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Input Generator for Denton Three-Dimensional Turbomachine-Blade-Row Analysis Code

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ABS:   A users manual is presented for a computer program that prepares the bulk
       of the input data set required for the Denton three dimensional
       turbomachine blade row analysis code. The Denton input is generated from a
       minimum of geometry and flow variable information by using cubic spline
       curve fitting procedures. The features of the program are discussed. The
       input is described and special instructions are included to assist in its
       preparation. Sample input and output are included.


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INPUT GENERATOR FOR DENTON THREE-DIMENSIONAL TURBOMACHINE-BLADE-ROW ANALYSIS CODE

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SUMMARY

This report is a users manual for a computer program (MERNEW3D) that prepares the bulk of the input dataset required for the Denton three-dimensional turbomachine-blade-row analysis code. The Denton input is generated from a minimum of geometry and flow variable information by using cubic spline curve fits for interpolation and extrapolation. The curve-fitting procedures are taken from the widely used MERIDL code, which performs a meridional stream surface analysis. The MERNEW3D program reads a MERIDL input dataset to provide most of the needed input information. A small additional dataset is required to complete the input.

The output produced by MERNEW3D contains geometry input, flow variable input, and control input as required by the Denton code. All of the geometry input, which is the bulk of the dataset, and some of the flow variable and control input are ready to use as is. Only a small amount of editing is required to complete the Denton input dataset.

In this report the features of the MERNEW3D program are discussed. The input is described in detail and special instructions are given to assist in its preparation. Sample input and output are included.

INTRODUCTION

The three-dimensional turbomachine-blade-row analysis code developed by Denton (refs. 1 and 2) has either been acquired or is being considered for acquisition by many U.S. manufacturers of aircraft gas-turbine engines. This code provides a time-marching solution of the Euler equations by using a finite-volume scheme. Axial-, radial-, and mixed-flow geometries, either stationary or rotating, can be analyzed.

For any flow analysis code the most burdensome part of preparing the input is describing the geometry of the flow passage. The Denton code requires the axial coordinate, the radial coordinate, the circumferential coordinate of one blade surface, and the blade tangential thickness for every streamwise grid location on each of the input blade-to-blade surfaces. Although the program can interpolate spanwise when generating the grid, it cannot interpolate in the streamwise direction. Since a minimum of three input planes (and often more) is usually required to describe the flow passage, the amount of input data is considerable.

To ease the burden of preparing geometry input, a computer program called MERNEW3D was developed that prepares the bulk of the input dataset required for the Denton code. This program was based on the extensive geometric features of the MERIDL code (ref. 3) in order to generate the Denton input from a minimum of geometric information. MERIDL is a widely used code for meridional stream surface analysis of turbomachine blade rows, and the MERNEW3D code, for convenience, can read a MERIDL input dataset. The dataset produced by the

MERNEW3D code contains all of the necessary geometry input, the required flow variable input, and some of the control variables. A very small amount of editing is then required to complete it.

This report is intended to be a users manual for the MERNEW3D code. The features of the program are discussed. The input is described in detail, and sample input and output are included.

PROGRAM DESCRIPTION

This program, called MERNEW3D, produces a Denton code input dataset from a minimum of required information. The bulk of the dataset is the information describing the geometry of the blading passage being analyzed. The grid for the Denton code is shown in figure 1. Since the Denton code can extrapolate the input geometry spanwise, but not streamwise, to produce the computational grid, the following information is required for each input blade-to-blade section at every grid line in the streamwise direction from upstream boundary to downstream boundary: an axial coordinate, a radial coordinate, a circumferential coordinate of one surface of the blade or of the periodic boundary, and the blade tangential thickness. Also required are the inlet flow characteristics, such as temperature, pressure, and flow direction, at each spanwise grid location and various control parameters.

The primary input provided to MERNEW3D is in the format of input for the MERIDL code, which is a widely used meridional stream surface analysis. The MERIDL input format was chosen (1) because MERIDL requires the same type of geometry and inlet flow information as does the Denton code, (2) because MERIDL has extensive interpolation and extrapolation capabilities and thus requires only a minimum of geometrical input, and (3) because MERIDL input datasets already exist for many of the cases to be analyzed by the Denton code. A small additional dataset is required to control the conversion of MERIDL input to Denton input, which is done by interpolation and extrapolation using cubic spline curve fits.

The MERNEW3D code works with the same input options as does the MERIDL code. Blade shape can be input in one of three ways: (1) mean camber-line coordinates and tangential thickness, (2) mean camber-line coordinates and normal thickness, and (3) coordinates for both surfaces. Blade shapes input as (2) or (3) are converted to (1). Leading- and trailing-edge mean-camber-line tangency angles may or may not be specified. This controls the method of grid extrapolation into the upstream and downstream regions. Inlet flow characteristics can be input either as functions of radius or stream function. Since MERNEW3D does no flow computations, conversion from stream function to radius is made with the assumption of constant flow per unit area.

Several options are available with regard to the streamwise grid locations (J lines in fig. 1) produced by MERNEW3D for the Denton input. The flow passage consists of an upstream region (upstream boundary to leading edge), a bladed region (leading edge to trailing edge), and a downstream region (trailing edge to downstream boundary), with the number of streamwise grid locations in each region being required as input. With no further input specified, MERNEW3D produces equally spaced grid lines on each blade-to-blade section. A grid expansion factor is provided to expand the grid spacing in the upstream and downstream regions so that an adequate distance between blade edges and computational boundaries can be obtained with a minimum number of grid points. A packing factor is provided to densify the grid in the leading- and trailing-edge regions. Finally, each J location in the bladed region can be individually specified.

Since MERIDL does not perform a blade-to-blade surface flow analysis, blunt leading and trailing edges are typically specified. MERNEW3D, as an option, will round off the leading edge, using the procedure of reference 4, in the same manner that MERIDL does when producing input data for TSONIC (ref. 5). The trailing edge is not rounded off because the Denton code is usually run with a cusp at the trailing edge to assure a smooth flow path. The leading edge may or may not require a cusp, and the rounded leading edge may have to be further modified to provide a smooth transition if a cusp is used. MERNEW3D can provide a maximum of two cusp points at both the leading- and trailing-edge regions.

The MERNEW3D code, as an option, will compute and print the blade surface curvatures for each of the Denton code input blade sections so that they can be checked for smoothness. It is a good idea, in general, to plot the Denton grid geometry produced by MERNEW3D because cubic spline curve fits can sometimes produce unexpected results and improperly specified cusps can add discontinuity rather than smoothness to the flow path.

The Denton code can accept any consistent set of units as input. MERNEW3D can either leave the units as they were in the MERIDL input or convert U.S. customary units to SI units.

MERNEW3D uses the following six subroutines, which are taken directly from reference 6:

(1) SPLINE - Calculates the first and second derivatives of a cubic spline curve at the spline points by using the end condition that the second derivative at either end point is one-half that of the next spline point.

(2) SPLISL - Same as SPLINE except that the end condition is a specified end-point slope.

(3) SPLINT - Interpolates based on a cubic spline curve with the same end conditions as SPLINE. Extrapolates with the second derivative being extrapolated linearly to zero and then remaining at zero.

(4) SPINSL - Same as SPLINT except that the end condition for both interpolation and extrapolation is a specified end-point slope.

(5) ROTATE - Rotates coordinates of one- or two-dimensional arrays.

(6) INRSCT - Calculates the coordinates of the point of intersection of two spline curves lying on a common plane.

INPUT

The bulk of the input is the MERIDL type of input, which will be described only to the extent necessary to prepare a dataset for MERNEW3D. This description is taken directly from reference 3. Since MERNEW3D can read an input dataset prepared for the MERIDL code, this dataset will be herein referred to as "MERIDL input." A small additional dataset provides the control variables for MERNEW3D. The MERIDL input is read from unit 05, and the MERNEW3D control input is read from unit 08.

MERIDL Input

Figure 2 shows the input form for MERIDL. To prepare a dataset specifically for MERNEW3D, some simplifications can be made as indicated on the figure. The records marked "OMIT" can be omitted because they are not read. The fields marked "BLANK" are read but can be left blank because these variables are not used. For these fields the variable names (e.g., MSFL) are not included in the input dictionary because they are of no consequence to the MERNEW3D program. Specific values that can be used for some of the variables are shown. Those referring to Denton input variable names are identified in figure 1. Remember that a dataset that was previously prepared for MERIDL can be used for MERNEW3D without change.

