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COMPUTATIONAL FLUID DYNAMICS STUDY OF THE VARIABLE-PITCH SPLIT-BLADE FAN CONCEPT

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LIST OF SYMBOLS

Symbols

A	flow area
c	chord
cp	specific heat
Fp	pressure forces
Fs	stream thrust
g	gap
H	enthalpy
H_T	total enthalpy
K_E	kinetic energy
$\dot{m}$	mass flow
M	mach number
MV	momentum
P	static pressure
P_T	total pressure
R	gas constant
T	static temperative
T_T	total temperative
V	velocity
V_c	corrected velocity
W	work
W_c	corrected weight flow
x	abscissa; parallel to axis

LIST OF SYMBOLS (concluded)

y	ordinance, normal to axis
α	flow angle
β_c	cord angle
ζ	normalized blade abscissa
η	normalized blade ordinate
η_c	fan efficiency
θ	blade surface angle
ϱ	static density

Subscripts

1	upstream condition, leading edge
2	downstream conditions, trailing edge
R	rotor conditions
u	upper surface
l	lower surface
x	x–direction
y	y–direction

Superscripts

$\bar{( )}$	average conditions
$( )'$	relative flow conditions, as seen by observer on blade row
$\vec{( )}$	vector quantity

COMPUTATIONAL FLUID DYNAMICS STUDY OF THE VARIABLE-PITCH SPLIT-BLADE FAN CONCEPT

SUMMARY

A computational fluid dynamics study was conducted to evaluate the feasibility of the variable-pitch split-blade supersonic fan concept. This fan configuration was conceived as a means to enable a supersonic fan to switch from the supersonic through-flow type of operation at high speeds to a conventional fan with subsonic inflow and outflow at low speeds. During this off-design, low-speed mode of operation the fan would operate with a substantial static pressure rise across the blade row like a conventional transonic fan; the front (variable-pitch) blade would be aligned with the incoming flow; and the aft blade would remain fixed in the position set by the supersonic design conditions. Because of these geometrical features, this low speed configuration would inherently have a large amount of turning and, thereby, would have the potential for a large total pressure increase in a single stage. Such a high-turning blade configuration is prone to flow separation; it was hoped that the channeling of the flow between the blades would act like a slotted wing and help alleviate this problem.

A total of 20 blade configurations representing various supersonic and transonic configurations were evaluated using a Navier Stokes CFD program called ADAPTNS because of its adaptive grid features. The flow fields generated by this computational procedure were processed by another data reduction program which calculated average flow properties and simulated fan performance. These results were employed to make quantitative comparisons and evaluations of blade performance.

The supersonic split-blade configurations generated performance comparable to a single-blade supersonic, through-flow fan configuration. Simulated rotor total pressure ratios of the order of 2.5 or better were achieved for Mach 2.0 inflow conditions. The corresponding fan efficiencies were approximately 75% or better.

The transonic split-blade configurations having large amounts of turning were able to generate large amounts of total turning and achieve simulated total pressure ratios of 3.0 or better with subsonic inflow conditions. These configurations had large losses and low fan efficiencies in the 70's %. They had large separated regions and low velocity wakes. Additional turning and diffusion of this flow in a subsequent stator row would probably be very inefficient. The high total pressure ratios indicated by the rotor performance would be substantially reduced by the stators, and the stage efficiency would be substantially lower. Such performance leaves this dual-mode fan concept to be less attractive than originally postulated.

Other configurations, with considerably less flow turning, indicated the flow could be diffused with much lower losses and can achieve higher fan efficiencies. These results indicate that total pressure ratios, higher than the current state-of-the-art, may be achievable with fixed-geometry split-blade configurations designed for subsonic inflow conditions.

1. INTRODUCTION

The variable-pitch, split-blade supersonic fan configuration was conceived under a previous UTRC/NASA study, reference 1, which evaluated the performance potential of supersonic through-flow fans for advanced engines for supersonic cruise aircraft. It evolved from a single-blade fixed-pitch supersonic through-flow fan configuration in order to provide the capability of operating over a wide range of inflow velocities varying from subsonic to the supersonic cruise condition. At low speeds the variable-pitch split-blade fan operates like a conventional fan, generating a substantial pressure rise, and has subsonic outflow velocities. At supersonic speeds the fan operates like a supersonic through-flow fan eliminating the need for a conventional supersonic inlet. If this dual mode of operation can be obtained, this fan configuration has the potential of providing a continuum of operation from take-off and subsonic flight, through the transonic region to the supersonic cruise condition.

1.1 Variable-Pitch Split-Blade Fan

The variable-pitch split-blade fan operates like a subsonic fan at subsonic speeds and like a supersonic fan at supersonic speeds. In order to operate in this manner some type of variable-pitch arrangement was required to align the blade with the relative inflow velocity. Rotating the entire blade was considered first, but the close spacing of the blades (required for the supersonic design condition) made this very difficult mechanically. Furthermore, at low speeds, the exiting flow was left with a large swirl component. The split-blade configuration shown in figure 1 appeared to solve, or at least reduce, the mechanical and aerodynamic problems associated with a variable-pitch fan. For the example shown in this figure, the blades were designed to provide the correct amount of turning at the supersonic, Mach 2 inflow condition. At this condition the front and aft blades are aligned to provide a shape which approximates a single long-chord blade required for the supersonic operating condition. For the configuration shown here, the front blade is shorter than the aft blade, and is designed to be rotated and be aligned with the incoming (relative) flow direction when operating off-design in the transonic mode with subsonic inflow. The aft blade is fixed and provides additional turning of the flow.

At the high-speed, supersonic inflow condition (V_1 = 2000 ft/sec), the flow remains supersonic and is turned as it passes through the blade row, with little change in the magnitude of the relative velocity ($V_1' = V_2'$ = 2500 ft/sec); the absolute exiting velocity (V_2 = 2700 ft/sec) is substantially greater than the incoming

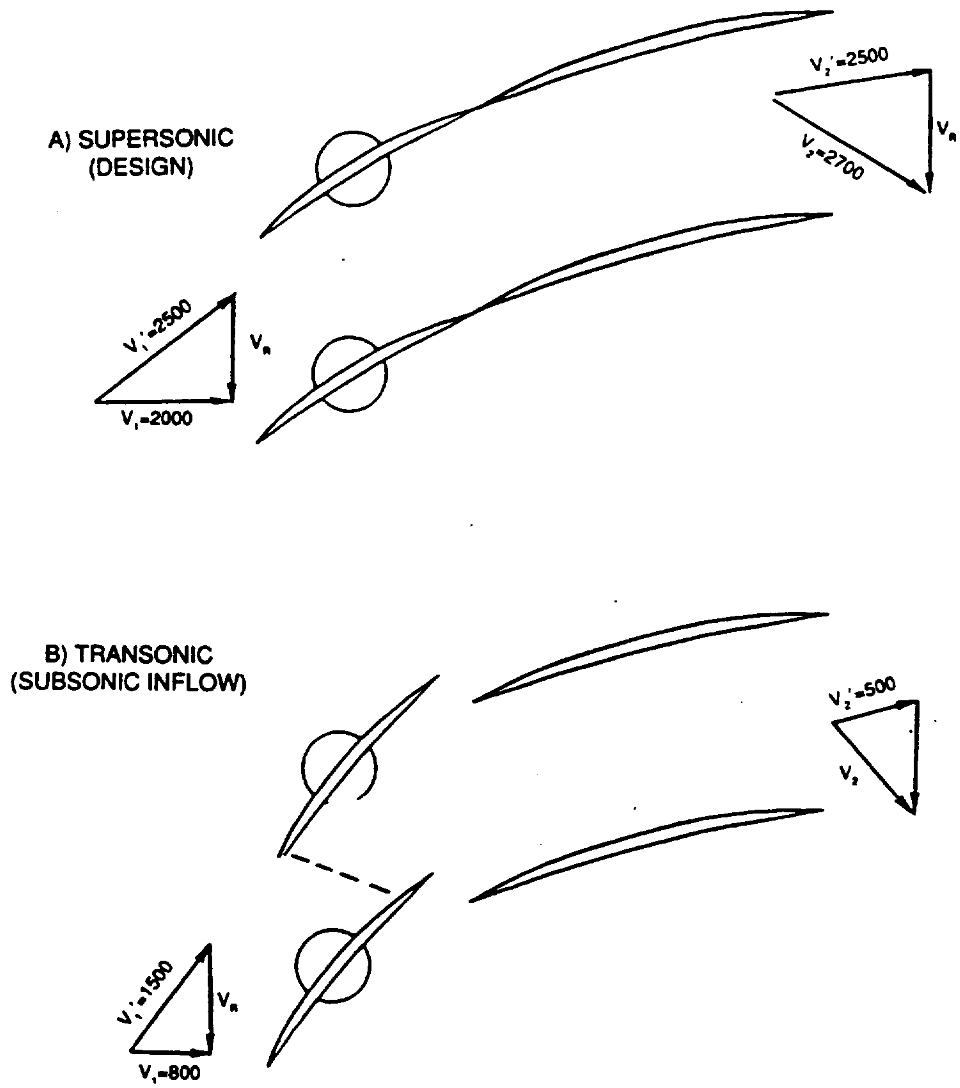

Figure 1. Variable-pitch split-blade fan.

velocity. Thus the flow is accelerated to a greater velocity and gains kinetic energy as it passes through the blade row. For this example the increase in total energy (enthalpy) is approximately 40%, and the total pressure of the exiting flow is approximately three times the incoming total pressure.

At the low-speed, transonic operating condition, the front blade is rotated considerably to be aligned with the flow when the incoming flow is subsonic (V_1 = 800 ft/sec), but the relative flow is supersonic

($V_1' = 1500$ ft/sec). At this condition, the front blades function like a "conventional" high speed fan; a strong shock (represented by the dashed line) forms in the blade row, the flow is decelerated to a subsonic velocity, and a large increase in static pressure is achieved. The aft blades are at a considerable angle relative to the front blades; they now act like a slotted wing flap and do additional turning of the subsonic flow. At this condition there is substantial flow turning and a large static pressure rise across the blade row; a large amount of work is done, the increase in total enthalpy is approximately 50%, and the total pressure of the exiting flow is approximately three and a half times the incoming total pressure. A variable-pitch split-stator (not shown) is required to accommodate the large range of flow angles leaving the rotor.

1.2 Performance Potential

Theoretical calculations were made to evaluate the performance potential of this configuration. The results, presented in figure 2, show the total pressure ratio generated for both the transonic (subsonic inflow) and supersonic through-flow operating regimes as a function of the inlet (M_1) and rotor (M_R) mach numbers. Note that the speed lines are not continuous between the transonic and supersonic operating conditions; this occurs because the flow is throttled in the transonic operating regime to achieve a substantial static pressure rise; the high back pressure increases the amount of work done; thus the throttled transonic performance is slightly higher than the unthrottled supersonic performance at the same rotor velocity. As shown in this figure, the variable-pitch split-blade fan has the potential for producing large total pressure ratios at both the transonic and supersonic operating condition.

The variable-pitch split-rotor acts like a variable camber blade, enabling it to accept a wide range of inflow velocities. It also offers the unique capability, at subsonic speeds, of combining the capabilities of a conventional fan plus an aft blade for additional flow turning. Theoretical calculations indicate that the split-blade fan has the potential for producing extremely large pressure ratios when operating in the transonic mode. However the calculation procedure used empirical correlations to determine the limiting flow conditions. More sophisticated analyses using state-of-the-art CFD calculations need to be done to determine the capability of this type of blading.

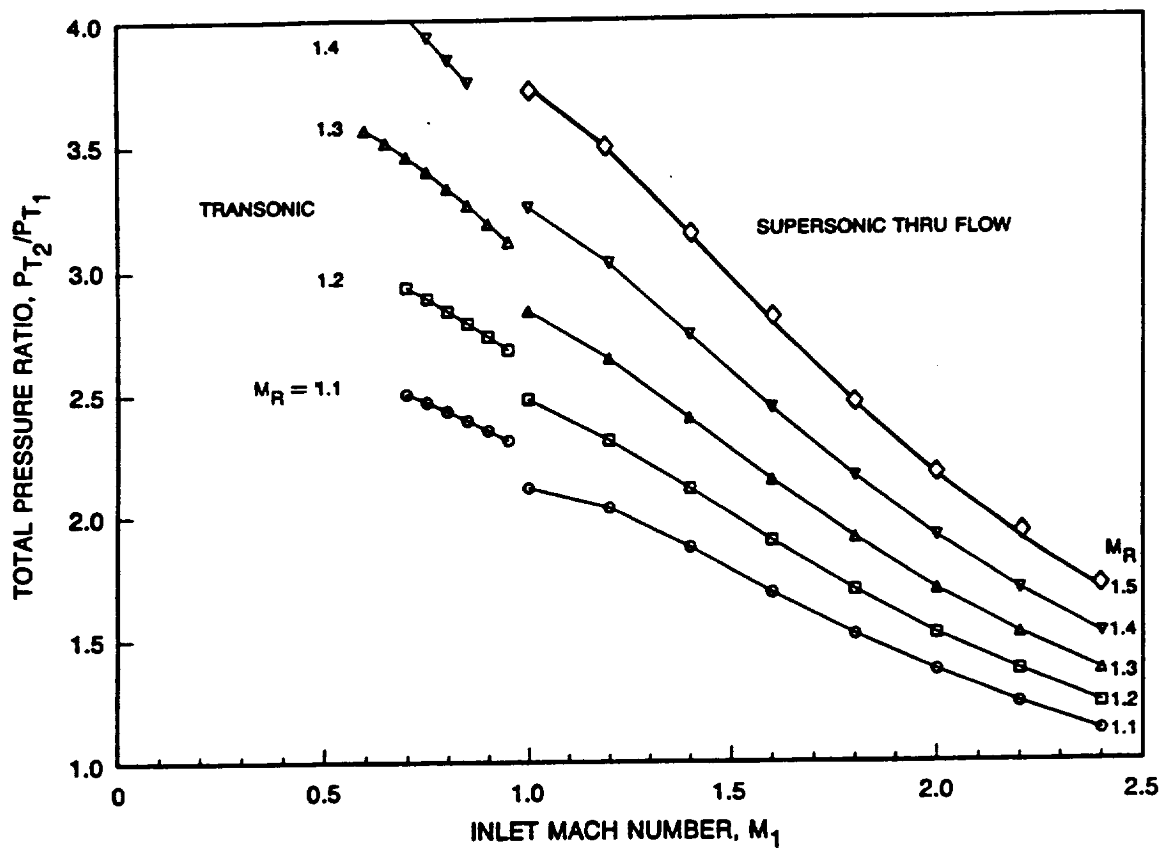

Figure 2. Split-blade fan performance potential.

1.3 Previous Studies of Variable-Pitch Fan

As noted earlier, the fan concept was conceived under a previous (ref. 1) study. The results of that study showed the variable-pitch split-blade fan to provide superior performance (when compared with a conventional fan engine) for both a Mach 2.3 supersonic transport and a Mach 5.0 cruise vehicle. This result led to several additional studies of this fan concept.

A conceptual design study of an engine employing this variable-pitch fan concept was conducted by P&W, reference 2. This study examined the mechanical problems associated with this variable-pitch fan. Concurrently, the aerodynamic problems were being investigated by UTRC. A previous study to develop the capability to analyze the split-blade fan was reported in reference 3. The present study improved upon these techniques, and used the procedures to analyze a variety of blade configurations at both the supersonic design condition and transonic operating conditions.

1.4 Program Objective and Scope

The objective of the present program was to evaluate the feasibility of operating a variable-pitch split-blade fan with both subsonic and supersonic inflow conditions. When operating with subsonic inflow the outflow is also subsonic, and a substantial static pressure rise is achieved across the blade row; when operating with supersonic inflow the outflow is also supersonic.

An analytical study was conducted using a Navier-Stokes code developed by Davis and Dannenhoffer called ADAPTNS (ref. 4). The scope of the present program (see fig. 3) consisted of: code modifications to handle the split-blade geometry; check-out of the code (at both supersonic and transonic flow conditions) with a baseline blade configuration; development of a procedure for evaluating the CFD results and generate hypothetical fan performance; evaluation of the impact of various supersonic and transonic design considerations; evaluation of various front and aft blades at transonic operating conditions, and an evaluation of the supersonic performance of an improved configuration. A total of 20 blade configurations were analyzed at various flow conditions totaling 56 CFD cases.

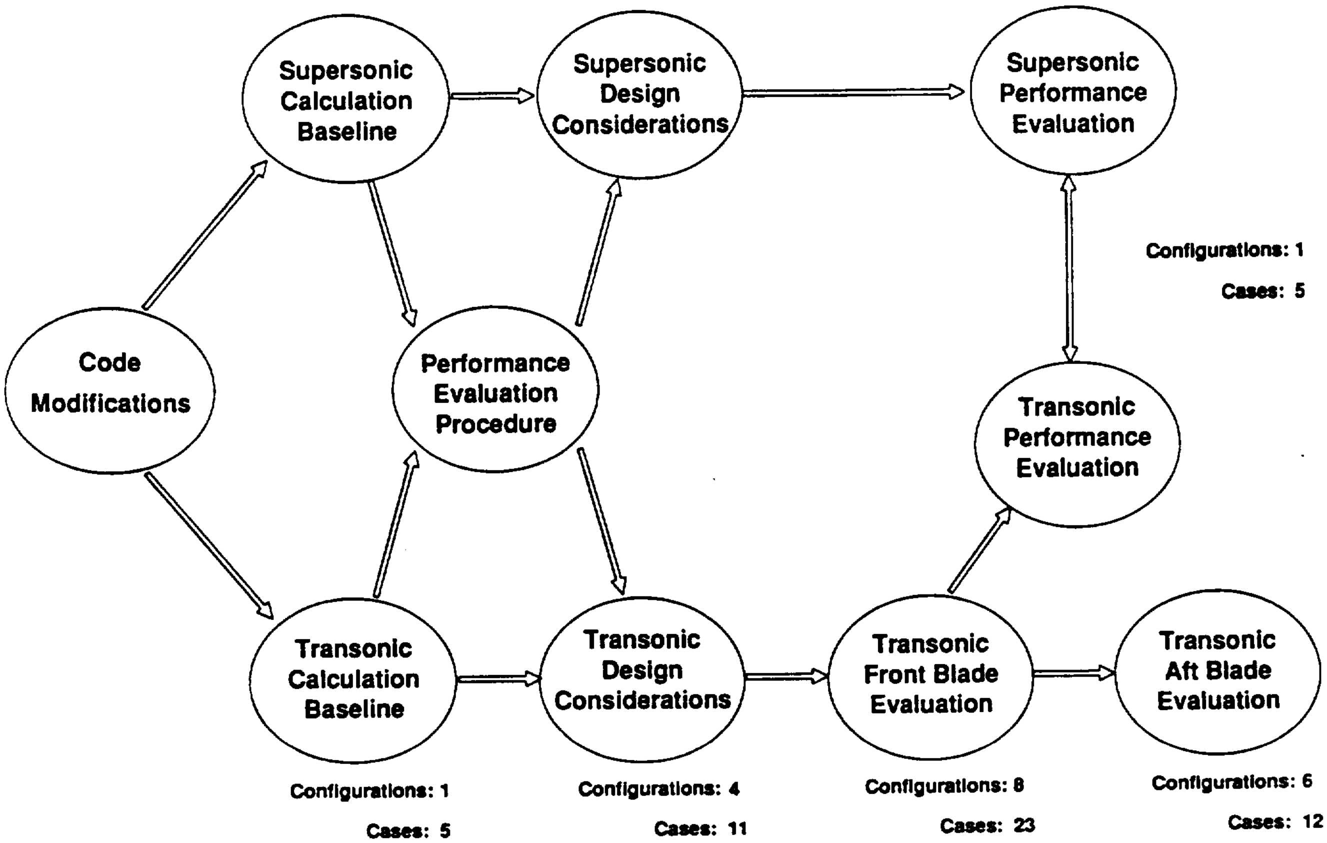

Figure 3. Program scope.

2. BLADE CONFIGURATIONS

A total of 20 different blade configurations were evaluated under this study. The baseline variable-pitch rotor configuration (VPR–6.1) used in the initial check–out of the calculation procedures was a derivative of the variable-pitch rotor–stator configuration used in the air turbo ramjet engine evaluated in the Mach 5 cruise vehicle study reported in reference 1. The relationship between this baseline configuration and the other 19 configurations is shown in the blade genealogy chart presented in figure 4. The effect of single versus split blading, and gap–to–chord were investigated at the supersonic operating condition using the single–bladed supersonic through flow fan, STFF–9, and the reduced gap VPR–6.1RG. The effect of the slot geometry between the fore and aft blades was investigated at the transonic operating condition using the VPR–6.2 and 7.1 blade configurations. Eight different front blades, VPR–9f through 16f, and six different aft blade

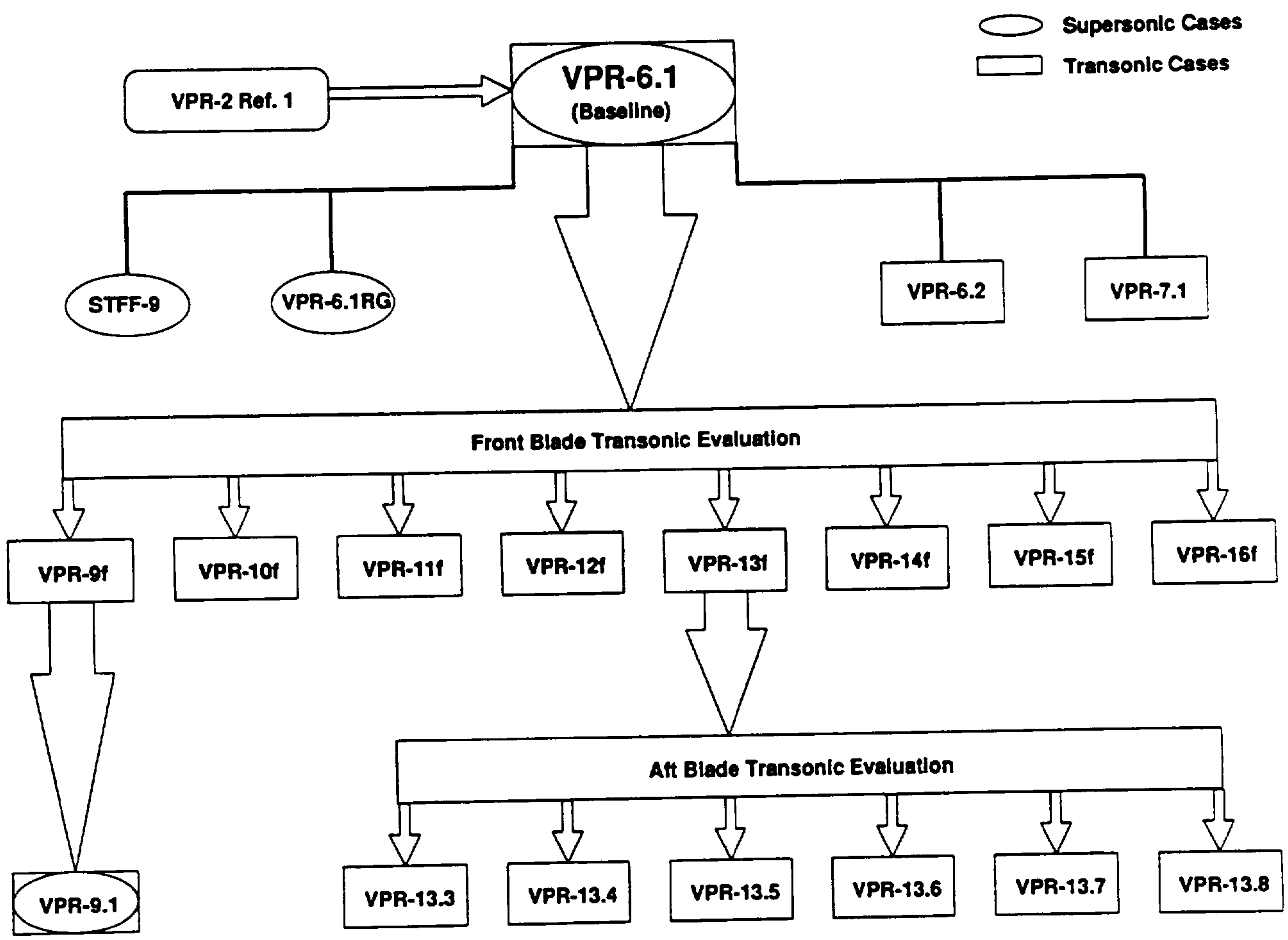

Figure 4. Blade genealogy.

configurations, VPR-13.3 through 13.8 were evaluated at the operating condition. The VPR-9f front blade was combined with the baseline aft blade to form the VPR-9.1 configuration which was evaluated at both the transonic and supersonic operating condition.

2.1 Blade Geometry and Nomenclature

Each of the blade configurations evaluated in this study is identified by the shape of the front and aft blades. Thus the baseline variable-pitch rotor configuration, VPR-6.1 is comprised of front blade #6 and aft blade #1. And if only the front blade is specified, the front blade is identified by an "f" and if only the aft blade is specified, the blade is identified by an "a". Thus configuration VPR-9f is a single front blade; configuration VPR-1a is an aft blade; and configuration VPR-9.1 is a split-blade configuration. The exception to this nomenclature is the single blade supersonic through flow fan, STFF-9.

The geometrical features used to describe a split-blade configuration are shown in figure 5. The blade location and orientation is defined by the blade chord and chord angle relative to the x-axis. For all configurations, except VPR-7.1, the leading edge of the aft blade is coincident with the trailing edge of the front blade at the supersonic design condition; and the front blade is rotated about its center shown by ⊕. Each configuration has a specified (constant) gap, g. The gap/chord is specified for each blade set, g/c_1 and g/c_2. The overall gap/chord is defined using the overall chord.

The specific geometry of each blade is described by polynomials which define the upper and lower surfaces relative to the blade chord (the normalized η, ζ coordinates shown on fig. 5). For example, the upper surface angles on the front portion of the blade are defined by

$$\theta_u = \theta_{u_1} + A\zeta + B\zeta^2 \text{ for } 0 < \zeta < \zeta_{t_u} \tag{2.1}$$

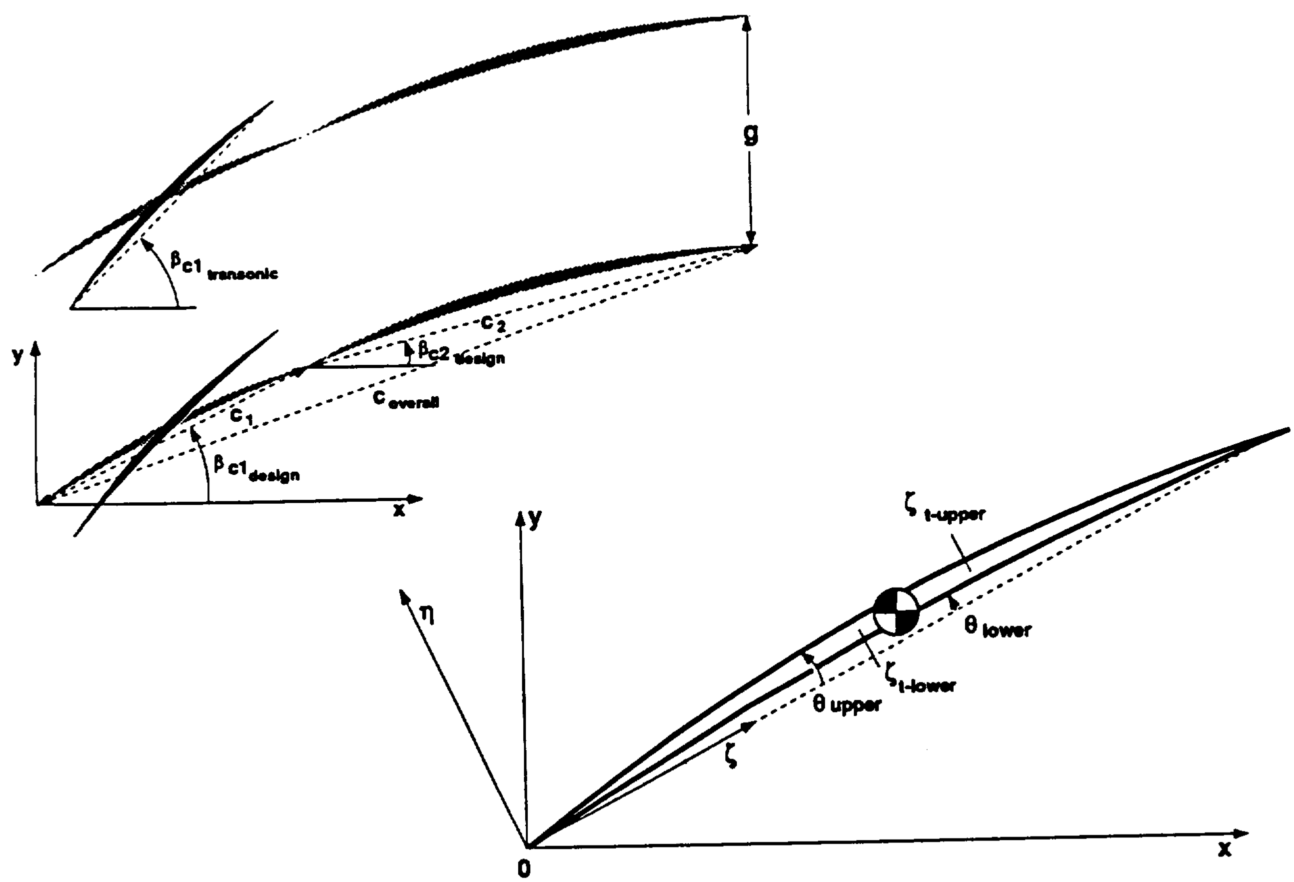

Figure 5. Blade geometrical features.

and on the aft portion of the blade by

$$\theta_u = \theta_{u_2} + C(1-\zeta) + D(1-\zeta)^2 \text{ for } \zeta_{t_u} < \zeta < 1.0 \qquad (2.2)$$

where θ_{u_1} and θ_{u_2} are the leading and trailing edge angles relative to the chord, ζ_{t_u} is the transition location defining the boundary between the two equations; the coefficients (A, B, C, D) are chosen to ensure that the coordinate, η, and the slope, θ, are continuous at the transition location. For all blades except VPR–7f and VPR–10f the slope derivative, $\delta\theta/\delta\eta$, is also continuous at the transition point.

A tabulation of the geometry specifications of each of the front and aft blades, evaluated in this study, is presented in Table 1. The polynomial coefficients defining the upper and lower blade surfaces are presented in the Appendix. Descriptions and sketches of the various front and aft blade configurations are presented under blade comparisons.

Table 1: Blade Geometry Specifications

($c_{overall}$ = 10.0in.)

		Front Blade				Aft Blade		
Name	$g/c_{overall}$	$c_1/c_{overall}$	$\beta_{c1_{design}}$	$\beta_{c1_{transonic}}$	$\Delta\beta_{1_{mean}}$	$c_2/c_{overall}$	$\beta_{c2_{design}}$	$\Delta\beta_{2_{mean}}$
VPR6f	0.3333	0.4000	29.37	47.89	17.00	n/a	n/a	n/a
VPR7f	|	0.4500	⊥	⊥	15.19	n/a	n/a	n/a
VPR9f	|	0.4000	32.37	50.89	11.00	n/a	n/a	n/a
VPR10f	|	|	36.87	55.35	5.97	n/a	n/a	n/a
VPR11f	|	|	|	52.39	6.74	n/a	n/a	n/a
VPR12f	|	|	|	58.39	0.0	n/a	n/a	n/a
VPR13f	|	|	|	|	5.95	n/a	n/a	n/a
VPR14f	|	|	⊥	|	15.97	n/a	n/a	n/a
VPR15f	|	|	39.87	|	11.01	n/a	n/a	n/a
VPR16f	⊥	⊥	⊥	⊥	12.65	n/a	n/a	n/a
VPR6.1	0.3333	0.4000	29.37	47.89	17.00	0.6000	15.62	22.50
VPR6.1RG	0.2222	|	|	|	|	|	⊥	⊥
VPR6.2	0.3333	⊥	|	|	⊥	|	21.60	30.76
VPR7.1	|	0.4500	⊥	⊥	15.19	|	15.62	22.50
VPR9.1	|	0.4000	32.37	50.89	11.00	|	⊥	⊥
VPR13.3	|	|	36.87	58.39	5.95	|	18.43	31.58
VPR13.4	|	|	|	|	|	|	21.43	37.59
VPR13.5	|	|	|	|	|	|	24.43	43.61
VPR13.6	|	|	|	|	|	|	⊥	31.58
VPR13.7	|	|	|	|	|	|	30.43	⊥
VPR13.8	⊥	⊥	⊥	⊥	⊥	⊥	43.39	12.00

2.2 Blade Comparisons

2.2.1 Front Blade Geometries.—All the front blades used in this study are compared in figure 6. They are shown in two groups: those on the left hand side have a continuous mean-line curvature; those on the right have a reflexed mean-line curvature. The baseline front blade VPR-6f is formed by two circular arcs; the lower surface turning 11 deg. The VPR-7f has the same lower surface as the baseline, but the blade is 5% longer to

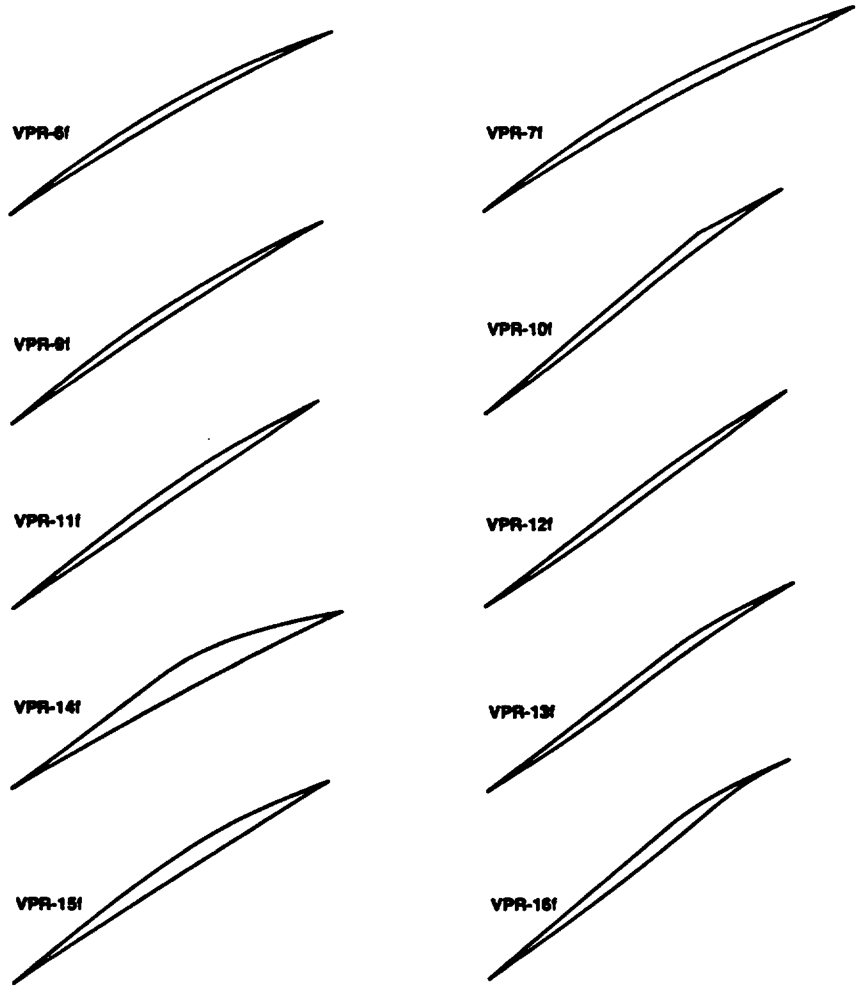

Figure 6. Front blade configurations

overlap the aft blade. The overlapping portion has the same contour as the front of the aft baseline blade. The VPR–9f blade is also a circular arc with less turning; the lower surface turns only 5 deg. The VPR–11f blade has a flat bottom; the upper surface formed by two circular arcs joining at the 60% chord. The VPR–15f blade has 3 deg of circular turning on the lower surface, but the upper surface is formed by two curves joining at the 62.5% chord, this blade is thicker with a t/c = 5%. The VPR–14f is similar to VPR–15f, however; it has a lower surface with 6 deg of turning and a thickness of 9%; it is the thickest blade evaluated. The front portion of the upper surface of these two blades are straight to minimize the flow expansion in the transonic mode when that surface is aligned with the inflow. Past the transition point the upper surface turns rapidly to join the trailing edge.

All the reflex blades shown in the right, except VPR-7f, have straight upper front surfaces to minimize the flow expansion; and the front portion of the lower surfaces turn up parallel to the upper surface, before turning down to the final angle. The VPR-12f blade has the least turning; the lower aft surface is parallel to the front upper surface; the upper rear surface turns down past the 62.5% chord to join the trailing edge. Blades VPR-10f and 13f have the same reflexed lower surface, turning down to -6 deg at the trailing edge relative to the leading edge upper surface. The upper surface of VPR-10f is composed of two straight lines intersecting at the 75% cord; the upper surface of VPR-13f has the same leading and trailing edge angles but the corner is rounded. The VPR-16f blade is similar to VPR-13f, but with reflexive turning to -15 deg at the trailing edge. The upper surface has more down turning in order to join the trailing edge. It is also the thickest of the reflex blades (t/c = 5%).

2.2.2 Aft Blade Geometries.—The aft blades used in this study are compared in figure 7. The baseline aft blade VPR-1a is formed by two circular arcs; the lower surface turning 16.5 deg. The leading and trailing edge angles are 6 deg. The VPR-2a has the same lower surface on the baseline but the leading edge angle was increased to 22.5 deg and the upper transition location ζ_{t_u} was moved to 15% chord. The maximum thickness was approximately the same as the baseline. The next six blades are a family of blades, all used with VPR-13f to systematically investigate the effect of turning and slot divergence on the transonic flow field. All blades were circular arc shapes. The first three blades of this family, VPR-3a-5a all had the same lower surface exit angle of 6 deg; they had various amounts of lower surface turning 24.87, 30.87 and 36.87 deg, respectively. Blade VPR-6a is the same as blade VPR-3a rotated 6 deg, it has a (lower surface) leading edge angle of 36.87 deg and a trailing edge angle of 12 deg. Blade VPR-7a is the same blade as VPR-3a rotated 12 deg, it has a (lower surface) leading edge angle of 42.87 deg and a trailing edge angle of 18 deg. Blade VPR-8a has only 6 deg of turning on the lower surface, the trailing edge angle is 40.4 deg.

2.2.3 VPR-6.1.—A sketch of the baseline configuration VPR-6.1 is shown in figure 8. The transonic orientation of the blades is shown by the solid lines; the dashed lines show the orientation of the front blade during supersonic operation. This fan was designed for a pressure ratio of approximately 2.8 at the $M_1 = 2.0$ inflow condition and a rotor speed, $M_R = 1.5$. The split blades were designed to form a continuous circular-arc lower surface contour having a leading edge angle of 34.9 deg and a trailing edge angle of 7.4 deg. The front (variable) blade has a mean chord of 40% of the total chord. The upper surfaces of these blades were

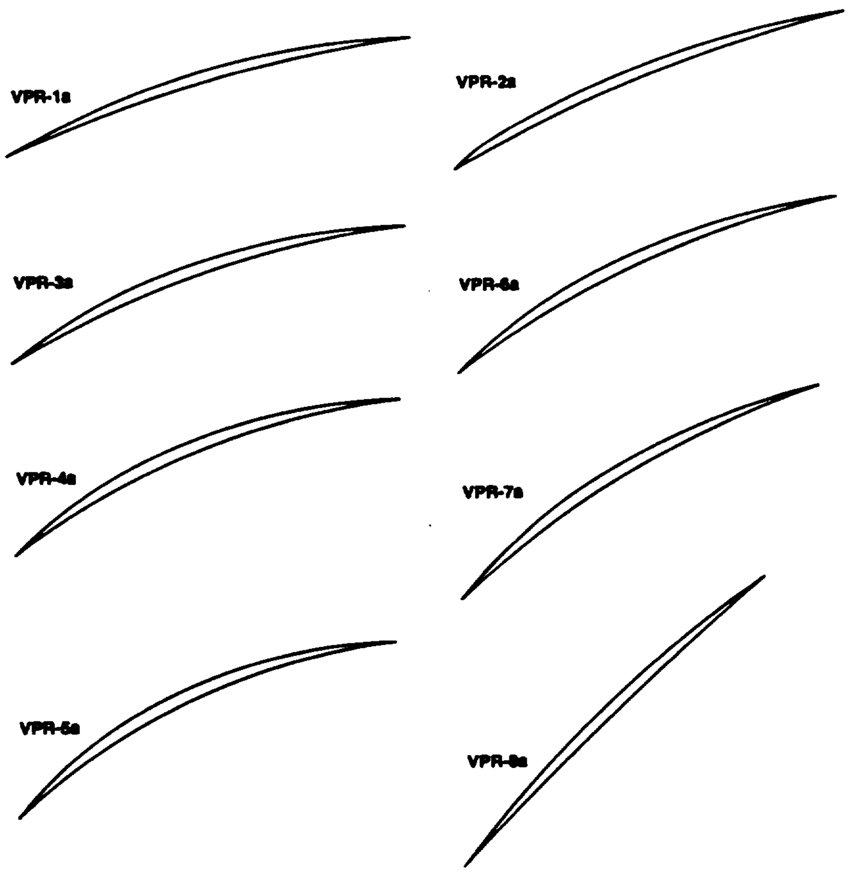

Figure 7. Aft blade configurations.

also circular–arcs with leading and trailing edge angles of 6 deg. These angles resulted in blades which were approximately 3% thick. The gap between adjacent blade sets was 0.333 of the total chord length of both blades.

At the transonic operating condition the front blade was rotated 18.5 deg about its center to align the leading edge of the upper surface to the incoming flow for an inflow $M_1 = 0.8$ and a rotor speed of $M_R = 1.3$. The relative flow angle for this condition is 58.4 deg. The lower surface angle at the leading edge of the front blade, as shown in the figure, is 53.4 deg. This rotation left a gap between the blades which is approximately 8% of the total chord length of both blades.

