https://ntrs.nasa.gov/search.jsp?R=19810007536 2020-03-21T15:17:59+00:00Z

NASA

National Aeronautics and
Space Administration

CORE COMPRESSOR EXIT STAGE STUDY

Volume II - Data and Performance Report for the Baseline Configurations

by

D.C. Wisler

GENERAL ELECTRIC COMPANY

NOVEMBER 1980

Prepared For

National Aeronautics and Space Administration

RECEIVED NASA STI FACILITY ACCESS DEPT.

Contract No. NAS3-20070

NASA-Lewis Research Center

(NASA-CR-159498) CORE COMPRESSOR EXIT STAGE STUDY. VOLUME 2: DATA AND PERFORMANCE REPORT FOR THE BASELINE CONFIGURATION (General Electric Co.) 178 p HC A09/MF A01 CSCL 21E G3/07

N81-16051

Unclas 41164

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-159498		

4. Title and Subtitle	5. Report Date
Core Compressor Exit Stage Study Volume II - Data and Performance Report for the Baseline Configuration	November, 1980
	6. Performing Organization Code R80AEG312
7. Author(s) D.C. Wisler	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address General Electric Company Aircraft Engine Group Cincinnati, Ohio 45215	11. Contract or Grant No. NAS3-20070
	13. Type of Report and Period Covered Data Report
12. Sponsoring Agency Name and Address NASA-Lewis Research Center 21000 Brookpark Road Cleveland, Ohio 44135	14. Sponsoring Agency Code

15. Supplementary Notes

Project Manager, Dr. Wojtech Rostafinski, Fluid Mechanics and Acoustics Division, NASA-Lewis Research Center, Cleveland, Ohio 44135

16. Abstract

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 test data and performance results for the baseline configuration consisting of Rotor A running with Stator A. 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 in two ways: (1) using four identical stages of blading so that test data would be obtained in a true multistage environment and (2) using a single stage of blading so that comparison with the multistage test results could be made.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Compressor Endwall Secondary Flow	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified		

* For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA-C-168 (Rev. 10-75)

TABLE OF CONTENTS

Section		Page
1.0	SUMMARY	1
2.0	INTRODUCTION	2
3.0	TEST APPARATUS AND PROCEDURE	3
	3.1 Low Speed Research Compressor Test Facility	3
	3.2 Test Stage	4
	3.3 Instrumentation	4
	3.4 Test Procedures	5
	3.5 Data Reduction	7
4.0	RESULTS AND DISCUSSION	10
	4.1 Shakedown Test	10
	4.2 Casing Treatment Test Results	10
	4.3 Overall Performance	11
	4.3.1 Four-Stage Configuration	11
	4.3.2 Single-Stage Configuration	12
	4.3.3 Comparison of Single-Stage and Multistage Results	12
	4.4 Reynolds Number Test Results	12
	4.5 Blade and Vane Surface Static Pressure Test Results	13
	4.5.1 Four-Stage Configuration (Third Stage as Test Stage)	13
	4.5.2 Single-Stage Configuration	14
	4.5.3 Four-Stage Configur `ion (First Stage as Test Stage)	15
	4.5.4 Comparison of Four-Stage and Single-Stage Results	15
	4.5.5 Comparisons with Potential Flow (CASC) Solutions	15
	4.6 Blade Element and Wall Boundary Layer Test Results	16
	4.6.1 Four-Stage Configuration (Third Stage as Test Stage)	16
	4.6.2 Single-Stage Configuration	19
	4.6.3 Four-Stage Configuration (First Stage as Test Stage)	20
5.0	CONCLUSIONS	21
6.0	LIST OF SYMBOLS AND ACRONYMNS	22
7.0	FIGURES	24
8.0	TABLES	121
9.0	REFERENCES	162

PRECEDING PAGE BLANK NOT FILMED

LIST OF ILLUSTRATIONS

Figure		Page
1.	Four-Stage Compressor Configuration Tested in the NASA-GE Core Compressor Exit Stage Study.	25
2.	Photograph of the Low Speed Research Compressor.	26
3.	Cross Section of 0.85 Radius Ratio Compressor Stage.	27
4.	Photograph of Rotor A Assembly for the Low Speed Research Compressor.	28
5.	Photograph of Stator A Assembly for the Low Speed Research Compressor.	29
6.	Rotating Total Pressure Rake at Rotor Exit Plane.	30
7.	Rotor Blade with Static Pressure Taps on Suction Surface.	31
8.	Prelimi ary Measurements of Swirl Angles.	32
9.	Preview Data Test Results Showing the Effects of Circumferential Groove Casing Treatment on Compressor Performance.	33
10.	Overall Performance for the Four-Stage Baseline Configuration Using Rotor A/Stator A.	34
11.	Radial Variations of Normalized Total Pressure Including Casing and Hub Normalized Static Pressure at the Casing Discharge for Various Throttle Settings, Four-Stage Configuration.	35
12.	Overall Performance of the Single-Stage Rotor A/Stator A Configuration.	36
13.	Comparison of Individual Stage Characteristics for the Single-Stage and Four-Stage Configurations, Rotor A Running with Stator A.	37
14.	Radial Variation of Normalized Total Pressure Including Casing and Hub Normalized Static Pressures at the Casing Discharge for Various Throttle Settings.	38
15.	Variation of the Performance of Rotor A/Stator A with Reynolds Number, Four-Stage Configuration.	39

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
16.	Variation of the Performance of Rotor A/Stator A with Reynolds Number, Four-Stage Configuration.	40
17.	Rotor Blade Surface Static Pressure Measurements for the Four-Stage Rotor A/Stator A Configuration, Third Stage Tested.	41
18.	Stator Vane Surface Static Pressure Measurements for the Four-Stage Rotor A/Stator A Configuration, Third Stage Tested.	42
19.	Rotor Blade Surface Static Pressure Measurements for the Single-Stage Rotor A/Stator A Configuration.	43
20.	Stator Vane Surface Static Pressure Measurements for the Single-Stage Rotor A/Stator A Configuration.	44
21.	Rotor Blade Surface Static Pressure Measurements for the Four-Stage Rotor A/Stator A Configuration, First Stage Tested.	45
22.	Stator Vane Surface Static Pressure Measurements for the Four-Stage Rotor A/Stator A Configuration, First Stage Tested.	46
23.	Comparison of Blade Surface Static Pressure Measurements for the Four-Stage Configuration (1st and 3rd Stages Tested) and the Single-Stage Configuration.	47
24.	Comparison of Vane Surface Static Pressure Measurements for the Four-Stage Configuration (1st and 3rd Stages Tested) and the Single-Stage Configuration.	48
25.	Blade Surface Velocity Distributions for Rotor A Operating Near the Design Point - Measurements Compared with Potential Flow CASC Solutions.	49
26.	Vane Surface Velocity Distributions for Stator A Operating Near the Design Point - Measurements Compared with Potential Flow CASC Solutions.	50
27.	Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Design Point Throttle.	51

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
28.	Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Peak Efficiency Throttle.	52
29.	Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise Throttle.	53
30.	Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Near Stall Throttle.	54
31.	Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Design Point Throttle.	55
32.	Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Peak Efficiency Throttle.	56
33.	Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise Throttle.	57
34.	Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Near Stall Throttle.	58
35.	Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.	59
36.	Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.	60
37.	Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, Third Stage Tested, Design Point Throttle.	61
38.	Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, Third Stage Tested, Peak Efficiency Throttle.	62
39.	Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise Throttle.	63

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
40.	Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, Third Stage Tested, Near Stall Throttle.	64
41.	Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, Third Stage Tested, Design Point Throttle.	65
42.	Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, Third Stage Tested, Peak Efficiency Throttle.	66
43.	Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise Throttle.	67
44.	Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, Third Stage Tested, Near Stall Throttle.	68
45.	Rotor Total Loss Coefficients, Wake Loss Coefficients, and Total Minus Wake Loss Coefficients for Rotor A/Stator A, Four-Stage Configuration, Third Stage Tested.	69
46.	Stator Total Loss Coefficients, Wake Loss Coefficients, and Total Minus Wake Loss Coefficients for Rotor A/Stator A, Four-Stage Configuration, Third Stage Tested.	70
47.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.	71
48.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.	72
49.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.	73
50.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.	74
51.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.	75
52.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.	76

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
53.	Diffusion Factor, Loss Coefficient and Deviation Angle Versus Incidence Angle, Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.	77
54.	Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Single-Stage Configuration, Design Point Throttle.	78
55.	Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Single-Stage Configuration, Peak Efficiency Throttle.	79
56.	Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Single-Stage Configuration, Peak Pressure Rise and Near Stall Throttle.	80
57.	Absolute Flow Angles for Rotor A/Stator A Single-Stage Configuration, Design Point Throttle.	81
58.	Absolute Flow Angles for Rotor A/Stator A Single-Stage Configuration, Peak Efficiency Throttle.	82
59.	Absolute Flow Angles for Rotor A/Stator A Single-Stage Configuration, Peak Pressure Rise and Near Stall Throttle.	83
60.	Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Single-Stage Configuration, Design Point Throttle.	84
61.	Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Single-Stage Configuration, Peak Efficiency Throttle.	85
62.	Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Single-Stage Configuration, Peak Pressure Rise/Near Stall Throttle.	86
63.	Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Single-Stage Configuration, Design Point Throttle.	87
64.	Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Single-Stage Configuration, Peak Efficiency Throttle.	88

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
65.	Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Single-Stage Configuration, Peak Pressure Rise/Near Stall Throttle.	89
66.	Rotor Total Loss Coefficients, Wake Loss Coefficients, and Total Minus Wake Loss Coefficients for Rotor A/ Stator A, Single-Stage Configuration.	90
67.	Stator Total Loss Coefficients for Rotor A/Stator A Single-Stage Configuration.	91
68.	Wake Loss Coefficients and Total Minus Wake Loss Coefficient for Rotor A/Stator A Single-Stage Configuration.	92
69.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Single-Stage Configuration.	93
70.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Single-Stage Configuration.	94
71.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Single-Stage Configuration.	95
72.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Single-Stage Configuration.	96
73.	Vector Diagram Quantities Versus Percent Immersion Rotor A/Stator A Single-Stage Configuration.	97
74.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Single-Stage Configuration.	98
75.	Diffusion Factor, Loss Coefficient and Deviation Angle Versus Incidence Angle, Rotor A/Stator A Single-Stage Configuration.	99
76.	Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Design Point Throttle.	100
77.	Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Peak Efficiency Throttle.	101

LIST OF ILLUSTRATIONS (Continued)

Figure		Page
78.	Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Peak Pressure Rise and Near Stall Throttle.	102
79.	Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, First Stage Tested. Design Point Throttle.	103
80.	Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Peak Efficiency Throttle.	104
81.	Absolute Air Angle for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Peak Pressure Rise and Near Stall Throttle.	105
82.	Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, First Stage Tested, Design Point Throttle.	106
83.	Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, First Stage Tested, Peak Efficiency Throttle.	107
84.	Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, First Stage Tested, Near Stall Throttle.	108
85.	Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, First Stage Tested, Design Point Throttle.	109
86.	Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, First Stage Tested, Peak Efficiency Throttle.	110
87.	Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, First Stage Tested, Peak Pressure Rise/Near Stall Throttle.	111
88.	Rotor Total Loss Coefficients, Wake Loss Coefficients, and Total Minus Wake Loss Coefficients for Rotor A/Stator A, Four-Stage Configuration, First Stage Tested.	112

LIST OF ILLUSTRATIONS (Concluded)

Figure		Page
89.	Stator Total Loss Coefficients, Wake Loss Coefficients, and Total Minus Wake Loss Coefficients for Rotor A/Stator A, Four-Stage Configuration, First Stage Tested.	113
90.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Four-Stage Configuration, First Stage Tested.	114
91.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Four-Stage Configuration, First Stage Tested.	115
92.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Configuration, First Stage Tested.	116
93.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Four-Stage Configuration, First Stage Tested.	117
94.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Four-Stage Configuration, First Stage Tested.	118
95.	Vector Diagram Quantities Versus Percent Immersion, Rotor A/Stator A Four-Stage Configuration, First Stage Tested.	119
96.	Diffusion Factor, Loss Coefficient and Deviation Angle Versus Incidence Angle, Rotor A/Stator A Four-Stage Configuration, First Stage Tested.	120

LIST OF TABLES

Table		Page
1.	Instrumentation for the Test Program.	122
2.	Location of Surface Static Pressure Taps on Instrumented Airfoils.	123
3.	Overall Test Plan Outline.	124
4.	Preview Data for Rotor A/Stator A.	125
5.	Blade Surface Static Pressures Four-Stage Configuration - Third Stage Is Test Stage.	126
6.	Vane Surface Static Pressures Four-Stage Configuration - Third Stage Is Test Stage.	127
7.	Blade Surface Static Pressures - Single-Stage Configuration.	128
8.	Vane Surface Static Pressures - Single-Stage Configuration.	129
9.	Blade Surface Static Pressures Four-Stage Configuration - First Stage Is Test Stage.	130
10.	Vane Surface Static Pressures Four-Stage Configuration - First Stage Is Test Stage.	131
11.	Normalized Absolute Total Pressure, Static Pressure, and Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.	132
12.	Rotor Loss Coefficients Determined from Relative Total Pressure Measurements, Four-Stage Configuration, Third Stage Tested.	134
13.	Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Design Point Throttle.	135
14.	Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Peak Efficiency Throttle.	136
15.	Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise Throttle.	137
16.	Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Near Stall Throttle.	138
17.	Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, Third Stage Tested, Design Point Throttle.	139

LIST OF TABLES (Continued)

Table		Page
18.	Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, Third Stage Tested, Peak Efficiency Throttle.	140
19.	Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise Throttle.	141
20.	Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, Third Stage Tested, Near Stall Throttle.	142
21.	Design Intent Performance for Rotor A/Stator A Computed for U_t = 63.82 mps (209.38 fps).	143
22.	Normalized Absolute Total Pressure, Static Pressure, and Flow Angles for Rotor A/Stator A Single-Stage Configuration.	144
23.	Rotor Loss Coefficients Determined from Relat[illegible]ressure Measurements, Single-Stage Configuration.	146
24.	Vector Diagram Parameters for Rotor A/Stator A Single-Stage Configuration, Design Point Throttle.	147
25.	Vector Diagram Parameters for Rotor A/Stator A Single-Stage Configuration, Peak Efficiency Throttle.	148
26.	Vector Diagram Parameters for Rotor A/Stator A Single-Stage Configuration, Peak Pressure Rise and Near Stall Throttle.	149
27.	Blade and Vane Element Performance for Rotor A/Stator A, Single-Stage Configuration, Design Point Throttle.	150
28.	Blade and Vane Element Performance for Rotor A/Stator A, Single-Stage Configuration, Peak Efficiency Throttle.	151
29.	Blade and Vane Element Performance for Rotor A/Stator A, Single-Stage Configuration, Peak Pressure Rise and Near Stall Throttle.	152
30.	Normalized Absolute Total Pressure, Static Pressure, and Flow Angles for Rotor A/Stator A Four-Stage Configuration, First Stage Tested.	153
31.	Rotor Loss Coefficients Determined from Relative Total Pressure Measurements, Four-Stage Configuration, First Stage Tested.	155

LIST OF TABLES (Concluded)

Table		Page
32.	Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Design Point Throttle.	156
33.	Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Peak Efficiency Throttle.	157
34.	Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Peak Pressure Rise and Near Stall Throttle.	158
35.	Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, First Stage Tested, Design Point Throttle.	159
36.	Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, First Stage Tested, Peak Efficiency Throttle.	160
37.	Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, First Stage Tested, Peak Pressure Rise and Near Stall Throttle.	161

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 test data and the performance results for the baseline compressor stage that was tested in the General Electric Low Speed Research Compressor. The aerodynamic design of this baseline stage, which is typical of those required in the rear stages of advanced, highly loaded core compressors, is described in Volume I of this report (Reference 1). The test results for those blading concepts that offer a promise of reducing end-wall losses are presented in later volumes of this report.

Overall performance data and various types of detailed performance data are presented for the baseline configuration along with the resulting vector diagrams, loss coefficients, and diffusion factors. The data taken for the baseline configuration show that the design intent pressure coefficient of 0.554 has been achieved at the design intent flow coefficient of 0.408. At the design pressure rise, the measured efficiency of 0.900 was equal to the design target.

2.0 INTRODUCTION

Recent preliminary design studies of advanced turbofan core compressors (Reference 2) 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 3, suggest that approximately half of the total loss in a multistage compressor rear stage is associated with the end-wall 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 end-wall boundary layers, it is believed that substantial improvements in that area are likely. Accordingly, a goal of a 15% reduction in rear stage end-wall boundary layer losses, 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 end-wall losses relative to a baseline design have been evaluated in a multistage environment. The test data and performance results for this baseline blading are described in this report.

3.0 TEST APPARATUS AND PROCEDURE

3.1 LOW SPEED RESEARCH COMPRESSOR TEST FACILITY

The Low Speed Research Compressor (LSRC) facility is designed to provide aerodynamic data on the performance and flow details of multistage axial flow compressors. The facility is generally used to determine the aerodynamic behavior of subsonic axial flow compressors where the flow characteristics are largely viscous or Reynolds number related and are not predominantly compressibility or Mach numbe. related. Although considerations of stage matching or choke margin cannot be studied in the LSRC, fundamental aspects of turbomachinery aerodynamics, such as airfoil surface boundary layer development and secondary flow or leakage flow effects, have been studied in the LSRC for the past 20 years. In effect, the LSRC duplicates many of the essential features of a small, high-speed compressor flow field in a large, low-speed machine where very detailed investigations can be conducted with conventional instrumentation and where the flow field can be observed directly by the use of tuft or flag probes inserted into the flow stream through a transparent casing.

The LSRC configuration for these tests, shown schematically in Figure 1, is a four-stage compressor having a constant casing diameter of 1.524 m (60 in.) and a radius ratio of 0.85. The axis of rotation of the compressor is vertical, and the flow enters from the top through a calibrated bellmouth/inlet system which filters and measures the flow. A bullet nose was inserted in the bellmouth to reduce the area of the flow measurement plane to a level slightly larger than the constant annulus area of the compressor stages. Convergence was selected to produce the largest dynamic head possible in the bellmouth and still allow a small amount of acceleration forward of the inlet guide vanes (IGV's) in order to reduce the wall boundary layers entering the compressor. After passing through the blading, the air is exhausted into a room on the lower floor of the building. The compressor exhaust system consists of a large, circular throttle plate that can be raised or lowered to increase the compressor back pressure by varying the exit area. The throttle is shown at its two extreme positions in Figure 1. The facility is driven from below by a 400-hp steam turbine. Rotative speed of the compressor can be controlled to within ±0.5 rpm. Power input to the compressor is determined by a strain gage-type torquemeter in the drive shaft between the gearbox and the lower main bearing. A photograph of the LSRC is shown in Figure 2.

A detailed cross section of one stage of the 0.85 radius ratio LSRC test vehicle is shown in Figure 3. Shrouded stators are used. Stator vanes and shrouds are mounted in casing rings that can be rotated about the axis of the compressor using screwjack actuators. This enables the vanes to be moved past fixed instrumentation in order to give the capability for performing a circumferential traverse with every instrument in the test vehicle.

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 blades and vanes are constructed of inexpensive plastic materials that are molded in high pressure dies so that outstanding uniformity is achieved. The blades are hydraulically smooth at the test Reynolds number, based on tip speed and blade chord of 360,000. Reynolds numbers of this magnitude are high enough to be above the critical value for compressor stages and, therefore, can provide a reasonable simulation of the performance of high-speed compressors.

The average rotor tip-clearance-to-blade-height ratio was 1.36% and the average stator seal-clearance-to-blade-height ratio 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.

3.2 TEST STAGE

The baseline Stage A is a low speed model of Stage 7 of the 10-stage, 23:1 pressure ratio AMAC study compressor whose preliminary design study was conducted under Contract NAS3-19444 (Reference 2). The low speed modeling was accomplished by modifying the camber line of the low speed airfoil sections so that the dimensionless suction surface velocity distributions of the low speed sections were similar to those of Stage 7 of the AMAC compressor. The baseline Rotor A consisted of airfoil sections having modified circular arc meanlines and circular arc thickness distributions. The baseline Stator A consisted of airfoil sections having a 65-series thickness distribution on modified circle arc meanlines. An IGV was designed which gave the required preswirl to the fluid entering the first rotor in order to achieve a multistage environment in as few stages as practical. Standard General Electric IGV design practices were employed. The details of the baseline Stage A design and the IGV design are presented in the Design Report (Reference 1).

A photograph of the assembled four-stage Rotor A is shown in Figure 4, and a photograph of an assembled Stator A ring is shown in Figure 5.

3.3 INSTRUMENTATION

The instrumentation used at various locations in the compressor is presented in Table 1. Standard total pressure rakes and wall static pressure taps were used to obtain overall pressure rise in the compressor. Airflow was measured using a calibrated bellmouth, and work input was obtained using a strain gage torquemeter. The torquemeter was calibrated using weights and a torque arm. The compressor was run without blading in order to measure tare torque and, thus, to obtain corrections for windage and bearing friction as a function of rotative speed.

In addition, the following instrumentation was used to provide more detailed measurements of the flow field within the compressor:

- A rotating total pressure rake was used to define accurately the rotor wake of the test stage. This rake, shown in Figure 6, is mounted on the rotating hub and can be traversed across one blade pitch. The pressures are read by a pressure transducer inside the rotor assembly, and the electrical signal is led out by a slipring. The blading shown in this photograph is from another program.

- 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. Blades instrumented to yield these data are shown in Figure 7. In Figure 7 the blades are sealed on the pressure side at the hub so that no flow can leak from the pressure surface to the suction surface. The locations of the surface static taps are given in Table 2. For rotors, the pressures are read by a pressure transducer/slipring device.

- Fast-response hot-film anemometers were located in an axial line aft of the four rotors in an attempt to detect the inception of rotating stall.

- Single-element transverse probes were used to obtain total pressure, static pressure, and flow angle measurements. The flow angle measurements were made using flag (tuft) probes which aligned themselves to the flow direction when immersed in the flow field. The value of the flow angle was determined by using a telescope/crosshair sighting device attached to a protractor.

The data recording and analysis procedures are automated. Pressures are measured using Bell & Howell Model No. 09384 low-pressure-range transducers having an accuracy of ±0.025% of the full-scale (12.44 kPa, 50 in. H_2O) reading. The transducer is calibrated using a micromanometer. The data are automatically recorded in a time-sharing computer data file by an automated data controller.

3.4 TEST PROCEDURES

The overall test program was divided into four parts as outlined in Table 3. The first part involved extensive testing of the baseline blading, Stage A (Rotor A/Stator A), in both four-stage and single-stage configurations. These test results are the subject of the present report. The second part involved a series of short screening tests to select the best rotor design and the best stator design based upon tests in four-stage configurations. These test results can be found in Volume III of this series. 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. The final part of the test program will consist of extensive testing of a new Rotor C design in a four-stage configuration with Stator B. Results of the test will be reported in Volume V.

After an initial shakedown test, three separate tests were conducted using Stage A blading. First, a four-stage configuration using the third stage as the test stage underwent extensive testing. This became the baseline configuration and the data obtained are outlined in Table 3, Item IB. Second, a single-stage configuration, using the third stage of the four-stage configuration discussed above as the test stage, was tested. A major objective of the single-stage testing was to determine, by comparison with the multistage test results, the effect that these differences have on overall and blade element performance and, thus, to assess the rationale for utilizing data from single-stage tests in the design of multistage compressors. The data obtained are shown in Table 3, Item IC. Since the IGV's were set during the shakedown test to give the same level of air angle as measured at the inlet to Rotor 3 in the multistage test of this blading near design-point operation, the single-stage testing was done at inlet air angles comparable to those in the multistage environment. Third, a four-stage configuration, using the first stage as the test stage, was tested; the data outlined in Table 3, Item ID, were obtained. The identical blading was used as the test stage in Items IB, IC, and ID.

Eight types of data were taken during the testing phase: stall-determination data, preview data, standard data, casing treatment data, Reynolds number data, blade surface pressure data, blade element data, and detailed wall boundary layer data. A description of each of these types of data is presented below.

Stall-determination data yield the stalling throttle setting by observing the sudden decrease in the static pressure rise across the compressor at stall and listening for the onset of rotating stall. Preview data provide stage characteristics and efficiency measurements based on casing static pressure rise, measured airflow, and measured torque. Standard data provide compressor performance based on mass-averaged total pressure rise from Rotor 1 inlet to Stator 4 exit, measured airflow, and measured torque. Casing treatment data provide a means of assuring that the first stage was not the stall-limiting stage. Reynolds number data are used to establish performance trends versus Reynolds number as an aid in extrapolating the test data to the somewhat higher Reynolds number levels of engines. Blade surface pressure data provide a means of determining regions of favorable leading edge loading (incidence), rates of diffusion, and regions of separated flow on the airfoil. Blade element data give blade element performance and stage vector diagram quantities based on total pressure, static pressure, and flow angle measured in a matrix of circumferential and radial locations across a blade pitch. Sufficient data are obtained to define the wake. Measurements are taken at the rotor inlet, rotor exit, and stator exit of the test stage. Detailed wall boundary layer data consist of total pressure, static pressure, and flow angle measurements as close as 1% of blade height to either end wall. Evaluation and comparison of all these data from the various configurations have provided a means of assessing the effectiveness of the particular design approaches employed for reducing losses in the end-wall region.

3.5 DATA REDUCTION

The data analysis procedures followed in reducing test data have been described in detail in a Data Analysis Plan prepared under this contract. A brief summary of these procedures is presented in the following:

- Airflow measurements are based on a calibration of the large bellmouth in which measurements of bellmouth and bullet nose static pressures were correlated with airflow. This calibration was based upon detailed radial and circumferential traverses of total and static pressure measurements in the bellmouth including boundary layer surveys.

- Power input to the compressor is measured by using a calibrated strain gage torquemeter and applying tare-torque corrections for windage and bearing friction.

- The environmental conditions are calculated from measured values of wet and dry bulb temperatures and barometric reference pressurizing standard equations.

- All pressures are converted to standard units by appropriate conversion factors and normalized. The pressures after normalization are in the form

$$P_{Normalized} = \frac{P_{Absolute} - P_{REF}}{\frac{1}{2} \rho_{REF} U_t^2} \quad (1)$$

The pressure coefficient, ψ', is computed from

$$\psi' = \frac{\Delta H(isen)}{\frac{1}{2} U_t^2} \quad (2)$$

where isentropic enthalpy rise is determined from measured pressure rise using standard thermodynamic relationships. Expanding these relationships in a power series to obtain pressure rise, ΔP, rather than pressure coefficient, and rearranging the resulting equation, yields the pressure coefficient in the form

$$\psi' = \frac{\Delta P}{\frac{1}{2} \rho_{REF} U_t^2} \left(\frac{1}{P_1/P_{REF}} \right) \left[1 - \frac{1}{2\gamma} \left(\frac{\Delta P}{P_1} \right) + \frac{\gamma+1}{6\gamma^2} \left(\frac{\Delta P}{P_1} \right)^2 + \dots \right] \quad (3)$$

For preview data, the pressure rise is determined from the casing static pressure measurement. For standard data, the pressure rise is determined from mass-averaged total pressure measurements.

Flow coefficient, ϕ, is computed from

$$\phi = \frac{W}{\bar{\rho} A U_t} \tag{4}$$

where W is the measured airflow, $\bar{\rho}$ is the average of the inlet and discharge density, and A is the annulus area of the compressor.

The work coefficient, ψ, is computed from

$$\psi = \frac{T}{\frac{1}{2} \rho_{REF} U_t^2 \phi R_t A} \tag{5}$$

where T is the measured torque corrected for windage and bearing friction, and ϕ is obtained from Equation 4.

The torque efficiency is the ratio of the isentropic enthalpy rise consistent with the pressure rise divided by the total enthalpy delivered to the compressor,

$$\eta = \frac{\psi'}{\psi} \tag{6}$$

The relative total pressure data obtained by using the rotating total pressure rake is reduced by using the following equation

$$P_t' = \left(P_t'\right)_{measured} + \left(\frac{R_m}{R_t}\right)^2 * \frac{1}{2} \rho_{REF} U_t^2 \tag{7}$$

which is based on the assumption that the fluid in the pressure lines has constant density ρ_{REF} and rotates at the wheel speed.

The loss coefficient, $\bar{\omega}$, is computed from the following equation

$$\bar{\omega} = \frac{P_{t_{in}} - P_{t_{out}}}{P_{t_{in}} - P_{s_{in}}} \tag{8}$$

Loss coefficients for the stators are obtained by subtracting the measured absolute total pressure at the stator exit from the measured absolute total pressure at the stator inlet. These measurements are taken in a matrix of radial and circumferential locations sufficient to define radial variations and to define the wake. Circumferential average values of pressure are computed. The loss coefficients for the rotors are then obtained by subtracting the measured exit relative total pressure from an estimate of the inlet relative total pressure. This estimate is obtained by averaging the three highest relative total pressures measured at the exit plane.

Theoretical velocity distributions along the suction and pressure surfaces of the blades and vanes in the Low Speed Research Compressor are computed by using the Cascade Analysis by Streamline Curvature (CASC) computer program discussed in Reference 1 for operation near the design point. In order to compare these CASC distributions with experimentally measured distributions, one must calculate the velocities on the blade and vane surfaces from the static pressures measured on these surfaces. The equation which relates the normalized velocities and the measured pressures is

$$\frac{V}{V_1} = \left(\frac{P_{T_1} - P_S}{P_{T_1} - P_{S_1}}\right)^{1/2} F_c \tag{9}$$

where the nonsubscripted variables indicate blade surface conditions, the subscript indicates upstream conditions, F_c is a compressibility correction (which was taken as unity since the Mach number was so low), and total pressure is assumed constant. For each radial immersion where comparisons were made, the blade surface static pressures, P_S, were obtained from experimental measurements. The total pressure used in Equation 9 was that value which made the minimum velocity ratio on the pressure surface as computed from the measured data equal to the minimum velocity ratio on the pressure surface as computed by CASC. Although this technique for obtaining total pressure does not provide valid comparisons of velocity magnitude between the CASC results and the experimental results, it does provide comparisons of the shape of surface velocity distributions that are useful in diagnosing differences in incidence angle and regions of flow separation.

4.0 RESULTS AND DISCUSSION

Test results for the baseline stage consisting of Rotor A running with Stator A are presented and discussed in the following paragraphs.

4.1 SHAKEDOWN TEST

A shakedown test was conducted on a four-stage configuration using Rotor A/Stator A blading. The purpose of this test was to verify the mechanical integrity of the new hardware and to determine if the inlet guide vanes (IGV's) and stator exit swirl angles were in reasonable agreement.

The first test run confirmed the mechanical integrity of the test vehicle. The mechanical operation of the rig was quite smooth and no difficulties were encountered.

Testing was then conducted to verify that the level of the swirl delivered by the IGV was reasonably close to that delivered by the stator vanes. Preliminary measurements of swirl angles, made at the exit of the IGV and at the exits of the stators, are presented in Figure 8. These flow angles were obtained at a midpassage circumferential position and, therefore, do not represent circumferential averaged values. Also, the small correction factor to the angles discussed in Section 4.6.1 was not applied to these data. At each radial immersion the IGV exit air angle shown in the figure is the average of the angles obtained for five throttle settings from wide-open to stall, while the stator exit air angles are the values obtained at a flow coefficient of 0.424, which is somewhat larger than the design flow coefficient of 0.407. The data indicate that the average IGV exit swirl angles after correction are about 0.6° to 1.0° smaller than the design distribution near the pitch line and about 1.5° to 2.5° smaller near 15% and 80% immersion. The IGV exit swirl angles begin to increase near the casing, becoming larger than design intent in the outer 5% immersion. The stator exit swirl angles agree reasonably well with the design distribution from 30% to 90% immersion but become larger than design between 10% and 20% immersion, probably from the effects of secondary flow. Based upon these preliminary results, it was decided to conduct all testing without any changes in stagger angle of the blading.

4.2 CASING TREATMENT TEST RESULTS

Tests in which preview data were taken were conducted for three different casing treatment window geometries in order to aid in determining the stall-limiting stage and to select the casing geometry to be used throughout the test series. The results are shown in Figure 9.

Although four identical stages were tested, the repeating stage environment was not established until Stage 2 or Stage 3. It is, thus, very desirable that Stage 1 not be the stall-limiting blading. In order to make this assessment, circumferential groove casing treatment was applied over the Stage 1 rotor tip exclusively. The 8.2% improvement in stall margin, shown in Figure 9 for this configuration, indicates that the first-stage rotor was indeed stall-limiting without casing treatment. This stall margin improvement was obtained with no measurable change in the rest of the pressure flow characteristic or in the efficiency curve. Circumferential groove casing treatment was then applied over all four rotor tips. The slight additional improvement in stall margin shown in Figure 9 indicates that Stage 1 is probably no longer stall-limiting when casing treatment is used. However, there was a loss in efficiency and a slight loss in pressure rise with treatment over all four rotor tips. Based on these test results, it was decided to conduct all four-stage tests in the program with circumferential groove casing treatment over Rotor 1 tip only and smooth windows over the rest of the rotors.

4.3 OVERALL PERFORMANCE

The overall performance of the baseline configuration, which consisted of Rotor A with Stator A, 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 1.36% and an average stator seal-clearance-to-blade-height of 0.78%. The test Reynolds number was 3.6×10^5. As discussed previously, casing treatment was applied over the tip of the first rotor only to assure that Stage 1 would not be the stall-limiting blading.

4.3.1 Four-Stage Configuration

The overall performance of the four-stage Rotor A/Stator A configuration is presented in Figure 10 and tabulated in Table 4. The design intent pressure coefficient of 0.555 has been achieved at the design intent flow coefficient of 0.407. At the design pressure rise, the measured efficiency of 0.900 was equal to the design target. Peak efficiency of 0.9045 occurs at a flow coefficient of 0.388, and peak pressure rise occurs at a flow coefficient of 0.363. At values of flow coefficient less than 0.363, the pressure flow characteristic rolls over and flattens out until a crisp rotating stall occurs.

The radial variation of normalized total pressure at the compressor discharge is presented in Figure 11. Of particular significance is the weakening and eventual collapse of the hub region at peak pressure rise. From 80% immersion to the hub, very little increase in total pressure rise has been achieved as the compressor is throttled from peak efficiency to peak pressure rise. Probing the hub region with tufts indicated that boundary layer separation was occurring on the stator vanes and becoming progressively worse as stall was approached. This results in the rollover and flattening of the pressure flow characteristic from peak pressure rise to stall, as shown in Figure 10.

4.3.2 Single-Stage Configuration

The overall performance of the single-stage Rotor A/Stator A configuration is presented in Figure 12. This configuration was tested without casing treatment over the rotor tip in order to make comparisons with the test stage (third stage) of the four-stage configuration. The data in Figure 12 show that the single-stage configuration is pumping more flow than the four-stage average and that the single-stage configuration achieves a higher peak pressure coefficient. However, the peak efficiency of the single-stage configuration is approximately 2.0 points lower (based on preview data) and 0.8 points lower (based on standard data) than that of the four-stage configuration.

4.3.3 Comparison of Single-Stage and Multistage Results

The individual characteristics of the single-stage and four-stage configurations are compared in Figure 13. For flow coefficients above 0.38, the single-stage characteristic compares favorably with the first-stage characteristic of the four-stage configuration, although the single-stage characteristic is not quite so steep at larger flow coefficients. Compared to the Stage 3 characteristic of the four-stage configuration, the single-stage characteristic has about the same slope but is operating at about 2.5% higher flow and about 4% higher pressure coefficients. The significant differences in the characteristics occur at flow coefficients below 0.38. Both the single stage and the first stage of the multistage configuration achieve significantly higher peak pressures than those of the other stages. This difference probably results from the cleaner, more constant inlet conditions at the first rotor inlet. During throttling, the first rotor inlet is not subjected to the thickened wakes, increased deviation angles, and separated flow that the downstream stages feel. Perhaps even more striking is the higher pressure achieved by the first stage of the four-stage configuration compared to the single-stage configuration. This could result from the casing treatment or from the stabilizing influence of the downstream stages pulling on the first stage of a multistage configuration.

A comparison of the radial variation of normalized total pressure at the compressor discharge is presented in Figure 14 for the single-stage and the four-stage configurations. Pressures for the four-stage configuration have been divided by four in order to make comparisons with the single-stage results. At both throttles presented, the single-stage data exhibits a reduction in total pressure rise at both the tip region (0%-20% immersion) and the hub region (20%-100% immersion) compared to the multistage results. At the peak pressure rise throttle the higher pressure rise achieved by the single-stage configuration is evident in the figure.

4.4 REYNOLDS NUMBER TEST RESULTS

The essentially incompressible flow in the test compressor allows stage performance to be presented as stage characteristics that are independent of speed, although there are small variations in performance due to Reynolds number. In order to determine these performance variations, a series of preview data points was taken at seven different rotative speeds covering a range of Reynolds numbers from 0.94 x 10^5 to 4.00 x 10^5. The results presented in Figures 15 and 16 serve as an aid in extrapolating the test data to the somewhat higher Reynolds number levels employed in engines.

4.5 BLADE AND VANE SURFACE STATIC PRESSURE TEST RESULTS

The measurements of static pressure on the blade and vane surfaces are presented in Figures 17 through 22 and tabulated in Tables 5 through 10 for (1) the four-stage configuration with the third stage as the test stage, (2) the single-stage configuration, and (3) the four-stage configuration with the first stage as the test stage. The measured pressures have been normalized by the dynamic head based on tip speed, 1/2 $\rho_{REF}U_t^2$. Suction surface measurements are presented as solid lines and pressure surface measurements as dashed lines. Data were obtained for an open throttle, the design throttle, the peak efficiency throttle, the peak pressure rise throttle, and the near stall throttle for the third stage. Open throttle data were not obtained for the single-stage test or the first-stage test.

4.5.1 Four-Stage Configuration (Third Stage as Test Stage)

The normalized static pressure measurements on the blade and vane surfaces are presented in Figures 17 and 18 and Tables 5 and 6, respectively, for the four-stage configuration with the third stage as the test stage.

The rotor data in Figure 17 indicate a uniform diffusion from the location of the peak suction surface velocity (minimum static pressure) to the trailing edge for all blade sections and all throttles except the peak pressure rise and near stall throttles close to the hub (Figures 17d and e, respectively). In this hub region, evidence of flow separation is seen as a distinct decrease in slope of the diffusion rate (static pressure gradient) on the suction surface of the blade. For the peak pressure rise throttle, this occurs at 70% chord for 90% immersion (Figure 17e) and at about 80% chord for 80% immersion (Figure 17d). For the near stall throttle this distinct decrease in diffusion rate occurs at 50% chord for 90% immersion (Figure 17e) and at 60% chord for 80% immersion (Figure 17d). Apparently, flow separation on the rotor begins at the hub and moves toward the leading edge and radially outward as the compressor is throttled. The increase in leading edge loading as the compressor is throttled toward stall is evident at all immersions.

There is evidence of the effects of secondary flow and tip leakage on the suction surface pressure distribution of the rotor over the first 25% of the chord (Figure 17a). This is seen as an increase in static pressure on the suction surface from zero to about 8% chord, followed by a decrease in static pressure from 8% to about 40% chord. This same type of profile was observed on the suction surface near the tip in Reference 4, although the location of maximum static pressure occurred further aft.

The stator data in Figure 18 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 and near stall throttles as seen in Figure 18c through 18e. For the peak pressure rise throttle, separation is indicated by the flat static pressure on the suction surface beginning at about 50% chord for 95% immersion and at 60% chord for 80% immersion (Figures 18e and d, respectively). For the near stall throttle, separation is indicated at about 20% chord for 95% immersion, at about 35% chord for 80% immersion, and at 60% chord for 50% immersion (Figures 18e, d, and c, respectively). Probing this region with a tuft probe confirmed the presence of large areas of separated flow. Flow separation for the stator apparently begins at the inner diameter and moves toward the leading edge and radially outward as the compressor is throttled.

The blade and vane surface static pressure measurements indicate that the Rotor A/Stator A four-stage baseline configuration is hub-weak.

4.5.2 Single-Stage Configuration

The normalized static pressure measurements on the blade and vane surfaces are shown in Figures 19 and 20 and Tables 7 and 8, respectively, for the single-stage configuration. This configuration was run without casing treatment over the rotor tip so that the stage geometry of the single stage matched that of the third stage of the four-stage configuration as closely as possible.

The rotor data in Figure 19 show a uniform diffusion from about 40% chord to the trailing edge for all throttles at 5%, 20%, and 50% immersions (Figures 19a, b, and c). No evidence of flow separation is apparent. However, for 80% and 90% immersions, Figures 19d and e, there is a substantial decrease in the rate of diffusion for all throttles beginning at about 70% immersion in Figure 19d and from 50% to 70% immersion, depending upon throttle, in Figure 19e. These diffusion rates are clearly different from those shown in Figure 17d and e for an embedded stage operating in a multistage environment. This will be discussed further in Section 4.5.4.

As seen before in Figure 17a, there is again evidence in Figure 19a of the effects of secondary flow and tip leakage on the suction surface pressure distribution of the rotor over the first 30% of the chord.

The stator data in Figure 20 indicate that, for all throttles and all immersions, there is a continuous diffusion from the point of minimum static pressure on the suction surface to the trailing edge, although there is a change in the rate of diffusion near the hub. This change in the rate of diffusion is most evident at 50% chord for 95% immersion, Figure 20e, at the peak pressure rise/near stall throttle.

4.5.3 Four-Stage Configuration (First Stage as Test Stage)

The normalized static pressure measurements on the blade and vane surfaces, presented in Figures 20 and 21 and Tables 9 and 10 for the four-stage configuration with the first stage as the test stage, are qualitatively similar to those shown in Figures 18 and 19 for the single-stage configuration. However, there are two regions where the differences are noteworthy. First, the rotor hub region for the four-stage configuration/first stage tested (Figures 21d, e) appears to be stronger than the hub region of the single-stage configuration (Figures 19d, e) as evidenced by the difference in the diffusion rate. Secondly, the rotor tip region shown in Figure 21a has a different suction-surface diffusion rate near stall from about 30% chord to 60% chord than that shown in Figure 19a. This is probably caused by the casing treatment. These differences are discussed in the next section.

4.5.4 Comparison of Four-Stage and Single-Stage Results

A comparison of blade surface static pressures for the four-stage and single-stage configurations is presented in Figure 23 for the design point throttle and the peak pressure rise throttle. For these comparisons the zero level of static pressure was taken as the maximum static pressure measured on the pressure surface, and the difference, ΔP, between this zero level and pressures at other locations on the airfoil was plotted. The data taken near the hub of the rotor for the single-stage configuration (Figures 23c, d, e, f) show evidence of flow separation in the change in slope and in the flattening of the suction-surface pressure distribution. This begins at about 80% chord in Figure 23c, 70% chord in Figures 23d and e, and 50% chord in Figure 23f. Neither of the other two configurations exhibits such a pronounced effect. Apparently, the other stages in the multistage configurations have a stabilizing effect on the rotor hub.

At the rotor tip (Figures 23a and b) the loading for both the single-stage configuration and the four-stage configuration with the first stage as the test stage is higher than that of the embedded stage.

A comparison of the vane surface static pressures for the multistage and single-stage configurations is presented in Figure 24. The data indicate that the stator is operating about the same for all configurations at the design point. However, at the peak pressure throttle the stator of both the single-stage and first-stage configurations is running with noticeably less flow separation in the hub (inner diameter region).

4.5.5 Comparisons with Potential Flow (CASC) Solutions

The velocity distributions along the suction and pressure surfaces of the blades and vanes were computed from the measured pressure distributions as discussed in Section 3.5. These velocity distributions were then compared with the potential flow CASC distributions. The results are presented in Figures 25 and 26. The spanwise locations of the CASC calculations did not always coincide with those of the static taps; the CASC immersions are indicated on the curves in these cases. All comparisons are made at the design point throttle setting.

Comparisons for the rotor are shown in Figure 25. The significant differences observed on the suction surface near the tip in Figure 25a are attributed to secondary flow/tip leakage effects (Reference 4). The suction surface velocities tend to be low from 5% to about 30% chord and high from 30% to 60%. These velocity perturbations are induced by the tip clearance vortex that moves away from the suction surface and away from the casing as percent chord increases. The test results are in good agreement with CASC at the pitch line shown in Figure 25b. Airfoil loadings near the leading edge, indicative of incidence angles, appear to be about as intended. Near the hub (Figure 25c) the leading edge loading is a little high, and there does appear to be slightly less peak suction-surface velocity diffusion than intended.

Comparisons for the stator are shown in Figure 26. Airfoil loading near the leading edge is larger than predicted, especially near the end walls, and the velocity diffusion on the aft portion of the airfoil is less than predicted. Evidently the stator is operating at higher incidence angles (leading edge airfoil loadings) at the design point than intended. This would help to explain the large regions of separated flow found on the stator hub as the compressor is throttled toward stall.

4.6 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.

4.6.1 Four-Stage Configuration (Third Stage as Test Stage)

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 30 and in Table II for the design point throttle, the peak efficiency throttle, the peak pressure rise throttle, and the near stall throttle. The difference between the total pressure at Plane 3.5 and 3.0 represents the total pressure rise across the rotor. The difference between the total pressures at Plane 3.5 and 4.0 represents the loss across the stator. The region of end-wall loss in the stator from 0% to 20% immersion and from 80% to 100% immersion is evident. The high-loss region from 60% immersion to the stator hub near stall is particularly noticeable in Figure 30. The Rotor A/Stator A configuration is hub-weak, and this large region of separated flow exists at the near stall throttle. These data are in agreement with the flattening of the vane surface static pressure measurements shown in Figures 18d and 18e for the near stall throttle.

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 Planes 3.5 and 4.0. This gives a pitch line 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 31 through 36 and in Table II for the design point throttle, the peak efficiency throttle, the peak pressure rise throttle, and the 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 data in Figure 31 indicate that the design intent swirl distribution has been achieved at the exit plane of the third stator. The increase in incidence and deviation angles as the compressor is throttled to stall is evident in Figures 31 through 34. The deviation angles near the outer diameter are lower for Stator 3 than for Stator 2, particularly near stall, perhaps because the hub is breaking down in Stage 3, although it is suspected that the flow angles in the outer 5% immersion at Stator 3 exit may have been read a few degrees low.

Total Pressure Circumferential Surveys and Loss Coefficients

Relative total pressure measurements across a circumferential blade spacing were obtained at 11 radial immersions using the rotating rake shown in Figure 6. The results are presented in Figures 37 through 40 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 40). An interesting feature of these circumferential surveys is the shape of the distribution near the tip of the blade. Both the loss region due to the wake and the loss region due to tip clearance/secondary flow effects can be seen.

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 41 through 44 for 11 of the 19 immersions. The distribution of static and total pressures shown in Figures 27 through 30 were obtained by computing the average, minimum, and maximum value of pressure shown in Figures 41 through 44 at each radial immersion. The large stator wakes in the vicinity of the hub near stall are clearly evident.

These detailed measurements were used to determine rotor and stator loss coefficients. The rotor loss coefficients computed from the relative total pressure measurements are presented in Figure 45 and Table 12. The stator loss coefficients computed from absolute total pressure measurements are presented in Figure 46. 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 wake loss coefficients in Figures 45b and 46b increase substantially between 60% and 100% immersion near stall as the flow separates on the suction surface of the blades and vanes. The tip clearance vortex loss is evident from zero to 15% immersion in Figure 45c.

Vector Diagram Quantities

Complete vector diagram quantities as well as loss coefficients, loss parameters, diffusion factors, incidence and deviation angles were computed from the quantities measured in the absolute frame of reference. The results are tabulated in Tables 13 through 21 for the various throttle settings. Several of these performance parameters have been plotted as a function of percent immersion in Figures 47 through 53. The design point intent 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. The rotor loss coefficients and D-factors and the stator incidence angles are somewhat larger than those used in designing the stage. In the end-wall region (particularly the outer diameter) the velocities are lower, and air angles, incidence angles, deviation angles, losses, and D-factors are larger than the design values.

The rotor total loss coefficients, computed from measuremens made in the absolute frame of reference, are somewhat larger at the design point than both the design intent and the loss coefficients computed from measurements made in the relative frame using the rotating rake (compare Figures 45 and 49). Since the rotor loss coefficients obtained from the relative frame measurements do not depend upon inaccuracies in flow angle measurements (particularly in the end-wall regions) and in vector diagram calculations, it is believed that they are the more reliable of the two. Also, the good agreement between the measured efficiencies and the design intent efficiency means that the actual loss coefficients were close to the design values. This lends additional credibility to the rotating rake loss coefficients, since these were closest to the design intent levels.

As the compressor is throttled toward stall, there is a general decrease in velocity levels and an increase in air angles, flow turning, incidence angles, deviation angles, and D-factors. The region of end-wall flow is distinctly defined by the data.

4.6.2 Single-Stage Configuration

Pressures

Detailed surveys of normalized total and static pressures at the rotor inlet (Plane 1.0), rotor exit (Plane 1.5), and the stator exit (Plane 2.0) are presented in Figures 54 through 56 and in Table 22 for the design point throttle, the peak efficiency throttle, and the peak pressure rise/near stall throttle. A description of these figures is qualitatively the same as that for the four-stage configuration in Section 4.6.1.

Flow Angles

Detailed surveys of absolute air angles at the rotor inlet, rotor exit, and stator exit are presented in Figures 57 through 59 and in Table 22 for the design point and the peak pressure rise/near stall throttles. Again, the description of these figures is similar to that for the four-stage configuration in Section 4.6.1.

Total Pressure Circumferential Surveys and Loss Coefficients

Relative total pressure measurements across a circumferential blade spacing were obtained for the single-stage configuration at 11 immersions using the rotating rake shown in Figure 6. These results are shown in Figures 60 through 62 for the various throttles. The loss region due to the rotor wake and the loss region due to tip clearance/secondary flow effects can be seen.

Absolute total pressure measurements across a circumferential vane spacing were obtained and the results, including boundary layer surveys, are presented in Figures 63 through 65.

These detailed measurements were used to determine the rotor and stator loss coefficients presented in Figures 66 through 68 and in Table 23. The increase in loss coefficient due to the tip clearance vortex is obvious in Figures 66c and 68b from zero to 15% immersion.

Vector Diagram Quantities

Complete vector diagram quantities, loss coefficients, loss parameters, diffusion factors, incidence angles, and deviation angles were computed from the measured quantities; the results are given in Tables 24 through 29 for the various throttle settings. Several of the performance parameters have been plotted as a function of percent immersion in Figures 69 through 75.

Generally, the discussion follows that of Section 4.6.1, vector diagram quantities for the four-stage configuration, and is not repeated here. It should be noted that a single stage reacts differently to throttling than an embedded stage. This can be seen by comparing the differences in axial velocities shown in Figures 47 and 69.

4.6.3 Four-Stage Configuration (First Stage as Test Stage)

Pressures

The detailed surveys of normalized total and static pressures at the first rotor inlet, first rotor exit, and first stator exit are presented in Figures 76 through 78 and in Table 30 for the various throttle settings. The description of these figures is similar to that of the four-stage configuration in Section 4.6.1.

Flow Angles

The detailed surveys of absolute air angles at the rotor inlet, rotor exit, and stator exit are presented in Figures 79 through 81 and in Table 30. The description of the figures is once again similar to that given in Section 4.6.1.

Total Pressure Circumferential Surveys and Loss Coefficients

The relative total pressure measurements across a circumferential blade spacing, obtained using the rotating rake, are presented in Figures 82 through 84.

The absolute total pressure measurements obtained across a circumferential vane spacing are shown in Figures 85 through 87.

The rotor/stator loss coefficients shown in Figures 88 and 89 and in Table 31 were determined from these detailed pressure measurements. The description of these curves is similar to that presented for the four-stage configuration in Section 4.6.1.

Vector Diagram Quantities

The complete vector diagram quantities, loss coefficients, diffusion factors, incidence angles, and deviation angles were computed from the measured quantities. The results are given in Tables 32 through 37 and in Figures 90 through 96. The discussion follows that of Section 4.6.1.

5.0 CONCLUSIONS

A low speed aerodynamic scale model of Stage 7 of the 10-stage, 23:1 pressure ratio AMAC study compressor was designed. This scale model, which formed the baseline Rotor A/Stator A configuration, was tested in General Electric's Low Speed Research Compressor test facility in multistage and single-stage buildups. The data show that the design intent pressure coefficient of 0.554 was achieved at the design intent flow coefficient of 0.408. At the design pressure rise, the measured efficiency of 0.900 was equal to the design target. Detailed test data were taken to obtain blade element performance.

The data obtained for the Stage A configuration described in this report will form a baseline for evaluating new blade and vane shapes that are intended to reduce end-wall losses. This evaluation will be reported in subsequent volumes.

6.0 LIST OF SYMBOLS AND ACRONYMS

Symbol	Definition
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
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
PS	Blade surface static pressure $\equiv P_{surface}-(P_B+P_{REF})$
P_{S_1}	Upstream static pressure
P_{T_1}	Total pressure
QU	Normalizing quantity = $1/2\ \rho_{REF}U_t^2$
R	Radius
Re	Reynolds number
T	Measured torque corected 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, REF Reference

S Static properties

T Total properties

t Tip

1 Upstream conditions

2 Downstream conditions

$\beta_1{}^*$ Inlet metal angle

$\beta_2{}^*$ Exit metal angle

7.0 FIGURES

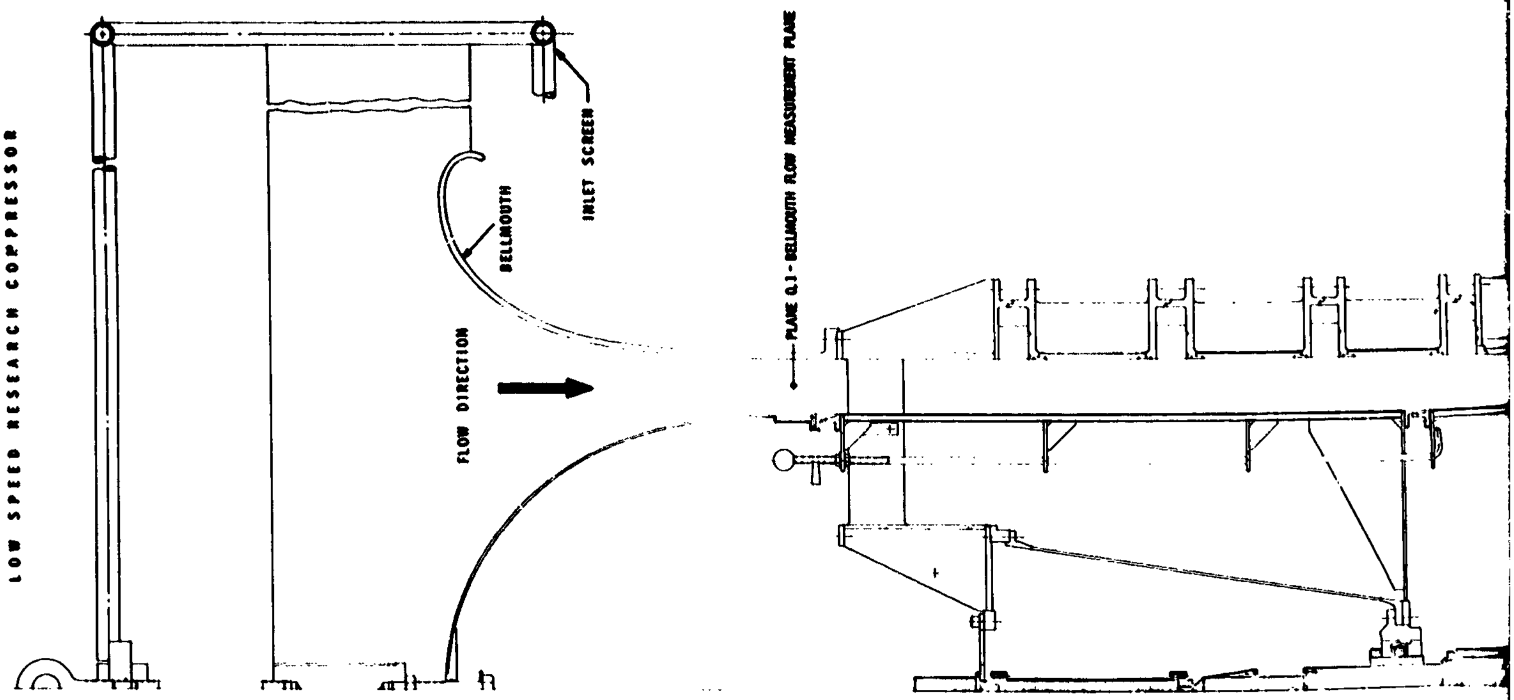
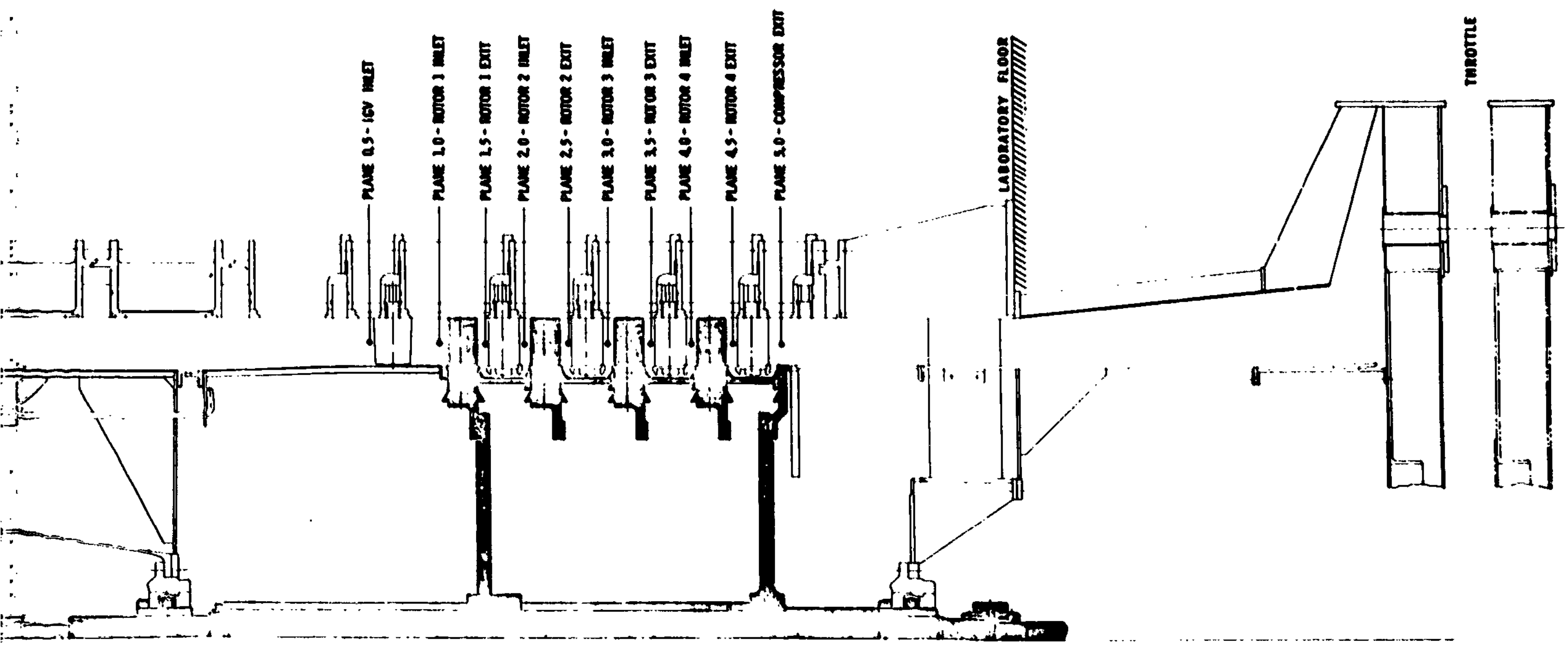


Figure 1. Four-Stage Compressor Configuration T

FOLDOUT



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

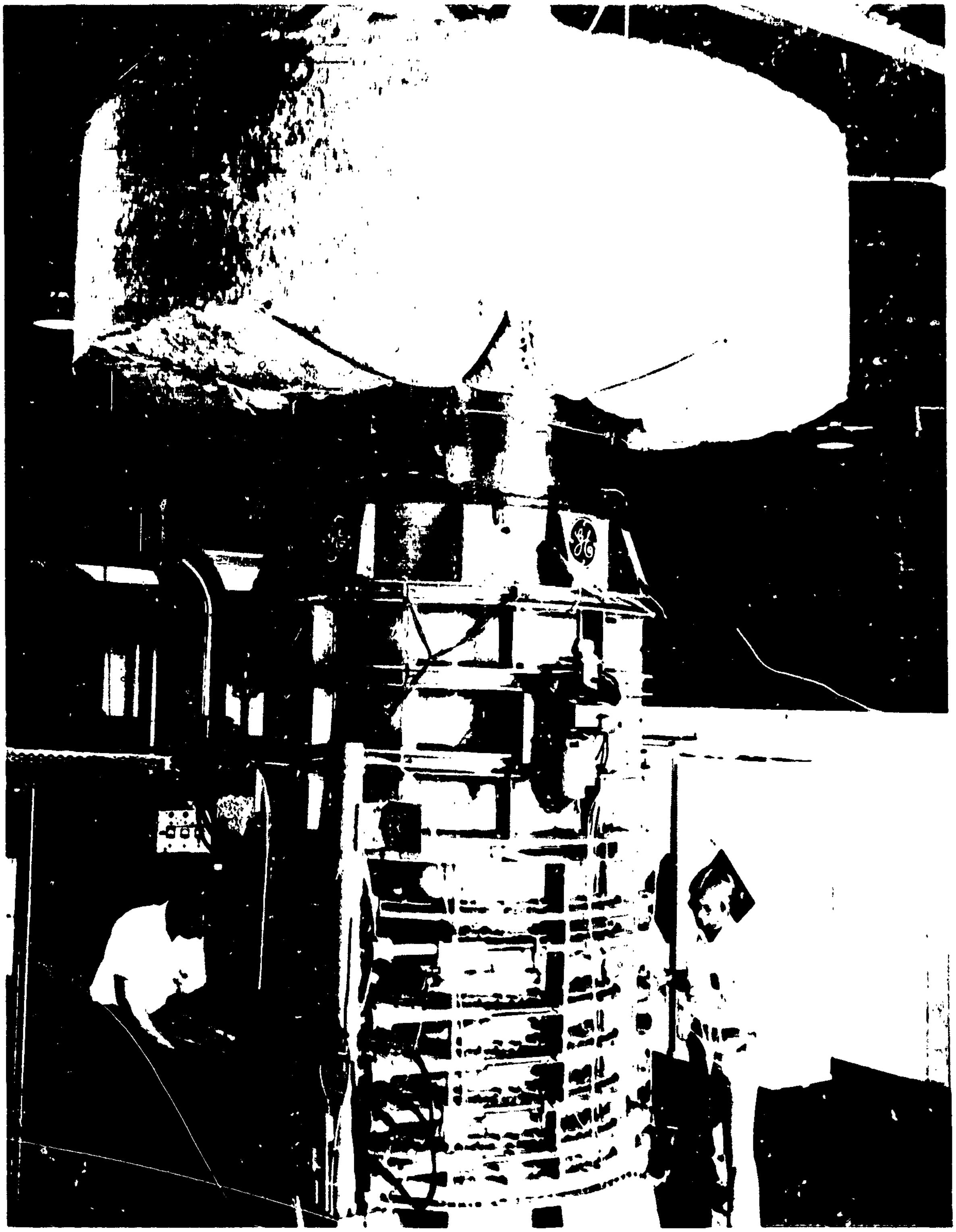


Figure 2. Photograph of the Low Speed Research Compressor.

ORIGINAL PAGE IS
OF POOR QUALITY

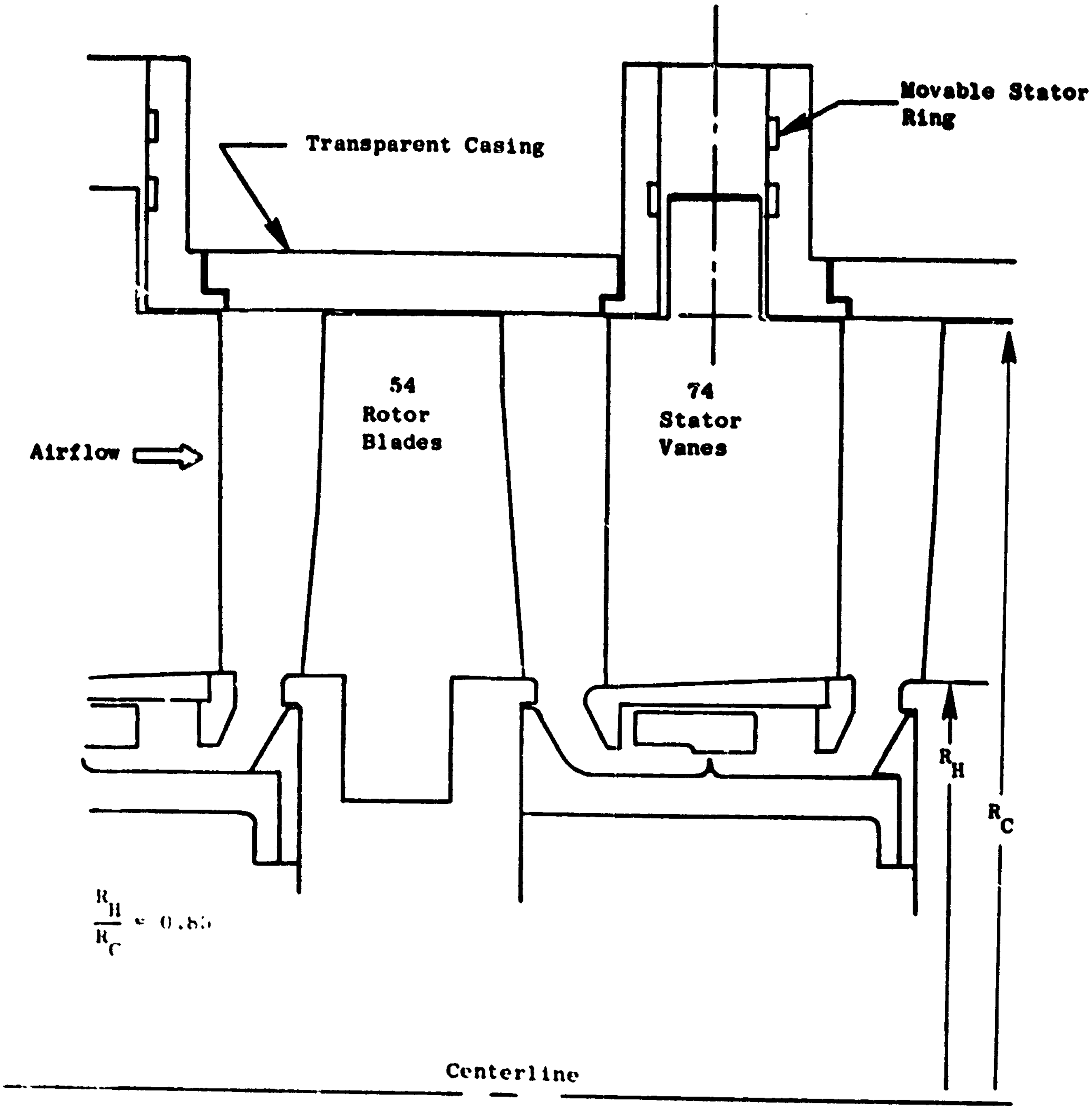


Figure 3. Cross Section of 0.85 Radius Ratio Compressor Stage.

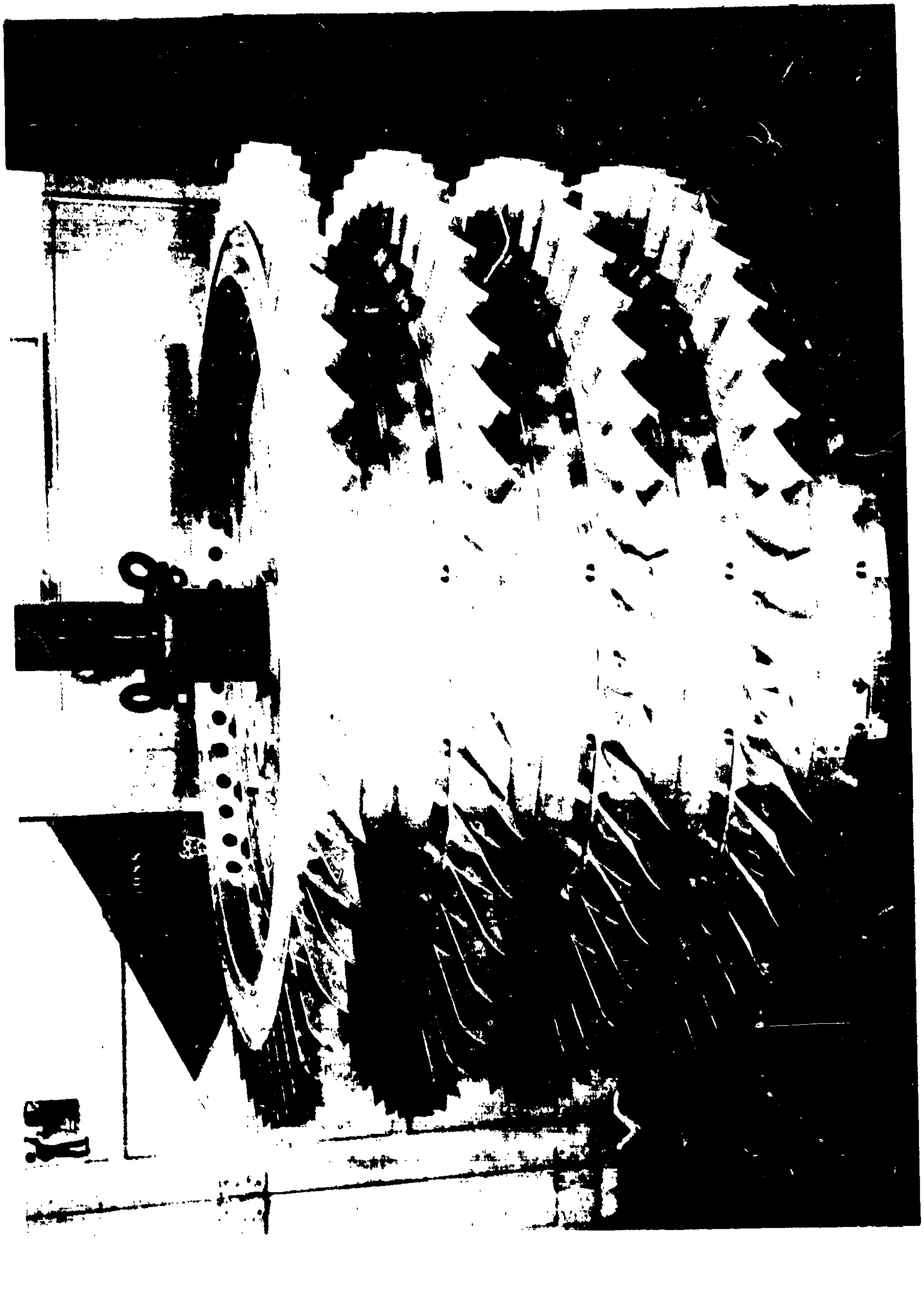


Figure 4. Photograph of Rotor A Assembly for the Low Speed Research Compressor.

ORIGINAL PAGE IS
OF POOR QUALITY

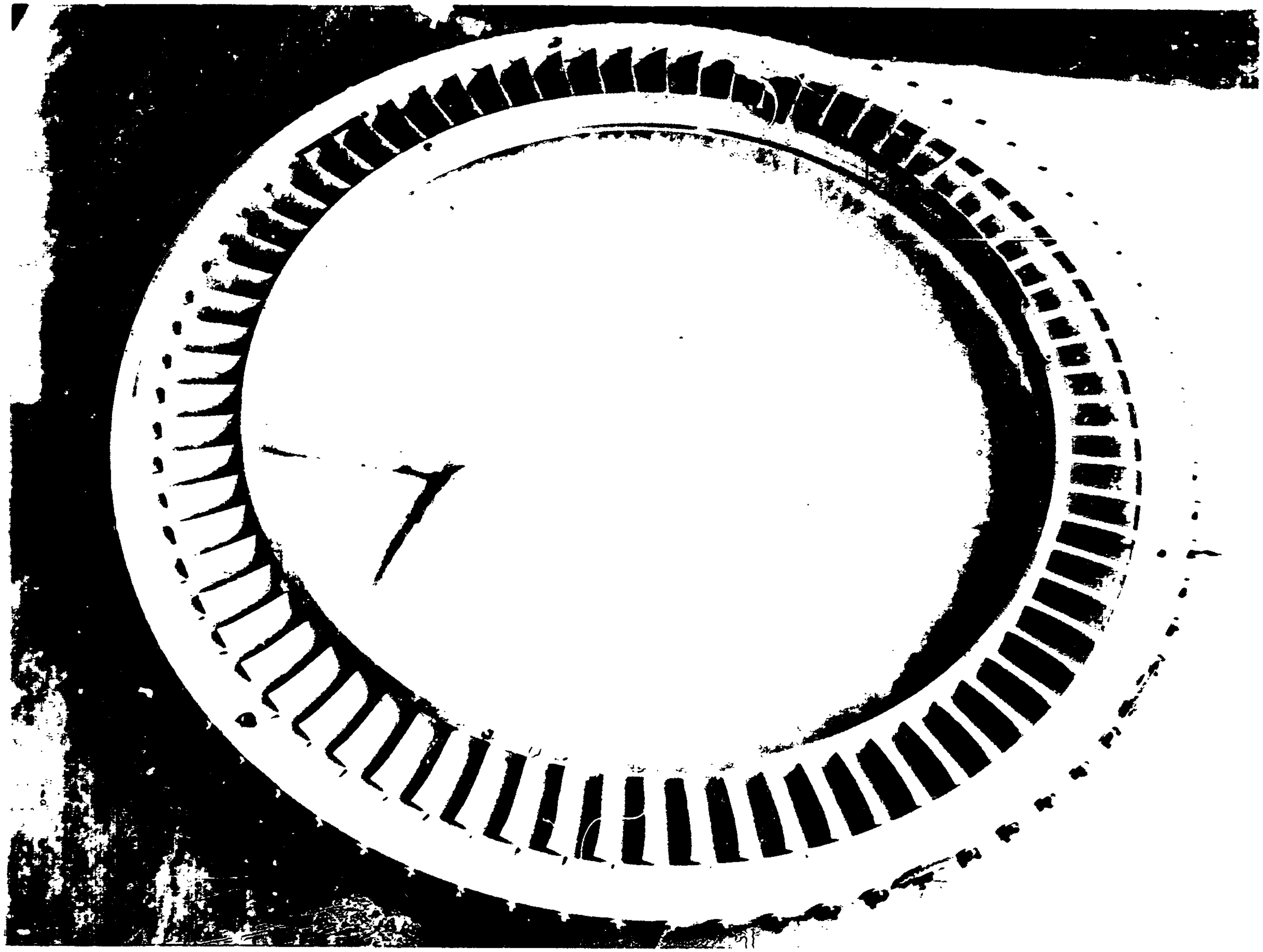


Figure 5. Photograph of Stator A Assembly for the Low Speed Research Compressor.

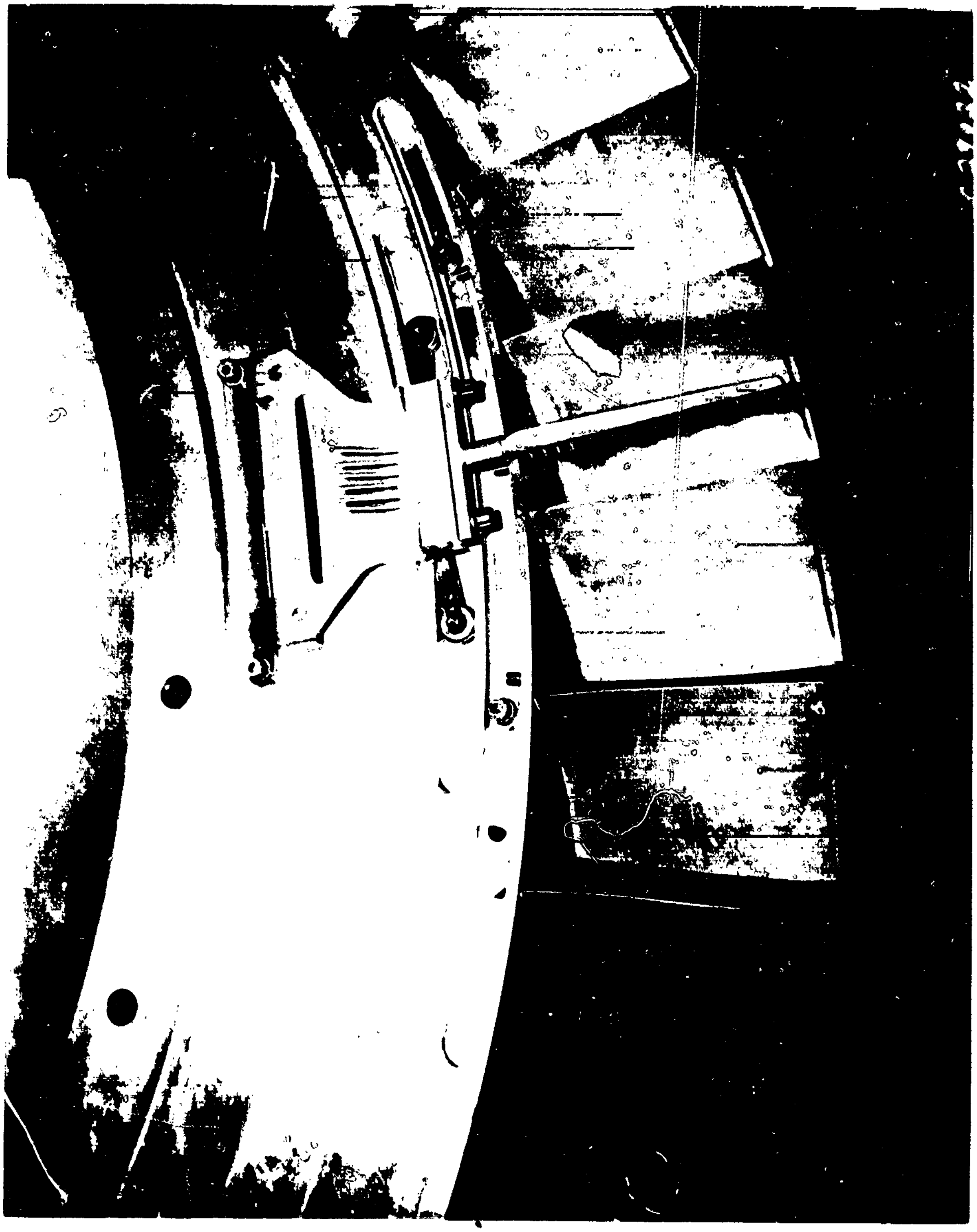


Figure 6. Rotating Total Pressure Rake at Rotor Exit Plane.

