NASA CR-159555
PWA-5583-25

(NASA-CR-159555) STUDY OF BLADE ASPECT RATIO ON A COMPRESSOR FRONT STAGE AERODYNAMIC AND MECHANICAL DESIGN REPORT (Pratt and Whitney Aircraft Group) 84 p HC A05/MF A01 CSCL 21E G3/07

N79-23085

Unclas
20888

STUDY OF BLADE ASPECT RATIO ON A COMPRESSOR FRONT STAGE

AERODYNAMIC AND MECHANICAL

DESIGN REPORT

by

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Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NASA-Lewis Research Center
Contract NAS3-20809

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I. SUMMARY

A low aspect ratio , single-stage compressor was designed to be representative of the first stage of an advanced multistage high pressure compressor (HPC). The purpose of the program is to demonstrate that low aspect ratio blading in an HPC front stage can provide high loading levels at high tip speeds with acceptable efficiency levels. This report presents the details of the aerodynamic and mechanical design of a low aspect ratio rotor and stator to meet these goals.

Design parameters were chosen to be typical of an advanced HPC front stage and to be compatible with existing rig hardware which accurately simulates engine conditions. This hardware includes an offset inlet transition duct that incorporates a preswirl vane simulating fan stator root or low-pressure compressor exit flow, engine type intermediate case struts, and a variable stagger inlet guide vane (IGV).

The design pressure ratio is 1.8 at an adiabatic efficiency of 88.5 percent. The design flow per unit annulus area at the rotor inlet is 195.3 kg/sec/m^2 (40.0 lbm/sec/ft^2) at the design tip speed of 442.0 m/sec (1450 ft/sec). The hub/tip ratio is 0.597 with a tip diameter of 0.691 m (27.2 in.) and a rotor aspect ratio of 1.3.

The high tip speed and inlet specific flow of the rotor were required to achieve the stage pressure ratio of 1.8, which is agressive but representative of front stages of advanced core compressors. Stator exit specific flow and absolute air angle were chosen to be realistic values to match downstream HPC stages. The axial spacing between the IGV, rotor, and stator is sufficient to allow for radial and circumferential probe traversing.

Because the rotor inlet relative Mach number range is 0.97 to 1.32 from root to tip, the rotor was designed with multiple-circular-arc (MCA) blade sections typical of fan design practice. Stator vane sections were also designed as MCA sections, approaching double circular arc (DCA) sections toward the outer portion of the span. The stator inlet absolute Mach number range is 0.88 to 0.69 from root to tip. The reaction level of the stage was set at 0.71 to ensure that the stator inlet absolute Mach number remains below 0.9. Both rotor and stator losses were estimated using a combination of fan and HPC experience.

II. INTRODUCTION

Future commercial aircraft powerplants, in order to reduce fuel consumption, will require compressors with higher pressure ratios and efficiencies than currently in use. This implies the use of higher tip speeds and higher stage loading levels (that is, higher stage pressure rise). Research on advanced compressor stages has shown that the use of relatively low aspect ratio blading can provide high levels of loading while maintaining high efficiency and adequate stability margin. NASA sponsored programs have provided design background data on low aspect ratio compressors with hub-tip ratios and tip speeds typical of middle and rear stages of high pressure compressors, but a gap in design data exists for low aspect ratio front stages.

The tip speeds required for a highly loaded front stage result in transonic and supersonic relative Mach numbers into the rotor, a condition similar to that encountered in fans. The design of highly loaded, high aspect ratio blading for the transonic/supersonic regime has been explored extensively and successfully under various NASA fan contracts (References 1, 2, and 3). This program will make use of the fan experience in the design of the low aspect ratio front stage. Test results will determine whether these fan design concepts are applicable to high pressure compressor (HPC) front stages.

III. AERODYNAMIC DESIGN

A. FLOWPATH AND VELOCITY VECTOR DIAGRAM DESIGN

The compressor flowpath was designed to utilize an existing inlet case and exit duct from a Pratt & Whitney Aircraft high pressure compressor research vehicle. This hardware includes inlet prerotation vanes to simulate a fan stator or low pressure compressor exit stator, intermediate case support struts, and variable inlet guide vanes (IGV) situated in a curved duct typical of an engine intermediate case (Figure 1). Contract requirements established the rotor inlet hub-tip ratio, rotor tip speed, inlet specific flow, pressure ratio, and approximate blade and vane aspect ratios, as listed in Table 1.

The flowpath design evolved from these requiements through a series of iterations using the axisymmetric streamline analysis outlined in Appendix A. The iterations were started using an assumed flowpath shape, estimated flow blockages, and estimated efficiency profiles. Rotor and stator blade sections were generated using assumed rotor and stator solidities and calculated flow conditions and velocity vectors. Adjustments were made to the flowpath shape and blade solidities to control velocities and loadings. Efficiencies were reestimated using the modified flowpath and aerodynamics. Blade sections were defined after each iteration to determine the blade leading and trailing edge locations to be use in the calculation.

TABLE 1

DESIGN PARAMETERS

Corrected Speed, rpm	12210
Rotor Tip Speed, m/sec (ft/sec)	442.0 (1450)
Corrected Flow, kg/sec (lbm/sec)	47.28 (104.24)
Corrected Weight Flow Per Unit Annulus Area, kg/m^2-sec (lbm/ft^2-sec)	195.3 (40.0)
Rotor Pressure Ratio	1.845
Stage Pressure Ratio	1.805
Rotor Adiabatic Efficiency, %	92.1
Stage Adiabatic Efficiency, %	88.5
Tip Diameter, meters (inches)	0.6901 (27.2)
Hub/Tip Ratio at Rotor Inlet	0.597
Rotor Tip Solidity	1.26
Rotor Aspect Ratio*	1.30
Stator Hub Solidity	1.426
Stator Aspect Ratio*	1.42
Stator Average Exit Flow Angle, degrees	16.0
Number of Rotor Blades	24
Number of Stator Vanes	30

*Aspect Ratio = average-airfoil-length/midspan-chord

Flowpath convergence and the incorporation of sufficient axial spacing between the existing IGV and the new rotor for instrumentation established the rotor inlet hub and tip diameters of 0.412 meter (16.24 in.) and 0.691 meter (27.2 in.), respectively, resulting in an inlet hub-tip ratio of 0.597.

With the required rotor tip speed of 442.0 m/sec (1450 ft/sec), the design speed corrected to standard inlet conditions is 12,210 rpm. Specific flow at the rotor inlet was set at 195.3 kg/m^2-sec (40 $lbm/sec-ft^2$) consistent with advanced HPC front stage technology. This yields an inlet corrected flow of 47.28 kg/sec (104.24 lbm/sec) to the rotor and 46.53 kg/sec (102.6 lbm/sec) into the rig inlet, assuming previously demonstrated losses with the same inlet case hardware.

Flowpath convergence and wall curvatures were chosen to control blade and wall loadings as well as to provide compatibility with typical downstream HPC stages. The average stage exit axial Mach number is 0.55 with an average exit angle of 16 degrees, which is representative of exit conditions of typical advanced technology HPC front stages. Mach number levels and blade loading balance were a result of reaction selection as controlled by the IGV exit angle, Figure 2. A relatively high reaction level of 0.71 was chosen in order to keep stator inlet Mach number levels below 0.9 across the span. The resultant rotor loadings are within experience levels. Inlet and exit Mach number profiles for the rotor and stator are shown in Figure 3.

Rotor losses were estimated by using a fan correlation of total loss versus relative inlet Mach number. Endwall losses related to the rotor work coefficient were added to this two-dimensional loss. Stator losses were calculated using a correlation of loss parameter versus diffusion factor and percent span. An endwall loss increment similar to that used for the rotor was added to this level. Figure 4 and Figure 5 show the final rotor and stator loss coefficient radial distributions. Details of the rotor and stator loss system are found in Appendix B.

Blockages were included in the aerodynamic design to account for boundary layer growth along casing walls as well as airfoil wakes. Data taken from tests with similar intermediate case configurations were used to estimate the rotor inlet blockage, accounting for wakes from both the support struts and IGV. The blockage distribution through the compressor was estimated from data obtained from front stages of Pratt & Whitney Aircraft HPC research vehicles and is summarized in Table 2.

TABLE 2

AERODYNAMIC DESIGN ANNULUS BLOCKAGES

Location	Endwall Blockage, %
Rotor L. E.	6.8
Rotor T. E.	5.8
Stator L. E.	4.9
Stator T. E.	4.9

The inlet duct loss, including the prerotation vane (PRV) and support struts, was taken from test results of a similar configuration. The IGV losses were estimated from Pratt & Whitney Aircraft's cascade system for 400 series airfoils. The total inlet pressure loss relative to the plenum is shown in Figure 6.

The surge margin requirement for the first stage of a typical high pressure ratio core compressor is approximately seven percent, utilizing the NASA surge margin definition (S.M. = $PR_S/PR_{OL} \times W_{OL}/W_S$). Stall margin for this stage was estimated with two different methods. The first method uses a Pratt & Whitney Aircraft correlation of static pressure rise loading parameter at surge based on mean line air triangles, and predicts a NASA surge margin of 10.5 percent. The second method for estimating surge margin uses the streamline program to predict diffusion factors at off-design flow conditions at design speed. Fan test data were used to correlate rotor tip D-factor versus aspect ratio to which these offdesign levels were compared. The second method predicts a nine percent NASA surge margin for this stage. Figure 7 shows the spanwise rotor and stator D-factors at design and nine percent surge margin level. Thus, the selected design will meet the seven percenct surge margin requirement for the first stage of a multi-stage core compressor.

The final flowpath design is shown in detail in Figure 8. The large spacing between rotor and stator is necessary for instrumentation and is not representative of typical HPC first stage spacing. As a result, the stator inlet Mach number is higher than for a closely spaced stator. Figure 9 shows the rotor and stator inlet and exit meridional velocity profiles. The relative and absolute air angles to which the blades and vanes were designed are shown in Figure 10.

A complete summary of the design velocity vector data calculated along streamlines at the rotor and stator leading and trailing edges is tabulated in Appendix C, Table 6 and Table 7.

B. ROTOR BLADE DESIGN

The rotor blade was designed to produce a total pressure ratio of 1.845 at a tip speed of 441.96 m/sec (1450 ft/sec). There are 24 blades with an aspect ratio of 1.3, based on average blade length and absol- ute chord length at midspan, with a tip solidity of 1.26.

Although double circular arc (DCA) airfoils have traditionally been used for first stage rotors of high pressure compressors, the relatively high inlet Mach number for this stage warranted the use of multiple-circular-arc (MCA) airfoils, which fan experience has shown to have lower losses at these Mach numbers. Thirteen MCA airfoil sections were designed on conical surfaces that approximate stream surfaces of revolution at 0, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, and 100 percents of flow. Airfoil sections were defined by specifying total and front chord, total and front camber, maximum thickness and its location chordwise, and leading and trailing edge radii, as defined by Figure 11.

The ratios of front chord to total chord, front to total camber, and location of maximum thickness were varied to achieve the desired incidence and critical channel area margin (A/A* min) as established from previous MCA fan rotor and stator experience. Since there are many combinations of these parameters that would satisfy the same incidence and area margin criteria, an additional analysis technique was used to ensure an optimized blade shape. A blade channel flowfield was calculated using a time-marching finite area (TMFA) procedure (described in Reference 4) for streamlines at approximately 20, 50, and 80 percent of span, which yielded pressure distributions throughout the channel for each blade shape selected. Front chord length, front camber level, and maximum thickness location chordwise were selected from iterations that attempted to minimize the shock loss calculated by the TMFA program and achieve a smooth diffusion of pressure on the blade surfaces. Final incidence and deviation selection were also influenced by the TMFA calculations within the constraints of MCA fan design experience.

The rotor chord at midspan was established from the 1.3 aspect ratio requirement. The ratio of tip chord to root chord was set at 1.2 to be consistent with the desired solidity at the blade tip (Figure 12). These chords also gave acceptable rotor loadings and satisfied structural requirements. The ratio of front-chord to total-chord (Figure 13) yields a transition point which varies from 85 to 98 percent of the distance from leading edge to the assumed normal shock location on the suction surface, depending on the radius. This distribution was the result of an iteration to minimize front camber while holding the desired minimum channel flow critical area ratio (A/A^* min) and incidence.

Rotor maximum thickness to chord ratio (t/c) was selected to provide mechanical stability while maintaining minimum airflow blockage. The radial distribution, shown in Figure 14, resulted from flutter considerations (see Section IV-B). The thickness ratio is 0.085 at the hub and 0.035 at the tip. The chordwise location of maximum thickness varies linearly from 55 to 65 percent from root to tip. These locations were chosen so that for a given total and front camber and a given total and front chord the leading edge wedge angle was the minimum possible without creating a cusp-shape in the front portion of the blade. This had a desirable effect on pressure distribution as calculated by TMFA. Airfoil leading and trailing edge radii were chosen to provide mechanical integrity.

Incidence angles for all supersonic inlet sections were chosen at a location termed the a' point, a point on the suction surface halfway between the leading edge and the point from which a Mach wave emanates that meets the leading edge of the adjacent blade. This incidence, together with the entrance region and channel area considerations, determines the leading edge incidence. For most sections the a' incidence was set at approximately 1.5 degrees, based on fan experience. This incidence angle is intended to account for blockage at the blade leading edge, development of the suction surface boundary layer, and bow-wave loss. Near the tip, this a' incidence was reduced to about 1.0 degree in order to improve the pressure distribution predicted from the TMFA program.

For sections near the root where the inlet Mach number was only slightly greater than 1.0, higher values of incidence to the a' point were required to provide adequate flow area while maintaining a smooth distribution of leading edge incidence. Streamline 1 has a suction surface incidence of -5 degrees, which fairs smoothly with the rest of the span and is consistent with hub sections of similar HPC rotors.

The resulting spanwise distribution of suction surface, mean camber line, and a' incidence is shown in Figure 15.

Deviation angles from 20 to 80 percent of span were calculated using Carter's rule plus adjustments based on fan and HPC rotor data. In the endwall regions of 0 to 20 percent and 80 to 100 percent spans, extra deviation was added. Figure 16 shows the resulting design deviation versus span for the rotor. The rotor inlet and exit metal angles resulting from the incidence and deviation selection are shown in Figure 17. The ratio of front camber to total camber was chosen to provide a minimum channel flow critical area ratio of approximately 1.03 for most of the span. In the outer 15 percent span the area was larger in order to keep front camber from becoming negative. These margins above choke have been shown to give good performance for many fans including References 1 through 3.

Rotor geometry on design conical surfaces is summarized in Appendix D, Table 8. For manufacturing purposes, the airfoil sections were redefined on planes normal to the stacking line, a radial line though the center of gravity of the root conical section. The resultant blade coordinates are presented in Appendix E, Table 10.

C. STATOR VANE DESIGN

The stator row has 30 vanes with multiple-circular-arc (MCA) airfoil sections designed on conical surfaces approximating stream surfaces of revolution. The airfoil shape approaches a double-circular-arc (DCA) near the lower Mach number tip region.

The vanes have a constant chord of 0.68 meters (2.68 in.), which yields solidities of 1.426, 1.176, and 1.0 respectively at root, mean, and tip. Aspect ratio is 1.42 based on average length and actual chord and 1.57 based on average length and axially projected chord at the hub. Front chord was selected slightly forward of the first covered section for the standard MCA root sections fairing to half of total chord at 80 percent span.

Maximum thickness-to-chord ratio was set to vary linearly from 0.05 at the hub to 0.07 at the tip to provide low losses while being adequate for mechanical integrity. The chordwise location of maximum thickness varied linearly from 60 percent chord at the hub to 50 percent at the tip. This minimized the leading edge wedge angle for the high Mach number hub sections while at the tip it was similar that of a DCA. Leading and trailing edge radii were set constant at 0.0002 meters (0.008 in.).

Incidence angle was set at -3.3 degrees to the suction surface at 20 percent span based on minimum loss data for similar MCA stators and influenced by the pressure patterns from the TMFA program. At 80 percent span where the DCA shape is approached, incidence to the mean camber line was set at -6.1 degrees. This incidence is halfway between minimum loss incidence and the incidence where choking effects cause a noticeable rise in losses. This selection is consistent with HPC stator design practice in order to ensure adequate surge margin. In the endwall regions from 0 to 20 percent and 80 to 100 percent spans, local overcambers in inlet metal angle, relative to the values that would be calculated without a boundary layer effect, were incorporated. The resulting spanwise incidence selection is shown in Figure 18.

Deviation angles in the 20 to 80 percent core region were based on Pratt & Whitney Aircraft's cascade system modified by correction factors from the results of tests of similar stators. At 80 percent span the DCA cascade prediction was used without corrections while in the high Mach number sections near the root, an MCA airfoil cascade system was used as a base for corrections. An extra deviation was added in the endwall regions in order to allow for the boundary layer induced falloff in exit air angle. Figure 19 shows the stator deviation, and Figure 20 shows the spanwise inlet and exit metal angle distribution resulting from the incidence and deviation selection.

Front camber was used to control the throat area of the channel between blades. The desired throat area ratio, A/A^* min, of approximately 1.05 was established by a correlation of data from Reference 5.

A complete summary of stator geometry on conical surfaces is presented in Appendix D, Table 9. For manufacturing purposes, the airfoil sections were redefined on planes normal to the stacking line. In order to obtain a straight leading edge projection to allow for ease in button design, the manufacturing sections have their centers of gravities offset from the stacking line, except at the very hub where the radial stacking line emanates. The resultant airfoil coordinates are presented in Appendix E, Table 11.

IV. STRUCTURAL AND VIBRATION ANALYSIS

A. INTRODUCTION

The structural and vibration analysis of the blading involved tuning the blade and vane geometries to avoid undesirable resonant conditions, stability calculations to ensure stable, flutter-free operation of blades and vanes, and steady stress analysis to satisfy overspeed and low cycle fatigue criteria. Additionally, a rotor frame critical speed analysis was performed to investigate the vibrational characteristics of the entire rig assembly.

The final rig design is capable of operating to 110 percent of design speed (13,431 rpm) with no anticipated structural limitations. Strain gages will be placed on the blades and vanes, and accelerometers on the cases to ensure rig safety.

B. BLADE RESONANCE TUNING

Coupled blade-disk resonances that may be excited in the operating range are of major importance in the design of a compressor stage. Circumferential and radial distortion exist in the inlet airstream and normally contain strong components of first through fourth order harmonics. The airfoil hub/tip ratio, aspect ratio as well as spanwise thickness distribution have been adjusted such that natural modes of the system do not occur at frequencies close to one, two, or three (1E, 2E, or 3E) excitations per revolution during high speed operation.

Additionally, for stages behind major support structures, such as the nine inlet struts immediately upstream of the rotor stage, strut passing and twice strut passing frequency can be encountered in the first four coupled spanwise modes of vibration. Another major source of excitation can be caused by the vanes immediately upstream (inlet guide vane) or downstream (stator) of the stage as well as from periodic obstructions in the flowpath such as instrumentation probes.

Results of a bladed disk frequency analysis are shown in Figure 21 with frequency predictions for spanwise modes of vibration shown by solid lines. Tip chordwise bending frequencies (dashed lines in Figure 21) were calculated using the finite element system NASTRAN, with prestress effects included. As can be seen, a first mode (easy bending) 2E frequency margin of 24 percent exists at redline speed (13,431 rpm) and a 3E 1st mode resonance is predicted to occur at 9500 rpm. Second and third mode (coupled stiff bending and first torsion modes, respectively) frequencies are sufficiently high to avoid low order excitation and low enough to avoid vane or strut passing excitation at high speed. Mode six (second easy spanwise bending mode) is predicted to have an 18E excitation (twice strut passing frequency) at 10,200 rpm. No significant vibratory stress is expected in the first four spanwise modes of vibration. Vane passing and probe excited resonant conditions occur low in the operating range and are not expected to be a concern.

C. VANE RESONANCE TUNING

Both the inlet guide vane and exit stators of the rig are variable. The stator vane frequencies have been calculated assuming that the vanes are pinned at the I.D. and O.D. bushings. Modeling of the circular end caps, extensions and activating arms was included to accurately predict resonant frequencies. The stator was designed so that the first mode frequency is sufficiently high to avoid low order (2E and 3E) or blade passing (24E) resonance at high speed.

The inlet guide vane is structurally very similar to a configuration that has been previously run to 12,000 rpm. No excessive vibratory stress was observed in previous testing. Analysis indicates the first mode frequency is 28 percent greater than the 2E excitation frequency at redline speed. A 3E first mode resonance is calculated to occur at 11,500 rpm.

Analysis of the stator indicates the first mode frequency is five percent greater than the 3E excitation frequency at 110 percent of design speed (13,431 rpm) and is acceptable (Figure 22). A 4E first mode resonance is calculated to occur at 10,570 rpm. No blade passing resonances are expected above 8000 rpm in the first four vibratory modes.

D. ROTOR BLADE AND STATOR VANE FLUTTER

A supersonic unstalled flutter analysis was performed on the blade at 110 percent of the aerodynamic design point (13,431 rpm) in order to ensure that flutter will not be a problem during operation of the rig. The minimum log decrement (a measure of the aerodynamic damping in the system) for each of the first three vibration modes is shown in Table 3.

TABLE 3

ROTOR BLADE FLUTTER ANALYSIS

	Mode	Min. Log Decrement	Excitation Order	Allowable Log Decrement
Forward Wave	1	0.01974	2E	>0
	2	0.01658	2E	>0.002
	3	0.00979	4E	>0
Backward Wave	1	0.00609	2E	>0
	2	0.00632	5E	>0.002
	3	0.00070	6E	>0

Speed = 13,431 rpm (110% of design speed)

Each of these values is above the minimum allowable log decrement, and the design is acceptable.

The stator vane bending flutter and torsional flutter parameters were calculated for both the inlet and exit stators. The calculated values fall well within the range of successful experience.

E. ROTOR BLADE AND DISK STEADY STRESS

Blade root stresses were minimized by circumferentially tilting the airfoil 0.889 mm (0.035 in.) at the tip to counteract the blade pressure loading. Combined centrifugal, untwist, gas bending, and counteracting tilt stresses have been calculated at 13,431 rpm. Predicted airfoil root stresses are shown in Table 4 together with the allowable stresses for AMS 4928 titanium alloy at 366°K (200°F). The maximum stress in the airfoil of 226 X 10^6 N/m^2(32,800 psi) occurs near the trailing edge of the airfoil root and is well below the allowable stress of 448 x 10^6 N/m^2 (65,000 psi).

TABLE 4

STATIC BLADE STRESSES

	Maximum	Allowable
Blade Root (0.035 Tilt)		
Leading Edge	215 X 10^6 N/m^2 (31,200 psi)	448 X 10^6 N/m^2 (65,000 psi)
Trailing Edge	226 X 10^6 N/m^2 (32,800 psi)	488 X 10^6 N/m^2 (65,000 psi)
Maximum Thickness	225 X 10^6 N/m^2 (32,600 psi)	448 X 10^6 N/m^2 (65,000 psi)
Blade Attachment		
Tension	199 X 10^6 N/m^2 (28,800 psi)	276 X 10^6 N/m^2 (40,000 psi)
Bearing	481 X 10^6 N/m^2 (69,700 psi)	448 X 10^6 N/m^2 (65,000 psi)
Bending	217 X 10^6 N/m^2 (31,400 psi)	276 X 10^6 N/m^2 (40,000 psi)
Shear	150 X 10^6 N/m^2 (21,700 psi)	276 X 10^6 N/m^2 (40,000 psi)

Calculated blade attachment P/A, tooth bending, tooth shear and contact surface bearing stress are also compared in Table 4 to stress allowables. The limiting stress in the blade attachment is the average bearing stress of 481 x 10^6 N/m^2 (69,700 psi), which exceeds the allowable bearing stress by seven percent. The bearing stress limit of 448 x 10^6 N/m^2 (65,000 psi) was established to minimize galling on the contact surface during long term service use and is not a relevent limit for the intended rig testing. Minor broach refinement would be required to satisfy the service stress limit.

A modified Goodman Diagram, Figure 23, indictes that at the maximum steady state stress level in the blade root of 226 X 10^6 N/m^2 (32,800 psi) the maximum allowable vibratory stress is 103 X 10^6 N/m^2 (15,000 psi).

Maximum allowable vibratory stress limits for the stator vanes are established based upon test experience with similar stator vane and attachment design. For the entrance and exit stators, a vibratory stress limit of 69 X 10^6 N/m^2 (10,000 psi) has been established.

F. RIG CRITICAL SPEED

The test rig utilizes existing hardware consisting of the rotor drive system, bearings, dampers, and primary rotor support structure that have been utilized in tests of a Pratt & Whitney Aircraft research fan to a speed of 12,400 rpm in the same stand. No linear vibration problems were encountered in this running. Inner and outer cases downstream of the inlet guide vane stator will be new to this rig. An existing inlet case from an advanced compressor is utilized forward of the inlet guide vane.

An existing rotor frame critical speed analysis was modified to reflect the new blade, disk, and cases appropriate to this configuration. Predicted rotor critical speeds and the amount of the total strain energy present in the rotor system are shown in Table 5. The first mode rotor critical speed at 8065 rpm is essentially a cantilevered rotor and number one bearing support structure mode pivoting about the exit strut case.

TABLE 5

CRITICAL SPEED ANALYSIS
ROTOR MODES

Critical Speed (rpm)	Rotor Strain Energy (%)
8,065	10.7
12,477	9.8
15,274	67.1

Design Speed - 12,210 rpm
Running Range - 6,105 rpm to 13, 431 rpm

Significant relative motion exists at the number one bearing location, and the viscous damper will be effective in suppressing response in this mode. The second rotor critical speed of interest is a rotor pitch mode about the number two bearing. Again the viscous damper in the number one location will be effective in suppressing response in this mode. The third mode, predicted to occur at fifteen percent above redline speed, is a fundamental drive shaft and coupling bending mode. Little case participation is noted and no relative motion is present at the bearings. This mode is sufficiently beyond the intended operating speed to be of no concern.

G. PROBE ANALYSIS

A frequency analysis of the four sets of probes provided by Pratt & Whitney Aircraft was made using a simple beam analysis. Each probe was assumed to be a cantilevered beam with a weight that included the probe itself as well as the kiel heads and the tubing. The results of this analysis (Figure 24) show that three of the probe frequencies are well above the 2E excitation frequency at redline speed (13,341 rpm), while the remaining probe has a 26 percent 2E margin at redline speed. The difference between the number of inlet guide vanes and blades creates a natural 4E excitation for the probe system. As seen in Figure 24, 4E resonant conditions are tuned to occur low in speed as well as above redline speed. Blade passing resonances (24E) are also avoided by tuning the first mode frequencies of each probe.