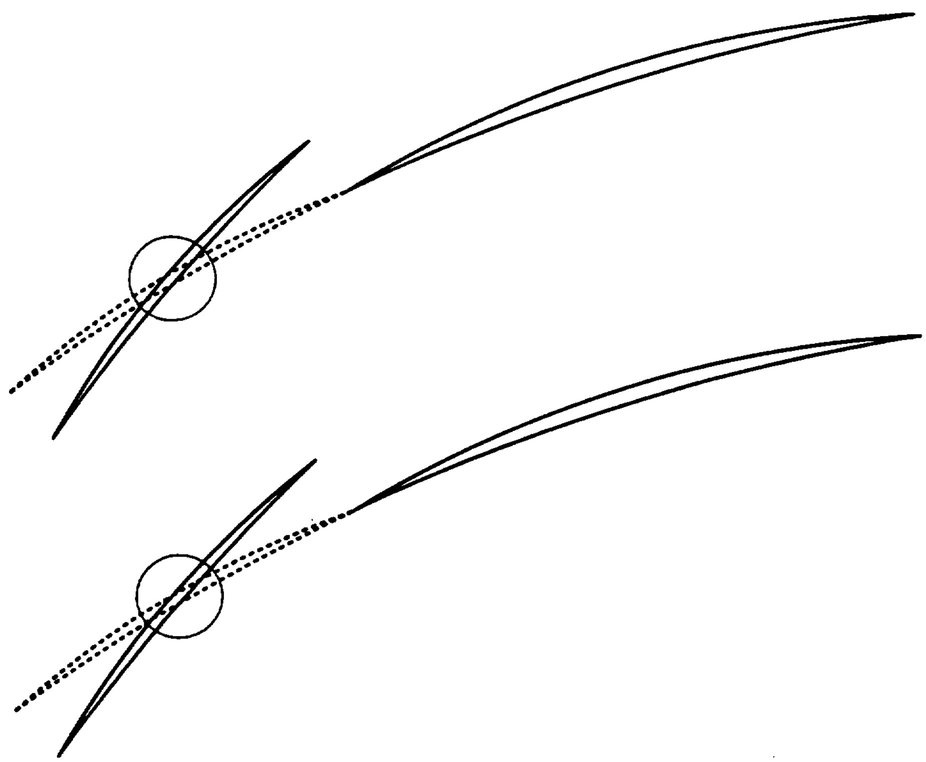

Figure 8. Baseline blade configuration - VPR 6.1.

2.2.4 VPR–6.2 and 7.1.—A sketch of these transonic configurations is shown in figure 9. The VPR–6.2 configuration was the modified VPR–6.1 used in the reference 3 study. The rear blade of the baseline configuration was rotated 6 deg and the leading edge angle was increased to 22.5 deg without altering the lower surface. This latter modification changed the thickness distribution of the aft blade, moving the location of maximum thickness forward, without changing the maximum thickness. These modifications changed the divergence of the "slot" formed by the lower trailing edge of the front blade and the upper leading edge of the aft blade. The resulting slot had a 5 deg convergence angle.

The VPR–7.1 configuration also had a modified "slot" geometry. The VPR–7.1 used the same aft blade as the baseline, and a similar but 5% longer front blade which overlapped the aft blade. The overlapping portion of this front blade was designed to mount flush with the aft blade at the supersonic design condition. Thus when the front blade was rotated away from the aft blade, the slot which was formed had a divergence which was equal to the amount of rotation. For this configuration the slot divergence was 17.5 deg.

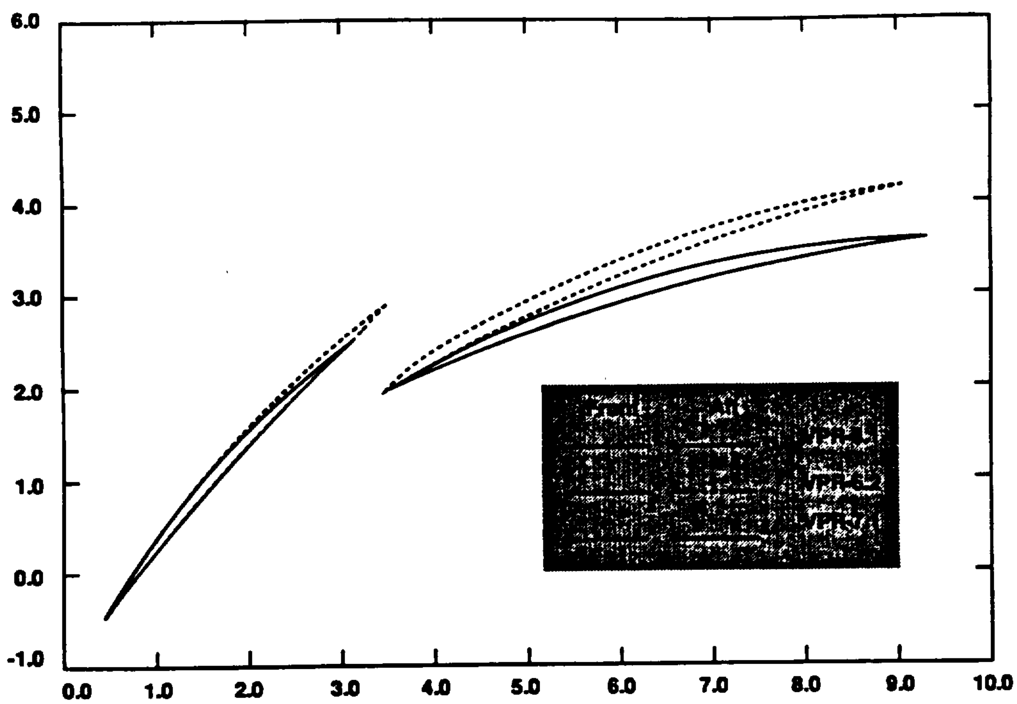

Figure 9. VPR 6.1, 6.2 and 7.1 blade configurations.

2.2.5 VPR-6.1, 9.1, and 13.3.—These three transonic blade configurations are compared in figure 10. The front blades, discussed above, are all rotated to have the upper leading edge surface parallel to the incoming flow angle of 58.4 deg. The aft blades were designed to have the leading edge of the lower surface continuous with the trailing edge of the lower surface of the front blade at the supersonic design condition. These blades have approximately the same amount of total turning at the supersonic design condition; the lower surface trailing edge angles are: 7.4, 7.4, 6.0 deg, respectively.

2.2.6 VPR-13 Family.—Six different aft blades were combined with the VPR-13f to investigate the effect of turning and slot divergence on the transonic flow field. These six configurations are shown in figure 11. The first three blades VPR-13.3–13.5 had the same lower surface exit angle, 6 deg, with various amounts of lower surface turning of 24.87, 30.87 and 36.87 deg, respectively. Blade VPR-13.6 has the same aft blade as 13.3 rotated 6 deg, it has a trailing edge angle of 12 deg; blade VPR-13.7 is the same as blade VPR-13.3 rotated 12 deg, it has a trailing edge angle of 18 degree. Blade VPR-13.8 has the same upper surface leading edge angle as the lower surface trailing edge angle of the front blade (in the transonic position); thereby providing a parallel channel between the blades for the flow to pass through. The lower surface of this blade turned 6 deg to an exit angle of 40.4 deg.

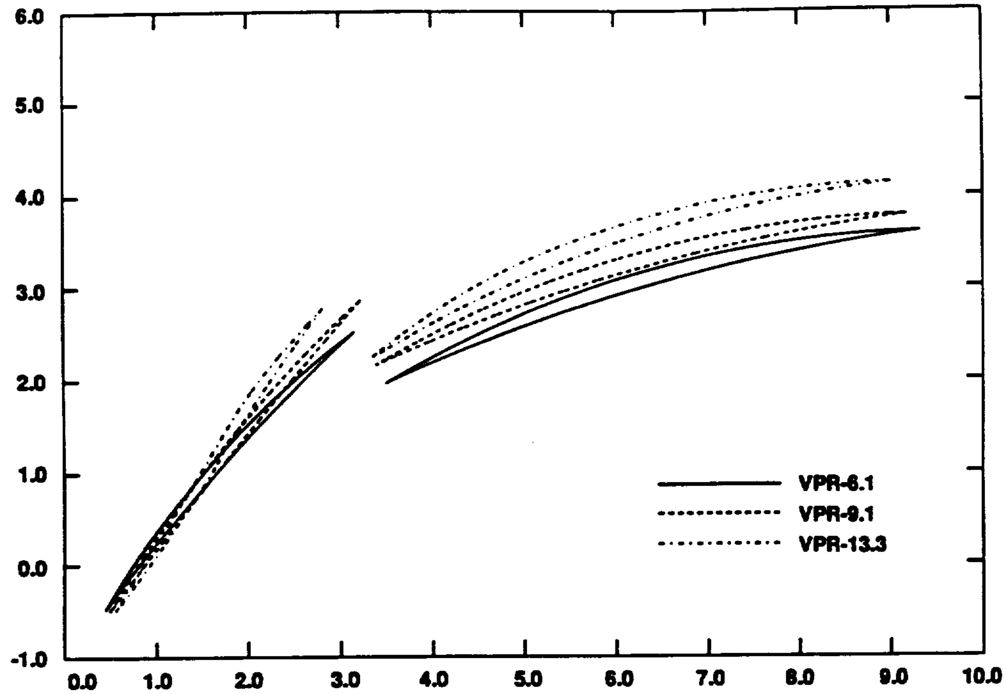

Figure 10. VPR 6.1, 9.1 and 13.3 blade configurations.

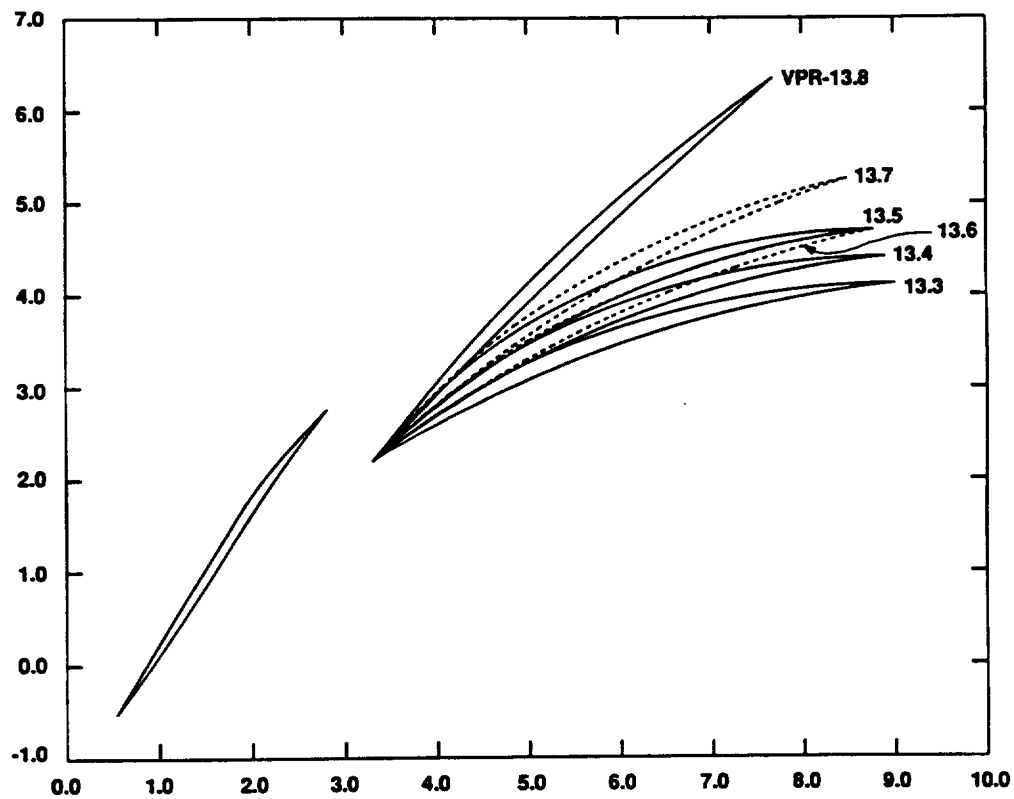

Figure 11. VPR–13 family of blades.

3. NAVIER–STOKES ANALYSIS TECHNIQUE

The calculation procedure used for the analysis of split–blade fans in this report is an unstructured grid embedding procedure developed by Davis and Dannenhoffer called ADAPTNS (ref. 4). In this approach, the Reynolds–averaged Navier–Stokes equations are integrated to steady state on successively refined grids until solutions on successive grids are "close" to each other. Embedded grids are generated by employing a fixed global grid and automatically sub–dividing the computational cells in the immediate vicinity of pertinent flow features. These flow features, such as stagnation points, shocks, and viscous layers, are located through the use of velocity and static pressure differences across computational grid cells, and cell averaged vorticity magnitude refinement parameters. The integration procedure used to solve the Navier–Stokes equations is a time marching, control volume scheme (ref. 5). A generalization of Ni's multiple–grid method (ref. 6) is used both for increasing the overall convergence rate as well as coupling the solutions on the various embedded grids. The Baldwin–Lomax (ref. 7) two–layer, algebraic turbulence model has been incorporated into the ADAPTNS adaptive grid procedure to calculate the turbulent eddy viscosity.

The ability to compute grid resolved solutions without the use of a fine grid throughout the computational domain, and the ability to analyze complex geometries, were the main reasons why ADAPTNS was chosen for the present split–blade fan analysis. Such an adaptive grid code is especially useful for new geometries, like the split–blade fan, where the flow structure is not known *a priori*.

Although the ADAPTNS code, as originally developed, can analyze fairly general cascades of single element airfoils, several modifications to the code were required to enable split–blade fan geometries to be evaluated. The four major changes to the code were: modifications of the *initial grid topology*, modification of the *far–field boundary conditions*, modification of the *refinement parameters* used to locate critical flow features, and a change in the *data structure associated with the turbulence model*. These modifications are discussed below.

3.1 Grid Topology

The ADAPTNS code was originally developed to analyze the flow through a single blade row of compressor, turbine, or fan blades. As the grid is adapted, individual grid cells may be divided or fused (un–divided) as needed, but the initial grid nodes remain. Hence, the initial grid provides a framework for any adaptation. The initial grid topology typically used to analyze single blade row geometries is a C–grid. For single blade row cascades, the C-grid provides high resolution in a vicinity of blunt leading edges. This type of grid system, however, is much more difficult to apply to the more complex geometry of the split-blade fan. After considering several different possible grid topologies, it was decided to use a modified H-grid for the present study. A typical initial modified H-grid is shown in figure 12. Although it is fairly easy to generate a modified H-grid for the split-blade fan geometry, it is difficult to generate one which has high resolution near the leading edge of a blunt airfoil. For this reason, the airfoils analyzed in this investigation had sharp leading edges.

ADAPTNS was designed to automatically refine or adapt the computational grid in regions where the flow is complicated, and to analyze flows in complex geometries. To accomplish this, the computational grid used is unstructured, meaning that the computational nodes are not required to be ordered in a regular pattern. Because the computational nodes are not ordered in a regular way, tables (called pointers) must be constructed which express where the computational nodes are in relationship to one another and to physical boundaries. As the computation proceeds the computational grid is automatically refined and the pointers are updated. The user, however, must supply a routine that sets up the initial grid and pointers. Such a routine did not previously exist for the split-blade fan geometry, and was completed in this effort.

The grid generation algorithm used to create modified H-grids for split-blade fans is a modified version of the Laplace grid generator written by Dannenhoffer (ref. 8) for the adaptive-grid, Euler-flow code MITOSIS. The grid generator is similar to that of Thompson et al. (ref. 9) in that the location of the grid lines are described by Laplace's equation. It has the advantage, however, that it can be used to generate unstructured grids. This procedure uses the same pointer system as that utilized by the Navier-Stokes flow solution technique. For viscous applications, such a grid is not adequate. In particular, the grid resolution near the blades and in the wakes is not fine enough to resolve the viscous shear layer. Even though the code will, in principle, adapt and eventually resolve these structures, the initial grid should be able to resolve to some degree the viscous layers. A modification to the initial grid Laplace generator was made which allows grid lines to be clustered near the blades. A typical viscous grid used in this investigation is shown in figure 12.

3.2 Far-Field Boundary Conditions

Early in this investigation, converged solutions for flows at supersonic inlet Mach numbers and moderate to high back pressures could not be obtained. For each case, a passage shock should sit at the leading edge of the upstream airfoil. However, this shock would eventually "pop out" of the passage and propagate forward of the blade row and out of the computational domain. Soon after, the solution procedure would diverge. This phenomenon was found to be due in part to the set of far-field boundary conditions used in the original ADAPTNS code. The quantities specified at the inflow boundary were the total temperature, total pressure, and incoming flow angle in the relative frame. This set of boundary conditions works well for subsonic relative inflow, but does not adequately represent the physical situation for supersonic relative but subsonic absolute inflow Mach numbers. For example, the inflow angle cannot be arbitrarily specified but rather must be found as part of the solution. The solution procedure will seek the inflow angle which satisfies the so-called unique incidence condition.

A more natural and physically meaningful set of upstream boundary conditions is to specify the upstream total conditions (specifically the total enthalpy as reported by Hall and Kepler (ref. 3) or total pressure and total temperature) and tangential velocity in the absolute frame of reference. These upstream boundary conditions were implemented into the ADAPTNS code and were found to prevent the shock from propagating forward and out of the computational domain. Furthermore, using these boundary conditions, the code correctly predicts the unique incidence inflow angle.

3.3 Turbulence Model

The turbulence model used in ADAPTNS is the Baldwin-Lomax turbulence model. In this model, the eddy viscosity is an algebraic function of the vorticity profile and the distance from the airfoil surface. It is convenient, therefore, to construct the turbulence model along grid lines which are approximately normal to the blade surfaces. However, because the grid is unstructured, tables must be constructed which give lists of nodes that lie on the grid lines which start at the surface of the airfoil (or the center of the wake) and run in the "normal" direction away from the airfoil. This list of nodes is known as the turbulence model data structure. In the current effort for the calculation of viscous flows in split-blade fans, a turbulence model data structure was created based upon the initial grid tangential grid lines. The eddy viscosity along these lines is calculated directly from the Baldwin-Lomax turbulence model and interpolated at all other nodes using the technique described in reference 4.

In the original version of ADAPTNS (C-grid, single element airfoil), the turbulence model encompassed the entire computational domain. Because of the complexity of the split-blade fan geometry, the current implementation of the turbulence model does not extend throughout the entire computational domain. Instead, four zones were set up in which the turbulence model is used as shown in figure 13. In regions not covered by one of the four zones, such as in front of the forward airfoil, the turbulence levels are expected to be small, and the eddy viscosity is taken to be zero.

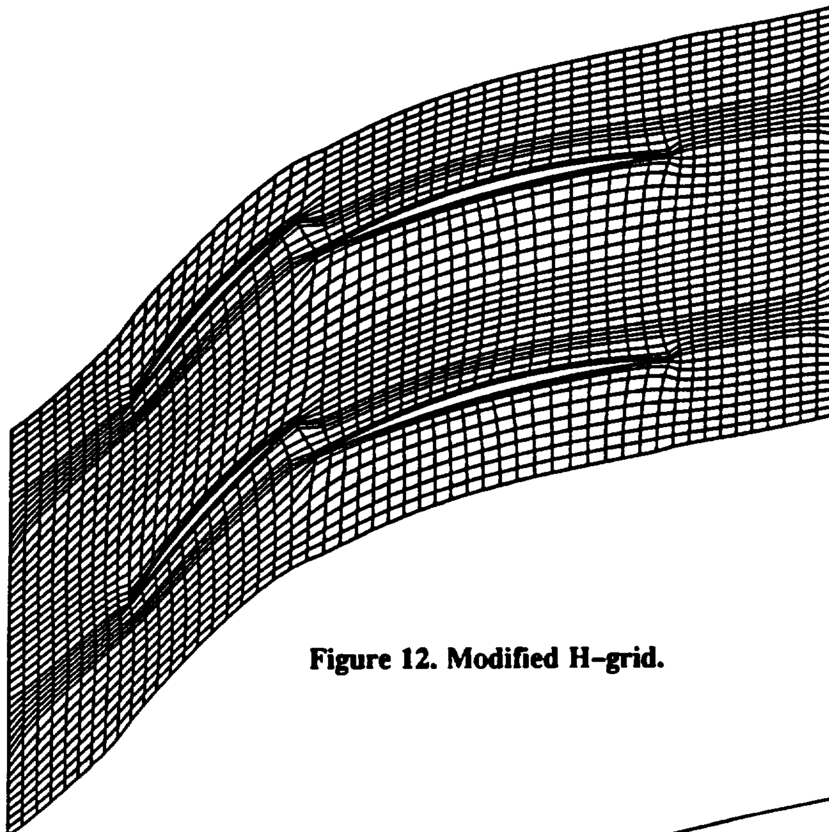

Figure 12. Modified H-grid.

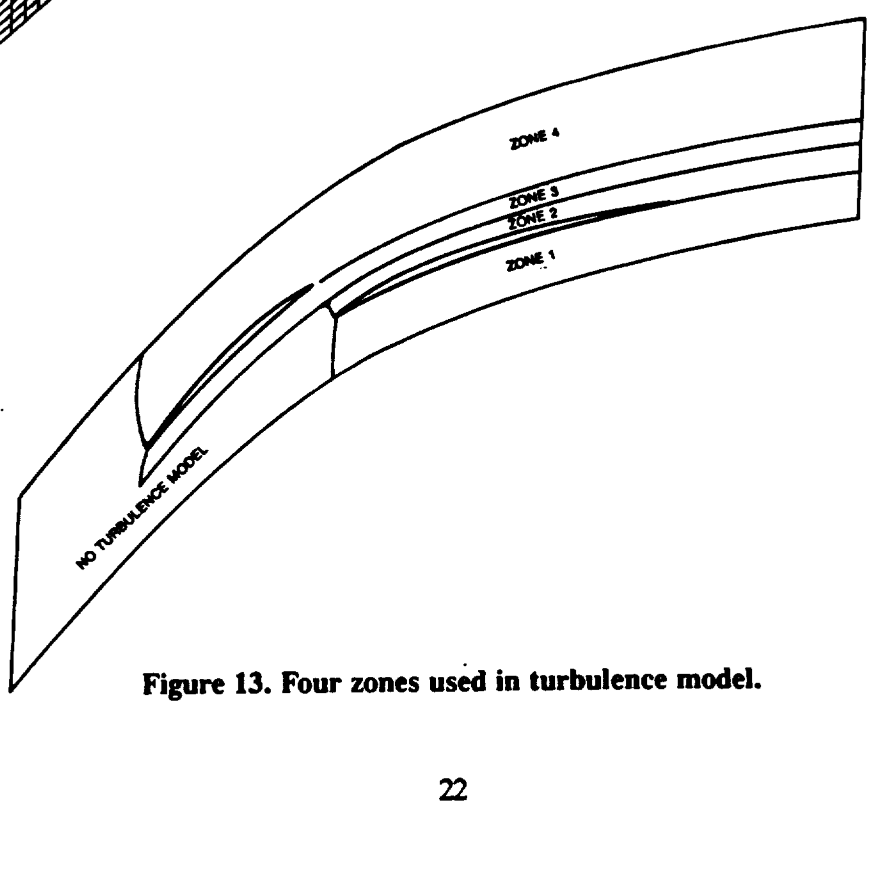

Figure 13. Four zones used in turbulence model.

3.4 Refinement Parameters

Computational grid cells in the immediate vicinity of critical flow features, such as shocks, stagnation points, and viscous layers, are sub-divided in order to reduce truncation error to a user specified global level of accuracy. Simultaneously, computational grid cells away from such flow features are, when possible, fused or undivided to eliminate any unnecessary computations. Flow features are located in the computational domain through the use of refinement parameters which have large values at these flow features and small values elsewhere.

In the original ADAPTNS code, flow features were detected using the velocity difference across computational cells and vorticity magnitude. The velocity difference was found to be a good parameter to locate inviscid phenomena such as stagnation points, shocks, and expansion waves. In addition, the velocity difference provided a good initial marker for defining the extent of viscous layers including boundary layers, shear layers, and wakes. The velocity difference parameter was not found to be sufficient, however, to track and completely encompass the viscous layers. For these viscous features, the vorticity magnitude was found to be a very good parameter to define the extent of the high velocity gradient, viscous regions.

In the current application of ADAPTNS to split-blade fans, it was found that the velocity difference parameter typically used to locate shocks and inviscid features was overwhelmed by the gradients located in the viscous layers. Thus, adaptation resulted in grid refinement around the viscous layers with little or no grid refinement around the shocks. Since the velocity difference parameter was also useful for locating viscous related features, a third parameter, namely the pressure difference across the computational cell, was introduced to detect the multiple shocks located in split-blade fan geometries. With the use of the pressure difference parameter, grid refinement was more evenly balanced between the viscous shear layers and the shocks.

4. NUMERICAL RESULTS

This section describes the results from the viscous ADAPTNS flow field calculation for the baseline fan configuration. The output is a two-dimensional array of detailed flow properties (P,T,V, θ). In order to relate these flow properties to fan performance, an evaluation procedure was developed to provide a quantitative measure of the flow field characteristics and the associated fan performance.

4.1 Baseline Fan Performance

Typical results from the viscous ADAPTNS flow-field calculation are described herein. The baseline fan configuration (VPR-6.1) was evaluated at both the supersonic design condition and the transonic operating condition. The input and output from these calculations are described below.

4.1.1 Supersonic Through-Flow Calculation.—The supersonic through-flow calculations were run with fan inflow conditions simulating flight at Mach = 2.4 and 36,000 ft altitude. A simple conical inlet was assumed to decelerate the flow to a Mach number (M_1) of 2.0 at the fan face. The resulting static temperature (T_1) was 440 R and the static pressure (P_1) was 4.08 psia. A rotor Mach number (M_R) of 1.5 was used (V_R = 1544 ft/sec). These absolute flow conditions resulted in a relative inlet Mach number (M_1') of 2.5. Note that all conditions relative to the blade are primed, the absolute conditions are unprimed. The total chord length of the split blades was assumed to be 10 in. The resulting Reynolds number based on the cord was 5,020,000. These inflow conditions were used for all the supersonic ADAPTNS calculations.

The ADAPTNS calculation procedure developed the grid structure shown in figure 14 for the baseline blade configuration. This is the grid which was generated after four levels of adaptation from the original grid. Thus, the smallest grid spacing is 1/16 the original grid size. The original grid had 1300 nodes; the final grid had 46,000 nodes. In the region of the shocks and viscous layer, the grid is packed so finely as to be indistinguishable (at this scale) from adjacent grids.

Figure 15 shows the Mach number contours which were generated. The oblique shocks from the leading edge and the acceleration of the flow over the upper surface of the blades can be clearly seen. The intersection of the upper surface of the two blades does not generate a shock of significant strength to show us on this contour plot. The subsonic boundary layer and wake is indicated by the blue regions. This solution predicts separation of the boundary layer from the upper surface of the second blade.

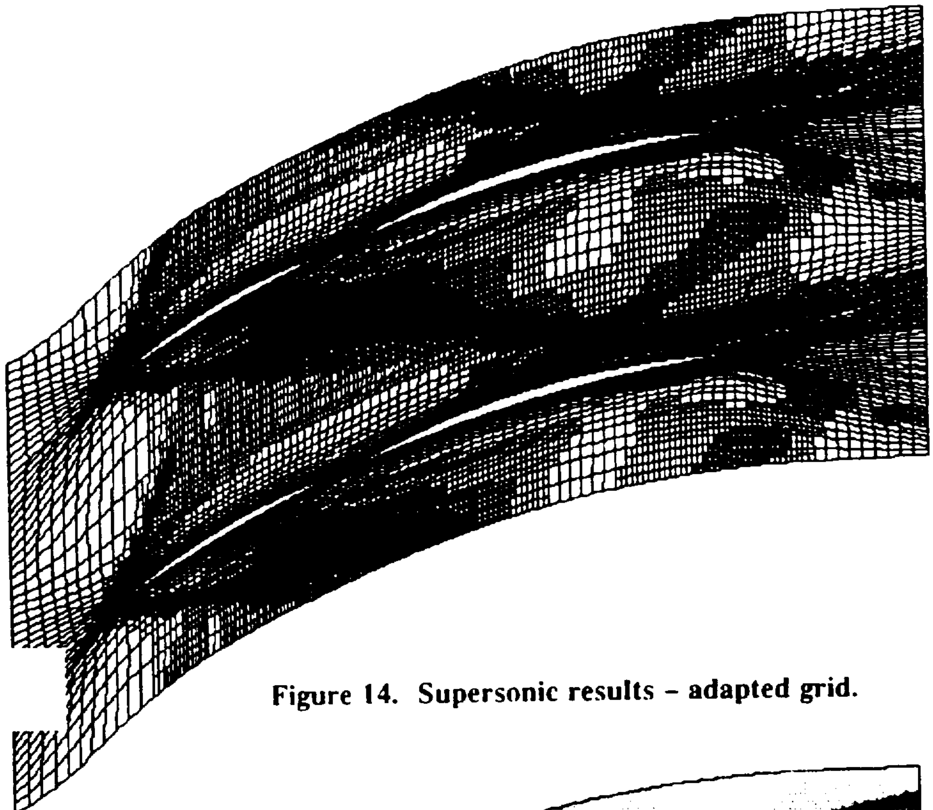

Figure 14. Supersonic results - adapted grid.

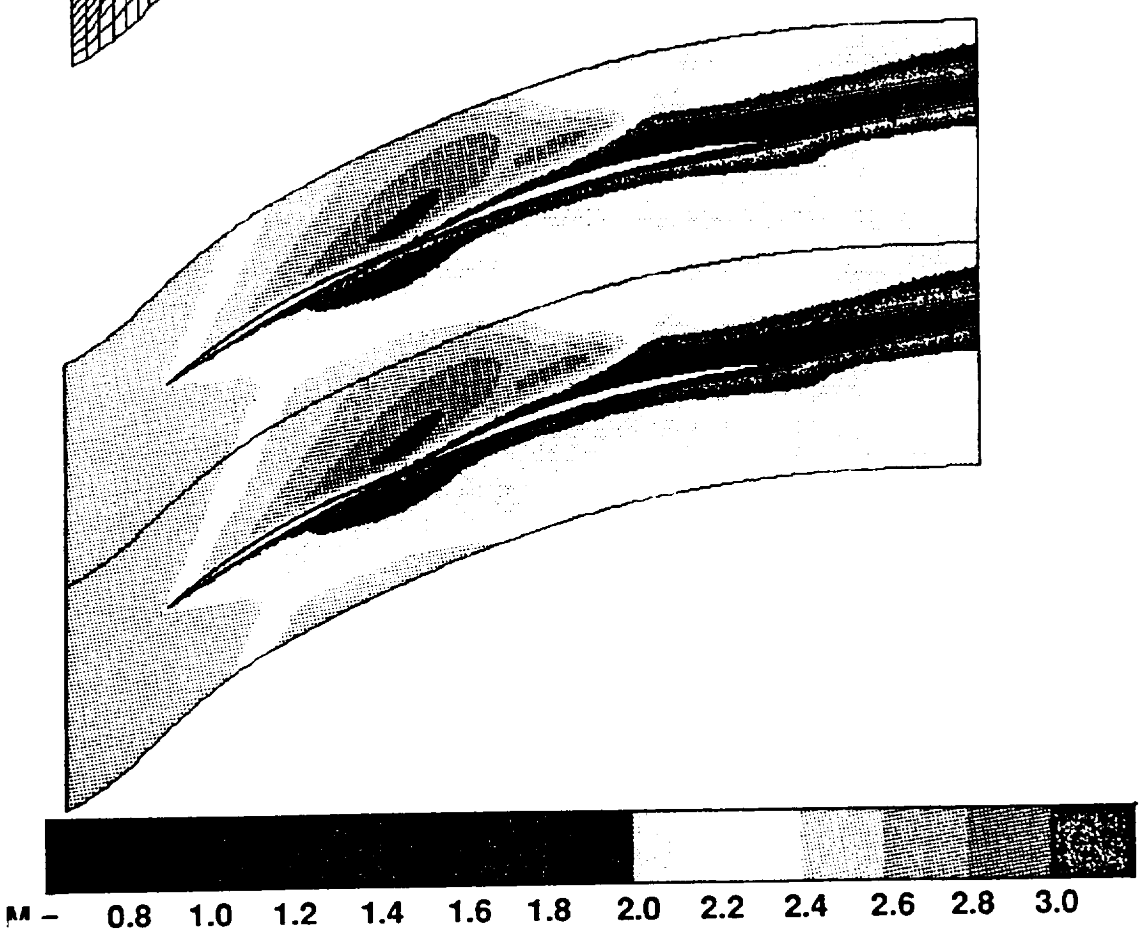

Figure 15. Supersonic results - mach contours.

Figure 16 shows the pressure contours. A small pressure increase (green) across the oblique shock from the leading edge followed by the large expansion (darker blue) over the upper surface and compression (yellow-red) over the lower surface characterize this flow field. There is no significant pressure disturbance emanating from the intersection of the upper surfaces of the two blades.

Figure 17 shows contours of the total pressure loss. The major loss (yellow-red) is associated with the boundary layer and the wake resulting from the separation of the boundary layer from the aft of the second blade.

The pressure coefficient distribution over the blades is shown in figure 18. At the leading edge, the pressures on the top and bottom are equal because the leading edge mean line was parallel to the incoming flow. The pressure drops along the upper surface of the blade and increases along the lower surface as seen

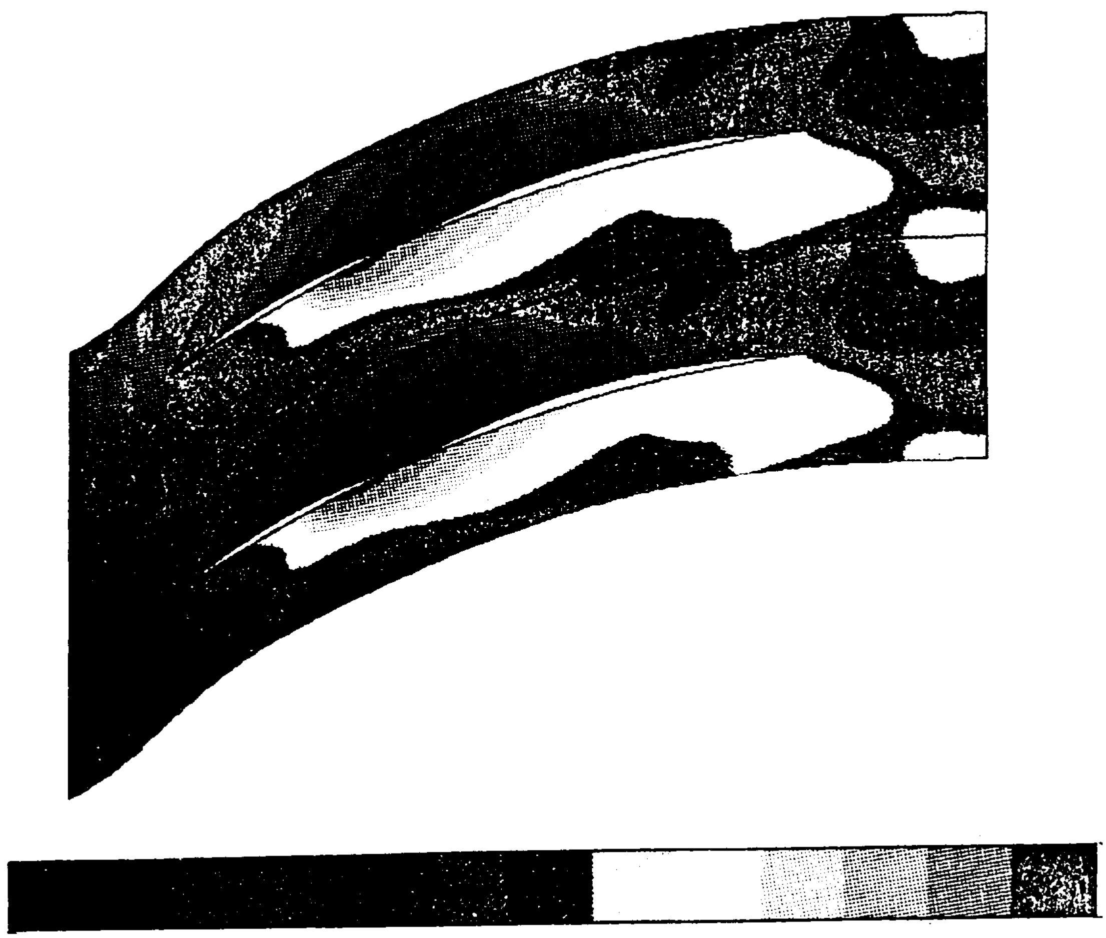

Figure 16. Supersonic results – pressure contours.

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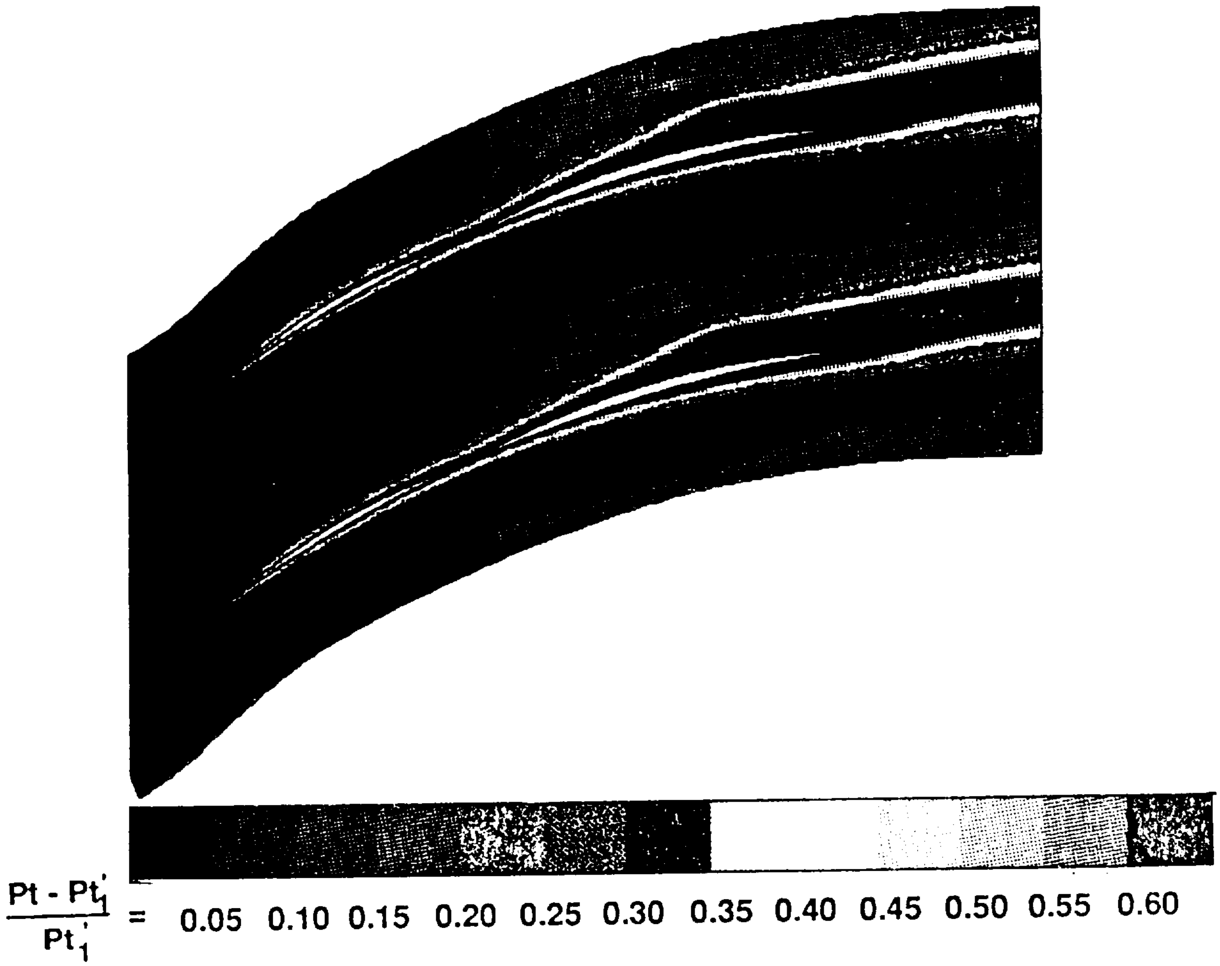

Figure 17. Supersonic results – total pressure loss contours.

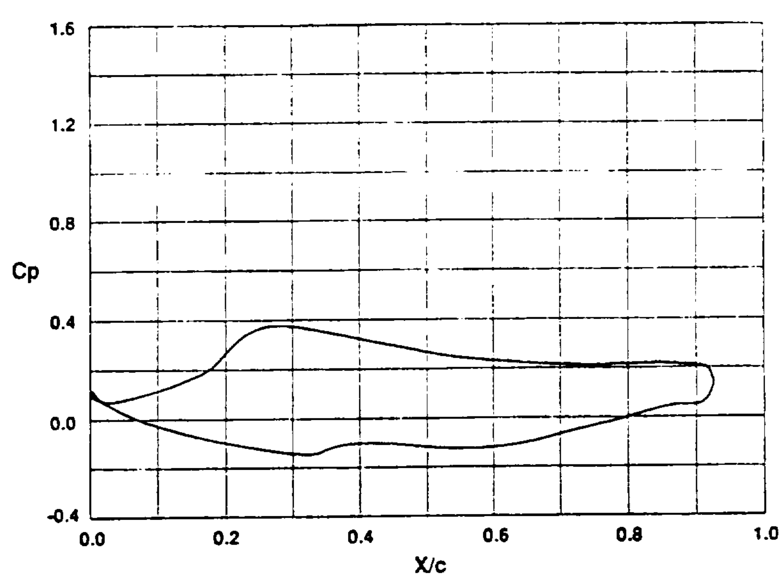

Figure 18. Supersonic results – pressure coefficient.

previously in the pressure contours shown in figure 16. The pressure increase over the aft region of the second blade is related to the flow separation from the upper surface.The pressures across the blade at the trailing edge are not equal; this pressure difference at the trailing edge causes an expansion from the corner of the lower surface which can be seen on the previous pressure contour plot.

Flow profiles at the downstream end of the flow field are shown in figure 19. The Mach number profile shows the large subsonic wake region; the inviscid region, outside the wake, has approximately the same Mach

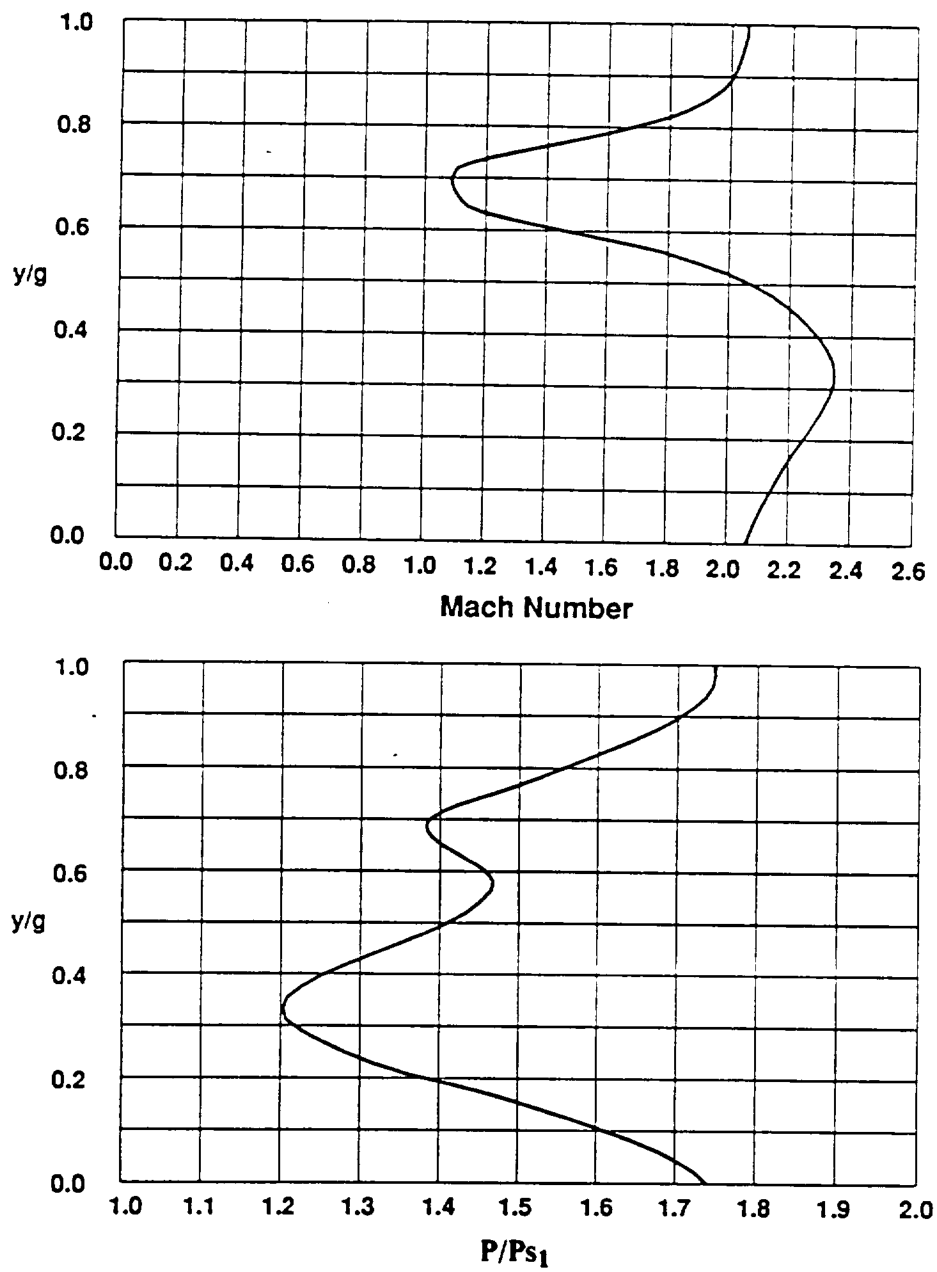

Figure 19. Supersonic results – flow profiles.

number as the incoming flow; testing to the fact that this blade configuration was designed to turn the flow, not change its speed. The pressure profile varies from a minimum downstream of the expansion from the lower corner, to a maximum just above the wake. These profiles (plus temperature, T_2', and flow direction, θ_2') were used in the performance evaluation procedure to define average flow properties.

