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HIGH-TIP-SPEED, LOW-LOADING TRANSONIC FAN STAGE

(Part 3 - Final Report)

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16 Abstract Tests were conducted on a high-tip-speed, low-loading transonic fan stage to determine the performance and inlet flow distortion tolerance of the design. The fan was designed for high efficiency at a moderate pressure ratio by designing the hub section to operate at minimum loss when the tip operates with an oblique shock. The design objective was an efficiency of 86 percent at a pressure ratio of 1.5, a specific flow (flow per unit annulus area) of 42 lb/sec-ft ² (205.1 kgm/sec-m ²), and a tip speed of 1600 ft/sec (488.6 m/sec). During testing, a peak efficiency of 84 percent was achieved at design speed and design specific flow. At the design speed and pressure ratio, the flow was 4 percent greater than design, efficiency was 81 percent, and a stall margin of 24 percent was obtained. The stall line was improved with hub radial distortion but was reduced when the stage was tested with tip radial and circumferential flow distortions. Blade-to-blade values of static pressures were measured over the rotor blade tips.					
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SUMMARY

A high-tip-speed, low-pressure-ratio transonic fan stage without inlet guide vanes was designed and tested to 110 percent of design speed to determine overall, blade element, and mechanical performance with uniform inlet flow, radially distorted inlet flow, and circumferentially distorted inlet flow. The design rotor relative Mach numbers were supersonic over 85 percent of the span at the inlet and 30 percent of the span at the exit. To achieve this condition, the rotor was designed to accommodate weak oblique shocks in the tip region of the blades. The stator design was conventionally subsonic with the primary role of turning the flow to axial and was configured with double-circular-arc airfoils. The stage was designed for a specific flow (flow per unit of annulus area) of 42 lb/sec-ft² (205.1 kgm/sec-m²) to deliver a pressure ratio of 1.5 at an efficiency of 86 percent and an equivalent tip speed of 1600 ft/sec (488.6 m/sec).

All testing was performed with the stator closed 3 deg from its nominal setting (greater stagger angle), which slightly improved stall margin and efficiency over the values obtained from other settings tested at design speed. With uniform inlet flow at design speed and pressure ratio, the stage efficiency was 81 percent, specific flow was 4 percent greater than design, and stall margin was 24 percent. The peak efficiency obtained at design speed was 84 percent, which corresponded to a pressure ratio of 1.67, 103 percent of design equivalent flow, and a stall margin of 10.5 percent. The design level of stage efficiency was achieved at the design specific flow, but at 95 percent of design speed and at a pressure ratio of 1.6. Rotor-only efficiency exceeded design goals, both at design speed and design flow rates, but at pressure ratios higher than design. The level of peak efficiency decayed rather uniformly as speed was increased to 90 percent of design speed, then abruptly increased by 3 points when speed was increased to 95 percent of design speed indicating the transition between the "unstarted" and "started" modes. These results, therefore, substantiate the quasi-three-dimensional characteristic procedure used in the design.

Shock patterns were not easily discernable from the static pressure contour plots derived from high-frequency-response instrumentation over the rotor blade tips. Tip leakage vortices, wall boundary layers, and the designed weakness of the tip shock system, all inferred from the plots, complicate the isolation of shock fronts. Holograms taken utilizing this fan stage under separate NASA Contract NAS 3-15336, however, showed shock patterns throughout the entire outer span of the blading. The shock system for the 100 percent design speed condition showed four major shock waves; (1) a leading edge shock, (2) a midspan damper shock, (3) a second damper shock, and (4) a trailing edge shock. The original design considered only the leading and trailing edge shocks.

The stall limit line was improved with hub-radial distortion, but was reduced when the stage was tested with circumferential and tip-radial flow distortions. Stage peak efficiency levels were decreased with all distortions tested. Over-attenuation resulted when the stage was subjected to hub radial distortion; however, amplification was obtained with tip radial distortion. With circumferential distortion, amplification occurred in the hub region and attenuation occurred in the mid passage and tip region.

INTRODUCTION

A low-loading, high-tip-speed transonic fan stage was designed, fabricated, and tested. A fan stage of this type would allow the drive turbine to operate at a higher rotational speed than would be suitable for fans having higher loading characteristics. Accordingly, turbine efficiency would be improved or the number of stages could be reduced, resulting in an engine having better performance and/or less weight and volume. The rotor design objective was, therefore, to deliver good efficiency at low work input by elimination of strong shock losses and shock-induced separation in the high-Mach-number tip region.

The rotor design, as reported herein, is actually a redesign of the rotor described in ref. 1 and also reported upon in refs. 2 and 3. The midspan dampers of the original design failed in initial testing to 110 percent of design speed possibly as a result of classical blade flutter. Design speed performance resulting from this test was encouraging, and only minimal modifications were considered to be necessary to relieve the structural problem while retaining the original aerodynamic features. Dampers with increased thickness and revised contact surfaces and altered thickness distribution of the blading immediately adjacent to the dampers were incorporated into a redesign, herein referred to as "the design." The blade thickness distribution was altered immediately adjacent to the midspan damper to provide a less marginal flutter parameter. The midspan damper was redesigned to (1) reduce the vibratory stress by increasing thickness and removing the notches to make the interlock a single plane and (2) reduce the steady-state loading by changing the contact angle. This rotor followed the same design procedures as outlined in ref. 1. The stator vanes from the initial test were not damaged and were retained.

Aerodynamic and mechanical design results for the rotor are presented in Appendix A. The stator was varied to arrive at the best stage operating characteristics. This report also presents the experimental data obtained from uniform and distorted inlet flows and compares these data to the design values. Tabulations of these data are presented in ref. 4. Symbols and performance parameter definitions used in this report are presented in Appendix B.

Holograms of the rotor flow field were made under Contract NAS 3-15336. The results of this holographic study are reported in ref. 5.

APPARATUS AND PROCEDURES

Test Facility

The fan stage was tested in the sea level compressor test cell shown in fig. 1. A single-stage, radial-inflow turbine driven by heated facility air provides power to the fan through a 1.477-to-1 gearbox. Filtered air enters the fan through a calibrated bellmouth, which also serves to check total flow measurement. An open-mesh, conical screen shrouds the bellmouth for protection against damage by foreign objects. The airflow exiting the fan is diffused and exhausted to a double-walled plenum and then to two separate discharge ducts: one of 35.38 in. (89.85 cm) inside diameter and one of 23.50 in. (59.69 cm) inside diameter. These large-diameter discharge ducts were necessary to minimize system pressure losses and thereby extend the range of performance mapping. Each discharge duct contains a butterfly valve for back-pressure control and an ASME* square-edge orifice plate for primary flow measurement.

Distortion tests were accomplished by series stacking screens of various porosities attached to a support grid with 2 in. (5.08 cm) square openings. This support grid is capable of rotating through 360 deg in 5 min for circumferential distortion testing. The support grid was not rotated during radial distortion testing and was removed during uniform inlet flow testing. Fig. 2 shows the hub-radial, tip-radial, and circumferential distortion screens mounted to the support grid.

Stage Configuration

The test configuration, shown in fig. 3, consists of an axial-flow fan with a single-exit-row, continuous-span stator and no inlet guide vanes. A detailed description of the stage appears in the design report (ref. 1). A redesigned rotor blade was necessitated by midspan damper failure that occurred on the original design during initial testing at 110 percent of design speed. The aerodynamic and mechanical details of this redesign appear in Appendix A of this report.

The stage was designed to deliver a total pressure ratio of 1.5 with an adiabatic efficiency of 86 percent at an inlet specific flow (flow per unit annulus area) of 42 lb/sec-ft² (205.1 kgm/sec-m²). The rotor was designed to operate at a tip speed of 1600 ft/sec (488.6 m/sec) to accomplish these objectives. To satisfy the range of test requirements, however, the rotor was mechanically designed to operate at 110 percent of the design speed or at a rotor tip speed of 1760 ft/sec (537.2 m/sec).

*American Society of Mechanical Engineers.

The rotor contained 40 blades of 2.64 aspect ratio with midspan dampers located at 30 percent of the span from the tip. The rotor inlet hub-to-tip radius ratio was 0.46. Design relative Mach numbers were supersonic over 85 percent of span at the inlet and 30 percent of span at the exit of the rotor. Nominal running tip clearance at design speed was 0.045 in. (0.114 cm) and 0.035 in. (0.089 cm) at 110 percent of design speed. Two views of the rotor blade are shown in fig. 4, and the bladed disc assembly is shown in fig. 5.

The stator consisted of 45 vanes of 3.10 aspect ratio. The vanes could be remotely controlled to rotate about their centers of gravity on the span-wise stacking line such as to vary the stagger angle by ± 10 deg from the design setting. Double-circular-arc airfoil sections were chosen for the design. At the design point, the maximum inlet Mach number occurs at the hub and was only 0.8:1 with a corresponding diffusion factor of 0.43. The stator vane leading edge was located axially 1.42 in. (3.61 cm) downstream of the rotor hub trailing edge. All performance testing was accomplished with the stator closed 3 deg from the as-designed setting (increasing the stagger angle.)

Instrumentation

Aerodynamic instrumentation.--Aerodynamic evaluation of the overall stage performance, rotor performance, blade element, and vane element data of the transonic fan stage required highly accurate sensing elements and utilized a computer-controlled data acquisition system. Accordingly, the types and designs of fixed sensing elements were carefully selected to provide the necessary accuracy, and the proper locations and distribution of all fixed instrumentation were determined to minimize blockage effects. Three categories of aerodynamic instrumentation were needed to provide three basic sets of data: (1) fixed instrumentation for evaluating overall stage performance, (2) traverses for determining rotor and stator element performance, and (3) high-response pressure transducers and stall sensors for evaluating transient and dynamic characteristics. A schematic of the test stage identifying the designated instrumentation stations and their corresponding axial locations is shown in fig. 6. A summary of the instrumentation station designations is shown below, and a schematic indicating the type of instrumentation and circumferential location of each station appears in fig. 7. Fig. 8 shows the fully instrumented test stage.

<u>Station number</u>	<u>Location</u>
0	Inlet bellmouth screen
1	Bellmouth instrumentation plane
2	Distortion screen plane
3, 4, 4.3, 4.6	Inlet duct instrumentation
5	Rotor inlet instrumentation plane

5.5	Rotor inlet traverse plane
6	Rotor leading edge
7	Rotor casing instrumentation
8	Rotor trailing edge
9	Rotor exit traverse plane
10	Stator leading edge
11	Stator trailing edge
12	Stage exit instrumentation plane
13	Plenum inlet plane
14	Downstream temperature mixing plane

The primary airflow measurement system consisted of ASME standard thin plate, square edged orifices located downstream in two straight pipe measuring sections. The orifice sizes were chosen to provide the largest orifice-to-pipe diameter ratio for which accurate coefficients are available in the ASME power test code of ref. 6. Accordingly, an 18.30-in. (46.48-cm) orifice was used in the 23.50-in. (59.69-cm) diameter pipe and a 27.13-in. (68.90-cm) orifice was used in the 35.38-in. (89.85-cm) diameter pipe. Two diametrically opposed sets of flange taps for each orifice were used. Each orifice temperature was measured by dual thermocouples located in accordance with ASME standards. Transverse (cruciform) pitot-static rakes located in the calibrated bellmouth section (station 1) provided a secondary check of the flow measurement. Station 1 instrumentation contained 29 elements located at centers of equal annular areas. The sum of the orifice flows agreed with that obtained from the bellmouth measurement to within ± 0.5 percent.

Speed was monitored and compared with two independent inductively coupled monopole electromagnetic pickups and counters. Overall system accuracy was ± 0.2 percent.

The inlet total temperature was measured at station 0 by fourteen chromel-constantan type E thermocouples of 0.020-in. (0.051-cm) wire diameter. Stator exit total temperatures (fig. 9a) were measured by six radial rakes with shielded high-recovery thermocouples. These rakes were circumferentially indexed to obtain readings evenly distributed across the stator vane at 0, 20, 40, 60, 80, and 100 percent gap. The seventh rake, which measured temperature at mid-gap, was located approximately 180 deg from the 40 and 60 percent gap thermocouples. These vane exit thermocouples were chromel-constantan, Type E, using 0.010-in. (0.025-cm) wire diameter. The thermocouple lead wires were calibrated for each temperature element. In addition, stage downstream temperatures (after radial and circumferential mixing) were measured in each exhaust duct at station 14, which gave a check to the station 12 measurements. All thermocouples were

channeled through constant-temperature ovens for reference. To check overall system performance and assure data validity, two standard temperatures (the melting point of ice and the boiling point of water) were monitored through each reference junction. These temperatures generally were maintained to within $\pm 0.5^{\circ}\text{F}$ ($\pm 0.1^{\circ}\text{K}$) of their standard.

The inlet total pressure was measured by the bellmouth cruciform pitot-static rake during uniform inlet flow testing and by two radial rakes located at station 5 during circumferential distortion testing. The station 5 rakes were removed for uniform inlet flow testing. The stator exit total pressures were measured by 11-element wake rakes (fig. 9b) evenly distributed circumferentially across the vane passage. Two wake rakes, 180 deg opposed, were used at each immersion. Wall static pressure tap locations are shown in fig. 7. A schematic of the stator channel static tap locations is shown in fig. 10. Pneumatic switches utilizing one calibrated pressure transducer per 45 pressures were used for most pressure measurements. To check system performance and assure data validity, two reference pressures for each transducer were supplied by dead weights at 0 and 80 percent of transducer full scale and monitored to maintain a recording accuracy of 0.3 percent of full range.

Radial rakes (fig. 11a), located at station 10 and midway between stator gaps, contained high-frequency-response pressure transducers for the detection of rotating stall. The rakes, separated by 180 deg, each had immersions that corresponded to 10, 47, and 90 percent of span.

Three different types of wedge probes (shown in figs. 11b, 11c, and 11d) were used for obtaining blade and vane element data. Total pressure, static pressure, absolute air angle, and temperature were measured with 60-deg and 30-deg wedge probes; static pressure and absolute air angle also were measured with an 8-deg wedge probe. During uniform inlet flow and radial distortion testing, stations 5.5 and 9 each were equipped with one 60-deg wedge probe and one 8-deg wedge probe, while two 60-deg wedge probes were located at station 12. During circumferential distortion testing, however, two 60-deg wedge probes and one 30-deg wedge probe were located at both stations 5.5 and 9. Wedge probes were calibrated for Mach number as a function of indicated static-to-total pressure ratio. Stator angles, discharge valve settings, and distortion screen angular positions were visually displayed and manually recorded by the data acquisition system.

Ten high-frequency-response pressure transducers were flush-mounted in two axial lines over the rotor blade tip. As shown in fig. 12, these transducers were located in two rows spanning one rotor passage along with ten corresponding wall static pressure taps that provided a reference level for each high-frequency-response transducer. A proximity detector, sensing a target on the front shaft assembly, provided a one-per-rotor-revolution pulse to locate a known blade passage and position relative to the transducer positions. The transducers have a linearity of one percent and rise time of less than two microseconds. A shock tube calibration of each transducer and a matching source follower was made and photographed prior to test to verify pressure level response.

The nine immersions of fixed instrumentation were defined by the intersection of the axial station and the design streamlines that pass through 5, 10, 15, 28.2, 47, 68.9, 85, 90, and 93.7 percent of the passage height measured from the tip at the rotor trailing edge.