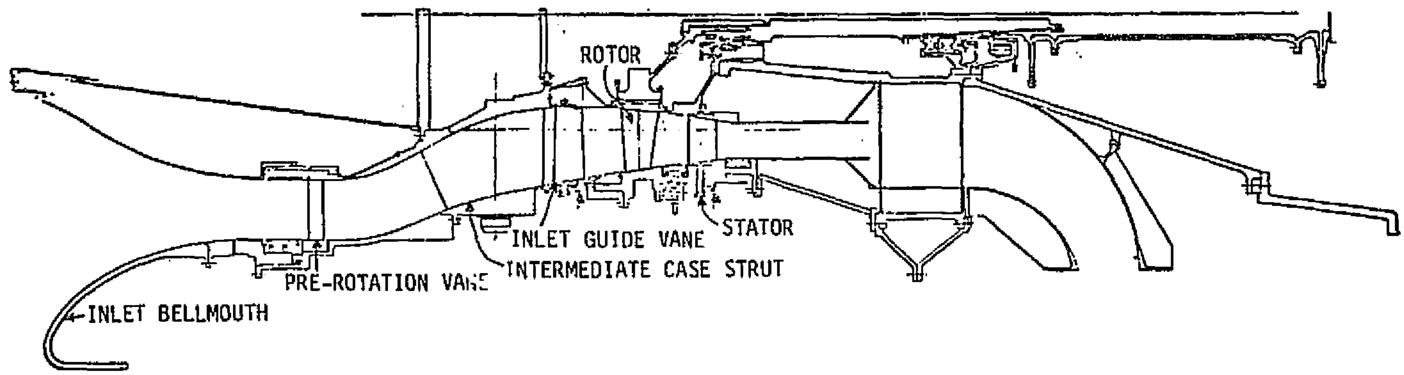


Figure 1 Flowpath of Low Aspect Ratio Front Stage Rig

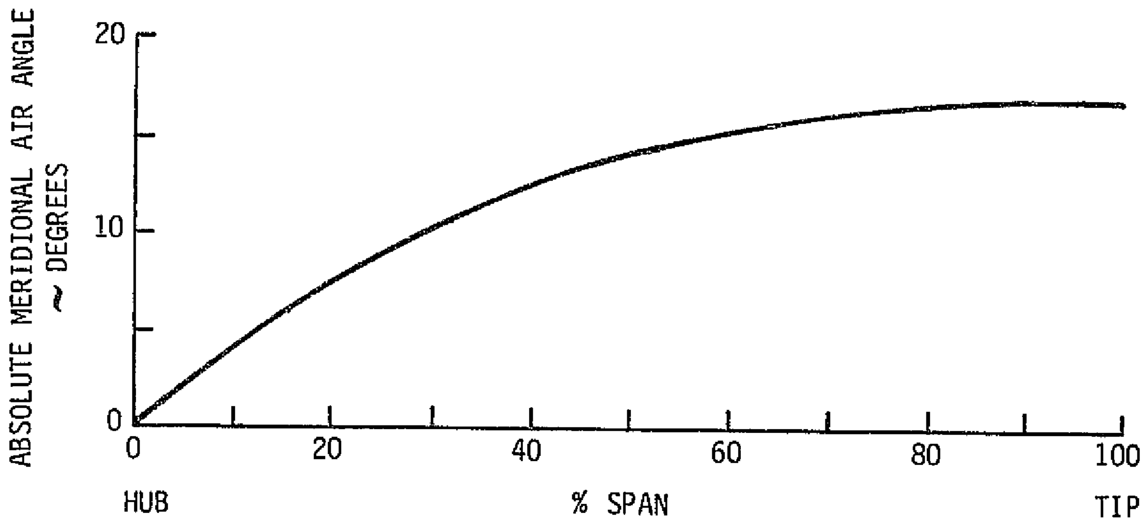


Figure 2 Inlet Guide Vane Exit Air Angle

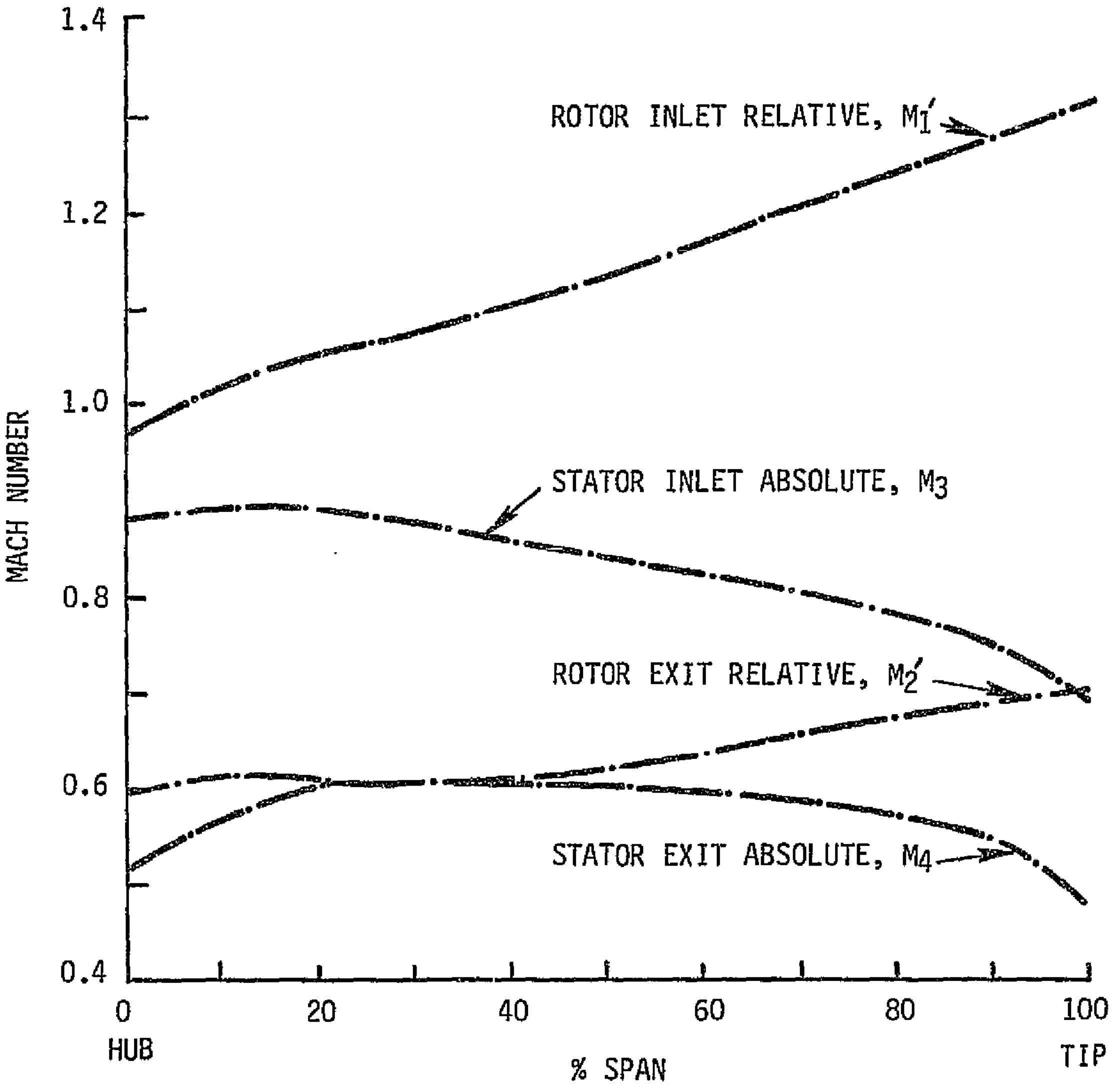


Figure 3 Rotor and Stator Inlet and Exit Mach Numbers

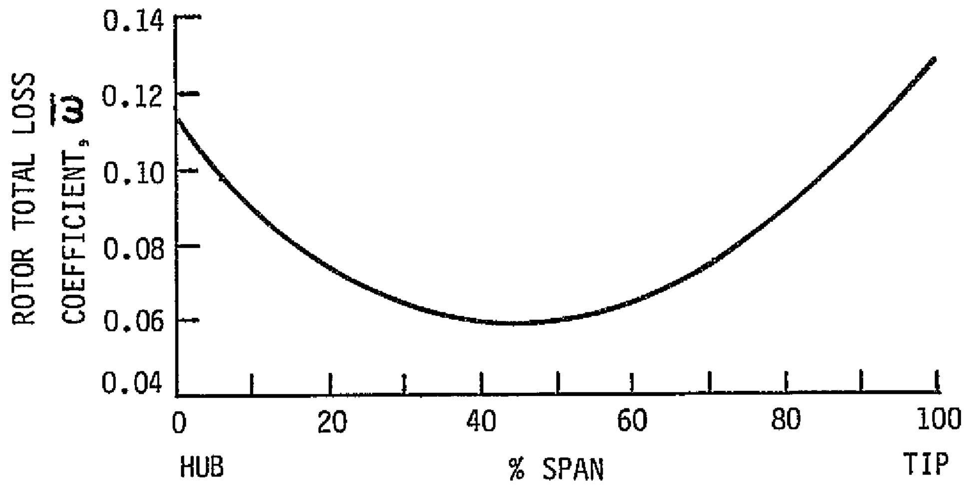


Figure 4 Rotor Loss Coefficient Versus Span

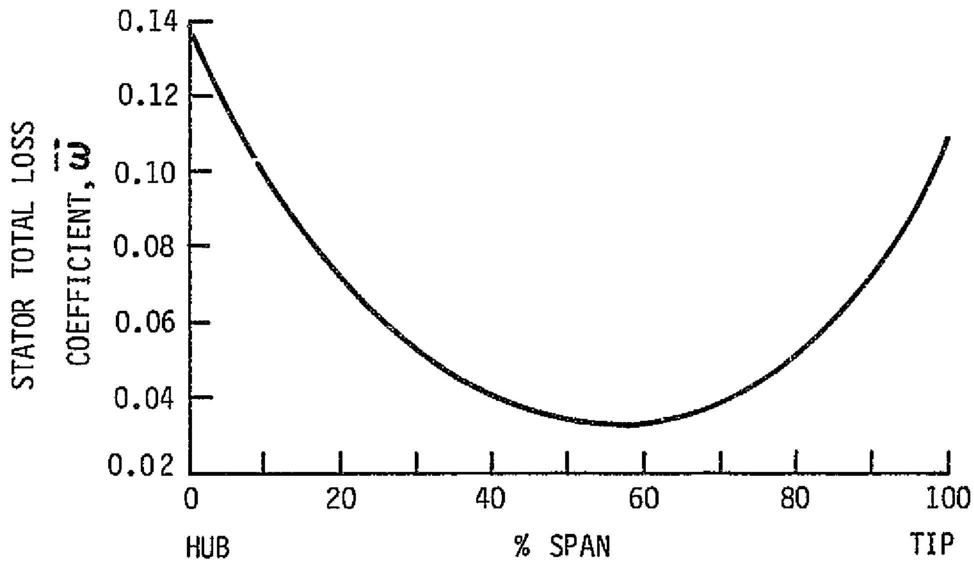


Figure 5 Stator Loss Coefficient Versus Span

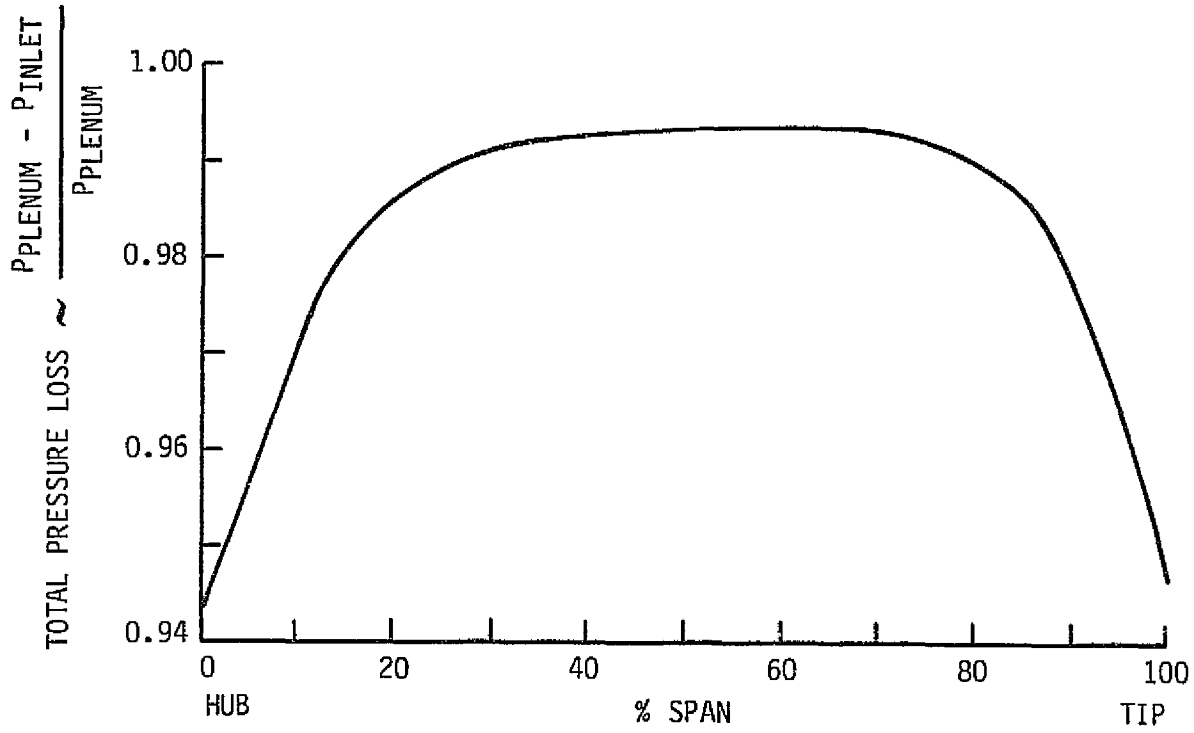


Figure 6 Inlet and IGV Total Pressure Loss Versus Span

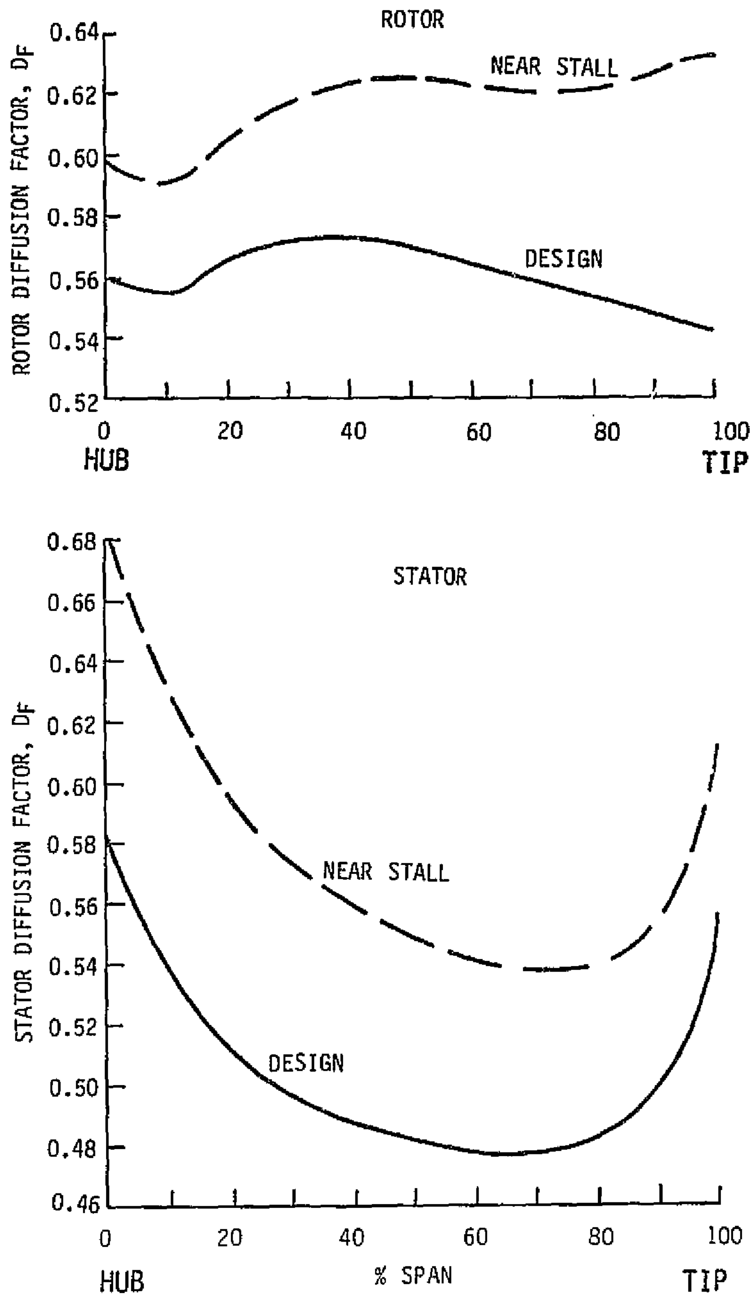


Figure 7 Rotor and Stator Diffusion Factor at Design and Near Stall

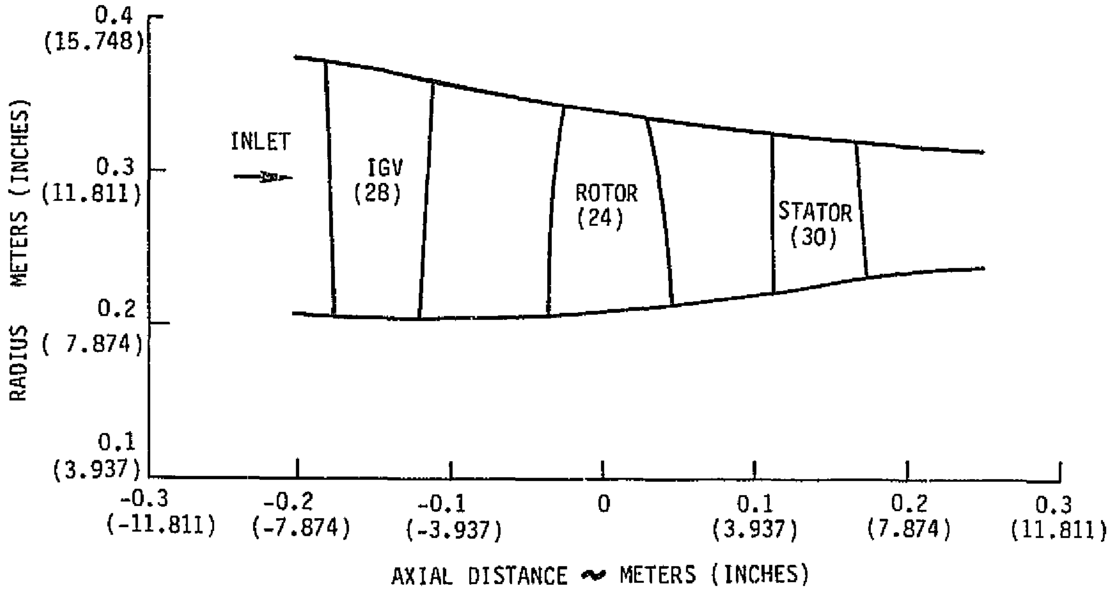


Figure 8 Compressor Stage Flowpath

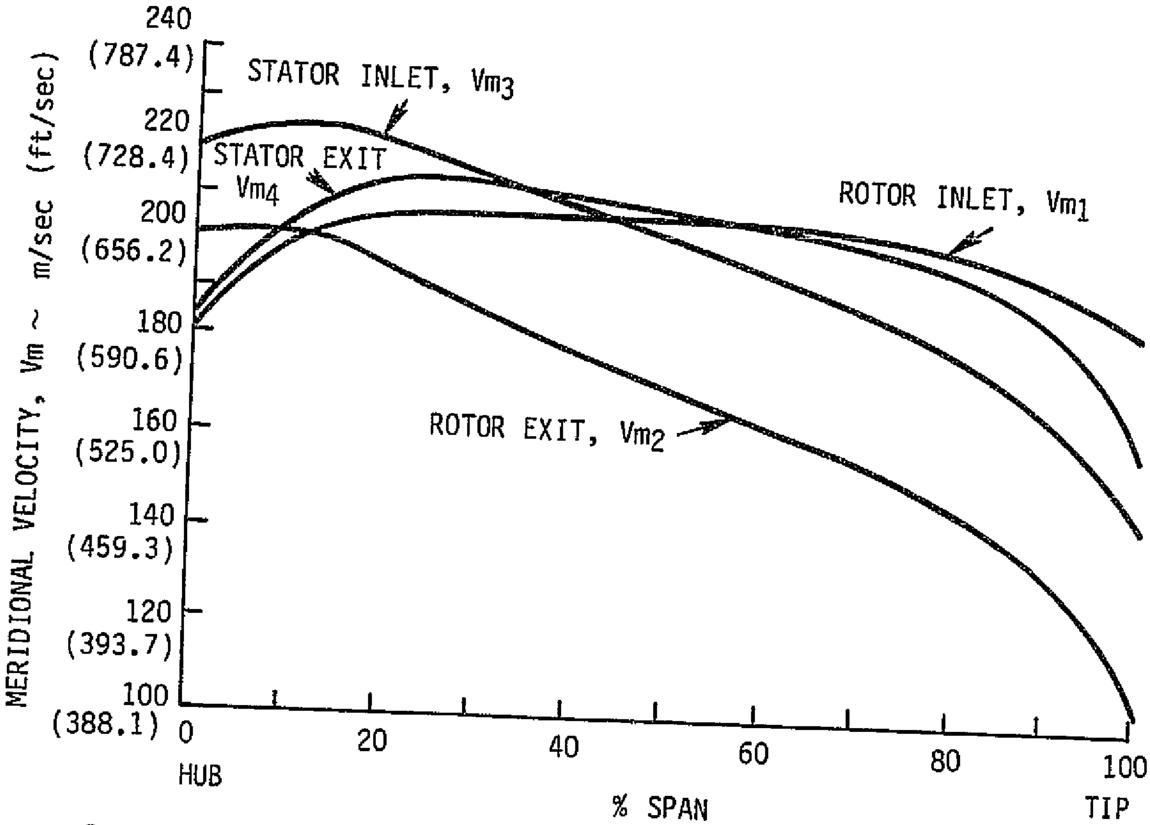


Figure 9 Meridional Velocity Profiles at Rotor and Stator Inlet and Exit

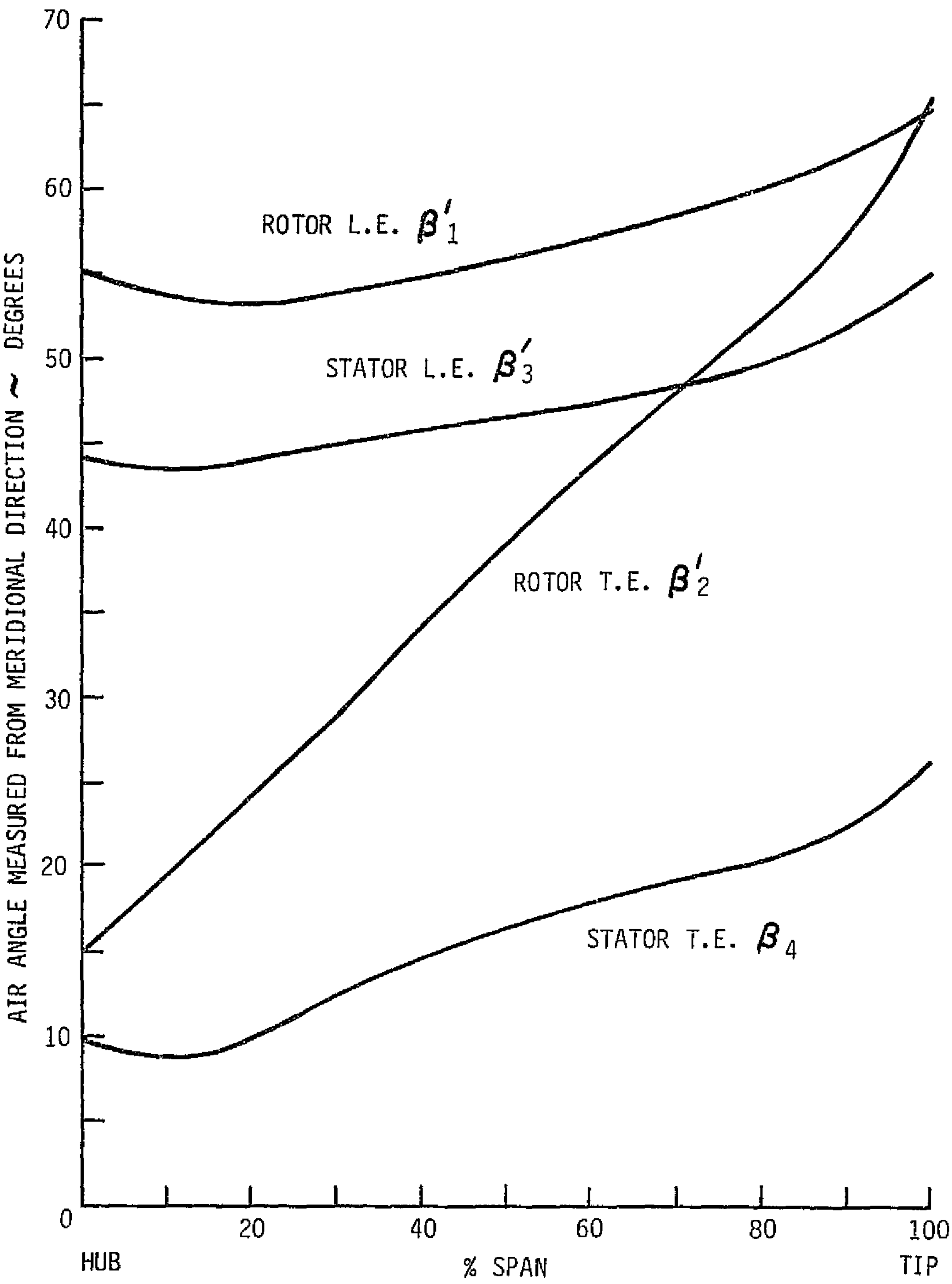


Figure 10 Design Air Angle Distributions for Rotor (Relative) and Stator (Absolute)

