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CORE COMPRESSOR EXIT STAGE STUDY

Volume V - Design and Performance Report for the Rotor C/Stator B Configurations

by

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GENERAL ELECTRIC COMPANY

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16. Abstract <p>The objective of the Core Compressor Exit Stage Study Program is to develop rear stage blading designs that have lower losses in their end-wall boundary layer regions. This report describes the design of Rotor C and the performance results for Rotor C running with Stator B. The overall technical approach in this efficiency improvement program utilizes General Electric's Low Speed Research Compressor as the principal investigative tool. Tests were conducted by using four identical stages of blading so that test data would be obtained in a true multistage environment.</p>					
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1.0 SUMMARY

The Core Compressor Exit Stage Study Program has the primary objective of developing rear stage blade designs that have improved efficiency by virtue of having lower losses in their end-wall boundary layer regions. Blading concepts that offer promise of reducing end-wall losses have been evaluated in a multistage environment. This report describes the design of Rotor C and the performance results for the Rotor C/Stator B compressor stage that was tested in the General Electric Low Speed Research Compressor. The aerodynamic design of Rotor C incorporated a stronger hub profile and a smoother pressure distribution on the rotor tip than those of Rotor B.

Overall performance data and various types of detailed performance data are presented along with the resulting vector diagrams, loss coefficients, and diffusion factors. The data taken for the Rotor C/Stator B configuration show that a small improvement in overall peak efficiency and range of the high efficiency region was obtained.

2.0 INTRODUCTION

Recent preliminary design studies of advanced turbofan core compressors (Reference 1) have indicated that such compressors must have very high efficiencies, as well as the advantages of compactness, light weight, and low cost, in order for advanced overall engine/aircraft systems to have an improved economic payoff. Loss mechanism assessments, such as those of Reference 2, suggest that approximately half of the total loss in a multistage compressor rear stage is associated with the endwall boundary layers. Since only a relatively small amount of past research has been dedicated to the problem of finding improved airfoil shapes for operation in multistage compressor endwall boundary layers, it is believed that substantial improvements in that area are likely. Accordingly, a goal of a 15% reduction in rear-stage endwall boundary layer losses, as compared to current technology levels, has been set. The Core Compressor Exit Stage Study Program is directed toward achieving this goal. Blading concepts that offer a promise of reducing endwall losses relative to a baseline design have been evaluated in a multistage environment. The design of Rotor C and performance results for the Rotor C/Stator B stage are described in this report.

3.0 DESIGN OF ROTOR C

3.1 LOW SPEED MODELING AND TESTING CONCEPT

The low speed modeling and testing concept is based on aerodynamic similarity. Fundamental fluid dynamic principles and reasoning are used to obtain normalized airfoil surface velocity distributions and Reynolds numbers for the low speed blading that are the same as those for the high-speed compressor. This low speed model is then tested in General Electric's Low Speed Research Compressor (LSRC) facility where the advantages of large size (1.5-m diameter) and low tip speed (60 m/sec) enable precise identification of aerodynamic losses without risk of instrumentation blockage effects. The details of the low speed modeling concept are presented in Volume I (Reference 3).

The baseline blading designed for the Core Compressor Exit Stage Study Program is basically a low speed model of the high-speed, advanced, multistage axial flow compressor (AMAC) described in Reference 1. Rotor C is a candidate design that has the potential of reducing endwall losses relative to the baseline.

3.2 TEST RESULTS OF ROTOR B WITH STATOR B

A four-stage configuration of Rotor B/Stator B was chosen as the best combination of blading designs based on the screening test results described in Volume III (Reference 4). When compared with the baseline Rotor A/Stator A configuration described in Volume II (Reference 5), Rotor B/Stator B showed (1) a 0.3- to 0.4-point improvement in design point efficiency and (2) a significant improvement in the pressure-flow characteristic near stall. These results are presented in Figure 1. In addition, the radial variation of normalized total pressure at the compressor discharge (Figure 2) indicates that the weak hub region of the baseline configuration has been strengthened - particularly at peak pressure rise - with the Rotor B/Stator B combination. The data show that Stator B is primarily responsible for this improvement.

Examination of the data revealed several areas where further improvements could be made. The hub pressure level was still low relative to that of other

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spanwise locations, indicating that further strengthening of the hub could be made. Static pressure measurements on the blade surfaces identified locations where a modification of the airfoil shape would be beneficial. The rotor tip region shown in Figure 3(a) exhibited an undesirable acceleration-deceleration-acceleration of the fluid along the forward half of the suction surface; this was attributable to secondary flow and tip leakage effects. The absence of a "spike" on the suction surface leading edge of the pitchline sections at peak pressure rise implied that higher incidence angles could be used. Evidence of flow separation at the rotor hub was seen in the distinct change in the rate of the suction surface diffusion which occurred near the trailing edge region. These areas of concern formed the basis for the design of Rotor C.

Further details of the Rotor B/Stator B test results are described in Volume IV (Reference 6).

3.3 ANALYSIS OF LOW SPEED ROTOR C VECTOR DIAGRAMS

As discussed in the previous section, the data from the Rotor B/Stator B configuration showed that further strengthening of the hub region could be beneficial. Consequently, Rotor C was designed to produce higher total pressure from pitchline-to-hub and lower total pressure from pitchline-to-tip than Rotors A and B, but with the same overall average. This radially non-constant distribution of total pressure for Rotor C of $\pm 24\%$ of stage exit dynamic head at the rotor exit plane is compared with that used for Rotors A and B in Figure 4. The higher hub total pressure increases the dynamic head entering the stator in this region and helps avoid excessive loading. The radial distribution of loss coefficient presented in Figure 5 was not changed from the values used for the previous designs. Stage exit swirl produced by Stator B was also imposed upon the Rotor C design (Figure 6). These profiles of rotor exit total pressure, loss coefficient, and stator discharge swirl, along with the necessary physical quantities of annulus dimensions, effective area coefficient, rotative speed, and airflow, were input into the circumferential average flow determination (CAFD) computer program to describe the axisymmetric flow field. The results of this analysis are compared to those of Stage A and Stator B in Figures 6 through 10. The stator inlet air angles (Figure 6) are not significantly different from those of Rotor B, but this is

not the case with the rotor relative air angles shown in Figure 7. The radial redistribution of flow produced by the steeper total pressure gradient of Rotor C results in higher rotor swirl angles along the outer span and in lower angles along the inner span, reaching maximum differences of 3° to 4° at the end walls. The flow redistribution of Rotor C is further emphasized in Figures 8 and 9 where the radial profiles of normalized axial velocity at the rotor inlet and exit planes are compared for Rotors A, B, and C. And finally, the radial variations in rotor and stator diffusion factors are presented in Figure 10. The diffusion factors of Rotor B are modeled quite accurately for Rotor C. However, the more severe pressure gradient produced by Rotor C increases the dynamic head entering the stator vanes in the hub region (with a corresponding decrease at the casing) and results in lower stator diffusion factors along the inner-half of the annulus and higher values from the pitch-line to the casing.

The vector diagram information is summarized in Table 1 for Rotor C running with Stator B.

3.4 BLADE SETTING PROCEDURE

The airfoil sections designed for Rotor C were specified to match the vector diagrams described in Section 3.3. The leading edge meanline angles were based on the "smooth flow" incidence angle correlation described in Volume I (Reference 3), with small modifications to account for the differences observed between the design intent and the experimental data of Rotor B. The trailing edge meanline angles were determined with a potential flow cascade analysis as described in Volume I (Reference 3). Experience has shown that the cascade exit air angle, β_{CASC} , is not always the same as the axisymmetric value, β_{CAFD} , obtained from the vector diagram analysis of Section 3.3. Figure 11 gives the radial distribution of this difference, called X_D , and indicates a subtle change from the Rotor B profile that was used for the Rotor C design in the tip region. Modifications to the airfoil meanline shapes [change in camber (DCAM)] and to thickness distributions were necessary in order to model the high speed blading and to achieve the desired surface velocity distributions. The incidence and deviation angles obtained by this procedure are shown in Figure 12. Further details of the blade setting procedure are described in Section 5.0 of Volume I (Reference 3).

3.5 ROTOR C AIRFOIL SECTION SHAPES

New airfoil shapes were required for Rotor C at all spanwise locations. In the pitchline and hub regions these shapes were only minor modifications of those for Rotor B; but over the outer 20% of the annulus height, major modifications to the meanline and thickness distributions produced completely unique shapes.

The blade setting procedure of Section 3.4 defined the radial distributions of edge angles (Figure 13) when the relative air angles from the vector diagram analysis of Section 3.3 were combined with the radial distributions of incidence and deviation angles shown in Figure 12. Incidence angles were increased over those of Rotor B by 2° at the pitchline and were smoothly blended into the same values at the hub and into slightly lower values (by less than 1°) at the tip. Deviation angles were generally the same or slightly lower than those of Rotor B. The smaller edge angles in the hub region resulted in a stagger 10% less than that of Rotor B, but due to fixed axial projection requirements the hub chord was reduced by 5%. As a consequence, the thickness-to-chord distribution at the hub was increased slightly in order to maintain the same physical thickness of the section. The airfoil geometry of Rotor C is summarized in Table 2.

The tip section of Rotor C was given a special meanline shape in recognition of the undesirable blade surface velocity distributions produced by the more conventional circular-arc shapes of Rotor B. The design was based on the differences between the design intent velocity distribution for Rotor B and the experimentally observed velocity distribution on the suction surface of Rotor B. These Rotor B differences that result from secondary flow/tip leakage effects are shown in Figure 14. The suction surface velocity is less than the Rotor B design intent from 0% to 35% along the blade surface and is greater than design intent from 35% to the trailing edge. The acceleration-deceleration-acceleration feature, measured on the suction surface of Rotor B, is considered to be undesirable. Based on these results, if Rotor C were designed in the same manner as Rotor B, a similar undesirable velocity distribution in the tip region would probably result. Therefore, an effort was made to compensate for the effects of the secondary flow/tip leakage.

First, the desired velocity distribution for Rotor C was established. This is shown as Rotor C CASC, Circle-Arc-Type Section in Figure 14. Then, in order to avoid the acceleration-deceleration-acceleration pattern, a velocity distribution was chosen which "overaccelerates" the potential flow solution relative to the desired distribution in the first 32% of the blade surface and "underaccelerates" it in the midportion of the blade. This modified distribution, which is like a mirror image of the Rotor B measurements, is shown in Figure 14 as Rotor C CASC-Special Profile. Designing for the "Special Profile" velocity distribution should provide the desired velocity distribution after secondary flow effects are encountered. Figure 15 presents a comparison of the tip section meanline shapes of Rotors B and C. Aside from its nonconventional shape, the Rotor C tip section stagger is higher by 3.3° in recognition of the vector diagram changes discussed in Section 3.3. By 20% immersion, a smooth transition has been made from the special meanline of the tip to the more conventional circular-arc shape. The airfoil sections at the pitchline and the hub are similar to those of Rotor B, with the most distinct difference occurring at the hub trailing edge. A 5° lower DCAM was applied at this location to reduce the high rate of suction surface diffusion that was observed with Rotor B. Comparisons of the chordwise variation of meanline angles for Rotors A, B, and C are shown in Figures 16 and 17. Comparisons of blade surface velocity distributions for Rotors A, B, and C are shown in Figure 18.

4.0 TEST APPARATUS AND PROCEDURE

4.1 LOW SPEED RESEARCH COMPRESSOR

The General Electric Low Speed Research Compressor (LSRC) facility, described in more detail in Volume II (Reference 5), was used for this test program. The LSRC configuration, used in the test program and shown schematically in Figure 19, consisted of four identical compressor stages having a constant casing diameter of 1.524 m (60 in.) and a radius ratio of 0.85. A photograph of the LSRC is shown in Figure 20. A detailed cross section of one stage is shown in Figure 21. The airfoils are 11.43 cm (4.5 in.) in span and approximately 9 cm (3.5 in.) in chord; large enough that blade edge and surface contours can be closely controlled during manufacture. The blade and vane construction described in Volume II (Reference 5) resulted in hydraulically smooth surfaces at the Reynolds numbers necessary to simulate high-speed compressor performance.

The average rotor tip clearance to blade height was 1.36% and the average stator seal clearance to blade height was 0.78%. Circumferential groove casing treatment was applied over the tip of only the first rotor to assure that Stage 1 would not be the stall limiting blading.

4.2 TEST STAGES

The test stage consisted of Rotor C and Stator B. The Rotor C design is described in detail in Section 3.0 and the Stator B design is presented in Volume I (Reference 3). A brief summary of these designs is given below.

Rotor C was designed to produce a radially nonconstant distribution of total pressure of $\pm 24\%$ of stage exit dynamic head, as compared to the $\pm 9\%$ distribution of Rotors A and B. The airfoil shape in the Rotor C tip region was designed to compensate for the effects of secondary flow and tip leakage. A comparison of the Rotor B and C airfoil tip sections is shown in Figure 15. Stator B embodies blade sections twisted closed locally in the endwall regions similar to those used in a highly loaded NASA single stage that had rather good performance for its loading level (Reference 7).

4.3 INSTRUMENTATION

The instrumentation used at various locations in the compressor for the Rotor C/Stator B test series is presented in Table 3. Standard total pressure rakes and wall static pressure taps were used. In addition, static pressure taps located on the blade and vane surfaces were used to determine the distribution of static pressure on the suction and pressure surfaces. For rotors, the pressures measured with a rotating rake were read by a pressure transducer/slipping device.

Details about the instrumentation and the data recording equipment are given in Volume II (Reference 5).

4.4 TEST PROCEDURE

The overall test program was divided into four parts as outlined in Table 4. The first part involved extensive testing of the baseline blading, Stage A (Rotor A/Stator A), in both four-stage and single-stage configurations. The test results can be found in Volume II (Reference 5) of this series. The second part involved a series of short screening tests to select the best rotor design and the best stator design based on tests in four-stage configurations. These test results can be found in Volume III (Reference 4). The third part involved extensive testing of the best rotor and best stator designs in combination using a four-stage compressor configuration. These test results can be found in Volume IV (Reference 6). The final part of the test program consists of extensive testing of a new Rotor C design in a four-stage configuration with Stator B; the test results are the subject of the present report.

Seven types of data were taken during the Rotor C/Stator B tests: pre-view data, stall determination data, casing treatment data, standard data, blade element data, blade surface pressure data, and detailed wall boundary layer data. A brief description of each of these types of data is presented in Volume II (Reference 5).

4.5 DATA REDUCTION AND ANALYSIS METHODS

The data analysis procedures used in processing test data are described in Volume II (Reference 5).

5.0 RESULTS AND DISCUSSION

The test results for the test stage consisting of Rotor C running with Stator B in a multistage environment are presented and discussed in the following paragraphs.

5.1 OVERALL PERFORMANCE

The overall performance of the test configuration, which consisted of Rotor C with Stator B, was determined from preview data and standard data. These test data are presented as graphs of pressure coefficient, work coefficient, and torque efficiency plotted as a function of flow coefficient. The tests were conducted at an average rotor tip-clearance-to-blade-height ratio of 1.53% and an average stator seal-clearance-to-blade-height ratio of 0.78%. The test Reynolds number was 3.6×10^5 . Casing treatment was applied over the tip of the first rotor only to assure that Stage 1 would not be the stall limiting blading.

The overall performance of Rotor C is compared with that of Rotor B in Figure 22. The pressure flow characteristics are nearly identical, but Rotor C stalls at 2% lower airflow. This could be because Rotor 1 tip is governing and Rotor C tip is more closed. A 0.2-point improvement in efficiency is obtained with Rotor C at flow coefficients larger than the design point value of 0.407. Peak efficiency for Rotor C is 0.9060 at a flow coefficient of 0.398, while that of Rotor B is 0.9047 at a flow coefficient of 0.396. Thus a small improvement in overall peak efficiency and an increase in the range of the high efficiency region is obtained with Rotor C. An additional 0.14 points in efficiency should be credited to Rotor C compared to Rotor B when adjustments for tip clearance are made. Rotor C is running with a slightly larger rotor tip-clearance-to-blade-height, e/h , of 1.53% compared to 1.43% for Rotor B. Preview data for Rotor C/Stator B is tabulated in Table 5.

The radial variation of normalized total pressure at the compressor discharge is presented in Figure 23. When compared with the Rotor B/Stator B profiles of Figure 2, the Rotor C profiles indicate that the pressure rise capacity of the hub region was strengthened as intended by design.

5.2 BLADE AND VANE SURFACE STATIC PRESSURE MEASUREMENTS

The measurements of static pressure on the blade and vane surfaces are presented in Figures 24 through 26 and tabulated in Tables 6 and 7 for the four-stage configuration with the third stage as the test stage. The measured pressures have been normalized by the dynamic head based on tip speed, $1/2 \rho_{\text{ref}} U_t^2$. Suction surface measurements are presented as solid lines and pressure surface measurements as dashed lines. Data were obtained for the design throttle, the peak efficiency throttle, and peak pressure rise/near stall throttle.

The Rotor C data in Figure 24 indicate a continuous diffusion from the location of the peak suction surface velocity (minimum static pressure) to the trailing edge for all blade sections from the pitchline to the tip. Evidence of flow separation near the hub can be seen in the distinct change in the slope of the static pressure distribution on the suction surface at 70% chord in Figure 24(d) and at 60% chord in Figure 24(e) for the peak pres-
sure/near stall throttle.

The increase in leading edge loading as the compressor is throttled toward stall is seen as a decrease in suction surface pressure and an increase in pressure surface pressure near the leading edge for all immersions. However, no large suction surface spike appears to form; this suggests that stall probably does not initiate because of excessive rotor incidence, although this is not certain. The variation with throttling of the suction surface pressure near the leading edge is less than the variation observed with Rotor B.

The pressure distribution in the tip region of Rotor C, shown in more detail in Figure 25, exhibits some of the "smoothing" on the suction surface that was intended by the special airfoil sections; the effects of secondary flow and tip leakage are still apparent.

The stator data in Figure 26 suggest that the diffusion pattern on the suction surface is not as healthy as that on the rotor. The rate of diffusion tends to decrease near the trailing edge indicating boundary layer separation may be developing. This flow separation on the suction surface becomes significantly more evident near the hub at the peak pressure rise

throttle as seen in Figure 26(d) and 26(e). For this case a significant flow separation has occurred between 30% and 40% chord, probably as a result of excessive incidence. Probing this region with a tuft probe confirmed the presence of large areas of separated flow. Also, the stator pressure distributions show less leading edge loading near the inner diameter at the design point than Rotor B but about the same near stall.

5.3 BLADE ELEMENT AND WALL BOUNDARY LAYER TEST RESULTS

Blade element data and wall boundary layer data provide vector diagram quantities from measured values of total pressure, static pressure, and flow angles in a matrix of circumferential and radial locations across a blade pitch. The radial surveys of pressure and flow angle, taken between adjacent stators, are used to fix the shape of the radial distribution; circumferential surveys are used to fix the absolute level of the distribution. The measurements are taken at the rotor inlet and at the rotor and stator discharges of the test stage. The bars in the figures indicate the variation of measured values across the circumferential blade spacing. The detailed wall boundary layer data are included in the radial profiles.

Pressures

Detailed surveys of normalized absolute total and static pressures at the third rotor inlet (Plane 3.0), third rotor exit (Plane 3.5), and third stator exit (Plane 4.0) are presented in Figures 27 through 29 and in Table 8 for the design point throttle, the near peak efficiency throttle and the peak pressure rise/near stall throttle. The difference between the total pressure at Planes 3.5 and 3.0 represents the absolute total pressure rise across the rotor. The difference between the total pressures at Planes 3.5 and 4.0 represents the loss across the stator.

Regions of endwall loss are evident in the stator from 0% to 20% immersion and from 80% to 100% immersion. The increased loss in the hub region near stall (Figure 29) is consistent with the flattening of the vane surface static pressure measurements shown in Figure 26(d) and (e).

The static pressure rise across the rotor is seen as the difference between the measured pressures in Planes 3.0 and 3.5 and that across the stator as the difference between the measured pressures in Planes 3.5 and 4.0. This gives a pitchline reaction at the design point throttle of about 64%.

Flow Angles

Detailed surveys of absolute air angles at the third rotor inlet, third rotor exit, and third stator exit are presented in Figures 30 through 34 and in Table 8 for the design point throttle, the near peak efficiency throttle, and the peak pressure rise/near stall throttle. A small correction factor to the flow angles, which is needed because of the geometry of the measuring system, was used in the data analysis. This correction would yield true flow angles that were about 0.5° larger than observed at 100% immersion and about 1.1° larger at zero percent immersion. The correction factor to the flow angles has not been incorporated into the data shown in the figures but has been incorporated in the data shown in the tables. The leading and trailing edge metal angles for the stator are shown in the figures so that the incidence and deviation angles are easily seen. The stator exit swirl angles appear to have a radial distribution that is somewhat more tilted toward smaller at 25% immersion and larger at 80% immersion than those for the Rotor B/Stator B four-stage configuration (Reference 6).

Total Pressure Circumferential Surveys and Loss Coefficients

Relative total pressure measurements across a circumferential blade spacing for Rotor C were obtained at 11 radial immersions using the rotating rake discussed in Reference 5. The results are presented in Figures 35 through 37 for the various throttles. The rotor wake is clearly evident as is the increased size of this wake near stall, particularly near the hub (Figure 37). The loss region near the tip, which is due to the wake and tip clearance/secondary flow effects, is very similar to that obtained for Rotor B/Stator B in Reference 6.

Absolute total pressure measurements across a circumferential stator vane spacing were obtained at 19 radial immersions, including the immersions for the boundary layer surveys. Representative samples of these measurements are shown in Figures 38 through 40 for 11 of the 19 immersions. The distributions of static and total pressures shown in Figures 27 through 29 were obtained by computing the average, minimum, and maximum value of pressure shown in Figures 38 through 40 at each radial immersion.

Rotor and stator loss coefficients were computed from these detailed measurements. The rotor loss coefficients computed from the relative total pressure measurements are presented in Figure 41 and Table 9. The stator loss coefficients computed from absolute total pressure measurements are presented in Figure 42. Both are in reasonable agreement with design intent. The total loss shown is the sum of the wake loss, the tip clearance vortex loss, free-stream loss, and miscellaneous losses. The rotor tip wake loss shown in Figure 41 is slightly less than that reported for Rotor B in Reference 6, although this may not be real. Stator loss at the tip (Figure 42) does not go negative as that reported in Reference 6.

Vector Diagram Quantities

Complete vector diagram quantities, as well as loss coefficients, loss parameters, diffusion factors, and incidence and deflection angles were computed from the quantities measured in the absolute frame of reference. The results are tabulated in Tables 10 through 16 for the various throttle settings. Several of these performance parameters have been plotted as a function of percent immersion in Figures 43 through 49. The design point incident is also plotted on each figure for reference. In most cases over the midportion of the span, the vector diagram quantities computed from measurements are in reasonable agreement with design intent for the design point throttle setting.

As discussed in Reference 4, Section 4.6.1 of Volume II, rotor total loss coefficients computed from the rotating rake measurements are considered to be more reliable than those computed from the absolute measurements. Consequently, only rotor total loss coefficients obtained from rotating rake measurements are presented in this section.

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6.0 CONCLUSIONS

A new rotor, Rotor C, was designed to compensate for the effects of secondary flow and tip leakage and to achieve other performance improvements such as strengthening the hub and incorporating improved airfoil shapes.

The following results were obtained:

- A small improvement in overall efficiency (0.1 to 0.48 points relative to Rotor A/Stator A) and an improvement in the range of the high efficiency region were obtained.
- A slightly lower stalling flow (2%) relative to Rotor B/Stator B was evident.
- A stronger hub profile was obtained per design intent.
- Part of the smoothing of the pressure distribution on the suction surface of the rotor tip was attained, albeit not by much.
- Rotor tip wake loss was reduced slightly.

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7.0 LIST OF SYMBOLS AND ACRONYMS

<u>Symbol</u>	<u>Definition</u>
A	Annulus area of the compressor
Alpha	Absolute air angle
AMAC	Advanced multistage axial flow compressor
Beta	Relative air angle
c	Stator shroud seal clearance
C	Absolute velocity
CU	Absolute tangential velocity
CZ	Axial velocity
CAFD	Circumferential average flow determination
DCAM	Change in Camber
CASC	Cascade analysis by streamline curvature
F_c	Compressibility correction factor
h	Annulus height
ID	Inside diameter
IGV	Inlet guide vane
LSRC	Low speed research compressor
OD	Outside diameter
P	Pressure
P_s	Blade surface static pressure $\equiv P_{\text{surface}} - (P_B + P_{\text{ref}})$
P_{s1}	Upstream static pressure
P_{T1}	Total Pressure
QU	Normalizing quantity = $1/2 \rho_{\text{ref}} U_t^2$

7.0 LIST OF SYMBOLS AND ACRONYMS (Continued)

<u>Symbol</u>	<u>Definition</u>
R	Radius
Re	Reynolds number
T	Measured torque corrected for windage/bearing friction
U_t	Wheel speed at tip
V	Air velocity
W	Relative velocity
WU	Relative tangential velocity
ϵ	Rotor tip clearance
η	Torque efficiency
ρ	Density
$\bar{\rho}$	Average density across annulus
ϕ	Flow coefficient
ψ	Work coefficient
ψ'	Pressure coefficient
$\bar{\omega}$	Loss coefficient
 <u>Subscript</u>	
B	Barometer
C	Casing
H	Hub
ref	Reference
S	Static properties

7.0 LIST OF SYMBOLS AND ACRONYMS (Concluded)

<u>Symbol</u>	<u>Definition</u>
T	Total properties
t	Tip
1	Upstream conditions
2	Downstream conditions
β_1^*	Inlet metal angle
β_2^*	Exit metal angle

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8.0 FIGURES

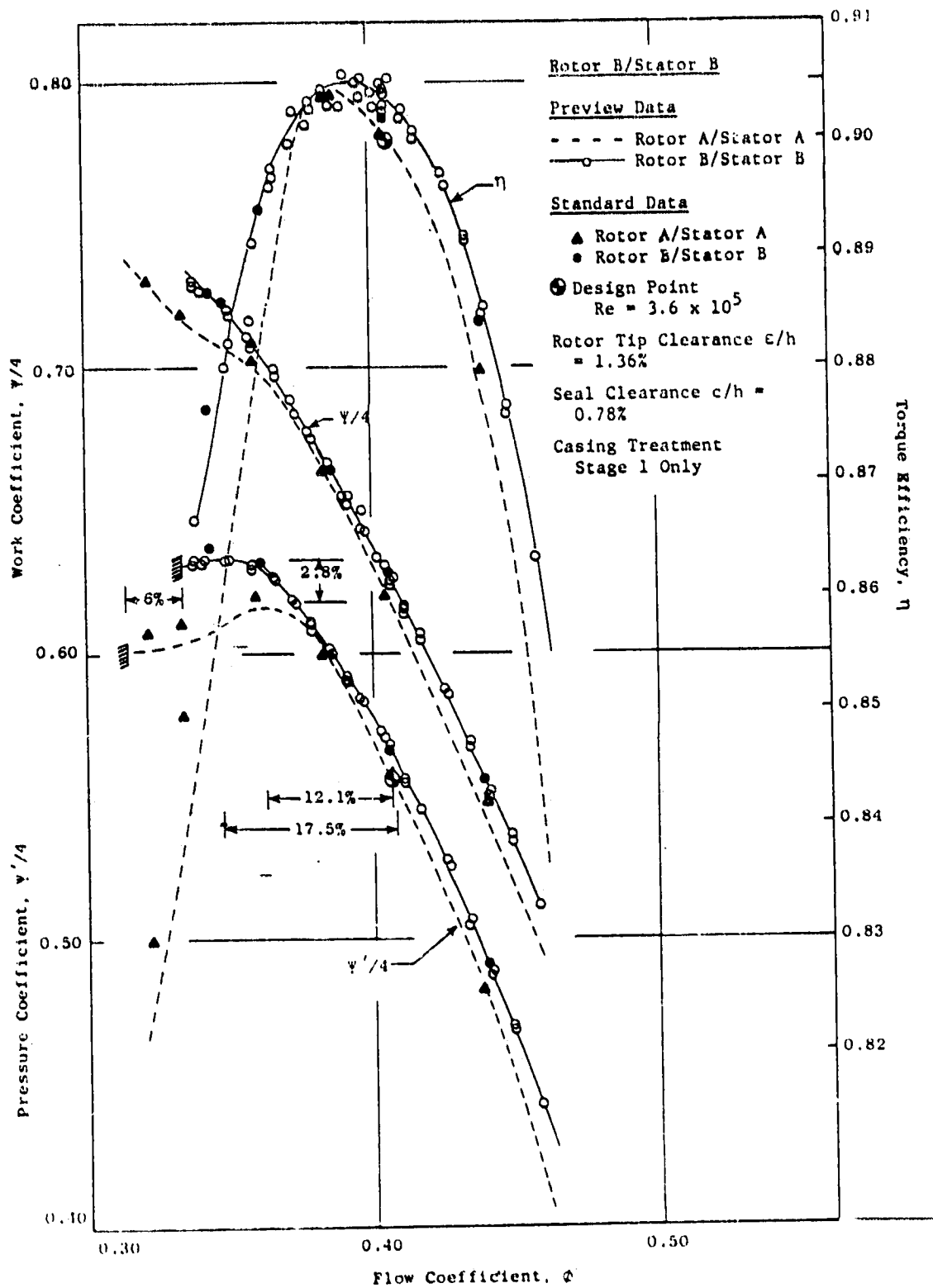


Figure 1. Overall Performance of Rotor B/Stator B Compared with the Overall Performance of Rotor A/Stator A.

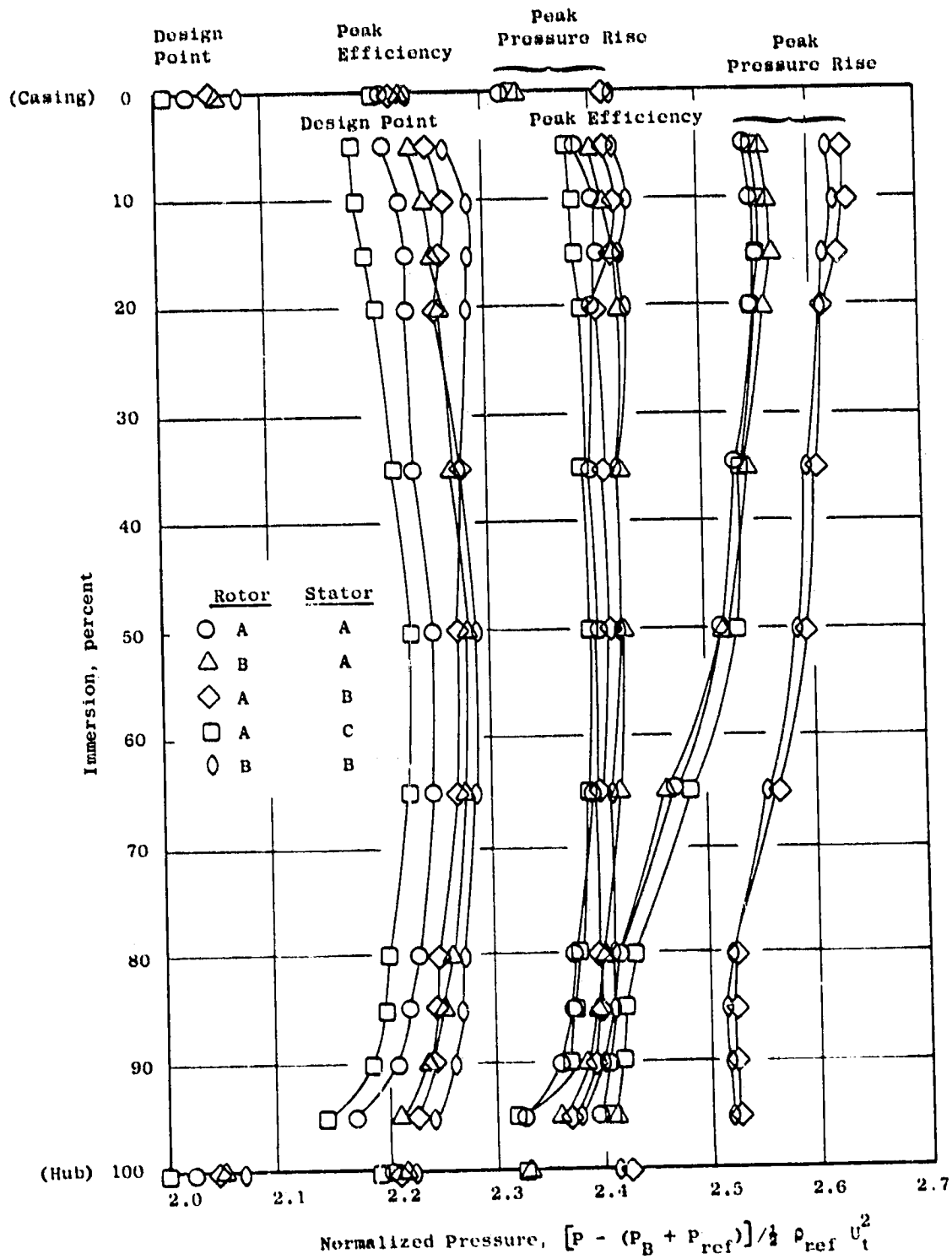


Figure 2. Radial Variation of Normalized Total Pressure Including Casing and Hub Normalized Static Pressures at the Compressor Discharge for Various Throttle Settings.

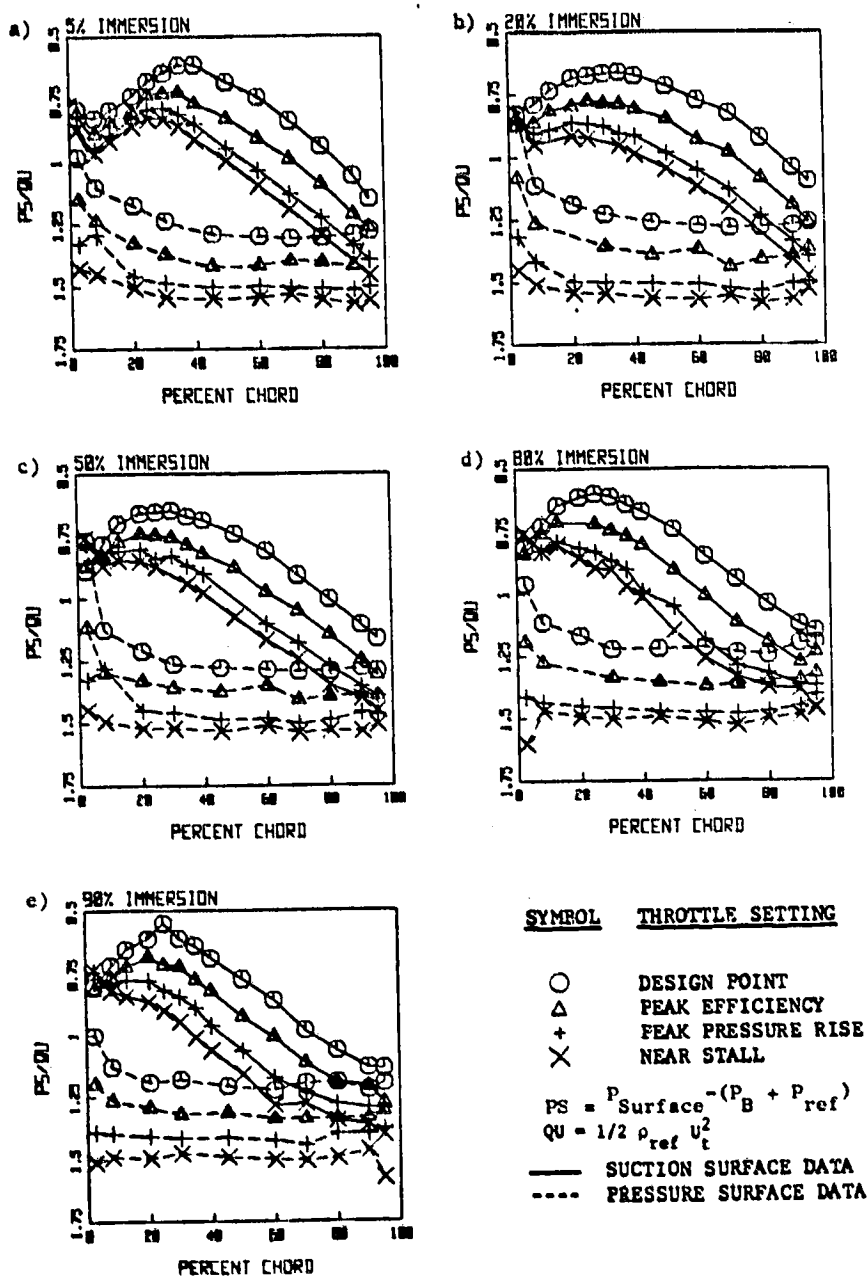


Figure 3. Rotor Surface Static Pressure Measurements for the Four-Stage Rotor B/Stator B Configuration; Third Stage Is Test Stage.

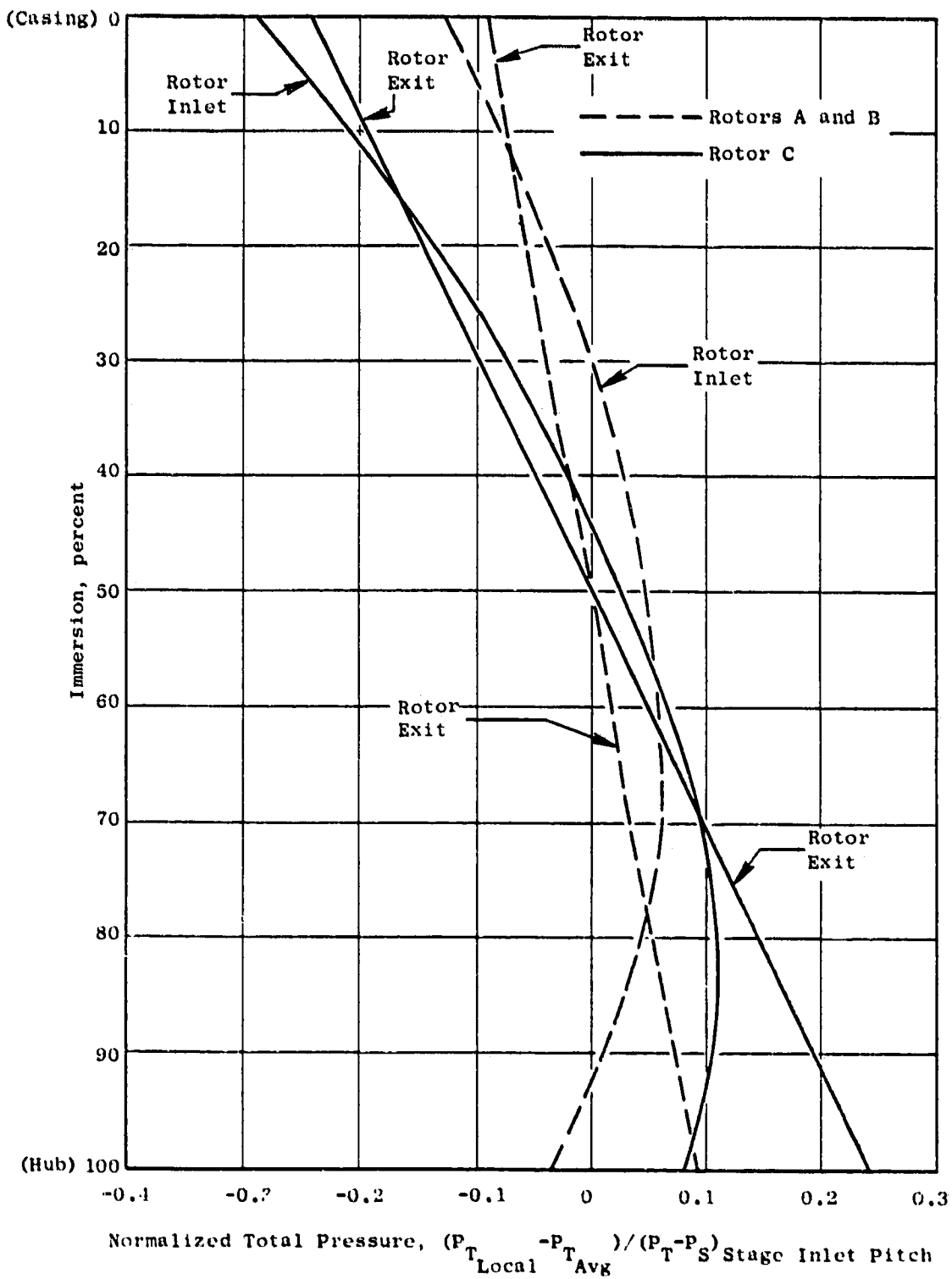


Figure 4. Radial Variation of Normalized Inlet and Exit Total Pressure for Rotors A, B, and C.