All aerodynamic data except those from high-frequency-response instrumentation were obtained in millivolts by an automatic data acquisition system and recorded, in counts, on magnetic tape. The data acquisition system used for recording fixed instrumentation displayed all measured parameters on a cathode ray tube in real time at 30-sec intervals. The data acquisition system used for recording blade element data and stall transient flow data recorded in 1-sec intervals. The high-frequency-response data were recorded on wide-band, multi-channel magnetic tape recorders.

Mechanical instrumentation.--Rotor blade vibrations were measured with dynamic strain gages located at four different positions (established from bench testing) on the blade and midspan damper and monitored through a slip ring. Stator vane vibration was similarly measured with strain gages located in two basic positions.

Shaft dynamics and bearing mechanical conditions were monitored with accelerometers located in the bearing housings on vertical and horizontal planes. In addition, bearing housing temperatures were measured with chromel-alumel thermocouples. The structure dynamic response was measured with velocity pickups located on the front frame in the vertical and horizontal positions.

Five capacitance-type calibrated clearanceometers were utilized to monitor rotor blade running tip clearances and untwist. Four clearanceometers spaced 90 deg apart were located at the rotor leading edge, and the fifth was placed at the trailing edge on a projection of the tip chord line from one leading edge probe.

Data from the mechanical instrumentation were monitored visually on oscilloscopes and recorded on wide-band magnetic tape recorders.

Test Procedure

Shakedown test.--Shakedown tests were conducted with the following objectives.

- (1) Establish mechanical integrity of the test vehicle.
- (2) Evaluate stress and vibration levels throughout the required test operating range.
- (3) Determine a stator setting at design speed that results in minimal influence on rotor stall.
- (4) Thoroughly check out instrumentation and data reduction programs.

Initially, a mechanical check-out to only 60 percent of design speed was conducted for procedure and vehicle familiarization. The test stage was fitted with Plexiglas windows contoured to the outer shroud adjacent to the rotor to check out the system required for the flow visualization program. (The windows were replaced with metal plugs for the shakedown test and all performance testing.) The flow visualization program was scheduled to be conducted following completion of the uniform inlet flow testing to make the most efficient use of available test time.

For the shakedown test, the fan stage was slowly accelerated to design speed with wide-open discharge valves and the stator stagger angle set at the nominal (design) position. Rotor and stator vibratory stresses, vibration levels on critical components, and rotor blade tip clearances were monitored and recorded during this acceleration. All stress and vibration levels were well within acceptable limits. Data at two design speed points (wide-open throttle and design pressure ratio) for overall and blade element performance were recorded to check instrumentation and data reduction programs. The stage was then stalled. The stall-created overspeed activated a facility safety valve in the drive turbine, resulting in a shutdown. Inspection after shutdown revealed that three rotor blades had sustained minor damage from foreign objects. The damage was caused by several pieces of braze material that had broken off at the junctions of the protective screen on the bellmouth. The screen was repaired, the three damaged blades replaced, the rotor disc reinstrumented, and the test resumed. Shakedown testing was concluded with the stator optimization test, wherein the stators were varied ± 5 deg from their nominal setting at design speed with flows from wide-open throttle to near-stall. A 3-deg-closed stator setting (increased stagger angle) was used for all performance testing because it slightly improved stall margin and efficiency over the values obtained from other settings tested at design speed.

Uniform inlet flow test.--Thirty-one overall and blade element performance data points were obtained with uniform inlet flow at speeds of 60, 70, 80, 90, 95, 100, and 110 percent of design speed. Four data points were taken at 60, 70, 80, and 110 percent of design speed, while 5 data points were taken at the other speeds. Stall flows were obtained at all speeds except at 110 percent design speed. High overspeed stall (110 percent of design speed) was deleted from the test program as a safety precaution to ensure successful completion of the flow visualization program. Because stall occurred abruptly during the shakedown test with nominal stators, the design speed stall was deferred until just prior to distortion testing. Near stall, only overall performance data points were taken at 80 and 100 percent speed. To maintain a measure of safety, the traversing wedge probes were retracted out of the flow path as stall was approached. High-frequency-response rotor casing transducer data were recorded for fifteen points: two at 80, three at 90, and five each at 95 and 100 percent of design speed. These data were utilized for developing blade tip static pressure contours.

Following completion of testing with uniform inlet flow and prior to distortion testing, the fan stage was configured for the flow visualization program. This was accomplished by removal of the traversing wedge probes and installation of contoured Plexiglas windows in the outer shroud. All fixed instrumentation was retained.

Distorted inlet flow test.--Prior to distortion testing, the rotatable distortion support grid was installed 17.2 in. (43.7 cm) upstream of the rotor leading edge; Plexiglas windows in the outer shroud were replaced with metal plugs; traversing wedge probes were reinstalled; and rotor inlet total pressure radial rakes were placed at station 5. Sixteen overall performance data points for the predistortion baseline configuration were obtained at 70, 90, and 100 percent of design speed at flows from wide-open throttle to stall. Five readings at 70, six at 90, and five at 100 percent speed were taken. This predistortion configuration was evaluated to establish baseline data prior to distortion testing in the event that performance with the distortion screen support grid would be substantially different than for uniform inlet flow.

Three layers of screens of open area ratio 0.585, 0.602, and 0.560 (varying from upstream to downstream) were attached to the distortion support grid to create the hub-radial, tip-radial, and circumferential distortion patterns at the rotor inlet. The radial distortion screens were sized to create a distortion pattern extending over 40 percent of the annulus area at the rotor inlet plane. The circumferential distortion screen was sized to create a 90-degree continuous segment of low pressure area at the rotor inlet plane.

Overall performance and blade element performance or flow distribution data were taken at twelve readings for hub-radial distortion, eleven readings for tip-radial distortion, and twelve readings for circumferential distortion. These data were obtained at speeds of 70, 90, and 100 percent of design speed and flows between wide-open throttle and stall. A data point was taken at 97 percent design speed with tip radial distortion to establish the distortion level at design flow. At design speed with hub-radial distortion, a facility system-induced instability was encountered prior to stall and was characterized by a low-frequency acoustic test cell resonance. An overall performance data point reading for circumferential distortion consisted of seven separate scans of data, wherein the distortion screen was indexed by 45 deg between scans (270 deg of total movement) referenced to the screen centerline. Flow distribution data were recorded for circumferential distortion while continuously rotating the distortion screen through 360 deg.

Rotor blade and stator vane vibrations were monitored for all testing, and stress levels were well within established limits. Rotor tip high-frequency-response instrumentation was not recorded during distortion testing.

Data Reduction Methods

Raw digitized data for determination of overall and blade element performance were measured in millivolts, converted to counts, recorded on magnetic tape, and transferred to printed output in engineering units corrected to standard day conditions. Analog data recorded on magnetic tape for analysis of stress and vibration levels, stall probe signals, tip clearance meters, and rotor casing high-response transducers were transferred to oscillograph traces for interpretation.

Overall performance.--The two total pressure elements corresponding to the same stator gap position and radial location were arithmetically averaged and the resultant eleven values circumferentially mass averaged. A constant circumferential static pressure, obtained by linearly interpolating an arithmetic average of the wall static pressures, was assumed. Stage exit total pressure was then calculated by radially mass averaging the nine immersion circumferential mass averages.

The circumferentially and radially mass-averaged stage exit total temperatures were obtained in the same manner as that used for calculating total pressures except for the added interpolation required to satisfy a one-to-one correspondence between the seven available temperature elements and the eleven pressure elements at the same immersion.

For circumferential distortion testing, seven separate data scans were recorded for distortion screen positions indexed by 45 deg over a 270-deg segment. An eighth scan was developed wherein the individual element exit pressures (both static and total) and temperatures were set equal to the arithmetic average of the previous seven scans. The stage exit total pressure and temperature were then circumferentially and radially mass averaged as previously described for uniform and radially distorted inlet flow testing.

Inlet total pressure for uniform inlet flow was set equal to the arithmetic average of the pitot-static elements downstream of the inlet bellmouth. For radially distorted inlet flow, an arithmetic average of radially mass-flow averaged pressures from the two fixed rakes at the rotor inlet was used as the inlet total pressure.

Circumferential distortion inlet total pressure was determined from the two fixed rakes at the rotor inlet in the following manner. Separation of both total and static pressures was maintained while under the influence of the distortion screen (± 45 deg from the screen centerline angular position) from that instrumentation located in the remaining 270-deg undistorted region for each data scan. The arithmetic average of these pressures taken over seven scans (seven different screen positions constituting a data point) for each immersion was then radially mass-averaged separately for both the distorted (minimum pressure region) and undistorted (maximum pressure region) rotor inlet segments. (These minimum and maximum radially mass-averaged pressures were used as the measure or index of the distortion.) Finally, the inlet total pressure was computed by circumferentially weighting the minimum pressure value over one-fourth the inlet annulus and the maximum pressure value over the remaining three-fourths of the inlet annulus.

Blade element performance.--Continuous traversing wedge probes at the rotor inlet plane, rotor exit plane, and stator exit plane were used to measure total pressure, total temperature, air angle, and static pressure for uniform and radially distorted inlet flow testing. Primary measurements of static pressure were obtained with the 8-deg wedge probes, while primary angle measurements were obtained with the 30-deg wedge probes. Angle-only measurements obtained from wedge probes were used at the stator exit plane for evaluating

stator vane element performance; the pressure and temperature data were taken from the circumferentially mass-averaged values determined from the fixed instrumentation.

All blade element parameters determined for the blade and vane leading and trailing edge positions were translated from the measuring planes accounting for continuity and radial equilibrium and assuming design streamline slopes. Rotor-only performance was based on the mass-averaged total pressures as measured by the radial surveys and the fixed temperature rakes at the stator exit plane. For near-stall data points, for which traverse data were not taken, the arithmetic average of the peak values of circumferential total pressure at the same immersion was used as the rotor exit radial pressure distribution.

Three fixed-position (30-deg and 60-deg) wedge probes calibrated for Mach number at each of the rotor inlet and rotor exit planes were used to measure flow distribution data at the measuring planes only (not translated to blade and vane leading and trailing edges) during a continuous 360-deg rotation of the distortion screen. Stator exit vector diagram parameters at the selected radial positions were based on the arithmetic average of the stage exit wake rake pressures as a function of the particular rake mean angular position, local temperature, and a linear interpolation of the localized wall static pressures.

Rotor casing static pressure contours.--Static pressure contours over the rotor blade tips were obtained by using continuously recorded variable pressure data measured by ten high-frequency-response transducers distributed axially and by correspondingly located wall static pressure taps for measurements of the average static pressure level. The transducer data were recorded at 120 in./sec (304.8 cm/sec) tape speed in the frequency modulation mode double extended. Also recorded and superimposed on these transducer signals were the one-per-revolution pulse for accurate positioning of a known blade passage, a 10 000-Hz reference signal for speed checks, and an Inter-range Instrumentation Group (IRIG) time code to provide a time reference. These recorded signals were reproduced at a tape speed of 1.875 in./sec (4.763 cm/sec) and inserted directly into an oscillograph and traced at 80 in./sec (203.2 cm/sec) paper speed. Each transducer trace was then referenced to the same point in time (instant of the one-per-revolution pulse). A computer program then converted manual measurements taken from the oscillograph traces over a one-blade-passing period plus the average pressure obtained from the wall static taps into isobaric values of pressure between a blade passage.

RESULTS AND DISCUSSION

Shakedown Tests

The shakedown tests were accomplished with uniform inlet flow and established that vibratory stress levels for the blades and vanes were well within acceptable limits over the required operating range. A stator setting of 3-deg closed was selected as a result of stator optimization tests and was used for all further testing.

Fig. 13 presents relevant efficiency and flow data obtained during stator optimization tests wherein the stator setting was varied between 5-deg open and 5-deg closed at design speed for two separate levels of pressure ratio. The data show that open (negative) settings reduce efficiency at both the design pressure ratio and the pressure ratio adjacent to stall, while reducing flow only at the near-stall pressure ratio. The closed (positive) settings, however, showed the opposite trend of increasing efficiency for both the lower and higher pressure ratios and increased flow at the near-stall pressure ratio. (It was felt that a significant flow rate reduction with increasing pressure ratio at design speed would result in reduced stall-margin at part speed.)

The stagger setting also was found to have a significant effect on the stator vane vibration, but the effect on rotor blade vibration was negligible. The measured rotor blade stress did not exceed ± 3 ksi ($\pm 20.68 \times 10^6$ N/m²). The stator vane stress approached ± 30 ksi ($\pm 206.8 \times 10^6$ N/m²) for the 5-deg-open setting and decreased to ± 4 ksi ($\pm 27.57 \times 10^6$ N/m²) with vibration levels becoming less random as the vanes were closed. The stator vanes responded at a predominant frequency of 620 Hz, which is the fundamental flexural natural frequency. The random character of the vibration at the open stator angles was indicative of separated flow. No regular modulation was seen that would have been indicative of rotating stall.

During shakedown testing, three rotor blades sustained minor damage from foreign objects (braze material from the bellmouth inlet screen) and had to be replaced prior to completion of the test. Check points of data taken prior to the blade replacements indicated no change in performance.

Uniform Inlet Flow

Rotor and stage overall performance.--Overall performance of the rotor and stage with the 3-deg-closed stator setting is tabulated in table 1 and shown in figs. 14 and 15. Stall was approached gradually such that stall transient flow data (1-sec intervals) was correlated with the slower responding overall performance data (30-sec intervals) to establish the stall-limit data point.

At design speed, the rotor achieved a peak efficiency of 89.7 percent at a pressure ratio of 1.724 and an equivalent flow 3 percent in excess of design. A pressure ratio of 1.512 and efficiency of 88 percent were the design objectives for the rotor. At design speed and pressure ratio, the rotor efficiency was 85.4 percent, but the flow rate was 4 percent greater than design.

The peak stage efficiency achieved at design speed was 83.7 percent at a pressure ratio of 1.669, whereas the design intent was 86.2 percent at a pressure ratio of 1.500. At this design pressure ratio and speed, an efficiency of 81.2 percent, and a stall margin of 24 percent were achieved. On the basis of a constant-throttle line passing through the design pressure ratio at design speed, stall margins of 23.2 percent at 90 percent speed and 32.8 percent at 70 percent speed were obtained.

The rotor efficiency exceeded 90 percent, and the stage met the design intent, but this occurred at 95 percent of design speed and a pressure ratio higher than design. Although the rotor was capable of producing efficiency levels higher than design at design speed, the efficiency loss across the stator was over twice the design prediction.

The level of peak efficiency decayed rather uniformly from 60 percent to 90 percent of design speed, then abruptly increased by 5.5 points for the rotor and 3 points for the stage when speed was increased to 95 percent of design speed indicating the transition between the "unstarted" and "started" operating modes. At 90 percent of design speed, the wide-open-throttle, rotor-only efficiency was 88.5 percent for a pressure ratio of 1.352 and then abruptly decayed to 85.8 percent for a pressure ratio of 1.429 with only a 1.3-percentage point reduction in flow. The remainder of the efficiency characteristic was continuous to stall. (The stage efficiency characteristic did not reflect this abrupt change in efficiency, however, because of compensating stator losses.) A thorough investigation of this rotor passage starting development is detailed in ref. 5. A summary of this material is included in this report together with pertinent holographic data.

Minimal data obtained on the original design prior to failure indicated a 2 percent over-design flow at design speed. The 4 percent over-design flow at design speed with the redesigned rotor results from a combination of two effects:

- (1) The start margin (defined in ref. 1) applied to this design was over-conservative.
- (2) The geometric throat area for the blading was 4 percent greater than for the original design.