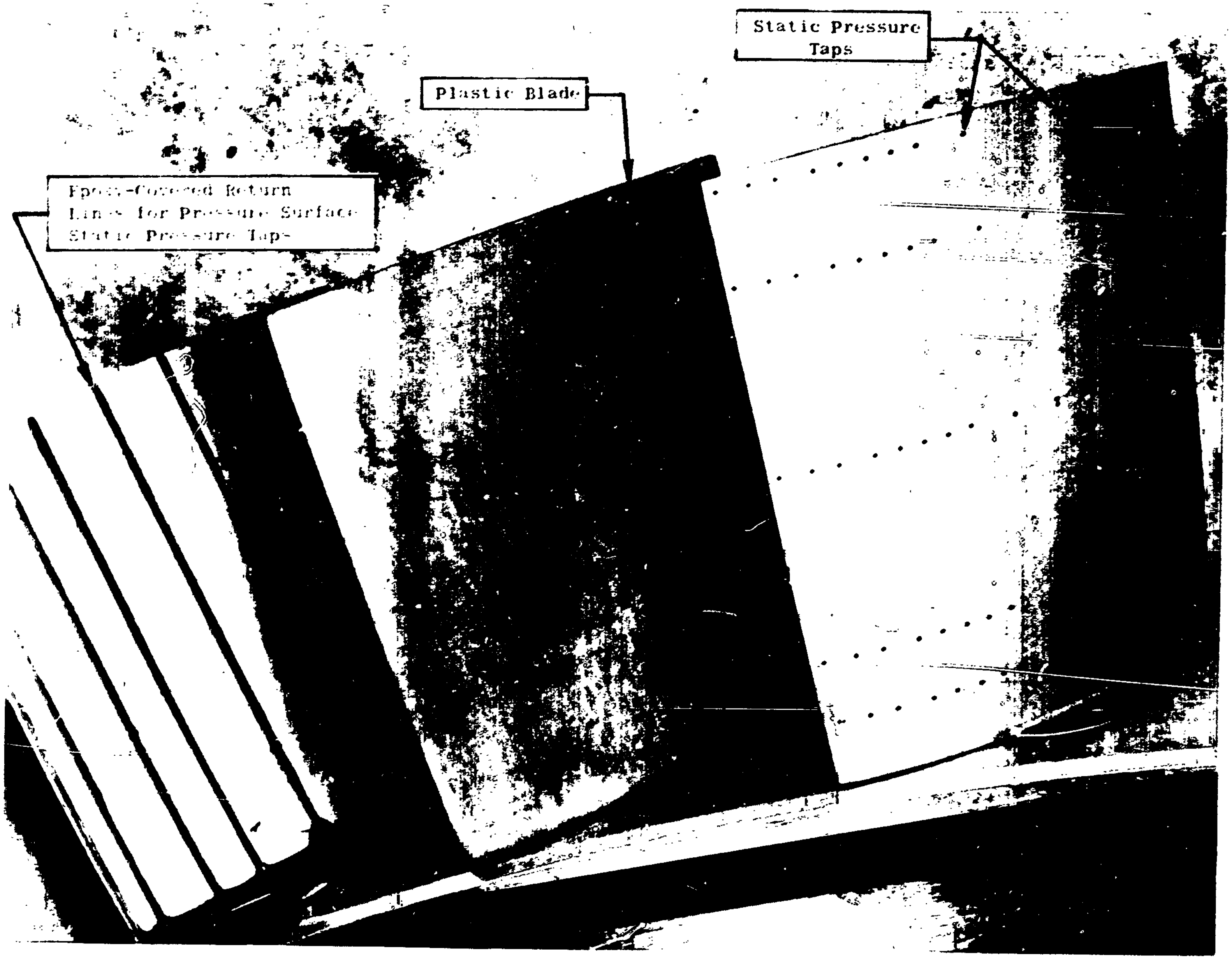


Figure 7. Rotor Blade with Static Pressure Taps on Suction Surface.

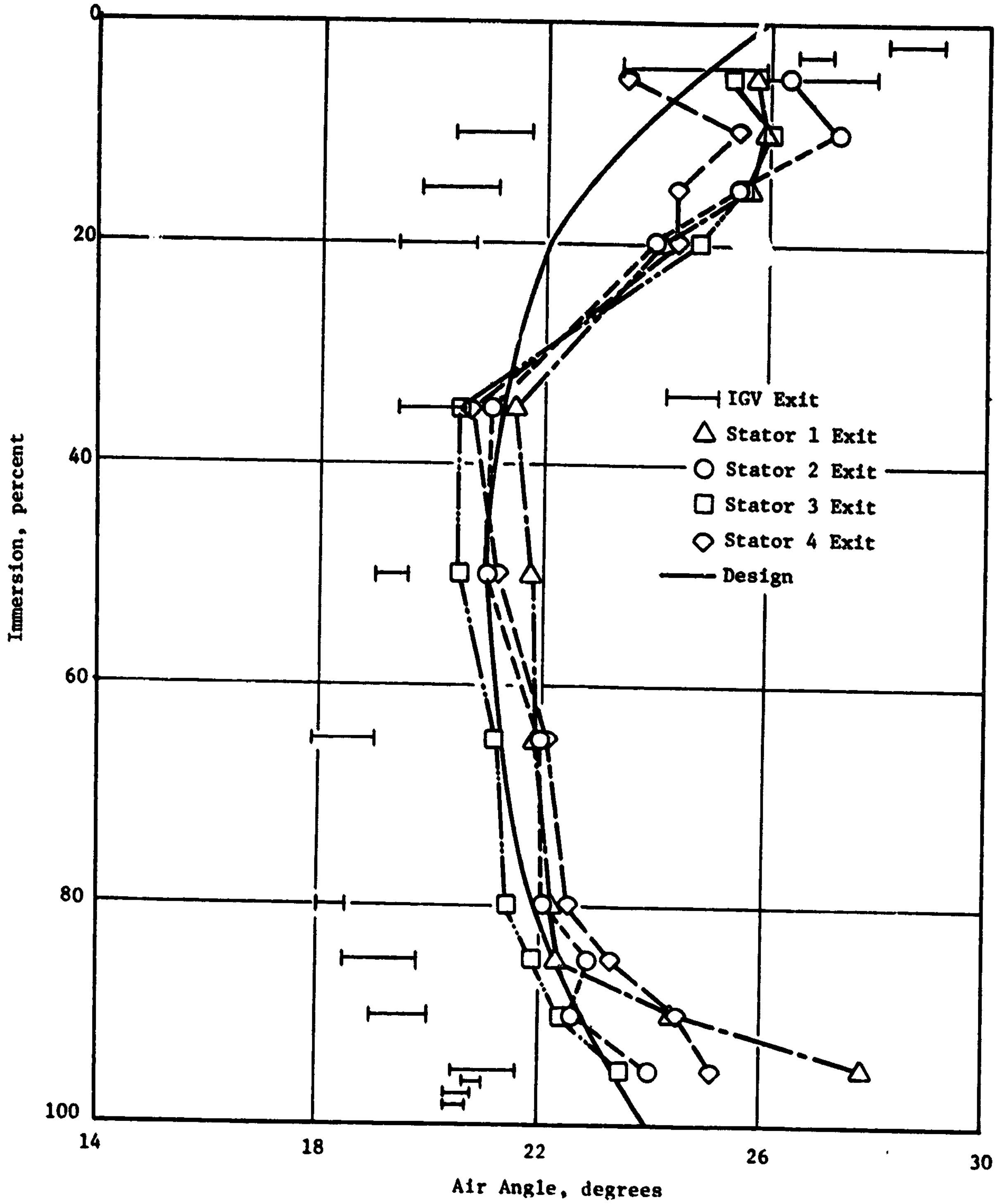


Figure 8. Preliminary Measurements of Swirl Angles.

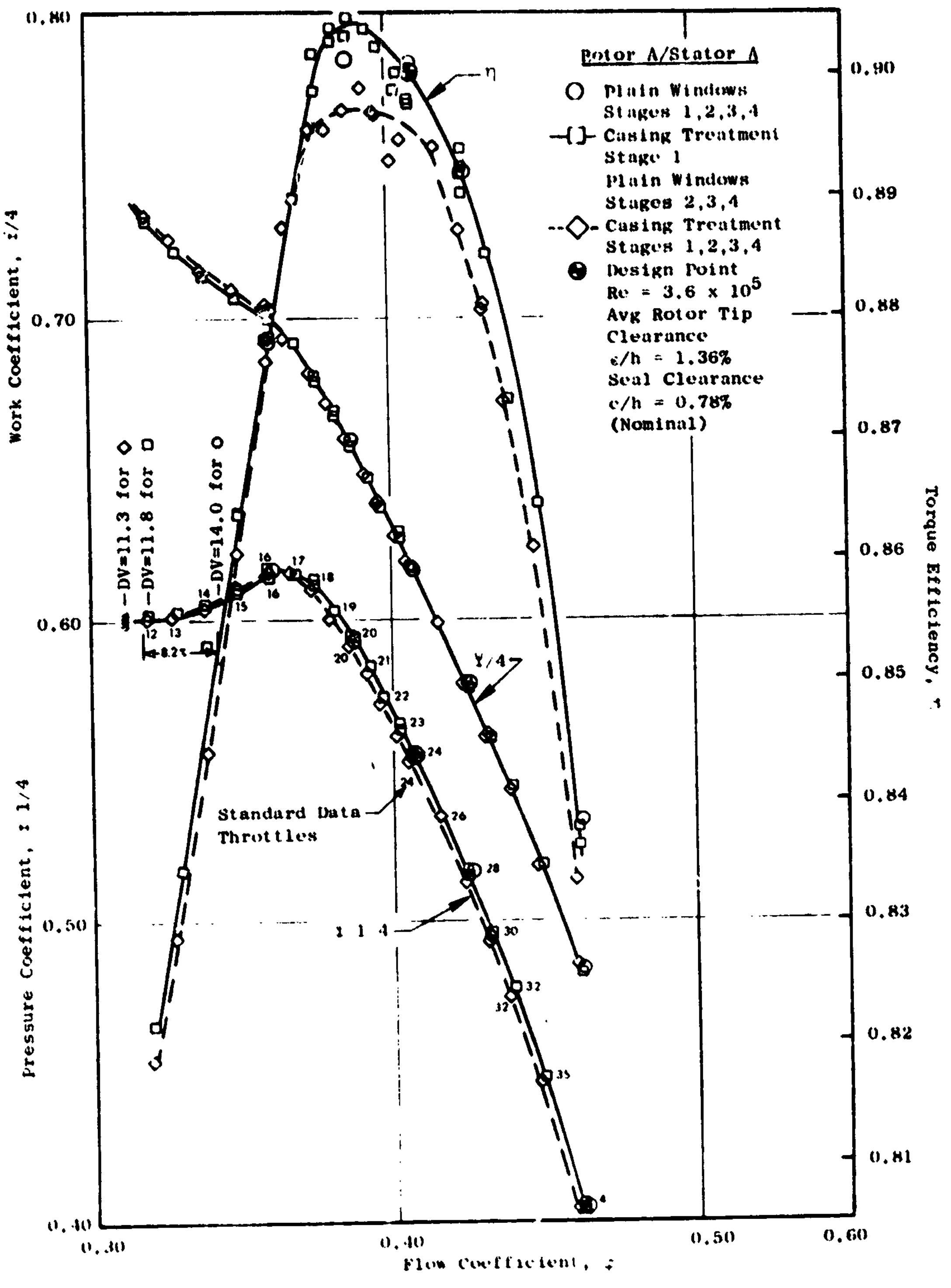


Figure 9. Preview Data Test Results Showing the Effects of Circumferential Groove Casing Treatment on Compressor Performance.

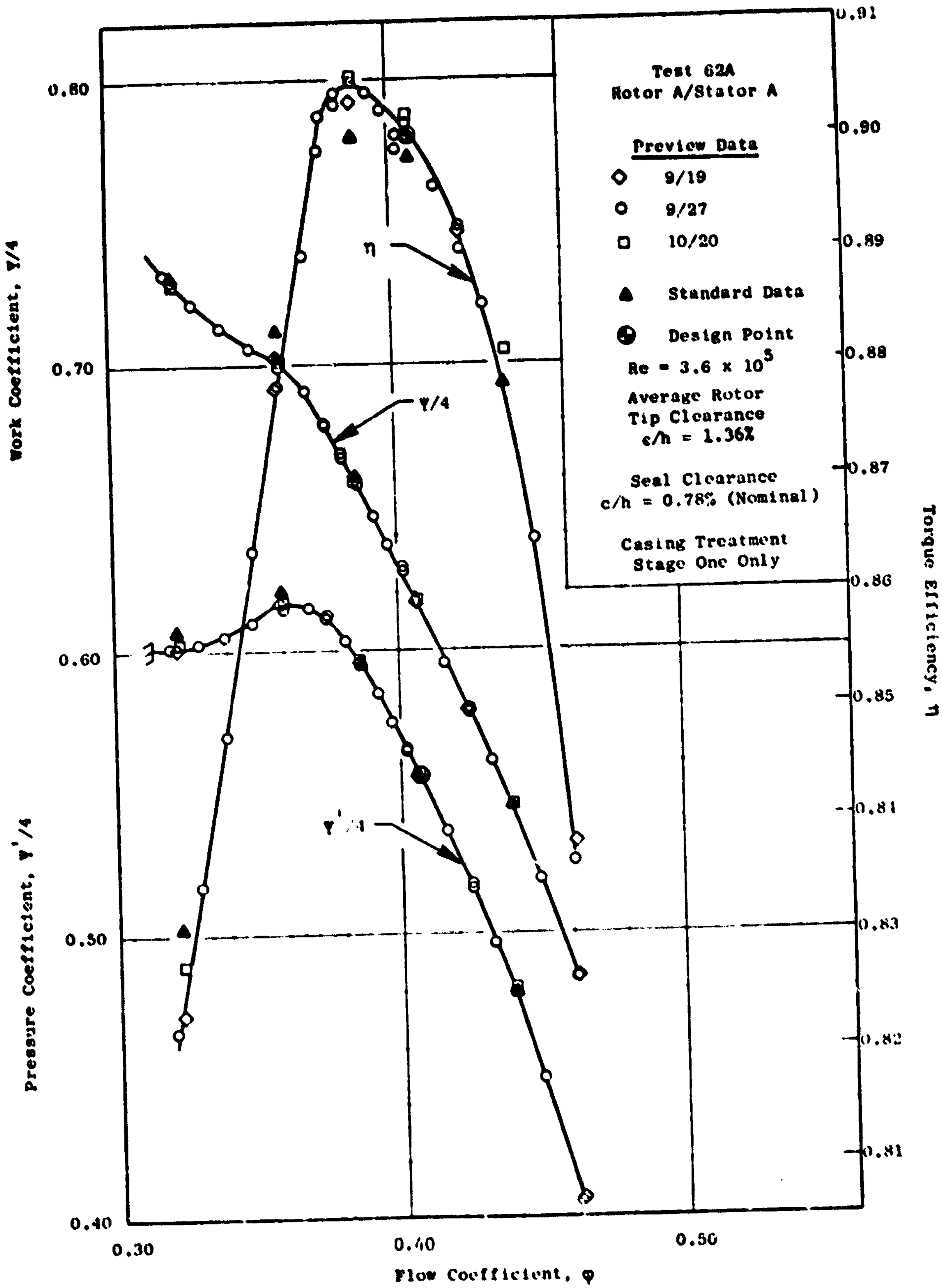


Figure 10. Overall Performance for the Four-Stage Baseline Configuration Using Rotor A/Stator A.

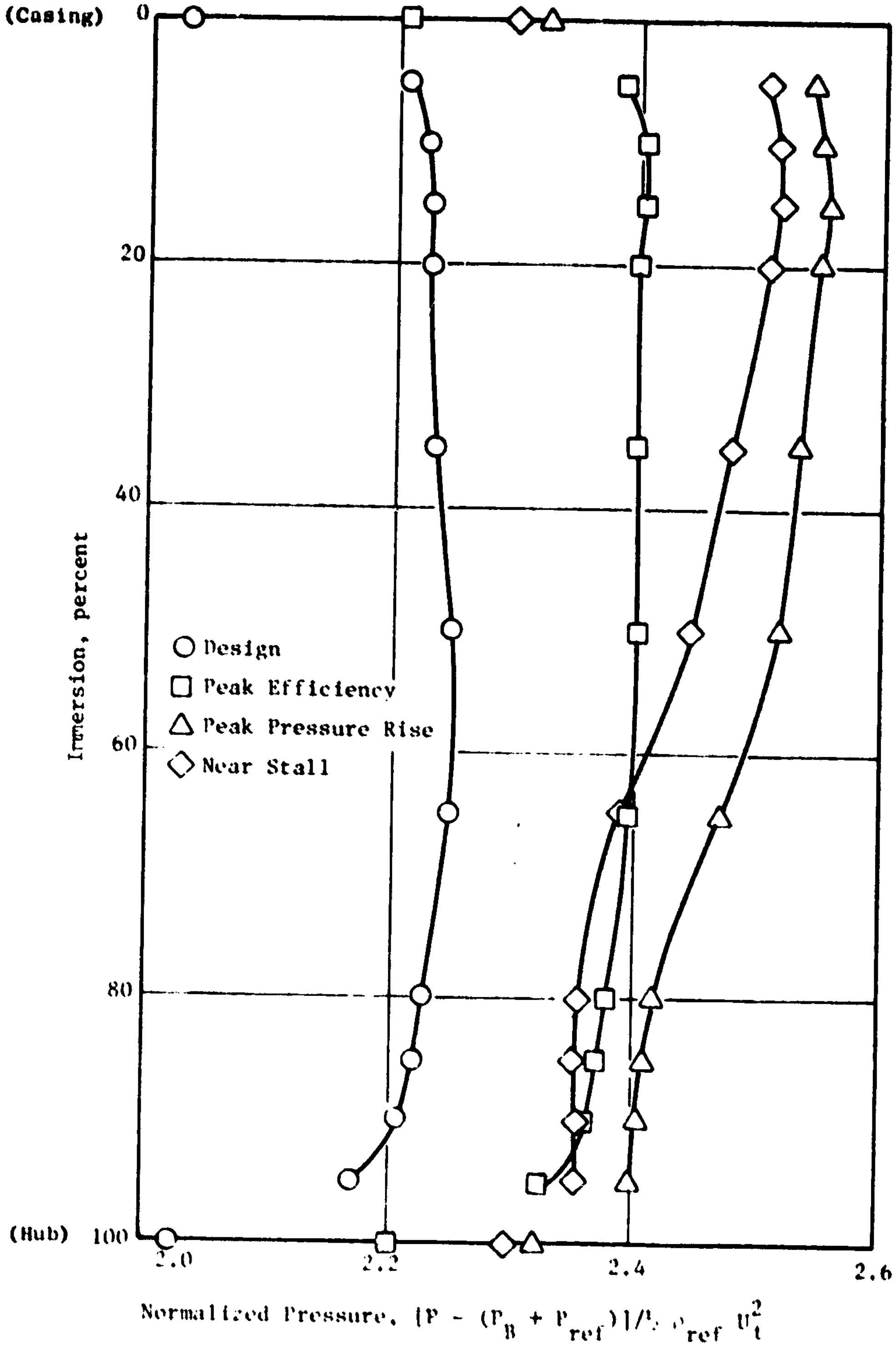


Figure 11. Radial Variations of Normalized Total Pressure Including Casing and Hub Normalized Static Pressure at the Casing Discharge for Various Throttle Setting, Four-Stage Configuration.

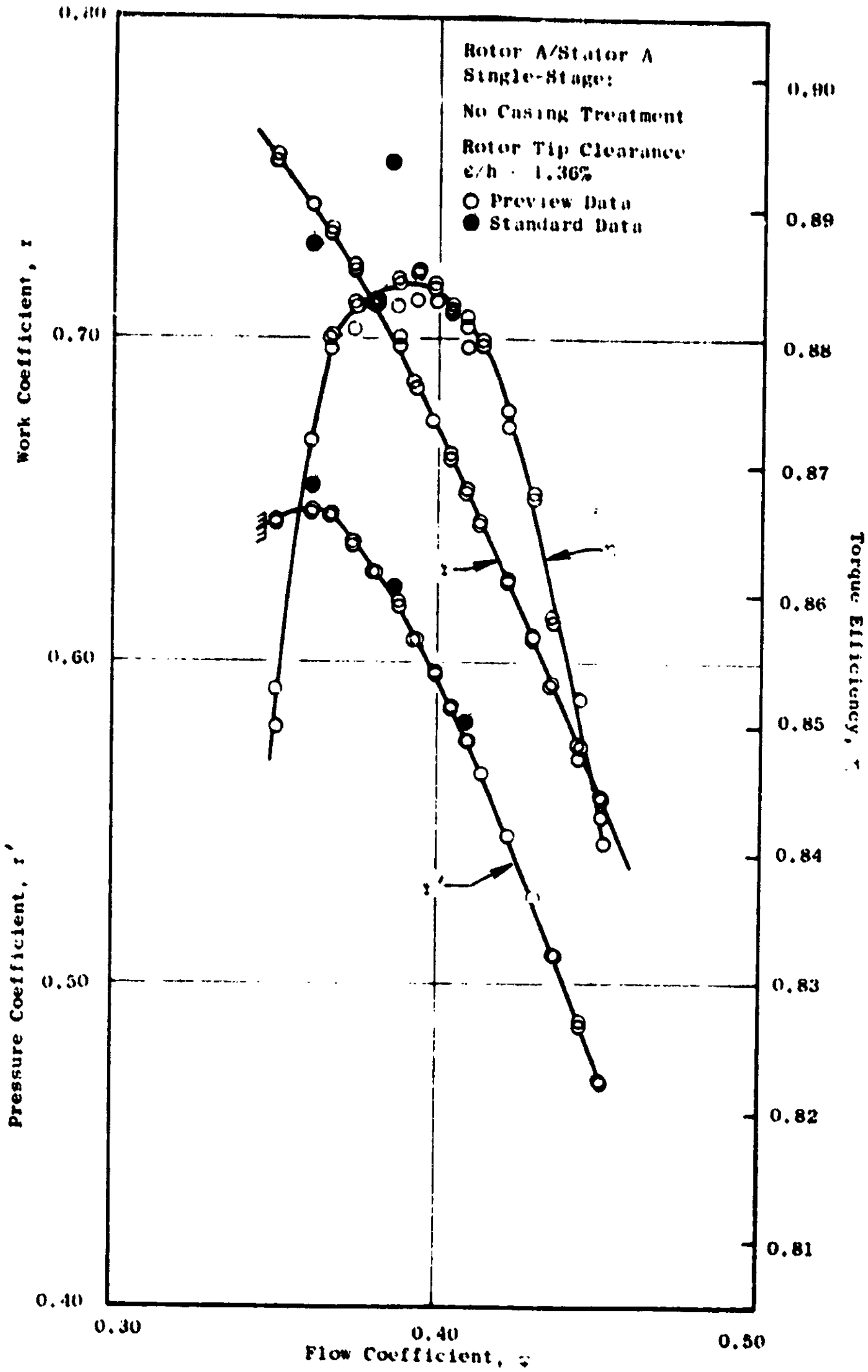


Figure 12. Overall Performance of the Single-Stage Rotor A/Stator A Configuration.

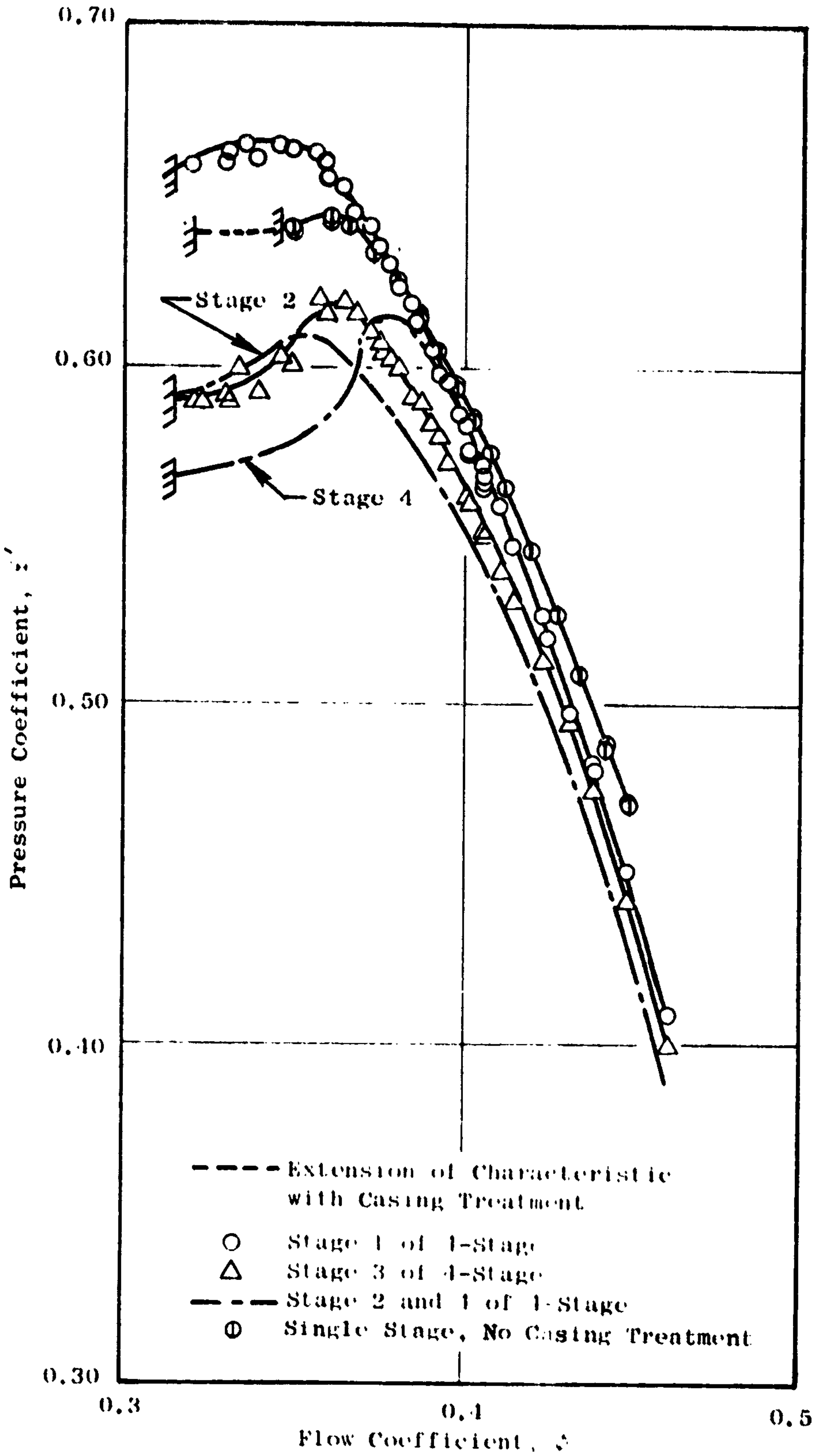


Figure 13. Comparison of Individual Stage Characteristics for the Single-Stage and Four Stage Configurations, Rotor A Running with Stator A.

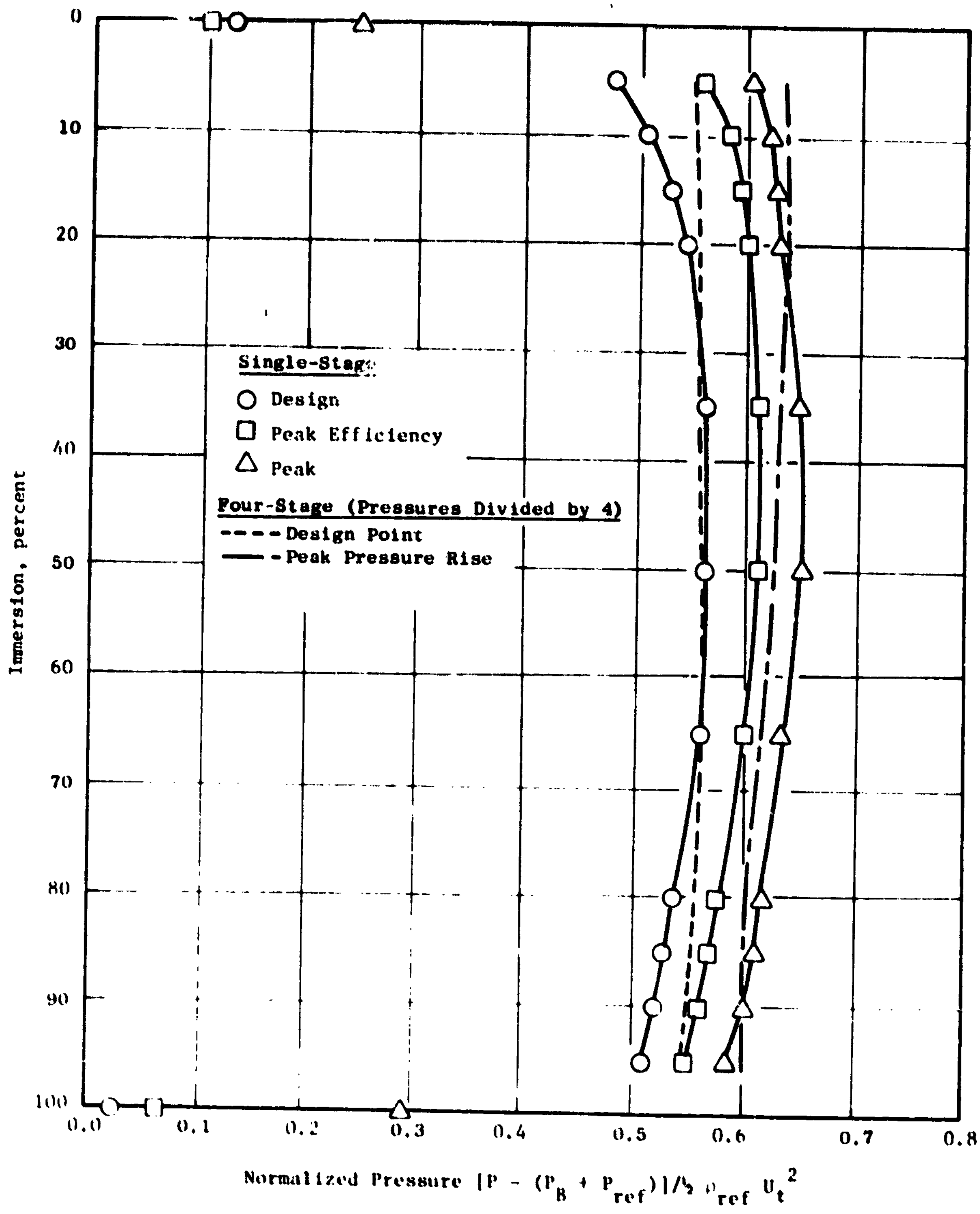


Figure 14. Radial Variation of Normalized Total Pressure Including Casing and Hub Normalized Static Pressures at the Casing Discharge for Various Throttle Settings.

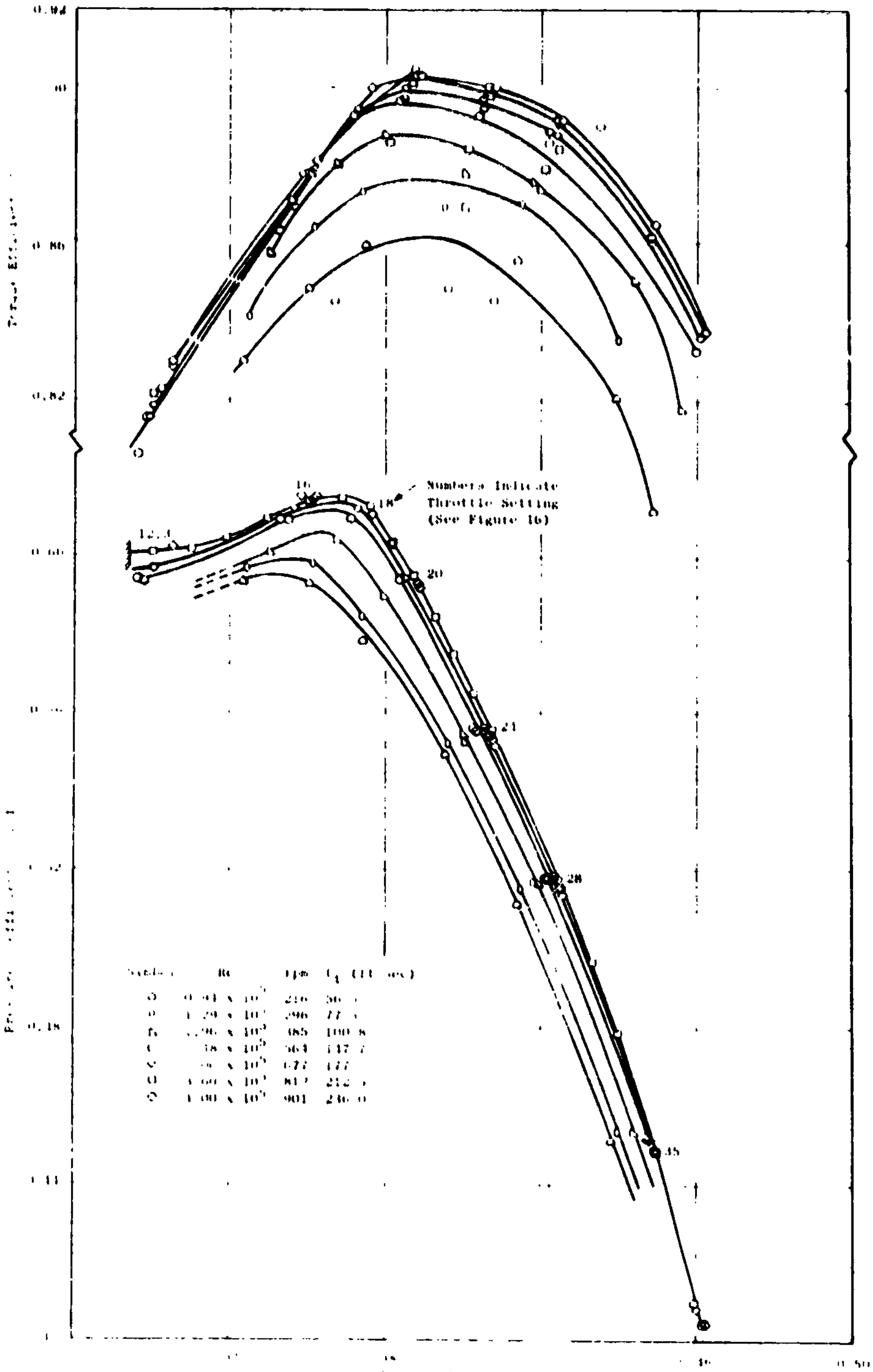


Figure 1o. Variation of the Perform e of Rotor A/Stator A with Reynolds Number, Fo Stage Configuration.

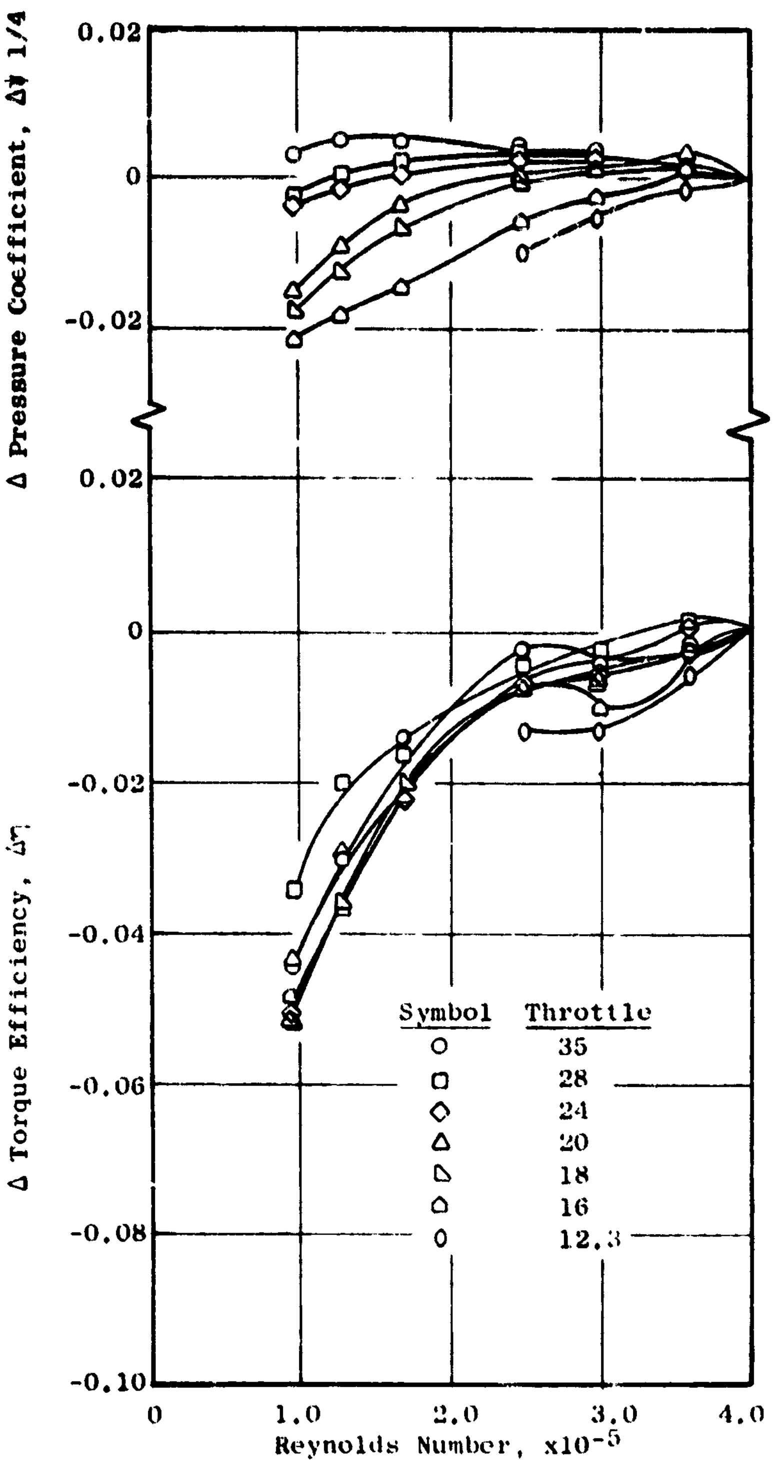


Figure 16. Variation of the Performance of Rotor A/Stator A with Reynolds Number, Four-Stage Configuration.

ORIGINAL PAGE IS
OF POOR QUALITY

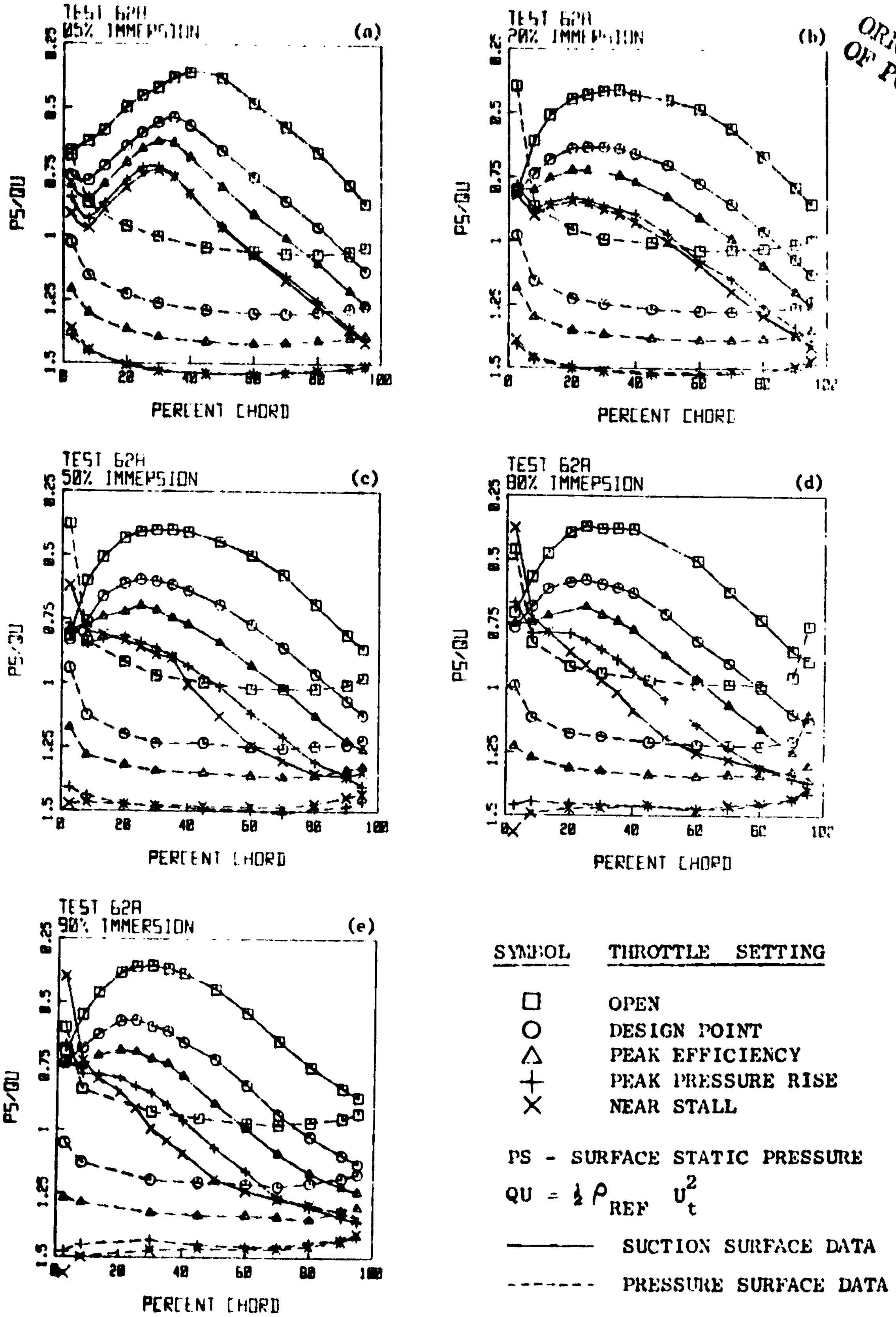


Figure [illegible]. Rotor Blade Surface Static Pressure Measurements for the Four-Stage Rotor A/Stator A Configuration, Third Stage Tested.

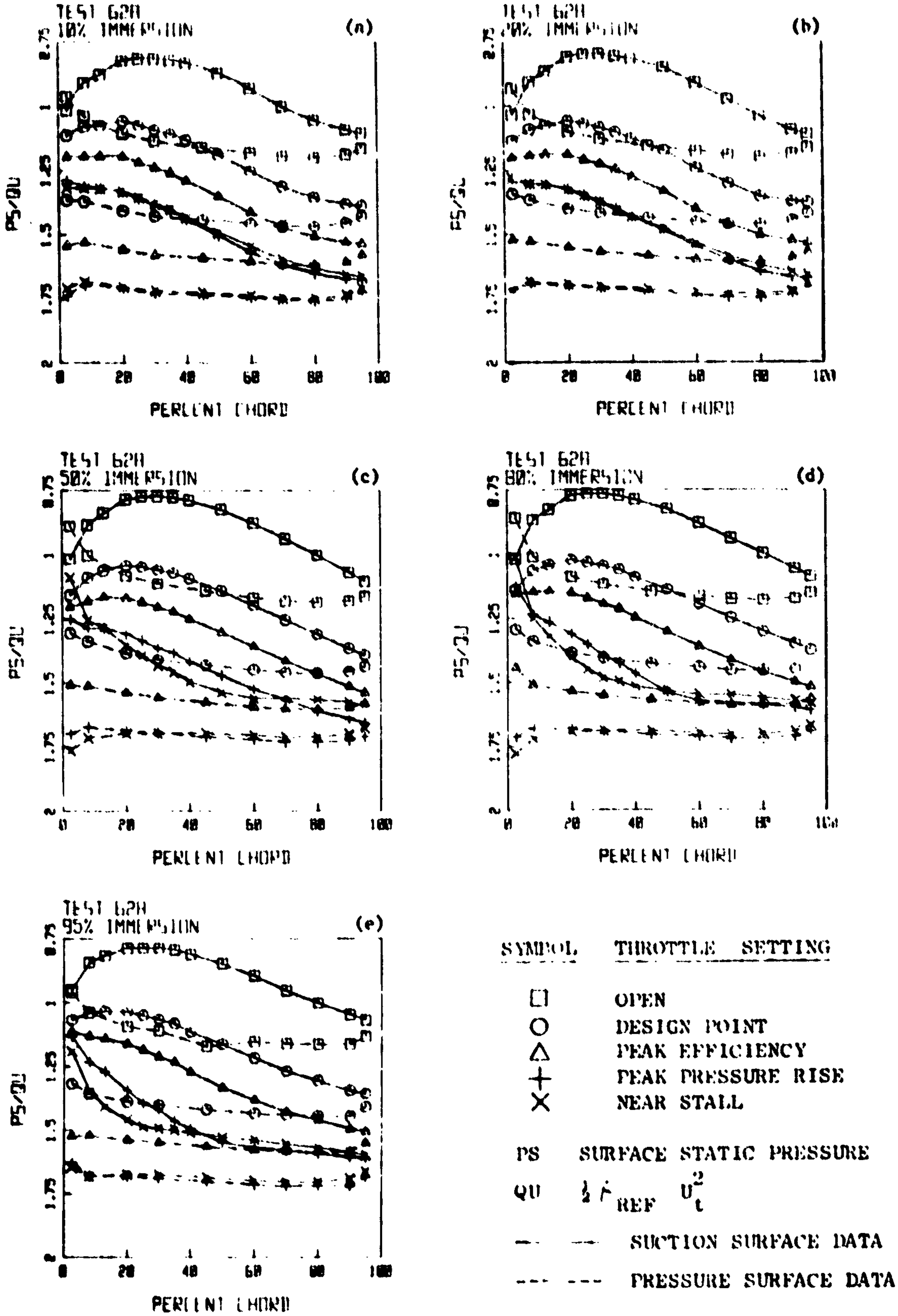


Figure 18. Stator Vane Surface Static Pressure Measurements for the Four-Stage Rotor A/Stator A Configuration, Third Stage Tested.

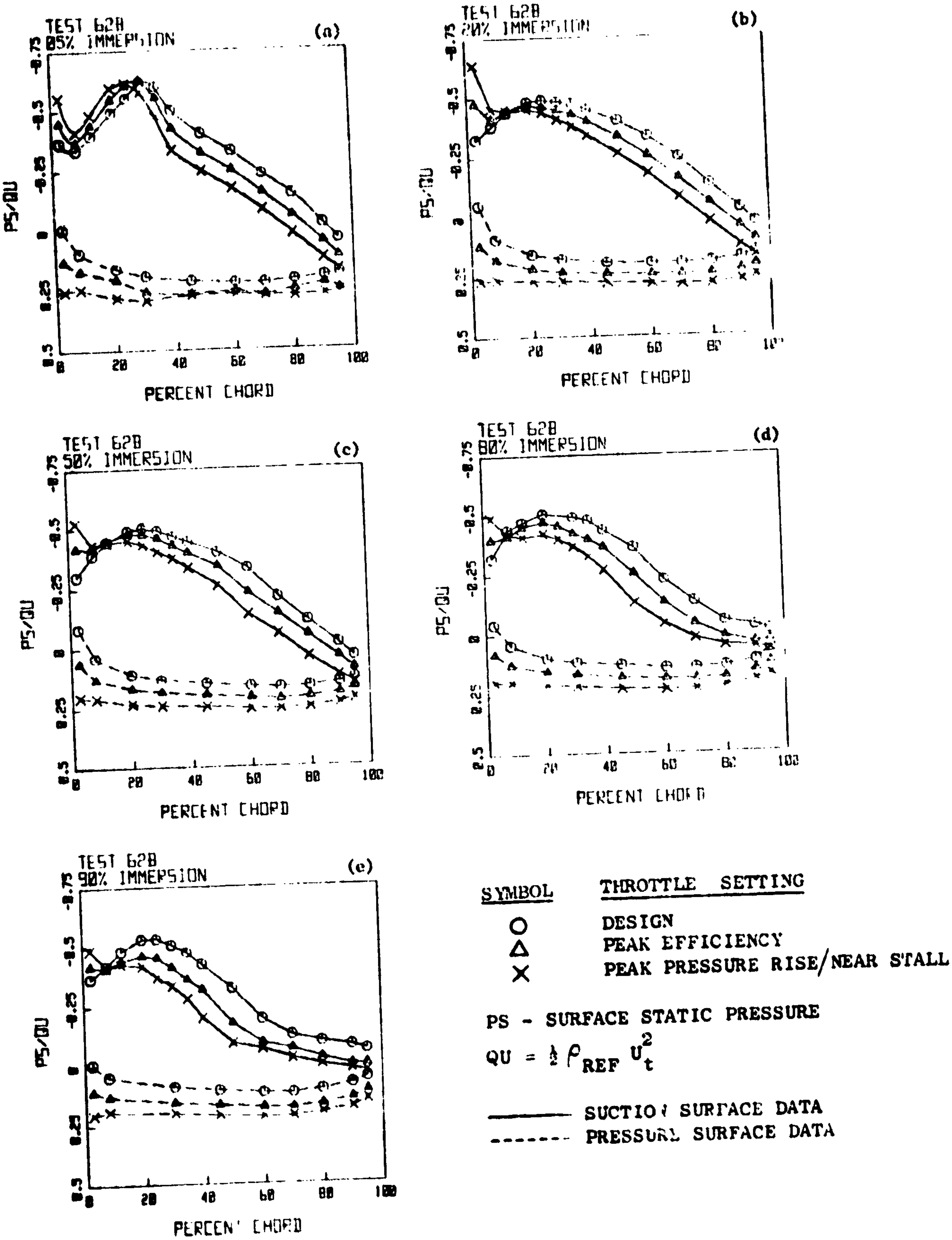


Figure 19. Rotor Blade Surface Static Pressure Measurements for the Single-Stage Rotor A/Stator A Configuration.

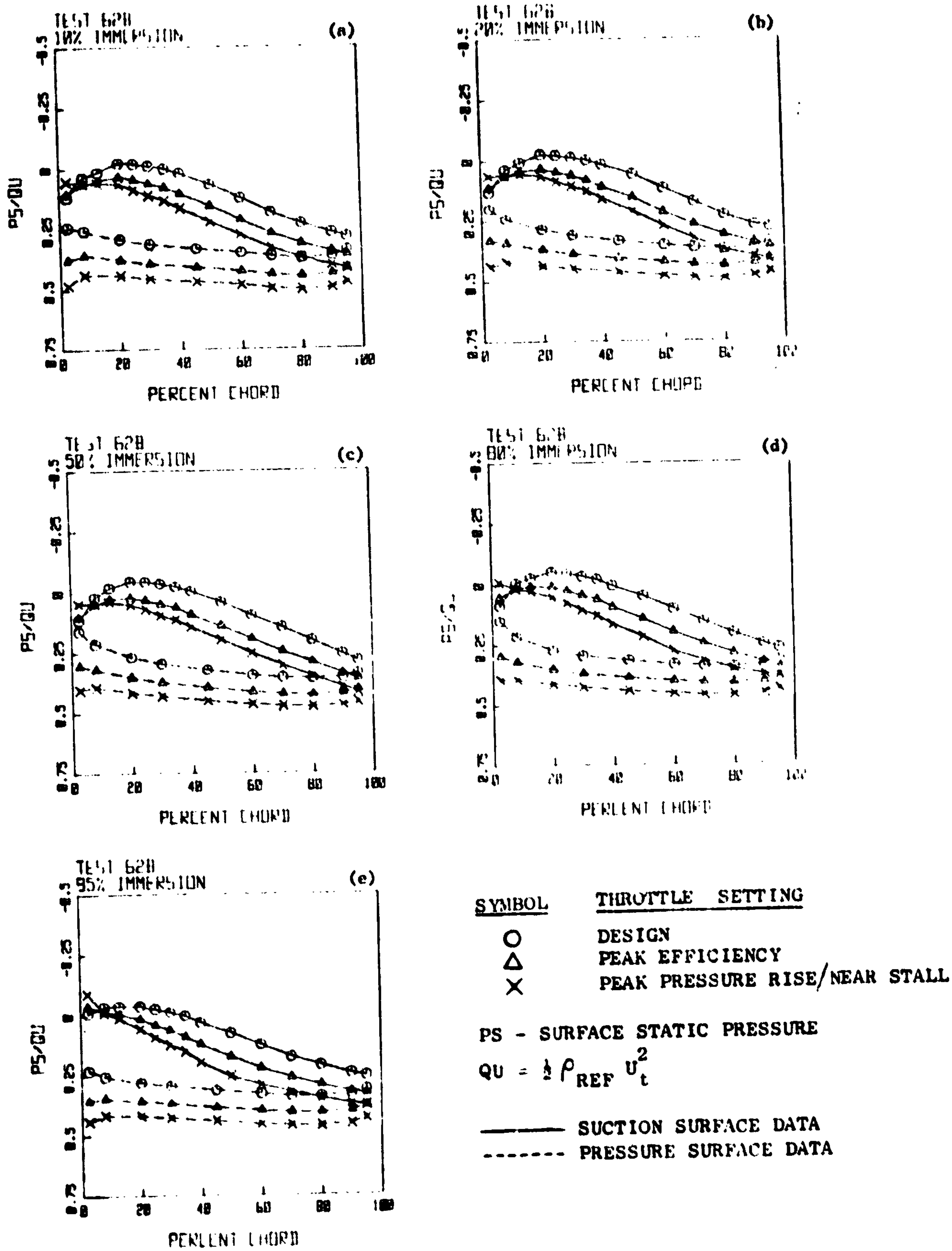


Figure 20. Stator Vane Surface Static Pressure Measurements for the Single-Stage Rotor A/Stator A Configuration.

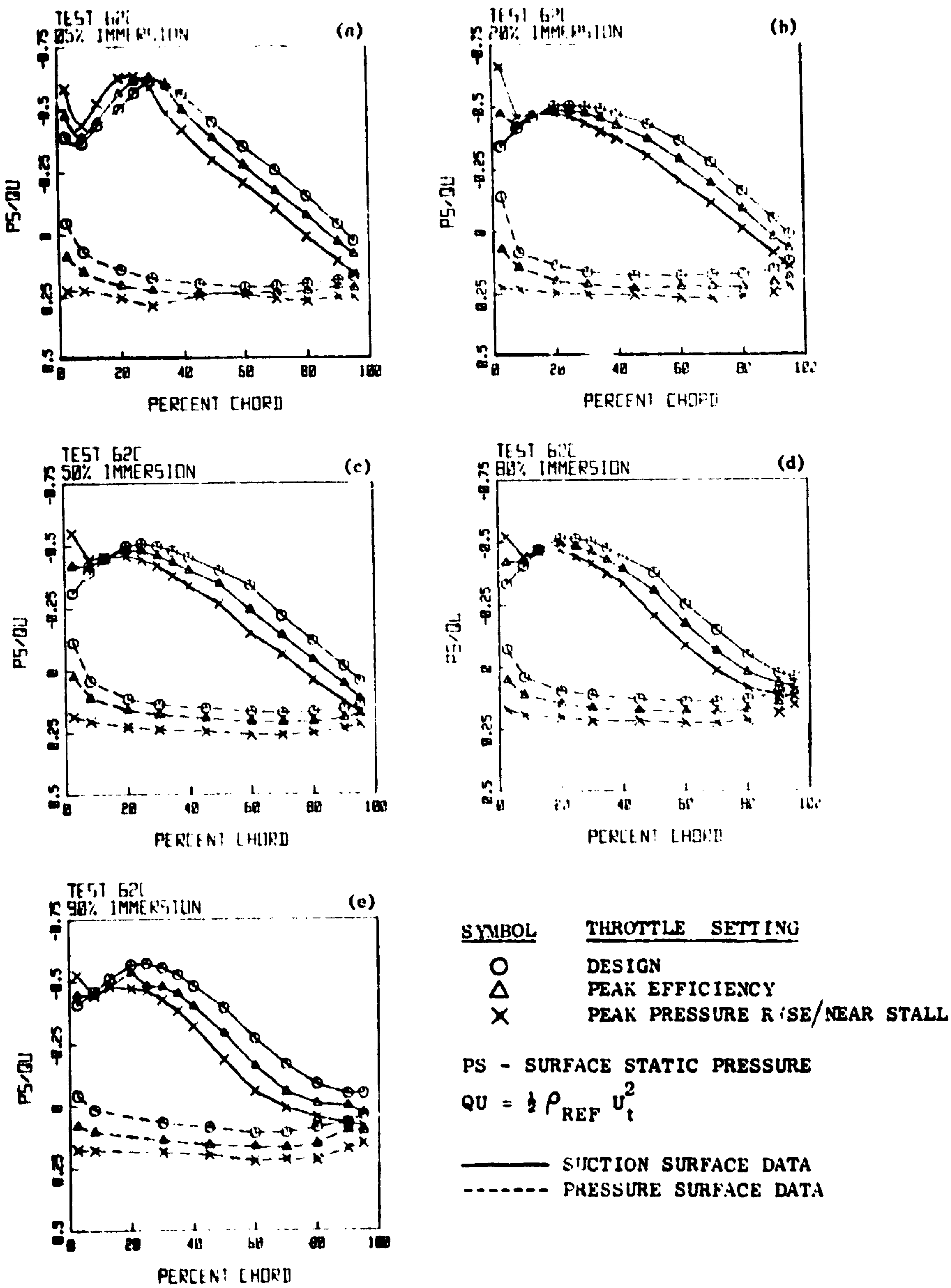


Figure 21. Rotor Blade Surface Static Pressure Measurements for the Four-Stage Rotor A/Stator A Configuration, First Stage Tested.

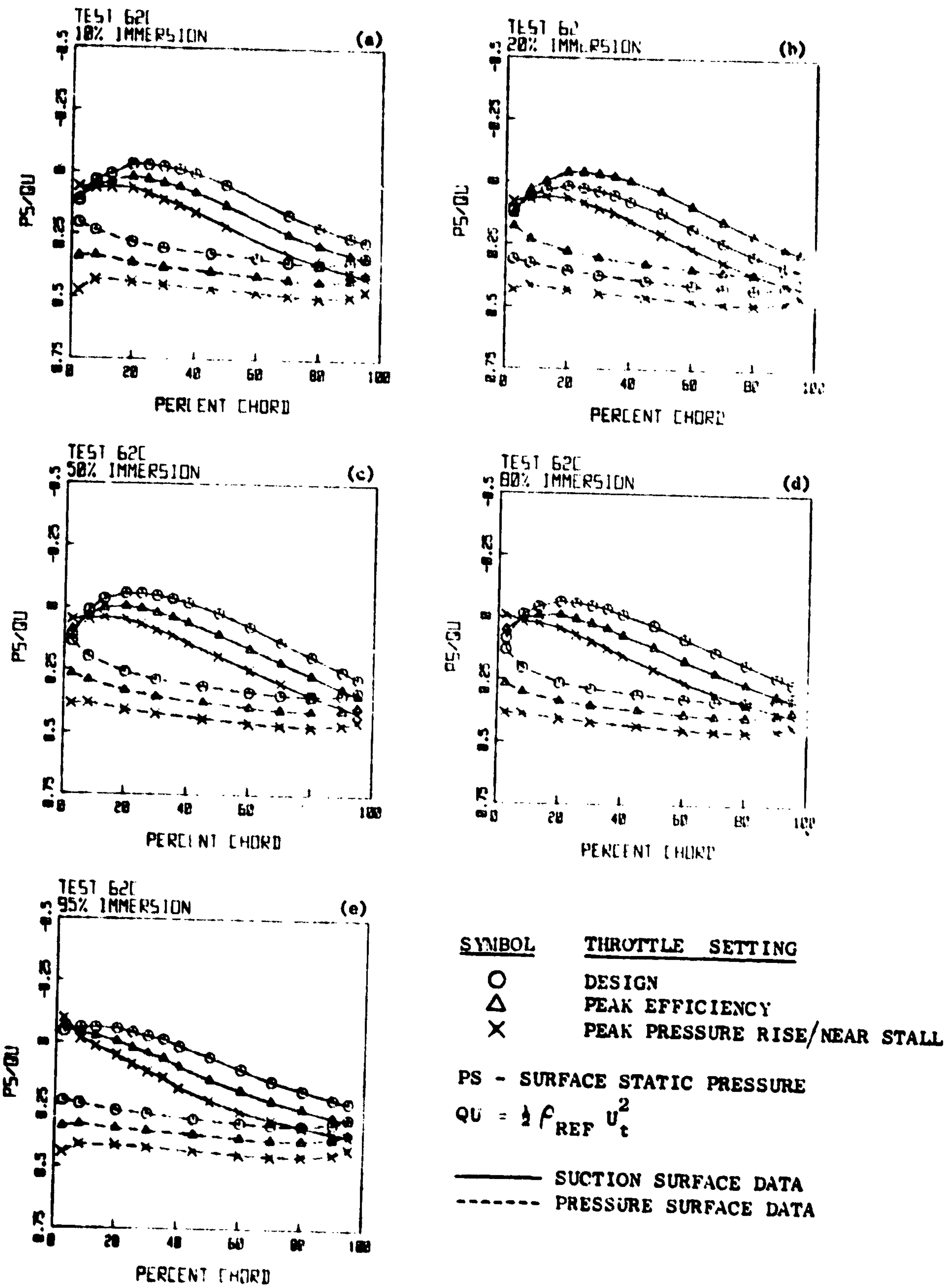


Figure 22. Stator Vane Surface Static Pressure Measurements for the Four-Stage Rotor A/Stator A Configuration, First Stage Tested.

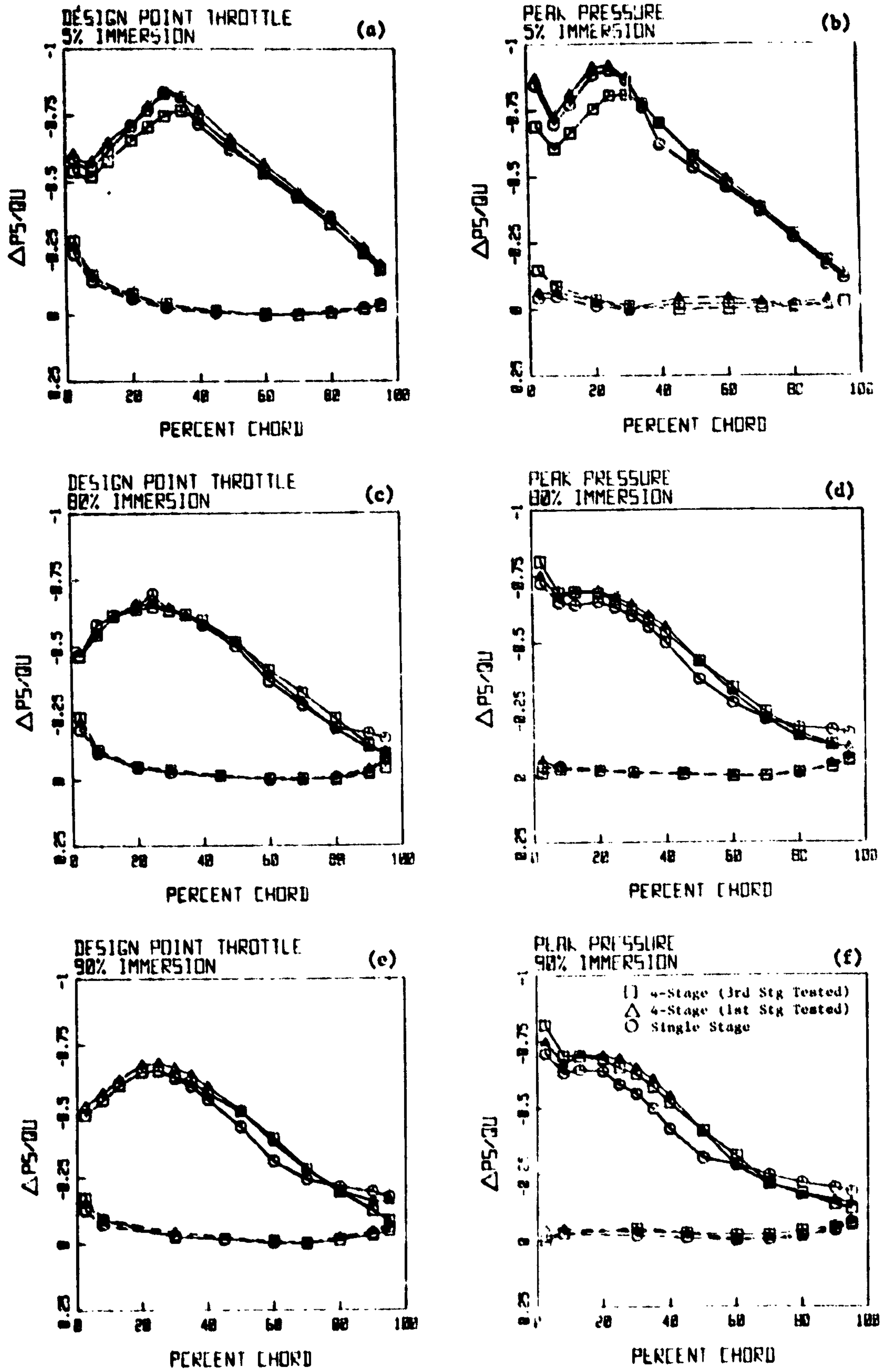


Figure 23. Comparison of Blade Surface Static Pressure Measurements for the Four-Stage Configuration (1st and 3rd Stages Tested) and the Single-Stage Configuration.

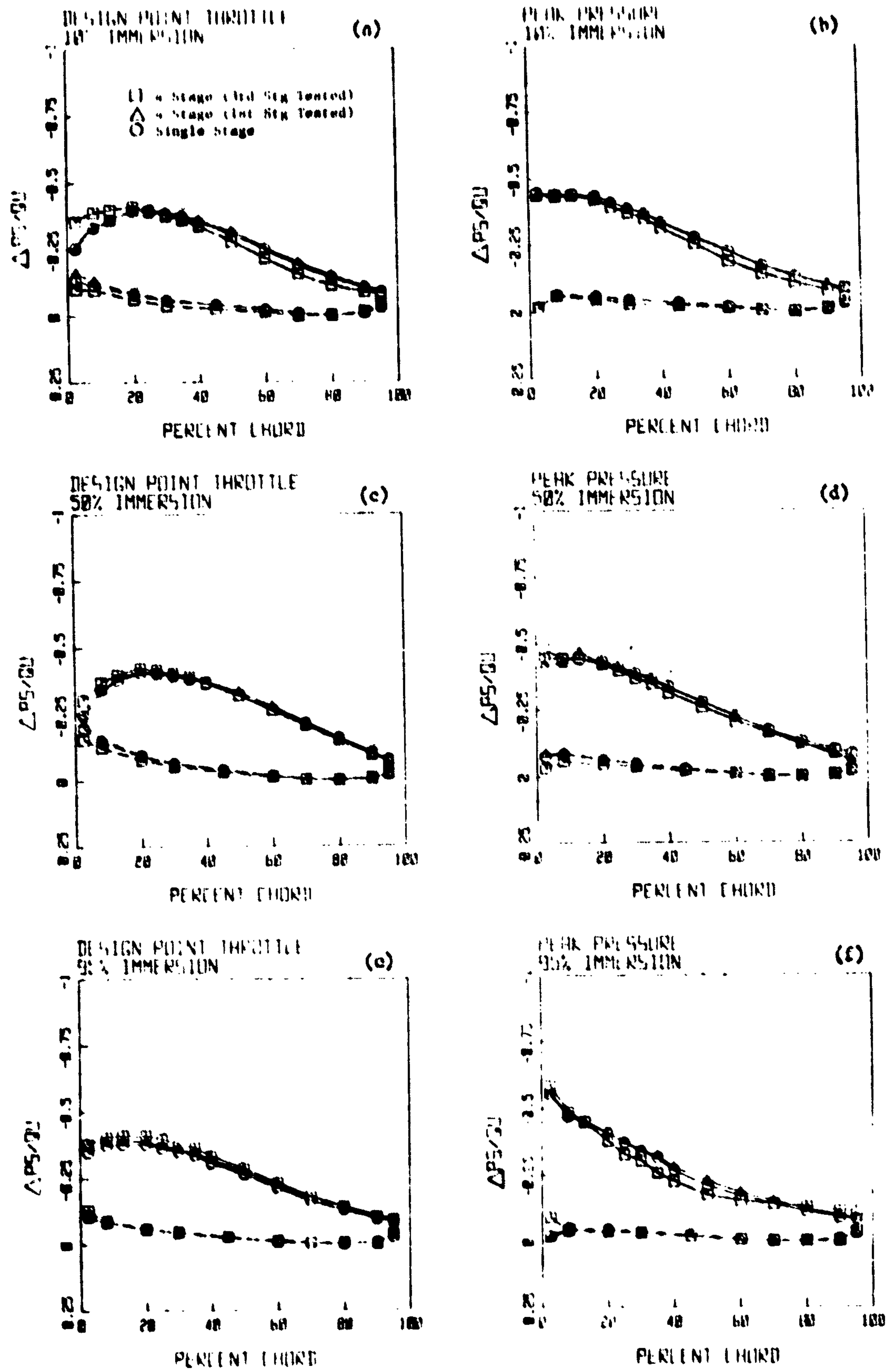


Figure 24. Comparison of Vane Surface Static Pressure Measurements for the Four-Stage Configuration (1st and 3rd Stages Tested) and the Single-Stage Configuration.

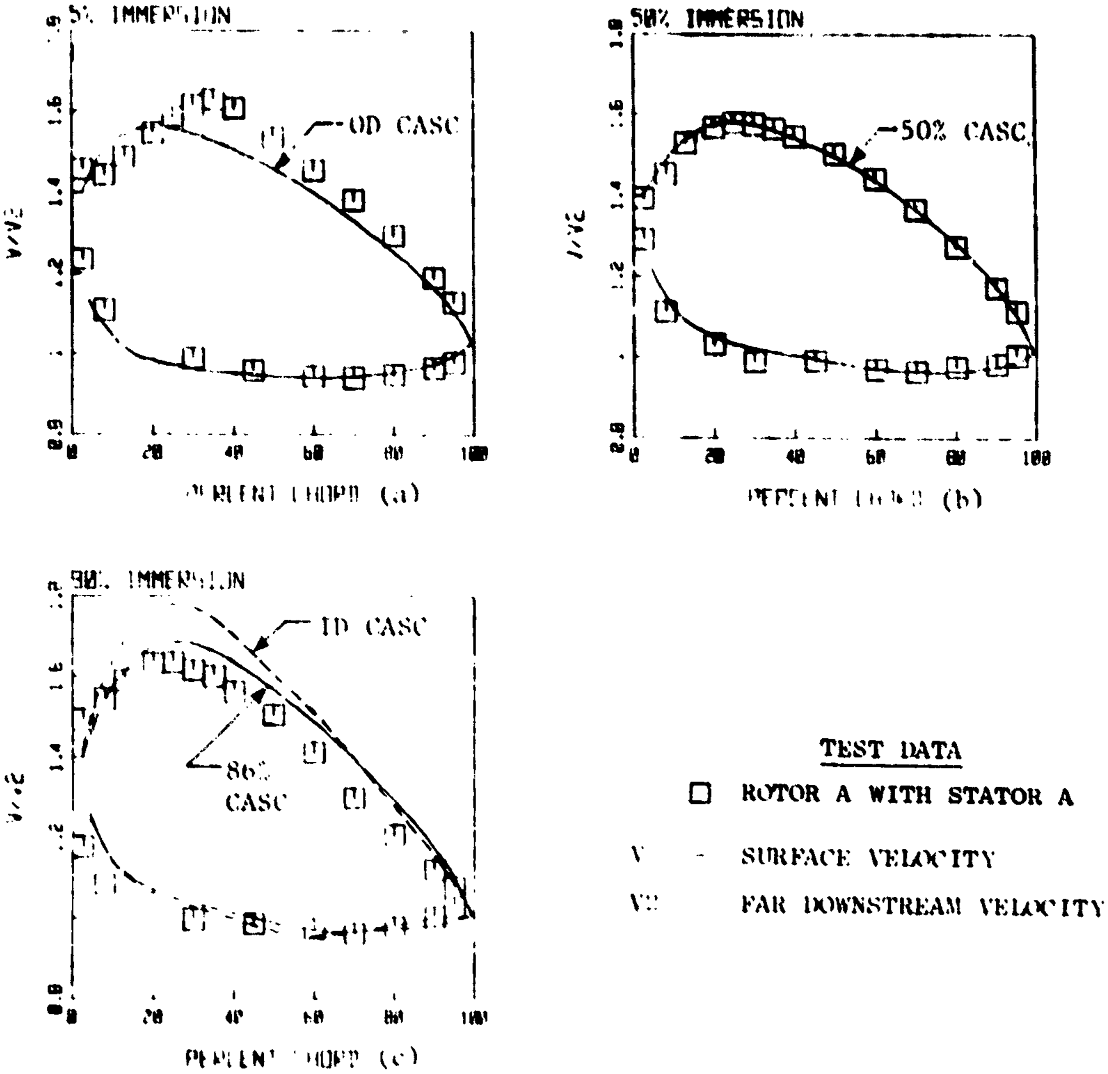


Figure 25. Blade Surface Velocity Distributions for Rotor A Operating Near Design Point - Measurements Compared with Potential Flow CASC Solutions.

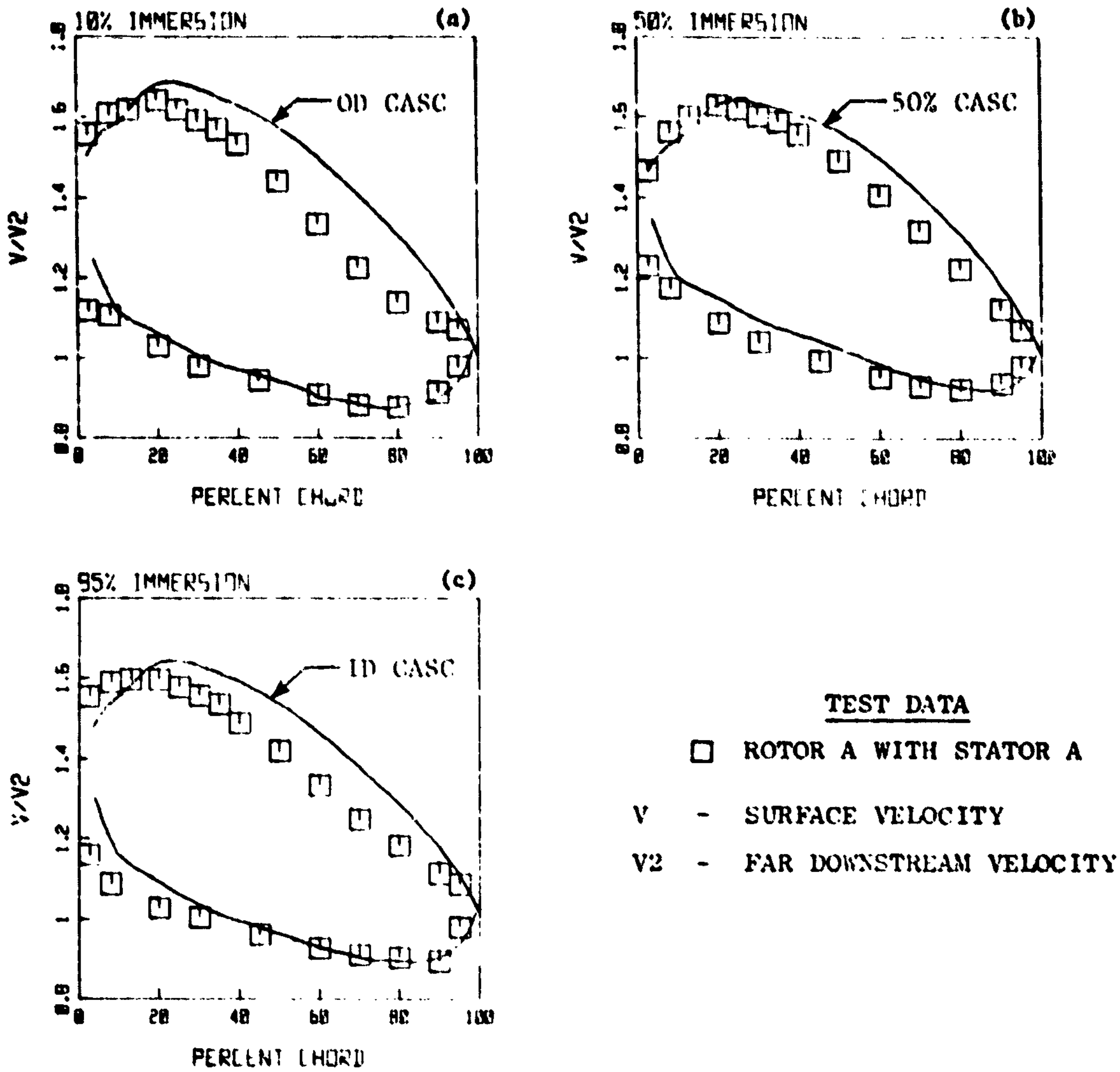


Figure 26. Vane Surface Velocity Distributions for Stator A Operating Near the Design Point - Measurements Compared with Potential Flow CASC Solutions.

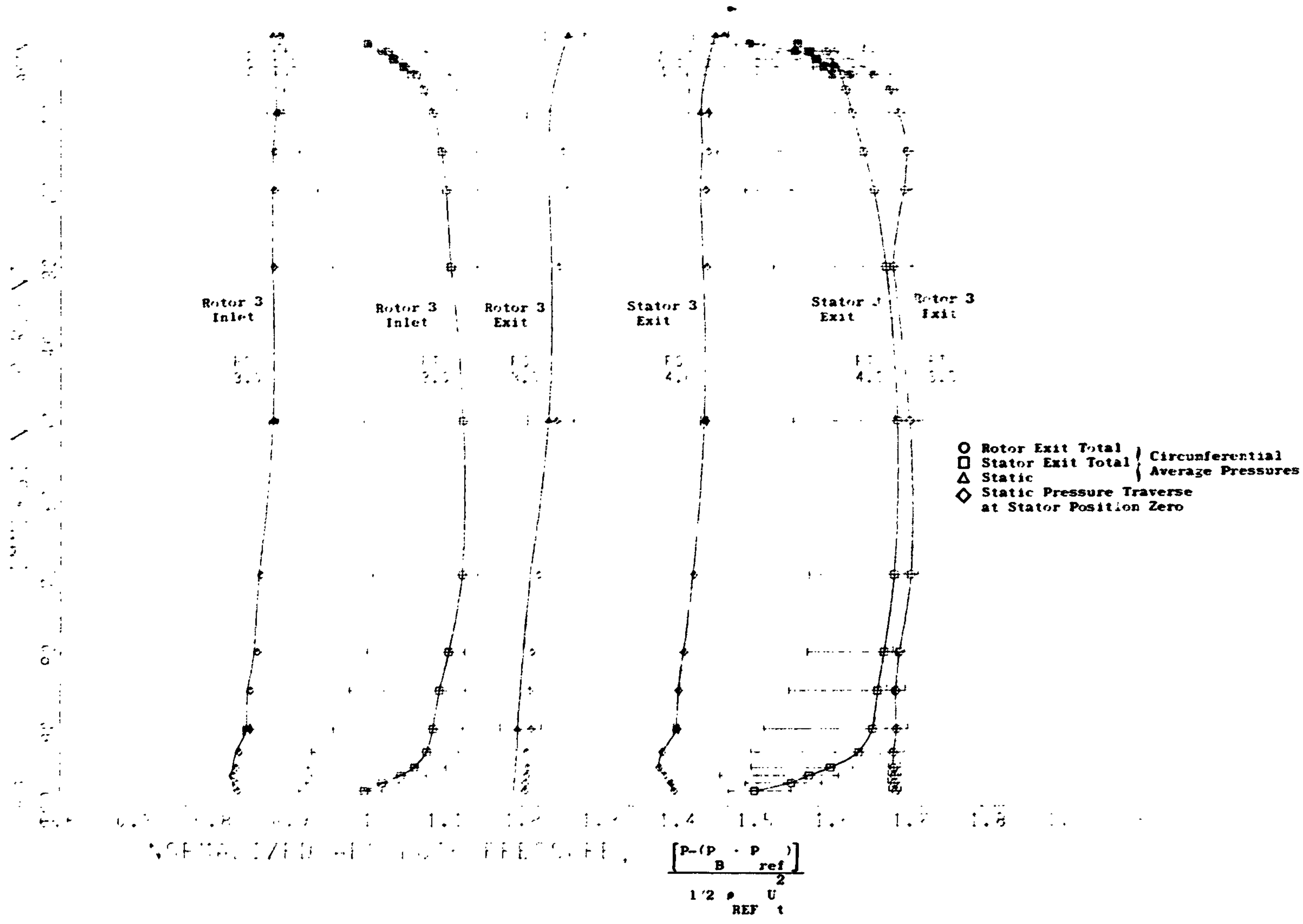


Figure 27. Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Design Point Throttle.