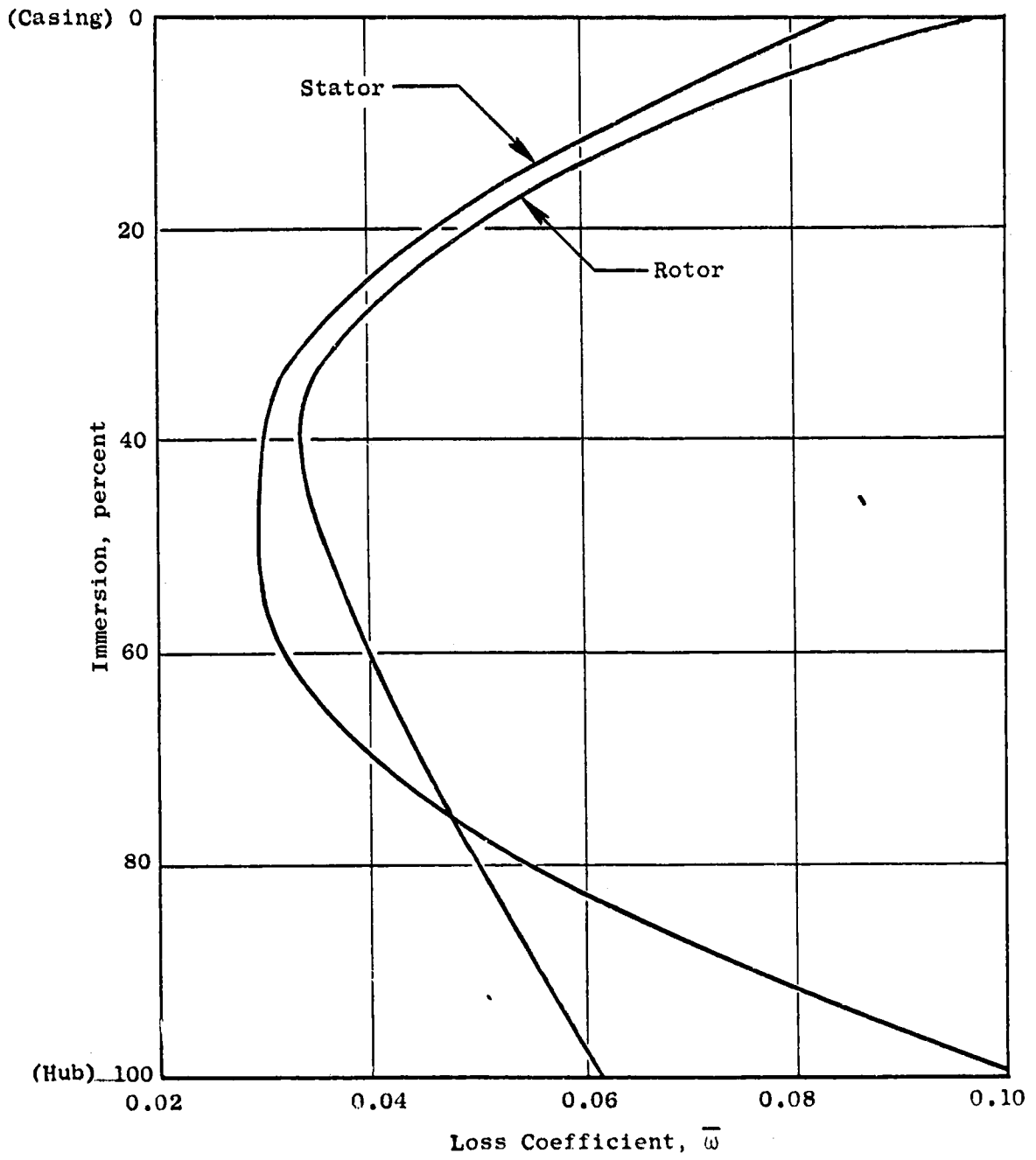


Figure 5. Rotor and Stator Loss Coefficients Versus Percent Immersion.

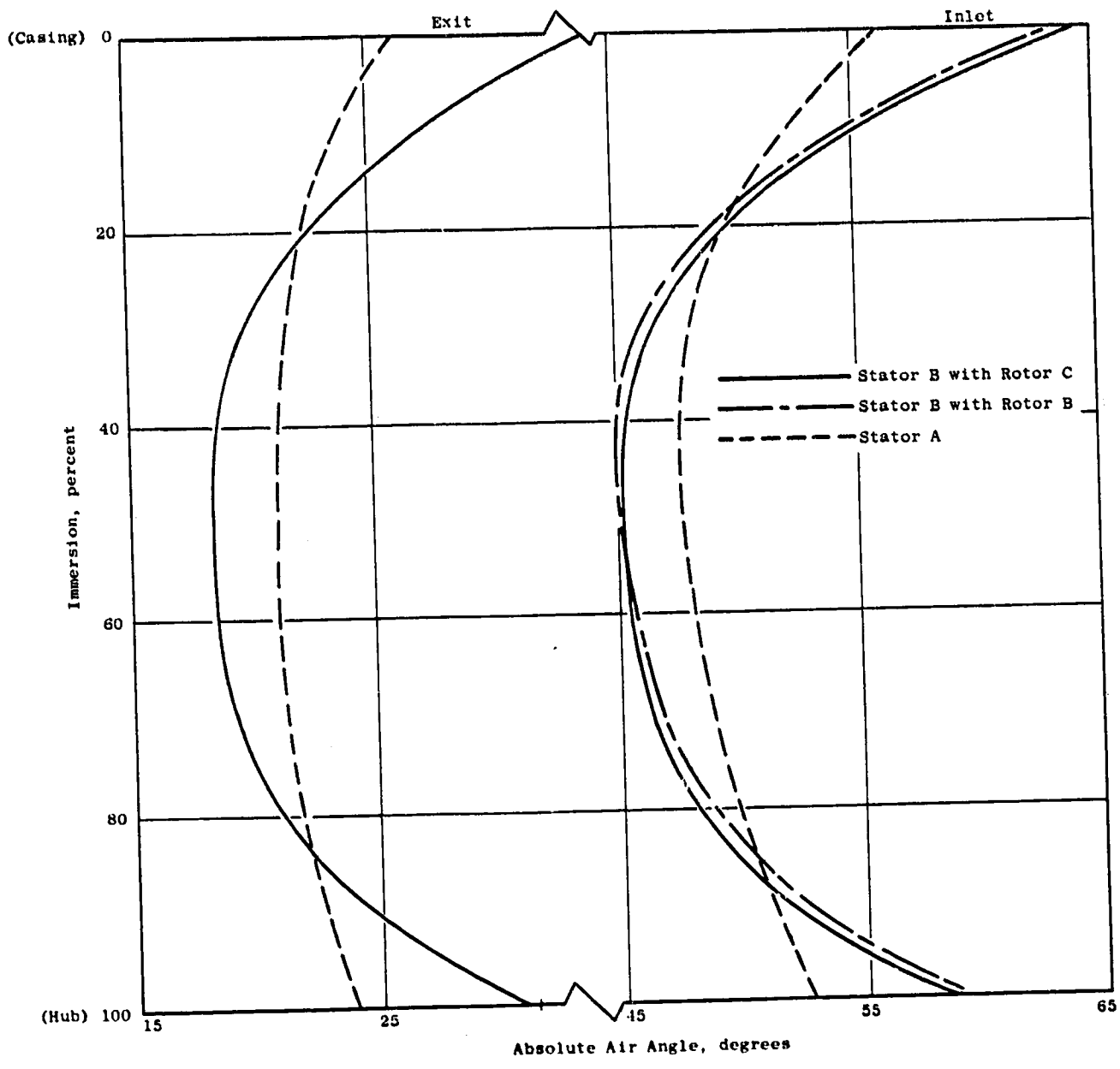


Figure 6. Comparison of the Radial Variation of Inlet and Exit Absolute Air Angles.

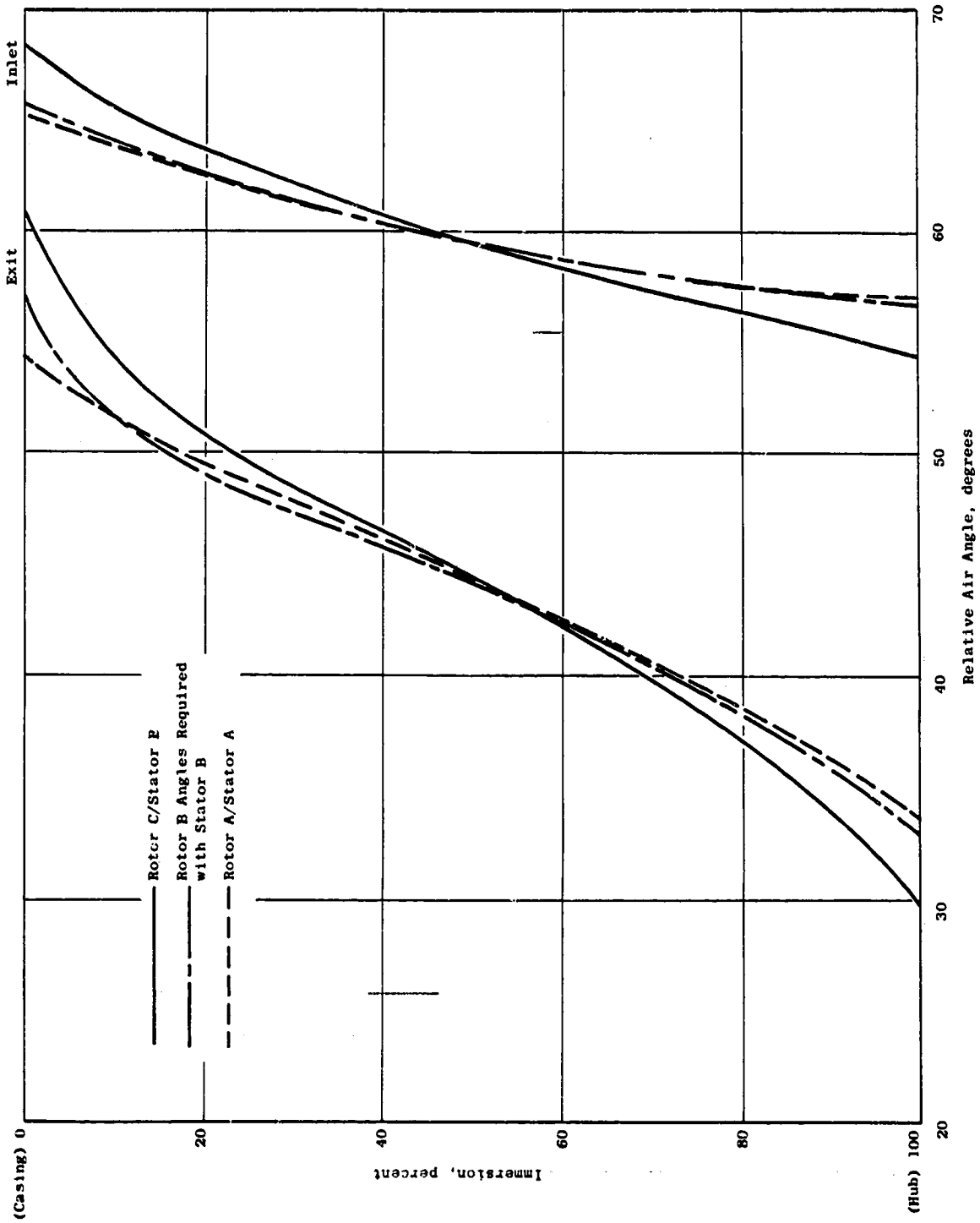


Figure 7. Comparison of the Radial Variation of Inlet and Exit Relative Air Angles for Rotors A, B, and C.

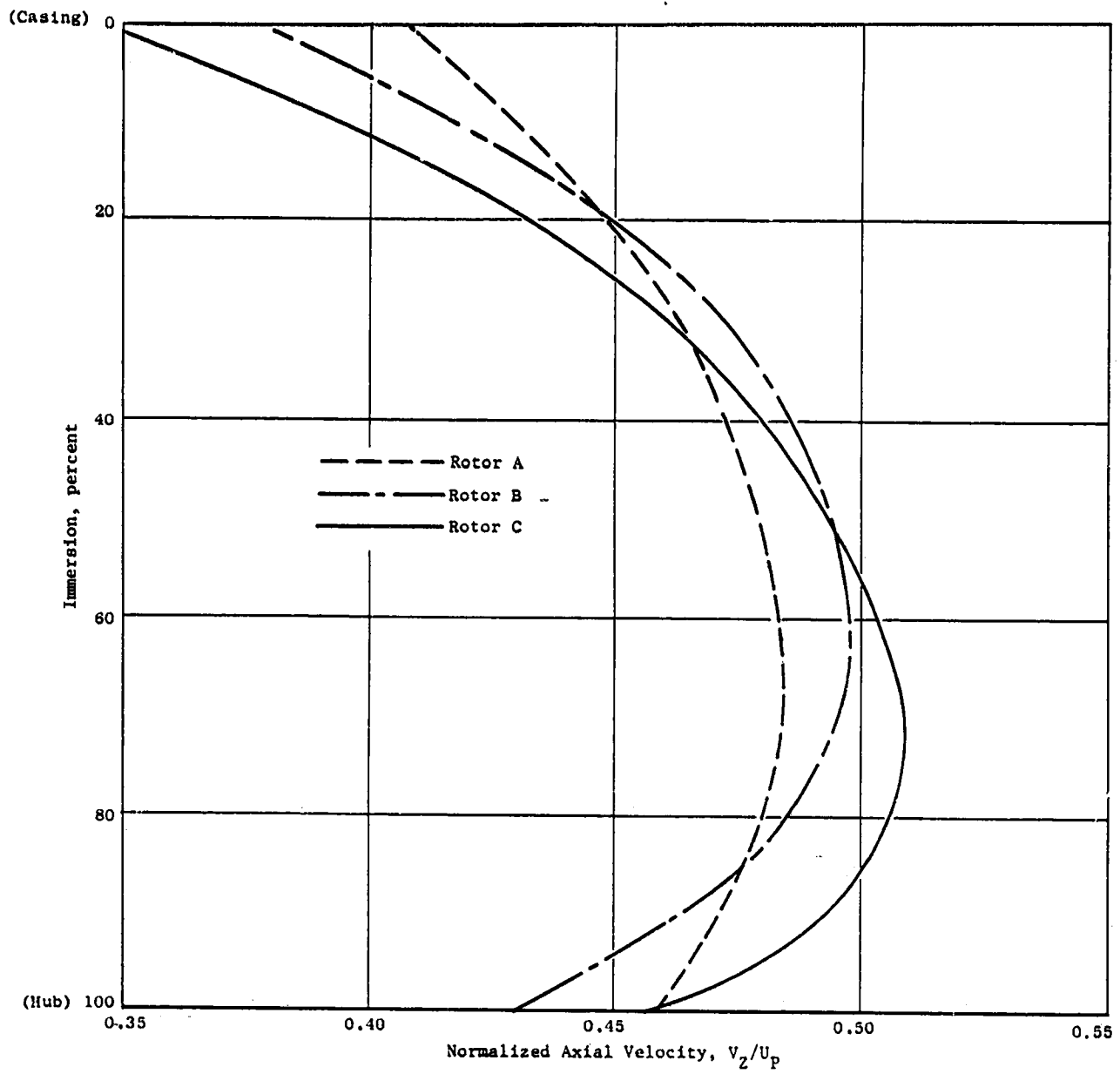


Figure 8. Comparison of the Radial Variation of Rotor Inlet Normalized Axial Velocity for Rotors A, B, and C.

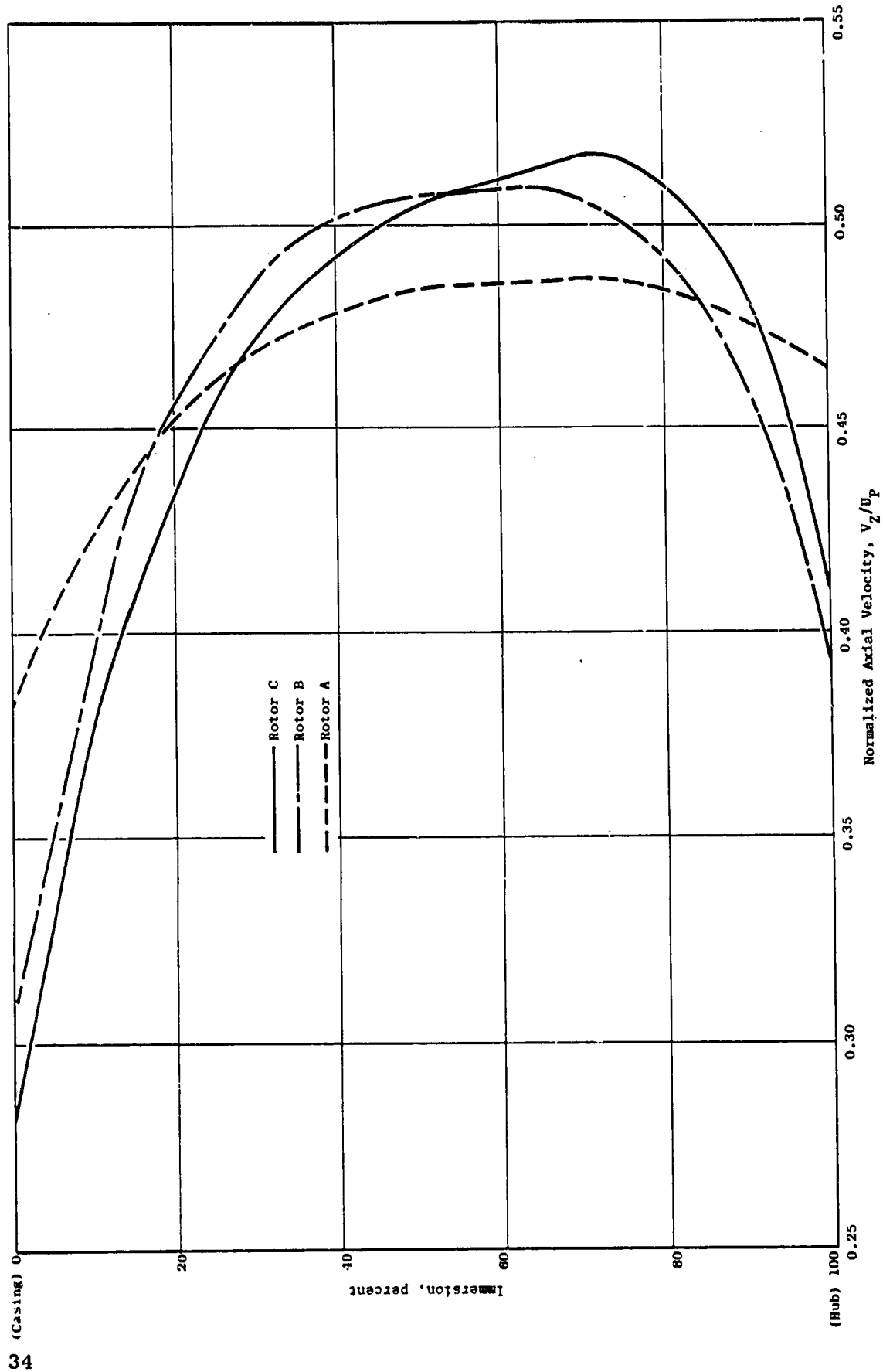


Figure 9. Comparison of the Radial Variation of Rotor Exit Normalized Axial Velocity for Rotors A, B, and C.

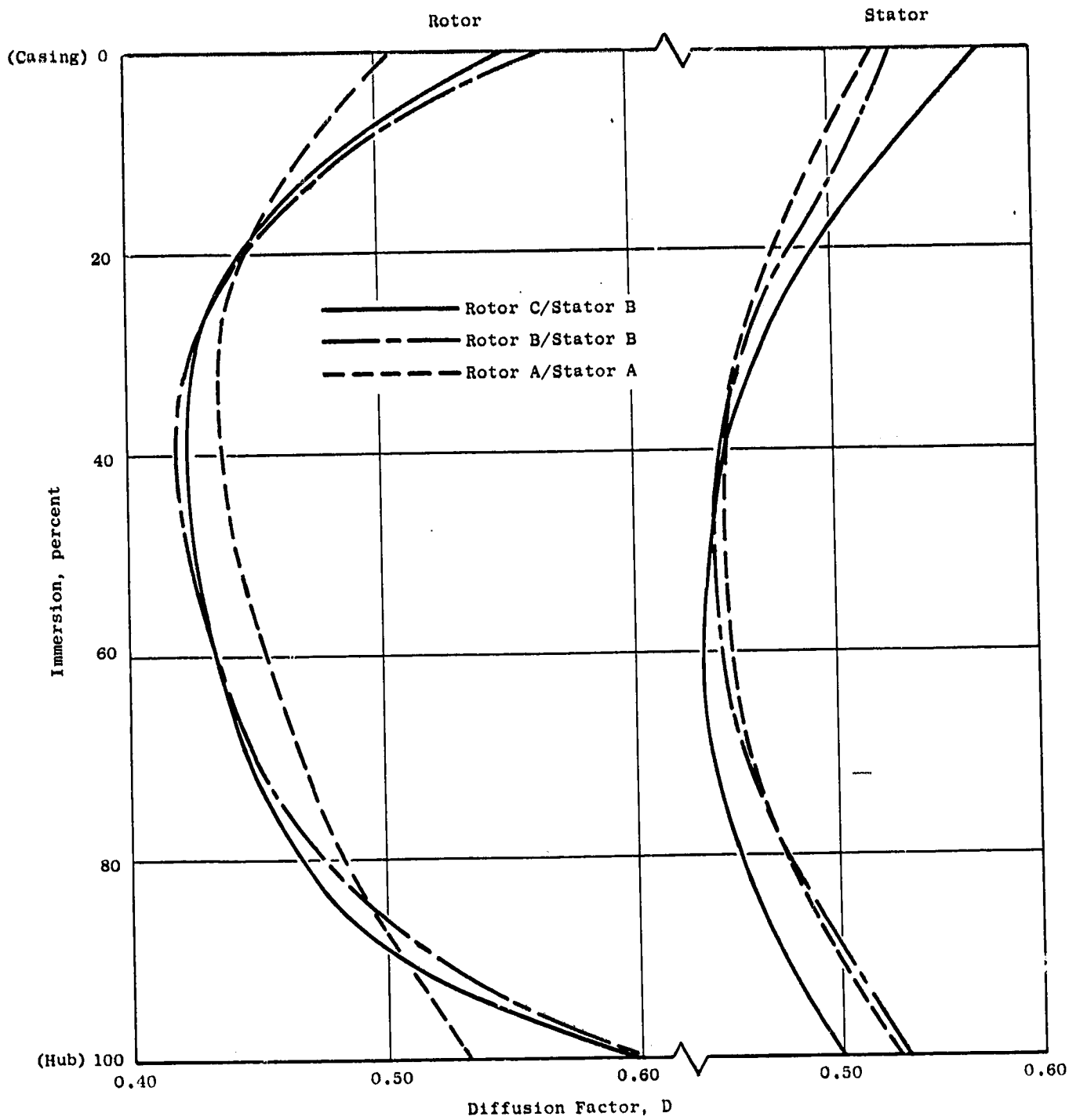


Figure 10. Comparison of the Radial Variation of Rotor and Stator Diffusion Factors Versus Percent Immersion.

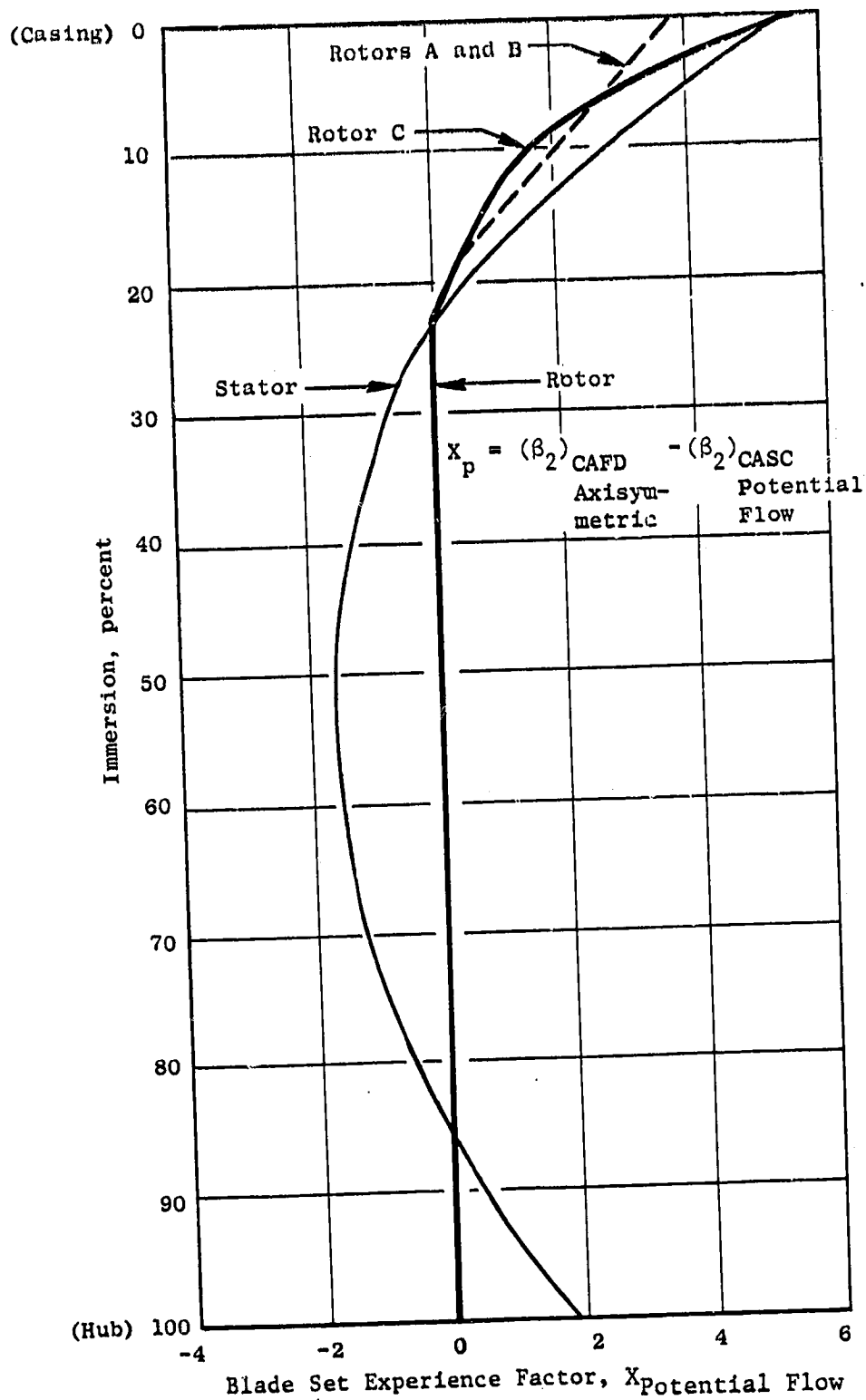


Figure 11. Radial Variation of the Difference Between CAFD and CASC Exit Air Angles for Rotors A, B, and C.

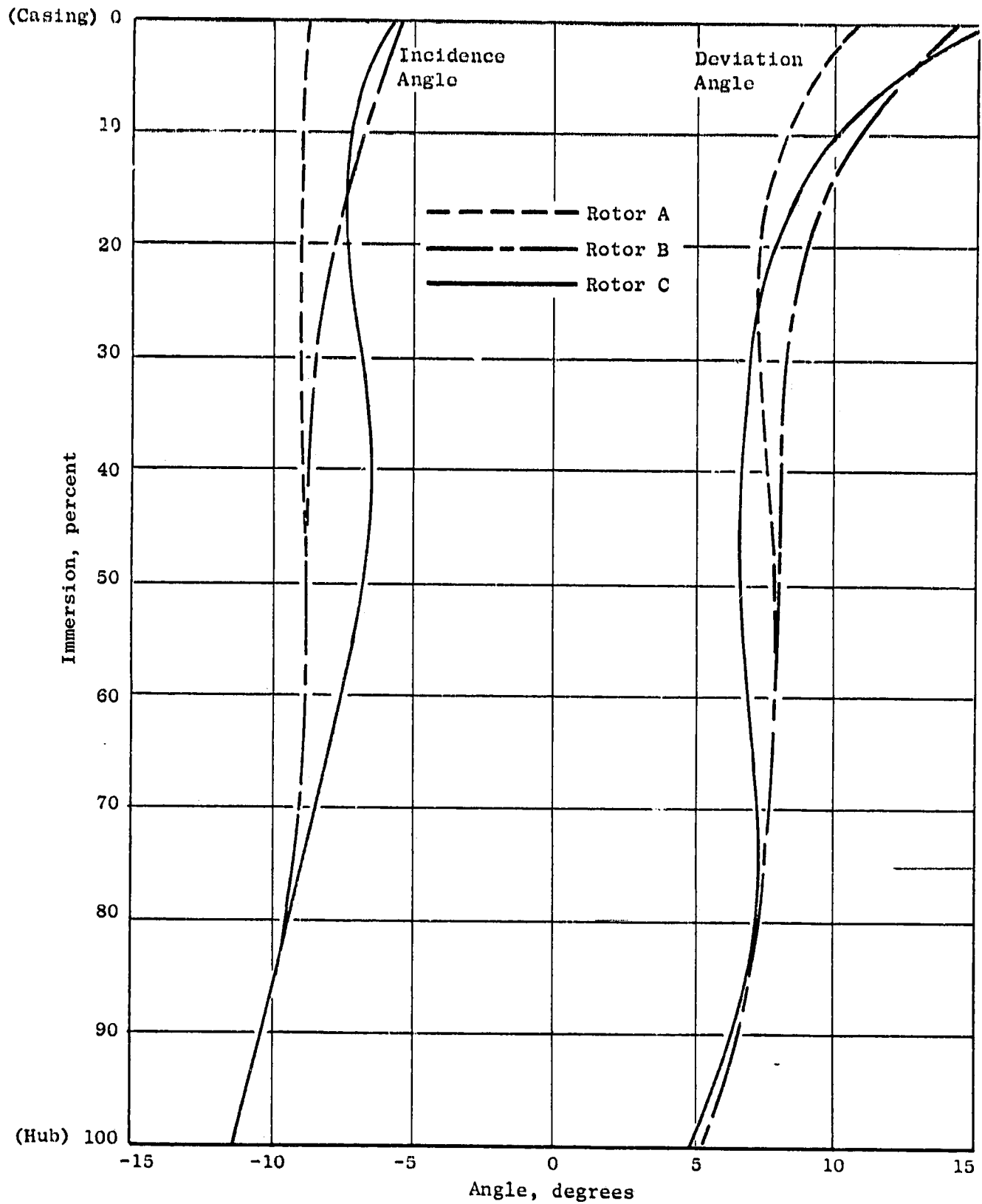


Figure 12. Incidence and Deviation Angle Versus Percent Immersion for Rotors A, B, and C.

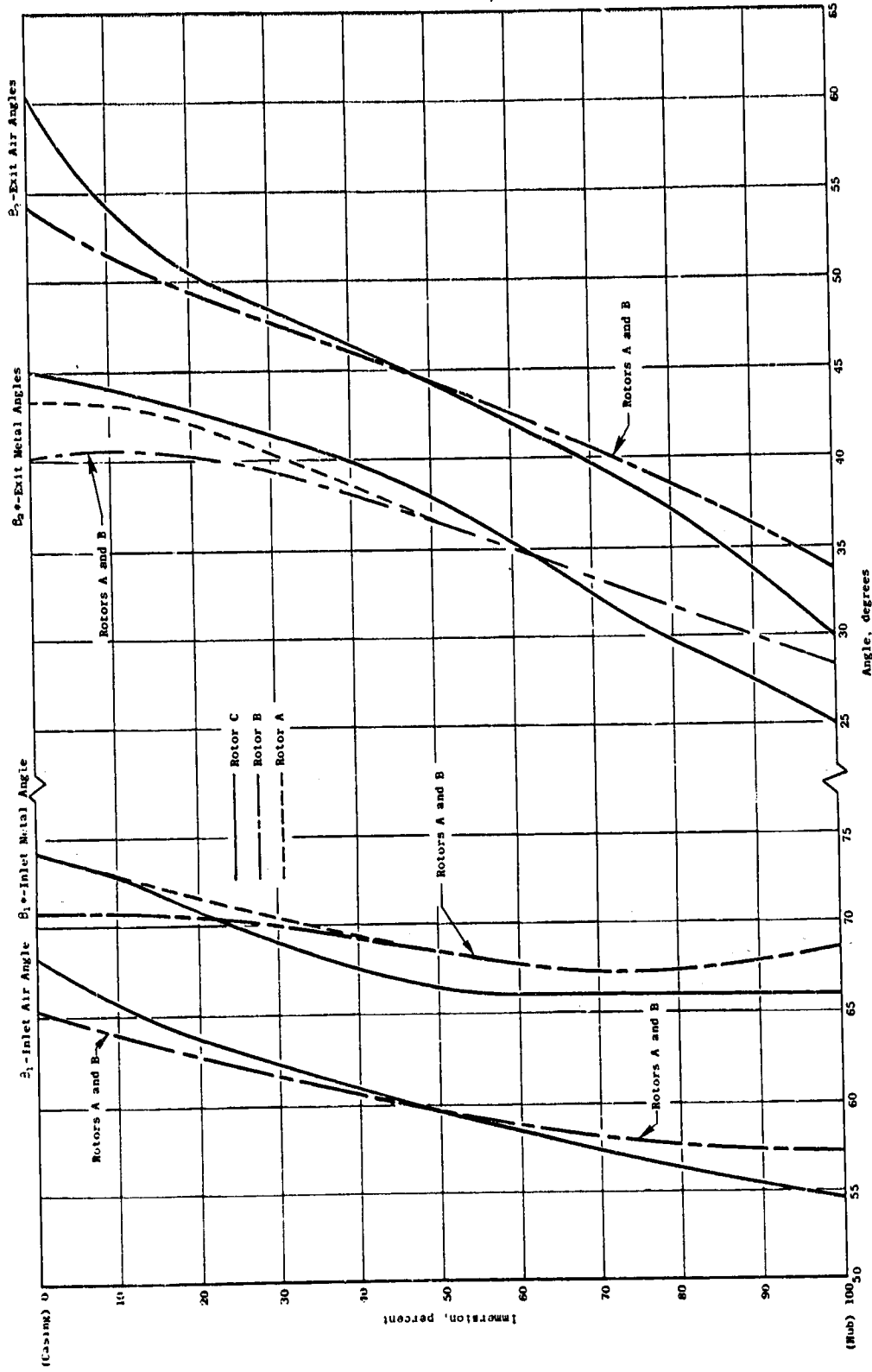


Figure 13. Radial Variation of Relative Air Angles and Leading and Trailing Edge Metal Angles for Rotors A, B, and C.

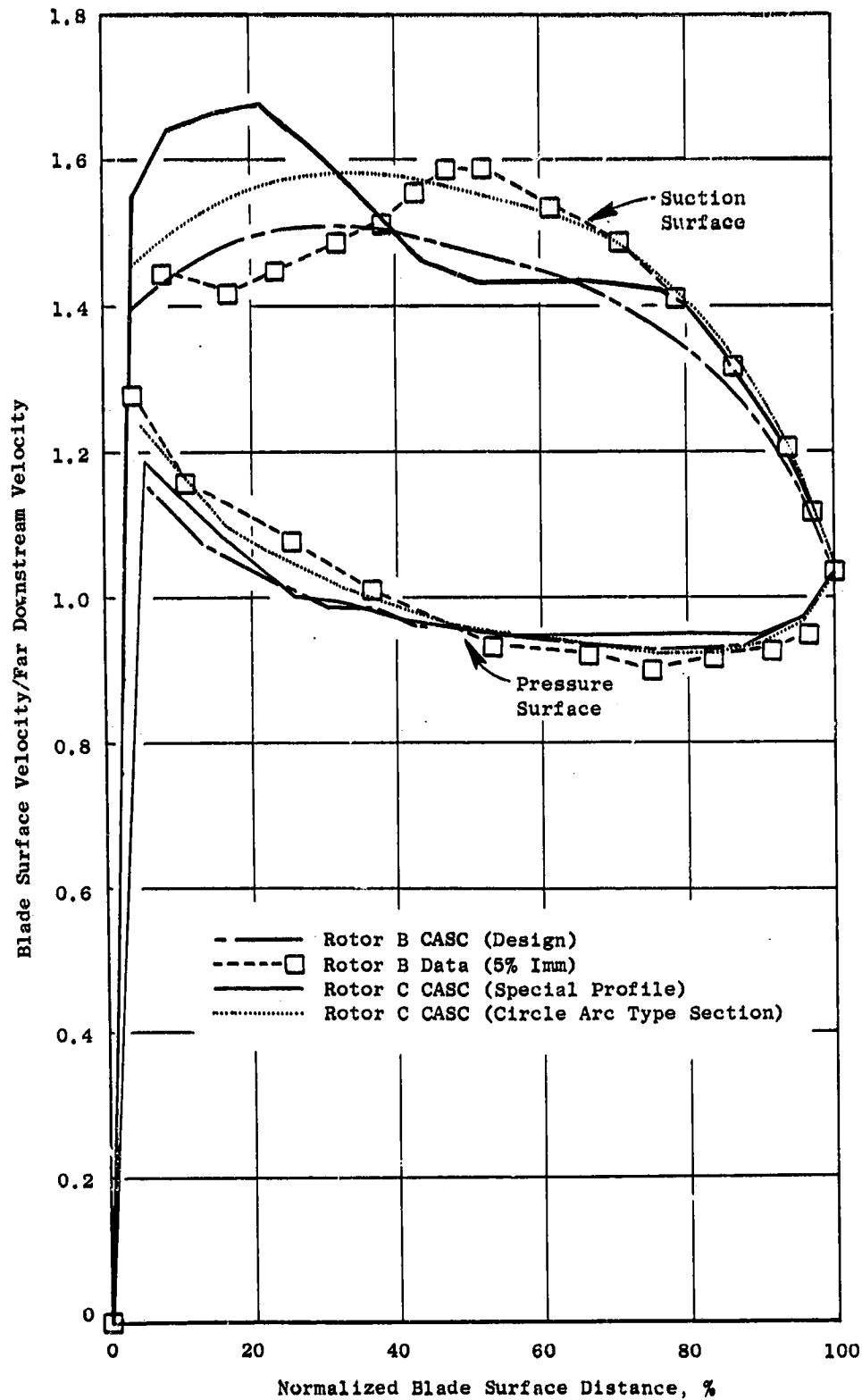


Figure 14. Comparison of the Normalized Blade Surface Velocity Distributions for the Tip Sections of Rotors B and C.