The first input data record is for a title, which identifies the problem. Any information can be put in the first 80 columns of this record. All of the numbers on the two input records beginning with MBI and LSFR are integers (no decimal point) in a five-column field. These must be all right adjusted. The input variables on all other data records are real numbers in 10-column fields.

Input variables are both geometric and nongeometric. The geometric input variables are shown in figures 3 to 5. Further information concerning the input variables is given in the section Special Instructions.

The input variables are described in terms of a consistent set of SI units: newtons, kilograms, meters, joules, kelvins, and seconds. The programs, however, will run with input in any consistent set of units.

The required input variables, in the order that they appear in figure 2, are as follows, where sections (a) to (h) refer to Special Instructions:

GAM	Specific-heat ratio
AR	Gas constant, J/(kg)(K)
OMEGA	Rotational speed, rad/sec. The direction of rotation (positive or negative) must be consistent with the blade surface θ-coordinates (i.e., OMEGA is positive if rotation is in the direction of positive θ).
MBI	Number of grid lines from upstream boundary to blade leading edge inclusive. This is the Denton input variable JLE. See fig. 1 and section (c).
MBO	Total number of grid lines from upstream boundary to blade trailing edge inclusive. This is the Denton input variable JTE. See fig. 1 and section (c).
MM	Total number of grid lines from upstream to downstream boundaries inclusive. This is the Denton input variable JM. Maximum is 100. See fig. 1 and section (c).
MHT	Total number of grid lines from hub to shroud inclusive. This is the Denton input variable KM. Maximum is 50. See fig. 1 and section (c).
NBL	Number of blades in total circumference of blade row
NHUB	Number of spline points given in ZHUB and RHUB arrays. Maximum is 50. See fig. 3 and section (b).
NTIP	Number of spline points given in ZTIP and RTIP arrays. Maximum is 50. See fig. 3 and section (b).
NIN	Number of data points given in upstream arrays of flow properties (SFIN, RADIN, TIP, PRIP, LAMIN, VTHIN). Maximum is 50. See fig. 4 and section (d).
NOUT	Set NOUT = 1
NBLPL	Number of blade planes or blade sections on which data (ZBL,RBL, etc.) are given to describe mean blade shape and blade thickness. Maximum is 50. See fig. 3 and section (e).
NPPP	Number of data points per blade section or blade plane in ZBL,RBL, etc., arrays. Maximum is 50. See fig. 5 and section (e).
LSFR	Integer (0 or 1) indicating whether upstream flow conditions are given as a function of stream function (0) or radius (1)
LTPL	Set LTPL = 0

LAMVT : Integer (0 or 1) indicating whether upstream whirl (0) or tangential velocity (1) is given as input

LROT Integer (0 or 1) indicating whether coordinate rotation (ANGROT) is necessary (1) or not (0) for hub and shroud spline fit curves. See section (g).

LBLAD Integer (0, 1, or 2) indicating which two blade-shape coordinates are given as input. If LBLAD = 0, blade mean θ-coordinate (THBL) and normal thickness t_n (TNBL) are given. If LBLAD = 1, blade mean θ-coordinate (THBL) and tangential θ-thickness t_θ/r (TTBL) are given. If LBLAD = 2, blade upper surface θ-coordinate (TH1BL) and blade lower surface θ-coordinate (TH2BL) are given. See fig. 5 and section (e).

LETEAN Integer (0 or 1) indicating whether leading- and trailing-edge mean blade shape angles β_{le} and β_{te} (BETALE and BETATE) are specified (1) or not (0). See fig. 5 and section (e).

ANGROT Rotation angle of axis used for all streamwise spline fit curves, deg. Omit this card if LROT is (0). See section (g).

ZHUB Array of z-coordinates of input points defining hub or bottom boundary of flow channel, m. See fig. 3 and section (b).

RHUB Array of r-coordinates of input points defining hub or bottom boundary of flow channel, m. See fig. 3 and section (b).

ZTIP Array of z-coordinates of input points defining shroud or top boundary of flow channel, m. See fig. 3 and section (b).

RTIP Array of r-coordinates of input points defining shroud or top boundary of flow channel, m. See fig. 3 and section (b).

ZHIN z-coordinate of intersection with hub profile of line on which upstream flow conditions are given, m. Leave this entire card blank if LSFR = 0, LAMVT = 0, and MBI $\neq$ 0. See fig. 4 and section (d).

ZTIN z-coordinate of intersection with shroud profile of line on which upstream flow conditions are given, m. See fig. 4 and section (d).

RHIN, RTIN r-coordinates corresponding to ZHIN and ZTIN, m. Leave these spaces blank if LROT = 0. If RADIN is given as input (LSFR = 1), RHIN and RTIN cannot be equal to each other.

SFIN Array of values of stream function for input points from hub to shroud along line on which upstream flow conditions are given. SFIN is given when LSFR = 0. See fig. 4 and section (d).

RADIN Array of r-coordinates of input points along line from hub to shroud on which upstream flow conditions are given, m. RADIN is given when LSFR = 1. See fig. 4 and section (d).

TIP Array of absolute total temperatures at input points along line from hub to shroud on which upstream flow conditions are given, K. See fig. 4 and section (d).

PRIP Array of absolute total pressures at input points along line from hub to shroud on which upstream flow conditions are given, N/m^2. See fig. 4 and section (d).

LAMIN Array of values of absolute whirl rV_θ at input points along line from hub to shroud on which upstream flow conditions are given, m^2/sec. LAMIN is given when LAMVT = 0. See fig. 4 and section (d).

VTHIN Array of values of absolute tangential velocity V_θ at input points along line from hub to shroud on which upstream flow conditions are given, m/sec. VTHIN is given when LAMVT = 1. See fig. 4 and section (d).

ZBL — Two-dimensional array of z-coordinates of points describing mean blade surface, m. See figs. 3 and 5 and section (e). This surface is described by a series (from 2 to 50) of blade sections from hub to shroud. The innermost (hub region) section is given first, followed by successive sections up to the outermost (shroud region).

RBL — Two-dimensional array of r-coordinates, corresponding to ZBL, of points describing mean blade surface, m. See fig. 3 and section (e).

THBL — Two-dimensional array of θ-coordinates, corresponding to ZBL, of points describing mean blade surface, rad. See fig. 5 and section (f). The tangential coordinate θ is positive in direction of positive rotation. The origin of θ-coordinates can be anywhere around the circumference. THBL is given only when LBLAD is 0 or 1.

TNBL — Two-dimensional array of blade thicknesses normal to mean camber line, corresponding to ZBL,RBL coordinates, m. When there is little blade lean, small blade surface curvatures, and near-parallel suction and pressure blade surfaces, it is feasible to use the blade normal thicknesses for TNBL array (LBLAD = 0). Otherwise it is recommended to give either the tangential thickness, TTBL (LBLAD = 1), or the suction and pressure blade surface coordinates, TH1BL and TH2BL (LBLAD = 2). See fig. 5(a) and section (e).

TTBL — Two-dimensional array of blade tangential (circumferential) thicknesses, corresponding to ZBL,RBL coordinates, rad. TTBL is the blade tangential thickness in meters, divided by RBL. TTBL is given only when LBLAD = 1. See fig. 5(b) and section (e).

TH1BL — Two-dimensional array of upper blade surface coordinates (fig. 5(c)) corresponding to ZBL,RBL coordinates, rad. TH1BL is given only when LBLAD = 2. See fig. 5(c) and section (e).

TH2BL — Two-dimensional array of lower blade surface coordinates (fig. 5(c)) corresponding to ZBL,RBL coordinates, rad. TH2BL is given only when LBLAD = 2. See fig. 5(c) and section (e).

BETALE — Array of leading-edge, mean-camber-line tangency angle, deg. BETALE is given only when LETEAN = 1; omit this card if LETEAN = 0. See fig. 5(d) and section (e).

BETATE — Array of trailing-edge, mean-camber-line tangency angles, deg. BETATE is given only when LETEAN = 1; omit this card if LETEAN = 0. See fig. 5(d) and section (e).

MERNEW3D Control Input

The MERNEW3D control input is in a namelist called INPUT2. This dataset provides the required information not provided by the MERIDL input dataset. Since this is a namelist dataset, only those variables having values different from the default values have to be included. The variables in INPUT2 are as follows, where sections (a) to (h) refer to Special Instructions:

NJUPST — Number of streamwise grid points in the upstream region (does not include leading-edge point). Default value is MBI - 1. See fig. 1 and section (c).