A start margin varying from 5 percent for section 1 to approximately 2.5 percent for section 8 was thought to be required to ensure passage starting at design speed for the original design and was retained for the redesign. A review of these data coupled with the extensive study of rotor passage starting development indicated that starting occurred at wide-open throttle

and 90 percent of design speed, which corresponds to 98.4 percent of design flow, or approximately 6 percent less flow than delivered at design speed and at a considerably lower relative Mach number than design. Using the methods presented in ref. 1, the design start margin could have been reduced.

Although the aerodynamic throat areas, i.e., start margin, of the original design were incorporated in the redesigned rotor blading, the added structural safety margins of the redesign, as reflected in axial and tangential tilts and pretwist to counteract steady-state stresses, resulted in a 4 percent larger throat area for the as-manufactured blade. If the steady-state stresses (not measured) were less than predicted and allowance is made for increased blockage of a 70 percent thicker midspan damper on the redesign, a flow 2 percent higher than that of the original design is reasonable. It can therefore be seen that a reduction in throat area required to pass design flow at design speed could result in insufficient start margin.

The rotor blade was mechanically tested for all operating conditions. At the highest pressure ratio of 1.67 investigated and 110 percent of design speed, the rotor strain gages indicated the maximum stress level of ± 3 ksi (20.69×10^6 N/m²) at a frequency of 1270 Hz. This frequency was close to the calculated first torsional natural frequency, but does not correspond to an integral order of rotational speed, possibly indicating that the blade was approaching a flutter condition. The analytically derived natural frequencies were considerably higher than those measured at any operating condition, probably because of the variation in fixity assumed at the midspan damper in the calculation.

An oscillograph trace from the high-frequency-response instrumentation used for detecting rotating stall is shown in fig. 16 for 90 percent of design speed and is typical of all speeds. The stall, although abrupt, is seen to originate in the tip region and then become a full span stall. The stall pulse had a frequency of recurrence of approximately 5.8 percent of rotor speed. The pressure amplitude is approximately 10.5 psi (7.24 N/cm²).

Blade element data.--Rotor spanwise pressure ratio and efficiency at the design speed and design stage pressure ratio is compared to the design prediction in fig. 17. The pressure ratio is significantly higher than design in both the tip region and the area adjacent to 70 percent span. The hub and region close to the midspan damper met design levels. The efficiency was moderately less than design at the end walls, but was significantly below design at the damper. The three-dimensional shock patterns seen in the hologram could account for the high losses in the midspan damper region.

Fig. 18 is the rotor spanwise distribution of total loss coefficient, diffusion factor, deviation angle, and suction surface incidence at the design speed and stage pressure ratio compared to design predictions. The span-wise distribution of total loss coefficient parallels the design intent if the integrated loss associated with the midspan damper was equally distributed radially as practiced in the design method of ref. 1. The resultant loss would match the design levels from mid-passage to 85 percent span, but exceeds the design values in the tip and end-wall regions. Except for these end-wall regions, the loss is greatest at mid-passage, which substantiates the design

assumptions of ref. 1. The diffusion factor was slightly higher throughout the span, with the largest discrepancy from design occurring at the hub (0.5 compared to 0.3). The deviation angle was approximately 2 deg less than design throughout most of the span, reaching almost 5 deg at 70 percent span and exceeding design only at the hub. Since this data point was 4 percent over design flow, the suction surface incidence was less than design, varying from approximately 1 deg less at the tip to over 6 deg less at the hub.

The inlet and exit relative Mach number spanwise distributions are compared to the design values in fig. 19. The inlet relative Mach number is in agreement with the design intent even with the 4 percent over design flow -- this affects the inlet relative Mach number by only 0.6 percent. The exit relative Mach number was less than predicted in the supersonic region, thereby shifting sonic velocity slightly outboard of the desired midspan damper location (ref. 1).

The stator spanwise total loss coefficient, diffusion factor, deviation angle, and suction surface incidence are compared to the design values for the design speed and stage pressure ratio in fig. 20. Of note are the severe end-wall losses at moderate diffusion factors and the significantly higher incidence near 30 percent span as influenced by the midspan damper.

Fig. 21 compares the spanwise stage element pressure ratio, temperature ratio, and resulting adiabatic efficiency at the design speed and pressure ratio to the design intent. The temperature ratio exceeds the design goal to 40 percent span and satisfies the design levels for the remainder of the span. The efficiencies of the end-wall and midspan damper regions are below design predictions.

Blade element performance at nine radial positions is tabulated in ref. 4. These data are presented in figs. 22a through 22i for the rotor and 23a through 23i for the stator in terms of total loss coefficient, diffusion factor, and deviation angle versus suction surface incidence angle. The design values are indicated in the figures. In general, these data show similar trends to the spanwise design speed and pressure ratio data previously presented.

Rotor blade tip static pressure contours.--The axial distribution of steady-state static pressures at the design speed and pressure ratio for both the hub and shroud is shown in fig. 24 compared to the design intent. Steady-state values of static pressure in the outer shroud over the rotor blade tips between stations 6 and 8 shown in the figure were coupled to high-frequency-response measurements to develop static-pressure contours within the rotor blade passage. Figs. 25 and 26 show typical high-frequency-response oscillograph traces. Fig. 25, obtained at design speed from wide-open throttle to near-stall, indicates the change in amplitude response through the blade passage at varying back pressures. The design shock system is superimposed on the blade tip (streamline 1) passage conical development in fig. A-4 of Appendix A.

The steady-state (time-averaged) axial distribution of static pressure along with the contours developed from the oscillograph traces are shown in figs. 27 through 41 for a range of operating conditions at 80, 90, 95, and 100 percent of design speed. Interpretation of these contour plots for defining shock pattern, strength, and location is complicated by several factors such as wall boundary layers, tip leakage vortices, and, primarily, by the large-diameter sensing surface of the transducer relative to the small dimensions to be resolved. A study of the figures, for example, reveals that most of the static pressure contours are normal, rather than parallel, to the predicted shock directions. Therefore, the contour plots should be viewed as a measure of qualitative, rather than of quantitative, value.

Figs. 27 and 28 obtained at 30 percent of design speed show steep gradients in static pressure upstream of the blade leading edge indicating the presence of a strong bow shock. This conclusion is substantiated by the holograms obtained at this condition and reported upon in ref. 5 wherein a strong detached bow shock was observed at the 80 percent of design speed, mid-throttle condition. When speed was increased to 86 percent of design speed, the bow shock detachment distance was reduced and at 90 percent of design speed, a strong, normal shock was recorded attached to the blade leading edge. A weak oblique shock system, as per design intent and indicative of passage starting, was not developed within the blade passage until 92 percent speed was reached. These strong bow shocks are, therefore, representative of the steep gradients in static pressures recorded through 90 percent of design speed as shown in figs. 30 and 31. The shock patterns as detected and included in ref. 5 are shown by dashed lines superimposed on fig. 31 for reading 106. Fig. 30, which corresponds to a lesser back pressure, shows steeper gradients in static pressure in the leading edge region, but these gradients do not influence the complete blade passage as for the higher back pressure condition shown in fig. 31.

The static pressure contours for wide-open throttle, 90 percent of design speed presented in fig. 29 from reading 103 show that static pressure gradients do not extend upstream of the leading edge, but are contained essentially within the passage. Holograms were obtained at this condition. The shock system and tip leakage vortex is shown superimposed in dashed lines on the contour plot. The leading-edge shock is seen to be oblique.

The rotor efficiency characteristic for 90 percent of design speed was previously shown (overall performance section) to decay abruptly from the wide-open throttle condition (reading 103) to the adjacent back-pressure condition corresponding to reading 101 indicating the effect between "started" and "unstarted" operating conditions. This started-to-unstarted transition is further substantiated by the extension of the static pressure gradients at the leading edge shown on the contour plots and the holograms recorded at this condition. This transition also is shown by the large passage-to-passage variations (primarily in the leading-edge region) of the oscillograph recordings of the high-frequency-response transducers over the rotor tip. A portion of this oscillograph record appears in fig. 26 and was obtained during the transient

between wide-open throttle and the next highest back-pressure condition. The peak-to-peak amplitude variation is shown to vary abruptly from 4.0 psi (2.8 N/cm²) for one passage to approximately 16.0 psi (11.0 N/cm²) for an adjacent passage. This is evident in the transducer signal just inside the blade leading edge (channel 3). A large variation also can be seen in the transducer signal just upstream of the blade leading edge (channel 2). The traces in the trailing-edge region (channels 8, 9, and 10), however, show reasonable passage-to-passage repeatability. The transition region was not approached from the low-flow end of the characteristic to determine hysteresis.

Figs. 32 through 36 are the contours obtained at 95 percent of design speed. Fig. 35 appears to be typical of the contours obtained at this speed, and shows the shock pattern (dashed lines) as determined from the holograms. The oblique shock at the leading edge is seen to curve sharply as it intersects the tip leakage vortex to become perpendicular to the suction surface. The next downstream shock was determined from ref. 5 to emanate from the midspan damper and is termed as such. The furthest downstream shock shown is identified as a second damper shock. Any trailing-edge shock was partially obscured by the midspan damper and, therefore, was not shown. The shock system is defined, however, at inboard streamlines to the midspan damper in ref. 5. The near-stall data point (reading 119) obtained at 95 percent of design speed indicates the progression of the contours forward of the leading edge, which may be indicative of passage unstarting.

Static-pressure passage contours at design speed are shown in figs. 37 through 41 in order of ascending pressure ratio. These contours are all similar to the more open throttle setting contours obtained at 95 percent of design speed. The shock pattern obtained from the holograms at the condition of wide-open throttle is superimposed on fig. 37 (reading 107) in dashed lines indicating that the pressure contours do not explicitly define shock fronts. The trailing-edge shock is shown at the intersection of the leading-edge oblique shock and the suction surface. Fig. 39, the design stage pressure ratio, also contains the superimposed shock patterns derived from ref. 5 shown by dashed lines. The shock system at design pressure ratio and speed showed four major shock waves (1) a leading edge shock, (2) a midspan damper shock, (3) a second damper shock, and (4) a trailing edge shock. Tip leakage vortices were also seen along the suction surface on the blade. A weak oblique shock extended from the blade leading edge to the suction surface near the trailing edge at the outer wall. The shock was bent sharply to become nearly perpendicular at the intersection of the suction surface. A segment of this shock appeared to continue obliquely and intersect the blade further along the chord away from the tip region. Details of this shock near the suction surface were obscured, however, by the coalescence of the midspan damper and trailing edge shock fringes as well as the tip vortices; the leading edge shock became visible outboard of the midspan damper shock, where it intersected the shock from the midspan damper. The midspan damper shock appeared to be a conically shaped shock emanating from the intersection of the leading edge of the midspan damper on the suction surface. The shock extended across the passage and the forward portion intersected the pressure surface of the opposite blade well forward of the midspan damper leading edge. The shock extended radially outward and intersected the pressure surface immediately behind the blade leading edge. The shock extended across

the passage and intersected the suction surface of the trailing edge near the outer wall. Further back in the passage, a second damper shock was observed, which emanated from the intersection of the midspan damper and pressure side of the blade. This shock was a highly warped surface nearly coinciding with the midspan damper and trailing edge shock at the blade trailing edge. The trailing edge shock appeared as a single bright fringe at the blade trailing edge. This shock was similar to the design trailing edge shock but was displaced slightly forward of the trailing edge. The shock intersected the suction surface of the blade slightly downstream of the leading edge shock. The four shock fronts appeared to coalesce near the blade trailing edge.

Predistortion Baseline Test

A distortion screen support grid was installed at station 3, rotor inlet total pressure rakes were installed at station 5, and the fan stage was tested from wide-open throttle to stall at 70, 90, and 100 percent of design speed. The purpose of this test was to evaluate the influence of the configuration changes on overall performance, since inlet total pressure was now measured and defined at station 5 rather than at station 1 as it was for uniform inlet flow.

A summary of the rotor-only and stage overall performance data is presented in table 2. These data are superimposed on the uniform inlet flow performance characteristics previously obtained for the rotor in fig. 42 and for the stage in fig. 43. Comparison of these data with that obtained for uniform inlet flow showed that repeatability was excellent. The only unexplained discrepancy was the 1.5 percent higher peak stage efficiency obtained at design speed. The abrupt decay in rotor efficiency from wide-open throttle to the adjacent lower flow condition at 90 percent of design speed was repeated. The agreement obtained for these data, therefore, established baseline data for comparing the results of distortion testing.

Hub-Radially Distorted Inlet Flow

Series stacking of annular screens on the distortion screen support grid suppressed the inner 40 percent of the rotor inlet area producing a distortion index $(P_{\max} - P_{\min})/P_{\max}$ of 0.158 at design flow, which occurred at design speed. The equivalent inlet total pressure spanwise profile obtained is shown by the lower curve of fig. 44.

Rotor and stage overall performance.--The rotor-only and stage overall data summary with hub radial distortion appears in table 3. These data are superimposed on the uniform inlet flow performance (dashed lines) in figs. 45 and 46 for the rotor and stage, respectively. The level of distortion index obtained versus design equivalent flow ratio is shown in fig. 47. This index ranged from 0.158 at design flow to approximately 0.05 at 60 percent of design flow. The wide-open throttle flow decreased by 7 percent at 70 percent of design speed, 2.5 percent at 90 percent of design speed, and 1.5 percent at

design speed. A significant decay in pressure ratio occurred at all speeds evaluated, resulting in a flat pressure ratio-flow characteristic when compared to that obtained with uniform inlet flow. A 4.5 point loss in peak efficiency resulted at design speed and a 6 point loss resulted at 70 percent of design speed.

The stall limit line was improved at 70 and 90 percent of design speed over that obtained with uniform inlet flow. Stall margins (as referenced from the constant throttle line developed with uniform inlet flow) of 44.3 and 50.4 percent were obtained at 90 percent and 70 percent of design speed, respectively. The general character of the stall is shown by the high-frequency-response stall probe oscillograph traces of fig. 48 for 90 percent of design speed. As for uniform inlet flow, the stall originated at the tip and progressed to the hub. The typical stall pulse had a frequency of recurrence of 6.7 percent of rotor speed and an amplitude of 6 psi (4.14 N/cm^2). The design speed line stall flow was not obtained however, because of the onset of an apparent facility-induced instability characterized by a test cell acoustic resonance. This phenomenon has been experienced in the past with similar test configurations. With throttling, the design speed characteristic increased to a pressure ratio of 1.59. Further throttling resulted in a flow reduction at constant pressure ratio until the facility instability was heard. Rotating stall was not detected, and rotor blade and stator vane vibratory stress levels remained within acceptable limits. The vibratory stress on the rotor blades reached only $\pm 4.5 \text{ ksi}$ ($\pm 31.0 \times 10^6 \text{ N/m}^2$) and the stator vanes reached a fluctuating $\pm 7.0 \text{ ksi}$ ($\pm 48.3 \times 10^6 \text{ N/m}^2$).

Blade element data.--Blade element performance at 9 radial positions for hub-radially distorted inlet flow in terms of total loss coefficient, diffusion factor, and deviation angle versus suction surface incidence is presented in figs. 49a through 49i for the rotor and 50a through 50i for the stator. A detailed tabulation of these data with additional performance parameters is contained in ref. 4.

Rotor tip incidence was approximately 2 deg less than that obtained with uniform inlet flow. Levels of diffusion factor and deviation were similar, however. Design values of rotor hub incidence with uniform inlet flow ranged from 2 deg to 4 deg less than design values at design speed. Rotor hub diffusion factors exceeded 0.65 (the highest seen in the testing of this stage), but losses were less than with uniform inlet flow at design speed. At design pressure ratio and speed, the local pressure ratio was higher at the hub and lower in the tip region, indicating that hub-radial distortion was over-attenuated in the hub region and amplified in the tip region.

