PZS2Xi * PXS2Zt)$
 $PZS1PE(IL,1) = -k1 * (PXS1Xi * PYS1Zt - PYS1Xi * PXS1Zt)$
 $PZS2PE(IL,1) = -k2 * (PXS2Xi * PYS2Zt - PYS2Xi * PXS2Zt)$

DO 55 i=2,IL-1

$PXS1Xi = (XS(1,1,i+1) - XS(1,1,i-1)) / 2 / XiStep$
 $PXS2Xi = (XS(2,1,i+1) - XS(2,1,i-1)) / 2 / XiStep$
 $PYS1Xi = (YS(1,1,i+1) - YS(1,1,i-1)) / 2 / XiStep$
 $PYS2Xi = (YS(2,1,i+1) - YS(2,1,i-1)) / 2 / XiStep$
 $PZS1Xi = (ZS(1,1,i+1) - ZS(1,1,i-1)) / 2 / XiStep$
 $PZS2Xi = (ZS(2,1,i+1) - ZS(2,1,i-1)) / 2 / XiStep$
 $PXS1Zt = (XS(1,2,i) - XS(1,1,i)) / ZtStep$
 $PXS2Zt = (XS(2,2,i) - XS(2,1,i)) / ZtStep$
 $PYS1Zt = (YS(1,2,i) - YS(1,1,i)) / ZtStep$
 $PYS2Zt = (YS(2,2,i) - YS(2,1,i)) / ZtStep$
 $PZS1Zt = (ZS(1,2,i) - ZS(1,1,i)) / ZtStep$
 $PZS2Zt = (ZS(2,2,i) - ZS(2,1,i)) / ZtStep$
 $PXS1PE(i,1) = -k1 * (PYS1Xi * PZS1Zt - PZS1Xi * PYS1Zt)$
 $PXS2PE(i,1) = -k2 * (PYS2Xi * PZS2Zt - PZS2Xi * PYS2Zt)$
 $PYS1PE(i,1) = k1 * (PXS1Xi * PZS1Zt - PZS1Xi * PXS1Zt)$
 $PYS2PE(i,1) = k2 * (PXS2Xi * PZS2Zt - PZS2Xi * PXS2Zt)$
 $PZS1PE(i,1) = -k1 * (PXS1Xi * PYS1Zt - PYS1Xi * PXS1Zt)$
 $PZS2PE(i,1) = -k2 * (PXS2Xi * PYS2Zt - PYS2Xi * PXS2Zt)$

55 CONTINUE

DO 70 k=2,KL-1

$PXS1Xi = (XS(1,k,2) - XS(1,k,1)) / XiStep$
 $PXS2Xi = (XS(2,k,2) - XS(2,k,1)) / XiStep$
 $PYS1Xi = (YS(1,k,2) - YS(1,k,1)) / XiStep$
 $PYS2Xi = (YS(2,k,2) - YS(2,k,1)) / XiStep$
 $PZS1Xi = (ZS(1,k,2) - ZS(1,k,1)) / XiStep$
 $PZS2Xi = (ZS(2,k,2) - ZS(2,k,1)) / XiStep$
 $PXS1Zt = (XS(1,k+1,1) - XS(1,k-1,1)) / 2 / ZtStep$
 $PXS2Zt = (XS(2,k+1,1) - XS(2,k-1,1)) / 2 / ZtStep$
 $PYS1Zt = (YS(1,k+1,1) - YS(1,k-1,1)) / 2 / ZtStep$
 $PYS2Zt = (YS(2,k+1,1) - YS(2,k-1,1)) / 2 / ZtStep$
 $PZS1Zt = (ZS(1,k+1,1) - ZS(1,k-1,1)) / 2 / ZtStep$
 $PZS2Zt = (ZS(2,k+1,1) - ZS(2,k-1,1)) / 2 / ZtStep$
 $PXS1PE(1,k) = -k1 * (PYS1Xi * PZS1Zt - PZS1Xi * PYS1Zt)$
 $PXS2PE(1,k) = -k2 * (PYS2Xi * PZS2Zt - PZS2Xi * PYS2Zt)$
 $PYS1PE(1,k) = k1 * (PXS1Xi * PZS1Zt - PZS1Xi * PXS1Zt)$
 $PYS2PE(1,k) = k2 * (PXS2Xi * PZS2Zt - PZS2Xi * PXS2Zt)$

PZS1PE(1,k)=-k1*(PXS1Xi*PYS1Zt-PYS1Xi*PXS1Zt)
PZS2PE(1,k)=-k2*(PXS2Xi*PYS2Zt-PYS2Xi*PXS2Zt)

PXS1Xi=(XS(1,k,IL)-XS(1,k,IL-1))/XiStep
PXS2Xi=(XS(2,k,IL)-XS(2,k,IL-1))/XiStep
PYS1Xi=(YS(1,k,IL)-YS(1,k,IL-1))/XiStep
PYS2Xi=(YS(2,k,IL)-YS(2,k,IL-1))/XiStep
PZS1Xi=(ZS(1,k,IL)-ZS(1,k,IL-1))/XiStep
PZS2Xi=(ZS(2,k,IL)-ZS(2,k,IL-1))/XiStep
PXS1Zt=(XS(1,k+1,IL)-XS(1,k-1,IL))/2/ZtStep
PXS2Zt=(XS(2,k+1,IL)-XS(2,k-1,IL))/2/ZtStep
PYS1Zt=(YS(1,k+1,IL)-YS(1,k-1,IL))/2/ZtStep
PYS2Zt=(YS(2,k+1,IL)-YS(2,k-1,IL))/2/ZtStep
PZS1Zt=(ZS(1,k+1,IL)-ZS(1,k-1,IL))/2/ZtStep
PZS2Zt=(ZS(2,k+1,IL)-ZS(2,k-1,IL))/2/ZtStep
PXS1PE(IL,k)=-k1*(PYS1Xi*PZS1Zt-PZS1Xi*PYS1Zt)
PXS2PE(IL,k)=-k2*(PYS2Xi*PZS2Zt-PZS2Xi*PYS2Zt)
PYS1PE(IL,k)= k1*(PXS1Xi*PZS1Zt-PZS1Xi*PXS1Zt)
PYS2PE(IL,k)= k2*(PXS2Xi*PZS2Zt-PZS2Xi*PXS2Zt)
PZS1PE(IL,k)=-k1*(PXS1Xi*PYS1Zt-PYS1Xi*PXS1Zt)
PZS2PE(IL,k)=-k2*(PXS2Xi*PYS2Zt-PYS2Xi*PXS2Zt)

DO 60 i=2,IL-1

PXS1Xi=(XS(1,k,i+1)-XS(1,k,i-1))/2/XiStep
PXS2Xi=(XS(2,k,i+1)-XS(2,k,i-1))/2/XiStep
PYS1Xi=(YS(1,k,i+1)-YS(1,k,i-1))/2/XiStep
PYS2Xi=(YS(2,k,i+1)-YS(2,k,i-1))/2/XiStep
PZS1Xi=(ZS(1,k,i+1)-ZS(1,k,i-1))/2/XiStep
PZS2Xi=(ZS(2,k,i+1)-ZS(2,k,i-1))/2/XiStep
PXS1Zt=(XS(1,k+1,i)-XS(1,k-1,i))/2/ZtStep
PXS2Zt=(XS(2,k+1,i)-XS(2,k-1,i))/2/ZtStep
PYS1Zt=(YS(1,k+1,i)-YS(1,k-1,i))/2/ZtStep
PYS2Zt=(YS(2,k+1,i)-YS(2,k-1,i))/2/ZtStep
PZS1Zt=(ZS(1,k+1,i)-ZS(1,k-1,i))/2/ZtStep
PZS2Zt=(ZS(2,k+1,i)-ZS(2,k-1,i))/2/ZtStep
PXS1PE(i,k)=-k1*(PYS1Xi*PZS1Zt-PZS1Xi*PYS1Zt)
PXS2PE(i,k)=-k2*(PYS2Xi*PZS2Zt-PZS2Xi*PYS2Zt)
PYS1PE(i,k)= k1*(PXS1Xi*PZS1Zt-PZS1Xi*PXS1Zt)
PYS2PE(i,k)= k2*(PXS2Xi*PZS2Zt-PZS2Xi*PXS2Zt)
PZS1PE(i,k)=-k1*(PXS1Xi*PYS1Zt-PYS1Xi*PXS1Zt)
PZS2PE(i,k)=-k2*(PXS2Xi*PYS2Zt-PYS2Xi*PXS2Zt)

60 CONTINUE

70 CONTINUE

PXS1Xi=(XS(1,KL,2)-XS(1,KL,1))/XiStep
PXS2Xi=(XS(2,KL,2)-XS(2,KL,1))/XiStep
PYS1Xi=(YS(1,KL,2)-YS(1,KL,1))/XiStep
PYS2Xi=(YS(2,KL,2)-YS(2,KL,1))/XiStep
PZS1Xi=(ZS(1,KL,2)-ZS(1,KL,1))/XiStep
PZS2Xi=(ZS(2,KL,2)-ZS(2,KL,1))/XiStep
PXS1Zt=(XS(1,KL,1)-XS(1,KL-1,1))/ZtStep
PXS2Zt=(XS(2,KL,1)-XS(2,KL-1,1))/ZtStep
PYS1Zt=(YS(1,KL,1)-YS(1,KL-1,1))/ZtStep
PYS2Zt=(YS(2,KL,1)-YS(2,KL-1,1))/ZtStep
PZS1Zt=(ZS(1,KL,1)-ZS(1,KL-1,1))/ZtStep

```

PZS2Zt=(ZS(2,KL,1)-ZS(2,KL-1,1))/ZtStep
PXS1PE(1,KL)=-k1*(PYS1Xi*PZS1Zt-PZS1Xi*PYS1Zt)
PXS2PE(1,KL)=-k2*(PYS2Xi*PZS2Zt-PZS2Xi*PYS2Zt)
PYS1PE(1,KL)= k1*(PXS1Xi*PZS1Zt-PZS1Xi*PXS1Zt)
PYS2PE(1,KL)= k2*(PXS2Xi*PZS2Zt-PZS2Xi*PXS2Zt)
PZS1PE(1,KL)=-k1*(PXS1Xi*PYS1Zt-PYS1Xi*PXS1Zt)
PZS2PE(1,KL)=-k2*(PXS2Xi*PYS2Zt-PYS2Xi*PXS2Zt)

```

```

PXS1Xi=(XS(1,KL,IL)-XS(1,KL,IL-1))/XiStep
PXS2Xi=(XS(2,KL,IL)-XS(2,KL,IL-1))/XiStep
PYS1Xi=(YS(1,KL,IL)-YS(1,KL,IL-1))/XiStep
PYS2Xi=(YS(2,KL,IL)-YS(2,KL,IL-1))/XiStep
PZS1Xi=(ZS(1,KL,IL)-ZS(1,KL,IL-1))/XiStep
PZS2Xi=(ZS(2,KL,IL)-ZS(2,KL,IL-1))/XiStep
PXS1Zt=(XS(1,KL,IL)-XS(1,KL-1,IL))/ZtStep
PXS2Zt=(XS(2,KL,IL)-XS(2,KL-1,IL))/ZtStep
PYS1Zt=(YS(1,KL,IL)-YS(1,KL-1,IL))/ZtStep
PYS2Zt=(YS(2,KL,IL)-YS(2,KL-1,IL))/ZtStep
PZS1Zt=(ZS(1,KL,IL)-ZS(1,KL-1,IL))/ZtStep
PZS2Zt=(ZS(2,KL,IL)-ZS(2,KL-1,IL))/ZtStep
PXS1PE(IL,KL)=-k1*(PYS1Xi*PZS1Zt-PZS1Xi*PYS1Zt)
PXS2PE(IL,KL)=-k2*(PYS2Xi*PZS2Zt-PZS2Xi*PYS2Zt)
PYS1PE(IL,KL)= k1*(PXS1Xi*PZS1Zt-PZS1Xi*PXS1Zt)
PYS2PE(IL,KL)= k2*(PXS2Xi*PZS2Zt-PZS2Xi*PXS2Zt)
PZS1PE(IL,KL)=-k1*(PXS1Xi*PYS1Zt-PYS1Xi*PXS1Zt)
PZS2PE(IL,KL)=-k2*(PXS2Xi*PYS2Zt-PYS2Xi*PXS2Zt)

```

```
DO 75 i=2,IL-1
```

```

PXS1Xi=(XS(1,KL,i+1)-XS(1,KL,i-1))/2/XiStep
PXS2Xi=(XS(2,KL,i+1)-XS(2,KL,i-1))/2/XiStep
PYS1Xi=(YS(1,KL,i+1)-YS(1,KL,i-1))/2/XiStep
PYS2Xi=(YS(2,KL,i+1)-YS(2,KL,i-1))/2/XiStep
PZS1Xi=(ZS(1,KL,i+1)-ZS(1,KL,i-1))/2/XiStep
PZS2Xi=(ZS(2,KL,i+1)-ZS(2,KL,i-1))/2/XiStep
PXS1Zt=(XS(1,KL,i)-XS(1,KL-1,i))/ZtStep
PXS2Zt=(XS(2,KL,i)-XS(2,KL-1,i))/ZtStep
PYS1Zt=(YS(1,KL,i)-YS(1,KL-1,i))/ZtStep
PYS2Zt=(YS(2,KL,i)-YS(2,KL-1,i))/ZtStep
PZS1Zt=(ZS(1,KL,i)-ZS(1,KL-1,i))/ZtStep
PZS2Zt=(ZS(2,KL,i)-ZS(2,KL-1,i))/ZtStep
PXS1PE(i,KL)=-k1*(PYS1Xi*PZS1Zt-PZS1Xi*PYS1Zt)
PXS2PE(i,KL)=-k2*(PYS2Xi*PZS2Zt-PZS2Xi*PYS2Zt)
PYS1PE(i,KL)= k1*(PXS1Xi*PZS1Zt-PZS1Xi*PXS1Zt)
PYS2PE(i,KL)= k2*(PXS2Xi*PZS2Zt-PZS2Xi*PXS2Zt)
PZS1PE(i,KL)=-k1*(PXS1Xi*PYS1Zt-PYS1Xi*PXS1Zt)
PZS2PE(i,KL)=-k2*(PXS2Xi*PYS2Zt-PYS2Xi*PXS2Zt)