NJONBL — Number of streamwise grid points in the bladed region (includes both leading- and trailing-edge points). Default value is MBO - MBI + 1. See fig. 1 and section (c).

NJDWST Number of streamwise grid points in the downstream region (does not include trailing-edge point). Default value is MM - MBO. See fig. 1 and section (c).

KM Total number of grid lines from hub to shroud inclusive. Default value is MHT. See fig. 1(a) and section (c).

IM Total number of grid lines across the passage in the circumferential (θ) direction. Default value is 11. See fig. 1(b).

NBLPC Number of blade-to-blade sections from hub to shroud to be included in the Denton input dataset. Default value is 3. See section (h).

SFRAC Array of streamwise grid point locations in bladed region specified as fraction of meridional distance from leading edge to trailing edge. The default is that this option is not used. See section (c).

GRDEXP Grid expansion factor that expands grid spacing in the upstream and downstream regions. Default value is 1.0. See section (c).

PACK Packing factor that densifies the grid near the leading and trailing edges within the bladed region. Default value is 1.0. See section (c).

CUSLE Cusp thickness at first point upstream of leading edge, specified as fraction of thickness at leading edge. Default value is 0.0.

CUSLE1 Cusp thickness at second point upstream of leading edge specified as fraction of thickness at leading edge. Default value is 0.0.

CUSTE Cusp thickness at first point downstream of trailing edge, specified as fraction of thickness at trailing edge. Default value is 0.5.

CUSTE1 Cusp thickness at second point downstream of trailing edge, specified as fraction of thickness at trailing edge. Default value is 0.0.

LECIRC Integer (0 or 1) indicating whether the leading edge is to be rounded off (1) or not (0).

ILETE Integer (0 or 1) indicating whether spanwise interpolation is to be made as a function of spanwise distance along a line of constant percent chord (0) or as a function of radius (1). Default value is 0. See section (h).

IUNITS Integer (1 or 2) indicating whether Denton input units are to be the same (1) as MERIDL input units or are to be converted to SI units (2) from MERIDL U.S. customary units. Default value is 1.

ICURV Integer (0 or 1) indicating whether blade surface slopes and curvatures (i.e., first and second derivatives, respectively, of θ versus m) for each of the Denton input blade sections are to be printed (1) or not (0). Default value is 0.

KCYL Integer ($\geq$0) indicating whether radius changes at the upstream and downstream boundaries are to be damped (>0) or not (0) and how many points (value of KCYL) at each boundary are to be affected by the damping. Default value is 0. See section (b).

CYL Damping factor for radius damping. Only used if KCYL > 0. Default value is 0.95. See section (b).

Special Instructions

Input should be checked thoroughly before it is submitted. Errors either in this code or in the Denton code, which uses as input the output from MERNEW3D, are commonly caused by the following: inconsistent units; improper sign for rotational speed and inlet tangential velocity or whirl; input for arrays not agreeing with the input bounds for those arrays; and upstream and downstream input not being of the form specified by LSFR, LTPL, and LAMVT.

Also geometric input into the hub and shroud arrays and the blade-geometry arrays should be smooth enough that the hub, shroud, and blade sections will be fit well with cubic spline curves (see section (f)). The output geometric arrays should be plotted to check for smoothness. All output should be checked, especially that from a new input data set, to see if it is reasonable.

(a) Units of measurement. - The International System of Units is used to illustrate the input variables. However, neither this program nor the Denton code uses any constants that depend on the system of units being used. Therefore, any consistent set of units can be used in preparing input for this program. For example, if force, length, temperature, and time are chosen independently, mass units are obtained from Force = Mass x Acceleration. The gas constant R must then have the units of (Force x Length)/(Mass x Temperature). Density is mass per unit volume and mass flow is mass per unit time. Output then gives velocity in the chosen units of length per unit time.

(b) Hub and shroud flow-channel geometry. - The hub and shroud flow-channel geometry is specified in the ZHUB,RHUB and ZTIP,RTIP arrays. Both of these curves must have the same z-origin (typically the blade leading edge at the hub). These two arrays must extend far enough upstream and downstream to cover the upstream and downstream boundaries of the grid, as well as the upstream flow data input station. If they do not extend this far, they will be linearly extrapolated and an incorrect flow channel may result. Relatively few points are needed to describe these smooth surfaces (2 to 10 is a typical range for NHUB and NTIP) in order to have the program calculate smooth, accurate spline fits of these surfaces (fig. 3).

In some instances a spinner, a tail cone, or a rapidly turning duct in the vicinity of the blade row will result in a flow path that is not readily amenable to analysis. In such a case the radius change in the regions of the upstream or downstream boundaries can be damped by using the variables KCYL and CYL. Starting at the KCYLth point from the boundary, the radius change from point to point (going toward the boundary) is reduced by a factor of $(CYL)^n$, where n varies from n = 1 at the KCYLth point to n = KCYL at the boundary.

(c) Computational grid. - The Denton grid in the meridional plane is shown in figure 1(a) and in the blade-to-blade plane in figure 1(b). The values of MBI, MBO, MM, and MHT, when set equal to the Denton variables JLE, JTE, JM, and KM, respectively (fig. 2), will determine the number of streamwise grid points in each of the three regions (upstream, blade, and downstream) and the number of spanwise grid points. Note that for an existing MERIDL input dataset, these values do not have to be made equal to the Denton variables because the MERNEW3D control input dataset can also provide this information, by means of the variables NJUPST, NJONBL, NJDWST, and KM, in addition to the number of bladewise grid points. The Denton input dataset is produced with both the bladewise and spanwise grid spacing arrays set for uniform spacing.

Several factors affect the streamwise grid locations (J lines in fig. 1) aside from the number in each region. With no further input specified, the grid lines are equally spaced from upstream to downstream boundaries, with the spacing determined by the meridional distance and number of locations in the bladed region. A grid expansion factor of GRDEXP > 1.0 will expand the grid spacing by geometric progression starting at the leading and trailing edges and moving toward the corresponding boundaries. A packing factor of PACK > 1.0 will densify the grid in the leading- and trailing-edge regions by compressing the grid spacing by geometric progression starting at midchord and moving toward the leading and trailing edges. Each J location in the blade region, if desired, can be individually specified as a fraction of meridional distance from leading edge to trailing edge by the array SFRAC. When SFRAC is used, GRDEXP can still be used, but of course PACK cannot be used.

(d) Upstream flow conditions. - Upstream flow conditions can be specified either as a function of the stream function (SFIN) or as a function of radius (RADIN). The upstream flow conditions are given in the SFIN (or RADIN), TIP, PRIP, and LAMIN (or VTHIN) arrays, which are all of length NIN (fig. 4). These flow conditions are used, along with the assumptions of conservation of angular momentum along streamlines and constant flow per unit area, to establish the flow field at the Denton upstream boundary.

If the upstream flow conditions are given as a function of stream function (SFIN), these input values apply at all points along streamlines upstream of the blade. If, in addition, the whirl is specified (LAMVT = 0), the ZHIN and ZTIN inputs are superfluous, so that these variables need not be specified. When ZHIN and ZTIN are required, the upstream conditions are given on a straight line that passes through the two points given by ZHIN on the hub and ZTIN on the shroud. This line may lie anywhere in the region from the blade leading edge upstream to the boundary. If LROT is 1, values for RHIN and RTIN must also be given as input.

The arrays of upstream input do not necessarily have to extend all the way from the hub to the shroud or lie on radial lines. They will be linearly extrapolated to the hub and the shroud, if necessary, by the program, should the user only give data in a portion of the flow channel.

(e) Mean blade surface and thickness coordinates. - The blade shape is described from hub to shroud by four arrays, all of which are two dimensional (figs. 3 and 5). Each of these arrays has NBLPL blade sections or planes, with NPPP points in each of these sections. When giving data for each of these four arrays, start each new section of data (NPPP points) at the beginning of a new line. There does not have to be any geometric relation between analogous points on adjacent blade sections. All of the ZBL data for all of the sections are given, followed by all of the RBL data, etc. The origin for the z-coordinates of ZBL should be the same as that used for all other z-coordinate input arrays. Of the four arrays necessary to describe the blade shape, ZBL and RBL are always given. There are three options, controlled by LBLAD, for the other two arrays (see LBLAD definition in the input dictionary).