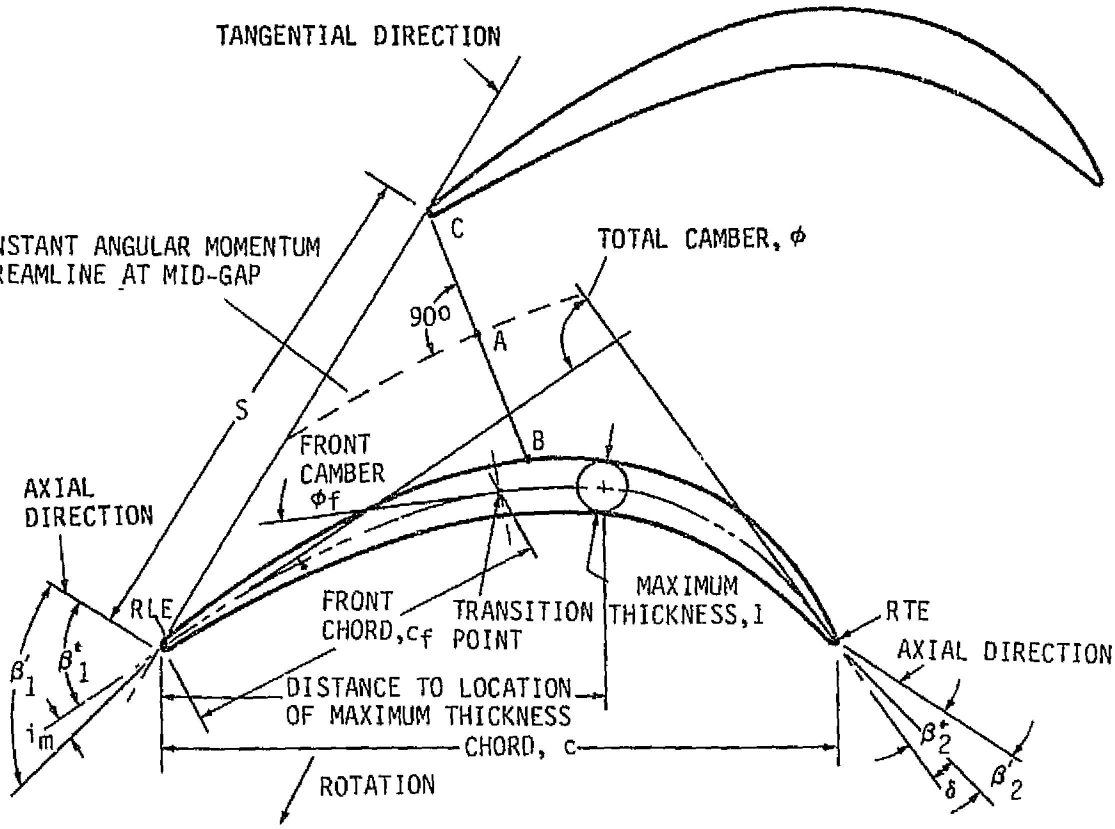


Figure 11 Multiple-Circular-Arc Airfoil Definitions and Cascade Relationships

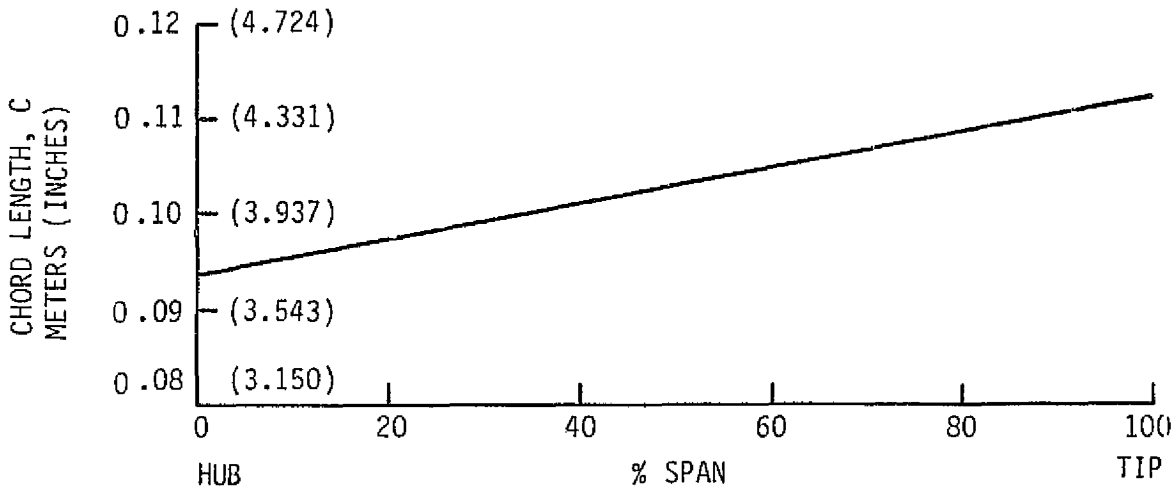


Figure 12 Rotor Total Chord Versus Span

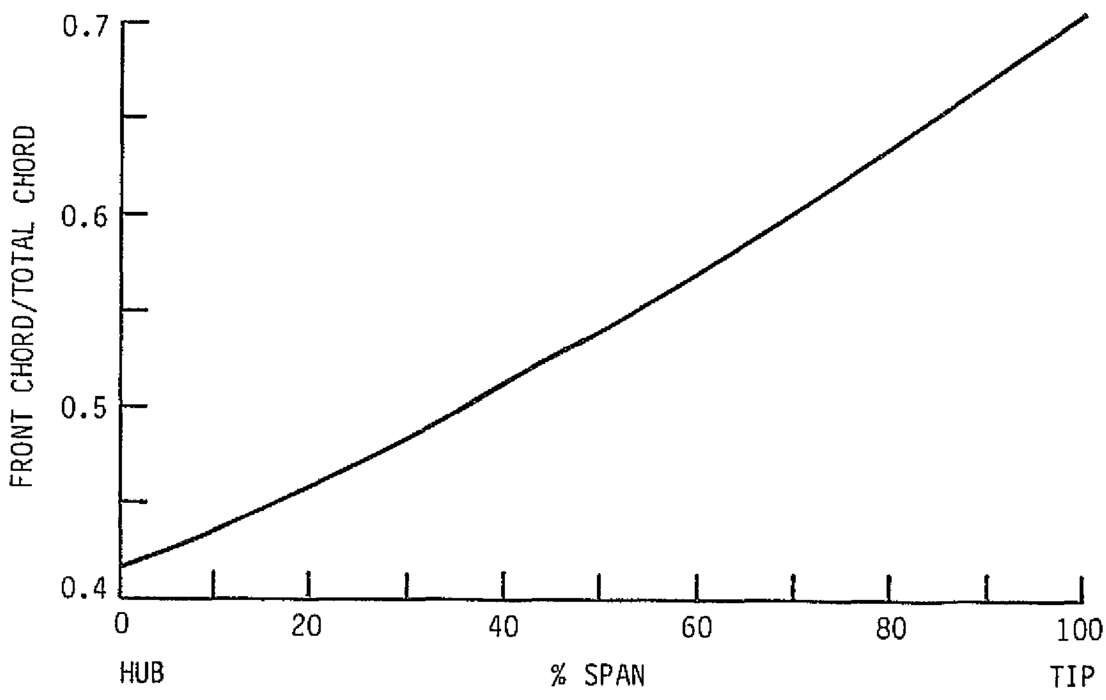


Figure 13 Ratio of Front Chort to Total Chord for Rotor

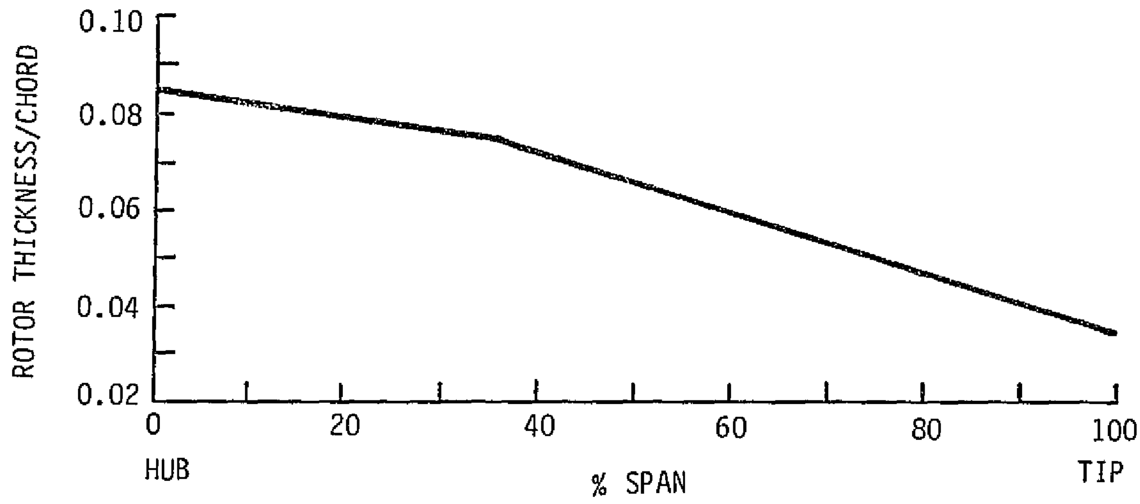


Figure 14 Rotor Thickness to Chord Ratio Versus Span

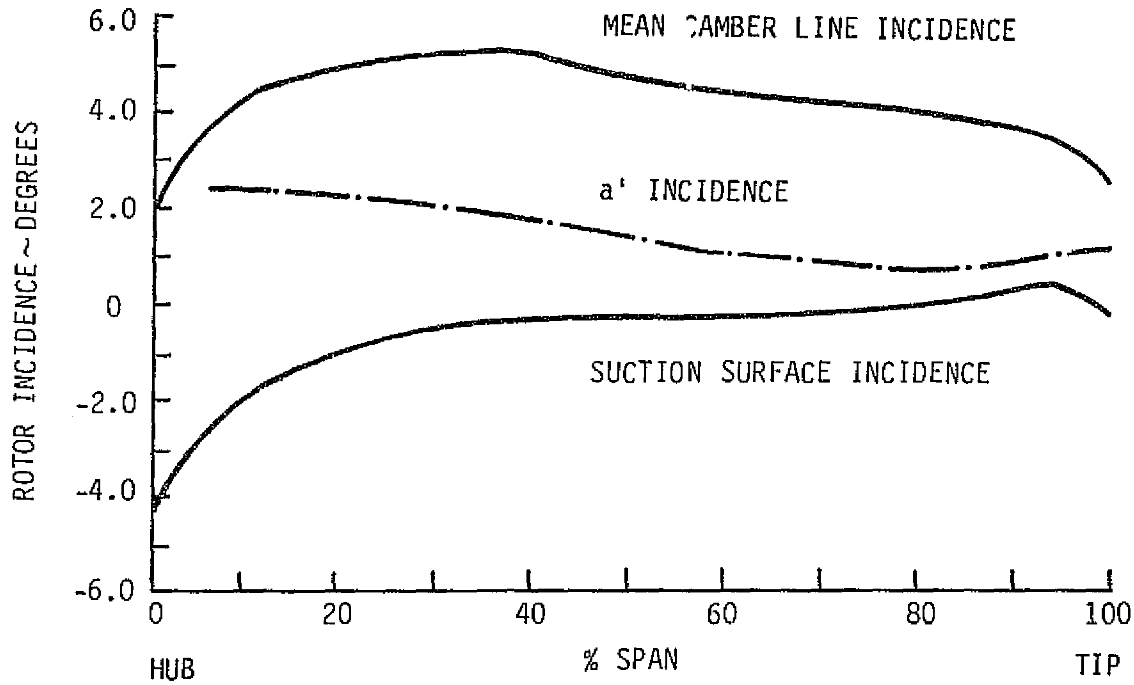


Figure 15 Rotor Incidence Versus Span

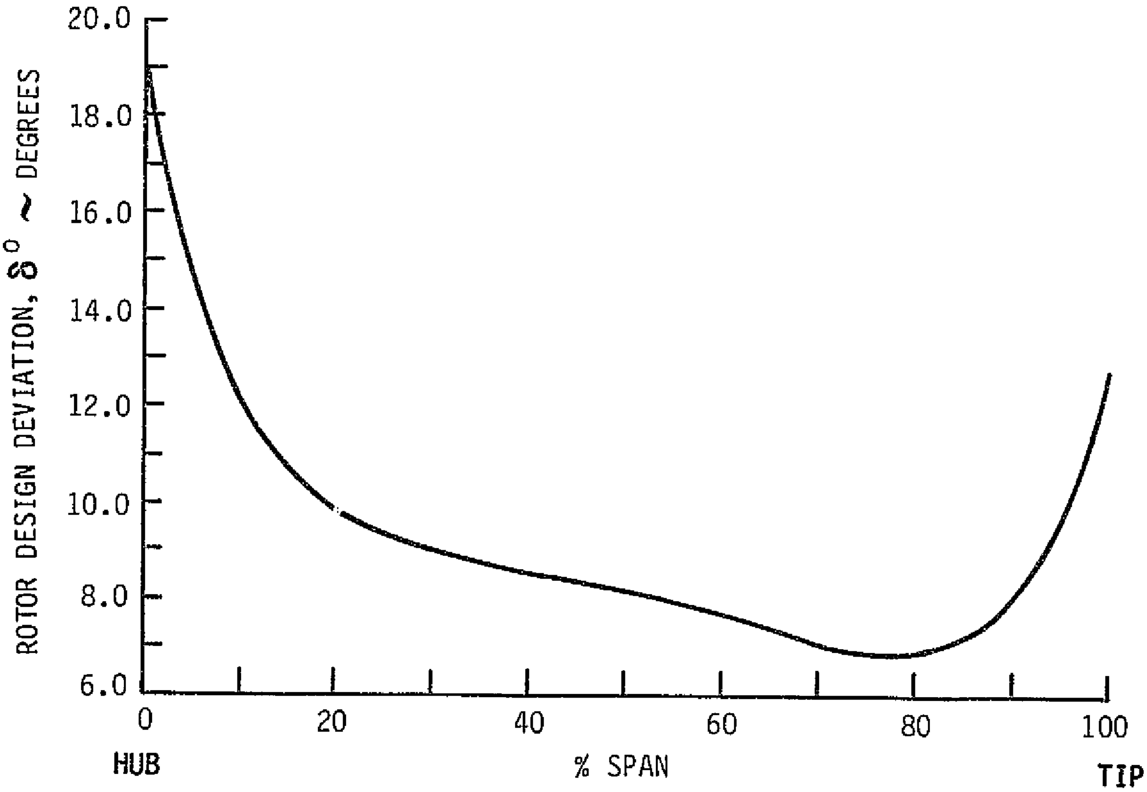


Figure 16 Rotor Deviation Versus Span

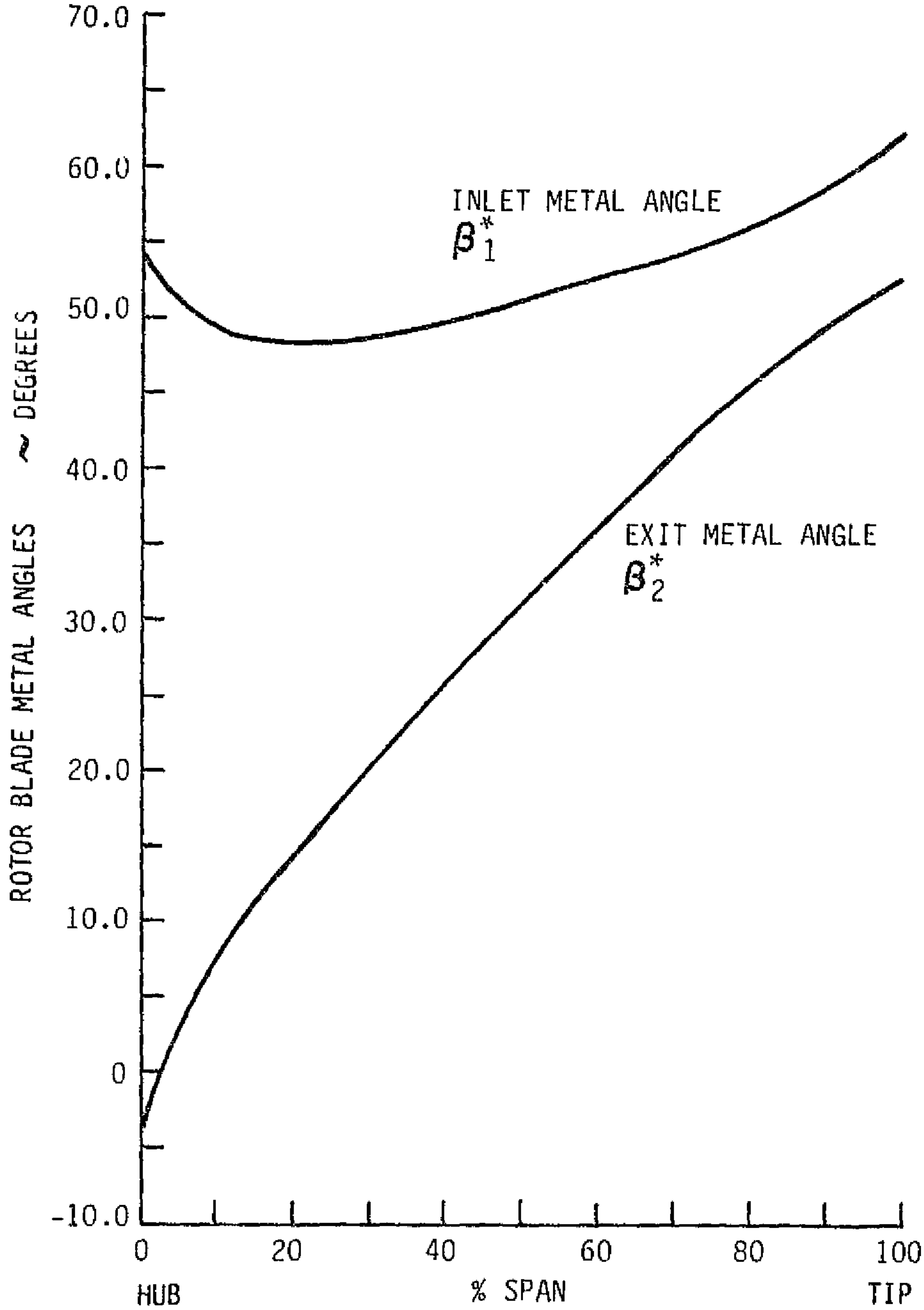


Figure 17 Rotor Inlet and Exit Metal Angle Versus Span

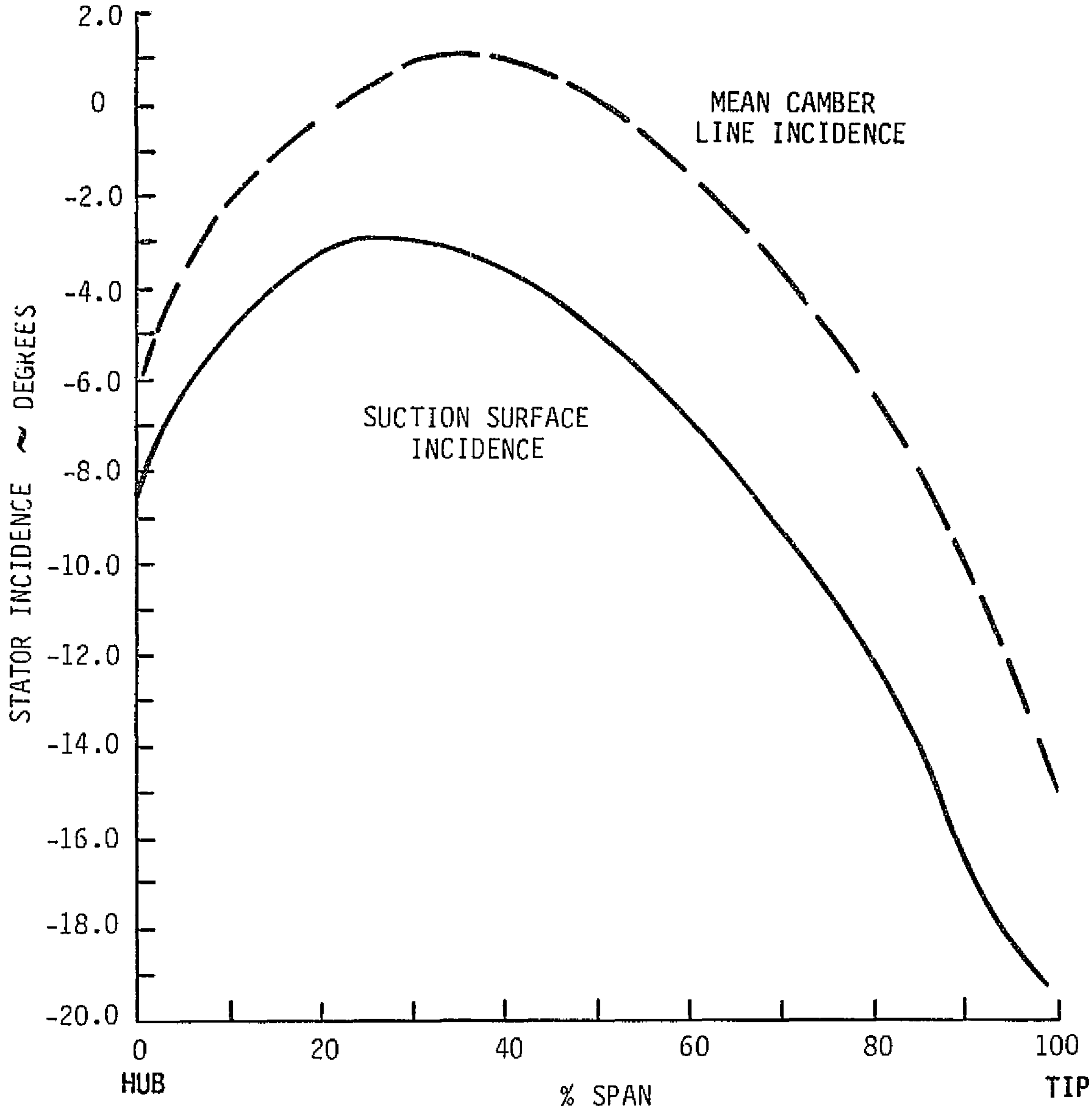


Figure 18 Stator Incidence Versus Span

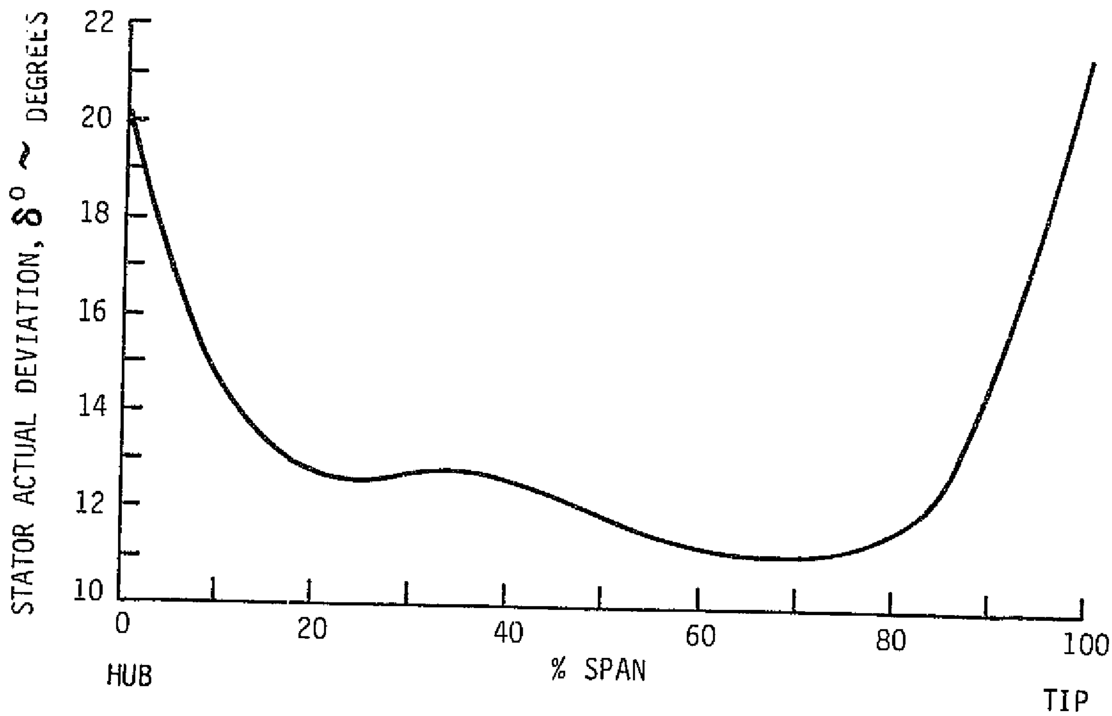


Figure 19 Stator Deviation Versus Span

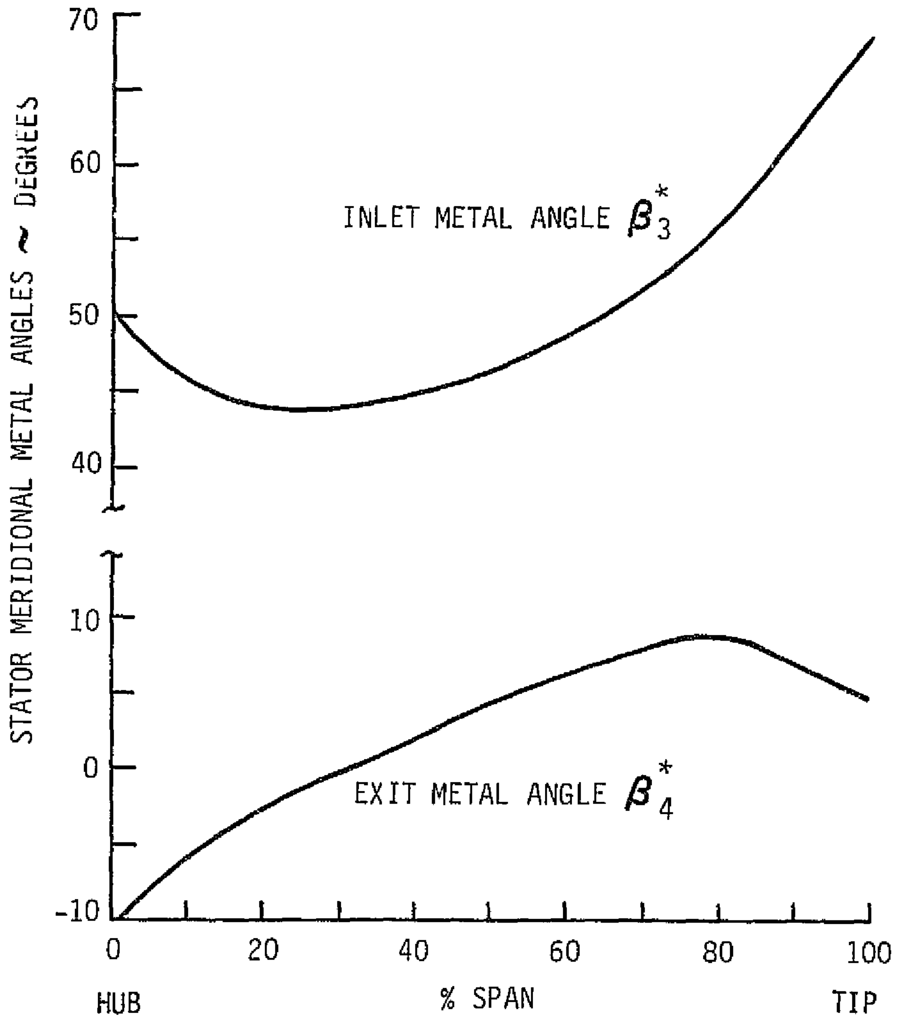


Figure 20 Stator Inlet and Exit Metal Angles Versus Span

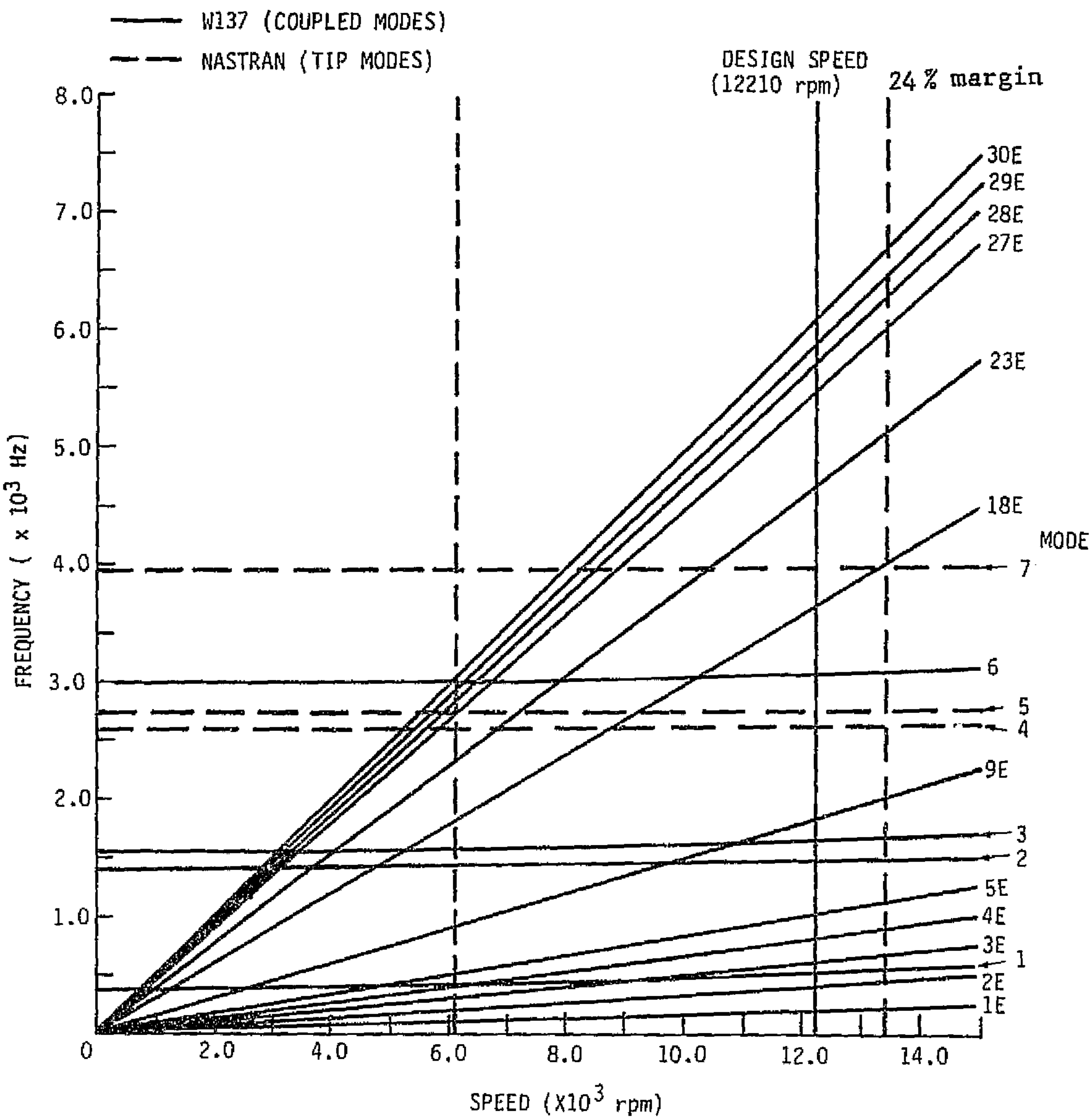


Figure 21 Blade-Disk Frequency Analysis

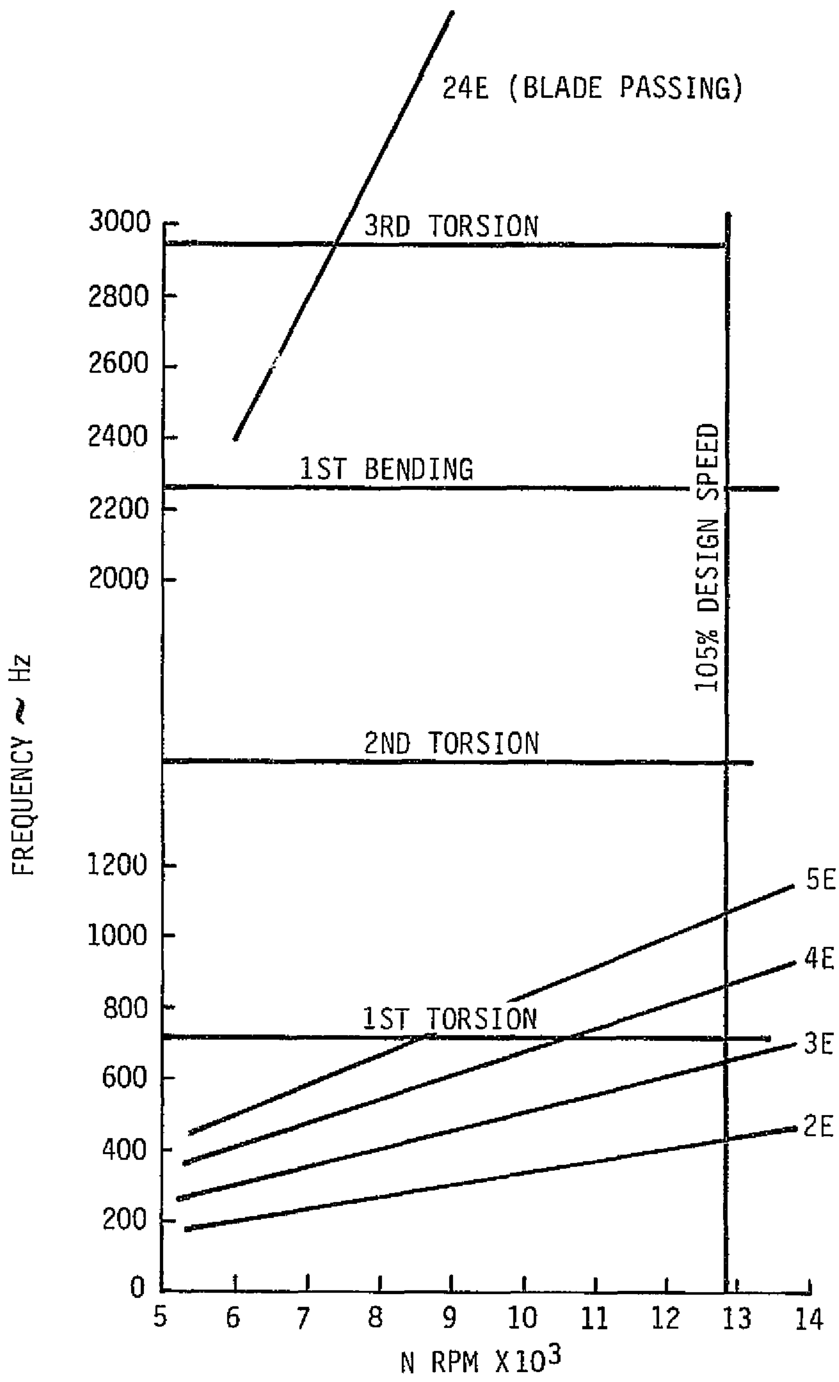


Figure 22 Stator Vane Vibration Analysis

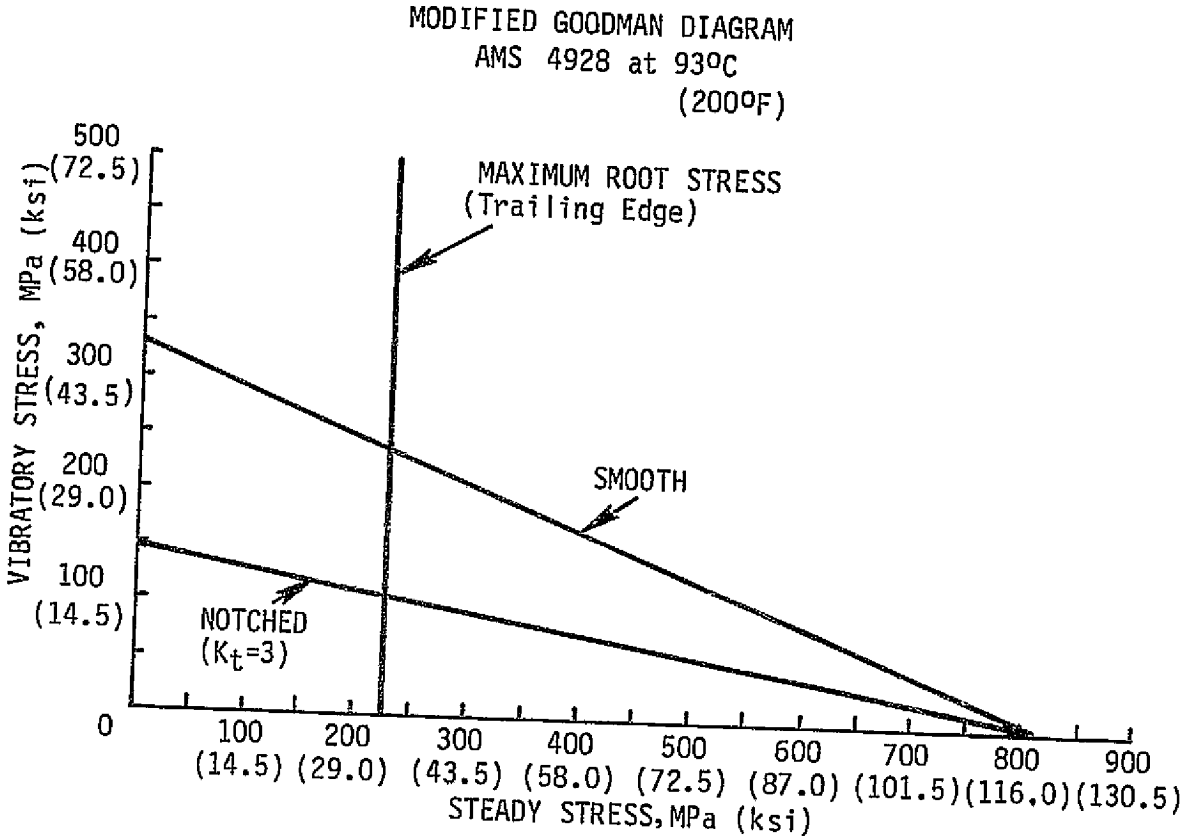


Figure 23 Modified Goodman Diagram

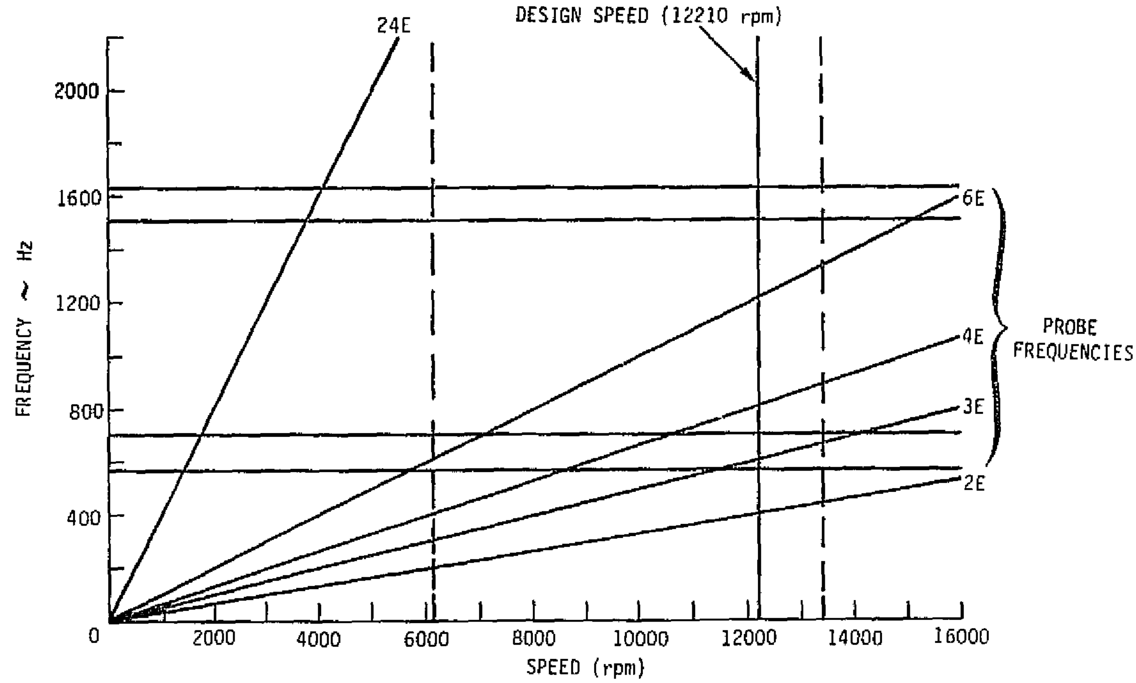


Figure 24 Probe Analysis

APPENDIX A

FLOW FIELD CALCULATION PROCEDURES

The aerodynamic flow field calculation used in this design assumes axisymmetric flow and uses solutions of continuity, energy, and radial equilibrium equations. These equations account for streamline curvature and radial gradients of enthalpy and entropy but neglect viscous terms. Calculations were performed on stations oriented at an angle with respect to the axial direction.

$$\frac{1}{2}\ \frac{\partial V^2_m}{\partial m} \cos(\lambda - \epsilon) - \frac{V^2_m}{R_C} \sin(\lambda - \epsilon)\ \frac{V^2_\theta}{r} + \frac{1}{\rho}\ \frac{\partial p}{\partial r} = 0$$

$$R_c = \frac{\partial \epsilon}{\partial m} = \text{streamline radius of curvature}$$

Enthalpy rise across a rotor for a streamline, ψ, is given by the Euler relationship:

$$H_{Rotor} = (U_2 V_{\theta 2}) - (U_1 V_{\theta 1})\psi$$

Weight flow is calculated by the continuity equation:

$$W = 2\pi \int_{y\ root}^{y\ tip} \frac{y}{\overline{K}}\ V_m\ \frac{\sin(\lambda - \epsilon)}{\sin\lambda}\ y\ dy$$

where $\overline{K}$ is the local blockage factor and y is the length along the calculation station from the centerline to the point of interest. Values of $\overline{K}$ are determined from the continuity equation and experimentally determined values of an endwall blockage parameter, $\overline{XK}$ defined as:

$$\overline{XK} = \frac{W}{\int_{root}^{tip} \overline{\rho C_m}\ dA}$$

where $\overline{\rho C_m}$ is the mass average value in the free stream flow.

APPENDIX B

LOSS SYSTEM

ROTOR

Rotor loss was estimated using a combination of Pratt & Whitney Aircraft's multiple-circular-arc fan loss correlation and high pressure compressor rotor experience. The fan system correlates total loss (profile plus shock loss) as a function of inlet relative Mach number and span. The endwall effects on a fan are included in the total loss at spans near the I.D. and O.D. The "core" region part of the fan system was used to calculate a base level of total loss for the rotor, corresponding to a 2-D type loss obtained from cascade data normally used for multi-stage compressor standard airfoil sections. Endwall losses were then added to this base level. Figure 4 shows the resulting spanwise total loss.

In the calculation of blade channel critical area ratios (A/A*), profile loss (total minus shock loss) was applied linearly from the first covered section to the trailing edge. The shock loss was assumed to be from a normal shock situated at the first covered section of the blade passage (Figure 11). The Mach number immediately upstream of the assumed shock midway between the blades was determined by satisfying the continuity and conservation of angular momentum equations, starting with the leading edge Mach number and air angle from the streamline calculation. This free-stream flow calculation accounted for streamtube contraction and radius change. The effect of blade blockage was introduced by adjusting the free-stream area ratio, A/A*, by the ratio of blade channel width to the width of free-stream (S cos), where S is blade spacing. The resulting A/A* established the upstream shock Mach number. Although the hub streamline had a slightly subsonic leading edge Mach number, this procedure yielded a supersonic Mach number at the first covered section channel entrance. All other streamlines had supersonic leading edge Mach numbers which increased in magnitude to the first covered section where they were assumed in calculating a normal shock loss.

STATOR

Stator loss was estimated using a P&WA correlation of total loss parameter (cos /2) versus diffusion factor for MCA stators made up primarily of data from References 1, 2, 3, and 5. The correlation has different values for various span locations which include endwall losses; however, only the "core" region level (20 % to 80 % span) was used to define a base value across the entire span. A similar endwall loss, as was used for the rotor, was added to this base level, consistent with designs of HPC standard airfoils. The resulting loss curve is shown in Figure 5.

APPENDIX C

AERODYNAMIC SUMMARY

TABLES 6 AND 7

TABLE 6

ROTOR AIRFOIL AERODYNAMIC SUMMARY PRINT

RUN NO 0 SPEED CODE 0 POINT NO 0

SL	V-1 M/SEC	V-2 M/SEC	VM-1 M/SEC	VM-2 M/SEC	VΘ-1 M/SEC	VΘ-2 M/SEC	U-1 M/SEC	U-2 M/SEC	V'-1 M/SEC	V'-2 M/SEC	VΘ'-1 M/SEC	VΘ'-2 M/SEC	RHOVM-1 KG/M2 SEC	RHOVM-2 KG/M2 SEC	EPSI-1 RADIAN	EPSI-2 RADIAN	PO/PO INLET
1	182.4	298.8	182.4	200.9	0.0	221.2	263.7	274.9	320.6	208.0	-263.7	-53.7	101.70	252.64	0.0680	0.1257	1.7470
2	193.4	298.1	193.2	201.8	8.1	219.5	276.1	283.8	330.4	211.8	-268.0	-64.3	192.88	258.91	0.0405	0.1045	1.7768
3	202.1	297.7	201.5	201.9	15.6	218.8	287.5	292.2	338.4	214.8	-271.9	-73.5	201.44	263.49	0.0181	0.0861	1.8040
4	208.5	293.6	206.6	193.8	28.2	220.5	308.5	308.4	348.2	212.8	-280.3	-87.9	206.10	259.26	-0.0106	0.0527	1.8300
5	210.7	286.6	207.5	185.0	36.1	218.0	327.9	324.0	358.0	213.2	-291.8	-106.0	206.49	252.26	-0.0491	0.0223	1.8300
6	212.5	279.1	207.7	176.6	42.6	216.1	346.2	339.3	367.8	215.3	-303.6	-123.2	206.45	244.70	-0.0755	-0.0064	1.6300
7	212.4	272.9	207.2	169.6	46.9	213.8	363.5	354.4	378.4	220.3	-316.6	-140.6	205.90	238.16	-0.0985	-0.0336	1.8390
8	212.0	267.1	206.0	162.9	49.8	211.6	380.6	369.2	389.2	226.7	-330.2	-157.6	204.95	231.50	-0.1188	-0.0597	1.6330
9	210.8	261.4	204.4	156.1	51.7	209.7	396.0	384.0	400.3	234.0	-344.2	-174.3	203.51	223.84	-0.1361	-0.0843	1.8286
10	208.6	255.6	201.8	147.6	53.0	207.9	411.3	398.9	411.2	241.3	-358.3	-191.0	201.05	213.25	-0.1502	-0.1068	1.8226
11	201.9	246.3	195.0	134.7	52.3	206.2	426.4	414.3	421.9	247.9	-374.1	-208.1	193.72	195.28	-0.1595	-0.1263	1.8049
12	197.0	238.3	192.3	124.1	51.9	203.5	433.9	422.3	427.6	251.6	-382.9	-218.9	188.48	179.79	-0.1603	-0.1333	1.7805
13	190.6	224.4	184.2	105.8	49.0	197.9	441.5	431.3	433.6	256.2	-392.5	-233.4	181.67	153.09	-0.1541	-0.1361	1.7350