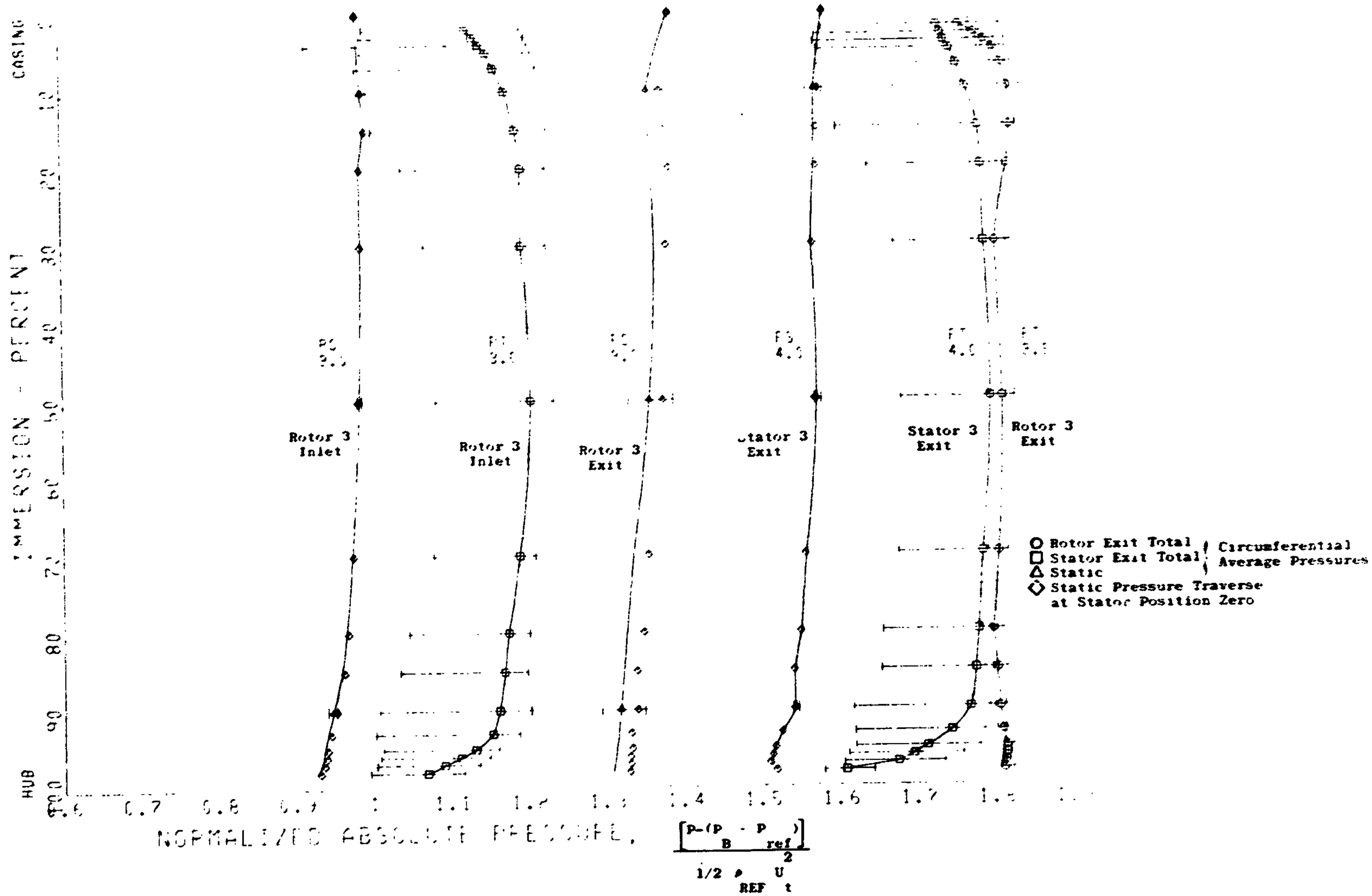
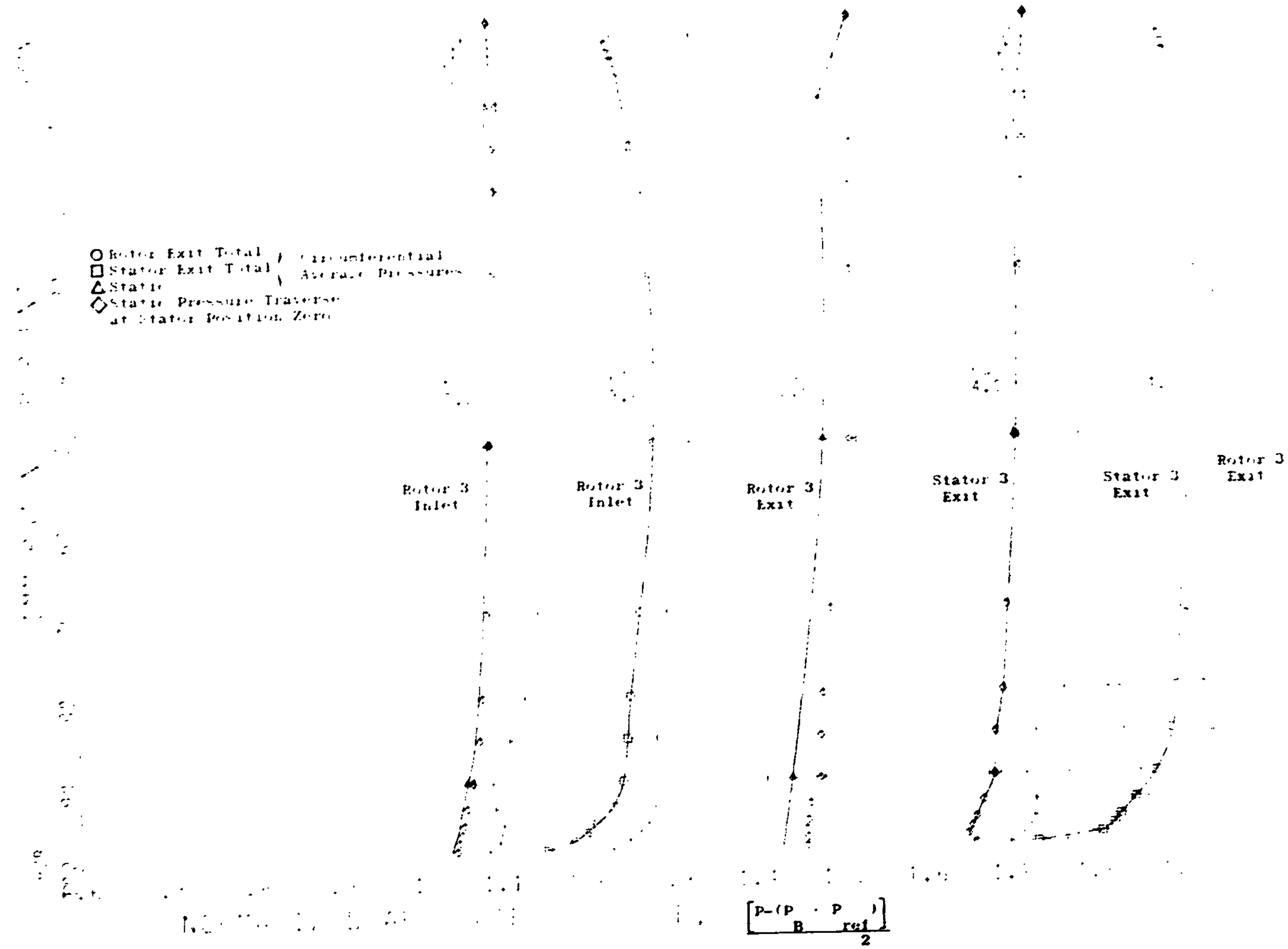


Figure 28. Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Peak Efficiency Throttle.



$$\frac{\left[P-(P_B - P_{ref})\right]}{1/2\ \rho_{REF}\ U_t^2}$$

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

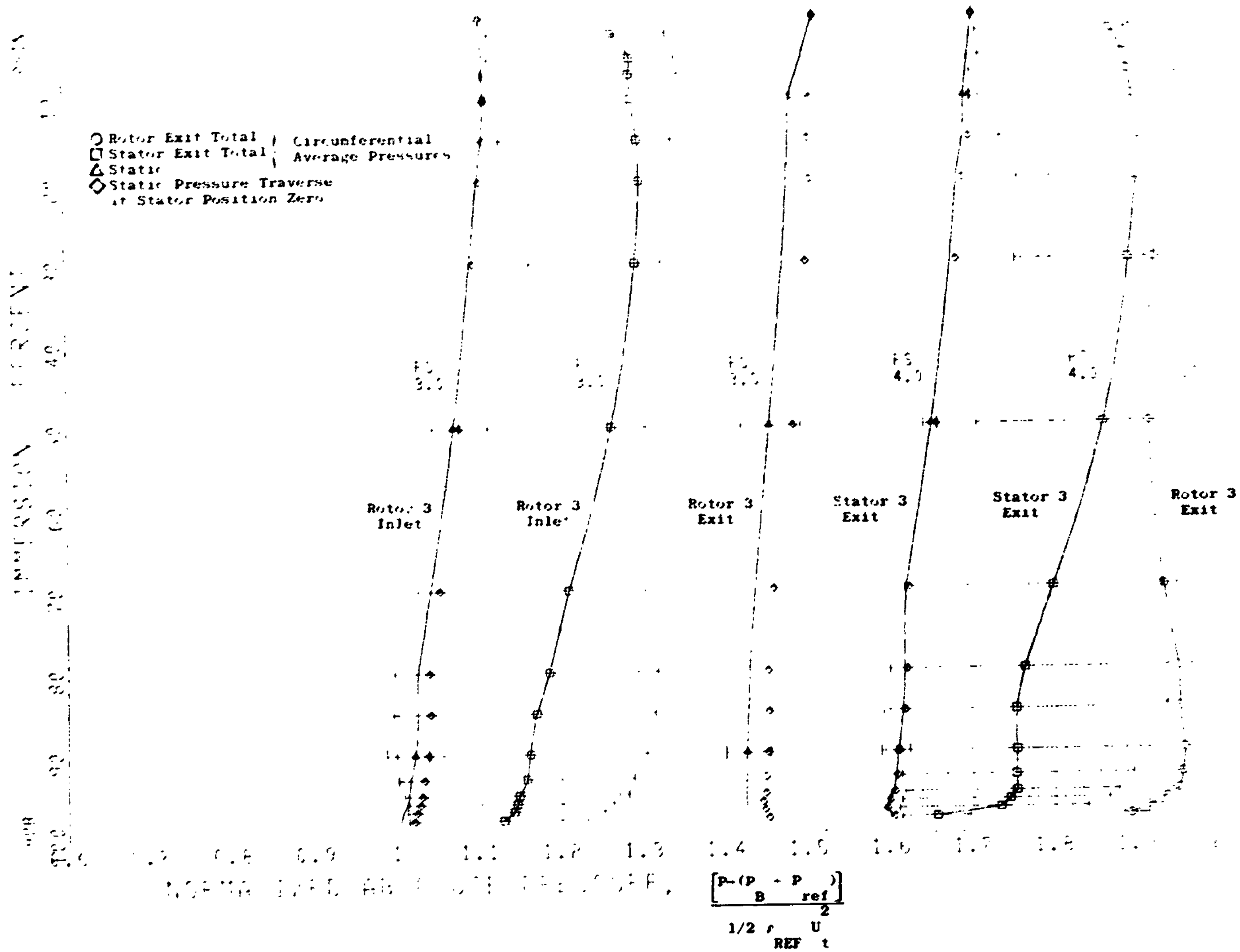


Figure 30. Normalized Absolute Total Pressures and Static Pressures for Rotor A/ Stator A Four-Stage Configuration, Third Stage Tested, Near Stall Throttle.

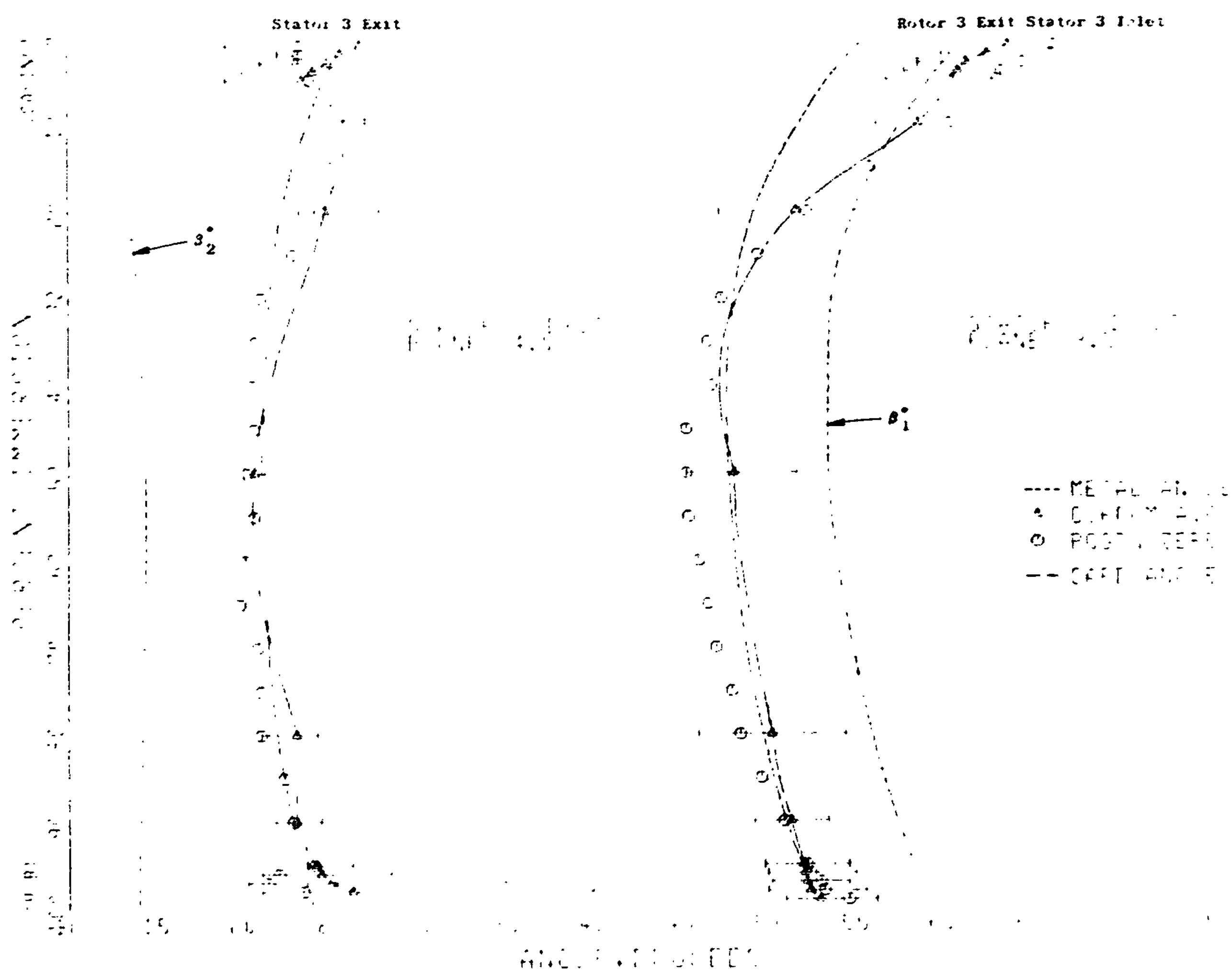


Figure 31. Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Design Point Throttle.

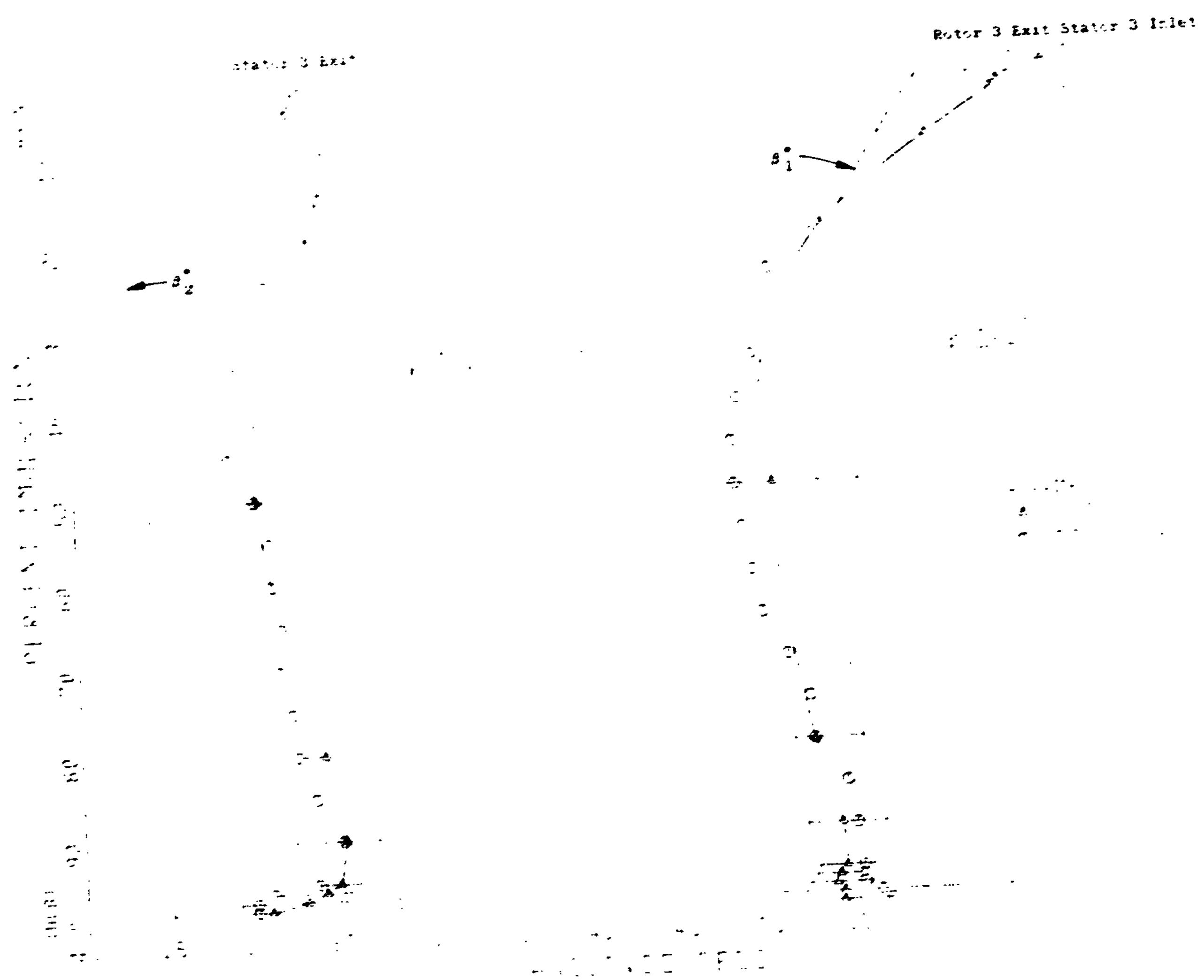


Figure 32. Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Peak Efficiency Throttle.

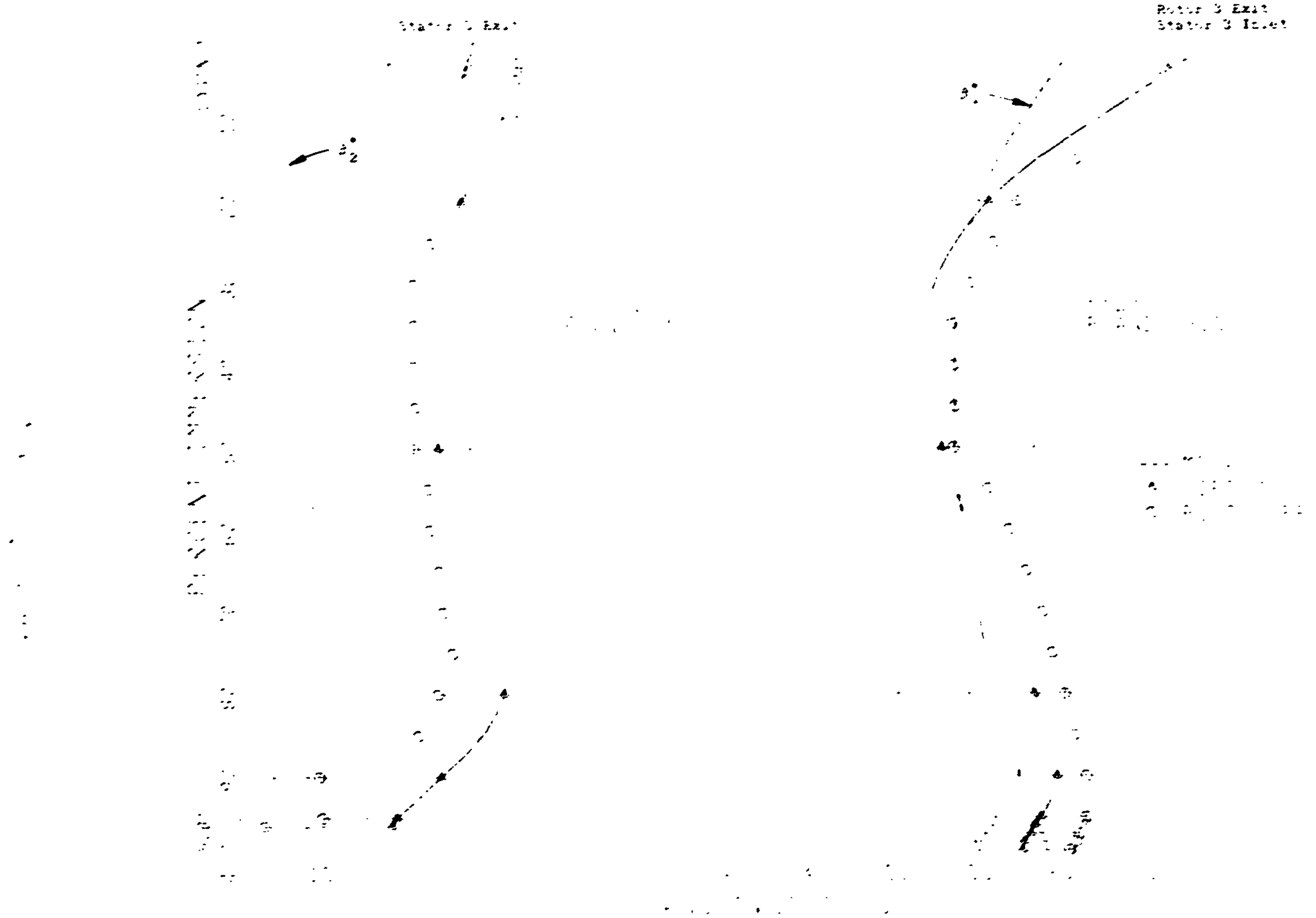


Figure 33. Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise Throttle.

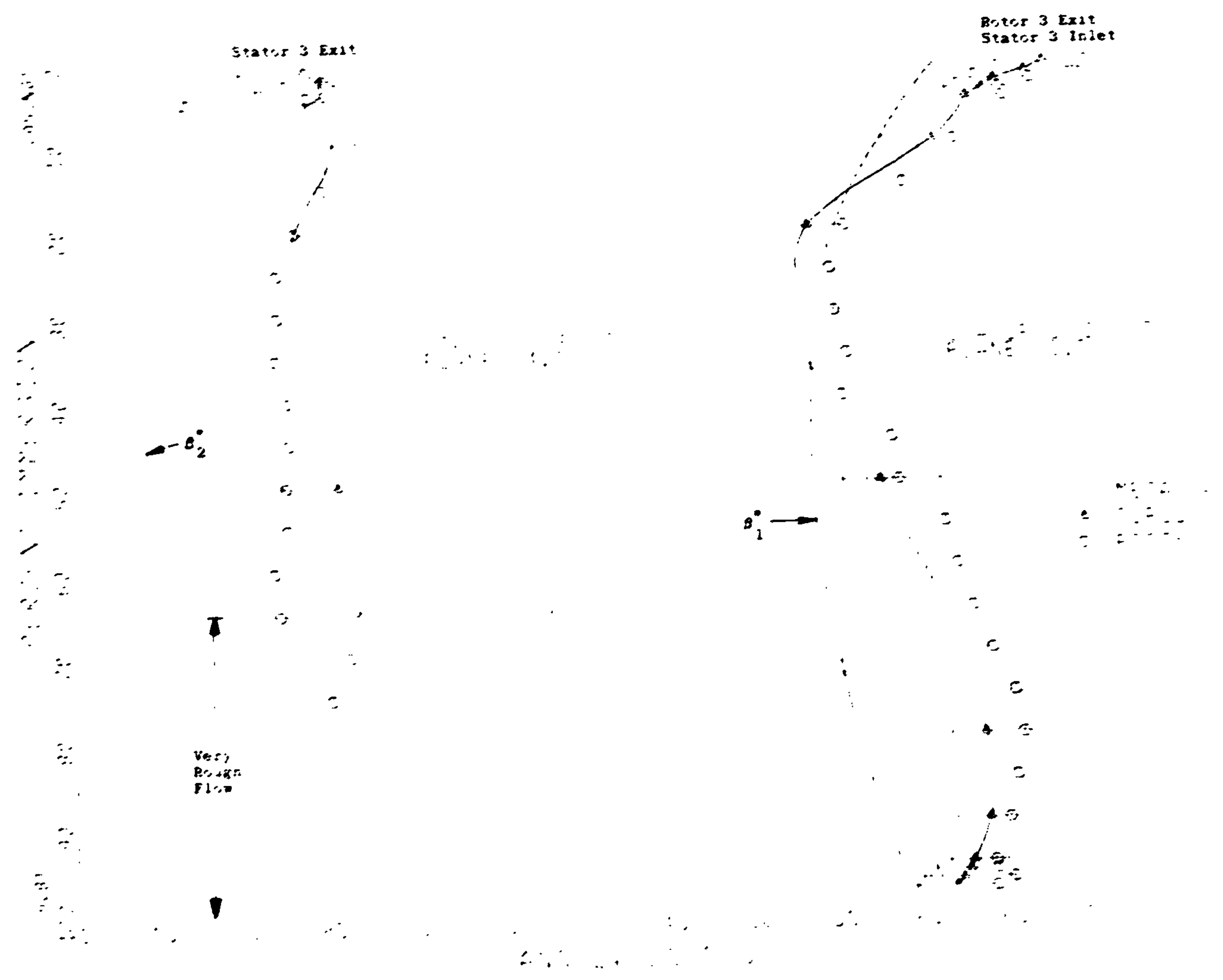


Figure 34. Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Near Stall Throttle.

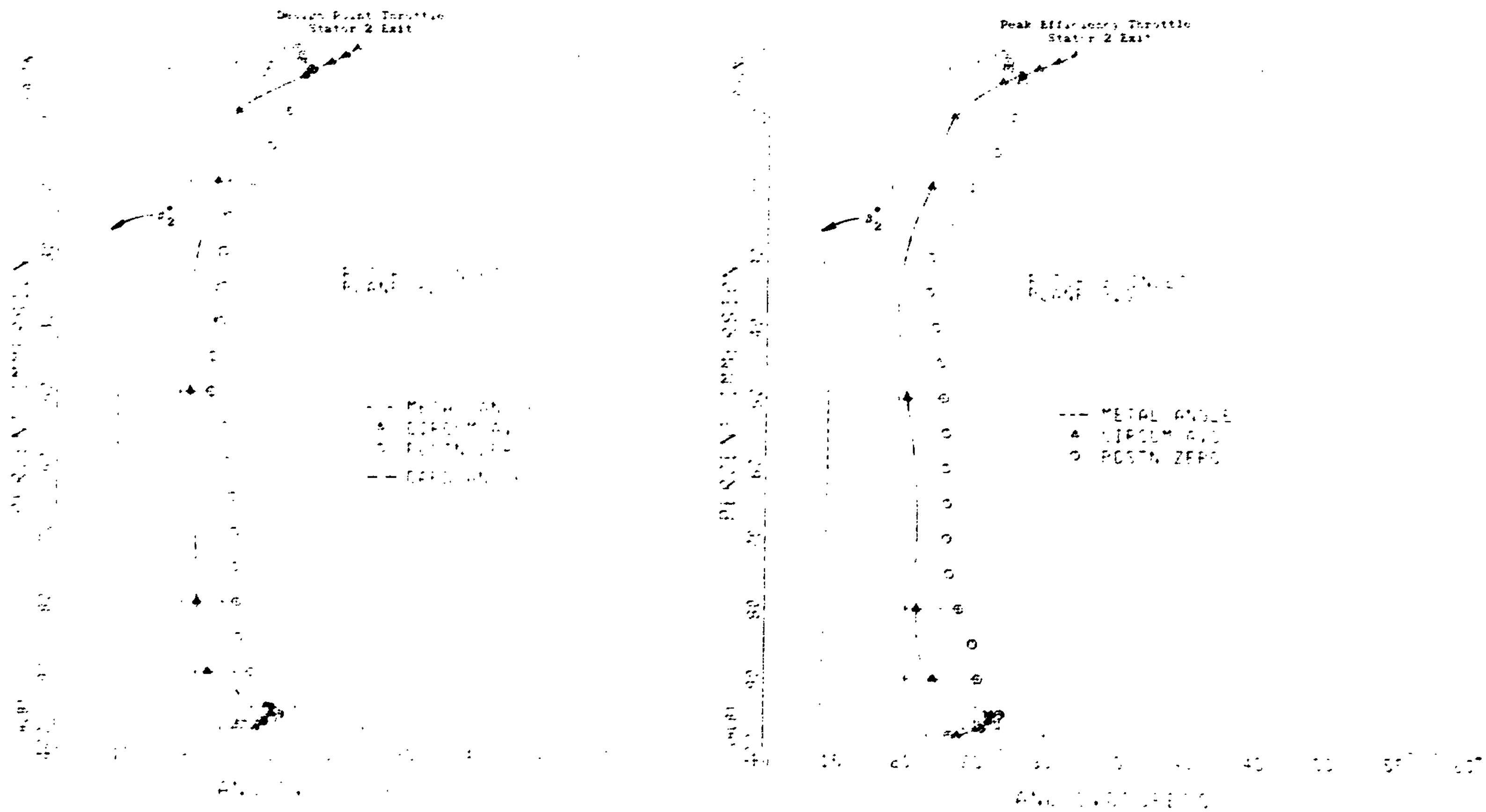


Figure 35. Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.

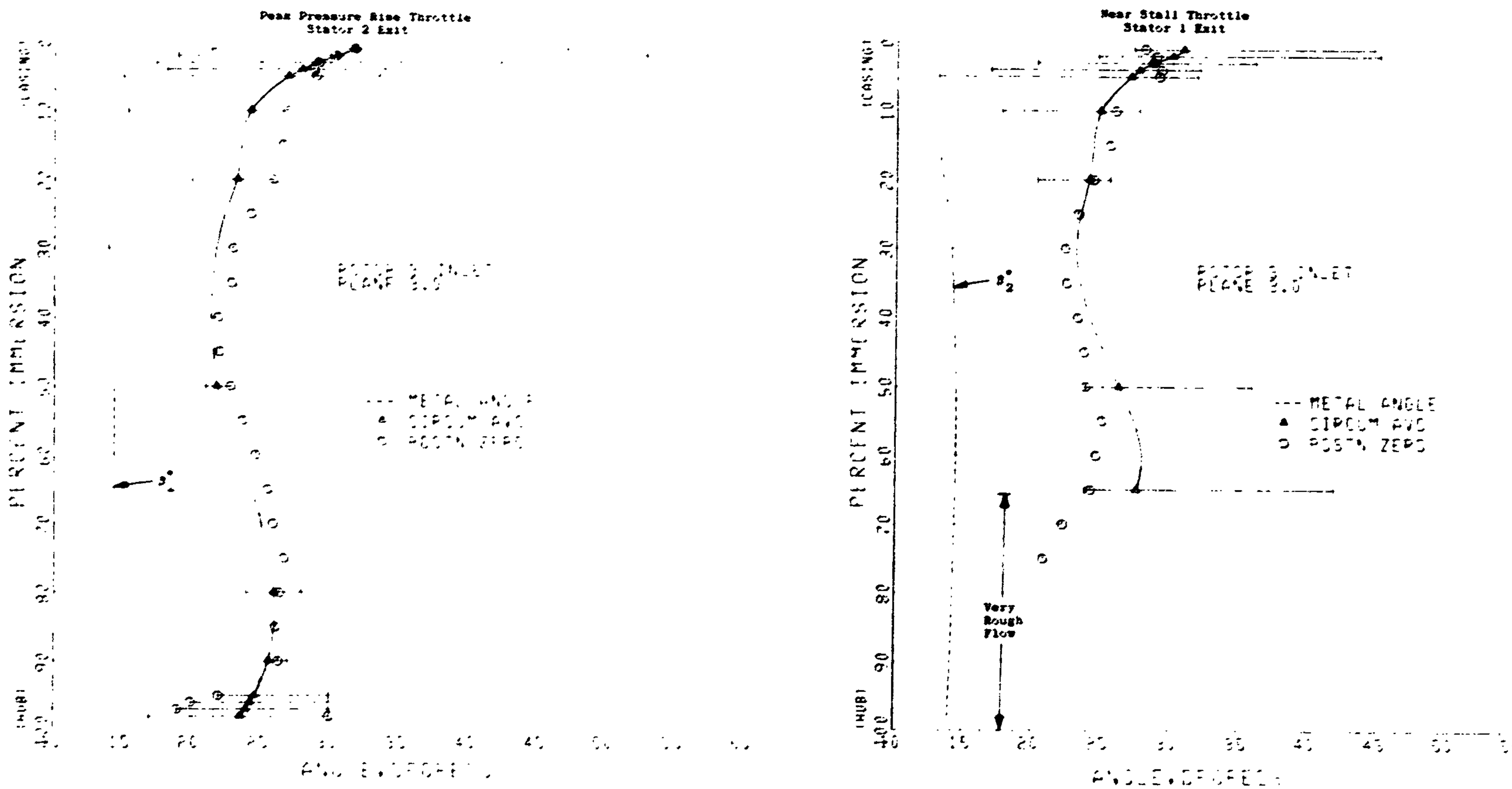


Figure 36. Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.

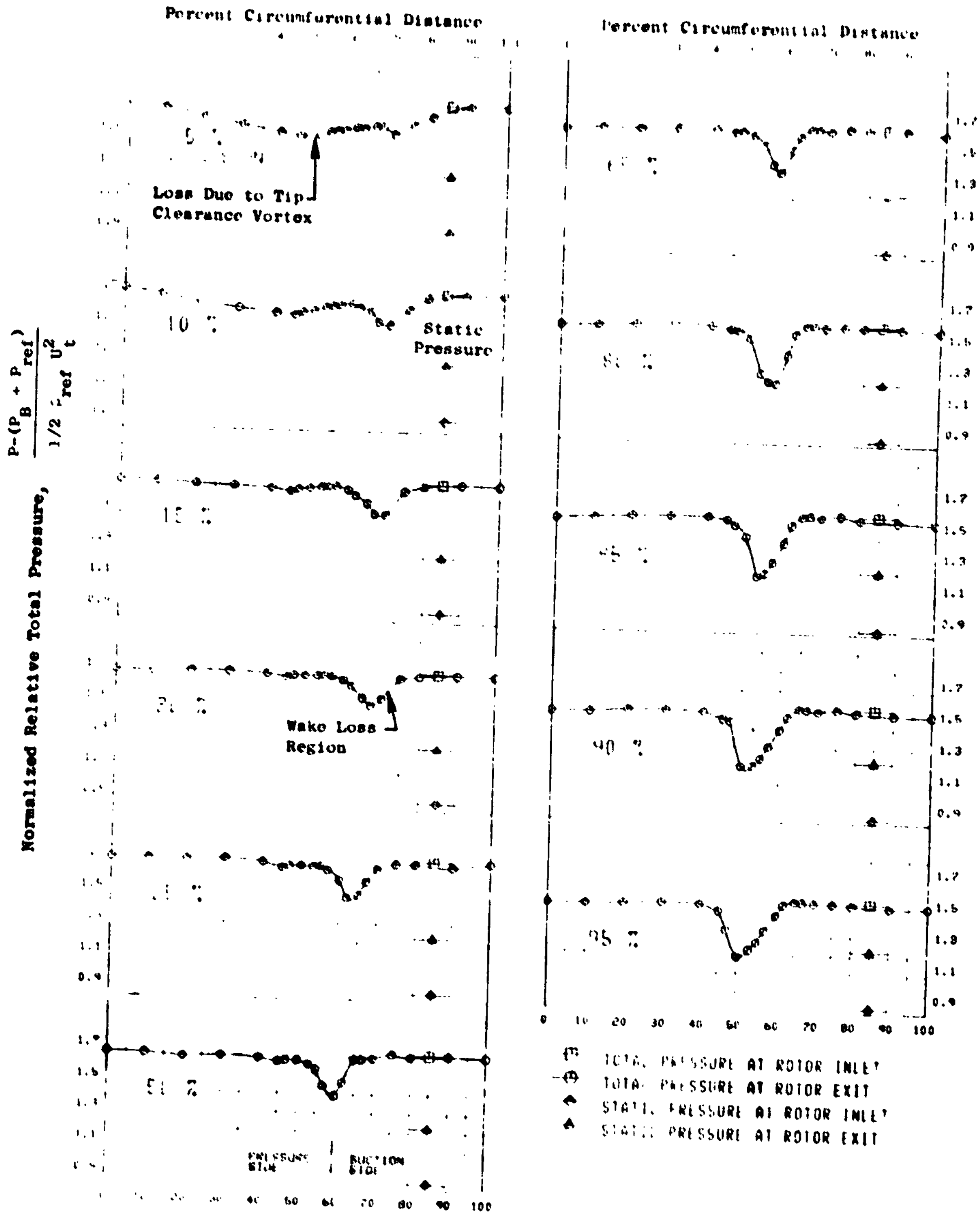


Figure 37. Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, Third Stage Tested, Design Point Throttle.

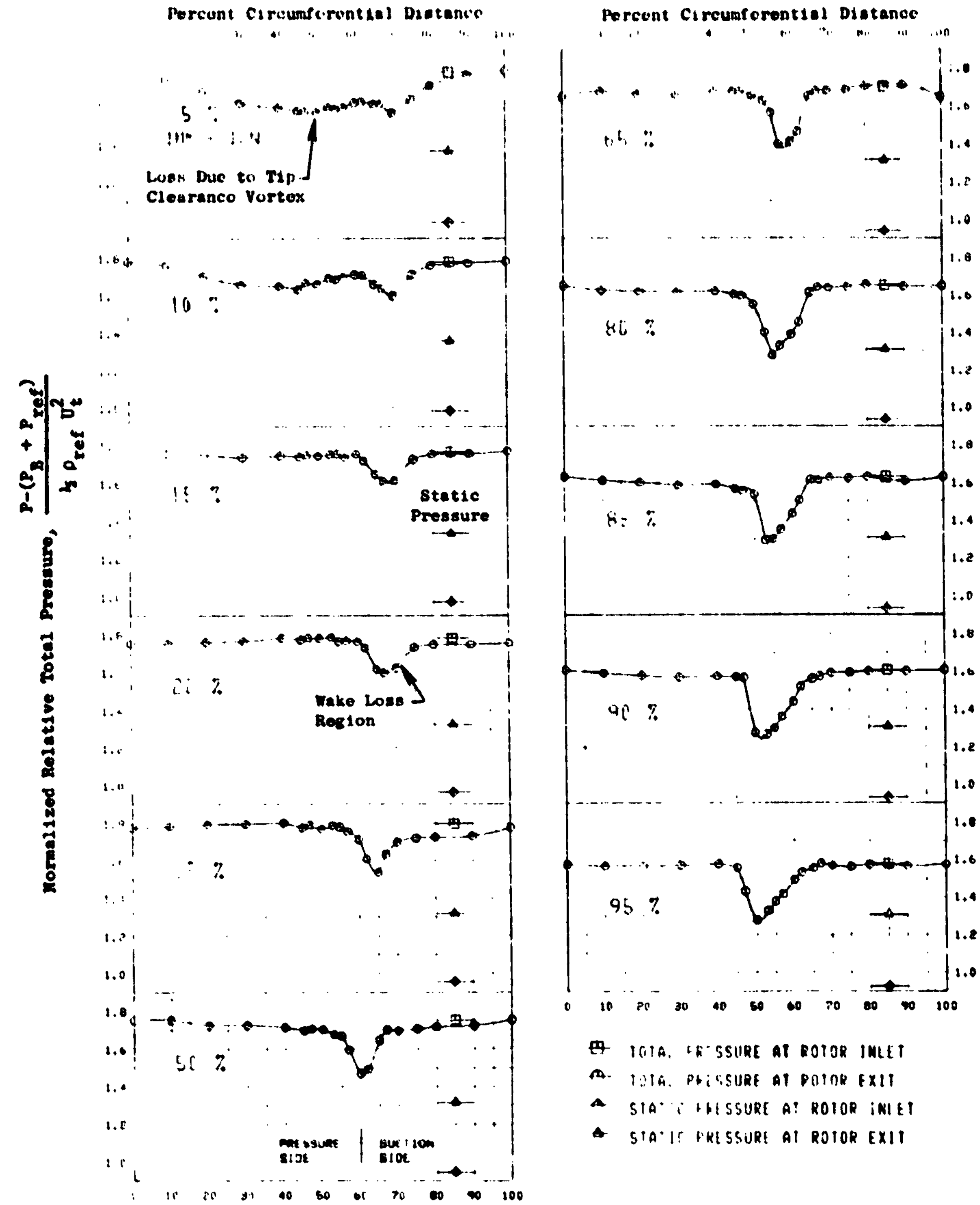


Figure 38. Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, Third Stage Tested, Peak Efficiency Throttle.

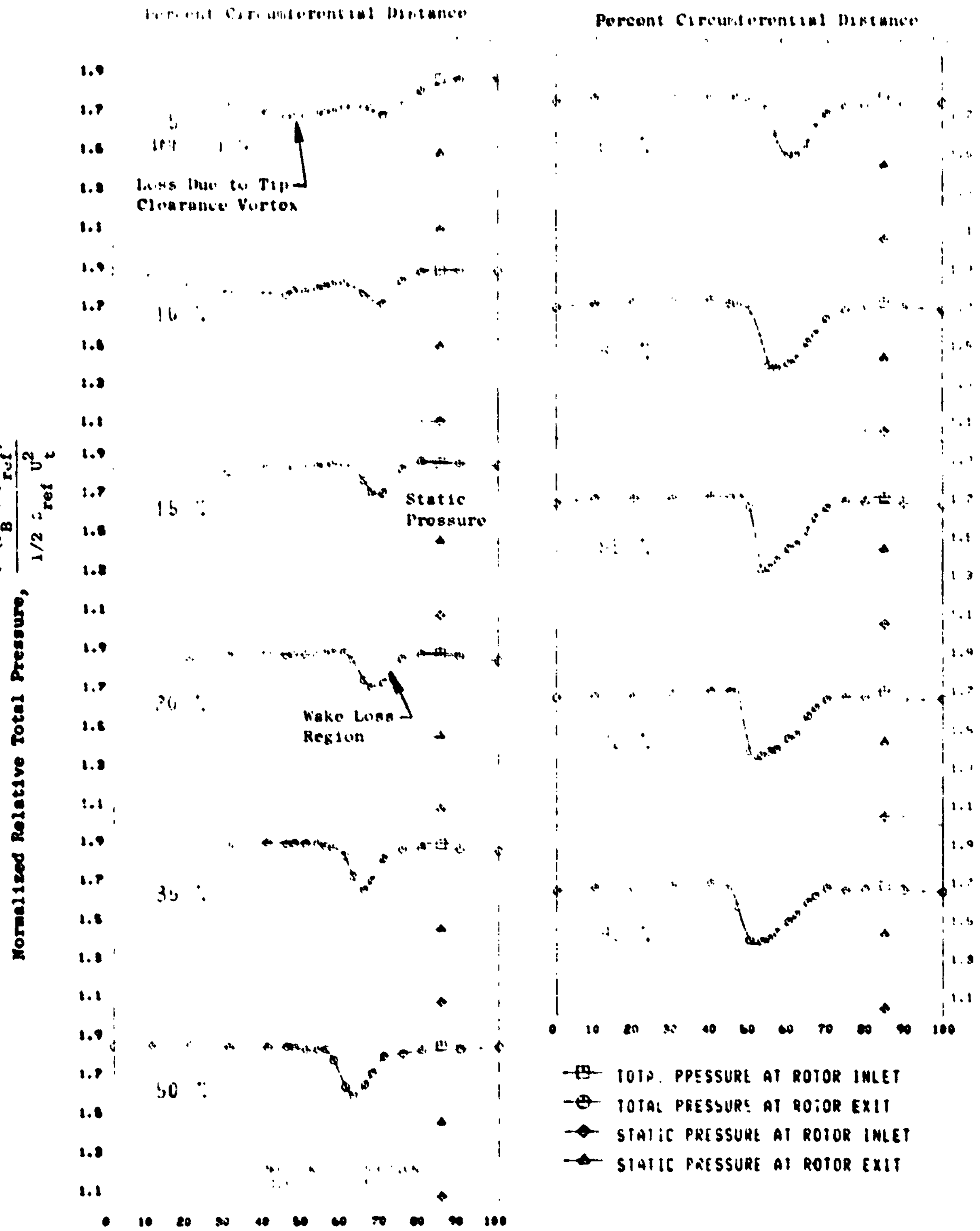


Figure 39. Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise Throttle.

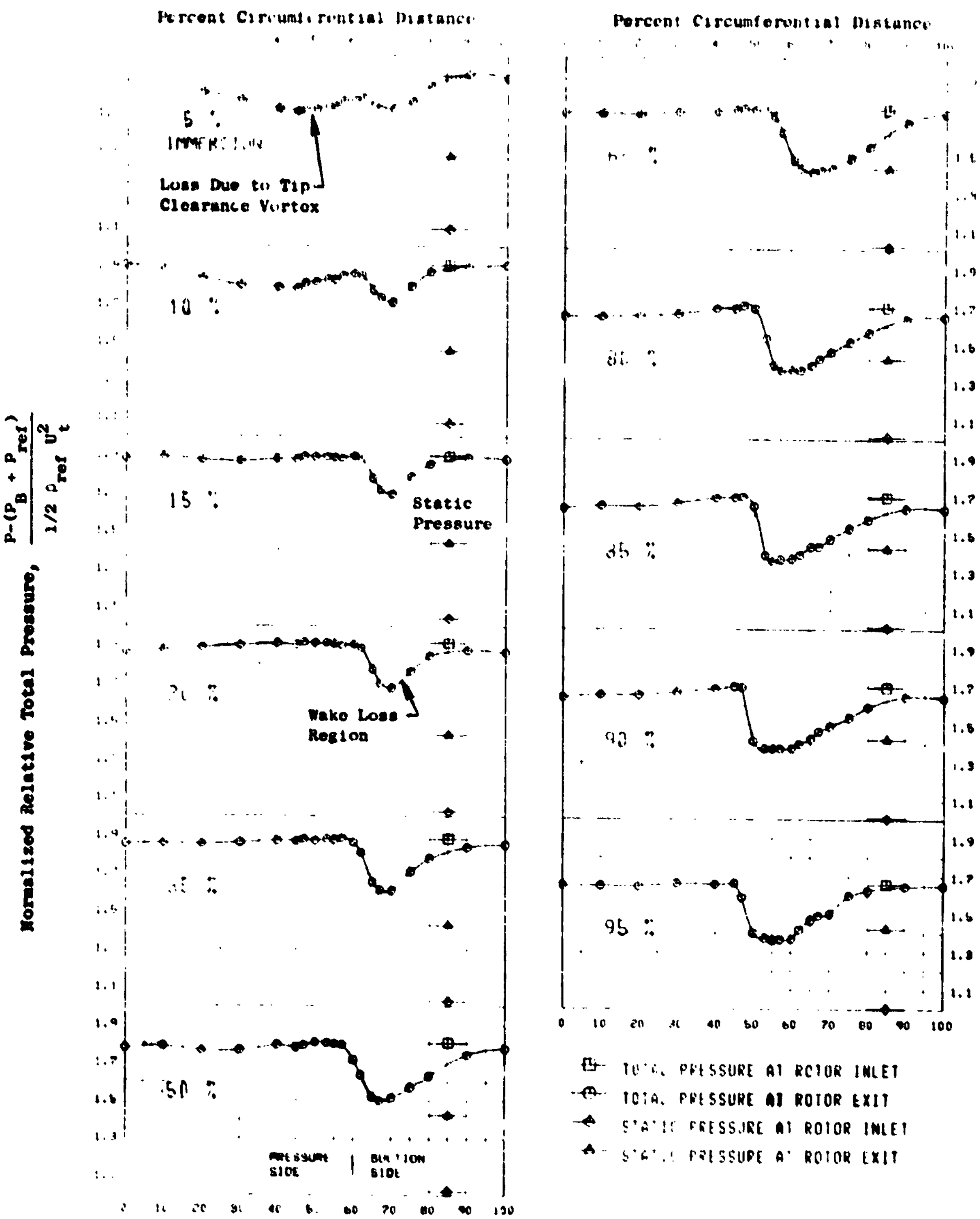


Figure 40. Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, Third Stage Tested, Near Stall Throttle.

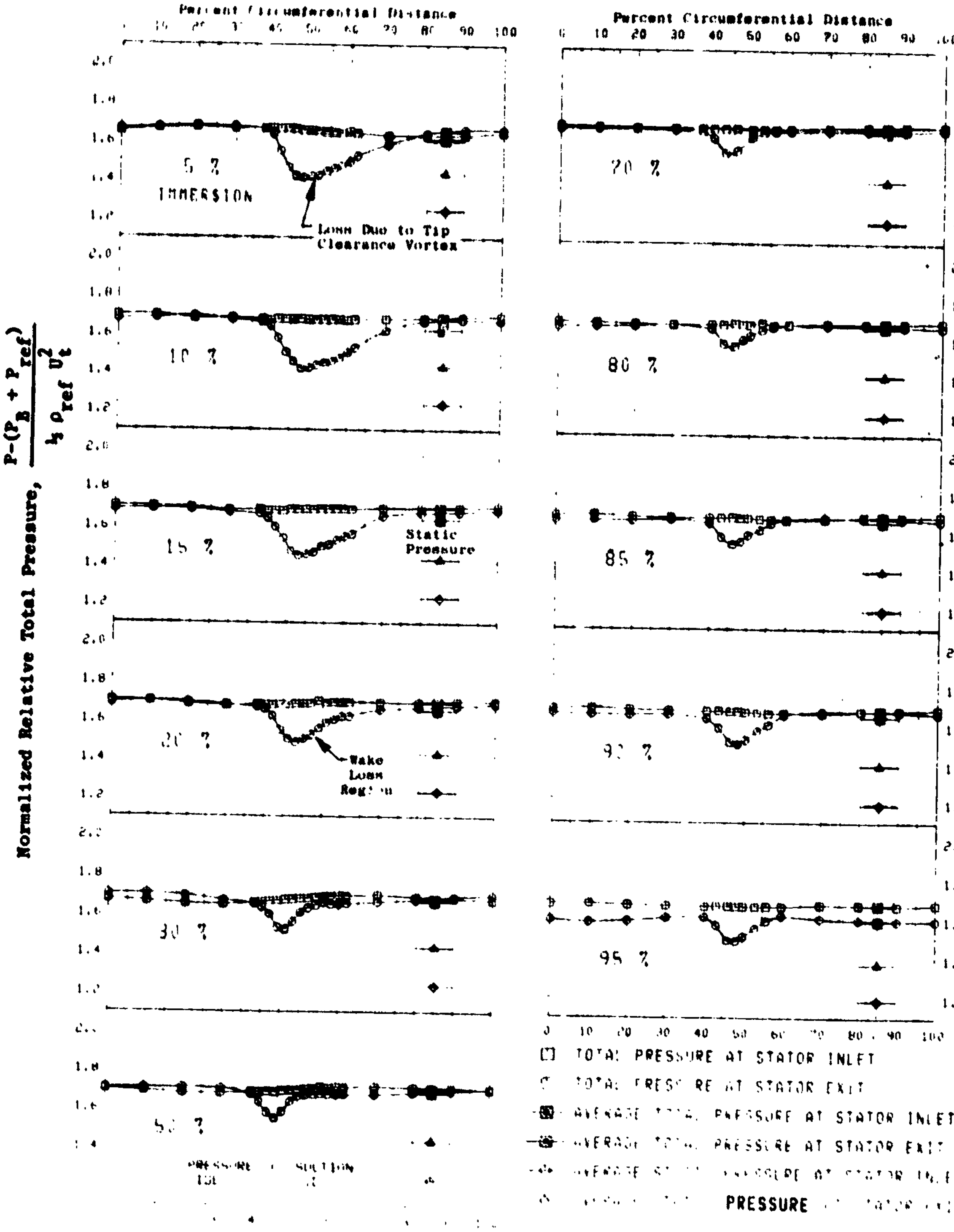


Figure 41. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, Third Stage Tested, Design Point Throttle.

ORIGINAL PAGE IS OF POOR QUALITY

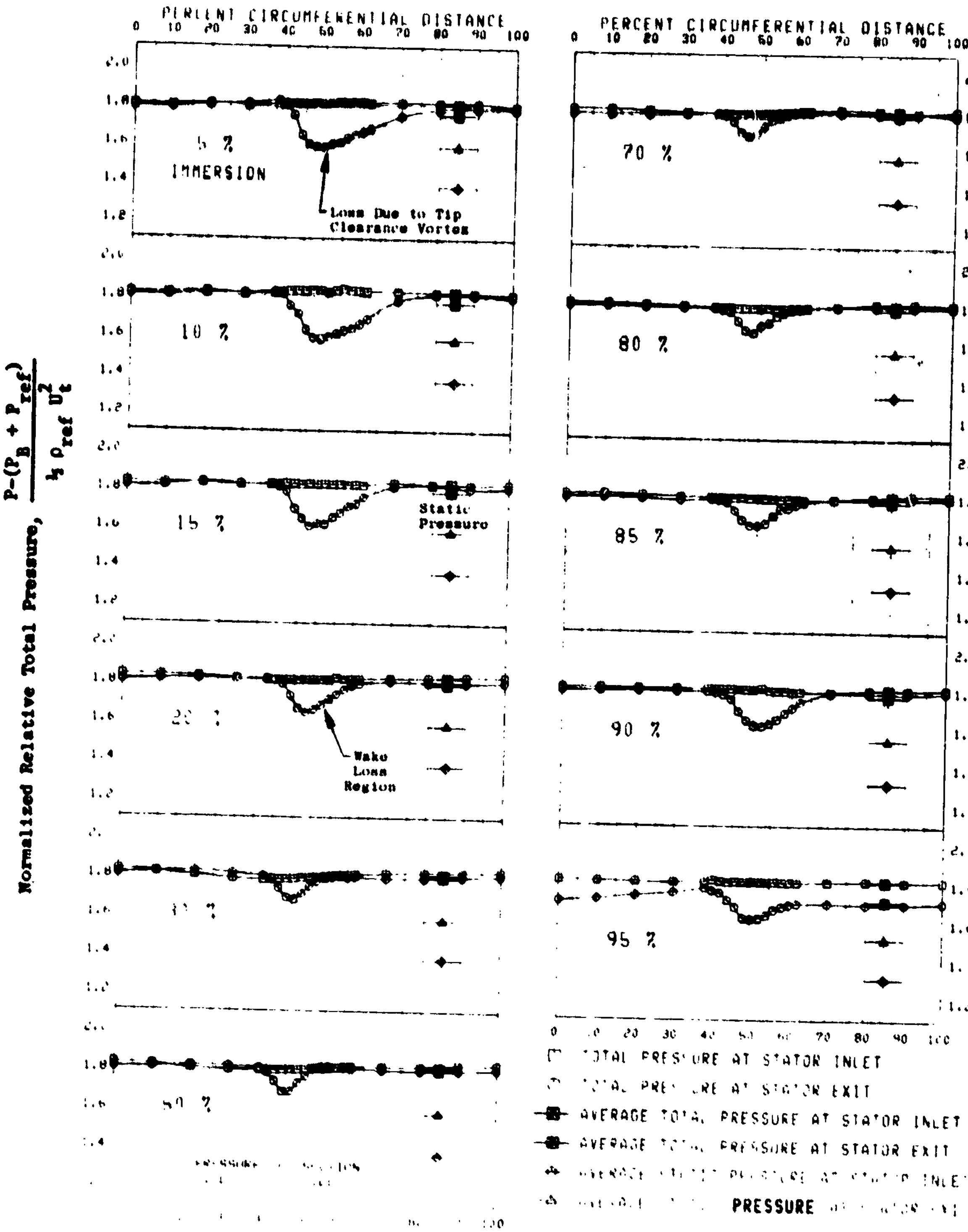


Figure 42. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, Third Stage Tested, Peak Efficiency Throttle.

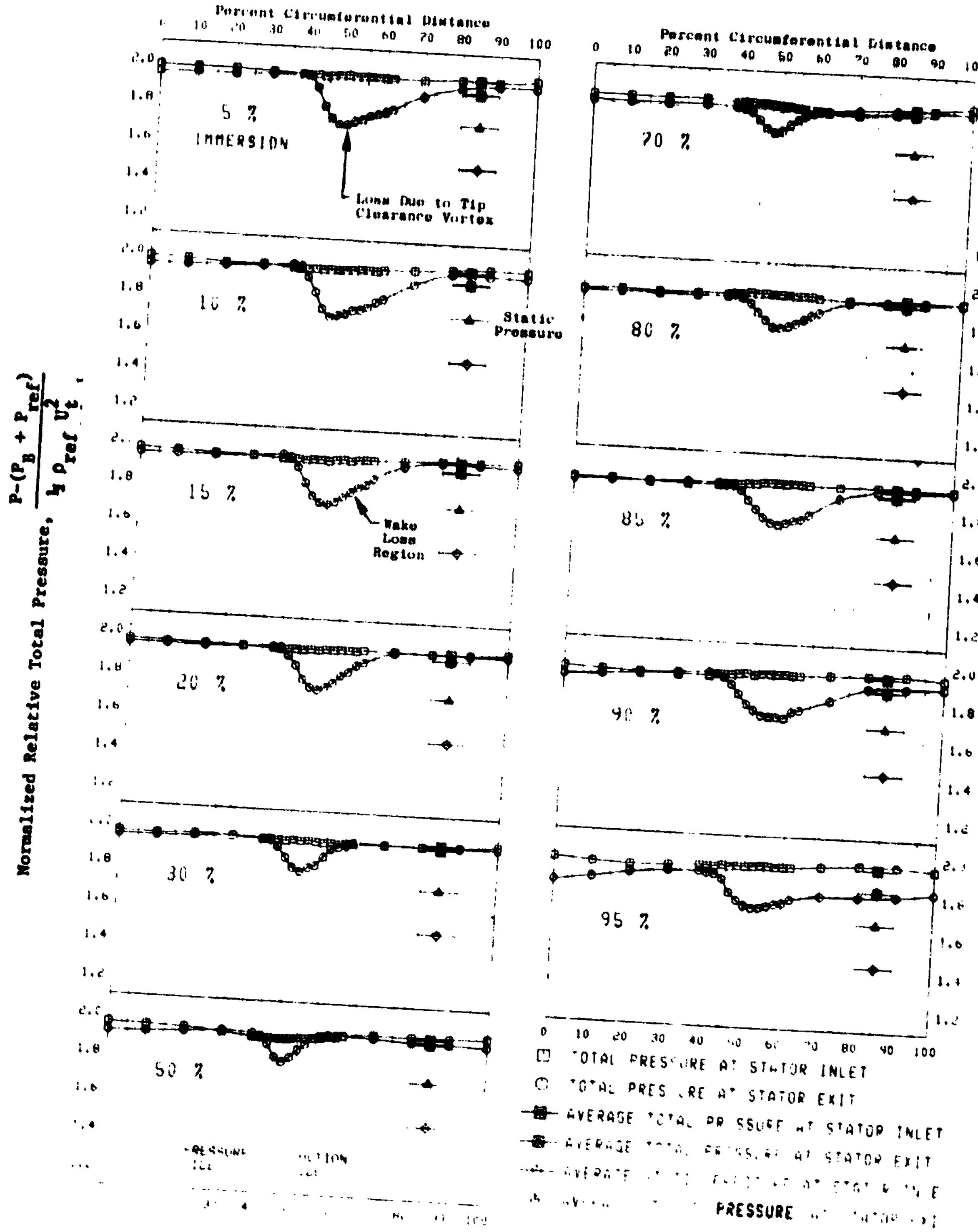


Figure 43. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise Throttle.

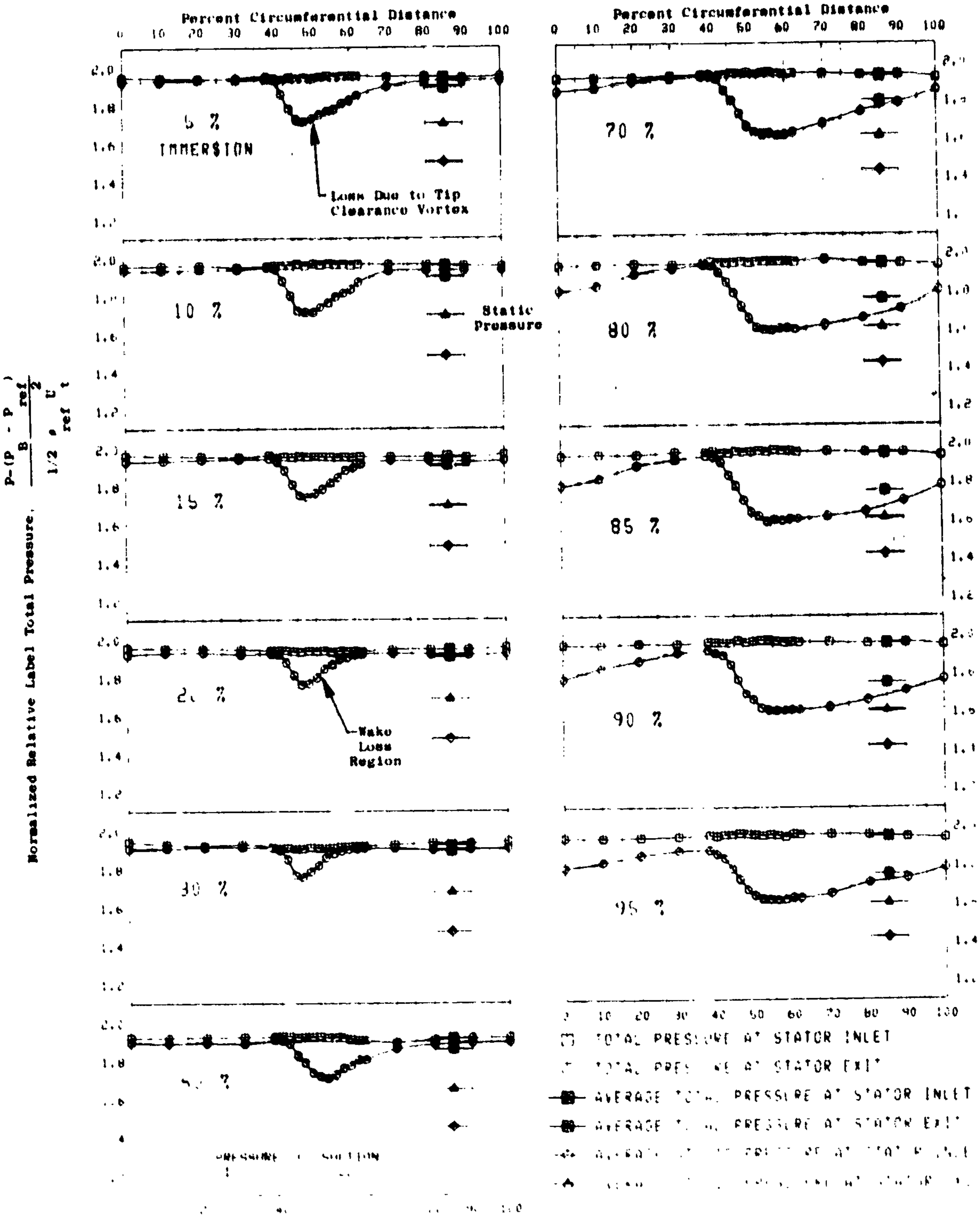


Figure 44. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, Third Stage Tested, Near Stall Throttle.

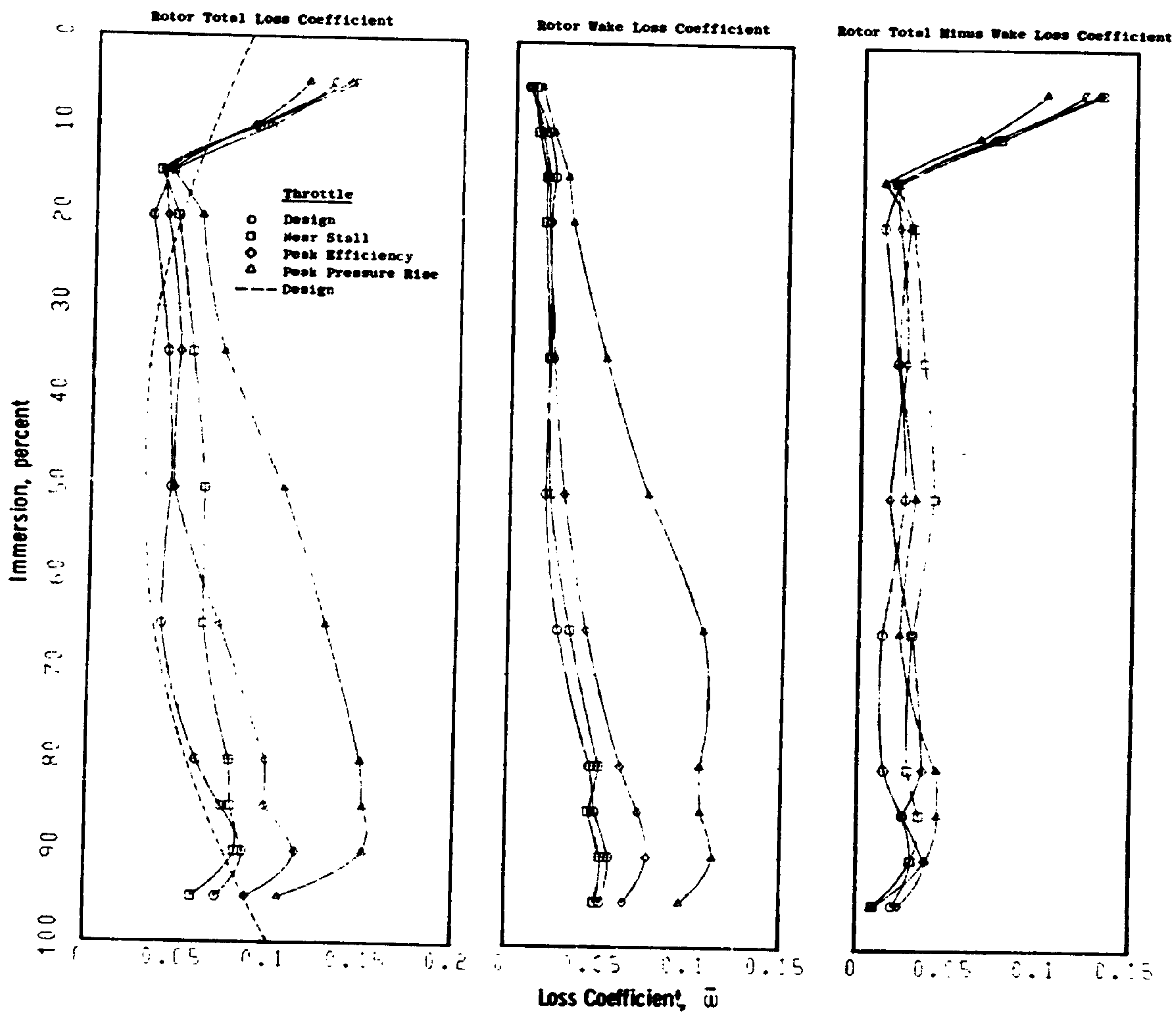


Figure 45. Rotor Total Loss Coefficients, Wake Loss Coefficients, and Total Minus Wake Loss Coefficients for Rotor A/Stator A, Four-Stage Configuration, Third Stage Tested.

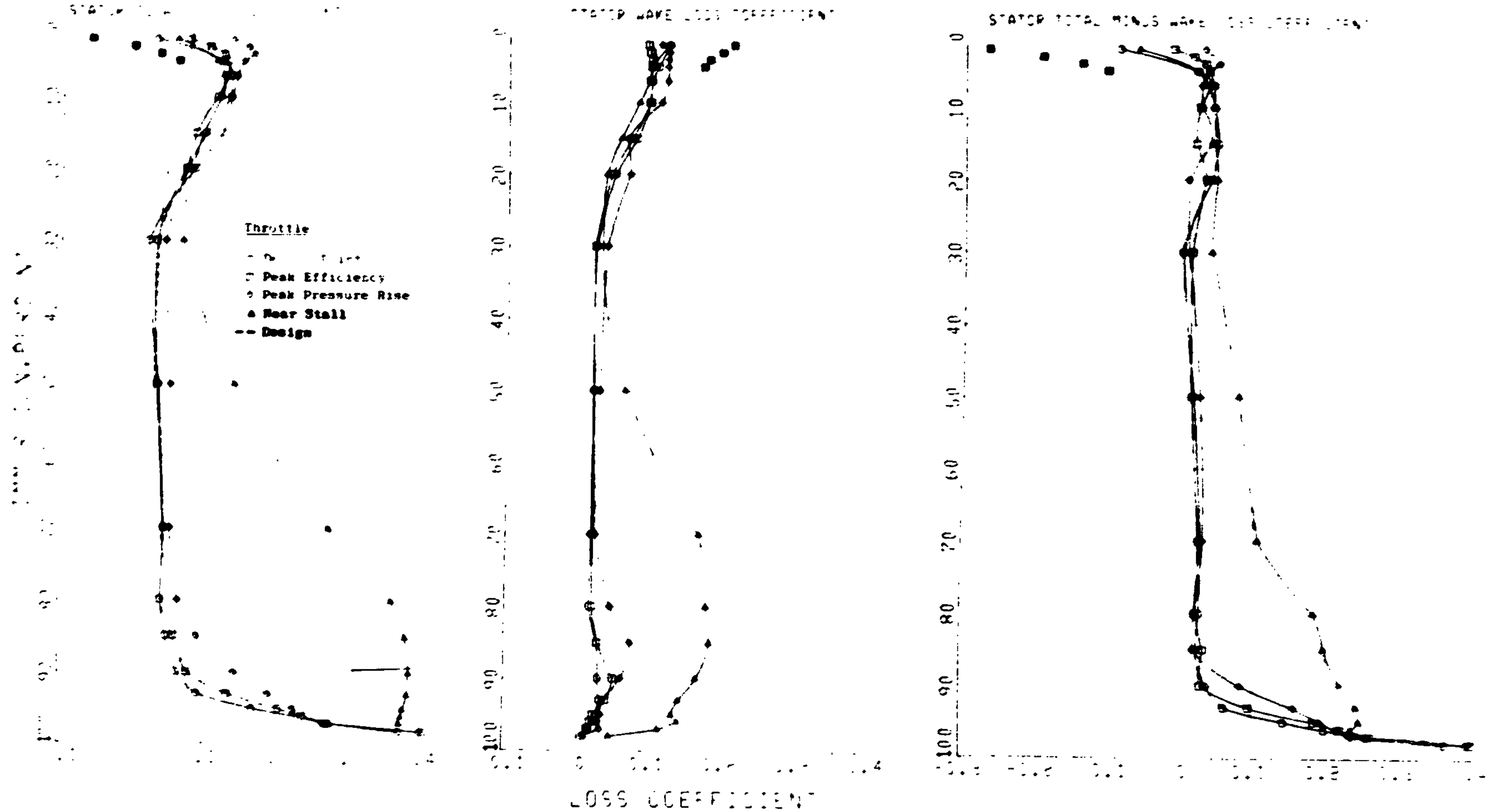


Figure 46. Stator Total Loss Coefficients, Wake Loss Coefficients, and Total Minus Wake Loss Coefficients for Rotor A/Stator A, Four-Stage Configuration, Third Stage Tested.

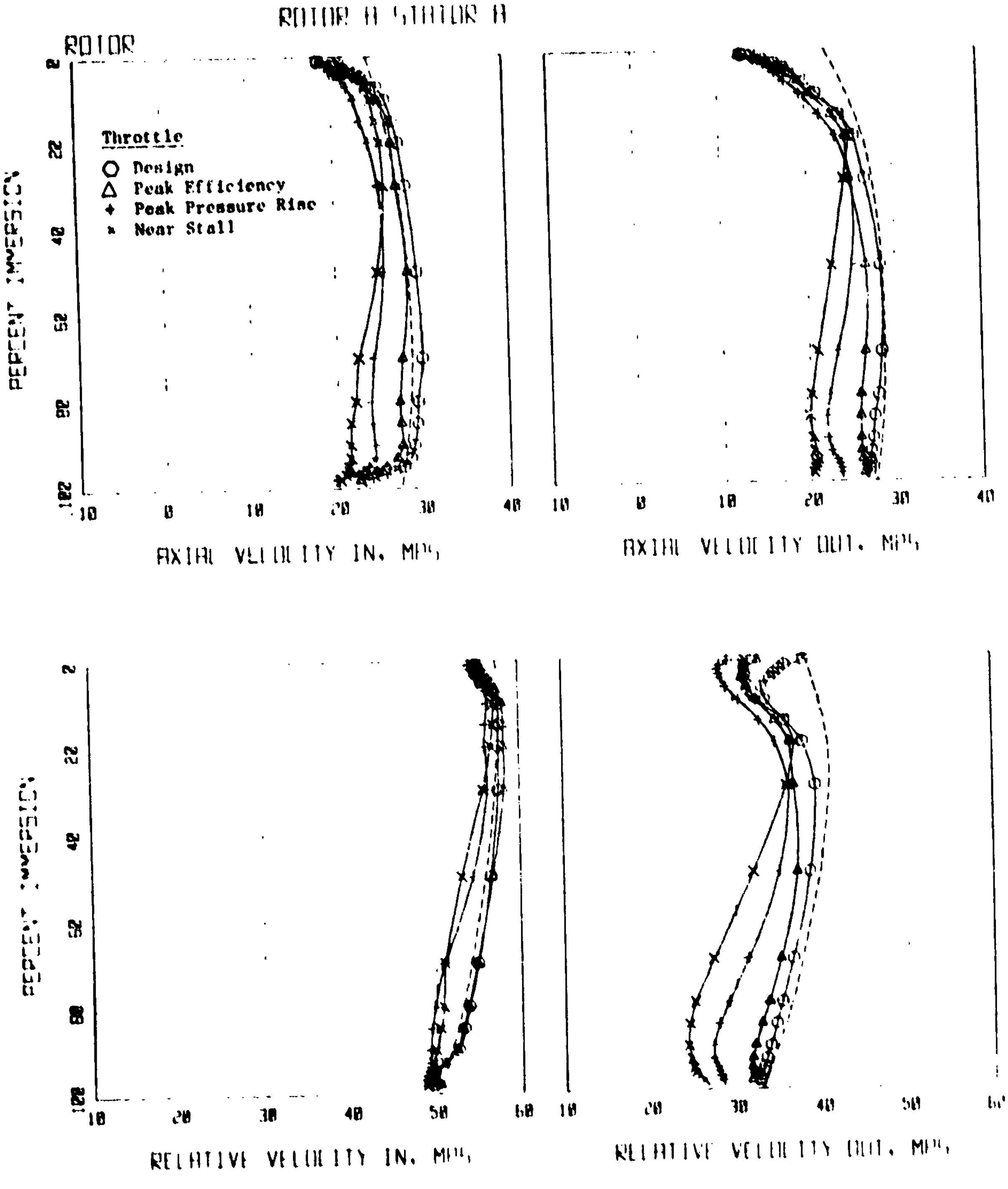


Figure 47. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Four-Stage Configuration, Third Stage Tested.

ORIGINAL PAGE IS
OF POOR QUALITY

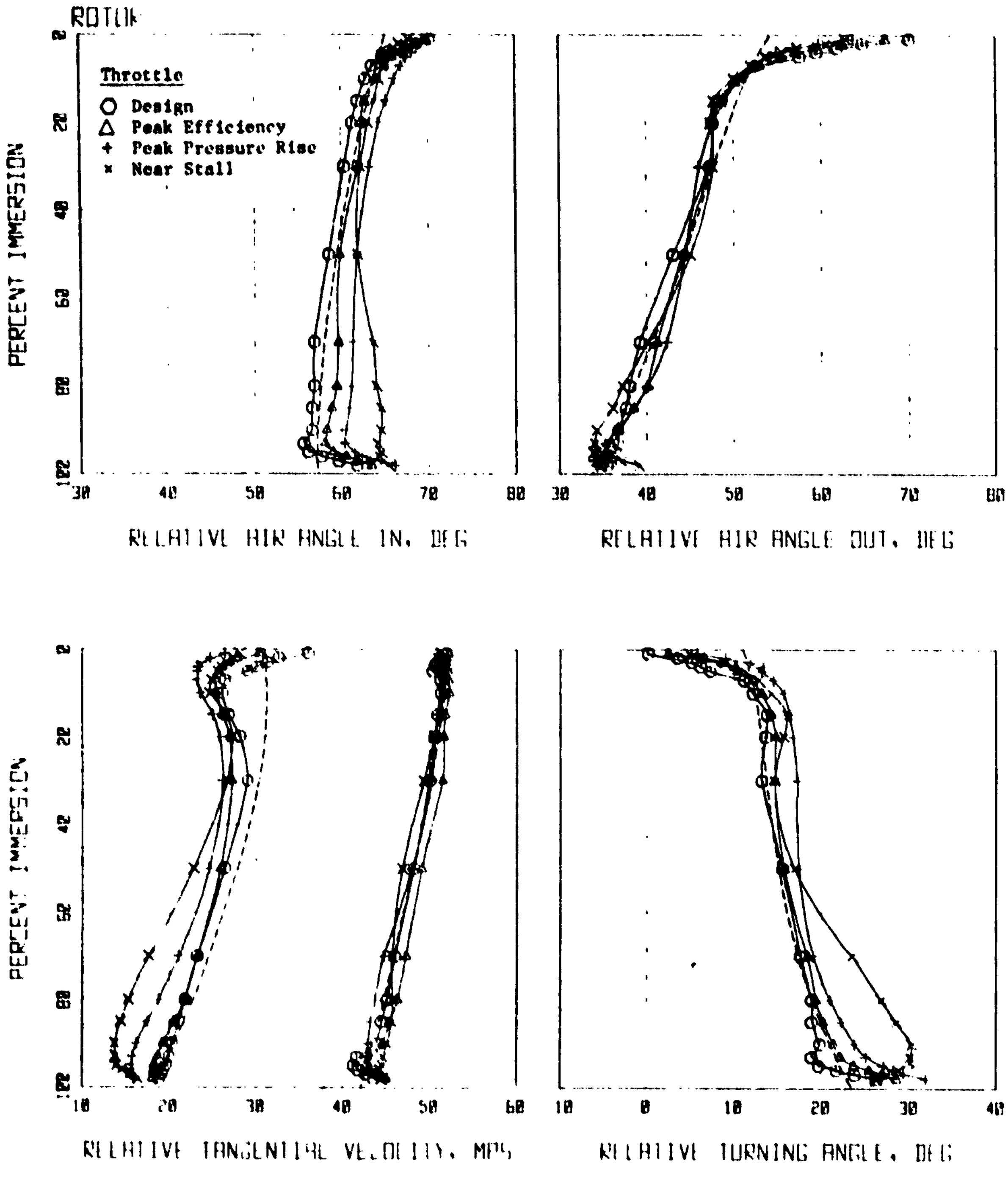
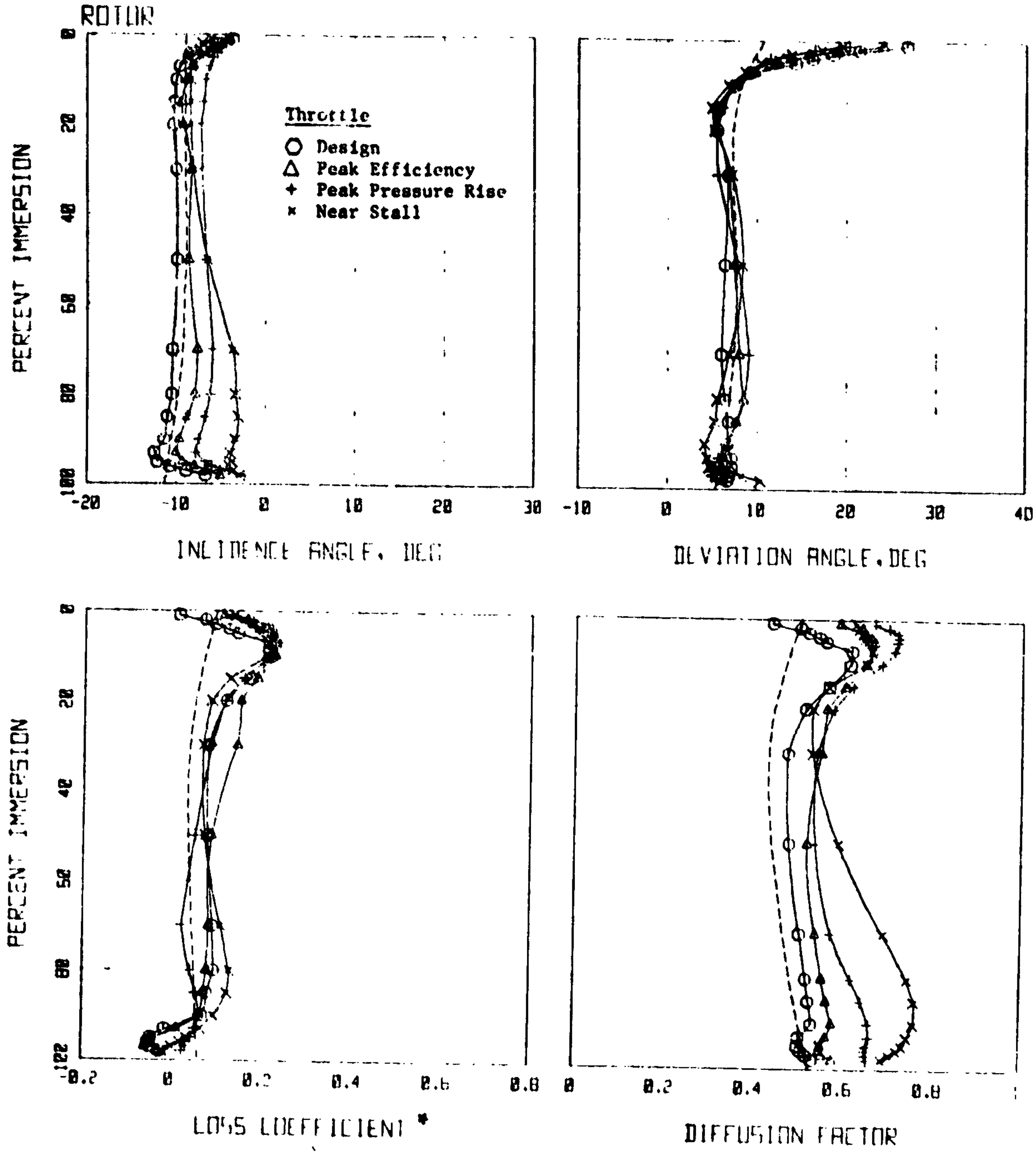


Figure 48. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Four-Stage Configuration, Third Stage Tested.