When LBLAD is 0 or 1, the THBL array must be given (figs. 5(a) and (b)). The THBL array is for input θ-coordinates of the blade mean camber surface. The TNBL array is given when LBLAD = 0 (fig. 5(a)). The TNBL array is for input blade thicknesses normal to the blade-section mean camber line and lies on a surface of revolution cutting through the blade (figs. 3 and 5). So, in general, the thicknesses lie on a curved line whose ends may be at different radii and may or may not be normal to the blade surfaces (fig. 5(a)). Because it is difficult to make the proper geometrical conversion, caution should be exercised when giving TNBL input. The TTBL array is used for input tangential (circumferential) blade thicknesses (when LBLAD = 1) and is given in radians (i.e., t_θ/r) (fig. 5(b)). Thick blades, blades with high curvature, or blades with significant lean should use TTBL input in preference to TNBL input. The TH1BL and TH2BL arrays are used to give blade surface θ-coordinates when LBLAD = 2 (fig. 5(c)).

In addition to the four arrays necessary to describe the blade, there are two one-dimensional arrays (BETALE and BETATE) that are optional. These arrays specify the leading- and trailing-edge mean-camber-line tangency angles in degrees. The angles are measured on the input blade-section surfaces (fig. 5(d)). Use LETEAN = 1 when BETALE and BETATE are given, and LETEAN = 0 when thay are not given.

The first blade section given at the hub or the last one at the blade tip does not necessarily have to conform to the hub or shroud profile. It can be given within the flow region, crossing the boundary, or completely outside the boundary (fig. 3). Extrapolation or interpolation will be used when necessary to obtain blade data where the blades meet the hub and shroud profiles.

(f) How to specify points for spline curves. - All of the input arrays are fit with cubic spline curves for purposes of interpolation and calculation of derivatives. A cubic spline curve is a piecewise cubic polynomial that expresses mathematically the shape taken by an idealized spline passing through the given points. By this method, smooth curves can be specified accurately with a few points, usually not more than four or five. Curves with uneven places, dips, or highly variable curvatures require more points and are more difficult to fit properly. As a guide, enough points should be specified so that a physical spline passing through these points would accurately follow the curve. The minimum number of points to follow the curve should be used, since closely spaced spline points require more significant digits for coordinate definition.

(g) Choosing a value for ANGROT. - If the flow is close to axial (within about 45° from axial), ANGROT need not be given (use LROT = 0). If the flow deviates more than 45° from axial, use LROT = 1 and specify ANGROT in degrees so as to minimize the maximum slope of the hub or shroud from the rotated axis. For example, a centrifugal compressor impeller, with axial inlet and radial discharge, should have ANGROT = 45°. A radial-inflow turbine rotor with axial discharge should have ANGROT = -45°.

(h) Denton input blade sections. - The MERNEW3D code produces a Denton input dataset with the first blade section being the hub and the last blade section being the shroud. This corresponds to the Denton input variable INPUT = 2. The number of input blade sections specified by NBLPC are equally spaced either as a function of spanwise distance along a line of constant percent chord or as a function of radius. For a blade row with straight endwalls and straight edges, both methods of interpolation produce the same interpolated blade sections. When there is a large amount of meridional turning, such as with a centrifugal compressor impeller, using a constant radial (rotated) spacing produces a discontinuity in the blade-section slope dr/dm at one or both of the blade edges. When one or both of the blade-row edges deviate from a straight line, the use of a constant spanwise distance can produce discontinuities in the section slope. The user can try both ways if there is a question as to which interpolation produces a smoother grid.

Sample Input

Input for a sample case, a 20-inch-tip-diameter axial-turbine stator having axial inflow and an exit angle of 67°, is presented in figure 6. The MERIDL input dataset, which was prepared for MERIDL and not specifically for MERNEW3D, is shown in figure 6(a) and the MERNEW3D control input dataset is shown in figure 6(b). The sample output will correspond to this input.

OUTPUT

The primary output from MERNEW3D is an input dataset for the "new" Denton code as described in reference 2. A small amount of editing is necessary before this dataset can be used because all of the required Denton input information is not available from MERIDL. This output is written on unit 06.

A secondary output is produced that contains the default values of the MERNEW3D control variables (i.e., the values prior to reading the MERNEW3D control input), some warning messages, the blade surface curvatures (if requested), and error messages. This output is written on unit 09.

Denton Input Dataset

The Denton input dataset produced from the sample input of figure 6 is shown in figure 7. The section marked "Geometry," which is the bulk of the dataset, is ready to use as is. The lines marked "Inlet flow variables" are the inlet conditions, the first three lines of which are taken directly from MERIDL and need no changes. The remaining lines may or may not require modifications depending on the case being run and the options being used by the Denton code user.

Since Denton code users possess a full description of the required input, such a description will not be given here.

MERNEW3D Control Output

The MERNEW3D control output produced by the sample input of figure 6 is shown in figure 8. Shown first are the default values of the control variables. The program prints these prior to reading the control input dataset. If MERNEW3D is being run interactively, both this output and input can be conveniently done at the user's terminal. Printed next are the blade surface slopes and curvatures that were requested by ICURV = 1. Finally there is a warning to the user to check the input before using it. This warning is always printed and is not caused by any specific condition.

There are two conditions in MERNEW3D that will produce warning messages but will not cause the program to abort. If the Denton upstream or downstream boundaries extend beyond the MERIDL input hub or shroud arrays, a warning message is given so that the user is made aware that extrapolation has taken place. If the solution for the leading-edge radius (LECIRC = 1) has not converged in 100 iterations, a message will tell the user that this has occurred and that the current value is being used. Error messages, which are associated with program aborts, are described in the next section and are also included in this output.

Error Messages

A number of error messages have been incorporated into the program. Input error is usually the cause for these error conditions.

(1) CALCULATION ABORTED WHILE TRYING TO COMPUTE LE RADIUS - POSSIBLY ZERO LE THICKNESS OR SURFACE CROSSOVER.

This message is written by MERNEW3D if the leading-edge roundoff calculation produces a zero or negative leading-edge radius.

(2) INRSCT HAS FAILED TO CONVERGE IN 20 ITERATIONS
TOLERANCE = 0.101000E-05
DISTANCE BETWEEN LAST TWO INTERSECTION POINTS = 0.678900E-05

Subroutine INRSCT finds the intersection coordinates of the spanwise lines connecting the input blade sections at each of the 5-percent chord locations with the hub and shroud contour lines by an iterative method. If the tolerance cannot be met after 20 iterations, the message is printed. If the distance between the last two intersection points is only slightly larger than the tolerance, a satisfactory solution will be obtained, with some loss of accuracy. If the distance is excessive, there is probably some error in the geometry input.

(3) SPLINE ERROR -- ONE OF THREE POSSIBLE CAUSES

1. ADJACENT X POINTS ARE DUPLICATES OF EACH OTHER.
2. SOME X POINTS ARE OUT OF SEQUENCE.
3. SOME X POINTS ARE UNDEFINED.

NUMBER OF POINTS = 3

X ARRAY	Y ARRAY
0.00000	10.000
0.00000	12.000
1.0000	15.000

The spline points for a spline curve must be distinct and given in sequence. If not, the spline fit subroutine (either SPLINE, SPLINT, SPLISL, or SPINSL) will print this message, and the program will terminate. Since spline curves are used so extensively in the program, it is difficult to state the possible cause of an error. However, the printout of the spline points should assist in pinpointing the cause of the error.

(4) SPLINE ERROR -- NUMBER OF SPLINE POINTS GIVEN IS LESS THAN TWO

NUMBER OF POINTS = -3

X ARRAY	Y ARRAY
0.00000	10.000

At least two points must be given to determine a spline curve. If not, the spline fit subroutine (SPLINE, SPLINT, SPLISL, or SPINSL) will print this message, and the program will terminate. The one printed spline point may give a clue as to the error.

REFERENCES

1. Denton, J. D.; and Singh, U. K.: Time Marching Methods for Turbomachinery Flow Calculation. Application of Numerical Methods to Flow Calculations in Turbomachines, Von Karmen Institute for Fluid Dynamics (Rhode-Saint-Genese, Belgium), 1979.