SL	B-1 DEGREE	B-2 DEGREE	B'-1 DEGREE	B'-2 DEGREE	M-1	M-2	M'-1	M'-2	INCS DEGREE	INCM DEGREE	DEV DEGREE	TURN DEGREE	D FAC	OMEGA-B TOTAL	LOSS-P TOTAL	PO2/PO1	%EFF-A TOTAL	%EFF-P TOTAL
1	0.0	47.8	55.23	15.00	0.5521	0.8546	0.9704	0.5948	-5.14	1.23	19.20	40.23	0.5593	0.1124	0.0321	1.8530	91.73	92.41
2	2.4	47.5	54.16	17.73	0.5874	0.8535	1.0036	0.6064	-2.61	3.66	14.37	36.44	0.5553	0.0997	0.0267	1.8450	92.19	92.83
3	4.4	47.4	53.44	20.05	0.6157	0.8528	1.0313	0.6154	-1.56	4.53	11.62	33.40	0.5528	0.0885	0.0257	1.8407	92.71	93.30
4	7.8	48.7	53.62	24.43	0.6370	0.8396	1.0628	0.6086	-0.74	5.06	9.67	29.18	0.5667	0.0731	0.0214	1.8487	93.64	94.17
5	9.9	49.7	54.59	29.80	0.6441	0.8155	1.0947	0.6082	-0.36	5.29	8.88	24.79	0.5723	0.0632	0.0183	1.8458	94.21	94.68
6	11.6	50.7	55.63	34.82	0.6486	0.7939	1.1253	0.6125	-0.28	4.98	8.33	20.81	0.5744	0.0599	0.0169	1.8428	94.25	94.72
7	12.7	51.5	56.81	39.54	0.6499	0.7739	1.1577	0.6246	-0.28	4.57	7.96	17.27	0.5709	0.0607	0.0166	1.8415	93.92	94.42
8	13.6	52.3	58.03	43.89	0.6485	0.7549	1.1907	0.6408	-0.21	4.34	7.50	14.14	0.5650	0.0659	0.0172	1.8415	93.17	93.73
9	14.2	53.2	59.28	47.98	0.6447	0.7362	1.2241	0.6589	-0.03	4.23	7.05	11.30	0.5586	0.0756	0.0188	1.8424	91.95	92.61
10	14.7	54.5	60.59	52.12	0.6374	0.7150	1.2564	0.6767	0.06	3.87	6.02	8.47	0.5529	0.0888	0.0238	1.8432	90.36	91.15
11	15.0	56.7	62.45	56.92	0.6153	0.6802	1.2857	0.6906	0.33	3.62	7.87	5.52	0.5511	0.1059	0.0225	1.8545	88.48	89.43
12	15.6	58.5	63.57	60.34	0.5992	0.6613	1.3007	0.6981	0.33	3.34	9.58	3.23	0.5490	0.1166	0.0227	1.8513	87.26	88.31
13	14.9	61.8	64.67	65.57	0.5764	0.6197	1.3157	0.7075	-0.21	2.54	13.05	-0.70	0.5434	0.1286	0.0212	1.8323	85.80	86.95

SL	V-1 FT/SEC	V-2 FT/SEC	VM-1 FT/SEC	VM-2 FT/SEC	VΘ-1 FT/SEC	VΘ-2 FT/SEC	U-1 FT/SEC	U-2 FT/SEC	V'-1 FT/SEC	V'-2 FT/SEC	VΘ'-1 FT/SEC	VΘ'-2 FT/SEC	RHOVM-1 LBM/FT2SEC	RHOVM-2 LBM/FT2SEC	EPSI-1 DEGREE	EPSI-2 DEGREE	PCT TE SPAN
1	598.5	980.4	598.5	659.2	0.0	725.7	865.2	902.0	1052.0	682.3	-865.2	-176.3	37.21	51.74	3.894	7.201	0.0000
2	634.4	978.2	633.9	662.2	26.6	720.0	905.9	931.1	1084.0	695.0	-879.3	-211.1	39.50	53.03	2.321	5.989	0.0568
3	662.9	976.7	661.0	662.3	51.1	717.8	943.3	958.9	1110.3	704.8	-892.2	-241.0	41.26	53.96	1.040	4.932	0.1109
4	684.1	963.2	677.8	635.9	92.4	723.5	1012.1	1011.9	1142.6	698.2	-919.8	-288.5	42.21	53.10	-1.066	3.022	0.2143
5	691.1	938.2	680.9	607.1	118.5	715.3	1075.8	1063.2	1174.7	699.7	-957.3	-347.8	42.29	51.66	-2.813	1.280	0.3142
6	695.7	915.8	681.5	579.5	139.7	709.2	1135.7	1113.3	1206.9	706.5	-996.1	-404.2	42.28	50.12	-4.324	-0.364	0.4119
7	696.9	895.4	679.7	556.4	153.7	701.5	1192.6	1162.7	1241.5	722.7	-1038.9	-461.2	42.17	48.78	-5.643	-1.927	0.5082
8	695.5	876.3	676.0	534.6	163.5	694.3	1246.9	1211.5	1277.1	743.8	-1083.4	-517.2	41.97	47.41	-6.804	-3.420	0.6033
9	691.8	857.7	670.6	512.1	169.6	688.1	1299.1	1260.0	1313.4	767.7	-1129.3	-572.0	41.68	45.65	-7.796	-4.831	0.6979
10	684.6	836.6	662.1	484.7	173.9	682.3	1349.5	1308.8	1349.3	791.9	-1175.6	-626.6	41.18	43.68	-8.609	-6.121	0.7930
11	662.5	808.1	639.9	442.1	171.5	676.5	1399.0	1359.2	1384.3	813.3	-1227.5	-682.7	39.60	40.00	-9.136	-7.225	0.8912
12	646.3	781.9	624.3	407.1	167.2	667.6	1423.6	1385.7	1403.0	825.4	-1256.4	-718.1	38.60	36.82	-9.182	-7.636	0.9428
13	625.3	736.3	604.2	347.0	160.8	649.4	1448.6	1415.0	1422.5	840.6	-1287.8	-765.6	37.21	31.35	-8.828	-7.795	1.0000

WCI/AI LBM/SEC SQFT	WCI/AI KG/SEC SQM	TO/TO INLET	PO/PO INLET	EFF-AD INLET %	EFF-P INLET %	TO2/TO1	PO2/PO1	EFF-AD ROTOR %	EFF-P ROTOR %
40.19	196.11	1.2075	1.8157	89.50	90.34	1.2075	1.8447	92.09	92.73

TABLE 6A

ROTOR AIRFOIL AERODYNAMIC SUMMARY PRINT

SL	V-1 M/SEC	V-2 M/SEC	VM-1 M/SEC	VM-2 M/SEC	VΘ-1 M/SEC	VΘ-2 M/SEC	U-1 M/SEC	U-2 M/SEC	V'-1 M/SEC	V'-2 M/SEC	VΘ'-1 M/SEC	VΘ'-2 M/SEC	RHOVM-1 KG/M2 SEC	RHOVM-2 KG/M2 SEC	EPSI-1 RADIAN	EPSI-2 RADIAN	PO/PO INLET
1																	
2																	
3																	
4																	
5																	
6	V_1	V_2	V_{m_1}	V_{m_2}	V_{θ_1}	V_{θ_2}	U_1	U_2	V'_1	V'_2	V'_{θ_1}	V'_{θ_2}	$\rho_1 V_{m_1}$	$\rho_2 V_{m_2}$	ϵ_1	ϵ_2	P_2/P_{in}
7																	
8																	
9																	
10																	
11																	
12																	
13																	

SL	B-1 DEGREE	B-2 DEGREE	B'-1 DEGREE	B'-2 DEGREE	M-1	M-2	M'-1	M'-2	INCS DEGREE	INCM DEGREE	DEV DEGREE	TURN DEGREE	D FAC	OMEGA-B TOTAL	LOSS-P TOTAL	PO2/PO1	%EFF-A TOTAL	%EFF-P TOTAL
1																		
2																		
3																		
4																		
5																		
6	β_1	β_2	β'_1	β'_2	M_1	M_2	M'_1	M'_2	i_{ss_1}	i_{m_1}	δ^o_2	$\Delta\beta'$	D	$\bar{\omega}$	$\frac{\bar{\omega}\cos\beta'_1}{2\sigma}$	P_2/P_1	$\eta_{ad_{2/1}}$	$\eta_{P_{2/1}}$
7																		
8																		
9																		
10																		
11																		
12																		
13																		

SL	V-1 FT/SEC	V-2 FT/SEC	VM-1 FT/SEC	VM-2 FT/SEC	VΘ-1 FT/SEC	VΘ-2 FT/SEC	U-1 FT/SEC	U-2 FT/SEC	V'-1 FT/SEC	V'-2 FT/SEC	VΘ'-1 FT/SEC	VΘ'-2 FT/SEC	RHOVM-1 LBM/FT2SEC	RHOVM-2 LBM/FT2SEC	EPSI-1 DEGREE	EPSI-2 DEGREE	PCT TE SPAN
1																	
2																	
3																	
4																	
5																	
6	V_1	V_2	V_{m_1}	V_{m_2}	V_{θ_1}	V_{θ_2}	U_1	U_2	V'_1	V'_2	V'_{θ_1}	V'_{θ_2}	$\rho_1 V_{m_1}$	$\rho_2 V_{m_2}$	ϵ_1	ϵ_2	% SPAN$_2$
7																	
8																	
9																	
10																	
11																	
12																	
13																	

	NC1/A1 LBM/SEC SQFT	NC1/A1 KG/SEC SQM	TO/TO INLET	PO/PO INLET	EFF-AD INLET %	EFF-P INLET %	TO2/TO1	PO2/PO1	EFF-AD ROTOR %	EFF-P ROTOR %
Spanwise Mass Averages	$W_1\sqrt{\theta_1}/\delta_1 A_1$		T_2/T_{in}	P_2/P_{in}	$\eta_{ad_{2/in}}$	$\eta_{P_{2/in}}$	T_2/T_1	P_2/P_1	$\eta_{ad_{2/1}}$	$\eta_{P_{2/1}}$

TABLE 7

STATOR AIRFOIL AERODYNAMIC SUMMARY PRINT

RUN NO 0 SPEED CODE 0 POINT NO 0

SL	V-1 M/SEC	V-2 M/SEC	VM-1 M/SEC	VM-2 M/SEC	VO-1 M/SEC	VO-2 M/SEC	RHOVM-1 KG/M2 SEC	RHOVM-2 KG/M2 SEC	PO/PO INLET	TO/TO INLET	%EFF-A TOT-INLET	%EFF-P TOT-INLET	EPSI-1 RADIAN	EPSI-2 RADIAN
1	306.4	188.5	219.7	185.7	213.6	32.3	271.07	272.40	1.6506	1.2100	73.29	75.09	0.1342	0.1612
2	308.1	200.5	222.8	198.0	212.9	31.7	278.75	294.00	1.6976	1.2073	78.69	80.21	0.1257	0.1429
3	309.6	209.4	224.6	206.8	213.2	32.5	284.59	310.37	1.7369	1.2053	83.18	84.42	0.1152	0.1269
4	308.8	217.8	220.4	214.0	216.3	40.2	283.90	325.12	1.7820	1.2048	87.57	88.53	0.0932	0.0982
5	303.7	218.1	214.2	212.5	215.3	49.2	279.77	325.27	1.7947	1.2031	89.51	90.34	0.0687	0.0715
6	298.5	217.8	207.4	210.3	214.7	56.5	274.50	323.80	1.8031	1.2024	90.60	91.34	0.0436	0.0459
7	293.4	216.8	201.1	207.7	213.6	62.2	269.39	320.97	1.8073	1.2028	90.78	91.52	0.0183	0.0209
8	288.2	215.2	194.5	204.6	212.6	66.8	263.63	316.63	1.8072	1.2044	90.06	90.85	-0.0070	-0.0039
9	282.9	212.8	187.4	200.9	211.9	70.2	256.54	310.72	1.8027	1.2074	88.39	89.30	-0.0321	-0.0290
10	276.7	208.7	178.7	195.7	211.2	72.6	246.62	301.82	1.7905	1.2112	85.71	86.83	-0.0571	-0.0549
11	268.4	200.9	166.3	186.6	210.7	75.9	230.53	284.69	1.7637	1.2180	80.69	82.16	-0.0827	-0.0830
12	261.0	192.1	156.9	175.6	208.6	76.0	217.54	267.15	1.7338	1.2204	77.23	78.91	-0.0958	-0.0985
13	248.5	175.6	142.3	157.5	203.8	77.6	197.18	237.90	1.6826	1.2200	72.81	74.71	-0.1095	-0.1162