4.1.2 Transonic Calculation.—As used herein, the term "transonic" refers to those conditions in which the absolute flow velocity at the fan face is subsonic and the relative flow velocity is supersonic. For these cases the exit static pressure was set to a specified value and the upstream total temperature and pressure were specified. The transonic calculations were run with inflow conditions simulating flight at Mach = 0.8 and 18,000 ft. altitude. The fan face flow conditions had the same total temperature (T_{T_1} = 513 R) and pressure (P_{T_1} = 11.2 psia) as the free-stream; i.e. the flow was isentropic across the subsonic conical inlet. For these calculations, the exiting flow is subcritical; therefore, both the back pressure and blade geometry will determine the fan-face conditions. At low back pressures the incidence of the front blade will set the flow Mach number; at high back pressures, the flow is throttled and the fan face Mach number is reduced. For these calculations the initial fan face Mach number and flow properties were set equal to the free-stream conditions M_1 = 0.8, T_1 = 457, P_1 = 7.47 psia. The solution conditions were usually close to these values. The nominal rotor Mach number was 1.3; the rotor velocity was 1358 ft/sec. These initial flow conditions resulted in a relative inlet Mach number of 1.53 and Reynolds number of 5,350,000 based on the 10 in. chord of the two blades.

The adapted grid structure for the baseline blade configuration is shown in figure 20. This grid had five levels of adaptation from the original grid presented in figure 12. The original grid had 1300 nodes; the final grid had 65,000 nodes. Most of these nodes are packed in the regions where there are strong pressure and velocity gradients.

Figure 21 shows the Mach number contours. The flow expansion over the upper surface of the front blade is seen by the red region just downstream of the leading edge. There appears to be two strong shocks in this figure; one standing near the leading edge of the front blade, and one near the trailing edge, just upstream of the aft blade. Both shocks interacted with the large wake (blue) due to boundary layer separation from the upper surface of the front blade. The flow was accelerated as it passed through the gap between the front and aft blades; this high velocity flow subsequently separated from the upper surface of the second blade forming a second wake. These two wakes did not merge by the end of the calculation region.

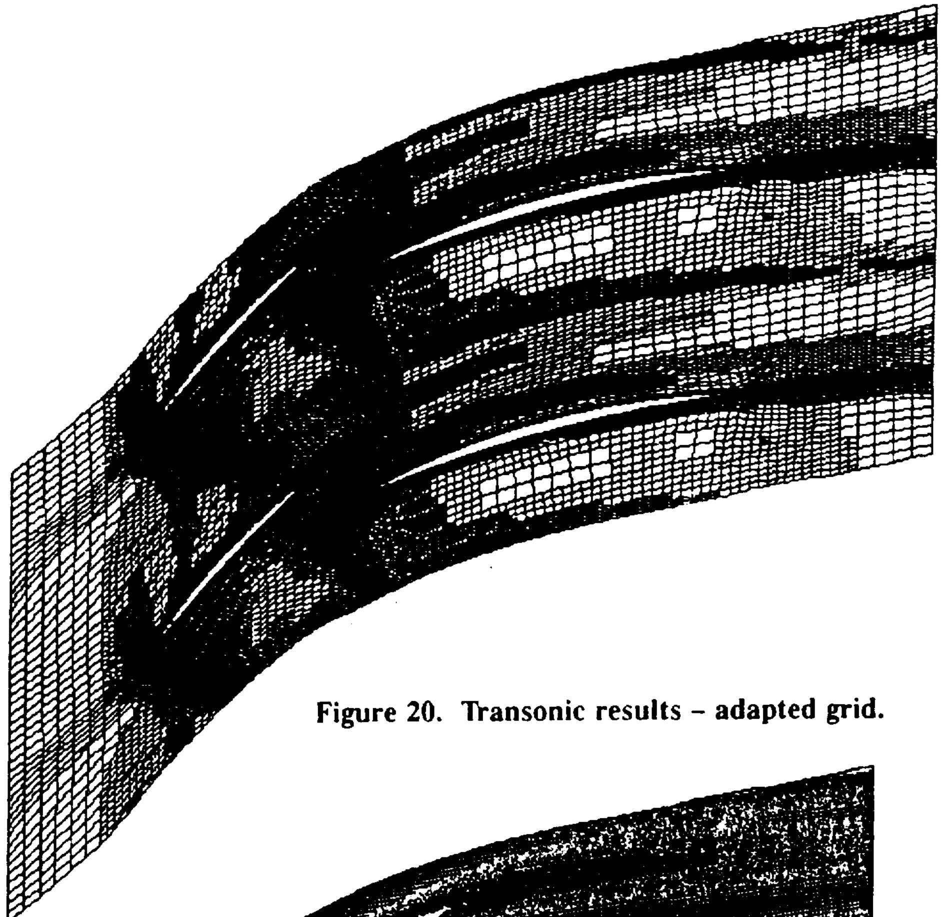

Figure 20. Transonic results – adapted grid.

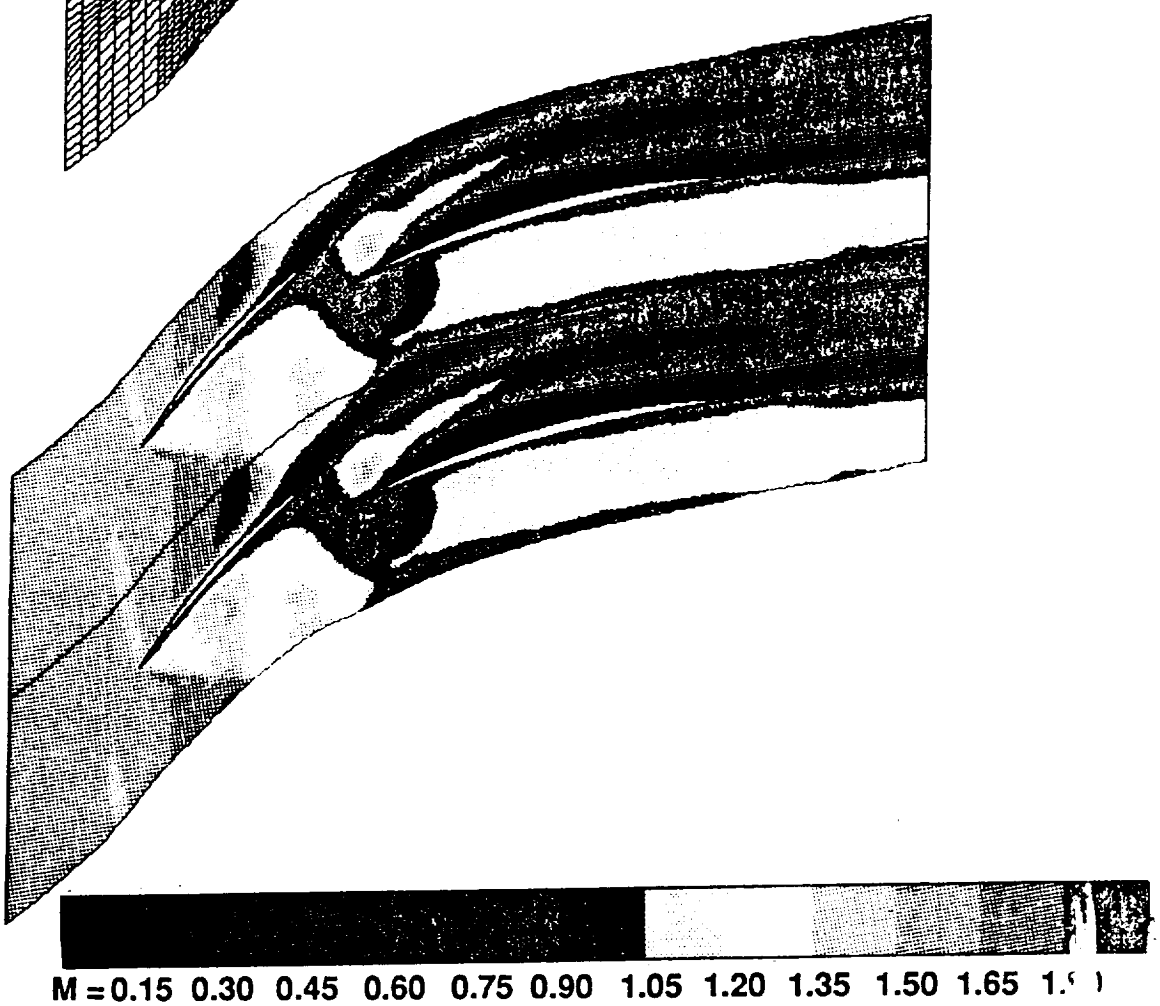

Figure 21. Transonic results – mach contours.

Figure 22 shows the pressure contours. The flow expansion (dark blue) and shock pressure rise (yellow) is evident in this figure. For this calculation the back pressure was set equal to 1.5 times the upstream static pressure.

Figure 23 shows the total pressure loss contours. The major losses (yellow-red) are associated with the boundary layer and wakes. The losses across the two strong shocks are minor.

The pressure coefficient distribution around the blades is shown in figure 24. The static pressure near the leading edge of the upper surface is approximately equal to the upstream static pressure; this is consistent with the unique incidence criterion for transonic inflow. The sharp pressure rises near the leading edge and just upstream of the trailing edge of the first blade are associated with the two shocks located in the flow field discussed previously with the Mach contours. The large pressure rise near the leading edge of the second blade is associated with the stagnation condition downstream of the second strong shock. The pressure drop is a

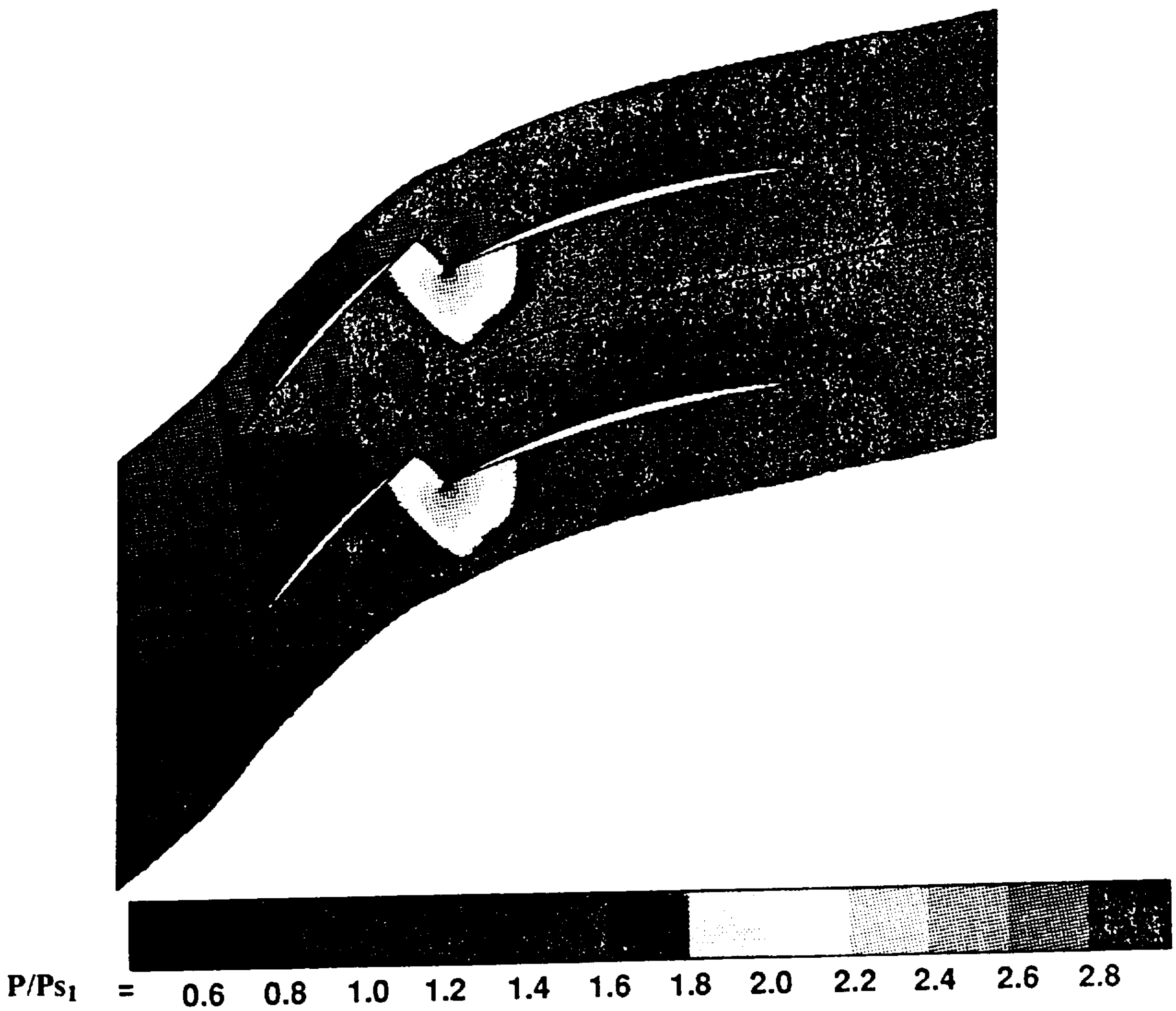

Figure 22. Transonic results - pressure contours.

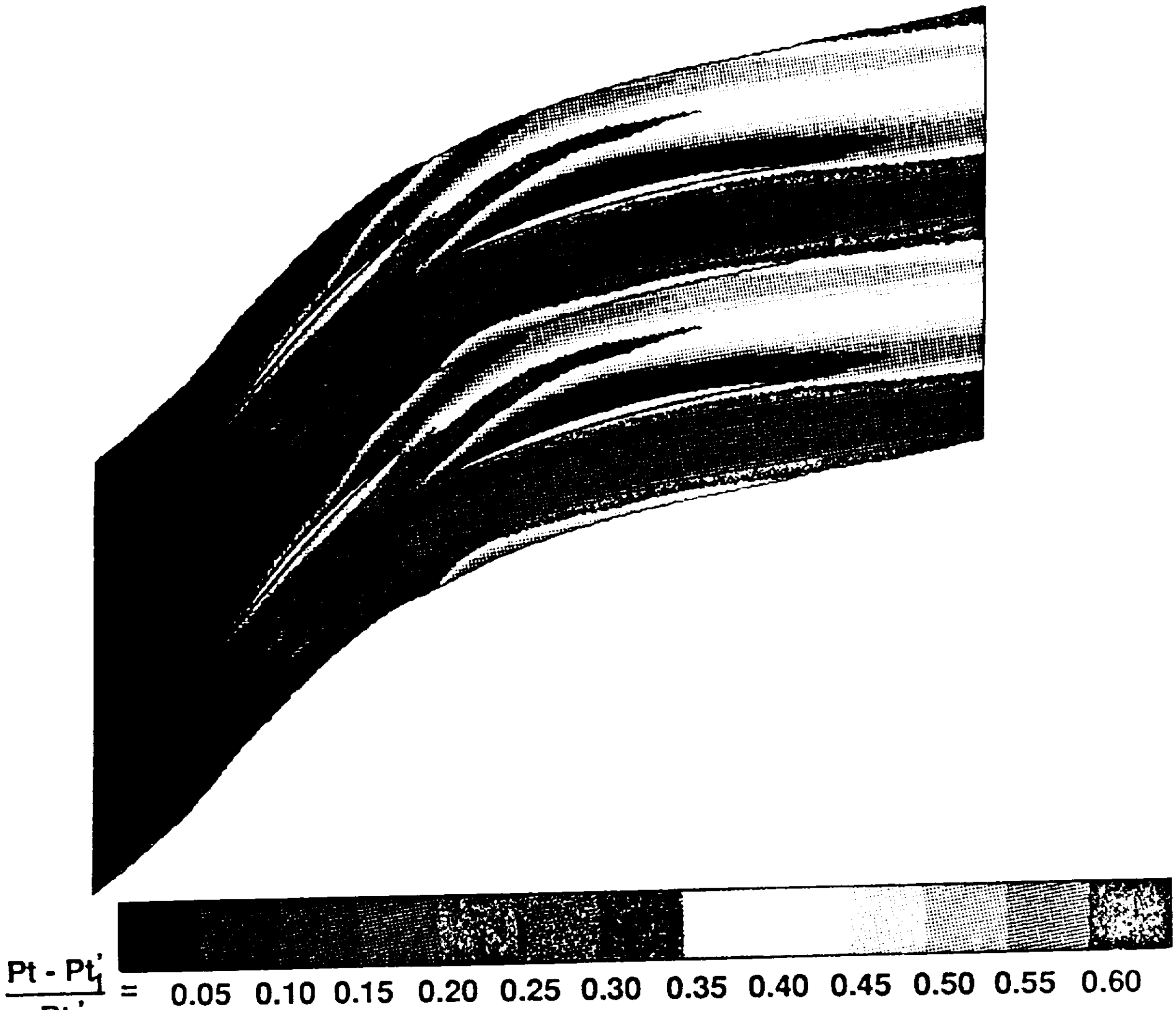

Figure 23. Transonic results – total pressure loss contours.

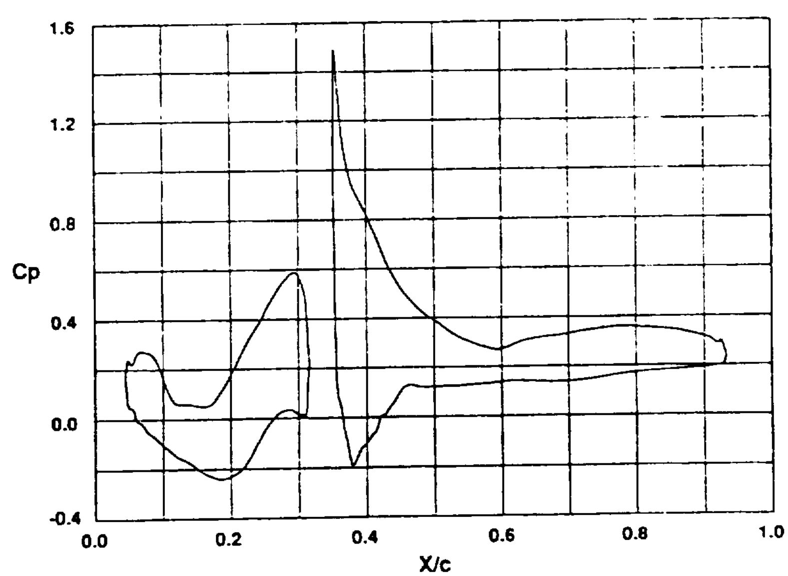

Figure 24. Transonic results – pressure coefficient.

consequence of the flow expansion over leading edge of the upper surface. Note, the nearly constant pressure in the wake region aft of the separated flow from the upper surface of the second blade.

Flow properties at the downstream end of the transonic flow field are shown in figure 25. The Mach number profile shows the two subsonic wake regions. The inviscid region (outside the wakes) is nearly sonic. The exit pressures are much more uniform than the supersonic through-flow case discussed previously. The treatment of these profiles is discussed in the next section.

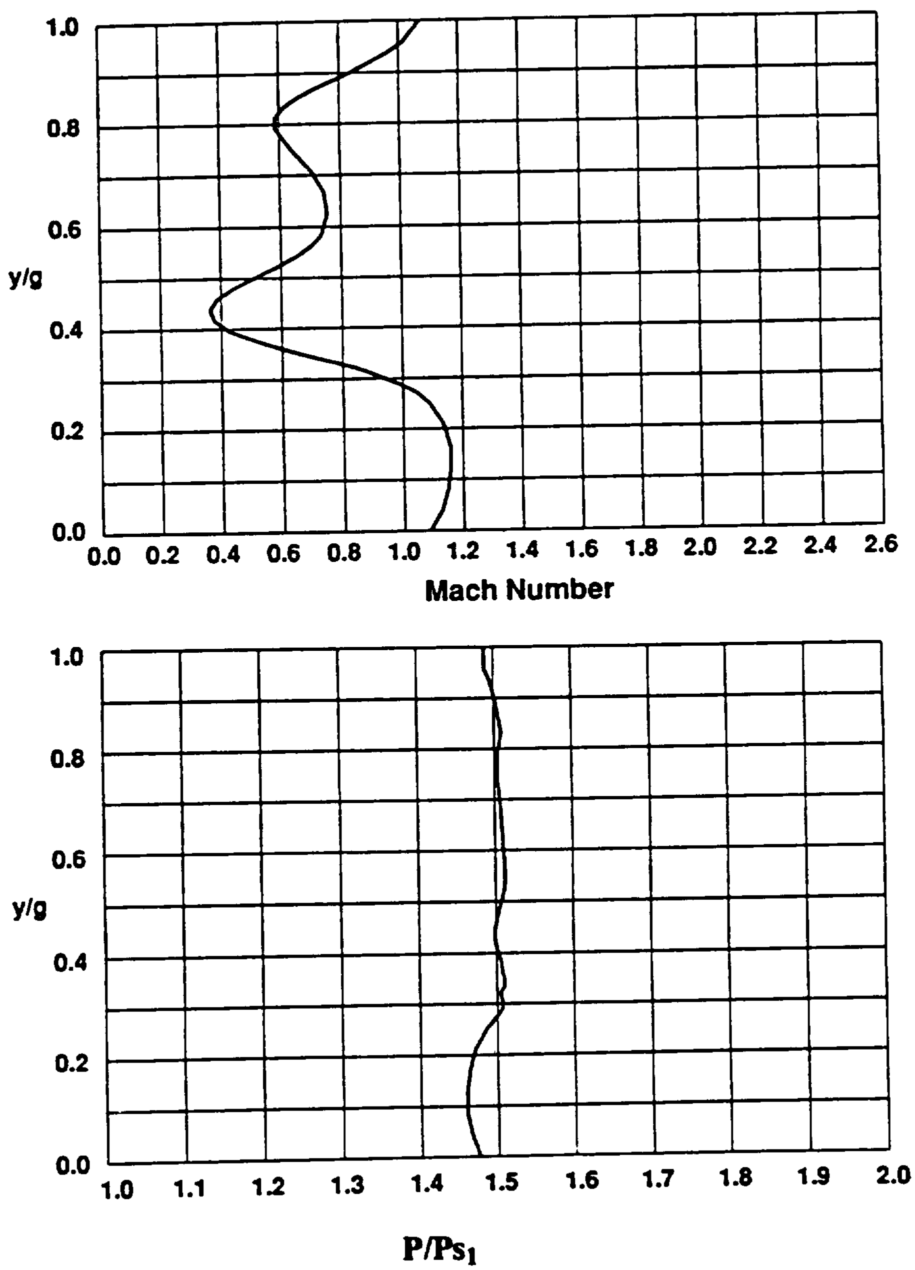

Figure 25. Transonic results – flow profiles.

4.2 Performance Evaluation Procedure

The flow profiles downstream of the fan blades were used to define average flow properties which could be used to define the performance of an elemental fan configuration. This procedure was employed to characterize the performance of each blade configuration at each operating condition. The performance of the various blade configurations were compared and evaluated using this derived fan performance.

4.2.1 Blade Performance Parameters.—A computational procedure was developed to use the flow properties (P', T', V', θ') along a vertical "zero-level" (original) grid line. The procedure includes the flow-data on the additional nodes added by the adaptation. The flow properties are tabulated along specified grid lines, subsequently called "station" even though the grid lines are not necessarily vertical; see figure 12.

The flow properties at each node are used to determine the local mass flux, momentum, energy, etc. at the specified station. These properties are then integrated to determine the vector flow properties defined below in Table 2. Note the elemental mass flow is a scalar and is that quantity which crosses the grid line. The elemental momentum, pressure force, and stream thrust are vector quantities. The enthalpy and kinetic energy are, of course, scalar quantities.

These integrated quantities are then used to define "average" flow properties which are used to determine fan performance. Two sets of "average" flow properties were defined, one called *Unmixed* and the other called *Mixed*. The *Unmixed* flow properties (pressure, temperature, velocity, etc.) are defined in Table 3. It should be noted that each of these properties are defined independently and, except for static pressure, are mass-average properties. The *Mixed* flow properties are found by the simultaneous solution of the continuity, x-momentum, y-momentum, energy, and state equations given in Table 4 for the five "average" properties: pressure, density, temperature, x-velocity, and y-velocity. The *Mixed* flow represents the flow conditions which would exist after mixing to a uniform condition in a hypothetical adiabatic, frictionless duct. The mixing that takes place causes an increase in the entropy and a decrease in the total pressure. By using these procedures, two sets of relative velocity, pressure, temperature, etc. across a blade row are defined. The rotational velocity ($V_R = V_1' \sin \theta_1'$) is added vectorially to the relative velocity ($\vec{V}_2'$) to obtain the absolute exit velocity (as seen by an observer moving with the engine). This absolute velocity and the static state properties can be used to define the total pressure and total temperature in the absolute system.

Table 2: Definition of Integrated Flow Quantities

Elemental Mass Flow	$d\dot{m} = \rho\vec{V} \cdot \vec{ds}$
Mass Flow	$\dot{m} = \int d\dot{m}$
Momentum	$\vec{M}_V = \int \vec{V} d\dot{m}$
Pressure Force	$\vec{F}_P = \int P\vec{ds}$
Stream-Thrust	$\vec{F}_S = \vec{M}_V + \vec{F}_P$
Enthalpy	$H = \int c_p T d\dot{m}$
Kinetic Energy	$K_E = \int (\frac{\vec{V} \cdot \vec{V}}{2}) d\dot{m}$
Total Enthalpy	$H_T = H + K_E$

Table 3: Unmixed Average Flow Properties

Static Pressure	$\bar{P} = \frac{\int P dA}{A}$
Total Pressure	$\bar{P}_T = \frac{\int P_T d\dot{m}}{\dot{m}}$
Temperature	$\bar{T} = \frac{H}{c_p \dot{m}}$
Total Temperature	$\bar{T}_T = \frac{H_T}{c_p \dot{m}}$
Velocity	$\bar{\vec{V}} = \frac{\vec{M}_V}{\dot{m}}$

Table 4: Mixed Average Flow Properties

Continuity	$\dot{m} = \bar{\rho} A_x \bar{V}_x$
X-Momentum	$F_{S_x} = \bar{P} A_x + \dot{m} \bar{V}_x$
Y-Momentum	$F_{S_y} = \dot{m} \bar{V}_y$
Energy	$H_T = \dot{m}[c_p \bar{T} + \frac{1}{2}(\bar{V}_x^2 + \bar{V}_y^2)]$
State	$\bar{P} = \bar{\rho} R \bar{T}$

Three additional parameters were defined to describe the fan performance: the work performed by the fan, the absolute fan total pressure ratio, and the fan efficiency. The parameter used to describe the work performed by the fan is the work done, W, normalized by the absolute incoming total enthalpy, H_{T_1}. This parameter was calculated using the following relationship:

$$\frac{W}{H_{T_1}} = \frac{\Delta F_{s_y} V_R}{\dot{m} H_{T_1}} \tag{4.1}$$

where ΔF_{s_y} is the change in the y–component of $\vec{F}_s$ between the fan inlet and exit. For a vertical exit plane survey, the change in stream thrust is equal to the change in the y–component of the flow momentum; i.e. $\Delta F_{s_y} = \dot{m} \Delta V_y$.

The absolute total pressure can be calculated from the exit static pressure and Mach number. It can also be calculated from the flow losses and the work done using the following relationship:

$$\frac{P_{T_2}}{P_{T_1}} = \frac{P_{T_2}'}{P_{T_1}'} \left(1 + \frac{W}{H_{T_1}} \right)^{\frac{\gamma}{\gamma-1}} \tag{4.2}$$

The fan efficiency is defined as the ideal work required to generate the actual total pressure ratio divided by the actual work:

$$\eta_c = \frac{\Delta h_{ideal}}{\Delta h_{actual}} = \frac{\left(\frac{P_{T_2}}{P_{T_1}}\right)^{\frac{\gamma-1}{\gamma}} - 1}{W/H_{T_1}} \tag{4.3}$$

These three parameters are used to define the elemental blade performance which is associated with the configurations analyzed.

4.2.2 Typical Blade Performance.—The preceding analysis was used to evaluate the performance of the various blade configurations. Examples of the results for the baseline configuration supersonic and transonic solutions are presented in figures 26 and 27.The supersonic performance, shown in figure 26, compares the *unmixed* and *mixed* average values of the relative total pressure ratio across the blades, P_{T_2}'/P_{T_1}'; the work done, W/H_{T_1}), the absolute total pressure ratio, P_{T_2}/P_{T_1}; and the fan efficiency, η_c, using a bar chart format. Note that the relative total pressure ratio (as seen by an observer moving with the blade row) is less than one, whereas the absolute total pressure ratio (as seen by an observer moving with the engine) is significantly greater than one. For both the relative and absolute frame of reference, the mixed exit total pressures are about 10% lower than the *unmixed*, mass-average total pressure. The absolute total pressure ratio of 2.5 is substantial for a single fan stage. The work done is the same by either definition of average flow properties. The fan efficiency is also higher for the *unmixed* or mass-average properties. The calculated efficiency, $\eta_c = 74\%$, is about 10 counts less than that predicted by the simple procedure used in reference 1 for estimating STFF fan performance.

The transonic performance for the baseline fan configuration, as shown in figure 27, presents the same type of information. The same trends between the *unmixed* and *mixed* flow characteristics are observed. For this example, a mass-average total pressure ratio of 3.2 was calculated for this single-stage fan operating at a rotor speed of 1350 ft/sec. The corresponding efficiency, $\eta_c = 72\%$, was low due to the large separated region in the exiting flow field.

The *unmixed*, mass-average properties are normally used by the industry to define fan performance because these properties quantify the potential performance of the flow. Subsequent mixing degrades this performance. Thus processes which use the flow immediately, such as a sudden discharge, are characterized

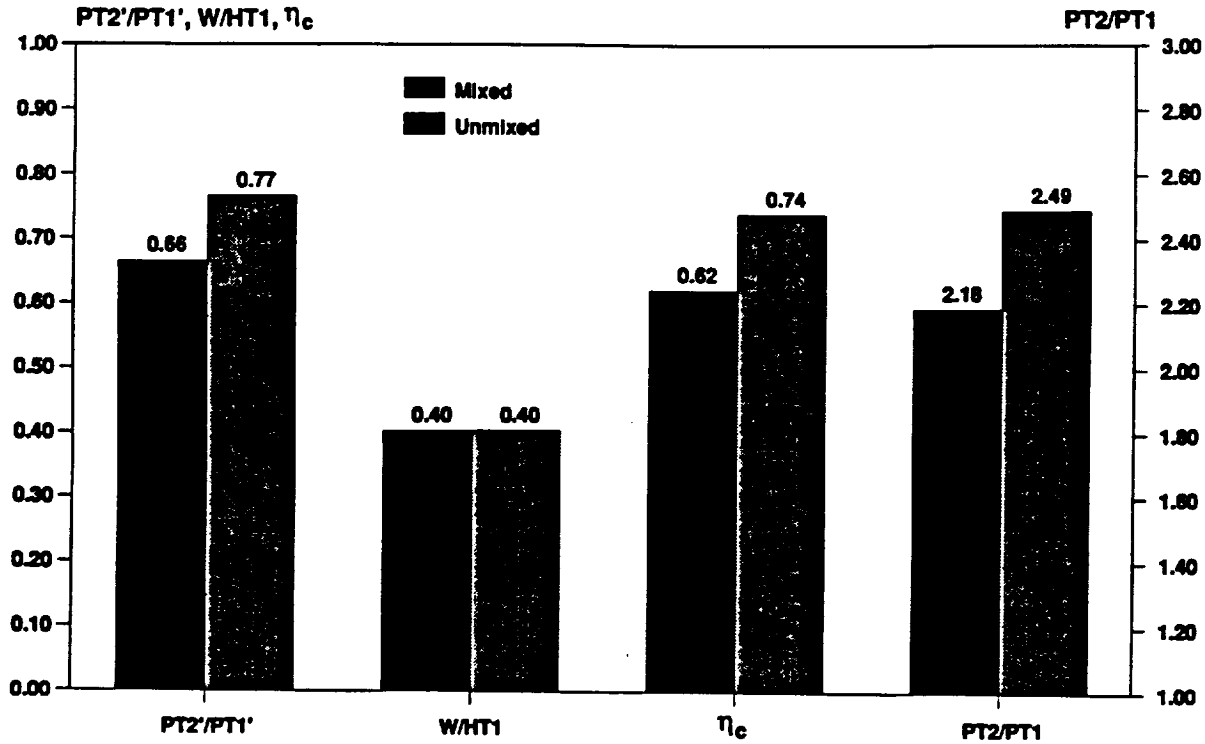

Figure 26. Supersonic performance – VPR–6.1.

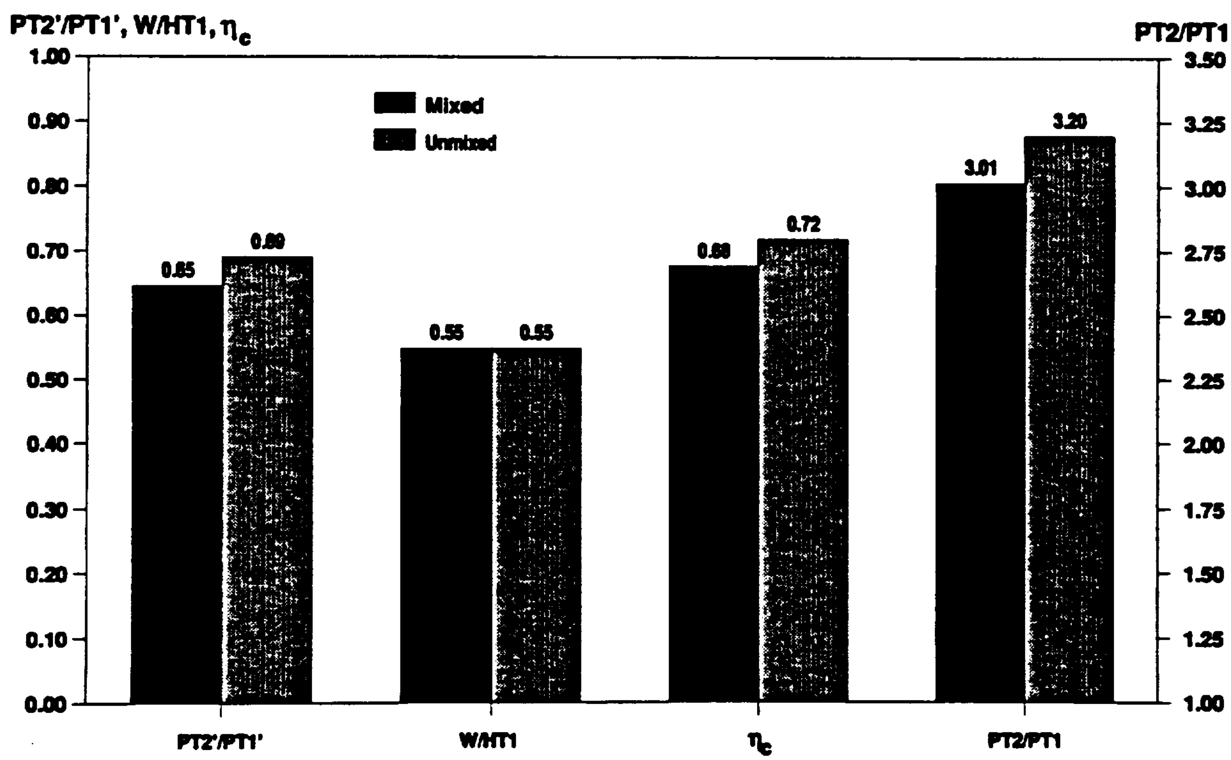

Figure 27. Transonic performance – VPR–6.1.

best by the mass-average properties; whereas, processes which require some mixing to occur have a lower performance potential. The *unmixed* properties are used in subsequent figures to describe the fan performance.

The fan performance described above represents the performance of the baseline fan configuration. These results showed that the ADAPTNS calculation procedure could be employed to predict both the supersonic and transonic performance of the split-blade configuration. That these results can be used to define meaningful fan performance parameters which can be used to evaluate and compare with other blade configurations.

5. PERFORMANCE EVALUATIONS

5.1 Supersonic Performance

The baseline configuration plus three others were evaluated at the supersonic design condition. They were: (1) the single blade configuration STFF-9 which had the same overall turning and lower surface contour as the baseline; (2) the reduced gap baseline configuration, VPR-6.1R6, which used the same blade geometry but reduced the gap by 33%; and a new configuration, VPR-9.1 which had a new front blade with reduced turning, but the same aft blade as the baseline. All four blades had the same amount of total turning.

The work done and relative total pressure ratio are compared in figure 28. Because all four configurations had the same amount of turning, they did a comparable amount of work. However, the single blade configuration and the new VPR-9.1 configuration did a little better job of turning the flow, and did a little more work than the baseline; the reduced gap configuration did a better job of channeling the flow and did marginally more work. The new blade configuration, VPR-9.1, has about the same total pressure losses as

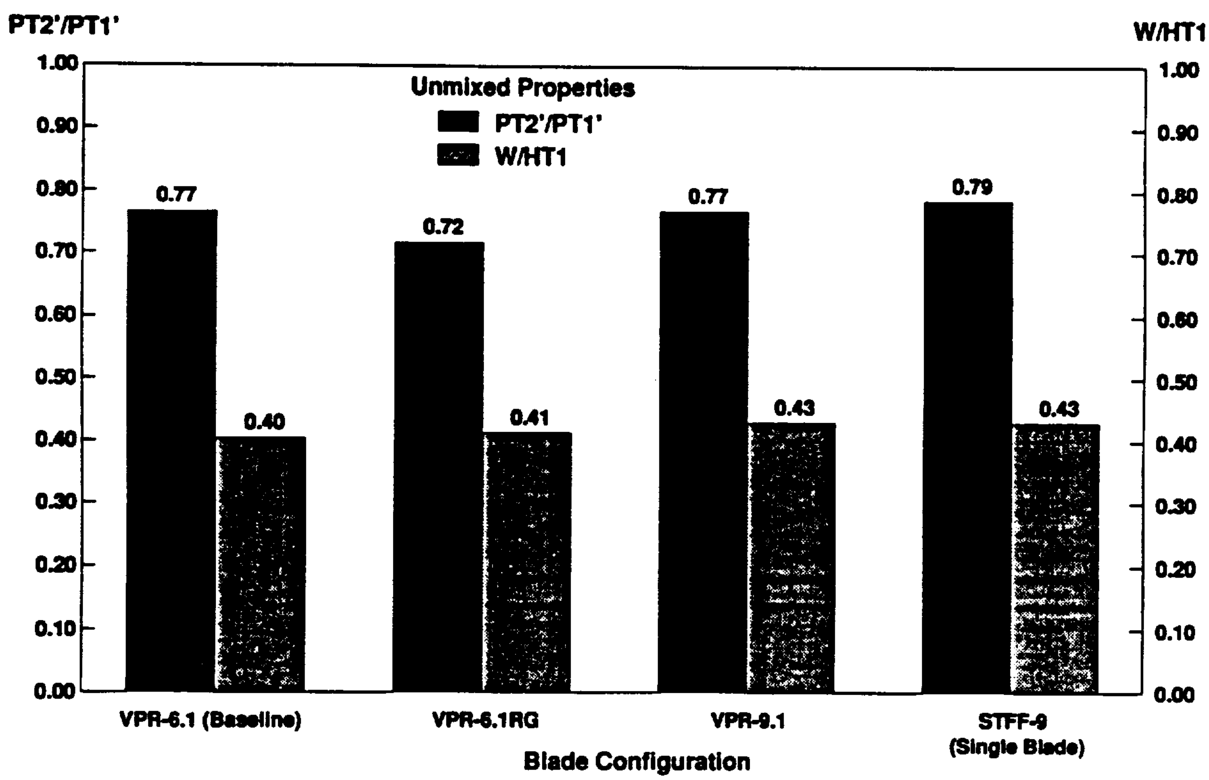

Figure 28. Supersonic performance comparisons – relative total pressure and work done.

the baseline, the single blade configuration STFF-9 is slightly (2%) more efficient. These three configurations had the same gap/chord ratio; thus they had the same surface to flow area. The reduced gap configuration VPR-6.1RG had the same blade surface area, but the reduced gap reduced the flow area. The surface to flow area of this configuration was 50% greater than the other three configurations. This resulted in increased friction losses. Although this configuration had less separated flow, the overall losses were 5% greater than the baseline and VPR-9.1 configurations.

The absolute total pressure ratio and fan efficiency are shown in figure 29. The absolute total pressure ratio is a function of both the flow losses and work done. Since the STFF-8 and VPR-9.1 blades did the same work, they generated comparable total pressure ratios, both a little higher than the baseline. And because of the greater losses of the reduced gap configuration, it had a slightly lower total pressure than the baseline.