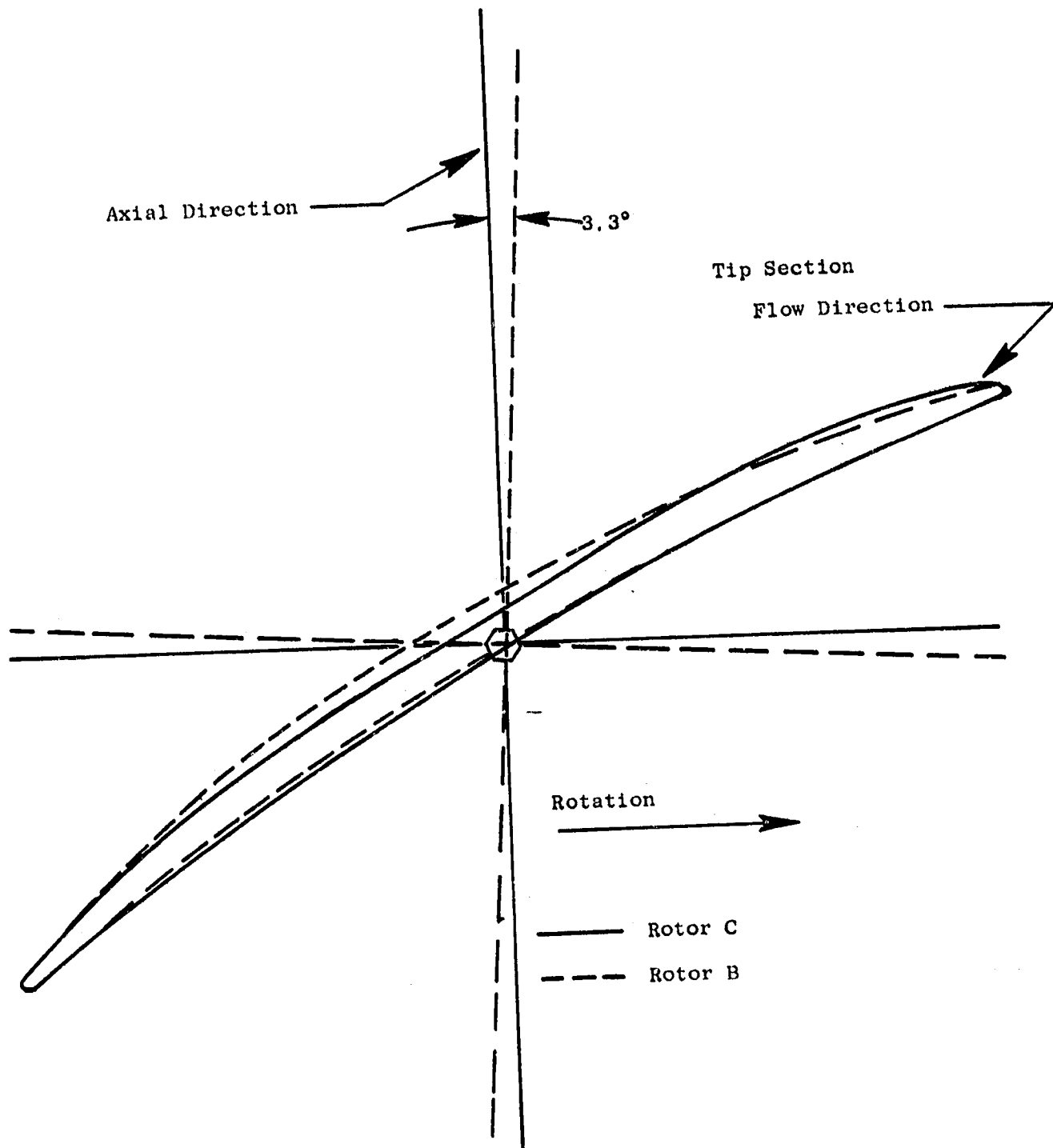


Figure 15. Comparison of Rotor C and Rotor B Tip Sections.

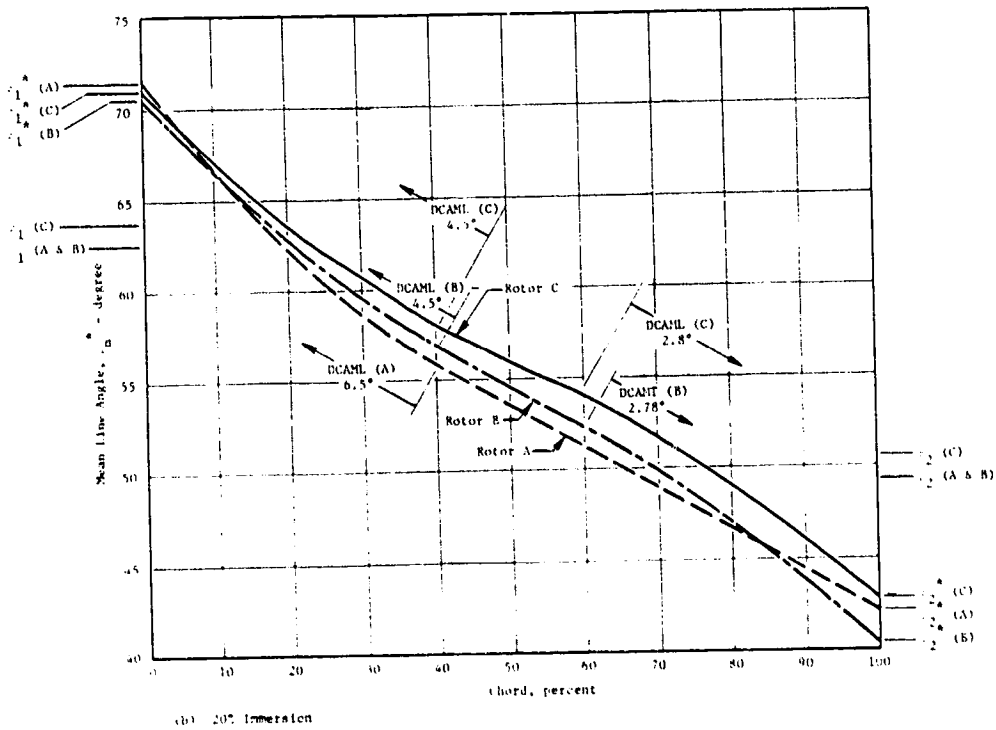
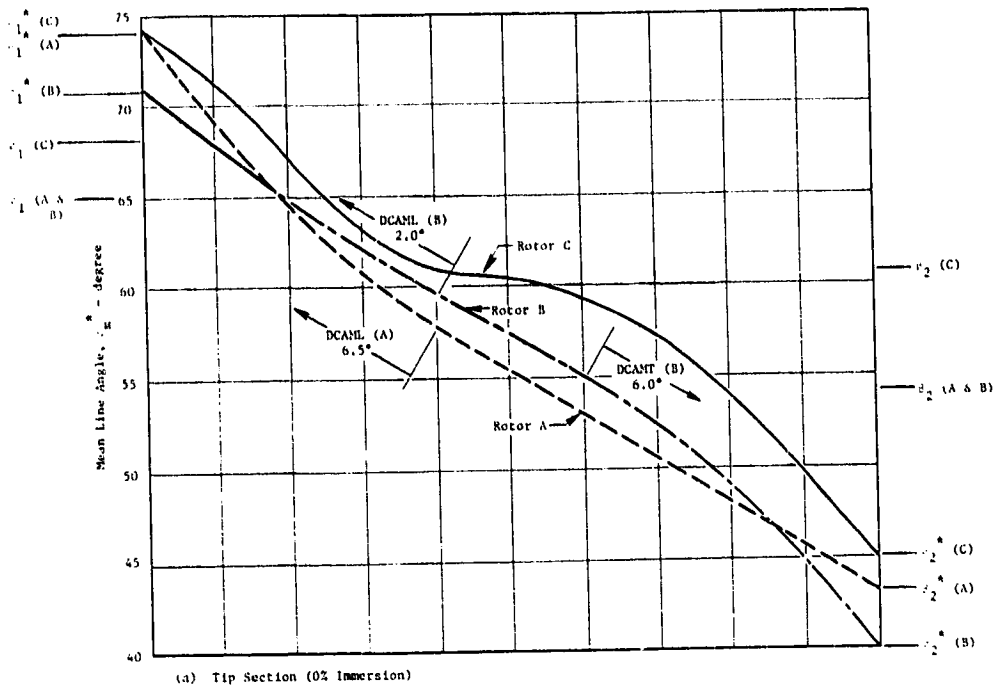
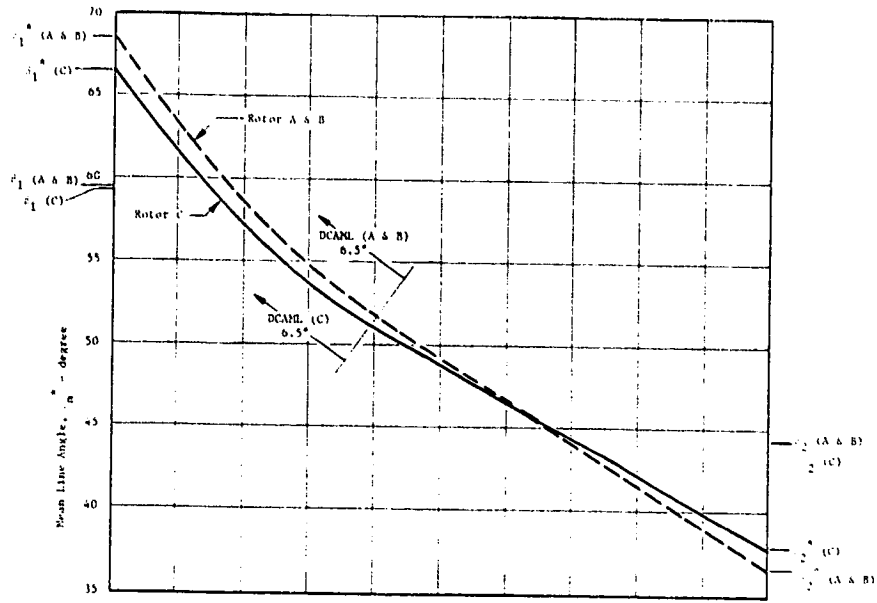


Figure 16. Comparison of the Chordwise Variation of Mean Line Angles for Rotors A, B, and C at 0% and 20% Radial Immersion from the Casing.



(a) 50% Immersion

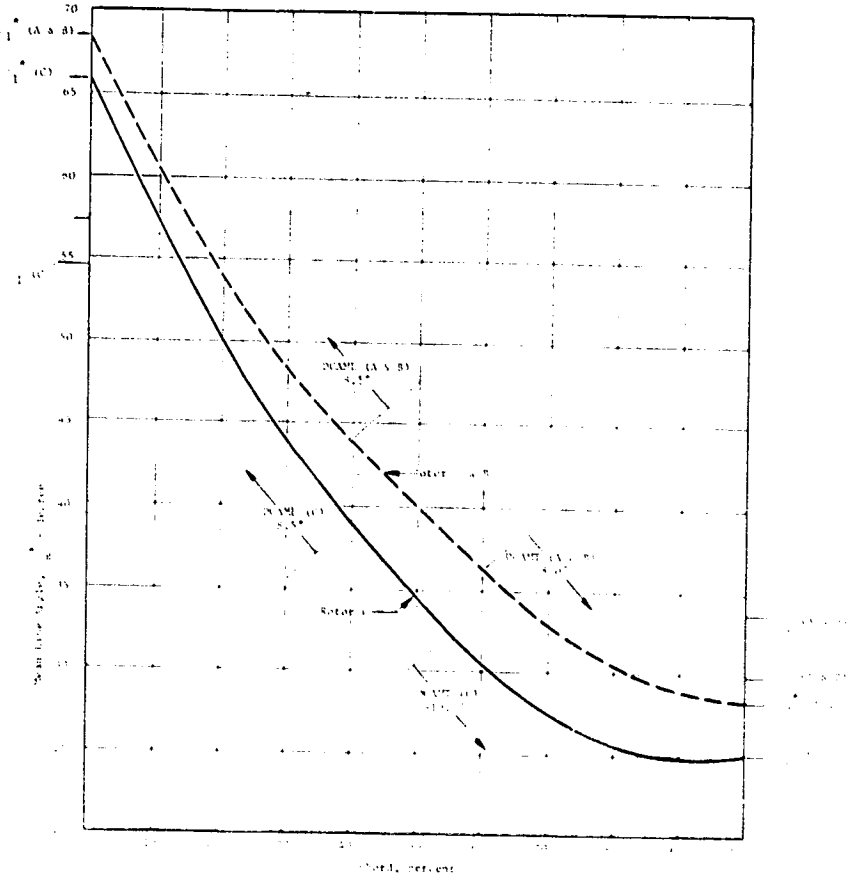


Figure 17. Comparison of the Chordwise Variation of Mean Line Angles for Rotors A, B, and C at 50% and 100% Radial Immersion from the Casing.

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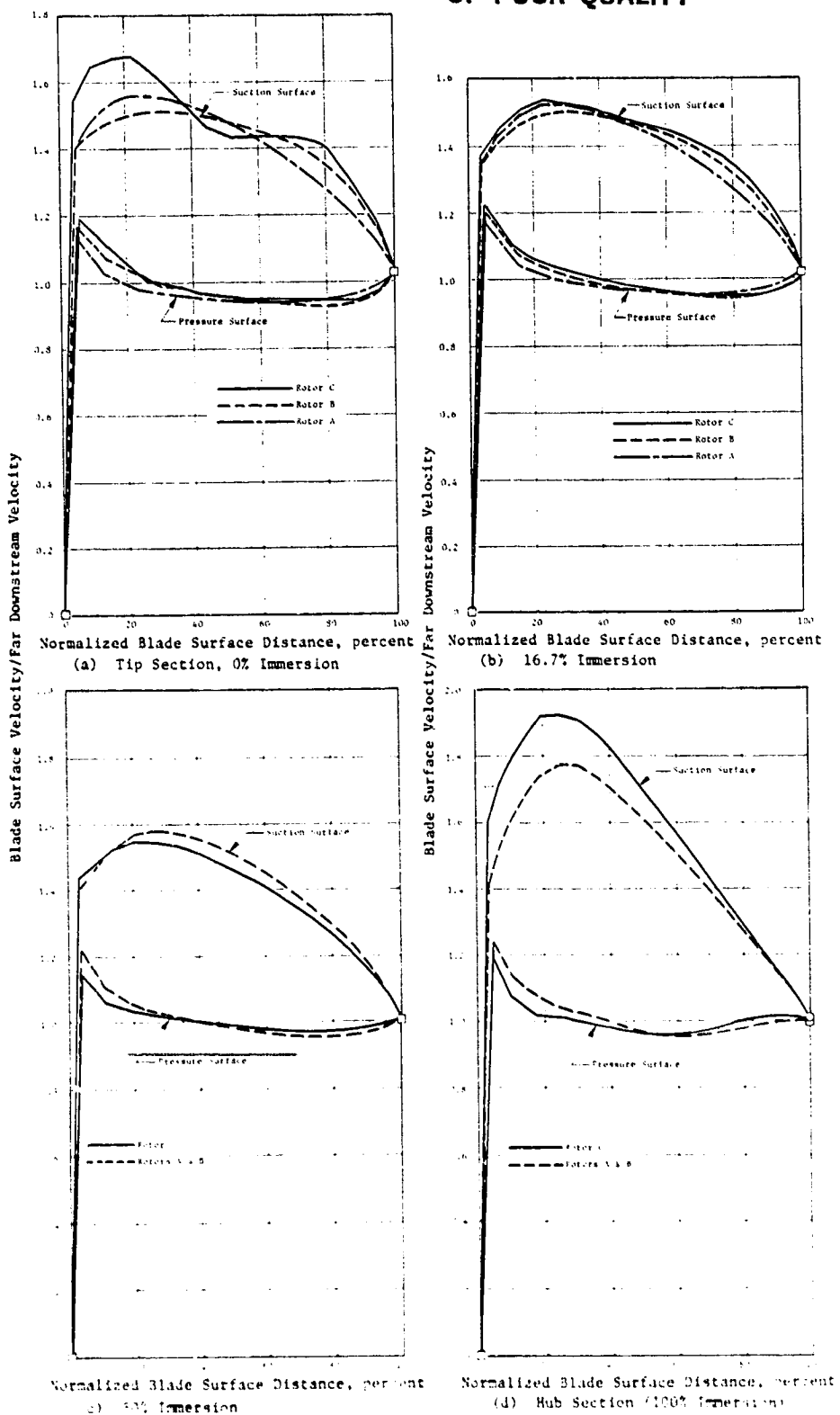


Figure 18. Comparison of the Blade Surface Velocity Distributions for Rotors A, B, and C at 0%, 16.7%, 50%, and 100% Radial Immersion from the Casing.

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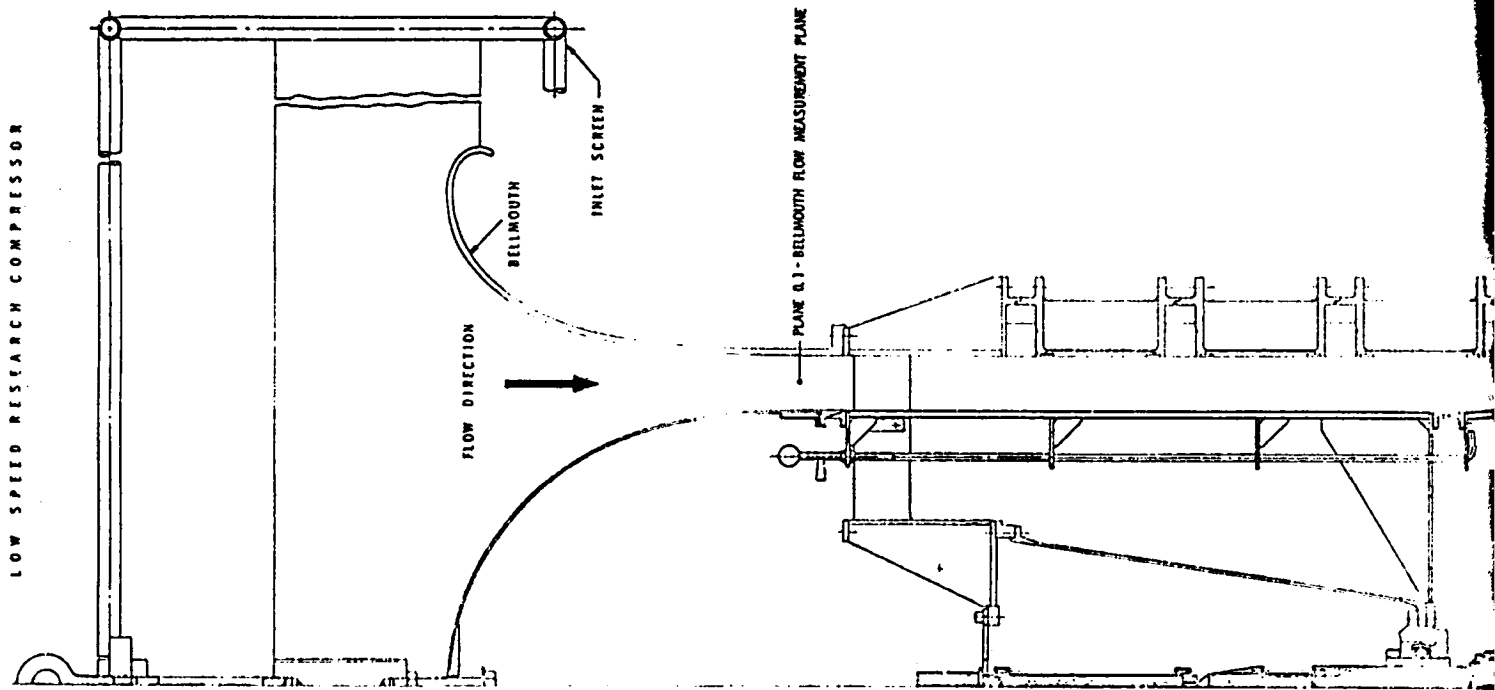
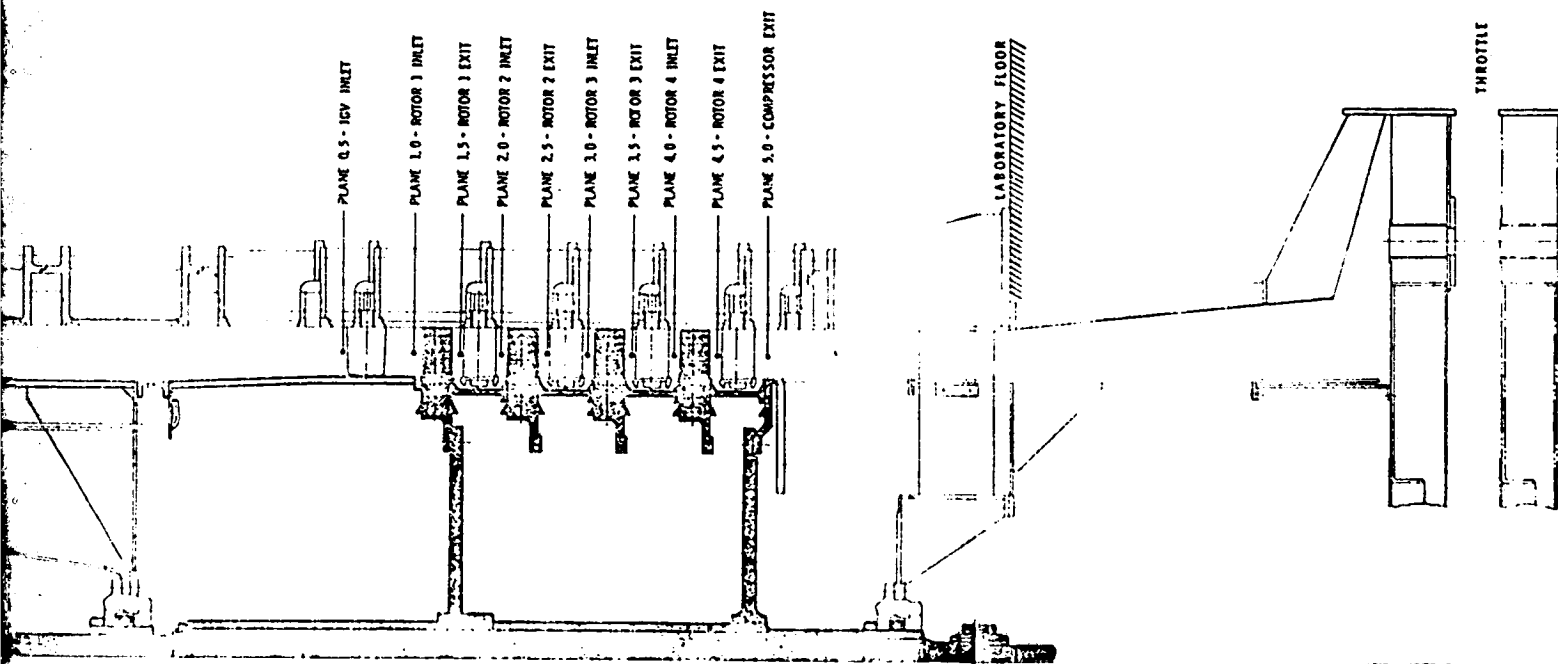


Figure 19. Four-Stage Compressor Configuration

EOLDOUT FRAME



Configuration Tested in the NASA-GE Core Compressor Exit Stage Study.

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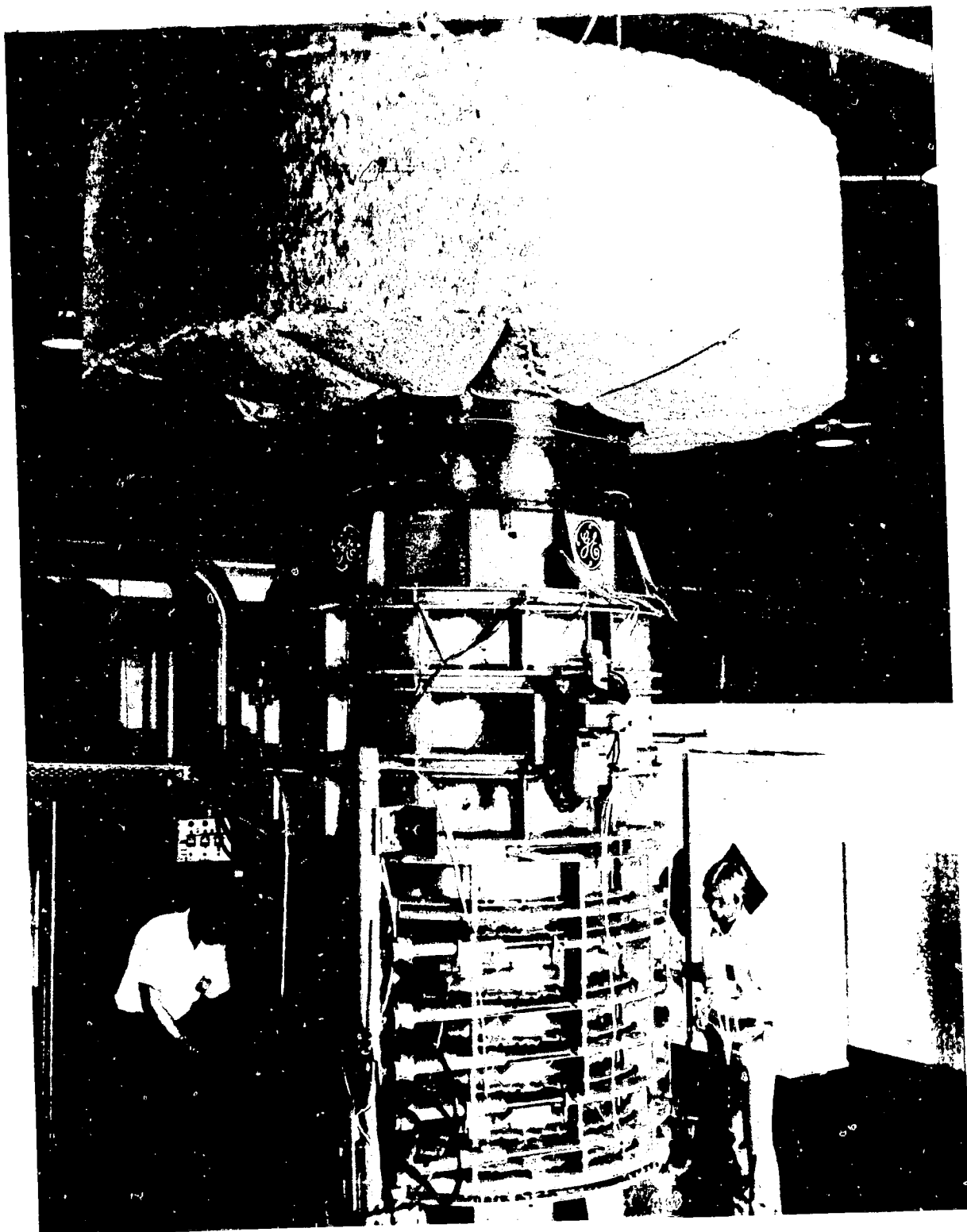


Figure 20. Photograph of the Low Speed Research Compressor.

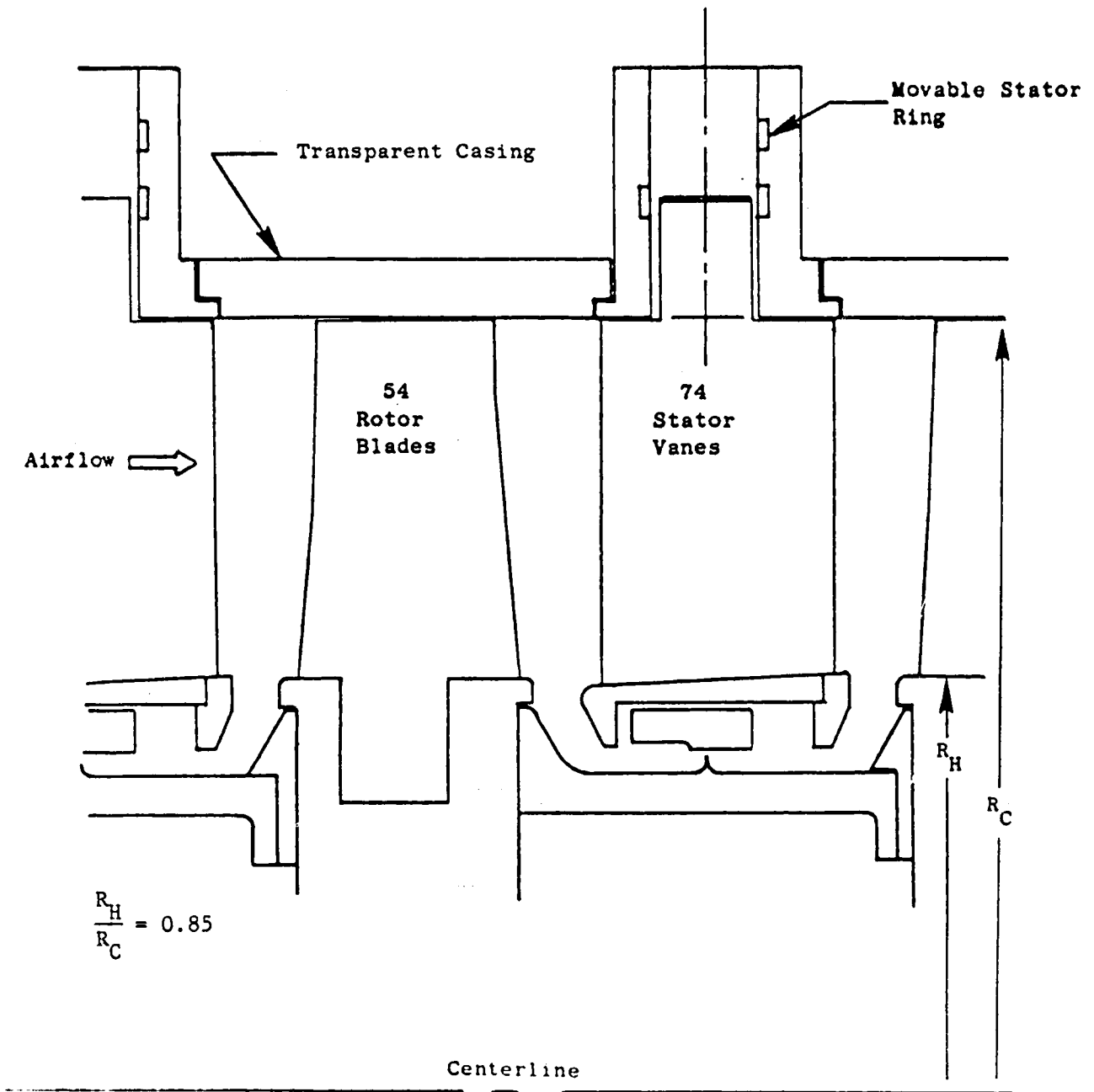


Figure 21. Cross Section of 0.85 Radius Ratio Compressor Stage.

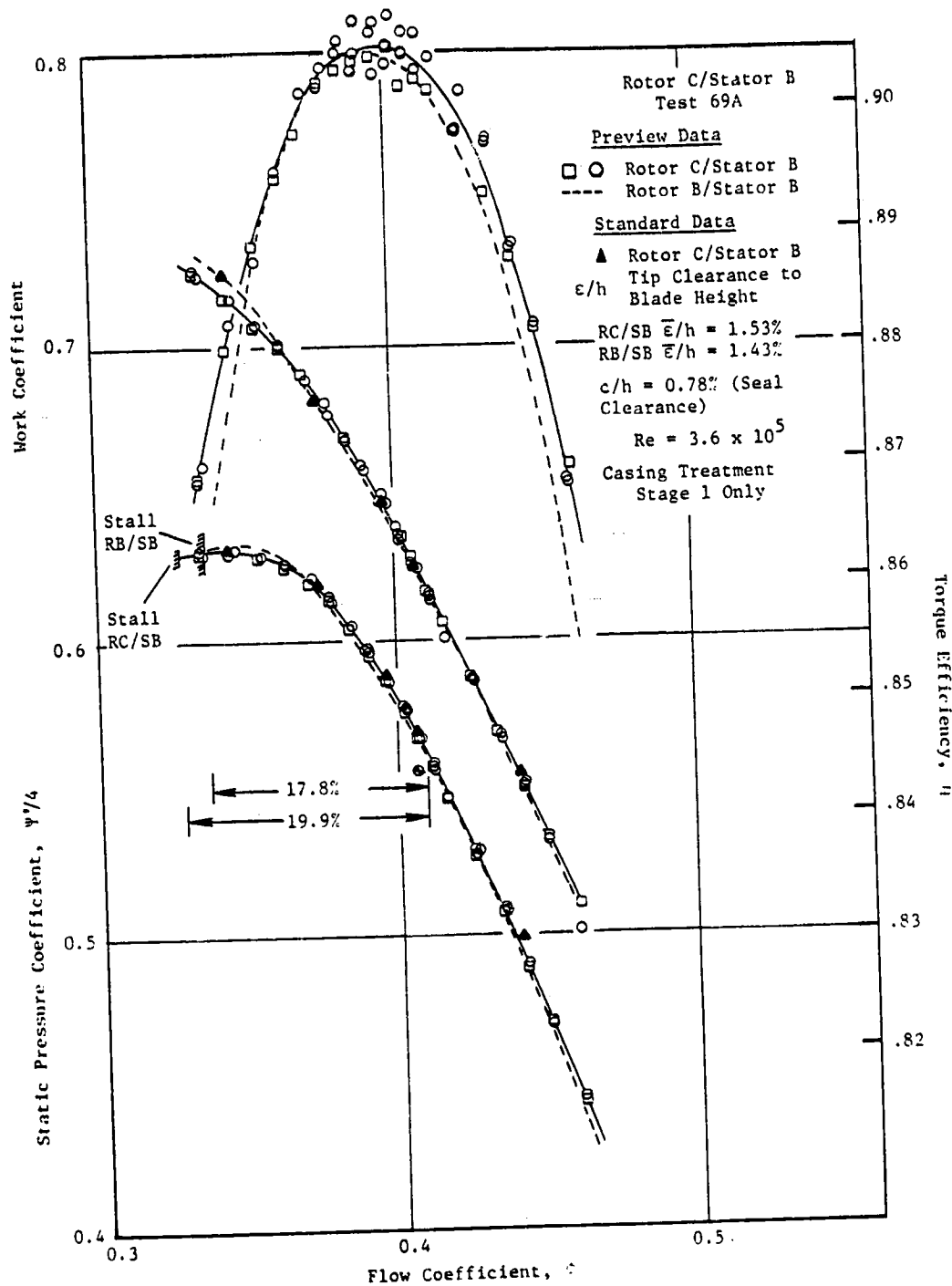


Figure 22. Overall Performance of Four-Stage Rotor C/Stator B Configuration Compared with That of Rotor B/Stator B.

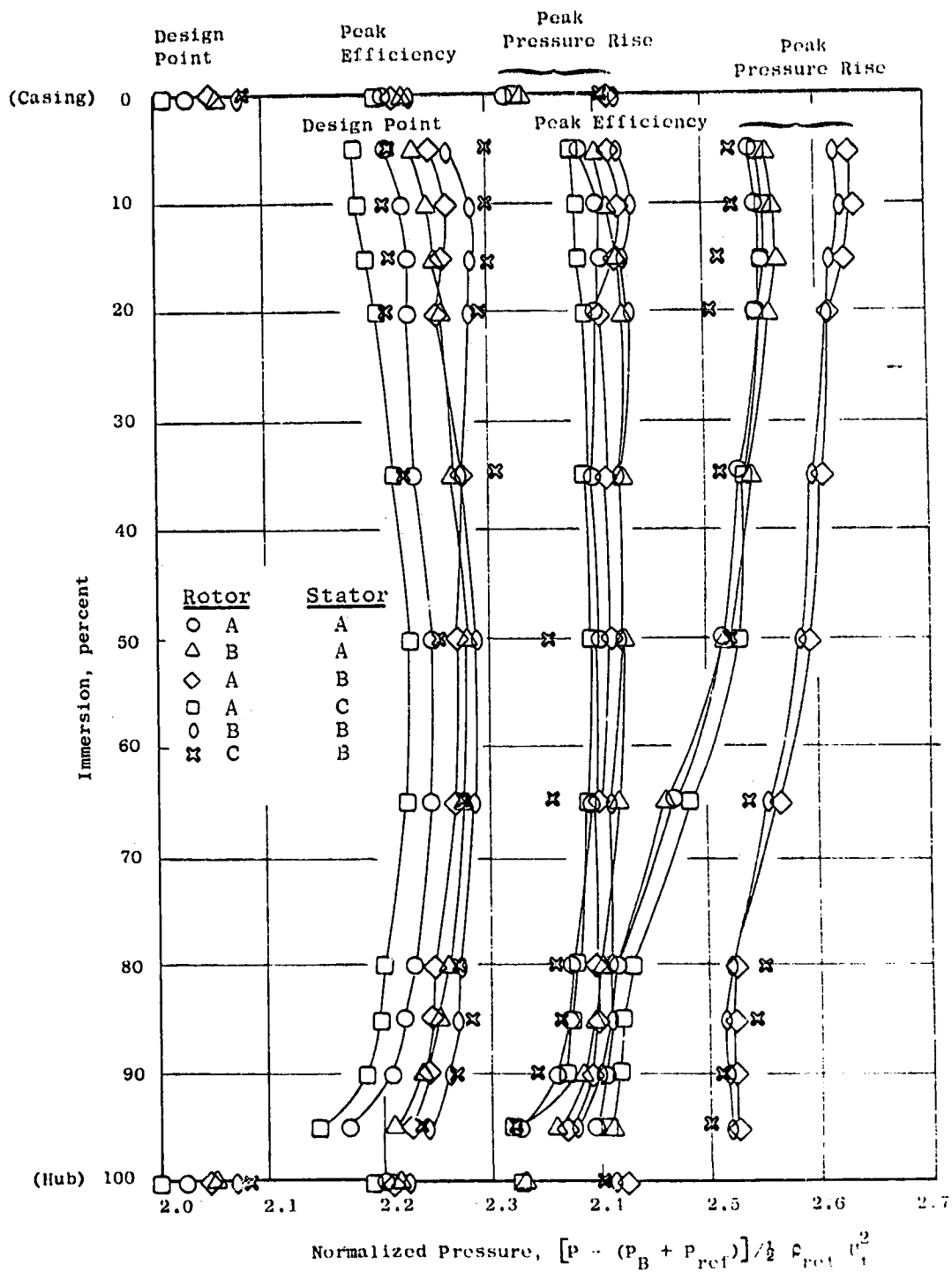


Figure 23. Radial Variations of Normalized Total Pressure Including Casing and Hub Normalized Static Pressure at the Casing Discharge for Various Throttle Settings, Four-Stage Configurations.