Stator end-wall losses were as severe as measured with uniform inlet flow. Measured hub incidence of the stator exceeded design values by as much as 16 deg.

Tip-Radially Distorted Inlet Flow

Series stacking of annular screens of the same open area ratio as used for generating hub-radial distortion suppressed the outer 40 percent of the rotor inlet area producing a distortion index $(P_{\max} - P_{\min})/P_{\max}$ of 0.153 at design

flow and 97 percent of design speed. The resulting equivalent inlet total pressure spanwise profile is shown by the upper curve of fig. 44.

Rotor and stage overall performance.--The rotor-only and stage overall data summary with tip-radially distorted inlet flow appears in table 4. These data are superimposed on the uniform inlet flow performance (dashed lines) in fig. 51 for the rotor and fig. 52 for the stage. The range of distortion index obtained versus design equivalent flow ratio is shown in fig. 47 and is identical to that obtained with hub-radially distorted inlet flow. The wide-open throttle flow at design speed decreased by approximately 2 percent from that obtained with uniform inlet flow, a 2.5 percent flow reduction was recorded at 90 percent speed, and virtually no difference was noted at 70 percent. A loss of 5 points in peak stage efficiency was evident, both at design speed and 70 percent of design speed. The level of peak rotor efficiency at 90 percent of design speed was approximately that obtained with uniform inlet flow, but stage efficiency was lower by 3 points, indicating higher stator losses.

The stall limit line was reduced from that obtained with uniform inlet flow. The stall margins as referenced from the constant throttle line developed with uniform inlet flow were 19.4, 12.1, and 13.0 percent at 100, 90, and 70 percent of design speed, respectively. A typical oscillograph trace of the high-frequency-response stall probes taken at design speed is shown in fig. 48. The stall progressed from tip to hub as with uniform inlet flow. The frequency of recurrence of the stall pulse was 6.02 percent of rotor speed. This stall pulse had a pressure amplitude of 9.0 psi (6.21 N/cm^2). The highest levels of vibratory stress measured with tip-radial distortion were $\pm 3 \text{ ksi}$ ($\pm 20.7 \times 10^6 \text{ N/m}^2$) for the rotor blades and $\pm 4.5 \text{ ksi}$ ($\pm 31.0 \times 10^6 \text{ N/m}^2$) for the stator vanes, which occurred at design speed just prior to stall. These levels were less than that seen during hub-radial distortion testing.

Blade element data.--Blade element performance at 9 radial positions for tip-radially distorted inlet flow in terms of total loss coefficient, diffusion factor, and deviation angle versus suction surface incidence angle is shown in figs. 53a through 53i for the rotor and 54a through 54i for the stator. These data and additional performance parameters are tabulated in ref. 4.

Rotor incidence angles were about 3 deg higher in the tip region and 3 deg lower adjacent to the hub than the angles obtained with uniform inlet flow. Stator incidence angles, however, were approximately the same, for comparable speeds, as seen during uniform inlet flow testing. The levels of deviation, loss, and loading throughout the span for both rotor and stator are not appreciably different than were seen with uniform inlet flow. At design pressure ratio and speed, the local pressure ratio was higher at the tip, whereas the hub pressure ratio was lower, indicating that tip-radial distortion was over-attenuated at the tip and amplified at the hub.

Circumferentially Distorted Inlet Flow

A 100-degree, full-span screen segment of the identical arrangement and open area ratio as previously used for radial distortion testing suppressed approximately 90 degrees of the rotor inlet measuring plane and produced a distortion index of 0.138 at design speed and flow.

Stage overall performance.--A stage overall data summary for 70, 90, and 100 percent of design speed is presented in table 5 for circumferential distortion. These data are superimposed on the uniform inlet flow performance (dashed lines) in fig. 55. The level of distortion index obtained versus design equivalent flow ratio appears in fig. 47, indicating that a distortion level range from 0.147 at 102 percent of design flow to 0.050 at 64 percent of design flow was covered. These distortion levels were lower than those resulting from radial distortion. The flow at wide-open throttle was reduced by approximately 2 percent at all speeds from that obtained with uniform inlet flow. A 3-point peak efficiency loss also resulted at all speeds evaluated.

The stall limit line with circumferentially distorted inlet flow was reduced from that obtained with uniform inlet flow, but not as severely as that obtained with tip-radial distortion. The stall margins as referenced from the constant throttle line developed with uniform inlet flow were 19.7, 20.9, and 27.9 percent at 100, 90, and 70 percent design speed, respectively. Fig. 48 shows a typical oscillograph trace of the stall instrumentation for design speed. The stall originated in the tip region with a stall pulse of 6.0 percent of rotor speed and a pressure amplitude of 12 psi (8.27 N/cm^2), higher than was seen during all other testing. This design speed stall also resulted in the highest vibratory stresses measured on the rotor of $\pm 20 \text{ ksi}$ ($\pm 137.9 \times 10^6 \text{ N/m}^2$). The stator vibratory stress level remained low, however, at $\pm 4.5 \text{ ksi}$ ($31.0 \times 10^6 \text{ N/m}^2$).

Circumferential variations of flow distribution parameters.--Typical hub and shroud wall static pressure, circumferential distributions at five axial stations between the distortion screen and rotor inlet planes are shown in fig. 56 for design speed (reading 284), wherein a static pressure decay behind the screen is indicated at all axial planes. Fig. 57 shows the total pressure distribution at design speed for 10, 47, and 90 percent of span obtained at the rotor inlet, rotor exit, and stage exit measuring planes. At design speed, the exit pressure distortion was amplified in the hub region, but attenuated in the midspan and tip regions. Only a small spanwise gradient in static pressure exists at the stage exit plane as seen in fig. 58. The circumferential distributions of absolute Mach number resulting from the static and total pressure distributions is shown in fig. 59. A significant feature is the low value of Mach number at the screen centerline adjacent to the hub at the stage exit plane.

The stage exit total temperature circumferential distribution obtained from fixed instrumentation is presented in fig. 60 for design speed data point reading 284. Fig. 61 presents the absolute velocity distribution showing the low value near the hub at station 12. Fig. 62 presents the measured flow angle distributions at the rotor inlet and exit plane for this design speed reading.

Rotor inlet preswirl (positive angles in the direction of rotor rotation) is created from 180 through 360 deg (viewed aft looking forward), while counter-swirl is created from zero to 180 deg. A 10-deg error, suspected to be due to an offset during calibration in rotor inlet angle, was experienced. The angle-changes are, however, consistent with those of the other two immersions. Fig. 63 presents the circumferential distribution of rotor inlet and rotor exit axial velocity for reading 284, which reflects what was previously seen in the distributions of absolute Mach number and absolute velocity.

Design speed circumferential distributions of relative Mach number, relative velocity, and relative flow angle at the rotor inlet and exit planes for 10, 47, and 90 percent span from the tip are presented in figs. 64, 65, and 66. The influence of the screen on these relative parameters is more severe in the streamline adjacent to the hub than in the midspan and tip regions. Tabulations of additional data showing circumferential variations of flow distribution parameters are presented in ref. 4.

CONCLUDING REMARKS

With uniform inlet flow, the fan stage produced a peak efficiency of 84 percent at the design tip speed of 1600 ft/sec (488.6 m/sec), but a higher-than-design flow and pressure ratio. The design stage efficiency goal of 86 percent was obtained at the design specific flow of 42 lb/sec-ft² (205.1 kgm/sec-m²), but at a pressure ratio of 1.6 instead of 1.5, and only 95 percent of design speed. A stall margin of 24 percent was achieved at the design speed and pressure ratio.

The rotor blade sections in the outboard, supersonic region exceeded design efficiency levels, thereby substantiating the method of characteristics design procedure and the assumption of oblique shocks. The subsonic sections adjacent to the hub, however, were moderately deficient because design incidence was not achieved. Inlet flow was shifted toward the hub resulting in rotor hub incidences considerably less than design. The stator vane incurred large end-wall losses, thereby preventing the stage from reaching the efficiency goal at design speed.

The transition between rotor-tip-passage "started" and "unstarted" operating modes was seen to occur as low as 90 percent of design speed, wherein an abrupt decay in rotor efficiency was obtained from wide-open throttle with only a small increase in back pressure. Data from the high-frequency-response instrumentation over the rotor tips and from holograms obtained under separate contract also substantiate this minimum speed of transition. The highest speed at which the passage was seen to unstart was at 95 percent of design speed, near stall, as indicated by the rotor tip high-frequency-response data. Holograms show the leading-edge shock to be oblique and attached for the started condition and detached and near normal to the passage for the unstarted condition.

Holograms taken at and near design speed show not only the leading-edge and trailing-edge shocks that were considered in the design of the fan stage, but also a conical shock emanating from the intersection of the midspan damper leading edge and blade suction surface and a second damper shock, neither of which were considered in the design analysis. Some of the high losses in the midspan damper region may be due to this shock system.

The stall limit line was reduced by both tip-radial and circumferential inlet distortion. Reduction in wide-open throttle flow, stall pressure ratio, and peak efficiency level resulted from all types of distortion tested.

TABLE 1
UNIFORM INLET FLOW PERFORMANCE DATA SUMMARY

$\frac{N}{\sqrt{r}} \frac{W}{\sqrt{r}}$ (N/) _{des}	Reading	$\frac{W}{\sqrt{r}} \frac{W}{\sqrt{r}}$ (W/) _{des}	$\frac{T_{T12} - T_{T5}}{T_{T5}}$	Rotor			Stator		
				P_{T9}/P_{T5}	η_{ad}	η_{poly}	P_{T12}/P_{T5}	η_{ad}	η_{poly}
0.60	59	0.686	0.0444	1.152	0.927	0.929	1.145	0.889	0.891
0.60	61	0.650	0.0548	1.185	0.908	0.910	1.179	0.880	0.883
0.60	62	0.618	0.0608	1.203	0.892	0.894	1.197	0.866	0.869
0.60	63	0.565	0.0695	1.223	0.853	0.857	1.213	0.816	0.821
0.60	64	0.499	0.0801	1.245	0.807	0.813	1.221	0.733	0.740
0.70	67	0.793	0.0627	1.210	0.891	0.894	1.196	0.835	0.839
0.70	69	0.764	0.0744	1.262	0.921	0.924	1.250	0.882	0.886
0.70	70	0.731	0.0833	1.289	0.904	0.907	1.277	0.869	0.873
0.70	71	0.656	0.0997	1.328	0.847	0.853	1.307	0.798	0.805
0.70	74	0.590	0.1095	1.347	0.811	0.813	1.310	0.732	0.742
0.80	75	0.881	0.0825	1.274	0.867	0.872	1.250	0.796	0.802
0.80	76	0.869	0.0991	1.338	0.876	0.881	1.324	0.841	0.847
0.80	80	0.842	0.1106	1.396	0.903	0.907	1.371	0.853	0.859
0.80	81	0.801	0.1236	1.440	0.888	0.894	1.415	0.842	0.850
0.80	83	0.742	0.1345	1.457	0.844	0.852	1.428	0.795	0.805
0.80	85	0.699	0.1438	1.468	0.806	0.816	1.424	0.738	0.750
0.90	103	0.984	0.1016	1.352	0.885	0.890	1.320	0.811	0.816
0.90	100	0.971	0.1252	1.429	0.858	0.865	1.414	0.830	0.838
0.90	101	0.957	0.1426	1.500	0.861	0.868	1.479	0.826	0.837
0.90	106	0.942	0.1530	1.545	0.865	0.873	1.524	0.834	0.844
0.90	115	0.887	0.1721	1.612	0.850	0.850	1.580	0.809	0.821
0.90	116	0.863	0.1764	1.621	0.840	0.850	1.574	0.782	0.795
0.95	104	1.019	0.1136	1.396	0.879	0.885	1.348	0.784	0.793
0.95	105	1.016	0.1353	1.490	0.892	0.898	1.449	0.825	0.834
0.95	117	1.008	0.1523	1.583	0.921	0.926	1.540	0.861	0.869
0.95	118	0.995	0.1665	1.640	0.900	0.907	1.604	0.855	0.864
0.95	119	0.952	0.1914	1.711	0.867	0.876	1.656	0.808	0.821
0.95	120	0.918	0.1966	1.709	0.842	0.853	1.658	0.788	0.803
1.00	107	1.040	0.1261	1.429	0.851	0.858	1.369	0.743	0.754
1.00	108	1.044	0.1462	1.510	0.854	0.863	1.475	0.803	0.813
1.00	128	1.041	0.1524	1.545	0.867	0.875	1.505	0.812	0.822
1.00	125	1.035	0.1677	1.623	0.884	0.892	1.572	0.821	0.832
1.00	126	1.031	0.1877	1.724	0.897	0.905	1.669	0.837	0.849
1.00	127	1.016	0.2060	1.770	0.860	0.871	1.738	0.827	0.840
^a 1.00	210	0.986	0.2201	1.806	0.836	0.849	1.763	0.796	0.812
1.10	109	1.079	0.1493	1.491	0.809	0.820	1.413	0.695	0.709
1.10	110	1.081	0.1589	1.522	0.802	0.814	1.475	0.738	0.752
1.10	113	1.082	0.1854	1.653	0.833	0.844	1.597	0.770	0.784
1.10	114	1.083	0.2049	1.736	0.832	0.845	1.682	0.779	0.794

^a Obtained during predistortion baseline testing.