SL	B-1 DEGREE	B-2 DEGREE	M-1	M-2	INCS DEGREE	INCM DEGREE	DEV DEGREE	TURN DEGREE	D-FAC	OMEGA-B TOTAL	LOSS-P TOTAL	PO2/ PO1	PO/PO STAGE	TO/TO STAGE	%EFF-A TOT-STG	%EFF-P TOT-STG
1	44.3	9.9	0.8796	0.5170	-6.98	-6.65	20.52	34.19	0.5858	0.1395	0.0482	0.9448	1.7507	1.2100	82.60	83.91
2	43.6	9.1	0.8865	0.5526	-6.29	-3.58	16.75	34.47	0.5548	0.1115	0.0396	0.9554	1.7628	1.2073	84.76	85.92
3	43.4	8.9	0.8924	0.5791	-4.92	-1.86	14.22	34.48	0.5330	0.0920	0.0335	0.9628	1.7723	1.2053	86.47	87.51
4	44.4	10.6	0.8898	0.6041	-2.98	0.68	12.75	33.76	0.5091	0.0652	0.0246	0.9738	1.8063	1.2048	89.25	90.10
5	45.1	13.0	0.8735	0.6055	-3.22	0.97	12.89	32.07	0.4964	0.0493	0.0192	0.9807	1.8102	1.2031	90.95	91.67
6	46.0	15.0	0.8568	0.6048	-3.83	0.82	12.70	30.92	0.4871	0.0386	0.0154	0.9853	1.8157	1.2024	91.76	92.42
7	46.7	16.7	0.8397	0.6019	-5.28	-0.19	11.83	30.07	0.4805	0.0336	0.0138	0.9876	1.8187	1.2028	91.83	92.48
8	47.5	18.1	0.8223	0.5966	-7.23	-1.76	11.48	29.47	0.4769	0.0346	0.0146	0.9876	1.8186	1.2044	91.10	91.81
9	48.5	19.3	0.8040	0.5888	-9.61	-3.79	11.17	29.24	0.4771	0.0409	0.0176	0.9858	1.8163	1.2073	89.61	90.44
10	49.8	20.4	0.7828	0.5757	-12.38	-6.25	11.78	29.43	0.4835	0.0529	0.0233	0.9824	1.8108	1.2112	87.51	88.50
11	51.7	22.2	0.7544	0.5513	-16.62	-10.26	15.13	29.51	0.4981	0.0726	0.0326	0.9772	1.8122	1.2180	84.88	86.08
12	53.1	24.0	0.7305	0.5252	-18.36	-11.89	17.95	29.09	0.5143	0.0877	0.0394	0.9738	1.8028	1.2203	83.18	84.50
13	55.1	26.3	0.6924	0.4778	-19.94	-13.39	21.57	28.80	0.5524	0.1102	0.0494	0.9698	1.7770	1.2200	81.09	82.55

SL	V-1 FT/SEC	V-2 FT/SEC	VM-1 FT/SEC	VM-2 FT/SEC	VO-1 FT/SEC	VO-2 FT/SEC	RHOVM-1 LBM/FT2SEC	RHOVM-2 LBM/FT2SEC	PCT TE SPAN	TO/TO INLET	%EFF-A TOT-INLET	%EFF-P TOT-INLET	EPSI-1 DEGREE	EPSI-2 DEGREE
1	1035.3	614.4	720.7	609.3	700.8	106.0	55.52	55.79	0.0000	1.2100	73.29	75.09	7.687	9.237
2	1011.0	657.9	730.9	649.6	698.5	104.1	57.09	60.21	0.0627	1.2073	78.69	80.21	7.205	8.189
3	1015.9	687.0	736.9	678.0	699.4	106.6	58.29	63.57	0.1207	1.2053	83.18	84.42	6.603	7.273
4	1013.2	714.5	723.1	702.2	709.7	131.9	58.14	66.59	0.2287	1.2048	87.57	88.53	5.339	5.626
5	996.3	715.6	702.7	697.2	706.3	161.4	57.30	66.62	0.3307	1.2031	89.51	90.34	3.937	4.097
6	979.5	714.6	680.5	690.1	704.5	185.5	56.22	66.32	0.4294	1.2024	90.60	91.34	2.501	2.630
7	962.5	711.5	659.7	681.6	700.9	204.0	55.17	65.74	0.5257	1.2028	90.78	91.52	1.046	1.196
8	945.6	706.1	638.3	671.3	697.7	219.0	53.99	64.85	0.6201	1.2044	90.06	90.85	-0.402	-0.226
9	928.1	698.3	614.9	659.2	695.2	230.4	52.54	63.64	0.7132	1.2074	88.39	89.30	-1.838	-1.661
10	907.7	684.8	586.2	642.1	693.1	238.1	50.51	61.82	0.8059	1.2112	85.71	86.83	-3.273	-3.146
11	880.6	659.3	545.6	610.4	691.2	249.2	47.21	58.31	0.8999	1.2180	80.69	82.16	-4.736	-4.758
12	856.3	630.3	514.7	576.1	684.3	255.9	44.55	54.71	0.9484	1.2204	77.23	78.91	-5.488	-5.643
13	815.5	576.0	467.0	516.7	668.5	254.7	40.38	48.72	1.0000	1.2200	72.81	74.71	-6.276	-6.658

NCORR INLET RPM	WCORR INLET LBM/SEC	WCORR INLET KG/SEC	TO/TO INLET	PO/PO INLET	EFF-AD INLET %	EFF-P INLET %	TO/TO STAGE	PO2/PO1	PO/PO STAGE	EFF-AD STAGE %	EFF-P STAGE %
12216.00	102.60	46.53	1.2075	1.7762	85.92	87.00	1.2075	0.9782	1.8045	88.50	89.40

TABLE 7A

STATOR AIRFOIL AERODYNAMIC SUMMARY PRINT

SL	V-1 M/SEC	V-2 M/SEC	VM-1 M/SEC	VM-2 M/SEC	VΘ-1 M/SEC	VΘ-2 M/SEC	RHOVM-1 KG/M2 SEC	RHOVM-2 KG/M2 SEC	PO/PO INLET	TO/TO INLET	%EFF-A TOT-INLET	%EFF-P TOT-INLET	EPSI-1 RADIAN	EPSI-2 RADIAN
1														
2														
3														
4														
5														
6	V_3	V_4	V_{m_3}	V_{m_4}	V_{θ_3}	V_{θ_4}	$\rho_3 V_{m_3}$	$\rho_4 V_{m_4}$	P_4/P_{in}	T_4/T_{in}	$\eta_{ad_{4/in}}$	$\eta_{p_{4/in}}$	ϵ_3	ϵ_4
7														
8														
9														
10														
11														
12														
13														

SL	B-1 DEGREE	B-2 DEGREE	M-1	M-2	INCS DEGREE	INCM DEGREE	DEV DEGREE	TURN DEGREE	D-FAC	OMEGA-B TOTAL	LOSS-P TOTAL	PO2/PO1	PO/PO STAGE	TO/TO STAGE	%EFF-A TOT-STG	%EFF-P TOT-STG
1																
2																
3																
4																
5																
6	β_3	β_4	M_3	M_4	i_{ss_3}	i_{m_3}	δ°_4	$\Delta\beta$	D	$\bar{\omega}$	$\frac{\bar{\omega}\cos\beta_4}{2\sigma}$	P_4/P_3	P_4/P_1	T_4/T_1	$\eta_{ad_{4/1}}$	$\eta_{p_{4/1}}$
7																
8																
9																
10																
11																
12																
13																

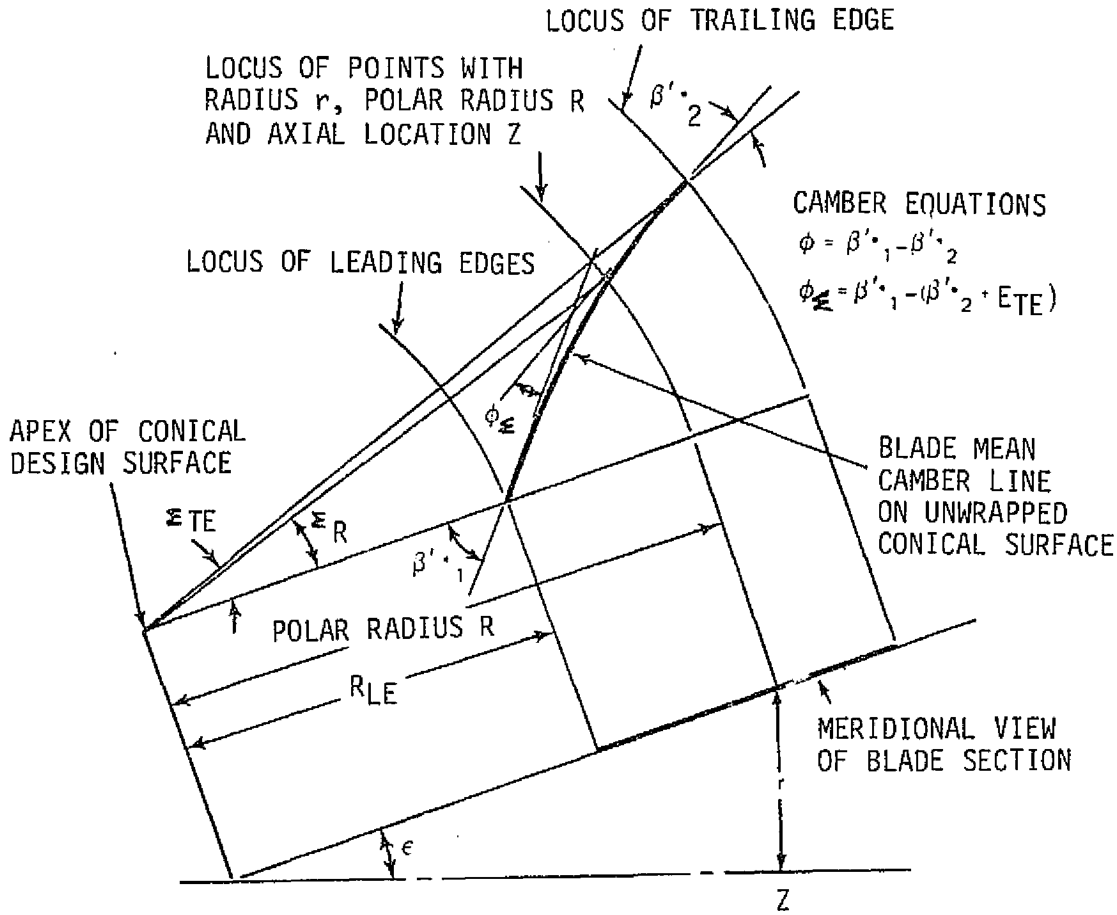
SL	V-1 FT/SEC	V-2 FT/SEC	VM-1 FT/SEC	VM-2 FT/SEC	VΘ-1 FT/SEC	VΘ-2 FT/SEC	RHOVM-1 LBM/FT2SEC	RHOVM-2 LBM/FT2SEC	PCT TE SPAN	TO/TO INLET	%EFF-A TOT-INLET	%EFF-P TOT-INLET	EPSI-1 DEGREE	EPSI-2 DEGREE
1														
2														
3														
4														
5														
6	V_3	V_4	V_{m_3}	V_{m_4}	V_{θ_3}	V_{θ_4}	$\rho_3 V_{m_3}$	$\rho_4 V_{m_4}$	$\%\ SPAN_4$	T_4/T_{in}	$\eta_{ad_{4/in}}$	$\eta_{p_{4/in}}$	ϵ_3	ϵ_4
7														
8														
9														
10														
11														
12														
13														

	NCORR INLET RPM	WCORR INLET LBM/SEC	WCORR INLET KG/SEC	TO/TO INLET	PO/PO INLET	EFF-AD INLET %	EFF-P INLET %	TO/TO STAGE	PO2/PO1	PO/PO STAGE	EFF-AD STAGE %	EFF-P STAGE %
Spanwise Mass Averages	$N/\sqrt{\theta_{in}}$	$W\sqrt{\theta_{in}}/\delta_{in}$		T_4/T_{in}	P_4/P_{in}	$\eta_{ad_{4/in}}$	$\eta_{p_{4/in}}$	T_4/T_1	P_4/P_3	P_4/P_1	$\eta_{ad_{4/1}}$	$\eta_{p_{4/1}}$

APPENDIX D

AIRFOIL GEOMETRY ON CONICAL SURFACES

TABLES 8 AND 9



MERIDIONAL VIEW AND POLAR REPRESENTATION OF BLADE MEAN-CAMBER-LINE

TABLE 8

Rotor Blade Geometry on Conical Surfaces

Diameter LE Inches	Diameter TE Inches	% Span LE	C inches	C_f inches	LER inches	TER inches	β_1* degrees	β_2* degrees	W.A. degrees	ØE degrees	$Ø_{fe}$ degrees	$\bar{\epsilon}$ degrees	E degrees	t/c_{max}	Location t/c max (% C)	a/c	σ
16.24	16.93	0	3.676	1.530	.0114	.01092	54.006	-4.200	13.06	56.87	14.10	6.153	1.332	.0850	55.0	.544	1.6934
17.01	17.47	7.0	3.728	1.607	.0106	.01025	50.476	-3.300	12.76	46.27	11.45	4.096	.909	.0831	55.7	.551	1.6519
17.71	17.98	13.4	3.775	1.677	.0099	.00961	48.900	8.345	12.37	40.01	10.61	2.433	.546	.0813	56.3	.552	1.6157
18.99	18.97	25.2	3.861	1.820	.0091	.00903	48.559	14.599	11.72	34.02	9.00	-.263	-.061	.0781	57.5	.565	1.5538
20.19	19.92	36.0	3.941	1.988	.0090	.00900	49.291	20.725	11.40	29.16	7.73	-2.436	-.595	.0750	58.6	.581	1.5012
21.31	20.86	46.3	4.016	2.143	.0090	"	50.635	26.311	10.57	25.41	6.53	-4.252	-1.082	.0689	59.6	.599	1.4551
22.37	21.79	56.0	4.087	2.282	.0090	"	52.218	31.400	9.73	22.34	5.44	-5.768	-1.520	.0631	60.6	.615	1.4142
23.39	22.71	65.3	4.136	2.445	.0090	"	53.667	36.225	9.13	19.35	4.37	-7.102	-1.912	.0573	61.5	.637	1.3776
24.37	23.62	74.2	4.221	2.606	.0090	"	55.023	40.784	8.53	16.49	3.22	-8.215	-2.251	.0517	62.4	.662	1.3443
25.31	24.54	82.9	4.285	2.780	.0090	"	56.687	45.200	7.63	14.01	2.12	-9.063	-2.524	.0463	63.3	.690	1.3135
26.25	[illegible]	91.4	4.348	2.943	.0090	"	58.797	48.989	6.57	12.50	1.34	-9.536	-2.6[illegible]	.0408	64.1	.716	1.2[illegible]
26.72	[illegible]	95.7	4.379	3.020	.0090	"	60.200	50.726	6.03	12.15	.98	-9.419	-2.676	.0380	64.6	.728	1.2697
27.13	[illegible]	100.0	4.411	3.110	.0090	"	62.332	52.521	5.46	12.32	.67	-8.736	-2.509	.0350	65.00	.743	1.2543

Diameter LE Meters	Diameter TE Meters		C meters	C_f meters	LER meters	TER meters	β_1* radians	β_2* radians	W.A. radians	ØE radians	$Ø_{fe}$ radians	$\bar{\epsilon}$ radians	E radians
.4125	.4300	0	.0934	.0389	.00029	.00028	.9426	-.0733	.2279	.9926	.2461	.1074	.0232
.4321	.4437	7.0	.0947	.0408	.00027	.00026	.8810	-.0576	.2227	.8076	.1998	.0715	.0159
.4498	.4567	13.4	.0959	.0426	.00025	.00024	.0535	.1456	.2159	.6983	.1852	.0425	.0095
.4823	.4818	25.2	.0981	.0462	.00023	.00023	.8475	.2548	.2046	.5938	.1571	-.0046	-.0011
.5128	.5060	36.0	.1001	.0505	.00023	.00023	.8603	.3618	.1990	.5089	.1349	-.0425	-.0104
.5413	.5298	46.3	.1020	.0544	.00023	"	.8837	.4592	.1845	.4435	.1140	-.0742	-.0189
.5682	[illegible]	56.0	.1038	.0580	"	"	.9114	.5480	.1698	.3899	.0949	-.1010	-.0265
[illegible]	.5768	65.3	.1056	.0621	"	"	.9367	.6322	.1593	.3377	.0763	-.1240	-.0334
.6190	.5999	74.2	.1072	.0662	"	"	.9603	.7118	.1489	.2878	.0562	-.1438	-.0393
.6429	.6233	82.9	.1088	.0706	"	"	.9894	.7889	.1332	.2443	.0370	-.1582	-.0441
.6668	.6474	91.4	.1104	.0748	"	"	1.0262	.8550	.1147	.2182	.0234	-.1664	-.0469
.6787	.6604	95.7	.1112	.0767	"	"	1.0507	.8853	.1052	.2121	.0171	-.1644	-.0467
.6906	.6746	100.0	.1120	.0790	"	"	1.0879	.9167	.0953	.2150	.0117	-.1525	-.0438

TABLE 9

Stator Vane Geometry on Conical Surfaces

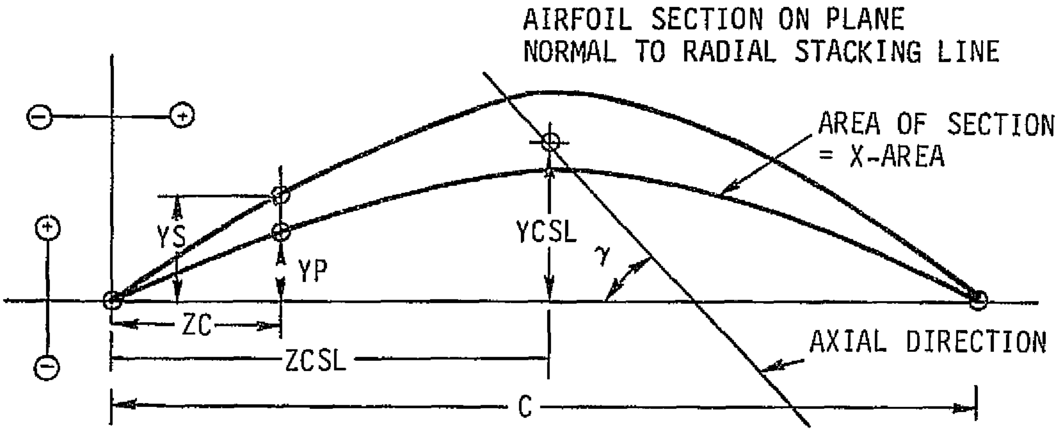
Diameter LE Inches	Diameter TE Inches	% Span LE	C inches	C_x inches	LER inches	TER inches	β_3^* degrees	β_4^* degrees	W.A. degrees	ØE degrees	ϕ_{fc} degrees	$\bar{\epsilon}$ degrees	E degrees	t/c_{max}	Location t/c max (% C)	a/c	σ
17.53	18.35	0	2.68	1.255	.008	.008	50.7	-10.66	4.97	60.23	20.98	9.69	1.13	.050	60.0	.538	1.426
18.01	18.79	5.8		1.258			47.15	- 7.61	5.69	53.70	17.76	9.32	1.06	.051	59.4	.545	1.3900
18.47	19.20	11.4		1.262			45.30	- 5.25	6.33	49.56	15.83	8.77	.99	.052	58.9	.549	1.3581
19.34	19.95	21.9		1.272			43.60	- 2.12	7.49	44.96	13.00	7.36	.84	.054	57.8	.559	1.3022
20.18	20.65	32.1		1.282			44.08	.11	8.52	43.31	12.36	5.76	.66	.056	56.8	.562	1.2531
21.00	21.33	42.0		1.291			45.06	2.28	9.48	42.29	12.88	4.10	.47	.058	55.8	.559	1.2089
21.80	21.99	51.7		1.299			46.80	4.77	10.37	41.74	14.00	2.41	.28	.060	54.8	.552	1.1685
22.59	22.64	61.2		1.307			49.16	6.53	11.19	42.55	16.03	.69	.08	.062	53.9	.540	1.1314
23.37	23.29	70.7		1.315			52.14	8.08	11.94	44.19	18.29	-1.07	-.13	.064	52.9	.528	1.0969
24.16	23.93	80.2		1.322			55.85	8.65	12.64	47.56	20.60	-2.90	-.36	.066	52.0	.522	1.0643
24.96	24.59	89.9		1.331			61.95	7.18	13.20	55.39	24.50	-4.87	-.61	.068	51.0	.518	1.0327
25.39	24.94	95.0		1.335			65.05	6.10	13.45	59.70	26.61	-5.90	-.75	.069	50.5	.516	1.0169
25.80	25.32	100.0		1.340			68.45	4.70	13.68	64.56	28.98	-6.31	-.80	.070	50.0	.514	1.0010

Diameter LE Meters	Diameter TE Meters		C meters	C_x meters	LER meters	TER meters	β_3^* radians	β_4^* radians	W.A. radians	ØE radians	ϕ_{fc} radians	$\bar{\epsilon}$ radians	E radians
.4453	.4661	0	.0681	.0319	.00020	.00020	.8849	-.1861	.0867	1.0512	.3662	.1691	.0197
.4575	.4773	5.8		.0320			.8229	-.1328	.0993	.9372	.3100	.1627	.0185
.4691	.4877	11.4		.0321			.7906	-.0916	.1105	.8650	.2763	.1531	.0173
.4912	.5067	21.9		.0323			.7624	-.0370	.1307	.7847	.2269	.1285	.0147
.5126	.5245	32.1		.0326			.7693	.0019	.1487	.7559	.2157	.1005	.0115
.5334	.5418	42.0		.0328			.7864	.0398	.1655	.7381	.2248	.0716	.0082
.5537	.5585	51.7		.0330			.8168	.0833	.1810	.7285	.2443	.0421	.0049
.5738	.5751	61.2		.0332			.8580	.1140	.1953	.7426	.2798	.0120	.0014
.5936	.5916	70.7		.0334			.9100	.1410	.2084	.7713	.3192	-.0187	-.0023
.6137	.6078	80.2		.0336			.9748	.1510	.2206	.8301	.3595	-.0506	-.0063
.6340	.6246	89.9		.0338			1.0812	.1253	.2304	.9667	.4276	-.0850	-.0106
.6449	.6335	95.0		.0339			1.1353	.1065	.2347	1.0420	.4644	-.1030	-.0131
.6553	.6431	100.0		.0340			1.1947	.0820	.2388	1.1268	.5054	-.1101	-.0140

APPENDIX E

AIRFOIL MANUFACTURING COORDINATES FOR SECTIONS NORMAL TO STACKING LINE

TABLES 10 AND 11



AIRFOIL COORDINATE DEFINITIONS FOR MANUFACTURING SECTIONS

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TABLE 10

ROTOR AIRFOIL MANUFACTURING COORDINATES

METERS			INCHES		
ZC	YP	YS	ZC	YP	YS
0.0	-0.0003	0.0003	0.0	-0.0100	0.0114
0.0003	-0.0002	0.0004	0.0161	-0.0071	0.0169
0.0030	0.0006	0.0019	0.1176	0.0236	0.0749
0.0060	0.0014	0.0035	0.2351	0.0565	0.1371
0.0090	0.0022	0.0050	0.3527	0.0886	0.1963
0.0119	0.0030	0.0064	0.4702	0.1196	0.2529
0.0149	0.0038	0.0078	0.5878	0.1494	0.3066
0.0179	0.0045	0.0091	0.7053	0.1781	0.3576
0.0209	0.0052	0.0103	0.8229	0.2055	0.4056
0.0239	0.0059	0.0114	0.9405	0.2316	0.4507
0.0269	0.0065	0.0125	1.0580	0.2562	0.4928
0.0299	0.0071	0.0135	1.1756	0.2794	0.5320
0.0328	0.0076	0.0144	1.2931	0.3010	0.5665
0.0358	0.0082	0.0153	1.4107	0.3211	0.6016
0.0388	0.0086	0.0160	1.5282	0.3391	0.6306
0.0418	0.0090	0.0166	1.6458	0.3543	0.6541
0.0448	0.0093	0.0171	1.7634	0.3661	0.6716
0.0478	0.0095	0.0174	1.8809	0.3744	0.6833
0.0508	0.0096	0.0175	1.9985	0.3791	0.6893
0.0537	0.0097	0.0175	2.1160	0.3801	0.6895
0.0567	0.0096	0.0174	2.2336	0.3774	0.6838
0.0597	0.0094	0.0171	2.3511	0.3710	0.6722
0.0627	0.0092	0.0166	2.4687	0.3607	0.6545
0.0657	0.0088	0.0160	2.5863	0.3464	0.6304
0.0687	0.0083	0.0152	2.7038	0.3279	0.5997
0.0717	0.0077	0.0143	2.8214	0.3049	0.5619
0.0746	0.0070	0.0131	2.9389	0.2773	0.5164
0.0776	0.0062	0.0117	3.0565	0.2446	0.4625
0.0806	0.0052	0.0101	3.1740	0.2066	0.3991
0.0836	0.0041	0.0083	3.2916	0.1627	0.3250
0.0866	0.0029	0.0061	3.4091	0.1122	0.2392
0.0896	0.0014	0.0035	3.5267	0.0545	0.1360
0.0923	-0.0001	0.0006	3.6352	-0.0059	0.0240
0.0926	-0.0003	0.0004	3.6443	-0.0109	0.0148

RADIUS (METERS) =	0.2103	RADIUS (INCHES) =	8.2788
CHORD (METERS) =	0.0926	CHORD (INCHES) =	3.6443
ZCSL (METERS) =	0.0487	ZCSL (INCHES) =	1.9167
YCSL (METERS) =	0.0105	YCSL (INCHES) =	0.4139
RLE (METERS) =	0.000280	RLE (INCHES) =	0.0110
RTE (METERS) =	0.000295	RTE (INCHES) =	0.0116
X-AREA(SQ.METERS) =	0.000513	X-AREA (SQ. IN.) =	0.7947
GAMMA-CHORD(RAD.) =	0.4849	GAMMA-CHORD(DEG.) =	27.78