The fan efficiencies show similar trends, for similar reasons, as the total pressure ratios. The single bladed STFF-9 had the highest efficiency which was 4% greater than the baseline, and the reduced gap

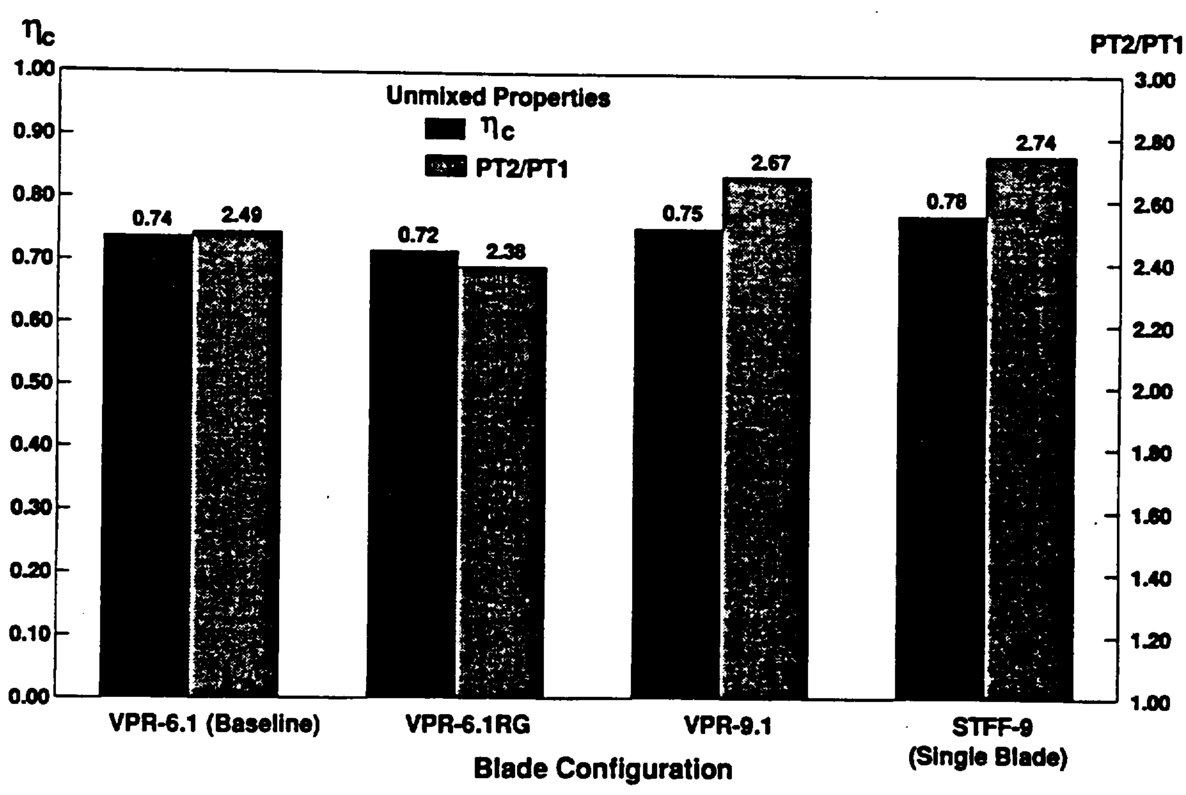

Figure 29. Supersonic performance comparisons – fan efficiency and absolute total pressure.

configuration was 2% lower. The new VPR-9.1 configuration was comparable to the single bladed configuration. The efficiency of the single blade, STFF-9 (η_c = 78%) is comparable to that achieved by a similar configuration in supersonic through-flow fan tests reported in reference 10.

5.2 Transonic Front Blade

During transonic operation the front blade of the variable-pitch split-blade fan is intended to operate much like a conventional high-speed fan with a "normal shock" located within the blade row; thereby generating a substantial pressure rise and reducing the exit flow to subsonic velocities before encountering the second fixed blade row which turns the flow to increase the work done. The front blade of the baseline configuration had a total turning of 11 deg on the lower compression surface and a mean camber turning of 17 deg. This is much higher than conventional fan blades which are designed to operate with transonic inflow conditions. After examining the flow pictures from the transonic calculations of the baseline configuration, we postulated that the flow separation from the upper surface of the front blade (see fig. 21) may be due to the excessive turning. Therefore, a set of front blades, all with less turning than VPR-6f, were selected for evaluation without an aft blade. The specifics of these blades are described in Section 2, and the blade geometries are presented in figure 6. To summarize, blades VPR-9f, 11f, 14f, 15f all have small but positive camber, and blades VPR-10f, 12f, 13f, 16f all have a reflex camber and a straight section on the upper front portion of the blades to eliminate the flow expansion over the upper surface.

Typical flow fields generated by these front blades ar shown in figure 30. This figure shows the Mach number contour for two front blades: VPR-9f is a continuous turning blade with 11 deg of mean-line turning; and blade VPR-12f is a reflexive blade with zero mean-line turning. The back pressure for these calculations were near the critical value which positioned the initial shock near the leading edge of the blade. Significant difference in the shock structure can be seen. For the reflexive blade, VPR-12f, the leading edge shock from the upper blade is strong, it crosses the passage, and interacts with the boundary layer on the aft diverging section of the lower blade, causing the flow to separate off the aft of the blade. For the curved blade, VPR-9f, the leading edge shock from the upper blade is weak, it coalesces with the strong shock which is associated with the separated region from the upper surface of the lower blade. The wake region from this blade is much larger than that from the zero turning blade.

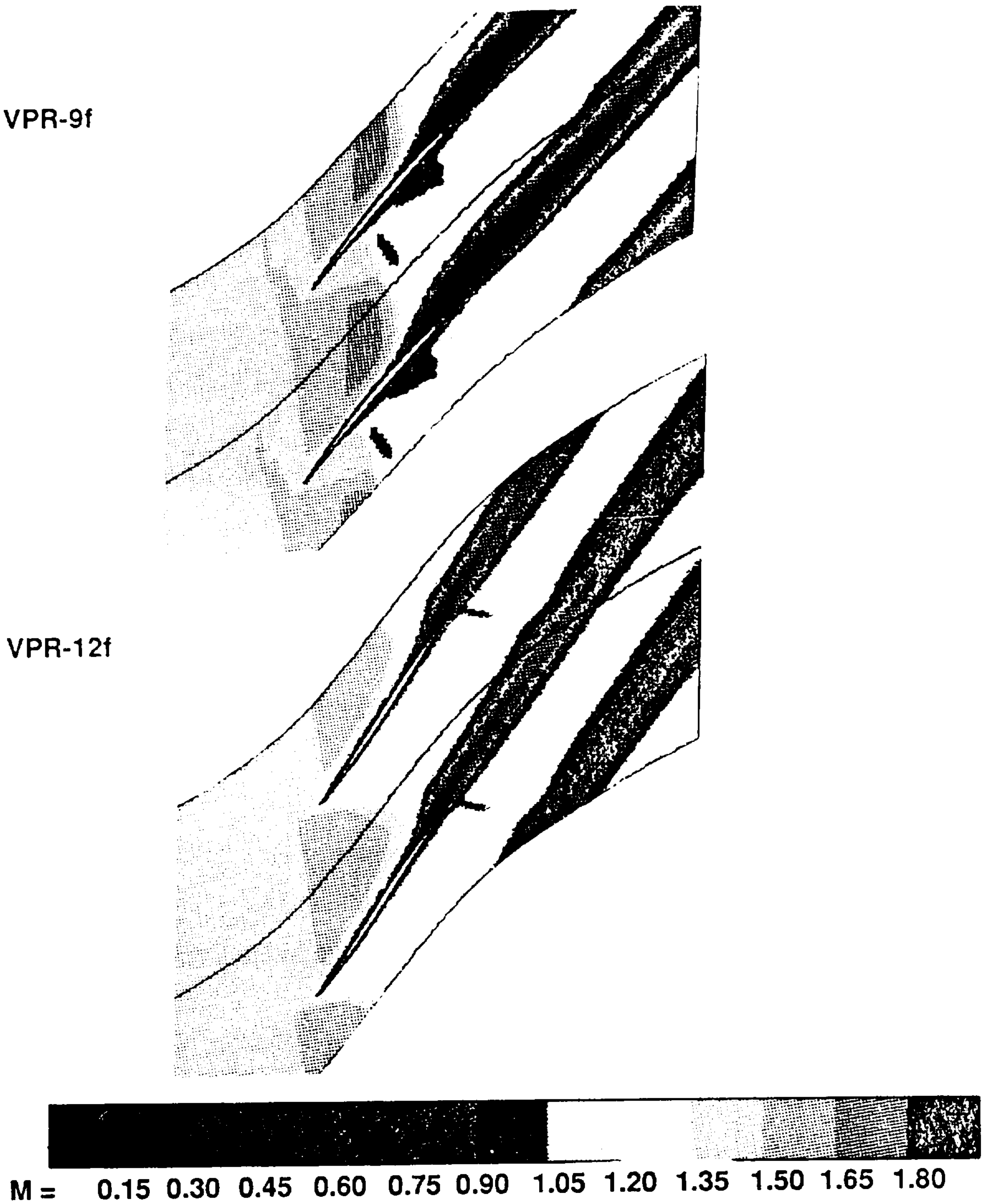

Figure 30. Transonic mach contours - front blade VPR-9f and 12f.

The flow fields shown for these two blades are dependent on the exit pressure; these calculations were run over a range of exit pressures. At low back pressure the inlet flow is supercritical and the (absolute) subsonic inflow Mach number is set by the unique incidence criteria; but at sufficiently high back pressures the "normal shock" moves up the blade passage toward leading edge, alters the incoming flow field, and reduces the inflow Mach number. This effect is shown in figure 31, in which the resulting corrected airflow per unit area is plotted as a function of the exit pressure normalized by the (absolute) inlet total pressure for blade configurations VPR-9f, 11f, 12f, 13f. These blades had very little camber; other blades with more camber achieved a critical back pressure, above which the flow became unstable and no solutions were achieved. The four blades shown reached a critical back pressure which exceeded the (absolute) upstream total pressure; however, this critical back pressure was only 45% of the relative incoming total pressure. At low pressures, the corrected airflow, W_c/A = 46 lb/sec/ft^2, was set by the unique incidence criteria, which aligned the flow with the angle of the initial upper surface of the blade plus the boundary layer displacement thickness angle of approximately 1 deg.

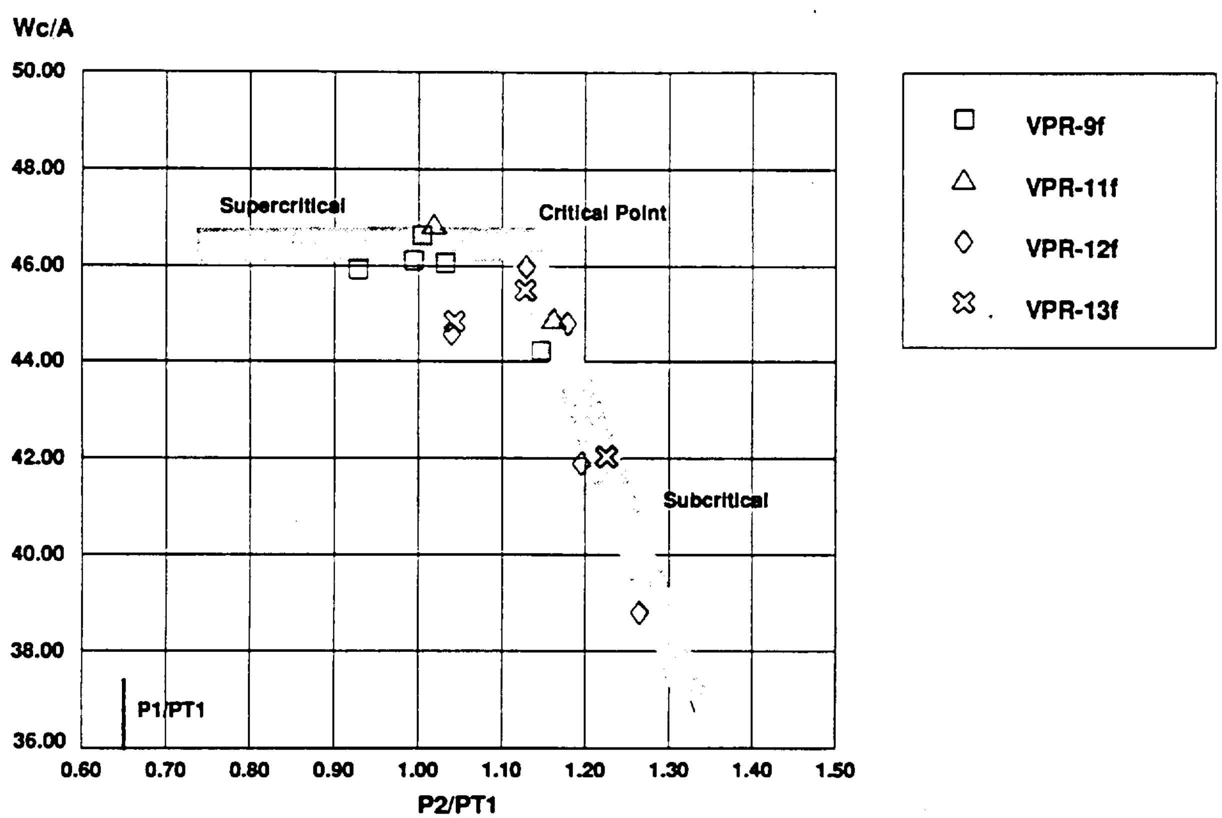

Figure 31. Transonic flow adjustment – front blade comparison.

The work done by these isolated front blades is also dependent on the back pressure as shown in figure 32. This is a consequence of two effects: (1) as the "normal shock" system moves forward in flow passage between the blades, the pressure first increases on the underside of the blade surface, thereby increasing the lift on the blade and the work done by the blade; thus, there is greater flow turning; and (2) for back pressures above the critical value, the airflow through the blade row is decreased, thereby resulting in more work per unit mass. For some of these configurations the work output was increased by 50% at the high exit pressures.

The total pressure losses associated with the isolated front blades is shown in figure 33. For supercritical operation, the mass-average total pressure losses are very low, approximately 5%, for the low camber blades (VPR-10f, 11f, 12f, 13f, 16f) and a little more (~7%) for the other blades (VPR-9f, 14f, 15f). For back pressures above the critical value, the losses increase when the shock system moves forward in the blade row. The mixed total pressure for these cases is about 5% lower than the mass-average values shown.

The fan performance parameters are shown in figure 34. In this figure the (absolute) total pressure ratio for each case is plotted as a function of the work done. Lines of constant fan efficiency are also plotted to the

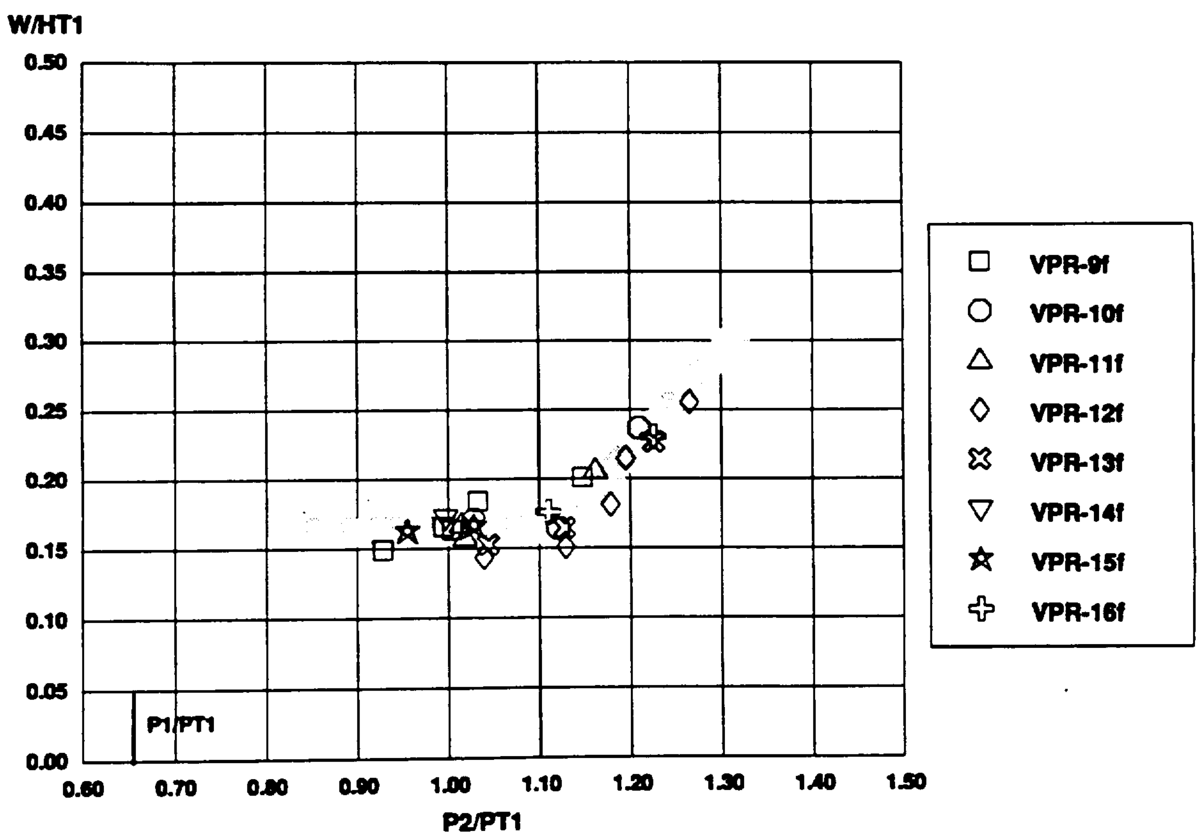

Figure 32. Transonic work done - front blade comparison.

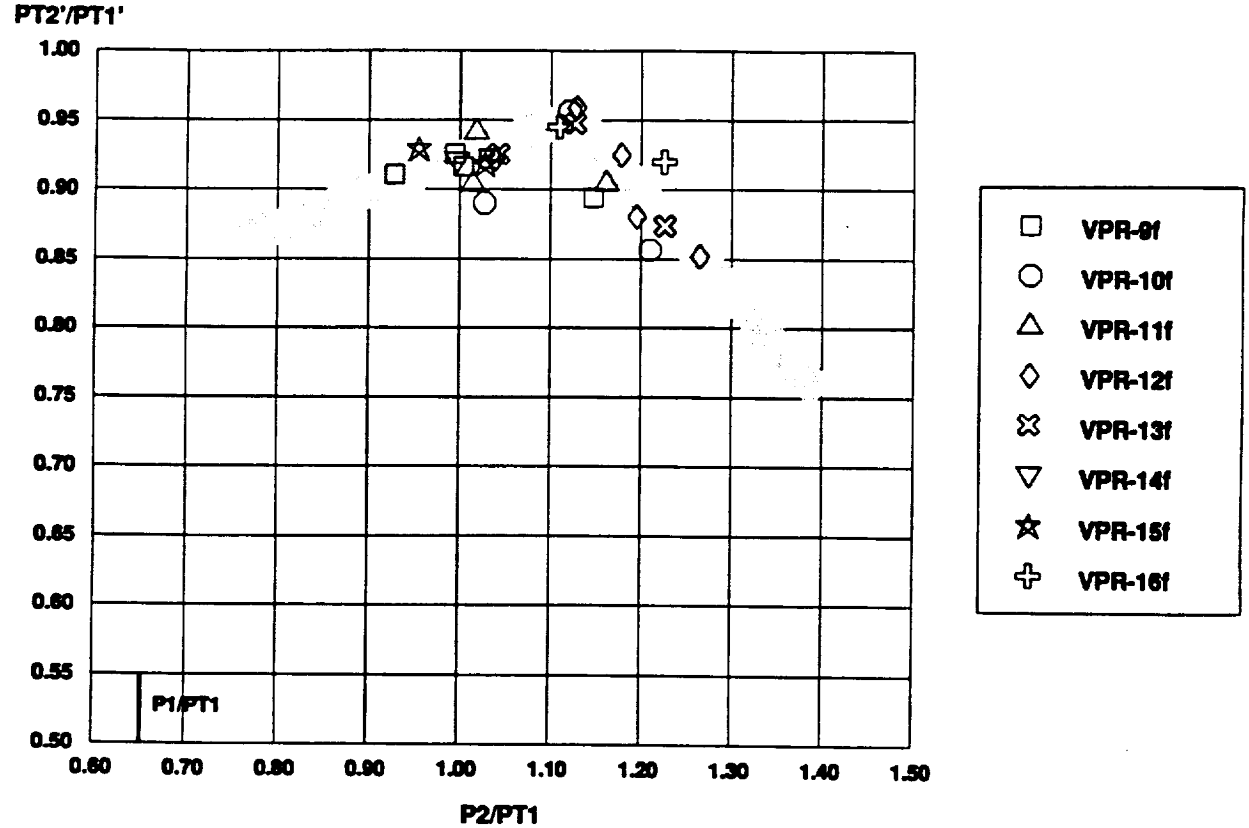

Figure 33. Transonic flow losses – front blade comparison.

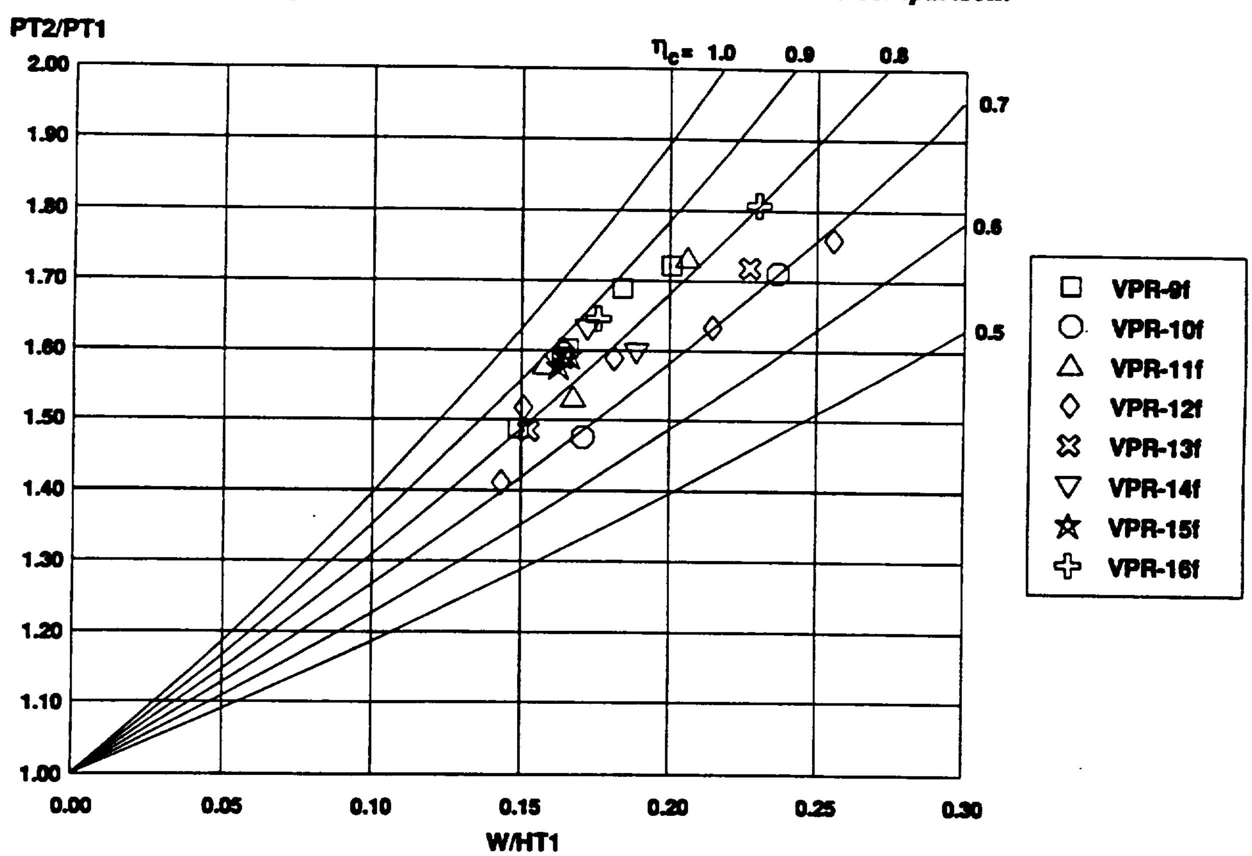

Figure 34. Transonic fan performance – front blade comparison.

same scale. Their manner of presentation shows the interrelationship between work done, total pressure generated, and the fan efficiency. The fan losses are a consequence of the relative total pressure losses which are not shown in this presentation. The maximum fan efficiencies obtained in these cases were in the high 80's%. They occurred near the critical operating point. The associated total pressure ratios were in the 1.5 to 1.7 range depending on the work done. The static pressure ratios were in the same range. For operation above the critical back pressure, more work is done, higher total pressures are achieved, but the fan efficiency drops off rapidly.

The front blade investigation, discussed above, led to some interesting conclusions about transonic fans. Those blades with significant camber had a lower critical static pressure rise and little to zero range of subcritical operation. Conversely, the low turning and reflexive blades had higher critical pressure rise, a larger range of subcritical operation, smaller wakes, and lower flow losses. The maximum fan efficiencies occurred near the critical pressure rise and were in the high 80's% for all of these configurations.

5.3 Transonic Aft Blades

A series of six aft blade configurations were selected to be evaluated with the front blade VPR-13f. This reflexive front blade had 6 deg of lower surface turning. The aft blades VPR-13.3 through 13.8 were all circular arc blades with various amounts of total turning and orientation. Blades VPR-13.2-13.5 had lower surfaces which turned 24.87, 30.87 and 36.87 deg, respectively. They were all oriented so the lower surface trailing edge angle was 6 deg. Configuration VPR-13.6 had the same aft blade shape as VPR-13.3, but rotated 6 deg, and configuration VPR-13.7 had the same aft blade shape as VPR-13.3, but rotated 12 deg. The aft blade of configuration VPR-13.8 had only 6 deg of turning on the lower surface and was oriented so the upper leading edge surface was parallel with the lower trailing edge of the front blade; thereby providing a parallel channel for the flow through the slot. The complete geometry of these configurations is presented in Table 1. Also included in these comparisons is the modified aft blade configuration, VPR-6.2, used in the reference 2 study.

The flow fields generated by two of these configurations is shown in figure 35. The figure shows the Mach number contours for the high turning VPR-13.3 and the low turning VPR-13.8. The back pressure for these calculations were near the critical value. For the high turning configurations the "normal shock" is located in the region between the front and aft blades; further increases in back pressure resulted in no stable solution. For the low turning configuration the shock moved up into the front passage, was stable in that location, and

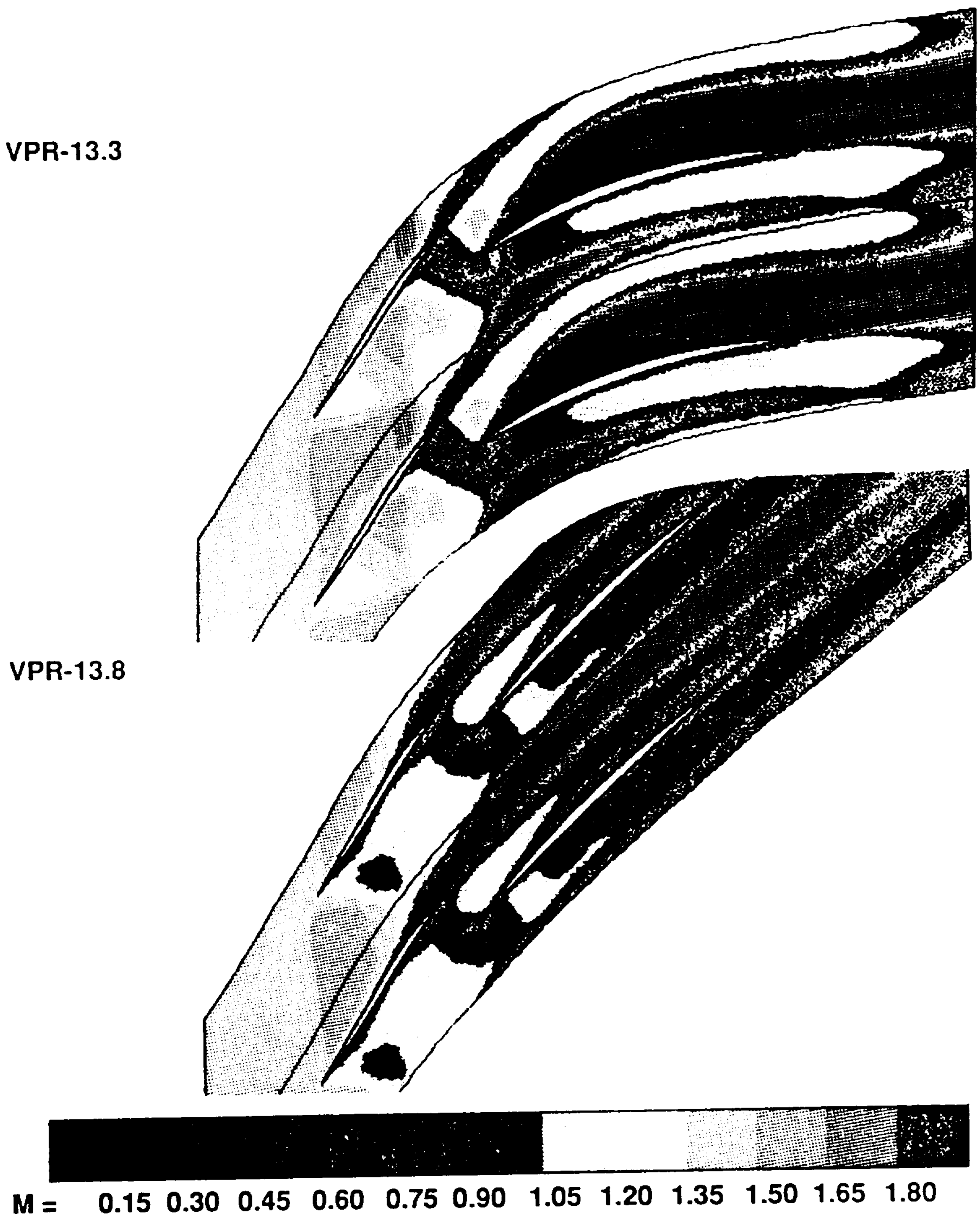

Figure 35. Transonic mach contours - VPR-13.3 and 13.8.

solutions were obtained for higher back pressures which reduced the inflow. Note the difference in the separated region for these two cases, the smaller wake region for the low turning case resulted in considerably less total pressure loss.

The work done by these aft blade configurations is shown in figure 36. There is a variation in the work done by the various blade configuration because there is a large variation in the total turning by the blades. Configurations VPR-13.3 to 13.5 did the most work, they all had a trailing edge of 6 deg. Configuration VPR-13.8 did the least work; it had a trailing edge angle of only 40 deg. The work done by this last configuration is dependent on the back pressure, the others are not. This is because the amount of flow turning for a blade configuration having little turning is a function of the change in exit flow velocity caused by the back pressure. This figure clearly shows the dependence of work done on the blade turning.

The relative total pressure losses through these blade configurations is shown in figure 37. In this figure the mass-average flow losses are plotted as a function of the blade turning. These results show that the flow

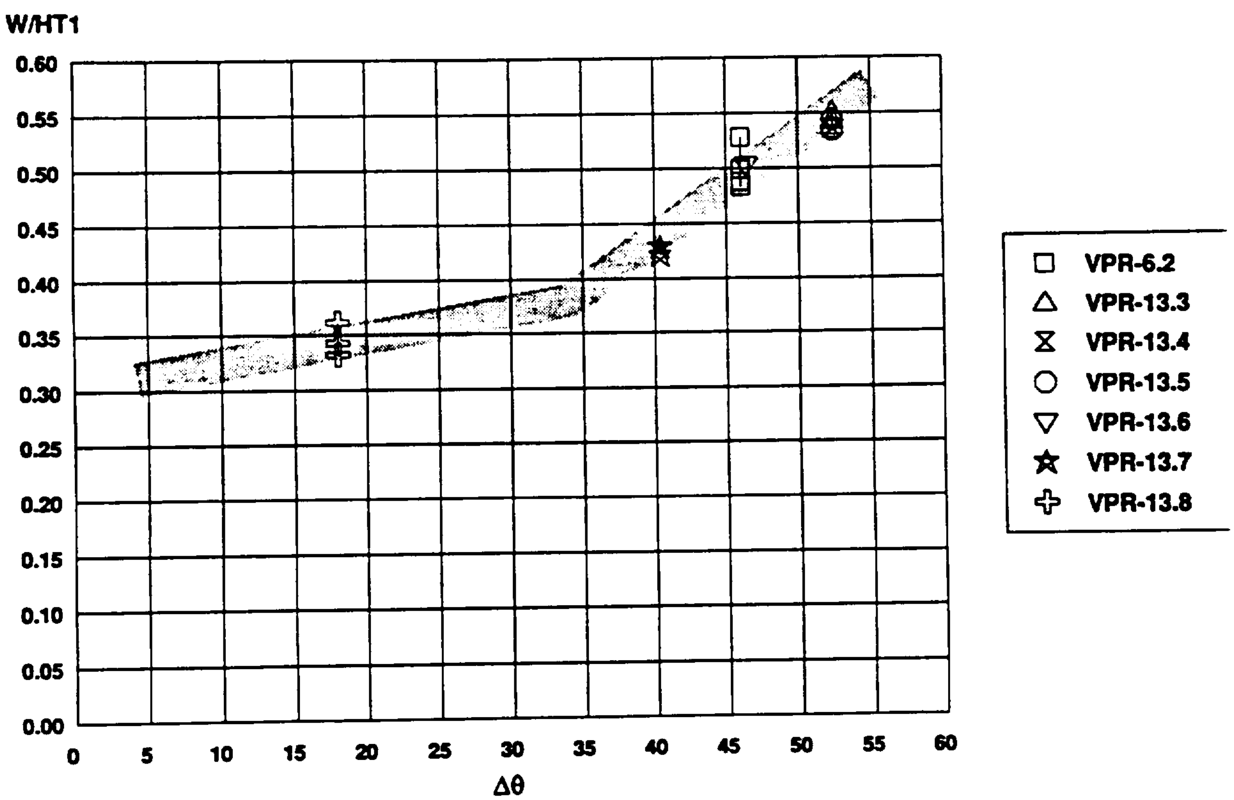

Figure 36. Transonic work done – aft blade comparison.

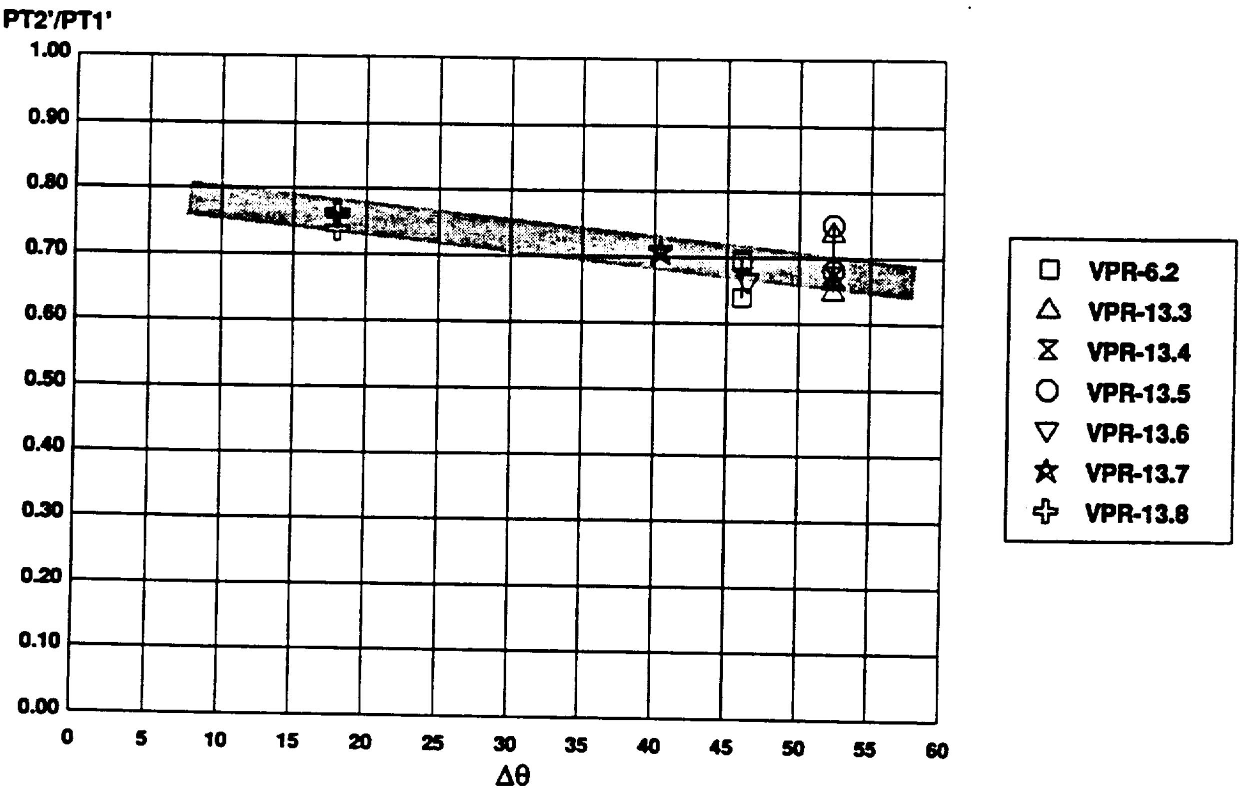

Figure 37. Transonic flow losses – aft blade comparison.

flow losses are reduced for lower amounts of blade turning. Furthermore the mixing losses (difference between mass-average and mixed) are also reduced for the configuration (VPR-13.8) with the least flow turning. Thus the flow from this blade configuration is in a more uniform condition for subsequent diffusion in a stator stage.

The fan performance which could be generated by these blade configurations is shown in figure 38. This figure shows both the fan total pressure ratio and fan total pressure ratio and fan efficiency as a function of the work done. The results show increasing total pressure ratio with increasing work done (increased turning), with efficiencies of about 70's%. After the previous figure showing considerably lower flow losses for the lower turning configuration, this result was at first surprising; however, the lower losses for VPR-13.8 are accompanied by lower work done and, hence, no improvement in the efficiency. On the positive side, blade total pressure ratios of 3 or more appear feasible in a single split-blade rotor stage.

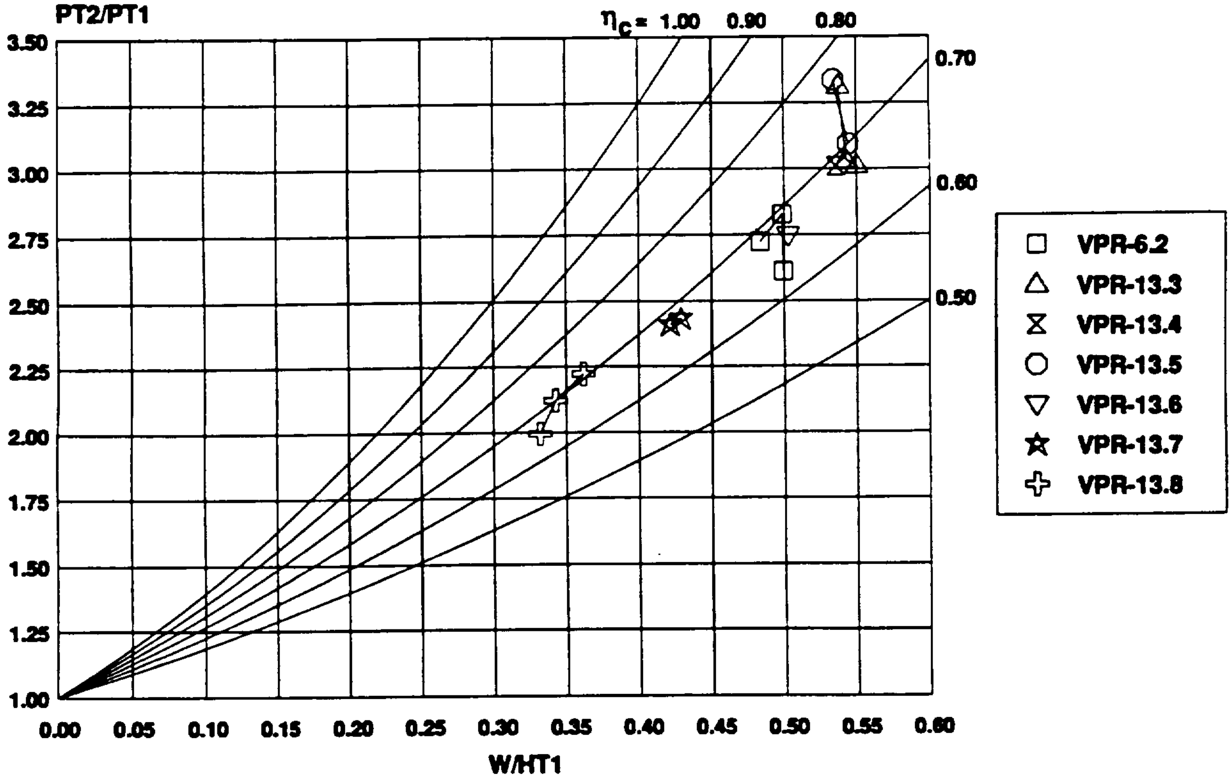

Figure 38. Transonic fan performance – aft blade comparison.

5.4 Transonic Split-Blade

The transonic performance of the baseline and three other blade configurations having the same total turning are compared herein. One of these, the VPR-13.3, is described previously. Another, the VPR-7.1, is a variation of the baseline, having a 5% longer front blade which overlaps the aft blade, forming a divergent nozzle in the slot between the two blades (see fig. 9). And the third, the VPR-9.1 combined the new front blade VPR-9f with the aft blade of the baseline.

The work done by these four split-blade configurations is shown in figure 39. These blades all had about the same amount of turning and, therefore, did about the same amount of work. And because the flow was turned nearly axial, the work was independent of back pressure.

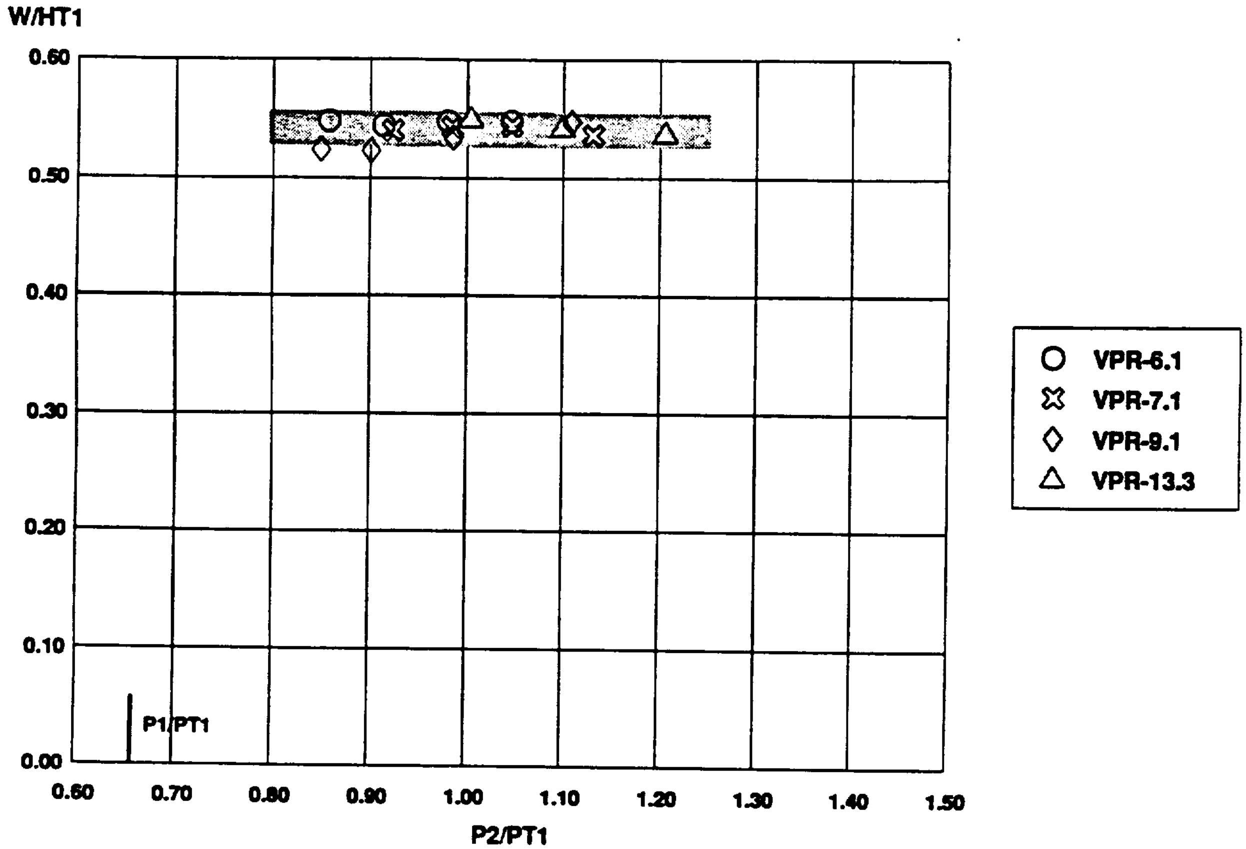

Figure 39. Transonic work done – split blade comparison.