TABLE 2
PREDISTORTION BASELINE PERFORMANCE DATA SUMMARY

$\frac{N/A_1}{(N/A_1)_{des}}$	Reading	$\frac{W\sqrt{z}/4}{(W\sqrt{z}/4)_{des}}$	$\frac{T_{T12}-T_{T5}}{T_{T5}}$	Rotor			Stage		
				P_{T9}/P_{T5}	τ_{ad}	τ_{poly}	P_{T12}/P_{T5}	τ_{ad}	τ_{poly}
0.70	195	0.791	0.0627	1.211	0.897	0.900	1.199	0.849	0.853
0.70	196	0.759	0.0744	1.258	0.911	0.914	1.246	0.872	0.876
0.70	197	0.737	0.0837	1.288	0.896	0.900	1.276	0.862	0.866
0.70	198	0.656	0.0989	1.330	0.858	0.864	1.311	0.814	0.821
0.70	199	0.581	0.1111	1.342	0.789	0.798	1.303	0.706	0.717
0.90	200	0.985	0.1033	1.356	0.380	0.885	1.329	0.818	0.825
0.90	201	0.967	0.1238	1.426	0.862	0.869	1.408	0.828	0.837
0.90	202	0.954	0.1426	1.505	0.861	0.876	1.485	0.837	0.846
0.90	203	0.943	0.1537	1.552	0.871	0.878	1.530	0.839	0.848
0.90	211	0.908	0.1652	1.593	0.861	0.870	1.565	0.824	0.835
0.90	204	0.865	0.1722	1.607	0.843	0.853	1.571	0.798	0.810
1.00	205	1.040	0.1284	1.437	0.850	0.857	1.395	0.777	0.787
1.00	206	1.040	0.1538	1.536	0.848	0.857	1.511	0.813	0.823
1.00	207	1.041	0.1691	1.610	0.862	0.871	1.583	0.827	0.838
1.00	208	1.035	0.1862	1.704	0.883	0.892	1.676	0.852	0.862
1.00	210	0.986	0.2201	1.806	0.836	0.849	1.763	0.796	0.812

TABLE 3
HUB RADIAL DISTORTION PERFORMANCE DATA SUMMARY

$\frac{N/\bar{\epsilon}}{(N/\bar{\epsilon})_{des}}$	Reading	$\frac{W\sqrt{\theta/A}}{(W\sqrt{\theta/A})_{des}}$	$\frac{T_{T12}-T_{T5}}{T_{T5}}$	Rotor			Stage		
				P_{T9}/P_{T5}	$\bar{T}_{ad}$	$\bar{T}_{poly}$	P_{T12}/P_{T5}	$\bar{T}_{ad}$	$\bar{T}_{poly}$
0.70	224	0.739	0.0663	1.217	0.872	0.875	1.200	0.806	0.811
0.70	225	0.706	0.0783	1.254	0.854	0.859	1.243	0.817	0.823
0.70	226	0.670	0.0840	1.275	0.856	0.861	1.258	0.805	0.811
0.70	227	0.594	0.0979	1.310	0.820	0.826	1.273	0.728	0.737
0.70	271	0.509	0.1221	1.330	0.695	0.707	1.284	0.605	0.619
^a 0.70	228	0.493							
0.90	229	0.953	0.1091	1.365	0.852	0.858	1.333	0.782	0.791
0.90	230	0.923	0.1296	1.454	0.870	0.877	1.416	0.805	0.814
0.90	231	0.872	0.1437	1.484	0.831	0.840	1.447	0.773	0.784
0.90	232	0.828	0.1549	1.500	0.793	0.804	1.465	0.742	0.756
0.90	233	0.800	0.1589	1.509	0.785	0.797	1.470	0.730	0.745
0.90	271	0.679	0.1895	1.547	0.701	0.718	1.479	0.622	0.642
^a 0.90	235	0.660							
1.00	223	1.022	0.1319	1.434	0.822	0.831	1.390	0.746	0.757
1.00	220	1.002	0.1604	1.560	0.845	0.854	1.517	0.787	0.799
1.00	221	0.991	0.1766	1.658	0.880	0.888	1.583	0.792	0.805
1.00	222	0.962	0.1832	1.661	0.852	0.862	1.589	0.769	0.784
1.00	237	0.921	0.1918	1.622	0.773	0.788	1.585	0.730	0.747

^a Stall flow only obtained.

TABLE 4
TIP RADIAL DISTORTION PERFORMANCE DATA SUMMARY

$\frac{N/\epsilon}{(N/\epsilon)_{des}}$	Reading	$\frac{W\sqrt{v}/\epsilon}{(W\sqrt{v}/\epsilon)_{des}}$	$\frac{T_{T12}-T_{T5}}{T_{T5}}$	Rotor			Stage		
				P_{T9}/P_{T5}	τ_{ad}	τ_{poly}	P_{T12}/P_{T5}	τ_{ad}	τ_{poly}
0.70	242	0.782	0.0693	1.236	0.900	0.903	1.217	0.832	0.836
0.70	242	0.748	0.0817	1.276	0.883	0.887	1.259	0.831	0.836
0.70	244	0.716	0.0897	1.299	0.865	0.870	1.281	0.817	0.823
0.70	245	0.677	0.0974	1.315	0.835	0.842	1.291	0.776	0.784
0.90	246	0.956	0.1160	1.377	0.825	0.833	1.336	0.743	0.753
0.90	248	0.948	0.1345	1.463	0.854	0.861	1.426	0.791	0.802
0.90	249	0.937	0.1526	1.538	0.858	0.866	1.500	0.804	0.814
0.90	272	0.920	0.1573	1.547	0.844	0.853	1.513	0.797	0.809
^a 0.90	250	0.910							
0.97	241	0.997	0.1595	1.544	0.828	0.839	1.498	0.766	0.779
1.00	251	1.021	0.1365	1.452	0.824	0.833	1.395	0.730	0.742
1.00	252	1.022	0.1604	1.552	0.834	0.844	1.500	0.764	0.777
1.00	253	1.023	0.1713	1.592	0.829	0.840	1.546	0.771	0.784
1.00	254	1.019	0.1795	1.635	0.840	0.851	1.585	0.781	0.795
1.00	272	1.004	0.2044	1.720	0.820	0.833	1.664	0.763	0.779
^a 1.00	255	0.984							

^a Stall flow only obtained.

TABLE 5
CIRCUMFERENTIAL DISTORTION PERFORMANCE DATA SUMMARY

$\frac{N/\sqrt{\theta}}{(N/\sqrt{\theta})_{des}}$	Reading	$\frac{W\sqrt{\theta/\delta}}{(W\sqrt{\theta/\delta})_{des}}$	$\frac{T_{T12}-T_{T5}}{T_{T5}}$	Stage		
				P_{T9}/P_{T5}	η_{ad}	η_{poly}
0.70	263	0.768	0.0664	1.208	0.834	0.838
0.70	264	0.736	0.0773	1.249	0.846	0.851
0.70	265	0.707	0.0848	1.267	0.824	0.830
0.70	266	0.635	0.0989	1.286	0.753	0.761
^a 0.70	267	0.591				
0.90	276	0.963	0.1124	1.350	0.795	0.803
0.90	278	0.940	0.1343	1.432	0.804	0.813
0.90	279	0.904	0.1492	1.469	0.777	0.789
0.90	280	0.859	0.1648	1.498	0.741	0.756
^a 0.90	281	0.833				
1.00	283	1.027	0.1374	1.412	0.753	0.764
1.00	284	1.021	0.1645	1.534	0.789	0.801
1.00	285	1.002	0.1836	1.586	0.765	0.780
1.00	286	0.979	0.1946	1.610	0.746	0.763
^a 1.00	287	0.940				
^a Stall flow only obtained.						
Note: rotor-only values not computed.						

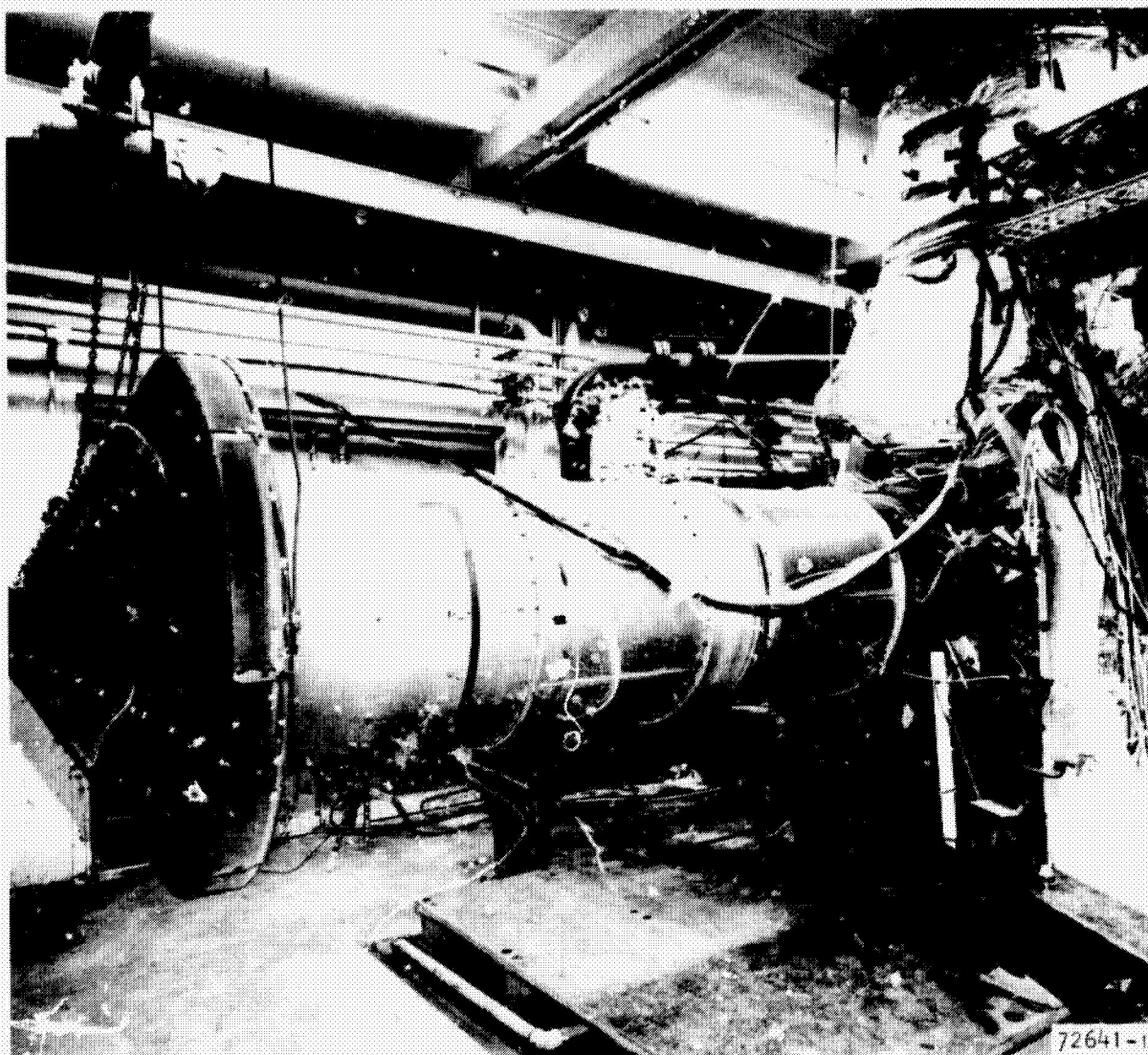
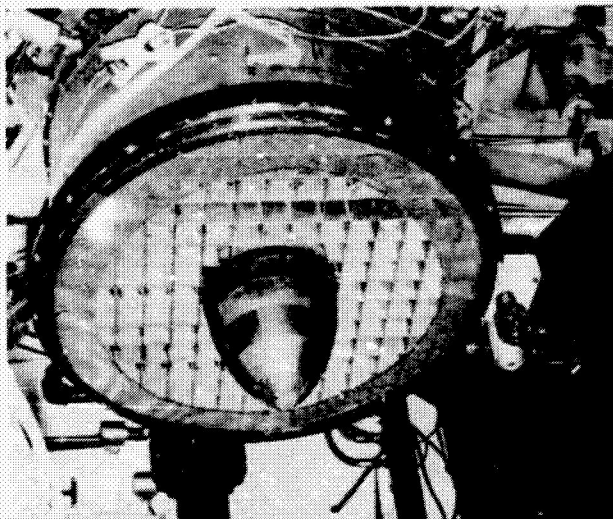


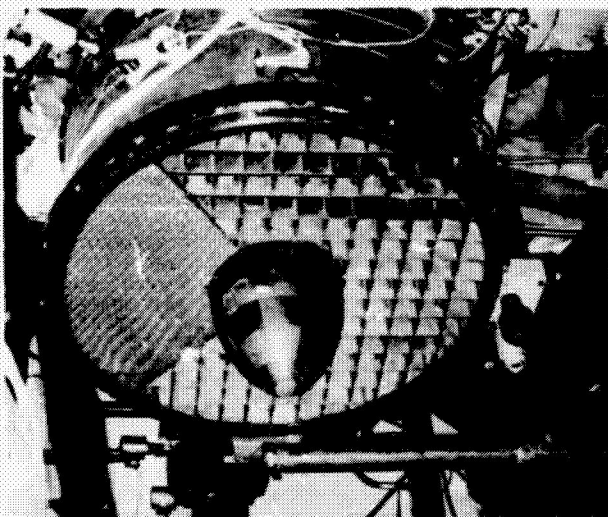
Figure 1.--Sea Level Compressor Test Cell.



(a) Hub-radial distortion screen.



(b) Tip-radial distortion screen.



(c) Circumferential distortion screen. F-18625

Figure 2.--Distortion Screens.

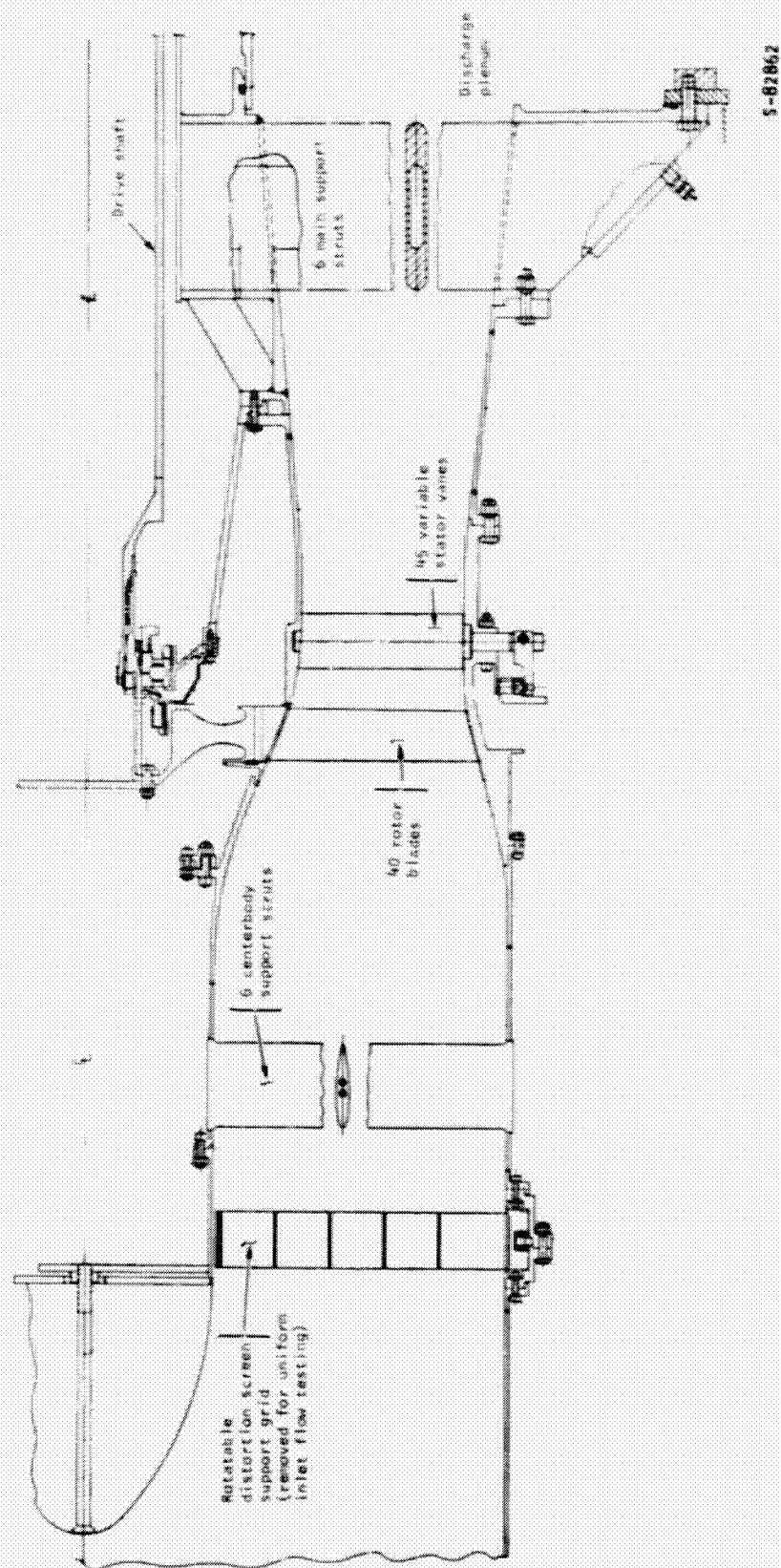


Figure 3.--Fan Cross Section.