```

```
75 CONTINUE
```

C Calculate the interior grid point locations.

```

DO 100 k=1,KL
  DO 90 i=1,IL
    DO 80 j=1,JL
      XPnt(i,j,k)=h1(j)
      *XS(1,k,i)+h2(j)*XS(2,k,i)
    $
  $

```

```

$          +h3(j)*PXS1PE(i,k)
$          +h4(j)*PXS2PE(i,k)
      YPnt(i,j,k)=h1(j)
$          *YS(1,k,i)+h2(j)*YS(2,k,i)
$          +h3(j)*PYS1PE(i,k)
$          +h4(j)*PYS2PE(i,k)
      ZPnt(i,j,k)=h1(j)
$          *ZS(1,k,i)+h2(j)*ZS(2,k,i)
$          +h3(j)*PZS1PE(i,k)
$          +h4(j)*PZS2PE(i,k)
80      CONTINUE
90      CONTINUE
100     CONTINUE

```

```

      RETURN
      END

```

C=====C

```

SUBROUTINE ForSrf(XPnt,YPnt,ZPnt,IL,JL,KL,k3,k4,BetaXi,BetaEt,
$      BetaZt,XS,YS,ZS,XiStep,EtStep,ZtStep,
$      h1,h2,h3,h4,h5,h6,h7,h8,
$      PXS1PE,PXS2PE,PYS1PE,PYS2PE,PZS1PE,PZS2PE,
$      PXS3Zt,PXS4Zt,PYS3Zt,PYS4Zt,PZS3Zt,PZS4Zt,
$      StrXi,StrEt,StrZt,MxGSiz,MxSrf)

```

C This procedure adjusts the grid so that the other two surfaces of the
C region are mapped correctly using the "four-boundary technique".

```

      INTEGER i, j, k, StrXi, StrEt, StrZt, IL, JL, KL

```

```

      REAL Xi, Eta, Zeta, XiNew, EtaNew, ZtaNew,
$      h1(MxGSiz), h2(MxGSiz), h3(MxGSiz), h4(MxGSiz),
$      h5(MxGSiz), h6(MxGSiz), h7(MxGSiz), h8(MxGSiz),
$      PXS3Xi, PXS4Xi, PYS3Xi, PYS4Xi, PZS3Xi, PZS4Xi,
$      PXS3PE, PXS4PE, PYS3PE, PYS4PE, PZS3PE, PZS4PE,
$      P2X00, P2X01, P2X10, P2X11, P2Y00, P2Y01, P2Y10, P2Y11,
$      P2Z00, P2Z01, P2Z10, P2Z11

```

```

      REAL k3, k4, BetaXi, BetaEt, BetaZt, XiStep, EtStep, ZtStep,
$      PXS1PE(MxGSiz,MxGsiz), PXS2PE(MxGSiz,MxGsiz),
$      PXS3Zt(MxGSiz,MxGsiz), PXS4Zt(MxGSiz,MxGsiz),
$      PYS1PE(MxGSiz,MxGsiz), PYS2PE(MxGSiz,MxGsiz),
$      PYS3Zt(MxGSiz,MxGsiz), PYS4Zt(MxGSiz,MxGsiz),
$      PZS1PE(MxGSiz,MxGsiz), PZS2PE(MxGSiz,MxGsiz),
$      PZS3Zt(MxGSiz,MxGsiz), PZS4Zt(MxGSiz,MxGsiz),
$      XS(MxSrf,MxGSiz,MxGsiz),
$      YS(MxSrf,MxGSiz,MxGsiz),
$      ZS(MxSrf,MxGSiz,MxGsiz),
$      XPnt(MxGSiz,MxGsiz,MxGSiz),
$      YPnt(MxGSiz,MxGsiz,MxGSiz),
$      ZPnt(MxGSiz,MxGsiz,MxGSiz)

```

C Calculate the h factors for the boundary surface 3-4 Hermite
C adjusting curves.

Zeta=0.0

DO 40 k=1,KL

CALL FAlNew(ZtaNew,Zeta,BetaZt,StrZt)

CALL FindHs(h5(k),h6(k),h7(k),h8(k),ZtaNew)

Zeta=Zeta+ZtStep

40 CONTINUE

C Calculate the derivative values along the constant Xi/Eta
C boundaries.

PXS3Xi=(XS(3,2,1)-XS(3,1,1))/XiStep
PXS4Xi=(XS(4,2,1)-XS(4,1,1))/XiStep
PYS3Xi=(YS(3,2,1)-YS(3,1,1))/XiStep
PYS4Xi=(YS(4,2,1)-YS(4,1,1))/XiStep
PZS3Xi=(ZS(3,2,1)-ZS(3,1,1))/XiStep
PZS4Xi=(ZS(4,2,1)-ZS(4,1,1))/XiStep
PXS3PE=(XS(3,1,2)-XS(3,1,1))/EtStep
PXS4PE=(XS(4,1,2)-XS(4,1,1))/EtStep
PYS3PE=(YS(3,1,2)-YS(3,1,1))/EtStep
PYS4PE=(YS(4,1,2)-YS(4,1,1))/EtStep
PZS3PE=(ZS(3,1,2)-ZS(3,1,1))/EtStep
PZS4PE=(ZS(4,1,2)-ZS(4,1,1))/EtStep
PXS3Zt(1,1)=-k3*(PYS3Xi*PZS3PE-PZS3Xi*PYS3PE)
PXS4Zt(1,1)=-k4*(PYS4Xi*PZS4PE-PZS4Xi*PYS4PE)
PYS3Zt(1,1)= k3*(PXS3Xi*PZS3PE-PZS3Xi*PXS3PE)
PYS4Zt(1,1)= k4*(PXS4Xi*PZS4PE-PZS4Xi*PXS4PE)
PZS3Zt(1,1)=-k3*(PXS3Xi*PYS3PE-PYS3Xi*PXS3PE)
PZS4Zt(1,1)=-k4*(PXS4Xi*PYS4PE-PYS4Xi*PXS4PE)

PXS3Xi=(XS(3,IL,1)-XS(3,IL-1,1))/XiStep
PXS4Xi=(XS(4,IL,1)-XS(4,IL-1,1))/XiStep
PYS3Xi=(YS(3,IL,1)-YS(3,IL-1,1))/XiStep
PYS4Xi=(YS(4,IL,1)-YS(4,IL-1,1))/XiStep
PZS3Xi=(ZS(3,IL,1)-ZS(3,IL-1,1))/XiStep
PZS4Xi=(ZS(4,IL,1)-ZS(4,IL-1,1))/XiStep
PXS3PE=(XS(3,IL,2)-XS(3,IL,1))/EtStep
PXS4PE=(XS(4,IL,2)-XS(4,IL,1))/EtStep
PYS3PE=(YS(3,IL,2)-YS(3,IL,1))/EtStep
PYS4PE=(YS(4,IL,2)-YS(4,IL,1))/EtStep
PZS3PE=(ZS(3,IL,2)-ZS(3,IL,1))/EtStep
PZS4PE=(ZS(4,IL,2)-ZS(4,IL,1))/EtStep
PXS3Zt(IL,1)=-k3*(PYS3Xi*PZS3PE-PZS3Xi*PYS3PE)
PXS4Zt(IL,1)=-k4*(PYS4Xi*PZS4PE-PZS4Xi*PYS4PE)
PYS3Zt(IL,1)= k3*(PXS3Xi*PZS3PE-PZS3Xi*PXS3PE)
PYS4Zt(IL,1)= k4*(PXS4Xi*PZS4PE-PZS4Xi*PXS4PE)
PZS3Zt(IL,1)=-k3*(PXS3Xi*PYS3PE-PYS3Xi*PXS3PE)
PZS4Zt(IL,1)=-k4*(PXS4Xi*PYS4PE-PYS4Xi*PXS4PE)

DO 45 i=2,IL-1

PXS3Xi=(XS(3,i+1,1)-XS(3,i-1,1))/2/XiStep

PXS4Xi=(XS(4,i+1,1)-XS(4,i-1,1))/2/XiStep

PYS3Xi=(YS(3,i+1,1)-YS(3,i-1,1))/2/XiStep

PYS4Xi=(YS(4,i+1,1)-YS(4,i-1,1))/2/XiStep

$PZS3Xi = (ZS(3,i+1,1) - ZS(3,i-1,1)) / 2 / XiStep$
 $PZS4Xi = (ZS(4,i+1,1) - ZS(4,i-1,1)) / 2 / XiStep$
 $PXS3PE = (XS(3,i,2) - XS(3,i,1)) / EtStep$
 $PXS4PE = (XS(4,i,2) - XS(4,i,1)) / EtStep$
 $PYS3PE = (YS(3,i,2) - YS(3,i,1)) / EtStep$
 $PYS4PE = (YS(4,i,2) - YS(4,i,1)) / EtStep$
 $PZS3PE = (ZS(3,i,2) - ZS(3,i,1)) / EtStep$
 $PZS4PE = (ZS(4,i,2) - ZS(4,i,1)) / EtStep$
 $PXS3Zt(i,1) = -k3 * (PYS3Xi * PZS3PE - PZS3Xi * PYS3PE)$
 $PXS4Zt(i,1) = -k4 * (PYS4Xi * PZS4PE - PZS4Xi * PYS4PE)$
 $PYS3Zt(i,1) = k3 * (PXS3Xi * PZS3PE - PZS3Xi * PXS3PE)$
 $PYS4Zt(i,1) = k4 * (PXS4Xi * PZS4PE - PZS4Xi * PXS4PE)$
 $PZS3Zt(i,1) = -k3 * (PXS3Xi * PYS3PE - PYS3Xi * PXS3PE)$
 $PZS4Zt(i,1) = -k4 * (PXS4Xi * PYS4PE - PYS4Xi * PXS4PE)$

45 CONTINUE

DO 60 j=2,JL-1

$PXS3Xi = (XS(3,2,j) - XS(3,1,j)) / XiStep$
 $PXS4Xi = (XS(4,2,j) - XS(4,1,j)) / XiStep$
 $PYS3Xi = (YS(3,2,j) - YS(3,1,j)) / XiStep$
 $PYS4Xi = (YS(4,2,j) - YS(4,1,j)) / XiStep$
 $PZS3Xi = (ZS(3,2,j) - ZS(3,1,j)) / XiStep$
 $PZS4Xi = (ZS(4,2,j) - ZS(4,1,j)) / XiStep$
 $PXS3PE = (XS(3,1,j+1) - XS(3,1,j-1)) / 2 / EtStep$
 $PXS4PE = (XS(4,1,j+1) - XS(4,1,j-1)) / 2 / EtStep$
 $PYS3PE = (YS(3,1,j+1) - YS(3,1,j-1)) / 2 / EtStep$
 $PYS4PE = (YS(4,1,j+1) - YS(4,1,j-1)) / 2 / EtStep$
 $PZS3PE = (ZS(3,1,j+1) - ZS(3,1,j-1)) / 2 / EtStep$
 $PZS4PE = (ZS(4,1,j+1) - ZS(4,1,j-1)) / 2 / EtStep$
 $PXS3Zt(1,j) = -k3 * (PYS3Xi * PZS3PE - PZS3Xi * PYS3PE)$
 $PXS4Zt(1,j) = -k4 * (PYS4Xi * PZS4PE - PZS4Xi * PYS4PE)$
 $PYS3Zt(1,j) = k3 * (PXS3Xi * PZS3PE - PZS3Xi * PXS3PE)$
 $PYS4Zt(1,j) = k4 * (PXS4Xi * PZS4PE - PZS4Xi * PXS4PE)$
 $PZS3Zt(1,j) = -k3 * (PXS3Xi * PYS3PE - PYS3Xi * PXS3PE)$
 $PZS4Zt(1,j) = -k4 * (PXS4Xi * PYS4PE - PYS4Xi * PXS4PE)$

$PXS3Xi = (XS(3,IL,j) - XS(3,IL-1,j)) / XiStep$
 $PXS4Xi = (XS(4,IL,j) - XS(4,IL-1,j)) / XiStep$
 $PYS3Xi = (YS(3,IL,j) - YS(3,IL-1,j)) / XiStep$
 $PYS4Xi = (YS(4,IL,j) - YS(4,IL-1,j)) / XiStep$
 $PZS3Xi = (ZS(3,IL,j) - ZS(3,IL-1,j)) / XiStep$
 $PZS4Xi = (ZS(4,IL,j) - ZS(4,IL-1,j)) / XiStep$
 $PXS3PE = (XS(3,IL,j+1) - XS(3,IL,j-1)) / 2 / EtStep$
 $PXS4PE = (XS(4,IL,j+1) - XS(4,IL,j-1)) / 2 / EtStep$
 $PYS3PE = (YS(3,IL,j+1) - YS(3,IL,j-1)) / 2 / EtStep$
 $PYS4PE = (YS(4,IL,j+1) - YS(4,IL,j-1)) / 2 / EtStep$
 $PZS3PE = (ZS(3,IL,j+1) - ZS(3,IL,j-1)) / 2 / EtStep$
 $PZS4PE = (ZS(4,IL,j+1) - ZS(4,IL,j-1)) / 2 / EtStep$
 $PXS3Zt(IL,j) = -k3 * (PYS3Xi * PZS3PE - PZS3Xi * PYS3PE)$
 $PXS4Zt(IL,j) = -k4 * (PYS4Xi * PZS4PE - PZS4Xi * PYS4PE)$
 $PYS3Zt(IL,j) = k3 * (PXS3Xi * PZS3PE - PZS3Xi * PXS3PE)$
 $PYS4Zt(IL,j) = k4 * (PXS4Xi * PZS4PE - PZS4Xi * PXS4PE)$
 $PZS3Zt(IL,j) = -k3 * (PXS3Xi * PYS3PE - PYS3Xi * PXS3PE)$
 $PZS4Zt(IL,j) = -k4 * (PXS4Xi * PYS4PE - PYS4Xi * PXS4PE)$