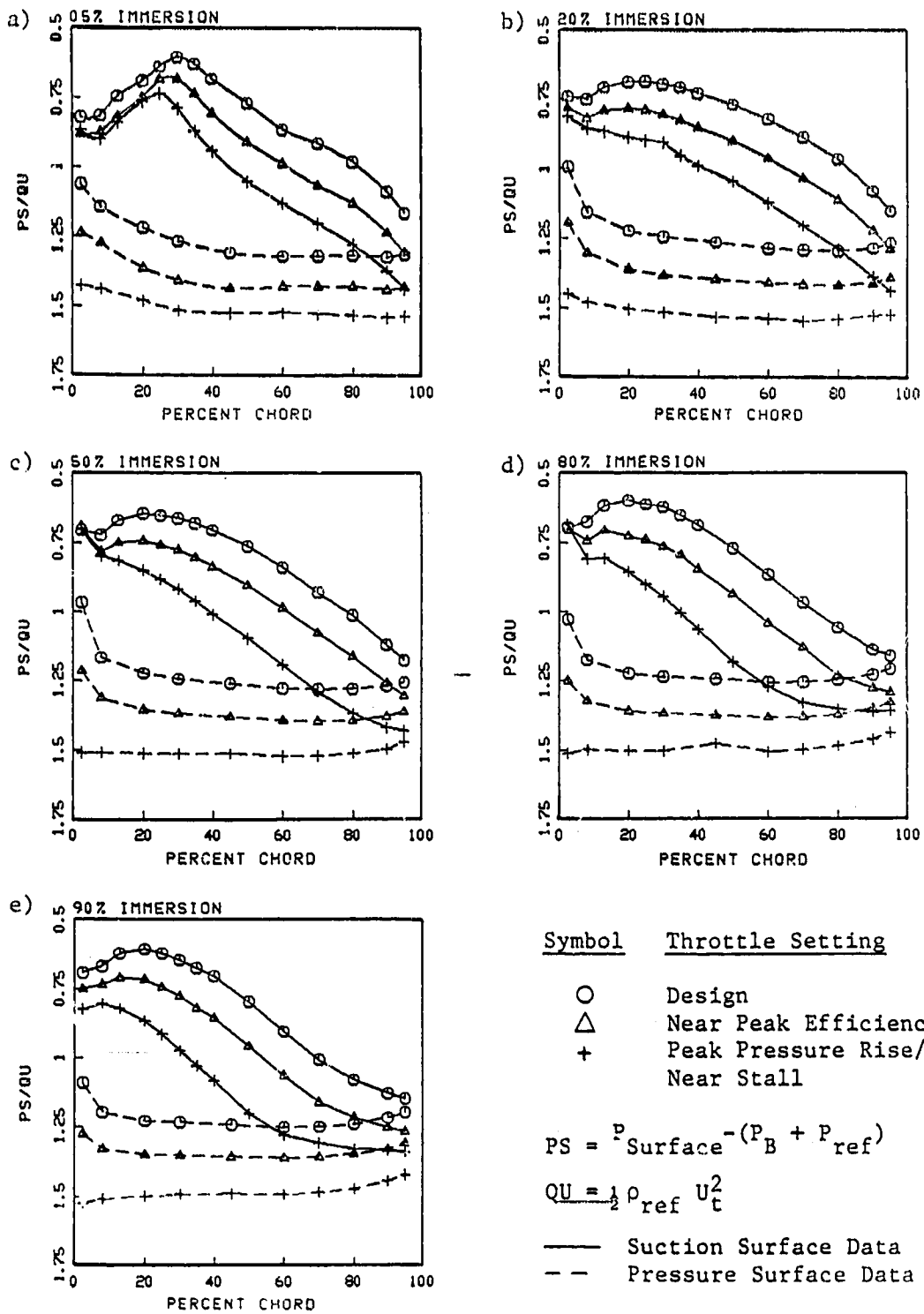


Figure 24. Rotor Blade Surface Static Pressure Measurements for the Four-Stage Rotor C/Stator B Configuration, Third Stage Tested.

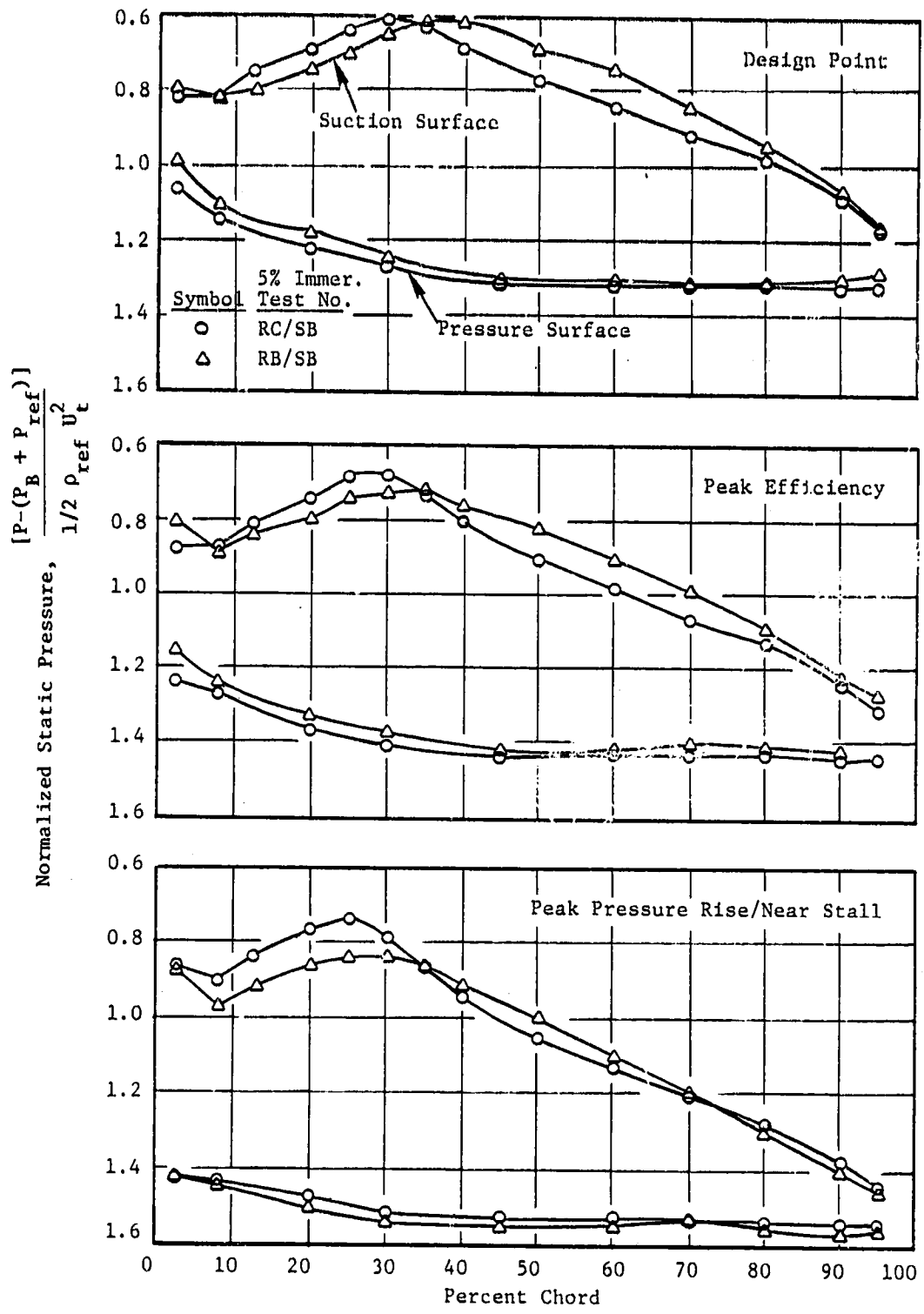


Figure 25. Static Pressure Measurements on the Blade Surface Near the Tip of Rotor C, Four-Stage Configuration, Third Stage Tested.

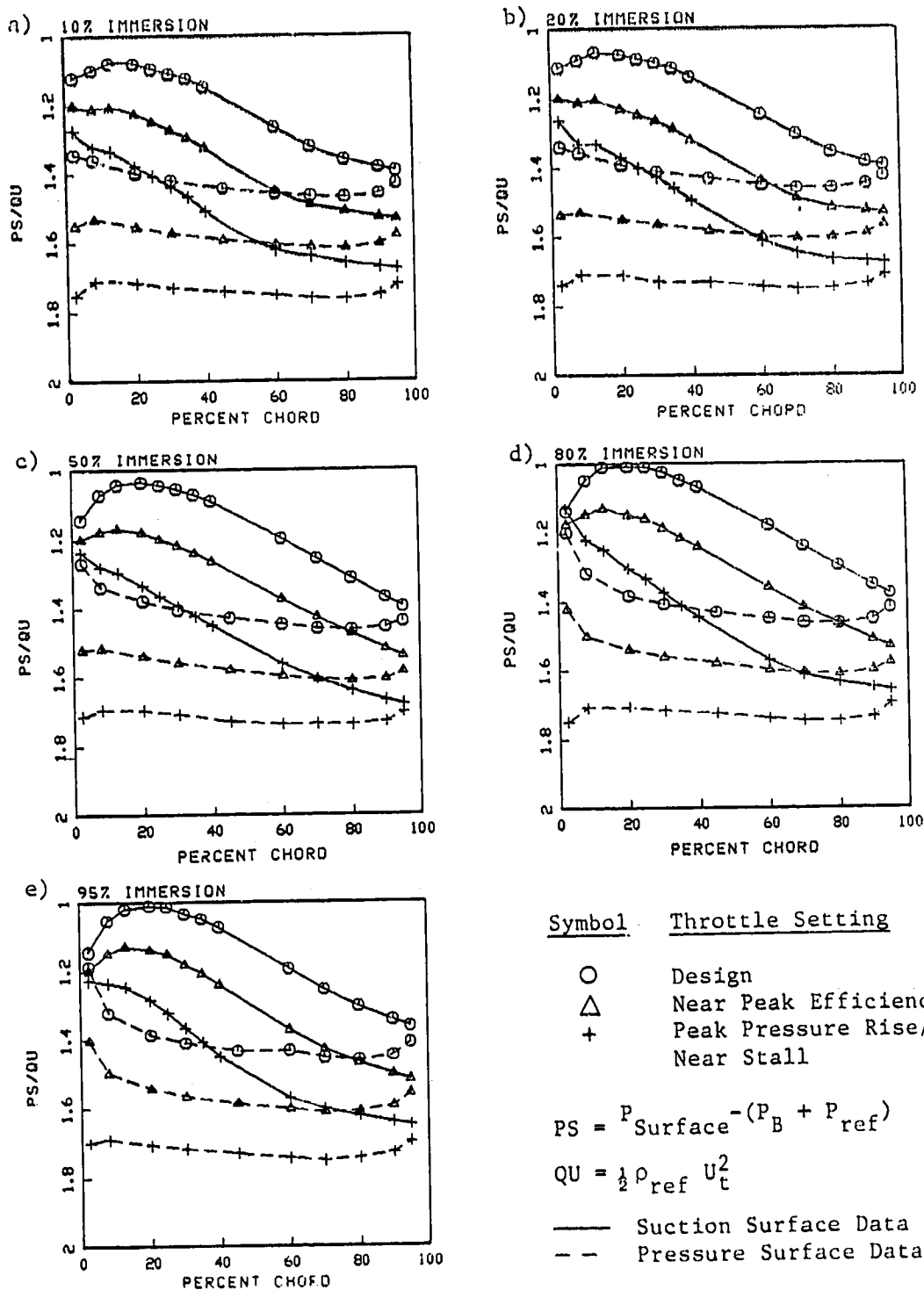


Figure 26. Stator Vane Surface Static Pressure Measurements for the Four-Stage Rotor C/Stator B Configuration, Third Stage Tested.

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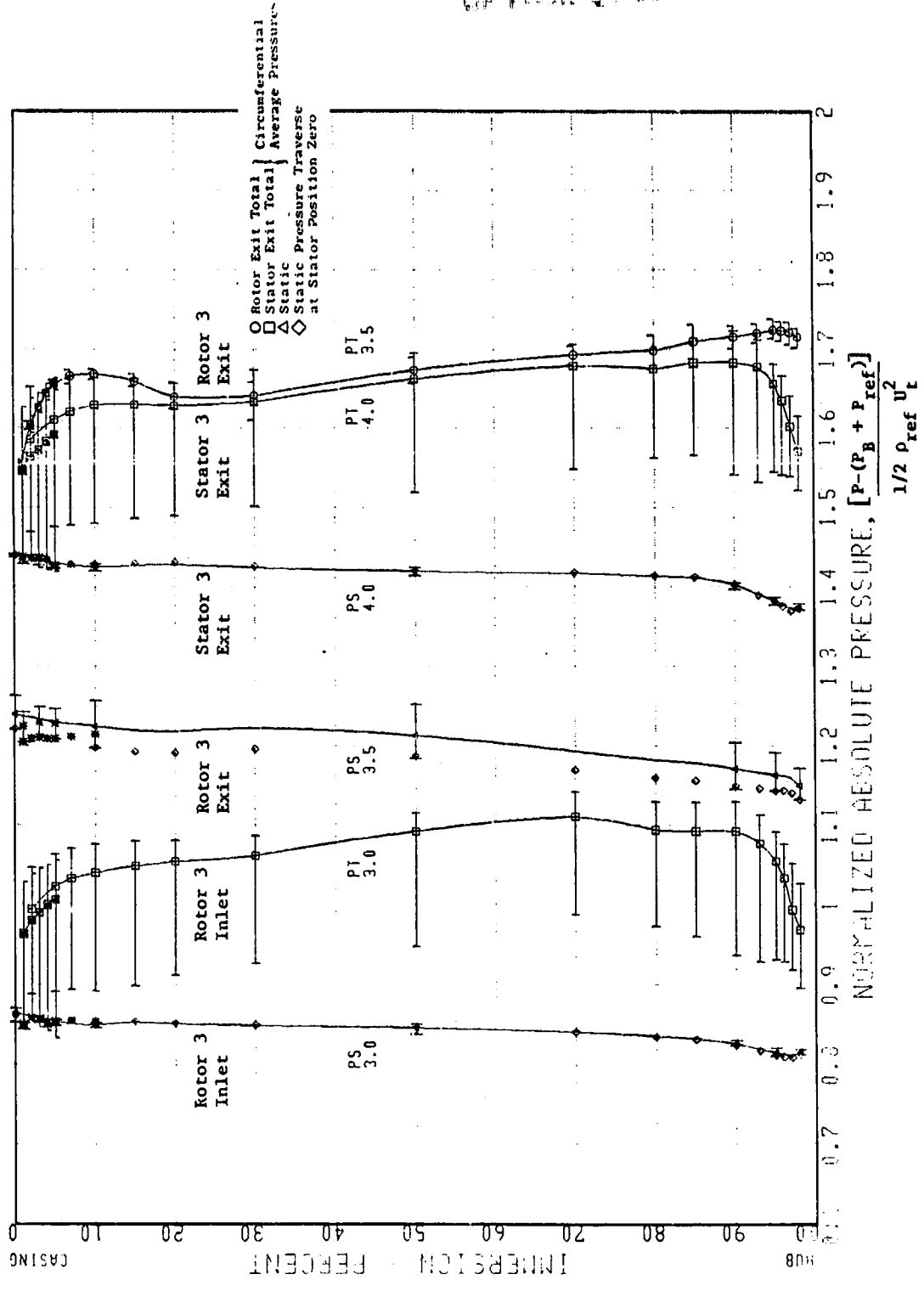


Figure 27. Normalized Absolute Total Pressures and Static Pressures for Rotor C/
Stator B Four-Stage Configuration, Third Stage Tested, Design
Point Throttle.

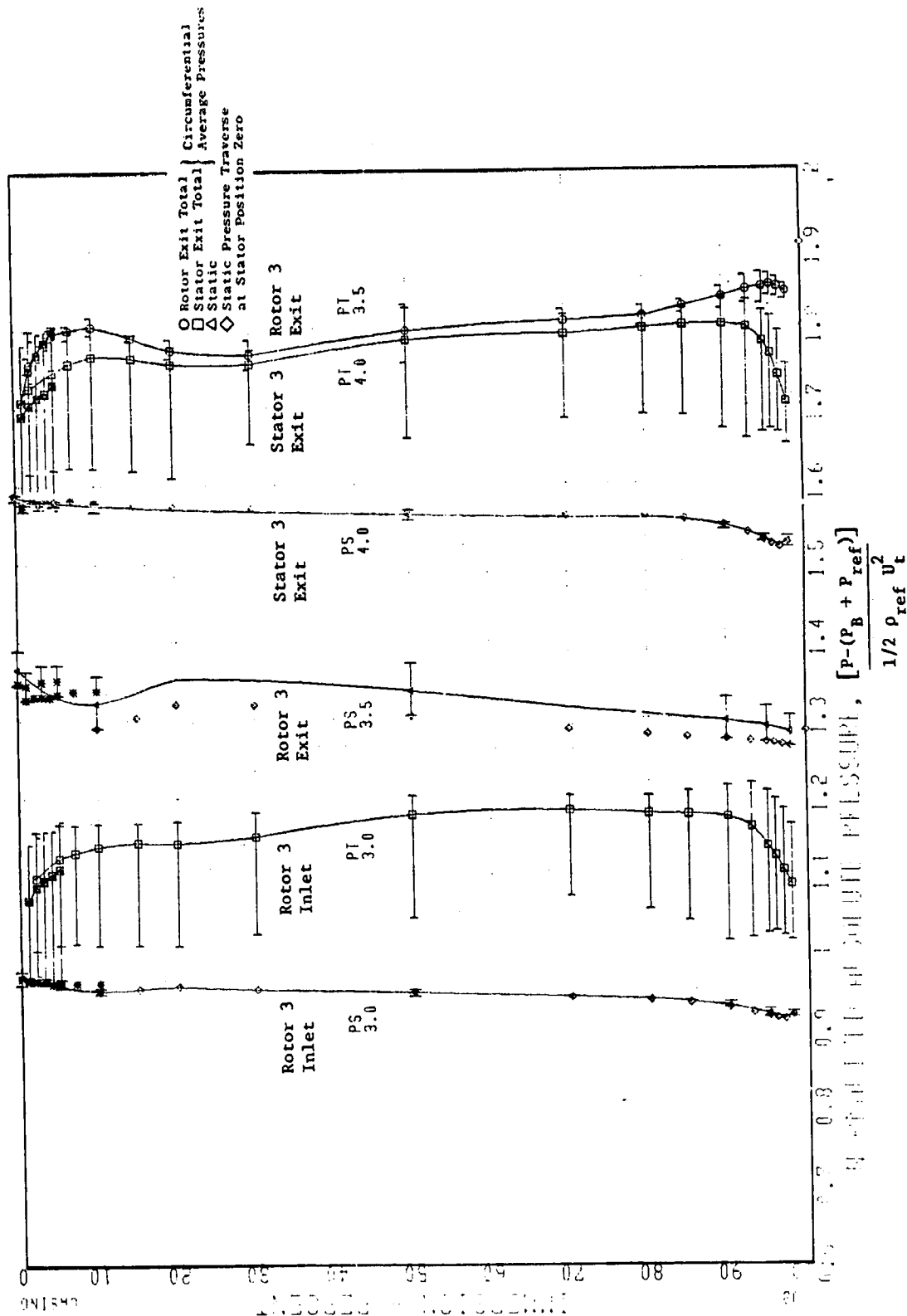


Figure 28. Normalized Absolute Total Pressures and Static Pressures for Rotor C/ Stator B Four-Stage Configuration, Third Stage Tested, Near Peak Efficiency Throttle.

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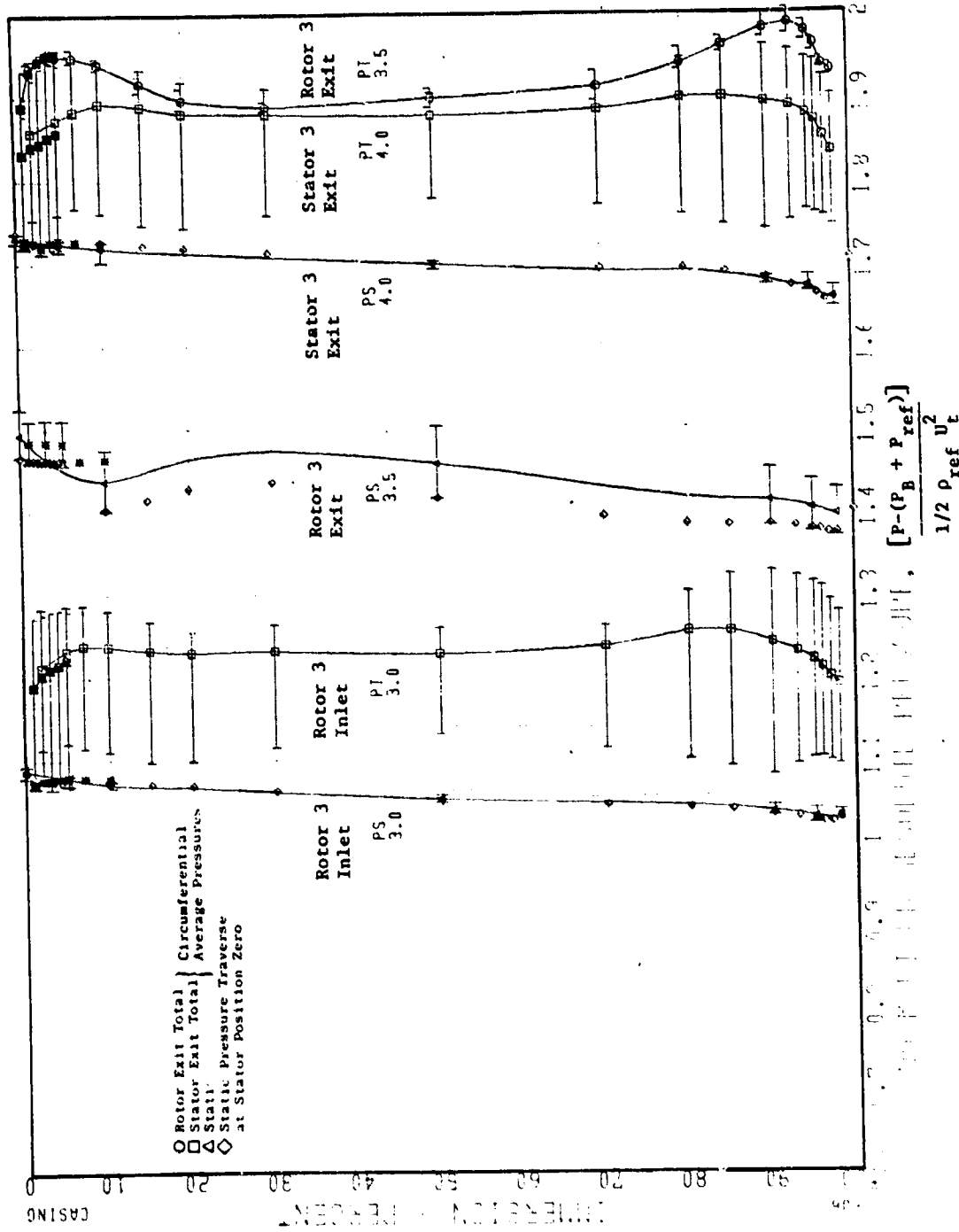


Figure 29. Normalized Absolute Total Pressures and Static Pressures for Rotor C/ Stator B Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise/Near Stall Throttle.

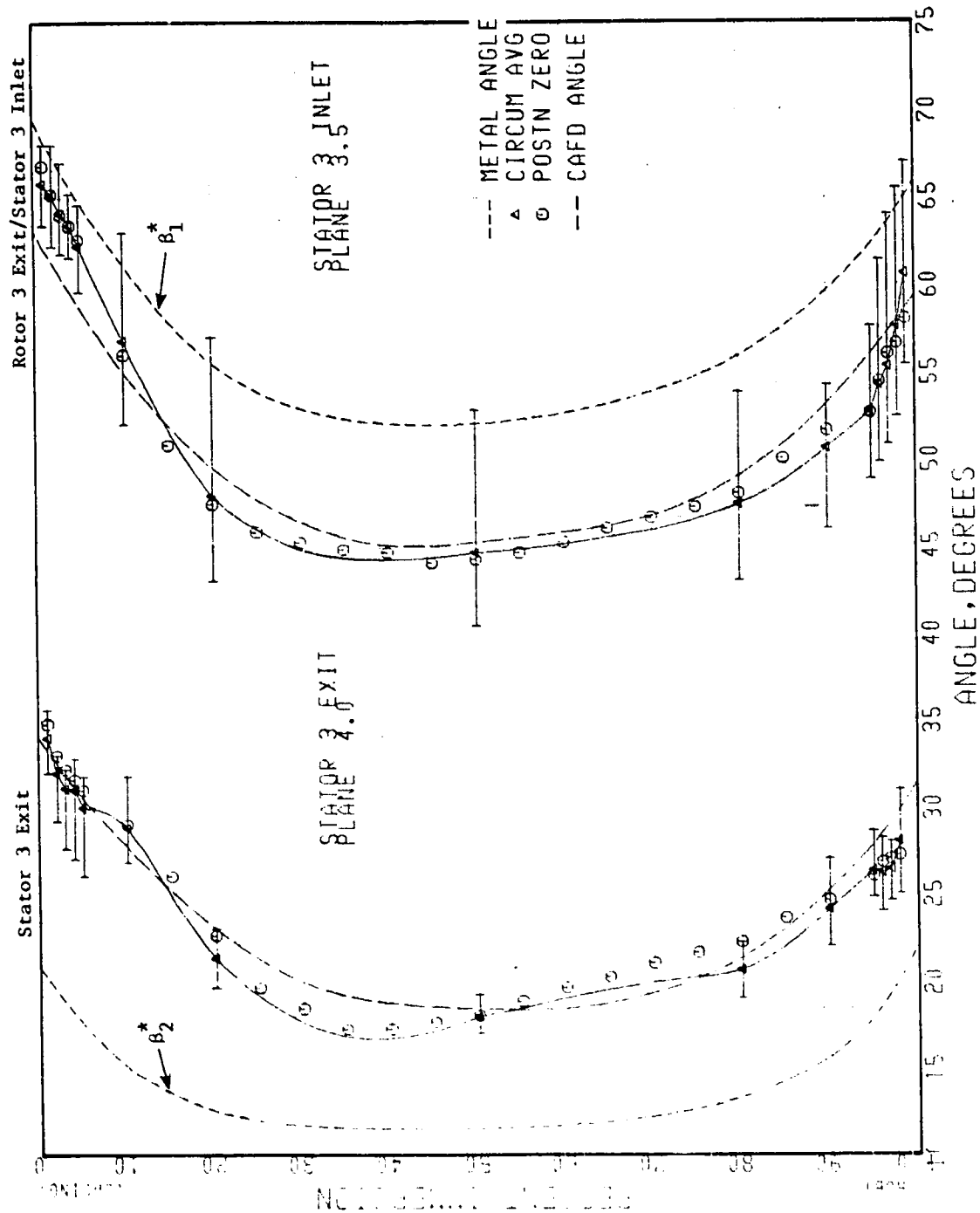


Figure 30. Absolute Flow Angles for Rotor C/Stator B Four-Stage Configuration, Third Stage Tested, Design Point Throttle.

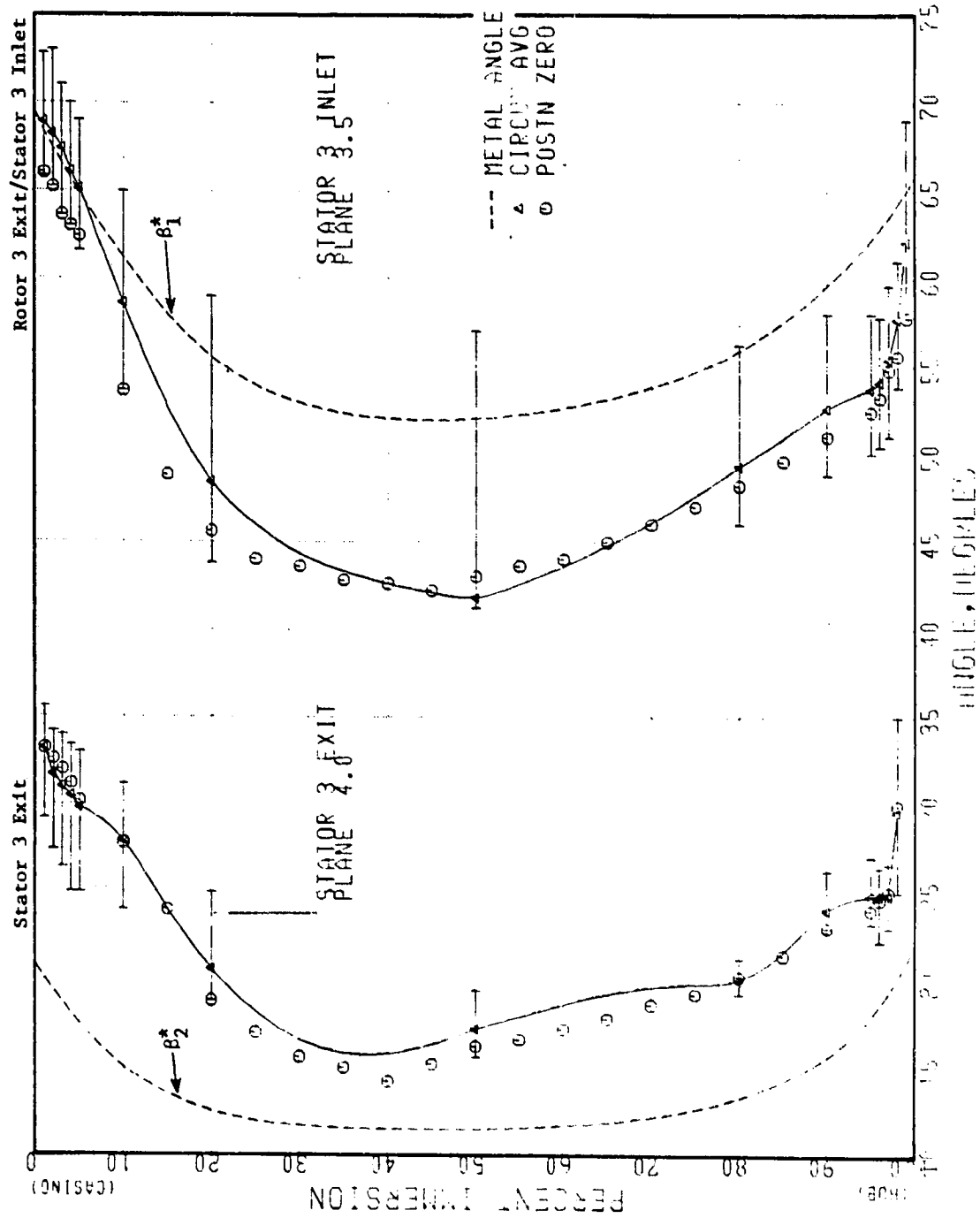


Figure 31. Absolute Flow Angles for Rotor C/Stator B Four-Stage Configuration, Third Stage Tested, Near Peak Efficiency Throttle.

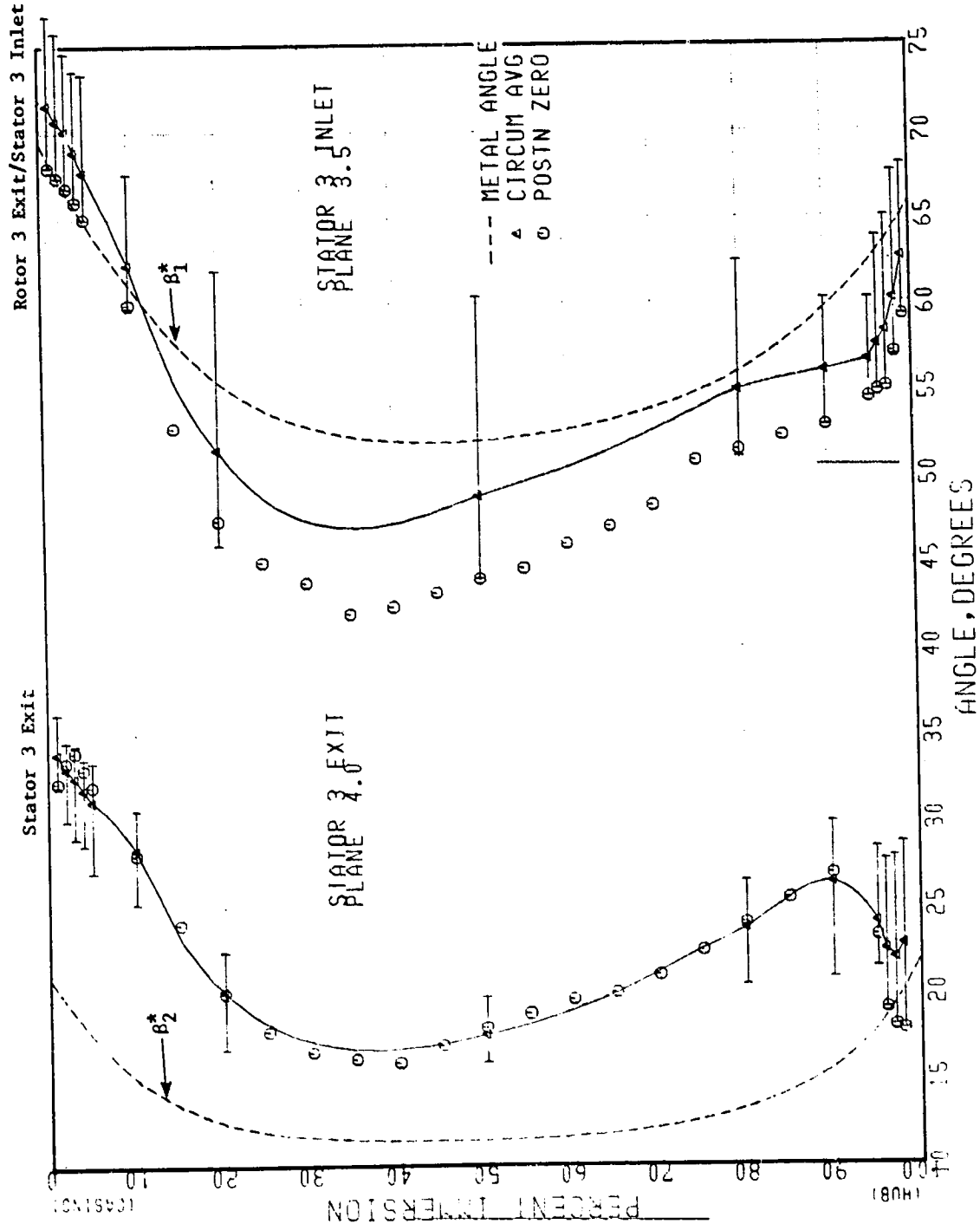


Figure 32. Absolute Flow Angles for Rotor C/Stator B Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise/Near Stall Throttle.

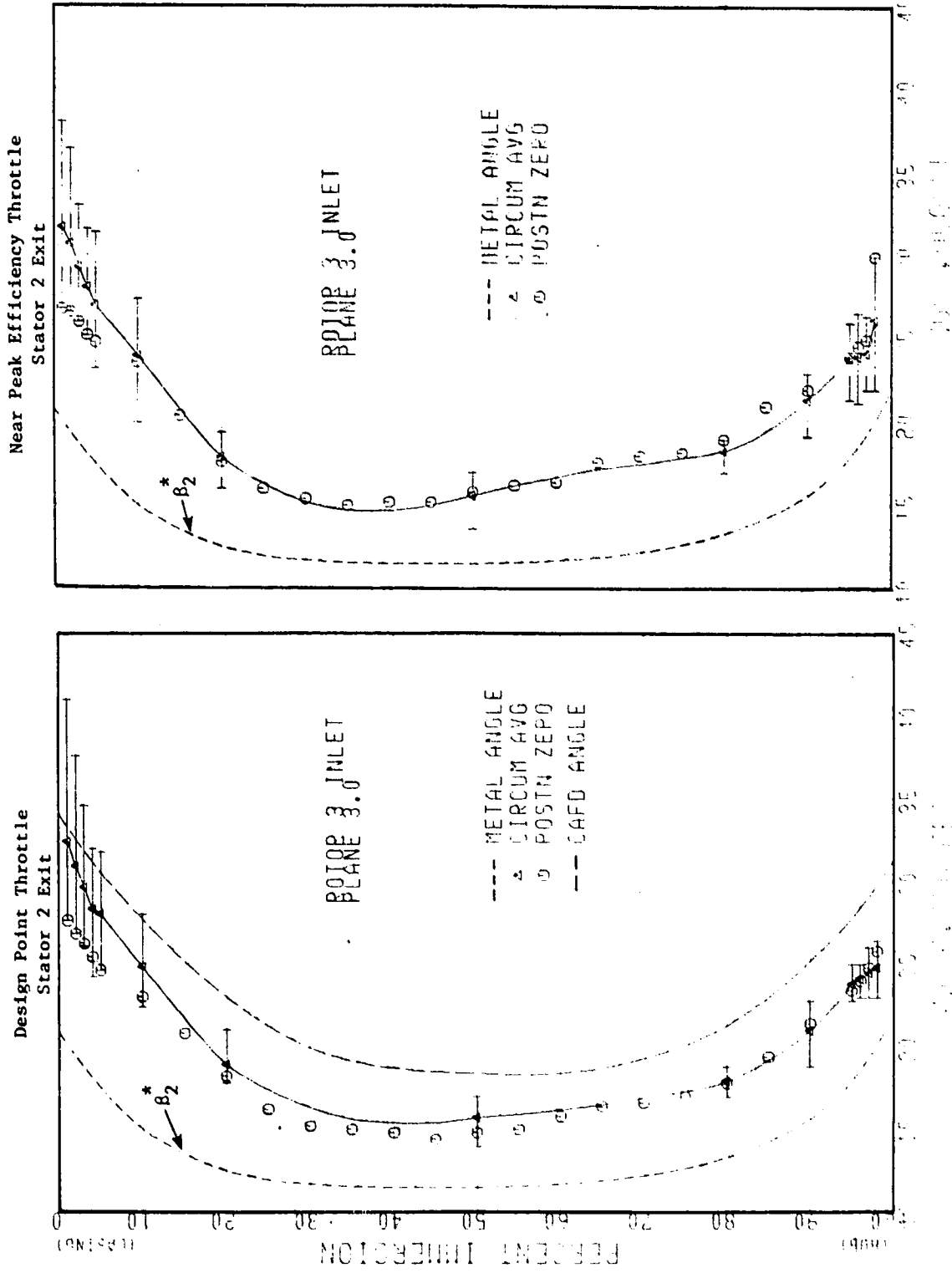


Figure 33. Absolute Flow Angles for Rotor C/Stator B Four-Stage Configuration, Third Stage Tested.