S-82862

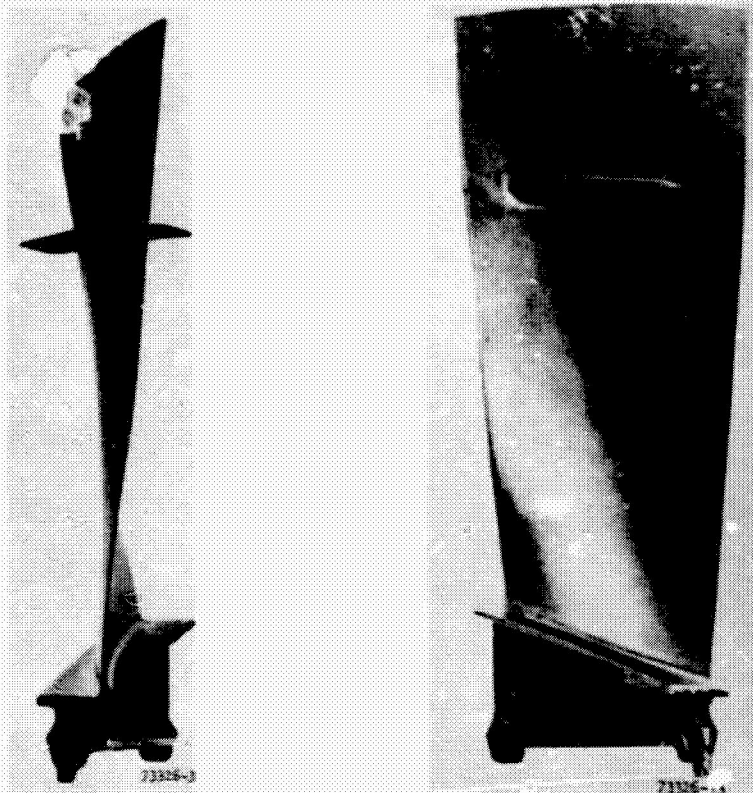
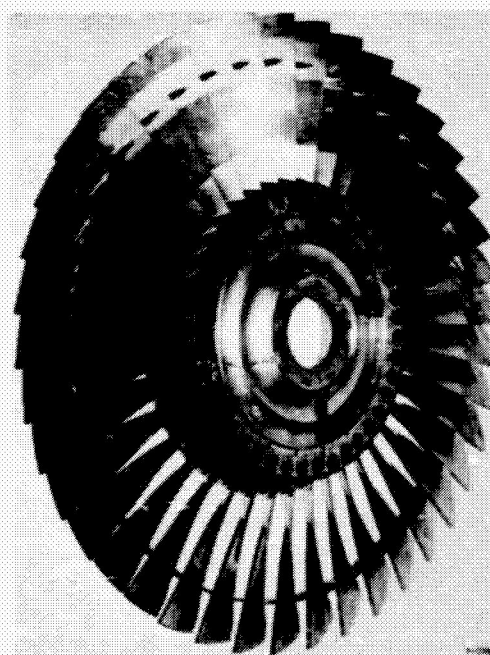


Figure 4.--Rotor Blade.



F-19102

Figure 5.--Bladed Disc Assembly.

Section number 0

Inlet duct

Inlet screen

Flow

Distortion screen support grid

Pilot static crank form

6. Inlet struts

4.5 sector vanes

6.0 rotor blades

1 2 3 4 5 6 7 8 9 10 11 12 13

Axial length, in.

-240 -220 -200 -180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60

33

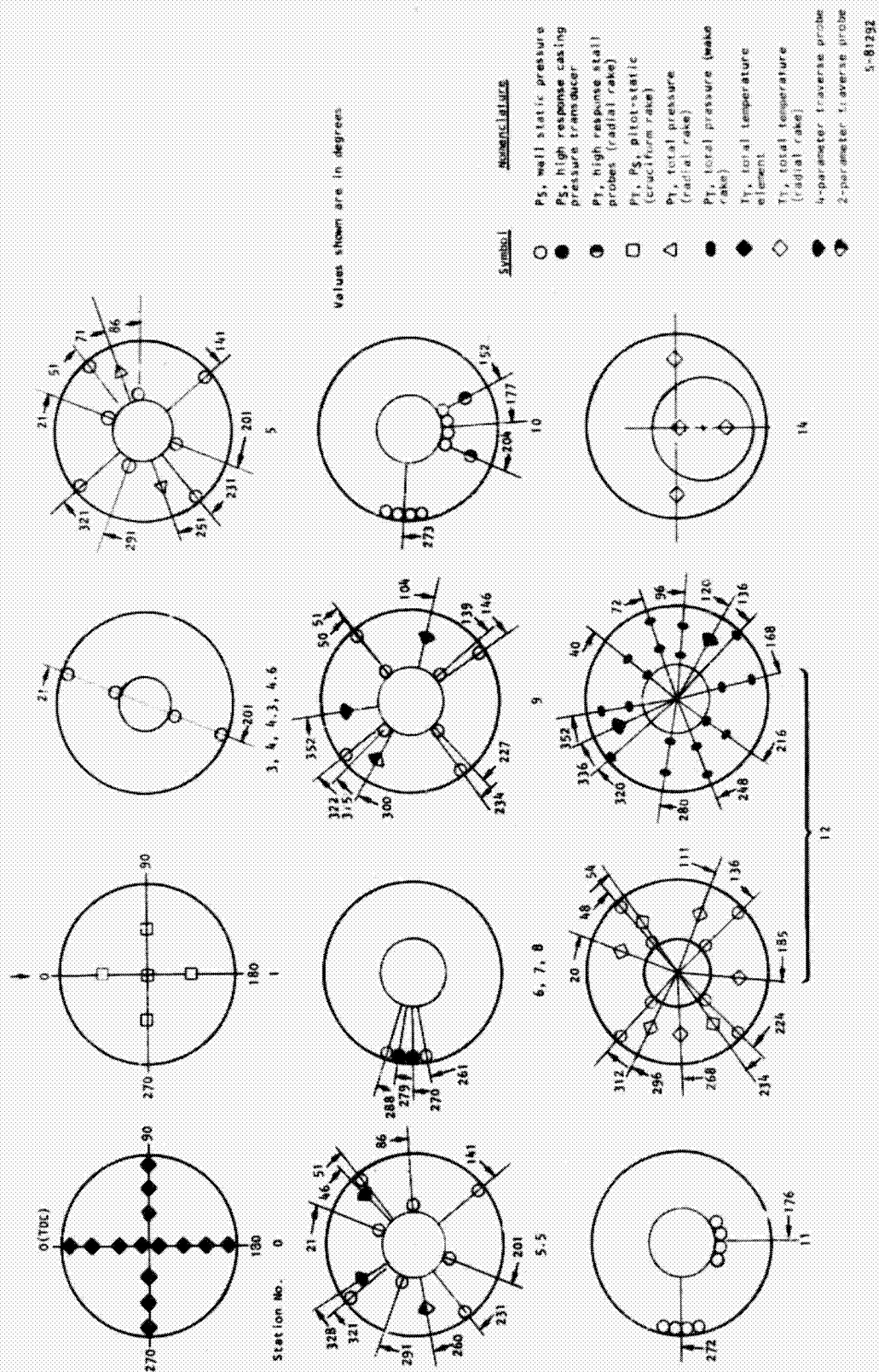
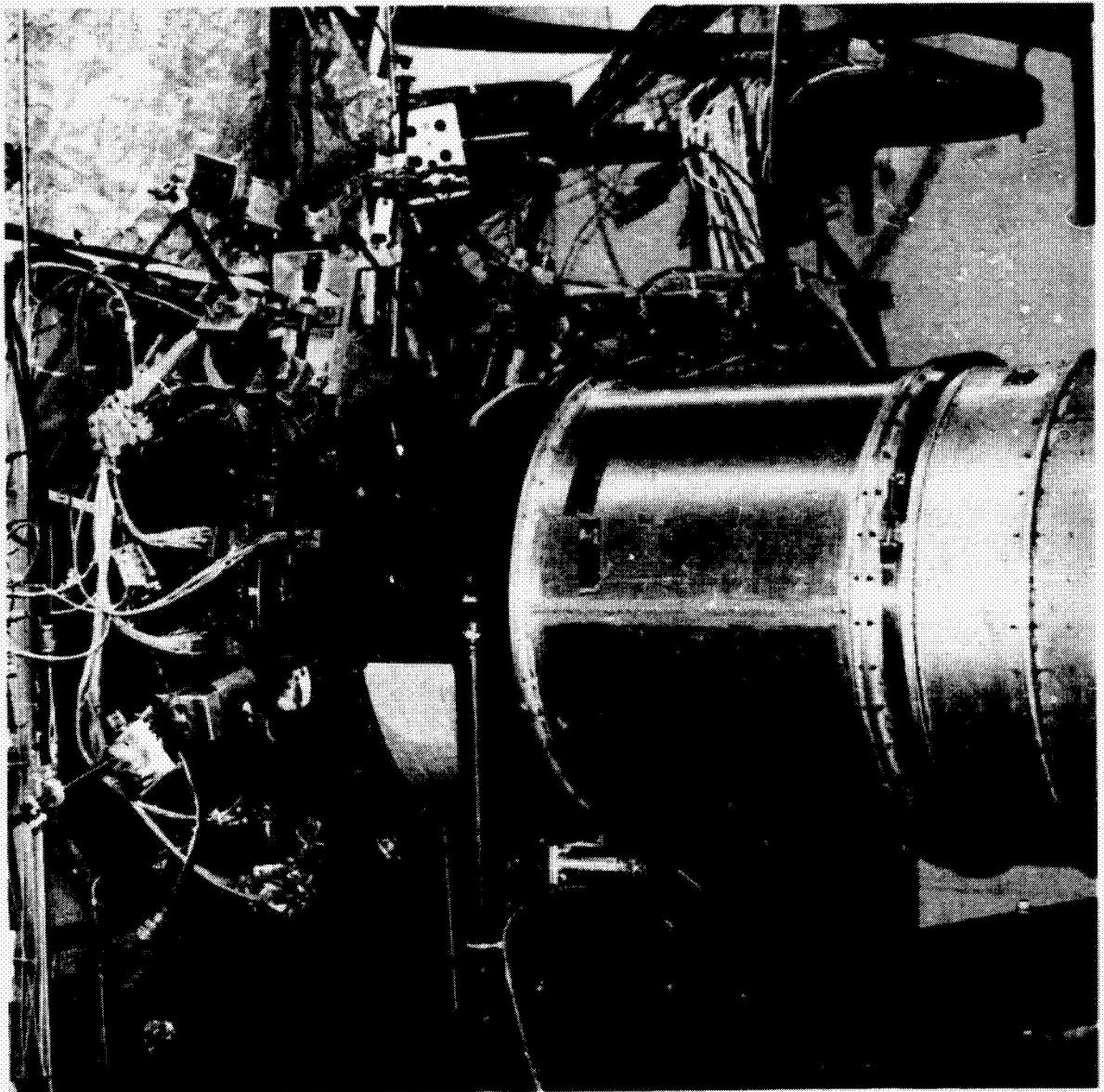
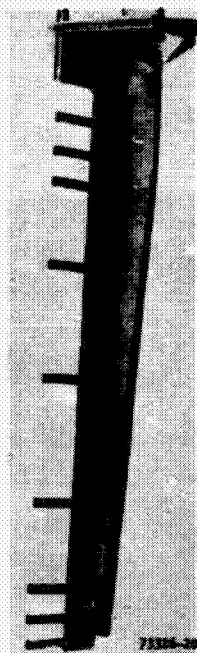


Figure 7.--Circumferential Position of Instrumentation Viewed Aft, Looking Forward.

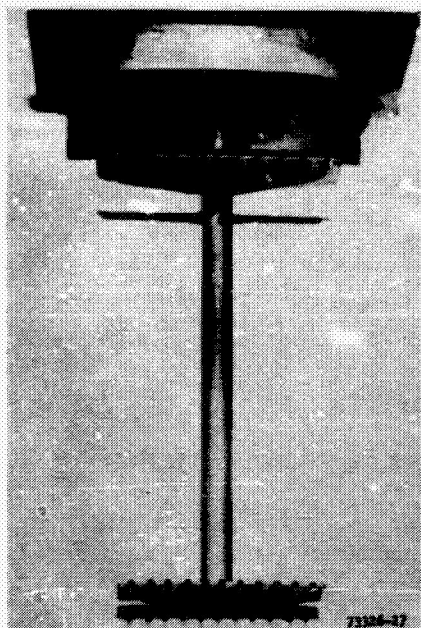


F-18623

Figure 8.--Instrumented Test Compressor.



(a) Temperature Rake.



(b) Total Pressure Rake.

Figure 9.--Stage Exit Temperature and Total Pressure Rakes.

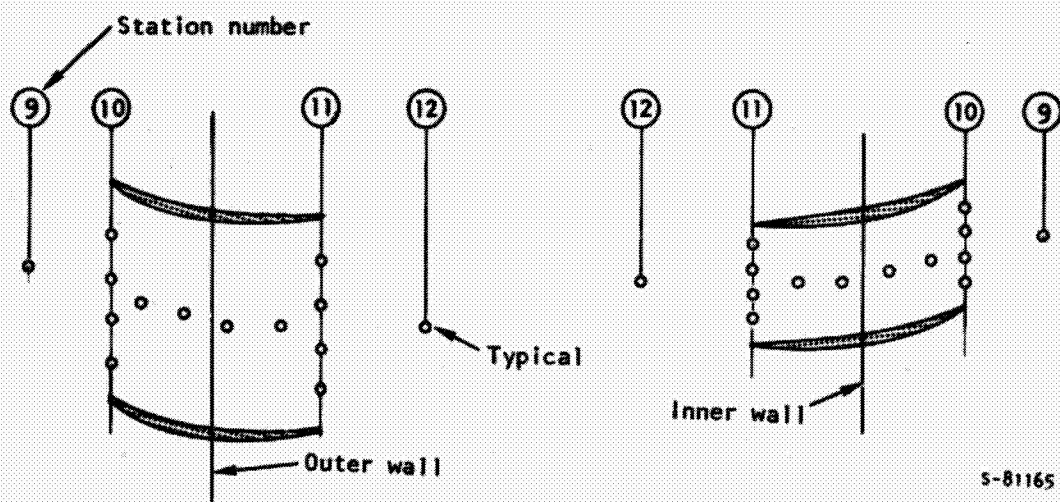
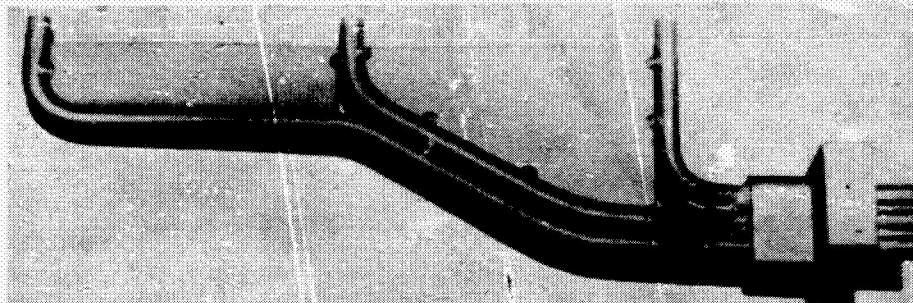


Figure 10.--Stator Channel Static Pressure Schematic.



(a) Stall Sensing Radial Rake.