DO 50 i=2,IL-1

PXS3Xi=(XS(3,i+1,j)-XS(3,i-1,j))/2/XiStep
PXS4Xi=(XS(4,i+1,j)-XS(4,i-1,j))/2/XiStep
PYS3Xi=(YS(3,i+1,j)-YS(3,i-1,j))/2/XiStep
PYS4Xi=(YS(4,i+1,j)-YS(4,i-1,j))/2/XiStep
PZS3Xi=(ZS(3,i+1,j)-ZS(3,i-1,j))/2/XiStep
PZS4Xi=(ZS(4,i+1,j)-ZS(4,i-1,j))/2/XiStep
PXS3PE=(XS(3,i,j+1)-XS(3,i,j-1))/2/EtStep
PXS4PE=(XS(4,i,j+1)-XS(4,i,j-1))/2/EtStep
PYS3PE=(YS(3,i,j+1)-YS(3,i,j-1))/2/EtStep
PYS4PE=(YS(4,i,j+1)-YS(4,i,j-1))/2/EtStep
PZS3PE=(ZS(3,i,j+1)-ZS(3,i,j-1))/2/EtStep
PZS4PE=(ZS(4,i,j+1)-ZS(4,i,j-1))/2/EtStep
PXS3Zt(i,j)=-k3*(PYS3Xi*PZS3PE-PZS3Xi*PYS3PE)
PXS4Zt(i,j)=-k4*(PYS4Xi*PZS4PE-PZS4Xi*PYS4PE)
PYS3Zt(i,j)= k3*(PXS3Xi*PZS3PE-PZS3Xi*PXS3PE)
PYS4Zt(i,j)= k4*(PXS4Xi*PZS4PE-PZS4Xi*PXS4PE)
PZS3Zt(i,j)=-k3*(PXS3Xi*PYS3PE-PYS3Xi*PXS3PE)
PZS4Zt(i,j)=-k4*(PXS4Xi*PYS4PE-PYS4Xi*PXS4PE)

50 CONTINUE

60 CONTINUE

PXS3Xi=(XS(3,2,JL)-XS(3,1,JL))/XiStep
PXS4Xi=(XS(4,2,JL)-XS(4,1,JL))/XiStep
PYS3Xi=(YS(3,2,JL)-YS(3,1,JL))/XiStep
PYS4Xi=(YS(4,2,JL)-YS(4,1,JL))/XiStep
PZS3Xi=(ZS(3,2,JL)-ZS(3,1,JL))/XiStep
PZS4Xi=(ZS(4,2,JL)-ZS(4,1,JL))/XiStep
PXS3PE=(XS(3,1,JL)-XS(3,1,JL-1))/EtStep
PXS4PE=(XS(4,1,JL)-XS(4,1,JL-1))/EtStep
PYS3PE=(YS(3,1,JL)-YS(3,1,JL-1))/EtStep
PYS4PE=(YS(4,1,JL)-YS(4,1,JL-1))/EtStep
PZS3PE=(ZS(3,1,JL)-ZS(3,1,JL-1))/EtStep
PZS4PE=(ZS(4,1,JL)-ZS(4,1,JL-1))/EtStep
PXS3Zt(1,JL)=-k3*(PYS3Xi*PZS3PE-PZS3Xi*PYS3PE)
PXS4Zt(1,JL)=-k4*(PYS4Xi*PZS4PE-PZS4Xi*PYS4PE)
PYS3Zt(1,JL)= k3*(PXS3Xi*PZS3PE-PZS3Xi*PXS3PE)
PYS4Zt(1,JL)= k4*(PXS4Xi*PZS4PE-PZS4Xi*PXS4PE)
PZS3Zt(1,JL)=-k3*(PXS3Xi*PYS3PE-PYS3Xi*PXS3PE)
PZS4Zt(1,JL)=-k4*(PXS4Xi*PYS4PE-PYS4Xi*PXS4PE)

PXS3Xi=(XS(3,IL,JL)-XS(3,IL-1,JL))/XiStep
PXS4Xi=(XS(4,IL,JL)-XS(4,IL-1,JL))/XiStep
PYS3Xi=(YS(3,IL,JL)-YS(3,IL-1,JL))/XiStep
PYS4Xi=(YS(4,IL,JL)-YS(4,IL-1,JL))/XiStep
PZS3Xi=(ZS(3,IL,JL)-ZS(3,IL-1,JL))/XiStep
PZS4Xi=(ZS(4,IL,JL)-ZS(4,IL-1,JL))/XiStep
PXS3PE=(XS(3,IL,JL)-XS(3,IL,JL-1))/EtStep
PXS4PE=(XS(4,IL,JL)-XS(4,IL,JL-1))/EtStep
PYS3PE=(YS(3,IL,JL)-YS(3,IL,JL-1))/EtStep
PYS4PE=(YS(4,IL,JL)-YS(4,IL,JL-1))/EtStep
PZS3PE=(ZS(3,IL,JL)-ZS(3,IL,JL-1))/EtStep
PZS4PE=(ZS(4,IL,JL)-ZS(4,IL,JL-1))/EtStep
PXS3Zt(IL,JL)=-k3*(PYS3Xi*PZS3PE-PZS3Xi*PYS3PE)
PXS4Zt(IL,JL)=-k4*(PYS4Xi*PZS4PE-PZS4Xi*PYS4PE)

```

PYS3Zt(IL,JL)= k3*(PXS3Xi*PZS3PE-PZS3Xi*PXS3PE)
PYS4Zt(IL,JL)= k4*(PXS4Xi*PZS4PE-PZS4Xi*PXS4PE)
PZS3Zt(IL,JL)=-k3*(PXS3Xi*PYS3PE-PYS3Xi*PXS3PE)
PZS4Zt(IL,JL)=-k4*(PXS4Xi*PYS4PE-PYS4Xi*PXS4PE)

```

```
DO 65 i=2,IL-1
```

```

  PXS3Xi=(XS(3,i+1,JL)-XS(3,i-1,JL))/2/XiStep
  PXS4Xi=(XS(4,i+1,JL)-XS(4,i-1,JL))/2/XiStep
  PYS3Xi=(YS(3,i+1,JL)-YS(3,i-1,JL))/2/XiStep
  PYS4Xi=(YS(4,i+1,JL)-YS(4,i-1,JL))/2/XiStep
  PZS3Xi=(ZS(3,i+1,JL)-ZS(3,i-1,JL))/2/XiStep
  PZS4Xi=(ZS(4,i+1,JL)-ZS(4,i-1,JL))/2/XiStep
  PXS3PE=(XS(3,i,JL)-XS(3,i,JL-1))/EtStep
  PXS4PE=(XS(4,i,JL)-XS(4,i,JL-1))/EtStep
  PYS3PE=(YS(3,i,JL)-YS(3,i,JL-1))/EtStep
  PYS4PE=(YS(4,i,JL)-YS(4,i,JL-1))/EtStep
  PZS3PE=(ZS(3,i,JL)-ZS(3,i,JL-1))/EtStep
  PXS3Zt(i,JL)=-k3*(PYS3Xi*PZS3PE-PZS3Xi*PYS3PE)
  PXS4Zt(i,JL)=-k4*(PYS4Xi*PZS4PE-PZS4Xi*PYS4PE)
  PYS3Zt(i,JL)= k3*(PXS3Xi*PZS3PE-PZS3Xi*PXS3PE)
  PYS4Zt(i,JL)= k4*(PXS4Xi*PZS4PE-PZS4Xi*PXS4PE)
  PZS3Zt(i,JL)=-k3*(PXS3Xi*PYS3PE-PYS3Xi*PXS3PE)
  PZS4Zt(i,JL)=-k4*(PXS4Xi*PYS4PE-PYS4Xi*PXS4PE)

```

```
65 CONTINUE
```

```

P2X00=0.0
P2X10=0.0
P2X01=0.0
P2X11=0.0
P2Y00=0.0
P2Y10=0.0
P2Y01=0.0
P2Y11=0.0
P2Z00=0.0
P2Z10=0.0
P2Z01=0.0
P2Z11=0.0

```

C Calculate the grid point locations everywhere.

```

DO 90 k=1,KL
  DO 80 i=1,IL
    DO 70 j=1,JL
      XPnt(i,j,k)=XPnt(i,j,k)
      $      +(XS(3,i,j)-h1(j)*XS(1,1,i)
      $      -h2(j)*XS(2,1,i)
      $      -h3(j)*PXS1PE(i,1)
      $      -h4(j)*PXS2PE(i,1))*h5(k)
      $      +(XS(4,i,j)-h1(j)*XS(1,KL,i)
      $      -h2(j)*XS(2,KL,i)
      $      -h3(j)*PXS1PE(i,KL)
      $      -h4(j)*PXS2PE(i,KL))*h6(k)
      $      +(PXS3Zt(i,j)-(h1(j)*PXS3Zt(i,1)
      $      +h2(j)*PXS3Zt(i,JL)
      $      +h3(j)*P2X00+h4(j)*P2X01))*h7(k)

```

```

$      +(PXS4Zt(i,j)-(h1(j)*PXS4Zt(i,1)
$          +h2(j)*PXS4Zt(i,JL)
$          +h3(j)*P2X10+h4(j)*P2X11))*h8(k)
YPnt(i,j,k)=YPnt(i,j,k)
$      +(YS(3,i,j)-h1(j)*YS(1,1,i)
$          -h2(j)*YS(2,1,i)
$          -h3(j)*PYS1PE(i,1)
$          -h4(j)*PYS2PE(i,1))*h5(k)
$      +(YS(4,i,j)-h1(j)*YS(1,KL,i)
$          -h2(j)*YS(2,KL,i)
$          -h3(j)*PYS1PE(i,KL)
$          -h4(j)*PYS2PE(i,KL))*h6(k)
$      +(PYS3Zt(i,j)-(h1(j)*PYS3Zt(i,1)
$          +h2(j)*PYS3Zt(i,JL)
$          +h3(j)*P2Y00+h4(j)*P2Y01))*h7(k)
$      +(PYS4Zt(i,j)-(h1(j)*PYS4Zt(i,1)
$          +h2(j)*PYS4Zt(i,JL)
$          +h3(j)*P2Y10+h4(j)*P2Y11))*h8(k)
ZPnt(i,j,k)=ZPnt(i,j,k)
$      +(ZS(3,i,j)-h1(j)*ZS(1,1,i)
$          -h2(j)*ZS(2,1,i)
$          -h3(j)*PZS1PE(i,1)
$          -h4(j)*PZS2PE(i,1))*h5(k)
$      +(ZS(4,i,j)-h1(j)*ZS(1,KL,i)
$          -h2(j)*ZS(2,KL,i)
$          -h3(j)*PZS1PE(i,KL)
$          -h4(j)*PZS2PE(i,KL))*h6(k)
$      +(PZS3Zt(i,j)-(h1(j)*PZS3Zt(i,1)
$          +h2(j)*PZS3Zt(i,JL)
$          +h3(j)*P2Z00+h4(j)*P2Z01))*h7(k)
$      +(PZS4Zt(i,j)-(h1(j)*PZS4Zt(i,1)
$          +h2(j)*PZS4Zt(i,JL)
$          +h3(j)*P2Z10+h4(j)*P2Z11))*h8(k)
70     CONTINUE
80     CONTINUE
90     CONTINUE

```

```

RETURN
END

```

C=====C

```

SUBROUTINE PrGrid (XPnt,YPnt,ZPnt,IL,JL,KL,MxGSiz)

```

C This procedure prints (to output) the grid point x, y, and z coordinates.

```

INTEGER i, j, k, IL, JL, KL

```

```

REAL XPnt(MxGSiz,MxGSiz,MxGSiz),
$     YPnt(MxGSiz,MxGSiz,MxGSiz),
$     ZPnt(MxGSiz,MxGSiz,MxGSiz)

```

```

WRITE(8,*) IL
WRITE(8,*) JL

```



```

WRITE(8,*) KL

DO 30 i=1,IL
  DO 20 j=1,JL
    DO 10 k=1,KL
      WRITE(8,35) XPnt(i,j,k),YPnt(i,j,k),ZPnt(i,j,k)
10    CONTINUE
20    CONTINUE
30    CONTINUE

35  FORMAT(1X,F10.6,3x,F10.6,3X,F10.6)

RETURN
END

```

C=====C

```

SUBROUTINE RdGrIn(IL,JL,KL,StrXi,StrEt,StrZt,NSurfs,kXi1,kXi2,
$      kEta1,kEta2,kZeta1,kZeta2,BetaXi,BetaEt,BetaZt,
$      XiStep,EtStep,ZtStep)

```

C This procedure reads in the desired grid information for grid control.

```

INTEGER IL, JL, KL, StrXi, StrEt, StrZt

```

```

REAL kXi1, kXi2, kEta1, kEta2, kZeta1, kZeta2,
$   BetaXi, BetaEt, BetaZt, XiStep, EtStep, ZtStep

```

```

READ(7,*) NSurfs

```

```

READ(7,*) IL
READ(7,*) JL
READ(7,*) KL

```

```

READ(7,*) StrXi
READ(7,*) StrEt
READ(7,*) StrZt

```

```

READ(7,*) kXi1
READ(7,*) kXi2
READ(7,*) kEta1
READ(7,*) kEta2
READ(7,*) kZeta1
READ(7,*) kZeta2

```

```

READ(7,*) BetaXi
READ(7,*) BetaEt
READ(7,*) BetaZt

```

```

XiStep=1.0/(IL-1)
EtStep=1.0/(JL-1)
ZtStep=1.0/(KL-1)

```

```

RETURN
END

```

C=====C

SUBROUTINE RdCvIn (x,y,z,NDPts,CrvNum,Tensn,MxBPts)