Peak Pressure Rise/Near Stall Throttle
Stator 2 Exit

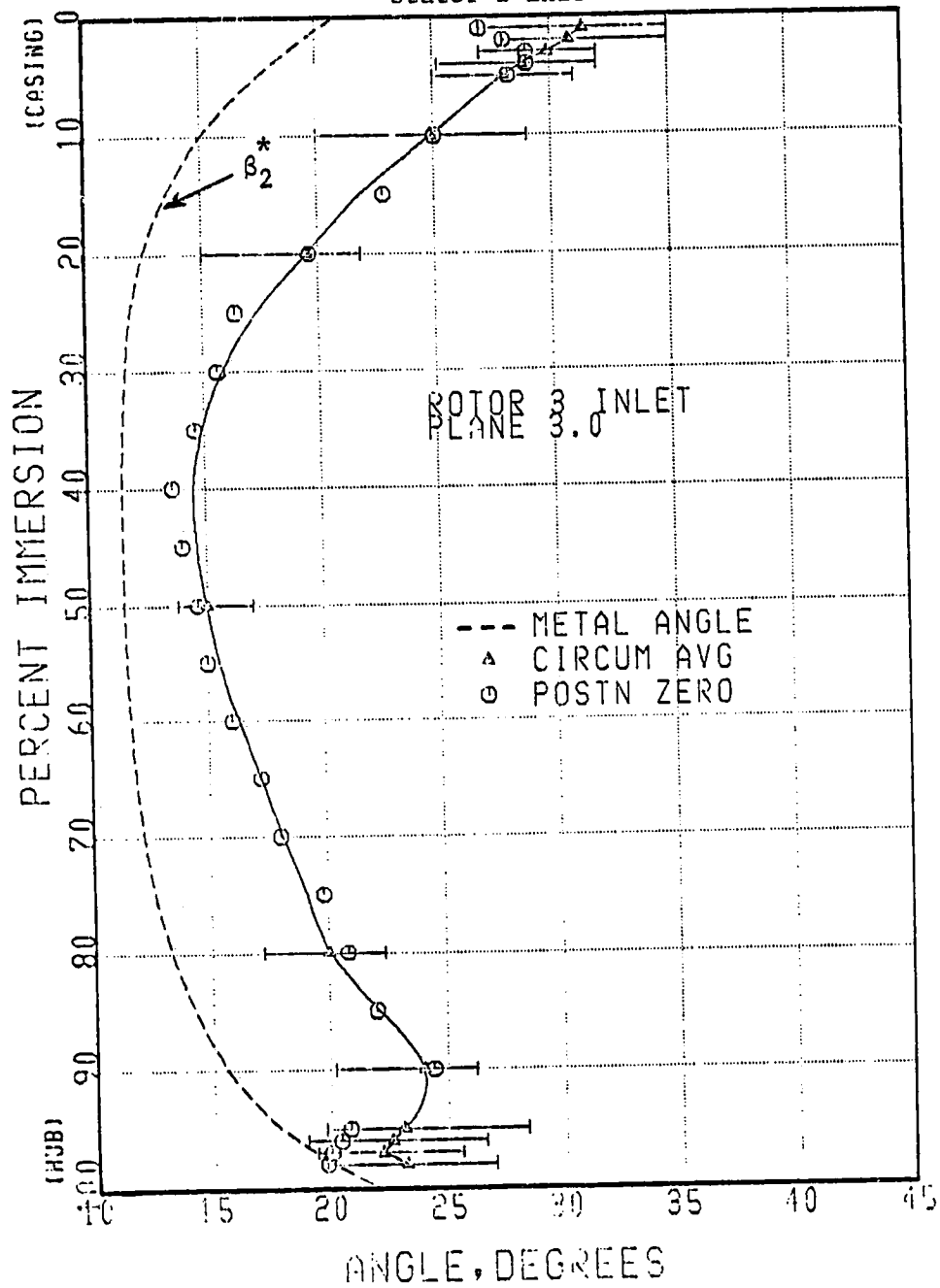


Figure 34. Absolute Flow Angles for Rotor C/Stator B
Four-Stage Configuration, Third Stage Tested.

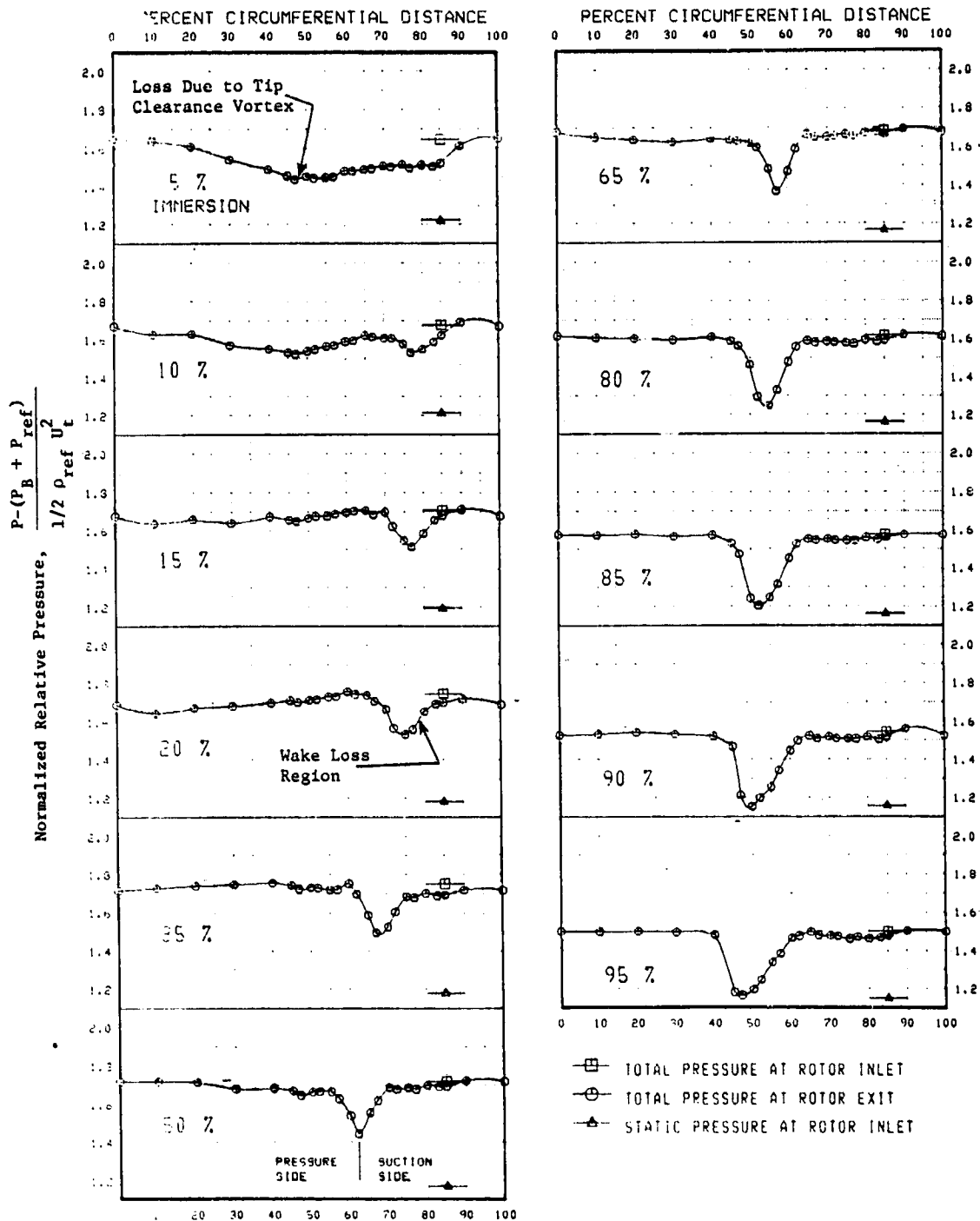


Figure 35. Circumferential Variation of Normalized Relative Total Pressure at Rotor C Exit, Four-Stage Configuration, Third Stage Tested, Design Point Throttle.

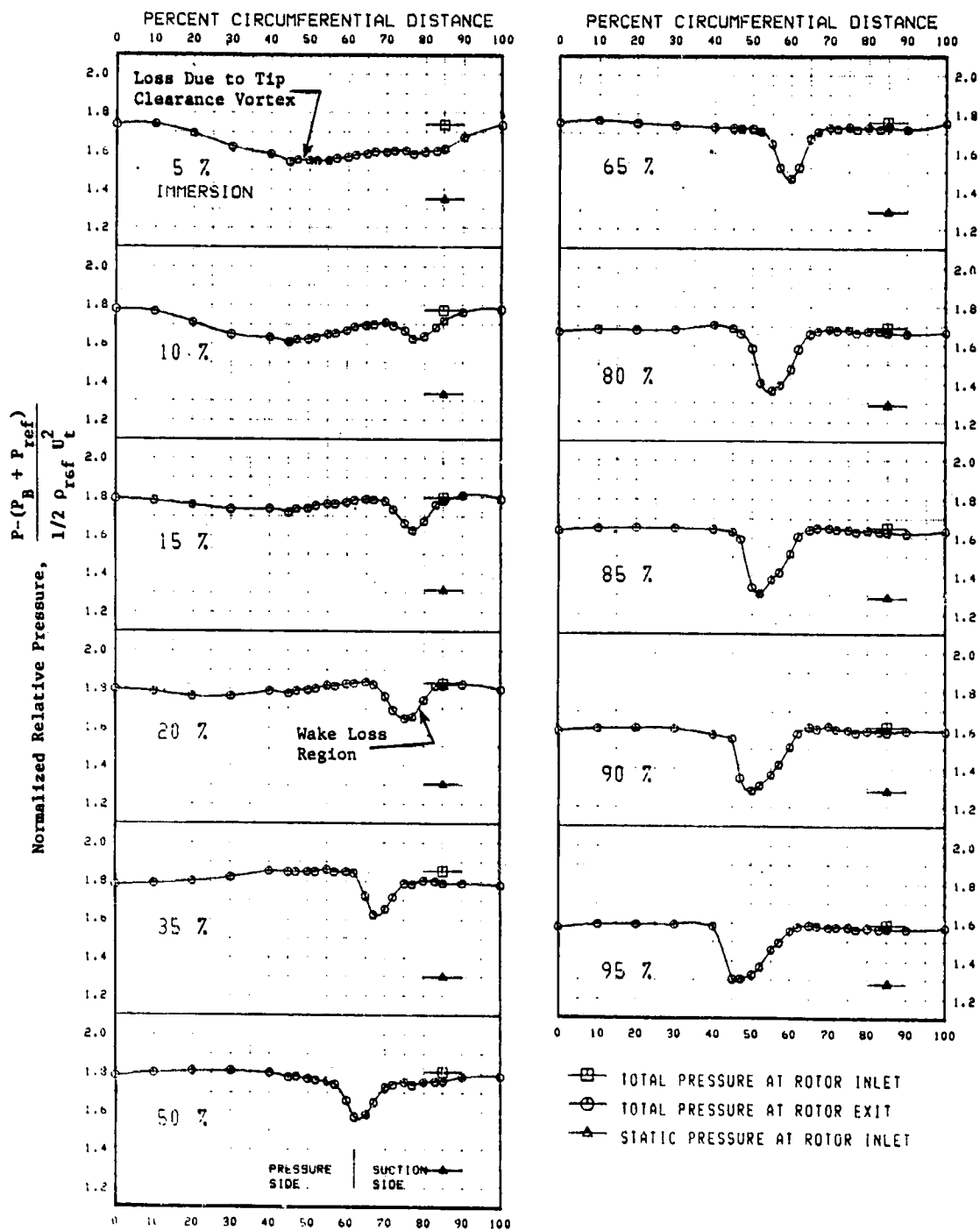


Figure 36. Circumferential Variation of Normalized Relative Total Pressure at Rotor C Exit, Four-Stage Configuration, Third Stage Tested, Near Peak Efficiency Throttle.

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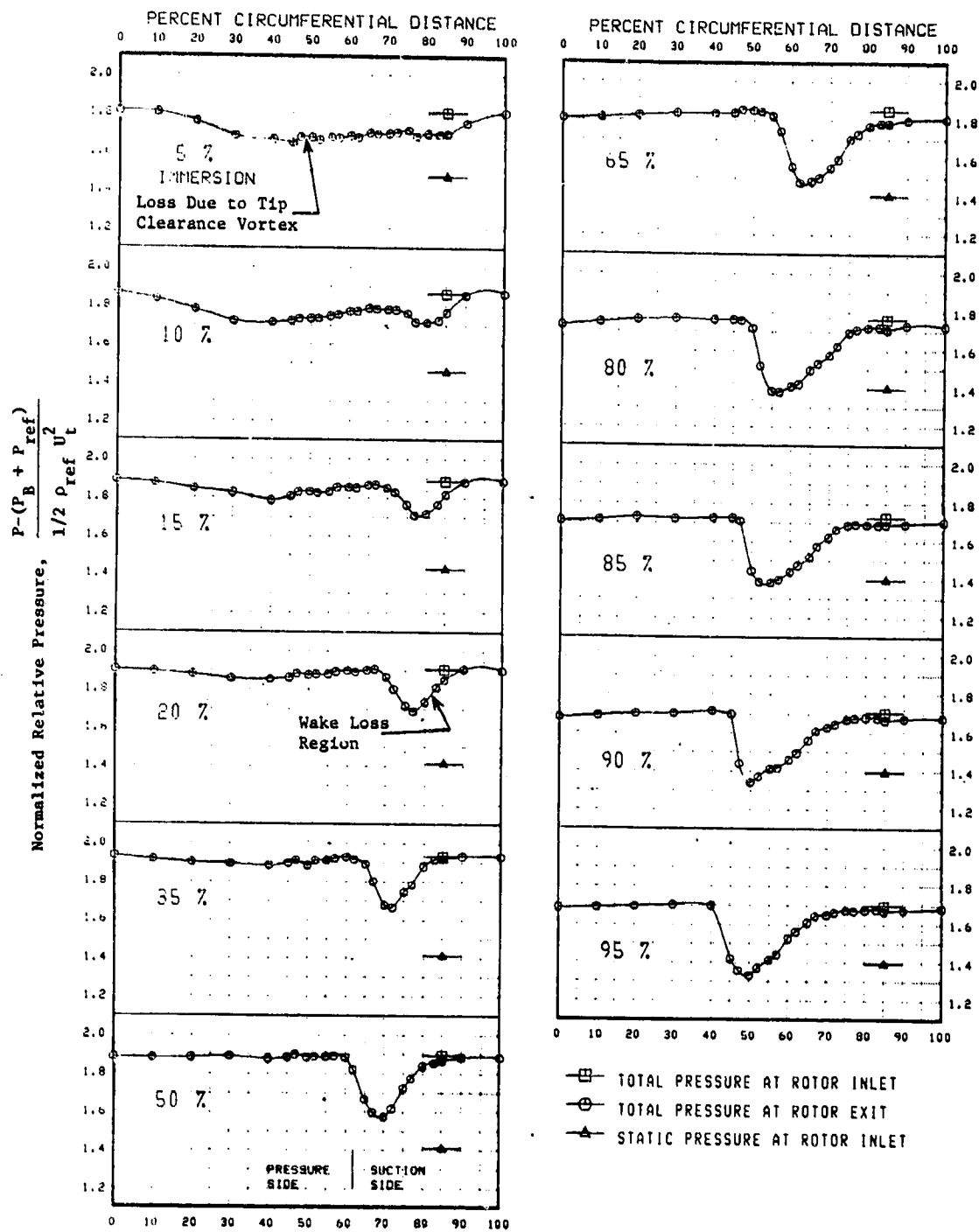


Figure 37. Circumferential Variation of Normalized Relative Total Pressure at Rotor C Exit, Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise/ Near Stall Throttle.

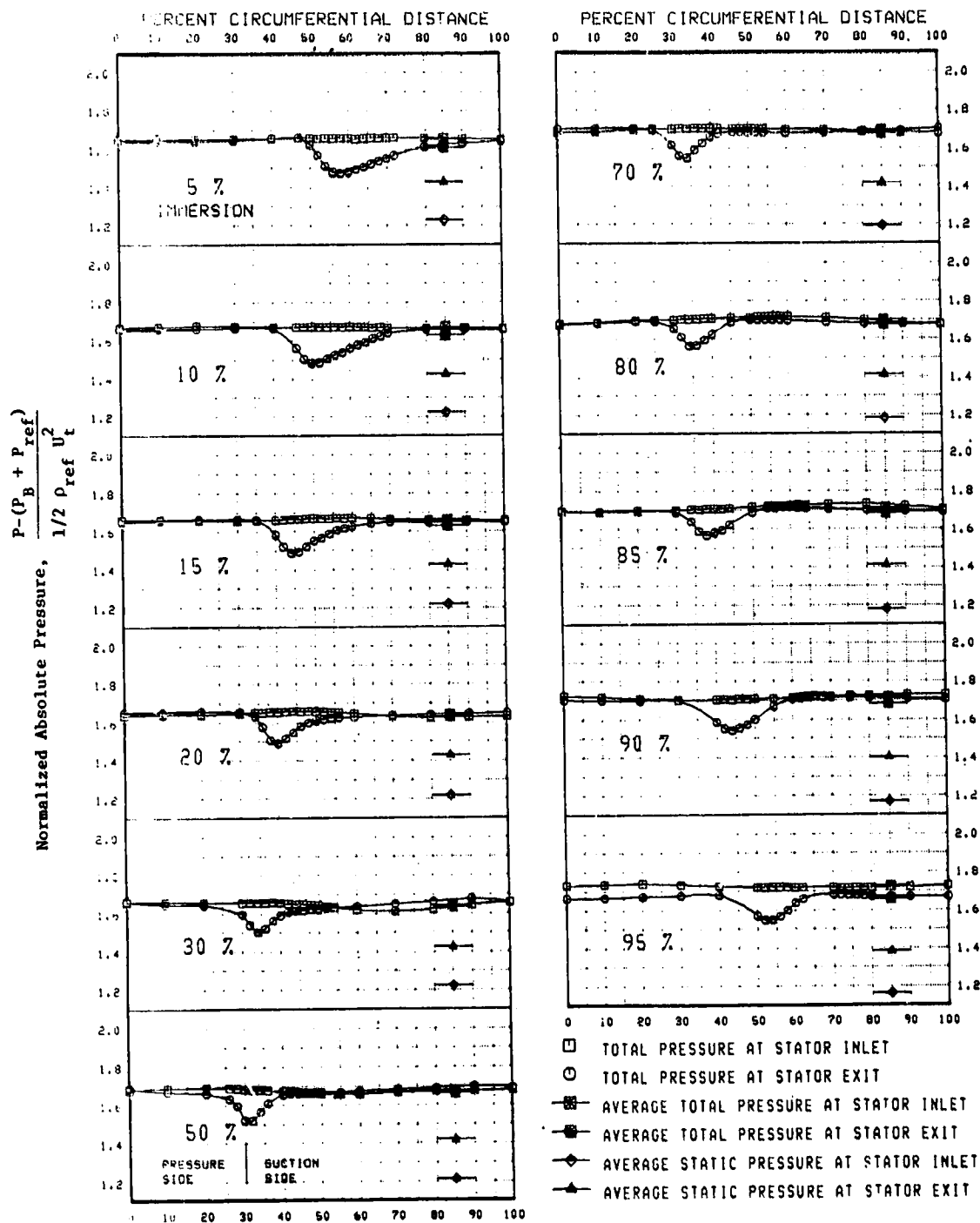


Figure 38. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Rotor C/Stator B Configuration, Third Stage Tested, Design Point Throttle.

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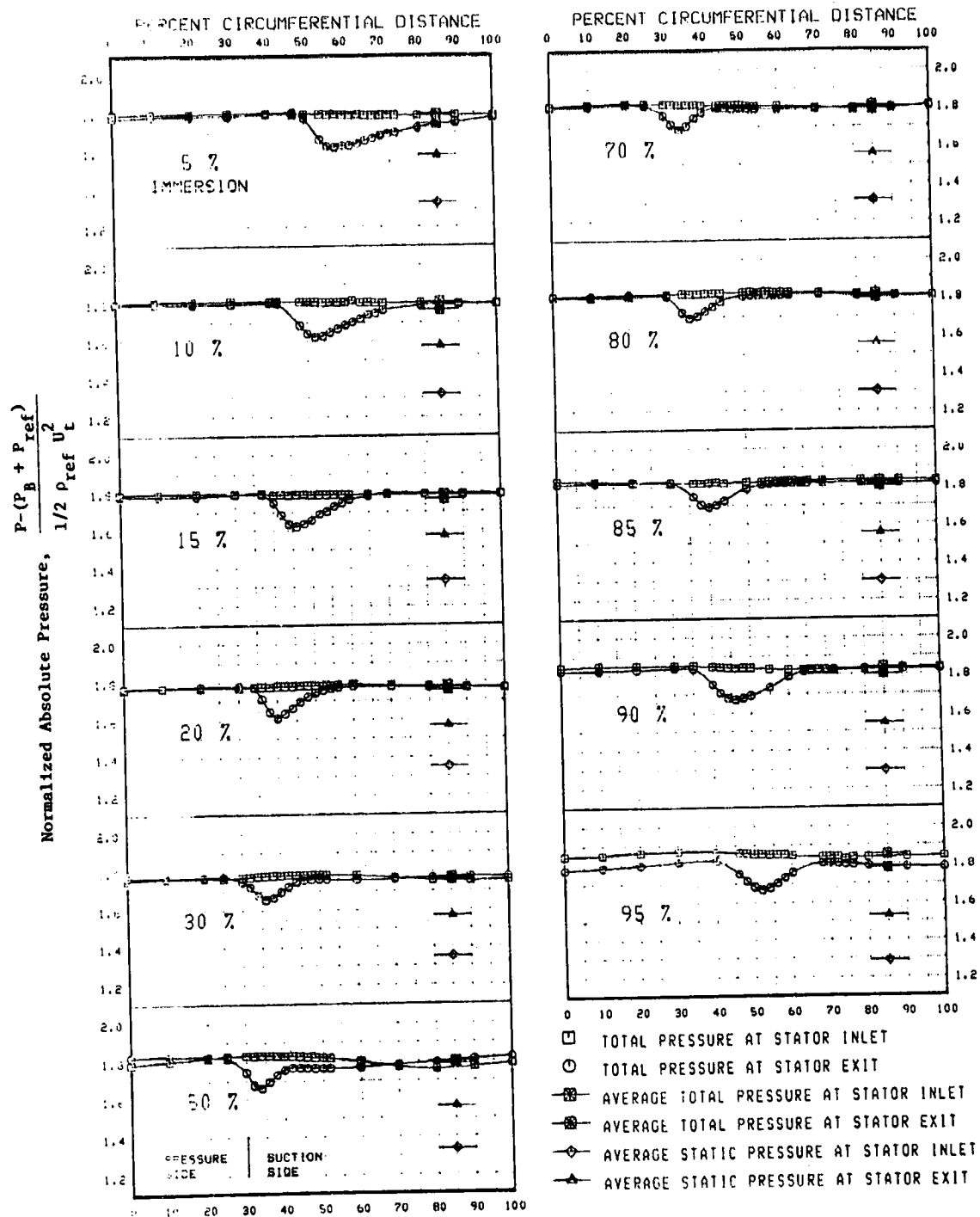


Figure 39. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Rotor C/Stator B Configuration, Third Stage Tested, Near Peak Efficiency Throttle.

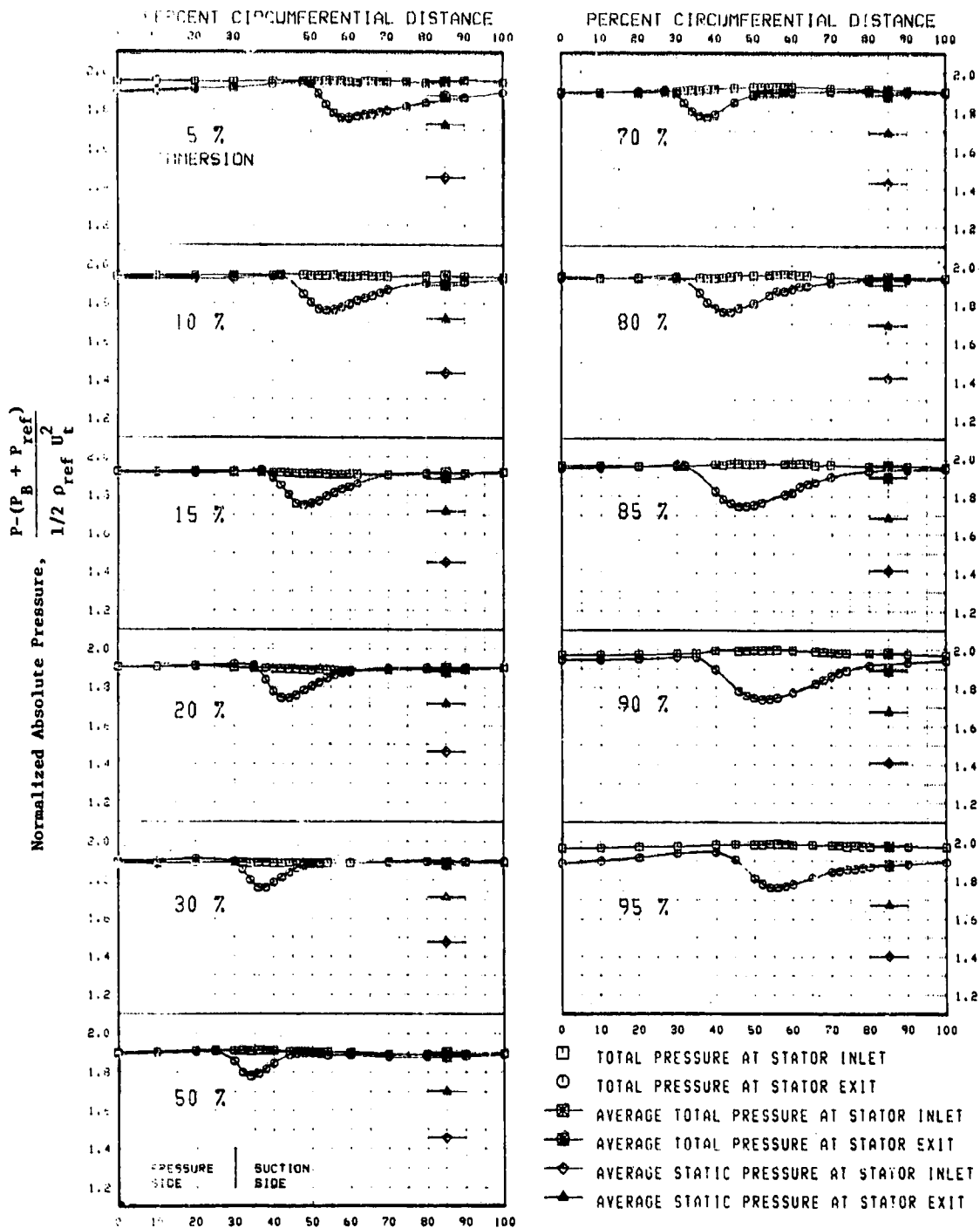


Figure 40. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Rotor C/Stator B Configuration, Third Stage Tested, Peak Pressure Rise/Near Stall Throttle.

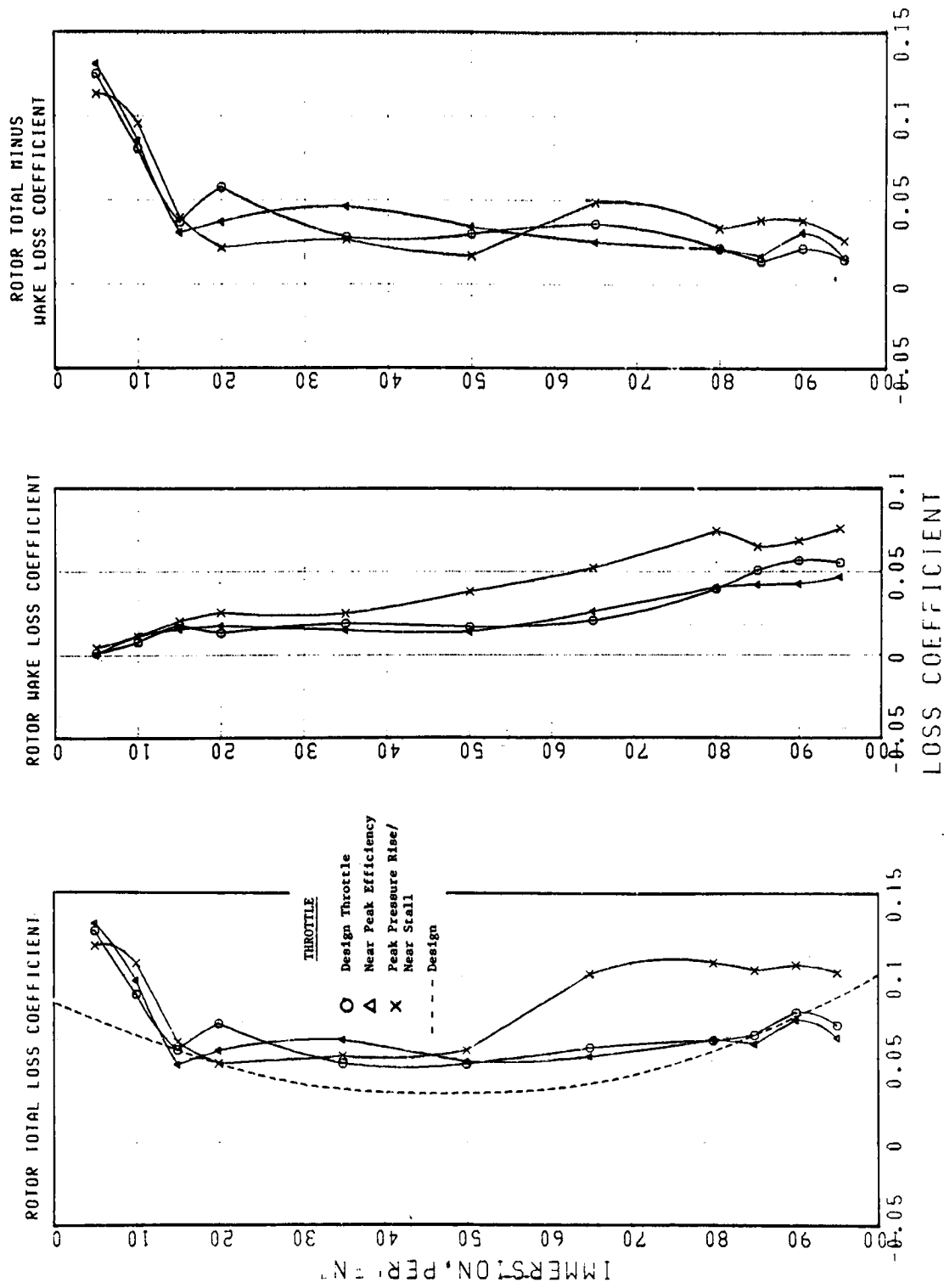


Figure 41. Rotor Total Loss Coefficients, Wake Loss Coefficients, and Total Minus Wake Loss Coefficients for Rotor C/Stator B, Four-Stage Configuration, Third Stage Tested.

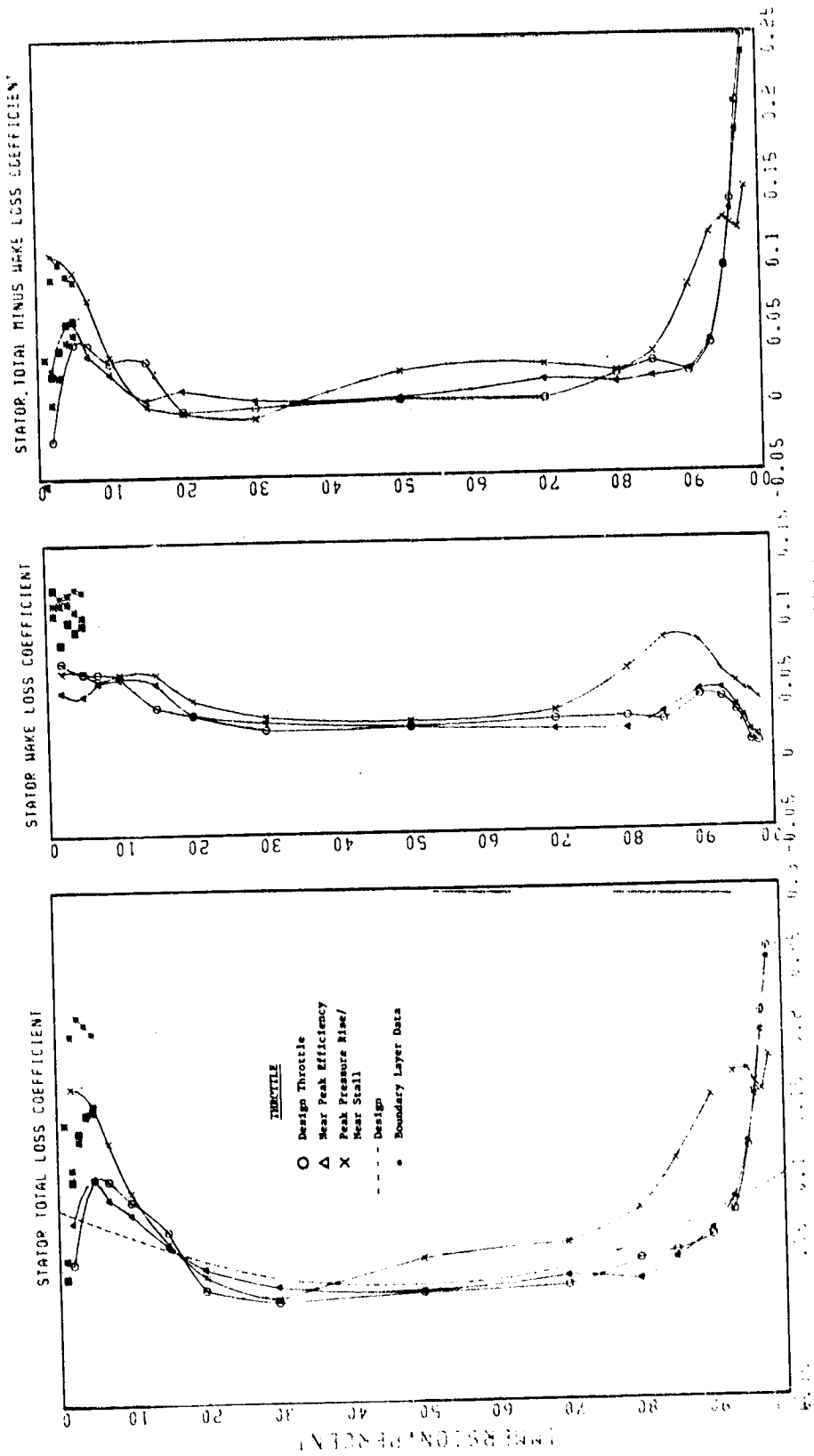


Figure 42. Stator Total Loss Coefficients, Wake Loss Coefficients, and Total Minus Wake Loss Coefficients for Rotor C/Stator B, Four-Stage Configuration, Third Stage Tested.

ROTOR C STATOR B
ROTOR

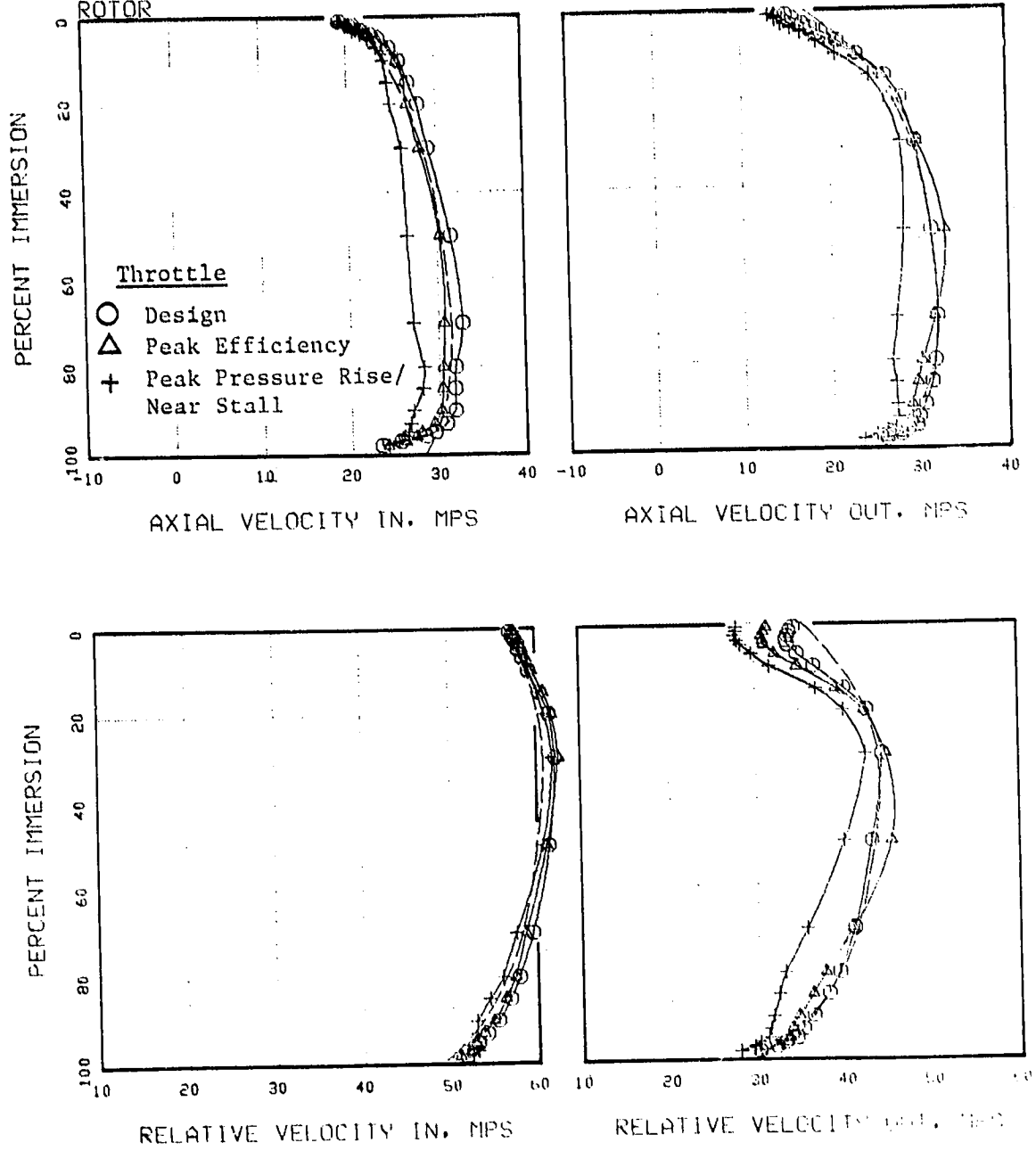


Figure 43. Vector Diagram Quantities Versus Percent Immersion, Rotor C/Stator B Four-Stage Configuration, Third Stage Tested.