73326-21



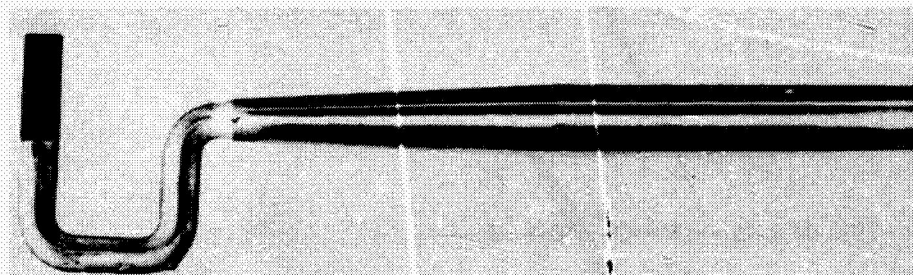
(b) 60-Deg Wedge Probe.

73326-25



(c) 30-Deg Wedge Probe.

73326-19



(d) 8-Deg Wedge Probe.

73326-18

F-18621

Figure 11.--Radial Rake and Wedge Probes.

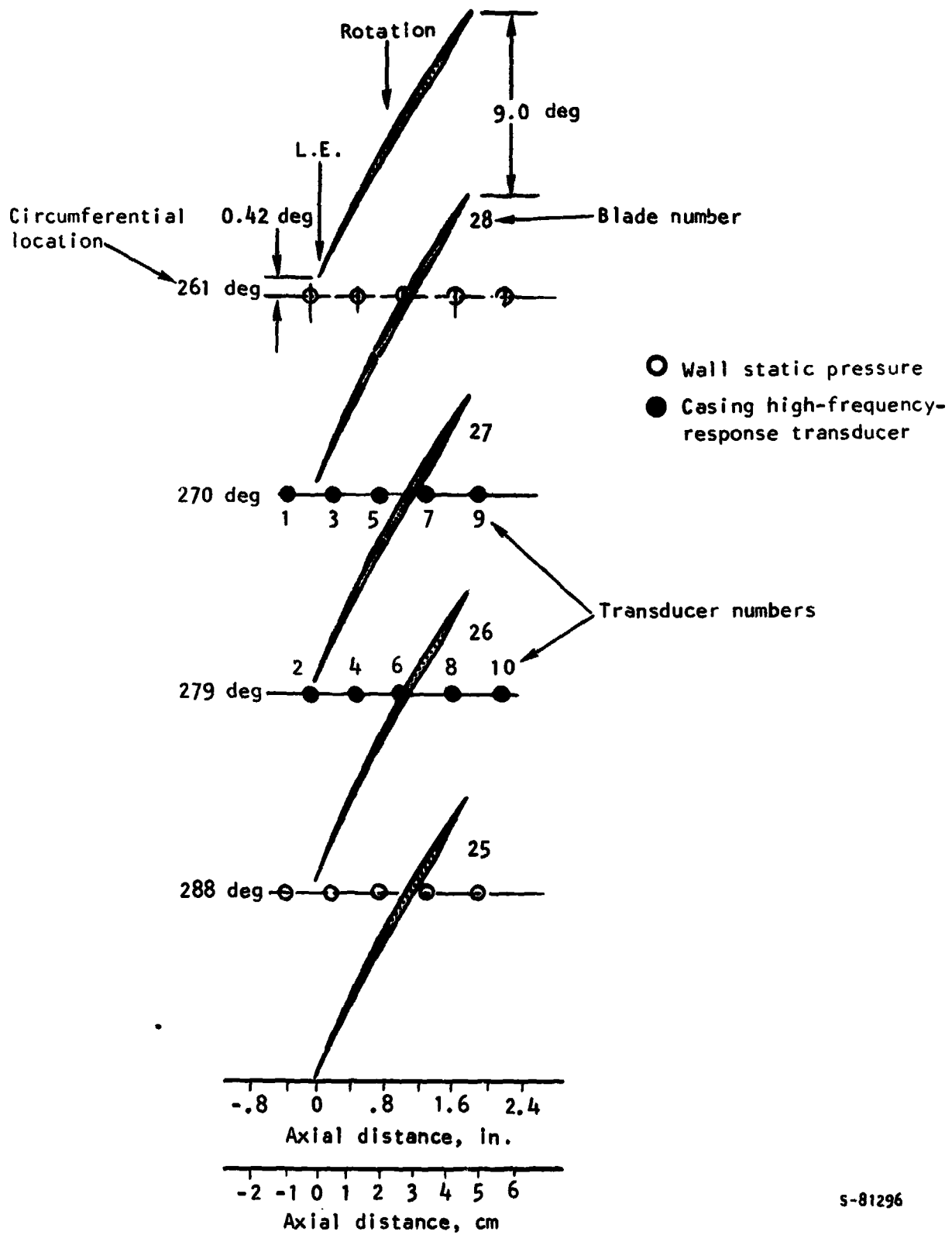


Figure 12.--High-Response Casing Pressure Transducer Locations.

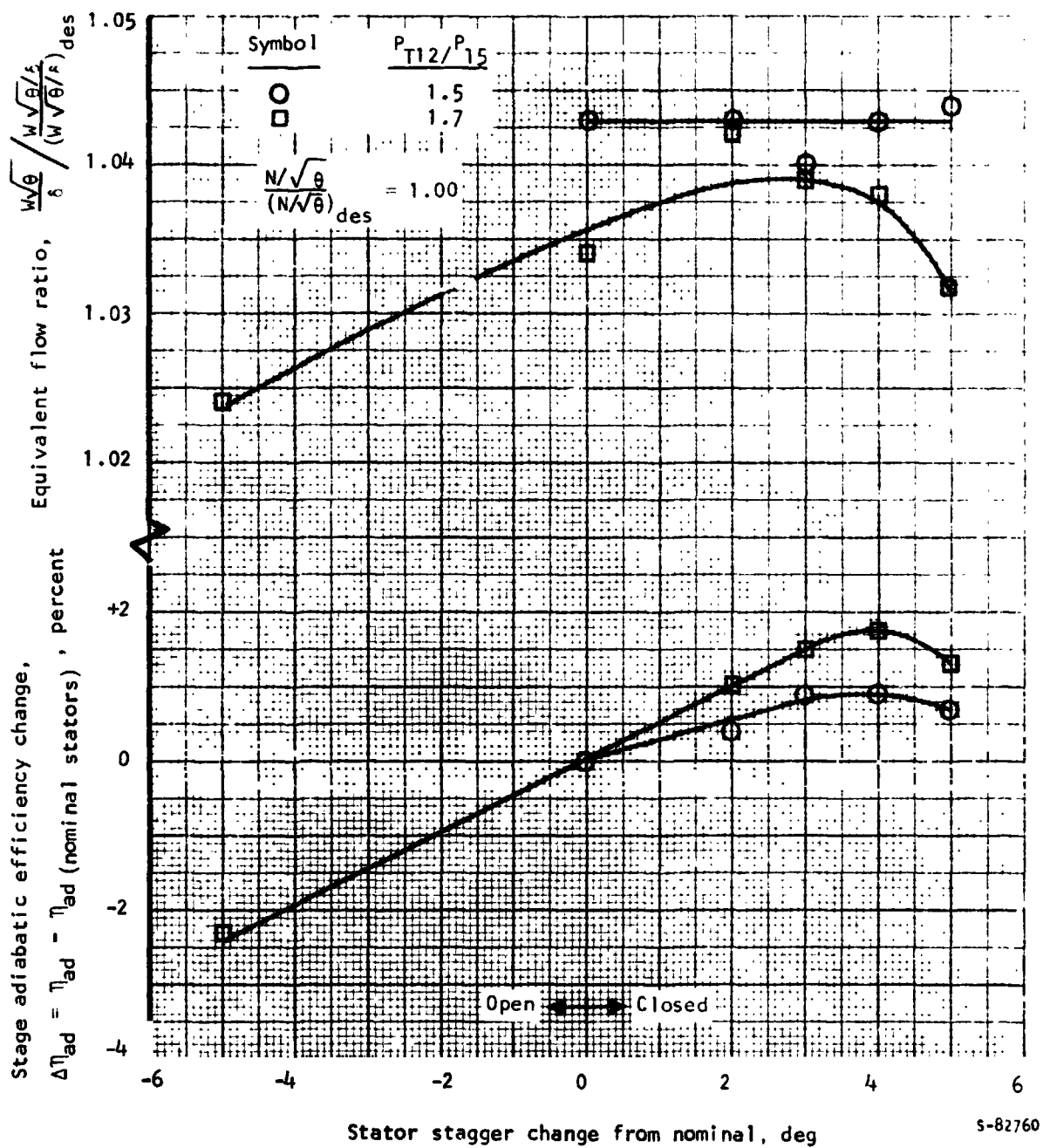


Figure 13.--Effect of Vane Stagger Settings on Stage Performance.

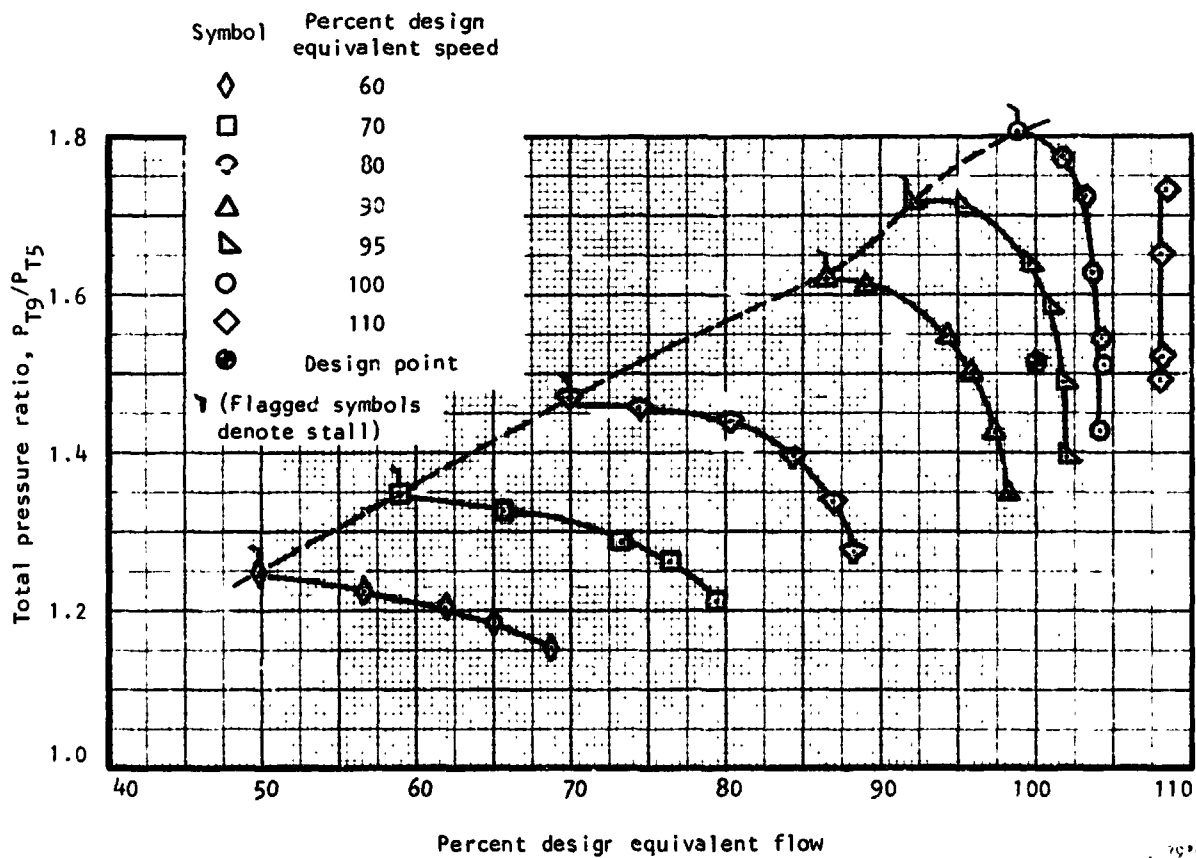
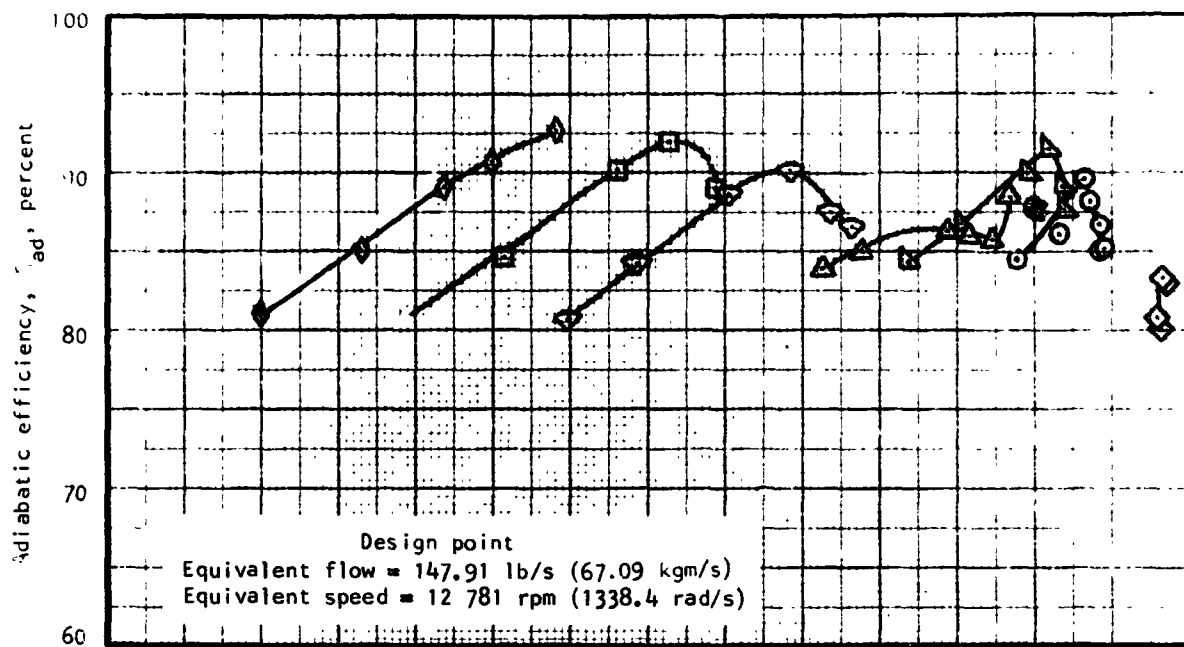
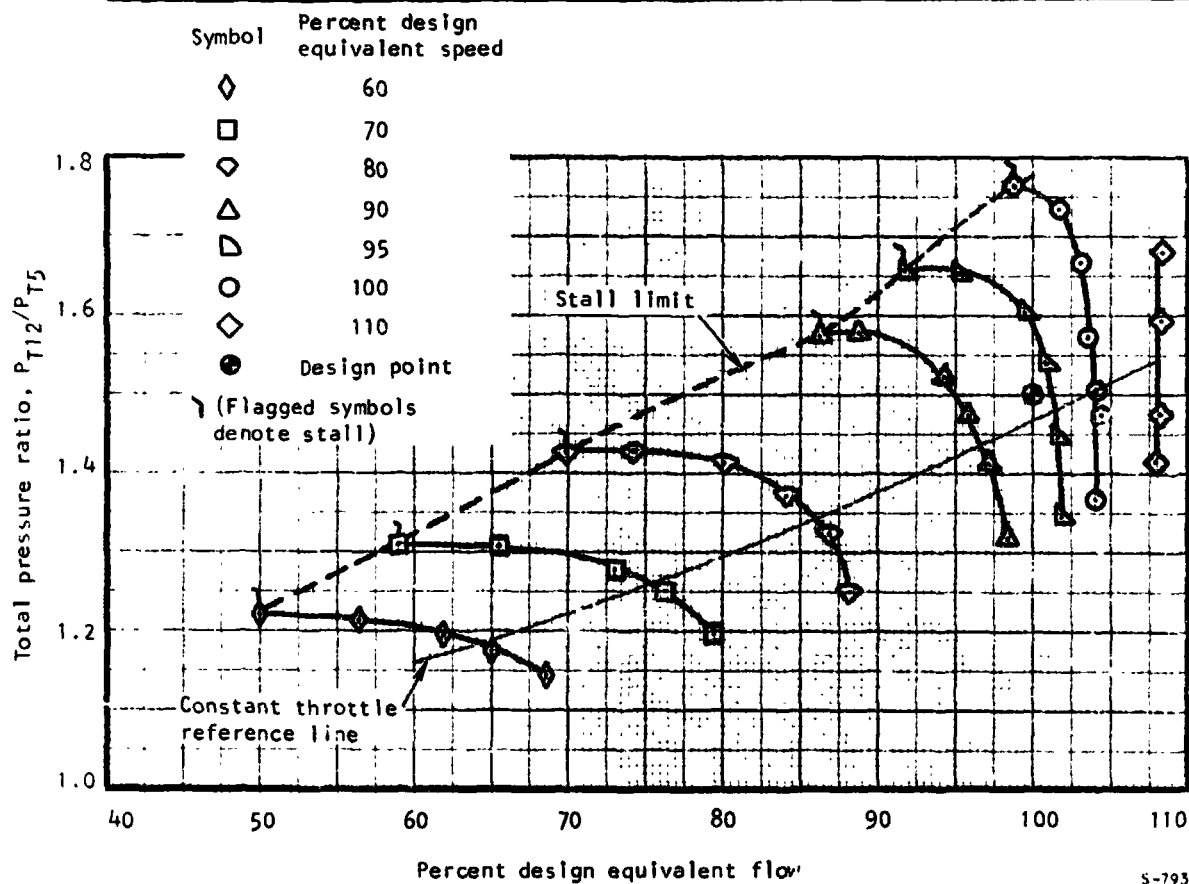
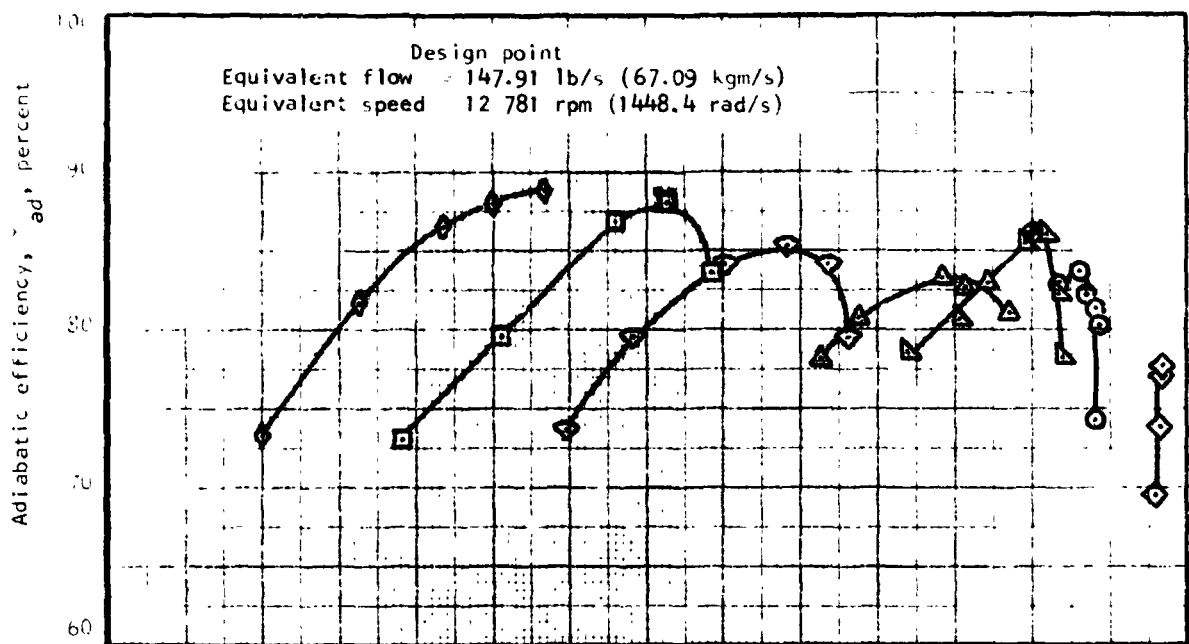