C This SUBROUTINE reads in the information concerning discrete points on
C the boundaries. This information is used for generating spline-fitted
C boundary approximation curves.

```
INTEGER CrvNum, i, NDPts(4)

REAL x(4,MxBPts), y(4,MxBPts),
$   z(4,MxBPts), Tensn(4)

READ(7,*) Tensn(CrvNum)
READ(7,*) NDPts(CrvNum)

DO 10 i=1,NDPts(CrvNum)
  READ(7,*) x(CrvNum,i), y(CrvNum,i), z(CrvNum,i)
10 CONTINUE

RETURN
END
```

C=====C

SUBROUTINE CalcS (x,y,z,s,NDPts,CrvNum,MxBPts)

C This SUBROUTINE calculates the spline parameter, s, as an approximate
C arc length.

```
INTEGER NDPts(4), CrvNum, i

REAL x(4,MxBPts), y(4,MxBPts),
$   z(4,MxBPts), s(4,MxBPts)

s(CrvNum,1)=0.0

DO 10 i=2,NDPts(CrvNum)
  s(CrvNum,i)=s(CrvNum,i-1)
  $   +SQRT( (x(CrvNum,i)-x(CrvNum,i-1))**2
  $   + (y(CrvNum,i)-y(CrvNum,i-1))**2
  $   + (z(CrvNum,i)-z(CrvNum,i-1))**2)
10 CONTINUE

RETURN
END
```

C=====C

SUBROUTINE SplMat (Diag,OfDiag,Right,w,s,NDPts,T,CrvNum,MxBPts)

C This SUBROUTINE forms the parametric tension spline matrix for a
C particular boundary curve data set.

```

INTEGER i, NDPts(4), CrvNum

REAL Diag(MxBPts), OfDiag(MxBPts), Right(MxBPts),
$   w(4,MxBPts), s(4,MxBPts), T, h, hm

Diag(1)=1.0
OfDiag(1)=0.0
Right(1)=0.0

DO 10 i=2,NDPts(CrvNum)-1
  h=s(CrvNum,i+1)-s(CrvNum,i)
  hm=s(CrvNum,i)-s(CrvNum,i-1)
  Diag(i)=(T*COSH(T*hm)/SINH(T*hm)-1/hm+T*COSH(T*h)/SINH(T*h)
$   -1/h)/T**2
  OfDiag(i)=(1/h-T/SINH(T*h))/T**2
  Right(i)=(w(CrvNum,i+1)-w(CrvNum,i))/h
$   -(w(CrvNum,i)-w(CrvNum,i-1))/hm
10 CONTINUE

Diag(NDPts(CrvNum))=1.0
OfDiag(NDPts(CrvNum)-1)=0.0
Right(NDPts(CrvNum))=0.0

RETURN
END

```

C=====C

SUBROUTINE SplSlv (Diag,OfDiag,Right,Deriv2,NDPts,CrvNum,MxBPts)

C This SUBROUTINE solves the diagonally dominant parametric tension
C spline matrix for a given data set using the Gauss-Seidel iteration.
C Convergence is assumed after 20 iterations.

```

INTEGER i, j, NDPts(4), CrvNum

REAL Diag(MxBPts), OfDiag(MxBPts), Right(MxBPts),
$   Deriv2(4,MxBPts)

C Initialize the second derivative matrix to all zeroes.

DO 10 i=1,NDPts(CrvNum)
  Deriv2(CrvNum,i)=0.0
10 CONTINUE

```

C Calculate the second derivative values using 20 iterations of
 C the Gauss-Seidel method.

```

    DO 30 j=1,20
      DO 20 i=2,NDPts(CrvNum)-1
        Deriv2(CrvNum,i)=(Right(i)-OfDiag(i)*Deriv2(CrvNum,i+1)
          $                               -OfDiag(i-1)*Deriv2(CrvNum,i-1))
          $                               /Diag(i)
20    CONTINUE
30    CONTINUE

    RETURN
    END
  
```

C=====C

FUNCTION SplVal (s,w,Deriv2,sval,T,n,CrvNum,MxBPts)

C This real function finds the w-value (x-value or y-value) corresponding
 C to a specified s-value using the parametric tension spline curve
 C generated for a particular boundary curve data set.

INTEGER n, CrvNum

REAL s(4,MxBPts), w(4,MxBPts), Deriv2(4,MxBPts),
 \$ sval, T, h, Interim, Temp1, Temp2

```

    Temp1=sval-s(CrvNum,n)
    h=s(CrvNum,n+1)-s(CrvNum,n)
    Temp2=s(CrvNum,n+1)-sval
    Interim=Deriv2(CrvNum,n)/T**2*SINH(T*Temp2)/SINH(T*h)
    $   +(w(CrvNum,n)-Deriv2(CrvNum,n)/T**2)*Temp2/h
    SplVal=Interim+Deriv2(CrvNum,n+1)/T**2*SINH(T*Temp1)
    $   /SINH(T*h)+(w(CrvNum,n+1)
    $   -Deriv2(CrvNum,n+1)/T**2)*Temp1/h
  
```

RETURN
 END

C=====C

SUBROUTINE PTSpln(x,y,z,s,XDeriv2,YDeriv2,ZDeriv2,Diag,OfDiag,
 \$ Right,NDPts,Tensn,CrvNum,MxBPts)

C This SUBROUTINE forms the main routine for the parametric tension
 C spline process.

INTEGER NDPts(4), CrvNum

REAL Diag(MxBPts), OfDiag(MxBPts), Right(MxBPts),
 \$ XDeriv2(4,MxBPts), YDeriv2(4,MxBPts),
 \$ ZDeriv2(4,MxBPts), Tensn,
 \$ x(4,MxBPts), y(4,MxBPts),
 \$ z(4,MxBPts), s(4,MxBPts)

```

CALL CalcS(x,y,z,s,NDPts,CrvNum,MxBPts)
CALL SplMat(Diag,OfDiag,Right,x,s,NDPts,Tensn,CrvNum,MxBPts)
CALL SplSlv(Diag,OfDiag,Right,XDeriv2,NDPts,CrvNum,MxBPts)
CALL SplMat(Diag,OfDiag,Right,y,s,NDPts,Tensn,CrvNum,MxBPts)
CALL SplSlv(Diag,OfDiag,Right,YDeriv2,NDPts,CrvNum,MxBPts)
CALL SplMat(Diag,OfDiag,Right,z,s,NDPts,Tensn,CrvNum,MxBPts)
CALL SplSlv(Diag,OfDiag,Right,ZDeriv2,NDPts,CrvNum,MxBPts)

```

```

RETURN
END

```

C=====C

```

SUBROUTINE FindHs(h1,h2,h3,h4,n)

```

C This SUBROUTINE computes the h factors used in Hermite interpolation.

```

REAL h1, h2, h3, h4, n

```

```

h1= 2*n**3-3*n**2+1
h2=-2*n**3+3*n**2
h3= n**3-2*n**2+n
h4= n**3-n**2

```

```

RETURN
END

```

C=====C

```

SUBROUTINE SplInt(n,s,SValue,NDPts,CurCrv,MxBPts)

```

C This SUBROUTINE finds the proper interval in which a point on a specified
C boundary lies. The interval indicates which initial data points the
C point in question lies between and thus which spline coefficients to use.

```

INTEGER i, n, CurCrv, NDPts(4)

```

```

REAL Temp, SValue, s(4,MxBPts)

```

```

n=1
i=NDPts(CurCrv)

```

```

10 IF ((n.EQ.1).AND.(i.GT.1)) THEN
    i=i-1
    Temp=SValue-s(CurCrv,i)

```

```

    IF (Temp.GT.0.0) THEN
        n=i
    ENDIF

```

```

    GOTO 10
ENDIF

```

```
RETURN
END
```

```
C=====C
```

```
SUBROUTINE FAINew(AlNew,Alpha,B,Str)
```

```
C This SUBROUTINE computes the new Alpha value after stretching as
C AlNew. Alpha is a dummy variable representing either Xi, Eta or Zeta.
```

```
INTEGER Str
```

```
REAL Alpha, Temp1, Temp2, B2, AlNew, B
```

```
AlNew=Alpha
Temp1=(B+1)/(B-1)
```

```
IF (Str.EQ.1) THEN
  Temp2=Temp1**(1-Alpha)
  AlNew=((B+1)-(B-1)*Temp2)/(Temp2+1)*1
ENDIF
```

```
IF (Str.EQ.2) THEN
  B2=0
  Temp2=Temp1**((Alpha-B2)/(1-B2))
  AlNew=((B+2*B2)*Temp2-B+2*B2)/((2*B2+1)*(1+Temp2))
ENDIF
```

```
IF (Str.EQ.3) THEN
  B2=0.5
  Temp2=Temp1**((Alpha-B2)/(1-B2))
  AlNew=((B+2*B2)*Temp2-B+2*B2)/((2*B2+1)*(1+Temp2))
ENDIF
```

```
RETURN
END
```

```
C=====C
```

```
SUBROUTINE EdgPts(X1,X2,X3,X4,Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,AL,BL,
$ AAStep,BBStep,x,y,z,s,zx,zy,zz,NDPts,Tensn,
$ StrAA,StrBB,BetaAA,BetaBB,MxBPts,MxGSiz)
```

```
C This SUBROUTINE calculates the grid point locations along the surface
C edges.
```

```
INTEGER ACt, BCt, n1, n2, n3, n4,
$ AL, BL, StrAA, StrBB, NDPts(4)
```

```
REAL AA, BB, AANew, BBNew, S1, S2, S3, S4, BBStep, AAStep,
$ S1AAR, S2AAR, S3BBR, S4BBR,
$ X1(MxGSiz), X2(MxGSiz), X3(MxGSiz), X4(MxGSiz),
$ Y1(MxGSiz), Y2(MxGSiz), Y3(MxGSiz), Y4(MxGSiz),
$ Z1(MxGSiz), Z2(MxGSiz), Z3(MxGSiz), Z4(MxGSiz),
```

```

$   x(4,MxBPts), y(4,MxBPts), z(4,MxBPts),
$   s(4,MxBPts), zx(4,MxBPts), zy(4,MxBPts),
$   zz(4,MxBPts), Tensn(4), BetaAA, BetaBB

```

```

S1AAR=s(1,NDPts(1))
S2AAR=s(2,NDPts(2))
S3BBR=s(3,NDPts(3))
S4BBR=s(4,NDPts(4))

```

C Calculate the grid point locations along boundaries 1 and 2.

```
AA=0.0
```

```

DO 10 ACt=1,AL
  CALL FAInew(AANew,AA,BetaAA,StrAA)
  S1=AANew*S1AAR
  S2=AANew*S2AAR
  CALL SplInt(n1,s,S1,NDPts,1,MxBPts)
  CALL SplInt(n2,s,S2,NDPts,2,MxBPts)
  X1(ACt)=SplVal(s,x,zx,S1,Tensn(1),n1,1,MxBPts)
  X2(ACt)=SplVal(s,x,zx,S2,Tensn(2),n2,2,MxBPts)
  Y1(ACt)=SplVal(s,y,zy,S1,Tensn(1),n1,1,MxBPts)
  Y2(ACt)=SplVal(s,y,zy,S2,Tensn(2),n2,2,MxBPts)
  Z1(ACt)=SplVal(s,z,zz,S1,Tensn(1),n1,1,MxBPts)
  Z2(ACt)=SplVal(s,z,zz,S2,Tensn(2),n2,2,MxBPts)
  AA=AA+AAStep

```

```
10 CONTINUE
```

C Calculate the grid point locations along boundaries 3 and 4.

```
BB=0.0
```

```

DO 20 BCt=1,BL
  CALL FAInew(BBNew,BB,BetaBB,StrBB)
  S3=BBNew*S3BBR
  S4=BBNew*S4BBR
  CALL SplInt(n3,s,S3,NDPts,3,MxBPts)
  CALL SplInt(n4,s,S4,NDPts,4,MxBPts)
  X3(BCt)=SplVal(s,x,zx,S3,Tensn(3),n3,3,MxBPts)
  X4(BCt)=SplVal(s,x,zx,S4,Tensn(4),n4,4,MxBPts)
  Y3(BCt)=SplVal(s,y,zy,S3,Tensn(3),n3,3,MxBPts)
  Y4(BCt)=SplVal(s,y,zy,S4,Tensn(4),n4,4,MxBPts)
  Z3(BCt)=SplVal(s,z,zz,S3,Tensn(3),n3,3,MxBPts)
  Z4(BCt)=SplVal(s,z,zz,S4,Tensn(4),n4,4,MxBPts)
  BB=BB+BBStep

```

```
20 CONTINUE
```

```

RETURN
END

```

C=====C

```

SUBROUTINE EdgDer(PX1PAA,PX2PAA,PY1PAA,PY2PAA,PZ1PAA,PZ2PAA,
$               PX3PBB,PX4PBB,PY3PBB,PY4PBB,PZ3PBB,PZ4PBB,
$               X1,X2,X3,X4,Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,

```

```

$           AL,BL,AAStep,BBStep,MxGSiz)

INTEGER  ACt, BCt, AL, BL

REAL  AAStep, BBStep, PX3PBB(MxGSiz), PX4PBB(MxGSiz),
$     PY3PBB(MxGSiz), PY4PBB(MxGSiz), PZ3PBB(MxGSiz),
$     PZ4PBB(MxGSiz), PX1PAA(MxGSiz), PX2PAA(MxGSiz),
$     PY1PAA(MxGSiz), PY2PAA(MxGSiz), PZ1PAA(MxGSiz),
$     PZ2PAA(MxGSiz), X1(MxGSiz), X2(MxGSiz), X3(MxGSiz),
$     X4(MxGSiz), Y1(MxGSiz), Y2(MxGSiz), Y3(MxGSiz),
$     Y4(MxGSiz), Z1(MxGSiz), Z2(MxGSiz), Z3(MxGSiz),
$     Z4(MxGSiz)