The relative total pressure ratio across these blades is shown in figure 40. They all had comparable flow losses due to the large separated regions over the top of the blades. And the mixing losses associated with the flow nonuniformity amount to an additional 10% reduction in the total pressure.

The performance of these four blade configurations are compared in figure 41. They all achieved total pressure ratios in excess of 3 and an efficiencies in the low 70's%. This is a very high pressure ratio for a single rotor stage; it is a consequence of the large amount of work done, $W/H_{T_1} \approx 0.54$; however, because of the large losses, the efficiency is low. Furthermore, much of the energy is still in kinetic energy, efficient conversion of this energy to pressure across a stator stage would be difficult because of the large separated flow region. This single-stage rotor performance might be attractive for an engine which is designed to accelerate through this transonic flight regime, but it would not be desirable for an engine which is designed to cruise there.

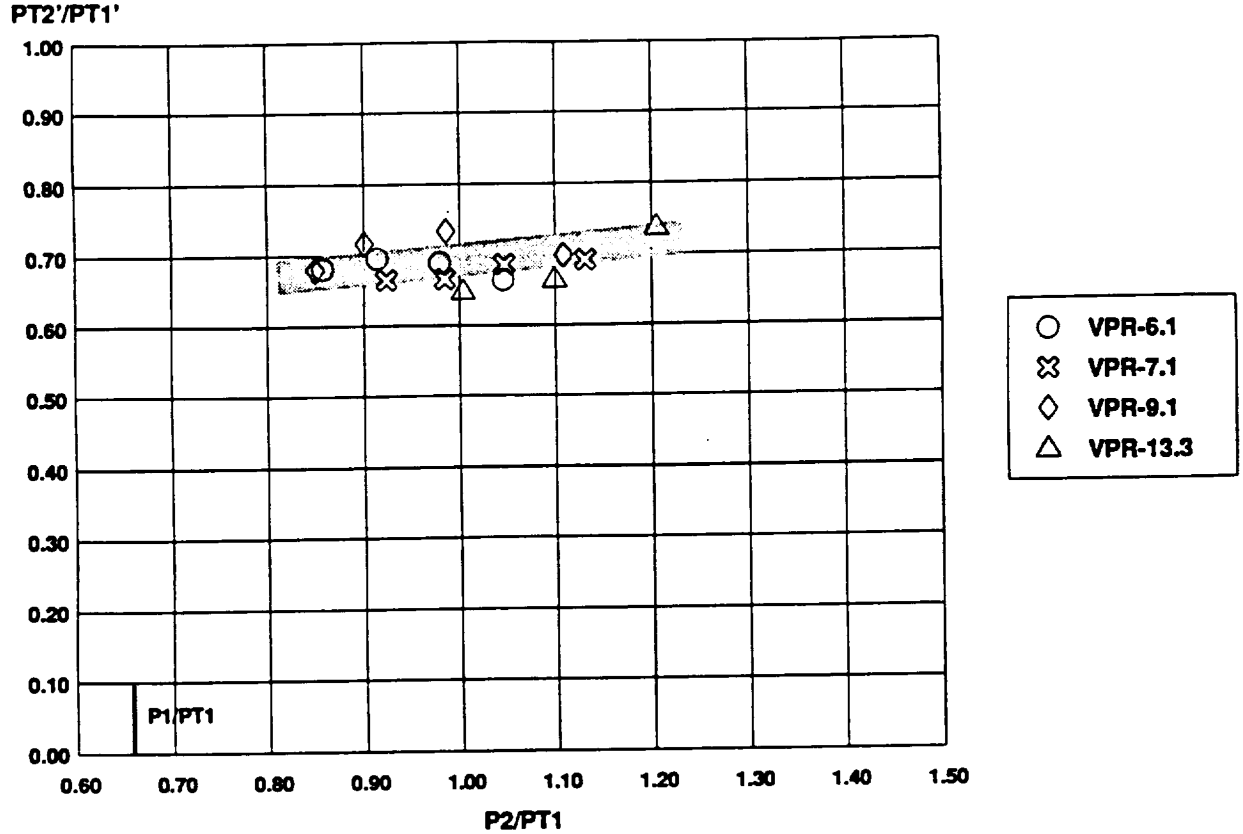

Figure 40. Transonic flow losses – split blade comparison.

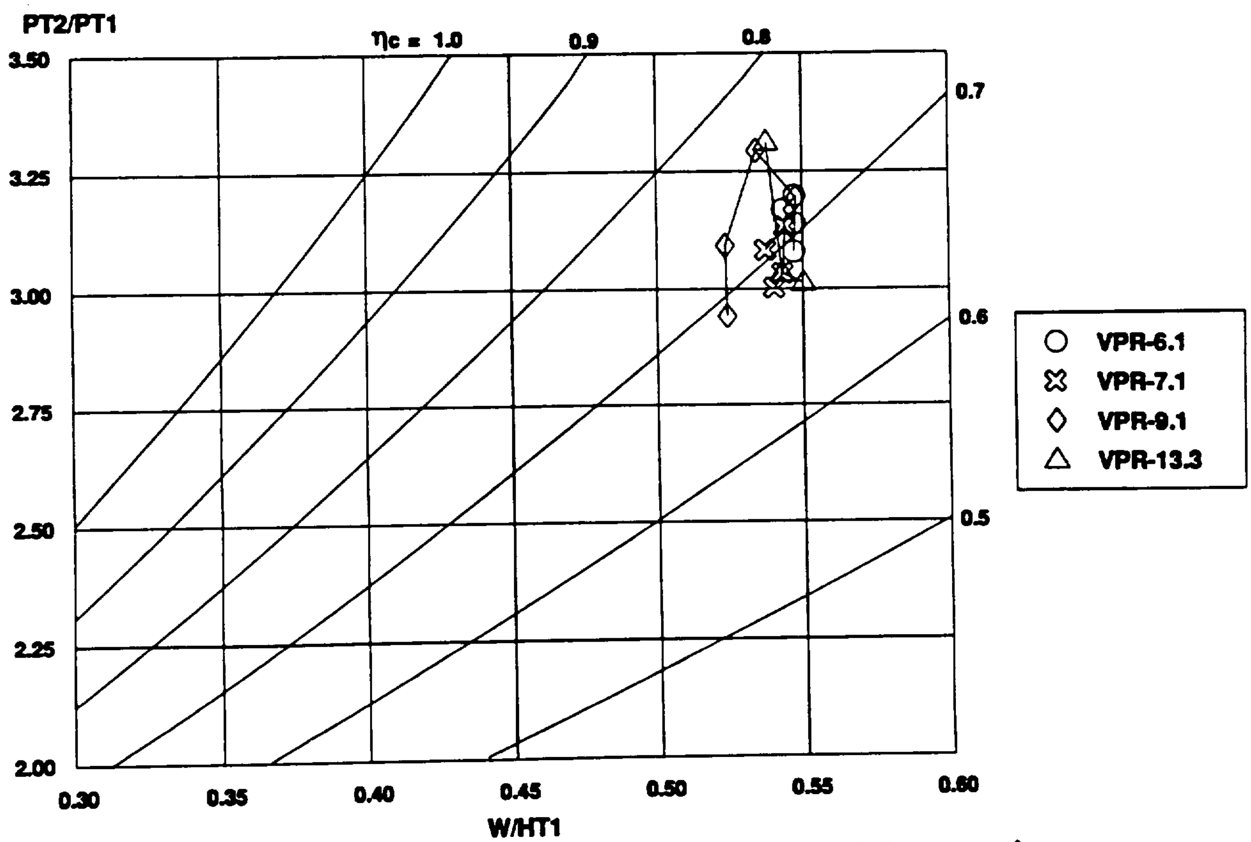

Figure 41. Transonic fan performance – split blade comparison.

6. CONCLUSIONS AND RECOMMENDATIONS

The analytical CFD study reported herein provided information about the performance potential of variable-pitch, split-blade fan configurations during operation at the supersonic design conditions and during off-design operation at transonic operating conditions with subsonic inflow into the fan. The results led to the following conclusions about supersonic and transonic fan configurations.

Supersonic Operation

1. A split-blade supersonic through-flow fan can provide performance comparable to a single-blade configuration. Both the baseline and VPR-9.1 configurations achieved rotor total pressure ratios of 2.5 and 2.6, respectively compared with 2.7 for the single blade STFF-9 configuration which had the same amount of total geometrical turning.

2. The fan efficiency of a supersonic through-flow fan is considerably less than a conventional subsonic fan. Rotor efficiencies ranging from 74 to 78% were calculated for the three configurations identified in 1 above.

3. Increasing the solidity of a supersonic fan to improve the flow turning may not improve the fan performance; the high solidity, reduced gap configuration, VPR-6.1RG, had higher viscous losses which resulted in a lower total pressure and lower efficiency than the baseline configuration.

Transonic Operation

4. Single blades with little or no net camber can operate at higher back pressures and with lower losses than blades with small amounts of camber. The low camber front blades (VPR-10f, 11f, 12f, 13f) were able to operate with back pressures which were approximately 10% greater than the front blades with moderate camber (VPR-9f, 14f, 15f). The low camber blades had relative total pressure loss of about 5% compared with about 7% for the higher camber blades. The higher cambered blades did more work which compensated for the increased losses. The resulting maximum rotor total pressure ratios ($P_{T_2}/P_{T_1} \approx 1.7$) and fan efficiencies ($\eta_c > 85\%$) were about the same for both the low and moderate cambered blades.

5. Split-blade configurations having low amounts of flow turning are able to operate with higher back pressures and lower losses than blade configurations with larger amounts of total turning. The low turning configuration, VPR-13.8, was able to operate at a back pressure which was approximately 1.9 times the upstream static pressure, with the "normal shock" located in the front blade row. The total pressure loss for this configuration was approximately 20%.

6. Split-blade configurations with large amounts of flow turning can achieve high rotor total pressure ratios, exceeding 3 times the upstream total pressure; however, the efficiencies of these configurations are low $\eta_c \leq 75\%$. The high turning configurations (VPR-6.1, 9.1, 13.3) could not operate above a back pressure of approximately 1.7 times the upstream static pressure, and the most forward stable location for the "normal shock" was in the region between the front and aft blades. The total pressure losses for these configurations were about 30%.

7. High turning split-blade configurations inherently have very non-uniform flow profiles due to flow separation from both the fore and aft blades. The greater the turning, the greater the low velocity wakes. The highly non-uniform wakes will be difficult to diffuse in the downstream stator row; therefore, the high total pressure generated by the rotor may not be achievable in a real fan configuration.

Feasibility of Split-Blade Fan

8. The variable-pitch split-blade fan was conceived as a means to enable a supersonic fan to operate like a conventional fan at transonic operating conditions, and generate substantial static and total pressure increases in a single stage with subsonic inflow and outflow. The present study has shown the supersonic performance to be comparable to a single-blade configuration. At transonic operating conditions substantial (mass-average) total pressure ratios were achieved in a single-stage; however, the flow was badly separated and the rotor efficiencies were low. Additional turning and diffusion of this flow across a subsequent stator row would probably be very inefficient, thereby, losing the advantage which was hoped to be achieved by this variable-pitch, split-blade configuration.

Recommendations

The results presented herein provide a comprehensive set of data about split-blade rotor configurations. Some limited success was achieved in obtaining high total pressure ratios in a single-stage; and a basic understanding of the flow processes was achieved. This information and the understanding of transonic split-blade characteristics should be used to improve the performance of transonic fans by using fixed-geometry, dual blades having more turning than conventional single blades; thereby providing increased total pressure ratios.

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APPENDIX
DETAILED BLADE PERFORMANCE

This section contains a series of tables summarizing the performance of each CFD run made during this investigation. Each page presents the data for one run. The blade geometry is listed at the top; the specified flow conditions are second; the unmixed or mass-average flow properties third; the mixed or stream-thrust average flow properties fourth, and the unmixed and mixed performance at the bottom.

List of Configurations/Runs

VPR-6.1-s1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.5000	-23.0000	0.0000	0.5000	-11.5000	23.0000	0.0000
Lower:	5.5000	-11.0000	0.0000	0.5000	-5.5000	11.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	29.3700	47.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Supersonic)

	P_{T1} = 31.92 psia	T_{T1} = 793.2 deg.R
V_R = 1543.7 ft/sec	P_2/P_{T1} = 0.128	A_2/A_1 = 0.8258
M_R = 1.50	V_{C_R} = 1248.2 ft/sec	W_C/A = 29.28

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	2.000		M_1'	=	2.500		M_2'	=	2.000		M_2	=	2.263	
V_1	=	2058.2	ft/sec	V_1'	=	2572.8	ft/sec	V_2'	=	2286.7	ft/sec	V_2	=	2587.0	ft/sec
α_1	=	0.00	deg.	α_1'	=	36.87	deg.	α_2'	=	7.48	deg.	α_2	=	-28.79	deg.
P_1	=	4.080	psia	P_1'	=	4.080	psia	P_2'	=	6.007	psia	P_2	=	6.007	psia
T_1	=	440.7	deg.R	T_1'	=	440.7	deg.R	T_2'	=	543.8	deg.R	T_2	=	543.8	deg.R
P_{T1}	=	31.92	psia	P_{T1}'	=	69.71	psia	P_{T2}'	=	53.39	psia	P_{T2}	=	79.46	psia
T_{T1}	=	793.2	deg.R	T_{T1}'	=	991.6	deg.R	T_{T2}'	=	984.3	deg.R	T_{T2}	=	1106.1	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	2.000		M_1'	=	2.500		M_2'	=	2.019		M_2	=	2.281	
V_1	=	2058.2	ft/sec	V_1'	=	2572.8	ft/sec	V_2'	=	2304.9	ft/sec	V_2	=	2603.1	ft/sec
α_1	=	0.00	deg.	α_1'	=	36.87	deg.	α_2'	=	7.42	deg.	α_2	=	-28.59	deg.
P_1	=	4.080	psia	P_1'	=	4.080	psia	P_2'	=	5.748	psia	P_2	=	5.748	psia
T_1	=	440.7	deg.R	T_1'	=	440.7	deg.R	T_2'	=	542.1	deg.R	T_2	=	542.1	deg.R
P_{T1}	=	31.92	psia	P_{T1}'	=	69.71	psia	P_{T2}'	=	46.35	psia	P_{T2}	=	69.73	psia
T_{T1}	=	793.2	deg.R	T_{T1}'	=	991.6	deg.R	T_{T2}'	=	984.3	deg.R	T_{T2}	=	1106.1	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.7659
V_2/V_1	=	1.2569
P_2/P_1	=	1.4724
T_2/T_1	=	1.2339
P_{T2}/P_{T1}	=	2.4891
T_{T2}/T_{T1}	=	1.3944
W/H_{T1}	=	0.4035
η_c	=	0.7376

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6649
V_2/V_1	=	1.2647
P_2/P_1	=	1.4089
T_2/T_1	=	1.2302
P_{T2}/P_{T1}	=	2.1842
T_{T2}/T_{T1}	=	1.3944
W/H_{T1}	=	0.4035
η_c	=	0.6197

VPR-6.1RG-s1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.5000	-23.0000	0.0000	0.5000	-11.5000	23.0000	0.0000
Lower:	5.5000	-11.0000	0.0000	0.5000	-5.5000	11.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	29.3700	47.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Supersonic)

		P_{T1} = 31.92 psia		T_{T1} = 793.2 deg.R	
V_R = 1543.7 ft/sec		P_2/P_{T1} = 0.128			A_2/A_1 = 0.8258
M_R = 1.50		V_{C_R} = 1248.2 ft/sec			W_C/A = 29.28

UNMIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 =	2.000	M_1' =	2.500	M_2' =	1.827	M_2 =	2.106
V_1 =	2058.2 ft/sec	V_1' =	2572.8 ft/sec	V_2' =	2169.9 ft/sec	V_2 =	2502.2 ft/sec
α_1 =	0.00 deg.	α_1' =	36.87 deg.	α_2' =	7.12 deg.	α_2 =	-30.62 deg.
P_1 =	4.080 psia	P_1' =	4.080 psia	P_2' =	7.321 psia	P_2 =	7.321 psia
T_1 =	440.7 deg.R	T_1' =	440.7 deg.R	T_2' =	587.2 deg.R	T_2 =	587.2 deg.R
P_{T1} =	31.92 psia	P_{T1}' =	69.71 psia	P_{T2}' =	49.96 psia	P_{T2} =	76.08 psia
T_{T1} =	793.2 deg.R	T_{T1}' =	991.6 deg.R	T_{T2}' =	984.9 deg.R	T_{T2} =	1114.1 deg.R

MIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 =	2.000	M_1' =	2.500	M_2' =	1.856	M_2 =	2.133
V_1 =	2058.2 ft/sec	V_1' =	2572.8 ft/sec	V_2' =	2196.9 ft/sec	V_2 =	2525.6 ft/sec
α_1 =	0.00 deg.	α_1' =	36.87 deg.	α_2' =	7.03 deg.	α_2 =	-30.31 deg.
P_1 =	4.080 psia	P_1' =	4.080 psia	P_2' =	6.913 psia	P_2 =	6.913 psia
T_1 =	440.7 deg.R	T_1' =	440.7 deg.R	T_2' =	583.3 deg.R	T_2 =	583.3 deg.R
P_{T1} =	31.92 psia	P_{T1}' =	69.71 psia	P_{T2}' =	43.25 psia	P_{T2} =	66.58 psia
T_{T1} =	793.2 deg.R	T_{T1}' =	991.6 deg.R	T_{T2}' =	984.9 deg.R	T_{T2} =	1114.1 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}' =	0.7166
V_2/V_1 =	1.2157
P_2/P_1 =	1.7944
T_2/T_1 =	1.3325
P_{T2}/P_{T1} =	2.3833
T_{T2}/T_{T1} =	1.4045
W/H_{T1} =	0.4129
η_c =	0.6822

MIXED PERFORMANCE

P_{T2}'/P_{T1}' =	0.6205
V_2/V_1 =	1.2271
P_2/P_1 =	1.6943
T_2/T_1 =	1.3235
P_{T2}/P_{T1} =	2.0857
T_{T2}/T_{T1} =	1.4045
W/H_{T1} =	0.4129
η_c =	0.5661

VPR-9.1-s1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	8.5000	-17.0000	0.0000	0.5000	-8.5000	17.0000	0.0000
Lower:	2.5000	-5.0000	0.0000	0.5000	-2.5000	5.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	32.3700	50.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Supersonic)

P_{T1} = 31.92 psia		T_{T1} = 793.2 deg.R
V_R = 1543.7 ft/sec	P_2/P_{T1} = 0.128	A_2/A_1 = 0.8258
M_R = 1.50	V_{C_R} = 1248.2 ft/sec	W_C/A = 29.28

UNMIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 2.000	M_1' = 2.500	M_2' = 2.015	M_2 = 2.320
V_1 = 2058.2 ft/sec	V_1' = 2572.8 ft/sec	V_2' = 2294.7 ft/sec	V_2 = 2642.2 ft/sec
α_1 = 0.00 deg.	α_1' = 36.87 deg.	α_2' = 5.41 deg.	α_2 = -30.16 deg.
P_1 = 4.080 psia	P_1' = 4.080 psia	P_2' = 5.887 psia	P_2 = 5.887 psia
T_1 = 440.7 deg.R	T_1' = 440.7 deg.R	T_2' = 539.8 deg.R	T_2 = 539.8 deg.R
P_{T1} = 31.92 psia	P_{T1}' = 69.71 psia	P_{T2}' = 53.58 psia	P_{T2} = 85.39 psia
T_{T1} = 793.2 deg.R	T_{T1}' = 991.6 deg.R	T_{T2}' = 984.0 deg.R	T_{T2} = 1126.8 deg.R

MIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 2.000	M_1' = 2.500	M_2' = 2.032	M_2 = 2.335
V_1 = 2058.2 ft/sec	V_1' = 2572.8 ft/sec	V_2' = 2312.2 ft/sec	V_2 = 2657.4 ft/sec
α_1 = 0.00 deg.	α_1' = 36.87 deg.	α_2' = 5.37 deg.	α_2 = -29.97 deg.
P_1 = 4.080 psia	P_1' = 4.080 psia	P_2' = 5.640 psia	P_2 = 5.640 psia
T_1 = 440.7 deg.R	T_1' = 440.7 deg.R	T_2' = 539.0 deg.R	T_2 = 539.0 deg.R
P_{T1} = 31.92 psia	P_{T1}' = 69.71 psia	P_{T2}' = 46.36 psia	P_{T2} = 74.48 psia
T_{T1} = 793.2 deg.R	T_{T1}' = 991.6 deg.R	T_{T2}' = 984.0 deg.R	T_{T2} = 1126.8 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.7686
V_2/V_1	=	1.2837
P_2/P_1	=	1.4430
T_2/T_1	=	1.2249
P_{T2}/P_{T1}	=	2.6749
T_{T2}/T_{T1}	=	1.4204
W/H_{T1}	=	0.4300
η_c	=	0.7550

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6650
V_2/V_1	=	1.2911
P_2/P_1	=	1.3825
T_2/T_1	=	1.2232
P_{T2}/P_{T1}	=	2.3331
T_{T2}/T_{T1}	=	1.4204
W/H_{T1}	=	0.4300
η_c	=	0.6369

STFF-9-s1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	19.7450	-39.4900	0.0000	0.5000	-19.7450	39.4900	0.0000
Lower:	13.7450	-27.4900	0.0000	0.5000	-13.7450	27.4900	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
10.000	21.1250	n/a

CONDITIONS: (Supersonic)

	P_{T1} = 31.92 psia		T_{T1} = 793.2 deg.R		
V_R = 1543.7 ft/sec		P_2/P_{T1} = 0.128			A_2/A_1 = 0.8258
M_R = 1.50		V_{C_R} = 1248.2 ft/sec			W_C/A = 29.28

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	2.000		M_1'	=	2.500		M_2'	=	2.069		M_2	=	2.373	
V_1	=	2058.2	ft/sec	V_1'	=	2572.8	ft/sec	V_2'	=	2331.2	ft/sec	V_2	=	2674.0	ft/sec
α_1	=	0.00	deg.	α_1'	=	36.87	deg.	α_2'	=	5.32	deg.	α_2	=	-29.77	deg.
P_1	=	4.080	psia	P_1'	=	4.080	psia	P_2'	=	5.639	psia	P_2	=	5.639	psia
T_1	=	440.7	deg.R	T_1'	=	440.7	deg.R	T_2'	=	528.5	deg.R	T_2	=	528.5	deg.R
P_{T1}	=	31.92	psia	P_{T1}'	=	69.71	psia	P_{T2}'	=	54.80	psia	P_{T2}	=	87.59	psia
T_{T1}	=	793.2	deg.R	T_{T1}'	=	991.6	deg.R	T_{T2}'	=	985.8	deg.R	T_{T2}	=	1128.5	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	2.000		M_1'	=	2.500		M_2'	=	2.089		M_2	=	2.391	
V_1	=	2058.2	ft/sec	V_1'	=	2572.8	ft/sec	V_2'	=	2349.2	ft/sec	V_2	=	2689.7	ft/sec
α_1	=	0.00	deg.	α_1'	=	36.87	deg.	α_2'	=	5.28	deg.	α_2	=	-29.58	deg.
P_1	=	4.080	psia	P_1'	=	4.080	psia	P_2'	=	5.387	psia	P_2	=	5.387	psia
T_1	=	440.7	deg.R	T_1'	=	440.7	deg.R	T_2'	=	526.5	deg.R	T_2	=	526.5	deg.R
P_{T1}	=	31.92	psia	P_{T1}'	=	69.71	psia	P_{T2}'	=	48.39	psia	P_{T2}	=	77.69	psia
T_{T1}	=	793.2	deg.R	T_{T1}'	=	991.6	deg.R	T_{T2}'	=	985.8	deg.R	T_{T2}	=	1128.5	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.7861
V_2/V_1	=	1.2992
P_2/P_1	=	1.3821
T_2/T_1	=	1.1992
P_{T2}/P_{T1}	=	2.7436
T_{T2}/T_{T1}	=	1.4227
W/H_{T1}	=	0.4300
η_c	=	0.7773

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6942
V_2/V_1	=	1.3068
P_2/P_1	=	1.3203
T_2/T_1	=	1.1946
P_{T2}/P_{T1}	=	2.4338
T_{T2}/T_{T1}	=	1.4227
W/H_{T1}	=	0.4300
η_c	=	0.6729

VPR-6.1-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.5000	-23.0000	0.0000	0.5000	-11.5000	23.0000	0.0000
Lower:	5.5000	-11.0000	0.0000	0.5000	-5.5000	11.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	29.3700	47.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Transonic)

P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R	
V_R = 1358.6 ft/sec	P_2/P_{T1} = 0.850		A_2/A_1 = 0.8258
M_R = 1.29	V_{C_R} = 1366.6 ft/sec		W_C/A = 46.96

UNMIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.769	M_1' = 1.506	M_2' = 0.981	M_2 = 1.459
V_1 = 807.5 ft/sec	V_1' = 1580.5 ft/sec	V_2' = 1122.9 ft/sec	V_2 = 1669.4 ft/sec
α_1 = 0.00 deg.	α_1' = 59.27 deg.	α_2' = 6.02 deg.	α_2 = -48.02 deg.
P_1 = 7.562 psia	P_1' = 7.562 psia	P_2' = 9.594 psia	P_2 = 9.594 psia
T_1 = 458.4 deg.R	T_1' = 458.4 deg.R	T_2' = 545.0 deg.R	T_2 = 545.0 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 19.05 psia	P_{T2} = 35.13 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 653.8 deg.R	T_{T2} = 780.8 deg.R

MIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.769	M_1' = 1.506	M_2' = 0.800	M_2 = 1.317
V_1 = 807.5 ft/sec	V_1' = 1580.5 ft/sec	V_2' = 943.8 ft/sec	V_2 = 1554.6 ft/sec
α_1 = 0.00 deg.	α_1' = 59.27 deg.	α_2' = 7.16 deg.	α_2 = -52.96 deg.
P_1 = 7.562 psia	P_1' = 7.562 psia	P_2' = 11.555 psia	P_2 = 11.555 psia
T_1 = 458.4 deg.R	T_1' = 458.4 deg.R	T_2' = 579.6 deg.R	T_2 = 579.6 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 17.61 psia	P_{T2} = 32.78 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 653.8 deg.R	T_{T2} = 780.8 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6804
V_2/V_1	= 2.0674
P_2/P_1	= 1.2687
T_2/T_1	= 1.1889
P_{T2}/P_{T1}	= 3.1404
T_{T2}/T_{T1}	= 1.5230
W/H_{T1}	= 0.5474
η_c	= 0.7066

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6289
V_2/V_1	= 1.9252
P_2/P_1	= 1.5279
T_2/T_1	= 1.2645
P_{T2}/P_{T1}	= 2.9297
T_{T2}/T_{T1}	= 1.5230
W/H_{T1}	= 0.5474
η_c	= 0.6568

VPR-6.1-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.5000	-23.0000	0.0000	0.5000	-11.5000	23.0000	0.0000
Lower:	5.5000	-11.0000	0.0000	0.5000	-5.5000	11.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	29.3700	47.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia				T_{T1} = 512.7 deg.R			
V_R = 1358.6 ft/sec			P_2/P_{T1} = 0.920				A_2/A_1 = 0.8258	
M_R = 1.30			V_{C_R} = 1366.6 ft/sec				W_C/A = 47.24	

UNMIXED STATION AVERAGES

Inlet																			
Inlet								**Exit**											
Absolute				**Relative**				**Relative**				**Absolute**							
M_1	=	0.783		M_1'	=	1.515		M_2'	=	0.951		M_2	=	1.423					
V_1	=	819.9	ft/sec	V_1'	=	1586.8	ft/sec	V_2'	=	1100.7	ft/sec	V_2	=	1647.6	ft/sec				
α_1	=	0.00	deg.	α_1'	=	58.89	deg.	α_2'	=	6.58	deg.	α_2	=	-48.42	deg.				
P_1	=	7.466	psia	P_1'	=	7.466	psia	P_2'	=	10.233	psia	P_2	=	10.233	psia				
T_1	=	456.7	deg.R	T_1'	=	456.7	deg.R	T_2'	=	557.5	deg.R	T_2	=	557.5	deg.R				
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	19.49	psia	P_{T2}	=	35.44	psia				
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	663.0	deg.R	T_{T2}	=	788.1	deg.R				

MIXED STATION AVERAGES

Inlet								**Exit**							
Absolute				**Relative**				**Relative**				**Absolute**			
M_1	=	0.783		M_1'	=	1.515		M_2'	=	0.751		M_2	=	1.270	
V_1	=	819.9	ft/sec	V_1'	=	1586.8	ft/sec	V_2'	=	898.7	ft/sec	V_2	=	1520.0	ft/sec
α_1	=	0.00	deg.	α_1'	=	58.89	deg.	α_2'	=	8.07	deg.	α_2	=	-54.17	deg.
P_1	=	7.466	psia	P_1'	=	7.466	psia	P_2'	=	12.436	psia	P_2	=	12.436	psia
T_1	=	456.7	deg.R	T_1'	=	456.7	deg.R	T_2'	=	595.8	deg.R	T_2	=	595.8	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	18.08	psia	P_{T2}	=	33.10	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	663.0	deg.R	T_{T2}	=	788.1	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6961
V_2/V_1	=	2.0094
P_2/P_1	=	1.3706
T_2/T_1	=	1.2207
P_{T2}/P_{T1}	=	3.1679
T_{T2}/T_{T1}	=	1.5372
W/H_{T1}	=	0.5436
η_c	=	0.7178

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6457
V_2/V_1	=	1.8539
P_2/P_1	=	1.6659
T_2/T_1	=	1.3045
P_{T2}/P_{T1}	=	2.9590
T_{T2}/T_{T1}	=	1.5372
W/H_{T1}	=	0.5436
η_c	=	0.6684

VPR-6.1-t3

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.5000	-23.0000	0.0000	0.5000	-11.5000	23.0000	0.0000
Lower:	5.5000	-11.0000	0.0000	0.5000	-5.5000	11.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	29.3700	47.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Transonic)

			P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R			
V_R	=	1358.6 ft/sec	P_2/P_{T1}	= 0.980		A_2/A_1	=	0.8258
M_R	=	1.30	V_{C_R}	= 1366.6 ft/sec		W_C/A	=	47.26

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.784		M_1'	=	1.515		M_2'	=	0.887		M_2	=	1.387	
V_1	=	820.9	ft/sec	V_1'	=	1587.3	ft/sec	V_2'	=	1027.8	ft/sec	V_2	=	1608.1	ft/sec
α_1	=	0.00	deg.	α_1'	=	58.86	deg.	α_2'	=	6.50	deg.	α_2	=	-50.58	deg.
P_1	=	7.458	psia	P_1'	=	7.458	psia	P_2'	=	10.968	psia	P_2	=	10.968	psia
T_1	=	456.6	deg.R	T_1'	=	456.6	deg.R	T_2'	=	559.3	deg.R	T_2	=	559.3	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	19.32	psia	P_{T2}	=	35.76	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	652.4	deg.R	T_{T2}	=	779.7	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.784		M_1'	=	1.515		M_2'	=	0.714		M_2	=	1.259	
V_1	=	820.9	ft/sec	V_1'	=	1587.3	ft/sec	V_2'	=	851.1	ft/sec	V_2	=	1501.3	ft/sec
α_1	=	0.00	deg.	α_1'	=	58.86	deg.	α_2'	=	7.86	deg.	α_2	=	-55.83	deg.
P_1	=	7.458	psia	P_1'	=	7.458	psia	P_2'	=	12.870	psia	P_2	=	12.870	psia
T_1	=	456.6	deg.R	T_1'	=	456.6	deg.R	T_2'	=	592.1	deg.R	T_2	=	592.1	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	18.07	psia	P_{T2}	=	33.72	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	652.4	deg.R	T_{T2}	=	779.7	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6900
V_2/V_1	=	1.9590
P_2/P_1	=	1.4707
T_2/T_1	=	1.2249
P_{T2}/P_{T1}	=	3.1968
T_{T2}/T_{T1}	=	1.5208
W/H_{T1}	=	0.5479
η_c	=	0.7187

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6454
V_2/V_1	=	1.8289
P_2/P_1	=	1.7256
T_2/T_1	=	1.2967
P_{T2}/P_{T1}	=	3.0142
T_{T2}/T_{T1}	=	1.5208
W/H_{T1}	=	0.5479
η_c	=	0.6763

VPR-6.1-t4

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.5000	-23.0000	0.0000	0.5000	-11.5000	23.0000	0.0000
Lower:	5.5000	-11.0000	0.0000	0.5000	-5.5000	11.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	29.3700	47.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R		
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.050			A_2/A_1 = 0.8258
M_R = 1.29		V_{C_R} = 1366.6 ft/sec			W_C/A = 46.59

UNMIXED STATION AVERAGES

Inlet Absolute			Inlet Relative			Exit Relative			Exit Absolute		
M_1	0.754		M_1'	1.495		M_2'	0.794		M_2	1.315	
V_1	792.6	ft/sec	V_1'	1572.9	ft/sec	V_2'	935.3	ft/sec	V_2	1548.8	ft/sec
α_1	0.00	deg.	α_1'	59.74	deg.	α_2'	7.27	deg.	α_2	-53.20	deg.
P_1	7.677	psia	P_1'	7.677	psia	P_2'	11.709	psia	P_2	11.709	psia
T_1	460.4	deg.R	T_1'	460.4	deg.R	T_2'	576.9	deg.R	T_2	576.9	deg.R
P_{T1}	11.19	psia	P_{T1}'	28.00	psia	P_{T2}'	18.61	psia	P_{T2}	34.46	psia
T_{T1}	512.7	deg.R	T_{T1}'	666.3	deg.R	T_{T2}'	653.9	deg.R	T_{T2}	780.8	deg.R

MIXED STATION AVERAGES

Inlet Absolute			Inlet Relative			Exit Relative			Exit Absolute		
M_1	0.754		M_1'	1.495		M_2'	0.677		M_2	1.232	
V_1	792.6	ft/sec	V_1'	1572.9	ft/sec	V_2'	812.2	ft/sec	V_2	1477.7	ft/sec
α_1	0.00	deg.	α_1'	59.74	deg.	α_2'	8.38	deg.	α_2	-57.06	deg.
P_1	7.677	psia	P_1'	7.677	psia	P_2'	12.968	psia	P_2	12.968	psia
T_1	460.4	deg.R	T_1'	460.4	deg.R	T_2'	599.0	deg.R	T_2	599.0	deg.R
P_{T1}	11.19	psia	P_{T1}'	28.00	psia	P_{T2}'	17.63	psia	P_{T2}	32.78	psia
T_{T1}	512.7	deg.R	T_{T1}'	666.3	deg.R	T_{T2}'	653.9	deg.R	T_{T2}	780.8	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	0.6646
V_2/V_1	1.9540
P_2/P_1	1.5251
T_2/T_1	1.2531
P_{T2}/P_{T1}	3.0801
T_{T2}/T_{T1}	1.5229
W/H_{T1}	0.5470
η_c	0.6930

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	0.6296
V_2/V_1	1.8643
P_2/P_1	1.6891
T_2/T_1	1.3011
P_{T2}/P_{T1}	2.9302
T_{T2}/T_{T1}	1.5229
W/H_{T1}	0.5470
η_c	0.6573

VPR-6.2-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.5000	-23.0000	0.0000	0.5000	-11.5000	23.0000	0.0000
Lower:	5.5000	-11.0000	0.0000	0.5000	-5.5000	11.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	29.3700	47.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	30.7700	-331.94	1213.1	0.1500	-14.2500	30.9350	-6.6881
Lower:	8.2500	-16.50	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	21.6200

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R
V_R = 1358.6 ft/sec	P_2/P_{T1} = 0.850	A_2/A_1 = 0.8258
M_R = 1.29	V_{C_R} = 1366.6 ft/sec	W_C/A = 46.61

UNMIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.754	M_1' = 1.496	M_2' = 0.989	M_2 = 1.355
V_1 = 793.5 ft/sec	V_1' = 1573.3 ft/sec	V_2' = 1137.7 ft/sec	V_2 = 1558.1 ft/sec
α_1 = 0.00 deg.	α_1' = 59.71 deg.	α_2' = 13.32 deg.	α_2 = -44.72 deg.
P_1 = 7.671 psia	P_1' = 7.671 psia	P_2' = 9.519 psia	P_2 = 9.519 psia
T_1 = 460.3 deg.R	T_1' = 460.3 deg.R	T_2' = 550.2 deg.R	T_2 = 550.2 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 19.40 psia	P_{T2} = 30.48 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 662.9 deg.R	T_{T2} = 757.2 deg.R

MIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.754	M_1' = 1.496	M_2' = 0.794	M_2 = 1.196
V_1 = 793.5 ft/sec	V_1' = 1573.3 ft/sec	V_2' = 943.9 ft/sec	V_2 = 1422.8 ft/sec
α_1 = 0.00 deg.	α_1' = 59.71 deg.	α_2' = 16.13 deg.	α_2 = -50.41 deg.
P_1 = 7.671 psia	P_1' = 7.671 psia	P_2' = 11.604 psia	P_2 = 11.604 psia
T_1 = 460.3 deg.R	T_1' = 460.3 deg.R	T_2' = 588.7 deg.R	T_2 = 588.7 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 17.58 psia	P_{T2} = 28.00 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 662.9 deg.R	T_{T2} = 757.2 deg.R

UNMIXED PERFORMANCE

P'_{T2}/P'_{T1}	= 0.6929
V_2/V_1	= 1.9636
P_2/P_1	= 1.2410
T_2/T_1	= 1.1954
P_{T2}/P_{T1}	= 2.7243
T_{T2}/T_{T1}	= 1.4770
W/H_{T1}	= 0.4836
η_c	= 0.6856

MIXED PERFORMANCE

P'_{T2}/P'_{T1}	= 0.6276
V_2/V_1	= 1.7932
P_2/P_1	= 1.5127
T_2/T_1	= 1.2791
P_{T2}/P_{T1}	= 2.5028
T_{T2}/T_{T1}	= 1.4770
W/H_{T1}	= 0.4836
η_c	= 0.6197

VPR-6.2-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.5000	-23.0000	0.0000	0.5000	-11.5000	23.0000	0.0000
Lower:	5.5000	-11.0000	0.0000	0.5000	-5.5000	11.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	29.3700	47.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	30.7700	-331.94	1213.1	0.1500	-14.2500	30.9350	-6.6881
Lower:	8.2500	-16.50	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	21.6200

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R		
V_R = 1358.6 ft/sec		P_2/P_{T1} = 0.920		A_2/A_1 = 0.8258	
M_R = 1.29		V_{C_R} = 1366.6 ft/sec		W_C/A = 46.62	

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.755		M_1'	=	1.496		M_2'	=	0.929		M_2	=	1.331	
V_1	=	793.5	ft/sec	V_1'	=	1573.4	ft/sec	V_2'	=	1080.0	ft/sec	V_2	=	1547.3	ft/sec
α_1	=	0.00	deg.	α_1'	=	59.71	deg.	α_2'	=	12.16	deg.	α_2	=	-46.97	deg.
P_1	=	7.670	psia	P_1'	=	7.670	psia	P_2'	=	10.250	psia	P_2	=	10.250	psia
T_1	=	460.3	deg.R	T_1'	=	460.3	deg.R	T_2'	=	562.1	deg.R	T_2	=	562.1	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	19.51	psia	P_{T2}	=	31.64	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	665.1	deg.R	T_{T2}	=	767.2	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.755		M_1'	=	1.496		M_2'	=	0.743		M_2	=	1.186	
V_1	=	793.5	ft/sec	V_1'	=	1573.4	ft/sec	V_2'	=	891.8	ft/sec	V_2	=	1422.3	ft/sec
α_1	=	0.00	deg.	α_1'	=	59.71	deg.	α_2'	=	14.78	deg.	α_2	=	-52.68	deg.
P_1	=	7.670	psia	P_1'	=	7.670	psia	P_2'	=	12.236	psia	P_2	=	12.236	psia
T_1	=	460.3	deg.R	T_1'	=	460.3	deg.R	T_2'	=	598.9	deg.R	T_2	=	598.9	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	17.66	psia	P_{T2}	=	29.12	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	665.1	deg.R	T_{T2}	=	767.2	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6968
V_2/V_1	=	1.9499
P_2/P_1	=	1.3363
T_2/T_1	=	1.2213
P_{T2}/P_{T1}	=	2.8285
T_{T2}/T_{T1}	=	1.4965
W/H_{T1}	=	0.4989
η_c	=	0.6933

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6307
V_2/V_1	=	1.7924
P_2/P_1	=	1.5953
T_2/T_1	=	1.3012
P_{T2}/P_{T1}	=	2.6031
T_{T2}/T_{T1}	=	1.4965
W/H_{T1}	=	0.4989
η_c	=	0.6300

VPR-6.2-t3

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.5000	-23.0000	0.0000	0.5000	-11.5000	23.0000	0.0000
Lower:	5.5000	-11.0000	0.0000	0.5000	-5.5000	11.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	29.3700	47.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	30.7700	-331.94	1213.1	0.1500	-14.2500	30.9350	-6.6881
Lower:	8.2500	-16.50	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	21.6200

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R	
V_R = 1358.6 ft/sec	P_2/P_{T1} = 0.980		A_2/A_1 = 0.8258
M_R = 1.26	V_{C_R} = 1366.6 ft/sec		W_C/A = 40.81