METERS			INCHES		
ZC	YP	YS	ZC	YP	YS
0.0	-0.0002	0.0003	0.0	-0.0092	0.0102
0.0002	-0.0002	0.0004	0.0097	-0.0072	0.0146
0.0030	0.0004	0.0016	0.1199	0.0163	0.0640
0.0061	0.0010	0.0029	0.2398	0.0411	0.1161
0.0091	0.0016	0.0042	0.3597	0.0649	0.1657
0.0122	0.0022	0.0054	0.4796	0.0876	0.2129
0.0152	0.0028	0.0065	0.5995	0.1092	[illegible]
0.0183	0.0033	0.0076	0.7194	0.1298	0.2998
0.0213	0.0038	0.0086	0.8393	0.1493	0.3395
0.0244	0.0043	0.0096	0.9592	0.1676	0.3768
0.0274	0.0047	0.0105	1.0790	0.1848	0.4116
0.0305	0.0051	0.0113	1.1989	0.2008	0.4440
0.0335	0.0055	0.0120	1.3188	0.2156	0.4738
0.0365	0.0058	0.0127	1.4387	0.2293	0.5017
0.0396	0.0061	0.0134	1.5586	0.2418	0.5266
0.0426	0.0064	0.0139	1.6785	0.2524	0.5471
0.0457	0.0066	0.0143	1.7984	0.2607	0.5627
0.0487	0.0068	0.0146	1.9183	0.2664	0.5733
0.0518	0.0068	0.0147	2.0382	0.2695	0.5781
0.0548	0.0069	0.0147	2.1581	0.2699	0.5774
0.0579	0.0068	0.0145	2.2780	0.2674	0.5725
0.0609	0.0067	0.0143	2.3979	0.2622	0.5618
0.0640	0.0065	0.0139	2.5178	0.2540	0.5457
0.0670	0.0062	0.0133	2.6377	0.2429	0.5240
0.0700	0.0058	0.0126	2.7576	0.2287	0.4965
0.0731	0.0054	0.0118	2.8775	0.2115	0.4630
0.0761	0.0049	0.0107	2.9974	0.1909	0.4231
0.0792	0.0042	0.0096	3.1172	0.1671	0.3763
0.0822	0.0035	0.0082	3.2371	0.1396	0.3222
0.0853	0.0028	0.0066	3.3570	0.1085	0.2598
0.0883	0.0019	0.0048	3.4769	0.0734	0.1883
0.0914	0.0009	0.0027	3.5968	0.0341	0.1062
0.0942	-0.0002	0.0005	3.7073	-0.0060	0.0194
0.0944	-0.0002	0.0003	3.7167	-0.0094	0.0120

RADIUS (METERS) =	0.2188	RADIUS (INCHES) =	8.61[illegible]
CHORD (METERS) =	0.0944	CHORD (INCHES) =	3.7167
ZCSL (METERS) =	0.0497	ZCSL (INCHES) =	1.9577
YCSL (METERS) =	0.0084	YCSL (INCHES) =	0.3289
RLE (METERS) =	0.000261	RLE (INCHES) =	0.0103
RTE (METERS) =	0.000277	RTE (INCHES) =	0.0109
X-AREA(SQ.METERS) =	0.000508	X-AREA (SQ. IN.) =	0.7867
GAMMA-CHORD(RAD.) =	0.5261	GAMMA-CHORD(DEG.) =	30.14

TABLE 10 (Continued)

METERS ZC	METERS YP	METERS YS	INCHES ZC	INCHES YP	INCHES YS
0.0	-0.0002	0.0002	0.0	-0.0088	0.0095
0.0002	-0.0002	0.0003	0.0093	-0.0071	0.0133
0.0031	0.0003	0.0015	0.1218	0.0135	0.0593
0.0062	0.0009	0.0027	0.2436	0.0349	0.1070
0.0093	0.0014	0.0039	0.3655	0.0551	0.1522
0.0124	0.0019	0.0050	0.4873	0.0743	0.1950
0.0155	0.0023	0.0060	0.6091	0.0922	0.2353
0.0186	0.0028	0.0069	0.7309	0.1090	0.2732
0.0217	0.0032	0.0078	0.8527	0.1247	0.3086
0.0248	0.0035	0.0087	0.9745	0.1391	0.3416
0.0278	0.0039	0.0095	1.0964	0.1524	0.3722
0.0309	0.0042	0.0102	1.2182	0.1645	0.4005
0.0340	0.0045	0.0108	1.3400	0.1753	0.4264
0.0371	0.0047	0.0114	1.4618	0.1850	0.4502
0.0402	0.0049	0.0120	1.5836	0.1935	0.4713
0.0433	0.0051	0.0124	1.7055	0.2006	0.4896
0.0464	0.0052	0.0128	1.8273	0.2058	0.5033
0.0495	0.0053	0.0130	1.9491	0.2089	0.5121
0.0526	0.0053	0.0131	2.0709	0.2100	0.5160
0.0557	0.0053	0.0131	2.1927	0.2089	0.5151
0.0588	0.0052	0.0129	2.3146	0.2056	0.5092
0.0619	0.0051	0.0127	2.4364	0.2002	0.4984
0.0650	0.0049	0.0123	2.5582	0.1926	0.4827
0.0681	0.0046	0.0117	2.6800	0.1827	0.4620
0.0712	0.0043	0.0111	2.8018	0.1707	0.4360
0.0743	0.0040	0.0103	2.9236	0.1565	0.4047
0.0774	0.0036	0.0093	3.0455	0.1400	0.3679
0.0804	0.0031	0.0083	3.1673	0.1212	0.3253
0.0835	0.0025	0.0070	3.2891	0.1000	0.2765
0.0866	0.0019	0.0056	3.4109	0.0765	0.2211
0.0897	0.0013	0.0040	3.5327	0.0507	0.1587
0.0928	0.0006	0.0023	3.6546	0.0223	0.0886
0.0957	-0.0002	0.0004	3.7674	-0.0061	0.0160
0.0959	-0.0002	0.0003	3.7764	-0.0083	0.0102

RADIUS (METERS) = 0.2266
CHORD (METERS) = 0.0959
ZCSL (METERS) = 0.0506
YCSL (METERS) = 0.0072
RLE (METERS) =0.000247
RTE (METERS) =0.000252
X-AREA(SQ.METERS)=0.000505
GAMMA-CHORD(RAD.)= 0.5581

RADIUS (INCHES) = 8.9212
CHORD (INCHES) = 3.7764
ZCSL (INCHES) = 1.9917
YCSL (INCHES) = 0.2824
RLE (INCHES) = 0.0097
RTE (INCHES) = 0.0099
X-AREA (SQ. IN.) = 0.7823
GAMMA-CHORD(DEG.)= 31.98

METERS ZC	METERS YP	METERS YS	INCHES ZC	INCHES YP	INCHES YS
0.0	-0.0002	0.0002	0.0	-0.0084	0.0089
0.0002	-0.0002	0.0003	0.0090	-0.0072	0.0120
0.0032	0.0002	0.0013	0.1248	0.0083	0.0519
0.0063	0.0006	0.0024	0.2495	0.0242	0.0931
0.0095	0.0010	0.0034	0.3743	0.0392	0.1321
0.0127	0.0014	0.0043	0.4990	0.0532	0.1689
0.0158	0.0017	0.0052	0.6238	0.0664	0.2035
0.0190	0.0020	0.0060	0.7486	0.0786	0.2360
0.0222	0.0023	0.0068	0.8733	0.0898	0.2664
0.0254	0.0025	0.0075	0.9981	0.1001	0.2947
0.0285	0.0028	0.0082	1.1228	0.1095	0.3209
0.0317	0.0030	0.0088	1.2476	0.1180	0.3451
0.0349	0.0032	0.0093	1.3724	0.1255	0.3672
0.0380	0.0034	0.0098	1.4971	0.1321	0.3874
0.0412	0.0035	0.0103	1.6219	0.1378	0.4056
0.0444	0.0036	0.0107	1.7466	0.1427	0.4224
0.0475	0.0037	0.0111	1.8714	0.1463	0.4356
0.0507	0.0038	0.0113	1.9962	0.1485	0.4446
0.0539	0.0038	0.0114	2.1209	0.1490	0.4493
0.0570	0.0038	0.0114	2.2457	0.1478	0.4493
0.0602	0.0037	0.0113	2.3704	0.1450	0.4447
0.0634	0.0036	0.0111	2.4952	0.1405	0.4354
0.0665	0.0034	0.0107	2.6200	0.1345	0.4216
0.0697	0.0032	0.0102	2.7447	0.1269	0.4032
0.0729	0.0030	0.0097	2.8695	0.1177	0.3801
0.0761	0.0027	0.0089	2.9942	0.1070	0.3522
0.0792	0.0024	0.0081	3.1190	0.0948	0.3194
0.0824	0.0021	0.0072	3.2438	0.0812	0.2815
0.0856	0.0017	0.0061	3.3685	0.0661	0.2385
0.0887	0.0013	0.0048	3.4933	0.0497	0.1900
0.0919	0.0008	0.0034	3.6180	0.0318	0.1357
0.0951	0.0003	0.0019	3.7428	0.0127	0.0755
0.0980	-0.0002	0.0003	3.8588	-0.0062	0.0137
0.0982	-0.0002	0.0002	3.8676	-0.0076	0.0090

RADIUS (METERS) = 0.2411
CHORD (METERS) = 0.0982
ZCSL (METERS) = 0.0520
YCSL (METERS) = 0.0059
RLE (METERS) =0.000235
RTE (METERS) =0.000236
X-AREA(SQ.METERS)=0.000503
GAMMA-CHORD(RAD.)= 0.6168

RADIUS (INCHES) = 9.4916
CHORD (INCHES) = 3.8676
ZCSL (INCHES) = 2.0472
YCSL (INCHES) = 0.2223
RLE (INCHES) = 0.0093
RTE (INCHES) = 0.0093
X-AREA (SQ. IN.) = 0.7802
GAMMA-CHORD(DEG.)= 35.34

TABLE 10 (Continued)

METERS			INCHES		
ZC	YP	YS	ZC	YP	YS
0.0	-0.0002	0.0002	0.0	-0.0084	0.0088
0.0002	-0.0002	0.0003	0.0091	-0.0076	0.0114
0.0032	0.0001	0.0012	0.1274	0.0029	0.0457
0.0065	0.0003	0.0021	0.2548	0.0135	0.0810
0.0097	0.0006	0.0029	0.3822	0.0235	0.1143
0.0129	0.0008	0.0037	0.5096	0.0327	0.1458
0.0162	0.0010	0.0045	0.6370	0.0412	0.1753
0.0194	0.0012	0.0052	0.7644	0.0491	0.2029
0.0227	0.0014	0.0058	0.8918	0.0562	0.2287
0.0259	0.0016	0.0064	1.0192	0.0627	0.2526
0.0291	0.0017	0.0070	1.1466	0.0686	0.2748
0.0324	0.0019	0.0075	1.2739	0.0738	0.2951
0.0356	0.0020	0.0080	1.4013	0.0784	0.3138
0.0388	0.0021	0.0084	1.5287	0.0824	0.3306
0.0421	0.0022	0.0088	1.6561	0.0859	0.3459
0.0453	0.0023	0.0091	1.7835	0.0888	0.3595
0.0485	0.0023	0.0094	1.9109	0.0913	0.3717
0.0518	0.0024	0.0097	2.0383	0.0930	0.3813
0.0550	0.0024	0.0098	2.1657	0.0936	0.3869
0.0582	0.0024	0.0099	2.2931	0.0930	0.3883
0.0615	0.0023	0.0098	2.4205	0.0913	0.3853
0.0647	0.0022	0.0095	2.5479	0.0884	0.3780
0.0680	0.0021	0.0093	2.6753	0.0844	0.3666
0.0712	0.0020	0.0089	2.8027	0.0792	0.3508
0.0744	0.0019	0.0084	2.9301	0.0731	0.3307
0.0777	0.0017	0.0078	3.0575	0.0660	0.3064
0.0809	0.0015	0.0071	3.1849	0.0579	0.2777
0.0841	0.0012	0.0062	3.3123	0.0489	0.2446
0.0874	0.0010	0.0053	3.4397	0.0391	0.2069
0.0906	0.0007	0.0042	3.5671	0.0285	0.1647
0.0938	0.0004	0.0030	3.6944	0.0171	0.1176
0.0971	0.0001	0.0017	3.8218	0.0050	0.0657
0.1001	-0.0002	0.0003	3.9403	-0.0067	0.0128
0.1003	-0.0002	0.0002	3.9492	-0.0076	0.0088

RADIUS (METERS) = 0.2547
CHORD (METERS) = 0.1003
ZCSL (METERS) = 0.0531
YCSL (METERS) = 0.0047
RLE (METERS) =0.000236
RTE (METERS) =0.000235
X-AREA(SQ.METERS)=0.000502
GAMMA-CHORD(RAD.)= 0.6817

RADIUS (INCHES) =10.0288
CHORD (INCHES) = 3.9492
ZCSL (INCHES) = 2.0911
YCSL (INCHES) = 0.1866
RLE (INCHES) = 0.0093
RTE (INCHES) = 0.0093
X-AREA (SQ. IN.) = 0.7778
GAMMA-CHORD(DEG.)= 39.06

METERS			INCHES		
ZC	YP	YS	ZC	YP	YS
0.0	-0.0002	0.0002	0.0	-0.0084	0.0087
0.0002	-0.0002	0.0003	0.0092	-0.0079	0.0109
0.0033	-0.0000	0.0010	0.1298	-0.0013	0.0399
0.0066	0.0001	0.0018	0.2595	0.0054	0.0697
0.0099	0.0003	0.0025	0.3892	0.0115	0.0978
0.0132	0.0004	0.0032	0.5190	0.0172	0.1243
0.0165	0.0006	0.0038	0.6487	0.0224	0.1491
0.0198	0.0007	0.0044	0.7785	0.0271	0.1723
0.0231	0.0008	0.0049	0.9082	0.0314	0.1939
0.0264	0.0009	0.0054	1.0380	0.0353	0.2140
0.0297	0.0010	0.0059	1.1677	0.0388	0.2325
0.0330	0.0011	0.0063	1.2975	0.0419	0.2495
0.0363	0.0011	0.0067	1.4272	0.0447	0.2650
0.0396	0.0012	0.0071	1.5570	0.0471	0.2791
0.0428	0.0013	0.0074	1.6867	0.0493	0.2918
0.0461	0.0013	0.0077	1.8165	0.0512	0.3031
0.0494	0.0013	0.0080	1.9462	0.0530	0.3134
0.0527	0.0014	0.0082	2.0760	0.0545	0.3221
0.0560	0.0014	0.0083	2.2057	0.0557	0.3287
0.0593	0.0014	0.0084	2.3355	0.0561	0.3318
0.0626	0.0014	0.0084	2.4652	0.0555	0.3307
0.0659	0.0014	0.0085	2.5950	0.0541	0.3257
0.0692	0.0013	0.0080	2.7247	0.0517	0.3167
0.0725	0.0012	0.0077	2.8545	0.0485	0.3038
0.0758	0.0011	0.0073	2.9842	0.0446	0.2868
0.0791	0.0010	0.0068	3.1140	0.0400	0.2660
0.0824	0.0009	0.0061	3.2437	0.0347	0.2413
0.0857	0.0007	0.0054	3.3735	0.0288	0.2126
0.0890	0.0006	0.0046	3.5032	0.0224	[illegible]
0.0923	0.0004	0.0036	3.6330	0.0154	[illegible]
0.0956	0.0002	0.0026	3.7627	0.0081	0.1025
0.0989	0.0000	0.0015	3.8925	0.0003	0.0576
0.1019	-0.0002	0.0003	4.0133	-0.0070	0.0120
0.1022	-0.0002	0.0002	4.0222	-0.0076	0.0086

RADIUS (METERS) = 0.2678
CHORD (METERS) = 0.1022
ZCSL (METERS) = 0.0541
YCSL (METERS) = 0.0038
RLE (METERS) =0.000235
RTE (METERS) =0.000234
X-AREA(SQ.METERS)=0.000479
GAMMA-CHORD(RAD.)= 0.7459

RADIUS (INCHES) =10.5436
CHORD (INCHES) = 4.0222
ZCSL (INCHES) = 2.1285
YCSL (INCHES) = 0.1497
RLE (INCHES) = 0.0093
RTE (INCHES) = 0.0092
X-AREA (SQ. IN.) = 0.7428
GAMMA-CHORD(DEG.)= 42.74

TABLE 10 (Continued)

METERS ZC	METERS YP	METERS YS	INCHES ZC	INCHES YP	INCHES YS
0.0	-0.0002	0.0002	0.0	-0.0084	0.0086
0.0002	-0.0002	0.0003	0.0091	-0.0082	0.0104
0.0034	-0.0001	0.0009	0.1320	-0.0047	0.0349
0.0067	-0.0000	0.0015	0.2640	-0.0013	0.0599
0.0101	0.0000	0.0021	0.3960	0.0018	0.0834
0.0134	0.0001	0.0027	0.5280	0.0046	0.1056
0.0168	0.0002	0.0032	0.6599	0.0071	0.1263
0.0201	0.0002	0.0037	0.7919	0.0093	0.1457
0.0235	0.0003	0.0042	0.9239	0.0113	0.1637
0.0268	0.0003	0.0046	1.0559	0.0130	0.1804
0.0302	0.0004	0.0050	1.1879	0.0147	0.1959
0.0335	0.0004	0.0053	1.3199	0.0161	0.2100
0.0369	0.0004	0.0057	1.4519	0.0174	0.2229
0.0402	0.0005	0.0060	1.5839	0.0186	0.2347
0.0436	0.0005	0.0062	1.7159	0.0197	0.2452
0.0469	0.0005	0.0065	1.8478	0.0208	0.2547
0.0503	0.0006	0.0067	1.9798	0.0220	0.2631
0.0536	0.0006	0.0069	2.1118	0.0232	0.2706
0.0570	0.0006	0.0070	2.2438	0.0246	0.2773
0.0603	0.0007	0.0071	2.3758	0.0256	0.2813
0.0637	0.0007	0.0072	2.5078	0.0261	0.2820
0.0671	0.0007	0.0071	2.6398	0.0258	0.2799
0.0704	0.0006	0.0069	2.7718	0.0249	0.2722
0.0738	0.0006	0.0066	2.9038	0.0234	0.2618
0.0771	0.0005	0.0063	3.0357	0.0213	0.2477
0.0805	0.0005	0.0058	3.1677	0.0188	0.2302
0.0838	0.0004	0.0053	3.2997	0.0158	0.2090
0.0872	0.0003	0.0047	3.4317	0.0124	0.1844
0.0905	0.0002	0.0040	3.5637	0.0098	0.1562
0.0939	0.0001	0.0032	3.6957	0.0049	0.1245
0.0972	0.0000	0.0023	3.8277	0.0008	0.0893
0.1006	-0.0001	0.0013	3.9597	-0.0035	0.0506
0.1037	-0.0002	0.0003	4.0827	-0.0073	0.0114
0.1039	-0.0002	0.0002	4.0917	-0.0076	0.0085

RADIUS (METERS) = 0.2804
CHORD (METERS) = 0.1039
ZCSL (METERS) = 0.0550
YCSL (METERS) = 0.0030
RLE (METERS) =0.000234
RTE (METERS) =0.000232
X-AREA(SQ.METERS)=0.000455
GAMMA-CHORD(RAD.)= 0.8072

RADIUS (INCHES) =11.0406
CHORD (INCHES) = 4.0917
ZCSL (INCHES) = 2.1636
YCSL (INCHES) = 0.1163
RLE (INCHES) = 0.0092
RTE (INCHES) = 0.0091
X-AREA (SQ. IN.) = 0.7053
GAMMA-CHORD(DEG.)= 46.25

METERS ZC	METERS YP	METERS YS	INCHES ZC	INCHES YP	INCHES YS
0.0	-0.0002	0.0002	0.0	-0.0080	0.0086
0.0002	-0.0002	0.0003	0.0089	-0.0080	0.0100
0.0034	-0.0002	0.0008	0.1343	-0.0078	0.0303
0.0068	-0.0002	0.0013	0.2687	-0.0077	0.0510
0.0102	-0.0002	0.0018	0.4030	-0.0075	0.0704
0.0136	-0.0002	0.0023	0.5374	-0.0076	0.0886
0.0171	-0.0002	0.0027	0.6717	-0.0077	0.1056
0.0205	-0.0002	0.0031	0.8061	-0.0078	0.1215
0.0239	-0.0002	0.0035	0.9404	-0.0079	0.1363
0.0273	-0.0002	0.0038	1.0748	-0.0081	0.1499
0.0307	-0.0002	0.0041	1.2091	-0.0083	0.1624
0.0341	-0.0002	0.0044	1.3435	-0.0083	0.1739
0.0375	-0.0002	0.0047	1.4778	-0.0083	0.1843
0.0409	-0.0002	0.0049	1.6122	-0.0082	0.1938
0.0444	-0.0002	0.0051	1.7465	-0.0079	0.2023
0.0478	-0.0002	0.0053	1.8809	-0.0074	0.2099
0.0512	-0.0002	0.0055	2.0152	-0.0068	0.2167
0.0546	-0.0001	0.0057	2.1496	-0.0057	0.2227
0.0580	-0.0001	0.0058	2.2839	-0.0042	0.2280
0.0614	-0.0001	0.0059	2.4183	-0.0027	0.2324
0.0648	-0.0000	0.0060	2.5526	-0.0012	0.2348
0.0682	0.0000	0.0059	2.6870	0.0001	0.2338
0.0717	0.0000	0.0058	2.8213	0.0008	0.2294
0.0751	0.0000	0.0056	2.9557	0.0010	0.2216
0.0785	0.0000	0.0053	3.0900	0.0008	0.2105
0.0819	0.0000	0.0050	3.2244	0.0003	0.1960
0.0853	-0.0000	0.0045	3.3587	-0.0005	0.1784
0.0887	-0.0000	0.0040	3.4931	-0.0016	0.1577
0.0921	-0.0001	0.0034	3.6274	-0.0028	0.1339
0.0955	-0.0001	0.0027	3.7618	-0.0041	0.1070
0.0990	-0.0001	0.0020	3.8961	-0.0054	0.0771
0.1024	-0.0002	0.0011	4.0305	-0.0068	0.0443
0.1056	-0.0002	0.0003	4.1557	-0.0077	0.0110
0.1058	-0.0002	0.0002	4.1648	-0.0078	0.0066

RADIUS (METERS) = 0.2927
CHORD (METERS) = 0.1058
ZCSL (METERS) = 0.0557
YCSL (METERS) = 0.0023
RLE (METERS) =0.000228
RTE (METERS) =0.000234
X-AREA(SQ.METERS)=0.000431
GAMMA-CHORD(RAD.)= 0.8637

RADIUS (INCHES) =11.5232
CHORD (INCHES) = 4.1648
ZCSL (INCHES) = 2.1948
YCSL (INCHES) = 0.0890
RLE (INCHES) = 0.0090
RTE (INCHES) = 0.0092
X-AREA (SQ. IN.) = 0.6687
GAMMA-CHORD(DEG.)= 49.49

TABLE 10 (Continued)

METERS ZC	METERS YP	METERS YS	INCHES ZC	INCHES YP	INCHES YS
0.0	-0.0002	0.0002	0.0	-0.0086	0.0086
0.0002	-0.0002	0.0002	0.0092	-0.0088	0.0098
0.0035	-0.0003	0.0007	0.1361	-0.0117	0.0258
0.0069	-0.0004	0.0011	0.2722	-0.0147	0.0420
0.0104	-0.0004	0.0015	0.4082	-0.0177	0.0573
0.0138	-0.0005	0.0018	0.5443	-0.0206	0.0715
0.0173	-0.0006	0.0022	0.6804	-0.0234	0.0847
0.0207	-0.0007	0.0025	0.8165	-0.0260	0.0970
0.0242	-0.0007	0.0028	0.9526	-0.0284	0.1083
0.0277	-0.0008	0.0030	1.0886	-0.0306	0.1188
0.0311	-0.0008	0.0033	1.2247	-0.0327	0.1283
0.0346	-0.0009	0.0035	1.3608	-0.0344	0.1370
0.0380	-0.0009	0.0037	1.4969	-0.0359	0.1449
0.0415	-0.0009	0.0039	1.6330	-0.0370	0.1519
0.0449	-0.0010	0.0040	1.7690	-0.0377	0.1583
0.0484	-0.0010	0.0042	1.9051	-0.0380	0.1640
0.0518	-0.0010	0.0043	2.0412	-0.0379	0.1690
0.0553	-0.0009	0.0044	2.1773	-0.0372	0.1734
0.0588	-0.0009	0.0045	2.3134	-0.0359	0.1773
0.0622	-0.0009	0.0046	2.4494	-0.0339	0.1811
0.0657	-0.0008	0.0047	2.5855	-0.0314	0.1841
0.0691	-0.0007	0.0047	2.7216	-0.0287	0.1853
0.0726	-0.0007	0.0047	2.8577	-0.0261	0.1837
0.0760	-0.0006	0.0046	2.9938	-0.0239	0.1791
0.0795	-0.0006	0.0044	3.1298	-0.0220	0.1714
0.0830	-0.0005	0.0041	3.2659	-0.0202	0.1609
0.0864	-0.0005	0.0037	3.4020	-0.0186	0.1474
0.0899	-0.0004	0.0033	3.5381	-0.0170	0.1311
0.0933	-0.0004	0.0028	3.6742	-0.0154	0.1120
0.0968	-0.0003	0.0023	3.8102	-0.0137	0.0902
0.1002	-0.0003	0.0017	3.9463	-0.0119	0.0656
0.1037	-0.0003	0.0010	4.0824	-0.0100	0.0383
0.1069	-0.0002	0.0003	4.2096	-0.0078	0.0104
0.1071	-0.0002	0.0002	4.2185	-0.0077	0.0084

RADIUS (METERS) = 0.3046
CHORD (METERS) = 0.1071
ZCSL (METERS) = 0.0562
YCSL (METERS) = 0.0015
RLE (METERS) =0.000235
RTE (METERS) =0.000228
X-AREA(SQ.METERS)=0.000407
GAMMA-CHORD(RAD.)= 0.9179

RADIUS (INCHES) =11.9938
CHORD (INCHES) = 4.2185
ZCSL (INCHES) = 2.2133
YCSL (INCHES) = 0.0582
RLE (INCHES) = 0.0093
RTE (INCHES) = 0.0090
X-AREA (SQ. IN.) = 0.6308
GAMMA-CHORD(DEG.)= 52.59

METERS ZC	METERS YP	METERS YS	INCHES ZC	INCHES YP	INCHES YS
0.0	-0.0002	0.0002	0.0	-0.0087	0.0087
0.0002	-0.0002	0.0002	0.0093	-0.0091	0.0096
0.0035	-0.0004	0.0006	0.1378	-0.0139	0.0219
0.0070	-0.0005	0.0009	0.2756	-0.0190	0.0345
0.0105	-0.0006	0.0012	0.4134	-0.0238	0.0462
0.0140	-0.0007	0.0014	0.5513	-0.0285	0.0570
0.0175	-0.0008	0.0017	0.6891	-0.0330	0.0671
0.0210	-0.0009	0.0019	0.8269	-0.0372	0.0765
0.0245	-0.0010	0.0022	0.9647	-0.0410	0.0850
0.0280	-0.0011	0.0024	1.1025	-0.0445	0.0929
0.0315	-0.0012	0.0025	1.2403	-0.0477	0.1001
0.0350	-0.0013	0.0027	1.3781	-0.0504	0.1067
0.0385	-0.0013	0.0029	1.5160	-0.0527	0.1127
0.0420	-0.0014	0.0030	1.6538	-0.0545	0.1181
0.0455	-0.0014	0.0031	1.7916	-0.0557	0.1230
0.0490	-0.0014	0.0032	1.9294	-0.0564	0.1275
0.0525	-0.0014	0.0033	2.0672	-0.0565	0.1316
0.0560	-0.0014	0.0034	2.2050	-0.0559	0.1353
0.0595	-0.0014	0.0035	2.3429	-0.0545	0.1388
0.0630	-0.0013	0.0036	2.4807	-0.0525	0.1421
0.0665	-0.0013	0.0037	2.6185	-0.0495	0.1452
0.0700	-0.0012	0.0038	2.7563	-0.0458	0.1484
0.0735	-0.0011	0.0038	2.8941	-0.0418	0.1497
0.0770	-0.0010	0.0038	3.0319	-0.0380	0.1484
0.0805	-0.0009	0.0037	3.1697	-0.0344	0.1442
0.0840	-0.0008	0.0035	3.3076	-0.0309	0.1371
0.0875	-0.0007	0.0032	3.4454	-0.0276	0.1271
0.0910	-0.0006	0.0029	3.5832	-0.0243	0.1142
0.0945	-0.0005	0.0025	3.7210	-0.0211	0.0986
0.0980	-0.0005	0.0020	3.8588	-0.0178	0.0802
0.1015	-0.0004	0.0015	3.9966	-0.0145	[illegible]
0.1050	-0.0003	0.0009	4.1345	-0.0112	[illegible]
0.1083	-0.0002	0.0003	4.2634	-0.0078	0.0101
0.1085	-0.0002	0.0002	4.2723	-0.0076	0.0084