```

C Calculate the derivative values along the constant AA boundaries.

```

PX1PAA(1)=(X1(2)-X1(1))/AAStep
PX2PAA(1)=(X2(2)-X2(1))/AAStep
PY1PAA(1)=(Y1(2)-Y1(1))/AAStep
PY2PAA(1)=(Y2(2)-Y2(1))/AAStep
PZ1PAA(1)=(Z1(2)-Z1(1))/AAStep
PZ2PAA(1)=(Z2(2)-Z2(1))/AAStep

PX1PAA(AL)=(X1(AL) -X1(AL-1))/AAStep
PX2PAA(AL)=(X2(AL) -X2(AL-1))/AAStep
PY1PAA(AL)=(Y1(AL) -Y1(AL-1))/AAStep
PY2PAA(AL)=(Y2(AL) -Y2(AL-1))/AAStep
PZ1PAA(AL)=(Z1(AL) -Z1(AL-1))/AAStep
PZ2PAA(AL)=(Z2(AL) -Z2(AL-1))/AAStep

```

```

DO 10 ACt=2,AL-1
  PX1PAA(ACt)= (X1(ACt+1)-X1(ACt-1))/2/AAStep
  PX2PAA(ACt)= (X2(ACt+1)-X2(ACt-1))/2/AAStep
  PY1PAA(ACt)= (Y1(ACt+1)-Y1(ACt-1))/2/AAStep
  PY2PAA(ACt)= (Y2(ACt+1)-Y2(ACt-1))/2/AAStep
  PZ1PAA(ACt)= (Z1(ACt+1)-Z1(ACt-1))/2/AAStep
  PZ2PAA(ACt)= (Z2(ACt+1)-Z2(ACt-1))/2/AAStep

```

10 CONTINUE

C Calculate the derivative values along the constant BB boundaries.

```

PX3PBB(1)= (X3(2)-X3(1))/BBStep
PX4PBB(1)= (X4(2)-X4(1))/BBStep
PY3PBB(1)= (Y3(2)-Y3(1))/BBStep
PY4PBB(1)= (Y4(2)-Y4(1))/BBStep
PZ3PBB(1)= (Z3(2)-Z3(1))/BBStep
PZ4PBB(1)= (Z4(2)-Z4(1))/BBStep

PX3PBB(BL)=(X3(BL) -X3(BL-1))/BBStep
PX4PBB(BL)=(X4(BL) -X4(BL-1))/BBStep
PY3PBB(BL)=(Y3(BL) -Y3(BL-1))/BBStep
PY4PBB(BL)=(Y4(BL) -Y4(BL-1))/BBStep
PZ3PBB(BL)=(Z3(BL) -Z3(BL-1))/BBStep
PZ4PBB(BL)=(Z4(BL) -Z4(BL-1))/BBStep

```

```

DO 20 BCt=2,BL-1

```



```

PX3PBB(BCt)= (X3(BCt+1)-X3(BCt-1))/2/BBStep
PX4PBB(BCt)= (X4(BCt+1)-X4(BCt-1))/2/BBStep
PY3PBB(BCt)= (Y3(BCt+1)-Y3(BCt-1))/2/BBStep
PY4PBB(BCt)= (Y4(BCt+1)-Y4(BCt-1))/2/BBStep
PZ3PBB(BCt)= (Z3(BCt+1)-Z3(BCt-1))/2/BBStep
PZ4PBB(BCt)= (Z4(BCt+1)-Z4(BCt-1))/2/BBStep

```

20 CONTINUE

```

RETURN
END

```

C=====C

```

SUBROUTINE TwoBnd(XS,YS,ZS,SrfNum,AL,BL,k1,k2,BetaAA,BetaBB,
$      AASStep,BBStep,h1,h2,h3,h4,X1,X2,X3,X4,
$      Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,PX1PBB,PX2PBB,
$      PY1PBB,PY2PBB,PZ1PBB,PZ2PBB,PX1PAA,PX2PAA,
$      PY1PAA,PY2PAA,PZ1PAA,PZ2PAA,PX3PBB,PX4PBB,
$      PY3PBB,PY4PBB,PZ3PBB,PZ4PBB,StrAA,StrBB,
$      MxGSiz,MxSrfs)

```

C This SUBROUTINE calculates the interior grid point locations between two C specified boundaries (1 and 2) using transfinite Hermite interpolation.

```

INTEGER ACt, BCt, AL, BL, StrAA, StrBB, SrfNum

```

```

REAL AA, BB, AANew, BBNew,
$   Box1i, Box1j, Box1k, Box2i, Box2j, Box2k,
$   Paren1i, Paren1j, Paren1k, Paren2i, Paren2j, Paren2k,
$   k1, k2, BetaAA, BetaBB, BBStep, AASStep,
$   h1(MxGSiz), h2(MxGSiz), h3(MxGSiz), h4(MxGSiz),
$   X1(MxGSiz), X2(MxGSiz), X3(MxGSiz), X4(MxGSiz),
$   Y1(MxGSiz), Y2(MxGSiz), Y3(MxGSiz), Y4(MxGSiz),
$   Z1(MxGSiz), Z2(MxGSiz), Z3(MxGSiz), Z4(MxGSiz)
REAL PX1PBB(MxGSiz), PX2PBB(MxGSiz),
$   PY1PBB(MxGSiz), PY2PBB(MxGSiz),
$   PZ1PBB(MxGSiz), PZ2PBB(MxGSiz),
$   PX1PAA(MxGSiz), PX2PAA(MxGSiz),
$   PY1PAA(MxGSiz), PY2PAA(MxGSiz),
$   PZ1PAA(MxGSiz), PZ2PAA(MxGSiz),
$   PX3PBB(MxGSiz), PX4PBB(MxGSiz),
$   PY3PBB(MxGSiz), PY4PBB(MxGSiz),
$   PZ3PBB(MxGSiz), PZ4PBB(MxGSiz),
$   XS(MxSrfs,MxGSiz,MxGSiz),
$   YS(MxSrfs,MxGSiz,MxGSiz),
$   ZS(MxSrfs,MxGSiz,MxGSiz)

```

C Calculate the h factors for the boundary 1-2 Hermite connecting C curves.

```

BB=0.0

```

```

DO 10 BCt=1,BL
  CALL FA1New(BBNew,BB,BetaBB,StrBB)

```

```

        CALL FindHs(h1(BCt),h2(BCt),h3(BCt),h4(BCt),BBNew)
        BB=BB+BBStep
10  CONTINUE

```

C Calculate the derivative values for grid line orthogonality.

```

AA=0.0

DO 20 ACt=1,AL
  CALL FAlNew(AANew,AA,BetaAA,StrAA)
  Box1i=  AA*( PY1PAA(AL)*PZ4PBB(1)
$         -PZ1PAA(AL)*PY4PBB(1))
$   +(1-AA)*( PY1PAA(1) *PZ3PBB(1)
$         -PZ1PAA(1) *PY3PBB(1))
  Box1j=  AA*( PX1PAA(AL)*PZ4PBB(1)
$         -PZ1PAA(AL)*PX4PBB(1))
$   +(1-AA)*( PX1PAA(1) *PZ3PBB(1)
$         -PZ1PAA(1) *PX3PBB(1))
  Box1k=  AA*( PX1PAA(AL)*PY4PBB(1)
$         -PY1PAA(AL)*PX4PBB(1))
$   +(1-AA)*( PX1PAA(1) *PY3PBB(1)
$         -PY1PAA(1) *PX3PBB(1))
  Box2i=  AA*( PY2PAA(AL)*PZ4PBB(BL)
$         -PZ2PAA(AL)*PY4PBB(BL))
$   +(1-AA)*( PY2PAA(1) *PZ3PBB(BL)
$         -PZ2PAA(1) *PY3PBB(BL))
  Box2j=  AA*( PX2PAA(AL)*PZ4PBB(BL)
$         -PZ2PAA(AL)*PX4PBB(BL))
$   +(1-AA)*( PX2PAA(1) *PZ3PBB(BL)
$         -PZ2PAA(1) *PX3PBB(BL))
  Box2k=  AA*( PX2PAA(AL)*PY4PBB(BL)
$         -PY2PAA(AL)*PX4PBB(BL))
$   +(1-AA)*( PX2PAA(1) *PY3PBB(BL)
$         -PY2PAA(1) *PX3PBB(BL))
  Paren1i=PY1PAA(ACt)*Box1k+PZ1PAA(ACt)*Box1j
  Paren1j=PX1PAA(ACt)*Box1k-PZ1PAA(ACt)*Box1i
  Paren1k=PX1PAA(ACt)*Box1j+PY1PAA(ACt)*Box1i
  Paren2i=PY2PAA(ACt)*Box2k+PZ2PAA(ACt)*Box2j
  Paren2j=PX2PAA(ACt)*Box2k-PZ2PAA(ACt)*Box2i
  Paren2k=PX2PAA(ACt)*Box2j+PY2PAA(ACt)*Box2i
  PX1PBB(ACt)=-k1*Paren1i
  PX2PBB(ACt)=-k2*Paren2i
  PY1PBB(ACt)= k1*Paren1j
  PY2PBB(ACt)= k2*Paren2j
  PZ1PBB(ACt)= k1*Paren1k
  PZ2PBB(ACt)= k2*Paren2k

  AA=AA+AAStep
20  CONTINUE

```

C Calculate the interior grid point locations.

```

DO 40 ACt=1,AL
  DO 30 BCt=1,BL
    XS(SrfNum,ACt,BCt)= h1(BCt)*X1(ACt)+h2(BCt)*X2(ACt)

```

```

$           +h3(BCt)*PX1PBB(ACt)+h4(BCt)*PX2PBB(ACt)
YS(SrfNum,ACt,BCt)= h1(BCt)*Y1(ACt)+h2(BCt)*Y2(ACt)
$           +h3(BCt)*PY1PBB(ACt)+h4(BCt)*PY2PBB(ACt)
ZS(SrfNum,ACt,BCt)= h1(BCt)*Z1(ACt)+h2(BCt)*Z2(ACt)
$           +h3(BCt)*PZ1PBB(ACt)+h4(BCt)*PZ2PBB(ACt)
30  CONTINUE
40  CONTINUE

RETURN
END

```

C=====C

```

SUBROUTINE ForBnd(XS,YS,ZS,SrfNum,AL,BL,k3,k4,BetaAA,BetaBB,
$           AASStep,BBStep,h1,h2,h3,h4,h5,h6,h7,h8,
$           X1,X2,X3,X4,Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,
$           PX1PBB,PX2PBB,PY1PBB,PY2PBB,PZ1PBB,PZ2PBB,
$           PX1PAA,PX2PAA,PY1PAA,PY2PAA,PZ1PAA,PZ2PAA,
$           PX3PBB,PX4PBB,PY3PBB,PY4PBB,PZ3PBB,PZ4PBB,
$           PX3PAA,PX4PAA,PY3PAA,PY4PAA,PZ3PAA,PZ4PAA,
$           StrAA,StrBB,MxGSiz,MxSrfs)

```

C This SUBROUTINE adjusts the grid so that the other two boundaries
C (3 and 4) of the surface are mapped correctly using transfinite Hermite
C interpolation.

```

INTEGER ACt, BCt, AL, BL, StrAA, StrBB, i, j, SrfNum

```

```

REAL AA, BB, AANew, BBNew,
$   Box3i, Box3j, Box3k, Box4i, Box4j, Box4k,
$   Paren3i, Paren3j, Paren3k, Paren4i, Paren4j, Paren4k,
$   P2Y00, P2Y01, P2Y10, P2Y11, P2X00, P2X01, P2X10, P2X11,
$   P2Z00, P2Z01, P2Z10, P2Z11,
$   k3, k4, BetaAA, BetaBB, BBStep, AASStep,
$   h1(MxGSiz), h2(MxGSiz), h3(MxGSiz), h4(MxGSiz),
$   h5(MxGSiz), h6(MxGSiz), h7(MxGSiz), h8(MxGSiz),
$   X1(MxGSiz), X2(MxGSiz), X3(MxGSiz), X4(MxGSiz),
$   Y1(MxGSiz), Y2(MxGSiz), Y3(MxGSiz), Y4(MxGSiz),
$   Z1(MxGSiz), Z2(MxGSiz), Z3(MxGSiz), Z4(MxGSiz)
REAL PX1PBB(MxGSiz), PX2PBB(MxGSiz),
$   PY1PBB(MxGSiz), PY2PBB(MxGSiz),
$   PZ1PBB(MxGSiz), PZ2PBB(MxGSiz),
$   PX1PAA(MxGSiz), PX2PAA(MxGSiz),
$   PY1PAA(MxGSiz), PY2PAA(MxGSiz),
$   PZ1PAA(MxGSiz), PZ2PAA(MxGSiz),
$   PX3PBB(MxGSiz), PX4PBB(MxGSiz),
$   PY3PBB(MxGSiz), PY4PBB(MxGSiz),
$   PZ3PBB(MxGSiz), PZ4PBB(MxGSiz),
$   PX3PAA(MxGSiz), PX4PAA(MxGSiz),
$   PY3PAA(MxGSiz), PY4PAA(MxGSiz),
$   PZ3PAA(MxGSiz), PZ4PAA(MxGSiz),
$   XS(MxSrfs,MxGSiz,MxGSiz),
$   YS(MxSrfs,MxGSiz,MxGSiz),
$   ZS(MxSrfs,MxGSiz,MxGSiz)

```

C Calculate the h factors for the boundary 3-4 Hermite adjusting
C curves.

```

AA=0.0

DO 10 ACt=1,AL
  CALL FAlNew(AANew,AA,BetaAA,StrAA)
  CALL FindHs(h5(ACt),h6(ACt),h7(ACt),h8(ACt),AANew)
  AA=AA+AAStep
10 CONTINUE