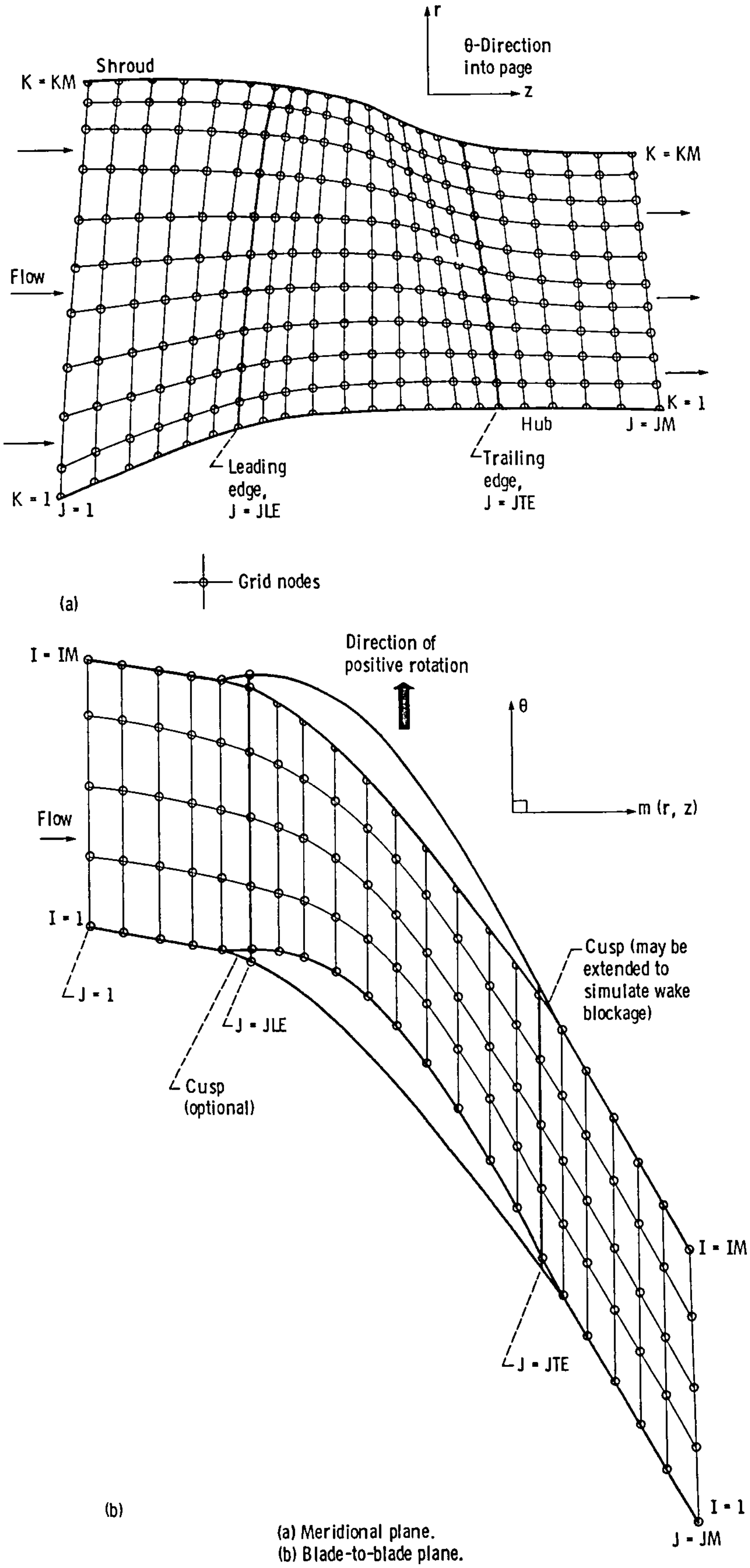
2. Denton, J. D.: An Improved Time Marching Method for Turbomachinery Flow Calculations. ASME Paper 82-GT-239, 1982.

3. Katsanis, T.; and McNally, W. D.: Revised FORTRAN Program for Calculating Velocities and Streamlines on the Hub-Shroud Mid-Channel Stream Surface of an AxialRadial-, or Mixed-Flow Turbomachine or Annular Duct. I - Users Manual. NASA TN D-8430, 1977.

4. Schumann, L. F.: FORTRAN program for Calculating Leadingand Trailing-Edge Geometry of Turbomachine Blades. NASA TM X-73679, 1977.

5. Wood, J. R.: Improved Method for Calculating Transonic Velocities on Blade-to-Blade Stream Surfaces of a Turbomachine. NASA TP-1772, 1981.

6. Katsanis, T.; and McNally, W. D.: Revised FORTRAN Program for Calculating Velocities and Streamlines on the Hub-Shroud Mid-Channel Stream Surface of an Axial-, Radial-, or Mixed-Flow Turbomachine or Annular Duct. II - Programmers Manual. NASA TN D-8431, 1977.



(a) Meridional plane.
(b) Blade-to-blade plane.

Figure 1. - Grid for Denton code.

1 5	6 10	11 15	16 20	21 25	26 30	31 35	36 40	41 45	46 50	51 55	56 60	61 65	66 70	71 75	76 80
TITLE															
GAM		AR		MSFL		OMEGA		REDFAC		VELTOL		FNEW		DNEW	
				BLANK				BLANK		BLANK		BLANK		BLANK	
MBI	MBO	MM	MHT	NBL	NHUB	NTIP	NIN	NOUT	NBLPL	NPPP	NOSTAT	NSL	NLOSS		
JLE	JTE	JM	KM					1.			BLANK	BLANK	BLANK		
LSFR	LTPL	LAMVT	LROT	LBLAD	LETEAN										
	0														
* ANGROT															
ZOMIN		ZOMBI		ZOMBO		ZOMOUT		ROMIN		ROMBI		ROMBO		ROMOUT	
BLANK		BLANK		BLANK		BLANK		BLANK		BLANK		BLANK		BLANK	
ZHUB (1 to NHUB)															
RHUB (1 to NHUB)															
ZTIP (1 to NTIP)															
RTIP (1 to NTIP)															
ZHIN		ZTIN		RHIN		RTIN									
SFIN (1 to NIN) or RADIN (1 to NIN)															
TIP (1 to NIN)															
PRIP (1 to NIN)															
LAMIN (1 to NIN) or VTHIN (1 to NIN)															
ZHOUT		ZTOUT		RHOUT		RTOUT									
BLANK		BLANK		BLANK		BLANK									
SFOUT (1 to NOUT) or RADOUT (1 to NOUT)															
BLANK															
PROP (1 to NOUT) or LOSOUT (1 to NOUT)															
BLANK															

LAMOUT (1 to NOUT) or VTHOUT (1 to NOUT)							
BLANK							
ZBL (1 to NPPP by 1 to NBLPL)							
RBL (1 to NPPP by 1 to NBLPL)							
THBL (1 to NPPP by 1 to NBLPL) or THIBL (1 to NPPP by 1 to NBLPL)							
TNBL (1 to NPPP by 1 to NBLPL) or TTBL (1 to NPPP by 1 to NBLPL) or TH2BL (1 to NPPP by 1 to NBLPL)							
* BETALE (1 to NBLPL)							
* BETATE (1 to NBLPL)							
ZHST (1 to NOSTAT)							
OMIT							
RHST (1 to NOSTAT)							
OMIT							
ZTST (1 to NOSTAT)							
OMIT							
RTST (1 to NOSTAT)							
OMIT							
FLFR (1 to NSL)							
OMIT							
PERCRD (1 to NLOSS)							
OMIT							
PERLOS (1 to NLOSS)							
OMIT							

IMESH	ISLINE	ISTATL	IPLOT	ISUPER	ITSON	IDEBUG
OMIT						

Figure 2. - Input form. (Cards denoted by asterisks are optional. See Input Dictionary.)

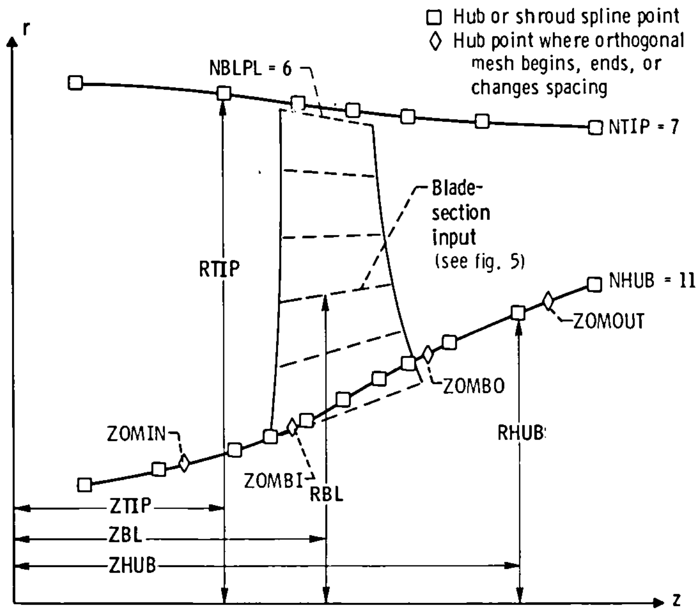


Figure 3. - Input variables - hub, shroud, and blade sections.