RADIUS (METERS) = 0.3164
CHORD (METERS) = 0.1085
ZCSL (METERS) = 0.0570
YCSL (METERS) = 0.0009
RLE (METERS) =0.000236
RTE (METERS) =0.000226
X-AREA(SQ.METERS)=0.000379
GAMMA-CHORD(RAD.)= 0.9701

RADIUS (INCHES) =12.4572
CHORD (INCHES) = 4.2723
ZCSL (INCHES) = 2.2441
YCSL (INCHES) = 0.0370
RLE (INCHES) = 0.0093
RTE (INCHES) = 0.0089
X-AREA (SQ. IN.) = 0.5873
GAMMA-CHORD(DEG.)= 55.58

TABLE 10 (Continued)

METERS			INCHES			METERS			INCHES		
ZC	YP	YS	ZC	YP	YS	ZC	YP	YS	ZC	YP	YS
0.0	−0.0002	0.0002	0.0	−0.0089	0.0088	0.0	−0.0002	0.0002	0.0	−0.0091	0.0090
0.0002	−0.0002	0.0002	0.0094	−0.0093	0.0095	0.0002	−0.0002	0.0002	0.0095	−0.0095	0.0096
0.0036	−0.0004	0.0005	0.1399	−0.0148	0.0192	0.0036	−0.0004	0.0005	0.1408	−0.0148	0.0183
0.0071	−0.0005	0.0007	0.2797	−0.0206	0.0289	0.0072	−0.0005	0.0007	0.2815	−0.0207	0.0268
0.0107	−0.0007	0.0010	0.4196	−0.0262	0.0378	0.0107	−0.0007	0.0009	0.4223	−0.0265	0.0345
0.0142	−0.0008	0.0012	0.5595	−0.0317	0.0461	0.0143	−0.0008	0.0011	0.5631	−0.0322	0.0414
0.0178	−0.0009	0.0014	0.6994	−0.0368	0.0536	0.0179	−0.0010	0.0012	0.7038	−0.0377	0.0477
0.0213	−0.0011	0.0015	0.8392	−0.0418	0.0606	0.0215	−0.0011	0.0014	0.8446	−0.0430	0.0534
0.0249	−0.0012	0.0017	0.9791	−0.0463	0.0669	0.0250	−0.0012	0.0015	0.9854	−0.0480	0.0585
0.0284	−0.0013	0.0018	1.1190	−0.0505	0.0727	0.0286	−0.0013	0.0016	1.1261	−0.0526	0.0632
0.0320	−0.0014	0.0020	1.2588	−0.0543	0.0780	0.0322	−0.0014	0.0017	1.2669	−0.0568	0.0673
0.0355	−0.0015	0.0021	1.3987	−0.0576	0.0829	0.0358	−0.0015	0.0018	1.4076	−0.0605	0.0711
0.0391	−0.0015	0.0022	1.5386	−0.0604	0.0874	0.0393	−0.0016	0.0019	1.5484	−0.0638	0.0746
0.0426	−0.0016	0.0023	1.6784	−0.0627	0.0914	0.0429	−0.0017	0.0020	1.6892	−0.0664	0.0777
0.0462	−0.0016	0.0024	1.8183	−0.0643	0.0952	0.0465	−0.0017	0.0020	1.8299	−0.0685	0.0807
0.0497	−0.0017	0.0025	1.9582	−0.0653	0.0987	0.0501	−0.0018	0.0021	1.9707	−0.0699	0.0835
0.0533	−0.0017	0.0026	2.0981	−0.0656	0.1020	0.0536	−0.0018	0.0022	2.1115	−0.0705	0.0862
0.0568	−0.0017	0.0027	2.2379	−0.0653	0.1052	0.0572	−0.0018	0.0023	2.2522	−0.0704	0.0889
0.0604	−0.0016	0.0028	2.3778	−0.0642	0.1083	0.0608	−0.0018	0.0023	2.3930	−0.0693	0.0917
0.0639	−0.0016	0.0028	2.5177	−0.0623	0.1113	0.0644	−0.0017	0.0024	2.5338	−0.0674	0.0946
0.0675	−0.0015	0.0029	2.6575	−0.0595	0.1143	0.0679	−0.0016	0.0025	2.6745	−0.0645	0.0977
0.0711	−0.0014	0.0030	2.7974	−0.0558	0.1175	0.0715	−0.0015	0.0026	2.8153	−0.0606	0.1011
0.0746	−0.0013	0.0031	2.9373	−0.0510	0.1207	0.0751	−0.0014	0.0027	2.9561	−0.0552	0.1054
0.0782	−0.0012	0.0031	3.0771	−0.0460	0.1224	0.0787	−0.0013	0.0028	3.0968	−0.0494	0.1086
0.0817	−0.0010	0.0031	3.2170	−0.0412	0.1212	0.0822	−0.0011	0.0028	3.2376	−0.0435	0.1096
0.0853	−0.0009	0.0030	3.3569	−0.0365	0.1172	0.0858	−0.0010	0.0027	3.3783	−0.0379	0.1076
0.0888	−0.0008	0.0028	3.4968	−0.0320	0.1103	0.0894	−0.0008	0.0026	3.5191	−0.0326	0.1027
0.0924	−0.0007	0.0026	3.6366	−0.0277	0.1004	0.0930	−0.0007	0.0024	3.6599	−0.0276	0.0948
0.0959	−0.0006	0.0022	3.7765	−0.0235	0.0878	0.0965	−0.0006	0.0021	3.8006	−0.0229	0.0839
0.0995	−0.0005	0.0018	3.9164	−0.0194	0.0723	0.1001	−0.0005	0.0018	3.9414	−0.0185	0.0699
0.1030	−0.0004	0.0014	4.0562	−0.0154	0.0539	0.1037	−0.0004	0.0013	4.0822	−0.0143	0.0528
0.1066	−0.0003	0.0008	4.1961	−0.0115	0.0326	0.1073	−0.0003	0.0008	4.2229	−0.0108	0.0325
0.1099	−0.0002	0.0003	4.3272	−0.0078	0.0099	0.1106	−0.0002	0.0003	4.3549	−0.0078	0.0099
0.1101	−0.0002	0.0002	4.3360	−0.0076	0.0084	0.1108	−0.0002	0.0002	4.3637	−0.0077	0.0085

RADIUS (METERS) = 0.3283	RADIUS (INCHES) =12.9242	RADIUS (METERS) = 0.3345	RADIUS (INCHES) =13.1682
CHORD (METERS) = 0.1101	CHORD (INCHES) = 4.3360	CHORD (METERS) = 0.1108	CHORD (INCHES) = 4.3637
ZCSL (METERS) = 0.0580	ZCSL (INCHES) = 2.2846	ZCSL (METERS) = 0.0585	ZCSL (INCHES) = 2.3023
YCSL (METERS) = 0.0006	YCSL (INCHES) = 0.0223	YCSL (METERS) = 0.0004	YCSL (INCHES) = 0.0153
RLE (METERS) =0.000239	RLE (INCHES) = 0.0094	RLE (METERS) =0.000242	RLE (INCHES) = 0.0095
RTE (METERS) =0.000224	RTE (INCHES) = 0.0088	RTE (METERS) =0.000225	RTE (INCHES) = 0.0088
X-AREA(SQ.METERS)=0.000347	X-AREA (SQ. IN.) = 0.5385	X-AREA(SQ.METERS)=0.000329	X-AREA (SQ. IN.) = 0.5104
GAMMA-CHORD(RAD.)= 1.0226	GAMMA-CHORD(DEG.)= 58.59	GAMMA-CHORD(RAD.)= 1.0543	GAMMA-CHORD(DEG.)= 60.40

TABLE 10 (Continued)

METERS			INCHES		
ZC	YP	YS	ZC	YP	YS
0.0	-0.0002	0.0002	0.0	-0.0092	0.0091
0.0002	-0.0002	0.0002	0.0096	-0.0095	0.0098
0.0036	-0.0003	0.0005	0.1418	-0.0128	0.0192
0.0072	-0.0004	0.0007	0.2836	-0.0168	0.0283
0.0108	-0.0005	0.0009	0.4254	-0.0210	0.0364
0.0144	-0.0006	0.0011	0.5671	-0.0253	0.0436
0.0180	-0.0008	0.0013	0.7089	-0.0297	0.0500
0.0216	-0.0009	0.0014	0.8507	-0.0341	0.0557
0.0252	-0.0010	0.0015	0.9925	-0.0383	0.0607
0.0288	-0.0011	0.0017	1.1343	-0.0423	0.0652
0.0324	-0.0012	0.0018	1.2761	-0.0460	0.0691
0.0360	-0.0013	0.0018	1.4179	-0.0493	0.0727
0.0396	-0.0013	0.0019	1.5597	-0.0522	0.0759
0.0432	-0.0014	0.0020	1.7014	-0.0546	0.0789
0.0468	-0.0014	0.0021	1.8432	-0.0564	0.0817
0.0504	-0.0015	0.0021	1.9850	-0.0575	0.0844
0.0540	-0.0015	0.0022	2.1268	-0.0579	0.0871
0.0576	-0.0015	0.0023	2.2686	-0.0575	0.0899
0.0612	-0.0014	0.0024	2.4104	-0.0564	0.0929
0.0648	-0.0014	0.0024	2.5522	-0.0544	0.0960
0.0684	-0.0013	0.0025	2.6939	-0.0515	0.0993
0.0720	-0.0012	0.0026	2.8357	-0.0476	0.1028
0.0756	-0.0011	0.0027	2.9775	-0.0425	0.1074
0.0792	-0.0009	0.0028	3.1193	-0.0366	0.1115
0.0828	-0.0008	0.0029	3.2611	-0.0308	0.1137
0.0864	-0.0006	0.0029	3.4029	-0.0254	0.1130
0.0900	-0.0005	0.0028	3.5447	-0.0208	0.1087
0.0936	-0.0004	0.0026	3.6865	-0.0169	0.1012
0.0972	-0.0003	0.0023	3.8282	-0.0137	0.0901
0.1008	-0.0003	0.0019	3.9700	-0.0112	0.0755
0.1044	-0.0002	0.0015	4.1118	-0.0094	0.0574
0.1080	-0.0002	0.0009	4.2536	-0.0085	0.0356
0.1114	-0.0002	0.0003	4.3855	-0.0085	0.0116
0.1116	-0.0002	0.0002	4.3954	-0.0085	0.0090

RADIUS (METERS) = 0.3411	RADIUS (INCHES) =13.4290
CHORD (METERS) = 0.1116	CHORD (INCHES) = 4.3954
ZCSL (METERS) = 0.0592	ZCSL (INCHES) = 2.3320
YCSL (METERS) = 0.0006	YCSL (INCHES) = 0.0221
RLE (METERS) =0.000244	RLE (INCHES) = 0.0096
RTE (METERS) =0.000253	RTE (INCHES) = 0.0100
X-AREA(SQ.METERS)=0.000311	X-AREA (SQ. IN.) = 0.4827
GAMMA-CHORD(RAD.)= 1.0926	GAMMA-CHORD(DEG.)= 62.60

TABLE 11

STATOR AIRFOIL MANUFACTURING COORDINATES

METERS			INCHES			METERS			INCHES		
ZC	YP	YS	ZC	YP	YS	ZC	YP	YS	ZC	YP	YS
0.0	-0.0002	0.0002	0.0	-0.0080	0.0087	0.0	-0.0002	0.0002	0.0	-0.0078	0.0085
0.0021	0.0006	0.0013	0.0845	0.0242	0.0509	0.0022	0.0005	0.0012	0.0848	0.0209	0.0480
0.0043	0.0014	0.0023	0.1689	0.0553	0.0915	0.0043	0.0012	0.0022	0.1697	0.0485	0.0858
0.0064	0.0022	0.0033	0.2534	0.0849	0.1299	0.0065	0.0019	0.0031	0.2545	0.0747	0.1215
0.0086	0.0029	0.0042	0.3379	0.1120	0.1662	0.0086	0.0025	0.0039	0.3394	0.0994	0.1551
0.0107	0.0035	0.0051	0.4223	0.1390	0.2003	0.0108	0.0031	0.0047	0.4242	0.1226	0.1868
0.0129	0.0042	0.0059	0.5068	0.1634	0.2323	0.0129	0.0037	0.0055	0.5090	0.1443	0.2164
0.0150	0.0047	0.0067	0.5913	0.1862	0.2623	0.0151	0.0042	0.0062	0.5939	0.1643	0.2440
0.0172	0.0053	0.0074	0.6758	0.2071	0.2901	0.0172	0.0046	0.0069	0.6787	0.1828	0.2697
0.0193	0.0057	0.0080	0.7602	0.2262	0.3159	0.0194	0.0051	0.0075	0.7635	0.1997	0.2935
0.0215	0.0062	0.0085	0.8447	0.2434	0.3395	0.0215	0.0055	0.0080	0.8484	0.2150	0.3152
0.0236	0.0066	0.0092	0.9292	0.2587	0.3611	0.0237	0.0058	0.0085	0.9332	0.2286	0.3351
0.0257	0.0069	0.0097	1.0136	0.2721	0.3806	0.0259	0.0061	0.0090	1.0181	0.2405	0.3531
0.0279	0.0072	0.0101	1.0981	0.2835	0.3981	0.0280	0.0064	0.0094	1.1029	0.2507	0.3694
0.0300	0.0074	0.0105	1.1626	0.2928	0.4132	0.0302	0.0066	0.0097	1.1877	0.2592	0.3834
0.0322	0.0076	0.0108	1.2670	0.2998	0.4249	0.0323	0.0067	0.0100	1.2726	0.2657	0.3946
0.0343	0.0077	0.0110	1.3515	0.3041	0.4330	0.0345	0.0069	0.0102	1.3574	0.2697	0.4023
0.0365	0.0078	0.0111	1.4360	0.3057	0.4371	0.0366	0.0069	0.0103	1.4423	0.2713	0.4063
0.0386	0.0077	0.0111	1.5204	0.3044	0.4373	0.0388	0.0069	0.0103	1.5271	0.2704	0.4066
0.0408	0.0076	0.0110	1.6049	0.3003	0.4335	0.0409	0.0068	0.0102	1.6119	0.2670	0.4032
0.0429	0.0074	0.0108	1.6894	0.2933	0.4256	0.0431	0.0066	0.0101	1.6968	0.2609	0.3960
0.0451	0.0072	0.0105	1.7739	0.2834	0.4137	0.0453	0.0064	0.0098	1.7816	0.2521	0.3849
0.0472	0.0069	0.0101	1.8583	0.2704	0.3975	0.0474	0.0061	0.0094	1.8665	0.2406	0.3698
0.0493	0.0065	0.0096	1.9428	0.2543	0.3769	0.0496	0.0057	0.0089	1.9513	0.2262	0.3505
0.0515	0.0060	0.0089	2.0273	0.2349	0.3517	0.0517	0.0053	0.0083	2.0361	0.2089	0.3269
0.0536	0.0054	0.0082	2.1117	0.2121	0.3216	0.0539	0.0048	0.0076	2.1210	0.1885	0.2987
0.0558	0.0047	0.0073	2.1962	0.1857	0.2861	0.0560	0.0042	0.0067	2.2058	0.1650	0.2656
0.0579	0.0040	0.0062	2.2807	0.1556	0.2450	0.0582	0.0035	0.0058	2.2907	0.1380	0.2273
0.0601	0.0031	0.0050	2.3651	0.1214	0.1977	0.0603	0.0027	0.0047	2.3755	0.1075	0.1831
0.0622	0.0021	0.0036	2.4496	0.0829	0.1433	0.0625	0.0019	0.0034	2.4603	0.0731	0.1327
0.0644	0.0010	0.0021	2.5341	0.0398	0.0810	0.0646	0.0009	0.0019	2.5452	0.0346	0.0750
0.0665	-0.0002	0.0003	2.6185	-0.0080	0.0099	0.0668	-0.0002	0.0002	2.6300	-0.0079	0.0095

RADIUS (METERS) = 0.2279	RADIUS (INCHES) = 8.9710	RADIUS (METERS) = 0.2338	RADIUS (INCHES) = 9.2041
CHORD (METERS) = 0.0665	CHORD (INCHES) = 2.6185	CHORD (METERS) = 0.0668	CHORD (INCHES) = 2.6300
ZCSL (METERS) = 0.0359	ZCSL (INCHES) = 1.4149	ZCSL (METERS) = 0.0359	ZCSL (INCHES) = 1.4143
YCSL (METERS) = 0.0074	YCSL (INCHES) = 0.2694	YCSL (METERS) = 0.0068	YCSL (INCHES) = 0.2693
RLE (METERS) =0.000204	RLE (INCHES) = 0.0080	RLE (METERS) =0.000203	RLE (INCHES) = 0.0080
RTE (METERS) =0.000203	RTE (INCHES) = 0.0080	RTE (METERS) =0.000204	RTE (INCHES) = 0.0080
X-AREA(SQ.METERS)=0.000156	X-AREA (SQ. IN.) = 0.2418	X-AREA(SQ.METERS)=0.000160	X-AREA (SQ. IN.) = 0.2487
GAMMA-CHORD(RAD.)= 0.3831	GAMMA-CHORD(DEG.)= 21.95	GAMMA-CHORD(RAD.)= 0.3908	GAMMA-CHORD(DEG.)= 22.39

TABLE 11 (Continued)

METERS			INCHES		
ZC	YP	YS	ZC	YP	YS
0.0	-0.0002	0.0002	0.0	-0.0078	0.0084
0.0022	0.0005	0.0012	0.0853	0.0184	0.0461
0.0043	0.0011	0.0021	0.1706	0.0436	0.0821
0.0065	0.0017	0.0029	0.2560	0.0675	0.1161
0.0087	0.0023	0.0038	0.3413	0.0901	0.1482
0.0108	0.0028	0.0045	0.4266	0.1113	0.1783
0.0130	0.0033	0.0052	0.5119	0.1311	0.2066
0.0152	0.0038	0.0059	0.5972	0.1496	0.2329
0.0173	0.0042	0.0065	0.6826	0.1665	0.2574
0.0195	0.0046	0.0071	0.7679	0.1821	0.2800
0.0217	0.0050	0.0076	0.8532	0.1962	0.3007
0.0238	0.0053	0.0081	0.9385	0.2087	0.3196
0.0260	0.0056	0.0086	1.0238	0.2198	0.3367
0.0282	0.0058	0.0089	1.1092	0.2293	0.3521
0.0303	0.0060	0.0093	1.1945	0.2373	0.3654
0.0325	0.0062	0.0096	1.2798	0.2434	0.3761
0.0347	0.0063	0.0097	1.3651	0.2471	0.3833
0.0368	0.0063	0.0098	1.4504	0.2484	0.3869
0.0390	0.0063	0.0098	1.5358	0.2475	0.3869
0.0412	0.0062	0.0097	1.6211	0.2442	0.3834
0.0433	0.0061	0.0096	1.7064	0.2384	0.3762
0.0455	0.0058	0.0093	1.7917	0.2301	0.3653
0.0477	0.0056	0.0089	1.8770	0.2193	0.3505
0.0498	0.0052	0.0084	1.9624	0.2059	0.3318
0.0520	0.0048	0.0078	2.0477	0.1898	0.3089
0.0542	0.0043	0.0072	2.1330	0.1709	0.2818
0.0563	0.0038	0.0064	2.2183	0.1491	0.2500
0.0585	0.0032	0.0054	2.3036	0.1244	0.2134
0.0607	0.0024	0.0044	2.3890	0.0964	0.1716
0.0628	0.0017	0.0031	2.4743	0.0652	0.1240
0.0650	0.0008	0.0018	2.5596	0.0305	0.0700
0.0672	-0.0002	0.0002	2.6449	-0.0078	0.0091

RADIUS (METERS) = 0.2393	RADIUS (INCHES) = 9.4202
CHORD (METERS) = 0.0672	CHORD (INCHES) = 2.6449
ZCSL (METERS) = 0.0361	ZCSL (INCHES) = 1.4196
YCSL (METERS) = 0.0065	YCSL (INCHES) = 0.2551
RLE (METERS) =0.000203	RLE (INCHES) = 0.0080
RTE (METERS) =0.000204	RTE (INCHES) = 0.0080
X-AREA(SQ.METERS)=0.000165	X-AREA (SQ. IN.) = 0.2561
GAMMA-CHORD(RAD.)= 0.4017	GAMMA-CHORD(DEG.)= 23.02

METERS			INCHES		
ZC	YP	YS	ZC	YP	YS
0.0	-0.0002	0.0002	0.0	-0.0076	0.0082
0.0022	0.0004	0.0011	0.0858	0.0152	0.0439
0.0044	0.0009	0.0020	0.1715	0.0371	0.0780
0.0065	0.0015	0.0028	0.2573	0.0578	0.1101
0.0087	0.0020	0.0036	0.3431	0.0774	0.1403
0.0109	0.0024	0.0043	0.4289	0.0958	0.1686
0.0131	0.0029	0.0050	0.5146	0.1131	0.1950
0.0153	0.0033	0.0056	0.6004	0.1291	0.2197
0.0174	0.0037	0.0062	0.6862	0.1440	0.2425
0.0196	0.0040	0.0067	0.7720	0.1577	0.2637
0.0218	0.0043	0.0072	0.8577	0.1702	0.2831
0.0240	0.0046	0.0076	0.9435	0.1815	0.3008
0.0261	0.0049	0.0080	1.0293	0.1916	0.3167
0.0283	0.0051	0.0084	1.1151	0.2005	0.3313
0.0305	0.0053	0.0087	1.2008	0.2082	0.3439
0.0327	0.0054	0.0090	1.2866	0.2143	0.3543
0.0349	0.0055	0.0092	1.3724	0.2183	0.3614
0.0370	0.0056	0.0093	1.4581	0.2201	0.3650
0.0392	0.0056	0.0093	1.5439	0.2196	0.3650
0.0414	0.0055	0.0092	1.6297	0.2168	0.3615
0.0436	0.0054	0.0090	1.7155	0.2110	0.3545
0.0458	0.0052	0.0087	1.8012	0.2044	0.3439
0.0479	0.0049	0.0084	1.8870	0.1946	0.3296
0.0501	0.0046	0.0079	1.9728	0.1825	0.3115
0.0523	0.0043	0.0074	2.0585	0.1679	0.2896
0.0545	0.0038	0.0067	2.1443	0.1509	0.2636
0.0566	0.0033	0.0059	2.2301	0.1313	0.2333
0.0588	0.0028	0.0050	2.3159	0.1090	0.1986
0.0610	0.0021	0.0040	2.4016	0.0841	0.1592
0.0632	0.0014	0.0029	2.4874	0.0564	0.1147
0.0654	0.0007	0.0016	2.5732	0.0258	0.0646
0.0675	-0.0002	0.0002	2.6590	-0.0076	0.0089

RADIUS (METERS) = 0.2495	RADIUS (INCHES) = 9.0239
CHORD (METERS) = 0.0675	CHORD (INCHES) = 2.6590
ZCSL (METERS) = 0.0363	ZCSL (INCHES) = 1.4300
YCSL (METERS) = 0.0059	YCSL (INCHES) = 0.2327
RLE (METERS) =0.000203	RLE (INCHES) = 0.0080
RTE (METERS) =0.000205	RTE (INCHES) = 0.0081
X-AREA(SQ.METERS)=0.000174	X-AREA (SQ. IN.) = 0.2695
GAMMA-CHORD(RAD.)= 0.4281	GAMMA-CHORD(DEG.)= 24.53

TABLE 11 (Continued)

METERS ZC	METERS YP	METERS YS	INCHES ZC	INCHES YP	INCHES YS
0.0	-0.0002	0.0002	0.0	-0.0076	0.0082
0.0022	0.0003	0.0011	0.0861	0.0131	0.0431
0.0044	0.0008	0.0019	0.1722	0.0329	0.0763
0.0066	0.0013	0.0027	0.2583	0.0517	0.1075
0.0088	0.0018	0.0035	0.3444	0.0693	0.1368
0.0109	0.0022	0.0042	0.4306	0.0860	0.1641
0.0131	0.0026	0.0048	0.5167	0.1015	0.1896
0.0153	0.0029	0.0054	0.6028	0.1160	0.2134
0.0175	0.0033	0.0060	0.6889	0.1295	0.2353
0.0197	0.0036	0.0065	0.7750	0.1419	0.2555
0.0219	0.0039	0.0070	0.8611	0.1533	0.2740
0.0241	0.0042	0.0074	0.9472	0.1637	0.2909
0.0262	0.0044	0.0078	1.0333	0.1730	0.3060
0.0284	0.0046	0.0081	1.1194	0.1813	0.3197
0.0306	0.0048	0.0084	1.2056	0.1888	0.3317
0.0328	0.0049	0.0087	1.2917	0.1948	0.3416
0.0350	0.0051	0.0088	1.3778	0.1990	0.3484
0.0372	0.0051	0.0089	1.4639	0.2010	0.3518
0.0394	0.0051	0.0089	1.5500	0.2009	0.3518
0.0416	0.0050	0.0088	1.6361	0.1987	0.3484
0.0437	0.0049	0.0087	1.7222	0.1942	0.3415
0.0459	0.0048	0.0084	1.8083	0.1876	0.3311
0.0481	0.0045	0.0081	1.8945	0.1787	0.3172
0.0503	0.0043	0.0076	1.9806	0.1676	0.2996
0.0525	0.0039	0.0071	2.0667	0.1542	0.2782
0.0547	0.0035	0.0064	2.1528	0.1385	0.2531
0.0569	0.0031	0.0057	2.2389	0.1204	0.2238
0.0591	0.0025	0.0048	2.3250	0.0999	0.1903
0.0612	0.0020	0.0039	2.4111	0.0769	0.1524
0.0634	0.0013	0.0028	2.4972	0.0514	0.1097
0.0656	0.0006	0.0016	2.5834	0.0232	0.0619
0.0678	-0.0002	0.0002	2.6695	-0.0074	0.0087

RADIUS (METERS) = 0.2593
CHORD (METERS) = 0.0678
ZCSL (METERS) = 0.0367
YCSL (METERS) = 0.0055
RLE (METERS) =0.000205
RTE (METERS) =0.000204
X-AREA(SQ.METERS)=0.000182
GAMMA-CHORD(RAD.)= 0.4520

RADIUS (INCHES) =10.2080
CHORD (INCHES) = 2.6695
ZCSL (INCHES) = 1.4434
YCSL (INCHES) = 0.2154
RLE (INCHES) = 0.0081
RTE (INCHES) = 0.0080
X-AREA (SQ. IN.) = 0.2822
GAMMA-CHORD(DEG.)= 25.90

METERS ZC	METERS YP	METERS YS	INCHES ZC	INCHES YP	INCHES YS
0.0	-0.0002	0.0002	0.0	-0.0075	0.0081
0.0022	0.0003	0.0011	0.0863	0.0125	0.0437
0.0044	0.0008	0.0020	0.1727	0.0316	0.0775
0.0066	0.0013	0.0028	0.2590	0.0497	0.1091
0.0088	0.0017	0.0035	0.3453	0.0666	0.1386
0.0110	0.0021	0.0042	0.4317	0.0825	0.1660
0.0132	0.0025	0.0049	0.5180	0.0973	0.1914
0.0153	0.0028	0.0055	0.6043	0.1110	0.2149
0.0175	0.0031	0.0060	0.6907	0.1237	0.2365
0.0197	0.0034	0.0065	0.7770	0.1354	0.2562
0.0219	0.0037	0.0070	0.8633	0.1460	0.2741
0.0241	0.0040	0.0074	0.9497	0.1556	0.2902
0.0263	0.0042	0.0077	1.0360	0.1642	0.3045
0.0285	0.0044	0.0081	1.1223	0.1717	0.3172
0.0307	0.0045	0.0083	1.2087	0.1784	0.3281
0.0329	0.0047	0.0086	1.2950	0.1838	0.3370
0.0351	0.0048	0.0087	1.3813	0.1875	0.3429
0.0373	0.0048	0.0088	1.4677	0.1891	0.3456
0.0395	0.0048	0.0088	1.5540	0.1888	0.3449
0.0417	0.0047	0.0087	1.6403	0.1865	0.3409
0.0439	0.0046	0.0085	1.7267	0.1820	0.3337
0.0460	0.0045	0.0082	1.8130	0.1756	0.3230
0.0482	0.0042	0.0078	1.8993	0.1671	0.3090
0.0504	0.0040	0.0074	1.9857	0.1565	0.2914
0.0526	0.0037	0.0069	2.0720	0.1438	0.2703
0.0548	0.0033	0.0062	2.1583	0.1289	0.2454
0.0570	0.0028	0.0055	2.2446	0.1119	0.2168
0.0592	0.0024	0.0047	2.3310	0.0927	0.1841
0.0614	0.0018	0.0037	2.4173	0.0712	0.1472
0.0636	0.0012	0.0027	2.5036	0.0473	0.1058
0.0658	0.0005	0.0015	2.5900	0.0211	0.0597
0.0680	-0.0002	0.0002	2.6763	-0.0074	0.0085