```

C Calculate the derivative values for grid line orthogonality.

```

BB=0.0

DO 20 BCt=1,BL
  CALL FAlNew(BBNew,BB,BetaBB,StrBB)
  Box3i= BB*( PY2PAA(1)*PZ3PBB(BL)
$         -PZ2PAA(1)*PY3PBB(BL))
$   +(1-BB)*( PY1PAA(1)*PZ3PBB(1)
$         -PZ1PAA(1)*PY3PBB(1))
  Box3j= BB*( PX2PAA(1)*PZ3PBB(BL)
$         -PZ2PAA(1)*PX3PBB(BL))
$   +(1-BB)*( PX1PAA(1)*PZ3PBB(1)
$         -PZ1PAA(1)*PX3PBB(1))
  Box3k= BB*( PX2PAA(1)*PY3PBB(BL)
$         -PY2PAA(1)*PX3PBB(BL))
$   +(1-BB)*( PX1PAA(1)*PY3PBB(1)
$         -PY1PAA(1)*PX3PBB(1))
  Box4i= BB*( PY2PAA(1)*PZ4PBB(BL)
$         -PZ2PAA(1)*PY4PBB(BL))
$   +(1-BB)*( PY1PAA(1)*PZ4PBB(1)
$         -PZ1PAA(1)*PY4PBB(1))
  Box4j= BB*( PX2PAA(1)*PZ4PBB(BL)
$         -PZ2PAA(1)*PX4PBB(BL))
$   +(1-BB)*( PX1PAA(1)*PZ4PBB(1)
$         -PZ1PAA(1)*PX4PBB(1))
  Box4k= BB*( PX2PAA(1)*PY4PBB(BL)
$         -PY2PAA(1)*PX4PBB(BL))
$   +(1-BB)*( PX1PAA(1)*PY4PBB(1)
$         -PY1PAA(1)*PX4PBB(1))
  Paren3i=PZ3PBB(BCt)*Box3j+PY3PBB(BCt)*Box3k
  Paren3j=PZ3PBB(BCt)*Box3i-PX3PBB(BCt)*Box3k
  Paren3k=PY3PBB(BCt)*Box3i+PX3PBB(BCt)*Box3j
  Paren4i=PZ4PBB(BCt)*Box4j+PY4PBB(BCt)*Box4k
  Paren4j=PZ4PBB(BCt)*Box4i-PX4PBB(BCt)*Box4k
  Paren4k=PY4PBB(BCt)*Box4i+PX4PBB(BCt)*Box4j
  PX3PAA(BCt)= k3*Paren3i
  PX4PAA(BCt)= k4*Paren4i
  PY3PAA(BCt)= k3*Paren3j
  PY4PAA(BCt)= k4*Paren4j
  PZ3PAA(BCt)=-k3*Paren3k
  PZ4PAA(BCt)=-k4*Paren4k

  BB=BB+BBStep

```

20 CONTINUE

C Set the cross-derivative terms equal to zero.

```

P2X00=0.0
P2X10=0.0
P2X01=0.0
P2X11=0.0
P2Y00=0.0
P2Y10=0.0
P2Y01=0.0
P2Y11=0.0
P2Z00=0.0
P2Z10=0.0
P2Z01=0.0
P2Z11=0.0

```

C Calculate the grid point locations everywhere.

```

DO 40 i=1,AL
  DO 30 j=1,BL
    XS(SrfNum,i,j)=XS(SrfNum,i,j)
    $      +(X3(j)-h1(j)*X1(1)
    $      -h2(j)*X2(1)
    $      -h3(j)*PX1PBB(1)
    $      -h4(j)*PX2PBB(1))*h5(i)
    $      +(X4(j)-h1(j)*X1(AL)
    $      -h2(j)*X2(AL)
    $      -h3(j)*PX1PBB(AL)
    $      -h4(j)*PX2PBB(AL))*h6(i)
    $      +(PX3PAA(j)-( h1(j)*PX3PAA(1)
    $      +h2(j)*PX3PAA(BL)
    $      +h3(j)*P2X00+h4(j)*P2X01))*h7(i)
    $      +(PX4PAA(j)-( h1(j)*PX4PAA(1)
    $      +h2(j)*PX4PAA(BL)
    $      +h3(j)*P2X10+h4(j)*P2X11))*h8(i)
    YS(SrfNum,i,j)=YS(SrfNum,i,j)
    $      +(Y3(j)-h1(j)*Y1(1)
    $      -h2(j)*Y2(1)
    $      -h3(j)*PY1PBB(1)
    $      -h4(j)*PY2PBB(1))*h5(i)
    $      +(Y4(j)-h1(j)*Y1(AL)
    $      -h2(j)*Y2(AL)
    $      -h3(j)*PY1PBB(AL)
    $      -h4(j)*PY2PBB(AL))*h6(i)
    $      +(PY3PAA(j)-( h1(j)*PY3PAA(1)
    $      +h2(j)*PY3PAA(BL)
    $      +h3(j)*P2Y00+h4(j)*P2Y01))*h7(i)
    $      +(PY4PAA(j)-( h1(j)*PY4PAA(1)
    $      +h2(j)*PY4PAA(BL)
    $      +h3(j)*P2Y10+h4(j)*P2Y11))*h8(i)

    ZS(SrfNum,i,j)=ZS(SrfNum,i,j)
    $      +(Z3(j)-h1(j)*Z1(1)
    $      -h2(j)*Z2(1)

```

```

$          -h3(j)*PZ1PBB(1)
$          -h4(j)*PZ2PBB(1))*h5(i)
$      +(Z4(j)-h1(j))*Z1(AL)
$          -h2(j)*Z2(AL)
$          -h3(j)*PZ1PBB(AL)
$          -h4(j)*PZ2PBB(AL))*h6(i)
$      +(PZ3PAA(j)-( h1(j)*PZ3PAA(1)
$          +h2(j)*PZ3PAA(BL)
$          +h3(j)*P2Z00+h4(j)*P2Z01))*h7(i)
$      +(PZ4PAA(j)-( h1(j)*PZ4PAA(1)
$          +h2(j)*PZ4PAA(BL)
$          +h3(j)*P2Z10+h4(j)*P2Z11))*h8(i)
30  CONTINUE
40  CONTINUE

```

```

RETURN
END

```

C=====C

TABLE 2-1. - GUIDE TO GRID CONTROL PARAMETERS LISTED IN
 FIGURES 2-1, 2-2, AND 2-6.

PARAMETER	RANGE	TRIAL VALUE	DESCRIPTION
StretchTypeXi StretchTypeEta StretchTypeZeta	0 - No clustering 1 - Clustering near lower surface 2 - Clustering near upper surface 3 - Clustering near both surfaces	n/a	Controls type of clustering in the Xi, Eta, and Zeta "directions"
kXi1 kXi2 kEta1 kEta2 kZeta1 kZeta2	$0.0 \leq k \leq \infty$ less curvature more curvature curvature	0.2	Controls curvature of the grid lines in the Xi, Eta, and Zeta "directions"
BetaXi BetaEta BetaZeta	$1.0 < \text{Beta} < \infty$ more clustering less clustering clustering	1.1	Controls amount of clustering in the Xi, Eta, and Zeta "directions"
Tension	$0.0 < \text{Tension} < \infty$ more curvature less curvature curvature	1.0	Controls curvature of the boundary spline curves
Method	2 - Two-Boundary Method 4 - Four-Boundary Method	n/a	Controls which method is used to form the grid

n - Number of Grids
Information for Grid 1
Information for Grid 2
Information for Grid 3

.
.
.

Information for Grid n

FIGURE 2-1. - DIAGRAM SHOWING OVERALL LAYOUT OF 2-D GRID INPUT FILE FOR GRID2D/3D.

t - Method for Grid n
Tension for Boundary Curve 1
Number of Discrete Points for Boundary Curve 1

List of discrete points for Boundary Curve 1.
List is made up of xy pairs, each pair on its own line.

Tension for Boundary Curve 2
Number of Discrete Points for Boundary Curve 2

List of discrete points for Boundary Curve 2.
List is made up of xy pairs, each pair on its own line.

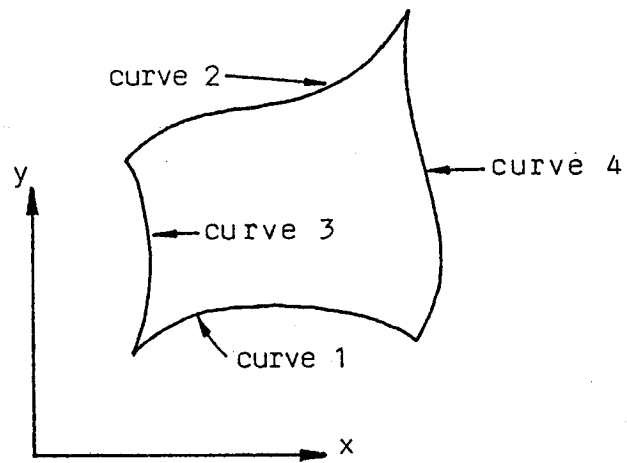
.
.
.

Tension for Boundary Curve t
Number of Discrete Points for Boundary Curve t

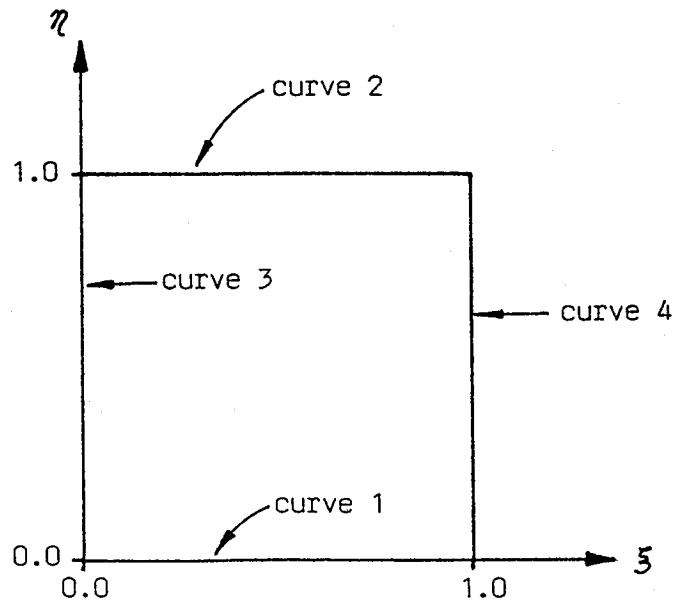
List of discrete points for Boundary Curve t.
List is made up of xy pairs, each pair on its own line.

IL - Number of Xi grid points for grid n
JL - Number of Eta grid points for grid n
StretchTypeXi
StretchTypeEta
KXi1
KXi2
KEta1 (necessary only if t=4)
KEta2 (necessary only if t=4)
BetaXi
BetaEta

FIGURE 2-2.- DIAGRAM SHOWING DETAILS OF SECTION MARKED "INFORMATION FOR GRID n" IN FIGURE 2-1.



(a)



(b)

(a) IN x - y COORDINATE SYSTEM.

(b) IN ξ - η COORDINATE SYSTEM (TRANSFORMED DOMAIN).

FIGURE 2-3. - SPATIAL DOMAIN.

```

2      Number of grids
2      Method for grid 1 =====
2.0    Tension for curve 1 of grid 1 -----
3      Number of nodal points for curve 1 of grid 1
0.0    0.0
5.0    0.5
10.0   0.0
2.0    Tension for curve 2 of grid 1 -----
4      Number of nodal points for curve 2 of grid 1
0.0    2.0
3.0    2.0
6.0    1.5
10.0   1.75
21     Number of Xi grid points for grid 1
7      Number of Eta grid points for grid 1
0      StretchTypeXi for grid 1
3      StretchTypeEta for grid 1
0.4    kXi1 for grid 1
0.4    kXi2 for grid 1
1.05   Beta.Xi for grid 1
1.05   Beta.Eta for grid 1
2      Method for grid 2 =====
2.0    Tension for curve 2 of grid 2 -----
3      Number of nodal points for curve 1 of grid 2
0.0    2.0
5.0    2.5
10.0   3.0
2.0    Tension for curve 2 of grid 2 -----
2      Number of nodal points for curve 2 of grid 2
0.0    5.0
10.0   5.0
21     Number of Xi grid points for grid 2
7      Number of Eta grid points for grid 2
0      StretchTypeXi for grid 2
3      StretchTypeEta for grid 2
0.4    kXi1 for grid 2
0.4    kXi2 for grid 2
1.05   Beta.Xi for grid 2
1.05   Beta.Eta for grid 2

```

FIGURE 2-4. - SAMPLE 2-D GRID INPUT FILE FOR GRID2D/3D.

```

1      Number of grids
2      Method for grid 1 =====
2.0    Tension for curve 1 of grid 1 -----
2      Number of nodal points for curve 1 of grid 1
1.0    0.0
9.0    0.0
10.0   0.0
2.0    Tension for curve 2 of grid 1 -----
6      Number of nodal points for curve 2 of grid 1
1.0    7.0
2.0    7.0
4.0    8.0
6.0    8.0
8.0    7.0
9.0    7.0
2.0    Tension for curve 3 of grid 1 -----
6      Number of nodal points for curve 3 of grid 1
1.0    0.0
1.0    1.0
0.3    3.0
0.3    4.0
1.0    6.0
1.0    7.0
2.0    Tension for curve 4 of grid 1 -----
6      Number of nodal points for curve 4 of grid 1
9.0    0.0
9.0    1.0
9.7    3.0
9.7    4.0
9.0    6.0
9.0    7.0
21     Number of Xi grid points for grid 1
21     Number of Eta grid points for grid 1
0      StretchTypeXi for grid 1
0      StretchTypeEta for grid 1
0.4    kXi1 for grid 1
0.4    kXi2 for grid 1
0.4    kEta1 for grid 1
0.4    kEta2 for grid 1
1.05   BetaXi for grid 1
1.05   BetaEta for grid 1

```

FIGURE 2-5. - SECOND SAMPLE 2-D GRID INPUT FILE FOR GRID2D/3D.

t - Method
IL - Number of Xi grid points
JL - Number of Eta grid points
KL - Number of Zeta grid points
StretchTypeXi
StretchTypeEta
StretchTypeZeta
KXi1
KXi2
KEta1
KEta2
KZeta1
KZeta2
BetaXi
BetaEta
BetaZeta
Tension for Boundary Curve 1
Number of Discrete Points for Boundary Curve 1

List of discrete points for Boundary Curve 1.
List is made up of xyz triples, each triple on its own line.