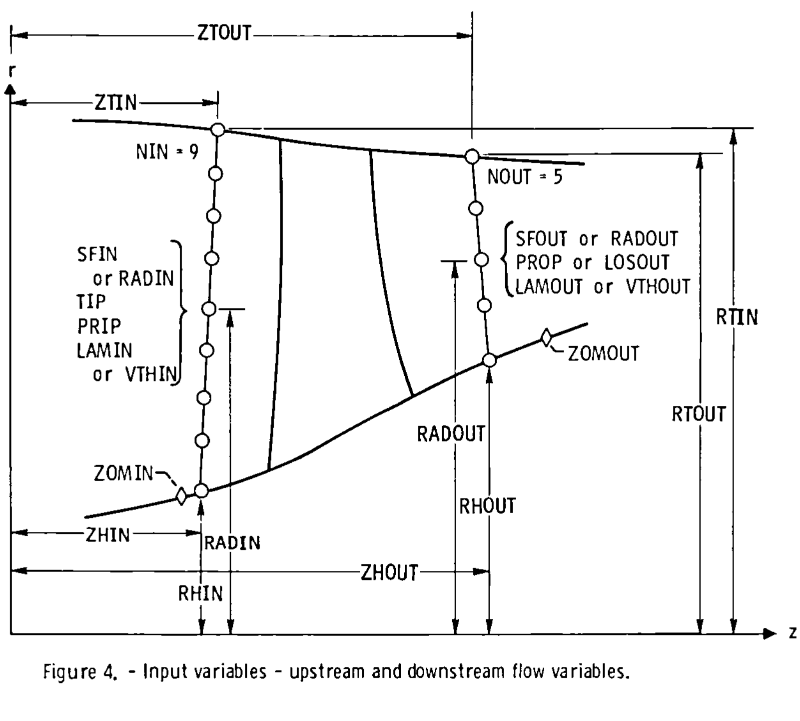


Figure 4. - Input variables - upstream and downstream flow variables.

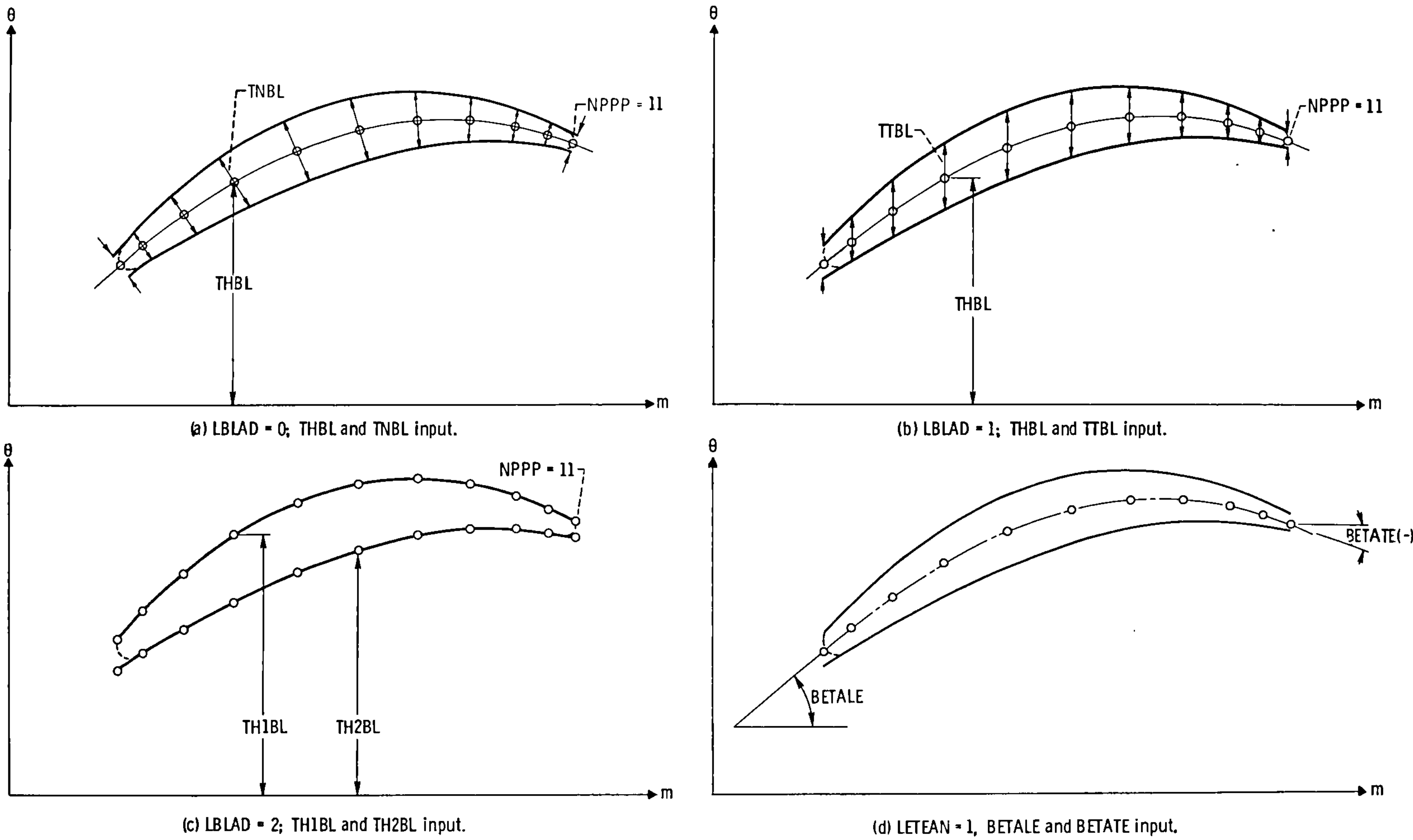


Figure 5. - Input variables - blade section. (RBL and ZBL must be given at each location (see fig. 3).) (TNBL is given in meters. THBL, TTBL, TH1BL, and TH2BL are given in radians.)

```
        STATOR 20 IN. ANNULAR CASCADE-CYLINDER
1.4          1716.48  0.31132    0.        1.0
  11   51   71   25   36    2    2    3    5    4   11   13   15
   1    1    0    0    1    1
 -0.12540   0.01500   0.14000   0.25080   0.00000   0.00000   0.00000   0.00000
 -0.12540   0.25080   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
  0.70833   0.70833   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
 -0.12540   0.25080
  0.83333   0.83333
 -0.06270  -0.06270   0.70833   0.83333   0.00000   0.00000   0.00000   0.00000
  0.70833   0.77083   0.83333
    545.8     545.8     545.8
   2062.6    2062.6    2062.6
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
  0.25080   0.25080   0.70833   0.83333   0.00000   0.00000   0.00000   0.00000
     0.00      0.25      0.50      0.75      1.00
  0.02000   0.02000   0.02000   0.02000   0.02000   0.00000   0.00000   0.00000
   -566.0    -572.0    -577.0    -586.0    -595.0
 0.0       0.015710  0.025136  0.037704  0.050272  0.062840  0.075408  0.087976
 0.100540  0.113110  0.125680
 0.0       0.015710  0.025136  0.037704  0.050272  0.062840  0.075408  0.087976
 0.100540  0.113110  0.125680
 0.0       0.015710  0.025136  0.037704  0.050272  0.062840  0.075408  0.087976
 0.100540  0.113110  0.125680
 0.0       0.015710  0.025136  0.037704  0.050272  0.062840  0.075408  0.087976
 0.100540  0.113110  0.125680
  0.67708   0.67708   0.67708   0.67708   0.67708   0.67708   0.67708   0.67708
  0.67708   0.67708   0.67708
  0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833
  0.70833   0.70833   0.70833
  0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083
  0.77083   0.77083   0.77083
  0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333
  0.83333   0.83333   0.83333
 0.182073  0.179978  0.177100  0.169783  0.158271  0.142163  0.120871  0.095083
 0.065934  0.031774 -0.009600
 0.174040  0.172038  0.169287  0.162293  0.152188  0.135891  0.115538  0.090888
 0.063026  0.030372 -0.009176
 0.159929  0.158089  0.155561  0.149134  0.139021  0.124873  0.106170  0.083519
 0.057916  0.027909 -0.008432
 0.147934  0.146232  0.143894  0.137949  0.128595  0.115507  0.098207  0.077255
 0.053572  0.025816 -0.007800
 0.037529  0.050470  0.057941  0.066443  0.072494  0.074432  0.071011  0.064015
 0.055471  0.040816  0.015368
 0.035873  0.048243  0.055385  0.063512  0.069296  0.071148  0.067878  0.061191
 0.053024  0.039015  0.014690
 0.032964  0.044331  0.050894  0.058362  0.063677  0.065379  0.062374  0.056230
 0.048725  0.035852  0.013499
 0.030492  0.041007  0.047077  0.053985  0.058902  0.060476  0.057696  0.052012
 0.045070  0.033163  0.012486
0.0        0.0        0.0        0.0
-67.0      -67.0      -67.0      -67.0
 -0.06270   0.00000   0.01250   0.02500   0.03750   0.05000   0.06250   0.07500
  0.08750   0.10000   0.12570   0.19810   0.25080
 -0.06270   0.00000   0.01250   0.02500   0.03750   0.05000   0.06250   0.07500
  0.08750   0.10000   0.12570   0.19810   0.25080
  0.00000   0.02500   0.05000   0.10000   0.12900     0.188     0.284     0.483
    0.688     0.792     0.861     0.896     0.948     0.974     1.000
   0   10   10   10    0   50    0
```