RADIUS (METERS) = 0.2688
CHORD (METERS) = 0.0680
ZCSL (METERS) = 0.0370
YCSL (METERS) = 0.0052
RLE (METERS) =0.000205
RTE (METERS) =0.000204
X-AREA(SQ.METERS)=0.000190
GAMMA-CHORD(RAD.)= 0.4741

RADIUS (INCHES) =10.5820
CHORD (INCHES) = 2.6763
ZCSL (INCHES) = 1.4570
YCSL (INCHES) = 0.2035
RLE (INCHES) = 0.0081
RTE (INCHES) = 0.0080
X-AREA (SQ. IN.) = 0.2941
GAMMA-CHORD(DEG.)= 27.16

TABLE 11 (Continued)

METERS			INCHES			METERS			INCHES		
ZC	YP	YS	ZC	YP	YS	ZC	YP	YS	ZC	YP	YS
0.0	-0.0002	0.0002	0.0	-0.0075	0.0082	0.0	-0.0002	0.0002	0.0	-0.0074	0.0083
0.0022	0.0003	0.0011	0.0864	0.0122	0.0446	0.0022	0.0003	0.0012	0.0865	0.0129	0.0466
0.0044	0.0008	0.0020	0.1729	0.0308	0.0791	0.0044	0.0008	0.0021	0.1730	0.0322	0.0829
0.0066	0.0012	0.0028	0.2593	0.0483	0.1111	0.0066	0.0013	0.0030	0.2595	0.0502	0.1164
0.0088	0.0016	0.0036	0.3458	0.0647	0.1409	0.0088	0.0017	0.0037	0.3460	0.0669	0.1473
0.0110	0.0020	0.0043	0.4322	0.0799	0.1684	0.0110	0.0021	0.0045	0.4325	0.0823	0.1757
0.0132	0.0024	0.0049	0.5187	0.0940	0.1938	0.0132	0.0025	0.0051	0.5191	0.0965	0.2018
0.0154	0.0027	0.0055	0.6051	0.1071	0.2171	0.0154	0.0028	0.0057	0.6056	0.1095	0.2255
0.0176	0.0030	0.0061	0.6916	0.1190	0.2383	0.0176	0.0031	0.0063	0.6921	0.1213	0.2469
0.0198	0.0033	0.0065	0.7780	0.1298	0.2575	0.0198	0.0034	0.0068	0.7786	0.1320	0.2660
0.0220	0.0035	0.0070	0.8644	0.1397	0.2747	0.0220	0.0036	0.0072	0.8651	0.1414	0.2830
0.0242	0.0038	0.0074	0.9509	0.1484	0.2900	0.0242	0.0038	0.0076	0.9516	0.1496	0.2978
0.0263	0.0040	0.0077	1.0373	0.1561	0.3034	0.0264	0.0040	0.0079	1.0381	0.1567	0.3105
0.0285	0.0041	0.0080	1.1238	0.1628	0.3150	0.0286	0.0041	0.0082	1.1246	0.1627	0.3212
0.0307	0.0043	0.0082	1.2102	0.1686	0.3247	0.0308	0.0043	0.0084	1.2111	0.1676	0.3298
0.0329	0.0044	0.0084	1.2967	0.1732	0.3324	0.0330	0.0043	0.0085	1.2976	0.1712	0.3361
0.0351	0.0045	0.0086	1.3831	0.1761	0.3373	0.0352	0.0044	0.0086	1.3841	0.1733	0.3399
0.0373	0.0045	0.0086	1.4696	0.1773	0.3391	0.0374	0.0044	0.0086	1.4706	0.1737	0.3405
0.0395	0.0045	0.0086	1.5560	0.1766	0.3377	0.0396	0.0044	0.0086	1.5572	0.1723	0.3382
0.0417	0.0044	0.0085	1.6424	0.1741	0.3331	0.0417	0.0043	0.0085	1.6437	0.1693	0.3328
0.0439	0.0043	0.0083	1.7289	0.1696	0.3254	0.0439	0.0042	0.0082	1.7302	0.1644	0.3243
0.0461	0.0041	0.0080	1.8153	0.1633	0.3145	0.0461	0.0040	0.0079	1.8167	0.1578	0.3127
0.0483	0.0039	0.0076	1.9018	0.1551	0.3002	0.0483	0.0038	0.0076	1.9032	0.1495	0.2980
0.0505	0.0037	0.0072	1.9882	0.1450	0.2827	0.0505	0.0035	0.0071	1.9897	0.1394	0.2800
0.0527	0.0034	0.0066	2.0747	0.1330	0.2618	0.0527	0.0032	0.0066	2.0762	0.1275	0.2588
0.0549	0.0030	0.0060	2.1611	0.1190	0.2373	0.0549	0.0029	0.0059	2.1627	0.1138	0.2342
0.0571	0.0026	0.0053	2.2475	0.1030	0.2093	0.0571	0.0025	0.0052	2.2492	0.0982	0.2061
0.0593	0.0022	0.0045	2.3340	0.0850	0.1774	0.0593	0.0021	0.0044	2.3357	0.0809	0.1745
0.0615	0.0017	0.0036	2.4204	0.0651	0.1416	0.0615	0.0016	0.0035	2.4222	0.0617	0.1390
0.0637	0.0011	0.0026	2.5069	0.0430	0.1016	0.0637	0.0010	0.0025	2.5088	0.0405	0.0996
0.0659	0.0005	0.0015	2.5933	0.0188	0.0573	0.0659	0.0004	0.0014	2.5953	0.0175	0.0561
0.0681	-0.0002	0.0002	2.6798	-0.0073	0.0084	0.0681	-0.0002	0.0002	2.6818	-0.0073	0.0083

RADIUS (METERS) = 0.2781	RADIUS (INCHES) =10.9480	RADIUS (METERS) = 0.2872	RADIUS (INCHES) =11.3090
CHORD (METERS) = 0.0681	CHORD (INCHES) = 2.6798	CHORD (METERS) = 0.0681	CHORD (INCHES) = 2.6818
ZCSL (METERS) = 0.0374	ZCSL (INCHES) = 1.4721	ZCSL (METERS) = 0.0378	ZCSL (INCHES) = 1.4901
YCSL (METERS) = 0.0048	YCSL (INCHES) = 0.1885	YCSL (METERS) = 0.0045	YCSL (INCHES) = 0.1782
RLE (METERS) =0.000206	RLE (INCHES) = 0.0081	RLE (METERS) =0.000207	RLE (INCHES) = 0.0082
RTE (METERS) =0.000204	RTE (INCHES) = 0.0080	RTE (METERS) =0.000204	RTE (INCHES) = 0.0080
X-AREA(SQ.METERS)=0.000197	X-AREA (SQ. IN.) = 0.3051	X-AREA(SQ.METERS)=0.000204	X-AREA (SQ. IN.) = 0.3158
GAMMA-CHORD(RAD.)= 0.5007	GAMMA-CHORD(DEG.)= 28.69	GAMMA-CHORD(RAD.)= 0.5243	GAMMA-CHORD(DEG.)= 30.04

TABLE 11 (Continued)

METERS ZC	METERS YP	METERS YS	INCHES ZC	INCHES YP	INCHES YS
0.0	-0.0002	0.0002	0.0	-0.0074	0.0083
0.0022	0.0004	0.0012	0.0864	0.0140	0.0491
0.0044	0.0009	0.0022	0.1728	0.0343	0.0875
0.0066	0.0014	0.0031	0.2592	0.0531	0.1228
0.0088	0.0018	0.0039	0.3456	0.0706	0.1553
0.0110	0.0022	0.0047	0.4319	0.0867	0.1849
0.0132	0.0026	0.0054	0.5183	0.1013	0.2119
0.0154	0.0029	0.0060	0.6047	0.1146	0.2363
0.0176	0.0032	0.0066	0.6911	0.1266	0.2581
0.0197	0.0035	0.0070	0.7775	0.1372	0.2775
0.0219	0.0037	0.0075	0.8639	0.1465	0.2944
0.0241	0.0039	0.0078	0.9503	0.1545	0.3090
0.0263	0.0041	0.0082	1.0367	0.1613	0.3213
0.0285	0.0042	0.0084	1.1231	0.1667	0.3312
0.0307	0.0043	0.0086	1.2095	0.1709	0.3389
0.0329	0.0044	0.0087	1.2959	0.1730	0.3442
0.0351	0.0044	0.0088	1.3822	0.1751	0.3469
0.0373	0.0044	0.0088	1.4686	0.1748	0.3465
0.0395	0.0044	0.0087	1.5550	0.1729	0.3433
0.0417	0.0043	0.0086	1.6414	0.1693	0.3370
0.0439	0.0042	0.0083	1.7278	0.1640	0.3278
0.0461	0.0040	0.0080	1.8142	0.1570	0.3155
0.0483	0.0038	0.0076	1.9006	0.1484	0.3001
0.0505	0.0035	0.0072	1.9870	0.1380	0.2817
0.0527	0.0032	0.0066	2.0734	0.1260	0.2600
0.0549	0.0029	0.0060	2.1598	0.1122	0.2350
0.0571	0.0025	0.0052	2.2462	0.0968	0.2066
0.0592	0.0020	0.0044	2.3326	0.0795	0.1746
0.0614	0.0015	0.0035	2.4189	0.0605	0.1390
0.0636	0.0010	0.0025	2.5053	0.0397	0.0996
0.0658	0.0004	0.0014	2.5917	0.0171	0.0560
0.0680	-0.0002	0.0002	2.6781	-0.0072	0.0083

RADIUS (METERS) = 0.2963 RADIUS (INCHES) =11.6670
CHORD (METERS) = 0.0680 CHORD (INCHES) = 2.6781
ZCSL (METERS) = 0.0385 ZCSL (INCHES) = 1.5159
YCSL (METERS) = 0.0041 YCSL (INCHES) = 0.1630
RLE (METERS) =0.000207 RLE (INCHES) = 0.0081
RTE (METERS) =0.000204 RTE (INCHES) = 0.0080
X-AREA(SQ.METERS)=0.000210 X-AREA (SQ. IN.) = 0.325
GAMMA-CHORD(RAD.)= 0.5536 GAMMA-CHORD(DEG.)= 31.72

METERS ZC	METERS YP	METERS YS	INCHES ZC	INCHES YP	INCHES YS
0.0	-0.0002	0.0002	0.0	-0.0074	0.0084
0.0022	0.0004	0.0013	0.0860	0.0158	0.0521
0.0044	0.0010	0.0024	0.1721	0.0377	0.0933
0.0066	0.0015	0.0033	0.2581	0.0579	0.1309
0.0087	0.0019	0.0042	0.3442	0.0766	0.1653
0.0109	0.0024	0.0050	0.4302	0.0938	0.1966
0.0131	0.0028	0.0057	0.5163	0.1094	0.2251
0.0153	0.0031	0.0064	0.6023	0.1236	0.2506
0.0175	0.0035	0.0069	0.6884	0.1363	0.2735
0.0197	0.0037	0.0075	0.7744	0.1475	0.2936
0.0219	0.0040	0.0079	0.8605	0.1574	0.3112
0.0240	0.0042	0.0083	0.9465	0.1658	0.3262
0.0262	0.0044	0.0086	1.0325	0.1729	0.3387
0.0284	0.0045	0.0089	1.1186	0.1785	0.3486
0.0306	0.0046	0.0090	1.2046	0.1828	0.3562
0.0328	0.0047	0.0092	1.2907	0.1857	0.3613
0.0350	0.0048	0.0092	1.3767	0.1871	0.3635
0.0372	0.0047	0.0092	1.4628	0.1869	0.3629
0.0393	0.0047	0.0091	1.5488	0.1849	0.3594
0.0415	0.0046	0.0090	1.6349	0.1812	0.3529
0.0437	0.0045	0.0087	1.7209	0.1758	0.3433
0.0459	0.0043	0.0084	1.8070	0.1686	0.3307
0.0481	0.0041	0.0080	1.8930	0.1597	0.3148
0.0503	0.0038	0.0075	1.9791	0.1489	0.2957
0.0525	0.0035	0.0069	2.0651	0.1363	0.2733
0.0546	0.0031	0.0063	2.1511	0.1218	0.2473
0.0568	0.0027	0.0055	2.2372	0.1054	0.2178
0.0590	0.0022	0.0047	2.3232	0.0870	0.1844
0.0612	0.0017	0.0037	2.4093	0.0666	0.1470
0.0634	0.0011	0.0027	2.4953	0.0441	0.1054
0.0656	0.0005	0.0015	2.5814	0.0194	0.0593
0.0678	-0.0002	0.0002	2.6674	-0.0073	0.0085

RADIUS (METERS) = 0.3055 RADIUS (INCHES) =12.0280
CHORD (METERS) = 0.0678 CHORD (INCHES) = 2.6674
ZCSL (METERS) = 0.0393 ZCSL (INCHES) = 1.5466
YCSL (METERS) = 0.0038 YCSL (INCHES) = 0.1482
RLE (METERS) =0.000207 RLE (INCHES) = 0.0082
RTE (METERS) =0.000204 RTE (INCHES) = 0.0080
X-AREA(SQ.METERS)=0.000216 X-AREA (SQ. IN.) = 0.3345
GAMMA-CHORD(RAD.)= 0.5881 GAMMA-CHORD(DEG.)= 33.69

TABLE 11 (Continued)

METERS ZC	METERS YP	METERS YS	INCHES ZC	INCHES YP	INCHES YS
0.0	-0.0002	0.0002	0.0	-0.0074	0.0089
0.0022	0.0005	0.0015	0.0857	0.0205	0.0586
0.0044	0.0012	0.0027	0.1714	0.0469	0.1059
0.0065	0.0018	0.0038	0.2571	0.0714	0.1487
0.0087	0.0024	0.0048	0.3428	0.0940	0.1878
0.0109	0.0029	0.0057	0.4284	0.1147	0.2232
0.0131	0.0034	0.0065	0.5141	0.1336	0.2552
0.0152	0.0038	0.0072	0.5998	0.1507	0.2839
0.0174	0.0042	0.0079	0.6855	0.1661	0.3095
0.0196	0.0046	0.0084	0.7712	0.1798	0.3321
0.0218	0.0049	0.0089	0.8569	0.1918	0.3517
0.0239	0.0051	0.0094	0.9426	0.2021	0.3684
0.0261	0.0054	0.0097	1.0282	0.2108	0.3824
0.0283	0.0055	0.0100	1.1139	0.2179	0.3935
0.0305	0.0057	0.0102	1.1996	0.2233	0.4018
0.0326	0.0058	0.0103	1.2853	0.2271	0.4074
0.0348	0.0058	0.0104	1.3710	0.2290	0.4100
0.0370	0.0058	0.0104	1.4567	0.2289	0.4093
0.0392	0.0058	0.0103	1.5424	0.2268	0.4054
0.0414	0.0057	0.0101	1.6280	0.2226	0.3983
0.0435	0.0055	0.0098	1.7137	0.2164	0.3878
0.0457	0.0053	0.0095	1.7994	0.2080	0.3739
0.0479	0.0050	0.0091	1.8851	0.1974	0.3564
0.0501	0.0047	0.0085	1.9708	0.1846	0.3354
0.0522	0.0043	0.0079	2.0565	0.1695	0.3105
0.0544	0.0039	0.0072	2.1422	0.1520	0.2816
0.0566	0.0034	0.0063	2.2279	0.1321	0.2486
0.0588	0.0028	0.0054	2.3135	0.1097	0.2111
0.0609	0.0022	0.0043	2.3992	0.0846	0.1688
0.0631	0.0014	0.0031	2.4849	0.0568	0.1213
0.0653	0.0007	0.0017	2.5706	0.0261	0.0681
0.0675	-0.0002	0.0002	2.6563	-0.0074	0.0090

RADIUS (METERS) = 0.3150
CHORD (METERS) = 0.0675
ZCSL (METERS) = 0.0404
YCSL (METERS) = 0.0036
RLE (METERS) =0.000269
RTE (METERS) =0.000204
X-AREA(SQ.METERS)=0.000222
GAMMA-CHORD(RAD.)= 0.6278

RADIUS (INCHES) =12.4020
CHORD (INCHES) = 2.6563
ZCSL (INCHES) = 1.5901
YCSL (INCHES) = 0.1417
RLE (INCHES) = 0.0082
RTE (INCHES) = 0.0080
X-AREA (SQ. IN.) = 0.3448
GAMMA-CHORD(DEG.)= 35.97

METERS ZC	METERS YP	METERS YS	INCHES ZC	INCHES YP	INCHES YS
0.0	-0.0002	0.0002	0.0	-0.0074	0.0091
0.0022	0.0006	0.0016	0.0855	0.0232	0.0622
0.0043	0.0013	0.0029	0.1710	0.0522	0.1129
0.0065	0.0020	0.0040	0.2565	0.0791	0.1587
0.0087	0.0026	0.0051	0.3420	0.1039	0.2004
0.0109	0.0032	0.0061	0.4275	0.1267	0.2383
0.0130	0.0037	0.0069	0.5130	0.1475	0.2722
0.0152	0.0042	0.0077	0.5985	0.1664	0.3029
0.0174	0.0047	0.0084	0.6840	0.1833	0.3300
0.0195	0.0050	0.0090	0.7695	0.1984	0.3540
0.0217	0.0054	0.0095	0.8550	0.2117	0.3747
0.0239	0.0057	0.0100	0.9405	0.2232	0.3925
0.0261	0.0059	0.0103	1.0260	0.2329	0.4072
0.0282	0.0061	0.0106	1.1116	0.2407	0.4190
0.0304	0.0063	0.0109	1.1971	0.2468	0.4279
0.0326	0.0064	0.0110	1.2825	0.2511	0.4338
0.0347	0.0064	0.0111	1.3681	0.2534	0.4365
0.0369	0.0064	0.0111	1.4536	0.2535	0.4359
0.0391	0.0064	0.0110	1.5391	0.2514	0.4319
0.0413	0.0063	0.0108	1.6246	0.2470	0.4245
0.0434	0.0061	0.0105	1.7101	0.2403	0.4136
0.0456	0.0059	0.0101	1.7956	0.2312	0.3991
0.0478	0.0056	0.0097	1.8811	0.2197	0.3808
0.0500	0.0052	0.0091	1.9666	0.2058	0.3587
0.0521	0.0048	0.0084	2.0521	0.1893	0.3325
0.0543	0.0043	0.0077	2.1376	0.1701	0.3020
0.0565	0.0038	0.0068	2.2231	0.1482	0.2669
0.0586	0.0031	0.0058	2.3086	0.1234	0.2270
0.0608	0.0024	0.0046	2.3941	0.0955	0.1819
0.0630	0.0016	0.0033	2.4796	0.0645	0.1309
0.0652	0.0008	0.0019	2.5651	0.0301	0.0736
0.0673	-0.0002	0.0002	2.6506	-0.0075	0.0093

RADIUS (METERS) = 0.3200
CHORD (METERS) = 0.0673
ZCSL (METERS) = 0.0409
YCSL (METERS) = 0.0036
RLE (METERS) =0.000210
RTE (METERS) =0.000204
X-AREA(SQ.METERS)=0.000226
GAMMA-CHORD(RAD.)= 0.6452

RADIUS (INCHES) =12.6000
CHORD (INCHES) = 2.6506
ZCSL (INCHES) = 1.6115
YCSL (INCHES) = 0.1404
RLE (INCHES) = 0.0083
RTE (INCHES) = 0.0080
X-AREA (SQ. IN.) = 0.3502
GAMMA-CHORD(DEG.)= 36.97

TABLE II (Continued)

METERS			INCHES		
ZC	YP	YS	ZC	YP	YS
0.0	-0.0002	0.0002	0.0	-0.0074	0.0095
0.0022	0.0007	0.0017	0.0854	0.0266	0.0666
0.0043	0.0015	0.0031	0.1709	0.0590	0.1214
0.0065	0.0023	0.0044	0.2563	0.0880	0.1715
0.0087	0.0030	0.0055	0.3418	0.1163	0.2157
0.0109	0.0036	0.0065	0.4272	0.1415	0.2565
0.0130	0.0042	0.0074	0.5127	0.1645	0.2927
0.0152	0.0047	0.0083	0.5981	0.1853	0.3253
0.0174	0.0052	0.0090	0.6836	0.2041	0.3542
0.0195	0.0056	0.0096	0.7690	0.2208	0.3796
0.0217	0.0060	0.0102	0.8544	0.2354	0.4017
0.0239	0.0063	0.0107	0.9399	0.2481	0.4205
0.0260	0.0066	0.0111	1.0253	0.2587	0.4360
0.0282	0.0068	0.0114	1.1108	0.2674	0.4485
0.0304	0.0070	0.0116	1.1962	0.2741	0.4577
0.0326	0.0071	0.0118	1.2816	0.2788	0.4638
0.0347	0.0071	0.0119	1.3671	0.2812	0.4666
0.0369	0.0071	0.0118	1.4525	0.2812	0.4658
0.0391	0.0071	0.0117	1.5380	0.2788	0.4615
0.0412	0.0070	0.0115	1.6234	0.2739	0.4536
0.0434	0.0068	0.0112	1.7089	0.2665	0.4419
0.0456	0.0065	0.0108	1.7943	0.2565	0.4265
0.0477	0.0062	0.0103	1.8798	0.2438	0.4071
0.0499	0.0058	0.0097	1.9652	0.2285	0.3836
0.0521	0.0053	0.0090	2.0506	0.2103	0.3558
0.0543	0.0048	0.0082	2.1361	0.1891	0.3235
0.0564	0.0042	0.0073	2.2215	0.1649	0.2862
0.0586	0.0035	0.0062	2.3070	0.1375	0.2437
0.0608	0.0027	0.0050	2.3924	0.1067	0.1955
0.0629	0.0018	0.0036	2.4779	0.0724	0.1409
0.0651	0.0009	0.0020	2.5633	0.0343	0.0792
0.0673	-0.0002	0.0002	2.6488	-0.0077	0.0096

RADIUS (METERS) = 0.3252		RADIUS (INCHES) = 12.8030	
CHORD (METERS) = 0.0673		CHORD (INCHES) = 2.6488	
ZCSL (METERS) = 0.0416		ZCSL (INCHES) = 1.6358	
YCSL (METERS) = 0.0035		YCSL (INCHES) = 0.1387	
RLE (METERS) = 0.000210		RLE (INCHES) = 0.0083	
RTE (METERS) = 0.000205		RTE (INCHES) = 0.0081	
X-AREA (SQ.METERS) = 0.000230		X-AREA (SQ. IN.) = 0.3565	
GAMMA-CHORD (RAD.) = 0.6629		GAMMA-CHORD (DEG.) = 37.98	

APPENDIX F

SYMBOLS AND DEFINITIONS

A - area - meters^2 (inches^2)

A/A* - ratio of actural area to critical area (where local Mach number is 1.0)

a' - a point on the suction surface of a blade halfway between the leading edge and the point from which a Mach wave emanates that meets the leading edge of the following blade

b - rotor semi-chord at 75 percent of span from root

c - aerodynamic chord along the flow surface - meters (inches)

D - diffusion factor

for rotor:

$$= 1 - \frac{V'_2}{V'_1} + \frac{r_2 V_{\theta 2} - r_1 V_{\theta 1}}{(r_1 + r_2)\sigma V'_1}$$

for stator:

$$= 1 - \frac{V_4}{V_3} + \frac{r_3 V_{\theta 3} - r_4 V_{\theta 4}}{(r_3 + r_4) V_3}$$

DCA - double-circular-arc

E - excitations per rotor revolution

E - angle between rays drawn to a conical design surface: one ray to the leaaing edge edge of an airfoil, the second to some points on the airfoil (see Appendix D)

H - stagnation enthalpy

i_m - incidence angle between inlet air direction and line tangent to blade mean camber line at leading edge, degrees

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i_{ss} - incidence angle between inlet air direction and line tangent to blade suction surface at leading edge, degrees

$\overline{K}$ - blockage factor, actual/effective flow area

LE - leading edge

m - unit length along meridional projection of streamline

M - Mach number

MCA - multiple-circular-arc blade

N - rotor speed, rpm

p - static pressure (psfa)

P - total or stagnation pressure (psfa)

R - distance from apex of design conical surface to point on blade - meters (inches)

R_C - streamline radius of curvature - meters (inches)

RLE - leading edge airfoil radius - meters (inches)

RTE - trailing edge airfoil radius - meters (inches)

r - radius - meters (inches)

s - blade spacing

T - temperature

t - blade maximum thickness, meters (inches)

TE - trailing edge

U - rotor tangential speed, m/sec (ft/sec)

V - air velocity

W - weight flow

WA - leading edge wedge angle

x conical	-	distance in unwrapped conical plane
Y_p	-	airfoil coordinate of pressure surface normal to chord line
Y_s	-	airfoil coordinate of suction surfce normal to chord line
Y_{ccg}	-	vertical distance to airfoil center of gravity from chord line
Y	-	length along calculation station
$Y_{conical}$	-	distance normal to x conical
Z	-	axial distance
Z*ratio	-	shroud modulus/airfoil modulus
Z_c	-	airfoil coordinate parallel to chord line
Z_{ccg}	-	horizontal distance to airfoil center of gravity from leading edge along chord line
β		absolute air angle = COT^{-1} (Vm/V_θ)
β'		relative air angle = $COT^{-1} \frac{(Vm)}{(V'\theta)}$
β^*	-	metal angle, angle between tangent to mean camber line and meridional direction
γ	-	blade chord angle, angle between chord and axial direction
$\delta°$	-	deviation angle - exit air angle minus metal angle at trailing edge
ϵ	-	angle between tangent to streamline projected on meridional plane and axial direction
$\bar{\epsilon}$		cone angle = $TAN^{-1} \frac{(r_{te} - r_{le})}{(z_{te} - z_{le})}$

η_{ad} - adiabatic efficiency

θ - circumferential direction

λ - angle of calculation station measured from axial direction

ρ - density

Σ - angle on conical surface of revolution

σ - solidity or stress

ϕ - camber angle, difference between blade angles at leading and trailing edges on conical surface

ϕ_{Σ} - camber angle, difference between blade angles at leading and trailing edges on the unwrapped conical surface

ϕ_f - front camber angle, difference between blade angles at leading edge and MCA transition point on the unwrapped conical surface

ψ - total amount of chord line twist displacement, degrees (radians)

$\bar{\omega}$ - total pressure loss coefficient,

$$\frac{P'_1\left[\frac{T'_2}{T'_1}\right]^{\frac{\gamma}{\gamma-1}} - P'_2}{P'_1 - P_1} \quad \text{(rotors)}$$

γ = Ratio Of Specific Heats

$$\frac{P_2 - P_3}{P_2 - p_3} \quad \text{(stators)}$$

Subscripts

av - average

ad - adiabatic

E - refers to camber definition which include epse angle E

APPENDIX F (Cont'd)

f	-	front
Ef	-	refers to front camber definitions which include epse angle E
in	-	inlet
LE	-	leading edge
m	-	meridional (velocity); mean camber line (angle)
p	-	profile (loss); polytropic (efficiency)
ss	-	suction surface
sh	-	shock
t	-	transition
TE	-	trailing edge
z	-	axial component
1	-	station into rotor along leading edge
2	-	station out of rotor along trailing edge
3	-	station into stator along leading edge
4	-	station out of stator along trailing edge

Superscripts

'	-	relative to rotor
*	-	designates blade metal angle
o	-	degrees of arc or temperature

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