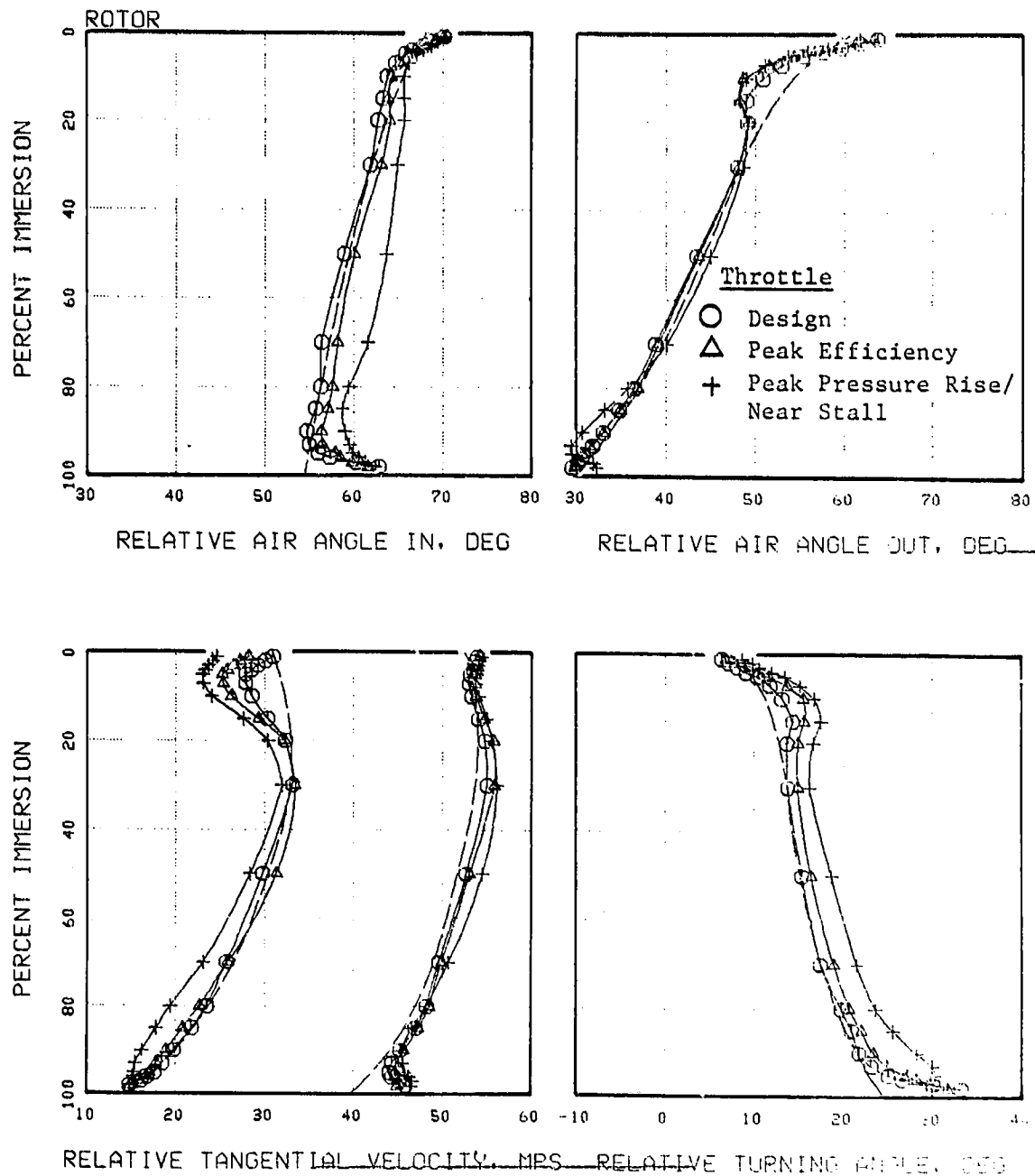


Figure 44. Vector Diagram Quantities Versus Percent Immersion, Rotor C/Stator B Four-Stage Configuration, Third Stage Tested.

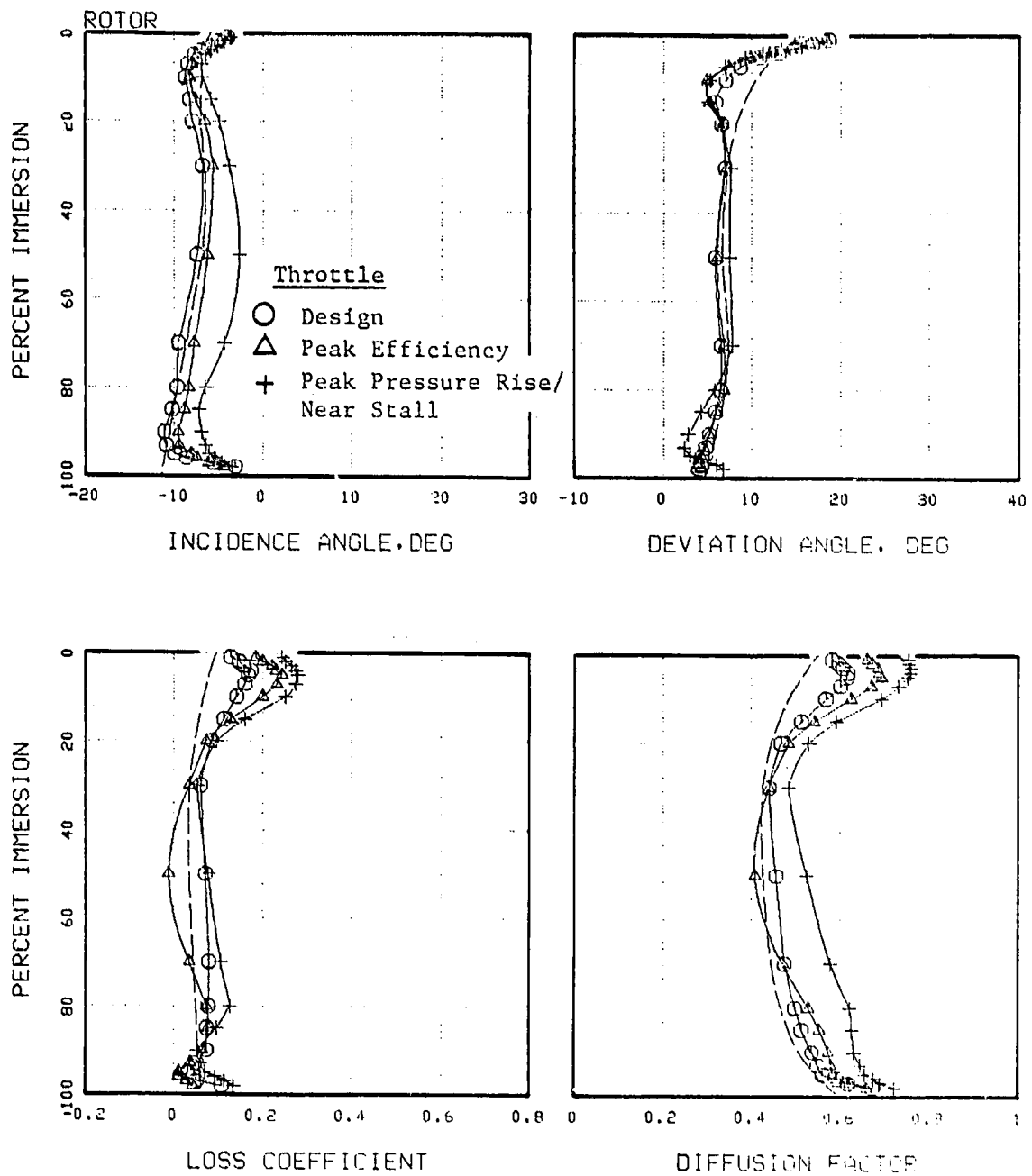


Figure 45. Vector Diagram Quantities Versus Percent Immersion, Rotor C/Stator B Four-Stage Configuration, Third Stage Tested.

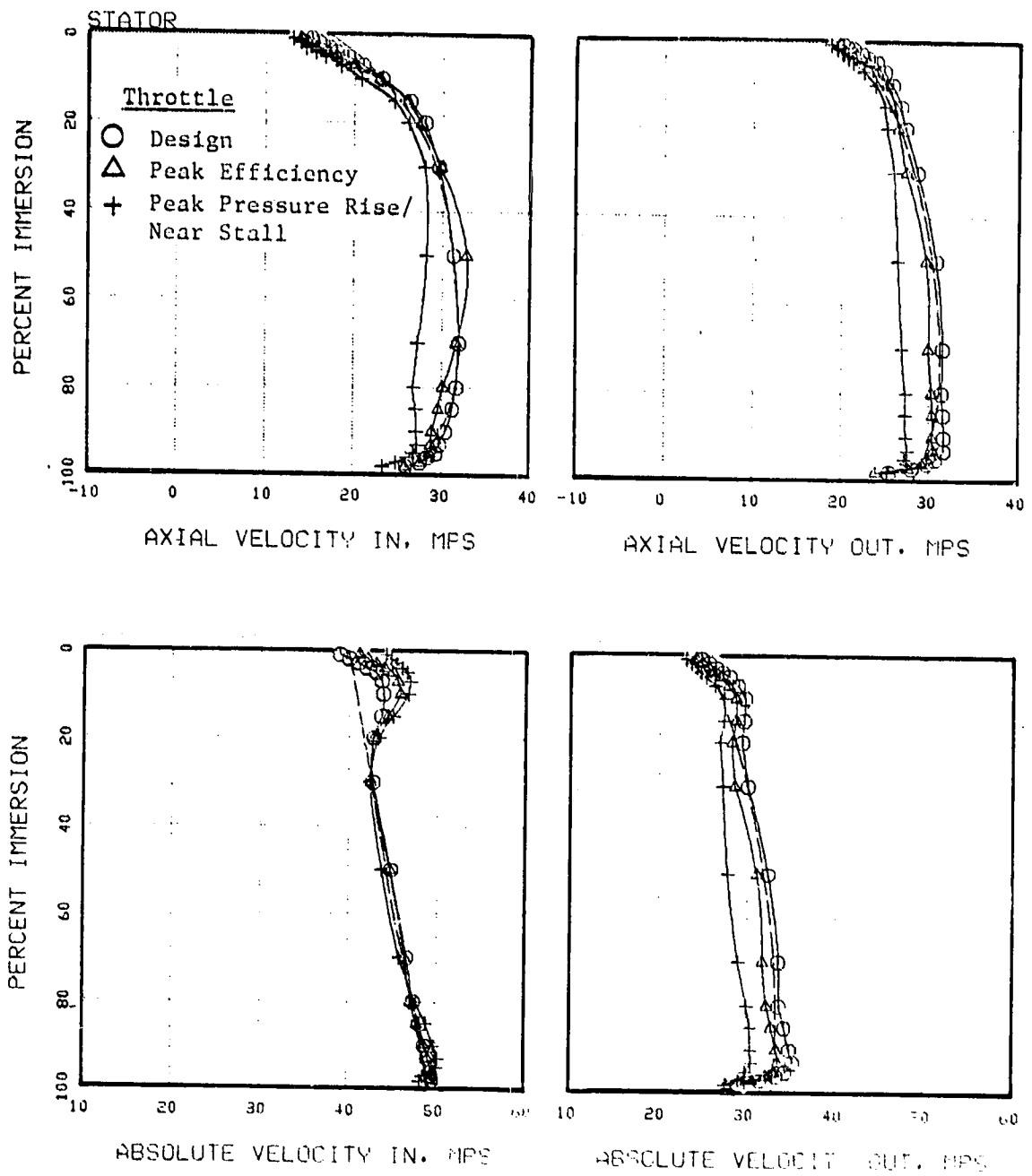


Figure 46. Vector Diagram Quantities Versus Percent Immersion, Rotor C/Stator B Four-Stage Configuration, Third Stage Tested.

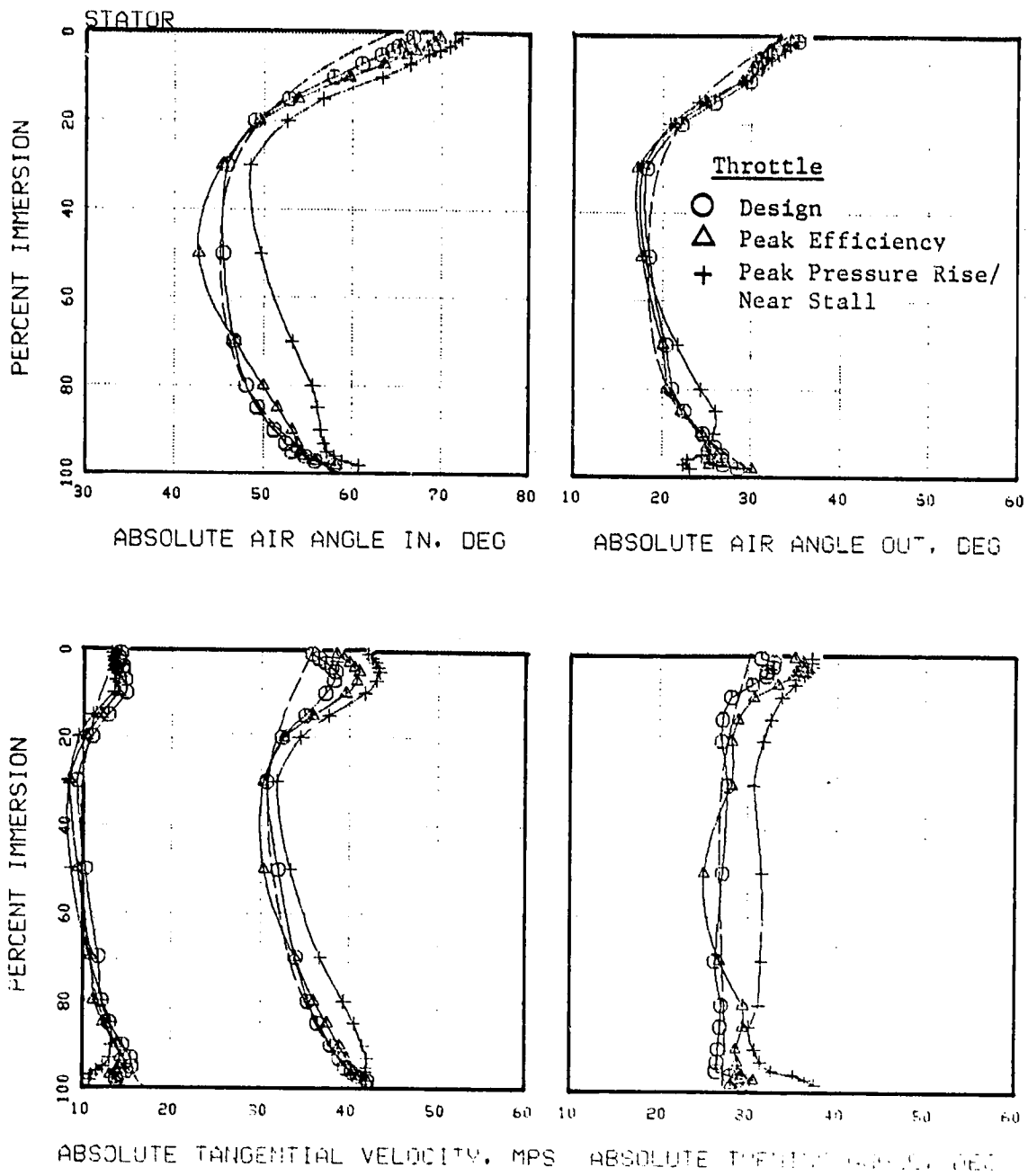


Figure 47. Vector Diagram Quantities Versus Percent Immersion, Rotor C/Stator C Four-Stage Configuration, Third Stage Tested.

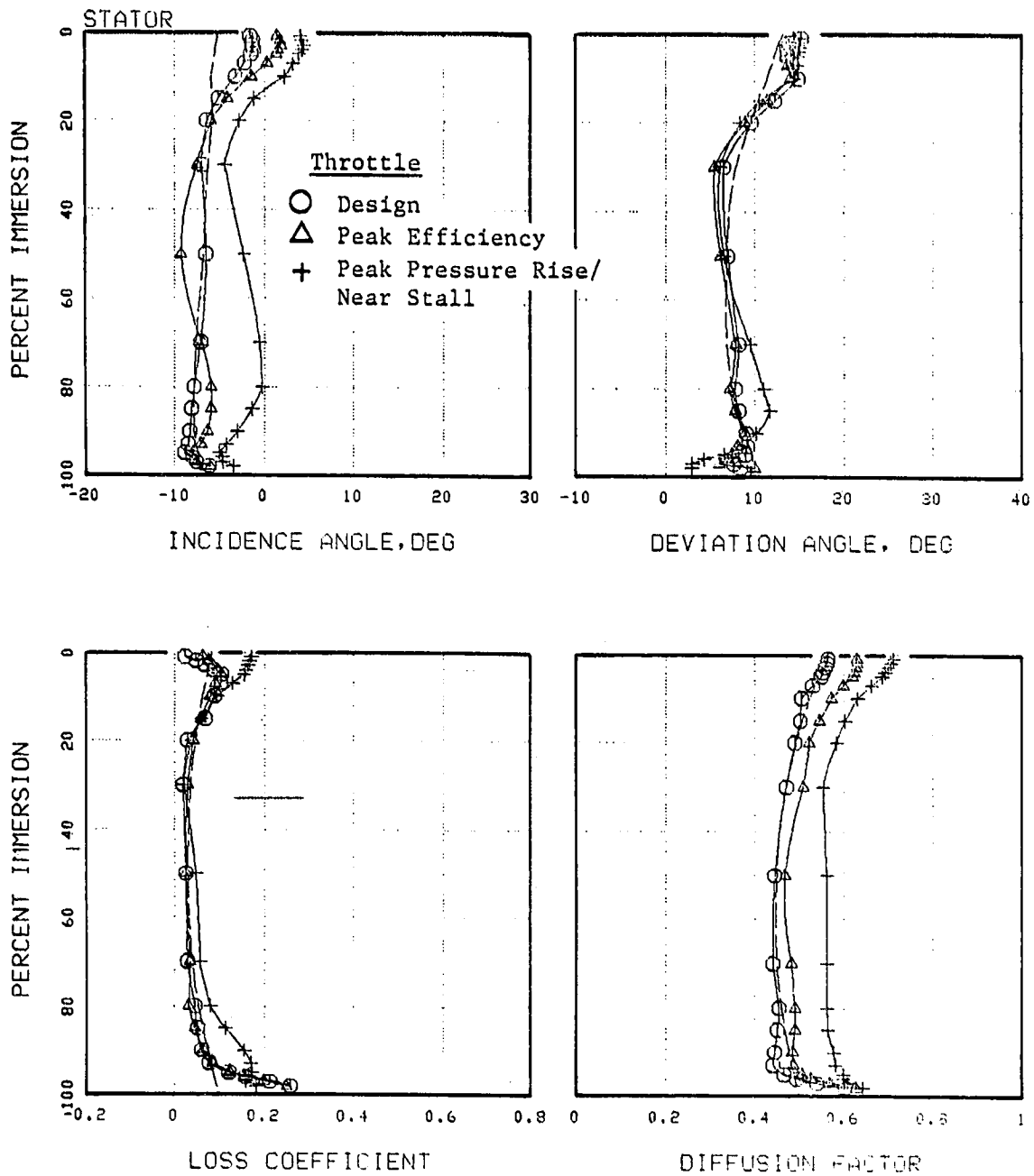


Figure 48. Vector Diagram Quantities Versus Percent Immersion, Rotor C/Stator B Four-Stage Configuration, Third Stage Tested.

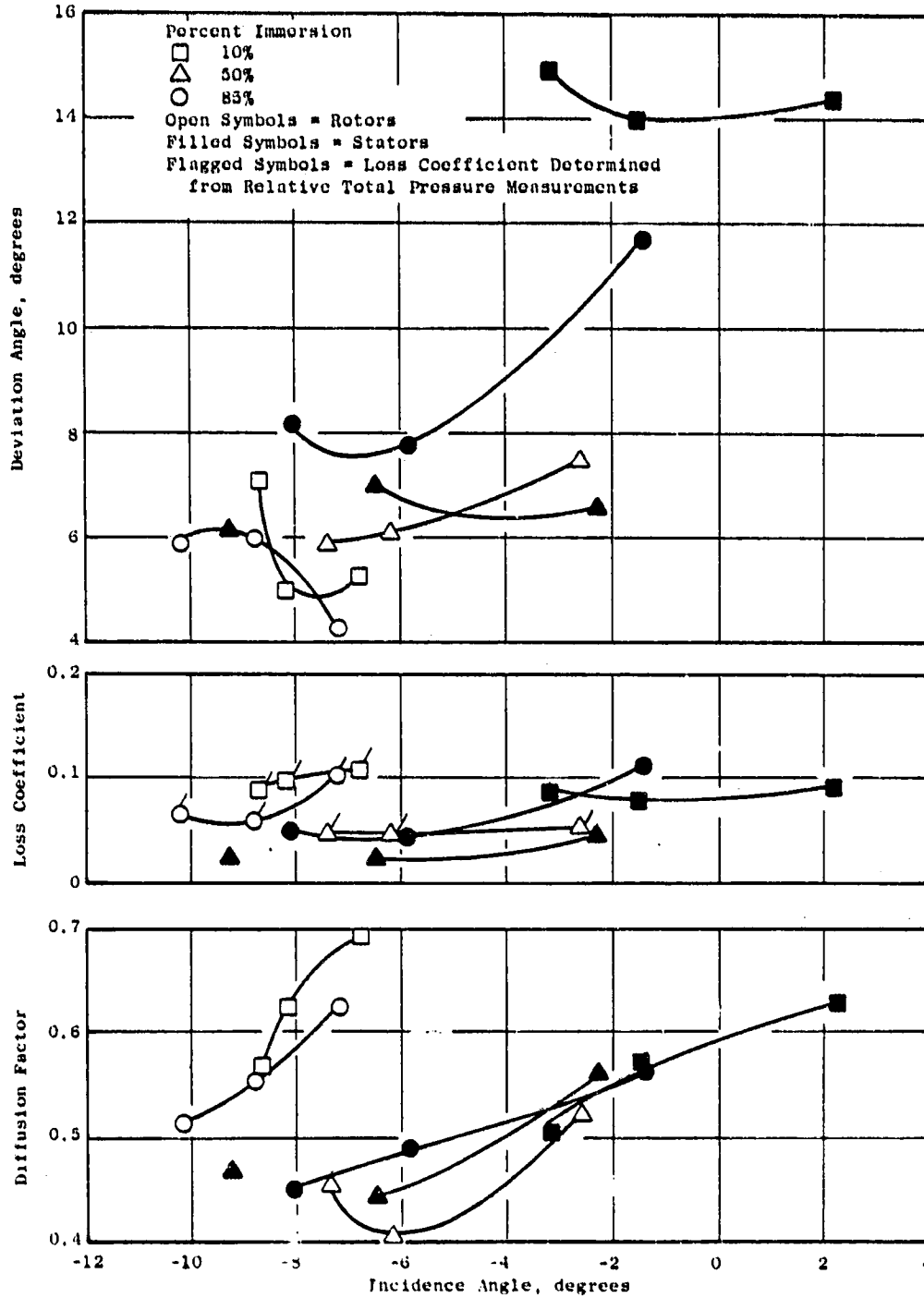


Figure 49. Diffusion Factor, Loss Coefficient and Deviation Angle Versus Incidence Angle, Rotor C/Stator B Four-Stage Configuration, Third Stage Tested.

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9.0 TABLES

Table 1. Vector Diagram Parameters for Rotor C/Stator B.

	Tip	SL1*	SL2	SL3	SL4	SL5	SL6	Pitch	SL7	SL8	SL9	SL10	SL11	SL12	Hub
<u>Rotor Inlet</u>															
r (cm)	76.20	75.51	74.87	73.67	72.53	71.43	70.35	70.35	69.27	68.19	67.10	65.97	65.38	64.77	
U (m/sec)	57.61	57.09	56.60	55.69	54.83	54.00	53.18	52.37	51.55	50.73	49.87	49.07	48.97	48.97	
V _o (m/sec)	45.32	45.96	46.36	46.55	46.17	45.40	44.43	43.38	42.16	40.52	38.14	36.38	34.13	34.13	
V _z (m/sec)	18.17	20.02	21.43	23.44	24.78	25.69	26.33	26.85	27.09	26.97	26.30	25.57	24.35	24.35	
β (deg)	68.17	66.46	65.19	63.27	61.77	60.50	59.34	58.25	57.27	56.41	55.36	54.91	54.46	54.46	
M'	0.143	0.147	0.150	0.153	0.153	0.153	0.151	0.149	0.147	0.143	0.136	0.130	0.123	0.123	
<u>Rotor Exit</u>															
r (cm)	76.20	75.41	74.74	73.55	72.45	71.38	70.33	69.28	68.23	67.15	66.03	65.43	64.77	64.77	
U (m/sec)	57.61	57.01	56.50	55.60	54.77	53.96	53.17	52.38	51.58	50.77	49.92	49.47	48.97	48.97	
V _o (m/sec)	26.70	27.51	28.06	28.53	28.19	27.29	26.04	26.61	22.93	20.69	17.58	15.39	12.55	12.55	
V _z (m/sec)	14.97	18.71	21.09	23.99	25.54	26.39	26.94	27.34	27.52	27.22	25.97	24.51	21.98	21.98	
β (deg)	60.74	55.75	53.07	49.96	47.85	45.95	44.02	41.98	39.77	37.23	34.10	32.13	29.74	29.74	
M'	0.089	0.097	0.103	0.109	0.111	0.111	0.110	0.108	0.105	0.100	0.092	0.085	0.074	0.074	
<u>Stator Inlet</u>															
r (cm)	76.20	75.41	74.74	73.55	72.44	71.38	70.33	69.28	68.23	67.15	66.03	65.43	64.77	64.77	
V _o (m/sec)	30.91	29.50	28.44	27.07	26.58	26.67	27.13	27.77	28.65	30.08	32.34	34.08	36.42	36.42	
V _z (m/sec)	14.90	18.68	21.09	24.00	25.57	26.43	26.97	27.37	27.55	27.22	25.97	24.51	22.01	22.01	
β (deg)	64.27	57.67	53.44	48.44	46.10	45.26	45.17	45.41	46.13	47.88	51.24	54.27	58.84	58.84	
M	0.100	0.102	0.104	0.106	0.108	0.110	0.112	0.114	0.116	0.119	0.121	0.123	0.124	0.124	
<u>Stator Exit</u>															
r (cm)	76.20	75.51	74.87	73.67	72.53	71.43	70.35	69.27	68.19	67.10	65.97	65.38	64.77	64.77	
V _o (m/sec)	12.19	11.03	10.15	9.05	8.59	8.50	8.69	8.90	9.33	10.15	11.67	12.98	14.78	14.78	
V _z (m/sec)	18.07	19.93	21.31	23.26	24.57	25.48	26.15	26.64	26.91	26.82	26.15	25.42	24.20	24.20	
β (deg)	34.00	28.95	25.48	21.27	19.27	18.52	18.36	18.49	19.09	20.72	24.02	27.03	31.40	31.40	
M	0.064	0.067	0.069	0.073	0.076	0.079	0.081	0.082	0.083	0.084	0.084	0.083	0.083	0.083	

*SL = Streamline

Table 2. Rotor C Airfoil Geometry.

	Tip		Pitch													Hub	
	SL1†	SL2	SL3	SL4	SL5	SL6	SL7	SL8	SL9	SL10	SL11	SL12	SL13	Hub SL12	Hub SL13		
Avg. Radius, R (cm)	76.20	75.46	74.81	73.61	72.49	71.41	70.34	69.28	68.21	67.13	66.00	65.41	64.77				
Chord, C (cm)	9.55	9.54	9.54	9.53	9.53	9.53	9.53	9.53	9.49	9.40	9.25	9.14	8.96				
Solidity, Σ	1.08	1.09	1.10	1.11	1.13	1.15	1.16	1.18	1.20	1.20	1.20	1.20	1.19				
β_1^* (deg)	74.0	73.5	72.5	70.6	68.7	67.2	66.3	66.0	65.9	65.9	65.9	65.9	65.9				
β_2^* (deg)	45.1	44.4	43.7	42.5	41.1	39.6	37.6	35.0	32.3	30.0	27.8	26.4	25.0				
Incidence, i (deg)	-5.8	-7.0	-7.3	-7.3	-6.9	-6.7	-7.0	-7.8	-8.6	-9.6	-10.5	-11.0	-11.4				
Deviation, δ (deg)	15.6	11.4	9.4	7.5	6.8	6.4	6.4	7.0	7.5	7.2	6.3	5.7	4.7				
Camber, ϕ (deg)	28.9	29.1	28.8	28.1	27.6	27.6	28.7	31.0	33.6	35.9	38.1	39.5	40.9				
Stagger, ξ (deg)	60.2	59.2	58.1	55.9	53.4	51.4	49.9	48.2	46.4	44.5	42.0	40.4	38.5				
Δ CAM _{LE} , (deg)	*	*	*	4.7	5.8	6.4	6.5	6.5	6.6	7.1	7.7	8.1	8.5				
Δ CAM _{TE} , (deg)	*	*	*	2.3	1.1	0.3	0	-0.3	-1.40	-3.2	-6.6	-9.5	-13.0				
Blend _{LE} , Z C	*	*	*	40	40	40	40	40	40	40	40	40	40				
Blend _{TE} , Z C	*	*	*	60	60	60	60	60	59	58	57	56	55				
t_{max}/C	0.036	0.042	0.046	0.051	0.055	0.059	0.062	0.066	0.070	0.076	0.082	0.086	0.090				
t_{TE}/C	0.011	0.011	0.012	0.012	0.012	0.013	0.013	0.013	0.014	0.014	0.015	0.015	0.016				
t_{max} Location, Z C	74	64	59	53	51	50	50	50	48	46	44	42	40				

† SL = Streamline

*† Special Airfoil Section

Table 3. Instrumentation for the Test Program.

Instrumentation	Plane Location										
	0.1 Bellmouth	0.5 IGV Inlet	1.0 R1 Inlet	1.5 S1 Inlet	2.0 R2 Inlet	2.5 S2 Inlet	3.0 R3 Inlet	3.5 S3 Inlet	4.0 R4 Inlet	4.5 S4 Inlet	5.0 Compressor Discharge
Static Pressure											
1. Casing Statics 11 Equally-Spaced Taps	X	X	X	X	X	X	X	X	X	X	X
2. Hub Statics 11 Equally-Spaced Taps	X	X	X								X
3. Hub Seal Cavity Static Pressures				X	X						
4. Single Element Traverse Probe*											
5. Blade or Vane Surface Static Pressure Taps						R3	S3				
Total Pressure											
1. 11 Element Radial Rake			X					X	X		X
2. Single Element Traverse Probe*								X	X		
3. Rotating Radial Rake										X	
Flow Angle											
1. Single Element Traverse Probe*											
Hot Film Probe*											

*Provisions for this instrumentation have been made at the planes indicated. However, the instrumentation was not in place for the screening tests.

Table 4. Overall Test Plan Outline for Complete Program.

I. Tests Using Stage A Blading (Reported in Ref. 1)	
A. Shakedown Test	5 data points
B. 4-Stage Configuration (Third Stage as Test Stage)	
1. Preview Data	15 data points
2. Stall Determination	As Appropriate
3. Casing Treatment Data	15 data points
4. Reynolds Number Data	30 data points
5. Standard Data	4 data points
6. Blade Element Data	4 data points
7. Blade Surface Pressure Data	2 data points
8. Detailed Wall Boundary Layer Data	2 data points
C. 1-Stage Configuration	
1. Preview Data	15 data points
2. Stall Determination	As Appropriate
3. Standard Data	4 data points
4. Blade Element Data	4 data points
5. Blade Surface Pressure Data	4 data points
6. Detailed Wall Boundary Layer Data	2 data points
D. 4-Stage Configuration (First Stage as Test Stage)	
1. Blade Element Data	4 data points
2. Blade Surface Pressure Data	4 data points
3. Detailed Wall Boundary Layer Data	2 data points
II. Screen Tests	
A. 4-Stage Configuration with Rotor B and Stator A	
1. Preview Data	15 data points
2. Stall Determination	As Appropriate
3. Standard Data	4 data points
4. Blade Surface Pressure Data	4 data points
B. 4-Stage Configuration with Stator B and Rotor A (Same Data as II.A.)	
C. 4-Stage Configuration with Stator C and Rotor A (Same Data as II.A.)	
D. 4-Stage Configuration with Rotor B and Stator B (Same Data as II.A.)	
III. Tests Using Rotor B and Stator B Designs	
A. 4-Stage Configuration, Third Stage as Test Stage	
1. Same Data as I.B., Except Delete I.B.3. and 4.	
2. Rotor Tip Clearance Data, Casement Treatment 4 Stages	
3. Rotor Tip Clearance Data, Casing Treatment Stage 1	
B. 1-Stage Configuration	
1. Same Data as I.C., Except Delete I.C.4. (Rotor Tip Clearance Data)	
IV. Tests Using Rotor C/Stator B Designs	
A. 4-Stage Configuration, Third Stage as Test Stage	
1. Same Data as I.B., Except Delete I.B.3. and 4.	

Table 5. Preview Data for Rotor C/Stator B.

TEST 69A CCESS B/U 16 ROTOR C : STATOR B		P. COEF		WORK.		TORQUE	
FLOW	COEF	CASING	COEF	COEF	EFFICI	EFFICI	EFFICI
0.46015	0.44403	0.51116	0.86867	0.46015	0.44331	0.51004	0.86917
0.44321	0.49043	0.55186	0.88868	0.45005	0.46982	0.53295	0.88154
0.42624	0.52916	0.58901	0.89838	0.44245	0.48827	0.55019	0.88745
0.41269	0.55819	0.61793	0.90333	0.43402	0.50778	0.56874	0.89280
0.40207	0.57776	0.63918	0.90391	0.42558	0.52711	0.58679	0.89829
0.39643	0.58769	0.65071	0.90315	0.41668	0.54662	0.60621	0.90169
0.39060	0.59730	0.66077	0.90394	0.41197	0.55645	0.61652	0.90257
0.37880	0.61491	0.68168	0.90205	0.40626	0.56663	0.62815	0.90206
0.33578	0.63174	0.72716	0.86878	0.40275	0.57595	0.63604	0.90352
0.36367	0.62747	0.70107	0.89503	0.39655	0.58621	0.64808	0.90454
0.46076	0.44272	0.50990	0.86825	0.39146	0.59499	0.65804	0.90419
0.45066	0.46979	0.53275	0.88183	0.38503	0.60439	0.66900	0.90343
0.44241	0.48908	0.55051	0.88840	0.37887	0.61423	0.68068	0.90237
0.43530	0.50839	0.56635	0.89765	0.37150	0.61994	0.69019	0.89822
0.42598	0.52786	0.58770	0.89819	0.36346	0.62548	0.69947	0.89422
0.41736	0.54759	0.60552	0.90433	0.35483	0.62863	0.70744	0.88850
0.41259	0.55649	0.61589	0.90355	0.34546	0.63017	0.71633	0.87972
0.40867	0.56709	0.62549	0.90665	0.33545	0.63054	0.72560	0.86899
0.40383	0.57720	0.63557	0.90817	0.24246	0.33118	0.92173	0.35931
0.39839	0.58702	0.64690	0.90744	0.19160	0.30734	1.15787	0.26543
0.39179	0.59622	0.65894	0.90481	0.36001	0.42412	0.64318	0.65941
0.38595	0.60514	0.66793	0.90600	0.40825	0.56847	0.62741	0.90607
0.37961	0.61264	0.67717	0.90470	0.38706	0.60585	0.66808	0.90686
0.37316	0.62182	0.68979	0.90147	0.34583	0.63286	0.71759	0.88193
0.36384	0.62712	0.70077	0.89490	0.40718	0.56867	0.62795	0.90560
0.35640	0.62886	0.70881	0.88720	0.38584	0.60643	0.66956	0.90571
0.34769	0.63198	0.71640	0.88215	0.34480	0.63215	0.71838	0.87996
0.33687	0.63045	0.72457	0.87010				
0.43561	0.50890	0.56732	0.89701				
0.42690	0.52912	0.58683	0.90167				
0.41267	0.55814	0.61575	0.90643				
0.40731	0.56757	0.62650	0.90594				
0.40267	0.57662	0.63684	0.90545				
0.39729	0.58732	0.64778	0.90666				
0.39151	0.59724	0.65804	0.90762				
0.38590	0.60560	0.66895	0.90531				

Table 6. Blade Surface Static Pressures, Four-Stage Rotor C/Stator B Configuration, Third Stage Is Test Stage.