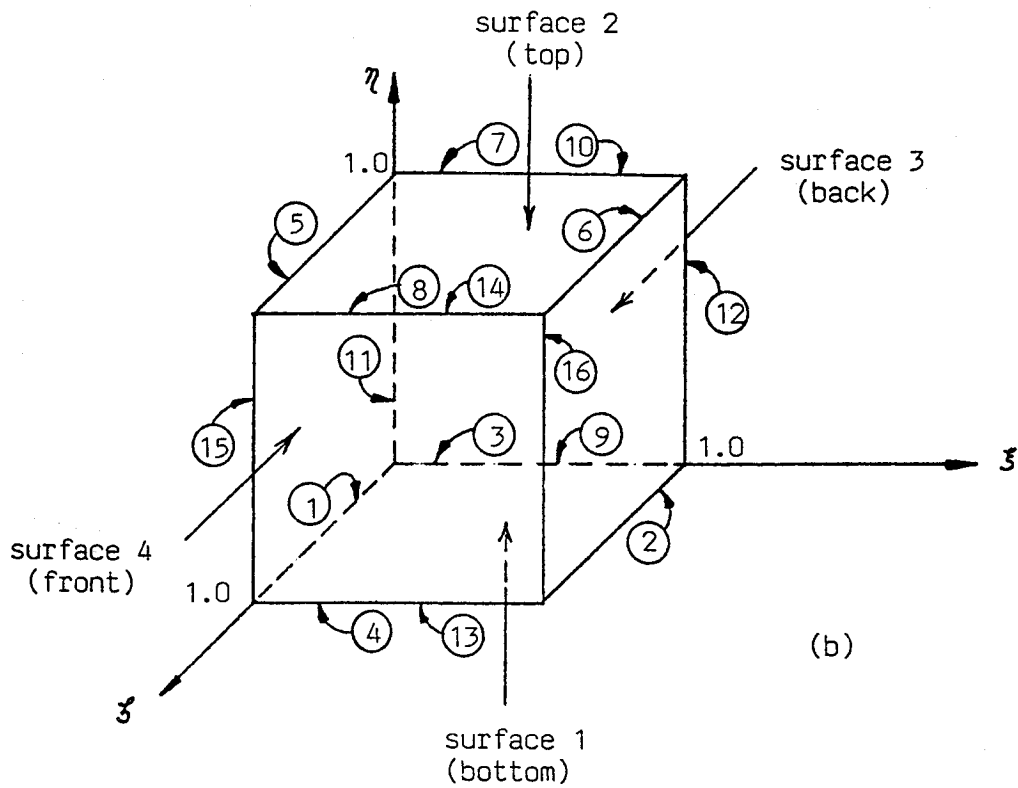
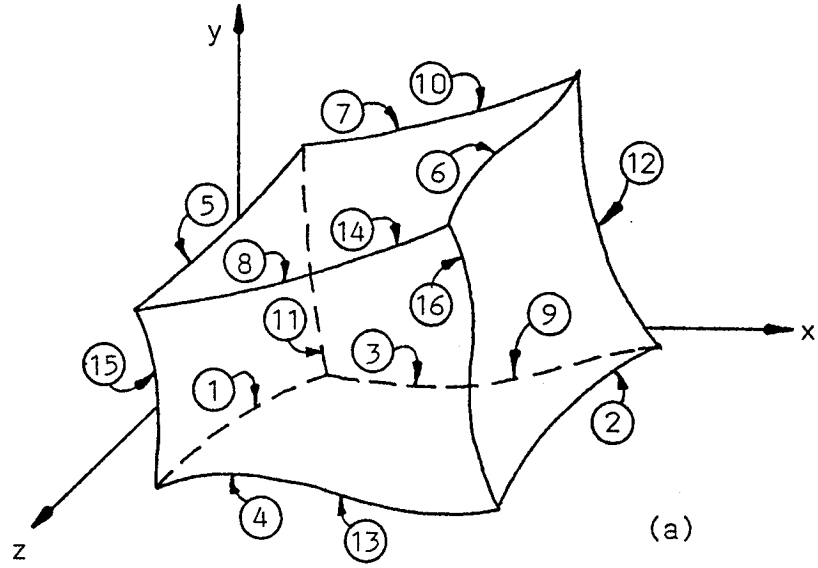
Tension for Boundary Curve 2
Number of Discrete Points for Boundary Curve 2

List of discrete points for Boundary Curve 2.
List is made up of xyz triples, each triple on its own line.

Tension for Boundary Curve 4t
Number of Discrete Points for Boundary Curve 4t

List of discrete points for Boundary Curve 4t.
List is made up of xyz triples, each triple on its own line.

FIGURE 2-6. - DIAGRAM SHOWING LAYOUT OF 3-D GRID INPUT FILE FOR GRID2D/3D.



(a) IN x - y - z COORDINATE SYSTEM.

(b) IN ξ - η - ζ COORDINATE SYSTEM (TRANSFORMED DOMAIN).

FIGURE 2-7. - SPATIAL DOMAIN.

```

2          Method =====
21         Number of Xi grid points
21         Number of Eta grid points
21         Number of Zeta grid points
0          StretchTypeXi
0          StretchTypeEta
0          StretchTypeZeta
0.4        kXi1
0.4        kXi2
0.4        kEta1
0.4        kEta2
0.4        kZeta1
0.4        kZeta2
1.05       BetaXi
1.05       BetaEta
1.05       BetaZeta
2.0        Tension for curve 1 -----
2          Number of nodal points for curve 1
0.0  0.0   0.0
6.0  0.0   0.0
2.0        Tension for curve 2 -----
2          Number of nodal points for curve 2
0.0  0.0   10.0
6.0  0.0   10.0
2.0        Tension for curve 3 -----
2          Number of nodal points for curve 3
0.0  0.0   0.0
0.0  0.0   10.0
2.0        Tension for curve 4 -----
2          Number of nodal points for curve 4
6.0  0.0   0.0
6.0  0.0   10.0
2.0        Tension for curve 5 -----
2          Number of nodal points for curve 5
0.0  6.0   0.0
6.0  6.0   0.0
2.0        Tension for curve 6 -----
2          Number of nodal points for curve 6
0.0  6.0   10.0
6.0  6.0   10.0
2.0        Tension for curve 7 -----
2          Number of nodal points for curve 7
0.0  6.0   0.0
0.0  6.0   10.0
2.0        Tension for curve 8 -----
2          Number of nodal points for curve 8
6.0  6.0   0.0
6.0  6.0   10.0

```

FIGURE 2-8. - SAMPLE 3-D GRID INPUT FILE FOR GRID2D/3D.

```

2          Number of Grids
2          Technique for Grid 1 =====
2.0        Tension for Curve 1 of Grid 1 -----
7          Number of Nodal Points for Curve 1 of Grid 1
0.0        0.0
0.5        0.0
3.0        0.5
5.0        0.5
8.0        0.0
9.0        0.0
10.0       0.0
2.0        Tension for Curve 2 of Grid 1 -----
8          Number of Nodal Points for Curve 2 of Grid 1
0.0        2.0
2.0        2.0
3.0        2.0
4.0        1.9
6.0        1.5
8.0        1.75
9.0        1.75
10.0       1.75
21         Number of Xi Grid Points for Grid 1 -----
11         Number of Eta Grid Points for Grid 1
0          Xi Direction Stretching Type for Grid 1
3          Eta Direction Stretching Type for Grid 1
0.2        kXi1 for Grid 1
0.2        kXi2 for Grid 1
1.005     Stretching Parameter BetaXi for Grid 1
1.005     Stretching Parameter BetaEta for Grid 1
2          Technique for Grid 2 =====
2.0        Tension for Curve 1 of Grid 2 -----
7          Number of Nodal Points for Curve 1 of Grid 2
0.0        2.0
2.0        2.0
3.0        2.0
5.0        2.5
8.0        3.0
9.0        3.0
10.0       3.0
2.0        Tension for Curve 2 of Grid 2 -----
2          Number of Nodal Points for Curve 2 of Grid 2
0.0        5.0
10.0       5.0
21         Number of Xi Grid Points for Grid 2 -----
11         Number of Eta Grid Points for Grid 2
0          Xi Direction Stretching Type for Grid 2
1          Eta Direction Stretching Type for Grid 2
0.4        kXi1 for Grid 2
0.4        kXi2 for Grid 2
1.01      Stretching Parameter BetaXi for Grid 2
1.01      Stretching Parameter BetaEta for Grid 2

```

FIGURE 4-1. - LISTINGS OF 2-D GRID INPUT FILE INLET.DAT.

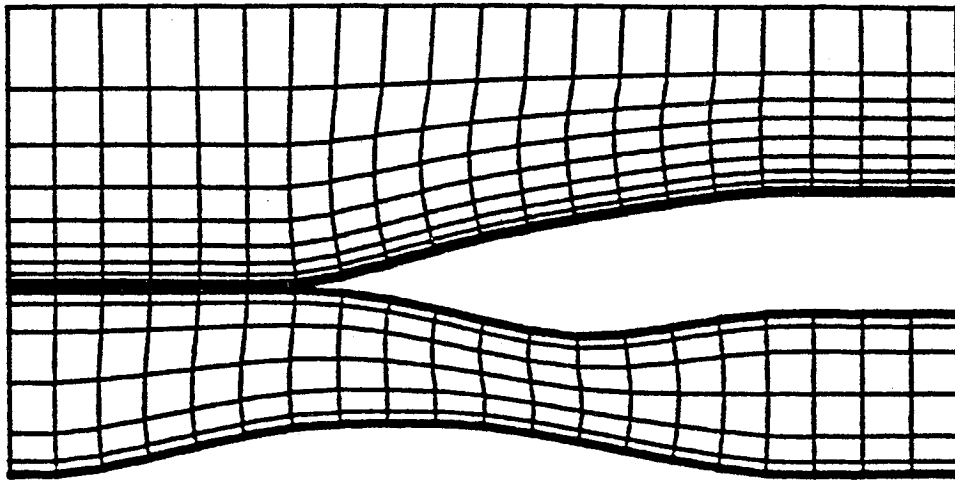


FIGURE 4.2. - GRID GENERATED BY GRID2D/3D USING INPUT FILE INLET.DAT (FIG. 4-1).


```

4      Technique
9      IL
21     JL
21     KL
3      StretchTypeXi
3      StretchTypeEta
0      StretchTypeZeta
2.0    kXi1
2.0    kXi2
2.0    kEta1
2.0    kEta2
2.0    kZeta1
2.0    kZeta2
1.01   BetaXi
1.01   BetaEta
1.05   BetaZeta
1.0    Tension 1 -----
2      Number of Points 1
-0.095 0.32183 0.0
0.0    0.32183 0.0
1.0    Tension 2 -----
2      Number of Points 2
-0.095 0.375 0.0
0.0    0.375 0.0
1.0    Tension 3 -----
2      Number of Points 3
-0.095 0.32183 0.0
-0.095 0.375 0.0
1.0    Tension 4 -----
2      Number of Points 4
0.0    0.32183 0.0
0.0    0.375 0.0
1.0    Tension 5 -----
2      Number of Points 5
-0.095 0.31247 0.07704
0.0    0.31247 0.07704
1.0    Tension 6 -----
2      Number of Points 6
-0.095 0.36410 0.08977
0.0    0.36410 0.08977
1.0    Tension 7 -----
2      Number of Points 7
-0.095 0.31247 0.07704
-0.095 0.36410 0.08977
1.0    Tension 8 -----
2      Number of Points 8
0.0    0.31247 0.07704
0.0    0.36410 0.08977

```

FIGURE 4-3. - LISTING OF 3-D GRID INPUT FILE ZONE1.DAT.

1.0	Tension 9 -----		
2	Number of Points 9		
-0.095	0.32183	0.0	
-0.095	0.375	0.0	
1.0	Tension 10 -----		
2	Number of Points 10		
-0.095	0.31247	0.07704	
-0.095	0.36410	0.08977	
1.0	Tension 11 -----		
4	Number of Points 11		
-0.095	0.32183	0.0	
-0.095	0.32104	0.02253	
-0.095	0.31751	0.05257	
-0.095	0.31247	0.07704	
1.0	Tension 12 -----		
4	Number of Points 12		
-0.095	0.375	0.0	
-0.095	0.37408	0.02625	
-0.095	0.36996	0.06125	
-0.095	0.36410	0.08977	
1.0	Tension 13 -----		
2	Number of Points 13		
0.0	0.32183	0.0	
0.0	0.375	0.0	
1.0	Tension 14 -----		
2	Number of Points 14		
0.0	0.31247	0.07704	
0.0	0.36410	0.08977	
2.0	Tension 15 -----		
6	Number of Points 15		
0.0	0.32183	0.0	
-0.00437	0.32174	0.00751	
-0.00787	0.32104	0.02253	
-0.00787	0.31751	0.05257	
-0.00437	0.31465	0.06758	
0.0	0.31247	0.07704	
2.0	Tension 16 -----		
6	Number of Points 16		
0.0	0.375	0.0	
-0.00437	0.37490	0.00875	
-0.00787	0.37409	0.02625	
-0.00787	0.36996	0.06125	
-0.00437	0.36664	0.07875	
0.0	0.36410	0.08977	

FIGURE 4-3. - CONCLUDED.

```

4      Technique
9      IL
21     JL
21     KL
3      StretchTypeXi
3      StretchTypeEta
0      StretchTypeZeta
2.0    kXi1
2.0    kXi2
2.0    kEta1
2.0    kEta2
2.0    kZeta1
2.0    kZeta2
1.01   BetaXi
1.01   BetaEta
1.05   BetaZeta
2.0    Tension 1 -----
12     Number of Points 1
0.00000  0.32183  0.00000
0.00474  0.32177  0.00637
0.00945  0.32167  0.01025
0.01416  0.32149  0.01472
0.01886  0.32122  0.01986
0.02357  0.32079  0.02582
0.02828  0.32016  0.03270
0.03299  0.31926  0.04062
0.03770  0.31800  0.04948
0.04241  0.31638  0.05899
0.04712  0.31438  0.06884
0.05297  0.31292  0.07521
2.0    Tension 2 -----
12     Number of Points 2
0.00000  0.37500  0.00000
0.00474  0.37493  0.00742
0.00945  0.37481  0.01194
0.01416  0.37461  0.01715
0.01886  0.37429  0.02314
0.02357  0.37379  0.03008
0.02828  0.37306  0.03810
0.03299  0.37200  0.04733
0.03770  0.37054  0.05765
0.04241  0.36865  0.06873
0.04712  0.36632  0.08021
0.05297  0.36462  0.08763

```

FIGURE 4-4. - LISTING OF 3-D GRID INPUT FILE ZONE2.DAT.