* See Figure 45 and discussion in Section 4.6.1 for loss coefficients computed from relative total pressure measurements.

Figure 49. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Four-Stage Configuration, Third Stage Tested.

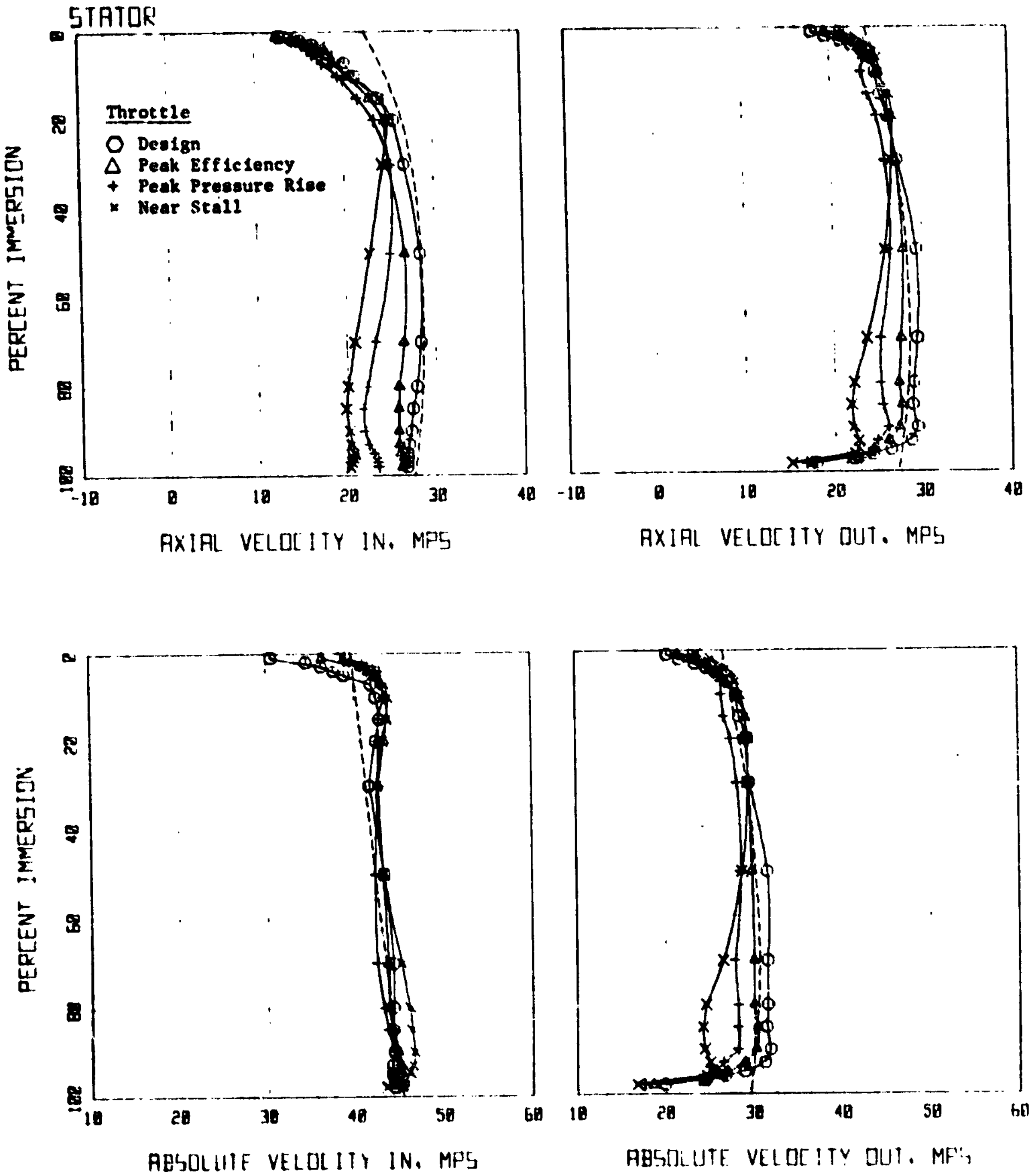


Figure 50. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Four-Stage Configuration, Third Stage Tested.

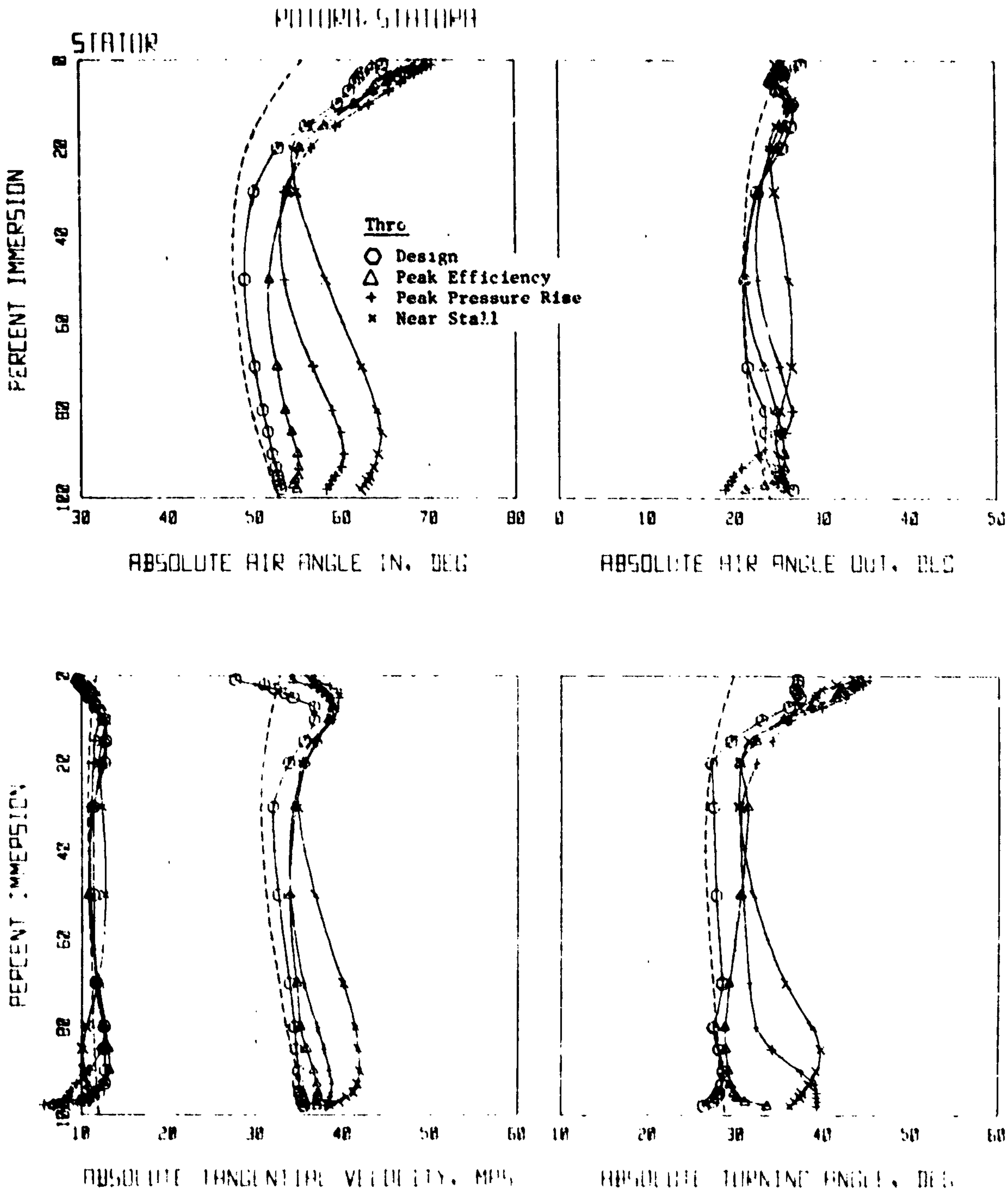


Figure 51. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Four-Stage Configuration, Third Stage Tested.

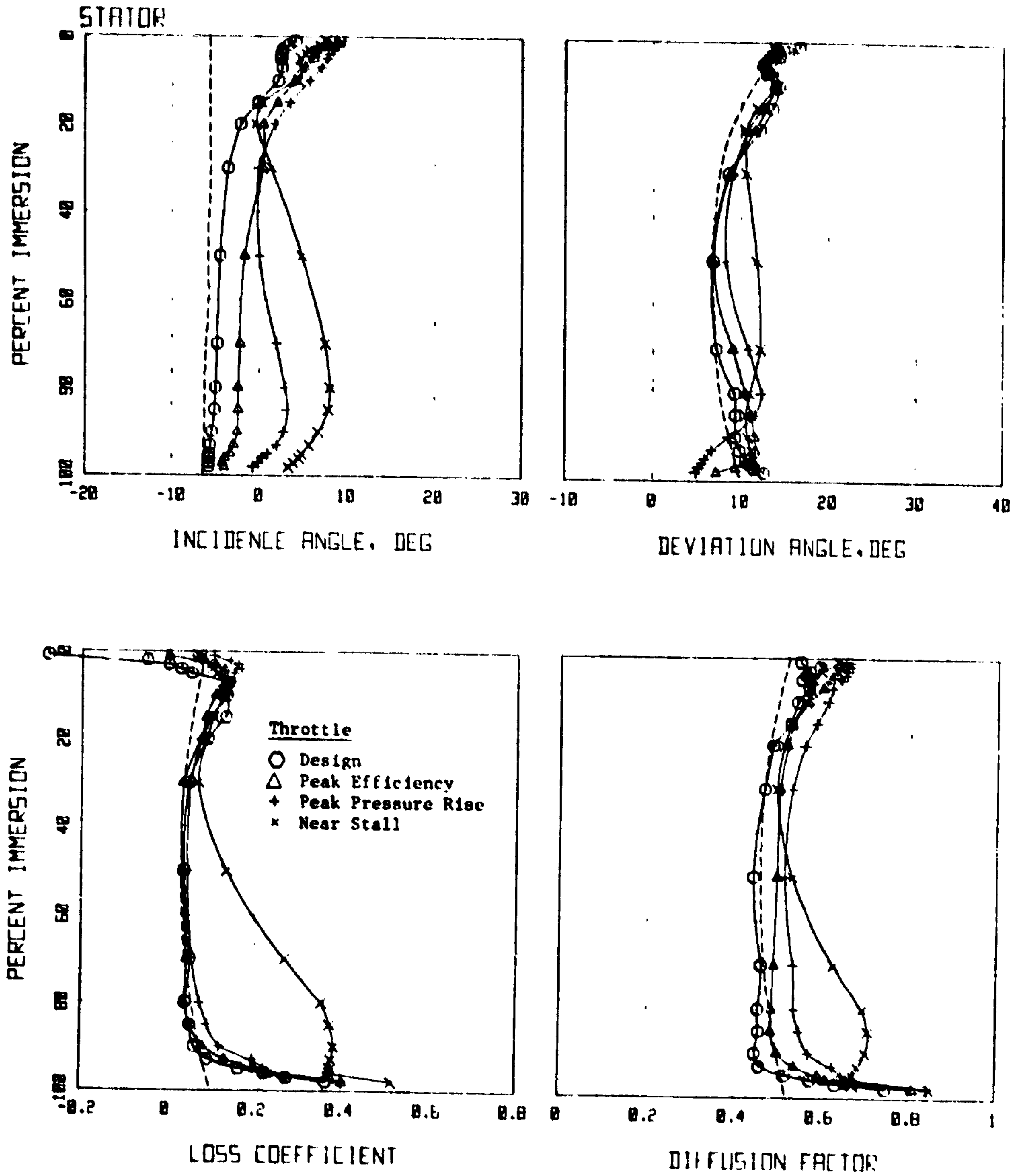


Figure 52. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Four-Stage Configuration, Third Stage Tested.

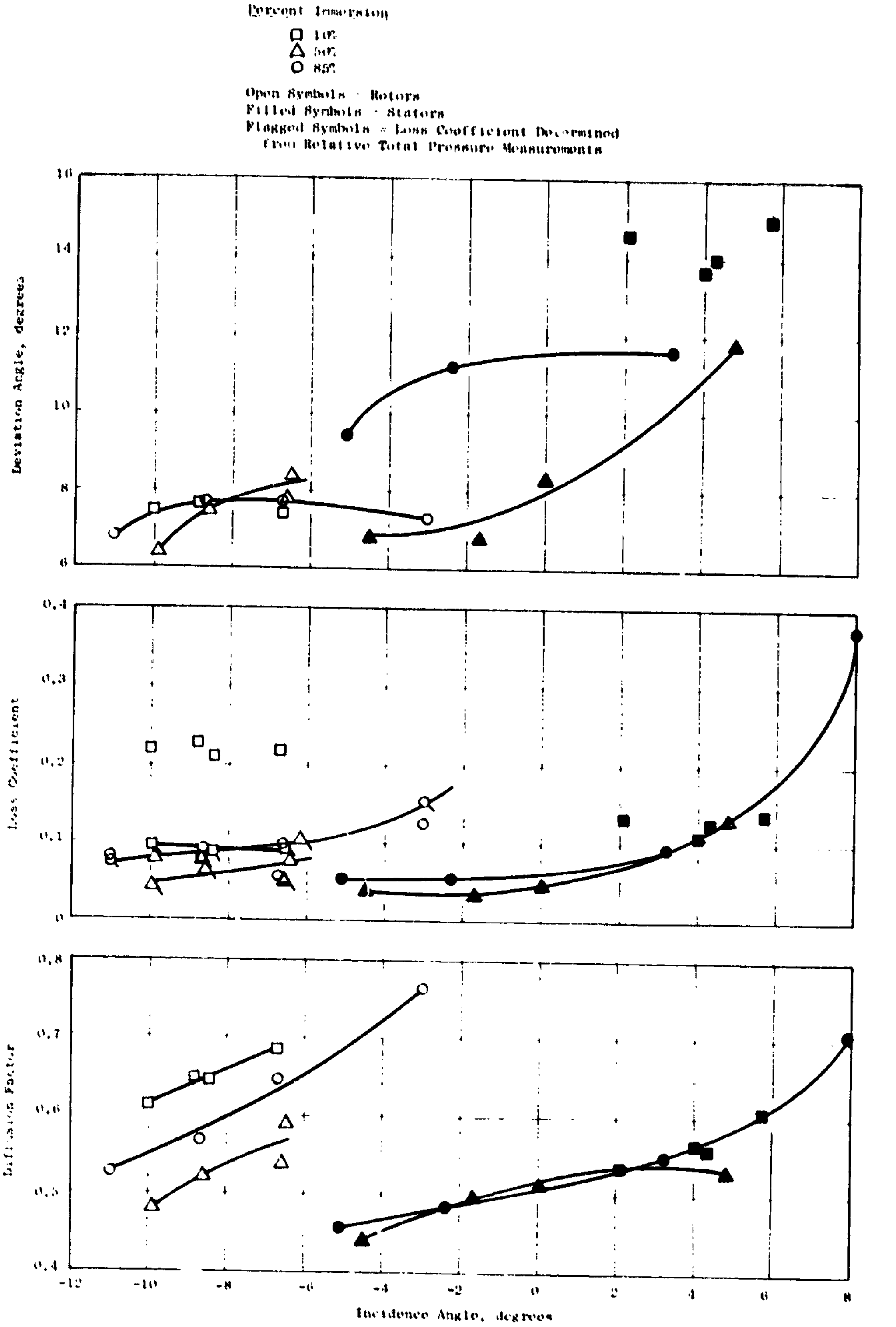


Figure 53. Diffusion Factor, Loss Coefficient and Deviation Angle Versus Incidence Angle, Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.

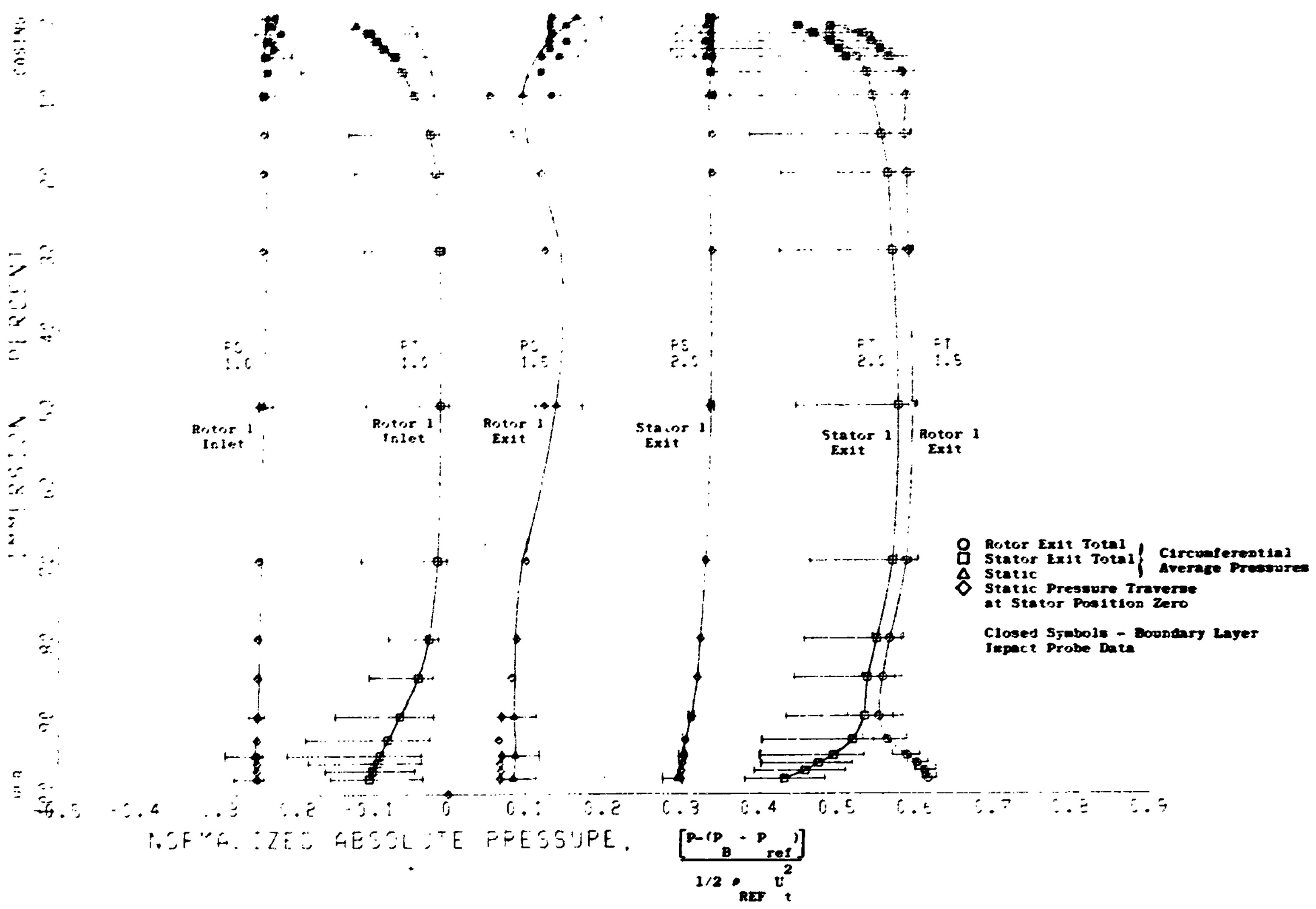


Figure 54. Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Single-Stage Configuration, Design Point Throttle.

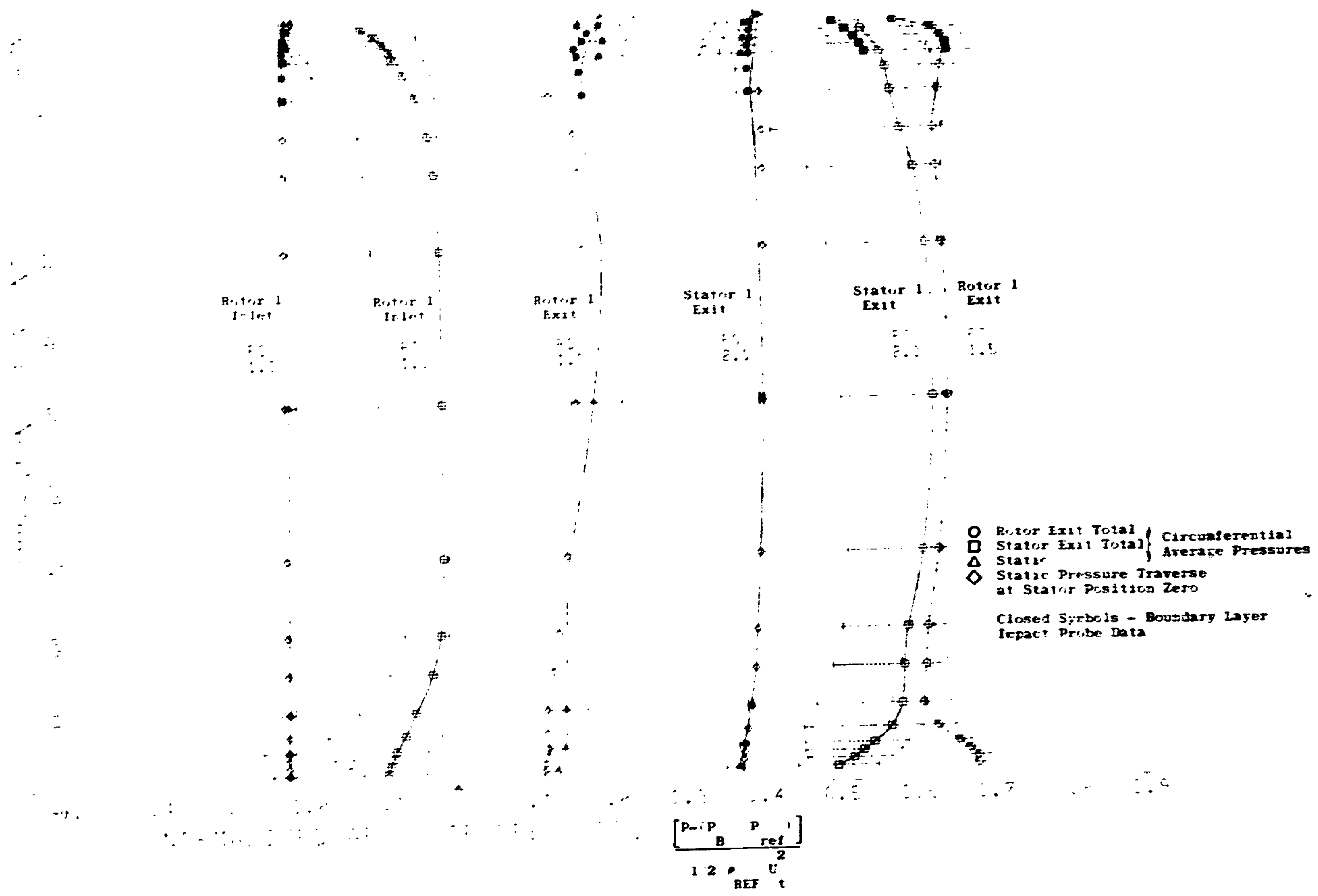


Figure 55. Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Single-Stage Configuration, Peak Efficiency Throttle.

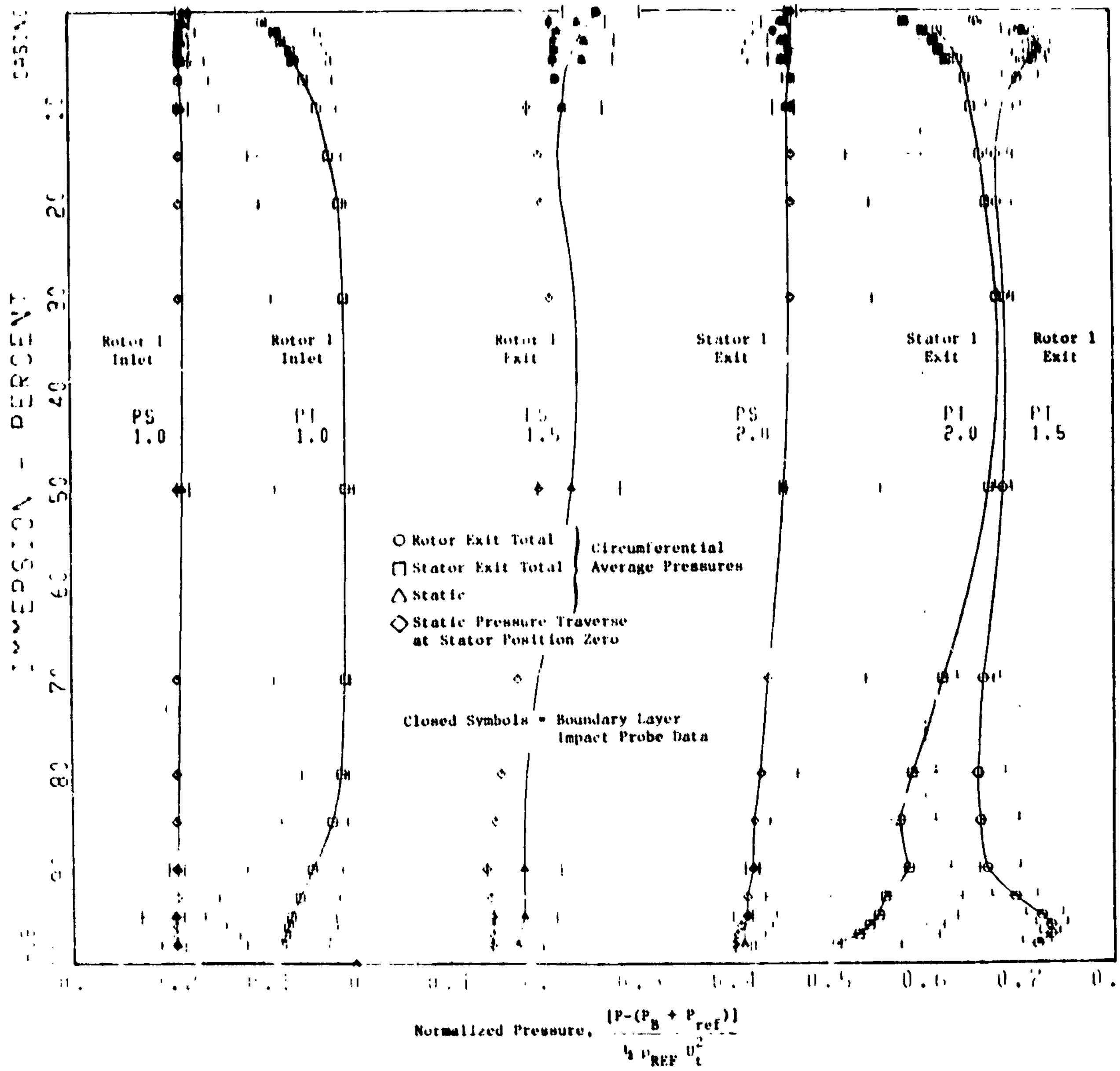


Figure 56. Normalized Absolute Total Pressures and Static Pressures for Rotor A/ Stator A Single-Stage Configuration, Peak Pressure Rise and Near Stall Throttle.

ORIGINAL PAGE IS
OF POOR QUALITY

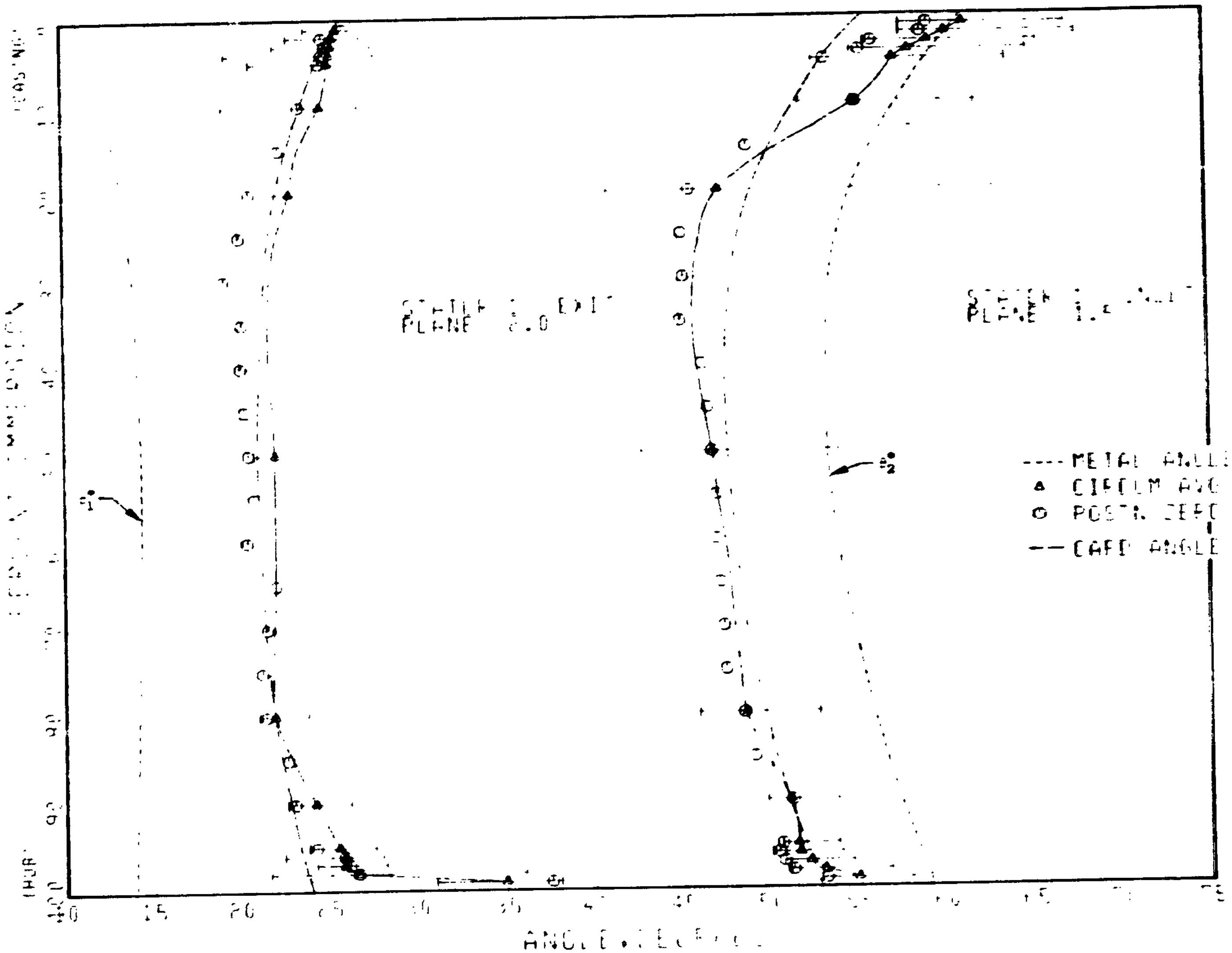


Figure 57. **Absolute Flow Angles for Rotor A/Stator A Single-Stage Configuration, Design Point Throttle.**

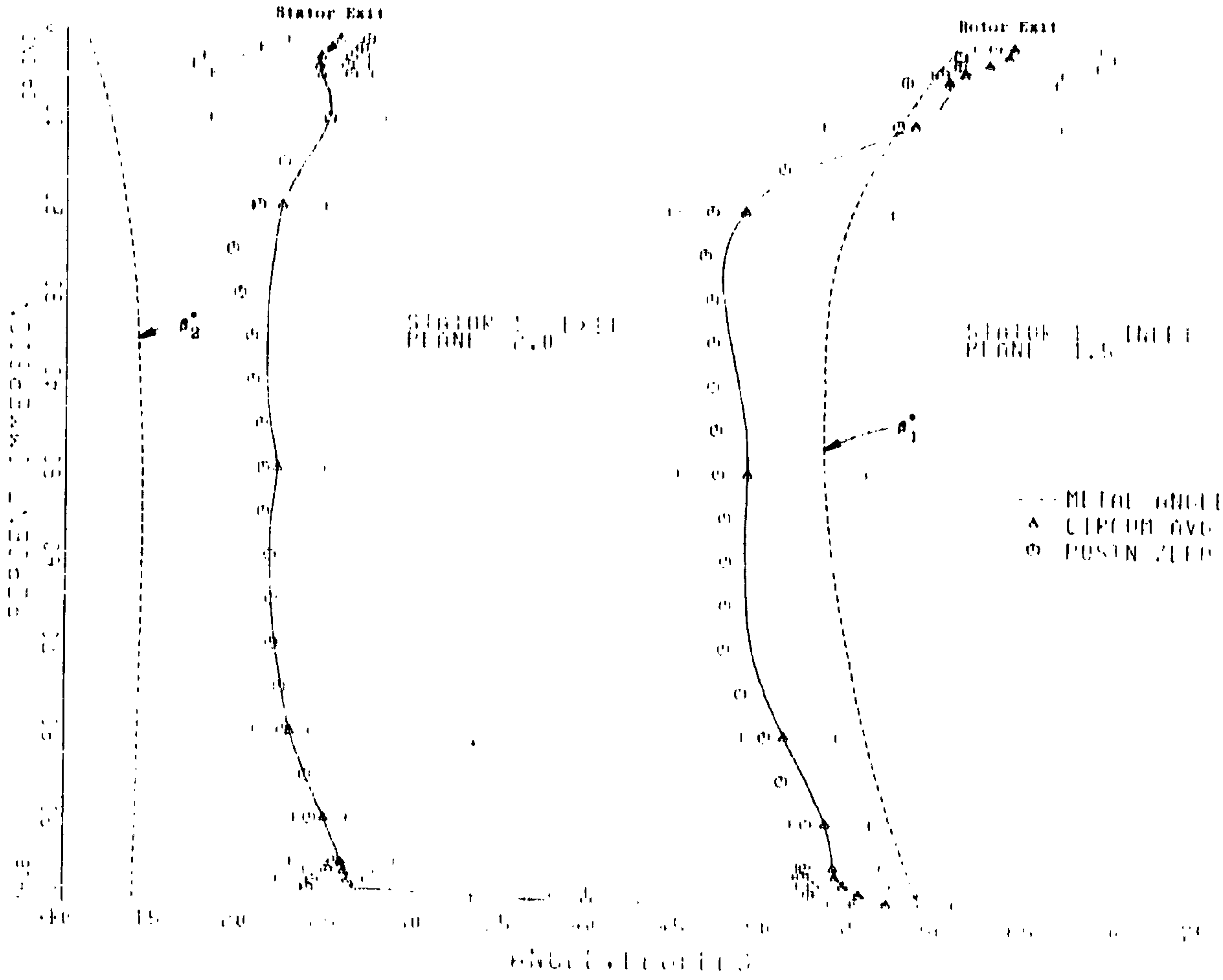


Figure 58. Absolute Flow Angles for Rotor A/Stator A Single-Stage Configuration, Peak Efficiency Throttle.

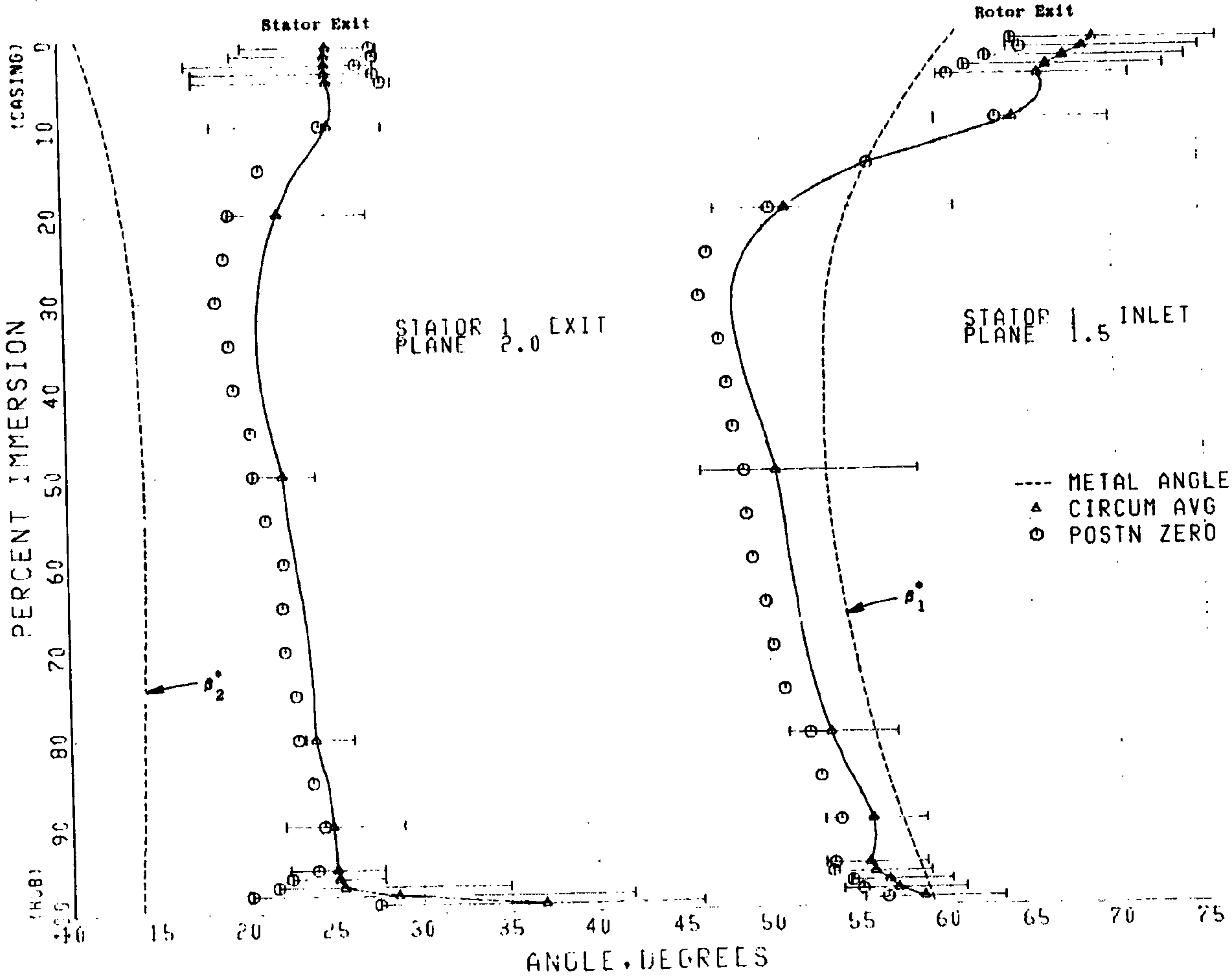


Figure 59. Absolute Flow Angles for Rotor A/Stator A Single-Stage Configuration, Peak Pressure Rise and Near Stall Throttle.

C-2

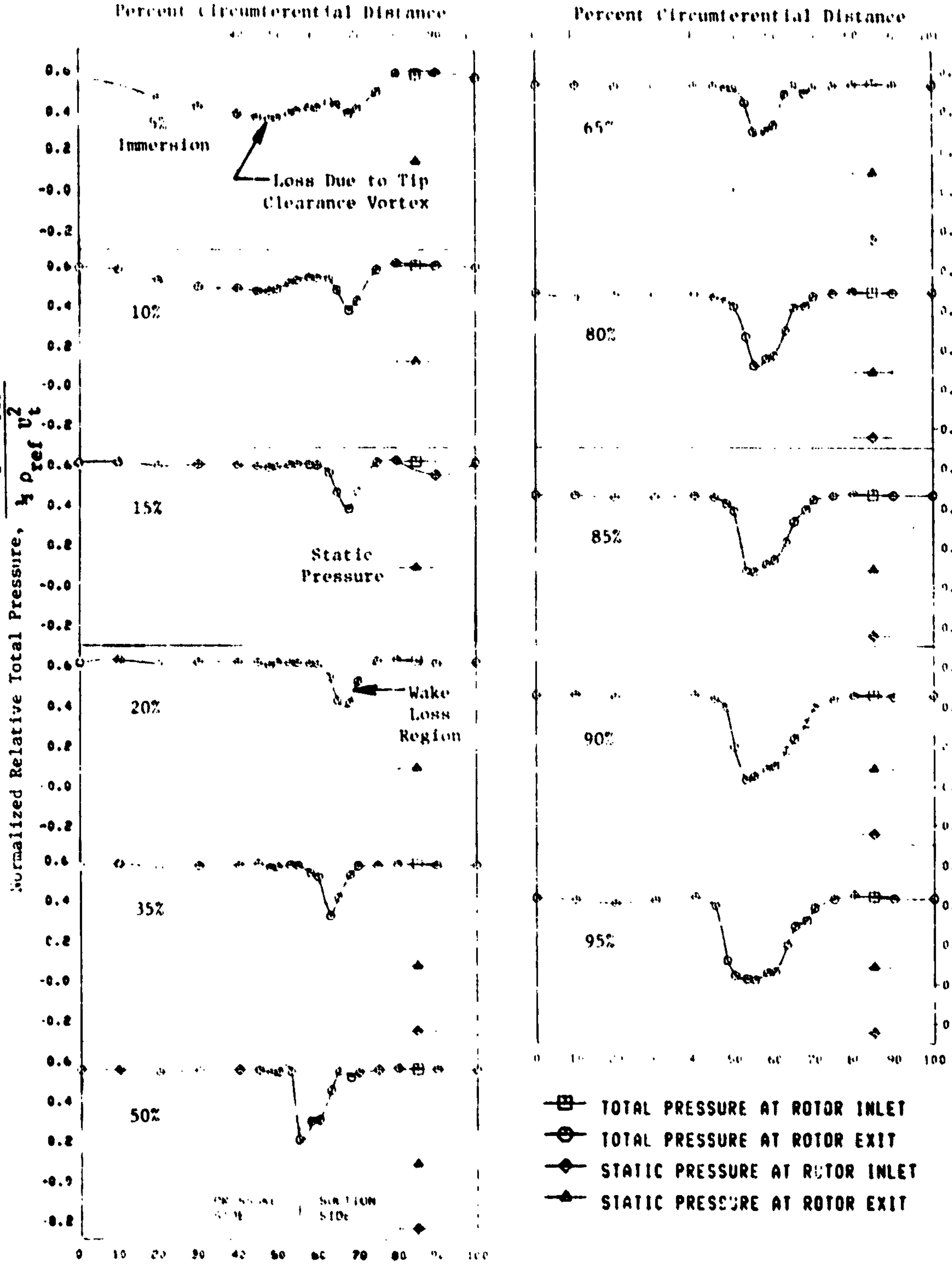


Figure 60. Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Single-Stage Configuration, Design Point Throttle.

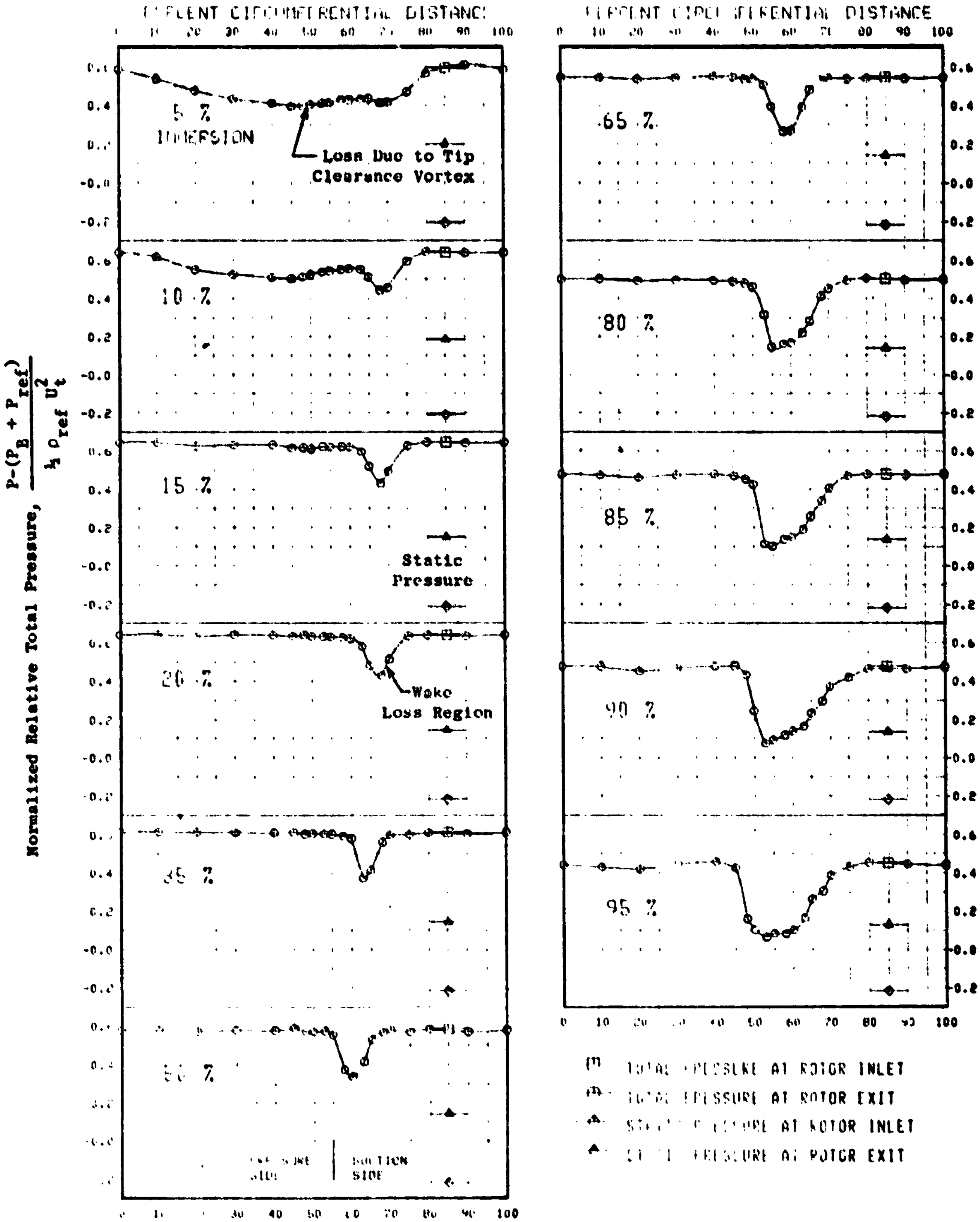


Figure 61. Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Single-Stage Configuration, Peak Efficiency Throttle.

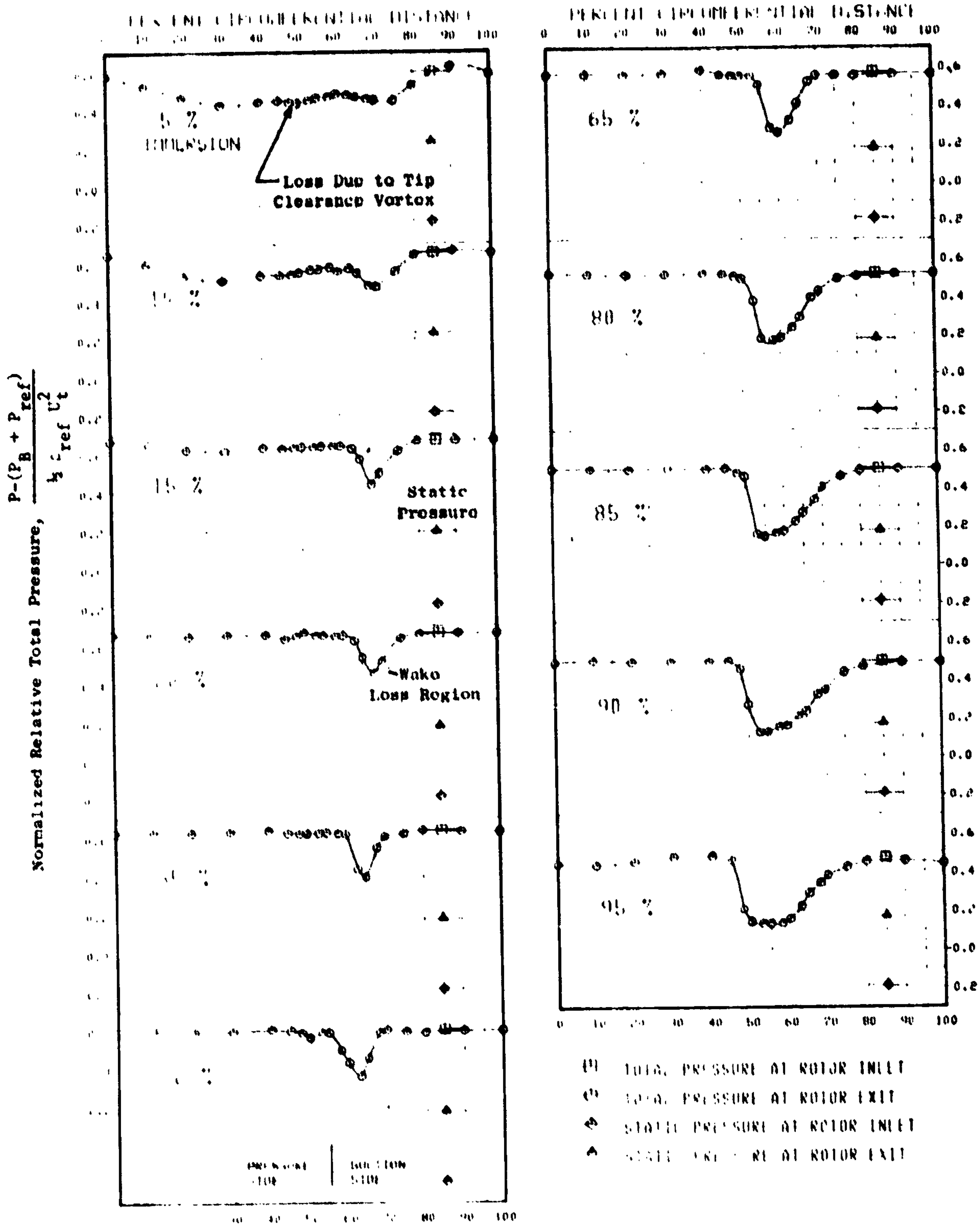


Figure 62. Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Single-Stage Configuration, Peak Pressure Rise Near Stall Throttle.

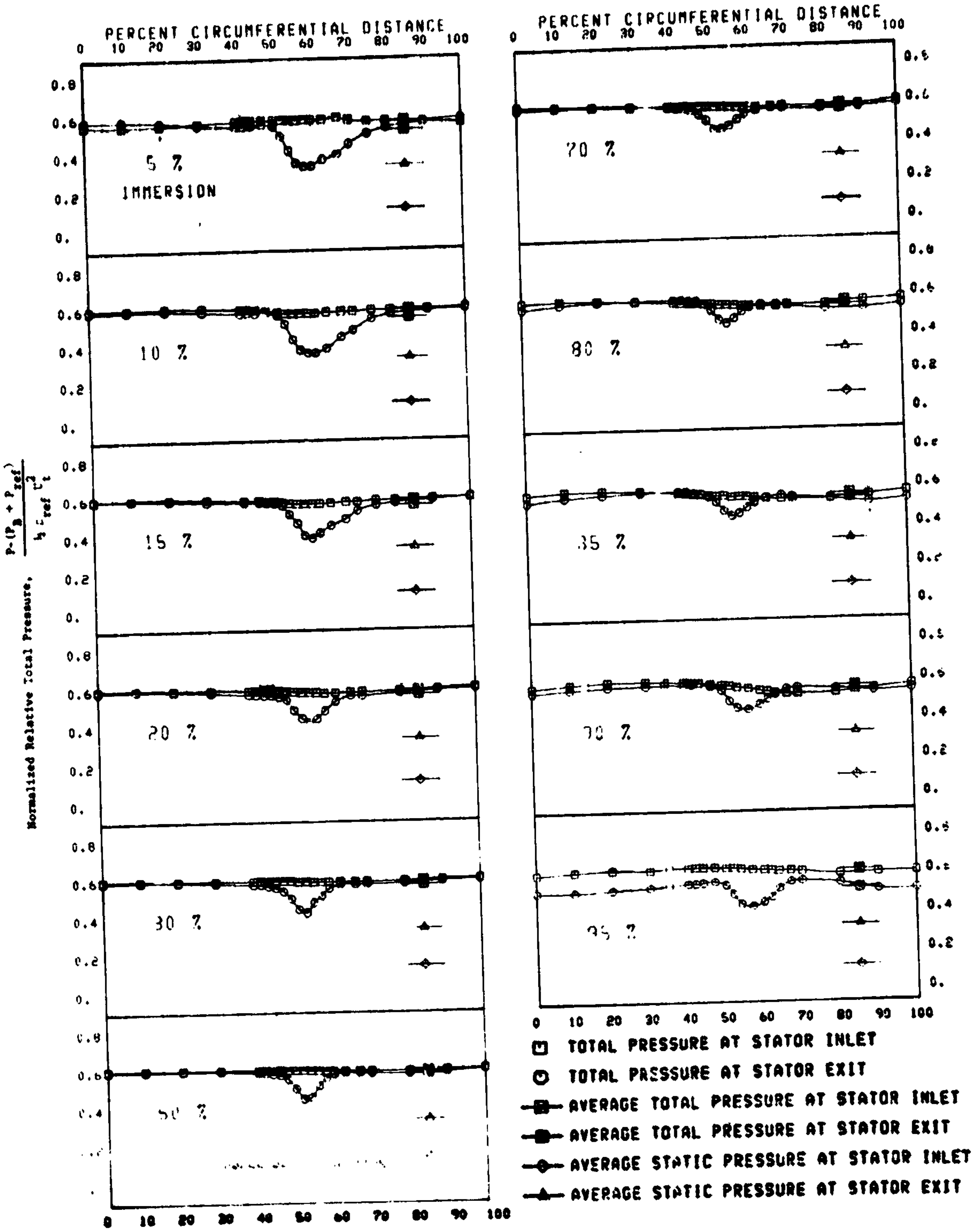


Figure 63. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Single-Stage Configuration, Design Point Throttle.

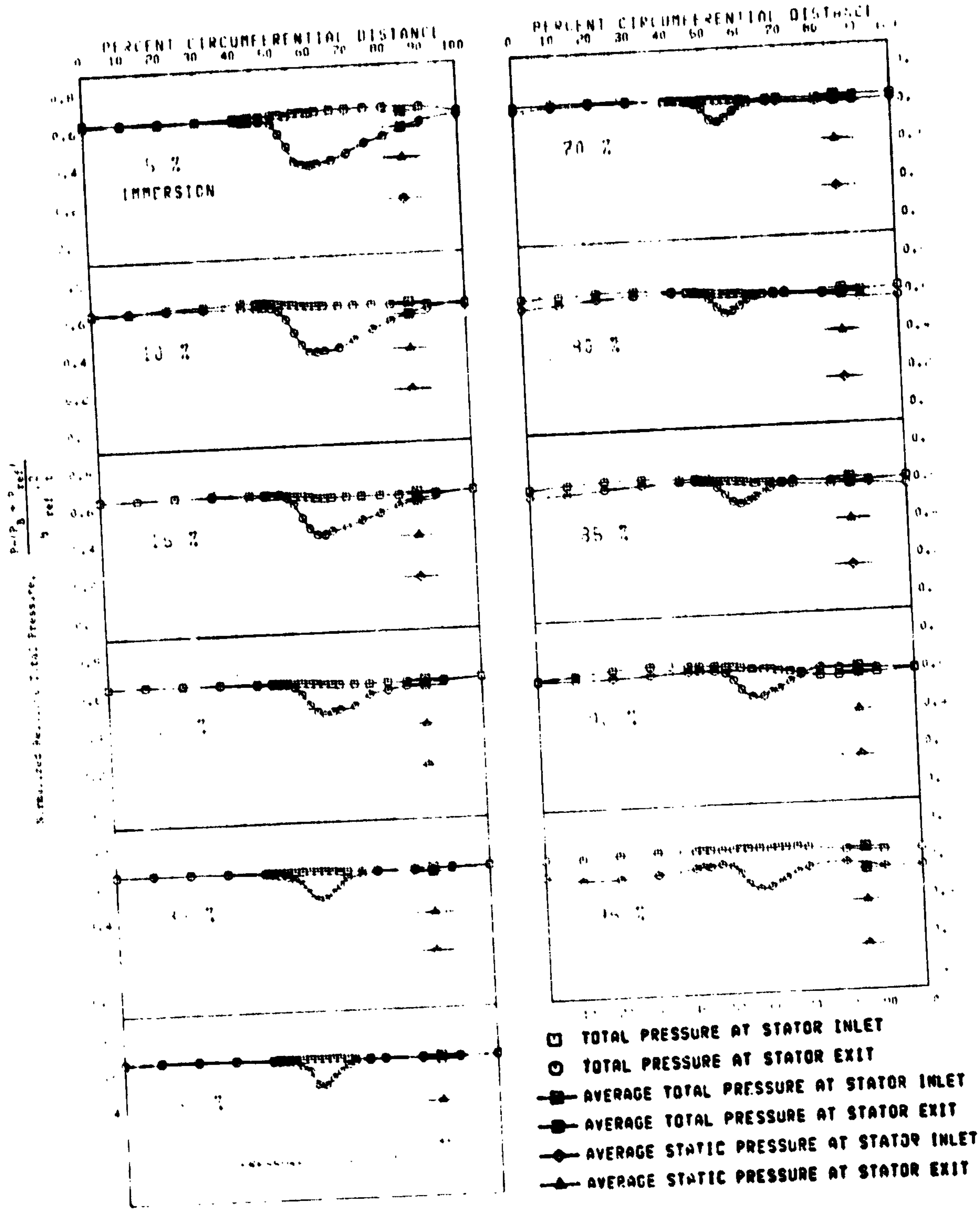


Figure 64. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Single-Stage Configuration, Peak Efficiency Throttle.

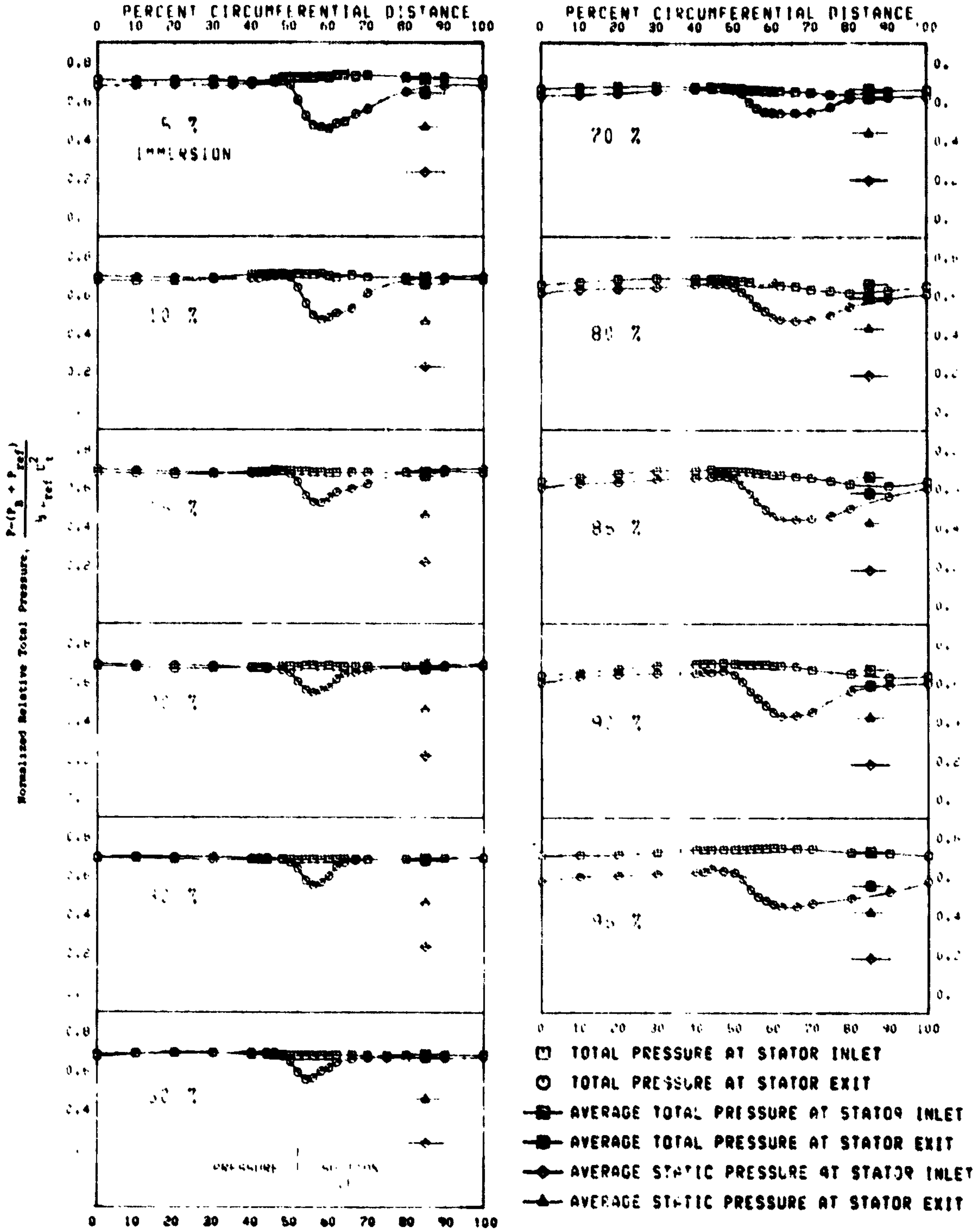


Figure 65. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Single-Stage Configuration, Peak Pressure Rise/Near Stall Throttle.

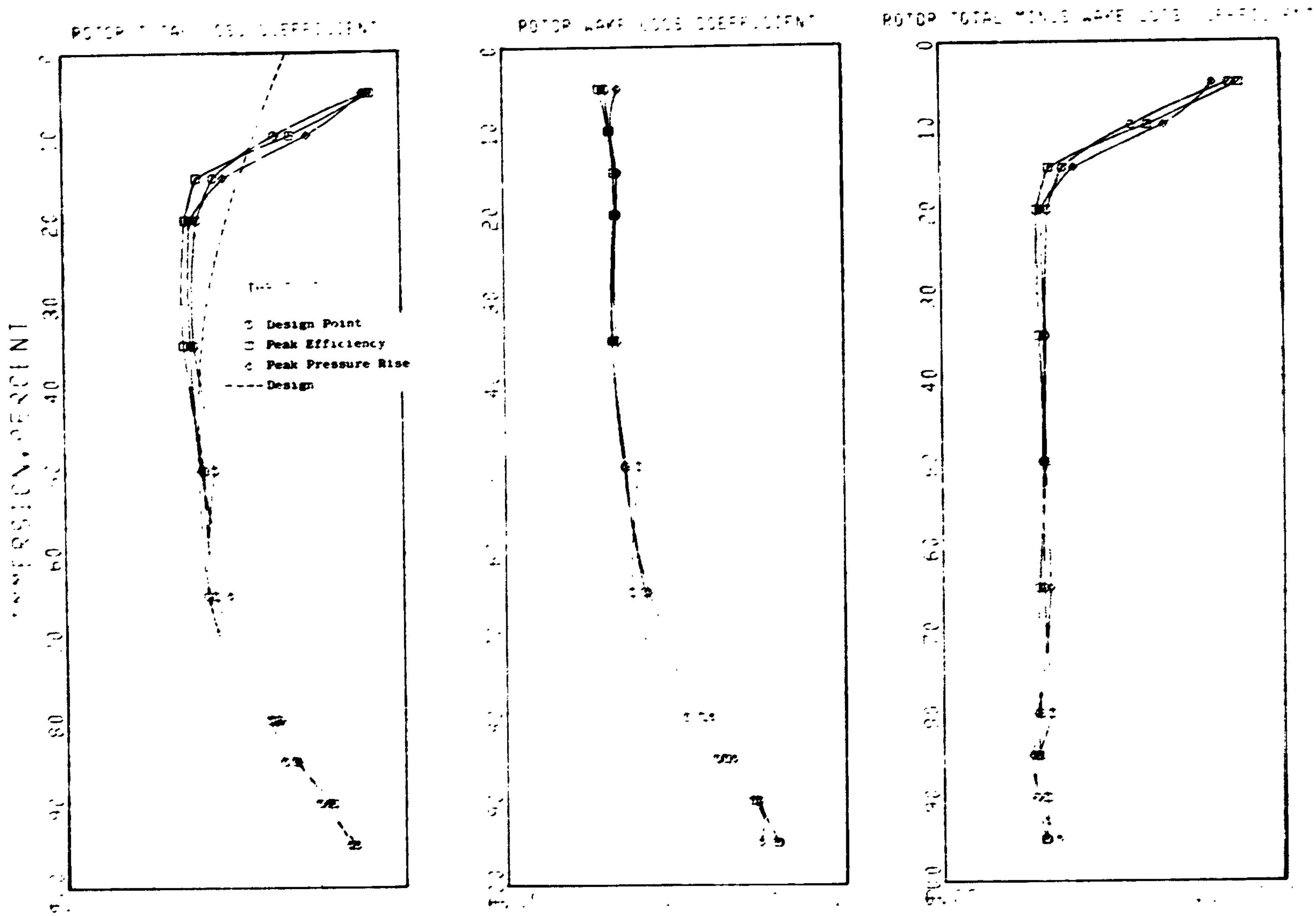


Figure 66. Rotor Total Loss Coefficients, Wake Loss Coefficients, and Total Minus Wake Loss Coefficients for Rotor A/Stator A, Single-Stage Configuration.

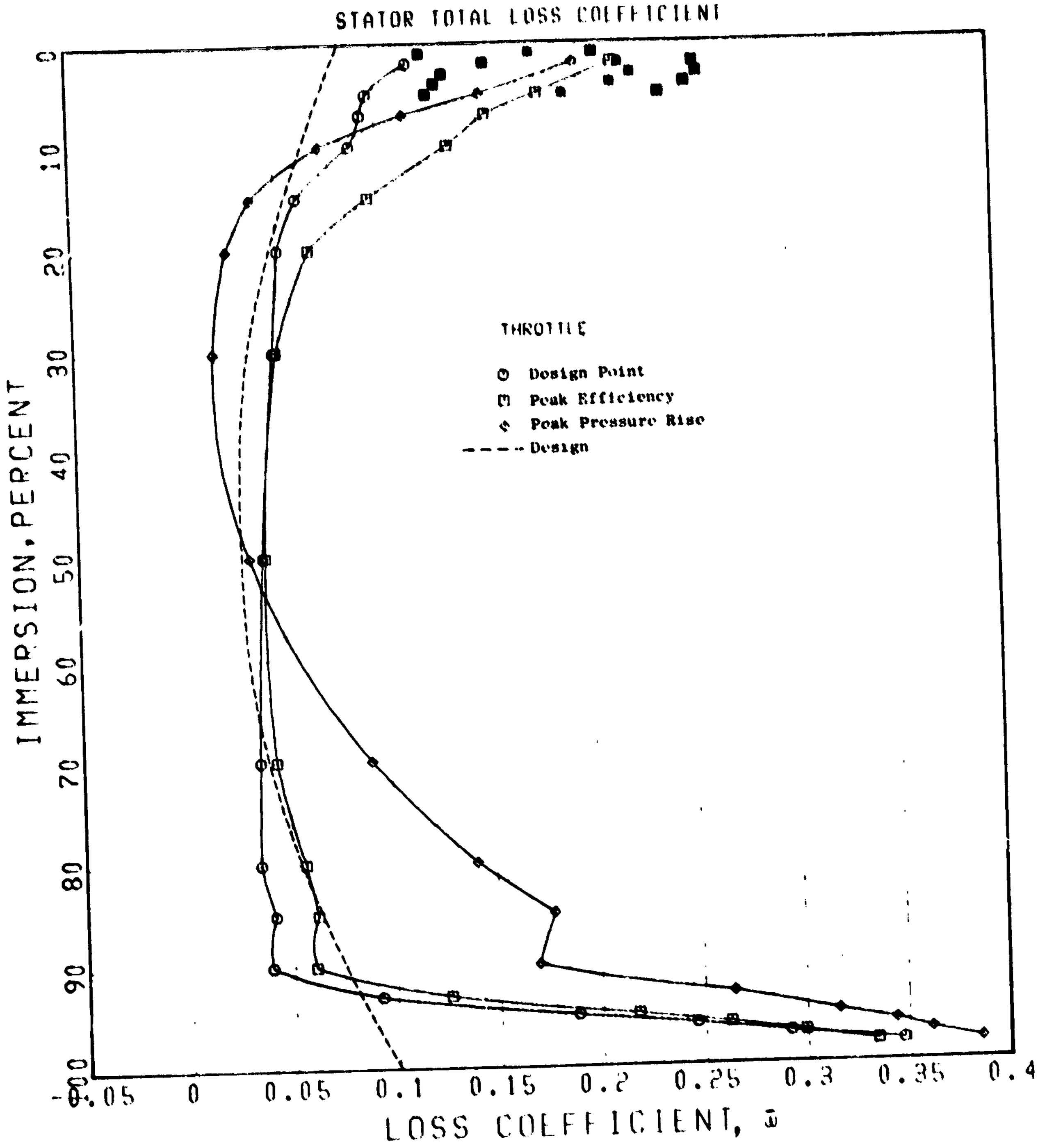


Figure 67. Stator Total Loss Coefficients for Rotor A Stator A Single-Stage Configuration.

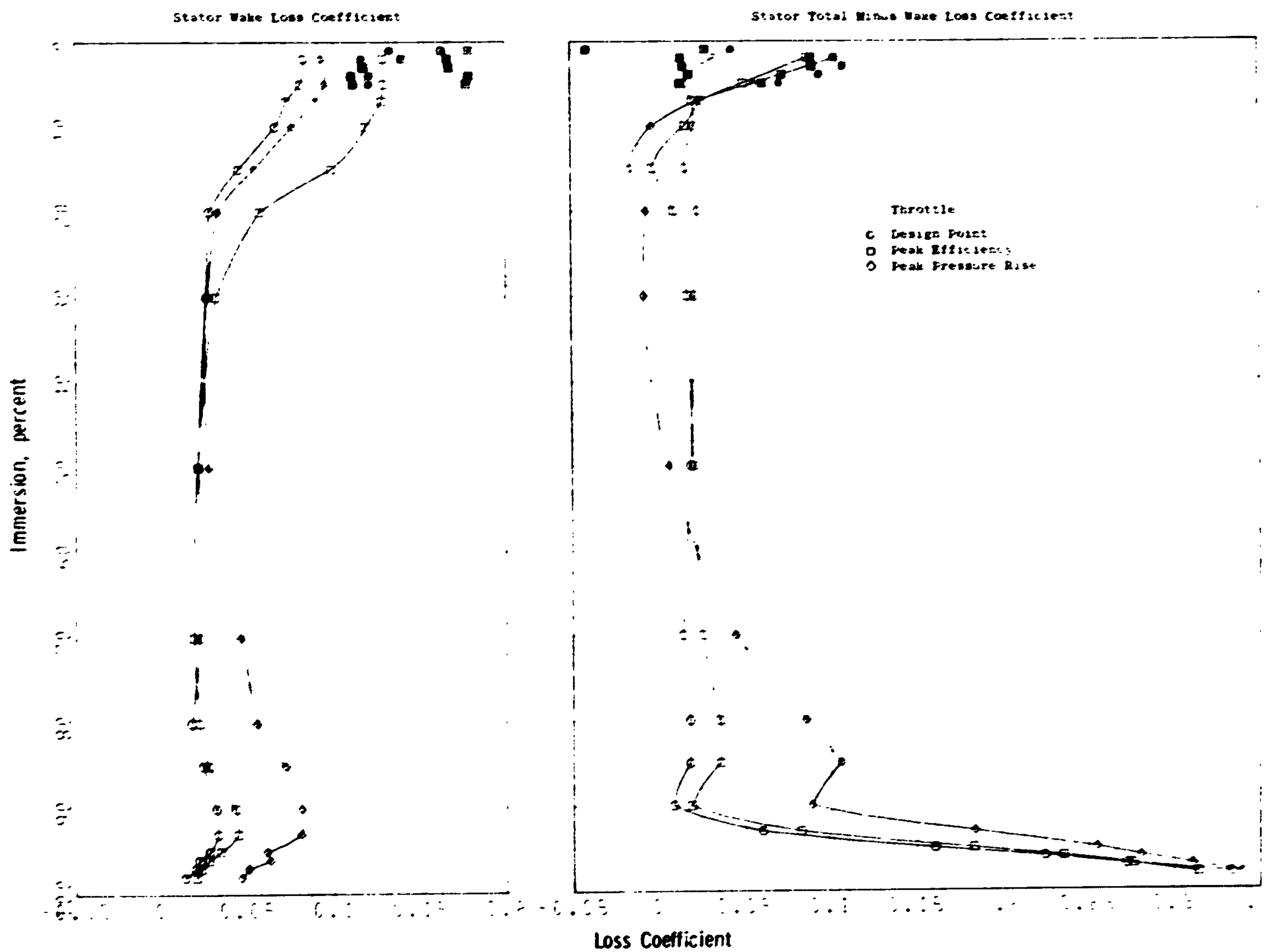


Figure 68. Wake Loss Coefficients and Total Minus Wake Loss Coefficient for Rotor A/Stator A Single-Stage Configuration.

ORIGINAL PAGE IS
OF POOR QUALITY

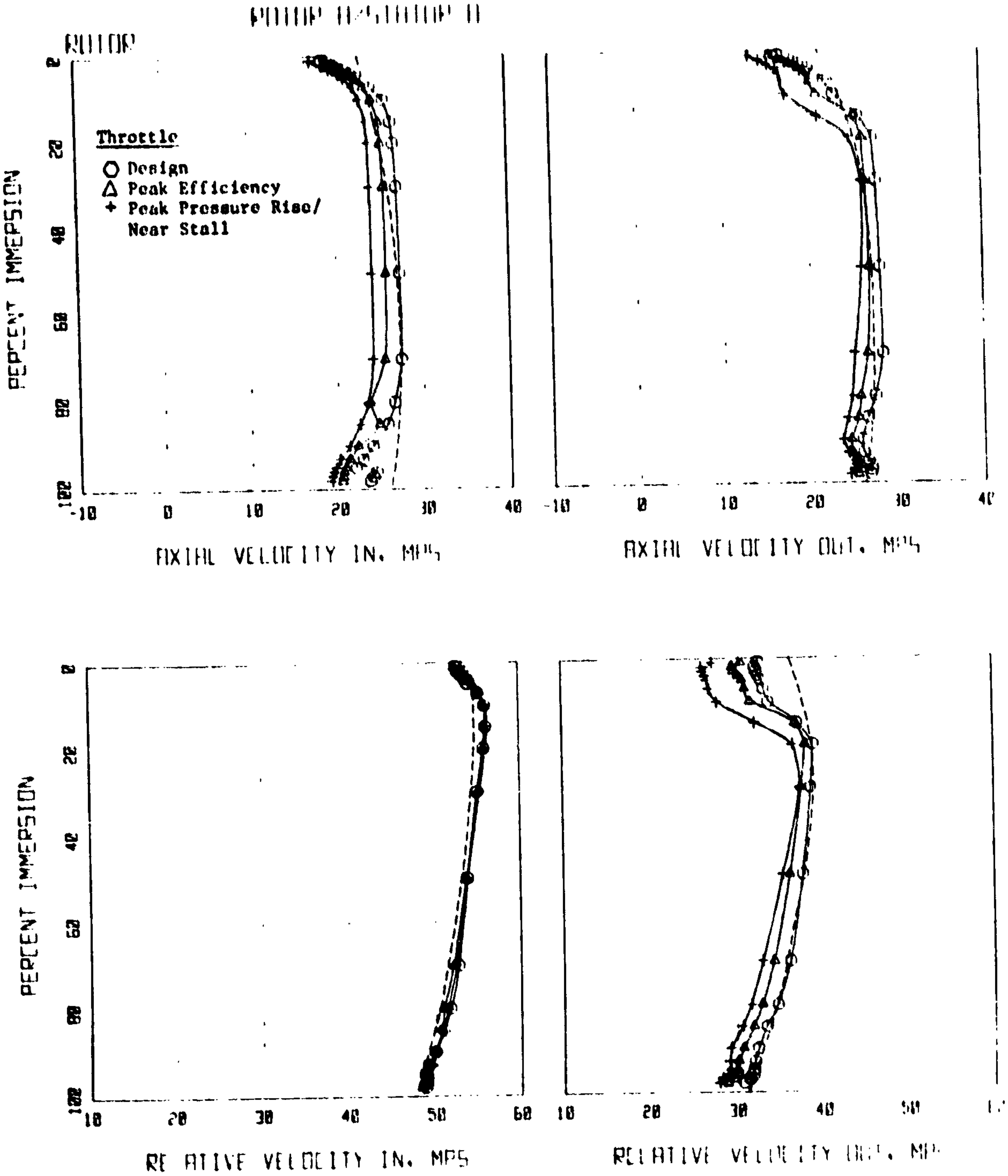


Figure 69. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Single-Stage Configuration.