IMMERSION(X)= 5			IMMERSION(X)= 2B			IMMERSION(X)= 5B		
PRESSURE SURFACE	DP	PPR	PRESSURE SURFACE	DP	PPR	PRESSURE SURFACE	DP	PPR
XCHORD			XCHORD			XCHORD		
2.50	1.3016	1.2758	2.50	1.1925	1.4507	2.50	1.0656	1.7148
8.00	1.1434	1.4385	8.00	1.1558	1.4799	8.00	1.1559	1.5909
13.00	1.2180	1.3638	13.00	1.2725	1.5041	13.00	1.2718	1.5314
20.00	1.2664	1.4869	20.00	1.2430	1.5152	20.00	1.2430	1.5124
30.00	1.3096	1.5156	30.00	1.2637	1.5328	30.00	1.2600	1.5174
45.00	1.3498	1.5252	45.00	1.2861	1.5377	45.00	1.2767	1.5228
60.00	1.3198	1.4285	60.00	1.2918	1.4162	60.00	1.2605	1.3929
70.00	1.3191	1.4285	70.00	1.2945	1.4584	70.00	1.2605	1.3951
80.00	1.3172	1.4298	80.00	1.2945	1.5399	80.00	1.2793	1.5126
90.00	1.3223	1.4394	90.00	1.2846	1.4103	90.00	1.2691	1.4962
95.00	1.3138	1.4319	95.00	1.2668	1.3983	95.00	1.2556	1.4744
IMMERSION(X)= 5			IMMERSION(X)= 2B			IMMERSION(X)= 5B		
SUCTION SURFACE	DP	PPR	SUCTION SURFACE	DP	PPR	SUCTION SURFACE	DP	PPR
XCHORD			XCHORD			XCHORD		
2.50	1.3283	1.8682	2.50	1.3392	1.8183	2.50	1.2963	1.6089
8.00	1.2158	1.8996	8.00	1.2499	1.8177	8.00	1.2232	1.7495
13.00	1.2451	1.8393	13.00	1.2772	1.8792	13.00	1.2716	1.8168
20.00	1.2684	1.7643	20.00	1.2676	1.8865	20.00	1.2466	1.8533
25.00	1.2387	1.7352	25.00	1.2849	1.8971	25.00	1.2533	1.8833
30.00	1.2044	1.7875	30.00	1.2957	1.9044	30.00	1.2774	1.9144
35.00	1.2353	1.8789	35.00	1.2843	1.9522	35.00	1.2638	1.8847
40.00	1.2381	1.9789	40.00	1.2789	1.9883	40.00	1.2702	1.8997
45.00	1.2381	1.9419	45.00	1.2692	1.8448	45.00	1.2645	1.8958
50.00	1.2381	1.9514	50.00	1.2613	1.8230	50.00	1.2411	1.8977
55.00	1.2381	1.1297	55.00	1.2613	1.8230	55.00	1.2411	1.8977
60.00	1.2381	1.2924	60.00	1.2613	1.8230	60.00	1.2411	1.8977
70.00	1.2381	1.2924	70.00	1.2613	1.8230	70.00	1.2411	1.8977
80.00	1.2381	1.2924	80.00	1.2613	1.8230	80.00	1.2411	1.8977
90.00	1.2381	1.2924	90.00	1.2613	1.8230	90.00	1.2411	1.8977
95.00	1.2381	1.2924	95.00	1.2613	1.8230	95.00	1.2411	1.8977
IMMERSION(X)= 5B			IMMERSION(X)= 2B			IMMERSION(X)= 5B		
PRESSURE SURFACE	DP	PPR	PRESSURE SURFACE	DP	PPR	PRESSURE SURFACE	DP	PPR
XCHORD			XCHORD			XCHORD		
2.50	1.2746	1.5245	2.50	1.0987	1.2746	2.50	1.0987	1.5245
8.00	1.1968	1.5082	8.00	1.1968	1.5082	8.00	1.1968	1.5082
13.00	1.3498	1.4991	13.00	1.2277	1.3498	13.00	1.2277	1.4991
20.00	1.2323	1.4919	20.00	1.2323	1.3510	20.00	1.2323	1.4919
30.00	1.2414	1.4898	30.00	1.2414	1.3565	30.00	1.2414	1.4898
45.00	1.2403	1.4916	45.00	1.2403	1.3613	45.00	1.2403	1.4916
60.00	1.2403	1.4916	60.00	1.2403	1.3613	60.00	1.2403	1.4916
70.00	1.2403	1.4916	70.00	1.2403	1.3613	70.00	1.2403	1.4916
80.00	1.2403	1.4916	80.00	1.2403	1.3613	80.00	1.2403	1.4916
90.00	1.2403	1.4916	90.00	1.2403	1.3613	90.00	1.2403	1.4916
95.00	1.2403	1.4916	95.00	1.2403	1.3613	95.00	1.2403	1.4916
IMMERSION(X)= 5B			IMMERSION(X)= 2B			IMMERSION(X)= 5B		
SUCTION SURFACE	DP	PPR	SUCTION SURFACE	DP	PPR	SUCTION SURFACE	DP	PPR
XCHORD			XCHORD			XCHORD		
2.50	1.7523	1.8248	2.50	1.0727	1.7523	2.50	1.0727	1.8248
8.00	1.7358	1.8049	8.00	1.0696	1.7358	8.00	1.0696	1.8049
13.00	1.7118	1.8221	13.00	1.0623	1.7118	13.00	1.0623	1.8221
20.00	1.7175	1.8672	20.00	1.0668	1.7175	20.00	1.0668	1.8672
30.00	1.7451	1.8156	30.00	1.0622	1.7451	30.00	1.0622	1.8156
45.00	1.7472	1.8144	45.00	1.0668	1.7472	45.00	1.0668	1.8144
60.00	1.7472	1.8144	60.00	1.0668	1.7472	60.00	1.0668	1.8144
70.00	1.7472	1.8144	70.00	1.0668	1.7472	70.00	1.0668	1.8144
80.00	1.7472	1.8144	80.00	1.0668	1.7472	80.00	1.0668	1.8144
90.00	1.7472	1.8144	90.00	1.0668	1.7472	90.00	1.0668	1.8144
95.00	1.7472	1.8144	95.00	1.0668	1.7472	95.00	1.0668	1.8144

Tabulated Surface Pressures Normalized by 1/2 ρ ref t

Throttle

- DP - Design Point
- PE - Peak Efficiency
- PPR - Peak Pressure Rise/ Near Stall

Table 7. Vane Surface Static Pressures, Four-Stage Rotor C/Stator B Configuration, Third Stage Is Test Stage.

IMPRESSION(X) = 18				IMPRESSION(X) = 20				IMPRESSION(X) = 50			
PRESSURE SURFACE		SUCTION SURFACE		PRESSURE SURFACE		SUCTION SURFACE		PRESSURE SURFACE		SUCTION SURFACE	
XCHORD	DP	PE	PPR	XCHORD	DP	PE	PPR	XCHORD	DP	PE	PPR
2.50	1.3443	1.5705	1.7574	2.50	1.1795	1.5750	1.7399	2.50	1.5602	1.5209	1.7121
8.00	1.3509	1.5301	1.7108	8.00	1.3361	1.5383	1.7009	8.00	1.3368	1.5154	1.6920
20.00	1.3959	1.5530	1.7152	20.00	1.3929	1.5395	1.7002	20.00	1.3715	1.5179	1.6955
30.00	1.4175	1.5696	1.7284	30.00	1.4122	1.5633	1.7304	30.00	1.4038	1.5502	1.7059
45.00	1.4474	1.5892	1.7397	45.00	1.4316	1.5716	1.7450	45.00	1.4270	1.5779	1.7200
60.00	1.4555	1.5936	1.7509	60.00	1.4511	1.5905	1.7450	60.00	1.4500	1.5963	1.7362
70.00	1.4532	1.6103	1.7599	70.00	1.4591	1.6042	1.7515	70.00	1.4589	1.6059	1.7352
80.00	1.4652	1.6126	1.7599	80.00	1.4592	1.6020	1.7483	80.00	1.4625	1.6090	1.7376
90.00	1.4558	1.6421	1.7480	90.00	1.4482	1.5992	1.7315	90.00	1.4561	1.6058	1.7295
95.00	1.4279	1.5764	1.7246	95.00	1.4247	1.5544	1.7101	95.00	1.4394	1.5018	1.7024
IMPRESSION(X) = 18				IMPRESSION(X) = 20				IMPRESSION(X) = 50			
PRESSURE SURFACE		SUCTION SURFACE		PRESSURE SURFACE		SUCTION SURFACE		PRESSURE SURFACE		SUCTION SURFACE	
XCHORD	DP	PE	PPR	XCHORD	DP	PE	PPR	XCHORD	DP	PE	PPR
2.50	1.1214	1.2025	1.2742	2.50	1.1095	1.1992	1.2634	2.50	1.1474	1.1506	1.2373
8.00	1.0932	1.2119	1.3242	8.00	1.0832	1.2112	1.3306	8.00	1.0697	1.1769	1.2789
13.00	1.0785	1.2071	1.3334	13.00	1.0657	1.2030	1.3376	13.00	1.0199	1.1608	1.2947
20.00	1.0387	1.2249	1.3772	20.00	1.0735	1.2304	1.3728	20.00	1.0138	1.1794	1.3336
25.00	1.0352	1.2484	1.4042	25.00	1.0735	1.2470	1.4076	25.00	1.0125	1.1993	1.3636
30.00	1.1194	1.2729	1.4358	30.00	1.0971	1.2645	1.4278	30.00	1.0533	1.2172	1.3932
35.00	1.1233	1.2941	1.4646	35.00	1.1122	1.2879	1.4509	35.00	1.0703	1.2387	1.4221
40.00	1.1474	1.3236	1.5066	40.00	1.1379	1.3207	1.4916	40.00	1.0887	1.2635	1.4582
40.00	1.1474	1.3219	1.5022	40.00	1.1379	1.3207	1.4916	40.00	1.0887	1.2635	1.4582
50.00	1.1428	1.3219	1.5022	50.00	1.1390	1.3208	1.4790	50.00	1.0968	1.2720	1.4286
60.00	1.2643	1.4499	1.6189	60.00	1.2400	1.4301	1.6136	60.00	1.1968	1.3720	1.5617
70.00	1.3211	1.4583	1.6381	70.00	1.3058	1.4909	1.6469	70.00	1.2553	1.4256	1.6035
80.00	1.3500	1.5075	1.6567	80.00	1.3568	1.5174	1.6659	80.00	1.3135	1.4748	1.6394
90.00	1.3814	1.5249	1.6691	90.00	1.3050	1.5252	1.6709	90.00	1.3693	1.5109	1.6669
95.00	1.1915	1.6307	1.6738	95.00	1.3944	1.5290	1.6741	95.00	1.3952	1.5486	1.6786
IMPRESSION(X) = 18				IMPRESSION(X) = 20				IMPRESSION(X) = 50			
PRESSURE SURFACE		SUCTION SURFACE		PRESSURE SURFACE		SUCTION SURFACE		PRESSURE SURFACE		SUCTION SURFACE	
XCHORD	DP	PE	PPR	XCHORD	DP	PE	PPR	XCHORD	DP	PE	PPR
2.50	1.1298	1.4199	1.7477	2.50	1.4199	1.4922	1.6909	2.50	1.1674	1.4922	1.6909
8.00	1.3163	1.4996	1.7962	8.00	1.4996	1.7962	1.8887	8.00	1.3217	1.4963	1.6887
13.00	1.3831	1.5393	1.7876	13.00	1.5393	1.7876	1.8887	13.00	1.3859	1.5424	1.7064
20.00	1.4975	1.5596	1.7160	20.00	1.4975	1.7160	1.8887	20.00	1.4892	1.5644	1.7163
30.00	1.4306	1.5787	1.7245	30.00	1.4306	1.7245	1.8887	30.00	1.4329	1.5951	1.7298
45.00	1.4489	1.5991	1.7388	45.00	1.4489	1.7388	1.8887	45.00	1.4324	1.6914	1.7411
60.00	1.4604	1.6069	1.7453	60.00	1.4604	1.7453	1.8887	60.00	1.4528	1.6114	1.7511
70.00	1.4632	1.6102	1.7450	70.00	1.4632	1.7450	1.8887	70.00	1.4608	1.6387	1.7442
80.00	1.4594	1.5903	1.7335	80.00	1.4594	1.7335	1.8887	80.00	1.4476	1.5941	1.7299
90.00	1.4179	1.5767	1.6943	90.00	1.4179	1.6943	1.8887	90.00	1.4108	1.5578	1.6977
IMPRESSION(X) = 18				IMPRESSION(X) = 20				IMPRESSION(X) = 50			
PRESSURE SURFACE		SUCTION SURFACE		PRESSURE SURFACE		SUCTION SURFACE		PRESSURE SURFACE		SUCTION SURFACE	
XCHORD	DP	PE	PPR	XCHORD	DP	PE	PPR	XCHORD	DP	PE	PPR
2.50	1.1450	1.1737	1.1204	2.50	1.1451	1.1595	1.2278	2.50	1.1451	1.1595	1.2278
8.00	1.0974	1.1459	1.2194	8.00	1.0974	1.1459	1.2194	8.00	1.0946	1.2362	1.2362
13.00	1.0909	1.1208	1.2494	13.00	1.0909	1.1208	1.2494	13.00	1.0946	1.2362	1.2362
20.00	1.0809	1.1179	1.3043	20.00	1.0809	1.1179	1.3043	20.00	1.0946	1.2362	1.2362
25.00	1.0896	1.1596	1.3347	25.00	1.0896	1.1596	1.3347	25.00	1.0946	1.2362	1.2362
30.00	1.0740	1.1855	1.3747	30.00	1.0740	1.1855	1.3747	30.00	1.0946	1.2362	1.2362
35.00	1.0803	1.2158	1.4121	35.00	1.0803	1.2158	1.4121	35.00	1.0946	1.2362	1.2362
40.00	1.0675	1.2405	1.4447	40.00	1.0675	1.2405	1.4447	40.00	1.0946	1.2362	1.2362
50.00	1.0548	1.2282	1.4348	50.00	1.0548	1.2282	1.4348	50.00	1.0946	1.2362	1.2362
60.00	1.1066	1.3590	1.5717	60.00	1.1066	1.3590	1.5717	60.00	1.0946	1.2362	1.2362
70.00	1.2304	1.4162	1.6127	70.00	1.2304	1.4162	1.6127	70.00	1.0946	1.2362	1.2362
80.00	1.2560	1.4641	1.6346	80.00	1.2560	1.4641	1.6346	80.00	1.0946	1.2362	1.2362
90.00	1.3517	1.5103	1.6408	90.00	1.3517	1.5103	1.6408	90.00	1.0946	1.2362	1.2362
95.00	1.3761	1.5306	1.6562	95.00	1.3761	1.5306	1.6562	95.00	1.0946	1.2362	1.2362

Tabulated Surface Pressures
Normalized by 1/2 Pref U_t²

Throttle

DP - Design Point
PE - Peak Efficiency
PPR - Peak Pressure Rise/
Near Stall

Table 8. Normalized Absolute Total Pressure, Static Pressure, and Flow Angles for Rotor C/Stator B Four-Stage Configuration, Third Stage Tested.

PERCENT IMMERSION	Design Point Throttle						Near Peak Efficiency					
	TOTAL PRESSURE			STATIC PRESSURE			TOTAL PRESSURE			STATIC PRESSURE		
	ROTOR 3 INLET	ROTOR 3 EXIT	STATOR 3 EXIT	ROTOR 3 INLET	ROTOR 3 EXIT	STATOR 3 EXIT	ROTOR 3 INLET	ROTOR 3 EXIT	STATOR 3 EXIT	ROTOR 3 INLET	ROTOR 3 EXIT	STATOR 3 EXIT
2.0	1.0988	1.7557	1.7253	0.9657	1.3483	1.5826	1.2124	1.9348	1.8588	1.6844	1.4731	1.7282
5.0	1.1236	1.7938	1.7455	0.9587	1.3388	1.5798	1.2325	1.9497	1.8728	1.6792	1.4511	1.7247
7.0	1.1382	1.7993	1.7564	0.9555	1.3234	1.5778	1.2387	1.9487	1.8735	1.6759	1.4422	1.7224
10.0	1.1375	1.8039	1.7656	0.9527	1.3218	1.5747	1.2377	1.9483	1.8929	1.6714	1.4374	1.7192
15.0	1.1438	1.7894	1.7633	0.9551	1.3353	1.5724	1.2325	1.9169	1.8891	1.6686	1.4493	1.7155
20.0	1.1419	1.7728	1.7554	0.9588	1.3519	1.5695	1.2290	1.8966	1.8803	1.6675	1.4638	1.7125
30.0	1.1495	1.7668	1.7549	0.9534	1.3585	1.5658	1.2319	1.8879	1.8795	1.6616	1.4731	1.7074
40.0	1.1774	1.7962	1.7847	0.9489	1.3356	1.5618	1.2277	1.8986	1.8777	1.6519	1.4578	1.6981
50.0	1.1822	1.7885	1.7917	0.9434	1.3136	1.5568	1.2359	1.9114	1.8848	1.6467	1.4277	1.6892
60.0	1.1778	1.8141	1.7994	0.9397	1.3046	1.5528	1.2534	1.9385	1.8976	1.6431	1.4147	1.6895
70.0	1.1763	1.8261	1.8023	0.9361	1.2995	1.5486	1.2532	1.9396	1.8913	1.6347	1.4111	1.6833
80.0	1.1723	1.8376	1.8029	0.9299	1.2911	1.5448	1.2391	1.9759	1.8913	1.6319	1.4059	1.6768
90.0	1.1529	1.8463	1.7988	0.9248	1.2911	1.5366	1.2274	1.9768	1.8868	1.6276	1.4059	1.6653
95.0	1.1349	1.8499	1.7883	0.9198	1.2879	1.5279	1.2181	1.9768	1.8765	1.6268	1.3917	1.6516
96.0	1.1224	1.8525	1.7647	0.9165	1.2868	1.5226	1.2885	1.9669	1.8687	1.6268	1.3917	1.6516
97.0	1.1036	1.8495	1.7378	0.9143	1.2838	1.5186	1.1975	1.9361	1.8499	1.6249	1.3944	1.6536
98.0	1.0862	1.8435	1.7033	0.9187	1.2882	1.5245	1.1892	1.9294	1.8318	1.6258	1.3933	1.6555

Peak Pressure Rise/Near Stall

PERCENT IMMERSION	TOTAL PRESSURE						STATIC PRESSURE					
	ROTOR 3			STATOR 3			ROTOR 3			STATOR 3		
	INLET	EXIT	EXIT	INLET	EXIT	EXIT	INLET	EXIT	EXIT	INLET	EXIT	EXIT
2.0	0.9942	1.6825	1.5855	0.8593	1.2351	1.4358	0.8537	1.2298	1.4298	0.8537	1.2298	1.4298
5.0	0.9727	1.6546	1.6182	0.8512	1.2272	1.4273	0.8512	1.2272	1.4273	0.8512	1.2272	1.4273
7.0	0.9328	1.6656	1.6284	0.8494	1.2247	1.4258	0.8494	1.2247	1.4258	0.8494	1.2247	1.4258
10.0	0.9481	1.6585	1.6298	0.8531	1.2196	1.4278	0.8531	1.2196	1.4278	0.8531	1.2196	1.4278
15.0	1.0489	1.6594	1.6282	0.8589	1.2179	1.4283	0.8589	1.2179	1.4283	0.8589	1.2179	1.4283
20.0	0.9544	1.6398	1.6282	0.8486	1.2222	1.4242	0.8486	1.2222	1.4242	0.8486	1.2222	1.4242
30.0	1.0512	1.6417	1.6333	0.8486	1.2222	1.4242	0.8486	1.2222	1.4242	0.8486	1.2222	1.4242
40.0	0.9923	1.6734	1.6622	0.8453	1.2125	1.4193	0.8453	1.2125	1.4193	0.8453	1.2125	1.4193
50.0	1.1184	1.6924	1.6786	0.8453	1.1927	1.4171	0.8453	1.1927	1.4171	0.8453	1.1927	1.4171
60.0	1.0947	1.6981	1.6749	0.8346	1.1817	1.4139	0.8346	1.1817	1.4139	0.8346	1.1817	1.4139
70.0	1.0926	1.7098	1.6824	0.8317	1.1778	1.4113	0.8317	1.1778	1.4113	0.8317	1.1778	1.4113
80.0	1.0715	1.7149	1.6824	0.8258	1.1784	1.4017	0.8258	1.1784	1.4017	0.8258	1.1784	1.4017
90.0	1.0764	1.7196	1.6769	0.8185	1.1662	1.3894	0.8185	1.1662	1.3894	0.8185	1.1662	1.3894
95.0	1.0542	1.7235	1.6559	0.8137	1.1622	1.3822	0.8137	1.1622	1.3822	0.8137	1.1622	1.3822
96.0	1.0327	1.7225	1.6347	0.8112	1.1622	1.3766	0.8112	1.1622	1.3766	0.8112	1.1622	1.3766
97.0	1.0327	1.7225	1.6347	0.8112	1.1622	1.3766	0.8112	1.1622	1.3766	0.8112	1.1622	1.3766
98.0	0.9682	1.7149	1.5697	0.8146	1.1496	1.3743	0.8146	1.1496	1.3743	0.8146	1.1496	1.3743

Table 8. Normalized Absolute Total Pressure, Static Pressure, and Flow Angles for Rotor C/Stator B Four-Stage Configuration, Third Stage Tested (Concluded).

PERCENT IMMERSION	Design Point Throttle						Near Peak Efficiency					
	MEASURED			CORRECTED			MEASURED			CORRECTED		
	ROTOR 3 INLET	STATOR 3 INLET	STATOR 3 EXIT	ROTOR 3 INLET	STATOR 3 INLET	STATOR 3 EXIT	ROTOR 3 INLET	STATOR 3 INLET	STATOR 3 EXIT	ROTOR 3 INLET	STATOR 3 INLET	STATOR 3 EXIT
1.0	32.4	65.0	34.0	33.7	65.9	35.3	31.7	68.9	33.2	33.0	59.8	34.5
2.0	23.6	55.1	22.0	32.2	56.2	32.3	30.7	68.2	31.7	32.0	59.2	33.0
3.0	23.3	64.1	31.1	36.5	66.2	32.4	30.7	67.4	31.0	30.5	68.4	32.3
4.0	28.3	63.1	31.0	28.5	64.5	32.2	28.1	66.1	30.5	29.3	67.1	31.7
5.0	28.0	62.2	30.0	29.2	63.5	31.2	27.0	65.1	29.8	28.1	66.1	31.0
10.0	24.9	56.9	26.8	25.8	58.6	29.9	24.0	58.6	27.9	25.0	59.8	29.0
15.0	21.7	51.7	24.9	22.6	52.9	25.8	20.8	52.7	24.0	21.7	53.9	25.0
20.0	18.9	47.9	21.3	19.7	49.1	22.1	17.9	48.4	20.5	18.6	49.6	21.4
25.0	17.4	46.0	19.1	18.3	47.1	19.8	15.3	46.0	18.2	16.9	47.1	18.9
30.0	15.6	44.3	16.8	16.9	46.0	18.2	13.2	44.3	16.6	15.8	45.5	17.2
35.0	15.4	44.3	16.7	15.9	45.2	17.3	11.7	43.3	15.8	15.2	44.3	16.4
40.0	15.4	44.3	17.1	15.9	45.3	17.7	10.7	42.6	15.8	15.2	43.6	16.3
45.0	15.7	44.6	17.9	16.2	45.5	18.5	10.0	42.1	15.3	15.2	43.6	16.3
50.0	15.9	44.8	18.4	16.4	45.7	19.0	9.6	41.8	15.6	15.6	43.6	16.4
55.0	16.2	45.1	19.0	16.6	46.0	19.5	9.2	41.6	15.6	15.6	43.6	16.4
60.0	16.5	45.5	19.5	17.0	46.3	20.0	8.8	41.5	15.6	15.6	43.6	16.4
65.0	16.9	45.9	19.9	17.3	46.7	20.4	8.4	41.4	15.6	15.6	43.6	16.4
70.0	17.3	46.3	20.8	17.7	47.3	21.1	8.0	41.3	15.6	15.6	43.6	16.4
75.0	17.9	46.5	22.2	18.3	48.2	22.1	7.5	41.2	15.6	15.6	43.6	16.4
80.0	19.2	48.7	22.0	19.6	49.4	22.5	7.0	41.1	15.6	15.6	43.6	16.4
90.0	21.0	50.6	24.1	21.5	51.3	24.6	6.5	41.0	15.6	15.6	43.6	16.4
95.0	23.8	52.7	26.3	24.3	53.4	26.8	6.0	40.9	15.6	15.6	43.6	16.4
96.0	24.1	54.2	26.4	24.6	54.8	26.7	5.8	40.8	15.6	15.6	43.6	16.4
97.0	24.5	55.3	26.4	25.0	55.9	26.9	5.6	40.7	15.6	15.6	43.6	16.4
98.0	24.8	57.6	28.0	25.3	58.2	28.6	5.4	40.6	15.6	15.6	43.6	16.4
99.0		60.6		25.3	61.2		5.2	40.5	15.6	15.6	43.6	16.4

Peak Pressure Rise/ Near Stall

PERCENT IMMERSION	MEASURED						CORRECTED					
	ROTOR 3 INLET			STATOR 3 EXIT			ROTOR 3 INLET			STATOR 3 EXIT		
	ROTOR 3 INLET	STATOR 3 INLET	STATOR 3 EXIT	ROTOR 3 INLET	STATOR 3 INLET	STATOR 3 EXIT	ROTOR 3 INLET	STATOR 3 INLET	STATOR 3 EXIT	ROTOR 3 INLET	STATOR 3 INLET	STATOR 3 EXIT
1.0	31.4	71.6	33.9	32.7	72.4	35.2	72.4	35.2	72.4	35.2	72.4	35.2
2.0	30.8	70.7	33.0	32.1	71.6	34.3	71.6	34.3	71.6	34.3	71.6	34.3
3.0	29.9	70.1	32.5	31.1	71.0	33.8	69.8	33.1	70.8	33.8	70.8	33.8
4.0	28.8	68.9	31.8	30.0	69.8	33.1	68.7	32.3	69.8	32.3	69.8	32.3
5.0	28.0	67.7	31.1	29.2	68.7	32.3	67.4	31.4	68.7	31.4	68.7	31.4
10.0	24.9	62.3	28.3	25.9	63.4	29.4	63.4	29.4	63.4	29.4	63.4	29.4
15.0	21.8	55.6	23.2	22.7	56.8	24.1	60.3	24.1	56.8	24.1	56.8	24.1
20.0	19.5	51.5	20.1	20.3	52.7	20.9	52.7	20.9	52.7	20.9	52.7	20.9
25.0	17.3	48.8	18.2	18.0	49.9	18.9	48.5	18.9	49.9	18.9	49.9	18.9
30.0	15.8	47.4	17.2	16.4	48.5	17.8	48.5	17.8	48.5	17.8	48.5	17.8
35.0	14.9	47.0	16.8	15.4	48.1	17.4	48.1	17.4	48.1	17.4	48.1	17.4
40.0	14.5	47.2	16.8	15.0	48.3	17.4	48.3	17.4	48.3	17.4	48.3	17.4
45.0	14.6	47.9	17.1	15.0	48.9	17.7	48.9	17.7	48.9	17.7	48.9	17.7
50.0	15.0	48.8	17.6	15.5	49.7	18.2	49.7	18.2	49.7	18.2	49.7	18.2
55.0	15.5	49.6	18.2	16.0	50.5	18.7	50.5	18.7	50.5	18.7	50.5	18.7
60.0	16.3	50.4	19.0	16.8	51.3	19.5	51.3	19.5	51.3	19.5	51.3	19.5
65.0	17.2	51.4	20.0	17.7	52.3	20.6	52.3	20.6	52.3	20.6	52.3	20.6
70.0	18.1	52.5	21.2	18.6	53.3	21.8	53.3	21.8	53.3	21.8	53.3	21.8
75.0	19.1	53.7	22.5	19.6	54.4	23.1	54.4	23.1	54.4	23.1	54.4	23.1
80.0	20.0	54.9	23.7	20.5	55.6	24.3	55.6	24.3	55.6	24.3	55.6	24.3
85.0	21.1	56.5	25.4	21.6	56.8	25.6	56.8	25.6	56.8	25.6	56.8	25.6
90.0	22.0	58.2	26.3	22.6	57.7	26.9	57.7	26.9	57.7	26.9	57.7	26.9
95.0	23.1	59.5	27.6	23.6	58.6	28.1	58.6	28.1	58.6	28.1	58.6	28.1
96.0	23.1	59.5	27.6	23.6	58.6	28.1	58.6	28.1	58.6	28.1	58.6	28.1
97.0	23.0	59.3	27.5	23.5	58.4	28.0	58.4	28.0	58.4	28.0	58.4	28.0
98.0	22.2	58.2	26.2	22.7	57.3	26.9	57.3	26.9	57.3	26.9	57.3	26.9
99.0	23.2	62.6	22.7	23.7	63.1	23.2	63.1	23.2	63.1	23.2	63.1	23.2

Table 9. Rotor C Loss Coefficients Determined from Relative Total Pressure Measurements, Four-Stage Configuration, Third Stage Tested.

Design Point Throttle						
TOTAL PRESSURE			ROTOR LOSS COEFFICIENT			
PERCENT IMMERSION	ROTOR 3 INLET	ROTOR 3 EXIT	PERCENT IMMERSION	TOTAL LOSS	WAKE LOSS	TOTAL MINUS WAKE LOSS
5.0	1.6435	1.5434	5.0	0.1268	0.0016	0.1252
10.0	1.6752	1.6019	10.0	0.0287	0.0079	0.0208
15.0	1.7032	1.6563	15.0	0.0552	0.0182	0.0370
20.0	1.7451	1.6815	20.0	0.0711	0.0133	0.0578
35.0	1.7503	1.7076	35.0	0.0472	0.0191	0.0281
50.0	1.7186	1.6775	50.0	0.0470	0.0170	0.0301
65.0	1.6818	1.6341	65.0	0.0558	0.0207	0.0361
80.0	1.6162	1.5683	80.0	0.0513	0.0397	0.0116
85.0	1.5749	1.5268	85.0	0.0647	0.0509	0.0138
90.0	1.5442	1.4879	90.0	0.0784	0.0568	0.0216
95.0	1.4996	1.4513	95.0	0.0704	0.0554	0.0150

Near Peak Efficiency Throttle						
TOTAL PRESSURE			ROTOR LOSS COEFFICIENT			
PERCENT IMMERSION	ROTOR 3 INLET	ROTOR 3 EXIT	PERCENT IMMERSION	TOTAL LOSS	WAKE LOSS	TOTAL MINUS WAKE LOSS
5.0	1.7369	1.6345	5.0	0.1315	0.0205	0.1110
10.0	1.7713	1.6919	10.0	0.0970	0.0115	0.0855
15.0	1.7938	1.7547	15.0	0.0456	0.0155	0.0301
20.0	1.8296	1.7817	20.0	0.0549	0.0176	0.0373
35.0	1.8541	1.7986	35.0	0.0615	0.0151	0.0463
50.0	1.8060	1.7646	50.0	0.0483	0.0140	0.0342
65.0	1.7573	1.7153	65.0	0.0517	0.0261	0.0255
80.0	1.6905	1.6439	80.0	0.0621	0.0406	0.0215
85.0	1.6477	1.6055	85.0	0.0592	0.0423	0.0169
90.0	1.6151	1.5647	90.0	0.0737	0.0426	0.0311
95.0	1.5873	1.5453	95.0	0.0629	0.0459	0.0170

Peak Pressure Rise/Near Stall Throttle						
TOTAL PRESSURE			ROTOR LOSS COEFFICIENT			
PERCENT IMMERSION	ROTOR 3 INLET	ROTOR 3 EXIT	PERCENT IMMERSION	TOTAL LOSS	WAKE LOSS	TOTAL MINUS WAKE LOSS
5.0	1.8071	1.7212	5.0	0.1130	0.0045	0.1085
10.0	1.8625	1.7774	10.0	0.1075	0.0115	0.0960
15.0	1.8840	1.8350	15.0	0.0601	0.0205	0.0396
20.0	1.9051	1.8655	20.0	0.0474	0.0255	0.0219
35.0	1.9325	1.8873	35.0	0.0517	0.0250	0.0267
50.0	1.8921	1.9457	50.0	0.0552	0.0391	0.0161
65.0	1.8496	1.7635	65.0	0.1012	0.0523	0.0489
80.0	1.7614	1.6837	80.0	0.1032	0.0745	0.0287
85.0	1.7241	1.6532	85.0	0.1036	0.0651	0.0385
90.0	1.7059	1.6342	90.0	0.1067	0.0587	0.0480
95.0	1.6958	1.6276	95.0	0.1022	0.0750	0.0272

Table 10. Vector Diagram Parameters for Rotor C/Stator B
Four-Stage Configuration, Third Stage Tested,
Design Point Throttle.

BLADE ELEMENT DATA ROTOR INLET TIP SPEED = 66.87 MPS (219.40 FPS)

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
	%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS
1.0	57.2	187.7	53.9	176.7	70.1	19.3	63.3	12.9	42.4	23.2	76.2	33.7
2.0	57.5	188.7	53.7	176.3	68.9	20.5	67.3	12.9	42.5	24.3	79.6	32.2
3.0	57.8	189.7	53.6	175.8	67.8	21.7	71.1	13.0	42.6	25.3	82.9	30.8
4.0	58.2	190.9	53.8	176.6	66.7	22.8	74.9	12.9	42.4	26.2	86.1	29.5
5.0	58.2	190.8	53.1	174.2	65.8	23.7	77.8	13.3	43.5	27.2	89.1	29.2
7.0	58.6	192.1	53.0	173.9	64.7	24.9	81.7	13.2	43.2	28.2	92.4	27.8
10.0	59.3	194.4	53.3	174.8	63.8	26.0	85.2	12.6	41.3	28.9	94.7	25.8
15.0	60.5	198.4	54.1	177.5	63.3	27.0	88.5	11.3	36.9	29.2	95.9	22.6
20.0	61.6	202.0	54.8	179.9	62.7	28.0	92.0	10.0	32.9	29.8	97.7	19.6
30.0	62.2	204.2	55.0	180.4	61.9	29.1	95.6	8.9	29.1	30.5	100.0	16.9
50.0	61.4	201.4	52.7	172.8	58.9	31.5	103.5	9.2	30.1	32.8	107.8	16.2
70.0	59.4	195.0	49.8	162.7	56.4	32.8	107.5	10.3	33.7	34.3	112.6	17.4
80.0	57.8	189.8	48.2	158.2	56.3	31.9	104.8	10.6	34.9	33.7	110.5	18.3
85.0	56.7	186.0	47.0	154.1	55.7	31.8	104.3	11.4	37.4	33.8	110.8	19.7
90.0	55.3	181.6	45.3	148.6	54.8	31.8	104.3	12.5	41.2	34.2	112.2	21.5
93.0	54.0	177.1	44.3	145.3	55.0	30.8	101.2	13.3	43.5	33.6	110.1	23.2
95.0	53.0	173.8	44.0	144.3	56.0	29.5	96.9	13.4	43.9	32.4	106.3	24.3
96.0	52.5	172.3	44.3	145.2	57.3	28.3	92.7	13.0	42.6	31.1	102.0	24.6
97.0	51.9	170.3	45.2	148.2	60.3	25.6	83.9	12.0	39.3	28.2	92.7	25.0
98.0	51.6	169.2	45.9	150.7	62.8	23.4	76.8	11.1	36.4	25.9	85.0	25.3

BLADE ELEMENT DATA ROTOR OUTLET / STATOR INLET

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
	%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS
1.0	34.5	113.1	31.0	101.6	63.7	15.2	49.8	35.8	117.5	38.9	127.6	66.8
2.0	34.1	111.8	30.1	98.7	61.7	16.0	52.7	36.6	120.1	40.0	131.1	66.1
3.0	33.9	111.3	29.3	96.2	59.6	17.1	56.1	37.3	122.3	41.0	134.5	65.2
4.0	33.7	110.6	28.5	93.6	57.6	18.0	59.0	38.0	124.5	42.0	137.8	64.5
5.0	33.9	111.1	27.9	91.6	55.3	19.2	63.0	38.5	126.2	43.0	141.0	63.3
7.0	34.9	114.4	27.9	91.4	52.9	21.0	68.8	38.3	125.7	43.7	143.3	61.1
10.0	35.8	120.7	28.6	92.7	50.8	23.2	76.1	37.3	122.4	43.9	144.2	58.0
15.0	40.2	131.9	30.4	99.8	49.0	26.3	86.3	35.0	114.7	43.7	143.5	52.9
20.0	42.8	140.5	32.4	106.4	49.1	28.0	91.8	32.4	106.4	42.8	140.5	49.1
30.0	44.5	145.3	33.2	108.8	48.1	29.6	97.2	30.7	100.8	42.7	140.0	45.9
50.0	43.2	141.9	29.8	97.9	43.5	31.3	102.7	32.0	105.1	44.8	146.9	45.5
70.0	41.1	134.7	25.8	84.8	38.9	31.9	104.7	34.0	111.6	46.6	153.0	46.7
80.0	39.3	129.0	23.5	77.0	36.5	31.6	103.5	35.4	116.1	47.4	155.6	48.1
85.0	38.0	124.8	21.8	71.4	34.8	31.2	102.4	36.6	120.1	48.1	157.8	49.4
90.0	36.2	118.9	19.8	64.9	33.0	30.4	99.6	38.1	124.9	45.7	159.7	51.3
93.0	35.0	114.9	18.5	60.7	31.8	29.7	97.6	39.0	128.1	49.1	161.1	52.6
95.0	34.3	112.5	17.6	57.8	30.8	29.4	96.5	39.7	130.3	49.4	162.2	53.3
96.0	33.0	108.1	16.8	55.1	30.6	28.4	93.0	40.4	132.7	49.4	162.1	54.8
97.0	32.0	104.9	16.1	52.8	30.1	27.6	90.6	41.1	134.7	49.5	162.3	55.9
98.0	30.0	98.3	14.8	48.6	29.5	26.0	85.4	42.2	138.6	49.6	162.8	58.2

BLADE ELEMENT DATA STATOR OUTLET

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
	%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS
1.0	56.2	184.4	52.5	172.2	68.9	20.1	65.9	14.3	46.9	24.7	80.9	35.3
2.0	56.8	186.3	52.6	172.7	67.8	21.3	69.9	14.0	46.0	25.5	83.7	33.3
3.0	57.0	186.9	52.4	172.1	66.8	22.2	72.9	14.1	46.3	26.3	86.4	32.4
4.0	56.8	186.3	52.0	170.5	66.0	22.9	75.3	14.5	47.6	27.1	89.1	32.2
5.0	57.1	187.3	51.9	170.2	65.1	23.9	78.3	14.5	47.6	27.9	91.6	31.2
7.0	57.1	187.3	51.4	168.6	64.0	24.8	81.5	14.8	48.5	28.9	94.8	30.7
10.0	57.1	187.4	51.0	167.3	63.0	25.7	84.5	14.9	48.8	29.7	97.5	29.9
15.0	58.8	193.1	52.5	172.1	62.9	26.7	87.5	12.9	42.4	29.6	97.2	25.8
20.0	60.3	197.7	53.8	176.4	63.0	27.2	89.3	11.1	36.4	29.4	96.5	22.1
30.0	61.5	201.6	54.4	178.6	62.1	28.6	93.7	9.4	31.0	30.1	98.7	18.2
50.0	60.0	197.0	51.6	169.2	59.0	30.7	100.9	10.3	33.8	32.4	106.4	18.5
70.0	57.5	188.6	48.1	157.8	56.6	31.5	103.4	11.8	38.6	33.6	110.4	20.4
80.0	56.3	184.6	46.7	153.2	55.9	31.4	103.0	12.2	39.9	33.7	110.5	21.1
85.0	55.2	181.0	45.2	148.3	54.9	31.6	103.8	13.1	43.1	34.3	112.4	22.5
90.0	53.6	176.0	43.3	142.0	53.7	31.7	103.9	14.6	47.8	34.9	114.4	24.6
93.0	52.7	172.9	42.1	138.0	52.8	31.7	104.0	15.5	50.7	35.3	115.7	25.9
95.0	51.8	170.0	41.8	137.0	53.5	30.7	100.7	15.6	51.1	34.4	112.9	26.8
96.0	51.6	169.4	42.2	130.4	54.6	29.8	97.7	15.1	49.4	33.4	109.5	26.7
97.0	51.2	168.0	42.8	140.5	56.5	28.1	92.3	14.3	47.0	31.6	103.5	26.9
98.0	50.1	164.4	43.1	141.4	59.2	25.5	83.7	13.9	45.7	29.1	95.4	28.6

Table 11. Vector Diagram Parameters for Rotor C/Stator B Four-Stage Configuration, Third Stage Tested, Near Peak Efficiency Throttle.