1.0	Tension 3 -----		
2	Number of Points 3		
	0.00000	0.32183	0.00000
	0.00000	0.37500	0.00000
1.0	Tension 4 -----		
2	Number of Points 4		
	0.05297	0.31292	0.07521
	0.05297	0.36462	0.08763
2.0	Tension 5 -----		
6	Number of Points 5		
	0.00000	0.31247	0.07704
	0.01063	0.31392	0.07091
	0.01533	0.31367	0.07200
	0.02004	0.31310	0.07447
	0.02475	0.31204	0.07879
	0.02946	0.31032	0.08531
2.0	Tension 6 -----		
6	Number of Points 6		
	0.00000	0.36410	0.08977
	0.01063	0.36578	0.08263
	0.01533	0.36550	0.08389
	0.02004	0.36482	0.08677
	0.02475	0.36359	0.09181
	0.02946	0.36158	0.09941
1.0	Tension 7 -----		
2	Number of Points 7		
	0.00000	0.31247	0.07704
	0.00000	0.36410	0.08977
1.0	Tension 8 -----		
2	Number of Points 8		
	0.02946	0.31032	0.08531
	0.02946	0.36158	0.09941
1.0	Tension 9 -----		
2	Number of Points 9		
	0.00000	0.32183	0.00000
	0.00000	0.37500	0.00000
1.0	Tension 10 -----		
2	Number of Points 10		
	0.00000	0.31247	0.07704
	0.00000	0.36410	0.08977
2.0	Tension 11 -----		
6	Number of Points 11		
	0.0	0.32183	0.0
	-0.00437	0.32174	0.00751
	-0.00787	0.32104	0.02253
	-0.00787	0.31751	0.05257
	-0.00437	0.31465	0.06758
	0.0	0.31247	0.07704

FIGURE 4-4. - CONTINUED.

2.0	Tension 12 -----	
6	Number of Points 12	
0.0	0.375	0.0
-0.00437	0.37490	0.00875
-0.00787	0.37409	0.02625
-0.00787	0.36996	0.06125
-0.00437	0.36664	0.07875
0.0	0.36410	0.08977
1.0	Tension 13 -----	
2	Number of Points 13	
0.05297	0.31292	0.07521
0.05297	0.36462	0.08763
1.0	Tension 14 -----	
2	Number of Points 14	
0.02946	0.31032	0.08531
0.02946	0.36158	0.09941
2.0	Tension 15 -----	
4	Number of Points 15	
0.05297	0.31292	0.07521
0.04513	0.31209	0.07858
0.03730	0.31122	0.08194
0.02946	0.31032	0.08531
2.0	Tension 16 -----	
4	Number of Points 16	
0.05297	0.36462	0.08763
0.04513	0.36365	0.09156
0.03730	0.36264	0.09548
0.02946	0.36158	0.09941

FIGURE 4-4. - CONCLUDED.

```

4      Technique
9      IL
21     JL
21     KL
3      StretchTypeXi
3      StretchTypeEta
0      StretchTypeZeta
2.0    kXi1
2.0    kXi2
2.0    kEta1
2.0    kEta2
2.0    kZeta1
2.0    kZeta2
1.01   BetaXi
1.01   BetaEta
1.05   BetaZeta
2.0    Tension 1 -----
4      Number of Points 1
0.05297  0.31292  0.07521
0.06125  0.30710  0.09624
0.07875  0.30133  0.11302
0.0875   0.30058  0.115
2.0    Tension 2 -----
4      Number of Points 2
0.05297  0.36462  0.08763
0.06125  0.35784  0.11214
0.07875  0.35112  0.13169
0.0875   0.35024  0.134
1.0    Tension 3 -----
2      Number of Points 3
0.05297  0.31292  0.07521
0.05297  0.36462  0.08763
1.0    Tension 4 -----
2      Number of Points 4
0.0875   0.30058  0.115
0.0875   0.35024  0.134
2.0    Tension 5 -----
6      Number of Points 5
0.02946  0.31032  0.08531
0.03417  0.30768  0.09437
0.03888  0.30398  0.10568
0.04359  0.29913  0.11873
0.04830  0.29306  0.13301
0.05297  0.28582  0.14792
2.0    Tension 6 -----
6      Number of Points 6
0.02946  0.36158  0.09941
0.03417  0.35852  0.10996
0.03888  0.35421  0.12314
0.04359  0.34855  0.13834
0.04830  0.34147  0.15499
0.05297  0.33304  0.17236

```

FIGURE 4-5. - LISTING OF 3-D GRID INPUT FILE ZONE3.DAT.

1.0	Tension 7 -----
2	Number of Points 7
0.02946	0.31032 0.08531
0.02946	0.36158 0.09941
1.0	Tension 8 -----
2	Number of Points 8
0.05297	0.28582 0.14792
0.05297	0.33304 0.17236
1.0	Tension 9 -----
2	Number of Points 9
0.05297	0.31292 0.07521
0.05297	0.36462 0.08763
1.0	Tension 10 -----
2	Number of Points 10
0.02946	0.31032 0.08531
0.02946	0.36158 0.09941
2.0	Tension 11 -----
4	Number of Points 11
0.05297	0.31292 0.07521
0.04513	0.31209 0.07858
0.03730	0.31122 0.08194
0.02946	0.31032 0.08531
2.0	Tension 12 -----
4	Number of Points 12
0.05297	0.36462 0.08763
0.04513	0.36365 0.09156
0.03730	0.36264 0.09548
0.02946	0.36158 0.09941
1.0	Tension 13 -----
2	Number of Points 13
0.0875	0.30058 0.115
0.0875	0.35024 0.134
1.0	Tension 14 -----
2	Number of Points 14
0.05297	0.28582 0.14792
0.05297	0.33304 0.17236
2.0	Tension 15 -----
5	Number of Points 15
0.0875	0.30058 0.115
0.08531	0.29856 0.12015
0.07875	0.29207 0.13517
0.07	0.28847 0.14268
0.05297	0.28582 0.14792
2.0	Tension 16 -----
5	Number of Points 16
0.0875	0.35024 0.134
0.08531	0.34789 0.14
0.07875	0.34032 0.1575
0.07	0.33613 0.16625
0.05297	0.33304 0.17236

FIGURE 4-5. - CONCLUDED.

```

4      Technique
9      IL
21     JL
21     KL
3      StretchTypeXi
3      StretchTypeEta
0      StretchTypeZeta
2.0    kXi1
2.0    kXi2
2.0    kEta1
2.0    kEta2
2.0    kZeta1
2.0    kZeta2
1.01   BetaXi
1.01   BetaEta
1.05   BetaZeta
2.0    Tension 1 -----
3      Number of Points 1
0.0875 0.30058 0.115
0.105  0.30058 0.115
0.1225 0.30058 0.115
2.0    Tension 2 -----
3      Number of Points 2
0.0875 0.35024 0.134
0.105  0.35024 0.134
0.1225 0.35024 0.134
1.0    Tension 3 -----
2      Number of Points 3
0.0875 0.30058 0.115
0.0875 0.35024 0.134
1.0    Tension 4 -----
2      Number of Points 4
0.1225 0.30058 0.115
0.1225 0.35024 0.134
2.0    Tension 5 -----
6      Number of Points 5
0.05297 0.28582 0.14792
0.06125 0.27391 0.16897
0.07875 0.26247 0.18623
0.0875  0.26140 0.18773
0.105   0.26140 0.18773
0.1225  0.26140 0.18773
2.0    Tension 6 -----
6      Number of Points 6
0.05297 0.33304 0.17236
0.06125 0.31916 0.19688
0.07875 0.30584 0.217
0.0875  0.30459 0.21875
0.105   0.30459 0.21875
0.1225  0.30459 0.21875

```

FIGURE 4-6. - LISTING OF 3-D GRID INPUT FILE ZONE4.DAT.

1.0	Tension 7 -----		
2	Number of Points 7		
0.05297	0.28582	0.14792	
0.05297	0.33304	0.17236	
1.0	Tension 8 -----		
2	Number of Points 8		
0.1225	0.26140	0.18773	
0.1225	0.30459	0.21875	
1.0	Tension 9 -----		
2	Number of Points 9		
0.0875	0.30058	0.115	
0.0875	0.35024	0.134	
1.0	Tension 10 -----		
2	Number of Points 10		
0.05297	0.28582	0.14792	
0.05297	0.33304	0.17236	
2.0	Tension 11 -----		
5	Number of Points 11		
0.0875	0.30058	0.115	
0.08531	0.29856	0.12015	
0.07875	0.29207	0.13517	
0.07	0.28847	0.14268	
0.05297	0.28582	0.14792	
2.0	Tension 12 -----		
5	Number of Points 12		
0.0875	0.35024	0.134	
0.08531	0.34789	0.14	
0.07875	0.34032	0.1575	
0.07	0.33613	0.16625	
0.05297	0.33304	0.17236	
1.0	Tension 13 -----		
2	Number of Points 13		
0.1225	0.30058	0.115	
0.1225	0.35024	0.134	
1.0	Tension 14 -----		
2	Number of Points 14		
0.1225	0.26140	0.18773	
0.1225	0.30459	0.21875	
1.0	Tension 15 -----		
4	Number of Points 15		
0.1225	0.30058	0.115	
0.1225	0.29207	0.13517	
0.1225	0.27619	0.16521	
0.1225	0.26140	0.18773	
1.0	Tension 16 -----		
4	Number of Points 16		
0.1225	0.35024	0.134	
0.1225	0.34032	0.1575	
0.1225	0.32182	0.1925	
0.1225	0.30459	0.21875	

FIGURE 4-6. - CONCLUDED.

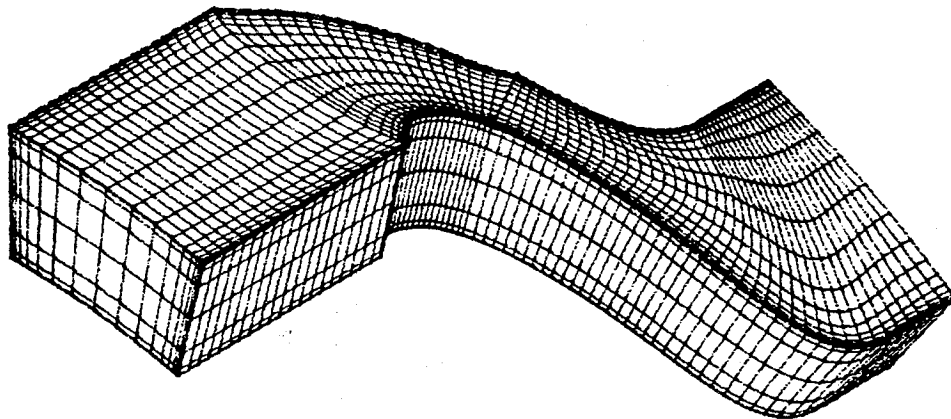


FIGURE 4-7. - GRID GENERATED BY GRID2D/3D USING 3-D GRID INPUT FILE STATOR.DAT (A COMBINATION OF FILES ZONE1.DAT, ZONE2.DAT, ZONE3.DAT, AND ZONE4.DAT).

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16. Abstract An efficient computer program, called GRID2D/3D, has been developed to generate single and composite grid systems within geometrically complex two- and three-dimensional (2- and 3-D) spatial domains that can deform with time. GRID2D/3D generates single grid systems by using algebraic grid generation methods based on transfinite interpolation in which the distribution of grid points within the spatial domain is controlled by stretching functions. All single grid systems generated by GRID2D/3D can have grid lines that are continuous and differentiable everywhere up to the second-order. Also, grid lines can intersect boundaries of the spatial domain orthogonally. GRID2D/3D generates composite grid systems by patching together two or more single grid systems. The patching can be discontinuous or continuous. For continuous composite grid systems, the grid lines are continuous and differentiable everywhere up to the second-order except at interfaces where different single grid systems meet. At interfaces where different single grid systems meet, the grid lines are only differentiable up to the first-order. For 2-D spatial domains, the boundary curves are described by using either cubic or tension spline interpolation. For 3-D spatial domains, the boundary surfaces are described by using either linear Coon's interpolation, bi-hyperbolic spline interpolation, or a new technique referred to as 3-D bi-directional Hermite interpolation. Since grid systems generated by algebraic methods can have grid lines that overlap one another, GRID2D/3D contains a graphics package for evaluating the grid systems generated. With the graphics package, the user can generate grid systems in an interactive manner with the grid generation part of GRID2D/3D. GRID2D/3D is written in FORTRAN 77 and can be run on any IBM PC, XT, or AT compatible computer. In order to use GRID2D/3D on workstations or mainframe computers, some minor modifications must be made in the graphics part of the program; no modifications are needed in the grid generation part of the program. This technical memorandum describes the theory and method used in GRID2D/3D. Part 1 of this technical memorandum, under a separate cover, contains the computer program, GRID2D/3D, and a user's manual.					
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