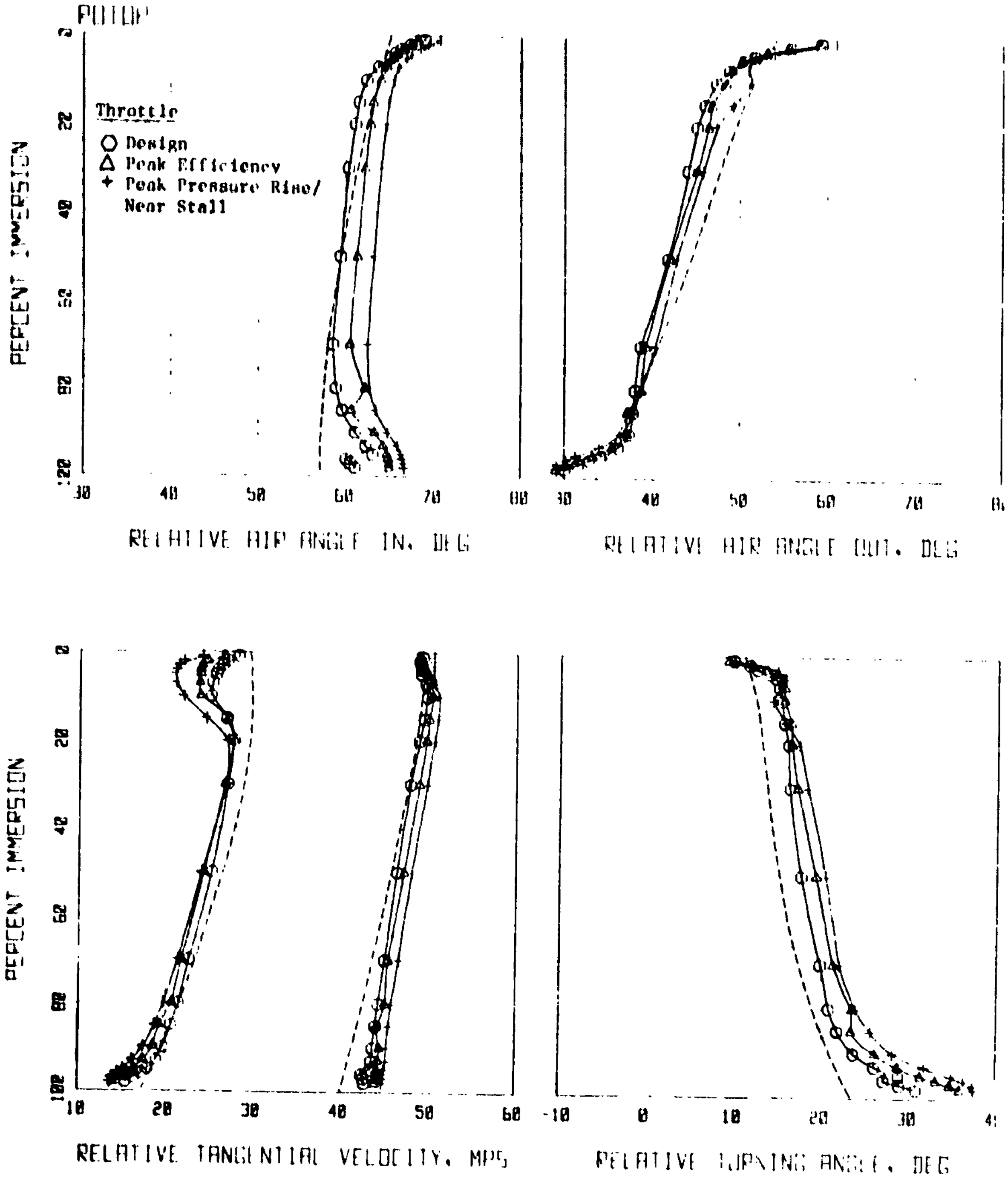
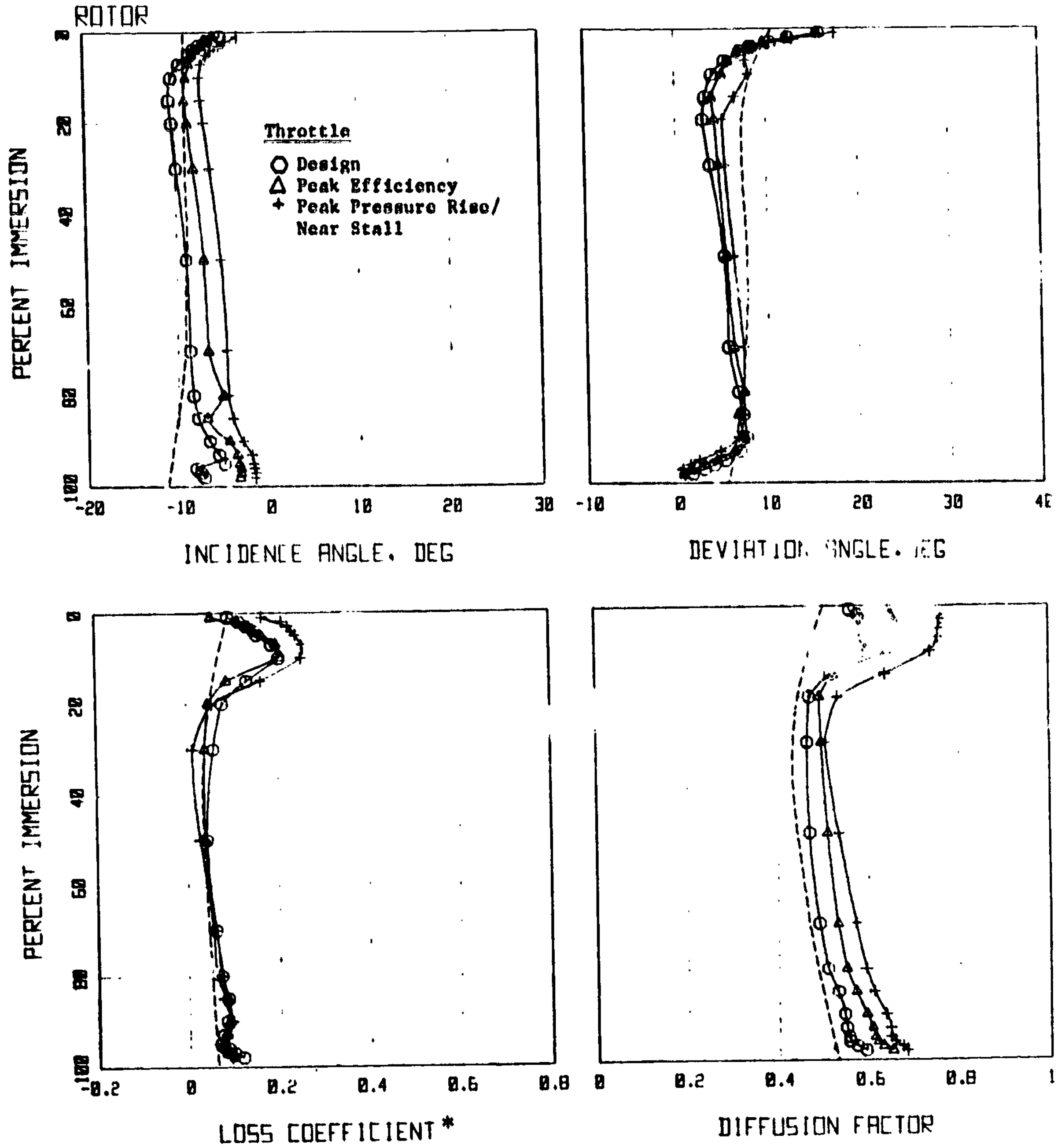


Figure 70. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Single-Stage Configuration.



* See Figure 66 and discussion in Section 4.6.1 for loss coefficients computed from relative total pressure measurements.

Figure 71. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Single-Stage Configuration.

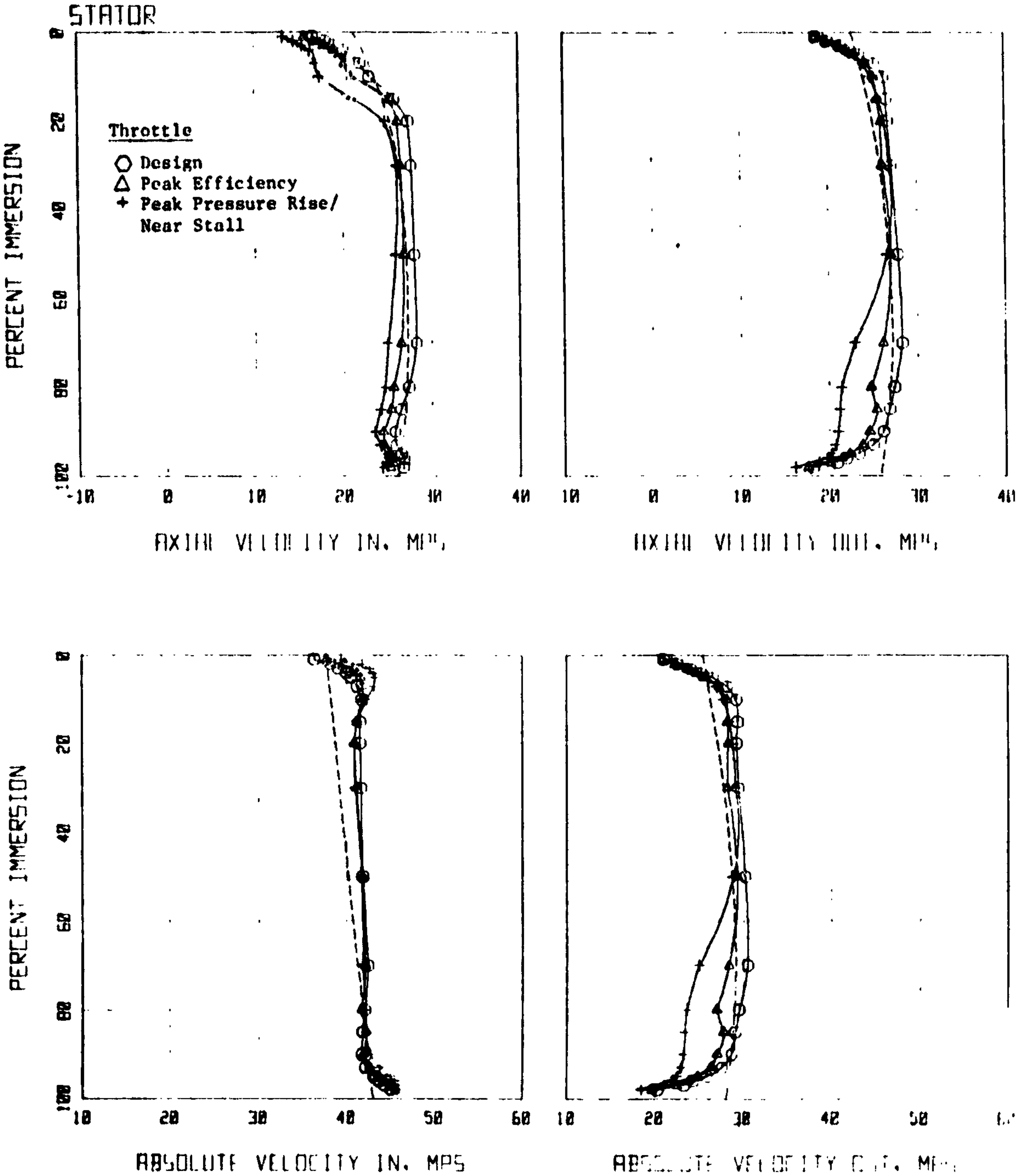


Figure 72. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Single-Stage Configuration.

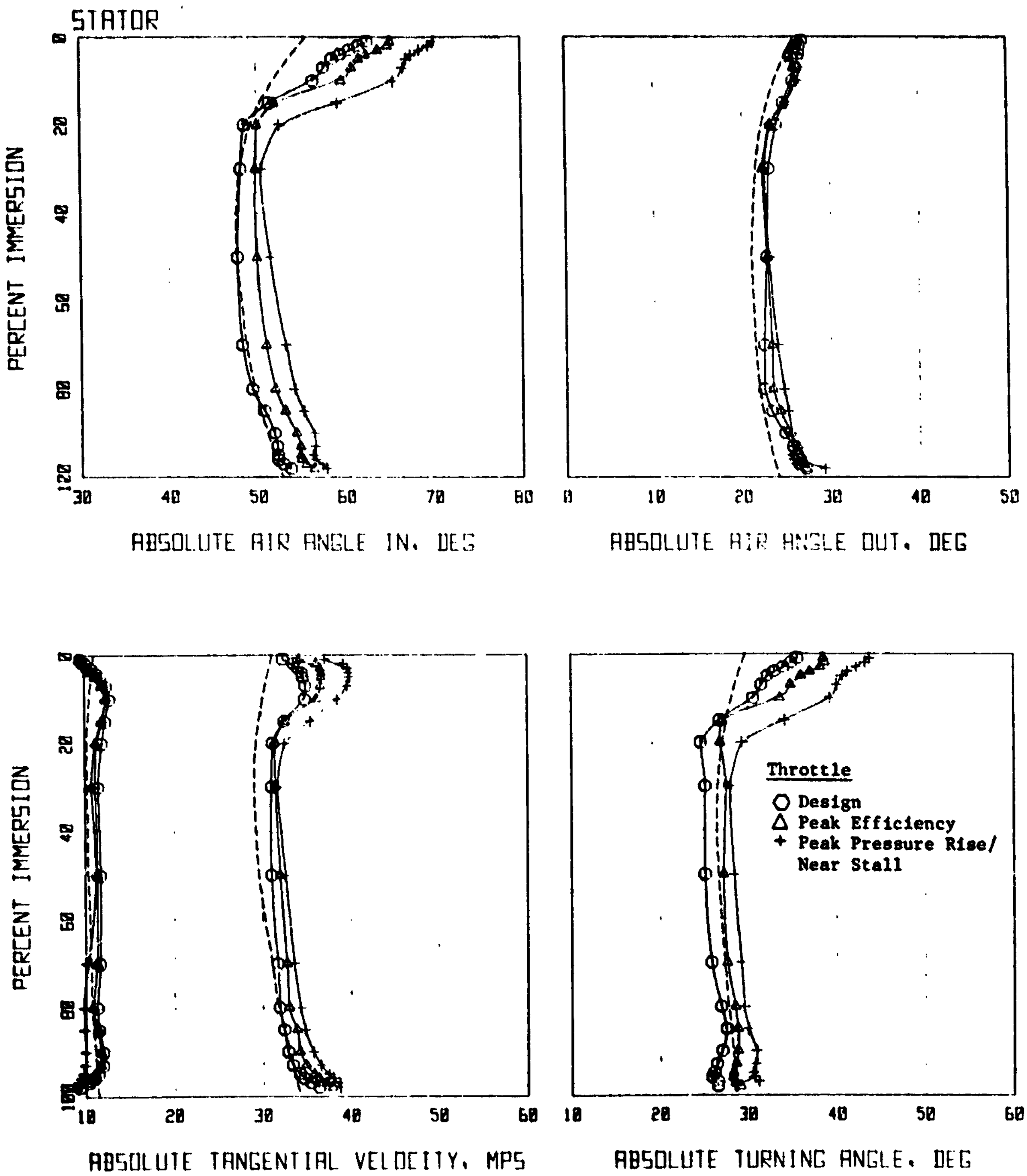


Figure 73. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Single-Stage Configuration.

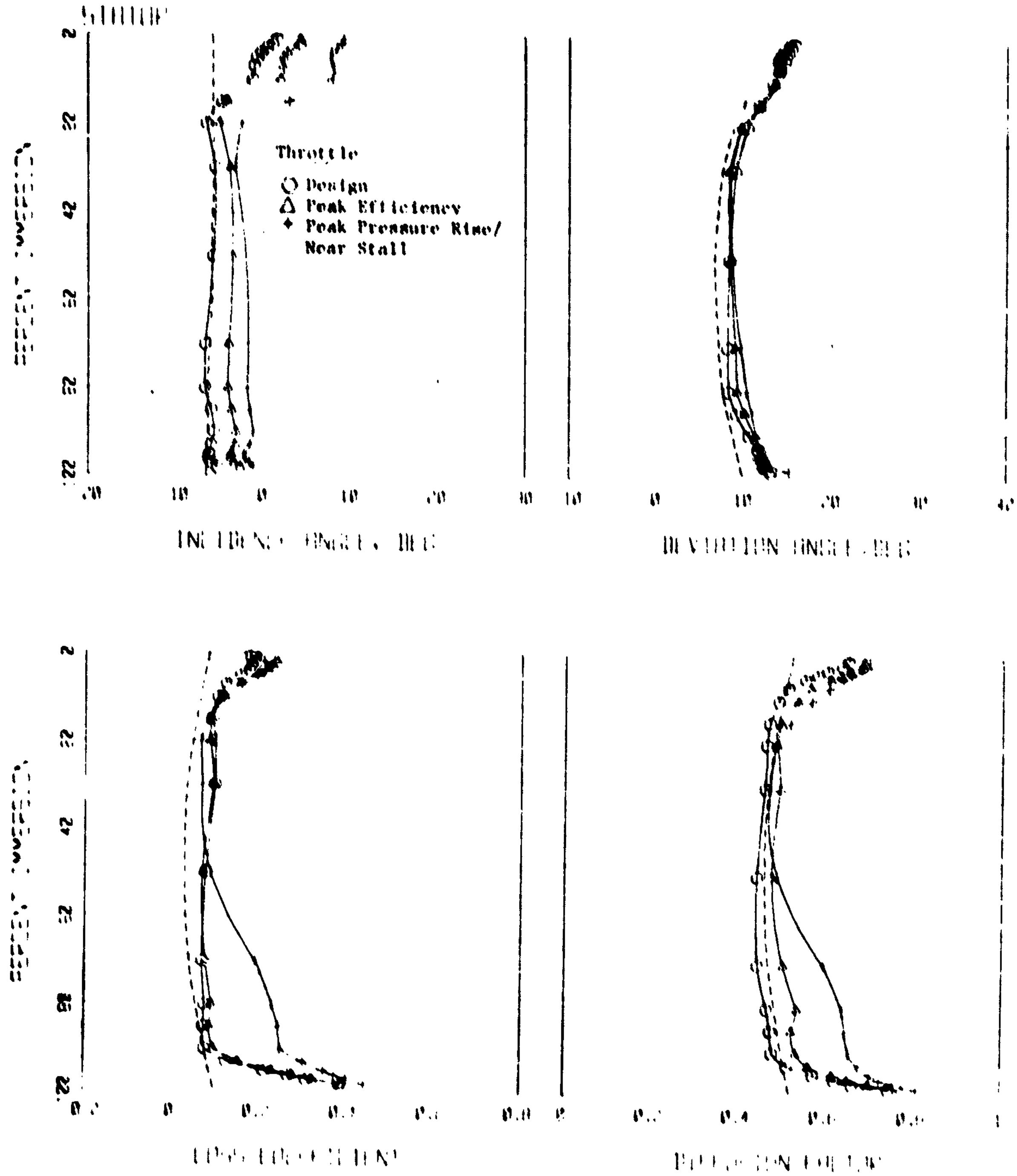


Figure 75. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Single-Stage Configuration.

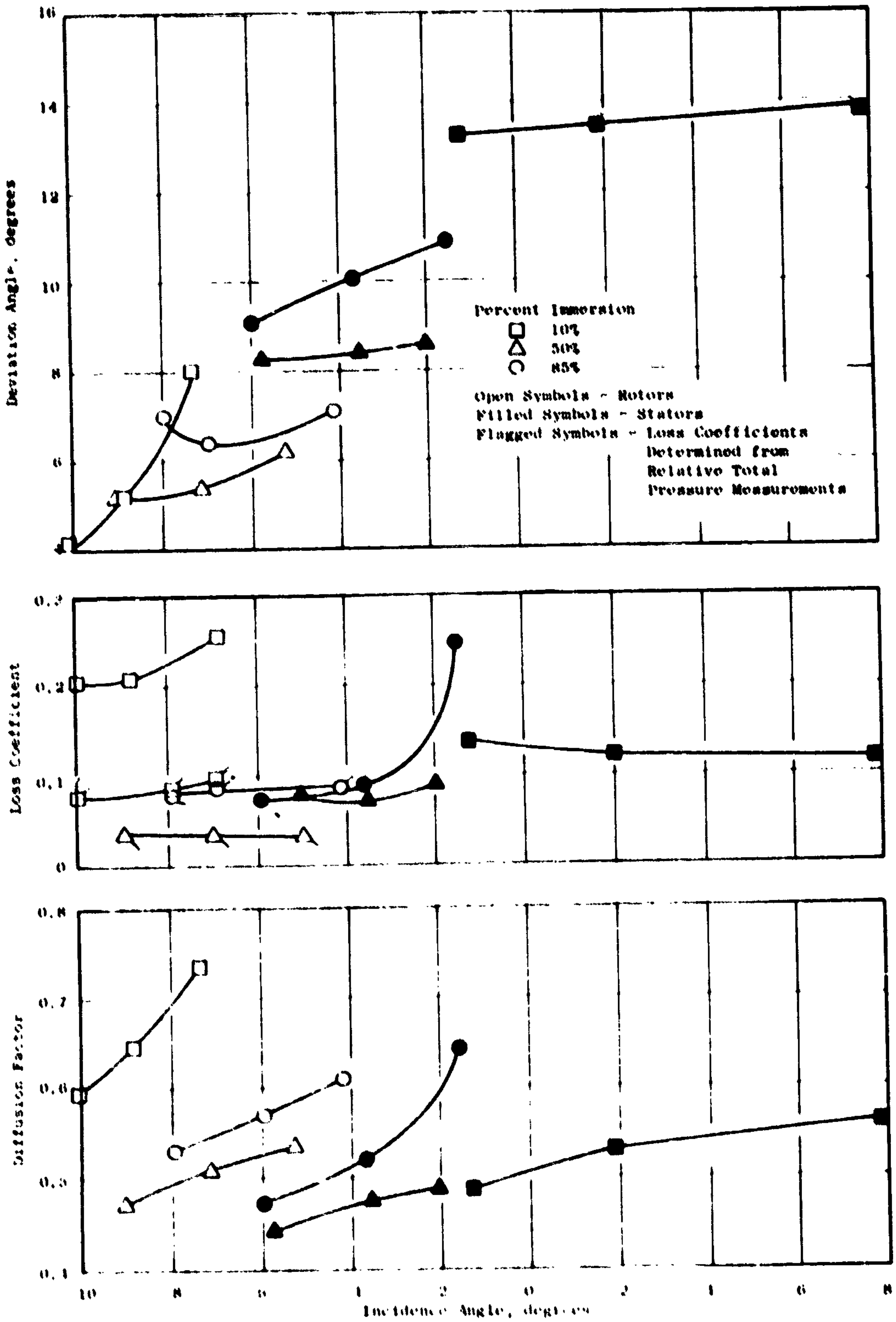


Figure 75. Diffusion Factor, Loss Coefficient and Deviation Angle Versus Incidence Angle, Rotor A Stator A Single-Stage Configuration.

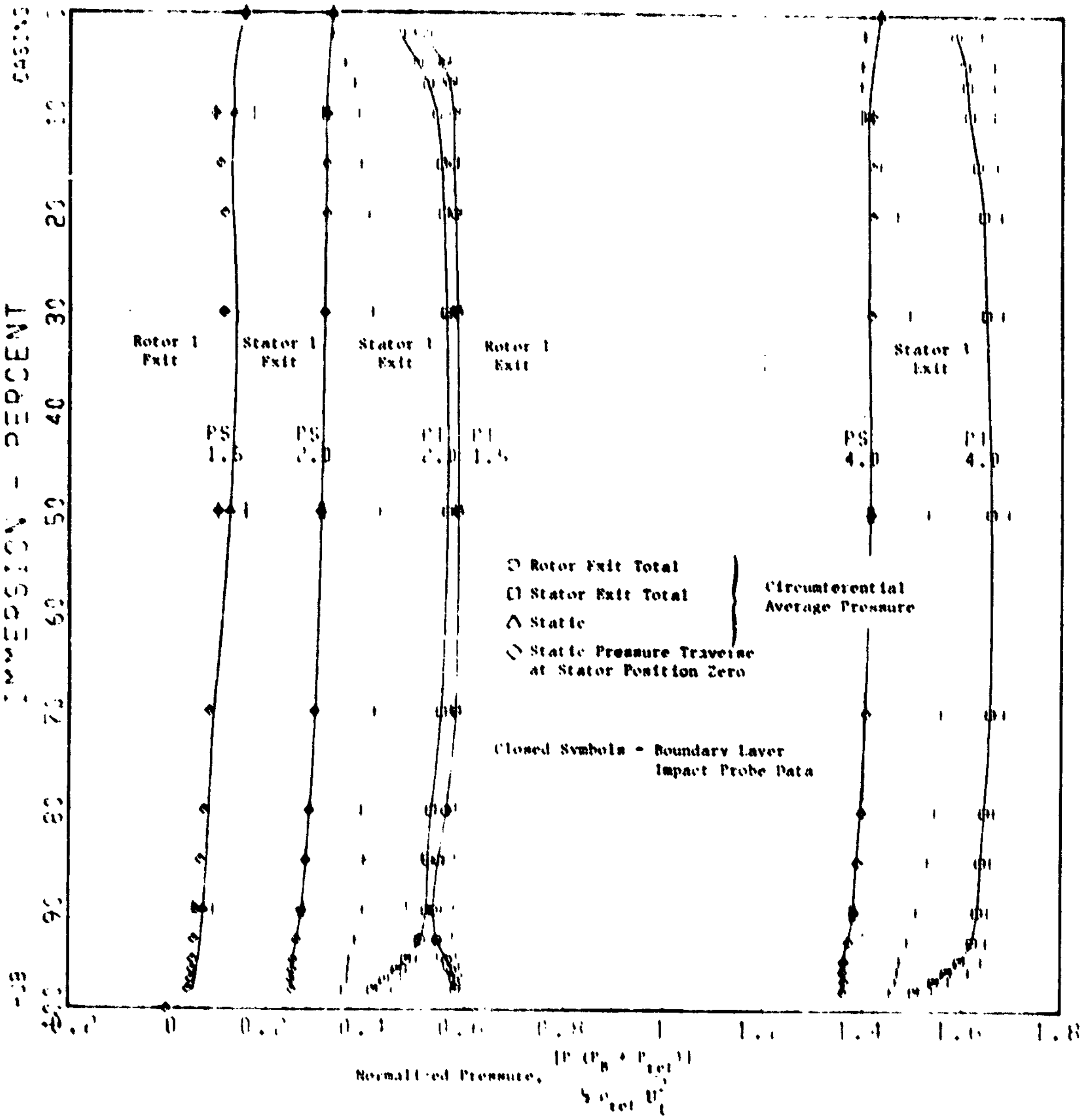


Figure 76. Normalized Absolute Total Pressures and Static Pressures for Rotor A Stator A Four-Stage Configuration, First Stage Tested, Design Point Throttle.

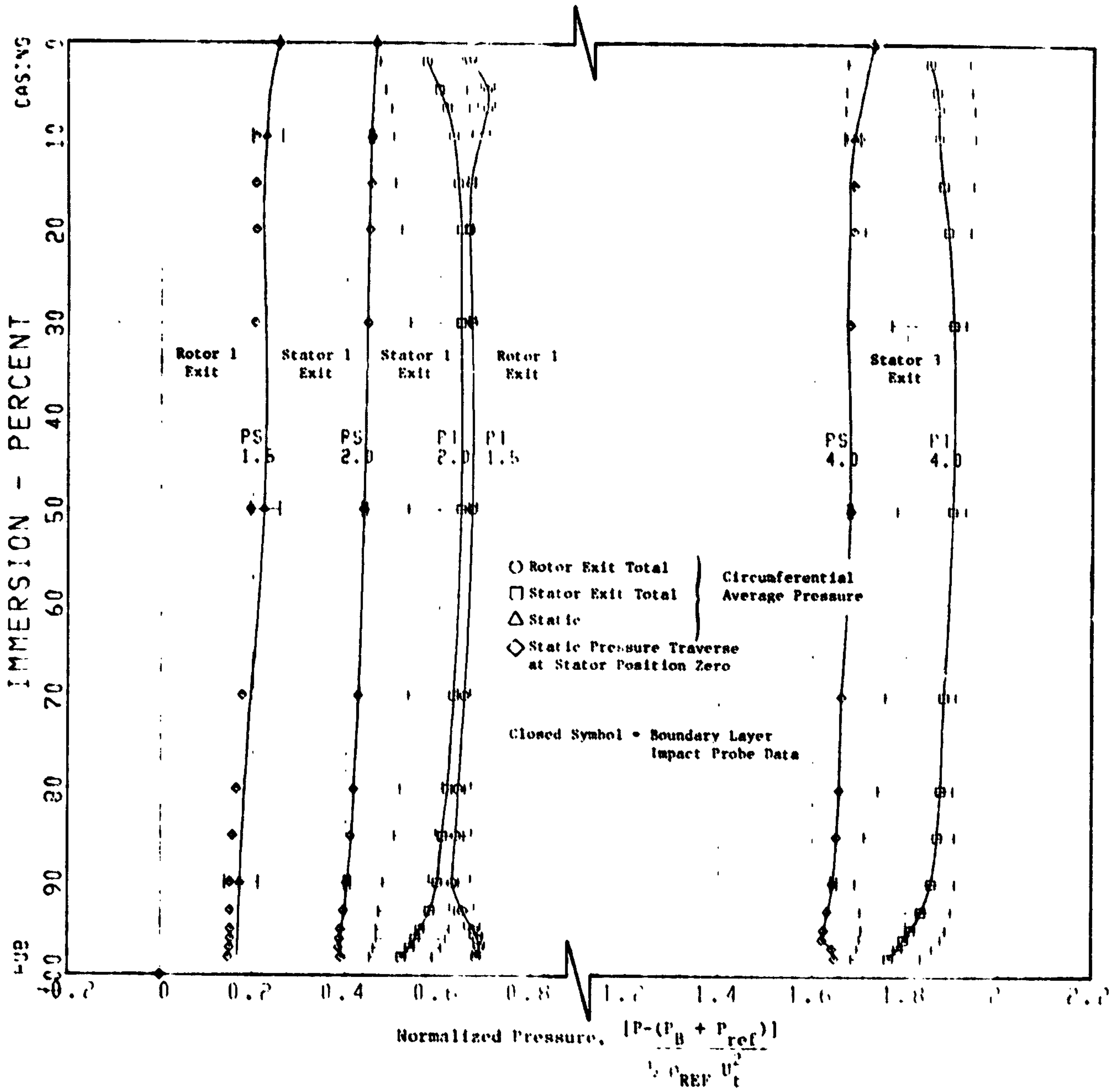


Figure 77. Normalized Absolute Total Pressures and Static Pressures for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Peak Efficiency Throttle.

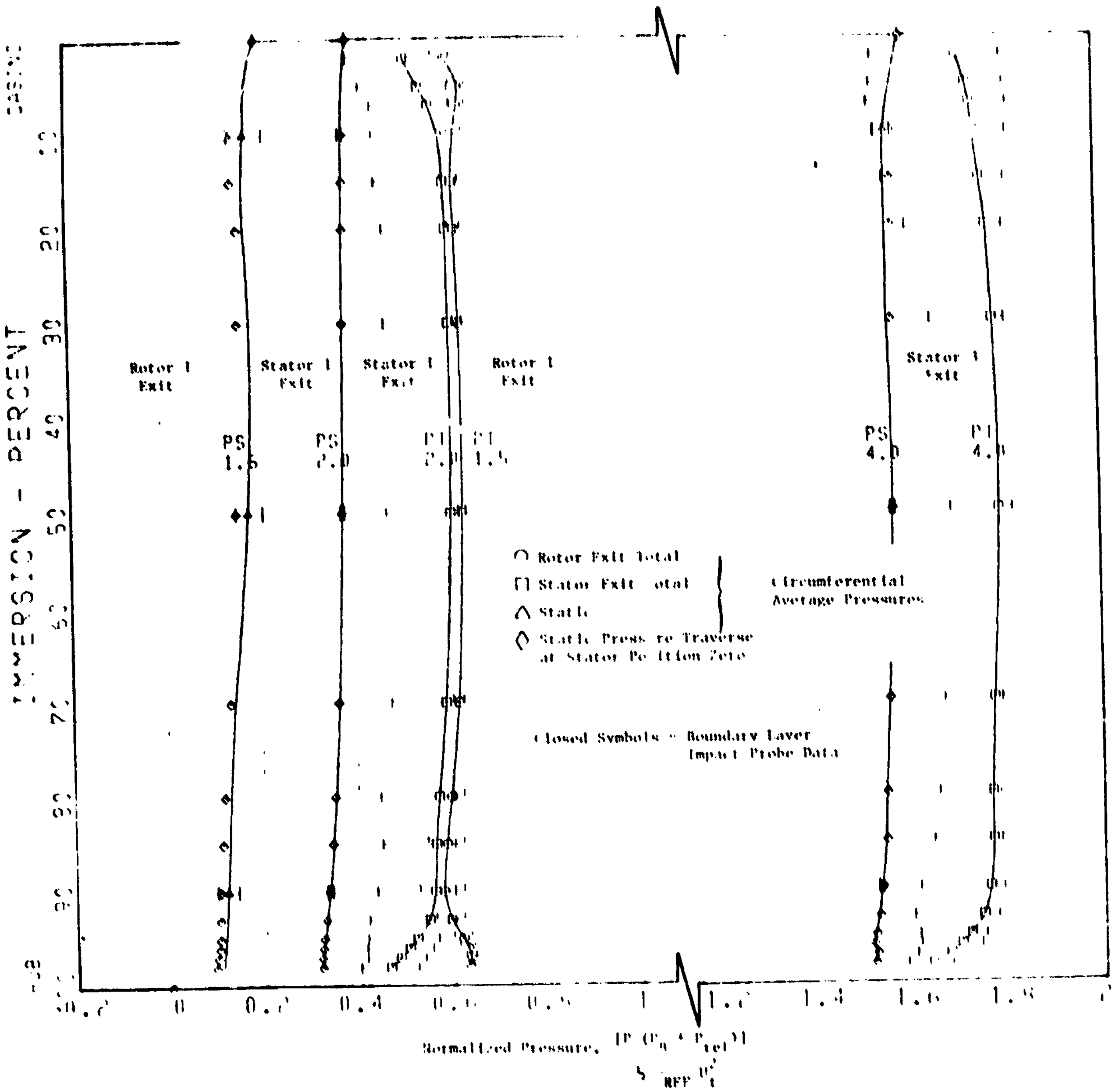


Figure 78. Normalized Absolute Total Pressures and Static Pressures for Rotor A/ Stator A Four-Stage Configuration, First Stage Tested, Peak Pressure Rise and Near Stall Throttle.

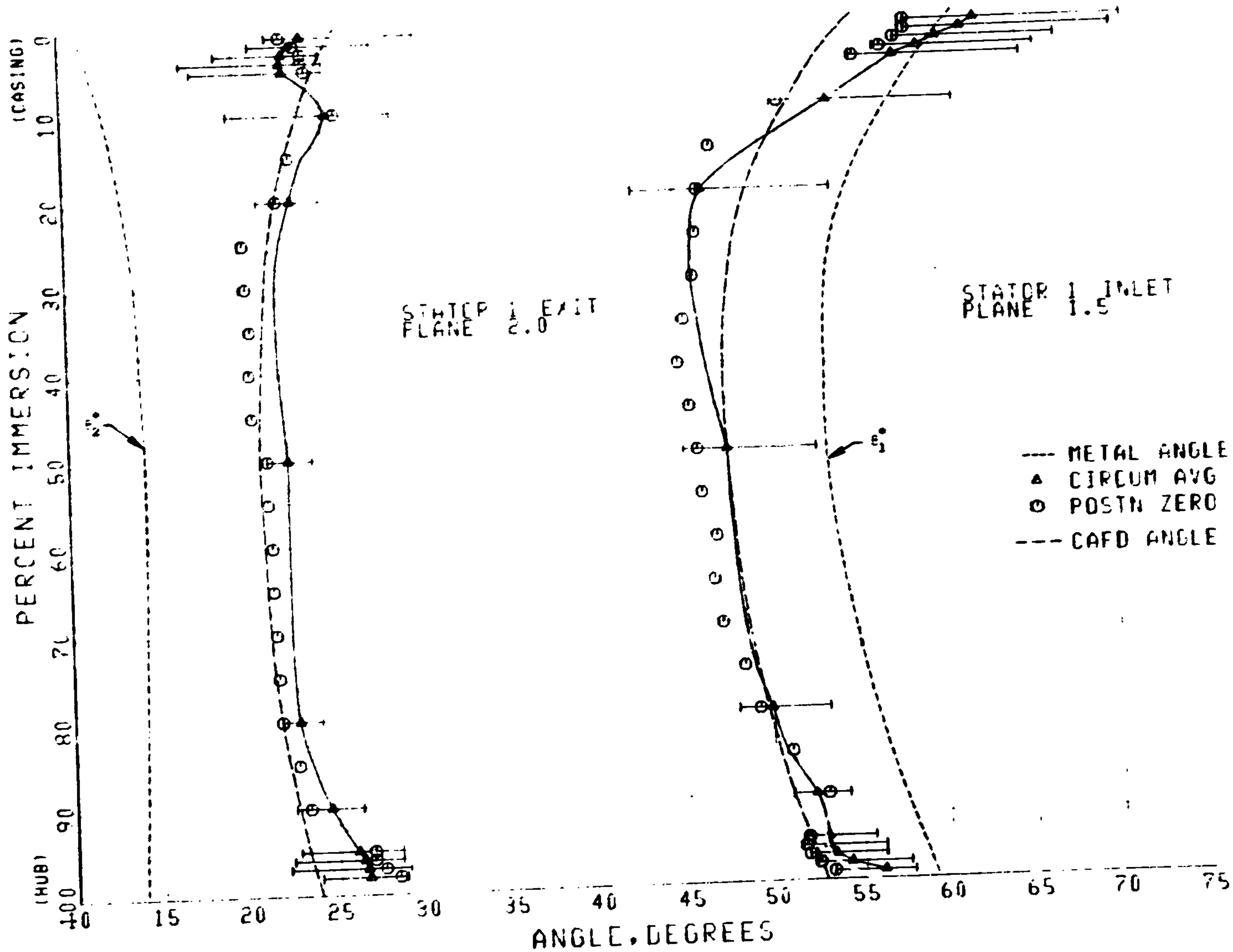


Figure 79. Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Design Point Throttle.

ORIGINAL PAGE IS
OF POOR QUALITY

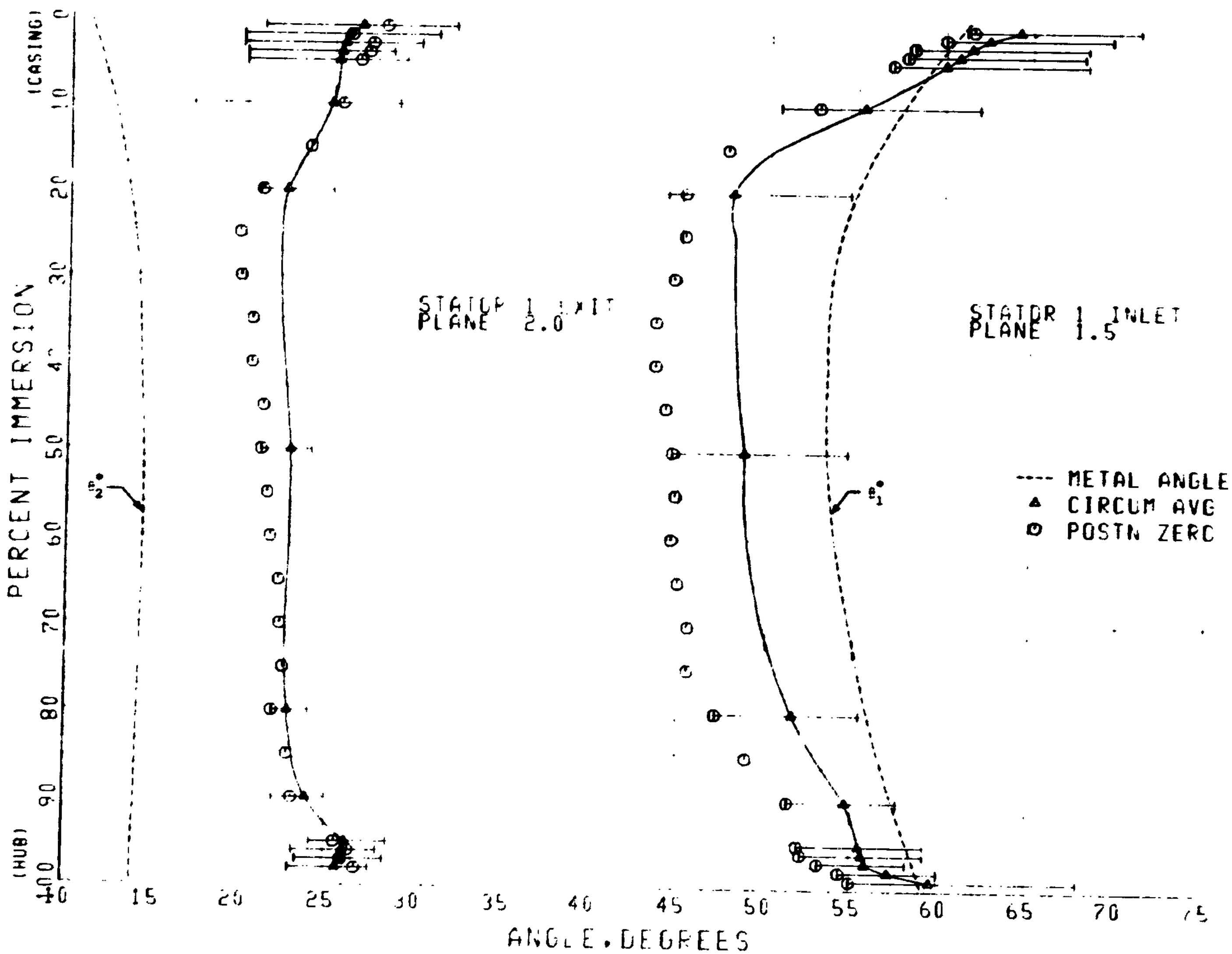


Figure 80. Absolute Flow Angles for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Peak Efficiency Throttle.

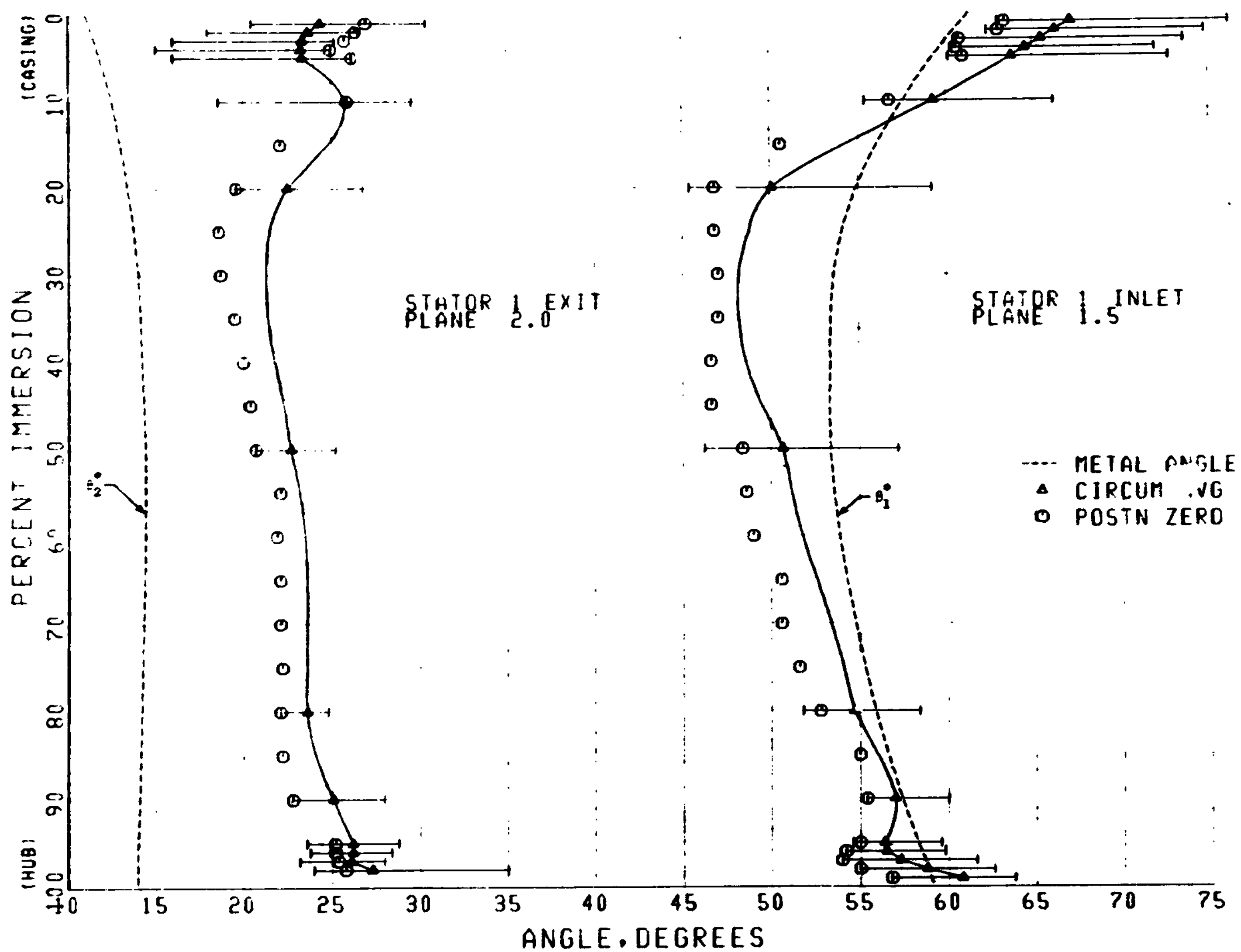


Figure 81. Absolute Air Angle for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Peak Pressure Rise and Near Stall Throttle.

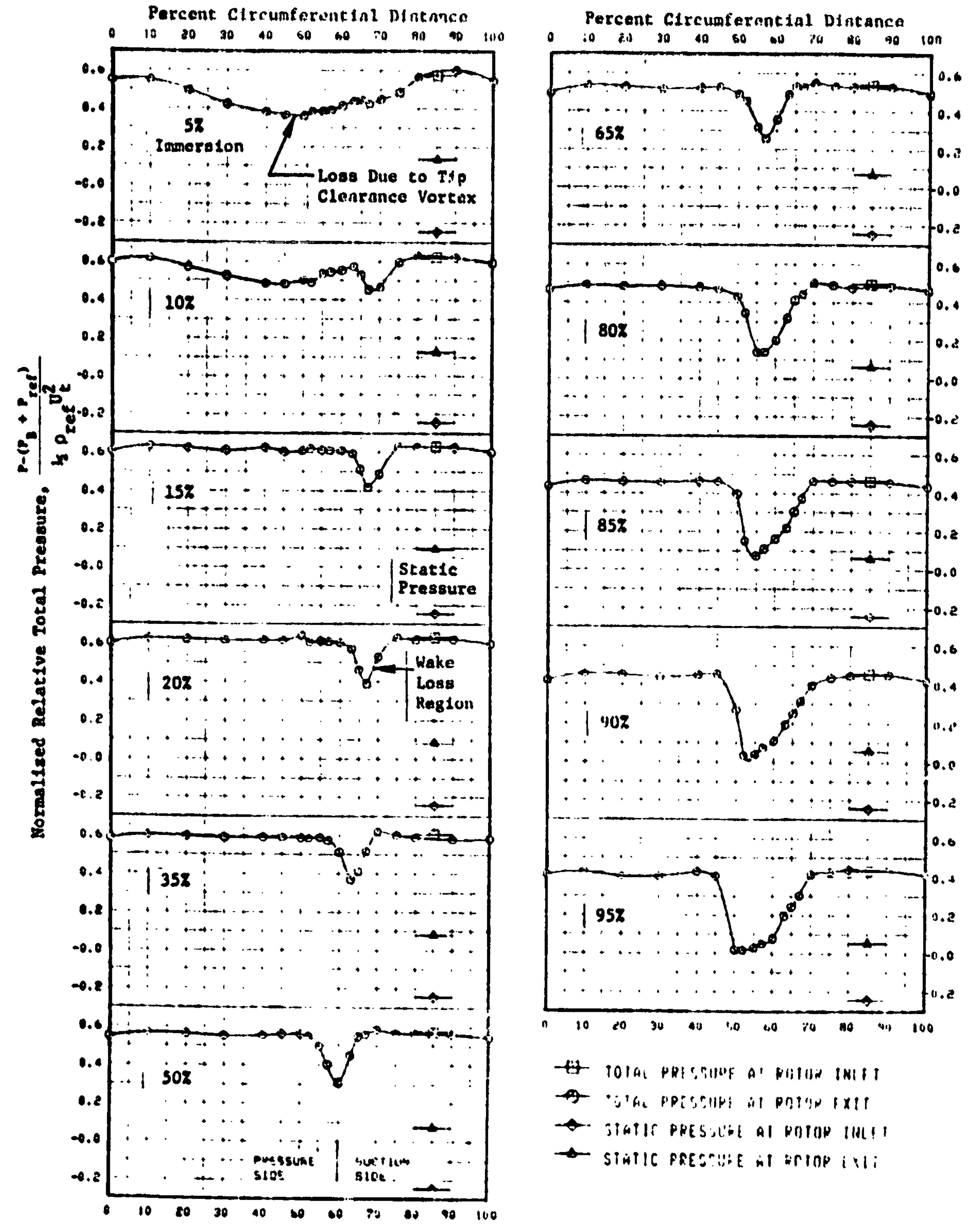


Figure 82. Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, First Stage Tested, Design Point Throttle.

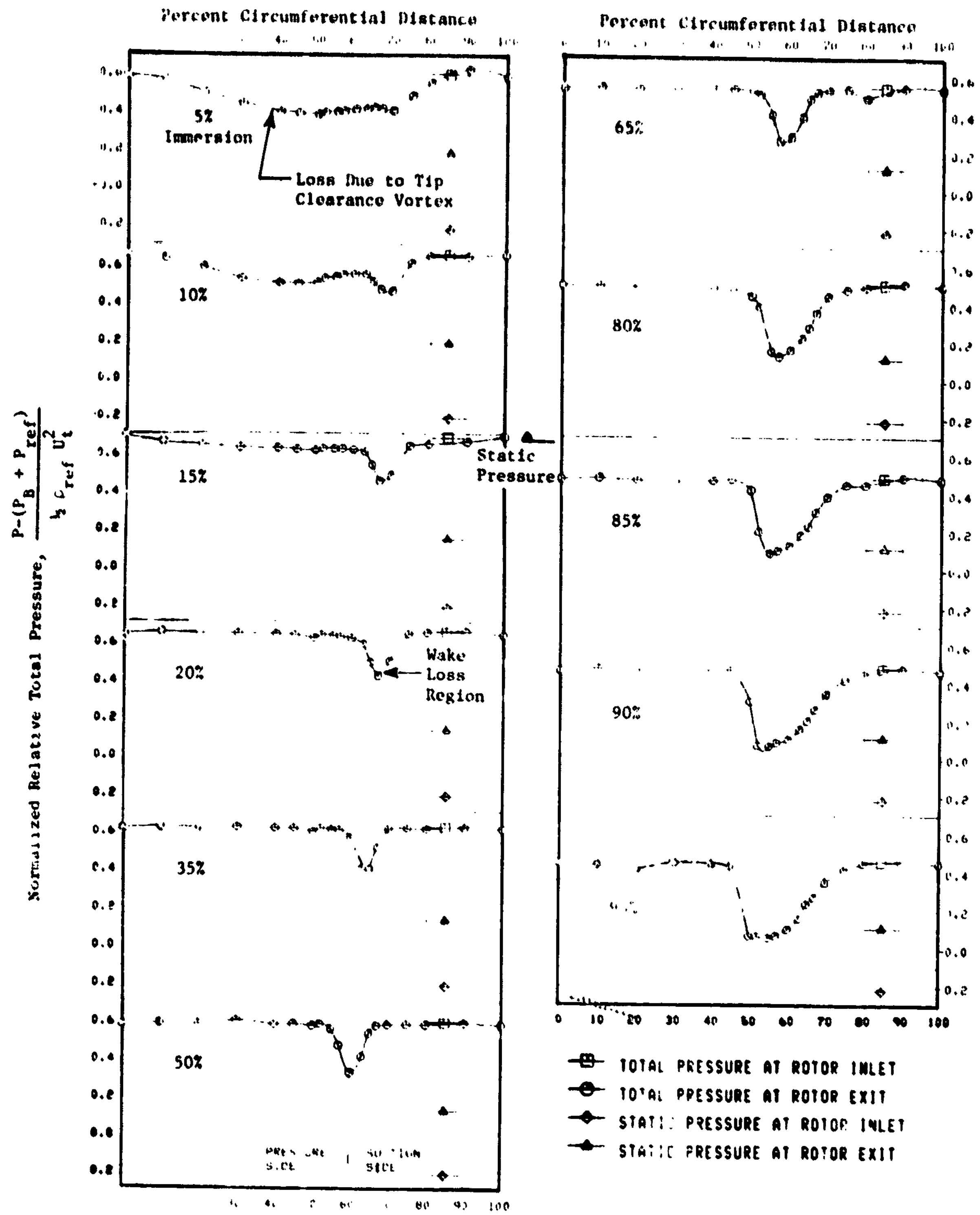


Figure 83. Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, First Stage Tested, Peak Efficiency Throttle.

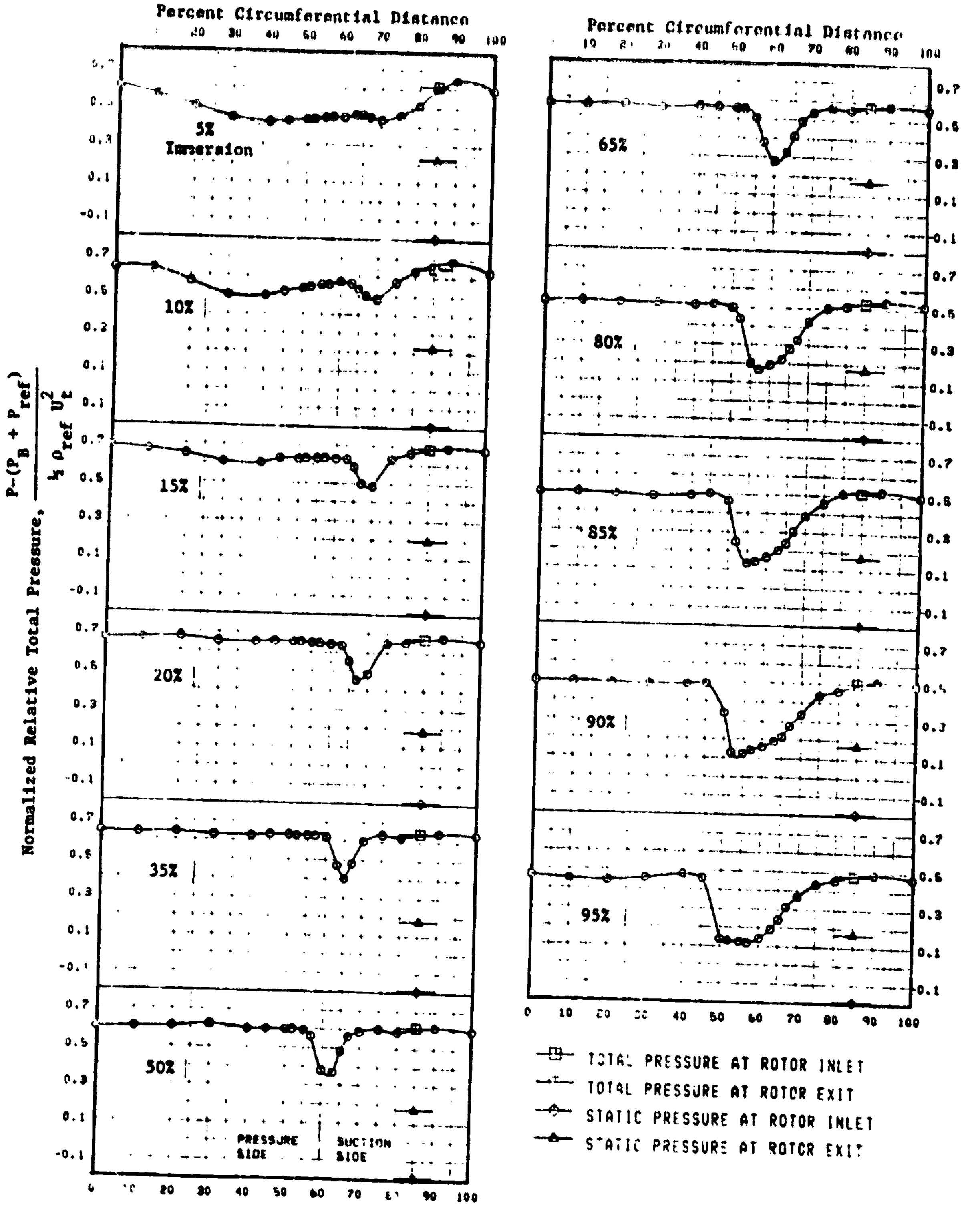


Figure 84. Circumferential Variation of Normalized Relative Total Pressure at Rotor Exit, Four-Stage Configuration, First Stage Tested, Near Stall Throttle.

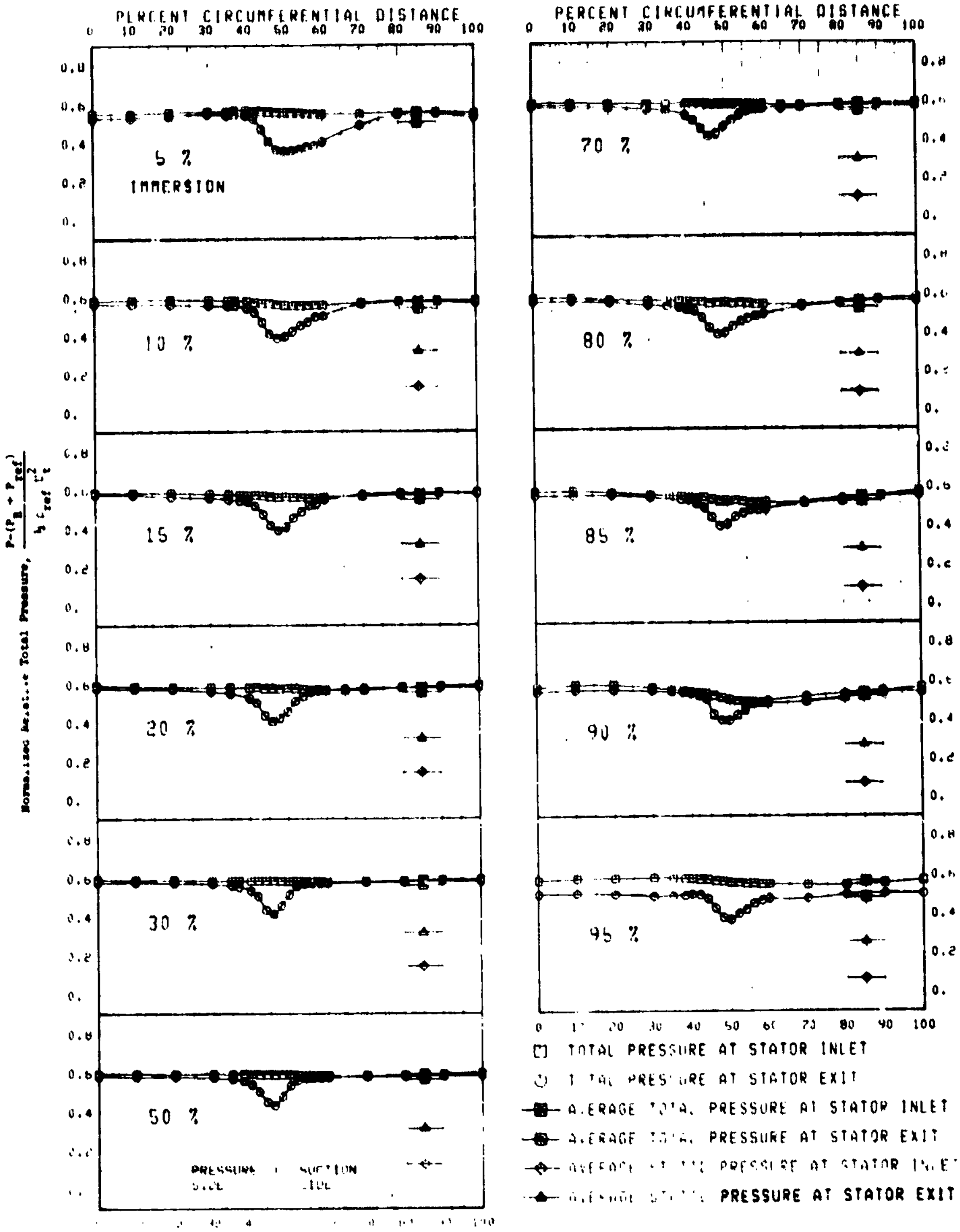


Figure 85. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, First Stage Tested, Design Point Throttle.

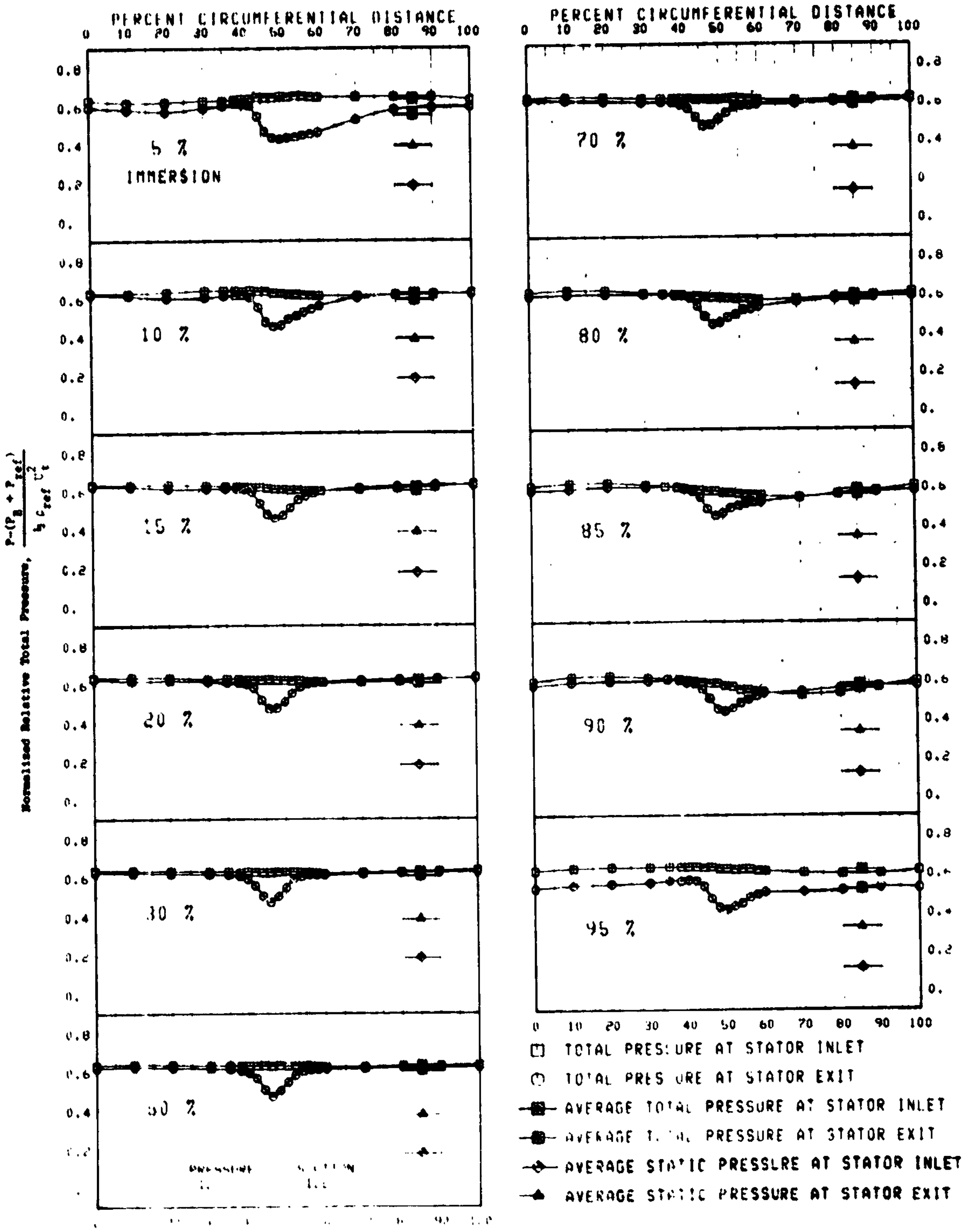


Figure 86. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four-Stage Configuration, First Stage Tested, Peak Efficiency Throttle.

ORIGINAL PAGE IS OF POOR QUALITY

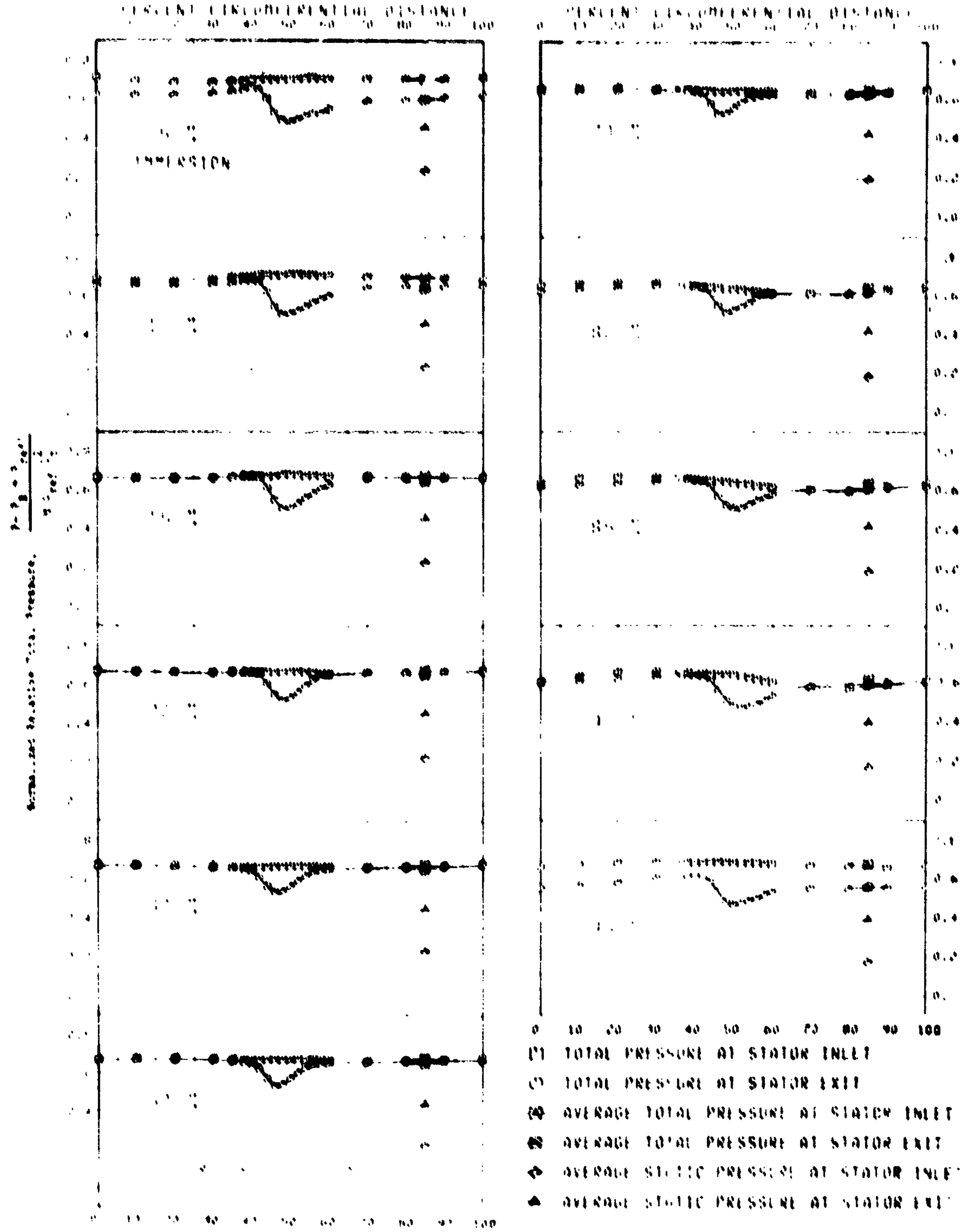


Figure 87. Circumferential Variation of Normalized Absolute Total Pressure and Static Pressure, Four Stage Configuration First Stage Tested, Peak Pressure Rise Near Stall Throttle.

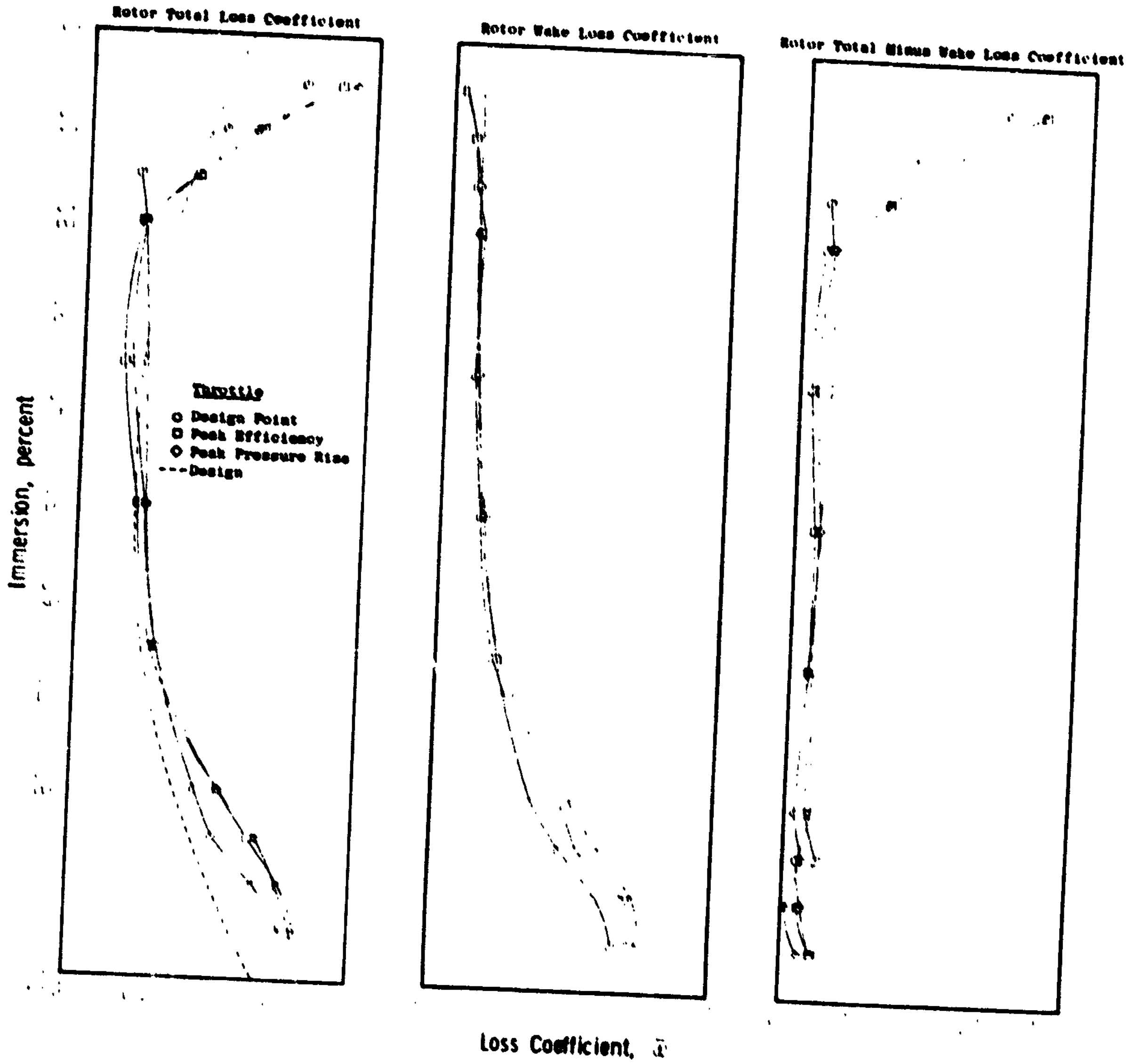


Figure 88. Rotor Total Loss Coefficients, Wake Loss Coefficients, and Total Minus Wake Loss Coefficients for Rotor A/Stator A, Four Stage Configuration, First Stage Tested.

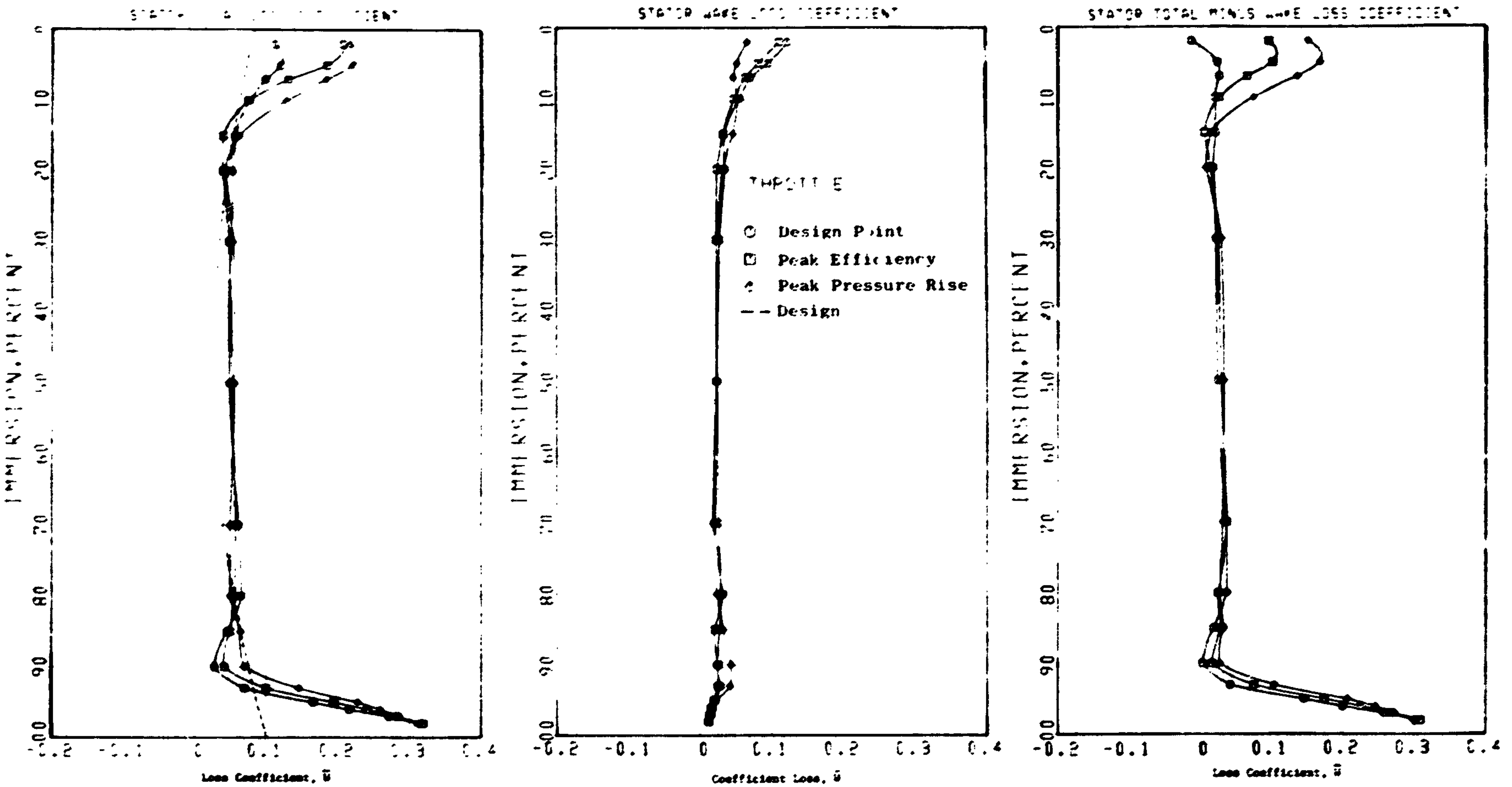


Figure 89. Stator Total Loss Coefficients, Wake Loss Coefficients, and Total Minus Wake Loss Coefficients for Rotor A/Stator A, Four-Stage Configuration, First Stage Tested.

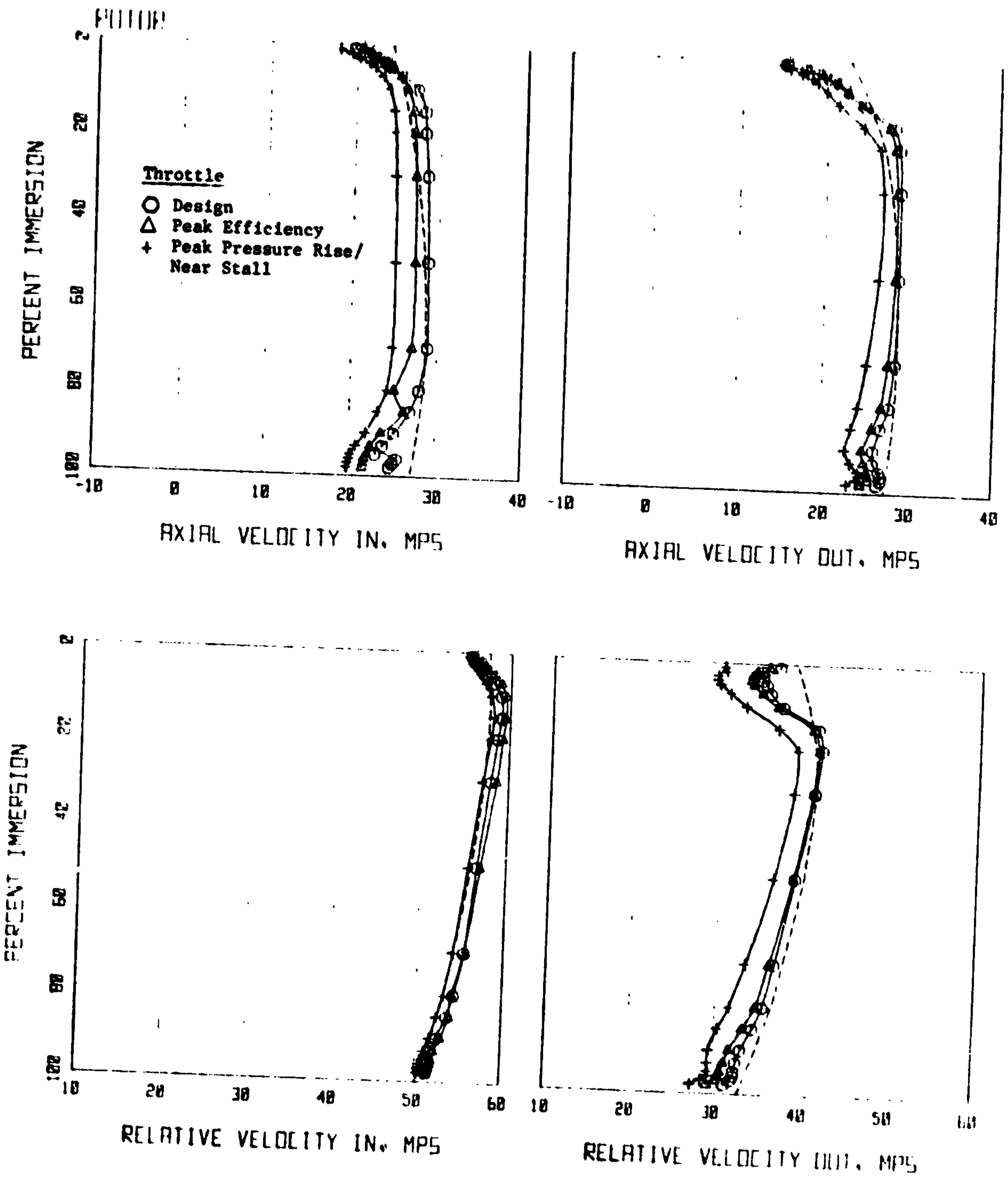


Figure 90. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Four-Stage Configuration, First Stage Tested.