BLADE ELEMENT DATA ROTOR INLET TIP SPEED * 66.87 MPS (219.40 FPS)

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
	%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS
1.0	57.5	188.7	54.2	177.7	70.1	19.3	63.5	12.6	41.3	23.1	75.7	33.0
2.0	57.6	189.1	53.9	176.9	69.1	20.4	66.9	12.8	41.9	24.1	79.0	32.0
3.0	58.0	190.3	53.9	176.7	68.0	21.5	70.6	12.7	41.7	25.0	82.0	30.5
4.0	58.3	191.3	53.8	176.4	67.0	22.6	74.2	12.7	41.7	25.9	85.1	29.3
5.0	58.7	192.5	53.7	176.2	66.1	23.6	77.5	12.7	41.6	26.8	88.0	28.1
7.0	59.0	193.7	53.7	176.1	65.2	24.6	80.7	12.5	41.0	27.6	90.5	26.9
10.0	59.7	195.8	53.8	176.6	64.3	25.7	84.4	12.0	39.5	28.4	93.2	25.0
15.0	60.9	199.8	54.8	179.7	63.9	26.6	87.2	10.6	34.7	28.6	93.9	21.6
20.0	61.9	203.1	55.8	183.1	64.1	26.8	88.0	9.1	29.7	28.3	92.9	18.6
30.0	62.6	205.3	55.9	183.4	63.1	28.1	92.3	8.0	26.1	29.2	95.9	15.3
50.0	61.1	200.6	53.1	174.2	60.1	30.3	99.4	8.8	28.8	31.5	103.5	16.1
70.0	58.6	192.1	49.9	163.6	58.2	30.7	100.7	10.0	32.7	32.3	105.9	18.0
80.0	57.3	187.9	48.5	159.0	57.6	30.5	100.1	10.4	34.1	32.2	105.7	18.8
85.0	56.2	184.4	47.3	155.1	57.1	30.4	99.8	11.1	36.3	32.4	106.2	20.0
90.0	54.8	179.6	45.7	149.9	56.4	30.2	99.0	12.2	39.9	32.5	106.7	21.9
93.0	53.6	175.8	44.8	146.9	56.5	29.4	96.5	12.8	41.9	32.1	105.2	23.4
95.0	52.6	172.7	44.7	146.5	57.9	27.9	91.5	12.7	41.6	30.6	100.5	24.4
96.0	52.4	172.0	44.8	146.9	58.5	27.3	89.4	12.5	40.9	30.0	98.3	24.5
97.0	52.1	171.0	45.1	148.0	59.8	26.1	85.6	12.0	39.5	28.7	94.3	24.7
98.0	50.9	167.1	44.9	147.2	61.6	24.1	79.1	12.2	40.0	27.0	88.7	26.7

BLADE ELEMENT DATA ROTOR OUTLET / STATOR INLET

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
	%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS
1.0	31.5	103.3	28.2	92.4	63.3	14.0	46.1	38.6	126.6	41.1	134.8	69.8
2.0	31.1	102.0	27.3	89.6	61.3	14.8	48.7	39.3	129.1	42.1	138.0	69.1
3.0	30.8	101.2	26.5	87.1	59.2	15.7	51.6	40.0	131.4	43.0	141.1	68.4
4.0	31.0	101.7	25.9	85.0	56.6	17.0	55.7	40.5	133.0	44.0	144.2	67.1
5.0	31.1	101.9	25.3	82.9	54.3	18.0	59.2	41.1	134.8	44.9	147.3	66.1
7.0	32.4	106.3	25.4	83.3	51.5	20.1	66.0	40.8	133.8	45.5	149.2	63.6
10.0	34.9	114.5	26.3	86.2	48.7	22.9	75.3	39.6	129.9	45.8	150.1	59.7
15.0	39.3	129.0	29.4	96.5	48.3	26.1	85.6	35.9	117.9	44.4	145.7	53.9
20.0	42.5	139.4	32.3	105.8	49.3	27.6	90.7	32.6	107.0	42.8	140.3	49.6
30.0	44.9	147.2	33.5	110.0	48.2	29.8	97.7	30.3	99.5	42.5	135.5	45.4
50.0	45.4	149.1	31.4	103.2	43.7	32.8	107.6	30.4	99.8	44.7	146.7	42.7
70.0	40.9	134.1	25.9	85.1	39.2	31.6	103.7	33.9	111.3	46.4	152.1	46.9
80.0	37.7	123.8	22.7	74.5	36.9	30.1	98.9	36.1	118.5	47.1	154.4	50.0
85.0	36.2	118.7	20.8	68.2	34.9	29.6	97.2	37.6	123.2	47.8	157.0	51.6
90.0	34.5	113.3	18.9	61.9	33.0	28.9	95.0	39.0	127.9	48.6	159.3	53.3
93.0	33.8	111.0	17.8	58.2	31.5	28.8	94.5	39.8	130.6	49.1	161.2	53.9
95.0	33.4	109.7	17.1	56.1	30.7	28.7	94.2	40.2	132.0	49.4	162.2	54.3
96.0	33.1	108.4	16.7	54.6	30.2	28.6	93.7	40.6	133.2	49.6	162.8	54.7
97.0	31.9	104.6	15.9	52.2	29.9	27.6	90.7	41.2	135.3	49.6	162.8	56.0
98.0	29.9	98.0	14.9	48.8	29.8	25.9	85.0	42.2	138.4	49.5	162.4	58.3

BLADE ELEMENT DATA STATOR OUTLET

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
	%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS
1.0	56.7	185.9	53.1	174.1	69.3	19.8	65.1	13.7	44.9	24.1	79.1	34.5
2.0	57.1	187.2	53.1	174.3	68.4	20.8	68.2	13.5	44.4	24.8	81.4	33.0
3.0	57.2	187.5	52.9	173.7	67.7	21.5	70.7	13.6	44.7	25.5	83.6	32.3
4.0	57.2	187.6	52.7	172.9	66.9	22.2	72.9	13.8	45.2	26.1	85.8	31.7
5.0	57.3	188.1	52.5	172.4	66.2	23.0	75.3	13.8	45.4	26.8	87.9	31.0
7.0	57.4	188.4	52.2	171.1	65.1	24.0	78.9	14.0	46.0	27.8	91.3	30.2
10.0	57.7	189.2	51.9	170.3	64.0	25.1	82.3	13.9	45.8	28.7	94.2	29.0
15.0	59.2	194.4	53.2	174.6	63.8	26.0	85.3	12.1	39.8	28.7	94.2	24.9
20.0	60.5	198.6	54.5	178.8	64.0	26.4	86.5	10.4	34.0	28.3	92.9	21.4
30.0	61.7	202.6	55.4	181.7	63.6	27.3	89.5	8.5	27.8	28.6	93.7	17.2
50.0	60.1	197.3	52.4	171.8	60.4	29.6	97.1	9.5	31.1	31.1	102.0	17.7
70.0	57.3	188.0	48.9	160.3	58.4	29.9	98.1	11.0	36.0	31.8	104.5	20.1
80.0	56.3	184.8	47.5	155.8	57.3	30.3	99.3	11.3	37.2	32.3	106.1	20.5
85.0	55.1	180.8	46.0	150.8	56.4	30.4	99.7	12.4	40.6	32.8	107.7	22.1
90.0	53.4	175.2	44.0	144.2	55.2	30.4	99.6	13.9	45.6	33.4	109.5	24.5
93.0	52.9	173.7	43.3	142.0	54.7	30.5	100.0	14.3	46.8	33.6	110.4	25.0
95.0	52.5	172.2	43.2	141.7	55.2	29.8	97.9	14.2	46.4	33.0	108.3	25.3
96.0	52.3	171.6	43.4	142.3	55.9	29.2	95.8	13.9	45.5	32.3	105.1	25.3
97.0	52.0	170.6	44.0	144.3	57.6	27.7	91.0	13.2	43.2	30.7	100.7	25.3
98.0	49.3	161.7	43.0	141.2	60.7	24.0	78.7	14.0	45.9	27.8	91.1	30.2

Table 12. Vector Diagram Parameters for Rotor C/Stator B
Four-Stage Configuration, Third Stage Tested,
Peak Pressure Rise/Near Stall Throttle.

BLADE ELEMENT DATA ROTOR INLET TIP SPEED = 66.87 MPS (219.40 FPS)

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
	%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS
1.0	57.7	189.3	54.4	178.6	70.4	19.2	62.9	12.3	40.5	22.8	74.8	32.7
2.0	57.7	189.3	54.1	177.6	69.5	20.0	65.5	12.6	41.2	23.6	77.4	32.1
3.0	57.8	189.7	54.0	177.0	68.7	20.8	68.3	12.6	41.4	24.4	79.9	31.1
4.0	58.1	190.6	53.9	176.8	67.8	21.7	71.3	12.6	41.3	25.1	82.4	30.0
5.0	58.3	191.2	53.8	176.4	67.1	22.5	73.9	12.6	41.4	25.8	84.7	29.2
7.0	58.6	192.3	53.7	176.1	66.2	23.5	77.1	12.5	41.0	26.6	87.3	27.9
10.0	59.2	194.4	54.1	177.4	65.7	24.2	79.3	11.8	38.7	26.9	88.2	25.9
15.0	60.3	197.8	55.0	180.6	65.7	24.6	80.8	10.3	33.9	26.7	87.6	22.7
20.0	61.0	200.0	55.6	182.5	65.7	24.9	81.8	9.2	30.3	26.6	87.2	20.3
30.0	61.9	203.2	56.2	184.3	64.9	26.1	85.7	7.7	25.3	27.2	89.3	16.4
50.0	60.6	198.9	54.5	178.7	63.7	26.6	87.4	7.4	24.3	27.7	90.7	15.5
70.0	57.5	188.7	50.7	166.3	61.6	27.2	89.2	9.2	30.1	28.7	94.1	18.6
80.0	55.9	183.5	48.2	158.2	59.4	28.3	92.9	10.6	34.8	30.3	99.3	20.5
85.0	54.4	178.6	46.6	152.9	58.7	28.1	92.2	11.7	38.5	30.4	99.9	22.6
90.0	52.9	173.6	45.4	149.1	59.0	27.1	89.0	12.4	40.7	29.8	97.9	24.5
93.0	52.9	173.4	45.6	149.7	59.5	26.7	87.5	11.9	39.1	29.2	95.8	24.0
95.0	52.8	173.4	45.8	150.2	59.9	26.4	86.5	11.6	37.9	28.8	94.5	23.6
96.0	52.9	173.7	46.2	151.4	60.5	25.9	85.1	11.1	36.4	28.2	92.5	23.1
97.0	53.0	173.8	46.6	152.7	61.3	25.3	82.9	10.6	34.7	27.4	89.9	22.7
98.0	52.3	171.7	46.4	152.4	62.4	24.1	79.1	10.6	34.8	26.3	83.4	23.7

BLADE ELEMENT DATA ROTOR OUTLET / STATOR INLET

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
	%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS
1.0	28.0	91.7	24.6	80.9	61.7	13.2	43.3	42.1	138.2	44.1	144.8	72.4
2.0	28.0	91.7	24.2	79.3	59.7	14.0	46.0	42.5	139.4	44.7	146.8	71.5
3.0	27.8	91.3	23.7	77.6	58.1	14.6	48.1	42.9	140.8	45.3	148.7	71.0
4.0	28.1	92.3	23.3	76.5	55.9	15.7	51.6	43.2	141.6	45.9	150.7	69.8
5.0	28.5	93.5	23.0	75.5	53.7	16.8	55.1	43.4	142.3	46.5	152.6	68.6
7.0	29.7	97.3	23.1	75.9	51.1	18.6	60.9	43.0	141.2	46.9	153.8	66.5
10.0	31.8	104.4	24.1	79.0	49.0	20.8	68.3	41.8	137.2	46.7	153.2	63.4
15.0	37.0	121.4	27.7	90.8	48.3	24.6	80.6	37.7	123.7	45.0	147.6	56.8
20.0	40.1	131.6	30.4	99.6	49.1	26.2	85.9	34.5	113.2	43.3	142.1	52.7
30.0	42.6	139.7	32.0	105.1	48.7	28.0	92.0	31.8	104.4	42.4	139.1	48.5
50.0	40.0	131.4	28.4	93.2	45.1	28.2	92.6	33.4	109.7	43.8	143.6	49.7
70.0	35.7	117.3	23.1	75.7	40.1	27.3	89.6	36.8	120.7	45.8	150.3	53.3
80.0	33.1	108.7	19.4	63.8	35.8	26.8	88.0	39.4	129.3	47.7	156.4	55.6
85.0	32.4	106.2	17.8	58.2	33.2	27.1	88.8	40.6	133.2	48.8	160.1	56.2
90.0	31.7	104.0	16.2	53.3	30.7	27.2	89.4	41.6	136.5	49.7	163.2	56.6
93.0	31.3	102.8	15.4	50.6	29.4	27.3	89.5	42.1	138.2	50.2	164.6	56.9
95.0	31.0	101.6	15.3	50.1	29.5	26.9	88.4	42.1	138.0	50.0	163.9	57.2
96.0	30.1	98.8	15.2	50.0	30.3	26.0	85.3	42.0	137.8	49.4	162.1	58.1
97.0	29.4	96.5	15.6	51.1	31.9	24.9	81.8	41.6	136.4	48.5	159.1	58.9
98.0	27.8	91.1	14.9	48.9	32.3	23.4	76.9	42.1	138.3	48.2	158.2	60.8

BLADE ELEMENT DATA STATOR OUTLET

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
	%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS
1.0	56.6	185.3	53.4	175.3	70.4	18.8	61.8	13.3	43.8	23.1	75.7	35.2
2.0	56.8	186.3	53.3	174.9	69.7	19.5	64.0	13.4	43.8	23.6	77.5	34.3
3.0	56.8	186.2	53.1	174.2	69.1	20.1	65.9	13.5	44.2	24.2	79.3	33.8
4.0	56.9	186.5	53.0	173.7	68.5	20.7	67.9	13.5	44.3	24.7	81.1	33.1
5.0	57.0	186.9	52.8	173.3	67.8	21.3	69.9	13.5	44.4	25.2	82.8	32.3
7.0	57.1	187.4	52.5	172.3	66.6	22.5	73.9	13.7	44.8	26.3	86.4	31.2
10.0	57.6	188.8	52.4	171.9	65.4	23.8	78.1	13.5	44.2	27.3	89.7	29.4
15.0	59.6	195.6	54.2	177.7	65.1	24.9	81.8	11.2	36.4	27.3	89.7	24.1
20.0	60.7	199.1	55.2	181.3	65.3	25.1	82.5	9.6	31.6	26.9	88.3	20.9
30.0	61.3	201.0	55.5	182.1	64.8	25.9	85.0	8.4	27.4	27.2	89.3	17.8
50.0	59.4	194.8	53.2	174.5	63.4	26.4	86.7	8.7	28.5	27.8	91.2	18.1
70.0	56.0	183.6	49.1	161.1	61.1	26.9	88.2	10.8	35.3	29.0	95.0	21.7
80.0	53.9	176.9	46.5	152.6	59.4	27.3	89.6	12.3	40.5	30.0	98.3	24.3
85.0	52.6	172.7	45.0	147.7	58.6	27.3	89.6	13.3	43.8	30.4	99.7	26.0
90.0	52.3	171.5	44.5	146.1	58.2	27.4	89.9	13.3	43.7	30.5	99.9	25.8
93.0	52.3	171.5	44.4	145.6	57.9	27.6	90.6	13.2	43.2	30.6	100.4	25.4
95.0	52.5	172.2	44.9	147.4	58.7	27.2	89.2	12.4	40.8	29.9	98.0	24.5
96.0	53.3	174.7	45.6	149.6	58.7	27.5	90.2	11.6	38.2	29.9	98.0	22.9
97.0	53.3	174.9	46.1	151.1	59.6	26.9	88.2	11.1	36.4	29.1	95.4	22.4
98.0	52.7	172.8	46.2	151.5	61.1	25.3	83.1	10.9	35.7	27.6	90.4	23.2

Table 13. Blade and Vane Element Performance for Rotor C/
Stator B, Four-Stage Configuration, Third Stage
Tested, Design Point Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED		REL. TURNING ANGLE DEG	LOSS COEF.	LOSS PARA.	REL. MACH NO. IN	DIFF. FACT.	REL. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG
	MPS	FPS								
1.0	66.8	219.07	6.4	0.129	0.113	0.162	0.582	0.098	-3.9	18.7
2.0	66.7	218.74	7.2	0.147	0.129	0.163	0.597	0.097	-5.0	16.9
3.0	66.6	218.41	8.2	0.158	0.141	0.164	0.606	0.096	-6.0	14.9
4.0	66.5	218.08	9.1	0.174	0.155	0.165	0.618	0.096	-6.9	13.1
5.0	66.4	217.75	10.4	0.169	0.153	0.165	0.616	0.096	-7.7	10.9
7.0	66.2	217.10	11.8	0.161	0.146	0.166	0.601	0.099	-8.4	8.8
10.0	65.9	216.11	13.1	0.142	0.130	0.168	0.569	0.104	-8.7	7.1
15.0	65.4	214.46	14.3	0.113	0.105	0.172	0.513	0.114	-8.2	5.9
20.0	64.9	212.82	13.7	0.086	0.080	0.175	0.468	0.121	-7.9	6.6
30.0	63.9	209.53	13.8	0.061	0.056	0.177	0.441	0.126	-6.8	7.0
50.0	61.9	202.94	15.4	0.071	0.067	0.174	0.456	0.123	-7.4	5.9
70.0	59.9	196.36	17.5	0.080	0.077	0.169	0.476	0.116	-9.5	6.6
80.0	58.8	193.07	19.8	0.078	0.076	0.164	0.499	0.111	-9.6	6.5
85.0	58.3	191.43	21.0	0.074	0.071	0.161	0.514	0.108	-10.2	5.9
90.0	57.8	189.78	21.8	0.073	0.071	0.157	0.537	0.103	-11.1	5.2
93.0	57.5	188.79	23.2	0.051	0.050	0.153	0.550	0.099	-10.9	4.8
95.0	57.3	188.14	25.1	0.032	0.031	0.150	0.560	0.097	-9.9	4.4
96.0	57.2	187.81	26.7	0.045	0.044	0.149	0.591	0.093	-8.6	4.4
97.0	57.1	187.48	30.2	0.051	0.050	0.147	0.618	0.091	-5.6	4.3
98.0	57.0	187.15	33.3	0.107	0.104	0.146	0.672	0.085	-3.1	4.0

TORQUE = 9875.74 IN.-LB.

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED		ABS. TURNING ANGLE DEG	ABS. MACH NO. IN	ABS. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.
	MPS	FPS								
1.0	66.8	219.07	31.5	0.110	0.070	-1.6	15.3	0.0224	0.0219	0.5638
2.0	66.7	218.74	32.9	0.113	0.072	-1.3	13.9	0.0463	0.0453	0.5634
3.0	66.6	218.41	32.8	0.116	0.075	-1.4	13.6	0.0678	0.0664	0.5592
4.0	66.5	218.08	32.2	0.119	0.077	-1.2	14.1	0.0870	0.0853	0.5530
5.0	66.4	217.75	32.1	0.122	0.079	-1.5	13.7	0.1045	0.1025	0.5492
7.0	66.2	217.10	30.5	0.124	0.082	-2.2	14.3	0.1031	0.1012	0.5306
10.0	65.9	216.11	28.1	0.125	0.084	-3.2	14.9	0.0883	0.0868	0.5059
15.0	65.4	214.46	27.1	0.124	0.084	-5.1	12.3	0.0673	0.0664	0.5030
20.0	64.9	212.82	27.0	0.121	0.083	-6.4	9.6	0.0275	0.0272	0.4914
30.0	63.9	209.53	27.7	0.121	0.085	-7.0	6.5	0.0184	0.0183	0.4720
50.0	61.9	202.94	27.1	0.127	0.092	-6.5	7.0	0.0243	0.0241	0.4457
70.0	59.9	196.36	26.3	0.132	0.095	-7.1	8.2	0.0276	0.0274	0.4420
80.0	58.8	193.07	27.0	0.134	0.095	-7.8	7.8	0.0449	0.0446	0.4554
85.0	58.3	191.43	26.9	0.136	0.097	-8.1	8.2	0.0501	0.0496	0.4513
90.0	57.8	189.78	26.7	0.138	0.099	-8.3	9.0	0.0597	0.0591	0.4450
93.0	57.5	188.79	26.6	0.139	0.100	-8.5	9.1	0.0772	0.0763	0.4408
95.0	57.3	188.14	26.5	0.140	0.097	-8.9	8.9	0.1205	0.1190	0.4655
96.0	57.2	187.81	28.1	0.140	0.095	-8.0	8.2	0.1579	0.1561	0.4343
97.0	57.1	187.48	29.0	0.140	0.089	-7.6	7.6	0.2120	0.2095	0.5405
98.0	57.0	187.15	29.6	0.141	0.082	-6.1	8.4	0.2569	0.2534	0.6022

Table 14. Blade and Vane Element Performance for Rotor C/Stator B, Four-Stage Configuration, Third Stage Tested, Near Peak Efficiency Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED		REL. TURNING ANGLE DEG	LOSS COEF.	LOSS PARA.	REL. MACH NO. IN	DIFF. FACT.	REL. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG
	MPS	FPS								
1.0	66.8	219.07	6.8	0.186	0.162	0.163	0.662	0.089	-3.8	18.4
2.0	66.7	218.74	7.8	0.201	0.177	0.164	0.673	0.088	-4.8	16.5
3.0	66.6	218.41	8.9	0.221	0.196	0.165	0.685	0.087	-5.7	14.5
4.0	66.5	218.08	10.4	0.231	0.208	0.165	0.688	0.088	-6.6	12.1
5.0	66.4	217.75	11.7	0.244	0.221	0.166	0.693	0.088	-7.4	9.9
7.0	66.2	217.10	13.7	0.233	0.214	0.168	0.670	0.092	-7.9	7.4
10.0	65.9	216.11	15.5	0.200	0.185	0.169	0.625	0.099	-8.2	5.0
15.0	65.4	214.46	15.6	0.129	0.120	0.173	0.543	0.111	-7.6	5.2
20.0	64.9	212.82	14.9	0.074	0.069	0.176	0.485	0.120	-6.5	6.8
30.0	63.9	209.53	14.9	0.036	0.034	0.178	0.441	0.127	-5.6	7.1
50.0	61.9	202.94	16.4	0.011	0.011	0.173	0.409	0.129	-6.2	6.1
70.0	59.9	196.36	19.0	0.035	0.033	0.166	0.472	0.116	-7.7	6.9
80.0	58.8	193.07	20.7	0.074	0.071	0.162	0.528	0.107	-8.3	6.9
85.0	58.3	191.43	22.1	0.078	0.075	0.159	0.553	0.103	-8.8	6.0
90.0	57.8	189.78	23.4	0.065	0.063	0.155	0.573	0.098	-9.5	5.2
93.0	57.5	188.79	25.0	0.037	0.036	0.152	0.579	0.096	-9.4	4.6
95.0	57.3	188.14	27.2	0.012	0.011	0.149	0.583	0.095	-8.0	4.3
96.0	57.2	187.81	28.3	0.010	0.010	0.149	0.593	0.094	-7.4	4.0
97.0	57.1	187.48	29.9	0.028	0.027	0.148	0.622	0.090	-6.1	4.0
98.0	57.0	187.15	31.8	0.043	0.042	0.145	0.660	0.085	-4.3	4.2

TORQUE = 9915.40 IN.-LB.

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED		ABS. TURNING ANGLE DEG	ABS. MACH NO. IN	ABS. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.
	MPS	FPS								
1.0	66.8	219.07	35.3	0.116	0.068	1.4	14.4	0.0628	0.0613	0.6294
2.0	66.7	218.74	36.2	0.119	0.070	1.7	13.6	0.0746	0.0730	0.6292
3.0	66.6	218.41	36.1	0.122	0.072	1.8	13.5	0.0854	0.0837	0.6267
4.0	66.5	218.08	35.4	0.125	0.074	1.5	13.6	0.0951	0.0932	0.6228
5.0	66.4	217.75	35.1	0.127	0.076	1.3	13.5	0.1041	0.1022	0.6197
7.0	66.2	217.10	33.4	0.129	0.079	0.3	13.8	0.0901	0.0885	0.5983
10.0	65.9	216.11	30.7	0.130	0.081	1.5	14.0	0.0794	0.0781	0.5730
15.0	65.4	214.46	28.9	0.126	0.081	-4.1	11.4	0.0575	0.0568	0.5453
20.0	64.9	212.82	28.2	0.121	0.080	-5.9	8.9	0.0413	0.0410	0.5233
30.0	63.9	209.53	28.2	0.120	0.081	-7.5	5.5	0.0286	0.0284	0.5104
50.0	61.9	202.94	25.0	0.127	0.088	-9.3	6.2	0.0250	0.0248	0.4688
70.0	59.9	196.36	26.8	0.131	0.090	-6.9	7.9	0.0338	0.0337	0.4827
80.0	58.8	193.07	29.5	0.133	0.092	-5.9	7.2	0.0308	0.0306	0.4907
85.0	58.3	191.43	29.5	0.136	0.093	-5.9	7.8	0.0452	0.0448	0.4906
90.0	57.8	189.78	28.7	0.138	0.094	-6.3	8.9	0.0642	0.0635	0.4848
93.0	57.5	188.79	28.9	0.137	0.095	-7.1	8.1	0.0856	0.0847	0.4876
95.0	57.3	188.14	29.0	0.140	0.093	-7.9	7.4	0.1238	0.1225	0.5038
96.0	57.2	187.81	29.4	0.141	0.092	-8.1	6.7	0.1550	0.1533	0.5267
97.0	57.1	187.48	30.7	0.141	0.087	-7.5	6.0	0.1987	0.1966	0.5681
98.0	57.0	187.15	29.1	0.140	0.079	-6.0	10.0	0.2490	0.2453	0.6265

Table 15. Blade and Vane Element Performance for Rotor C/Stator B, Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise/Near Stall Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED		REL. TURNING ANGLE DEG	LOSS COEF.	LOSS PARA.	REL. MACH NO. IN	DIFF. FACT.	REL. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG
	MPS	FPS								
1.0	66.8	219.07	8.7	0.245	0.215	0.164	0.754	0.079	-3.6	16.7
2.0	66.7	218.74	9.8	0.252	0.223	0.164	0.755	0.079	-4.3	14.9
3.0	66.6	218.41	10.6	0.265	0.236	0.164	0.760	0.079	-5.1	13.4
4.0	66.5	218.08	12.0	0.274	0.247	0.165	0.758	0.080	-5.8	11.3
5.0	66.4	217.75	13.4	0.280	0.254	0.165	0.753	0.081	-6.4	9.3
7.0	66.2	217.10	15.1	0.275	0.252	0.166	0.732	0.084	-6.9	7.0
10.0	65.9	216.11	16.7	0.252	0.233	0.168	0.693	0.090	-6.8	5.3
15.0	65.4	214.46	17.5	0.161	0.149	0.171	0.592	0.105	-5.8	5.1
20.0	64.9	212.82	16.6	0.096	0.089	0.173	0.529	0.114	-4.9	6.6
30.0	63.9	209.53	16.2	0.053	0.049	0.176	0.485	0.121	-3.8	7.6
50.0	61.9	202.94	18.7	0.077	0.073	0.172	0.525	0.113	-2.6	7.5
70.0	59.9	196.36	21.5	0.106	0.102	0.163	0.578	0.101	-4.3	7.8
80.0	58.8	193.07	23.6	0.126	0.122	0.159	0.622	0.094	-6.5	5.8
85.0	58.3	191.43	25.6	0.096	0.093	0.154	0.626	0.092	-7.2	4.3
90.0	57.8	189.78	28.3	0.052	0.050	0.150	0.631	0.090	-6.9	2.9
93.0	57.5	188.79	30.1	0.060	0.059	0.150	0.645	0.089	-6.4	2.4
95.0	57.3	188.14	30.4	0.069	0.068	0.150	0.655	0.088	-6.0	3.1
96.0	57.2	187.81	30.2	0.092	0.090	0.150	0.675	0.085	-5.4	4.2
97.0	57.1	187.48	29.4	0.114	0.111	0.150	0.689	0.083	-4.6	6.0
98.0	57.0	187.15	30.1	0.135	0.132	0.148	0.721	0.079	-3.5	6.8

TORQUE = 10.124.79 IN.-LB.

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED		ABS. TURNING ANGLE DEG	ABS. MACH NO. IN	ABS. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.
	MPS	FPS								
1.0	66.8	219.07	37.2	0.125	0.065	4.0	15.2	0.1707	0.1666	0.7101
2.0	66.7	218.74	37.2	0.127	0.067	4.1	14.9	0.1663	0.1625	0.7043
3.0	66.6	218.41	37.2	0.128	0.068	4.4	15.1	0.1622	0.1586	0.6983
4.0	66.5	218.08	36.7	0.130	0.070	4.2	15.0	0.1579	0.1546	0.6921
5.0	66.4	217.75	36.3	0.132	0.071	3.8	14.8	0.1542	0.1511	0.6861
7.0	66.2	217.10	35.3	0.133	0.075	3.2	14.8	0.1287	0.1263	0.6619
10.0	65.9	216.11	33.9	0.132	0.077	2.2	14.4	0.0943	0.0927	0.6312
15.0	65.4	214.46	32.6	0.127	0.077	-1.2	10.6	0.0595	0.0589	0.6029
20.0	64.9	212.82	31.8	0.123	0.076	-2.8	8.4	0.0365	0.0362	0.5839
30.0	63.9	209.53	30.7	0.120	0.077	-4.4	6.1	0.0203	0.0201	0.5542
50.0	61.9	202.94	31.6	0.124	0.079	-2.3	6.6	0.0473	0.0470	0.5623
70.0	59.9	196.36	31.5	0.130	0.082	-0.5	9.5	0.0566	0.0562	0.5621
80.0	58.8	193.07	31.3	0.135	0.085	-0.3	11.0	0.0792	0.0784	0.5631
85.0	58.3	191.43	30.2	0.138	0.086	-1.4	11.7	0.1130	0.1117	0.5648
90.0	57.8	189.78	30.8	0.141	0.086	-3.0	10.2	0.1555	0.1537	0.5773
93.0	57.5	188.79	31.5	0.142	0.087	-4.2	8.6	0.1709	0.1690	0.5816
95.0	57.3	188.14	32.7	0.142	0.085	-5.0	6.6	0.1728	0.1711	0.5985
96.0	57.2	187.81	35.2	0.140	0.085	-4.7	4.3	0.1640	0.1626	0.5986
97.0	57.1	187.48	36.5	0.137	0.082	-4.6	3.0	0.1591	0.1578	0.6079
98.0	57.0	187.15	37.6	0.137	0.078	-3.5	3.0	0.1821	0.1804	0.6426

Table 16. Design Intent Performance for Rotor A/Stator A
Computed for $U_t = 63.82$ mps (209.38 fps).

BLADE ELEMENT DATA ROTOR INLET													
IMMER %	W		WU		BETA DEG	CZ		CU		C		ALPHA DEG	
	MPS	FPS	MPS	FPS		MPS	FPS	MPS	FPS	MPS	FPS		
0	56.7	186.0	52.6	172.8	68.2	21.1	69.2	14.3	46.8	25.4	83.5	34.1	
5	58.0	190.1	53.3	174.7	68.7	22.9	75.1	13.1	43.1	26.4	86.6	29.8	
10	59.0	193.5	53.7	176.2	65.6	24.4	80.1	12.2	39.9	27.3	89.5	26.5	
20	60.3	197.9	54.0	177.3	63.6	26.8	87.9	10.8	35.5	28.9	94.8	22.0	
30	60.8	199.5	53.7	176.3	62.1	28.5	93.4	10.1	33.2	30.2	99.1	19.6	
40	60.6	199.0	52.9	173.5	60.7	29.7	97.3	10.0	32.7	31.3	102.6	16.6	
50	60.0	197.0	51.7	169.7	59.5	30.5	100.1	10.1	33.2	32.1	105.4	14.3	
60	59.3	194.6	50.5	165.5	58.3	31.1	102.2	10.4	34.1	32.8	107.7	12.5	
70	58.2	191.0	49.0	160.7	57.3	31.5	103.2	10.9	35.8	33.3	109.2	11.1	
80	56.4	185.2	47.0	154.0	56.3	31.3	102.7	11.9	39.0	33.5	109.8	20.8	
90	53.6	175.9	44.1	144.6	55.4	30.5	99.9	13.8	45.2	33.4	109.7	24.3	
95	51.5	168.9	42.0	137.9	54.9	29.6	97.0	15.3	60.1	33.3	109.2	27.7	
100	48.7	159.6	39.6	129.8	54.5	28.3	92.8	17.2	56.5	33.1	108.7	31.4	

BLADE ELEMENT DATA ROTOR OUTLET / STATOR INLET													
IMMER %	W		WU		BETA DEG	CZ		CU		C		ALPHA DEG	
	MPS	FPS	MPS	FPS		MPS	FPS	MPS	FPS	MPS	FPS		
0	55.5	186.5	51.0	161.7	60.7	17.3	56.8	35.9	117.7	39.8	130.7	64.3	
5	37.8	124.1	31.7	104.0	56.9	20.6	67.6	34.7	113.8	40.4	132.5	59.3	
10	39.8	130.7	32.3	113.0	54.2	23.2	76.3	33.6	110.2	40.8	134.0	55.3	
20	42.7	140.0	33.0	108.4	50.8	27.0	88.6	31.8	104.4	41.7	136.9	49.7	
30	44.0	144.4	32.9	108.1	48.4	29.3	96.0	30.9	101.5	42.6	139.6	46.6	
40	44.2	144.9	32.0	104.9	46.4	30.5	100.1	30.9	101.3	43.4	142.4	45.4	
50	43.6	143.0	30.4	99.8	44.3	31.2	102.5	31.4	103.1	44.3	145.3	45.2	
60	42.7	140.2	28.7	94.0	42.1	31.7	104.1	32.2	105.6	45.2	148.4	45.4	
70	41.5	136.3	26.6	87.2	39.7	32.0	104.9	33.3	109.2	46.2	151.5	46.2	
80	39.5	129.4	23.7	77.8	37.0	31.5	103.4	35.1	115.3	47.2	154.9	48.1	
90	35.9	117.8	20.0	65.5	33.7	29.9	98.0	37.9	124.3	48.3	158.3	51.8	
95	33.0	108.3	17.4	57.1	31.9	28.1	92.2	39.9	130.9	48.8	160.1	54.8	
100	29.4	96.4	14.3	47.7	29.7	25.5	83.8	42.3	138.7	49.4	161.9	58.8	

BLADE ELEMENT DATA STATOR OUTLET													
IMMER %	W		WU		BETA DEG	CZ		CU		C		ALPHA DEG	
	MPS	FPS	MPS	FPS		MPS	FPS	MPS	FPS	MPS	FPS		
0	56.8	186.2	52.7	172.9	68.2	21.0	68.8	14.2	46.4	25.3	83.0	34.0	
5	58.3	191.2	53.4	175.1	66.6	22.8	74.8	13.0	42.7	26.3	86.1	29.7	
10	59.3	194.7	53.7	176.3	65.4	24.3	79.8	12.1	39.6	27.1	89.0	26.4	
20	60.5	198.9	54.1	177.5	63.5	26.6	87.3	10.7	35.2	28.7	94.0	22.0	
30	60.8	199.4	53.7	176.3	62.1	28.2	92.6	10.0	33.0	30.0	98.3	19.6	
40	60.5	198.5	53.0	173.8	60.8	29.4	96.5	9.9	32.4	31.0	101.8	16.6	
50	59.9	196.5	51.8	169.9	59.6	30.3	99.3	10.0	33.0	31.9	104.6	14.3	
60	59.2	194.1	50.5	165.8	58.5	30.9	101.3	10.3	33.9	32.6	106.9	12.5	
70	58.1	190.7	49.1	161.0	57.5	31.2	102.5	10.8	35.4	33.1	108.5	11.1	
80	56.5	185.3	47.0	154.3	56.6	31.1	102.2	11.8	38.8	33.3	109.2	20.8	
90	53.7	176.3	44.2	144.9	55.6	30.3	99.5	13.7	44.8	33.3	109.1	24.3	
95	51.6	169.3	42.1	138.1	55.1	29.4	96.4	15.2	49.9	33.1	108.7	27.6	
100	48.5	159.0	39.6	130.0	54.6	28.1	92.2	17.2	56.3	32.9	108.0	31.4	

ROTOR BLADE ELEMENT PERFORMANCE													
IMMER (%)	WHEEL SPEED		REL. TURNING ANGLE DEG	LOSS COEF.	LOSS PARA.	REL. MACH NO. IN	DIFF. MACH FACT.	REL. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG			
	MPS	FPS											
0	57.6	189.00	7.4	0.096	0.085	0.143	0.551	0.089	-5.8	15.6			
5	57.2	187.58	9.8	0.080	0.072	0.146	0.514	0.095	-6.8	12.5			
10	56.7	186.17	11.3	0.067	0.061	0.149	0.485	0.100	-6.9	10.5			
20	55.9	183.33	12.8	0.048	0.044	0.152	0.446	0.108	-7.0	8.3			
30	55.0	180.50	13.7	0.037	0.034	0.153	0.427	0.111	-6.6	7.3			
40	54.2	177.66	14.3	0.034	0.032	0.153	0.423	0.111	-6.5	6.8			
50	53.3	174.83	15.2	0.035	0.033	0.152	0.427	0.110	-6.8	6.7			
60	52.4	171.99	16.2	0.039	0.037	0.150	0.434	0.108	-7.7	7.1			
70	51.6	169.16	17.6	0.044	0.042	0.147	0.446	0.105	-8.6	7.4			
80	50.7	166.32	19.3	0.049	0.047	0.142	0.467	0.099	-9.6	7.0			
90	49.8	163.49	21.6	0.055	0.053	0.135	0.507	0.091	-10.5	5.9			
95	49.4	162.07	23.0	0.058	0.056	0.129	0.545	0.083	-11.0	5.5			
100	49.0	160.65	24.7	0.061	0.060	0.123	0.600	0.074	-11.4	4.7			

STATOR VANE ELEMENT PERFORMANCE													
IMMER %	WHEEL SPEED		ABS. TURNING ANGLE DEG	ABS. MACH NO. IN	ABS. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.			
	MPS	FPS											
0	57.6	189.00	30.3	0.100	0.064	-5.1	13.2	0.0840	0.0821	0.5600			
5	57.2	187.58	29.6	0.102	0.067	-5.6	12.2	0.0730	0.0717	0.5240			
10	56.7	186.17	28.9	0.103	0.069	-5.9	11.4	0.0630	0.0621	0.5240			
20	55.9	183.33	27.7	0.105	0.073	-5.8	9.5	0.0460	0.0456	0.4940			
30	55.0	180.50	27.0	0.107	0.078	-6.3	7.9	0.0350	0.0347	0.4710			
40	54.2	177.66	26.8	0.109	0.078	-6.6	7.1	0.0300	0.0298	0.4570			
50	53.3	174.83	26.8	0.112	0.081	-6.8	6.9	0.0290	0.0288	0.4500			
60	52.4	171.99	26.9	0.114	0.082	-7.2	6.8	0.0320	0.0318	0.4470			
70	51.6	169.16	27.1	0.116	0.083	-7.6	6.9	0.0390	0.0387	0.4500			
80	50.7	166.32	27.3	0.119	0.084	-7.8	7.5	0.0530	0.0526	0.4810			
90	49.8	163.49	27.5	0.122	0.084	-7.8	8.7	0.0740	0.0733	0.4770			
95	49.4	162.07	27.2	0.123	0.083	-7.4	9.7	0.0870	0.0859	0.4880			
100	49.0	160.65	27.4	0.124	0.083	-7.0	9.4	0.1010	0.0994	0.5000			

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END DATE

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