(a) MERIDL input dataset.

```
&INPUT2 NJUPST=12,NJONBL=25,NJDWST=12,IM=13,KM=6,GRDEXP=1.05,IUNITS=2,ICURV=1 &END
```

(b) MERNEW3D control input.

Figure 6. - Sample input.

```
L. G. STATOR 20 IN. ANNULAR CASCADE-CYLINDER
13    49     6    36 1000    13    37     3
 1     2     0     0     1     0
 1     1     1     1     1     1
 0.30480
-0.08335  -0.07440  -0.06587  -0.05774  -0.05000  -0.04264  -0.03562  -0.02894
-0.02257  -0.01651  -0.01074  -0.00524   0.00000   0.00524   0.01047   0.01571
 0.02095   0.02618   0.03142   0.03666   0.04189   0.04713   0.05237   0.05760
 0.06284   0.06808   0.07331   0.07855   0.08379   0.08902   0.09426   0.09950
 0.10473   0.10997   0.11521   0.12044   0.12568   0.13092   0.13641   0.14219
 0.14825   0.15461   0.16130   0.16832   0.17568   0.18342   0.19154   0.20007
 0.20903
 0.30480
 0.12236   0.12236   0.12236   0.12236   0.12236   0.[illegible]236   0.12236   0.12236
 0.12236   0.12236   0.12236   0.12236   0.12236   0.13445   0.13777   0.13895
 0.13945   0.13948   0.13886   0.13772   0.13621   0.13408   0.13094   0.12666
 0.12145   0.11550   0.10879   0.10126   0.09301   0.08428   0.07516   0.06545
 0.05489   0.04313   0.02978   0.01482  -0.00130  -0.01623  -0.03179  -0.04539
-0.05967  -0.07467  -0.09041  -0.10694  -0.12430  -0.14253  -0.16167  -0.18176
-0.20286
 0.30480
 0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
 0.00000   0.00000   0.00000   0.00000   0.00000   0.02418   0.03082   0.03417
 0.03703   0.03976   0.04228   0.04456   0.04658   0.04827   0.04953   0.05027
 0.05040   0.04984   0.04869   0.04704   0.04505   0.04291   0.04070   0.03814
 0.03493   0.03075   0.02526   0.01837   0.01041   0.00520   0.00000   0.00000
 0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
 0.00000
 0.30480
 0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833
 0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833
 0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833
 0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833
 0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833
 0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833   0.70833
 0.70833
 0.30480
-0.08335  -0.07439  -0.06587  -0.05774  -0.05000  -0.04264  -0.03562  -0.02894
-0.02257  -0.01651  -0.01074  -0.00524   0.00000   0.00524   0.01047   0.01571
 0.02095   0.02618   0.03142   0.03666   0.04189   0.04713   0.05237   0.05760
 0.06284   0.06808   0.07331   0.07855   0.08379   0.08902   0.09426   0.09950
 0.10473   0.10997   0.11521   0.12044   0.12568   0.13092   0.13641   0.14219
 0.14825   0.15461   0.16130   0.16832   0.17568   0.18342   0.19154   0.20007
 0.20903
 0.30480
 0.12236   0.12236   0.12236   0.12236   0.12236   0.12236   0.12236   0.12236
 0.12236   0.12236   0.12236   0.12236   0.12236   0.13445   0.13777   0.13895
 0.13943   0.13949   0.13894   0.13776   0.13597   0.13352   0.13034   0.12635
 0.12145   0.11559   0.10882   0.10124   0.09300   0.08428   0.07517   0.06545
 0.05489   0.04312   0.02978   0.01482  -0.00130  -0.01623  -0.03179  -0.04539
-0.05967  -0.07467  -0.09041  -0.10694  -0.12430  -0.14253  -0.16167  -0.18176
-0.20286
 0.30480
 0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000

 0.00000   0.00000   0.00000   0.00000   0.00000   0.02417   0.03081   0.03417
 0.03703   0.03976   0.04228   0.04456   0.04658   0.04827   0.04953   0.05027
 0.05040   0.04984   0.04869   0.04704   0.04505   0.04292   0.04070   0.03814
 0.03493   0.03075   0.02526   0.01837   0.01041   0.00520   0.00000   0.00000
 0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
 0.00000
 0.30480
 0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083
 0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083
 0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083
 0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083
 0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083
 0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083   0.77083
 0.77083
 0.30480
-0.08335  -0.07439  -0.06587  -0.05774  -0.05000  -0.04264  -0.03562  -0.02894
-0.02257  -0.01651  -0.01074  -0.00524   0.00000   0.00524   0.01047   0.01571
 0.02095   0.02618   0.03142   0.03666   0.04189   0.04713   0.05237   0.05760
 0.06284   0.06808   0.07331   0.07855   0.08379   0.08902   0.09426   0.09950
 0.10473   0.10997   0.11521   0.12044   0.12568   0.13092   0.13641   0.14219
 0.14825   0.15461   0.16130   0.16832   0.17568   0.18342   0.19154   0.20007
 0.20903
 0.30480
 0.12236   0.12236   0.12236   0.12236   0.12236   0.12236   0.12236   0.12236
 0.12236   0.12236   0.12236   0.12236   0.12236   0.13445   0.13777   0.13895
 0.13943   0.13949   0.13894   0.13776   0.13597   0.13352   0.13034   0.12635
 0.12145   0.11559   0.10882   0.10124   0.09299   0.08428   0.07517   0.06545
 0.05489   0.04312   0.02978   0.01482  -0.00130  -0.01623  -0.03179  -0.04539
-0.05967  -0.07467  -0.09041  -0.10694  -0.12430  -0.14253  -0.16167  -0.18176
-0.20286
 0.30480
 0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
 0.00000   0.00000   0.00000   0.00000   0.00000   0.02417   0.03081   0.03417
 0.03703   0.03976   0.04228   0.04456   0.04658   0.04827   0.04953   0.05027
 0.05040   0.04984   0.04869   0.04704   0.04505   0.04291   0.04070   0.03814
 0.03493   0.03075   0.02526   0.01837   0.01041   0.00520   0.00000   0.00000
 0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
 0.00000
 0.30480
 0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333
 0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333
 0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333
 0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333
 0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333
 0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333   0.83333
 0.83333
1004.638     1.400     0.400     0.020     0.000     0.000     0.020    -0.800
  25.000
101325.0  101325.0  101325.0  101325.0
 98757.8   98757.7   98757.7   98757.8   98757.8   98757.8
 303.222   303.222   303.222   303.222   303.222   303.222
   0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000

   0.001     0.000     0.000    -0.000    -0.001    -0.001
   1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000
5000 5000 5000 5000 5000
1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1
   0    0    0    1   49
```

Geometry

Inlet flow variables

Figure 7. - Denton input dataset from sample input.

```
NJUPST=10   NJONBL=41   NJDWST=20   IM=11   KM=25   NBLPC= 3   KCYL= 0   GRDEXP=1.000
 CUSLE=0.000   CUSTE=0.500   CUSLE1=0.000   CUSTE1=0.000
 PACK=1.000   IUNITS= 1   LECIRC= 1   ICURV= 0   ILETE= 0   CYL=0.950
```