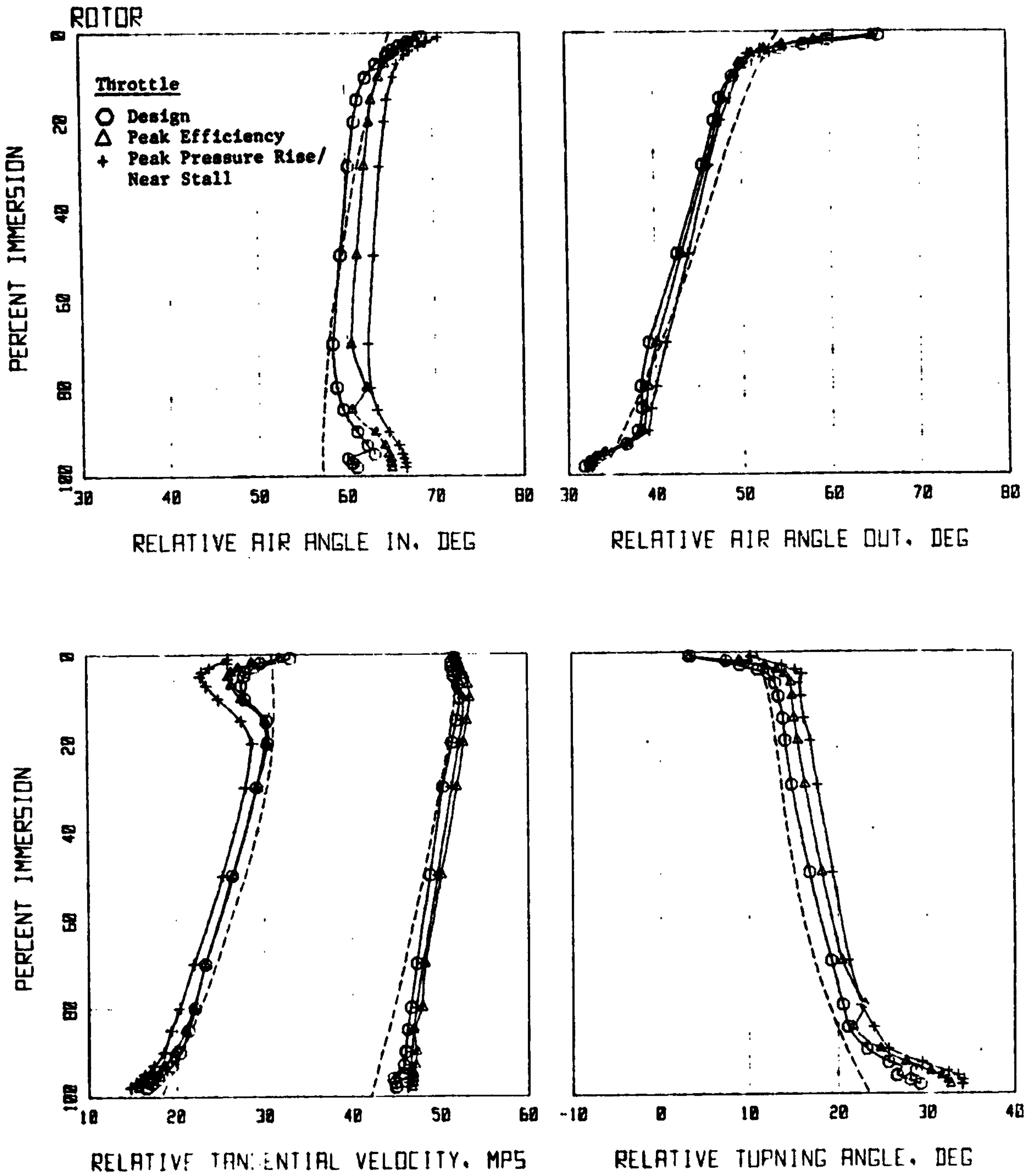
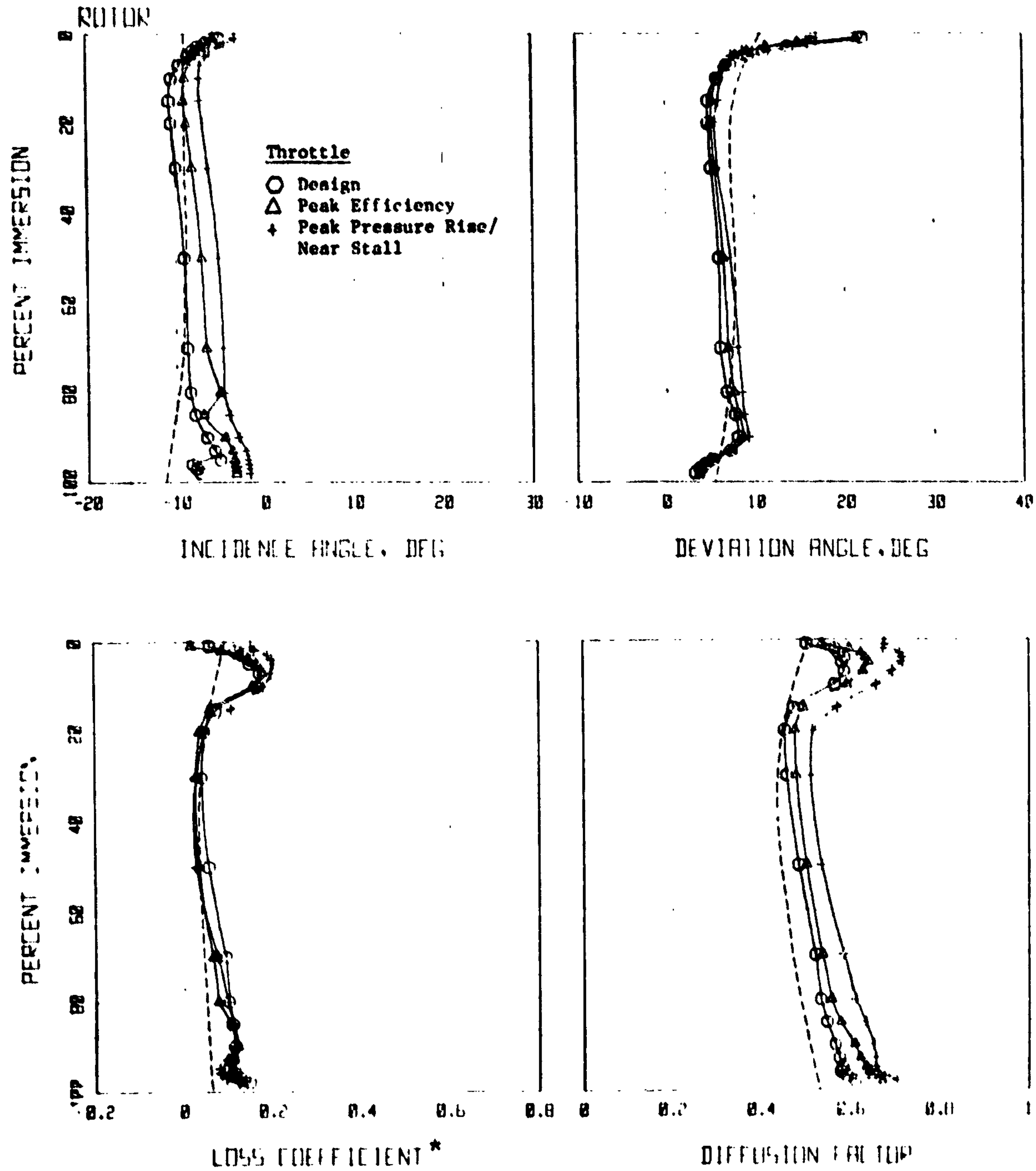


Figure 91. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Four-Stage Configuration, First Stage Tested.



* See Figure 88 and discussion in Section 4.6.1 for loss coefficients computed from relative total pressure measurements.

Figure 92. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Four-Stage Configuration, First Stage Tested.

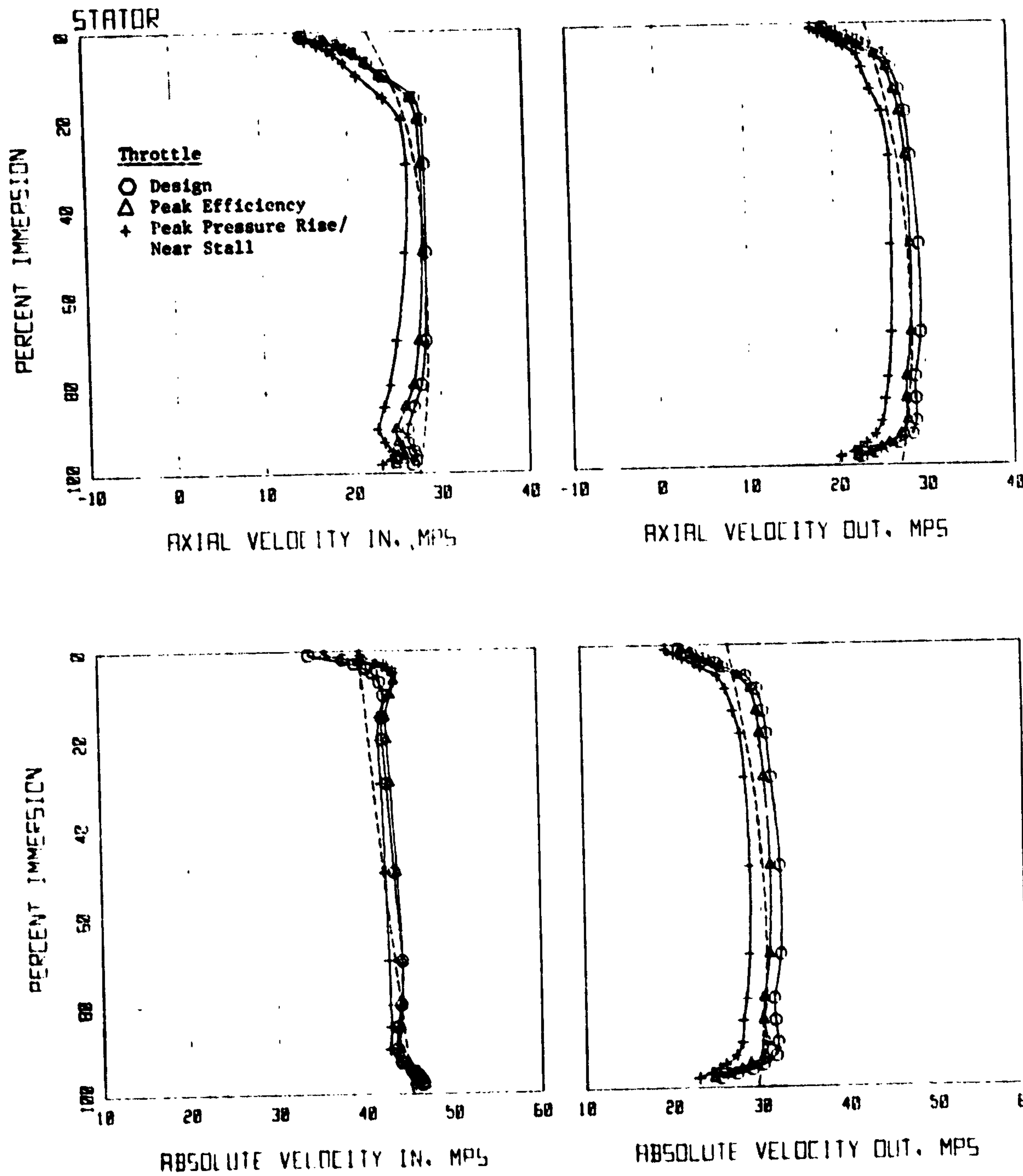


Figure 93. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Four-Stage Configuration, First Stage Tested.

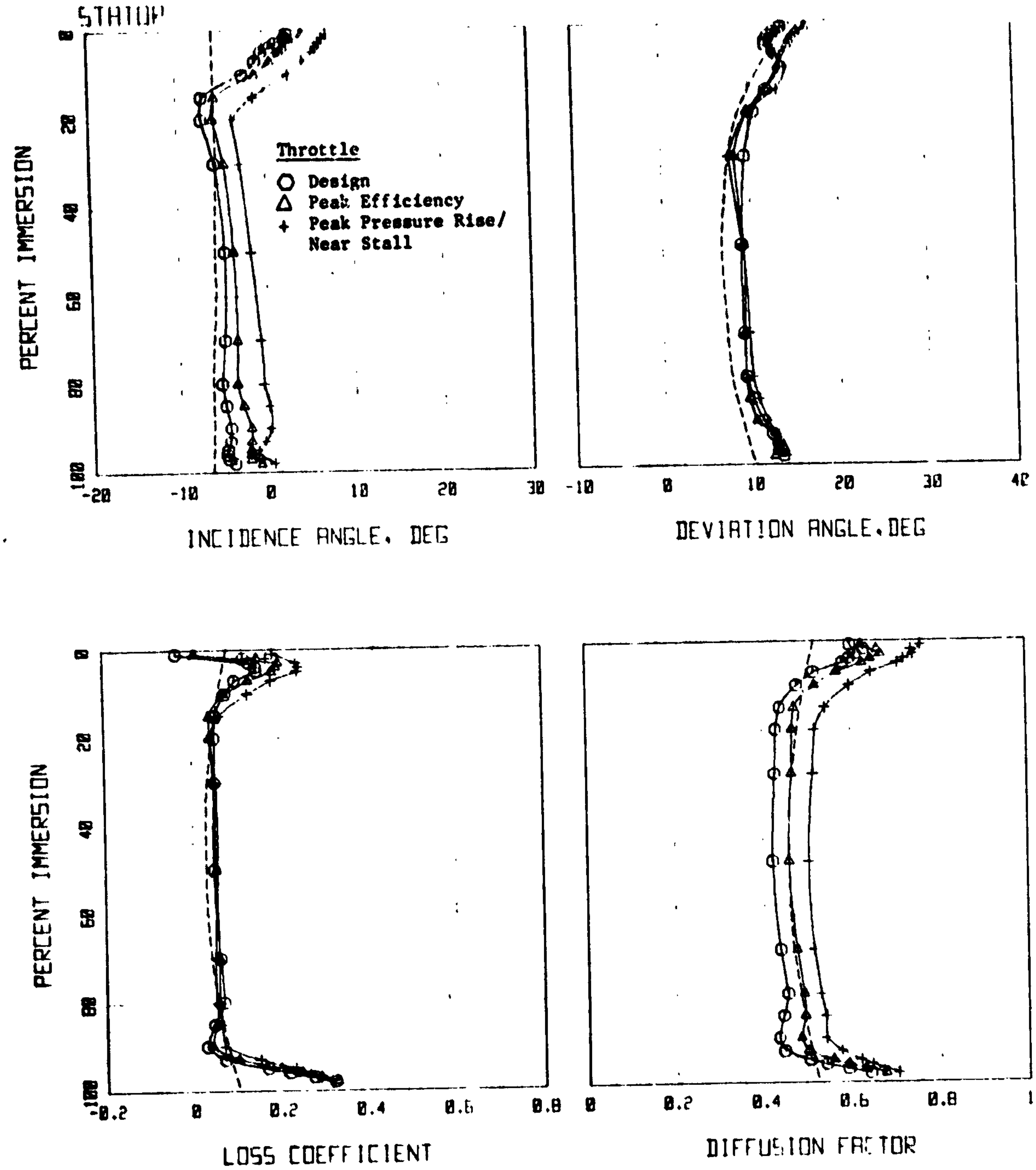


Figure 94. **Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Four-Stage Configuration, First Stage Tested.**

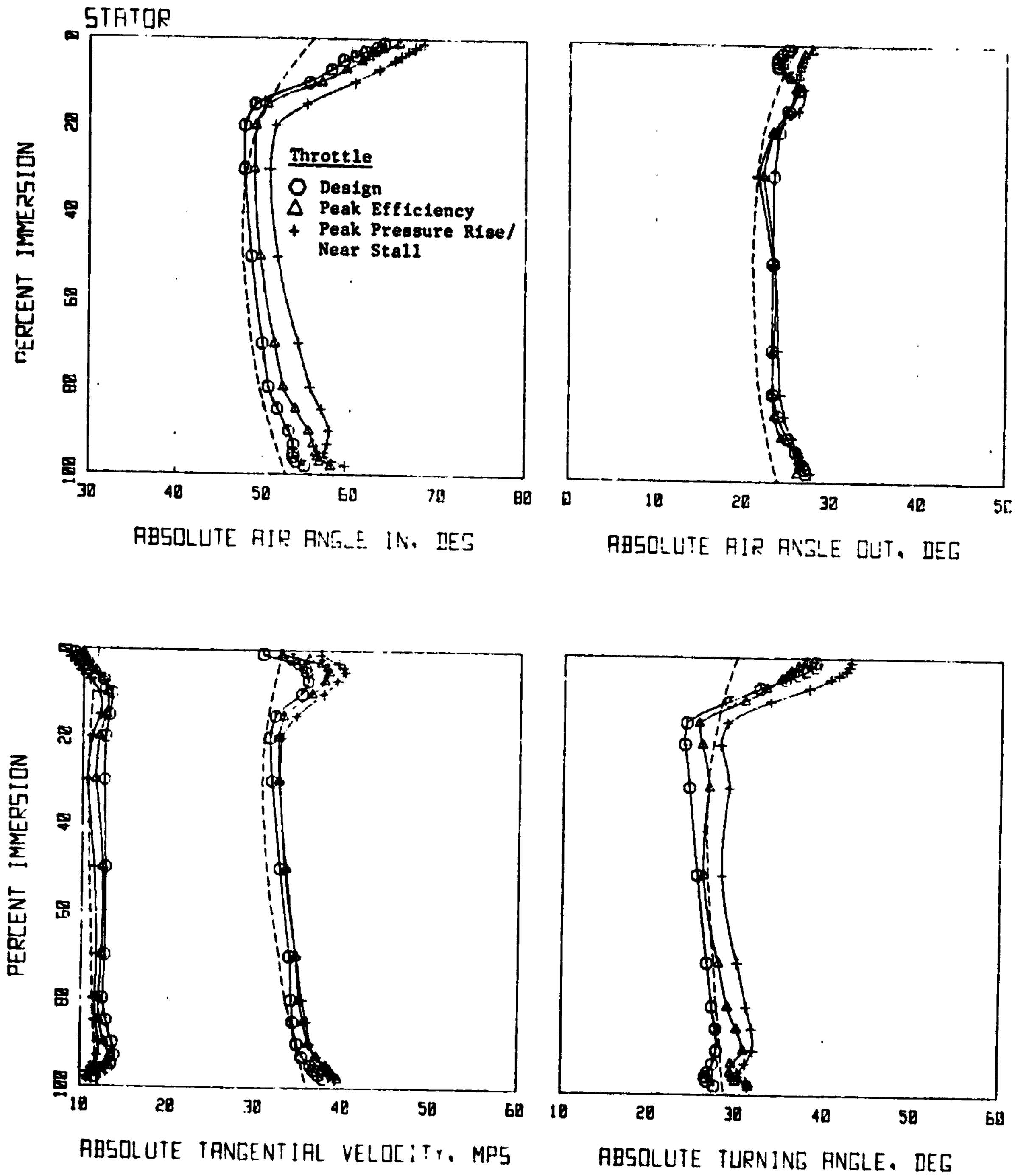


Figure 95. Vector Diagram Quantities Versus Percent Immersion, Rotor A/ Stator A Four-Stage Configuration, First Stage Tested.

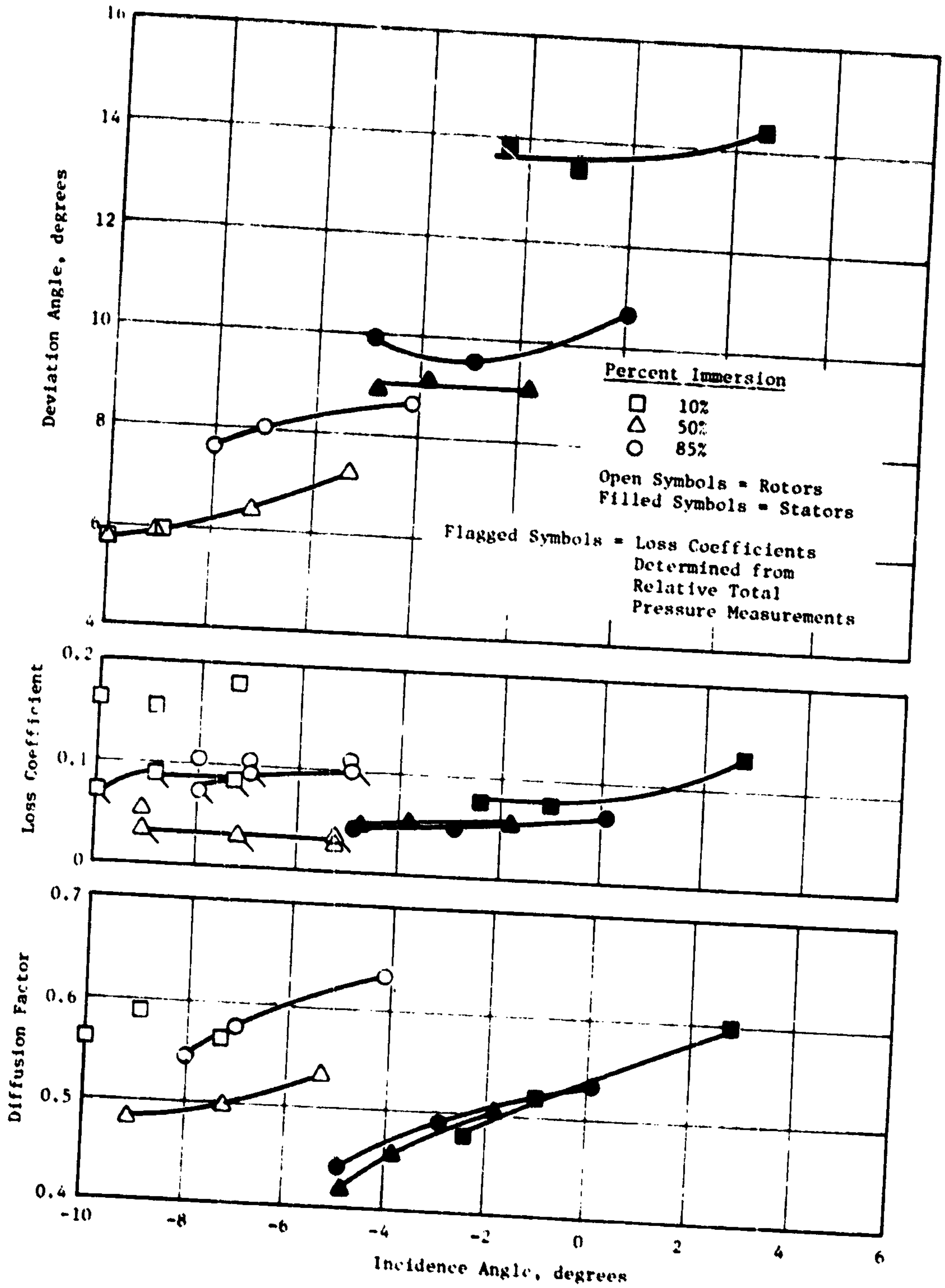


Figure 96. Diffusion Factor Loss Coefficient and Deviation Angle Versus Incidence Angle, Rotor A/Stator A Four-Stage Configuration, First Stage Tested.

8.0 TABLES

Table 1. 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	X	X	X	X	X	
4. Single Element Traverse Probe*							X	X	X		
5. Blade or Vane Surface Static Pressure Taps							R3	S3			
Total Pressure											
1. 11 Element Radial Rake*			X				X	X	X		X
2. Single Element Traverse Probe*			X				X	X	X		X
3. Rotating Radial Rake								X			
Flow Angle											
1. Single Element Traverse Probe*			X				X	X	X		X
Hot Film Probe*				X		X		X		X	

*Provisions for this instrumentation have been made at the planes indicated. However, the instrumentation may not always be in place for every test.

Table 2. Location of Surface Static Pressure Taps on Instrumented Airfoils.

Rotor

Suction Surface Tap Number	Suction Surface Percent Chord (%)	Distance From L.E. cm (in.)	Pressure Surface Tap Number	Pressure Surface Percent Chord (%)	Distance From L.E. cm (in.)
1	2.5	0.229 (0.090)	1	2.5	0.229 (0.090)
2	8.0	0.726 (0.286)	2	8.0	0.726 (0.286)
3	13.0	1.184 (0.466)	3	20.0	1.821 (0.717)
4	20.0	1.821 (0.717)	4	30.0	2.733 (1.076)
5	25.0	2.276 (0.896)	5	45.0	4.100 (1.614)
6	30.0	2.733 (1.076)	6	60.0	5.466 (2.152)
7	35.0	3.188 (1.255)	7	70.0	6.375 (2.510)
8	40.0	3.642 (1.434)	8	80.0	7.287 (2.869)
9	50.0	4.554 (1.793)	9	90.0	8.199 (3.228)
10	60.0	5.466 (2.152)	10	95.0	8.654 (3.407)
11	70.0	6.375 (2.510)			
12	80.0	7.287 (2.869)			
13	90.0	8.199 (3.228)			
14	95.0	8.654 (3.407)			

Stator

Suction Surface Tap Number	Suction Surface Percent Chord (%)	Distance From L.E. cm (in.)	Pressure Surface Tap Number	Pressure Surface Percent Chord (%)	Distance From L.E. cm (in.)
1	2.5	0.198 (0.078)	1	2.5	0.198 (0.078)
2	8.0	0.632 (0.249)	2	8.0	0.632 (0.249)
3	13.0	1.029 (0.405)	3	20.0	1.580 (0.622)
4	20.0	1.580 (0.622)	4	30.0	2.372 (0.934)
5	25.0	1.979 (0.779)	5	45.0	3.556 (1.400)
6	30.0	2.372 (0.934)	6	60.0	4.745 (1.868)
7	35.0	2.766 (1.089)	7	70.0	5.535 (2.179)
8	40.0	3.162 (1.245)	8	80.0	6.327 (2.491)
9	50.0	3.955 (1.557)	9	90.0	7.117 (2.802)
10	60.0	4.745 (1.868)	10	95.0	7.513 (2.958)
11	70.0	5.535 (2.179)			
12	80.0	6.327 (2.491)			
13	90.0	7.117 (2.802)			
14	95.0	7.513 (2.958)			

Radial Location of Pressure Taps

Rotor Immersion cm (in.) from Casing	Rotor Percent Immersion from Casing (%)	Stator Immersion cm (in.) from Casing	Stator Percent Immersion from Casing (%)
0.572 (0.225)	5	1.143 (0.450)	10
2.286 (0.900)	20	2.286 (0.900)	20
5.715 (2.250)	50	5.715 (2.250)	50
9.144 (3.600)	80	9.144 (3.600)	80
10.287 (4.050)	90	10.859 (4.275)	95

Table 3. Overall Test Plan Outline.

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. Screening 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 (4-Stage Configuration, Third Stage as Test Stage)	
1. Same Data as I.B	
2. Rotor Tip Clearance Data	
IV. Tests Using Rotor C and Stator B Designs	
(4-Stage Configuration, Third Stage as Test Stage)	
1. Same Data as I.B	

Table 4. Preview Data for Rotor A/Stator A.

Test 62A — **Four-Stage Configuration, Third Stage Tested**

FLOW COEF	PRES COEF	WORK COEF	TORQUE EFF
0.31957	0.60028	0.73335	0.81855
0.32006	0.60134	0.73206	0.82144
0.32781	0.60122	0.72550	0.82870
0.32980	0.60217	0.72178	0.83428
0.33441	0.60366	0.71511	0.84415
0.33927	0.60484	0.71370	0.84748
0.34871	0.61062	0.70941	0.86075
0.34948	0.60975	0.70601	0.86365
0.34964	0.60987	0.70607	0.86375
0.35979	0.61646	0.70329	0.87653
0.36022	0.61391	0.69902	0.87624
0.36722	0.61484	0.69285	0.88741
0.36870	0.61485	0.69107	0.88970
0.37438	0.60914	0.68027	0.89544
0.37530	0.61098	0.67988	0.89865
0.37591	0.61235	0.67914	0.90168
0.37978	0.60057	0.67067	0.89547
0.38156	0.60290	0.66715	0.90370
0.38172	0.60330	0.66840	0.90261
0.38576	0.59139	0.65948	0.89704
0.38752	0.59492	0.65754	0.90461
0.39152	0.58244	0.64790	0.89897
0.39295	0.58444	0.64667	0.90377
0.39586	0.57209	0.63786	0.89689
0.39601	0.57257	0.63854	0.89669
0.39705	0.53596	0.62729	0.85440
0.39738	0.57449	0.63672	0.90227
0.40137	0.56187	0.62691	0.89625
0.40246	0.56492	0.62855	0.89876
0.40267	0.56399	0.62658	0.90012
0.40512	0.55324	0.61835	0.89470
0.40681	0.55398	0.61701	0.89768
0.40684	0.55468	0.61771	0.89796
0.40730	0.55565	0.60369	0.92043
0.40761	0.55574	0.61673	0.90111
0.41550	0.53493	0.59340	0.89394
0.42354	0.51314	0.57834	0.88726
0.42458	0.51536	0.57888	0.89027
0.42466	0.51757	0.57902	0.89388
0.42500	0.51535	0.57767	0.89211
0.43122	0.49392	0.56091	0.88056
0.43143	0.49530	0.56215	0.88107
0.43239	0.49635	0.56075	0.88515
0.43804	0.47527	0.54441	0.87301
0.43958	0.47860	0.54491	0.87831
0.44774	0.44723	0.51938	0.86107
0.44923	0.44862	0.51890	0.86455
0.46001	0.40544	0.48643	0.83351
0.46133	0.40460	0.48377	0.83634

Test 62B — **Single-Stage Configuration**

FLOW COEF	PRES COEF	WORK COEF	TORQUE EFF
0.45211	0.47023	0.55776	0.84306
0.44515	0.48674	0.57421	0.84767
0.43691	0.50913	0.59304	0.85849
0.43089	0.52711	0.60723	0.86804
0.42328	0.54610	0.62529	0.87337
0.41486	0.56521	0.64237	0.87989
0.41016	0.57552	0.65271	0.88175
0.40504	0.58532	0.66316	0.88263
0.40012	0.59646	0.67462	0.88414
0.39440	0.60675	0.68726	0.88286
0.38873	0.61816	0.70043	0.88255
0.38194	0.62753	0.71080	0.88285
0.37516	0.63723	0.72349	0.88079
0.36776	0.64496	0.73274	0.88020
0.36234	0.64707	0.74185	0.87225
0.35095	0.64360	0.75711	0.85008
0.45273	0.46929	0.55798	0.84105
0.44600	0.48978	0.57357	0.85219
0.43778	0.50914	0.59359	0.85774
0.43117	0.52763	0.60920	0.86754
0.42363	0.54639	0.62483	0.87446
0.41511	0.56589	0.64337	0.87957
0.41053	0.57606	0.65394	0.88091
0.40558	0.58640	0.66470	0.88220
0.40035	0.59644	0.67478	0.88390
0.39466	0.60701	0.68583	0.88507
0.38891	0.61667	0.69733	0.88433
0.38266	0.62777	0.71094	0.88302
0.37576	0.63683	0.72162	0.88250
0.36814	0.64554	0.73321	0.88042
0.36289	0.64699	0.74165	0.87236
0.35086	0.64381	0.75492	0.85282
0.41034	0.57506	0.65402	0.87926
0.40532	0.58648	0.66499	0.88193
0.40021	0.59584	0.67492	0.88284
0.39483	0.60700	0.68563	0.88530
0.38898	0.61722	0.69759	0.88478
0.38265	0.62736	0.71070	0.88272
0.37566	0.63763	0.72247	0.88256
0.36804	0.64555	0.73424	0.87920

Test 62C — **Four-Stage Configuration, First Stage Tested**

FLOW COEF	PRES COEF	WORK COEF	TORQUE EFF
0.32445	0.59689	0.72827	0.81960
0.32645	0.59732	0.72543	0.82227
0.32756	0.59782	0.72419	0.82550
0.32892	0.59764	0.72334	0.82622
0.35685	0.61656	0.70408	0.87569
0.36173	0.62193	0.70411	0.88329
0.36680	0.61945	0.69612	0.88978
0.36847	0.62038	0.69430	0.89354
0.37360	0.61497	0.68465	0.89522
0.37943	0.60688	0.67386	0.90060
0.38540	0.59912	0.66288	0.90381
0.38775	0.59711	0.66095	0.90341
0.39094	0.58956	0.65206	0.90414
0.39629	0.57993	0.64181	0.90358
0.40129	0.56988	0.63147	0.90247
0.40623	0.55937	0.62075	0.90112
0.40882	0.55613	0.61664	0.90186
0.41044	0.54938	0.61118	0.89888
0.41961	0.52925	0.59118	0.89523
0.42815	0.51161	0.57357	0.89198
0.43621	0.49015	0.55554	0.88230
0.44326	0.47370	0.53945	0.87812
0.45227	0.44566	0.51605	0.86358
0.46515	0.40242	0.48152	0.83574

AL PAGE IS
OF POOR QUALITY

Table 5. Blade Surface Static Pressures Four-Stage Configuration - Third Stage Is Test Stage.

IMMERSION(%)= 5.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR	NS
2.50	1.0251	1.2078	1.3957	1.3607
8.00	1.1533	1.2937	1.4500	1.4453
20.00	1.2256	1.3645	1.5026	1.5053
30.00	1.2614	1.3937	1.5253	1.5294
45.00	1.2676	1.4127	1.5378	1.5335
60.00	1.2994	1.4201	1.5358	1.5413
70.00	1.3025	1.4166	1.5329	1.5371
80.00	1.2957	1.4089	1.5278	1.5278
90.00	1.2927	1.3986	1.5206	1.5187
95.00	1.2697	1.3883	1.5105	1.5092

SUCTION SURFACE

%CHORD	DP	PE	PPR	NS
2.50	0.7637	0.8011	0.8477	0.9107
8.00	0.7825	0.8531	0.9103	0.9068
13.00	0.7235	0.7356	0.8[illegible]	0.8[illegible]
20.00	0.6466	0.7107	0.7512	0.8062
25.00	0.6142	0.6567	0.7305	0.7563
30.00	0.6554	0.6[illegible]	0.7279	0.7367
35.00	0.6337	0.6342	0.7635	0.7634
40.00	0.6354	0.6[illegible]	0.8330	0.8232
50.00	0.6632	0.8053	0.9530	0.9625
60.00	0.7667	0.9126	1.0462	1.0734
70.00	0.8591	1.0057	1.1551	1.1696
80.00	0.9507	1.1036	1.2522	1.2712
90.00	1.0731	1.2107	1.3544	1.3624
95.00	1.1336	1.2682	1.4045	1.4125

IMMERSION(%)= 20.000

PRESSURE SURFACE

DP	PE	PPR	NS
0.9783	1.1849	1.4056	1.3894
1.1569	1.2960	1.4661	1.4583
1.2254	1.3512	1.4980	1.4989
1.2459	1.3653	1.5118	1.5094
1.2657	1.3816	1.5227	1.5163
1.2735	1.3876	1.5241	1.5179
1.2749	1.3881	1.5186	1.5096
1.2713	1.3819	1.5163	1.5104
1.2559	1.3687	1.5066	1.4882
1.2310	1.3455	1.4793	1.4652

SUCTION SURFACE

DP	PE	PPR	NS
0.8103	0.7965	0.7844	0.8241
0.7360	0.7998	0.8775	0.8999
0.6804	0.7537	0.8465	0.8645
0.6378	0.7232	0.8298	0.8455
0.6334	0.7228	0.8435	0.8514
0.6323	0.7297	0.8607	0.8784
0.6382	0.7440	0.8772	0.8942
0.6577	0.7689	0.8935	0.9240
0.7004	0.8247	0.9694	0.9993
0.7724	0.9062	1.0753	1.0898
0.8530	0.9886	1.1453	1.1951
0.9577	1.0925	1.2495	1.2891
1.0663	1.1954	1.3357	1.3644
1.1258	1.2499	1.3831	1.4091

IMMERSION(%)= 50.000

PRESSURE SURFACE

DP	PE	PPR	NS
0.9423	1.1742	1.4101	1.4745
1.1243	1.2829	1.4416	1.4676
1.1971	1.3217	1.4743	1.4749
1.2334	1.3434	1.4819	1.4784
1.2317	1.3498	1.4916	1.4809
1.2482	1.3617	1.4964	1.4841
1.2527	1.3665	1.5081	1.4859
1.2431	1.3604	1.4908	1.4717
1.2370	1.3365	1.4825	1.4447
1.2178	1.3266	1.4598	1.4327

SUCTION SURFACE

DP	PE	PPR	NS
0.8297	0.7912	0.7687	0.6161
0.7562	0.7717	0.8455	0.7984
0.6596	0.7397	0.8273	0.8080
0.6101	0.7214	0.8138	0.8324
0.5948	0.6956	0.8380	0.8552
0.6004	0.7137	0.8605	0.8864
0.6141	0.7433	0.8938	0.8973
0.6378	0.7693	0.9314	1.0036
0.6926	0.8396	1.0122	1.1264
0.7703	0.9299	1.1155	1.2425
0.8580	1.0178	1.2061	1.3010
0.9613	1.1265	1.3083	1.3530
1.0655	1.2249	1.3616	1.3636
1.1228	1.2568	1.4013	1.3468

IMMERSION(%)= 80.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR	NS
2.50	0.9926	[illegible]	1.4614	1.5665
8.00	1.1149	1.2735	1.4464	1.4904
20.00	1.1768	1.3150	1.4523	1.4717
30.00	1.1888	1.3256	1.4594	1.4701
45.00	1.2[illegible]	1.3314	1.4633	1.4605
60.00	1.2214	1.3481	1.4733	1.4793
70.00	1.2234	1.3415	1.4722	1.4602
80.00	1.2265	1.3418	1.4591	1.4537
90.00	1.2093	1.3274	1.4391	1.4346
95.00	1.1842	1.3041	1.4140	1.3965

SUCTION SURFACE

%CHORD	DP	PE	PPR	NS
2.50	0.7634	0.7502	0.6676	0.3750
5.00	0.6816	0.7445	0.7864	0.7250
13.00	0.6109	0.7172	0.7828	0.7803
20.00	0.5875	0.6753	0.7869	0.8580
25.00	0.5780	0.6820	0.8123	0.9095
30.00	0.5941	0.7193	0.8486	0.9691
35.00	0.6080	0.7376	0.8681	1.0168
40.00	0.6285	0.7732	0.9350	1.0860
50.00	0.7096	0.8724	1.0421	1.1922
60.00	0.8161	0.9642	1.1410	1.2523
70.00	0.9317	1.0664	1.2333	1.2817
80.00	0.9[illegible]63	1.[illegible]90	1.3399	1.3009
90.00	1.0393	1.2515	1.3543	1.3371
95.00	1.1302	1.3032	1.3702	1.3481

IMMERSION(%)= 90.000

PRESSURE SURFACE

DP	PE	PPR	NS
1.0498	1.2673	1.4779	1.5642
1.1287	1.2859	1.4507	1.4996
0.8812	0.8806	0.8643	0.8545
1.1962	1.3246	1.4325	1.4719
1.2048	1.3354	1.4503	1.4654
1.2124	1.3354	1.4581	1.4654
1.2216	1.3417	1.4592	1.4657
1.2088	1.3515	1.4420	1.4560
1.1908	1.3156	1.4320	1.4347
1.1732	1.3035	1.4195	1.4081

SUCTION SURFACE

DP	PE	PPR	NS
0.7364	0.7414	0.6643	0.3967
0.6775	0.7508	0.7797	0.7276
0.6229	0.7070	0.7811	0.7978
0.5720	0.6873	0.7942	0.8491
0.5673	0.6918	0.8261	0.9124
0.5909	0.7201	0.8505	0.9920
0.6098	0.7377	0.8992	1.0399
0.6548	0.7873	0.9590	1.0885
0.7215	0.8961	1.0660	1.1922
0.8223	0.9917	1.1608	1.2385
0.9382	1.0906	1.2641	1.2709
1.0244	1.1695	1.3021	1.2941
1.0978	1.2240	1.3422	1.3231
1.1335	1.2434	1.3585	1.3456

Tabulated Surface Pressures Normalized by $\frac{1}{2}\rho_{REF} U_t^2$

THROTTLE

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

Table 6. Vane Surface Static Pressures Four-Stage Configuration - Third Stage Is Test Stage.

IMMERSION(%)= 10.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR	NS
2.50	1.3[illegible]47	1.5432	1.7396	1.7095
8.00	1.3639	1.5300	1.6[illegible]5	1.6830
20.00	1.4057	1.5579	1.7096	1.7041
30.00	1.4270	1.5777	1.7269	1.7177
45.00	1.4412	1.5901	1.7333	1.7262
60.00	1.4554	1.6032	1.7436	1.7361
70.00	1.4655	1.6157	1.7506	1.7457
80.00	1.4667	1.6173	1.7573	1.7458
90.00	1.4531	1.6051	1.7444	1.7333
95.00	1.4271	1.5765	1.7203	1.7085

SUCTION SURFACE

%CHORD	DP	PE	PPR	NS
2.50	1.1135	1.1961	1.2904	1.3164
8.00	1.0794	1.1944	1.3103	1.3184
13.00	1.0731	1.1939	1.3177	1.3210
20.00	1.0561	1.1948	1.3334	1.3312
25.00	1.0728	1.2174	1.3607	1.3545
30.00	1.0911	1.2374	1.3832	1.3788
35.00	1.1059	1.2595	1.4053	1.4010
40.00	1.1303	1.2893	1.4404	1.4327
50.00	1.1885	1.3489	1.5012	1.4915
60.00	1.2510	1.4116	1.5674	1.5429
70.00	1.3106	1.4673	1.6140	1.5951
80.00	1.3538	1.5050	1.6481	1.6291
90.00	1.3778	1.5262	1.6709	1.6535
95.00	1.3863	1.5334	1.6719	1.6609

IMMERSION(%)= 20.000

PRESSURE SURFACE

DP	PE	PPR	NS
1.3418	1.5210	1.7113	1.7147
1.3641	1.5258	1.6881	1.6844
1.3997	1.5507	1.6999	1.6969
1.4170	1.5673	1.7087	1.7048
1.4350	1.5830	1.7234	1.7139
1.4486	1.5982	1.7362	1.7234
1.4584	1.6048	1.7434	1.7304
1.4586	1.6050	1.7444	1.7320
1.4432	1.5906	1.7302	1.7196
1.4163	1.5656	1.7027	1.6911

SUCTION SURFACE

DP	PE	PPR	NS
1.1320	1.1998	1.2802	1.2789
1.0897	1.1918	1.3017	1.3007
1.0730	1.1868	1.3045	1.3038
1.0574	1.1892	1.3227	1.3247
1.0681	1.2078	1.3463	1.3480
1.0842	1.2250	1.3726	1.3730
1.1009	1.2466	1.3968	1.4052
1.1257	1.2757	1.4308	1.4308
1.1704	1.3312	1.4808	1.4779
1.2405	1.4007	1.5466	1.5354
1.2991	1.4579	1.5962	1.5829
1.3504	1.5013	1.6437	1.6222
1.3692	1.5220	1.6642	1.6441
1.3732	1.5313	1.6671	1.6546

IMMERSION(%)= 50.000

PRESSURE SURFACE

DP	PE	PPR	NS
1.3059	1.5066	1.6988	1.7639
1.3374	1.5117	1.6722	1.7142
1.3830	1.5376	1.6845	1.6958
1.4070	1.5552	1.6925	1.6962
1.4290	1.5747	1.7095	1.6954
1.4474	1.5927	1.7192	1.7032
1.4575	1.6001	1.7306	1.7118
1.4610	1.6030	1.7309	1.7096
1.4546	1.5969	1.7245	1.6984
1.4358	1.5803	1.7090	1.6784

SUCTION SURFACE

DP	PE	PPR	NS
1.1576	1.2021	1.2507	1.0900
1.0895	1.1814	1.2846	1.2555
1.0617	1.1655	1.2848	1.2842
1.0398	1.1686	1.3076	1.3511
1.0462	1.1838	1.3323	1.3918
1.0585	1.2040	1.3620	1.4292
1.0695	1.2205	1.3816	1.4556
1.0930	1.2505	1.4161	1.4942
1.1399	1.3019	1.4690	1.5353
1.1976	1.3580	1.5225	1.5590
1.2541	1.4141	1.5645	1.5593
1.3099	1.4634	1.6101	1.5648
1.3649	1.5146	1.6386	1.5740
1.3913	1.5393	1.6552	1.5912

IMMERSION(%)= 80.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR	NS
2.50	1.2932	1.4410	1.7129	1.7776
8.00	1.3380	1.5097	1.6801	1.7193
20.00	1.3847	1.5351	1.6829	1.6924
30.00	1.4059	1.5512	1.6915	1.6897
45.00	1.4275	1.5685	1.7044	1.6902
60.00	1.4421	1.5821	1.7121	1.6993
70.00	1.4540	1.5905	1.7205	1.7047
80.00	1.4540	1.5902	1.7226	1.7009
90.00	1.4487	1.5845	1.7130	1.6934
95.00	1.3228	1.5640	1.6919	1.6694

SUCTION SURFACE

%CHORD	DP	PE	PPR	NS
2.50	1.1380	1.1566	1.1275	1.0131
8.00	1.0615	1.1466	1.2353	1.2506
13.00	1.0421	1.1434	1.2641	1.3197
20.00	1.0228	1.1518	1.3126	1.4037
25.00	1.0337	1.1719	1.3514	1.4487
30.00	1.0471	1.1940	1.3999	1.4833
35.00	1.0602	1.2139	1.4238	1.4981
40.00	1.0905	1.2488	1.4660	1.5167
50.00	1.1384	1.3037	1.5401	1.5336
60.00	1.1934	1.3611	1.5718	1.5484
70.00	1.2492	1.4137	1.5824	1.5508
80.00	1.3013	1.4610	1.5873	1.5601
90.00	1.3495	1.4996	1.5985	1.5718
95.00	1.3733	1.5187	1.6079	1.5828

IMMERSION(%)= 95.000

PRESSURE SURFACE

DP	PE	PPR	NS
1.3186	1.5233	1.6278	1.6448
1.3568	1.5200	1.6780	1.6815
1.3873	1.5375	1.6817	1.6740
1.3985	1.5461	1.6871	1.6739
1.4173	1.5618	1.7002	1.6839
1.4324	1.5758	1.7129	1.6972
1.4401	1.5826	1.7191	1.7036
1.4424	1.5846	1.7185	1.7030
1.4463	1.5843	1.7196	1.6895
1.4088	1.5514	1.6840	1.6636

SUCTION SURFACE

DP	PE	PPR	NS
1.0663	1.1128	1.1317	1.1915
1.0397	1.1307	1.2314	1.3475
1.0346	1.1393	1.2699	1.4076
1.0339	1.1596	1.3409	1.4598
1.0480	1.1838	1.3923	1.4841
1.0638	1.2101	1.4165	1.4917
1.0807	1.2315	1.4628	1.4980
1.1136	1.2709	1.4931	1.5080
1.1608	1.3314	1.5457	1.5253
1.2153	1.3807	1.5671	1.5366
1.2677	1.4275	1.5788	1.5541
1.3057	1.4600	1.5912	1.5666
1.3435	1.4943	1.6041	1.5870
1.3567	1.5062	1.6079	1.5978

Tabulated Surface Pressures Normalized by $\frac{1}{2} \rho_{REF} U_t^2$

THROTTLE

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

Table 7. Blade Surface Static Pressures - Single-Stage Configuration.

IMMERSION(%)= 5.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	-0.0078	0.1288	0.2499
8.00	0.0925	0.1884	0.2438
20.00	0.1590	0.2054	0.2794
30.00	0.1912	0.2560	0.2902
45.00	0.2111	0.2668	0.2703
60.00	0.2189	0.2566	0.2692
70.00	0.2199	0.2710	0.2726
80.00	0.2097	0.2494	0.2764
90.00	0.1965	0.2267	0.2708
95.00	0.1836	0.2510	0.2623

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	-0.3598	-0.4509	-0.5556
8.00	-0.3361	-0.3696	-0.4098
13.00	-0.3957	-0.4378	-0.4817
20.00	-0.4909	-0.5464	-0.5959
25.00	-0.5508	-0.6051	-0.6115
30.00	-0.6163	-0.6250	-0.5766
35.00	-0.6005	-0.5541	-0.4741
40.00	-0.5002	-0.4246	-0.3334
50.00	-0.4013	-0.3219	-0.2446
60.00	-0.3284	-0.2475	-0.1716
70.00	-0.2320	-0.1537	-0.0811
80.00	-0.1481	-0.0563	0.0182
90.00	-0.0219	0.0528	0.1225
95.00	0.0435	0.1144	0.1711

IMMERSION(%)= 20.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	-0.0528	0.1159	0.2607
8.00	0.0490	0.1767	0.2582
20.00	0.1551	0.2142	0.2663
30.00	0.1747	0.2300	0.2679
45.00	0.1922	0.2384	0.2733
60.00	0.1953	0.2421	0.2801
70.00	0.1960	0.2443	0.2833
80.00	0.1909	0.2401	0.2827
90.00	0.1757	0.2265	0.2699
95.00	0.1526	0.2049	0.2494

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	-0.3270	-0.4783	-0.6405
8.00	-0.3816	-0.4098	-0.4554
13.00	-0.4387	-0.4430	-0.4452
20.00	-0.4818	-0.4653	-0.4510
25.00	-0.4897	-0.4628	-0.4394
30.00	-0.4832	-0.4468	-0.4099
35.00	-0.4764	-0.4292	-0.3814
40.00	-0.4488	-0.3993	-0.3414
50.00	-0.4017	-0.3363	-0.2644
60.00	-0.3335	-0.2537	-0.1794
70.00	-0.2459	-0.1574	-0.0786
80.00	-0.1339	-0.0530	0.0244
90.00	-0.0296	0.0453	0.1252
95.00	0.0292	0.1005	0.1678

IMMERSION(%)= 50.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	-0.0834	0.0822	0.2015
8.00	0.0411	0.1298	0.2087
20.00	0.1091	0.1683	0.2323
30.00	0.1325	0.1836	0.2400
45.00	0.1478	0.1962	0.2449
60.00	0.1611	0.2098	0.2544
70.00	0.1668	0.2164	0.2572
80.00	0.1631	0.2098	0.2508
90.00	0.1506	0.1943	0.2357
95.00	0.1316	0.1738	0.2168

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	-0.3021	-0.4193	-0.5268
8.00	-0.3891	-0.4164	-0.4344
13.00	-0.4447	-0.4497	-0.4424
20.00	-0.4899	-0.4769	-0.4494
25.00	-0.5018	-0.4765	-0.4330
30.00	-0.4911	-0.4597	-0.4031
35.00	-0.4680	-0.4280	-0.3746
40.00	-0.4455	-0.3988	-0.3345
50.00	-0.3996	-0.3418	-0.2601
60.00	-0.3327	-0.2288	-0.1357
70.00	-0.2099	-0.1413	-0.0581
80.00	-0.1115	-0.0499	0.0413
90.00	-0.0139	0.0425	0.1202
95.00	0.0422	0.0933	0.1510

IMMERSION(%)= 80.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	-0.0444	0.0793	0.1960
8.00	0.0420	0.1250	0.1966
20.00	0.0984	0.1539	0.2095
30.00	0.1154	0.1657	0.2149
45.00	0.1282	0.1796	0.2263
60.00	0.1421	0.1889	0.2322
70.00	0.1413	0.1906	0.2310
80.00	0.1362	0.1832	0.2195
90.00	0.1153	0.1559	0.1963
95.00	0.0679	0.1235	0.1708

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	-0.3230	-0.3985	-0.4900
8.00	-0.4400	-0.4138	-0.4202
13.00	-0.4712	-0.4526	-0.4101
20.00	-0.5061	-0.4729	-0.4222
25.00	-0.5[illegible]39	-0.4554	-0.4020
30.00	-0.4922	-0.4237	-0.3700
35.00	-0.4786	-0.3987	-0.3268
40.00	-0.4369	-0.3660	-0.2697
50.00	-0.3634	-0.2534	-0.1307
60.00	-0.2760	-0.1312	-0.0420
70.00	-0.1350	-0.0409	0.0188
80.00	-0.0515	0.0144	0.0501
90.00	-0.0294	0.0392	0.0597
95.00	-0.0113	0.0324	0.0709

IMMERSION(%)= 90.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	-0.0081	0.1067	0.2047
8.00	0.0457	0.1277	0.1918
20.00	0.4557	0.4686	0.4578
30.00	0.0885	0.1553	0.2003
45.00	0.1036	0.1667	0.2091
60.00	0.1169	0.1784	0.2182
70.00	0.1192	0.1805	0.2162
80.00	0.1066	0.1695	0.2037
90.00	0.0833	0.1443	0.1824
95.00	0.0592	0.1152	0.1521

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	-0.3678	-0.4199	-0.4888
8.00	-0.4216	-0.4085	-0.4144
13.00	-0.4824	-0.4431	-0.4265
20.00	-0.5317	-0.4620	-0.4203
25.00	-0.5332	-0.4554	-0.3707
30.00	-0.5065	-0.4133	-0.3349
35.00	-0.4749	-0.3616	-0.2790
40.00	-0.4259	-0.3192	-0.2014
50.00	-0.3225	-0.1749	-0.0915
60.00	-0.1925	-0.0932	-0.0667
70.00	-0.1230	-0.0667	-0.0270
80.00	-0.[illegible]350	-0.0269	0.0017
90.00	-0.0734	0.0039	0.0213
95.00	-0.0575	0.0038	0.0356

Tabulated Surface Pressures Normalized by $\frac{1}{2}\rho_{REF}U_t^2$

THROTTLE

- **DP - Design Point**
- **PE - Peak Efficiency**
- **PPR - Peak Pressure Rise**

Table 8. Vane Surface Static Pressures - Single-Stage Configuration.

IMMERSION(%)= 10.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	0.2421	0.3788	0.4636
8.00	0.2552	0.3578	0.4399
20.00	0.2928	0.3784	0.4440
30.00	0.3138	0.3952	0.4571
45.00	0.3323	0.4091	0.4686
60.00	0.3499	0.4271	0.4824
70.00	0.3646	0.4400	0.4970
80.00	0.3722	0.4471	0.5025
90.00	0.3634	0.4389	0.4955
95.00	0.3412	0.4169	0.4742

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	0.1177	0.1064	0.0527
8.00	0.0385	0.0651	0.0598
13.00	0.0152	0.0518	0.0612
20.00	-0.0223	0.0347	0.0659
25.00	-0.0177	0.0472	0.0888
30.00	-0.0100	0.0630	0.1124
35.00	0.0021	0.0794	0.1335
40.00	0.0206	0.1046	0.1648
50.00	0.0671	0.1566	0.2226
60.00	0.1230	0.2142	0.2764
70.00	0.1839	0.2698	0.3302
80.00	0.2296	0.3126	0.3711
90.00	0.2690	0.3458	0.4035
95.00	0.2869	0.3616	0.4175

IMMERSION(%)= 20.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	0.1993	0.3289	0.4366
8.00	0.2409	0.3401	0.4195
20.00	0.2846	0.3681	0.4335
30.00	0.3086	0.3861	0.4468
45.00	0.3323	0.4054	0.4612
60.00	0.3512	0.4214	0.4769
70.00	0.3630	0.4318	0.4851
80.00	0.3686	0.4375	0.4895
90.00	0.3602	0.4282	0.4802
95.00	0.3402	0.4094	0.4616

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	0.1314	0.1124	0.0631
8.00	0.0386	0.0655	0.0604
13.00	0.0078	0.0459	0.0567
20.00	-0.0238	0.0349	0.0640
25.00	-0.0214	0.0477	0.0802
30.00	-0.0119	0.0622	0.1061
35.00	-0.0016	0.0804	0.1262
40.00	0.0175	0.1089	0.1584
50.00	0.0579	0.1532	0.2110
60.00	0.1170	0.2154	0.2721
70.00	0.1731	0.2675	0.3251
80.00	0.2282	0.3125	0.3725
90.00	0.2710	0.3433	0.4018
95.00	0.2803	0.3580	0.4141

IMMERSION(%)= 50.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	0.1597	0.3016	0.4008
8.00	0.2117	0.3167	0.3921
20.00	0.2667	0.3512	0.4131
30.00	0.2958	0.3717	0.4291
45.00	0.3206	0.3937	0.4474
60.00	0.3439	0.4136	0.4648
70.00	0.3542	0.4224	0.4735
80.00	0.3592	0.4266	0.4764
90.00	0.3534	0.4210	0.4708
95.00	0.3386	0.4066	0.4577

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	0.1121	0.1002	0.0446
8.00	0.0182	0.0496	0.0444
13.00	-0.0200	0.0274	0.0385
20.00	-0.0454	0.0225	0.0505
25.00	-0.0436	0.0323	0.0687
30.00	-0.0351	0.0493	0.0939
35.00	-0.0237	0.0636	0.1115
40.00	-0.0058	0.0910	0.1428
50.00	0.0396	0.1387	0.1959
60.00	0.0949	0.1930	0.2521
70.00	0.1445	0.2452	0.3036
80.00	0.2011	0.2915	0.3502
90.00	0.2569	0.3383	0.3954
95.00	0.2850	0.3603	0.4157

IMMERSION(%)= 80.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	0.1488	0.2945	0.3918
8.00	0.2134	0.3181	0.3917
20.00	0.2713	0.3512	0.4102
30.00	0.2944	0.3682	0.4239
45.00	0.3148	0.3862	0.4398
60.00	0.3327	0.4021	0.4531
70.00	0.3408	0.4088	0.4602
80.00	0.3436	0.4110	0.4604
90.00	0.3372	0.4042	0.4544
95.00	0.3219	0.3902	0.4377

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	0.0867	0.0524	-0.0094
8.00	-0.0070	0.0140	0.0166
13.00	-0.0283	0.0063	0.0276
20.00	-0.0518	0.0081	0.0515
25.00	-0.0457	0.0241	0.0756
30.00	-0.0343	0.0438	0.1043
35.00	-0.0212	0.0610	0.1266
40.00	0.0053	0.0934	0.1642
50.00	0.0479	0.1421	0.2159
60.00	0.1024	0.1976	0.2782
70.00	0.1551	0.2465	0.3181
80.00	0.2041	0.2888	0.3531
90.00	0.2491	0.3264	0.3753
95.00	0.2688	0.3413	0.3811

IMMERSION(%)= 95.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	0.2295	0.3552	0.4412
8.00	0.2529	0.3454	0.415[illegible]
20.00	0.2793	0.3584	0.4[illegible]
30.00	0.2935	0.3683	0.4[illegible]
45.00	0.3119	0.3848	0.4408
60.00	0.3300	0.3999	0.4560
70.00	0.3391	0.4074	0.4613
80.00	0.3406	0.4093	0.4631
90.00	0.3339	0.4025	0.4558
95.00	0.3131	0.3823	0.4344

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	-0.0082	-0.0379	-0.0895
8.00	-0.0353	-0.0149	-0.0104
13.00	-0.0373	-0.0059	0.0122
20.00	-0.0374	0.0158	0.0563
25.00	-0.0246	0.0420	0.0917
30.00	-0.0117	0.0631	0.1240
35.00	0.0029	0.0902	0.1488
40.00	0.0312	0.1206	0.1958
50.00	0.0752	0.1731	0.2543
60.00	0.1247	0.2215	0.2918
70.00	0.1758	0.2620	0.3239
80.00	0.2113	0.2926	0.3508
90.00	0.2449	0.3231	0.3728
95.00	0.2565	0.3314	0.3803

Tabulated Surface Pressures Normalized by $\frac{1}{2} \rho_{REF} U_t^2$

THROTTLE

DP - Design Point
PE - Peak Efficiency
PPR - Peak Pressure Rise

Table 9. Blade Surface Static Pressures Four-Stage Configuration - First Stage Is Test Stage.

IMMERSION(%)= 5.000

PRESSURE SURFACE %CHORD	DP	PE	PPR
2.50	-0.0480	0.0866	0.2267
8.00	0.0684	0.1490	0.2246
20.00	0.1414	0.2053	0.2541
30.00	0.1760	[illegible]	0.2873
45.00	0.1983	0.2396	0.2454
60.00	0.2138	0.2356	0.2446
70.00	0.2088	0.2349	0.2599
80.00	0.1996	0.2293	0.2675
90.00	0.1859	0.2106	0.2517
95.00	0.1706	0.2176	0.2542

SUCTION SURFACE %CHORD	DP	PE	PPR
2.50	-0.3901	-0.4761	-0.5835
8.00	-0.3643	-0.3908	-0.4371
13.00	-0.4359	-0.4529	-0.5248
20.00	-0.5008	-0.5622	-0.6249
25.00	-0.5653	-0.6112	-0.6314
30.00	-0.6118	-0.6281	-0.5882
35.00	-0.6036	-0.5972	-0.4842
40.00	-0.5603	-0.4992	-0.4182
50.00	-0.4500	-0.3856	-0.2962
60.00	-0.3514	-0.2769	-0.2058
70.00	-0.2560	-0.1733	-0.1024
80.00	-0.1523	-0.0745	0.0095
90.00	-0.0389	0.0315	0.1075
95.00	0.0276	0.0809	0.1599

IMMERSION(%)= 20.000

PRESSURE SURFACE %CHORD	DP	PE	PPR
2.50	-0.1403	0.0713	0.2244
8.00	0.0845	0.1432	0.2316
20.00	0.1350	0.1995	0.2476
30.00	0.1635	0.2131	0.2534
45.00	0.1777	0.2313	0.2559
60.00	0.1791	0.2225	0.2674
70.00	0.1755	0.2234	0.2710
80.00	0.1731	0.2239	0.2609
90.00	0.1547	0.2056	0.2466
95.00	0.1214	0.1847	0.2211

SUCTION SURFACE %CHORD	DP	PE	PPR
2.50	-0.3425	-0.4745	-0.6637
8.00	-0.4150	-0.4231	-0.4593
13.00	-0.4563	-0.4676	-0.4721
20.00	-0.5065	-0.4850	-0.4753
25.00	-0.5065	-0.4869	-0.4622
30.00	-0.5023	-0.4752	-0.4358
35.00	-0.4943	-0.4541	-0.4018
40.00	-0.4715	-0.4259	-0.3740
50.00	-0.4296	-0.3707	-0.3027
60.00	-0.3641	-0.2890	-0.2030
70.00	-0.2760	-0.1930	-0.1130
80.00	-0.1603	-0.0886	-0.0111
90.00	-0.0502	0.0242	0.0884
95.00	0.0130	0.0708	0.1411

IMMERSION(%)= 50.000

PRESSURE SURFACE %CHORD	DP	PE	PPR
2.50	-0.1134	0.0238	0.1653
8.00	0.0424	0.1098	0.2066
20.00	0.1136	0.1597	0.2285
30.00	0.1367	0.1791	0.2385
45.00	0.1511	0.1953	0.2467
60.00	0.1661	0.2084	0.2604
70.00	0.1711	0.2109	0.2617
80.00	0.1655	0.2084	0.2542
90.00	0.1549	0.1953	0.2379
95.00	0.1386	0.1772	0.2179

SUCTION SURFACE %CHORD	DP	PE	PPR
2.50	-0.3118	-0.4199	-0.5507
8.00	-0.3932	-0.4149	-0.4453
13.00	-0.4490	-0.4496	-0.4527
20.00	-0.4973	-0.4818	-0.4589
25.00	-0.5079	-0.4806	-0.4441
30.00	-0.4979	-0.4595	-0.4205
35.00	-0.4794	-0.4335	-0.3795
40.00	-0.4552	-0.4013	-0.3397
50.00	-0.3994	-0.3467	-0.2676
60.00	-0.3410	-0.2412	-0.1487
70.00	-0.2186	-0.1406	-0.0646
80.00	-0.1190	-0.0423	0.0390
90.00	-0.0168	0.0349	0.1265
95.00	0.0437	0.1148	0.1690

IMMERSION(%)= 80.000

PRESSURE SURFACE %CHORD	DP	PE	PPR
2.50	-0.0747	0.0496	0.1687
8.00	0.0377	0.1107	0.1925
20.00	0.0952	0.1457	0.2025
30.00	0.1108	0.1620	0.2163
45.00	0.1283	0.1745	0.2175
60.00	0.1330	0.1807	0.2263
70.00	0.1402	0.1826	0.2276
80.00	0.1296	0.1732	0.2175
90.00	0.1021	0.1432	0.1862
95.00	0.0696	0.1057	0.1549

SUCTION SURFACE %CHORD	DP	PE	PPR
2.50	-0.3350	-0.4207	-0.5245
8.00	-0.4077	-0.4263	-0.4438
13.00	-0.4716	-0.4693	-0.4662
20.00	-0.5175	-0.4951	-0.4687
25.00	-0.5163	-0.4840	-0.4438
30.00	-0.5039	-0.4629	-0.4165
35.00	-0.4778	-0.4294	-0.3755
40.00	-0.4406	-0.3922	-0.3344
50.00	-0.3785	-0.3053	-0.2049
60.00	-0.2516	-0.1735	-0.0864
70.00	-0.1482	-0.0639	0.0135
80.00	-0.0485	0.0221	0.0836
90.00	0.0264	0.0683	0.1123
95.00	0.0396	0.0783	0.1198

IMMERSION(%)= 90.000

PRESSURE SURFACE %CHORD	DP	PE	PPR
2.50	-0.0439	0.0777	0.1753
8.00	0.0152	0.1045	0.1780
20.00	0.8287	0.8117	0.7708
30.00	0.0677	0.1389	0.1875
45.00	0.0868	0.1572	0.1967
60.00	0.1101	0.1657	0.2224
70.00	0.1088	0.1698	0.2174
80.00	0.0882	0.1545	0.2157
90.00	0.0671	0.0979	0.1719
95.00	0.0386	0.1045	0.1505

SUCTION SURFACE %CHORD	DP	PE	PPR
2.50	-0.4092	-0.4477	-0.5262
8.00	-0.4585	-0.4416	-0.4476
13.00	-0.5112	-0.4850	-0.4785
20.00	-0.5657	-0.5369	-0.4739
25.00	-0.5720	-0.4834	-0.4635
30.00	-0.5543	-0.4788	-0.4278
35.00	-0.5279	-0.4519	-0.3833
40.00	-0.4827	-0.4003	-0.3207
50.00	-0.3940	-0.2917	-0.1859
60.00	-0.2708	-0.1611	-0.0582
70.00	-0.1665	-0.0562	0.0088
80.00	-0.0876	-0.0087	0.0473
90.00	-0.0485	0.0009	0.0716
95.00	-0.0505	0.0287	0.0821

Tabulated Surface Pressures Normalized by $\frac{1}{2}\rho_{REF} U_t^2$

THROTTLE

DP - Design Point
PE - Peak Efficiency
PPR - Peak Pressure Rise

Table 10. Vane Surface Static Pressures Four-Stage Configuration - First Stage Is Test Stage.

IMMERSION(%)= 10.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	0.2054	0.3406	0.4761
8.00	0.2346	0.3352	0.4340
[illegible]	0.2616	0.3630	[illegible]
30.00	0.3038	0.3809	0.4530
45.00	0.3244	0.3973	0.4655
60.00	0.3418	0.4156	0.4800
70.00	0.3582	0.4289	0.4921
80.00	0.3653	0.4366	0.4995
90.00	0.3574	0.4294	0.4932
95.00	0.3364	0.4068	0.4731

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	0.1153	0.1078	0.0603
8.00	0.0337	0.0575	0.0638
13.00	0.0030	0.0424	0.0527
20.00	-0.0303	0.0199	0.0640
25.00	-0.0281	0.0296	0.0856
30.00	-0.0223	0.0435	0.1091
35.00	-0.0124	0.0575	0.1286
40.00	0.0060	0.0814	0.1604
50.00	0.0503	0.1323	0.2170
60.00	0.0442	0.0413	0.0387
70.00	0.1684	0.2450	0.3260
80.00	0.2164	0.2905	0.3653
90.00	0.2568	0.3268	0.4004
95.00	0.2753	0.3434	0.4169

IMMERSION(%)= 20.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	0.3106	0.1780	0.4326
8.00	0.3254	0.2305	0.4162
20.00	0.3554	0.2783	0.4318
30.00	0.3742	0.3026	0.4449
45.00	0.3940	0.3269	0.4592
60.00	0.4112	0.3468	0.4740
70.00	0.4221	0.3587	0.4837
80.00	0.4264	0.3645	0.4875
90.00	0.4182	0.3566	0.4785
95.00	0.3996	0.3387	0.4558

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	0.1146	0.1295	0.0788
8.00	0.0539	0.0315	0.0668
13.00	0.0340	-0.0027	0.0606
20.00	0.0154	-0.0393	0.0642
25.00	0.0246	-0.039[illegible]	0.0828
30.00	0.0373	-0.0328	0.1041
35.00	0.0522	-0.0226	0.1223
40.00	0.0784	-0.0043	0.1543
50.00	0.1215	0.0351	0.2071
60.00	0.1839	0.0946	0.2643
70.00	0.2405	0.1557	0.3171
80.00	0.2910	0.2111	0.3652
90.00	0.3325	0.2621	0.4042
95.00	0.3479	0.2812	0.4183

IMMERSION(%)= 50.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	0.1360	0.2672	0.3852
8.00	0.1974	0.2910	0.3827
20.00	0.2583	0.3321	0.4071
30.00	0.2876	0.3554	0.4239
45.00	0.3121	0.3772	0.4422
60.00	0.3360	0.3978	0.4599
70.00	0.3466	0.4082	0.4686
80.00	0.3517	0.4122	0.4718
90.00	0.3466	0.4072	0.4655
95.00	0.3316	0.3926	0.4523

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	0.1096	0.0882	0.0483
8.00	0.0113	0.0309	0.0462
13.00	-0.0350	0.0018	0.0376
20.00	-0.0563	-0.0046	0.0473
25.00	-0.0571	0.0040	0.0661
30.00	-0.0487	0.0193	0.0889
35.00	-0.0381	0.0365	0.1098
40.00	-0.0213	0.0588	0.1398
50.00	0.0198	0.1065	0.1921
60.00	0.0741	0.1617	0.2470
70.00	0.1340	0.2170	0.2993
80.00	0.1918	0.2692	0.3491
90.00	0.2497	0.3218	0.3939
95.00	0.2791	0.3466	0.4137

IMMERSION(%)= 80.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	0.1298	0.2672	0.3838
8.00	0.2032	0.2992	0.3852
20.00	0.2626	0.3352	0.4050
30.00	0.2843	0.3530	0.4178
45.00	0.3062	0.3713	0.4330
60.00	0.3231	0.3866	0.4467
70.00	0.3317	0.3938	0.4533
80.00	0.3332	0.3955	0.4544
90.00	0.3265	0.3889	0.4472
95.00	0.3111	0.3729	0.4315

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	0.0839	0.0477	-0.0081
8.00	-0.0134	0.0035	0.0163
13.00	-0.0427	-0.0096	0.0708
20.00	-0.0641	-0.0106	0.0417
25.00	-0.0590	0.0051	0.0671
30.00	-0.0490	0.0233	0.0930
35.00	-0.0360	0.0421	0.1215
40.00	-0.0126	0.0708	0.1515
50.00	0.0292	0.1171	0.2043
60.00	0.0825	0.1709	0.2582
70.00	0.1338	0.2195	0.3039
80.00	0.1835	0.2612	0.3420
90.00	0.2342	0.3078	0.3741
95.00	0.2541	0.3281	0.3873

IMMERSION(%)= 95.000

PRESSURE SURFACE

%CHORD	DP	PE	PPR
2.50	0.2342	0.3386	0.4440
8.00	0.2452	0.3286	0.4122
20.00	0.2712	0.3435	0.4152
30.00	0.2856	0.3542	0.4235
45.00	0.3047	0.3697	0.4354
60.00	0.3222	0.3858	0.4511
70.00	0.3301	0.3934	0.4569
80.00	0.3319	0.3950	0.4585
90.00	0.3247	0.3862	0.4502
95.00	0.3025	0.3645	0.4285

SUCTION SURFACE

%CHORD	DP	PE	PPR
2.50	-0.0451	-0.0882	-0.0970
8.00	-0.0599	-0.0389	-0.0165
13.00	-0.0607	-0.0280	0.0133
20.00	-0.0576	-0.0062	0.0500
25.00	-0.0419	0.0192	0.0838
30.00	-0.0275	0.0422	0.1152
35.00	-0.0146	0.0611	0.1388
40.00	0.0135	0.0954	0.1809
50.00	0.0566	0.1474	0.2325
60.00	0.1057	0.1918	0.2754
70.00	0.1536	0.2335	0.3087
80.00	0.1904	0.2659	0.3386
90.00	0.2256	0.2981	0.3652
95.00	0.2393	0.3098	0.3742

Tabulated Surface Pressures Normalized by $\frac{1}{2} \rho_{REF} U_t^2$

THROTTLE

DP - Design Point
PE - Peak Efficiency
PPR - Peak Pressure Rise

Table 11. Normalized Absolute Total Pressure, Static Pressure and Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested.

Design Point Throttle

Percent Immersion	Total Pressure Rotor 3 Inlet	Total Pressure Rotor 3 Exit	Total Pressure Stator 3 Exit	Static Pressure Rotor 3 Inlet	Static Pressure Rotor 3 Exit	Static Pressure Stator 3 Exit
1	0.9953	1.4907	1.5551	0.875	1.255	1.450
2	1.0156	1.5494	1.5698	0.875	1.250	1.445
3	1.0285	1.5763	1.5780	0.875	1.245	1.435
4	1.0441	1.5993	1.5893	0.875	1.243	1.434
5	1.0551	1.6199	1.5988	0.875	1.240	1.430
7	1.0680	1.6737	1.6141	0.875	1.235	1.428
10	1.0800	1.6850	1.6250	0.875	1.233	1.425
15	1.0918	1.6937	1.6370	0.875	1.235	1.430
20	1.0973	1.6902	1.6507	0.875	1.240	1.433
30	1.1042	1.6750	1.6660	0.875	1.240	1.435
50	1.1202	1.6967	1.6810	0.875	1.230	1.430
70	1.1189	1.6985	1.6772	0.865	1.210	1.425
80	1.1016	1.6830	1.6650	0.855	1.195	1.415
85	1.0898	1.6785	1.6568	0.845	1.193	1.407
90	1.0818	1.6798	1.6497	0.840	1.190	1.395
93	1.0741	1.6759	1.6317	0.830	1.190	1.385
95	1.0585	1.6762	1.5952	0.825	1.190	1.385
96	1.0405	1.6773	1.5695	0.825	1.190	1.390
97	1.0166	1.6768	1.5448	0.825	1.190	1.395
98	0.9941	1.6787	1.4974	0.830	1.187	1.40

Peak Efficiency Throttle

Percent Immersion	Total Pressure Rotor 3 Inlet	Total Pressure Rotor 3 Exit	Total Pressure Stator 3 Exit	Static Pressure Rotor 3 Inlet	Static Pressure Rotor 3 Exit	Static Pressure Stator 3 Exit
1	1.115	1.715	1.715	0.990	1.390	1.600
2	1.125	1.760	1.730	0.990	1.380	1.592
3	1.135	1.780	1.737	0.988	1.375	1.585
4	1.140	1.795	1.741	0.988	1.370	1.583
5	1.150	1.805	1.750	0.985	1.367	1.580
7	1.160	1.815	1.755	0.985	1.361	1.575
10	1.173	1.820	1.770	0.985	1.357	1.575
15	1.190	1.825	1.785	0.987	1.359	1.575
20	1.195	1.820	1.785	0.989	1.360	1.575
30	1.195	1.805	1.790	0.989	1.360	1.576
50	1.205	1.810	1.795	0.981	1.355	1.576
70	1.188	1.805	1.785	0.975	1.340	1.563
80	1.173	1.795	1.777	0.965	1.330	1.555
85	1.167	1.800	1.775	0.955	1.323	1.547
90	1.160	1.805	1.765	0.945	1.315	1.540
93	1.150	1.807	1.741	0.937	1.310	1.525
95	1.130	1.811	1.710	0.931	1.310	1.532
96	1.110	1.812	1.695	0.929	1.308	1.525
97	1.090	1.810	1.672	0.925	1.307	1.524
98	1.067	1.807	1.605	0.920	1.306	1.520

Peak Pressure Rise Throttle

Percent Immersion	Total Pressure Rotor 3 Inlet	Total Pressure Rotor 3 Exit	Total Pressure Stator 3 Exit	Static Pressure Rotor 3 Inlet	Static Pressure Rotor 3 Exit	Static Pressure Stator 3 Exit
1	1.2250	1.9150	1.8750	1.095	1.525	1.740
2	1.2339	1.9388	1.8804	1.095	1.510	1.732
3	1.2298	1.9565	1.8854	1.095	1.501	1.725
4	1.2371	1.9663	1.8878	1.095	1.495	1.722
5	1.2401	1.9607	1.8912	1.093	1.490	1.720
7	1.2461	1.9629	1.8965	1.093	1.485	1.715
10	1.2507	1.9585	1.8954	1.090	1.480	1.715
15	1.2612	1.9498	1.9039	1.091	1.483	1.720
20	1.2715	1.9486	1.9147	1.092	1.485	1.720
30	1.2804	1.9472	1.9274	1.092	1.485	1.720
50	1.2821	1.9366	1.9133	1.085	1.480	1.705
70	1.2627	1.9257	1.9008	1.075	1.465	1.700
80	1.2509	1.9271	1.8958	1.067	1.455	1.690
85	1.2468	1.9350	1.8899	1.062	1.448	1.685
90	1.2410	1.9411	1.8808	1.055	1.440	1.675
93	1.2285	1.9432	1.8457	1.045	1.435	1.665
95	1.2094	1.9440	1.8280	1.040	1.430	1.660
96	1.1964	1.9449	1.8200	1.035	1.430	1.657
97	1.1846	1.9426	1.8067	1.035	1.427	1.655
98	1.1519	1.9336	1.7309	1.030	1.425	1.650

Near Stall Throttle

Percent Immersion	Total Pressure Rotor 3 Inlet	Total Pressure Rotor 3 Exit	Total Pressure Stator 3 Exit	Static Pressure Rotor 3 Inlet	Static Pressure Rotor 3 Exit	Static Pressure Stator 3 Exit
1	1.2550	1.8850	1.8600	1.107	1.510	1.720
2	1.2692	1.8995	1.8764	1.110	1.505	1.715
3	1.2750	1.9200	1.8800	1.110	1.500	1.710
4	1.2850	1.9300	1.8870	1.110	1.495	1.705
5	1.2908	1.9434	1.8930	1.111	1.495	1.705
7	1.2891	1.9547	1.8985	1.111	1.490	1.700
10	1.2920	1.9591	1.9013	1.110	1.485	1.697
15	1.2985	1.9539	1.9087	1.110	1.485	1.695
20	1.3006	1.9441	1.9067	1.105	1.485	1.690
30	1.2946	1.9260	1.8946	1.095	1.480	1.680
50	1.2628	1.9177	1.8534	1.070	1.455	1.650
70	1.2097	1.9346	1.7991	1.050	1.432	1.625
80	1.1857	1.9513	1.7652	1.035	1.427	1.615
85	1.1700	1.9526	1.7541	1.028	1.425	1.610
90	1.1619	1.9589	1.7554	1.020	1.425	1.607
93	1.1569	1.9558	1.7533	1.015	1.425	1.600
95	1.1474	1.9522	1.7545	1.007	1.426	1.597
96	1.1448	1.9367	1.7462	1.006	1.427	1.595
97	1.1409	1.9174	1.7351	1.005	1.428	1.590
98	1.1285	1.8942	1.6571	1.003	1.429	1.585

Table 11. Normalized Absolute Total Pressure, Static Pressure and Flow Angles for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested (Concluded).