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.582		M_1'	=	1.392		M_2'	=	0.791		M_2	=	1.227	
V_1	=	625.1	ft/sec	V_1'	=	1495.5	ft/sec	V_2'	=	936.2	ft/sec	V_2	=	1452.0	ft/sec
α_1	=	0.00	deg.	α_1'	=	65.29	deg.	α_2'	=	13.97	deg.	α_2	=	-51.27	deg.
P_1	=	8.895	psia	P_1'	=	8.895	psia	P_2'	=	10.963	psia	P_2	=	10.963	psia
T_1	=	480.1	deg.R	T_1'	=	480.1	deg.R	T_2'	=	582.3	deg.R	T_2	=	582.3	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	17.90	psia	P_{T2}	=	29.24	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	661.4	deg.R	T_{T2}	=	763.9	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.582		M_1'	=	1.392		M_2'	=	0.650		M_2	=	1.124	
V_1	=	624.8	ft/sec	V_1'	=	1495.4	ft/sec	V_2'	=	787.4	ft/sec	V_2	=	1360.8	ft/sec
α_1	=	0.00	deg.	α_1'	=	65.30	deg.	α_2'	=	16.68	deg.	α_2	=	-56.34	deg.
P_1	=	8.896	psia	P_1'	=	8.896	psia	P_2'	=	12.334	psia	P_2	=	12.334	psia
T_1	=	480.2	deg.R	T_1'	=	480.2	deg.R	T_2'	=	609.8	deg.R	T_2	=	609.8	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	16.39	psia	P_{T2}	=	27.14	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	661.4	deg.R	T_{T2}	=	763.9	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6393
V_2/V_1	=	2.3228
P_2/P_1	=	1.2326
T_2/T_1	=	1.2127
P_{T2}/P_{T1}	=	2.6138
T_{T2}/T_{T1}	=	1.4900
W/H_{T1}	=	0.4996
η_c	=	0.6323

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.5854
V_2/V_1	=	2.1779
P_2/P_1	=	1.3864
T_2/T_1	=	1.2699
P_{T2}/P_{T1}	=	2.4260
T_{T2}/T_{T1}	=	1.4900
W/H_{T1}	=	0.4996
η_c	=	0.5767

VPR-6.2-t4

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.5000	-23.0000	0.0000	0.5000	-11.5000	23.0000	0.0000
Lower:	5.5000	-11.0000	0.0000	0.5000	-5.5000	11.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	29.3700	47.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	30.7700	-331.94	1213.1	0.1500	-14.2500	30.9350	-6.6881
Lower:	8.2500	-16.50	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	21.6200

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R
V_R = 1358.6 ft/sec	P_2/P_{T1} = 1.050	A_2/A_1 = 0.8258
M_R = 1.24	V_{C_R} = 1366.2 ft/sec	W_C/A = 28.46

UNMIXED STATION AVERAGES

Inlet																							
Inlet Absolute				Inlet Relative				Exit Relative				Exit Absolute			
M_1	=	0.361		M'_1	=	1.291		M'_2	=	0.564		M_2	=	1.125	
V_1	=	395.6	ft/sec	V'_1	=	1415.0	ft/sec	V'_2	=	688.5	ft/sec	V_2	=	1372.8	ft/sec
α_1	=	-.01	deg.	α'_1	=	73.76	deg.	α'_2	=	13.45	deg.	α_2	=	-60.81	deg.
P_1	=	10.229	psia	P'_1	=	10.229	psia	P'_2	=	11.744	psia	P_2	=	11.744	psia
T_1	=	499.9	deg.R	T'_1	=	499.9	deg.R	T'_2	=	619.5	deg.R	T_2	=	619.5	deg.R
P_{T1}	=	11.19	psia	P'_{T1}	=	27.99	psia	P'_{T2}	=	14.92	psia	P_{T2}	=	26.33	psia
T_{T1}	=	512.9	deg.R	T'_{T1}	=	666.5	deg.R	T'_{T2}	=	661.5	deg.R	T_{T2}	=	778.9	deg.R

MIXED STATION AVERAGES

Inlet Absolute				Inlet Relative				Exit Relative				Exit Absolute			
M_1	=	0.360		M'_1	=	1.291		M'_2	=	0.514		M_2	=	1.095	
V_1	=	394.5	ft/sec	V'_1	=	1414.7	ft/sec	V'_2	=	631.2	ft/sec	V_2	=	1345.0	ft/sec
α_1	=	-.01	deg.	α'_1	=	73.81	deg.	α'_2	=	14.70	deg.	α_2	=	-63.01	deg.
P_1	=	10.235	psia	P'_1	=	10.235	psia	P'_2	=	12.150	psia	P_2	=	12.150	psia
T_1	=	500.0	deg.R	T'_1	=	500.0	deg.R	T'_2	=	628.3	deg.R	T_2	=	628.3	deg.R
P_{T1}	=	11.19	psia	P'_{T1}	=	28.00	psia	P'_{T2}	=	14.55	psia	P_{T2}	=	25.77	psia
T_{T1}	=	512.9	deg.R	T'_{T1}	=	666.5	deg.R	T'_{T2}	=	661.5	deg.R	T_{T2}	=	778.9	deg.R

UNMIXED PERFORMANCE

P'_{T2}/P'_{T1}	=	0.5329
V_2/V_1	=	3.4701
P_2/P_1	=	1.1480
T_2/T_1	=	1.2393
P_{T2}/P_{T1}	=	2.3532
T_{T2}/T_{T1}	=	1.5185
W/H_{T1}	=	0.5284
η_c	=	0.5242

MIXED PERFORMANCE

P'_{T2}/P'_{T1}	=	0.5196
V_2/V_1	=	3.4092
P_2/P_1	=	1.1872
T_2/T_1	=	1.2567
P_{T2}/P_{T1}	=	2.3021
T_{T2}/T_{T1}	=	1.5185
W/H_{T1}	=	0.5284
η_c	=	0.5091

VPR-6.2-t5

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.5000	-23.0000	0.0000	0.5000	-11.5000	23.0000	0.0000
Lower:	5.5000	-11.0000	0.0000	0.5000	-5.5000	11.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	29.3700	47.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	30.7700	-331.94	1213.1	0.1500	-14.2500	30.9350	-6.6881
Lower:	8.2500	-16.50	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	21.6200

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R		
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.120		A_2/A_1 = 0.8258	
M_R = 1.23		V_{C_R} = 1366.6 ft/sec		W_C/A = 10.81	

UNMIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.132	M_1' = 1.233	M_2' = 0.305	M_2 = 0.913
V_1 = 146.3 ft/sec	V_1' = 1366.5 ft/sec	V_2' = 381.1 ft/sec	V_2 = 1142.2 ft/sec
α_1 = 0.00 deg.	α_1' = 83.85 deg.	α_2' = 41.51 deg.	α_2 = -75.53 deg.
P_1 = 11.056 psia	P_1' = 11.056 psia	P_2' = 12.480 psia	P_2 = 12.480 psia
T_1 = 510.8 deg.R	T_1' = 510.8 deg.R	T_2' = 651.4 deg.R	T_2 = 651.4 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 13.26 psia	P_{T2} = 21.31 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 664.2 deg.R	T_{T2} = 760.7 deg.R

MIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.128	M_1' = 1.233	M_2' = 0.238	M_2 = 0.890
V_1 = 141.6 ft/sec	V_1' = 1366.0 ft/sec	V_2' = 299.5 ft/sec	V_2 = 1117.7 ft/sec
α_1 = 0.00 deg.	α_1' = 84.05 deg.	α_2' = 57.49 deg.	α_2 = -81.72 deg.
P_1 = 11.064 psia	P_1' = 11.064 psia	P_2' = 12.705 psia	P_2 = 12.705 psia
T_1 = 511.0 deg.R	T_1' = 511.0 deg.R	T_2' = 656.7 deg.R	T_2 = 656.7 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.01 psia	P_{T2}' = 13.22 psia	P_{T2} = 21.25 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 664.2 deg.R	T_{T2} = 760.7 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.4736
V_2/V_1	=	7.8056
P_2/P_1	=	1.1288
T_2/T_1	=	1.2752
P_{T2}/P_{T1}	=	1.9044
T_{T2}/T_{T1}	=	1.4837
W/H_{T1}	=	0.4879
η_c	=	0.4142

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.4721
V_2/V_1	=	7.8905
P_2/P_1	=	1.1483
T_2/T_1	=	1.2851
P_{T2}/P_{T1}	=	1.8989
T_{T2}/T_{T1}	=	1.4837
W/H_{T1}	=	0.4879
η_c	=	0.4122

VPR-7.1-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.4233	-25.8747	0.0000	0.4445	-11.5000	23.0000	0.0000
Lower:	5.4233	-12.3748	0.0000	0.8889	-1.9517	21.3771	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.5000	29.4467	47.9667

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Transonic)

V_R = 1358.6 ft/sec	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R	
M_R = 1.29	P_2/P_{T1} = 0.920		A_2/A_1 = 0.8258
	V_{C_R} = 1366.6 ft/sec		W_C/A = 46.91

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.767		M_1'	=	1.505		M_2'	=	0.913		M_2	=	1.387	
V_1	=	805.7	ft/sec	V_1'	=	1579.5	ft/sec	V_2'	=	1065.3	ft/sec	V_2	=	1618.1	ft/sec
α_1	=	0.00	deg.	α_1'	=	59.33	deg.	α_2'	=	7.20	deg.	α_2	=	-49.22	deg.
P_1	=	7.576	psia	P_1'	=	7.576	psia	P_2'	=	10.336	psia	P_2	=	10.336	psia
T_1	=	458.7	deg.R	T_1'	=	458.7	deg.R	T_2'	=	566.0	deg.R	T_2	=	566.0	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	18.64	psia	P_{T2}	=	33.58	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	664.5	deg.R	T_{T2}	=	788.0	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.767		M_1'	=	1.505		M_2'	=	0.751		M_2	=	1.264	
V_1	=	805.7	ft/sec	V_1'	=	1579.5	ft/sec	V_2'	=	899.9	ft/sec	V_2	=	1514.3	ft/sec
α_1	=	0.00	deg.	α_1'	=	59.33	deg.	α_2'	=	8.53	deg.	α_2	=	-54.00	deg.
P_1	=	7.576	psia	P_1'	=	7.576	psia	P_2'	=	12.088	psia	P_2	=	12.088	psia
T_1	=	458.7	deg.R	T_1'	=	458.7	deg.R	T_2'	=	597.1	deg.R	T_2	=	597.1	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	17.58	psia	P_{T2}	=	31.91	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	664.5	deg.R	T_{T2}	=	788.0	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6657
V_2/V_1	=	2.0083
P_2/P_1	=	1.3642
T_2/T_1	=	1.2341
P_{T2}/P_{T1}	=	3.0013
T_{T2}/T_{T1}	=	1.5370
W/H_{T1}	=	0.5404
η_c	=	0.6826

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6279
V_2/V_1	=	1.8795
P_2/P_1	=	1.5955
T_2/T_1	=	1.3019
P_{T2}/P_{T1}	=	2.8521
T_{T2}/T_{T1}	=	1.5370
W/H_{T1}	=	0.5404
η_c	=	0.6460

VPR-7.1-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.4233	-25.8747	0.0000	0.4445	-11.5000	23.0000	0.0000
Lower:	5.4233	-12.3748	0.0000	0.8889	-1.9517	21.3771	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.5000	29.4467	47.9667

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R
V_R = 1358.6 ft/sec	P_2/P_{T1} = 0.980	A_2/A_1 = 0.8258
M_R = 1.29	V_{C_R} = 1366.6 ft/sec	W_C/A = 46.90

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.767		M_1'	=	1.504		M_2'	=	0.857		M_2	=	1.350	
V_1	=	804.9	ft/sec	V_1'	=	1579.1	ft/sec	V_2'	=	1006.7	ft/sec	V_2	=	1585.4	ft/sec
α_1	=	0.00	deg.	α_1'	=	59.36	deg.	α_2'	=	7.26	deg.	α_2	=	-50.96	deg.
P_1	=	7.582	psia	P_1'	=	7.582	psia	P_2'	=	11.016	psia	P_2	=	11.016	psia
T_1	=	458.8	deg.R	T_1'	=	458.8	deg.R	T_2'	=	573.8	deg.R	T_2	=	573.8	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	18.67	psia	P_{T2}	=	33.94	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	661.9	deg.R	T_{T2}	=	786.8	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.767		M_1'	=	1.504		M_2'	=	0.726		M_2	=	1.253	
V_1	=	804.9	ft/sec	V_1'	=	1579.1	ft/sec	V_2'	=	870.7	ft/sec	V_2	=	1502.7	ft/sec
α_1	=	0.00	deg.	α_1'	=	59.36	deg.	α_2'	=	8.41	deg.	α_2	=	-55.03	deg.
P_1	=	7.582	psia	P_1'	=	7.582	psia	P_2'	=	12.447	psia	P_2	=	12.447	psia
T_1	=	458.8	deg.R	T_1'	=	458.8	deg.R	T_2'	=	598.8	deg.R	T_2	=	598.8	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	17.67	psia	P_{T2}	=	32.36	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	661.9	deg.R	T_{T2}	=	786.8	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6668
V_2/V_1	=	1.9696
P_2/P_1	=	1.4528
T_2/T_1	=	1.2507
P_{T2}/P_{T1}	=	3.0335
T_{T2}/T_{T1}	=	1.5346
W/H_{T1}	=	0.5431
η_c	=	0.6869

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6311
V_2/V_1	=	1.8670
P_2/P_1	=	1.6416
T_2/T_1	=	1.3053
P_{T2}/P_{T1}	=	2.8922
T_{T2}/T_{T1}	=	1.5346
W/H_{T1}	=	0.5431
η_c	=	0.6527

VPR-7.1-t3

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.4233	-25.8747	0.0000	0.4445	-11.5000	23.0000	0.0000
Lower:	5.4233	-12.3748	0.0000	0.8889	-1.9517	21.3771	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.5000	29.4467	47.9667

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R		
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.050		A_2/A_1 = 0.8258	
M_R = 1.29		V_{C_R} = 1366.6 ft/sec		W_C/A = 46.93	

UNMIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1	= 0.768		M_1'	= 1.505		M_2'	= 0.829		M_2	= 1.330	
V_1	= 806.5	ft/sec	V_1'	= 1579.9	ft/sec	V_2'	= 979.2	ft/sec	V_2	= 1570.0	ft/sec
α_1	= 0.00	deg.	α_1'	= 59.31	deg.	α_2'	= 7.33	deg.	α_2	= -51.79	deg.
P_1	= 7.570	psia	P_1'	= 7.570	psia	P_2'	= 11.719	psia	P_2	= 11.719	psia
T_1	= 458.5	deg.R	T_1'	= 458.5	deg.R	T_2'	= 580.3	deg.R	T_2	= 580.3	deg.R
P_{T1}	= 11.19	psia	P_{T1}'	= 28.00	psia	P_{T2}'	= 19.22	psia	P_{T2}	= 35.04	psia
T_{T1}	= 512.7	deg.R	T_{T1}'	= 666.3	deg.R	T_{T2}'	= 663.9	deg.R	T_{T2}	= 789.2	deg.R

MIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1	= 0.768		M_1'	= 1.505		M_2'	= 0.667		M_2	= 1.214	
V_1	= 806.5	ft/sec	V_1'	= 1579.9	ft/sec	V_2'	= 807.5	ft/sec	V_2	= 1469.1	ft/sec
α_1	= 0.00	deg.	α_1'	= 59.31	deg.	α_2'	= 8.90	deg.	α_2	= -57.11	deg.
P_1	= 7.570	psia	P_1'	= 7.570	psia	P_2'	= 13.503	psia	P_2	= 13.503	psia
T_1	= 458.5	deg.R	T_1'	= 458.5	deg.R	T_2'	= 609.6	deg.R	T_2	= 609.6	deg.R
P_{T1}	= 11.19	psia	P_{T1}'	= 28.00	psia	P_{T2}'	= 18.20	psia	P_{T2}	= 33.34	psia
T_{T1}	= 512.7	deg.R	T_{T1}'	= 666.3	deg.R	T_{T2}'	= 663.9	deg.R	T_{T2}	= 789.2	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6864
V_2/V_1	= 1.9467
P_2/P_1	= 1.5480
T_2/T_1	= 1.2654
P_{T2}/P_{T1}	= 3.1324
T_{T2}/T_{T1}	= 1.5394
W/H_{T1}	= 0.5441
η_c	= 0.7089

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6500
V_2/V_1	= 1.8216
P_2/P_1	= 1.7837
T_2/T_1	= 1.3294
P_{T2}/P_{T1}	= 2.9803
T_{T2}/T_{T1}	= 1.5394
W/H_{T1}	= 0.5441
η_c	= 0.6729

VPR-7.1-t4

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	11.4233	-25.8747	0.0000	0.4445	-11.5000	23.0000	0.0000
Lower:	5.4233	-12.3748	0.0000	0.8889	-1.9517	21.3771	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.5000	29.4467	47.9667

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Transonic)

		P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R	
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.120			A_2/A_1 = 0.8258
M_R = 1.29		V_{C_R} = 1366.6 ft/sec			W_C/A = 46.41

UNMIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1 =	0.746		M_1' =	1.491		M_2' =	0.748		M_2 =	1.260	
V_1 =	785.7	ft/sec	V_1' =	1569.4	ft/sec	V_2' =	892.0	ft/sec	V_2 =	1503.2	ft/sec
α_1 =	0.00	deg.	α_1' =	59.96	deg.	α_2' =	9.06	deg.	α_2 =	-54.13	deg.
P_1 =	7.731	psia	P_1' =	7.731	psia	P_2' =	12.661	psia	P_2 =	12.661	psia
T_1 =	461.3	deg.R	T_1' =	461.3	deg.R	T_2' =	592.3	deg.R	T_2 =	592.3	deg.R
P_{T1} =	11.19	psia	P_{T1}' =	28.00	psia	P_{T2}' =	19.38	psia	P_{T2} =	34.50	psia
T_{T1} =	512.7	deg.R	T_{T1}' =	666.3	deg.R	T_{T2}' =	664.6	deg.R	T_{T2} =	786.4	deg.R

MIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1 =	0.746		M_1' =	1.491		M_2' =	0.596		M_2 =	1.156	
V_1 =	785.7	ft/sec	V_1' =	1569.4	ft/sec	V_2' =	727.3	ft/sec	V_2 =	1411.7	ft/sec
α_1 =	0.00	deg.	α_1' =	59.96	deg.	α_2' =	11.14	deg.	α_2 =	-59.64	deg.
P_1 =	7.731	psia	P_1' =	7.731	psia	P_2' =	14.258	psia	P_2 =	14.258	psia
T_1 =	461.3	deg.R	T_1' =	461.3	deg.R	T_2' =	620.6	deg.R	T_2 =	620.6	deg.R
P_{T1} =	11.19	psia	P_{T1}' =	28.00	psia	P_{T2}' =	18.12	psia	P_{T2} =	32.67	psia
T_{T1} =	512.7	deg.R	T_{T1}' =	666.3	deg.R	T_{T2}' =	664.6	deg.R	T_{T2} =	786.4	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}' =	0.6921
V_2/V_1 =	1.9133
P_2/P_1 =	1.6377
T_2/T_1 =	1.2840
P_{T2}/P_{T1} =	3.0837
T_{T2}/T_{T1} =	1.5340
W/H_{T1} =	0.5373
η_c =	0.7064

MIXED PERFORMANCE

P_{T2}'/P_{T1}' =	0.6471
V_2/V_1 =	1.7969
P_2/P_1 =	1.8443
T_2/T_1 =	1.3452
P_{T2}/P_{T1} =	2.9201
T_{T2}/T_{T1} =	1.5340
W/H_{T1} =	0.5373
η_c =	0.6667

VPR-9f-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	8.5000	-17.0000	0.0000	0.5000	-8.5000	17.0000	0.0000
Lower:	2.5000	-5.0000	0.0000	0.5000	-2.5000	5.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	32.3700	50.8900

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R		
V_R = 1358.6 ft/sec		P_2/P_{T1} = 0.900		A_2/A_1 = 0.8677	
M_R = 1.29		V_{C_R} = 1366.6 ft/sec		W_C/A = 45.92	

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.727		M_1'	=	1.478		M_2'	=	1.162		M_2	=	0.815	
V_1	=	767.6	ft/sec	V_1'	=	1560.5	ft/sec	V_2'	=	1299.1	ft/sec	V_2	=	907.5	ft/sec
α_1	=	0.00	deg.	α_1'	=	60.53	deg.	α_2'	=	50.62	deg.	α_2	=	-21.61	deg.
P_1	=	7.868	psia	P_1'	=	7.868	psia	P_2'	=	10.387	psia	P_2	=	10.387	psia
T_1	=	463.6	deg.R	T_1'	=	463.6	deg.R	T_2'	=	519.8	deg.R	T_2	=	516.5	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	25.50	psia	P_{T2}	=	16.64	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	663.5	deg.R	T_{T2}	=	585.8	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.727		M_1'	=	1.478		M_2'	=	1.044		M_2	=	0.636	
V_1	=	767.6	ft/sec	V_1'	=	1560.5	ft/sec	V_2'	=	1194.7	ft/sec	V_2	=	726.0	ft/sec
α_1	=	0.00	deg.	α_1'	=	60.53	deg.	α_2'	=	56.89	deg.	α_2	=	-27.72	deg.
P_1	=	7.868	psia	P_1'	=	7.868	psia	P_2'	=	11.801	psia	P_2	=	12.064	psia
T_1	=	463.6	deg.R	T_1'	=	463.6	deg.R	T_2'	=	544.8	deg.R	T_2	=	542.0	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	23.54	psia	P_{T2}	=	15.84	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	663.5	deg.R	T_{T2}	=	585.8	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9109
V_2/V_1	=	1.1822
P_2/P_1	=	1.3202
T_2/T_1	=	1.1141
P_{T2}/P_{T1}	=	1.4878
T_{T2}/T_{T1}	=	1.1427
W/H_{T1}	=	0.1490
η_c	=	0.8069

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.8407
V_2/V_1	=	0.9457
P_2/P_1	=	1.5333
T_2/T_1	=	1.1690
P_{T2}/P_{T1}	=	1.4161
T_{T2}/T_{T1}	=	1.1427
W/H_{T1}	=	0.1490
η_c	=	0.7015

VPR-9f-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	8.5000	-17.0000	0.0000	0.5000	-8.5000	17.0000	0.0000
Lower:	2.5000	-5.0000	0.0000	0.5000	-2.5000	5.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	32.3700	50.8900

CONDITIONS: (Transonic)

		P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R	
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.000			A_2/A_1 = 0.8677
M_R = 1.29		V_{C_R} = 1366.6 ft/sec			W_C/A = 46.11

UNMIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1	0.734		M_1'	1.483		M_2'	1.122		M_2	0.818	
V_1	774.5	ft/sec	V_1'	1563.8	ft/sec	V_2'	1265.3	ft/sec	V_2	920.1	ft/sec
α_1	0.00	deg.	α_1'	60.32	deg.	α_2'	49.64	deg.	α_2	-23.82	deg.
P_1	7.816	psia	P_1'	7.816	psia	P_2'	11.126	psia	P_2	11.126	psia
T_1	462.7	deg.R	T_1'	462.7	deg.R	T_2'	529.2	deg.R	T_2	526.0	deg.R
P_{T1}	11.19	psia	P_{T1}'	28.00	psia	P_{T2}'	25.91	psia	P_{T2}	17.93	psia
T_{T1}	512.7	deg.R	T_{T1}'	666.3	deg.R	T_{T2}'	664.3	deg.R	T_{T2}	595.3	deg.R

MIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1	0.734		M_1'	1.483		M_2'	0.982		M_2	0.613	
V_1	774.5	ft/sec	V_1'	1563.8	ft/sec	V_2'	1136.3	ft/sec	V_2	707.3	ft/sec
α_1	0.00	deg.	α_1'	60.32	deg.	α_2'	57.64	deg.	α_2	-32.11	deg.
P_1	7.816	psia	P_1'	7.816	psia	P_2'	12.855	psia	P_2	13.137	psia
T_1	462.7	deg.R	T_1'	462.7	deg.R	T_2'	556.9	deg.R	T_2	553.7	deg.R
P_{T1}	11.19	psia	P_{T1}'	28.00	psia	P_{T2}'	23.84	psia	P_{T2}	16.93	psia
T_{T1}	512.7	deg.R	T_{T1}'	666.3	deg.R	T_{T2}'	664.3	deg.R	T_{T2}	595.3	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	0.9256
V_2/V_1	1.1881
P_2/P_1	1.4235
T_2/T_1	1.1368
P_{T2}/P_{T1}	1.6030
T_{T2}/T_{T1}	1.1613
W/H_{T1}	0.1658
η_c	0.8704

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	0.8515
V_2/V_1	0.9133
P_2/P_1	1.6808
T_2/T_1	1.1966
P_{T2}/P_{T1}	1.5136
T_{T2}/T_{T1}	1.1613
W/H_{T1}	0.1658
η_c	0.7581

VPR-9f-t3

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	8.5000	-17.0000	0.0000	0.5000	-8.5000	17.0000	0.0000
Lower:	2.5000	-5.0000	0.0000	0.5000	-2.5000	5.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	32.3700	50.8900

CONDITIONS: (Transonic)

			P_{T1} = 11.19 psia			T_{T1} = 512.7 deg.R		
V_R	=	1358.6 ft/sec	P_2/P_{T1}	=	1.080	A_2/A_1	=	0.8677
M_R	=	1.29	V_{C_R}	=	1366.6 ft/sec	W_C/A	=	46.06

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.732		M_1'	=	1.482		M_2'	=	1.091		M_2	=	0.838	
V_1	=	772.5	ft/sec	V_1'	=	1562.8	ft/sec	V_2'	=	1238.4	ft/sec	V_2	=	948.5	ft/sec
α_1	=	0.00	deg.	α_1'	=	60.38	deg.	α_2'	=	48.01	deg.	α_2	=	-25.84	deg.
P_1	=	7.831	psia	P_1'	=	7.831	psia	P_2'	=	11.549	psia	P_2	=	11.549	psia
T_1	=	463.0	deg.R	T_1'	=	463.0	deg.R	T_2'	=	535.7	deg.R	T_2	=	532.5	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	25.81	psia	P_{T2}	=	18.90	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	664.8	deg.R	T_{T2}	=	605.3	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.732		M_1'	=	1.482		M_2'	=	0.932		M_2	=	0.611	
V_1	=	772.5	ft/sec	V_1'	=	1562.8	ft/sec	V_2'	=	1087.5	ft/sec	V_2	=	710.8	ft/sec
α_1	=	0.00	deg.	α_1'	=	60.38	deg.	α_2'	=	57.45	deg.	α_2	=	-35.93	deg.
P_1	=	7.831	psia	P_1'	=	7.831	psia	P_2'	=	13.533	psia	P_2	=	13.843	psia
T_1	=	463.0	deg.R	T_1'	=	463.0	deg.R	T_2'	=	566.4	deg.R	T_2	=	563.2	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	23.71	psia	P_{T2}	=	17.81	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	664.8	deg.R	T_{T2}	=	605.3	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9220
V_2/V_1	=	1.2279
P_2/P_1	=	1.4747
T_2/T_1	=	1.1502
P_{T2}/P_{T1}	=	1.6891
T_{T2}/T_{T1}	=	1.1806
W/H_{T1}	=	0.1840
η_c	=	0.8781

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.8470
V_2/V_1	=	0.9201
P_2/P_1	=	1.7677
T_2/T_1	=	1.2164
P_{T2}/P_{T1}	=	1.5921
T_{T2}/T_{T1}	=	1.1806
W/H_{T1}	=	0.1840
η_c	=	0.7723

VPR-9f-t4

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	8.5000	-17.0000	0.0000	0.5000	-8.5000	17.0000	0.0000
Lower:	2.5000	-5.0000	0.0000	0.5000	-2.5000	5.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	32.3700	50.8900

CONDITIONS: (Transonic)

			P_{T1}	=	11.19 psia	T_{T1}	=	512.7 deg.R			
V_R	=	1358.6 ft/sec	P_2/P_{T1}	=	1.100				A_2/A_1	=	0.8677
M_R	=	1.29	V_{C_R}	=	1366.6 ft/sec				W_C/A	=	46.64

UNMIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 =	0.756	M_1' =	1.497	M_2' =	1.143	M_2 =	0.853
V_1 =	794.6 ft/sec	V_1' =	1573.9 ft/sec	V_2' =	1288.2 ft/sec	V_2 =	958.0 ft/sec
α_1 =	0.00 deg.	α_1' =	59.68 deg.	α_2' =	48.23 deg.	α_2 =	-22.67 deg.
P_1 =	7.662 psia	P_1' =	7.662 psia	P_2' =	11.236 psia	P_2 =	11.236 psia
T_1 =	460.1 deg.R	T_1' =	460.1 deg.R	T_2' =	528.8 deg.R	T_2 =	524.9 deg.R
P_{T1} =	11.19 psia	P_{T1}' =	28.00 psia	P_{T2}' =	25.66 psia	P_{T2} =	17.80 psia
T_{T1} =	512.7 deg.R	T_{T1}' =	666.3 deg.R	T_{T2}' =	666.7 deg.R	T_{T2} =	596.8 deg.R

MIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 =	0.756	M_1' =	1.497	M_2' =	0.965	M_2 =	0.585
V_1 =	794.6 ft/sec	V_1' =	1573.9 ft/sec	V_2' =	1121.1 ft/sec	V_2 =	678.1 ft/sec
α_1 =	0.00 deg.	α_1' =	59.68 deg.	α_2' =	58.84 deg.	α_2 =	-33.13 deg.
P_1 =	7.662 psia	P_1' =	7.662 psia	P_2' =	13.491 psia	P_2 =	13.825 psia
T_1 =	460.1 deg.R	T_1' =	460.1 deg.R	T_2' =	562.1 deg.R	T_2 =	558.5 deg.R
P_{T1} =	11.19 psia	P_{T1}' =	28.00 psia	P_{T2}' =	24.51 psia	P_{T2} =	17.43 psia
T_{T1} =	512.7 deg.R	T_{T1}' =	666.3 deg.R	T_{T2}' =	666.7 deg.R	T_{T2} =	596.8 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9166
V_2/V_1	=	1.2057
P_2/P_1	=	1.4664
T_2/T_1	=	1.1407
P_{T2}/P_{T1}	=	1.5911
T_{T2}/T_{T1}	=	1.1641
W/H_{T1}	=	0.1635
η_c	=	0.8681

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.8757
V_2/V_1	=	0.8534
P_2/P_1	=	1.8044
T_2/T_1	=	1.2138
P_{T2}/P_{T1}	=	1.5585
T_{T2}/T_{T1}	=	1.1641
W/H_{T1}	=	0.1635
η_c	=	0.8268

VPR-9f-t5

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	8.5000	-17.0000	0.0000	0.5000	-8.5000	17.0000	0.0000
Lower:	2.5000	-5.0000	0.0000	0.5000	-2.5000	5.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	32.3700	50.8900

CONDITIONS: (Transonic)

			P_{T1}	=	11.19 psia		T_{T1}	=	512.7 deg.R		
V_R	=	1358.6 ft/sec	P_2/P_{T1}	=	1.200				A_2/A_1	=	0.8677
M_R	=	1.28	V_{C_R}	=	1366.6 ft/sec				W_C/A	=	44.23

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.671		M_1'	=	1.443		M_2'	=	0.994		M_2	=	0.774	
V_1	=	713.2	ft/sec	V_1'	=	1534.4	ft/sec	V_2'	=	1149.3	ft/sec	V_2	=	891.8	ft/sec
α_1	=	0.00	deg.	α_1'	=	62.30	deg.	α_2'	=	49.75	deg.	α_2	=	-30.42	deg.
P_1	=	8.274	psia	P_1'	=	8.274	psia	P_2'	=	12.840	psia	P_2	=	12.840	psia
T_1	=	470.3	deg.R	T_1'	=	470.3	deg.R	T_2'	=	556.0	deg.R	T_2	=	552.6	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	25.04	psia	P_{T2}	=	19.27	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	666.7	deg.R	T_{T2}	=	615.7	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.671		M_1'	=	1.443		M_2'	=	0.866		M_2	=	0.589	
V_1	=	713.2	ft/sec	V_1'	=	1534.4	ft/sec	V_2'	=	1022.5	ft/sec	V_2	=	693.0	ft/sec
α_1	=	0.00	deg.	α_1'	=	62.30	deg.	α_2'	=	58.71	deg.	α_2	=	-41.03	deg.
P_1	=	8.274	psia	P_1'	=	8.274	psia	P_2'	=	14.475	psia	P_2	=	14.765	psia
T_1	=	470.3	deg.R	T_1'	=	470.3	deg.R	T_2'	=	579.7	deg.R	T_2	=	575.7	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	23.62	psia	P_{T2}	=	18.67	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	666.7	deg.R	T_{T2}	=	615.7	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.8946
V_2/V_1	=	1.2504
P_2/P_1	=	1.5519
T_2/T_1	=	1.1749
P_{T2}/P_{T1}	=	1.7227
T_{T2}/T_{T1}	=	1.2010
W/H_{T1}	=	0.2007
η_c	=	0.8379

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.8435
V_2/V_1	=	0.9717
P_2/P_1	=	1.7845
T_2/T_1	=	1.2241
P_{T2}/P_{T1}	=	1.6694
T_{T2}/T_{T1}	=	1.2010
W/H_{T1}	=	0.2007
η_c	=	0.7858

VPR-9.1-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	8.5000	-17.0000	0.0000	0.5000	-8.5000	17.0000	0.0000
Lower:	2.5000	-5.0000	0.0000	0.5000	-2.5000	5.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	32.3700	50.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R
V_R = 1358.6 ft/sec	P_2/P_{T1} = 0.850	A_2/A_1 = 0.8258
M_R = 1.29	V_{C_R} = 1366.6 ft/sec	W_C/A = 46.38

UNMIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.745	M_1' = 1.490	M_2' = 0.957	M_2 = 1.398
V_1 = 784.2 ft/sec	V_1' = 1568.7 ft/sec	V_2' = 1103.4 ft/sec	V_2 = 1612.4 ft/sec
α_1 = 0.00 deg.	α_1' = 60.00 deg.	α_2' = 8.89 deg.	α_2 = -47.46 deg.
P_1 = 7.741 psia	P_1' = 7.741 psia	P_2' = 9.503 psia	P_2 = 9.503 psia
T_1 = 461.5 deg.R	T_1' = 461.5 deg.R	T_2' = 553.6 deg.R	T_2 = 553.6 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 19.02 psia	P_{T2} = 32.91 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 660.8 deg.R	T_{T2} = 775.8 deg.R

MIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.745	M_1' = 1.490	M_2' = 0.716	M_2 = 1.214
V_1 = 784.2 ft/sec	V_1' = 1568.7 ft/sec	V_2' = 859.8 ft/sec	V_2 = 1456.6 ft/sec
α_1 = 0.00 deg.	α_1' = 60.00 deg.	α_2' = 11.44 deg.	α_2 = -54.65 deg.
P_1 = 7.741 psia	P_1' = 7.741 psia	P_2' = 11.918 psia	P_2 = 11.918 psia
T_1 = 461.5 deg.R	T_1' = 461.5 deg.R	T_2' = 599.3 deg.R	T_2 = 599.3 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 16.78 psia	P_{T2} = 29.43 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 660.8 deg.R	T_{T2} = 775.8 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6794
V_2/V_1	= 2.0560
P_2/P_1	= 1.2275
T_2/T_1	= 1.1996
P_{T2}/P_{T1}	= 2.9423
T_{T2}/T_{T1}	= 1.5134
W/H_{T1}	= 0.5241
η_c	= 0.6891

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.5994
V_2/V_1	= 1.8574
P_2/P_1	= 1.5396
T_2/T_1	= 1.2986
P_{T2}/P_{T1}	= 2.6307
T_{T2}/T_{T1}	= 1.5134
W/H_{T1}	= 0.5241
η_c	= 0.6074

VPR-9.1-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	8.5000	-17.0000	0.0000	0.5000	-8.5000	17.0000	0.0000
Lower:	2.5000	-5.0000	0.0000	0.5000	-2.5000	5.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	32.3700	50.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R
V_R = 1358.6 ft/sec	P_2/P_{T1} = 0.900	A_2/A_1 = 0.8258
M_R = 1.29	V_{C_R} = 1366.6 ft/sec	W_C/A = 46.16

UNMIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1	= 0.736	M_1'	= 1.484	M_2'	= 0.955	M_2	= 1.396
V_1	= 776.2 ft/sec	V_1'	= 1564.7 ft/sec	V_2'	= 1100.0 ft/sec	V_2	= 1609.0 ft/sec
α_1	= 0.00 deg.	α_1'	= 60.26 deg.	α_2'	= 8.99 deg.	α_2	= -47.53 deg.
P_1	= 7.803 psia	P_1'	= 7.803 psia	P_2'	= 10.078 psia	P_2	= 10.078 psia
T_1	= 462.5 deg.R	T_1'	= 462.5 deg.R	T_2'	= 552.6 deg.R	T_2	= 552.6 deg.R
P_{T1}	= 11.19 psia	P_{T1}'	= 28.00 psia	P_{T2}'	= 20.07 psia	P_{T2}	= 34.60 psia
T_{T1}	= 512.7 deg.R	T_{T1}'	= 666.3 deg.R	T_{T2}'	= 661.5 deg.R	T_{T2}	= 776.3 deg.R

MIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1	= 0.736	M_1'	= 1.484	M_2'	= 0.656	M_2	= 1.171
V_1	= 776.2 ft/sec	V_1'	= 1564.7 ft/sec	V_2'	= 793.3 ft/sec	V_2	= 1417.1 ft/sec
α_1	= 0.00 deg.	α_1'	= 60.26 deg.	α_2'	= 12.51 deg.	α_2	= -56.87 deg.
P_1	= 7.803 psia	P_1'	= 7.803 psia	P_2'	= 13.107 psia	P_2	= 13.107 psia
T_1	= 462.5 deg.R	T_1'	= 462.5 deg.R	T_2'	= 609.2 deg.R	T_2	= 609.2 deg.R
P_{T1}	= 11.19 psia	P_{T1}'	= 28.00 psia	P_{T2}'	= 17.49 psia	P_{T2}	= 30.62 psia
T_{T1}	= 512.7 deg.R	T_{T1}'	= 666.3 deg.R	T_{T2}'	= 661.5 deg.R	T_{T2}	= 776.3 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.7167
V_2/V_1	= 2.0729
P_2/P_1	= 1.2916
T_2/T_1	= 1.1947
P_{T2}/P_{T1}	= 3.0934
T_{T2}/T_{T1}	= 1.5142
W/H_{T1}	= 0.5235
η_c	= 0.7274

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6248
V_2/V_1	= 1.8257
P_2/P_1	= 1.6798
T_2/T_1	= 1.3171
P_{T2}/P_{T1}	= 2.7372
T_{T2}/T_{T1}	= 1.5142
W/H_{T1}	= 0.5235
η_c	= 0.6368

VPR-9.1-t3

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	8.5000	-17.0000	0.0000	0.5000	-8.5000	17.0000	0.0000
Lower:	2.5000	-5.0000	0.0000	0.5000	-2.5000	5.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	32.3700	50.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Transonic)

		P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R			
V_R	= 1358.6 ft/sec	P_2/P_{T1}	= 1.000			A_2/A_1	= 0.8258
M_R	= 1.29	V_{C_R}	= 1366.6 ft/sec			W_C/A	= 46.42

UNMIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1	= 0.747	M_1'	= 1.491	M_2'	= 0.967	M_2	= 1.421
V_1	= 786.0 ft/sec	V_1'	= 1569.6 ft/sec	V_2'	= 1115.4 ft/sec	V_2	= 1639.9 ft/sec
α_1	= 0.00 deg.	α_1'	= 59.95 deg.	α_2'	= 7.59 deg.	α_2	= -47.61 deg.
P_1	= 7.728 psia	P_1'	= 7.728 psia	P_2'	= 11.027 psia	P_2	= 11.027 psia
T_1	= 461.2 deg.R	T_1'	= 461.2 deg.R	T_2'	= 553.9 deg.R	T_2	= 553.9 deg.R
P_{T1}	= 11.19 psia	P_{T1}'	= 28.00 psia	P_{T2}'	= 20.56 psia	P_{T2}	= 36.86 psia
T_{T1}	= 512.7 deg.R	T_{T1}'	= 666.3 deg.R	T_{T2}'	= 663.0 deg.R	T_{T2}	= 783.3 deg.R

MIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1	= 0.747	M_1'	= 1.491	M_2'	= 0.605	M_2	= 1.157
V_1	= 786.0 ft/sec	V_1'	= 1569.6 ft/sec	V_2'	= 736.7 ft/sec	V_2	= 1410.0 ft/sec
α_1	= 0.00 deg.	α_1'	= 59.95 deg.	α_2'	= 11.54 deg.	α_2	= -59.21 deg.
P_1	= 7.728 psia	P_1'	= 7.728 psia	P_2'	= 14.925 psia	P_2	= 14.925 psia
T_1	= 461.2 deg.R	T_1'	= 461.2 deg.R	T_2'	= 617.9 deg.R	T_2	= 617.9 deg.R
P_{T1}	= 11.19 psia	P_{T1}'	= 28.00 psia	P_{T2}'	= 19.11 psia	P_{T2}	= 34.24 psia
T_{T1}	= 512.7 deg.R	T_{T1}'	= 666.3 deg.R	T_{T2}'	= 663.0 deg.R	T_{T2}	= 783.3 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.7344
V_2/V_1	= 2.0865
P_2/P_1	= 1.4269
T_2/T_1	= 1.2009
P_{T2}/P_{T1}	= 3.2953
T_{T2}/T_{T1}	= 1.5280
W/H_{T1}	= 0.5343
η_c	= 0.7598

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6824
V_2/V_1	= 1.7940
P_2/P_1	= 1.9313
T_2/T_1	= 1.3396
P_{T2}/P_{T1}	= 3.0610
T_{T2}/T_{T1}	= 1.5280
W/H_{T1}	= 0.5343
η_c	= 0.7049

VPR-9.1-t4

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	8.5000	-17.0000	0.0000	0.5000	-8.5000	17.0000	0.0000
Lower:	2.5000	-5.0000	0.0000	0.5000	-2.5000	5.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	32.3700	50.8900

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	14.2500	-28.5000	0.0000	0.5000	-14.2500	28.5000	0.0000
Lower:	8.2500	-16.5000	0.0000	0.5000	-8.2500	16.5000	0.0000

c_2	β_C
6.0000	15.6200

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R	
V_R = 1358.6 ft/sec	P_2/P_{T1} = 1.100		A_2/A_1 = 0.8258
M_R = 1.29	V_{CR} = 1366.6 ft/sec		W_C/A = 46.09

UNMIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.734	M_1' = 1.482	M_2' = 0.770	M_2 = 1.294
V_1 = 773.7 ft/sec	V_1' = 1563.4 ft/sec	V_2' = 914.5 ft/sec	V_2 = 1537.8 ft/sec
α_1 = 0.00 deg.	α_1' = 60.34 deg.	α_2' = 7.34 deg.	α_2 = -53.86 deg.
P_1 = 7.822 psia	P_1' = 7.822 psia	P_2' = 12.406 psia	P_2 = 12.406 psia
T_1 = 462.8 deg.R	T_1' = 462.8 deg.R	T_2' = 587.5 deg.R	T_2 = 587.5 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 19.57 psia	P_{T2} = 35.73 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 662.1 deg.R	T_{T2} = 789.3 deg.R

MIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.734	M_1' = 1.482	M_2' = 0.641	M_2 = 1.204
V_1 = 773.7 ft/sec	V_1' = 1563.4 ft/sec	V_2' = 777.4 ft/sec	V_2 = 1460.4 ft/sec
α_1 = 0.00 deg.	α_1' = 60.34 deg.	α_2' = 8.64 deg.	α_2 = -58.24 deg.
P_1 = 7.822 psia	P_1' = 7.822 psia	P_2' = 13.804 psia	P_2 = 13.804 psia
T_1 = 462.8 deg.R	T_1' = 462.8 deg.R	T_2' = 611.8 deg.R	T_2 = 611.8 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 18.20 psia	P_{T2} = 33.67 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 662.1 deg.R	T_{T2} = 789.3 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6990
V_2/V_1	= 1.9876
P_2/P_1	= 1.5860
T_2/T_1	= 1.2693
P_{T2}/P_{T1}	= 3.1940
T_{T2}/T_{T1}	= 1.5397
W/H_{T1}	= 0.5478
η_c	= 0.7183

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6502
V_2/V_1	= 1.8877
P_2/P_1	= 1.7648
T_2/T_1	= 1.3219
P_{T2}/P_{T1}	= 3.0096
T_{T2}/T_{T1}	= 1.5397
W/H_{T1}	= 0.5478
η_c	= 0.6754

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GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	3.0000	0.0000	0.0000	0.7500	-8.9350	0.0000	0.0000
Lower:	-3.0000	12.0000	0.0000	0.5000	-3.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	55.3507

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R		
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.000		A_2/A_1 = 0.8677	
M_R = 1.27		V_{C_R} = 1366.6 ft/sec		W_C/A = 42.81	

UNMIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1	0.631		M_1'	1.420		M_2'	1.064		M_2	0.698	
V_1	674.1	ft/sec	V_1'	1516.7	ft/sec	V_2'	1206.9	ft/sec	V_2	793.9	ft/sec
α_1	0.00	deg.	α_1'	63.61	deg.	α_2'	54.44	deg.	α_2	-29.61	deg.
P_1	8.555	psia	P_1'	8.555	psia	P_2'	11.495	psia	P_2	11.495	psia
T_1	474.8	deg.R	T_1'	474.8	deg.R	T_2'	535.9	deg.R	T_2	538.3	deg.R
P_{T1}	11.19	psia	P_{T1}'	28.00	psia	P_{T2}'	24.93	psia	P_{T2}	16.51	psia
T_{T1}	512.7	deg.R	T_{T1}'	666.3	deg.R	T_{T2}'	661.2	deg.R	T_{T2}	595.9	deg.R

MIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1	0.631		M_1'	1.420		M_2'	1.000		M_2	0.615	
V_1	674.1	ft/sec	V_1'	1516.7	ft/sec	V_2'	1150.9	ft/sec	V_2	709.1	ft/sec
α_1	0.00	deg.	α_1'	63.61	deg.	α_2'	59.03	deg.	α_2	-33.10	deg.
P_1	8.555	psia	P_1'	8.555	psia	P_2'	12.342	psia	P_2	12.229	psia
T_1	474.8	deg.R	T_1'	474.8	deg.R	T_2'	551.0	deg.R	T_2	554.1	deg.R
P_{T1}	11.19	psia	P_{T1}'	28.00	psia	P_{T2}'	23.37	psia	P_{T2}	15.78	psia
T_{T1}	512.7	deg.R	T_{T1}'	666.3	deg.R	T_{T2}'	661.2	deg.R	T_{T2}	595.9	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	0.8906
V_2/V_1	1.1777
P_2/P_1	1.3437
T_2/T_1	1.1337
P_{T2}/P_{T1}	1.4756
T_{T2}/T_{T1}	1.1624
W/H_{T1}	0.1708
η_c	0.6883

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	0.8346
V_2/V_1	1.0519
P_2/P_1	1.4295
T_2/T_1	1.1669
P_{T2}/P_{T1}	1.4105
T_{T2}/T_{T1}	1.1624
W/H_{T1}	0.1708
η_c	0.6044

VPR-10f-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	3.0000	0.0000	0.0000	0.7500	-8.9350	0.0000	0.0000
Lower:	-3.0000	12.0000	0.0000	0.5000	-3.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	55.3507

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R		
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.100		A_2/A_1 = 0.8677	
M_R = 1.29		V_{C_R} = 1366.6 ft/sec		W_C/A = 45.86	

UNMIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 =	0.725	M_1' =	1.477	M_2' =	1.058	M_2 =	0.680
V_1 =	765.5 ft/sec	V_1' =	1559.4 ft/sec	V_2' =	1207.8 ft/sec	V_2 =	776.9 ft/sec
α_1 =	0.00 deg.	α_1' =	60.60 deg.	α_2' =	55.17 deg.	α_2 =	-29.24 deg.
P_1 =	7.884 psia	P_1' =	7.884 psia	P_2' =	12.540 psia	P_2 =	12.540 psia
T_1 =	463.9 deg.R	T_1' =	463.9 deg.R	T_2' =	542.5 deg.R	T_2 =	543.9 deg.R
P_{T1} =	11.19 psia	P_{T1}' =	28.00 psia	P_{T2}' =	26.79 psia	P_{T2} =	17.86 psia
T_{T1} =	512.7 deg.R	T_{T1}' =	666.3 deg.R	T_{T2}' =	665.4 deg.R	T_{T2} =	597.4 deg.R

MIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 =	0.725	M_1' =	1.477	M_2' =	0.992	M_2 =	0.583
V_1 =	765.5 ft/sec	V_1' =	1559.4 ft/sec	V_2' =	1147.1 ft/sec	V_2 =	676.5 ft/sec
α_1 =	0.00 deg.	α_1' =	60.60 deg.	α_2' =	60.53 deg.	α_2 =	-33.37 deg.
P_1 =	7.884 psia	P_1' =	7.884 psia	P_2' =	13.545 psia	P_2 =	13.432 psia
T_1 =	463.9 deg.R	T_1' =	463.9 deg.R	T_2' =	555.9 deg.R	T_2 =	559.3 deg.R
P_{T1} =	11.19 psia	P_{T1}' =	28.00 psia	P_{T2}' =	25.42 psia	P_{T2} =	16.92 psia
T_{T1} =	512.7 deg.R	T_{T1}' =	666.3 deg.R	T_{T2}' =	665.4 deg.R	T_{T2} =	597.4 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9570
V_2/V_1	=	1.0149
P_2/P_1	=	1.5905
T_2/T_1	=	1.1725
P_{T2}/P_{T1}	=	1.5967
T_{T2}/T_{T1}	=	1.1654
W/H_{T1}	=	0.1641
η_c	=	0.8716

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9078
V_2/V_1	=	0.8837
P_2/P_1	=	1.7037
T_2/T_1	=	1.2058
P_{T2}/P_{T1}	=	1.5121
T_{T2}/T_{T1}	=	1.1654
W/H_{T1}	=	0.1641
η_c	=	0.7641

VPR-10f-t3

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	3.0000	0.0000	0.0000	0.7500	-8.9350	0.0000	0.0000
Lower:	-3.0000	12.0000	0.0000	0.5000	-3.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	55.3507

CONDITIONS: (Transonic)

		P_{T1}	=	11.19 psia	T_{T1}	=	512.7 deg.R	
V_R = 1358.6 ft/sec		P_2/P_{T1}	=	1.200			A_2/A_1	= 0.8677
M_R = 1.27		V_{C_R}	=	1366.6 ft/sec			W_C/A	= 40.91

UNMIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 = 0.584		M_1' = 1.393		M_2' = 0.891		M_2 = 0.676	
V_1 = 627.2	ft/sec	V_1' = 1496.4	ft/sec	V_2' = 1042.4	ft/sec	V_2 = 794.0	ft/sec
α_1 = 0.00	deg.	α_1' = 65.22	deg.	α_2' = 54.58	deg.	α_2 = -42.94	deg.
P_1 = 8.880	psia	P_1' = 8.880	psia	P_2' = 13.538	psia	P_2 = 13.538	psia
T_1 = 479.9	deg.R	T_1' = 479.9	deg.R	T_2' = 570.2	deg.R	T_2 = 574.6	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 23.99	psia	P_{T2} = 19.15	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 664.4	deg.R	T_{T2} = 632.7	deg.R

MIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 = 0.584		M_1' = 1.393		M_2' = 0.826		M_2 = 0.607	
V_1 = 627.2	ft/sec	V_1' = 1496.4	ft/sec	V_2' = 979.4	ft/sec	V_2 = 721.9	ft/sec
α_1 = 0.00	deg.	α_1' = 65.22	deg.	α_2' = 60.68	deg.	α_2 = -47.98	deg.
P_1 = 8.880	psia	P_1' = 8.880	psia	P_2' = 14.394	psia	P_2 = 14.202	psia
T_1 = 479.9	deg.R	T_1' = 479.9	deg.R	T_2' = 584.6	deg.R	T_2 = 589.3	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 22.53	psia	P_{T2} = 18.21	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 664.4	deg.R	T_{T2} = 632.7	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.8570
V_2/V_1	=	1.2659
P_2/P_1	=	1.5245
T_2/T_1	=	1.1973
P_{T2}/P_{T1}	=	1.7116
T_{T2}/T_{T1}	=	1.2342
W/H_{T1}	=	0.2366
η_c	=	0.7015

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.8047
V_2/V_1	=	1.1511
P_2/P_1	=	1.5994
T_2/T_1	=	1.2280
P_{T2}/P_{T1}	=	1.6278
T_{T2}/T_{T1}	=	1.2342
W/H_{T1}	=	0.2366
η_c	=	0.6313

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GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	6.0000	-9.6000	0.0000	0.6250	-7.4844	0.0000	53.2225
Lower:	0.0000	0.0000	0.0000	0.6250	0.0000	0.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	33.8700	52.3920

CONDITIONS: (Transonic)

		P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R				
V_R	=	1358.6 ft/sec	P_2/P_{T1}	=	1.000	A_2/A_1	=	0.8677
M_R	=	1.28	V_{C_R}	=	1366.6 ft/sec	W_C/A	=	44.95

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.693		M_1'	=	1.457		M_2'	=	1.091		M_2	=	0.759	
V_1	=	735.1	ft/sec	V_1'	=	1544.7	ft/sec	V_2'	=	1234.7	ft/sec	V_2	=	858.2	ft/sec
α_1	=	0.00	deg.	α_1'	=	61.58	deg.	α_2'	=	51.85	deg.	α_2	=	-26.24	deg.
P_1	=	8.113	psia	P_1'	=	8.113	psia	P_2'	=	11.349	psia	P_2	=	11.349	psia
T_1	=	467.7	deg.R	T_1'	=	467.7	deg.R	T_2'	=	532.8	deg.R	T_2	=	531.6	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	25.33	psia	P_{T2}	=	17.13	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	663.3	deg.R	T_{T2}	=	595.5	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.693		M_1'	=	1.457		M_2'	=	0.989		M_2	=	0.614	
V_1	=	735.1	ft/sec	V_1'	=	1544.7	ft/sec	V_2'	=	1142.3	ft/sec	V_2	=	708.6	ft/sec
α_1	=	0.00	deg.	α_1'	=	61.58	deg.	α_2'	=	58.19	deg.	α_2	=	-32.40	deg.
P_1	=	8.113	psia	P_1'	=	8.113	psia	P_2'	=	12.632	psia	P_2	=	12.722	psia
T_1	=	467.7	deg.R	T_1'	=	467.7	deg.R	T_2'	=	554.7	deg.R	T_2	=	553.7	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	23.62	psia	P_{T2}	=	16.41	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	663.3	deg.R	T_{T2}	=	595.5	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9048
V_2/V_1	=	1.1675
P_2/P_1	=	1.3989
T_2/T_1	=	1.1367
P_{T2}/P_{T1}	=	1.5317
T_{T2}/T_{T1}	=	1.1617
W/H_{T1}	=	0.1675
η_c	=	0.7735

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.8436
V_2/V_1	=	0.9640
P_2/P_1	=	1.5681
T_2/T_1	=	1.1840
P_{T2}/P_{T1}	=	1.4670
T_{T2}/T_{T1}	=	1.1617
W/H_{T1}	=	0.1675
η_c	=	0.6909

VPR-11f-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	6.0000	-9.6000	0.0000	0.6250	-7.4844	0.0000	53.2225
Lower:	0.0000	0.0000	0.0000	0.6250	0.0000	0.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	33.8700	52.3920

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R		
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.100		A_2/A_1 = 0.8677	
M_R = 1.29		V_{C_R} = 1366.6 ft/sec		W_C/A = 46.83	

UNMIXED STATION AVERAGES

Inlet		Inlet		Exit		Exit	
Absolute		Relative		Relative		Absolute	
M_1 = 0.764		M_1' = 1.502		M_2' = 1.148		M_2 = 0.808	
V_1 = 802.2	ft/sec	V_1' = 1577.8	ft/sec	V_2' = 1292.9	ft/sec	V_2 = 908.4	ft/sec
α_1 = 0.00	deg.	α_1' = 59.44	deg.	α_2' = 50.21	deg.	α_2 = -23.12	deg.
P_1 = 7.603	psia	P_1' = 7.603	psia	P_2' = 11.392	psia	P_2 = 11.392	psia
T_1 = 459.1	deg.R	T_1' = 459.1	deg.R	T_2' = 527.5	deg.R	T_2 = 526.4	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 26.38	psia	P_{T2} = 17.65	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 666.7	deg.R	T_{T2} = 593.8	deg.R

MIXED STATION AVERAGES

Inlet		Inlet		Exit		Exit	
Absolute		Relative		Relative		Absolute	
M_1 = 0.764		M_1' = 1.502		M_2' = 0.992		M_2 = 0.584	
V_1 = 802.2	ft/sec	V_1' = 1577.8	ft/sec	V_2' = 1147.7	ft/sec	V_2 = 675.4	ft/sec
α_1 = 0.00	deg.	α_1' = 59.44	deg.	α_2' = 59.86	deg.	α_2 = -31.98	deg.
P_1 = 7.603	psia	P_1' = 7.603	psia	P_2' = 13.423	psia	P_2 = 13.524	psia
T_1 = 459.1	deg.R	T_1' = 459.1	deg.R	T_2' = 557.0	deg.R	T_2 = 555.8	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 25.17	psia	P_{T2} = 17.04	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 666.7	deg.R	T_{T2} = 593.8	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.9423
V_2/V_1	= 1.1325
P_2/P_1	= 1.4983
T_2/T_1	= 1.1466
P_{T2}/P_{T1}	= 1.5776
T_{T2}/T_{T1}	= 1.1583
W/H_{T1}	= 0.1578
η_c	= 0.8816

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.8992
V_2/V_1	= 0.8420
P_2/P_1	= 1.7787
T_2/T_1	= 1.2107
P_{T2}/P_{T1}	= 1.5235
T_{T2}/T_{T1}	= 1.1583
W/H_{T1}	= 0.1578
η_c	= 0.8100

VPR-11f-t3

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	6.0000	-9.6000	0.0000	0.6250	-7.4844	0.0000	53.2225
Lower:	0.0000	0.0000	0.0000	0.6250	0.0000	0.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	33.8700	52.3920

CONDITIONS: (Transonic)

		P_{T1} = 11.19 psia			T_{T1} = 512.7 deg.R			
V_R	=	1358.6 ft/sec	P_2/P_{T1}	=	1.200	A_2/A_1	=	0.8677
M_R	=	1.28	V_{C_R}	=	1366.6 ft/sec	W_C/A	=	44.88

UNMIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 =	0.691	M_1' =	1.456	M_2' =	0.998	M_2 =	0.761
V_1 =	733.0 ft/sec	V_1' =	1543.8 ft/sec	V_2' =	1150.3 ft/sec	V_2 =	876.8 ft/sec
α_1 =	0.00 deg.	α_1' =	61.65 deg.	α_2' =	50.31 deg.	α_2 =	-32.11 deg.
P_1 =	8.128 psia	P_1' =	8.128 psia	P_2' =	12.999 psia	P_2 =	12.999 psia
T_1 =	467.9 deg.R	T_1' =	467.9 deg.R	T_2' =	552.9 deg.R	T_2 =	552.1 deg.R
P_{T1} =	11.19 psia	P_{T1}' =	28.00 psia	P_{T2}' =	25.35 psia	P_{T2} =	19.37 psia
T_{T1} =	512.7 deg.R	T_{T1}' =	666.3 deg.R	T_{T2}' =	664.7 deg.R	T_{T2} =	616.6 deg.R

MIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 =	0.691	M_1' =	1.456	M_2' =	0.872	M_2 =	0.594
V_1 =	733.0 ft/sec	V_1' =	1543.7 ft/sec	V_2' =	1027.3 ft/sec	V_2 =	699.0 ft/sec
α_1 =	0.00 deg.	α_1' =	61.65 deg.	α_2' =	59.41 deg.	α_2 =	-41.91 deg.
P_1 =	8.128 psia	P_1' =	8.128 psia	P_2' =	14.636 psia	P_2 =	14.723 psia
T_1 =	467.9 deg.R	T_1' =	467.9 deg.R	T_2' =	576.9 deg.R	T_2 =	575.9 deg.R
P_{T1} =	11.19 psia	P_{T1}' =	28.00 psia	P_{T2}' =	24.03 psia	P_{T2} =	18.69 psia
T_{T1} =	512.7 deg.R	T_{T1}' =	666.3 deg.R	T_{T2}' =	664.7 deg.R	T_{T2} =	616.6 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}' =	0.9054
V_2/V_1 =	1.1961
P_2/P_1 =	1.5994
T_2/T_1 =	1.1799
P_{T2}/P_{T1} =	1.7315
T_{T2}/T_{T1} =	1.2027
W/H_{T1} =	0.2060
η_c =	0.8246

MIXED PERFORMANCE

P_{T2}'/P_{T1}' =	0.8584
V_2/V_1 =	0.9535
P_2/P_1 =	1.8115
T_2/T_1 =	1.2308
P_{T2}/P_{T1} =	1.6711
T_{T2}/T_{T1} =	1.2027
W/H_{T1} =	0.2060
η_c =	0.7673

VPR-12f-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-5.9960	0.0000	42.6379
Lower:	-6.0000	12.0000	0.0000	0.5000	0.0000	0.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R
V_R = 1358.6 ft/sec	P_2/P_{T1} = 1.000	A_2/A_1 = 0.8677
M_R = 1.28	V_{C_R} = 1366.6 ft/sec	W_C/A = 44.58

UNMIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 = 0.682		M_1' = 1.450		M_2' = 1.105		M_2 = 0.653	
V_1 = 723.6	ft/sec	V_1' = 1539.3	ft/sec	V_2' = 1247.8	ft/sec	V_2 = 739.9	ft/sec
α_1 = 0.00	deg.	α_1' = 61.96	deg.	α_2' = 57.25	deg.	α_2 = -26.16	deg.
P_1 = 8.197	psia	P_1' = 8.197	psia	P_2' = 11.625	psia	P_2 = 11.625	psia
T_1 = 469.1	deg.R	T_1' = 469.1	deg.R	T_2' = 530.8	deg.R	T_2 = 533.7	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 25.80	psia	P_{T2} = 15.79	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 663.6	deg.R	T_{T2} = 583.4	deg.R

MIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 = 0.682		M_1' = 1.450		M_2' = 1.066		M_2 = 0.609	
V_1 = 723.6	ft/sec	V_1' = 1539.3	ft/sec	V_2' = 1215.2	ft/sec	V_2 = 695.8	ft/sec
α_1 = 0.00	deg.	α_1' = 61.96	deg.	α_2' = 59.85	deg.	α_2 = -27.84	deg.
P_1 = 8.197	psia	P_1' = 8.197	psia	P_2' = 12.140	psia	P_2 = 12.011	psia
T_1 = 469.1	deg.R	T_1' = 469.1	deg.R	T_2' = 540.7	deg.R	T_2 = 543.1	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 24.86	psia	P_{T2} = 15.43	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 663.6	deg.R	T_{T2} = 583.4	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9214
V_2/V_1	=	1.0226
P_2/P_1	=	1.4181
T_2/T_1	=	1.1377
P_{T2}/P_{T1}	=	1.4113
T_{T2}/T_{T1}	=	1.1380
W/H_{T1}	=	0.1434
η_c	=	0.7216

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.8880
V_2/V_1	=	0.9616
P_2/P_1	=	1.4652
T_2/T_1	=	1.1578
P_{T2}/P_{T1}	=	1.3793
T_{T2}/T_{T1}	=	1.1380
W/H_{T1}	=	0.1434
η_c	=	0.6713

VPR-12f-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-5.9960	0.0000	42.6379
Lower:	-6.0000	12.0000	0.0000	0.5000	0.0000	0.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R		
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.100			A_2/A_1 = 0.8677
M_R = 1.29		V_{C_R} = 1366.6 ft/sec			W_C/A = 45.98

UNMIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1	= 0.730		M_1'	= 1.480		M_2'	= 1.074		M_2	= 0.632	
V_1	= 769.8	ft/sec	V_1'	= 1561.5	ft/sec	V_2'	= 1222.1	ft/sec	V_2	= 721.3	ft/sec
α_1	= 0.00	deg.	α_1'	= 60.46	deg.	α_2'	= 58.00	deg.	α_2	= -28.44	deg.
P_1	= 7.851	psia	P_1'	= 7.851	psia	P_2'	= 12.633	psia	P_2	= 12.633	psia
T_1	= 463.3	deg.R	T_1'	= 463.3	deg.R	T_2'	= 539.0	deg.R	T_2	= 542.0	deg.R
P_{T1}	= 11.19	psia	P_{T1}'	= 28.00	psia	P_{T2}'	= 26.86	psia	P_{T2}	= 16.98	psia
T_{T1}	= 512.7	deg.R	T_{T1}'	= 666.3	deg.R	T_{T2}'	= 665.1	deg.R	T_{T2}	= 589.0	deg.R

MIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1	= 0.730		M_1'	= 1.480		M_2'	= 1.028		M_2	= 0.575	
V_1	= 769.8	ft/sec	V_1'	= 1561.5	ft/sec	V_2'	= 1180.7	ft/sec	V_2	= 662.3	ft/sec
α_1	= 0.00	deg.	α_1'	= 60.46	deg.	α_2'	= 61.57	deg.	α_2	= -31.06	deg.
P_1	= 7.851	psia	P_1'	= 7.851	psia	P_2'	= 13.312	psia	P_2	= 13.160	psia
T_1	= 463.3	deg.R	T_1'	= 463.3	deg.R	T_2'	= 549.1	deg.R	T_2	= 552.5	deg.R
P_{T1}	= 11.19	psia	P_{T1}'	= 28.00	psia	P_{T2}'	= 26.04	psia	P_{T2}	= 16.46	psia
T_{T1}	= 512.7	deg.R	T_{T1}'	= 666.3	deg.R	T_{T2}'	= 665.1	deg.R	T_{T2}	= 589.0	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9596
V_2/V_1	=	0.9370
P_2/P_1	=	1.6090
T_2/T_1	=	1.1698
P_{T2}/P_{T1}	=	1.5179
T_{T2}/T_{T1}	=	1.1489
W/H_{T1}	=	0.1507
η_c	=	0.8402

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9300
V_2/V_1	=	0.8603
P_2/P_1	=	1.6761
T_2/T_1	=	1.1924
P_{T2}/P_{T1}	=	1.4717
T_{T2}/T_{T1}	=	1.1489
W/H_{T1}	=	0.1507
η_c	=	0.7744

VPR-12f-t3

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-5.9960	0.0000	42.6379
Lower:	-6.0000	12.0000	0.0000	0.5000	0.0000	0.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R
V_R = 1358.6 ft/sec	P_2/P_{T1} = 1.200	A_2/A_1 = 0.8677
M_R = 1.27	V_{C_R} = 1366.6 ft/sec	W_C/A = 41.89

UNMIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.607	M_1' = 1.406	M_2' = 0.939	M_2 = 0.645
V_1 = 650.7 ft/sec	V_1' = 1506.4 ft/sec	V_2' = 1087.2 ft/sec	V_2 = 751.1 ft/sec
α_1 = 0.00 deg.	α_1' = 64.41 deg.	α_2' = 56.86 deg.	α_2 = -40.59 deg.
P_1 = 8.719 psia	P_1' = 8.719 psia	P_2' = 13.376 psia	P_2 = 13.376 psia
T_1 = 477.4 deg.R	T_1' = 477.4 deg.R	T_2' = 558.3 deg.R	T_2 = 564.0 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 24.66 psia	P_{T2} = 18.28 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 661.0 deg.R	T_{T2} = 617.4 deg.R

MIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.607	M_1' = 1.406	M_2' = 0.889	M_2 = 0.597
V_1 = 650.6 ft/sec	V_1' = 1506.4 ft/sec	V_2' = 1040.7 ft/sec	V_2 = 702.6 ft/sec
α_1 = 0.00 deg.	α_1' = 64.41 deg.	α_2' = 61.25 deg.	α_2 = -43.83 deg.
P_1 = 8.719 psia	P_1' = 8.719 psia	P_2' = 14.049 psia	P_2 = 13.825 psia
T_1 = 477.4 deg.R	T_1' = 477.4 deg.R	T_2' = 570.8 deg.R	T_2 = 576.3 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 23.47 psia	P_{T2} = 17.59 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 661.0 deg.R	T_{T2} = 617.4 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	0.8810
V_2/V_1	1.1542
P_2/P_1	1.5342
T_2/T_1	1.1814
P_{T2}/P_{T1}	1.6342
T_{T2}/T_{T1}	1.2043
W/H_{T1}	0.2146
η_c	0.7019

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	0.8383
V_2/V_1	1.0799
P_2/P_1	1.5856
T_2/T_1	1.2071
P_{T2}/P_{T1}	1.5727
T_{T2}/T_{T1}	1.2043
W/H_{T1}	0.2146
η_c	0.6434

VPR-12f-t4

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-5.9960	0.0000	42.6379
Lower:	-6.0000	12.0000	0.0000	0.5000	0.0000	0.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia			T_{T1} = 512.7 deg.R	
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.300			A_2/A_1 = 0.8677
M_R = 1.26		V_{C_R} = 1366.6 ft/sec			W_C/A = 38.80

UNMIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 =	0.538	M_1' =	1.369	M_2' =	0.851	M_2 =	0.656
V_1 =	580.8 ft/sec	V_1' =	1477.5 ft/sec	V_2' =	999.5 ft/sec	V_2 =	775.4 ft/sec
α_1 =	0.00 deg.	α_1' =	66.86 deg.	α_2' =	56.74 deg.	α_2 =	-48.70 deg.
P_1 =	9.186 psia	P_1' =	9.186 psia	P_2' =	14.158 psia	P_2 =	14.158 psia
T_1 =	484.6 deg.R	T_1' =	484.6 deg.R	T_2' =	573.4 deg.R	T_2 =	581.0 deg.R
P_{T1} =	11.19 psia	P_{T1}' =	28.00 psia	P_{T2}' =	23.86 psia	P_{T2} =	19.69 psia
T_{T1} =	512.7 deg.R	T_{T1}' =	666.3 deg.R	T_{T2}' =	661.0 deg.R	T_{T2} =	638.6 deg.R

MIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 =	0.538	M_1' =	1.369	M_2' =	0.792	M_2 =	0.605
V_1 =	580.7 ft/sec	V_1' =	1477.5 ft/sec	V_2' =	941.4 ft/sec	V_2 =	723.4 ft/sec
α_1 =	0.00 deg.	α_1' =	66.86 deg.	α_2' =	63.02 deg.	α_2 =	-53.20 deg.
P_1 =	9.186 psia	P_1' =	9.186 psia	P_2' =	14.923 psia	P_2 =	14.644 psia
T_1 =	484.6 deg.R	T_1' =	484.6 deg.R	T_2' =	587.2 deg.R	T_2 =	595.0 deg.R
P_{T1} =	11.19 psia	P_{T1}' =	28.00 psia	P_{T2}' =	22.58 psia	P_{T2} =	18.75 psia
T_{T1} =	512.7 deg.R	T_{T1}' =	666.3 deg.R	T_{T2}' =	661.0 deg.R	T_{T2} =	638.6 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}' =	0.8524
V_2/V_1 =	1.3351
P_2/P_1 =	1.5413
T_2/T_1 =	1.1990
P_{T2}/P_{T1} =	1.7598
T_{T2}/T_{T1} =	1.2457
W/H_{T1} =	0.2555
η_c =	0.6858

MIXED PERFORMANCE

P_{T2}'/P_{T1}' =	0.8065
V_2/V_1 =	1.2457
P_2/P_1 =	1.5942
T_2/T_1 =	1.2279
P_{T2}/P_{T1} =	1.6762
T_{T2}/T_{T1} =	1.2457
W/H_{T1} =	0.2555
η_c =	0.6224

VPR-12f-t5

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-5.9960	0.0000	42.6379
Lower:	-6.0000	12.0000	0.0000	0.5000	0.0000	0.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R
V_R = 1358.6 ft/sec	P_2/P_{T1} = 1.150	A_2/A_1 = 0.8677
M_R = 1.28	V_{C_R} = 1366.6 ft/sec	W_C/A = 44.81

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.689		M_1'	=	1.454		M_2'	=	1.006		M_2	=	0.639	
V_1	=	730.7	ft/sec	V_1'	=	1542.6	ft/sec	V_2'	=	1156.7	ft/sec	V_2	=	737.1	ft/sec
α_1	=	0.00	deg.	α_1'	=	61.73	deg.	α_2'	=	57.18	deg.	α_2	=	-34.06	deg.
P_1	=	8.145	psia	P_1'	=	8.145	psia	P_2'	=	13.188	psia	P_2	=	13.188	psia
T_1	=	468.2	deg.R	T_1'	=	468.2	deg.R	T_2'	=	549.7	deg.R	T_2	=	553.5	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	25.90	psia	P_{T2}	=	17.78	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	663.9	deg.R	T_{T2}	=	603.3	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.689		M_1'	=	1.454		M_2'	=	0.959		M_2	=	0.586	
V_1	=	730.7	ft/sec	V_1'	=	1542.6	ft/sec	V_2'	=	1113.3	ft/sec	V_2	=	682.6	ft/sec
α_1	=	0.00	deg.	α_1'	=	61.73	deg.	α_2'	=	61.01	deg.	α_2	=	-37.03	deg.
P_1	=	8.145	psia	P_1'	=	8.145	psia	P_2'	=	13.866	psia	P_2	=	13.693	psia
T_1	=	468.2	deg.R	T_1'	=	468.2	deg.R	T_2'	=	560.8	deg.R	T_2	=	564.6	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	25.04	psia	P_{T2}	=	17.28	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	663.9	deg.R	T_{T2}	=	603.3	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9250
V_2/V_1	=	1.0088
P_2/P_1	=	1.6191
T_2/T_1	=	1.1821
P_{T2}/P_{T1}	=	1.5896
T_{T2}/T_{T1}	=	1.1769
W/H_{T1}	=	0.1813
η_c	=	0.7808

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.8944
V_2/V_1	=	0.9342
P_2/P_1	=	1.6811
T_2/T_1	=	1.2058
P_{T2}/P_{T1}	=	1.5444
T_{T2}/T_{T1}	=	1.1769
W/H_{T1}	=	0.1813
η_c	=	0.7292

VPR-13f-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R				
V_R = 1358.6 ft/sec	P_2/P_{T1} = 1.000				A_2/A_1 = 0.8677		
M_R = 1.28	V_{C_R} = 1366.6 ft/sec				W_C/A = 44.85		

UNMIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 = 0.690		M_1' = 1.455		M_2' = 1.088		M_2 = 0.691	
V_1 = 732.1	ft/sec	V_1' = 1543.3	ft/sec	V_2' = 1232.3	ft/sec	V_2 = 782.7	ft/sec
α_1 = 0.00	deg.	α_1' = 61.68	deg.	α_2' = 55.17	deg.	α_2 = -26.73	deg.
P_1 = 8.134	psia	P_1' = 8.134	psia	P_2' = 11.675	psia	P_2 = 11.675	psia
T_1 = 468.0	deg.R	T_1' = 468.0	deg.R	T_2' = 533.5	deg.R	T_2 = 533.9	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 25.93	psia	P_{T2} = 16.61	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 663.1	deg.R	T_{T2} = 588.8	deg.R

MIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 = 0.690		M_1' = 1.455		M_2' = 1.032		M_2 = 0.604	
V_1 = 732.1	ft/sec	V_1' = 1543.3	ft/sec	V_2' = 1183.2	ft/sec	V_2 = 693.8	ft/sec
α_1 = 0.00	deg.	α_1' = 61.68	deg.	α_2' = 59.32	deg.	α_2 = -29.90	deg.
P_1 = 8.134	psia	P_1' = 8.134	psia	P_2' = 12.479	psia	P_2 = 12.450	psia
T_1 = 468.0	deg.R	T_1' = 468.0	deg.R	T_2' = 546.6	deg.R	T_2 = 548.8	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 24.54	psia	P_{T2} = 15.93	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 663.1	deg.R	T_{T2} = 588.8	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.9262
V_2/V_1	= 1.0691
P_2/P_1	= 1.4353
T_2/T_1	= 1.1408
P_{T2}/P_{T1}	= 1.4850
T_{T2}/T_{T1}	= 1.1486
W/H_{T1}	= 0.1526
η_c	= 0.7839

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.8766
V_2/V_1	= 0.9477
P_2/P_1	= 1.5306
T_2/T_1	= 1.1724
P_{T2}/P_{T1}	= 1.4243
T_{T2}/T_{T1}	= 1.1486
W/H_{T1}	= 0.1526
η_c	= 0.6968

VPR-13f-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

CONDITIONS: (Transonic)

			P_{T1}	=	11.19 psia	T_{T1}	=	512.7 deg.R		
V_R	=	1358.6 ft/sec	P_2/P_{T1}	=	1.100				A_2/A_1	= 0.8677
M_R	=	1.28	V_{C_R}	=	1366.6 ft/sec				W_C/A	= 45.51

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.712		M_1'	=	1.469		M_2'	=	1.052		M_2	=	0.679	
V_1	=	753.4	ft/sec	V_1'	=	1553.5	ft/sec	V_2'	=	1200.8	ft/sec	V_2	=	775.4	ft/sec
α_1	=	0.00	deg.	α_1'	=	60.99	deg.	α_2'	=	55.31	deg.	α_2	=	-29.21	deg.
P_1	=	7.975	psia	P_1'	=	7.975	psia	P_2'	=	12.617	psia	P_2	=	12.617	psia
T_1	=	465.4	deg.R	T_1'	=	465.4	deg.R	T_2'	=	542.6	deg.R	T_2	=	543.2	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	26.55	psia	P_{T2}	=	17.78	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	664.3	deg.R	T_{T2}	=	596.1	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.712		M_1'	=	1.469		M_2'	=	0.986		M_2	=	0.581	
V_1	=	753.4	ft/sec	V_1'	=	1553.5	ft/sec	V_2'	=	1140.3	ft/sec	V_2	=	672.6	ft/sec
α_1	=	0.00	deg.	α_1'	=	60.99	deg.	α_2'	=	60.56	deg.	α_2	=	-33.64	deg.
P_1	=	7.975	psia	P_1'	=	7.975	psia	P_2'	=	13.599	psia	P_2	=	13.541	psia
T_1	=	465.4	deg.R	T_1'	=	465.4	deg.R	T_2'	=	556.1	deg.R	T_2	=	558.4	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	25.34	psia	P_{T2}	=	17.01	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	664.3	deg.R	T_{T2}	=	596.1	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9483
V_2/V_1	=	1.0292
P_2/P_1	=	1.5820
T_2/T_1	=	1.1671
P_{T2}/P_{T1}	=	1.5895
T_{T2}/T_{T1}	=	1.1627
W/H_{T1}	=	0.1644
η_c	=	0.8612

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9051
V_2/V_1	=	0.8927
P_2/P_1	=	1.6978
T_2/T_1	=	1.1999
P_{T2}/P_{T1}	=	1.5210
T_{T2}/T_{T1}	=	1.1627
W/H_{T1}	=	0.1644
η_c	=	0.7743

VPR-13f-t3

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

CONDITIONS: (Transonic)

			P_{T1}	=	11.19 psia			T_{T1}	=	512.7 deg.R	
V_R	=	1358.6 ft/sec	P_2/P_{T1}	=	1.200			A_2/A_1	=	0.8677	
M_R	=	1.27	V_{C_R}	=	1366.6 ft/sec			W_C/A	=	42.03	

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.611		M'_1	=	1.408		M'_2	=	0.903		M_2	=	0.672	
V_1	=	654.3	ft/sec	V'_1	=	1508.0	ft/sec	V'_2	=	1054.4	ft/sec	V_2	=	787.1	ft/sec
α_1	=	0.00	deg.	α'_1	=	64.28	deg.	α'_2	=	54.82	deg.	α_2	=	-41.23	deg.
P_1	=	8.694	psia	P'_1	=	8.694	psia	P'_2	=	13.724	psia	P_2	=	13.724	psia
T_1	=	477.0	deg.R	T'_1	=	477.0	deg.R	T'_2	=	567.4	deg.R	T_2	=	570.3	deg.R
P_{T1}	=	11.19	psia	P'_{T1}	=	28.00	psia	P'_{T2}	=	24.48	psia	P_{T2}	=	19.24	psia
T_{T1}	=	512.7	deg.R	T'_{T1}	=	666.3	deg.R	T'_{T2}	=	663.3	deg.R	T_{T2}	=	626.5	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.611		M'_1	=	1.408		M'_2	=	0.843		M_2	=	0.602	
V_1	=	654.3	ft/sec	V'_1	=	1507.9	ft/sec	V'_2	=	995.6	ft/sec	V_2	=	713.3	ft/sec
α_1	=	0.00	deg.	α'_1	=	64.29	deg.	α'_2	=	60.41	deg.	α_2	=	-46.19	deg.
P_1	=	8.694	psia	P'_1	=	8.694	psia	P'_2	=	14.556	psia	P_2	=	14.421	psia
T_1	=	477.0	deg.R	T'_1	=	477.0	deg.R	T'_2	=	580.8	deg.R	T_2	=	584.2	deg.R
P_{T1}	=	11.19	psia	P'_{T1}	=	28.00	psia	P'_{T2}	=	23.17	psia	P_{T2}	=	18.42	psia
T_{T1}	=	512.7	deg.R	T'_{T1}	=	666.3	deg.R	T'_{T2}	=	663.3	deg.R	T_{T2}	=	626.5	deg.R

UNMIXED PERFORMANCE

P'_{T2}/P'_{T1}	=	0.8743
V_2/V_1	=	1.2029
P_2/P_1	=	1.5787
T_2/T_1	=	1.1956
P_{T2}/P_{T1}	=	1.7198
T_{T2}/T_{T1}	=	1.2221
W/H_{T1}	=	0.2271
η_c	=	0.7379

MIXED PERFORMANCE

P'_{T2}/P'_{T1}	=	0.8276
V_2/V_1	=	1.0901
P_2/P_1	=	1.6588
T_2/T_1	=	1.2246
P_{T2}/P_{T1}	=	1.6469
T_{T2}/T_{T1}	=	1.2221
W/H_{T1}	=	0.2271
η_c	=	0.6747

VPR-13.3-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	20.4350	-44.8700	0.0000	0.4000	-17.8487	33.8928	0.0000
Lower:	12.4350	-24.8700	0.0000	0.5000	-12.4350	24.8700	0.0000

c_2	β_C
6.0000	18.4350

CONDITIONS: (Transonic)

P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R	
V_R = 1358.6 ft/sec	P_2/P_{T1} = 1.000		A_2/A_1 = 0.8258
M_R = 1.28	V_{C_R} = 1366.6 ft/sec		W_C/A = 45.23

UNMIXED STATION AVERAGES

Inlet		Inlet		Exit		Exit	
Absolute		Relative		Relative		Absolute	
M_1 = 0.703		M_1' = 1.463		M_2' = 0.817		M_2 = 1.334	
V_1 = 744.2	ft/sec	V_1' = 1549.1	ft/sec	V_2' = 962.9	ft/sec	V_2 = 1571.9	ft/sec
α_1 = 0.00	deg.	α_1' = 61.29	deg.	α_2' = 6.63	deg.	α_2 = -52.52	deg.
P_1 = 8.045	psia	P_1' = 8.045	psia	P_2' = 11.232	psia	P_2 = 11.232	psia
T_1 = 466.6	deg.R	T_1' = 466.6	deg.R	T_2' = 577.7	deg.R	T_2 = 577.7	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 18.17	psia	P_{T2} = 33.71	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 658.7	deg.R	T_{T2} = 787.2	deg.R

MIXED STATION AVERAGES

Inlet		Inlet		Exit		Exit	
Absolute		Relative		Relative		Absolute	
M_1 = 0.703		M_1' = 1.463		M_2' = 0.588		M_2 = 1.178	
V_1 = 744.2	ft/sec	V_1' = 1549.1	ft/sec	V_2' = 715.0	ft/sec	V_2 = 1433.5	ft/sec
α_1 = 0.00	deg.	α_1' = 61.29	deg.	α_2' = 8.95	deg.	α_2 = -60.48	deg.
P_1 = 8.045	psia	P_1' = 8.045	psia	P_2' = 13.484	psia	P_2 = 13.484	psia
T_1 = 466.6	deg.R	T_1' = 466.6	deg.R	T_2' = 616.2	deg.R	T_2 = 616.2	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 17.03	psia	P_{T2} = 31.78	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 658.7	deg.R	T_{T2} = 787.2	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6490
V_2/V_1	= 2.1122
P_2/P_1	= 1.3962
T_2/T_1	= 1.2382
P_{T2}/P_{T1}	= 3.0132
T_{T2}/T_{T1}	= 1.5355
W/H_{T1}	= 0.5502
η_c	= 0.6732

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6084
V_2/V_1	= 1.9262
P_2/P_1	= 1.6762
T_2/T_1	= 1.3207
P_{T2}/P_{T1}	= 2.8407
T_{T2}/T_{T1}	= 1.5355
W/H_{T1}	= 0.5502
η_c	= 0.6317

VPR-13.3-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	20.4350	-44.8700	0.0000	0.4000	-17.8487	33.8928	0.0000
Lower:	12.4350	-24.8700	0.0000	0.5000	-12.4350	24.8700	0.0000

c_2	β_C
6.0000	18.4350

CONDITIONS: (Transonic)

		P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R	
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.100			A_2/A_1 = 0.8258
M_R = 1.28		V_{C_R} = 1366.6 ft/sec			W_C/A = 44.61

UNMIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1	= 0.683		M_1'	= 1.451		M_2'	= 0.752		M_2	= 1.274	
V_1	= 724.7	ft/sec	V_1'	= 1539.8	ft/sec	V_2'	= 894.9	ft/sec	V_2	= 1516.5	ft/sec
α_1	= 0.00	deg.	α_1'	= 61.92	deg.	α_2'	= 8.20	deg.	α_2	= -54.26	deg.
P_1	= 8.189	psia	P_1'	= 8.189	psia	P_2'	= 12.302	psia	P_2	= 12.302	psia
T_1	= 468.9	deg.R	T_1'	= 468.9	deg.R	T_2'	= 589.8	deg.R	T_2	= 589.8	deg.R
P_{T1}	= 11.19	psia	P_{T1}'	= 28.00	psia	P_{T2}'	= 18.63	psia	P_{T2}	= 33.94	psia
T_{T1}	= 512.7	deg.R	T_{T1}'	= 666.3	deg.R	T_{T2}'	= 660.5	deg.R	T_{T2}	= 785.3	deg.R

MIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1	= 0.683		M_1'	= 1.451		M_2'	= 0.563		M_2	= 1.150	
V_1	= 724.7	ft/sec	V_1'	= 1539.8	ft/sec	V_2'	= 688.4	ft/sec	V_2	= 1404.6	ft/sec
α_1	= 0.00	deg.	α_1'	= 61.92	deg.	α_2'	= 10.69	deg.	α_2	= -61.21	deg.
P_1	= 8.189	psia	P_1'	= 8.189	psia	P_2'	= 14.186	psia	P_2	= 14.186	psia
T_1	= 468.9	deg.R	T_1'	= 468.9	deg.R	T_2'	= 621.1	deg.R	T_2	= 621.1	deg.R
P_{T1}	= 11.19	psia	P_{T1}'	= 28.00	psia	P_{T2}'	= 17.60	psia	P_{T2}	= 32.24	psia
T_{T1}	= 512.7	deg.R	T_{T1}'	= 666.3	deg.R	T_{T2}'	= 660.5	deg.R	T_{T2}	= 785.3	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6656
V_2/V_1	= 2.0925
P_2/P_1	= 1.5022
T_2/T_1	= 1.2578
P_{T2}/P_{T1}	= 3.0337
T_{T2}/T_{T1}	= 1.5318
W/H_{T1}	= 0.5430
η_c	= 0.6871

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6286
V_2/V_1	= 1.9381
P_2/P_1	= 1.7323
T_2/T_1	= 1.3245
P_{T2}/P_{T1}	= 2.8819
T_{T2}/T_{T1}	= 1.5318
W/H_{T1}	= 0.5430
η_c	= 0.6503

VPR-13.3-t3

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	20.4350	-44.8700	0.0000	0.4000	-17.8487	33.8928	0.0000
Lower:	12.4350	-24.8700	0.0000	0.5000	-12.4350	24.8700	0.0000

c_2	β_C
6.0000	18.4350

CONDITIONS: (Transonic)

		P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R				
V_R	=	1358.6 ft/sec	P_2/P_{T1}	=	1.200	A_2/A_1	=	0.8258
M_R	=	1.28	V_{C_R}	=	1366.6 ft/sec	W_C/A	=	45.33

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.706		M_1'	=	1.465		M_2'	=	0.761		M_2	=	1.266	
V_1	=	747.4	ft/sec	V_1'	=	1550.6	ft/sec	V_2'	=	910.3	ft/sec	V_2	=	1515.2	ft/sec
α_1	=	0.00	deg.	α_1'	=	61.18	deg.	α_2'	=	8.80	deg.	α_2	=	-53.58	deg.
P_1	=	8.021	psia	P_1'	=	8.021	psia	P_2'	=	13.487	psia	P_2	=	13.487	psia
T_1	=	466.2	deg.R	T_1'	=	466.2	deg.R	T_2'	=	596.0	deg.R	T_2	=	596.0	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	20.66	psia	P_{T2}	=	37.07	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	667.4	deg.R	T_{T2}	=	789.5	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.706		M_1'	=	1.465		M_2'	=	0.473		M_2	=	1.086	
V_1	=	747.4	ft/sec	V_1'	=	1550.6	ft/sec	V_2'	=	586.6	ft/sec	V_2	=	1345.8	ft/sec
α_1	=	0.00	deg.	α_1'	=	61.18	deg.	α_2'	=	13.74	deg.	α_2	=	-64.95	deg.
P_1	=	8.021	psia	P_1'	=	8.021	psia	P_2'	=	16.277	psia	P_2	=	16.277	psia
T_1	=	466.2	deg.R	T_1'	=	466.2	deg.R	T_2'	=	638.7	deg.R	T_2	=	638.7	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	18.98	psia	P_{T2}	=	34.17	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	667.4	deg.R	T_{T2}	=	789.5	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.7379
V_2/V_1	=	2.0273
P_2/P_1	=	1.6816
T_2/T_1	=	1.2785
P_{T2}/P_{T1}	=	3.3141
T_{T2}/T_{T1}	=	1.5400
W/H_{T1}	=	0.5378
η_c	=	0.7590

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6779
V_2/V_1	=	1.8007
P_2/P_1	=	2.0294
T_2/T_1	=	1.3702
P_{T2}/P_{T1}	=	3.0544
T_{T2}/T_{T1}	=	1.5400
W/H_{T1}	=	0.5378
η_c	=	0.6987

VPR-13.4-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	23.4350	-50.8700	0.0000	0.4000	-20.8764	39.9390	0.0000
Lower:	15.4350	-30.8700	0.0000	0.5000	-15.4350	30.8700	0.0000

c_2	β_C
6.0000	21.4350

CONDITIONS: (Transonic)

			P_{T1} =	11.19	psia	T_{T1} =	512.7	deg.R
V_R =	1358.6	ft/sec	P_2/P_{T1} =	1.100		A_2/A_1 =	0.8258	
M_R =	1.28		V_{C_R} =	1366.6	ft/sec	W_C/A =	44.89	

UNMIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1 =	0.692		M_1' =	1.456		M_2' =	0.755		M_2 =	1.264	
V_1 =	733.3	ft/sec	V_1' =	1543.9	ft/sec	V_2' =	897.7	ft/sec	V_2 =	1503.5	ft/sec
α_1 =	0.00	deg.	α_1' =	61.64	deg.	α_2' =	9.23	deg.	α_2 =	-53.89	deg.
P_1 =	8.125	psia	P_1' =	8.125	psia	P_2' =	12.309	psia	P_2 =	12.309	psia
T_1 =	467.9	deg.R	T_1' =	467.9	deg.R	T_2' =	588.9	deg.R	T_2 =	588.9	deg.R
P_{T1} =	11.19	psia	P_{T1}' =	28.00	psia	P_{T2}' =	18.85	psia	P_{T2} =	33.68	psia
T_{T1} =	512.7	deg.R	T_{T1}' =	666.3	deg.R	T_{T2}' =	660.5	deg.R	T_{T2} =	781.6	deg.R

MIXED STATION AVERAGES

Inlet						Exit					
Absolute			Relative			Relative			Absolute		
M_1 =	0.692		M_1' =	1.456		M_2' =	0.584		M_2 =	1.149	
V_1 =	733.3	ft/sec	V_1' =	1543.9	ft/sec	V_2' =	712.0	ft/sec	V_2 =	1400.5	ft/sec
α_1 =	0.00	deg.	α_1' =	61.64	deg.	α_2' =	11.67	deg.	α_2 =	-60.14	deg.
P_1 =	8.125	psia	P_1' =	8.125	psia	P_2' =	14.052	psia	P_2 =	14.052	psia
T_1 =	467.9	deg.R	T_1' =	467.9	deg.R	T_2' =	618.3	deg.R	T_2 =	618.3	deg.R
P_{T1} =	11.19	psia	P_{T1}' =	28.00	psia	P_{T2}' =	17.70	psia	P_{T2} =	31.90	psia
T_{T1} =	512.7	deg.R	T_{T1}' =	666.3	deg.R	T_{T2}' =	660.5	deg.R	T_{T2} =	781.6	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6733
V_2/V_1	=	2.0502
P_2/P_1	=	1.5149
T_2/T_1	=	1.2586
P_{T2}/P_{T1}	=	3.0105
T_{T2}/T_{T1}	=	1.5246
W/H_{T1}	=	0.5358
η_c	=	0.6908

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6324
V_2/V_1	=	1.9098
P_2/P_1	=	1.7294
T_2/T_1	=	1.3215
P_{T2}/P_{T1}	=	2.8521
T_{T2}/T_{T1}	=	1.5246
W/H_{T1}	=	0.5358
η_c	=	0.6516

VPR-13.5-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	26.4350	-56.8700	0.0000	0.4000	-23.9086	45.9926	0.0000
Lower:	18.4350	-36.8700	0.0000	0.5000	-18.4350	36.8700	0.0000

c_2	β_C
6.0000	24.4350

CONDITIONS: (Transonic)

			P_{T1}	=	11.19 psia	T_{T1}	=	512.7 deg.R			
V_R	=	1358.6 ft/sec	P_2/P_{T1}	=	1.000				A_2/A_1	=	0.8258
M_R	=	1.28	V_{C_R}	=	1366.6 ft/sec				W_C/A	=	45.54

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.713		M_1'	=	1.470		M_2'	=	0.991		M_2	=	1.433	
V_1	=	754.4	ft/sec	V_1'	=	1554.0	ft/sec	V_2'	=	1150.1	ft/sec	V_2	=	1663.7	ft/sec
α_1	=	0.00	deg.	α_1'	=	60.96	deg.	α_2'	=	7.37	deg.	α_2	=	-46.72	deg.
P_1	=	7.968	psia	P_1'	=	7.968	psia	P_2'	=	11.133	psia	P_2	=	11.133	psia
T_1	=	465.3	deg.R	T_1'	=	465.3	deg.R	T_2'	=	560.7	deg.R	T_2	=	560.7	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	20.99	psia	P_{T2}	=	37.33	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	669.2	deg.R	T_{T2}	=	789.5	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.713		M_1'	=	1.470		M_2'	=	0.494		M_2	=	1.089	
V_1	=	754.4	ft/sec	V_1'	=	1554.0	ft/sec	V_2'	=	612.3	ft/sec	V_2	=	1349.1	ft/sec
α_1	=	0.00	deg.	α_1'	=	60.96	deg.	α_2'	=	13.94	deg.	α_2	=	-63.86	deg.
P_1	=	7.968	psia	P_1'	=	7.968	psia	P_2'	=	15.825	psia	P_2	=	15.825	psia
T_1	=	465.3	deg.R	T_1'	=	465.3	deg.R	T_2'	=	638.0	deg.R	T_2	=	638.0	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	18.70	psia	P_{T2}	=	33.35	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	669.2	deg.R	T_{T2}	=	789.5	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.7497
V_2/V_1	=	2.2052
P_2/P_1	=	1.3973
T_2/T_1	=	1.2051
P_{T2}/P_{T1}	=	3.3372
T_{T2}/T_{T1}	=	1.5400
W/H_{T1}	=	0.5342
η_c	=	0.7694

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6681
V_2/V_1	=	1.7882
P_2/P_1	=	1.9861
T_2/T_1	=	1.3712
P_{T2}/P_{T1}	=	2.9814
T_{T2}/T_{T1}	=	1.5400
W/H_{T1}	=	0.5342
η_c	=	0.6857

VPR-13.5-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	26.4350	-56.8700	0.0000	0.4000	-23.9086	45.9926	0.0000
Lower:	18.4350	-36.8700	0.0000	0.5000	-18.4350	36.8700	0.0000

c_2	β_C
6.0000	24.4350

CONDITIONS: (Transonic)

			P_{T1} = 11.19 psia			T_{T1} = 512.7 deg.R		
V_R	=	1358.6 ft/sec	P_2/P_{T1}	=	1.150	A_2/A_1	=	0.8258
M_R	=	1.28	V_{C_R}	=	1366.6 ft/sec	W_C/A	=	44.94

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.693		M_1'	=	1.457		M_2'	=	0.712		M_2	=	1.247	
V_1	=	734.8	ft/sec	V_1'	=	1544.6	ft/sec	V_2'	=	853.5	ft/sec	V_2	=	1495.0	ft/sec
α_1	=	0.00	deg.	α_1'	=	61.59	deg.	α_2'	=	8.41	deg.	α_2	=	-55.61	deg.
P_1	=	8.115	psia	P_1'	=	8.115	psia	P_2'	=	12.969	psia	P_2	=	12.969	psia
T_1	=	467.7	deg.R	T_1'	=	467.7	deg.R	T_2'	=	598.0	deg.R	T_2	=	598.0	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	19.06	psia	P_{T2}	=	34.64	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	663.4	deg.R	T_{T2}	=	788.7	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.693		M_1'	=	1.457		M_2'	=	0.573		M_2	=	1.155	
V_1	=	734.8	ft/sec	V_1'	=	1544.6	ft/sec	V_2'	=	700.3	ft/sec	V_2	=	1413.1	ft/sec
α_1	=	0.00	deg.	α_1'	=	61.59	deg.	α_2'	=	10.27	deg.	α_2	=	-60.81	deg.
P_1	=	8.115	psia	P_1'	=	8.115	psia	P_2'	=	14.412	psia	P_2	=	14.412	psia
T_1	=	467.7	deg.R	T_1'	=	467.7	deg.R	T_2'	=	622.6	deg.R	T_2	=	622.6	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	18.00	psia	P_{T2}	=	32.99	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	663.4	deg.R	T_{T2}	=	788.7	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6808
V_2/V_1	=	2.0346
P_2/P_1	=	1.5982
T_2/T_1	=	1.2785
P_{T2}/P_{T1}	=	3.0962
T_{T2}/T_{T1}	=	1.5386
W/H_{T1}	=	0.5442
η_c	=	0.7004

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6429
V_2/V_1	=	1.9232
P_2/P_1	=	1.7760
T_2/T_1	=	1.3311
P_{T2}/P_{T1}	=	2.9489
T_{T2}/T_{T1}	=	1.5386
W/H_{T1}	=	0.5442
η_c	=	0.6653

VPR-13.6-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	20.4350	-44.8700	0.0000	0.4000	-17.8487	33.8928	0.0000
Lower:	12.4350	-24.8700	0.0000	0.5000	-12.4350	24.8700	0.0000

c_2	β_C
6.0000	24.4350

CONDITIONS: (Transonic)

P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R	
V_R = 1358.6 ft/sec	P_2/P_{T1} = 1.100		A_2/A_1 = 0.8258
M_R = 1.28	V_{C_R} = 1366.6 ft/sec		W_C/A = 45.06

UNMIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.697	M_1' = 1.459	M_2' = 0.741	M_2 = 1.196
V_1 = 738.6 ft/sec	V_1' = 1546.4 ft/sec	V_2' = 883.1 ft/sec	V_2 = 1425.4 ft/sec
α_1 = 0.00 deg.	α_1' = 61.47 deg.	α_2' = 14.33 deg.	α_2 = -53.11 deg.
P_1 = 8.086 psia	P_1' = 8.086 psia	P_2' = 12.409 psia	P_2 = 12.409 psia
T_1 = 467.3 deg.R	T_1' = 467.3 deg.R	T_2' = 591.2 deg.R	T_2 = 591.2 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 18.59 psia	P_{T2} = 30.75 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 659.7 deg.R	T_{T2} = 763.9 deg.R

MIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.697	M_1' = 1.459	M_2' = 0.632	M_2 = 1.119
V_1 = 738.6 ft/sec	V_1' = 1546.4 ft/sec	V_2' = 765.4 ft/sec	V_2 = 1355.6 ft/sec
α_1 = 0.00 deg.	α_1' = 61.47 deg.	α_2' = 16.59 deg.	α_2 = -57.24 deg.
P_1 = 8.086 psia	P_1' = 8.086 psia	P_2' = 13.567 psia	P_2 = 13.567 psia
T_1 = 467.3 deg.R	T_1' = 467.3 deg.R	T_2' = 611.0 deg.R	T_2 = 611.0 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 17.75 psia	P_{T2} = 29.65 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 659.7 deg.R	T_{T2} = 763.9 deg.R

UNMIXED PERFORMANCE

P'_{T2}/P'_{T1}	= 0.6641
V_2/V_1	= 1.9298
P_2/P_1	= 1.5346
T_2/T_1	= 1.2652
P_{T2}/P_{T1}	= 2.7485
T_{T2}/T_{T1}	= 1.4901
W/H_{T1}	= 0.5029
η_c	= 0.6660

MIXED PERFORMANCE

P'_{T2}/P'_{T1}	= 0.6340
V_2/V_1	= 1.8354
P_2/P_1	= 1.6778
T_2/T_1	= 1.3076
P_{T2}/P_{T1}	= 2.6508
T_{T2}/T_{T1}	= 1.4901
W/H_{T1}	= 0.5029
η_c	= 0.6387

VPR-13.7-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	20.4350	-44.8700	0.0000	0.4000	-17.8487	33.8928	0.0000
Lower:	12.4350	-24.8700	0.0000	0.5000	-12.4350	24.8700	0.0000

c_2	β_C
6.0000	30.4350

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R		
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.000			A_2/A_1 = 0.8258
M_R = 1.28		V_{C_R} = 1366.6 ft/sec			W_C/A = 45.15

UNMIXED STATION AVERAGES

Inlet		Inlet		Exit		Exit	
Absolute		Relative		Relative		Absolute	
M_1 = 0.700		M_1' = 1.461		M_2' = 0.897		M_2 = 1.178	
V_1 = 741.4	ft/sec	V_1' = 1547.7	ft/sec	V_2' = 1047.9	ft/sec	V_2 = 1376.3	ft/sec
α_1 = 0.00	deg.	α_1' = 61.38	deg.	α_2' = 21.63	deg.	α_2 = -44.95	deg.
P_1 = 8.066	psia	P_1' = 8.066	psia	P_2' = 11.196	psia	P_2 = 11.196	psia
T_1 = 466.9	deg.R	T_1' = 466.9	deg.R	T_2' = 567.6	deg.R	T_2 = 567.6	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 19.77	psia	P_{T2} = 27.23	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 663.1	deg.R	T_{T2} = 729.3	deg.R

MIXED STATION AVERAGES

Inlet		Inlet		Exit		Exit	
Absolute		Relative		Relative		Absolute	
M_1 = 0.700		M_1' = 1.461		M_2' = 0.677		M_2 = 1.002	
V_1 = 741.4	ft/sec	V_1' = 1547.7	ft/sec	V_2' = 818.1	ft/sec	V_2 = 1210.6	ft/sec
α_1 = 0.00	deg.	α_1' = 61.38	deg.	α_2' = 28.18	deg.	α_2 = -53.43	deg.
P_1 = 8.066	psia	P_1' = 8.066	psia	P_2' = 13.569	psia	P_2 = 13.569	psia
T_1 = 466.9	deg.R	T_1' = 466.9	deg.R	T_2' = 607.3	deg.R	T_2 = 607.3	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 18.45	psia	P_{T2} = 25.75	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 663.1	deg.R	T_{T2} = 729.3	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.7062
V_2/V_1	=	1.8564
P_2/P_1	=	1.3881
T_2/T_1	=	1.2157
P_{T2}/P_{T1}	=	2.4341
T_{T2}/T_{T1}	=	1.4226
W/H_{T1}	=	0.4289
η_c	=	0.6748

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.6590
V_2/V_1	=	1.6328
P_2/P_1	=	1.6824
T_2/T_1	=	1.3008
P_{T2}/P_{T1}	=	2.3015
T_{T2}/T_{T1}	=	1.4226
W/H_{T1}	=	0.4289
η_c	=	0.6270

VPR-13.7-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	20.4350	-44.8700	0.0000	0.4000	-17.8487	33.8928	0.0000
Lower:	12.4350	-24.8700	0.0000	0.5000	-12.4350	24.8700	0.0000

c_2	β_C
6.0000	30.4350

CONDITIONS: (Transonic)

		P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R	
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.100			A_2/A_1 = 0.8258
M_R = 1.28		V_{C_R} = 1366.6 ft/sec			W_C/A = 45.19

UNMIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.701	M_1' = 1.462	M_2' = 0.821	M_2 = 1.101
V_1 = 742.9 ft/sec	V_1' = 1548.4 ft/sec	V_2' = 969.9 ft/sec	V_2 = 1300.8 ft/sec
α_1 = 0.00 deg.	α_1' = 61.33 deg.	α_2' = 24.54 deg.	α_2 = -47.29 deg.
P_1 = 8.054 psia	P_1' = 8.054 psia	P_2' = 12.303 psia	P_2 = 12.303 psia
T_1 = 466.7 deg.R	T_1' = 466.7 deg.R	T_2' = 580.4 deg.R	T_2 = 580.4 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 19.88 psia	P_{T2} = 26.96 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 662.6 deg.R	T_{T2} = 725.1 deg.R

MIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.701	M_1' = 1.462	M_2' = 0.643	M_2 = 0.962
V_1 = 742.9 ft/sec	V_1' = 1548.4 ft/sec	V_2' = 780.2 ft/sec	V_2 = 1166.2 ft/sec
α_1 = 0.00 deg.	α_1' = 61.33 deg.	α_2' = 31.08 deg.	α_2 = -55.04 deg.
P_1 = 8.054 psia	P_1' = 8.054 psia	P_2' = 14.243 psia	P_2 = 14.243 psia
T_1 = 466.7 deg.R	T_1' = 466.7 deg.R	T_2' = 611.9 deg.R	T_2 = 611.9 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 18.82 psia	P_{T2} = 25.80 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 662.6 deg.R	T_{T2} = 725.1 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.7100
V_2/V_1	= 1.7510
P_2/P_1	= 1.5275
T_2/T_1	= 1.2435
P_{T2}/P_{T1}	= 2.4100
T_{T2}/T_{T1}	= 1.4144
W/H_{T1}	= 0.4216
η_c	= 0.6777

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.6721
V_2/V_1	= 1.5698
P_2/P_1	= 1.7684
T_2/T_1	= 1.3111
P_{T2}/P_{T1}	= 2.3062
T_{T2}/T_{T1}	= 1.4144
W/H_{T1}	= 0.4216
η_c	= 0.6396

VPR-13.8-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	9.0000	-18.0000	0.0000	0.5000	-9.0000	18.0000	0.0000
Lower:	3.0000	-6.0000	0.0000	0.5000	-3.0000	6.0000	0.0000

c_2	β_C
6.0000	43.3920

CONDITIONS: (Transonic)

V_R = 1358.6 ft/sec	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R	
M_R = 1.28	P_2/P_{T1} = 1.200		A_2/A_1 = 0.8258
	V_{C_R} = 1366.6 ft/sec		W_C/A = 44.94

UNMIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1	= 0.693	M'_1	= 1.457	M'_2	= 0.790	M_2	= 0.875
V_1	= 734.8 ft/sec	V'_1	= 1544.6 ft/sec	V'_2	= 937.8 ft/sec	V_2	= 1038.9 ft/sec
α_1	= 0.00 deg.	α'_1	= 61.59 deg.	α'_2	= 40.23 deg.	α_2	= -46.44 deg.
P_1	= 8.114 psia	P'_1	= 8.114 psia	P'_2	= 13.423 psia	P_2	= 13.423 psia
T_1	= 467.7 deg.R	T'_1	= 467.7 deg.R	T'_2	= 586.1 deg.R	T_2	= 586.1 deg.R
P_{T1}	= 11.19 psia	P'_{T1}	= 28.00 psia	P'_{T2}	= 20.66 psia	P_{T2}	= 22.33 psia
T_{T1}	= 512.7 deg.R	T'_{T1}	= 666.3 deg.R	T'_{T2}	= 661.0 deg.R	T_{T2}	= 677.6 deg.R

MIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1	= 0.693	M'_1	= 1.457	M'_2	= 0.768	M_2	= 0.855
V_1	= 734.8 ft/sec	V'_1	= 1544.6 ft/sec	V'_2	= 915.4 ft/sec	V_2	= 1018.7 ft/sec
α_1	= 0.00 deg.	α'_1	= 61.59 deg.	α'_2	= 41.44 deg.	α_2	= -47.65 deg.
P_1	= 8.114 psia	P'_1	= 8.114 psia	P'_2	= 13.698 psia	P_2	= 13.698 psia
T_1	= 467.7 deg.R	T'_1	= 467.7 deg.R	T'_2	= 591.2 deg.R	T_2	= 591.2 deg.R
P_{T1}	= 11.19 psia	P'_{T1}	= 28.00 psia	P'_{T2}	= 20.24 psia	P_{T2}	= 22.08 psia
T_{T1}	= 512.7 deg.R	T'_{T1}	= 666.3 deg.R	T'_{T2}	= 661.0 deg.R	T_{T2}	= 677.6 deg.R

UNMIXED PERFORMANCE

P'_{T2}/P'_{T1}	= 0.7379
V_2/V_1	= 1.4138
P_2/P_1	= 1.6543
T_2/T_1	= 1.2532
P_{T2}/P_{T1}	= 1.9957
T_{T2}/T_{T1}	= 1.3217
W/H_{T1}	= 0.3321
η_c	= 0.6573

MIXED PERFORMANCE

P'_{T2}/P'_{T1}	= 0.7229
V_2/V_1	= 1.3863
P_2/P_1	= 1.6882
T_2/T_1	= 1.2641
P_{T2}/P_{T1}	= 1.9734
T_{T2}/T_{T1}	= 1.3217
W/H_{T1}	= 0.3321
η_c	= 0.6455

VPR-13.8-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	9.0000	-18.0000	0.0000	0.5000	-9.0000	18.0000	0.0000
Lower:	3.0000	-6.0000	0.0000	0.5000	-3.0000	6.0000	0.0000

c_2	β_C
6.0000	43.3920

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R		
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.300		A_2/A_1 = 0.8258	
M_R = 1.28		V_{C_R} = 1366.6 ft/sec		W_C/A = 44.90	

UNMIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.692	M_1' = 1.456	M_2' = 0.741	M_2 = 0.857
V_1 = 733.5 ft/sec	V_1' = 1544.0 ft/sec	V_2' = 885.7 ft/sec	V_2 = 1024.3 ft/sec
α_1 = 0.00 deg.	α_1' = 61.64 deg.	α_2' = 41.07 deg.	α_2 = -49.32 deg.
P_1 = 8.124 psia	P_1' = 8.124 psia	P_2' = 14.542 psia	P_2 = 14.542 psia
T_1 = 467.9 deg.R	T_1' = 467.9 deg.R	T_2' = 595.0 deg.R	T_2 = 595.0 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 21.40 psia	P_{T2} = 23.75 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 662.3 deg.R	T_{T2} = 684.3 deg.R

MIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.692	M_1' = 1.456	M_2' = 0.714	M_2 = 0.832
V_1 = 733.5 ft/sec	V_1' = 1544.0 ft/sec	V_2' = 857.7 ft/sec	V_2 = 1000.2 ft/sec
α_1 = 0.00 deg.	α_1' = 61.64 deg.	α_2' = 42.72 deg.	α_2 = -50.95 deg.
P_1 = 8.124 psia	P_1' = 8.124 psia	P_2' = 14.884 psia	P_2 = 14.884 psia
T_1 = 467.9 deg.R	T_1' = 467.9 deg.R	T_2' = 601.1 deg.R	T_2 = 601.1 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 20.90 psia	P_{T2} = 23.44 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 662.3 deg.R	T_{T2} = 684.3 deg.R

UNMIXED PERFORMANCE

P'_{T2}/P'_{T1}	=	0.7642
V_2/V_1	=	1.3965
P_2/P_1	=	1.7900
T_2/T_1	=	1.2716
P_{T2}/P_{T1}	=	2.1233
T_{T2}/T_{T1}	=	1.3349
W/H_{T1}	=	0.3426
η_c	=	0.7005

MIXED PERFORMANCE

P'_{T2}/P'_{T1}	=	0.7466
V_2/V_1	=	1.3636
P_2/P_1	=	1.8321
T_2/T_1	=	1.2847
P_{T2}/P_{T1}	=	2.0951
T_{T2}/T_{T1}	=	1.3349
W/H_{T1}	=	0.3426
η_c	=	0.6868

VPR-13.8-t3

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-11.9029	0.0000	84.6432
Lower:	-6.0000	12.0000	0.0000	0.5000	-6.0000	12.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

Aft Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	9.0000	-18.0000	0.0000	0.5000	-9.0000	18.0000	0.0000
Lower:	3.0000	-6.0000	0.0000	0.5000	-3.0000	6.0000	0.0000

c_2	β_C
6.0000	43.3920

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R	
V_R = 1358.6 ft/sec	P_2/P_{T1} = 1.400		A_2/A_1 = 0.8258
M_R = 1.26	V_{C_R} = 1366.6 ft/sec		W_C/A = 39.55

UNMIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 = 0.554		M_1' = 1.377		M_2' = 0.658		M_2 = 0.833	
V_1 = 596.9	ft/sec	V_1' = 1483.9	ft/sec	V_2' = 796.4	ft/sec	V_2 = 1008.2	ft/sec
α_1 = 0.00	deg.	α_1' = 66.28	deg.	α_2' = 42.55	deg.	α_2 = -54.42	deg.
P_1 = 9.082	psia	P_1' = 9.082	psia	P_2' = 15.632	psia	P_2 = 15.632	psia
T_1 = 483.0	deg.R	T_1' = 483.0	deg.R	T_2' = 609.0	deg.R	T_2 = 609.0	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 21.26	psia	P_{T2} = 24.87	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 664.0	deg.R	T_{T2} = 695.8	deg.R

MIXED STATION AVERAGES

Inlet				Exit			
Absolute		Relative		Relative		Absolute	
M_1 = 0.554		M_1' = 1.377		M_2' = 0.626		M_2 = 0.806	
V_1 = 596.6	ft/sec	V_1' = 1483.8	ft/sec	V_2' = 761.5	ft/sec	V_2 = 980.9	ft/sec
α_1 = 0.00	deg.	α_1' = 66.29	deg.	α_2' = 45.02	deg.	α_2 = -56.72	deg.
P_1 = 9.083	psia	P_1' = 9.083	psia	P_2' = 16.026	psia	P_2 = 16.026	psia
T_1 = 483.0	deg.R	T_1' = 483.0	deg.R	T_2' = 615.7	deg.R	T_2 = 615.7	deg.R
P_{T1} = 11.19	psia	P_{T1}' = 28.00	psia	P_{T2}' = 20.87	psia	P_{T2} = 24.59	psia
T_{T1} = 512.7	deg.R	T_{T1}' = 666.3	deg.R	T_{T2}' = 664.0	deg.R	T_{T2} = 695.8	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.7594
V_2/V_1	= 1.6892
P_2/P_1	= 1.7212
T_2/T_1	= 1.2609
P_{T2}/P_{T1}	= 2.2231
T_{T2}/T_{T1}	= 1.3572
W/H_{T1}	= 0.3617
η_c	= 0.7089

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.7455
V_2/V_1	= 1.6441
P_2/P_1	= 1.7644
T_2/T_1	= 1.2747
P_{T2}/P_{T1}	= 2.1977
T_{T2}/T_{T1}	= 1.3572
W/H_{T1}	= 0.3617
η_c	= 0.6975

VPR-14f-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.5000	-25.9467	0.0000	103.7868
Lower:	-6.0000	-6.0000	0.0000	0.5000	-12.0000	6.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	36.8700	58.3920

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R		
V_R = 1358.6 ft/sec		P_2/P_{T1} = 1.000		A_2/A_1 = 0.8677	
M_R = 1.27		V_{C_R} = 1366.6 ft/sec		W_C/A = 42.95	

UNMIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.635	M_1' = 1.422	M_2' = 1.135	M_2 = 0.904
V_1 = 677.8 ft/sec	V_1' = 1518.3 ft/sec	V_2' = 1274.5 ft/sec	V_2 = 1011.9 ft/sec
α_1 = 0.00 deg.	α_1' = 63.49 deg.	α_2' = 45.54 deg.	α_2 = -24.89 deg.
P_1 = 8.529 psia	P_1' = 8.529 psia	P_2' = 10.303 psia	P_2 = 10.303 psia
T_1 = 474.4 deg.R	T_1' = 474.4 deg.R	T_2' = 524.7 deg.R	T_2 = 521.4 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 24.39 psia	P_{T2} = 17.89 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 662.1 deg.R	T_{T2} = 605.1 deg.R

MIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.635	M_1' = 1.422	M_2' = 0.921	M_2 = 0.608
V_1 = 677.8 ft/sec	V_1' = 1518.3 ft/sec	V_2' = 1073.9 ft/sec	V_2 = 707.7 ft/sec
α_1 = 0.00 deg.	α_1' = 63.49 deg.	α_2' = 57.69 deg.	α_2 = -37.20 deg.
P_1 = 8.529 psia	P_1' = 8.529 psia	P_2' = 12.693 psia	P_2 = 12.984 psia
T_1 = 474.4 deg.R	T_1' = 474.4 deg.R	T_2' = 566.2 deg.R	T_2 = 563.4 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 21.96 psia	P_{T2} = 16.67 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 662.1 deg.R	T_{T2} = 605.1 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.8710
V_2/V_1	= 1.4929
P_2/P_1	= 1.2080
T_2/T_1	= 1.0990
P_{T2}/P_{T1}	= 1.5990
T_{T2}/T_{T1}	= 1.1804
W/H_{T1}	= 0.1888
η_c	= 0.7603

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.7843
V_2/V_1	= 1.0442
P_2/P_1	= 1.5224
T_2/T_1	= 1.1876
P_{T2}/P_{T1}	= 1.4901
T_{T2}/T_{T1}	= 1.1804
W/H_{T1}	= 0.1888
η_c	= 0.6394

VPR-15f-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	-20.1600	0.6250	-19.0190	0.0000	79.2460
Lower:	-6.0000	-3.0000	0.0000	0.5000	-9.0000	3.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	39.8700	58.3920

CONDITIONS: (Transonic)

P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R	
V_R = 1358.6 ft/sec	P_2/P_{T1} = 1.000		A_2/A_1 = 0.8677
M_R = 1.29	V_{C_R} = 1366.6 ft/sec		W_C/A = 45.70

UNMIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.719	M_1' = 1.473	M_2' = 1.161	M_2 = 0.842
V_1 = 760.0 ft/sec	V_1' = 1556.7 ft/sec	V_2' = 1300.4 ft/sec	V_2 = 941.4 ft/sec
α_1 = 0.00 deg.	α_1' = 60.78 deg.	α_2' = 48.88 deg.	α_2 = -22.97 deg.
P_1 = 7.926 psia	P_1' = 7.926 psia	P_2' = 10.685 psia	P_2 = 10.685 psia
T_1 = 464.6 deg.R	T_1' = 464.6 deg.R	T_2' = 522.4 deg.R	T_2 = 520.7 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 26.01 psia	P_{T2} = 17.63 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 664.2 deg.R	T_{T2} = 593.9 deg.R

MIXED STATION AVERAGES

Inlet		Exit	
Absolute	Relative	Relative	Absolute
M_1 = 0.719	M_1' = 1.473	M_2' = 0.996	M_2 = 0.609
V_1 = 760.0 ft/sec	V_1' = 1556.7 ft/sec	V_2' = 1149.7 ft/sec	V_2 = 702.0 ft/sec
α_1 = 0.00 deg.	α_1' = 60.78 deg.	α_2' = 58.35 deg.	α_2 = -31.64 deg.
P_1 = 7.926 psia	P_1' = 7.926 psia	P_2' = 12.719 psia	P_2 = 12.867 psia
T_1 = 464.6 deg.R	T_1' = 464.6 deg.R	T_2' = 554.2 deg.R	T_2 = 552.9 deg.R
P_{T1} = 11.19 psia	P_{T1}' = 28.00 psia	P_{T2}' = 23.97 psia	P_{T2} = 16.53 psia
T_{T1} = 512.7 deg.R	T_{T1}' = 666.3 deg.R	T_{T2}' = 664.2 deg.R	T_{T2} = 593.9 deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.9290
V_2/V_1	= 1.2387
P_2/P_1	= 1.3482
T_2/T_1	= 1.1207
P_{T2}/P_{T1}	= 1.5761
T_{T2}/T_{T1}	= 1.1584
W/H_{T1}	= 0.1625
η_c	= 0.8544

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	= 0.8562
V_2/V_1	= 0.9237
P_2/P_1	= 1.6235
T_2/T_1	= 1.1900
P_{T2}/P_{T1}	= 1.4776
T_{T2}/T_{T1}	= 1.1584
W/H_{T1}	= 0.1625
η_c	= 0.7264

VPR-15f-t2

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	-20.1600	0.6250	-19.0190	0.0000	79.2460
Lower:	-6.0000	-3.0000	0.0000	0.5000	-9.0000	3.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	39.8700	58.3920

CONDITIONS: (Transonic)

			P_{T1} = 11.19 psia		T_{T1} = 512.7 deg.R			
V_R	=	1358.6 ft/sec	P_2/P_{T1} = 1.100			A_2/A_1	=	0.8677
M_R	=	1.29	V_{C_R} = 1366.6 ft/sec			W_C/A	=	46.46

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.748		M_1'	=	1.492		M_2'	=	1.123		M_2	=	0.817	
V_1	=	787.6	ft/sec	V_1'	=	1570.4	ft/sec	V_2'	=	1270.4	ft/sec	V_2	=	921.6	ft/sec
α_1	=	0.00	deg.	α_1'	=	59.90	deg.	α_2'	=	49.52	deg.	α_2	=	-24.19	deg.
P_1	=	7.715	psia	P_1'	=	7.715	psia	P_2'	=	11.498	psia	P_2	=	11.498	psia
T_1	=	461.0	deg.R	T_1'	=	461.0	deg.R	T_2'	=	532.2	deg.R	T_2	=	529.9	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	25.69	psia	P_{T2}	=	17.80	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	666.7	deg.R	T_{T2}	=	598.6	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.748		M_1'	=	1.492		M_2'	=	0.976		M_2	=	0.598	
V_1	=	787.6	ft/sec	V_1'	=	1570.4	ft/sec	V_2'	=	1132.6	ft/sec	V_2	=	692.6	ft/sec
α_1	=	0.00	deg.	α_1'	=	59.90	deg.	α_2'	=	58.64	deg.	α_2	=	-32.97	deg.
P_1	=	7.715	psia	P_1'	=	7.715	psia	P_2'	=	13.437	psia	P_2	=	13.644	psia
T_1	=	461.0	deg.R	T_1'	=	461.0	deg.R	T_2'	=	559.9	deg.R	T_2	=	558.7	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	24.75	psia	P_{T2}	=	17.37	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	666.7	deg.R	T_{T2}	=	598.6	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9177
V_2/V_1	=	1.1701
P_2/P_1	=	1.4902
T_2/T_1	=	1.1493
P_{T2}/P_{T1}	=	1.5909
T_{T2}/T_{T1}	=	1.1676
W/H_{T1}	=	0.1662
η_c	=	0.8533

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.8841
V_2/V_1	=	0.8793
P_2/P_1	=	1.7685
T_2/T_1	=	1.2118
P_{T2}/P_{T1}	=	1.5530
T_{T2}/T_{T1}	=	1.1676
W/H_{T1}	=	0.1662
η_c	=	0.8061

VPR-16f-t1

GEOMETRY

Front Blade:

	θ_1	a	b	ζ_T	θ_2	c	d
Upper:	0.0000	0.0000	0.0000	0.6250	-16.2945	0.0000	115.8722
Lower:	-6.0000	8.0000	0.0000	0.7500	-15.0000	60.0000	0.0000

c_1	β_{Design}	$\beta_{Transonic}$
4.0000	39.8700	58.3920

CONDITIONS: (Transonic)

	P_{T1} = 11.19 psia	T_{T1} = 512.7 deg.R
V_R = 1358.6 ft/sec	P_2/P_{T1} = 1.200	A_2/A_1 = 0.8677
M_R = 1.28	V_{C_R} = 1366.6 ft/sec	W_C/A = 44.89

UNMIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.691		M_1'	=	1.456		M_2'	=	0.941		M_2	=	0.708	
V_1	=	733.2	ft/sec	V_1'	=	1543.8	ft/sec	V_2'	=	1094.1	ft/sec	V_2	=	827.2	ft/sec
α_1	=	0.00	deg.	α_1'	=	61.65	deg.	α_2'	=	52.26	deg.	α_2	=	-40.90	deg.
P_1	=	8.127	psia	P_1'	=	8.127	psia	P_2'	=	13.715	psia	P_2	=	13.715	psia
T_1	=	467.9	deg.R	T_1'	=	467.9	deg.R	T_2'	=	563.0	deg.R	T_2	=	567.6	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	25.76	psia	P_{T2}	=	20.23	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	664.5	deg.R	T_{T2}	=	632.3	deg.R

MIXED STATION AVERAGES

Inlet								Exit							
Absolute				Relative				Relative				Absolute			
M_1	=	0.691		M_1'	=	1.456		M_2'	=	0.868		M_2	=	0.619	
V_1	=	733.2	ft/sec	V_1'	=	1543.8	ft/sec	V_2'	=	1022.7	ft/sec	V_2	=	735.7	ft/sec
α_1	=	0.00	deg.	α_1'	=	61.65	deg.	α_2'	=	59.84	deg.	α_2	=	-45.18	deg.
P_1	=	8.127	psia	P_1'	=	8.127	psia	P_2'	=	14.909	psia	P_2	=	14.500	psia
T_1	=	467.9	deg.R	T_1'	=	467.9	deg.R	T_2'	=	577.5	deg.R	T_2	=	587.3	deg.R
P_{T1}	=	11.19	psia	P_{T1}'	=	28.00	psia	P_{T2}'	=	24.37	psia	P_{T2}	=	18.78	psia
T_{T1}	=	512.7	deg.R	T_{T1}'	=	666.3	deg.R	T_{T2}'	=	664.5	deg.R	T_{T2}	=	632.3	deg.R

UNMIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.9201
V_2/V_1	=	1.1282
P_2/P_1	=	1.6877
T_2/T_1	=	1.2131
P_{T2}/P_{T1}	=	1.8085
T_{T2}/T_{T1}	=	1.2335
W/H_{T1}	=	0.2302
η_c	=	0.8014

MIXED PERFORMANCE

P_{T2}'/P_{T1}'	=	0.8706
V_2/V_1	=	1.0035
P_2/P_1	=	1.7843
T_2/T_1	=	1.2551
P_{T2}/P_{T1}	=	1.6789
T_{T2}/T_{T1}	=	1.2335
W/H_{T1}	=	0.2302
η_c	=	0.6932

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Report Documentation Page

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16. Abstract

A computational fluid dynamics study was conducted to evaluate the feasibility of the variable-pitch split-blade supersonic fan concept. This fan configuration was conceived as a means to enable a supersonic fan to switch from the supersonic through-flow type of operation at high speeds to a conventional fan with subsonic inflow and outflow at low speeds. During this off-design, low speed mode of operation the fan would operate with a substantial static pressure rise across the blade row like a conventional transonic fan; the front (variable-pitch) blade would be aligned with the incoming flow; and the aft blade would remain fixed in the position set by the supersonic design conditions. Because of these geometrical features, this low speed configuration would inherently have a large amount of turning and, thereby, would have the potential for a large total pressure increase in a single stage. Such a high-turning blade configuration is prone to flow separation; it was hoped that the channeling of the flow between the blades would act like a slotted wing and help alleviate this problem.

A total of 20 blade configurations representing various supersonic and transonic configurations were evaluated using a Navier Stokes CFD program called ADAPTNS because of its adaptive grid features. The flow generated by this computational procedure were processed by another data reduction program which calculated average flow properties and simulated fan performance. These results were employed to make quantitative comparisons and evaluations of blade performance.

The supersonic split-blade configurations generated performance comparable to a single-blade supersonic, through-flow fan configuration. Simulated rotor total pressure ratios of the order of 2.5 or better were achieved for Mach 2.0 inflow conditions. The corresponding fan efficiencies were approximately 75% or better.

The transonic split-blade configurations having large amounts of turning were able to generate large amounts of total turning and achieve simulated total pressure ratios of 3.0 or better with subsonic inflow conditions. These configurations had large losses and low fan efficiencies in the 70's%. They had large separated regions and low velocity wakes. Additional turning and diffusion of this flow in a subsequent stator row would probably be very inefficient. The high total pressure ratios indicated by the rotor performance would be substantially reduced by the stators, and the stage efficiency would be substantially lower. Such performance leaves this dual-mode fan concept to be less attractive than originally postulated.

Other configurations, with considerably less flow turning, indicated the flow could be diffused with much lower losses and can achieve higher fan efficiencies. These results indicate that total pressure ratios, higher than the current state-of-the-art, may be achievable with fixed-geometry split-blade configurations designed for subsonic inflow conditions.

17. Key Words (Suggested by Author(s))

Variable-Pitch Split-Blade
Supersonic Through Flow Fan
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