K= 1

J	UPPER DT/DS	UPPER D2T/DS2	LOWER DT/DS	LOWER D2T/DS2
13	0.430885E 01	-0.300724E 03	-0.433572E 01	0.308427E 03
14	0.194668E 01	-0.601448E 03	-0.191304E 01	0.616855E 03
15	0.366518E 00	-0.205427E 01	-0.474274E 00	-0.673545E 02
16	0.230909E 00	-0.497384E 02	-0.631605E 00	0.726565E 01
17	0.673152E-01	-0.127421E 02	-0.667860E 00	-0.2111[illegible]E 02
18	-0.738818E-01	-0.411846E 02	-0.789784E 00	-0.254539E 02
19	-0.248134E 00	-0.253667E 02	-0.893961E 00	-0.143339E 02
20	-0.354904E 00	-0.154112E 02	-0.937462E 00	-0.228019E 01
21	-0.473659E 00	-0.299444E 02	-0.977563E 00	-0.130355E 02
22	-0.695751E 00	-0.548779E 02	-0.109767E 01	-0.328380E 02
23	-0.100359E 01	-0.626919E 02	-0.127758E 01	-0.358722E 02
24	-0.129068E 01	-0.469570E 02	-0.141147E 01	-0.152654E 02
25	-0.150751E 01	-0.358633E 02	-0.144963E 01	0.689178E 00
26	-0.170299E 01	-0.387955E 02	-0.146815E 01	-0.776007E 01
27	-0.192031E 01	-0.442051E 02	-0.153612E 01	-0.182012E 02
28	-0.213647E 01	-0.383488E 02	-0.163713E 01	-0.203738E 02
29	-0.229903E 01	-0.237351E 02	-0.173583E 01	-0.173224E 02
30	-0.240308E 01	-0.160063E 02	-0.182158E 01	-0.154276E 02
31	-0.252608E 01	-0.309674E 02	-0.189583E 01	-0.129308E 02
32	-0.271917E 01	-0.427795E 02	-0.195639E 01	-0.101992E 02
33	-0.299096E 01	-0.610209E 02	-0.201242E 01	-0.111998E 02
34	-0.337301E 01	-0.848923E 02	-0.208027E 01	-0.147126E 02
35	-0.382631E 01	-0.882333E 02	-0.215155E 01	-0.125118E 02
36	-0.421406E 01	-0.598562E 02	-0.219129E 01	-0.266529E 01
37	-0.444914E 01	-0.299281E 02	-0.220176E 01	-0.133265E 01

K= 2

J	UPPER DT/DS	UPPER D2T/DS2	LOWER DT/DS	LOWER D2T/DS2
13	0.395904E 01	-0.276327E 03	-0.398391E 01	0.283457E 03
14	0.178851E 01	-0.552654E 03	-0.175737E 01	0.566914E 03
15	0.336735E 00	-0.181376E 01	-0.436447E 00	-0.624200E 02
16	0.209055E 00	-0.469502E 02	-0.584310E 00	0.594744E 01
17	0.613458E-01	-0.946376E 01	-0.614012E 00	-0.172916E 02
18	-0.531801E-01	-0.342765E 02	-0.711104E 00	-0.197900E 02
19	-0.217034E 00	-0.283034E 02	-0.810495E 00	-0.181700E 02
20	-0.366288E 00	-0.287003E 02	-0.901626E 00	-0.166351E 02
21	-0.522634E 00	-0.310121E 02	-0.985664E 00	-0.154614E 02
22	-0.694168E 00	-0.345008E 02	-0.106348E 01	-0.142570E 02
23	-0.884558E 00	-0.382139E 02	-0.113634E 01	-0.135714E 02
24	-0.109664E 01	-0.427865E 02	-0.120767E 01	-0.136709E 02
25	-0.133250E 01	-0.473038E 02	-0.127932E 01	-0.136995E 02
26	-0.156849E 01	-0.428244E 02	-0.135266E 01	-0.143100E 02
27	-0.178257E 01	-0.389365E 02	-0.142955E 01	-0.150549E 02
28	-0.196796E 01	-0.318682E 02	-0.150916E 01	-0.153502E 02
29	-0.210770E 01	-0.215019E 02	-0.159023E 01	-0.156116E 02
30	-0.220526E 01	-0.157573E 02	-0.167093E 01	-0.152073E 02
31	-0.232202E 01	-0.288362E 02	-0.174284E 01	-0.122569E 02
32	-0.249993E 01	-0.391120E 02	-0.179898E 01	-0.918488E 01
33	-0.274864E 01	-0.558744E 02	-0.184946E 01	-0.100960E 02
34	-0.309919E 01	-0.780106E 02	-0.191129E 01	-0.135184E 02
35	-0.351592E 01	-0.811472E 02	-0.197696E 01	-0.115599E 02
36	-0.387242E 01	-0.550059E 02	-0.201363E 01	-0.244850E 01
37	-0.408846E 01	-0.275030E 02	-0.202325E 01	-0.122425E 01

K= 3

J	UPPER DT/DS	UPPER D2T/DS2	LOWER DT/DS	LOWER D2T/DS2
13	0.366220E 01	-0.255609E 03	-0.368520E 01	0.262201E 03
14	0.165440E 01	-0.511218E 03	-0.162563E 01	0.524402E 03
15	0.311513E 00	-0.166511E 01	-0.403692E 00	-0.577160E 02
16	0.193413E 00	-0.434400E 02	-0.540402E 00	0.550304E 01
17	0.567372E-01	-0.875985E 01	-0.567867E 00	-0.159926E 02
18	-0.492205E-01	-0.317080E 02	-0.657745E 00	-0.183340E 02
19	-0.200776E 00	-0.261746E 02	-0.749745E 00	-0.168032E 02
20	-0.338783E 00	-0.265340E 02	-0.834014E 00	-0.153814E 02
21	-0.483334E 00	-0.286735E 02	-0.911708E 00	-0.142919E 02
22	-0.642031E 00	-0.319370E 02	-0.983688E 00	-0.131988E 02
23	-0.818288E 00	-0.353797E 02	-0.105119E 01	-0.125828E 02
24	-0.101455E 01	-0.395771E 02	-0.111721E 01	-0.126320E 02
25	-0.123264E 01	-0.437273E 02	-0.118340E 01	-0.126511E 02
26	-0.145083E 01	-0.396030E 02	-0.125117E 01	-0.132297E 02
27	-0.164883E 01	-0.360188E 02	-0.132225E 01	-0.139161E 02
28	-0.182037E 01	-0.294935E 02	-0.139591E 01	-0.142174E 02
29	-0.194966E 01	-0.198859E 02	-0.147093E 01	-0.144348E 02
30	-0.203990E 01	-0.145806E 02	-0.154562E 01	-0.140891E 02
31	-0.214788E 01	-0.266567E 02	-0.161215E 01	-0.113209E 02
32	-0.231239E 01	-0.361742E 02	-0.166405E 01	-0.850171E 01
33	-0.254241E 01	-0.516765E 02	-0.171073E 01	-0.932727E 01
34	-0.286671E 01	-0.721779E 02	-0.176793E 01	-0.125167E 02
35	-0.325228E 01	-0.750788E 02	-0.182872E 01	-0.107026E 02
36	-0.358207E 01	-0.508753E 02	-0.186264E 01	-0.225170E 01
37	-0.378188E 01	-0.254377E 02	-0.187149E 01	-0.112585E 01

``` 
*************** CHECK YOUR INPUT DATASET *********************

*** WARNING ***
THE CONVERSION OF TO,PO AND VT FROM MERIDL TO DENTON INPUT STATIONS USES CONSTANT FLOW PER UNIT AREA AT BOTH STATIONS
THIS MAY GIVE INCORRECT VALUES FOR DENTON INPUT

***** ALWAYS PLOT GEOMETRY BEFORE USING IT *****
```

Figure 8. - MERNEW3D control output from sample input.

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15. Supplementary Notes

16. Abstract

This report is a users manual for a computer program that prepares the bulk of the input dataset required for the Denton three-dimensional turbomachine-blade-row analysis code. The Denton input is generated from a minimum of geometry and flow variable information by using cubic spline curve-fitting procedures. The features of the program are discussed. The input is described in detail, and special instructions are included to assist in its preparation. Sample input and output are included.

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