Design Point Throttle

Percent Immersion	Measured Rotor 3 Inlet	Measured Rotor 3 Exit	Measured Stator 3 Exit	Corrected Rotor 3 Inlet	Corrected Rotor 3 Exit	Corrected Stator 3 Exit
1	31.2	63.8	26.7	32.5	64.9	27.9
2	30.4	62.6	25.6	31.7	63.7	26.7
3	29.4	61.4	24.8	30.6	62.5	25.9
4	28.0	60.9	24.0	29.2	62.1	25.0
5	27.5	60.6	23.4	28.6	61.7	24.4
7	24.2	59.9	24.0	25.2	61.0	25.0
10	22.8	58.6	25.8	23.8	59.7	26.8
15	22.0	54.8	25.6	22.9	56.0	26.6
20	21.4	51.6	24.7	22.2	52.8	25.6
30	20.3	48.9	21.8	21.0	50.0	22.6
50	19.5	48.0	20.6	20.1	48.9	21.2
70	19.8	49.2	21.0	20.3	50.0	21.5
80	20.1	50.2	23.0	20.6	50.9	23.5
85	20.5	50.8	23.0	21.0	51.5	23.5
90	20.9	51.3	23.0	21.4	52.0	23.5
93	24.5	51.7	23.5	25.0	52.4	24.0
95	25.5	52.0	24.1	26.0	52.6	24.6
96	25.4	52.1	24.4	25.9	52.7	24.9
97	24.9	52.2	25.0	25.4	52.8	25.5
98	24.3	52.4	26.2	24.8	53.0	26.7

Peak Efficiency Throttle

Percent Immersion	Measured Rotor 3 Inlet	Measured Rotor 3 Exit	Measured Stator 3 Exit	Corrected Rotor 3 Inlet	Corrected Rotor 3 Exit	Corrected Stator 3 Exit
1	31.8	68.8	24.4	33.1	69.7	25.5
2	30.6	67.4	24.0	31.9	68.4	25.1
3	29.2	65.6	23.6	30.4	66.6	24.6
4	28.0	64.8	23.3	29.2	65.8	24.3
5	26.6	64.4	23.1	27.7	65.4	24.1
7	25.0	62.7	24.2	26.1	63.8	25.2
10	23.2	60.5	25.2	24.2	61.6	26.2
15	22.3	57.0	24.9	23.2	58.1	25.9
20	21.6	54.2	24.1	22.4	55.3	25.0
30	19.9	53.0	22.0	20.6	54.0	22.8
50	20.0	50.8	20.6	20.6	51.7	21.2
70	20.4	51.8	22.8	20.9	52.6	23.4
80	20.8	52.8	24.2	21.3	53.5	24.8
85	21.4	53.5	24.8	21.9	54.2	25.4
90	22.0	54.2	25.2	22.5	54.9	25.7
93	24.3	54.4	25.2	24.8	55.0	25.7
95	26.2	54.4	24.8	26.7	55.0	25.3
96	26.0	54.0	24.0	26.5	54.6	24.5
97	25.5	53.8	22.9	26.0	54.4	23.4
98	23.8	54.2	20.8	24.3	54.8	21.2

Peak Pressure Rise Throttle

Percent Immersion	Measured Rotor 3 Inlet	Measured Rotor 3 Exit	Measured Stator 3 Exit	Corrected Rotor 3 Inlet	Corrected Rotor 3 Exit	Corrected Stator 3 Exit
1	31.8	69.6	24.2	33.1	70.5	25.3
2	30.5	68.5	24.0	31.8	69.4	25.1
3	29.0	67.5	23.9	30.2	68.5	25.0
4	28.0	66.5	23.7	29.2	67.5	24.7
5	27.0	66.0	23.6	28.1	67.0	24.6
7	25.4	64.6	24.8	26.5	65.6	25.8
10	24.3	62.2	26.0	25.3	63.3	27.0
15	24.0	58.4	24.4	24.9	59.5	25.4
20	23.3	55.5	23.4	24.2	56.6	24.3
30	21.3	52.5	22.3	22.1	53.5	23.1
50	21.8	52.6	22.0	22.5	53.5	22.7
70	25.5	56.0	24.6	26.1	56.7	25.2
80	26.0	58.2	26.0	26.6	58.9	26.6
85	26.0	59.2	25.2	26.6	59.8	25.8
90	25.6	59.6	22.2	26.1	60.2	22.7
93	25.1	59.3	20.3	25.6	59.9	20.8
95	24.6	58.6	19.5	25.1	59.2	19.9
96	24.3	58.2	19.2	24.8	58.8	19.6
97	24.0	58.0	18.8	24.5	58.6	19.2
98	23.6	57.6	18.5	24.1	58.2	18.9

Near Stall Throttle

Percent Immersion	Measured Rotor 3 Inlet	Measured Rotor 3 Exit	Measured Stator 3 Exit	Corrected Rotor 3 Inlet	Corrected Rotor 3 Exit	Corrected Stator 3 Exit
1	30.8	67.4	23.8	32.1	68.4	24.9
2	30.0	66.3	24.8	31.2	67.3	25.9
3	28.6	64.5	24.8	29.8	65.6	25.9
4	27.6	63.8	24.8	28.8	64.9	25.9
5	27.0	62.8	23.9	28.1	63.9	24.9
7	25.6	62.2	25.0	26.7	63.3	26.1
10	24.8	60.8	25.5	25.8	61.9	26.5
15	24.2	55.2	24.0	25.2	56.4	24.9
20	24.0	53.3	23.1	24.9	54.4	24.0
30	24.3	53.9	23.8	25.1	54.9	24.6
50	26.2	57.4	25.5	26.9	58.2	26.2
70	27.2	61.6	25.9	27.9	62.3	26.5
80	25.8	63.4	24.6	26.4	64.0	25.2
85	25.6	63.9	24.2	26.2	64.5	24.7
90	25.8	63.6	24.4	26.4	64.1	24.9
93	26.2	63.1	24.7	26.7	63.6	25.2
95	26.4	62.6	25.0	26.9	63.1	25.5
96	26.6	62.4	25.0	27.1	62.9	25.5
97	26.8	62.0	25.2	27.3	62.5	25.7
98	27.0	61.6	25.4	27.5	62.1	25.9

Table 12. Rotor 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	1.6795	1.5765	5.0	0.1296	0.0076	0.1219
10.0	1.6844	1.6000	10.0	0.0948	0.0184	0.0763
15.0	1.6705	1.6367	15.0	0.0425	0.0226	0.0199
20.0	1.6703	1.6452	20.0	0.0316	0.0199	0.0117
35.0	1.6795	1.6467	35.0	0.0409	0.0211	0.0198
50.0	1.6606	1.6160	50.0	0.0435	0.0192	0.0243
65.0	1.6040	1.5746	65.0	0.0396	0.0269	0.0127
80.0	1.5504	1.5159	80.0	0.0601	0.0459	0.0142
85.0	1.5443	1.4926	85.0	0.0737	0.0487	0.0250
90.0	1.5203	1.4616	90.0	0.0863	0.0566	0.0297
95.0	1.4895	1.4416	95.0	0.0720	0.0523	0.0197

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	1.7813	1.6682	5.0	0.1428	0.0111	0.1316
10.0	1.7757	1.7062	10.0	0.0882	0.0132	0.0750
15.0	1.7642	1.7367	15.0	0.0356	0.0178	0.0178
20.0	1.7811	1.7452	20.0	0.0451	0.0173	0.0278
35.0	1.7949	1.7507	35.0	0.0546	0.0204	0.0342
50.0	1.7517	1.7048	50.0	0.0620	0.0216	0.0404
65.0	1.6997	1.6543	65.0	0.0626	0.0335	0.0292
80.0	1.6504	1.5969	80.0	0.0779	0.0505	0.0274
85.0	1.6310	1.5777	85.0	0.0791	0.0453	0.0338
90.0	1.6050	1.5510	90.0	0.0820	0.0523	0.0297
95.0	1.5760	1.5381	95.0	0.0588	0.0493	0.0095

Peak Pressure Rise 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	1.8744	1.7671	5.0	0.1378	0.0081	0.1297
10.0	1.8767	1.8086	10.0	0.0867	0.0151	0.0717
15.0	1.8703	1.8409	15.0	0.0375	0.0189	0.0186
20.0	1.8817	1.8503	20.0	0.0395	0.0194	0.0201
35.0	1.8918	1.8533	35.0	0.0479	0.0232	0.0246
50.0	1.8372	1.8033	50.0	0.0452	0.0294	0.0157
65.0	1.7872	1.7360	65.0	0.0713	0.0425	0.0286
80.0	1.7247	1.6607	80.0	[illegible]	0.0674	0.0355
85.0	1.7022	1.6403	85.0	[illegible]	0.0724	0.0251
90.0	1.6956	1.6222	90.0	0.1148	0.0774	0.0375
95.0	1.6804	1.6245	95.0	0.0881	0.0650	0.0231

Near Stall Throttle

TOTAL PRESSURE			ROTOR LOSS COEFFICIENT			
PERCENT IMMERSION	ROTOR 3 INLET	ROTOR 2 EXIT	PERCENT IMMERSION	TOTAL LOSS	WAKE LOSS	TOTAL MINUS WAKE LOSS
5.0	1.8938	1.8033	5.0	0.1155	0.0148	0.1007
10.0	1.9027	1.8350	10.0	0.0855	0.0215	0.0640
15.0	1.8949	1.8625	15.0	0.0412	0.0296	0.0116
20.0	1.9116	1.8642	20.0	0.0587	0.0326	0.0260
35.0	1.8813	1.8243	35.0	0.0710	0.0516	0.0202
50.0	1.8042	1.7270	50.0	0.1051	0.0752	0.0299
65.0	1.7331	1.6449	65.0	0.1290	0.1068	0.0222
80.0	1.6978	1.5973	80.0	0.1493	0.1058	0.0435
85.0	1.6939	1.5929	85.0	0.1509	0.1065	0.0444
90.0	1.6938	1.5920	90.0	0.1514	0.1131	0.0379
95.0	1.6610	1.5923	95.0	0.1059	0.0959	0.0100

Table 13. Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Design Point Throttle.

BLADE ELEMENT DATA ROTOR INLET TIP SPEED = 03.62 MPS (209.30 FPS)

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS	DEG
1.0	55.1	180.8	51.9	170.4	70.2	18.5	60.6	11.8	38.7	21.9	71.9	32.5
2.0	55.0	180.4	51.2	167.9	68.3	20.1	66.0	12.4	40.8	23.7	77.6	31.7
3.0	55.1	180.9	50.8	166.7	67.0	21.4	70.2	12.7	41.7	24.9	81.7	30.6
4.0	55.6	182.3	50.7	166.3	65.6	22.8	74.8	12.7	41.8	26.1	85.6	29.2
5.0	55.7	182.6	50.4	165.5	64.6	23.5	77.2	12.9	42.3	26.8	88.0	28.0
7.0	57.1	187.3	51.2	168.0	63.6	25.3	82.8	11.9	39.2	27.9	91.6	25.2
10.0	57.6	189.0	51.3	168.3	62.8	26.2	86.0	11.6	37.9	28.6	94.0	23.8
15.0	57.7	189.2	50.9	167.2	61.9	27.0	88.6	11.4	37.5	29.3	96.2	22.9
20.0	57.6	189.1	50.6	166.0	61.2	27.6	90.5	11.3	37.1	29.8	97.8	22.2
30.0	57.5	188.6	50.0	164.2	60.3	28.3	92.9	10.9	35.8	30.3	99.5	21.0
50.0	56.5	185.4	48.2	158.3	58.5	29.4	96.4	10.8	35.4	31.3	102.7	20.1
70.0	54.9	180.1	46.0	150.9	56.8	29.9	98.3	11.1	36.5	31.9	104.8	20.3
80.0	53.8	176.5	45.1	148.0	56.8	29.3	96.1	11.0	36.2	31.3	102.7	20.6
85.0	53.2	174.5	44.4	145.8	56.5	29.2	95.9	11.2	36.9	31.3	102.7	21.0
90.0	52.5	172.3	43.9	144.0	56.5	28.8	94.7	11.3	37.1	31.0	101.7	21.4
93.0	50.4	165.3	41.6	136.6	55.6	28.4	93.0	13.3	43.6	31.3	102.7	25.0
95.0	49.6	162.7	41.2	135.3	56.1	27.5	90.4	13.5	44.3	30.7	100.6	26.0
96.0	49.4	162.1	41.8	137.1	57.6	26.4	86.5	12.9	42.2	29.3	96.2	25.9
97.0	49.4	162.1	42.7	140.0	59.6	24.9	81.7	11.9	38.9	27.6	90.5	25.4
98.0	49.5	162.3	43.6	143.2	61.7	23.3	76.5	10.8	35.4	25.7	84.3	24.8

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	DEG
1.0	38.2	125.4	36.0	118.1	70.1	12.9	42.3	27.7	91.0	30.6	100.3	64.9
2.0	36.0	118.0	32.6	106.9	64.8	15.2	49.9	31.0	101.8	34.6	113.4	63.7
3.0	35.4	116.3	31.3	102.7	61.9	16.6	54.5	32.2	105.7	36.3	118.9	62.5
4.0	34.8	114.3	30.1	98.7	59.5	17.6	57.7	33.4	109.5	37.7	123.7	62.1
5.0	34.3	112.6	29.0	95.2	57.6	18.3	60.1	34.3	112.6	38.9	127.7	61.7
7.0	33.3	109.1	26.4	86.8	52.5	20.2	66.2	36.7	120.4	41.9	137.4	61.0
10.0	33.7	110.6	26.1	85.7	50.7	21.3	69.8	36.7	120.5	42.4	139.3	59.7
15.0	35.9	117.8	26.8	88.0	48.2	23.9	78.3	35.6	116.6	42.8	140.5	56.0
20.0	38.0	124.7	26.1	92.3	47.6	25.6	83.8	33.8	110.8	42.4	139.0	52.8
30.0	39.4	129.3	29.0	95.1	47.2	26.7	87.6	32.0	104.8	41.6	136.6	50.0
50.0	38.7	127.0	26.4	86.7	43.0	28.3	92.8	32.6	106.9	43.2	141.6	48.9
70.0	36.6	120.2	23.2	76.1	39.2	28.3	93.0	33.9	111.3	44.2	145.0	50.0
80.0	35.3	115.8	21.8	71.4	38.0	27.8	91.1	34.4	112.8	44.2	145.0	50.9
85.0	34.6	113.4	21.1	69.3	37.6	27.3	89.7	34.6	113.4	44.1	144.6	51.5
90.0	33.9	111.2	20.3	66.7	36.7	27.1	89.1	34.9	114.5	44.2	145.0	52.0
93.0	33.4	109.7	20.0	65.7	36.7	26.8	87.8	34.9	114.5	44.0	144.3	52.4
95.0	33.1	108.6	19.7	64.6	36.4	26.6	87.3	35.0	114.9	44.0	144.3	52.6
96.0	33.0	108.2	19.4	63.6	35.9	26.7	87.5	35.2	115.6	44.2	145.0	52.7
97.0	32.8	107.7	19.2	63.1	35.8	26.6	87.3	35.3	115.8	44.2	145.0	52.8
98.0	32.6	107.1	18.9	62.2	35.4	26.6	87.2	35.5	116.4	44.3	145.5	53.0

BLADE ELEMENT DATA STATOR OUTLET

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS	DEG
1.0	57.1	187.3	54.2	177.7	71.4	18.0	59.1	9.6	31.4	20.4	66.9	27.9
2.0	57.2	187.7	53.8	176.5	69.9	19.5	63.9	9.8	32.3	21.8	71.6	26.7
3.0	57.3	187.9	53.2	174.6	68.1	21.2	69.5	10.3	33.8	23.6	77.3	25.9
4.0	57.5	188.6	52.9	173.5	66.7	22.5	73.9	10.6	34.6	24.9	81.6	25.0
5.0	57.6	189.1	52.6	172.5	65.6	23.6	77.5	10.8	35.3	26.0	85.2	24.4
7.0	57.2	187.6	51.6	169.3	61.3	24.7	80.9	11.5	37.9	27.2	89.3	25.0
10.0	56.1	183.9	50.1	164.4	63.2	25.1	82.4	12.7	41.8	28.2	92.4	26.8
15.0	55.8	182.9	49.6	162.7	62.6	25.5	83.6	12.8	42.0	28.5	93.6	26.6
20.0	55.8	183.2	49.2	161.4	61.6	26.4	86.7	12.7	41.7	29.3	96.3	25.6
30.0	56.6	185.6	49.6	162.7	61.0	27.3	89.5	11.4	37.3	29.5	96.9	22.6
50.0	55.9	183.5	47.6	156.2	58.2	29.3	96.3	11.4	37.5	31.5	103.3	21.2
70.0	54.1	177.6	45.5	149.4	57.1	29.3	96.1	11.6	38.0	31.5	103.3	21.5
80.0	52.2	171.4	43.5	142.9	56.3	28.9	94.7	12.6	41.4	31.5	103.3	23.5
85.0	51.8	170.1	43.1	141.5	56.2	28.7	94.3	12.6	41.2	31.4	102.9	23.5
90.0	51.5	169.0	42.5	139.4	55.4	29.2	95.7	12.7	41.7	31.8	104.4	23.5
93.0	50.9	167.0	42.2	138.5	55.6	28.5	93.4	12.7	41.7	31.2	102.3	24.0
95.0	50.1	164.3	42.7	140.0	58.3	26.2	86.0	12.6	39.5	28.9	94.7	24.6
96.0	49.7	162.9	43.3	142.2	60.6	24.2	79.5	11.3	37.0	26.7	87.7	24.9
97.0	49.2	161.4	44.0	144.4	63.3	22.0	72.2	10.5	34.5	24.4	80.0	25.5
98.0	48.8	160.1	45.5	149.2	68.5	17.8	58.3	9.0	29.4	19.0	65.3	26.7

Table 14. Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Peak Efficiency Throttle.

BLADE ELEMENT DATA ROTOR INLET TIP SPEED = 64.67 MPS (212.17 FPS)

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	55.5	182.1	52.2	171.2	69.9	18.9	62.1	12.4	40.6	22.6	74.2	33.1
2.0	55.7	182.8	52.0	170.7	68.8	20.0	65.5	12.4	40.6	23.5	77.1	31.9
3.0	56.1	184.0	51.9	170.4	67.6	21.1	69.4	12.4	40.6	24.5	80.5	30.4
4.0	56.5	185.2	52.1	170.9	67.1	21.8	71.4	12.2	40.0	25.0	81.9	29.2
5.0	56.9	186.7	52.1	170.8	66.0	23.0	75.5	12.1	39.6	26.0	85.3	27.7
7.0	57.5	188.6	52.2	171.3	65.1	24.0	78.9	11.8	38.7	26.8	87.8	26.1
10.0	58.1	190.6	52.3	171.6	64.0	25.3	83.0	11.4	37.4	27.8	91.1	24.2
15.0	58.2	191.0	51.8	170.0	62.7	26.5	86.9	11.4	37.4	28.8	94.6	23.2
20.0	58.2	190.9	51.6	169.3	62.3	26.8	88.1	11.1	36.5	29.1	95.3	22.4
30.0	58.2	191.1	51.5	169.0	62.0	27.2	89.2	10.3	33.6	29.1	95.3	20.6
50.0	56.7	186.1	49.1	161.2	59.8	28.3	93.0	10.7	35.1	30.3	99.4	20.6
70.0	54.8	179.6	47.3	155.2	59.6	27.6	90.5	10.6	34.7	29.5	96.9	20.9
80.0	53.7	176.1	46.3	151.8	59.4	27.2	89.2	10.6	34.9	29.2	95.8	21.3
85.0	53.0	173.9	45.4	149.0	58.8	27.3	89.7	11.0	36.2	29.5	96.7	21.9
90.0	52.3	171.6	44.6	146.2	58.2	27.4	89.9	11.4	37.3	29.7	97.4	22.5
93.0	50.9	166.8	43.2	141.8	58.0	26.8	87.9	12.4	40.8	29.5	96.9	24.8
95.0	49.6	162.8	42.6	139.7	58.9	25.5	83.6	12.9	42.3	28.6	93.7	26.7
96.0	49.6	162.6	43.2	141.6	60.4	24.3	79.9	12.2	40.0	27.2	89.3	26.5
97.0	49.7	162.9	43.8	143.8	61.8	23.3	76.6	11.4	37.5	26.0	85.3	26.0
[illegible] 0	50.3	165.0	45.0	147.6	63.4	22.4	73.3	10.1	33.2	24.5	80.5	24.3

BLADE ELEMENT DATA ROTOR OUTLET / STATOR INLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	32.9	107.8	30.4	99.7	67.4	12.5	41.0	34.2	112.2	36.4	119.4	69.7
2.0	31.3	102.8	27.8	91.3	62.5	14.4	47.2	36.6	120.2	39.4	129.2	68.4
3.0	31.4	103.0	27.0	88.6	59.2	16.0	52.5	37.4	122.6	40.7	133.4	66.6
4.0	31.2	102.4	26.2	86.1	57.0	16.9	55.5	38.0	124.8	41.6	136.6	65.8
5.0	31.0	101.9	25.7	84.2	55.6	17.5	57.3	38.5	126.3	42.3	138.7	65.4
7.0	31.6	103.7	25.3	83.1	53.1	18.9	62.0	38.7	126.9	43.0	141.2	63.8
10.0	32.7	107.2	25.4	83.3	50.9	20.6	67.5	38.3	125.7	43.5	142.6	61.6
15.0	34.8	114.0	26.1	85.7	48.6	22.9	75.2	37.1	121.7	43.6	143.1	58.1
20.0	36.5	119.8	27.0	88.7	47.6	24.6	80.8	35.7	117.1	43.3	142.2	55.3
30.0	36.9	121.1	27.2	89.2	47.3	24.9	81.8	34.6	113.4	42.6	139.8	54.0
50.0	37.2	121.9	25.9	85.1	44.1	26.6	87.3	33.9	111.2	43.1	141.4	51.7
70.0	35.2	115.3	23.2	76.2	41.2	26.4	86.6	34.7	113.7	43.6	142.9	52.6
80.0	33.8	110.9	21.8	71.6	40.1	25.8	84.7	35.1	115.1	43.6	142.9	53.5
85.0	32.9	108.1	20.6	67.5	38.5	25.7	84.4	35.8	117.6	44.1	144.8	54.2
90.0	32.1	105.3	19.3	63.3	36.8	25.7	84.2	36.6	120.2	44.7	146.7	54.9
93.0	31.8	104.3	18.7	61.2	35.9	25.7	84.4	37.0	121.3	45.0	147.8	55.0
95.0	31.7	103.9	18.3	60.1	35.3	25.8	84.7	37.1	121.8	45.2	148.4	55.0
96.0	31.9	104.8	18.3	60.0	34.9	26.2	85.8	37.1	121.6	45.4	148.8	54.6
97.0	32.0	105.1	18.3	60.1	34.8	26.3	86.2	36.9	121.2	45.3	148.7	54.4
98.0	31.7	103.9	18.1	59.5	34.8	26.0	85.2	37.0	121.5	45.2	148.4	54.8

BLADE ELEMENT DATA STATOR OUTLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	58.6	192.2	55.3	181.3	70.4	19.5	63.9	9.3	30.6	21.6	70.9	25.5
2.0	58.5	191.9	54.4	178.6	68.3	21.4	70.3	10.1	33.0	23.7	77.6	25.1
3.0	58.5	192.0	54.0	177.2	67.1	22.6	74.0	10.4	34.1	24.8	81.5	24.6
4.0	58.6	192.1	53.8	176.6	66.6	23.1	75.7	10.5	34.3	25.3	83.1	24.3
5.0	58.6	192.1	53.4	175.3	65.7	24.0	78.6	10.8	35.3	26.3	86.2	24.1
7.0	57.9	189.8	52.4	172.1	64.8	24.4	80.2	11.5	37.9	27.0	88.7	25.2
10.0	57.1	187.4	51.2	168.1	63.6	25.2	82.8	12.5	40.9	28.1	92.3	26.2
15.0	56.9	186.6	50.4	165.5	62.3	26.3	86.1	12.8	41.9	29.2	95.8	25.9
20.0	56.9	186.6	50.4	165.2	62.1	26.4	86.8	12.4	40.6	29.2	95.8	25.0
30.0	57.2	187.6	50.3	165.1	61.5	27.2	89.1	11.4	37.5	29.5	96.7	22.8
50.0	56.3	184.8	49.0	160.8	60.3	27.8	91.2	10.8	35.5	29.8	97.8	21.2
70.0	53.6	175.7	45.9	150.7	58.9	27.5	90.4	11.[illegible]	39.2	30.0	98.5	23.4
80.0	52.0	170.6	44.3	145.3	58.2	27.2	89.4	12.6	41.4	30.0	98.5	24.6
85.0	51.3	168.4	43.4	142.3	57.5	27.5	90.2	13.1	42.9	30.4	99.8	25.4
90.0	50.7	166.3	42.8	140.3	57.4	27.2	89.3	13.2	43.2	30.2	99.2	25.7
93.0	50.3	165.1	43.1	141.3	58.7	26.0	85.4	12.6	41.3	28.9	94.9	25.7
95.0	50.2	164.7	43.9	144.1	60.9	24.3	79.7	11.5	37.8	26.9	88.2	25.3
96.0	50.4	165.5	44.4	145.8	61.8	23.9	78.4	10.9	35.8	26.3	86.2	24.5
97.0	50.8	166.5	45.5	149.3	63.5	22.5	73.8	9.8	32.0	24.5	80.4	23.4
98.0	51.4	168.7	48.4	158.9	70.1	17.3	56.8	6.7	22.1	18.6	60.9	21.2

ORIGINAL PAGE IS
OF POOR QUALITY

Table 15. Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise Throttle.

BLADE ELEMENT DATA ROTOR INLET TIP SPEED = 63.32 MPS (207.73 FPS)

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS	DEG
1.0	54.3	178.0	50.9	166.9	69.4	18.9	62.0	12.4	40.6	22.6	74.1	33.1
2.0	54.6	179.0	50.9	167.0	68.6	19.7	64.6	12.2	40.1	23.2	76.1	31.8
3.0	55.1	180.9	51.4	168.7	68.7	19.9	65.2	11.6	38.1	23.0	75.5	30.2
4.0	55.4	181.8	51.5	168.9	68.1	20.4	67.1	11.5	37.6	23.4	76.9	29.2
5.0	55.7	182.6	51.5	168.9	67.6	21.2	69.4	11.4	37.2	24.0	78.8	28.1
7.0	56.2	184.3	51.7	169.8	66.6	21.8	71.7	10.9	35.8	24.4	80.1	26.5
10.0	56.4	185.0	51.6	169.4	66.1	22.6	74.3	10.7	35.2	25.1	82.2	25.3
15.0	56.1	184.0	51.0	167.3	65.2	23.3	76.6	10.9	35.7	25.8	84.5	24.9
20.0	56.0	183.8	50.6	165.9	64.3	24.1	79.1	10.9	35.6	26.4	86.7	24.2
30.0	56.2	184.4	50.2	164.8	63.2	25.2	82.6	10.2	33.6	27.2	89.1	22.1
50.0	54.4	178.3	48.0	157.4	61.8	25.6	83.9	10.6	34.8	27.7	90.8	22.5
70.0	50.9	167.0	44.7	146.7	61.3	24.3	79.8	12.0	39.2	27.1	88.9	20.1
80.0	49.8	163.5	43.7	143.3	61.1	23.9	78.6	12.0	39.5	26.8	87.9	20.6
85.0	49.4	162.1	43.2	141.8	60.8	24.0	78.6	12.0	39.4	26.8	87.9	20.6
90.0	49.2	161.5	42.9	140.6	60.4	24.2	79.3	11.9	39.1	26.9	88.4	20.1
93.0	49.2	161.4	42.8	140.4	60.3	24.3	79.7	11.7	38.3	26.9	88.4	25.6
95.0	49.2	161.4	43.3	142.1	61.5	23.4	76.7	11.0	36.1	25.8	84.7	25.1
96.0	49.2	161.5	43.7	143.2	62.3	22.7	74.6	10.5	34.6	25.1	82.2	24.8
97.0	49.2	161.5	44.0	144.4	63.2	22.1	72.4	10.1	33.1	24.3	79.6	24.5
98.0	49.3	161.7	45.1	148.1	66.1	19.8	65.0	8.9	29.1	21.7	71.2	24.1

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	DEG
1.0	29.4	96.4	26.4	86.5	63.7	12.9	42.4	36.8	120.9	39.0	128.1	70.5
2.0	28.5	93.6	24.7	81.0	59.8	14.3	46.9	38.4	126.1	41.0	134.5	69.4
3.0	28.3	92.7	23.7	77.8	56.9	15.4	50.5	39.3	129.0	42.2	138.5	68.5
4.0	28.4	93.2	23.3	76.4	54.9	16.3	53.5	39.7	130.1	42.9	140.7	67.5
5.0	28.7	94.0	23.3	76.5	54.3	16.6	54.6	39.5	129.6	42.9	140.7	67.0
7.0	29.2	95.8	23.2	76.2	52.5	17.7	58.2	39.4	129.4	43.2	141.9	65.6
10.0	30.6	100.2	23.6	77.5	50.5	19.4	63.6	38.8	127.1	43.3	142.2	63.3
15.0	33.0	108.4	25.0	82.1	49.1	21.6	70.8	36.9	121.0	42.7	140.2	59.5
20.0	34.8	114.1	25.8	84.5	47.6	23.4	76.7	35.7	117.0	42.6	139.9	56.6
30.0	36.3	119.2	26.2	85.9	46.0	25.2	82.7	34.3	112.5	42.6	139.6	53.5
50.0	35.1	115.1	24.6	80.7	44.4	25.0	82.1	34.0	111.4	42.2	138.4	53.5
70.0	31.4	102.9	21.1	69.4	42.3	23.2	76.0	35.5	116.6	42.4	139.2	56.7
80.0	29.1	95.3	18.8	61.6	40.1	22.2	72.8	37.0	121.2	43.1	141.4	58.9
85.0	28.0	91.7	17.5	57.3	38.5	21.8	71.6	37.8	124.0	43.6	143.2	59.8
90.0	27.3	89.6	16.3	53.6	36.6	21.9	71.8	38.4	126.1	44.2	145.1	60.2
93.0	27.3	89.6	15.8	51.8	35.2	22.3	73.2	38.7	127.0	44.7	146.5	59.9
95.0	27.7	91.0	15.7	51.4	34.3	22.9	75.1	38.6	126.7	44.9	147.3	59.2
96.0	28.0	91.9	15.7	51.7	34.1	23.2	76.0	38.5	126.2	44.9	147.3	58.8
97.0	28.1	92.2	15.7	51.5	33.9	23.3	76.5	38.4	126.0	44.9	147.4	58.6
98.0	28.4	93.1	16.0	52.5	34.2	23.4	76.9	38.0	124.7	44.7	146.5	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	DEG
1.0	57.3	187.9	53.4	175.2	68.6	20.7	67.9	9.8	32.2	22.9	75.2	25.3
2.0	57.2	187.7	52.9	173.7	67.5	21.7	71.2	10.2	33.4	24.0	78.7	25.1
3.0	57.1	187.5	52.5	172.2	66.5	22.6	74.1	10.5	34.6	24.9	81.8	25.0
4.0	57.1	187.5	52.3	171.6	66.1	23.0	75.4	10.6	34.9	25.3	83.1	24.7
5.0	57.1	187.3	52.1	170.9	65.7	23.4	76.6	10.7	35.2	25.7	84.3	24.6
7.0	56.4	184.9	51.1	167.6	64.8	23.8	78.1	11.6	37.9	26.5	86.8	25.8
10.0	55.5	182.2	50.3	165.0	64.7	23.5	77.3	12.1	39.6	26.5	86.8	27.0
15.0	55.9	183.4	50.4	165.3	64.1	24.2	79.5	11.5	37.8	26.8	88.0	25.4
20.0	56.0	183.7	50.1	164.2	63.2	25.1	82.3	11.4	37.3	27.5	90.3	24.3
30.0	55.8	183.0	49.4	162.0	62.1	26.0	85.2	11.1	36.4	28.2	92.6	23.1
50.0	54.4	178.3	47.5	155.9	60.8	26.4	86.5	11.0	36.2	28.6	93.8	22.7
70.0	51.4	168.5	44.8	146.8	60.4	25.2	82.7	11.9	39.1	27.9	91.5	25.2
80.0	49.9	163.7	43.0	141.2	59.4	25.2	82.8	12.7	41.6	28.2	92.6	26.6
85.0	49.9	163.7	42.9	140.9	59.2	25.4	83.4	12.3	40.4	28.2	92.6	25.8
90.0	51.0	167.3	43.8	143.9	59.1	26.0	85.4	10.9	35.8	28.2	92.6	22.7
93.0	51.4	168.7	45.1	147.9	61.1	24.7	81.1	9.4	30.8	26.5	86.8	20.8
95.0	51.5	169.0	45.5	149.3	61.9	24.2	79.3	8.8	28.8	25.7	84.3	19.9
96.0	51.5	169.0	45.7	150.0	62.4	23.7	77.8	8.5	27.8	25.2	82.6	19.6
97.0	51.6	168.8	46.1	151.4	63.5	22.8	74.8	8.0	26.1	24.1	79.2	19.2
98.0	51.1	167.6	48.3	158.4	70.7	16.7	54.7	5.7	18.8	17.6	57.8	18.9

Table 16. Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, Third Stage Tested, Near Stall Throttle.

BLADE ELEMENT DATA ROTOR INLET TIP SPEED = 64.42 MPS (211.34 FPS)

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	55.3	181.5	51.3	168.2	67.8	20.8	68.1	13.0	42.8	24.5	80.4	32.1
2.0	55.4	181.8	51.0	167.2	66.7	21.8	71.4	13.3	43.5	25.5	83.6	31.2
3.0	55.9	183.5	51.2	168.1	66.1	[illegible]	73.6	12.9	42.3	25.9	84.9	29.8
4.0	56.3	184.5	51.2	167.9	65.3	23.4	76.6	12.9	42.2	26.7	87.5	28.8
5.0	56.4	185.2	51.2	167.9	64.9	23.8	78.0	12.7	41.8	27.0	88.5	28.1
7.0	56.9	186.8	51.6	169.3	64.8	24.1	79.0	12.1	39.8	27.0	88.5	26.7
10.0	57.1	187.3	51.5	169.1	64.4	24.5	80.5	11.9	39.0	27.3	89.4	25.8
15.0	57.0	186.9	51.2	168.0	63.8	25.0	82.0	11.8	38.6	27.6	90.7	25.2
20.0	56.7	185.9	50.6	166.0	63.1	25.5	83.7	11.9	39.0	28.1	92.3	24.9
30.0	55.7	182.8	49.4	162.0	62.2	25.8	84.6	12.1	39.8	28.5	93.5	25.1
50.0	53.1	174.2	46.9	153.9	61.9	24.9	81.6	12.7	41.6	27.9	91.6	26.9
70.0	51.0	167.2	45.7	150.0	63.6	22.5	73.9	11.9	39.2	25.5	83.6	27.9
80.0	50.8	166.6	45.7	149.9	64.0	22.1	72.5	11.0	36.1	24.7	81.0	26.4
85.0	50.4	165.4	45.6	149.6	64.5	21.5	70.7	10.6	34.8	24.0	78.8	26.2
90.0	49.9	163.7	45.1	148.0	64.5	21.4	70.0	10.6	34.8	23.8	78.2	26.4
93.0	49.5	162.3	44.6	146.3	64.1	21.4	70.3	10.8	35.5	24.0	78.8	26.7
95.0	49.2	161.5	44.5	145.9	64.5	21.1	69.2	10.8	35.3	23.7	77.7	26.9
96.0	49.1	161.0	44.3	145.3	64.3	21.1	69.3	10.9	35.6	23.8	77.9	27.1
97.0	48.9	160.4	44.3	145.2	64.7	20.8	68.2	10.8	35.4	23.4	76.8	27.3
98.0	48.8	160.0	44.4	145.7	65.4	20.1	66.0	10.5	34.5	22.7	74.5	27.5

BLADE ELEMENT DATA ROTOR OUTLET / STATOR INLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	31.5	103.3	28.1	92.1	62.9	14.2	46.7	36.2	118.9	38.9	127.6	68.4
2.0	31.3	102.7	27.3	89.6	60.6	15.3	50.2	36.9	121.1	40.0	131.1	67.3
3.0	31.5	103.3	26.6	87.1	57.3	16.9	55.6	37.6	123.3	41.2	135.2	65.6
4.0	31.5	103.2	26.0	85.3	55.6	17.7	58.1	38.0	124.8	42.0	137.6	64.9
5.0	31.7	103.8	25.6	83.9	53.7	18.7	61.2	38.4	125.9	42.7	140.0	63.9
7.0	31.6	103.6	24.9	81.8	52.0	19.4	63.6	38.8	127.3	43.4	142.3	63.3
10.0	32.1	105.4	24.7	81.1	50.1	20.5	67.4	38.7	127.1	43.8	143.8	61.9
15.0	35.9	117.7	26.6	87.3	47.7	24.1	79.0	36.4	119.3	43.6	143.1	56.4
20.0	37.0	121.5	27.3	89.6	47.4	25.0	82.0	35.2	115.4	43.1	141.5	54.4
30.0	36.1	118.5	26.7	87.7	47.6	24.3	79.7	34.8	114.1	42.4	139.2	54.9
50.0	32.1	105.4	22.8	74.7	45.0	22.7	74.4	36.8	120.8	43.2	141.9	58.2
70.0	27.4	89.7	17.7	57.9	40.1	20.9	68.5	40.0	131.2	45.1	148.0	62.3
80.0	25.2	82.7	15.3	50.1	37.2	20.1	65.8	41.4	135.9	46.0	151.0	64.0
85.0	24.5	80.4	14.5	47.5	36.1	19.8	64.9	41.7	136.9	46.2	151.5	64.5
90.0	24.4	80.2	13.8	45.2	34.2	20.2	66.2	41.9	137.6	46.5	152.7	64.1
93.0	24.7	81.0	13.9	45.5	34.0	20.4	67.1	41.6	136.4	46.3	152.0	63.6
95.0	25.0	82.1	14.0	46.0	33.9	20.7	68.0	41.2	135.3	46.1	151.4	63.1
96.0	25.2	82.8	14.7	48.2	35.5	20.5	67.3	40.4	132.7	45.3	148.8	62.9
97.0	25.6	84.1	15.5	50.9	37.1	20.4	66.9	39.5	129.7	44.5	146.0	62.5
98.0	26.1	85.8	16.5	54.1	39.1	20.2	66.2	38.5	126.2	43.4	142.5	62.1

BLADE ELEMENT DATA STATOR OUTLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	58.4	191.7	54.3	178.2	68.2	21.5	70.6	10.0	32.8	23.7	77.9	24.9
2.0	57.8	189.7	53.1	174.3	66.6	22.8	74.9	11.1	36.5	25.4	83.3	25.9
3.0	57.7	189.3	52.7	172.8	65.7	23.5	77.2	11.4	37.6	26.2	85.8	25.9
4.0	57.6	188.9	52.2	171.2	64.8	24.3	79.9	11.8	38.9	27.1	88.8	25.9
5.0	57.9	190.1	52.2	171.4	64.2	25.1	82.2	11.7	38.4	27.7	90.7	24.9
7.0	57.2	187.8	51.3	168.4	63.6	25.3	83.0	12.4	40.7	28.2	92.4	26.1
10.0	56.7	186.1	50.6	166.2	63.0	25.6	83.9	12.8	42.0	28.6	93.8	26.5
15.0	57.1	187.4	50.6	166.0	62.2	26.5	86.9	12.4	40.5	29.2	95.9	24.9
20.0	57.2	187.7	50.5	165.7	61.8	26.9	88.2	12.0	39.3	29.4	96.5	24.0
30.0	56.0	183.8	49.2	161.5	61.3	26.7	87.7	12.3	40.3	29.4	96.5	24.6
50.0	53.5	175.4	46.9	153.7	61.0	25.8	84.5	12.7	41.8	28.7	94.3	26.2
70.0	51.6	169.1	45.8	150.1	62.4	23.7	77.9	11.0	39.0	26.5	87.1	26.5
80.0	51.3	168.2	46.2	151.6	64.1	22.2	72.9	10.5	34.4	24.6	80.6	25.2
85.0	51.0	167.4	46.1	151.1	64.4	21.9	71.9	10.1	33.3	24.2	79.3	24.7
90.0	50.5	165.7	45.4	149.0	63.8	22.1	72.6	10.3	33.8	24.4	80.1	24.9
93.0	50.1	164.5	44.6	146.8	63.0	22.6	74.1	10.7	35.0	25.0	82.0	25.2
95.0	49.8	163.5	44.3	145.5	62.7	22.7	74.6	10.9	35.7	25.2	82.7	25.5
96.0	[illegible]	163.2	44.5	146.1	63.4	22.2	72.7	10.6	34.8	24.6	80.6	25.5
97.0	49.6	162.6	44.5	146.1	63.8	21.8	71.4	10.5	34.5	24.2	79.3	25.7
98.0	49.9	163.8	47.6	156.1	72.2	15.1	49.5	7.4	24.1	16.8	55.1	25.9

Table 17. Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, Third Stage Tested, Design Point Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED MPS	WHEEL SPEED FPS	REL. TURNING ANGLE DEG	LOSS* COEF.	LOSS PARA.	REL MACH NO. IN	DIFF. FACT.	REL. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG
1.0	63.7	209.07	0.1	0.012	0.010	0.158	0.441	0.110	-3.7	26.7
2.0	63.6	208.75	3.5	0.070	0.061	0.158	0.503	0.103	-5.4	21.4
3.0	63.5	208.44	5.1	0.094	0.083	0.158	0.521	0.102	-6.7	18.5
4.0	63.4	208.12	6.1	0.124	0.110	0.159	0.545	0.100	-7.9	16.2
5.0	63.3	207.81	7.2	0.143	0.128	0.160	0.561	0.098	-8.6	14.3
7.0	63.1	207.18	11.1	0.213	0.195	0.164	0.617	0.095	-9.6	9.3
10.0	62.9	206.24	12.1	0.220	0.202	0.165	0.615	0.097	-10.0	7.5
15.0	62.4	204.67	13.7	0.173	0.160	0.165	0.567	0.103	-10.2	5.5
20.0	61.9	203.10	13.6	0.119	0.111	0.165	0.516	0.109	-10.3	6.5
30.0	60.9	199.96	13.1	0.081	0.076	0.165	0.477	0.113	-10.0	6.8
50.0	59.0	193.68	15.5	0.079	0.075	0.162	0.481	0.111	-9.9	6.4
70.0	57.1	187.40	17.6	0.091	0.087	0.157	0.506	0.105	-10.4	6.0
80.0	56.2	184.25	18.9	0.094	0.090	0.154	0.521	0.101	-10.5	6.4
85.0	55.7	182.68	18.9	0.080	0.077	0.153	0.528	0.099	-11.0	6.8
90.0	55.2	181.11	19.8	0.070	0.067	0.151	0.535	0.097	-11.3	6.7
93.0	54.9	180.17	18.9	-.014	-.013	0.145	0.508	0.096	-12.4	7.2
95.0	54.7	179.54	19.7	-.045	-.014	0.142	0.506	0.095	-12.1	7.2
96.0	54.6	179.23	21.7	-.050	-.048	0.142	0.513	0.094	-10.7	6.9
97.0	54.5	178.92	23.8	-.046	-.045	0.142	0.524	0.094	-8.8	6.9
98.0	54.4	178.60	26.3	.024	-.024	0.142	0.538	0.093	-6.7	6.7

TORQUE 8798.52 IN.-LB.

* See Figure 45 and Table 12 for loss coefficients computed from relative total pressure measurements.

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED MPS	WHEEL SPEED FPS	ABS. TURNING ANGLE DEG	ABS. MACH NO. IN	ABS. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.
1.0	63.7	209.07	37.0	0.088	0.058	4.0	16.7	-.2766	-.2724	0.5453
2.0	63.6	208.75	37.0	0.099	0.062	3.2	15.4	-.0500	-.0493	0.5882
3.0	63.5	208.44	36.7	0.104	0.067	2.5	14.4	0.	0.	0.5661
4.0	63.4	208.12	37.0	0.108	0.071	2.4	13.4	0.0280	0.0277	0.5567
5.0	63.3	207.81	37.3	0.111	0.074	2.4	12.6	0.0526	0.0520	0.5492
7.0	63.1	207.18	36.0	0.120	0.078	2.5	12.9	0.1364	0.1347	0.5644
10.0	62.9	206.24	32.9	0.122	0.081	2.1	14.3	0.1322	0.1309	0.5382
15.0	62.4	204.67	29.4	0.123	0.082	0.2	13.6	0.1304	0.1286	0.5238
20.0	61.9	203.10	27.1	0.121	0.084	-2.2	12.2	0.0889	0.0878	0.4946
30.0	60.9	199.96	27.4	0.119	0.085	-3.6	8.6	0.0460	0.0455	0.4661
50.0	59.0	193.68	27.7	0.124	0.090	-4.5	6.8	0.0364	0.0361	0.4421
70.0	57.1	187.40	28.4	0.127	0.090	-1.8	7.2	0.0510	0.0506	0.4607
80.0	56.2	184.25	27.4	0.127	0.090	5.0	9.3	0.0408	0.0404	0.4540
85.0	55.7	182.68	28.0	0.126	0.090	5.1	9.4	0.0513	0.0508	0.4558
90.0	55.2	181.11	28.5	0.127	0.091	5.4	9.4	0.0612	0.0606	0.4476
93.0	54.9	180.17	28.4	0.126	0.089	5.6	9.9	0.0928	0.0919	0.4583
95.0	54.7	179.54	28.0	0.126	0.083	5.7	10.6	0.1649	0.1633	0.5165
96.0	54.6	179.23	27.8	0.122	0.076	5.7	10.9	0.2245	0.2222	0.5746
97.0	54.5	178.92	27.3	0.127	0.070	-5.8	11.5	0.2755	0.2725	0.6330
98.0	54.4	178.60	26.3	0.122	0.067	5.8	12.7	0.3651	0.3608	0.7479

Table 18. Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, Third Stage Tested, Peak Efficiency Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED MPS	WHEEL SPEED FPS	REL. TURNING ANGLE DEG	LOSS* COEF.	LOSS PARA.	REL. MACH NO. IN	DIFF. FACT.	REL. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG
1.0	64.6	211.85	2.4	0.112	0.096	0.158	0.591	0.094	-4.0	24.1
2.0	64.5	211.53	6.4	0.164	0.143	0.159	0.639	0.089	-4.9	19.1
3.0	64.4	211.22	8.5	0.176	0.156	0.160	0.646	0.089	-6.0	15.8
4.0	64.3	210.90	10.1	0.198	0.177	0.161	0.659	0.089	-6.4	13.7
5.0	64.2	210.58	10.3	0.214	0.193	0.162	0.668	0.088	-7.4	12.3
7.0	64.0	209.94	12.0	0.226	0.206	0.164	0.665	0.090	-8.1	9.8
10.0	63.7	208.99	13.1	0.227	0.208	0.166	0.649	0.093	-8.8	7.7
15.0	63.2	207.40	14.2	0.188	0.174	0.166	0.604	0.099	-9.4	5.8
20.0	62.7	205.80	14.7	0.151	0.140	0.166	0.563	0.104	-9.2	5.5
30.0	61.8	202.62	14.6	0.144	0.134	0.166	0.552	0.105	-8.3	6.9
50.0	59.8	196.26	15.7	0.088	0.083	0.162	0.521	0.106	-8.6	7.5
70.0	57.9	189.89	18.4	0.083	0.079	0.156	0.541	0.100	-7.6	8.0
80.0	56.9	186.71	19.3	0.078	0.075	0.153	0.557	0.096	-7.9	8.5
85.0	56.4	185.12	20.2	0.071	0.068	0.151	0.568	0.094	-8.7	7.7
90.0	55.9	183.53	21.4	0.064	0.062	0.149	0.581	0.091	-9.6	6.8
93.0	55.6	182.57	22.2	0.013	0.013	0.145	0.568	0.091	-10.0	6.3
95.0	55.5	181.94	23.7	-.044	-.042	0.142	0.557	0.090	-9.3	6.1
96.0	55.4	181.62	25.5	-.053	-.052	0.141	0.555	0.091	-7.9	5.8
97.0	55.3	181.30	27.0	-.057	-.055	0.142	0.559	0.091	-6.6	5.9
98.0	55.2	180.98	28.6	-.028	-.027	0.143	0.583	0.090	-5.0	6.1

TORQUE = 8998.55 IN.-LB.

*** See Figure 45 and Table 12 for loss coefficients computed from relative total pressure measurements.**

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED MPS	WHEEL SPEED FPS	ABS. TURNING ANGLE DEG	ABS MACH NO. IN	ABS. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.
1.0	64.6	211.85	41.2	0.104	0.061	8.8	14.3	0.	0.	0.6507
2.0	64.5	211.53	43.3	0.112	0.067	7.9	13.7	0.0789	0.0780	0.6403
3.0	64.4	211.22	42.0	0.116	0.071	6.5	13.1	0.1062	0.1049	0.6262
4.0	64.3	210.90	41.5	0.119	0.072	6.2	12.7	0.1271	0.1256	0.6288
5.0	64.2	210.58	41.3	0.120	0.075	6.1	12.3	0.1256	0.1241	0.6133
7.0	64.0	209.94	38.5	0.123	0.077	5.2	13.1	0.1322	0.1305	0.5973
10.0	63.7	208.99	35.4	0.124	0.080	4.0	13.7	0.1080	0.1065	0.5651
15.0	63.2	207.40	32.3	0.124	0.083	2.0	12.8	0.0858	0.0847	0.5297
20.0	62.7	205.80	30.3	0.123	0.083	0.4	11.6	0.0761	0.0752	0.5182
30.0	61.8	202.62	31.3	0.121	0.084	0.4	8.8	0.0337	0.0334	0.5010
50.0	59.8	196.26	30.5	0.123	0.085	-1.7	6.8	0.0330	0.0327	0.4958
70.0	57.9	189.89	29.2	0.121	0.085	-2.2	9.1	0.0430	0.0426	0.4897
80.0	56.9	186.71	28.7	0.124	0.085	-2.1	10.5	0.0387	0.0383	0.4954
85.0	56.4	185.12	28.8	0.126	0.092	-2.4	11.2	0.0524	0.0518	0.4839
90.0	55.9	183.53	29.1	0.127	0.085	[illegible]	11.6	0.0816	0.0807	0.4992
93.0	55.6	182.57	29.3	0.128	0.082	-2.9	11.7	0.1328	0.1313	0.5378
95.0	55.5	181.94	29.7	0.129	0.076	3.2	11.3	0.2016	0.1994	0.5930
96.0	55.4	181.62	30.1	0.129	0.075	3.9	10.5	0.2321	0.2298	0.6112
97.0	55.3	181.30	31.0	0.129	0.070	4.2	9.4	0.2744	0.2719	0.6570
98.0	55.2	180.98	31.6	0.129	0.053	4.0	7.2	0.4032	0.4007	0.8099

Table 19. Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, Third Stage Tested, Peak Pressure Rise Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED MPS	WHEEL SPEED FPS	REL. TURNING ANGLE DEG	LOSS* COEF.	LOSS PARA.	REL. MACH NO. IN	DIFF. FACT.	REL. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG
1.0	63.2	207.42	5.7	0.128	0.111	0.155	0.668	0.084	-4.5	20.3
2.0	63.1	207.11	8.9	0.175	0.151	0.156	0.700	0.082	-5.1	16.4
3.0	63.0	206.80	11.8	0.208	0.183	0.158	0.720	0.081	-5.0	13.5
4.0	62.9	206.48	13.3	0.220	0.193	0.159	0.722	0.081	-5.4	11.5
5.0	62.8	206.17	13.1	0.227	0.206	0.159	0.719	0.082	-5.9	11.0
7.0	62.7	205.55	14.4	0.237	0.216	0.161	0.713	0.084	-6.2	9.2
10.0	62.4	204.61	15.7	0.219	0.202	0.162	0.685	0.087	-6.7	7.3
15.0	61.9	203.06	16.2	0.158	0.146	0.161	0.621	0.095	-6.9	6.3
20.0	61.4	201.50	16.7	0.117	0.108	0.160	0.579	0.100	-7.2	5.5
30.0	60.5	198.38	17.2	0.087	0.082	0.161	0.543	0.104	-7.1	5.6
50.0	58.6	192.15	17.4	0.052	0.050	0.156	0.539	0.100	-6.6	7.8
70.0	56.7	185.92	19.0	0.023	0.022	0.146	0.576	0.090	-5.9	9.1
80.0	55.7	182.80	21.0	0.041	0.039	0.143	0.621	0.083	-6.2	8.5
85.0	55.2	181.24	22.3	0.055	0.053	0.142	0.646	0.080	-6.7	7.7
90.0	54.8	179.69	23.8	0.063	0.061	0.141	0.662	0.078	-7.4	6.6
93.0	54.5	178.75	25.1	0.054	0.053	0.141	0.664	0.078	-7.8	5.7
95.0	54.3	178.13	27.1	0.045	0.041	0.141	0.660	0.079	-6.7	5.1
96.0	54.2	177.82	28.2	0.031	0.030	0.141	0.657	0.080	-6.0	5.1
97.0	54.1	177.51	29.3	0.034	0.033	0.141	0.658	0.080	-5.1	5.0
98.0	54.0	177.19	31.9	0.025	0.024	0.141	0.659	0.081	-2.3	5.5

TORQUE = 8451.44 IN.-LB.

* See Figure 45 and Table 12 for loss coefficients computed from relative total pressure measurements.

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED MPS	WHEEL SPEED FPS	ABS. TURNING ANGLE DEG	ABS. MACH NO IN	ABS. MACH NO OUT	INCID. ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.
1.0	63.2	207.42	45.2	0.112	0.065	9.6	14.1	0.1026	0.1013	0.6606
2.0	63.1	207.11	44.4	0.117	0.069	8.9	13.7	0.1395	0.1378	0.6611
3.0	63.0	206.80	43.5	0.121	0.071	8.4	13.4	0.1579	0.1560	0.6529
4.0	62.9	206.48	42.7	0.123	0.072	7.8	13.1	0.1660	0.1640	0.6512
5.0	62.8	206.17	42.4	0.123	0.073	7.7	12.8	0.1489	0.1472	0.6402
7.0	62.7	205.55	39.8	0.124	0.076	7.0	13.7	0.1423	0.1404	0.6185
10.0	62.4	204.61	36.2	0.121	0.076	5.7	14.5	0.1354	0.1335	0.6094
15.0	61.9	203.06	34.1	0.122	0.077	3.4	12.3	0.0964	0.0952	0.5843
20.0	61.4	201.50	32.3	0.122	0.079	1.7	10.8	0.0753	0.0714	0.5575
30.0	60.5	198.38	30.5	0.122	0.081	-0.1	9.1	0.0497	0.0492	0.5300
50.0	58.6	192.15	30.8	0.121	0.082	0.0	8.5	0.0440	0.0435	0.5131
70.0	56.7	185.92	31.5	0.121	0.080	1.9	10.9	0.0543	0.0537	0.5334
80.0	55.7	182.80	32.3	0.123	0.081	3.0	12.4	0.0737	0.0728	0.5353
85.0	55.2	181.24	34.1	0.125	0.081	3.2	11.6	0.0924	0.0913	0.5401
90.0	54.8	179.69	37.5	0.127	0.081	2.8	8.6	0.1200	0.1190	0.5689
93.0	54.5	178.75	39.1	0.128	0.076	2.0	6.7	0.1961	0.1947	0.6254
95.0	54.3	178.13	39.3	0.128	0.073	0.9	5.9	0.2233	0.2218	0.6470
96.0	54.2	177.82	39.2	0.129	0.072	0.3	5.6	0.2427	0.2412	0.6597
97.0	54.1	177.51	39.4	0.129	0.069	-0.1	5.2	0.2674	0.2658	0.6859
98.0	54.0	177.19	39.3	0.128	0.050	-0.7	4.9	0.4020	0.3996	0.8433

Table 20. Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, Third Stage Tested, Near Stall Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED MPS	WHEEL SPEED FPS	REL. TURNING ANGLE DEG	LOSS* COEF.	LOSS PARA.	REL. MACH NO. IN	DIFF. FACT.	REL. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG
1.0	64.3	211.02	4.8	0.135	0.118	0.158	0.626	0.090	-6.1	19.5
2.0	64.2	210.71	6.1	0.153	0.135	0.158	0.633	0.089	-7.1	17.2
3.0	64.1	210.39	8.9	0.171	0.153	0.160	0.641	0.090	-7.5	13.9
4.0	64.0	210.07	9.7	0.188	0.169	0.161	0.648	0.090	-8.2	12.3
5.0	63.9	209.75	11.2	0.190	0.173	0.161	0.649	0.090	-8.5	10.4
7.0	63.7	209.12	12.8	0.212	0.194	0.163	0.661	0.090	-8.4	8.7
10.0	63.5	208.17	14.2	0.210	0.193	0.163	0.652	0.092	-8.4	6.9
15.0	63.0	206.58	16.1	0.128	0.119	0.163	0.567	0.102	-8.4	5.0
20.0	62.5	205.00	15.7	0.086	0.080	0.162	0.532	0.106	-8.4	5.3
30.0	61.5	201.83	14.6	0.069	0.065	0.159	0.532	0.103	-8.1	7.2
50.0	59.6	195.49	16.9	0.073	0.069	0.152	0.591	0.092	-6.5	8.4
70.0	57.7	189.35	23.5	0.109	0.105	0.146	0.693	0.078	-3.6	6.9
80.0	56.7	185.98	26.8	0.130	0.126	0.145	0.748	0.072	-3.3	5.6
85.0	56.2	184.39	28.5	0.125	0.121	0.144	0.764	0.070	-3.0	5.3
90.0	55.7	182.81	30.3	0.095	0.093	0.143	0.763	0.070	-3.3	4.2
93.0	55.4	181.86	30.1	0.066	0.061	0.141	0.749	0.070	-3.9	4.5
95.0	55.2	181.22	30.5	0.035	0.031	0.141	0.739	0.071	-3.7	4.7
96.0	55.1	180.91	28.8	0.020	0.019	0.140	0.726	0.072	-4.0	6.5
97.0	55.0	180.59	27.5	0.002	0.002	0.140	0.710	0.073	-3.7	8.3
98.0	54.9	180.27	26.3	-.018	-.018	0.139	0.693	0.074	-2.9	10.4

TORQUE = 8566.56 IN.-LB.

* See Figure 45 and Table 12 for loss coefficients computed from relative total pressure measurements.

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED MPS	WHEEL SPEED FPS	ABS. TURNING ANGLE DEG	ABS. MACH NO. IN	ABS. MACH NO. OUT	INCID ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.
1.0	64.3	211.02	43.5	0.111	0.068	7.5	13.7	0.0667	0.0659	0.6311
2.0	64.2	210.71	41.4	0.114	0.072	6.8	14.5	0.0633	0.0625	0.5958
3.0	64.1	210.39	39.7	0.118	0.075	5.5	14.4	0.0952	0.0943	0.5918
4.0	64.0	210.07	39.0	0.120	0.077	5.2	14.2	0.0989	0.0976	0.5778
5.0	63.9	209.75	39.0	0.122	0.079	4.6	13.1	0.1111	0.1098	0.5753
7.0	63.7	209.12	37.2	0.124	0.080	4.7	13.9	0.1247	0.1231	0.5682
10.0	63.5	208.17	35.4	0.125	0.081	4.3	14.0	0.1263	0.1246	0.5591
15.0	63.0	206.58	31.4	0.124	0.083	0.2	11.9	0.1021	0.1009	0.5266
20.0	62.5	205.00	30.5	0.123	0.084	-0.5	10.5	0.0870	0.0860	0.5095
30.0	61.5	201.83	30.3	0.121	0.084	1.3	10.6	0.0674	0.0666	0.4948
50.0	59.6	195.49	32.0	0.123	0.082	4.8	11.8	0.1342	0.1325	0.5308
70.0	57.7	189.35	35.[illegible]	0.129	0.076	7.5	12.2	0.2684	0.2650	0.6754
80.0	56.7	185.98	38.8	0.131	0.070	8.1	11.0	0.3537	0.3498	0.6933
85.0	56.2	184.39	37.[illegible]	0.132	0.06[illegible]	[illegible].9	10.6	0.3738	0.3699	0.7066
90.0	55.7	182.81	39.2	0.133	0.070	6.[illegible]	10.8	0.383[illegible]	0.3791	0.7021
93.0	55.4	181.86	38.4	0.132	0.071	5.[illegible]	11.[illegible]	0.3774	0.3733	0.6820
95.0	55.2	181.22	37.6	0.132	0.072	4.8	11.5	0.3745	0.3701	0.6709
96.0	55.1	180.91	37.1	0.129	0.070	4.5	11.5	0.3740	0.3700	0.6753
97.0	55.0	180.59	36.8	0.127	0.069	3.9	11.7	0.3722	0.3681	0.6720
98.0	54.9	180.27	[illegible]6.2	0.124	0.048	3.3	11.9	0.5150	0.5093	0.8493

Table 21. 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 MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
0.	57.4	188.2	52.1	170.8	65.1	24.1	79.2	11.8	38.6	26.8	88.1	26.0
10.3	57.6	189.0	51.7	169.5	63.7	25.5	83.6	11.2	36.6	27.8	91.3	23.6
20.3	57.5	188.8	51.0	167.4	62.4	26.6	87.3	10.9	35.6	28.7	94.3	22.2
30.1	57.1	187.5	50.1	164.5	61.3	27.4	90.0	10.8	35.5	29.5	96.7	21.5
39.8	56.6	185.6	49.1	161.2	60.3	28.0	91.9	10.9	35.6	30.0	98.5	21.2
49.5	55.9	183.5	48.2	158.1	59.5	28.4	93.1	10.9	35.8	30.4	99.8	21.0
59.2	55.1	180.7	47.1	154.4	58.7	28.6	93.9	11.1	36.4	30.7	100.7	21.3
69.0	54.2	177.8	46.0	150.8	58.0	28.7	94.2	11.2	36.9	30.8	101.2	21.4
79.0	53.2	174.5	44.9	147.2	57.6	28.5	93.6	11.4	37.4	30.7	100.8	21.8
89.3	51.8	169.9	43.5	142.8	57.2	28.0	92.0	11.7	38.5	30.4	99.7	22.7
100.0	50.2	164.5	42.1	138.3	57.2	27.2	89.2	12.1	39.7	29.8	97.6	24.0

BLADE ELEMENT DATA ROTOR OUTLET / STATOR INLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
0.	38.3	125.5	31.0	101.8	54.2	22.4	73.3	32.8	107.6	39.7	130.2	55.7
10.8	40.0	131.2	31.2	102.4	51.3	25.0	82.0	31.6	103.6	40.3	132.1	51.6
20.8	40.9	134.2	31.0	101.7	49.3	26.7	87.5	30.8	101.1	40.8	133.7	49.1
30.5	41.0	134.5	30.3	99.4	47.8	27.6	90.6	30.6	100.4	41.2	135.3	48.0
40.1	40.5	133.0	29.2	95.7	46.0	28.2	92.4	30.8	101.0	41.7	136.9	47.6
49.7	39.9	130.8	27.9	91.5	44.4	28.5	93.4	31.2	102.3	42.2	138.5	47.6
59.3	38.9	127.5	26.3	86.4	42.7	28.6	93.7	31.8	104.3	42.7	140.3	48.1
69.1	37.8	124.0	24.7	81.0	40.8	28.6	93.9	32.6	106.9	43.3	142.1	48.6
79.1	36.6	119.9	22.9	75.0	38.7	28.5	93.6	33.4	109.5	43.9	144.0	49.5
89.3	34.9	114.4	20.7	67.9	36.4	28.1	92.0	34.6	113.4	44.5	146.1	50.9
100.0	32.9	107.9	18.2	59.8	33.7	27.4	89.8	36.0	118.2	45.2	148.4	52.7

BLADE ELEMENT DATA STATOR OUTLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
0.	57.4	188.2	52.1	171.0	65.3	24.0	78.8	11.7	38.3	26.7	87.5	26.0
10.3	57.6	189.0	51.7	169.8	63.9	25.3	83.0	11.1	36.4	27.6	90.7	23.7
20.3	57.5	188.7	51.1	167.7	62.7	26.4	86.7	10.8	35.3	28.5	93.6	22.2
30.1	57.1	187.4	50.2	164.8	61.5	27.2	89.3	10.7	35.2	29.3	96.0	21.5
39.8	56.5	185.5	49.2	161.5	60.6	27.8	91.2	10.8	35.4	29.8	97.8	21.2
49.5	55.9	183.3	48.3	158.4	59.7	28.2	92.4	10.8	35.5	30.2	99.0	21.0
59.2	55.0	180.6	47.1	154.7	58.9	28.4	93.2	11.0	36.1	30.5	99.9	21.2
69.0	54.2	177.7	46.1	151.1	58.3	28.5	93.5	11.2	36.6	30.6	100.4	21.4
79.0	53.1	174.3	45.0	147.8	57.8	28.3	92.9	11.3	37.1	30.5	100.0	21.8
89.3	51.7	169.7	43.6	143.1	57.5	27.8	91.2	11.6	38.2	30.1	98.9	22.7
100.0	50.1	164.4	42.2	138.6	57.4	27.0	88.5	12.0	39.4	29.5	96.9	24.0

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED MPS	WHEEL SPEED FPS	REL TURNING ANGLE DEG	LOSS COEF	LOSS PARA	REL MACH NO. IN	DIFF. FACT.	REL. MACH NO OUT	INCID. ANGLE DEG	DEV. ANGLE DEG
0.	57.6	189.00	10.9	0.096	0.087	0.152	0.505	0.101	-8.9	10.8
10.3	56.7	186.08	12.4	0.069	0.063	0.153	0.470	0.106	-9.0	8.2
20.3	55.9	183.24	13.1	0.049	0.045	0.153	0.445	0.108	-9.0	7.3
30.1	55.0	180.47	13.7	0.038	0.035	0.151	0.435	0.108	-9.0	7.3
39.8	54.2	177.72	14.3	0.034	0.032	0.150	0.435	0.107	-8.9	7.5
49.5	53.3	174.97	15.1	0.036	0.034	0.148	0.442	0.106	-8.9	7.7
59.2	52.5	172.22	16.0	0.040	0.038	0.146	0.455	0.103	-9.1	7.7
69.0	51.6	169.44	17.2	0.044	0.042	0.144	0.467	0.100	-9.2	7.4
79.0	50.8	166.60	18.8	0.050	0.048	0.141	0.485	0.097	-9.7	7.0
89.3	49.9	163.68	20.8	0.055	0.053	0.137	0.505	0.092	-10.5	6.3
100.0	49.0	160.65	23.5	0.061	0.060	0.133	0.530	0.087	-11.3	5.3

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED MPS	WHEEL SPEED FPS	ABS TURNING ANGLE DEG	ABS MACH NO IN	ABS MACH NO OUT	INCID ANGLE DEG	DEV ANGLE DEG	LOSS COFF	LOSS PARA	DIFF. FACT.
0	57.6	189.00	29.7	0.105	0.070	-5.7	18.0	0.0840	0.0829	0.5200
10.8	56.7	186.08	28.0	0.107	0.073	-5.7	11.1	0.0625	0.0618	0.4950
20.8	55.9	183.24	27.0	0.108	0.075	-5.5	8.7	0.0458	0.0454	0.4770
30.5	55.0	180.47	26.5	0.109	0.077	-5.6	7.5	0.0345	0.0342	0.4650
40.1	54.2	177.72	26.4	0.110	0.079	-5.6	7.0	0.0300	0.0297	0.4580
49	53.3	174.97	26.6	0.112	0.080	-5.9	6.6	0.0296	0.0294	0.4580
59.3	52.5	172.22	26.9	0.113	0.081	-5.8	6.8	0.0316	0.0313	0.4600
69.1	51.6	169.44	27.3	0.115	0.081	-6.1	7.1	0.0392	0.0389	0.4650
79.1	50.8	166.60	27.7	0.116	0.081	-6.3	7.5	0.0535	0.0531	0.4800
89.3	49.9	163.68	28.2	0.118	0.080	-6.3	8.8	0.0740	0.0733	0.4970
100.0	49.0	160.65	28.7	0.120	0.076	-6.5	10.0	0.1010	0.1000	0.5200

Table 22. Normalized Absolute Total Pressure, Static Pressure and Flow Angles for Rotor A/Stator A Single-Stage Configuration.

Design Point Throttle

Percent Immersion	Total Pressure: Rotor Inlet	Total Pressure: Rotor Exit	Total Pressure: Stator Exit	Static Pressure: Rotor Inlet	Static Pressure: Rotor Exit	Static Pressure: Stator Exit
1	-0.106	0.510	0.446	-0.236	0.149	0.325
2	-0.089	0.540	0.461	-0.236	0.143	0.323
3	-0.077	0.555	0.485	-0.235	0.140	0.322
4	-0.069	0.570	0.494	-0.235	0.135	0.319
5	-0.062	0.578	0.509	-0.235	0.132	0.317
7	-0.045	0.589	0.533	-0.235	0.127	0.315
10	-0.028	0.596	0.547	-0.235	0.123	0.313
15	-0.014	0.593	0.550	-0.233	0.125	0.315
20	-0.011	0.595	0.549	-0.232	0.126	0.315
30	-0.007	0.599	0.553	-0.233	0.129	0.316
50	-0.011	0.599	0.562	-0.238	0.124	0.313
70	-0.015	0.594	0.560	-0.242	0.105	0.305
80	-0.033	0.574	0.538	-0.246	0.094	0.300
85	-0.048	0.562	0.527	-0.248	0.087	0.296
90	-0.074	0.552	0.516	-0.250	0.080	0.291
93	-0.089	0.556	0.495	-0.249	0.074	0.286
95	-0.099	[illegible]	0.467	-0.249	0.070	0.283
96	-0.065	0.587	0.447	-0.249	0.067	0.284
97	-0.071	0.599	0.433	-0.248	0.065	0.285
98	-0.076	0.612	0.399	-0.247	0.062	0.286

Peak Efficiency Throttle

Percent Immersion	Total Pressure: Rotor Inlet	Total Pressure: Rotor Exit	Total Pressure: Stator Exit	Static Pressure: Rotor Inlet	Static Pressure: Rotor Exit	Static Pressure: Stator Exit
1	-0.093	0.592	0.517	-0.232	0.207	0.398
2	-0.080	0.631	0.529	-0.227	0.202	0.395
3	-0.069	0.648	0.545	-0.223	0.198	0.392
4	-0.057	0.656	0.556	-0.220	0.194	0.390
5	-0.049	0.660	0.567	-0.217	0.191	0.389
7	-0.035	0.660	0.587	-0.211	0.186	0.386
10	-0.023	0.656	0.600	-0.208	0.183	0.385
15	-0.012	0.647	0.606	-0.207	0.188	0.389
20	-0.009	0.647	0.608	-0.206	0.194	0.390
30	-0.008	0.651	0.607	-0.207	0.193	0.390
50	-0.010	0.651	0.618	-0.210	0.178	0.385
70	-0.018	0.635	0.598	-0.215	0.155	0.378
80	-0.048	0.613	0.570	-0.217	0.142	0.372
85	-0.033	0.619	0.577	-0.219	0.136	0.367
90	-0.069	0.606	0.560	-0.220	0.131	0.360
93	-0.084	0.618	0.543	-0.222	0.127	0.353
95	-0.090	0.639	0.520	-0.223	0.124	0.351
96	-0.093	0.655	0.506	-0.223	0.123	0.350
97	-0.095	0.670	0.491	-0.224	0.121	0.353
98	-0.096	0.679	0.461	-0.224	0.120	0.355

Peak Pressure Rise, Near Stall Throttle

Percent Immersion	Total Pressure: Rotor Inlet	Total Pressure: Rotor Exit	Total Pressure: Stator Exit	Static Pressure: Rotor Inlet	Static Pressure: Rotor Exit	Static Pressure: Stator Exit
1	-0.070	0.658	0.584	-0.181	0.243	0.455
2	-0.057	0.704	0.596	-0.181	0.237	0.453
3	-0.048	0.717	0.608	-0.180	0.233	0.452
4	-0.037	0.725	0.621	-0.180	0.230	0.450
5	-0.030	0.726	0.630	-0.180	0.227	0.449
7	-0.021	0.720	0.642	-0.180	0.225	0.447
10	-0.016	0.707	0.652	-0.180	0.230	0.444
15	-0.010	0.692	0.655	-0.180	0.239	0.439
20	-0.008	0.687	0.658	-0.180	0.241	0.436
30	-0.006	0.689	0.658	-0.180	0.240	0.431
50	-0.010	0.688	0.647	-0.184	0.225	0.423
70	-0.017	0.669	0.580	-0.189	0.203	0.412
80	-0.027	0.662	0.553	-0.191	0.189	0.404
85	-0.040	0.663	0.546	-0.192	0.187	0.399
90	-0.058	0.660	0.539	-0.193	0.175	0.393
93	-0.072	0.683	0.529	-0.194	0.174	0.387
95	-0.077	0.709	0.521	-0.194	0.171	0.385
96	-0.079	0.720	0.514	-0.194	0.170	0.385
97	-0.081	0.728	0.503	-0.194	0.169	0.385
98	-0.083	0.724	0.477	-0.195	0.168	0.385

Table 22. Normalized Absolute Total Pressure, Static Pressure and Flow Angles for Rotor A/Stator A Single-Stage Configuration (Concluded).

Design Point Throttle

Percent Immersion	Measured Rotor 1 Inlet	Measured Rotor 1 Exit	Measured Stator 1 Exit	Corrected Rotor 1 Inlet	Corrected Rotor 1 Exit	Corrected Stator 1 Exit
1	29.9	61.4	25.8	31.2	62.6	26.9
2	28.6	60.4	25.6	29.8	61.6	26.7
3	27.1	59.4	25.5	28.3	60.6	26.6
4	25.8	58.3	25.4	26.9	59.5	26.5
5	24.9	57.4	25.3	26.0	58.6	26.4
7	22.3	56.4	25.1	23.3	57.6	26.2
10	20.4	55.2	24.8	21.3	56.4	25.8
15	19.6	50.2	23.8	20.4	51.4	24.7
20	19.6	47.3	23.0	20.4	48.5	23.9
30	19.6	47.0	22.0	20.3	48.1	22.7
50	19.0	46.8	22.0	19.6	47.7	22.4
70	18.2	47.4	21.8	18.7	48.2	22.4
80	18.4	48.6	21.9	18.9	49.3	23.2
85	18.8	50.0	22.7	19.2	50.7	24.7
90	19.6	51.1	24.2	20.0	51.6	25.6
93	20.4	51.4	25.1	20.9	52.1	26.0
95	20.8	51.5	25.5	21.3	52.2	26.3
96	20.8	51.6	25.8	21.3	52.2	26.3
97	20.6	52.2	25.8	21.0	52.8	26.3
98	20.5	53.0	26.6	20.9	53.6	27.1

Peak Efficiency Throttle

Percent Immersion	Measured Rotor 1 Inlet	Measured Rotor 1 Exit	Measured Stator 1 Exit	Corrected Rotor 1 Inlet	Corrected Rotor 1 Exit	Corrected Stator 1 Exit
1	30.5	64.1	25.6	31.8	65.2	26.7
2	28.4	63.8	25.1	29.6	64.9	26.2
3	26.9	62.7	24.5	28.0	63.8	25.6
4	25.6	61.3	24.4	26.7	62.4	25.5
5	24.0	60.4	24.5	25.0	61.6	25.6
7	22.0	59.6	24.9	23.0	60.8	25.9
10	20.5	58.5	25.0	21.4	59.6	26.0
15	19.8	50.8	24.0	20.6	52.0	24.9
20	19.5	48.8	22.3	20.3	50.0	23.2
30	19.2	48.7	21.5	19.9	49.8	22.3
50	19.0	49.0	22.1	19.6	49.9	22.8
70	19.0	50.1	22.7	19.5	50.9	23.3
80	19.2	51.2	22.9	19.7	51.9	23.4
85	19.3	52.3	23.7	19.8	53.0	24.2
90	19.6	53.6	24.9	20.0	54.3	25.4
93	20.3	54.1	25.6	20.8	54.7	26.1
95	20.6	54.1	25.9	21.1	54.7	26.4
96	20.6	54.2	26.1	21.0	54.8	26.6
97	20.7	54.7	26.3	21.1	55.3	26.8
98	20.8	55.6	26.6	21.2	56.2	27.1

Peak Pressure Rise, Near Stall Throttle

Percent Immersion	Measured Rotor 1 Inlet	Measured Rotor 1 Exit	Measured Stator 1 Exit	Corrected Rotor 1 Inlet	Corrected Rotor 1 Exit	Corrected Stator 1 Exit
1	30.3	69.2	25.3	31.6	70.1	26.4
2	28.4	68.6	25.2	29.6	69.5	26.3
3	27.1	67.5	25.2	28.3	68.5	26.3
4	25.9	66.5	25.2	27.0	67.5	26.3
5	25.0	66.0	25.3	26.1	67.0	26.4
7	23.0	65.6	25.5	24.2	66.6	26.6
10	21.1	64.5	25.3	22.0	65.5	26.3
15	19.8	58.0	24.1	20.6	59.1	25.0
20	19.6	51.3	22.3	20.4	52.5	23.2
30	19.4	49.3	21.7	20.1	50.4	22.5
50	19.0	50.5	22.3	19.6	51.4	23.0
70	18.6	52.3	23.3	19.1	53.1	23.9
80	18.8	53.4	24.0	19.3	54.1	24.6
85	19.2	54.4	24.5	19.7	55.1	25.1
90	19.7	55.7	24.9	20.1	56.3	25.4
93	20.2	55.8	25.1	20.6	56.4	25.6
95	20.8	55.5	25.1	21.3	56.1	25.6
96	20.8	55.8	25.2	21.3	56.4	25.7
97	20.8	56.6	25.5	21.2	57.2	26.0
98	20.9	57.1	28.6	21.3	57.7	29.2

Table 23. Rotor Loss Coefficients Determined from Relative Total Pressure Measurements, Single-Stage Configuration.

Design Point Throttle

TOTAL PRESSURE			ROTOR LOSS COEFFICIENT			
PERCENT IMMERSION	ROTOR 1 INLET	ROTOR 1 EXIT	PERCENT IMMERSION	TOTAL LOSS	WAKE LOSS	TOTAL MINUS WAKE LOSS
5.0	0.5814	0.4740	5.0	[illegible]	[illegible]	0.1201
10.0	0.6226	0.5570	10.0	[illegible]	[illegible]	0.0625
15.0	0.6306	0.5940	15.0	0.0392	0.0174	0.0218
20.0	0.6204	0.6030	20.0	0.0294	0.0167	0.0127
35.0	0.6000	0.5702	35.0	0.0270	[illegible]	[illegible]
50.0	0.5630	0.5320	50.0	[illegible]	[illegible]	0.0094
65.0	0.5316	0.5053	65.0	0.0341	0.0247	0.0094
80.0	0.4864	0.4351	80.0	[illegible]	0.0568	[illegible]
85.0	0.4627	0.4069	85.0	[illegible]	[illegible]	[illegible]
90.0	0.4544	0.3845	90.0	[illegible]	0.0955	0.0046
95.0	0.4370	0.3546	95.0	[illegible]	0.1108	[illegible]

Peak Efficiency Throttle

TOTAL PRESSURE			ROTOR LOSS COEFFICIENT			
PERCENT IMMERSION	ROTOR 1 INLET	ROTOR 1 EXIT	PERCENT IMMERSION	TOTAL LOSS	WAKE LOSS	TOTAL MINUS WAKE LOSS
5.0	0.5949	0.4079	5.0	0.1332	0.0071	0.1261
10.0	0.6392	0.5673	10.0	0.0850	0.0131	0.0719
15.0	0.6456	0.6207	15.0	0.0293	0.0156	[illegible]
20.0	0.6411	0.6221	20.0	0.0225	[illegible]	[illegible]
35.0	0.6129	0.5956	35.0	0.0211	0.0140	0.0071
50.0	0.5851	0.5594	50.0	0.0323	0.0215	0.0109
65.0	0.5407	0.5190	65.0	0.0389	0.0325	0.0065
80.0	0.5023	0.4499	80.0	[illegible]	0.0661	0.0070
85.0	0.4707	0.4192	85.0	0.0856	0.0797	0.0060
90.0	0.4759	0.4017	90.0	[illegible]	0.0974	0.0106
95.0	0.4532	0.3727	95.0	0.1196	0.1099	0.0098

Peak Pressure Rise/Near Stall Throttle

TOTAL PRESSURE			ROTOR LOSS COEFFICIENT			
PERCENT IMMERSION	ROTOR 1 INLET	ROTOR 1 EXIT	PERCENT IMMERSION	TOTAL LOSS	WAKE LOSS	TOTAL MINUS WAKE LOSS
5.0	0.5985	0.4902	5.0	0.1285	0.0182	0.1103
10.0	0.6542	0.5747	10.0	0.0953	[illegible]	0.0815
15.0	0.6690	0.6306	15.0	[illegible]	[illegible]	0.0282
20.0	0.6636	0.6422	20.0	[illegible]	0.0166	0.0087
35.0	0.6361	0.6155	35.0	[illegible]	0.0142	[illegible]
50.0	0.6020	0.5779	50.0	0.0307	0.0207	[illegible]
65.0	0.5702	0.5343	65.0	0.0475	0.0345	[illegible]
80.0	0.5206	0.4662	80.0	0.0768	[illegible]	0.0055
85.0	0.4978	0.4302	85.0	[illegible]	0.0844	[illegible]
90.0	0.4947	0.4230	90.0	[illegible]	[illegible]	[illegible]
95.0	0.4717	0.3938	95.0	0.1173	0.1001	0.0173

Table 24. Vector Diagram Parameters for Rotor A/Stator A Single-Stage Configuration, Design Point Throttle.

BLADE ELEMENT DATA ROTOR INLET   TIP SPEED = 60.69 MPS (199.12 FPS)

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS	DEG
1.0	52.7	172.8	49.2	161.6	69.0	18.7	61.5	11.4	37.3	21.9	71.9	31.2
2.0	52.9	173.6	48.9	160.4	67.4	20.2	66.3	11.6	38.1	23.3	76.4	29.8
3.0	53.4	175.1	49.0	160.6	66.3	21.3	69.8	11.5	37.6	24.2	79.2	28.3
4.0	53.8	176.6	49.1	161.1	65.6	22.1	72.4	11.2	36.9	24.8	81.2	26.9
5.0	54.1	177.6	49.1	161.2	65.0	22.7	74.5	11.1	36.4	25.3	82.9	26.0
7.0	55.2	181.1	49.6	162.6	63.7	24.3	79.8	10.5	34.4	26.5	86.9	23.3
10.0	56.0	183.7	49.7	163.1	62.4	25.8	84.5	10.1	33.0	27.7	90.7	21.3
15.0	56.1	184.1	49.4	162.0	61.5	26.6	87.4	9.9	32.6	28.4	93.3	20.4
20.0	55.8	182.9	48.9	160.4	61.1	26.8	87.9	10.0	32.7	28.6	93.7	20.4
30.0	55.0	180.6	47.9	157.2	60.3	27.1	88.9	10.1	33.0	28.9	94.8	20.3
50.0	53.8	176.6	46.4	152.3	59.4	27.3	89.5	9.7	31.9	29.0	95.0	19.6
70.0	52.7	172.9	45.0	147.7	58.5	27.4	90.0	9.3	30.5	29.0	95.0	18.7
80.0	51.7	169.5	44.3	145.4	58.9	26.5	87.1	9.1	29.8	28.1	92.0	18.9
85.0	50.9	167.0	44.0	144.3	59.6	25.7	84.2	9.0	29.5	27.2	89.2	19.2
90.0	49.9	163.6	43.7	143.5	61.1	23.9	78.6	8.8	28.7	25.5	83.6	20.0
93.0	49.1	161.1	43.6	142.9	62.3	22.7	74.5	8.7	28.5	24.3	79.7	20.9
95.0	48.7	159.8	43.5	142.7	63.1	21.9	71.9	8.6	28.1	23.5	77.2	21.3
96.0	48.9	160.5	42.5	139.4	60.1	24.3	79.7	9.5	31.1	26.1	85.5	21.3
97.0	48.9	160.3	42.7	139.9	60.6	23.9	78.3	9.2	30.2	25.6	83.9	21.0
98.0	48.8	160.0	42.8	140.3	61.1	23.5	77.0	9.0	29.5	25.1	82.4	20.9

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	DEG
1.0	32.8	107.6	28.2	92.6	59.3	16.7	54.7	32.4	106.2	36.4	119.5	62.6
2.0	32.4	106.2	26.9	88.1	55.9	18.1	59.3	33.6	110.4	38.2	125.3	61.6
3.0	32.5	106.7	26.3	86.4	53.9	19.1	62.6	34.1	111.8	39.1	128.1	60.6
4.0	32.8	107.5	25.8	84.7	51.8	20.2	66.2	34.5	113.2	40.0	131.2	59.5
5.0	33.1	108.6	25.6	84.0	50.5	21.0	68.8	34.6	113.6	40.5	132.8	58.6
7.0	33.4	109.7	25.2	82.6	48.8	22.0	72.1	34.9	114.4	41.2	135.2	57.6
10.0	33.9	111.4	25.0	82.0	47.3	23.0	75.4	34.8	114.2	41.7	136.8	56.4
15.0	37.2	122.1	26.8	88.1	46.0	25.8	84.6	32.5	106.6	41.5	136.1	51.4
20.0	39.0	128.0	27.7	90.9	45.1	27.4	90.1	31.2	102.2	41.5	136.2	48.5
30.0	38.7	126.8	27.0	88.5	44.1	27.7	90.9	31.0	101.7	41.6	136.4	48.1
50.0	37.7	123.6	25.2	82.5	41.8	28.0	92.0	31.0	101.7	41.8	137.1	47.7
70.0	36.2	118.6	22.6	74.3	38.7	28.2	92.5	31.7	103.9	42.4	139.1	48.2
80.0	34.7	114.0	21.5	70.5	38.1	27.3	89.6	31.9	104.8	42.0	137.8	49.3
85.0	33.4	109.7	20.6	67.4	37.8	26.4	86.6	32.4	106.3	41.8	137.1	50.7
90.0	32.4	106.2	19.7	64.7	37.4	25.7	84.3	32.8	107.6	41.7	136.7	51.8
93.0	32.0	105.1	19.0	62.2	36.2	25.8	84.6	33.3	109.1	42.1	138.1	52.1
95.0	31.9	104.6	18.0	58.9	34.2	26.4	86.5	34.1	111.8	43.1	141.4	52.2
96.0	31.8	104.4	17.3	56.8	32.9	26.7	87.6	34.6	113.7	43.7	143.5	52.2
97.0	31.4	102.9	16.5	54.1	31.6	26.7	87.5	35.4	116.1	44.3	145.4	52.8
98.0	30.8	100.9	15.5	50.8	30.1	26.6	87.2	36.3	119.0	45.0	147.6	53.6

BLADE ELEMENT DATA STATOR OUTLET

IMMER	W		WU		BETA	CZ		CU		C		ALPHA
%	MPS	FPS	MPS	FPS	DEG	MPS	FPS	MPS	FPS	MPS	FPS	DEG
1.0	54.4	178.4	51.1	167.5	69.7	18.7	61.4	9.5	31.3	21.0	69.0	26.9
2.0	54.2	177.9	50.4	165.3	68.1	20.0	65.8	10.1	33.2	22.5	73.7	26.7
3.0	54.1	177.4	49.6	162.8	66.4	21.5	70.4	10.8	35.4	24.0	78.8	26.6
4.0	54.0	177.1	49.0	160.8	65.0	22.6	74.2	11.3	37.1	25.3	83.0	26.5
5.0	53.9	176.9	48.4	158.9	63.7	23.7	77.8	11.8	38.7	26.5	86.9	26.4
7.0	53.9	176.8	47.6	156.1	61.8	25.3	83.1	12.5	40.9	28.2	92.6	26.2
10.0	53.9	176.8	47.0	154.2	60.6	26.3	86.3	12.8	41.9	29.2	96.0	25.8
15.0	54.0	177.3	47.0	154.3	60.3	26.6	87.3	12.3	40.3	29.3	96.2	24.7
20.0	54.1	177.4	47.0	154.2	60.2	26.7	87.7	11.9	39.0	29.2	96.0	23.9
30.0	53.8	176.4	46.4	152.4	59.6	27.1	88.9	11.5	37.8	29.4	96.6	23.0
50.0	52.5	172.2	44.5	146.0	57.8	27.8	91.3	11.7	38.2	30.2	99.0	22.7
70.0	51.2	167.9	42.7	140.0	56.4	28.2	92.6	11.6	38.2	30.5	100.2	22.4
80.0	50.2	164.6	42.1	138.2	56.9	27.3	89.4	11.3	37.0	29.5	96.8	22.4
85.0	49.3	161.8	41.5	136.0	57.1	26.7	87.6	11.5	37.7	29.1	95.3	23.2
90.0	48.1	157.9	40.5	132.8	57.1	26.0	85.4	12.0	39.5	28.7	94.1	24.7
93.0	47.3	155.3	40.2	132.0	58.1	24.9	81.7	12.0	39.3	27.6	90.7	25.6
95.0	46.8	153.7	40.6	133.3	60.0	23.3	76.4	11.4	37.4	25.9	85.1	26.0
96.0	46.6	152.7	41.1	134.8	61.8	21.9	71.7	10.9	35.6	24.4	80.1	26.3
97.0	46.5	152.4	41.5	136.2	63.2	20.8	68.3	10.3	33.9	23.3	76.3	26.3
98.0	46.2	151.5	42.5	139.4	66.8	18.1	59.3	9.3	30.5	20.3	66.6	27.1

Table 25. Vector Diagram Parameters for Rotor A/Stator A Single-Stage Configuration, Peak Efficiency Throttle.

BLADE ELEMENT DATA ROTOR INLET TIP SPEED = 60.88 MPS (199.71 FPS)

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	52.5	172.2	48.8	160.1	68.2	19.3	63.3	12.0	39.3	22.7	74.5	31.8
2.0	53.2	174.4	49.1	161.2	67.4	20.3	66.6	11.6	38.0	23.4	76.7	29.6
3.0	53.7	176.0	49.3	161.9	66.7	21.1	69.2	11.3	37.0	23.9	78.5	28.0
4.0	54.1	177.5	49.4	162.2	65.8	22.0	72.1	11.1	36.4	24.6	80.7	26.7
5.0	54.7	179.5	49.8	163.5	65.4	22.6	74.2	10.6	34.8	25.0	82.0	25.0
7.0	55.5	182.0	50.2	164.8	64.7	23.5	77.2	10.0	32.8	25.6	83.9	23.0
10.0	56.0	183.7	50.4	165.3	64.0	24.4	80.1	9.6	31.4	26.2	86.0	21.4
15.0	56.0	183.7	50.0	164.1	63.1	25.2	82.6	9.5	31.2	26.9	88.3	20.6
20.0	55.8	183.0	49.7	162.9	62.8	25.4	83.2	9.4	30.8	27.1	88.8	20.3
30.0	55.1	180.9	48.9	160.3	62.2	25.6	83.9	9.3	30.4	27.2	89.2	19.9
50.0	53.7	176.1	47.2	154.7	61.3	25.7	84.2	9.2	30.1	27.3	89.4	19.6
70.0	52.1	170.9	45.4	149.1	60.5	25.5	83.6	9.1	29.7	27.1	88.8	19.5
80.0	50.9	167.0	45.1	148.0	62.2	23.6	77.4	8.5	27.7	25.1	82.2	19.7
85.0	50.7	166.2	44.2	145.0	60.6	24.7	81.1	8.9	29.2	26.3	86.2	19.8
90.0	49.8	163.3	44.5	146.1	63.3	22.2	73.0	8.1	26.7	23.7	77.7	20.0
93.0	49.1	161.2	44.3	145.5	64.3	21.2	69.4	8.0	26.4	22.6	74.3	20.8
95.0	48.8	160.2	44.2	145.0	64.7	20.7	68.0	8.0	26.3	22.2	72.9	21.1
96.0	48.7	159.9	44.2	145.0	64.9	20.5	67.2	7.9	26.0	22.0	72.1	21.0
97.0	48.6	159.4	44.1	144.7	65.0	20.4	66.9	7.9	26.0	21.9	71.8	21.1
98.0	48.5	159.0	44.0	144.4	65.0	20.3	66.6	7.9	26.0	21.8	71.5	21.2

BLADE ELEMENT DATA ROTOR OUTLET / STATOR INLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	30.8	101.1	26.5	87.0	59.2	15.7	51.6	34.3	112.4	37.7	123.7	65.2
2.0	29.8	97.7	24.6	80.7	55.5	16.8	55.1	36.1	118.4	39.8	130.6	64.9
3.0	29.9	98.1	24.0	78.6	53.1	17.9	58.7	36.6	120.2	40.8	133.8	63.8
4.0	30.5	100.0	23.8	78.2	51.3	19.0	62.4	36.7	120.3	41.3	135.5	62.4
5.0	30.9	101.3	23.8	78.0	50.2	19.7	64.7	36.7	120.3	41.6	136.6	61.6
7.0	31.2	102.4	23.7	77.7	49.2	20.3	66.7	36.6	120.0	41.8	137.3	60.8
10.0	31.8	104.3	23.8	78.2	48.4	21.0	69.0	36.1	118.5	41.8	137.2	59.6
15.0	37.0	121.3	27.0	88.6	46.8	25.3	82.9	32.5	106.7	41.2	135.1	52.0
20.0	38.1	125.1	27.7	90.8	46.4	26.2	86.1	31.4	103.0	40.9	134.2	50.0
30.0	37.6	123.3	26.7	87.5	45.1	26.5	86.9	31.5	103.3	41.1	135.0	49.8
50.0	36.2	118.7	24.3	79.6	42.0	26.8	88.1	32.0	105.1	41.8	137.2	49.9
70.0	34.3	112.5	21.8	71.4	39.3	26.5	86.9	32.7	107.4	42.1	138.2	50.9
80.0	32.9	108.1	20.7	67.8	38.8	25.6	84.1	32.9	107.9	41.7	136.9	51.9
85.0	31.9	104.6	19.3	63.4	37.2	25.3	83.2	33.8	110.9	42.2	138.6	53.0
90.0	30.7	100.6	18.6	61.0	37.2	24.4	80.0	34.1	111.8	41.9	137.4	54.3
93.0	30.1	98.9	17.5	57.6	35.5	24.5	80.4	34.8	114.3	42.6	139.7	54.7
95.0	30.0	98.6	16.5	54.2	33.3	25.1	82.3	35.7	117.1	43.6	143.1	54.7
96.0	30.0	98.3	15.8	51.8	31.7	25.5	83.5	36.3	119.1	44.3	145.5	54.8
97.0	29.6	97.0	14.9	48.9	30.2	25.5	83.8	37.1	121.8	45.1	147.8	55.3
98.0	28.9	94.7	14.1	46.2	29.1	25.2	82.6	37.8	124.2	45.5	149.1	56.2

BLADE ELEMENT DATA STATOR OUTLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	54.6	179.3	51.4	168.5	69.8	18.7	61.2	9.4	30.9	20.9	68.6	26.7
2.0	54.6	179.2	50.9	166.9	68.5	19.9	65.2	9.8	32.2	22.2	72.8	26.2
3.0	54.7	179.4	50.4	165.2	66.8	21.4	70.1	10.3	33.6	23.7	77.7	25.6
4.0	54.6	179.2	49.9	163.6	65.7	22.3	73.1	10.6	34.9	24.7	81.0	25.5
5.0	54.5	178.8	49.4	162.0	64.8	23.0	75.6	11.1	36.3	25.6	83.9	25.6
7.0	54.1	177.6	48.3	158.5	63.0	24.4	80.1	11.9	39.1	27.2	89.1	25.9
10.0	53.9	176.8	47.6	156.2	61.9	25.2	82.6	12.4	40.5	28.1	92.2	26.0
15.0	54.0	177.2	47.6	156.1	61.6	25.6	83.9	11.9	39.2	28.2	92.6	24.9
20.0	54.5	178.6	47.9	157.2	61.3	26.0	85.3	11.2	36.6	28.3	92.8	23.2
30.0	54.1	177.6	47.4	155.6	61.0	26.1	85.7	10.7	35.2	28.2	92.6	22.3
50.0	52.4	172.0	45.0	147.5	59.9	27.0	88.5	11.3	37.2	29.3	96.0	22.8
70.0	50.5	165.7	43.2	141.8	58.7	26.1	85.6	11.3	36.9	28.4	93.3	23.3
80.0	49.4	162.2	42.8	140.5	59.8	24.7	81.1	10.8	35.3	27.0	88.5	23.4
85.0	48.8	160.0	41.7	136.8	58.6	25.3	83.0	11.4	37.5	27.8	91.1	24.2
90.0	47.7	156.6	41.0	134.5	59.0	24.5	80.2	11.7	38.3	27.1	88.9	25.4
93.0	47.1	154.6	40.7	133.6	59.6	23.7	77.7	11.7	38.3	26.4	86.7	26.1
95.0	46.7	153.4	41.1	134.8	61.3	22.3	73.1	11.1	36.5	24.9	81.7	26.4
96.0	46.6	152.7	41.4	135.7	62.5	21.4	70.1	10.8	35.3	23.9	78.5	26.6
97.0	46.4	152.2	41.8	137.3	64.2	20.1	65.8	10.2	33.4	22.5	73.8	26.8
98.0	46.4	152.1	42.9	140.8	67.6	17.5	57.5	9.0	29.6	19.7	64.7	27.1

Table 26. Vector Diagram Parameters for Rotor A/Stator A Single-Stage Configuration, Peak Pressure Rise and Near Stall Throttle.

BLADE ELEMENT DATA ROTOR INLET   TIP SPEED = 61.35 MPS (201.27 FPS)

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	53.4	175.3	50.5	165.8	70.8	17.4	57.1	10.7	35.2	20.5	67.1	31.6
2.0	53.8	176.6	50.5	165.5	69.4	18.8	61.6	10.7	35.1	21.6	70.9	29.6
3.0	54.2	177.7	50.5	165.6	68.5	19.6	64.4	10.6	34.7	22.3	73.2	28.3
4.0	54.5	178.8	50.4	165.4	67.5	20.7	67.8	10.6	34.7	23.2	76.2	27.0
5.0	54.7	179.6	50.4	165.4	66.9	21.3	70.0	10.5	34.4	23.8	78.0	26.1
7.0	55.3	181.6	50.6	166.2	66.0	22.3	73.2	10.1	33.0	24.5	80.3	24.2
10.0	56.0	183.9	51.1	167.6	65.5	23.0	75.6	9.3	30.6	24.9	81.6	22.0
15.0	56.2	184.6	51.0	167.4	61.9	23.7	77.7	8.9	29.3	25.3	83.1	20.6
20.0	56.0	183.6	50.6	166.1	64.6	23.9	78.3	8.9	29.2	25.5	83.6	20.4
30.0	55.2	181.3	49.8	163.3	64.0	24.0	78.9	8.8	29.0	25.6	84.0	20.1
50.0	53.8	176.7	48.1	157.8	63.2	24.1	79.2	8.6	28.2	25.6	84.0	19.6
70.0	52.4	171.9	46.6	152.7	62.5	24.1	78.9	8.4	27.4	25.5	83.6	19.1
80.0	51.4	168.7	45.8	150.1	62.7	23.5	77.0	8.2	27.0	24.9	81.6	19.3
85.0	50.7	166.4	45.5	149.1	63.4	22.5	73.9	8.1	26.5	23.9	78.5	19.7
90.0	50.0	164.0	45.3	148.5	64.8	21.2	69.5	7.8	25.6	22.8	74.0	20.1
93.0	49.5	162.3	45.2	148.3	65.9	20.1	65.8	7.6	24.9	21.4	70.4	20.6
95.0	49.0	160.9	45.0	147.5	66.3	19.6	64.2	7.6	25.0	21.0	68.9	21.3
96.0	49.0	160.6	44.9	147.5	66.5	19.4	63.6	7.6	24.8	20.8	68.3	21.3
97.0	48.9	160.3	44.9	147.4	66.6	19.2	63.1	7.5	24.6	20.6	67.7	21.2
98.0	48.7	159.9	44.8	147.1	66.7	19.1	62.8	7.5	24.6	20.5	67.4	21.3

BLADE ELEMENT DATA ROTOR OUTLET / STATOR INLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	27.5	90.4	24.1	79.1	61.0	13.3	43.6	37.1	121.8	39.4	129.4	70.1
2.0	26.3	86.2	21.9	71.9	56.3	14.5	47.6	39.2	128.8	41.8	137.3	69.5
3.0	26.4	86.7	21.4	70.2	53.9	15.5	50.9	39.7	130.2	42.6	139.8	68.5
4.0	26.7	87.7	21.1	69.3	52.1	16.4	53.7	39.9	130.8	43.1	141.4	67.5
5.0	26.9	88.2	21.0	68.9	51.2	16.6	55.1	39.9	130.8	43.3	141.9	67.0
7.0	27.1	88.9	21.1	69.3	51.0	17.0	55.8	39.6	129.9	43.1	141.4	66.6
10.0	28.0	91.8	21.9	71.8	51.3	17.4	57.2	38.5	126.4	42.3	138.8	65.5
15.0	32.3	[illegible]	24.5	80.5	[illegible]	21.1	69.1	35.4	116.2	41.2	135.2	59.1
20.0	36.7	120.4	27.0	88.7	[illegible]	24.8	81.5	32.5	106.6	40.9	134.2	52.5
30.0	37.5	123.0	26.9	88.3	[illegible]	26.1	85.6	31.7	103.9	41.0	134.6	50.4
50.0	35.4	116.1	24.1	79.1	42.8	25.9	85.0	32.6	107.0	41.7	136.7	51.4
70.0	33.0	108.1	21.4	70.3	40.4	25.0	82.1	33.5	109.8	41.8	137.1	53.1
80.0	31.6	[illegible]	19.8	65.0	39.7	24.6	80.7	34.2	112.1	42.1	138.2	54.1
85.0	30.6	100.3	18.8	61.8	37.9	24.1	79.1	34.7	113.9	42.2	138.6	55.1
90.0	29.3	96.3	17.5	57.4	36.5	23.5	77.2	35.6	116.7	42.6	139.9	56.3
93.0	29.1	95.4	16.3	53.5	34.0	24.1	79.0	36.5	[illegible]	43.7	143.4	56.4
95.0	29.2	95.9	15.2	50.0	31.3	24.9	81.8	37.4	122.6	44.9	147.4	56.1
96.0	29.0	95.1	14.6	47.9	30.2	25.0	82.1	37.9	124.4	45.4	149.0	56.4
97.0	28.3	92.9	13.9	45.5	29.2	24.7	81.1	38.6	126.5	45.8	150.3	57.2
98.0	27.9	91.5	13.7	44.8	29.2	24.3	79.7	38.7	126.9	45.7	149.9	57.7

BLADE ELEMENT DATA STATOR OUTLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	55.1	180.7	51.5	168.9	68.9	19.6	64.4	9.8	32.1	21.9	71.9	26.4
2.0	54.9	180.3	50.9	167.0	67.7	20.7	67.8	10.3	33.6	23.1	75.7	26.3
3.0	54.8	179.8	50.4	165.2	66.6	21.6	70.9	10.7	35.1	24.1	79.1	26.3
4.0	54.7	179.1	49.8	163.3	65.4	22.6	74.2	11.2	36.8	25.2	82.8	26.3
5.0	54.5	178.9	49.3	161.8	64.6	23.2	76.3	11.6	37.9	26.0	85.2	26.4
7.0	54.3	178.0	48.6	159.5	63.5	24.1	79.0	12.1	39.6	27.0	88.4	26.6
10.0	54.1	177.6	48.0	157.6	62.4	24.9	81.8	12.4	40.6	27.8	91.3	26.3
15.0	54.4	178.4	47.9	157.2	61.6	25.7	84.3	12.0	39.5	28.4	93.1	25.0
20.0	54.9	180.3	48.2	158.0	61.1	26.4	86.7	11.3	37.2	28.8	94.4	23.2
30.0	54.5	178.9	47.4	155.7	60.3	26.9	88.1	11.1	36.6	29.1	95.4	22.5
50.0	52.7	172.7	45.4	149.1	59.5	26.6	87.2	11.3	37.1	28.9	94.8	23.0
70.0	50.3	164.9	44.7	146.8	62.8	22.9	75.0	10.2	33.3	25.0	82.1	23.9
80.0	49.1	161.0	44.2	144.9	63.9	21.4	70.3	9.8	32.2	23.6	77.3	24.6
85.0	48.5	159.0	43.6	143.0	63.9	21.2	69.5	9.9	32.6	23.4	76.8	25.1
90.0	47.9	157.1	43.0	141.2	63.7	21.0	69.0	10.0	32.9	23.3	76.5	25.4
93.0	47.6	156.1	42.8	140.5	64.0	20.7	68.0	10.0	32.7	23.0	75.4	25.6
95.0	47.4	155.5	42.8	140.6	64.5	20.3	66.5	9.8	32.0	22.5	73.8	25.6
96.0	47.3	155.2	43.0	141.0	65.1	19.7	64.7	9.5	31.3	21.9	71.9	25.7
97.0	47.1	154.6	43.2	141.7	66.3	18.8	61.8	9.2	30.2	21.0	68.8	26.0
98.0	46.2	151.6	43.3	142.0	69.3	16.1	53.0	9.0	29.7	18.5	60.7	29.2

Table 27. Blade and Vane Element Performance for Rotor A/Stator A, Single-Stage Configuration, Design Point Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED MPS	WHEEL SPEED FPS	REL. TURNING ANGLE DEG	LOSS * COEF.	LOSS PARA.	REL. MACH NO. IN	DIFF. FACT.	REL. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG
1.0	60.6	198.82	9.7	0.094	0.083	0.153	0.563	0.095	-4.9	15.9
2.0	60.5	198.52	11.5	0.119	0.107	0.153	0.581	0.094	-6.4	12.5
3.0	60.4	198.22	12.4	0.136	0.124	0.155	0.587	0.094	-7.3	10.6
4.0	60.3	197.93	13.8	0.152	0.138	0.156	0.591	0.095	-7.9	8.5
5.0	60.2	197.63	14.5	0.157	0.144	0.157	0.589	0.096	-8.4	7.2
7.0	60.1	197.03	14.9	0.189	0.174	0.160	0.597	0.097	-9.5	5.5
10.0	59.8	196.13	15.2	0.205	0.190	0.162	0.596	0.098	-10.4	4.1
15.0	59.3	194.64	15.5	0.133	0.125	0.163	0.519	0.108	-10.7	3.3
20.0	58.9	193.15	16.0	0.078	0.073	0.162	0.472	0.113	-10.4	3.0
30.0	58.0	190.16	16.2	0.058	0.055	0.159	0.466	0.112	-10.0	3.7
50.0	56.1	184.19	17.6	0.042	0.040	0.156	0.470	0.109	-9.0	5.2
70.0	54.3	178.21	19.8	0.061	0.059	0.153	0.490	0.105	-8.7	5.5
80.0	53.4	175.23	20.8	0.071	0.068	0.150	0.508	0.101	-8.4	6.5
85.0	53.0	173.73	21.8	0.085	0.082	0.148	0.530	0.097	-7.9	7.0
90.0	52.5	172.24	23.7	0.082	0.079	0.144	0.544	0.094	-6.7	7.4
93.0	52.2	171.34	26.1	0.074	0.072	0.142	0.548	0.093	-5.7	6.7
95.0	52.0	170.75	28.9	0.069	0.067	0.141	0.554	0.092	-5.1	5.0
96.0	52.0	170.45	27.2	0.084	0.082	0.142	0.535	0.092	-8.2	3.8
97.0	51.9	170.15	29.0	0.098	0.096	0.142	0.571	0.091	-7.7	2.7
98.0	51.8	169.85	30.9	0.117	0.114	0.141	0.591	0.089	-7.3	1.4

TORQUE = 8645.45 IN.-LB.

*** See Figure 66 and Table 23 for loss coefficients computed from relative total pressure measurements.**

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED MPS	WHEEL SPEED FPS	ABS. TURNING ANGLE DEG	ABS. MACH NO. IN	ABS. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.
1.0	60.6	198.82	35.6	0.105	0.061	1.6	15.8	0.1773	0.1748	0.6466
2.0	60.5	198.52	34.9	0.111	0.065	1.1	15.4	0.1990	0.1962	0.6322
3.0	60.4	198.22	34.0	0.113	0.070	0.5	15.1	0.1807	0.1782	0.5979
4.0	60.3	197.93	33.0	0.116	0.073	-0.2	14.8	0.1747	0.1721	0.5750
5.0	60.2	197.63	32.2	0.117	0.077	0.7	14.6	0.1547	0.1526	0.5473
7.0	60.1	197.03	31.5	0.119	0.082	1.0	14.0	0.1212	0.119[illegible]	0.5092
10.0	59.8	196.13	30.6	0.121	0.08[illegible]	1.2	13.3	0.1036	0.102[illegible]	0.4873
15.0	59.3	194.64	26.7	0.120	0.08[illegible]	4.7	11.7	0.0919	0.0903	0.4672
20.0	58.9	193.15	24.6	[illegible]	0.08[illegible]	6.5	10.4	0.0981	0.0970	0.4613
30.0	58.0	190.16	25.1	0.120	0.08[illegible]	5.5	9.0	0.0979	0.0969	0.4583
50.0	56.1	184.19	25.1	0.121	0.08	5.7	8.3	0.0779	0.0771	0.4402
70.0	54.3	178.21	25.8	0.123	0.086	6.6	8.1	0.0695	0.0689	0.4419
80.0	53.4	175.23	26.9	0.122	0.085	6.6	8.2	0.0750	0.0741	0.4640
85.0	53.0	173.73	27.5	0.121	0.084	-5.9	9.1	0.0737	0.0730	0.4727
90.0	52.5	172.24	27.0	0.121	0.083	-5.6	10.6	0.0763	0.0755	0.4777
93.0	52.2	171.34	26.4	0.122	0.080	5.9	11.6	0.1266	0.1252	0.5112
95.0	52.0	170.75	26.1	0.125	0.075	6.1	12.0	0.2139	0.2114	0.5724
96.0	52.0	170.15	25.9	[illegible]	0.071	-6.2	12.3	0.2692	0.2661	0.6216
97.0	51.9	170.15	26.5	0.128	0.067	5.8	12.3	0.3109	0.3073	0.6616
98.0	51.8	169.85	26.5	0.130	0.059	-5.2	13.1	0.3873	0.3826	0.7459

Table 28. Blade and Vane Element Performance for Rotor A/Stator A, Single-Stage Configuration, Peak Efficiency Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED MPS	WHEEL SPEED FPS	REL. TURNING ANGLE DEG	LOSS* COEF	LOSS PARA.	REL MACH NO IN	DIFF FACT	REL MACH NO. OUT	INCID ANGLE DEG	DEV. ANGLE DEG
1.0	60.8	199.44	9.1	0.056	0.050	0.152	0.610	0.089	-5.7	15.8
2.0	60.7	199.14	11.8	0.116	0.104	0.151	0.654	0.086	-6.4	12.2
3.0	60.6	198.84	13.5	0.110	0.127	[illegible]	0.661	0.086	-7.0	9.8
4.0	60.5	198.54	14.6	0.151	0.138	0.156	[illegible]	0.088	7.7	8.0
5.0	60.4	198.24	15.2	0.169	[illegible]	0.158	[illegible]	0.089	-8.0	6.9
7.0	60.2	197.64	15.5	[illegible]	0.153	0.160	0.653	0.090	-8.4	5.9
10.0	60.0	196.74	15.5	[illegible]	0.193	[illegible]	[illegible]	0.092	-8.8	5.2
15.0	59.5	195.25	16.3	0.089	[illegible]	0.162	0.526	0.107	-9.0	4.0
20.0	59.1	193.75	16.4	0.017	[illegible]	0.161	0.481	0.110	-8.7	4.3
30.0	58.1	190.75	17.1	[illegible]	[illegible]	[illegible]	[illegible]	0.109	-8.1	4.7
50.0	56.3	184.76	19.3	[illegible]	[illegible]	[illegible]	0.500	0.105	-7.1	5.4
70.0	54.5	[illegible]	[illegible]	0.051	[illegible]	0.151	0.51	0.099	-6.7	6.1
80.0	53.6	175.77	[illegible]	0.060	[illegible]	[illegible]	0.519	0.095	-5.1	7.2
85.0	53.1	174.27	[illegible]	0.081	[illegible]	[illegible]	0.570	[illegible]	-6.9	6.4
90.0	52.7	[illegible]	26.1	0.158	[illegible]	[illegible]	0.591	[illegible]	-4.5	7.2
93.0	52.1	171.08	28.8	0.081	[illegible]	[illegible]	[illegible]	0.087	-3.7	6.0
95.0	52.2	171.28	31.4	0.075	[illegible]	0.141	0.61	0.087	-3.5	4.1
96.0	52.1	170.98	32.2	0.075	[illegible]	0.141	0.61	0.087	3.3	2.7
97.0	52.0	170.68	34.8	0.091	[illegible]	0.141	0.63	0.085	-3.3	1.3
98.0	51.9	170.38	35.9	0.096	[illegible]	0.130	0.65	0.083	-3.4	0.4

TORQUE = [illegible] IN-LB.

* See Figure 66 and Table 23 for loss coefficients computed from relative total pressure measurements.

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED MPS	WHEEL SPEED FPS	ABS. TURNING ANGLE DEG	ABS. MACH NO IN	ABS. MACH NO. OUT	INCID ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.
1.0	60.8	[illegible]	[illegible]	0.109	[illegible]	4.3	15.6	[illegible]	0.1921	0.6812
2.0	60.7	[illegible]	[illegible]	0.115	[illegible]	1.4	[illegible]	[illegible]	[illegible]	0.6788
3.0	60.6	[illegible]	[illegible]	0.113	[illegible]	[illegible]	[illegible]	[illegible]	0.2260	0.6500
4.0	60.5	[illegible]	[illegible]	0.110	0.071	2.8	[illegible]	0.2105	[illegible]	0.6278
5.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.6057
7.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.5613
10.0	60.0	[illegible]	[illegible]	0.121	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15.0	59.5	[illegible]	[illegible]	0.119	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20.0	59.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30.0	58.1	190.75	[illegible]	[illegible]	[illegible]	[illegible]	8.3	[illegible]	[illegible]	[illegible]
50.0	56.3	184.76	27.2	[illegible]	[illegible]	[illegible]	8.1	[illegible]	[illegible]	[illegible]
70.0	54.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
80.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
85.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
90.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
93.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
95.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
96.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
97.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
98.0	[illegible]	[illegible]	[illegible]	0.131	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 29. Blade and Vane Element Performance for Rotor A/Stator A, Single-Stage Configuration, Peak Pressure Rise and Near Stall Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED MPS	WHEEL SPEED FPS	REL. TURNING ANGLE DEG	LOSS* COEF.	LOSS PARA.	REL. MACH NO. IN	DIFF. FACT.	REL. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG
1.0	61.3	200.97	9.8	0.169	0.148	0.155	0.714	0.080	-3.1	17.6
2.0	61.2	200.67	13.1	0.212	0.191	0.156	0.758	0.076	-4.4	13.0
3.0	61.1	200.36	14.7	0.226	0.205	0.157	0.761	0.077	-5.1	10.5
4.0	61.0	200.06	15.4	0.233	0.213	0.158	0.758	0.077	-6.0	8.7
5.0	60.9	199.76	15.6	0.241	0.221	0.159	0.756	0.078	-6.5	7.9
7.0	60.7	199.16	15.0	0.256	0.235	0.160	0.756	0.079	-7.1	7.8
10.0	60.4	198.25	14.2	0.253	0.232	0.163	0.739	0.081	-7.3	8.1
15.0	60.0	196.74	15.7	0.164	0.151	0.163	0.639	0.094	-7.2	6.5
20.0	59.5	195.23	17.3	0.055	0.052	0.162	0.534	0.106	-6.9	5.2
30.0	58.6	192.21	18.3	0.013	0.013	0.160	0.505	0.109	-6.3	5.4
50.0	56.7	186.17	20.4	0.028	0.027	0.156	0.534	0.103	-5.2	6.2
70.0	54.9	180.14	22.0	0.059	0.057	0.152	0.571	0.096	-4.7	7.2
80.0	54.0	177.12	23.9	0.074	0.072	0.149	0.592	0.092	-4.6	7.1
85.0	53.5	175.61	25.6	0.075	0.072	0.147	0.610	0.089	-4.1	7.1
90.0	53.1	174.10	28.2	0.094	0.091	0.145	0.636	0.085	-3.0	6.5
93.0	52.8	173.19	31.3	0.081	0.079	0.143	0.646	0.084	-2.1	4.5
95.0	52.6	172.59	35.0	0.066	0.065	0.142	0.646	0.085	-1.9	2.1
96.0	52.5	172.29	36.3	0.071	0.063	0.142	0.655	0.084	-1.8	1.1
97.0	52.4	171.99	37.4	0.085	0.083	0.142	0.673	0.082	-1.7	0.3
98.0	52.3	171.68	37.5	0.091	0.089	0.141	0.682	0.081	-1.7	0.5

TORQUE = 8789.44 IN.-LB.

* See Figure 66 and Table 23 for loss coefficients computed from relative total pressure measurements.

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED MPS	WHEEL SPEED FPS	ABS. TURNING ANGLE DEG	ABS. MACH NO. IN	ABS. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.
1.0	61.3	200.97	43.7	0.114	0.064	9.2	15.2	0.1783	0.1759	0.6920
2.0	61.2	200.67	43.2	0.121	0.067	9.0	15.0	0.2313	0.2281	0.6961
3.0	61.1	200.36	42.2	0.123	0.070	8.4	14.8	0.2252	0.2222	0.6772
4.0	61.0	200.06	41.2	0.125	0.073	7.8	14.6	0.2101	0.2073	0.6519
5.0	60.9	199.76	40.6	0.125	0.075	7.7	14.6	0.1924	0.1898	0.6336
7.0	60.7	199.16	40.0	0.125	0.079	8.0	14.5	0.1576	0.1554	0.6025
10.0	60.4	198.25	39.2	0.123	0.081	7.9	13.8	0.1153	0.1137	0.5626
15.0	60.0	196.74	34.1	0.119	0.082	3.0	12.0	0.0817	0.0807	0.5141
20.0	59.5	195.23	29.3	0.119	0.093	2.5	9.7	0.0650	0.0643	0.4810
30.0	58.6	192.21	27.9	0.119	0.081	-3.2	8.5	0.0690	0.0684	0.4687
50.0	56.7	186.17	28.4	0.121	0.084	-2.0	8.6	0.0886	0.0877	0.4860
70.0	54.9	180.14	29.2	0.121	0.072	1.7	9.6	0.1910	0.1890	0.5928
80.0	54.0	177.12	29.5	0.122	0.068	1.8	10.3	0.2304	0.2280	0.6362
85.0	53.5	175.61	30.0	0.122	0.068	-1.5	10.[illegible]	0.2458	0.2431	0.6430
90.0	53.1	174.10	30.9	0.121	0.068	-1.1	11.[illegible]	0.2495	0.2467	0.6527
93.0	52.8	173.19	30.8	0.127	0.067	-1.5	11.6	0.3026	0.2932	0.6749
95.0	52.6	172.59	30.5	0.130	0.065	-2.2	11.6	0.3494	0.3456	0.7023
96.0	52.5	172.29	30.7	0.132	0.064	-2.1	11.7	0.3745	0.3704	0.7237
97.0	52.4	171.99	31.2	0.133	0.061	-1.5	12.0	0.4025	0.3980	0.7535
98.0	52.3	171.68	28.5	0.132	0.054	-1.1	15.1	0.4442	0.4380	0.8083

Table 3.. Normalized Absolute Total Pressure, Static Pressure and Flow Angles for Rotor A/Stator A Four-Stage Configuration, First Stage Tested.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Peak Efficiency Throttle						
	Total Pressure			Static Pressure		
[illegible]	Rotor 1 Inlet	Rotor 1 Exit	Stator 1 Exit	Rotor 1 Inlet	Rotor 1 Exit	Stator 1 Exit
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]						
	Total Pressure			Static Pressure		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Stator 1 Exit
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 36. Normalized Absolute Total Pressure, Static Pressure and Flow Angles for Rotor A/Stator A Four-Stage Configuration, First Stage Tested (Concluded).

Design Point Throttle

Percent Immersion	Measured Rotor 1 Inlet	Measured Rotor 1 Exit	Measured Stator 1 Exit	Corrected Rotor 1 Inlet	Corrected Rotor 1 Exit	Corrected Stator 1 Exit
1	29.9	62.6	24.0	31.2	63.7	25.1
2	28.6	61.8	23.3	29.8	62.9	24.3
3	27.1	60.4	22.9	28.3	61.6	23.9
4	25.8	59.3	22.8	26.9	60.5	23.8
5	24.9	57.9	22.9	26.0	59.1	23.9
7	22.3	56.5	24.3	23.3	57.7	25.3
10	20.4	54.0	25.3	21.3	55.2	26.3
15	19.6	47.8	24.1	20.4	49.0	25.0
20	19.6	46.6	23.1	20.4	47.8	24.0
30	19.6	46.7	22.6	20.3	47.8	23.4
50	19.0	47.7	22.6	19.6	48.6	23.7
70	18.2	49.1	22.7	18.7	49.9	23.3
80	18.4	49.9	22.9	18.9	50.6	23.4
85	18.8	51.0	23.5	19.1	51.7	24.0
90	19.6	52.3	24.6	20.0	53.0	25.1
93	20.4	52.8	25.5	20.9	53.5	26.0
95	20.8	52.9	26.1	21.3	53.5	26.6
96	20.8	52.9	26.4	21.3	53.5	26.9
97	20.6	53.3	26.6	21.0	53.9	27.1
98	20.5	54.2	26.7	20.9	54.8	27.2

Peak Efficiency Throttle

Percent Immersion	Measured Rotor 1 Inlet	Measured Rotor 1 Exit	Measured Stator 1 Exit	Corrected Rotor 1 Inlet	Corrected Rotor 1 Exit	Corrected Stator 1 Exit
1	30.5	64.3	26.6	31.8	65.4	27.8
2	28.4	62.5	25.8	29.6	63.6	26.9
3	26.9	61.5	25.6	28.0	62.6	26.7
4	25.6	60.8	25.4	26.7	62.0	26.5
5	24.0	60.0	25.3	25.0	61.2	26.4
7	22.0	58.2	25.2	23.0	59.4	26.3
10	20.5	55.4	24.9	21.4	56.6	25.9
15	19.8	49.2	24.1	20.6	50.4	25.0
20	19.5	47.9	22.4	20.3	49.1	23.3
30	19.2	47.8	21.4	19.9	48.9	22.2
50	19.0	48.7	22.8	19.4	49.6	23.5
70	19.0	50.5	22.8	19.5	51.3	23.4
80	19.2	51.6	22.8	19.7	52.3	23.3
85	19.3	53.0	23.1	19.8	53.7	23.6
90	19.6	54.7	23.9	20.0	55.3	24.4
93	20.3	55.2	25.8	20.8	55.8	26.3
95	20.6	55.5	26.2	21.1	56.1	26.7
96	20.6	55.7	26.1	21.0	56.3	26.6
97	20.7	55.9	26.0	21.1	56.5	26.5
98	20.8	57.2	25.7	21.2	57.8	26.2

Peak Pressure Rise, Near Stall Throttle

Percent Immersion	Measured Rotor 1 Inlet	Measured Rotor 1 Exit	Measured Stator 1 Exit	Corrected Rotor 1 Inlet	Corrected Rotor 1 Exit	Corrected Stator 1 Exit
1	30.3	67.2	24.4	31.6	68.2	25.5
2	28.4	66.3	23.7	29.6	67.3	24.8
3	27.1	65.5	23.4	28.3	66.5	24.4
4	25.9	64.6	23.3	27.0	65.6	24.3
5	25.0	63.8	23.4	26.1	64.9	24.4
7	23.2	62.0	24.1	24.2	63.1	25.1
10	21.1	59.3	25.8	22.0	60.4	26.8
15	19.8	53.7	25.2	20.6	54.9	26.2
20	19.6	50.1	22.5	20.4	51.3	23.4
30	19.4	49.6	20.9	20.1	50.7	21.6
50	19.0	50.7	22.7	19.6	51.6	23.4
70	18.6	53.2	23.3	19.1	54.0	23.9
80	18.8	54.7	23.6	19.3	55.4	24.2
85	19.2	56.0	24.2	19.7	56.7	24.7
90	19.7	57.0	25.1	20.1	57.6	25.6
93	20.2	56.8	25.8	20.6	57.4	26.3
95	20.8	56.4	26.2	21.3	57.0	26.7
96	20.8	56.5	26.2	21.3	57.1	26.7
97	20.8	57.3	26.1	21.2	57.9	26.6
98	20.9	58.8	27.3	21.3	59.4	27.8

Table 31. Rotor Loss Coefficients Determined from Relative Total Pressure Measurements, Four-Stage Configuration, First Stage Tested.

Design Point Throttle						
TOTAL PRESSURE			ROTOR LOSS COEFFICIENT			
PERCENT IMMERSION	ROTOR 1 INLET	ROTOR 1 EXIT	PERCENT IMMERSION	TOTAL LOSS	WAVE LOSS	TOTAL MINUS WAVE LOSS
5.0	0.5744	0.4822	5.0	[illegible]	0.0062	0.1064
[illegible]	[illegible]	0.5605	10.0	[illegible]	0.0117	0.0596
[illegible]	[illegible]	0.6075	15.0	[illegible]	0.0145	0.0123
[illegible]	[illegible]	[illegible]	20.0	[illegible]	[illegible]	0.0144
[illegible]	[illegible]	0.5785	35.0	[illegible]	0.0174	0.0162
[illegible]	[illegible]	0.5434	50.0	[illegible]	0.0233	0.0125
[illegible]	[illegible]	0.5053	65.0	[illegible]	[illegible]	0.0112
[illegible]	[illegible]	[illegible]	80.0	[illegible]	0.0538	0.0134
[illegible]	0.4508	[illegible]	85.0	[illegible]	[illegible]	0.0073
[illegible]	0.4555	[illegible]	90.0	[illegible]	0.0897	0.0096
[illegible]	[illegible]	0.3558	95.0	[illegible]	0.0987	0.0155

Peak Efficiency Throttle						
TOTAL PRESSURE			ROTOR LOSS COEFFICIENT			
PERCENT IMMERSION	ROTOR 1 INLET	ROTOR 1 EXIT	PERCENT IMMERSION	TOTAL LOSS	WAVE LOSS	TOTAL MINUS WAVE LOSS
5.0	0.5020	0.4948	5.0	[illegible]	[illegible]	0.1254
10.0	0.6475	0.5689	10.0	[illegible]	0.0114	[illegible]
15.0	[illegible]	0.6256	15.0	[illegible]	0.0131	[illegible]
20.0	0.6498	0.6246	20.0	[illegible]	[illegible]	[illegible]
35.0	0.6162	0.5983	35.0	[illegible]	[illegible]	[illegible]
50.0	0.5864	0.5634	50.0	[illegible]	[illegible]	[illegible]
[illegible]	0.5480	0.5182	65.0	[illegible]	[illegible]	[illegible]
[illegible]	0.5000	0.4586	80.0	[illegible]	[illegible]	[illegible]
[illegible]	0.4855	0.4180	85.0	[illegible]	[illegible]	0.0174
[illegible]	0.4000	0.4007	90.0	[illegible]	[illegible]	0.0005
[illegible]	0.4550	0.3734	95.0	[illegible]	0.1750	[illegible]

Peak Pressure Rise/Near Stall Throttle						
TOTAL PRESSURE			ROTOR LOSS COEFFICIENT			
PERCENT IMMERSION	ROTOR 1 INLET	ROTOR 1 EXIT	PERCENT IMMERSION	TOTAL LOSS	WAVE LOSS	TOTAL MINUS WAVE LOSS
5.0	0.6164	0.5039	5.0	0.1392	0.0147	0.1246
10.0	0.6519	0.5702	10.0	0.0873	0.0151	0.0722
15.0	[illegible]	0.6370	15.0	0.0581	0.0146	0.0435
20.0	0.6740	0.6472	20.0	0.0309	0.0147	0.0162
35.0	0.6432	0.6216	35.0	0.0259	0.0169	0.0090
50.0	0.6141	0.5858	50.0	0.0351	0.0221	0.0129
[illegible]	0.5725	0.5396	[illegible]	0.0430	0.0340	[illegible]
[illegible]	0.5269	0.4702	80.0	[illegible]	0.0740	0.0049
85.0	0.5127	0.4423	[illegible]	0.0998	0.0901	0.0097
90.0	0.5015	0.4243	90.0	[illegible]	0.1093	0.0020
95.0	0.4777	0.3973	95.0	[illegible]	0.1110	[illegible]

Table 32. Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Design Point Throttle.

BLADE ELEMENT DATA ROTOR INLET TIP SPEED = 63.82 MPS (209.38 FPS)

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	55.4	181.7	51.7	169.8	69.9	19.7	64.8	12.0	39.3	23.1	75.8	31.2
2.0	55.6	182.5	51.4	168.6	67.3	21.3	69.9	12.2	40.1	24.6	80.6	29.8
3.0	56.1	184.1	51.4	168.8	66.3	22.4	73.5	12.1	39.6	25.5	83.5	28.3
4.0	56.6	185.7	51.6	169.3	65.5	23.3	76.3	11.8	38.8	26.1	85.6	26.9
5.0	56.9	186.8	51.6	169.4	64.9	23.9	78.5	11.7	38.4	26.6	87.4	26.0
7.0	58.1	190.5	52.1	170.9	63.6	25.6	84.1	11.1	36.3	27.9	91.6	23.3
10.0	58.9	193.2	52.3	171.5	62.4	27.2	89.1	10.6	34.8	29.1	95.6	21.3
15.0	59.0	193.6	51.9	170.3	61.4	28.1	92.2	10.5	34.4	30.0	98.4	20.4
20.0	58.6	192.4	51.4	168.6	61.0	28.2	92.6	10.5	34.5	30.1	98.6	20.4
30.0	57.9	189.9	50.3	165.2	60.3	28.6	93.7	10.6	34.8	30.5	99.9	20.3
50.0	56.6	185.8	48.8	160.0	59.3	28.8	94.3	10.3	33.7	30.5	100.2	19.6
70.0	55.4	181.8	47.3	155.2	58.4	28.9	94.9	9.8	32.2	30.5	100.2	18.7
80.0	54.3	178.3	46.6	152.8	58.8	26.0	91.8	9.6	31.4	29.6	97.0	18.9
85.0	53.5	175.7	46.2	151.6	59.5	27.0	88.7	9.5	31.1	28.7	94.0	19.2
90.0	52.4	172.0	46.0	150.8	61.1	25.2	82.8	9.2	30.3	26.9	88.2	20.0
93.0	51.7	169.5	45.8	150.2	62.2	23.9	78.5	9.1	30.0	25.6	84.1	20.9
95.0	51.2	169.0	45.7	150.0	63.0	23.1	75.8	9.0	29.6	24.8	81.4	21.3
96.0	51.5	168.8	44.6	146.5	60.0	25.6	84.0	10.0	32.8	27.5	90.2	21.3
97.0	51.4	168.6	44.6	147.1	60.5	25.1	82.5	9.7	31.8	27.0	88.4	21.0
98.0	51.3	168.3	44.9	147.5	61.0	24.7	81.1	9.5	31.1	26.5	86.9	20.9

BLADE ELEMENT DATA ROTOR OUTLET / STATOR INLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	36.4	119.3	33.1	108.7	65.5	15.0	49.2	30.6	100.4	34.1	111.7	63.7
2.0	34.3	112.6	29.7	97.4	59.8	17.2	56.4	33.9	111.3	38.0	124.8	62.9
3.0	34.4	112.9	29.0	95.0	57.1	18.6	61.0	34.6	113.4	39.3	128.8	61.6
4.0	34.4	112.8	28.0	91.9	54.4	19.9	65.4	35.4	116.2	40.6	133.3	60.5
5.0	34.9	114.6	27.8	91.3	52.7	21.1	69.2	35.5	116.5	41.3	135.5	59.1
7.0	35.4	116.3	27.5	90.1	50.7	22.4	73.5	35.7	117.1	42.1	138.2	57.7
10.0	36.9	121.0	27.9	91.6	49.0	24.1	79.2	35.0	114.7	42.5	139.3	55.2
15.0	41.1	134.8	30.4	99.6	47.5	27.7	90.8	32.0	105.1	42.3	138.9	49.0
20.0	41.6	136.6	30.5	100.0	46.9	28.4	93.1	31.4	103.1	42.3	138.9	47.8
30.0	40.9	134.3	29.2	96.0	45.5	28.6	93.9	31.7	104.0	42.7	140.1	47.8
50.0	38.9	127.7	26.4	86.5	42.5	28.6	93.9	32.7	107.1	43.4	142.5	48.6
70.0	36.7	120.4	23.3	76.3	39.2	28.4	93.1	33.9	111.1	44.2	144.9	49.9
80.0	35.5	116.5	22.1	72.5	38.3	27.8	91.3	34.1	111.8	44.0	144.3	50.6
85.0	34.4	112.8	21.4	70.3	38.4	26.9	88.3	34.3	112.4	43.6	142.9	51.7
90.0	33.1	108.7	20.4	66.9	37.9	26.1	85.7	34.8	114.2	43.5	142.8	53.0
93.0	32.6	106.9	19.5	63.9	36.6	26.1	85.7	35.4	116.3	44.0	144.5	53.5
95.0	32.4	106.4	18.3	60.1	34.3	26.8	87.8	36.4	119.5	45.2	148.3	53.5
96.0	32.4	106.3	17.9	58.6	33.3	27.0	88.7	36.8	120.7	45.6	149.7	53.5
97.0	32.1	105.2	17.2	56.6	32.5	27.0	88.6	37.3	122.3	46.0	151.1	53.9
98.0	31.3	102.7	16.6	54.3	31.8	26.6	87.1	37.9	124.3	46.3	151.8	54.8

BLADE ELEMENT DATA STATOR OUTLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	58.0	190.2	54.7	179.4	70.4	19.2	63.1	9.0	29.6	21.2	69.7	25.1
2.0	58.0	190.4	54.2	177.9	68.9	20.7	67.9	9.4	30.8	22.7	74.6	24.3
3.0	58.1	190.5	53.8	176.4	67.6	22.0	72.0	9.8	32.1	24.0	78.9	23.9
4.0	58.0	190.3	53.2	174.6	66.3	23.1	75.8	10.2	33.6	25.3	82.9	23.8
5.0	57.9	189.9	52.8	173.1	65.5	23.8	78.1	10.6	34.7	26.1	85.5	23.9
7.0	57.1	187.2	50.9	166.8	63.8	25.9	85.0	12.3	40.3	28.7	94.1	25.3
10.0	56.3	184.8	49.6	162.7	61.5	26.7	87.7	13.3	43.6	29.9	98.0	26.3
15.0	56.6	185.8	49.4	162.1	60.6	27.6	90.7	13.0	42.5	30.5	100.2	25.0
20.0	56.8	186.4	49.3	161.8	60.1	28.2	92.5	12.6	41.3	30.9	101.3	24.0
30.0	56.4	184.9	48.5	159.1	59.2	28.7	94.3	12.5	40.9	31.3	102.8	23.4
50.0	54.9	180.2	46.3	151.9	57.3	29.5	96.9	12.7	41.8	32.2	105.5	23.3
70.0	53.3	174.9	44.4	145.6	56.2	29.5	96.9	12.7	41.8	32.2	105.5	23.3
80.0	52.3	171.5	43.6	143.2	56.4	28.8	94.4	12.5	41.1	31.4	103.0	23.4
85.0	51.6	169.2	42.8	140.5	55.9	28.8	94.4	12.9	42.2	31.5	103.4	24.0
90.0	50.6	166.1	41.6	136.6	55.2	28.8	94.5	13.6	44.5	31.8	104.5	25.1
93.0	49.9	163.6	41.0	134.5	55.1	28.4	93.2	13.9	45.7	31.6	103.8	26.0
95.0	49.2	161.4	41.2	135.1	56.7	26.9	88.3	13.5	44.4	30.1	98.8	26.6
96.0	48.8	160.2	41.5	136.2	58.0	25.7	84.4	13.1	43.0	28.9	94.8	26.9
97.0	48.5	159.3	42.1	138.2	60.0	24.1	79.2	12.4	40.7	27.1	89.0	27.1
98.0	48.4	158.7	42.8	140.4	62.1	22.5	73.9	11.6	38.2	25.4	83.2	27.2

Table 33. Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Peak Efficiency Throttle.

BLADE ELEMENT DATA ROTOR INLET TIP SPEED = 64.67 MPS (212.17 FPS)

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	55.7	182.8	51.8	170.0	68.2	20.6	67.4	12.8	41.9	24.2	79.4	31.8
2.0	56.5	185.2	52.2	171.1	67.3	21.6	70.9	12.3	40.4	24.9	81.6	29.6
3.0	57.0	187.0	52.4	171.8	66.6	22.5	73.7	12.0	39.4	25.5	83.6	28.0
4.0	57.5	188.5	52.5	172.2	65.8	23.4	76.8	11.8	38.7	26.2	86.0	26.7
5.0	58.1	190.7	52.9	173.5	65.3	24.1	79.0	11.3	37.0	26.6	87.3	25.0
7.0	58.9	193.4	53.3	175.0	64.6	25.1	82.2	10.6	34.9	27.2	89.3	23.0
10.0	59.5	195.1	53.5	175.5	63.9	26.0	85.3	10.2	33.5	27.9	91.6	21.4
15.0	59.5	195.2	53.1	174.2	63.0	26.8	88.0	10.1	33.2	28.7	94.0	20.6
20.0	59.2	194.4	52.7	173.0	62.7	27.0	88.6	10.0	32.8	28.8	94.5	20.3
30.0	58.6	192.2	51.9	170.2	62.1	27.2	89.3	9.9	32.4	29.0	95.0	19.9
50.0	57.0	187.1	50.1	164.3	61.2	27.3	89.7	9.8	32.0	29.0	95.2	19.6
70.0	55.4	181.6	48.2	158.3	60.5	27.1	89.1	9.6	31.6	28.8	94.5	19.5
80.0	54.1	177.5	47.9	157.2	62.2	25.1	82.4	9.0	29.5	26.7	87.5	19.7
85.0	53.8	176.6	46.9	154.0	60.5	26.3	86.4	9.5	31.1	28.0	91.8	19.8
90.0	52.9	173.5	47.3	155.1	63.2	23.7	77.7	8.7	28.4	25.2	82.7	20.0
93.0	52.2	171.3	47.1	154.5	64.2	22.5	73.9	8.6	28.1	24.1	79.1	20.8
95.0	51.9	170.2	46.9	154.0	64.6	22.1	72.4	8.5	28.0	23.7	77.6	21.1
96.0	51.8	169.8	46.9	154.0	64.9	21.8	71.6	8.4	27.6	23.4	76.8	21.0
97.0	51.6	169.4	46.8	153.6	64.9	21.7	71.3	8.4	27.7	23.3	76.5	21.1
98.0	51.5	168.9	46.7	153.3	65.0	21.6	71.0	8.4	27.7	23.2	76.2	21.2

BLADE ELEMENT DATA ROTOR OUTLET / STATOR INLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	35.2	115.3	31.9	104.5	64.8	14.9	48.8	32.7	107.3	35.9	117.9	65.4
2.0	33.7	110.5	28.7	94.2	58.3	17.6	57.8	35.8	117.4	39.9	130.8	63.6
3.0	33.2	109.0	27.2	89.1	54.7	19.1	62.7	37.2	122.1	41.8	137.2	62.6
4.0	33.1	108.7	26.4	86.6	52.6	20.0	65.8	37.9	124.3	42.9	140.7	62.0
5.0	33.4	109.5	26.1	85.5	51.2	20.9	68.4	38.1	125.1	43.5	142.6	61.2
7.0	34.4	112.9	26.4	86.5	49.8	22.1	72.6	37.6	123.5	43.7	143.2	59.4
10.0	36.3	119.1	27.5	90.1	49.0	23.7	77.9	36.2	118.9	43.3	142.1	56.6
15.0	40.6	133.2	30.2	99.1	47.9	27.1	89.0	33.0	108.3	42.7	140.2	50.4
20.0	41.2	135.3	30.3	99.5	47.2	27.9	91.7	32.4	106.3	42.8	140.3	49.1
30.0	40.7	133.4	29.2	95.9	45.9	28.2	92.7	32.5	106.7	43.1	141.3	48.9
50.0	38.7	127.0	26.5	86.8	43.0	28.2	92.6	33.4	109.4	43.7	143.4	49.6
70.0	36.1	118.5	23.3	76.5	40.1	27.6	90.5	34.6	113.4	44.2	145.1	51.3
80.0	34.7	113.8	22.0	72.0	39.1	26.9	88.1	35.0	114.7	44.1	144.6	52.3
85.0	33.3	109.4	21.0	68.7	38.8	25.9	85.1	35.5	116.4	43.9	144.2	53.7
90.0	31.8	104.2	19.8	65.0	38.5	24.8	81.5	36.1	118.5	43.8	143.8	55.3
93.0	31.2	102.3	18.6	61.1	36.6	25.0	82.0	37.0	121.4	44.7	146.5	55.8
95.0	30.8	101.0	17.3	56.9	34.2	25.4	83.5	38.1	125.0	45.8	150.3	56.1
96.0	30.6	100.3	16.8	55.1	33.2	25.6	83.9	38.6	126.6	46.3	151.8	56.3
97.0	30.4	99.7	16.4	53.7	32.5	25.6	83.9	38.9	127.6	46.6	152.7	56.5
98.0	29.3	96.0	15.7	51.4	32.3	24.7	81.1	39.5	129.6	46.6	152.9	57.8

BLADE ELEMENT DATA STATOR OUTLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	57.7	189.5	54.5	178.9	70.6	19.0	62.4	10.0	33.0	[illegible]	70.6	27.8
2.0	57.8	189.8	54.2	177.9	69.5	20.1	65.9	10.2	33.6	22.6	74.0	26.9
3.0	57.8	189.5	53.9	176.8	68.7	20.8	68.2	10.5	34.4	23.3	76.4	26.7
4.0	57.6	189.1	53.2	174.7	67.3	22.1	72.4	11.0	36.2	24.7	81.0	26.5
5.0	57.5	188.8	52.7	173.1	66.3	23.0	75.4	11.4	37.5	25.7	84.2	26.4
7.0	57.4	188.2	51.7	169.5	64.1	24.9	81.7	12.3	40.4	27.8	91.2	26.3
10.0	57.3	187.9	50.9	167.0	62.6	26.2	86.1	12.8	42.0	29.2	95.7	25.9
15.0	57.3	188.0	50.6	165.9	61.7	27.0	88.6	12.7	41.5	29.8	97.8	25.0
20.0	57.8	189.8	50.8	166.7	61.3	27.6	90.7	11.9	39.1	30.1	98.8	23.3
30.0	57.6	189.0	50.2	164.8	60.5	28.2	92.7	11.5	37.9	30.5	100.1	22.2
50.0	55.3	181.5	47.4	155.6	58.8	28.5	93.4	12.4	40.7	31.1	101.9	23.5
70.0	[illegible]	[illegible]	45.6	149.5	57.9	28.4	93.1	12.3	40.4	30.9	101.5	23.4
80.0	[illegible]	[illegible]	[illegible]	147.2	58.0	27.8	91.3	12.0	39.5	30.3	99.4	23.3
85.0	52.2	171.3	44.3	145.3	57.8	27.7	90.8	12.1	39.9	30.2	99.2	23.6
90.0	51.4	[illegible]	43.3	141.9	57.1	27.8	91.3	12.7	41.6	30.6	100.3	24.4
93.0	50.1	[illegible]	42.2	138.3	57.1	27.1	89.1	13.5	[illegible]	30.3	99.4	26.3
95.0	49.6	[illegible]	42.5	139.4	58.2	25.7	84.2	13.0	42.5	28.7	94.3	26.7
96.0	49.5	162.5	42.9	140.8	59.8	24.0	81.2	12.5	40.9	27.7	90.9	26.6
97.0	49.4	[illegible]	43.5	142.6	61.4	23.5	77.2	11.8	38.7	26.3	86.4	26.5
98.0	49.5	162.3	44.3	145.2	63.3	22.1	72.4	10.9	35.7	24.6	80.7	26.2

Table 34. Vector Diagram Parameters for Rotor A/Stator A Four-Stage Configuration, First Stage Tested, Peak Pressure Rise and Near Stall Throttle.

BLADE ELEMENT DATA ROTOR INLET TIP SPEED = 63.32 MPS (207.73 FPS)

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	55.1	180.9	52.1	171.0	70.7	18.0	59.1	11.1	36.4	21.2	69.5	31.6
2.0	55.6	182.3	52.0	170.8	69.3	19.4	63.8	11.1	36.4	22.4	73.4	29.6
3.0	55.9	183.4	52.1	170.9	68.5	20.3	66.7	11.0	35.9	23.1	75.7	28.3
4.0	56.2	184.5	52.0	170.6	67.4	21.4	70.2	10.9	35.9	24.0	78.8	27.0
5.0	56.5	185.4	52.0	170.6	66.8	22.1	72.5	10.8	35.6	24.6	80.8	26.1
7.0	57.1	187.4	52.2	171.4	66.0	23.1	75.8	10.4	34.2	25.3	83.1	24.2
10.0	57.8	189.8	52.7	172.9	65.5	23.9	78.3	9.7	31.7	25.7	84.4	22.0
15.0	58.1	190.5	52.6	172.7	64.8	24.5	80.4	9.2	30.3	26.2	86.0	20.6
20.0	57.8	189.5	52.2	171.3	64.5	24.7	81.0	9.2	30.2	26.4	86.5	20.4
30.0	57.0	187.2	51.3	168.4	63.9	24.9	81.7	9.1	30.0	26.5	87.0	20.1
50.0	55.6	182.4	49.7	162.9	63.1	25.0	81.9	8.9	29.2	26.5	87.0	19.6
70.0	54.1	177.5	48.0	157.6	62.4	24.9	81.7	8.6	28.4	26.4	86.5	19.1
80.0	53.1	174.2	47.2	154.9	62.6	24.3	79.7	8.5	27.9	25.7	84.4	19.3
85.0	52.4	171.8	46.9	153.8	63.4	23.3	76.5	8.4	27.4	24.8	81.3	19.7
90.0	51.6	169.3	46.7	153.2	64.7	21.9	71.9	8.1	26.5	23.3	76.6	20.1
93.0	51.0	167.5	46.6	153.0	65.8	20.8	68.1	7.8	25.7	22.2	72.8	20.6
95.0	50.6	166.1	46.4	152.2	66.2	20.2	66.4	7.9	25.9	21.7	71.3	21.3
96.0	50.5	165.8	46.4	152.1	66.4	20.1	65.9	7.8	25.7	21.5	70.7	21.3
97.0	50.4	165.5	46.3	152.0	66.6	19.9	65.3	7.8	25.5	21.4	70.1	21.2
98.0	50.3	165.1	46.2	151.7	66.6	19.8	65.0	7.8	25.5	21.3	69.8	21.3

BLADE ELEMENT DATA ROTOR OUTLET / STATOR INLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	30.0	98.4	26.1	85.7	60.4	14.7	48.3	37.1	121.7	39.9	130.9	68.2
2.0	30.2	99.[illegible]	25.0	85.4	59.2	15.4	50.5	37.1	121.7	40.2	131.8	67.3
3.0	29.2	95.9	23.9	78.4	54.7	16.8	55.3	39.1	128.4	42.6	139.8	66.5
4.0	29.2	95.9	23.1	75.9	52.2	17.9	58.6	39.9	130.6	43.6	143.2	65.6
5.0	29.5	96.8	22.9	75.2	50.8	18.6	61.0	39.9	131.0	44.0	144.5	64.9
7.0	30.7	100.9	23.6	77.6	50.1	19.7	64.5	39.0	128.0	43.7	143.3	63.1
10.0	32.6	107.1	24.9	81.6	49.5	21.1	69.3	37.5	123.0	43.0	141.2	60.4
15.0	36.5	119.9	27.5	90.2	48.7	24.1	78.9	34.4	112.9	42.0	137.7	54.9
20.0	38.8	127.3	28.7	94.2	47.6	26.1	85.6	32.7	107.3	41.8	137.3	51.3
30.0	38.5	126.3	27.9	91.4	46.2	26.6	87.2	32.6	107.0	42.1	138.0	50.7
50.0	36.4	119.5	25.3	82.9	43.8	26.3	86.2	33.3	109.3	42.4	139.1	51.6
70.0	33.4	109.5	22.0	72.3	41.2	25.1	82.2	34.6	113.6	42.7	140.2	54.0
80.0	31.7	103.9	20.4	66.9	40.0	24.2	79.5	35.3	115.9	42.8	140.5	55.4
85.0	30.4	99.8	19.4	63.5	39.4	23.5	77.0	35.9	117.7	42.9	140.7	56.7
90.0	29.4	96.5	18.6	61.0	39.1	22.8	74.8	36.2	118.6	42.7	140.2	57.6
93.0	29.3	96.1	17.4	57.2	36.4	23.5	77.3	37.1	121.6	43.9	144.1	57.4
95.0	29.4	96.6	16.4	54.0	33.9	24.4	80.1	37.8	124.2	45.0	147.8	57.0
96.0	29.3	96.2	16.0	52.4	32.9	24.6	80.6	38.2	125.4	45.4	149.1	57.1
97.0	28.6	93.8	15.4	50.4	32.3	24.2	79.3	38.8	127.1	45.7	149.8	57.9
98.0	27.4	89.9	14.8	48.5	32.6	23.1	75.7	39.2	128.6	45.5	149.3	59.4

BLADE ELEMENT DATA STATOR OUTLET

IMMER %	W MPS	W FPS	WU MPS	WU FPS	BETA DEG	CZ MPS	CZ FPS	CU MPS	CU FPS	C MPS	C FPS	ALPHA DEG
1.0	57.5	[illegible]	54.7	[illegible]	71.8	17.6	58.3	8.5	27.9	19.7	64.6	25.5
2.0	57.6	189.0	54.5	178.7	70.9	18.7	61.3	8.6	28.4	20.6	67.5	24.8
3.0	57.5	[illegible]	[illegible]	[illegible]	69.8	19.7	64.6	9.0	29.4	21.6	71.0	24.4
4.0	57.4	[illegible]	[illegible]	[illegible]	69.5	20.8	68.4	9.5	31.0	22.9	75.1	24.3
5.0	[illegible]	[illegible]	53.[illegible]	174.1	67.8	21.5	70.4	9.8	32.1	23.6	77.4	24.4
7.0	[illegible]	186.0	51.8	170.0	65.8	23.0	75.6	10.8	35.5	25.5	83.5	25.1
10.0	55.6	182.5	50.4	165.4	64.8	23.5	77.2	11.9	39.2	26.4	86.6	26.8
15.0	55.5	182.1	49.9	[illegible]	63.7	24.4	80.1	12.0	39.5	27.2	89.3	26.2
20.0	[illegible]	[illegible]	50.3	[illegible]	62.9	25.6	83.9	11.1	36.3	27.9	91.4	23.4
30.0	[illegible]	185.4	50.0	164.0	62.0	26.4	86.5	10.5	34.4	28.4	93.1	21.6
50.0	54.0	177.2	47.1	154.6	60.6	26.4	86.6	11.4	37.6	28.8	94.4	23.4
70.0	[illegible]	[illegible]	45.0	[illegible]	59.6	26.2	86.1	11.7	38.2	28.7	91.[illegible]	23.9
80.0	51.1	[illegible]	44.1	[illegible]	59.5	25.0	81.6	11.6	38.1	28.3	92.8	24.2
85.0	50.4	165.3	43.5	[illegible]	59.6	25.4	83.2	11.7	38.5	27.9	91.6	24.7
90.0	49.5	162.4	42.7	140.1	59.4	25.0	82.1	12.1	39.6	27.8	91.2	25.6
93.0	[illegible]	[illegible]	42.4	139.3	60.1	24.2	79.5	12.0	39.5	27.1	88.8	26.3
95.0	48.5	159.0	42.6	139.8	61.3	23.1	75.9	11.7	38.4	25.9	85.1	26.7
96.0	48.4	158.7	42.9	140.6	62.2	22.4	73.6	11.3	37.2	25.1	82.5	26.7
97.0	48.3	158.6	43.2	141.6	63.1	21.7	71.3	10.9	35.9	24.3	79.8	26.6
98.0	47.8	156.8	43.3	142.0	64.8	20.2	66.4	10.7	35.2	22.9	75.1	27.8

Table 35. Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, First Stage Tested, Design Point Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED MPS	WHEEL SPEED FPS	REL. TURNING ANGLE DEG	LOSS* COEF.	LOSS PARA.	REL. MACH NO. IN	DIFF. FACT.	REL. MACH NO. OUT	INCID. ANGLE DEG.	DEV. ANGLE DEG
1.0	63.7	209.07	3.4	0.060	0.051	0.159	0.500	0.104	-5.0	22.1
2.0	63.6	208.75	7.5	0.119	[illegible]	0.160	0.561	0.098	-6.5	16.4
3.0	[illegible]	208.44	9.1	0.135	[illegible]	0.161	0.572	0.099	-7.4	13.8
4.0	[illegible]	208.12	11.1	[illegible]	0.138	[illegible]	0.585	0.098	-8.0	11.1
5.0	[illegible]	[illegible]	12.3	0.151	0.133	0.168	0.579	0.100	-8.5	9.4
7.0	[illegible]	207.18	13.0	0.174	0.150	0.167	0.584	0.102	-9.5	7.4
10.0	62.9	206.24	13.4	0.166	0.151	0.169	0.563	0.106	-10.4	5.8
15.0	62.4	204.67	13.9	0.074	0.069	0.169	0.470	0.118	-10.7	4.8
20.0	61.9	203.10	14.1	0.046	0.042	0.168	0.450	0.119	-10.5	4.8
30.0	60.9	[illegible]	14.8	0.041	[illegible]	0.166	0.455	0.117	-10.0	5.1
50.0	59.0	193.68	16.8	[illegible]	[illegible]	0.162	[illegible]	0.112	-9.1	5.9
70.0	[illegible]	187.40	19.2	[illegible]	[illegible]	0.159	0.519	0.105	-8.8	6.0
80.0	56.2	[illegible]	20.5	0.100	[illegible]	0.156	0.531	0.102	-8.5	6.7
85.0	55.7	[illegible]	21.1	0.108	[illegible]	0.151	0.515	[illegible]	-8.0	7.6
90.0	[illegible]	181.11	23.2	[illegible]	0.109	0.150	[illegible]	[illegible]	-6.7	7.9
93.0	[illegible]	[illegible]	25.6	[illegible]	[illegible]	[illegible]	[illegible]	0.093	-5.8	7.1
95.0	[illegible]	179.54	28.7	[illegible]	[illegible]	0.147	[illegible]	[illegible]	-5.2	5.1
96.0	54.6	[illegible]	[illegible]	0.112	[illegible]	0.148	[illegible]	[illegible]	-8.3	4.3
97.0	54.5	[illegible]	28.1	0.121	[illegible]	0.147	[illegible]	0.092	-7.8	3.6
98.0	54.4	[illegible]	29.2	[illegible]	[illegible]	0.147	[illegible]	0.090	-7.4	3.1

TORQUE = 8916.71 IN.-LB.

* See Figure 86 and Table 31 for loss coefficients computed from relative total pressure measurements.

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED MPS	WHEEL SPEED FPS	ABS. TURNING ANGLE DEG	ABS. MACH NO. IN	ABS MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.
1.0	63.7	209.07	38.7	0.098	0.061	2.8	[illegible]	-.0317	-.0213	0.6023
2.0	63.6	208.75	38.6	0.109	[illegible]	[illegible]	[illegible]	0.1215	0.1201	0.5330
3.0	[illegible]	208.44	37.7	0.112	[illegible]	1.5	[illegible]	[illegible]	[illegible]	0.6136
4.0	[illegible]	208.12	36.7	0.116	[illegible]	0.8	12.1	[illegible]	[illegible]	0.5998
5.0	63.3	[illegible]	35.2	0.118	[illegible]	[illegible]	[illegible]	0.1511	[illegible]	[illegible]
7.0	63.1	207.18	32.4	0.121	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10.0	[illegible]	206.24	28.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15.0	[illegible]	204.67	24.0	0.121	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.4395
20.0	61.9	203.10	23.8	0.121	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30.0	60.9	199.93	24.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50.0	59.0	193.68	25.4	[illegible]	0.092	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70.0	[illegible]	[illegible]	26.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
80.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
85.0	[illegible]	[illegible]	27.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
90.0	[illegible]	181.11	27.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
93.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-4.5	[illegible]	[illegible]	[illegible]	[illegible]
95.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
96.0	[illegible]	[illegible]	[illegible]	0.131	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
97.0	[illegible]	[illegible]	26.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
98.0	[illegible]	[illegible]	27.6	[illegible]	0.073	-4.0	[illegible]	[illegible]	[illegible]	[illegible]

Table 36. Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, First Stage Tested, Peak Efficiency Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMEP (%)	WHEEL SPEED MPS	WHEEL SPEED FPS	REL. TURNING ANGLE DEG	LOSS* COEF.	LOSS PARA.	REL. MACH NO. IN	DIFF. FACT.	REL. MACH NO. OUT	INCID. ANGLE DEG	DEV. ANGLE DEG
1.0	64.6	211.85	3.4	0.019	0.016	0.159	0.535	0.100	-5.7	21.4
2.0	64.5	211.53	9.0	0.088	0.079	0.161	0.596	0.096	-6.5	14.9
3.0	64.4	211.22	11.9	0.125	0.113	0.163	0.622	0.095	-7.0	11.4
4.0	64.3	210.90	13.2	0.147	0.131	0.164	0.633	0.094	-7.7	9.3
5.0	64.2	210.58	14.1	0.168	0.154	0.166	0.639	0.095	-8.1	7.9
7.0	64.0	209.91	14.8	0.179	0.164	0.168	0.627	0.098	-8.5	6.6
10.0	63.7	208.99	14.9	0.159	0.147	0.170	0.590	0.103	-8.9	5.8
15.0	63.2	207.40	15.1	0.060	0.056	0.170	0.492	0.116	-9.1	5.2
20.0	62.7	205.80	15.5	0.036	0.034	0.169	0.474	0.117	-8.8	5.1
30.0	61.8	202.62	16.3	0.028	0.026	0.167	0.477	0.116	-8.2	5.5
50.0	59.8	196.26	18.2	0.034	0.033	0.163	0.499	0.110	-7.2	6.4
70.0	57.9	189.89	20.4	0.065	0.062	0.158	0.535	0.103	-6.7	6.9
80.0	56.9	186.71	23.0	0.076	0.073	0.154	0.555	0.099	-5.1	7.5
85.0	56.4	185.12	21.7	0.107	0.103	0.154	0.576	0.095	-7.0	8.0
90.0	55.9	183.53	24.7	0.120	0.115	0.151	0.608	0.090	-4.6	8.5
93.0	55.6	182.57	27.6	0.109	0.106	0.149	0.621	0.089	-3.8	7.1
95.0	55.5	181.91	30.4	0.106	0.103	0.148	0.634	0.088	-3.6	5.0
96.0	55.4	181.[illegible]	31.7	0.109	0.106	0.148	0.641	0.087	-3.4	4.1
97.0	55.3	181.30	32.4	0.109	0.107	0.147	0.646	0.087	-3.4	3.6
98.0	55.2	180.98	32.7	0.131	0.128	0.147	0.671	0.083	-3.4	3.5

TORQUE = 9002.[illegible]3 IN. LB.

* See Figure 88 and Table 31 for loss coefficients computed from relative total pressure measurements.

STATOR VANE ELEMENT PERFORMANCE

IMMER %	WHEEL SPEED MPS	WHEEL SPEED FPS	ABS. TURNING ANGLE DEG	ABS. MACH NO. IN	ABS MACH NO OUT	INCID ANGLE DEG	DEV. ANGLE DEG	LOSS COEF.	LOSS PARA.	DIFF. FACT.
1.0	64.6	211.85	37.6	0.10[illegible]	0.061	4.5	16.6	0.0097	0.0096	0.6265
2.0	64.5	211.53	36.7	0.114	[illegible]	3.1	15.6	0.1530	0.1509	0.6630
3.0	64.4	211.22	35.9	0.119	0.066	2.6	15.2	0.2014	0.1986	0.6715
4.0	64.3	210.90	35.5	0.12[illegible]	0.070	2.3	[illegible]	0.1963	0.1937	0.6492
5.0	64.2	210.58	34.8	0.121	0.073	1.9	14.6	0.1867	0.1841	0.6287
7.0	64.0	209.91	33.1	0.124	0.079	0.8	14.1	0.1322	0.1304	0.5705
10.0	63.7	208.99	30.7	0.123	0.083	-1.0	13.4	0.0761	0.0751	0.5195
15.0	63.2	207.40	25.4	0.12[illegible]	0.085	5.[illegible]	[illegible]	0.0411	0.0409	[illegible]
20.0	62.7	205.80	25.8	0.12[illegible]	0.086	5.9	9.8	0.0313	0.0308	[illegible]
30.0	61.8	202.62	26.7	0.123	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50.0	59.8	196.26	26.1	0.124	0.088	3.3	9.1	[illegible]	[illegible]	0.4574
70.0	57.9	189.89	[illegible]	0.126	0.088	[illegible]	9.1	[illegible]	[illegible]	[illegible]
80.0	56.9	186.71	29.0	0.126	[illegible]	3.6	[illegible]	[illegible]	[illegible]	[illegible]
85.0	56.4	185.12	30.1	0.125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
90.0	55.9	183.53	30.9	0.125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
93.0	55.6	182.57	29.5	[illegible]	0.086	[illegible]	[illegible]	[illegible]	[illegible]	0.4961
95.0	55.5	181.91	29.4	0.130	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.5540
96.0	55.4	[illegible]	[illegible]	0.132	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.5325
97.0	55.3	181.30	30.0	0.133	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.6265
98.0	55.2	180.98	31.6	0.133	[illegible]	1.0	[illegible]	[illegible]	0.3213	0.6741

Table 37. Blade and Vane Element Performance for Rotor A/Stator A, Four-Stage Configuration, First Stage Tested, Peak Pressure Rise and Near Stall Throttle.

ROTOR BLADE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED MPS	WHEEL SPEED FPS	REL TURNING ANGLE DEG	LOSS* COEF	LOSS PARA	REL. MACH NO. IN	DIFF. FACT	REL. MACH NO OUT	INCID. ANGLE DEG	DEV. ANGLE DEG
1.0	[illegible]	[illegible]	10.3	0.154	0.136	0.158	[illegible]	0.086	-3.2	17.0
2.0	63.1	[illegible]	10.1	[illegible]	[illegible]	0.159	[illegible]	0.086	-4.4	15.9
3.0	63.0	[illegible]	13.8	0.19	[illegible]	0.160	[illegible]	[illegible]	-5.2	11.3
4.0	62.9	[illegible]	15.3	[illegible]	0.184	0.161	[illegible]	0.084	-6.1	8.8
5.0	62.8	206.17	16.0	0.204	0.187	0.162	[illegible]	0.084	-6.6	7.5
7.0	62.7	205.55	15.8	0.198	0.182	0.164	0.692	0.088	-7.2	6.9
10.0	[illegible]	[illegible]	15.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-7.3	6.3
15.0	[illegible]	[illegible]	[illegible]	0.109	0.100	[illegible]	[illegible]	[illegible]	-7.3	5.9
20.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.111	-7.0	5.5
30.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.508	0.110	-6.4	5.8
50.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.159	[illegible]	0.104	-5.3	7.2
70.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.533	0.095	[illegible]	8.0
80.0	[illegible]	[illegible]	[illegible]	0.099	[illegible]	[illegible]	0.610	0.091	[illegible]	8.4
85.0	[illegible]	[illegible]	21.0	0.111	0.106	0.150	[illegible]	0.087	[illegible]	8.6
90.0	[illegible]	[illegible]	[illegible]	0.111	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.1
93.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.9
95.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-2.0	1.7
96.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.081	1.9	3.9
97.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.8	3.5
98.0	[illegible]	[illegible]	21.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-1.8	3.9

TORQUE [illegible]

* See Figure 86 and Table 31 for loss coefficients computed from relative total pressure measurements.

STATOR VANE ELEMENT PERFORMANCE

IMMER (%)	WHEEL SPEED MPS	WHEEL SPEED FPS	ABS TURNING ANGLE DEG	ABS MACH NO IN	ABS MACH NO OUT	INCID. ANGLE DEG	DEV. ANGLE DEG	LOSS COEF	LOSS PARA	DIFF. FACT.
1.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

9.0 REFERENCES

1. Wisler, D.C., "Core Compressor Exit Stage Study, Volume I - Blading Design," NASA CR-135391, December 1977.

2. Wisler, D.C., Koch, C.C., and Smith, L.H., Jr., "Preliminary Design Study of Advanced Multistage Axial Flow Core Compressors," NASA CR-135133, February 1977.

3. Koch, C.C., and Smith, L.H., Jr., "Loss Sources and Magnitudes in Axial-Flow Compressors," Transactions of ASME, Journal of Engineering for Power, Vol. 98, Series A, No. 3, July 1976, page 411.

4. Lakshminarayana, B., and Horlock, J.H., "Leakage and Secondary Flows in Compressor Cascades," R&M No. 3483, Dept. of Mechanical Engineering, University of Liverpool, London, England, March 1965.