Figure 14.--Rotor Performance, Uniform Inlet Flow.



S-79306

Figure 15.--Stage Performance, Uniform Inlet Flow.

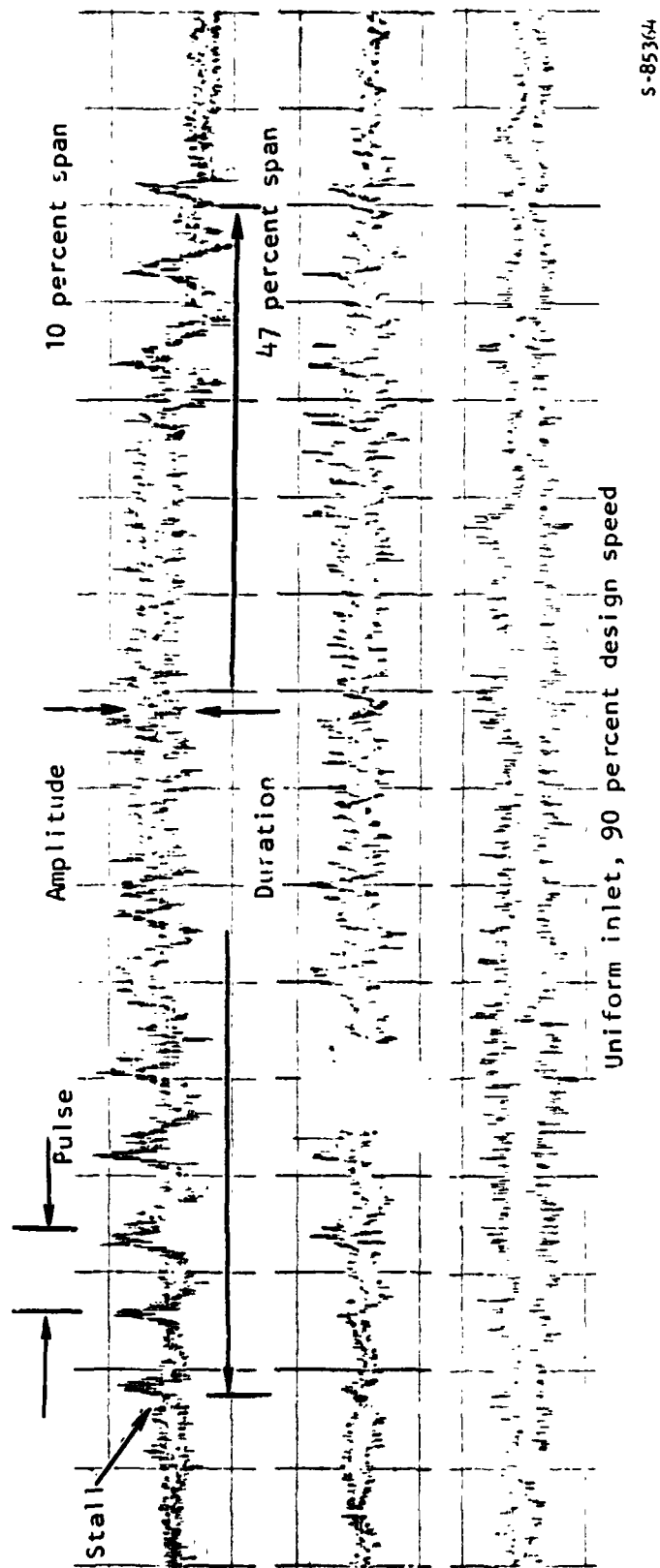
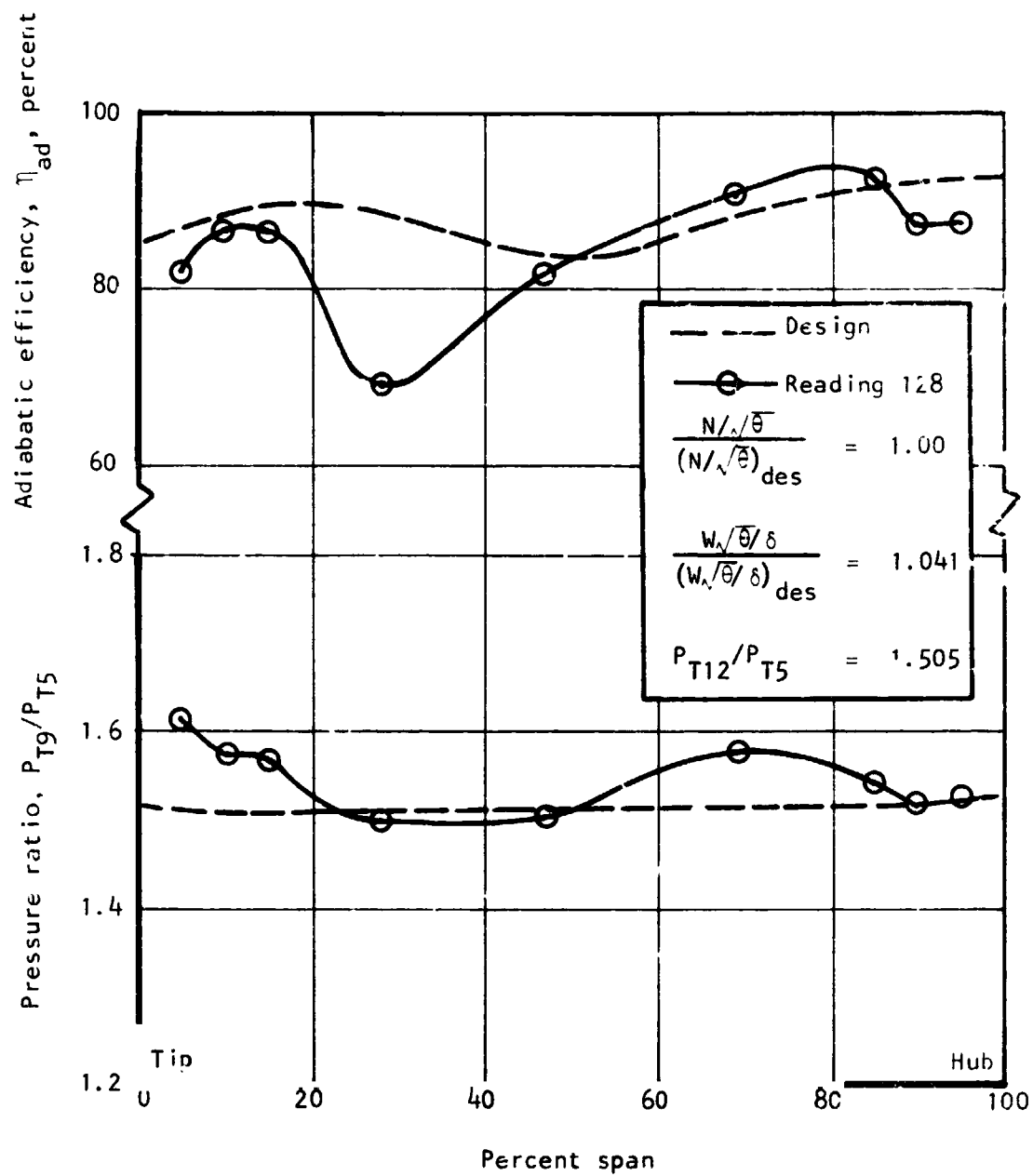
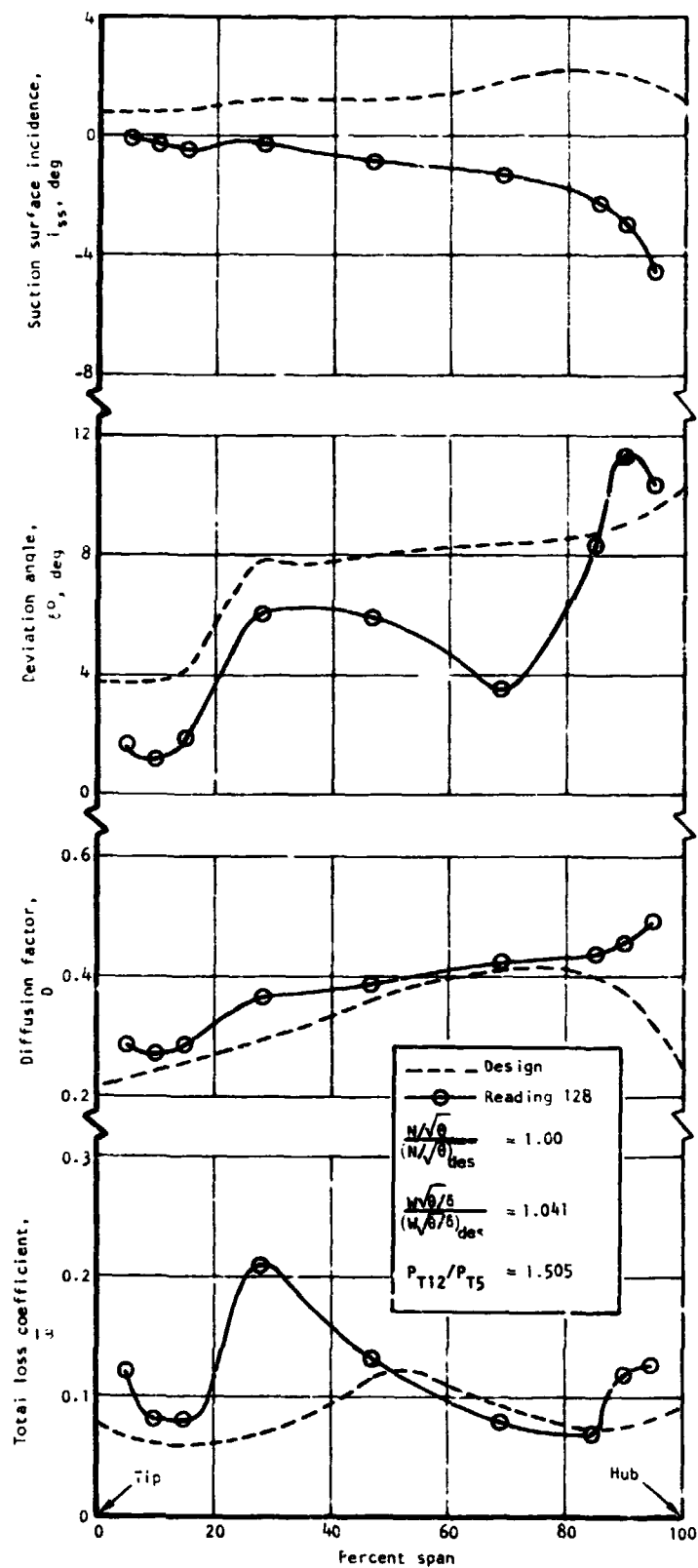


Figure 16.---Uniform Inlet Flow Stall Oscillograph Trace at
90 Percent Design Speed.



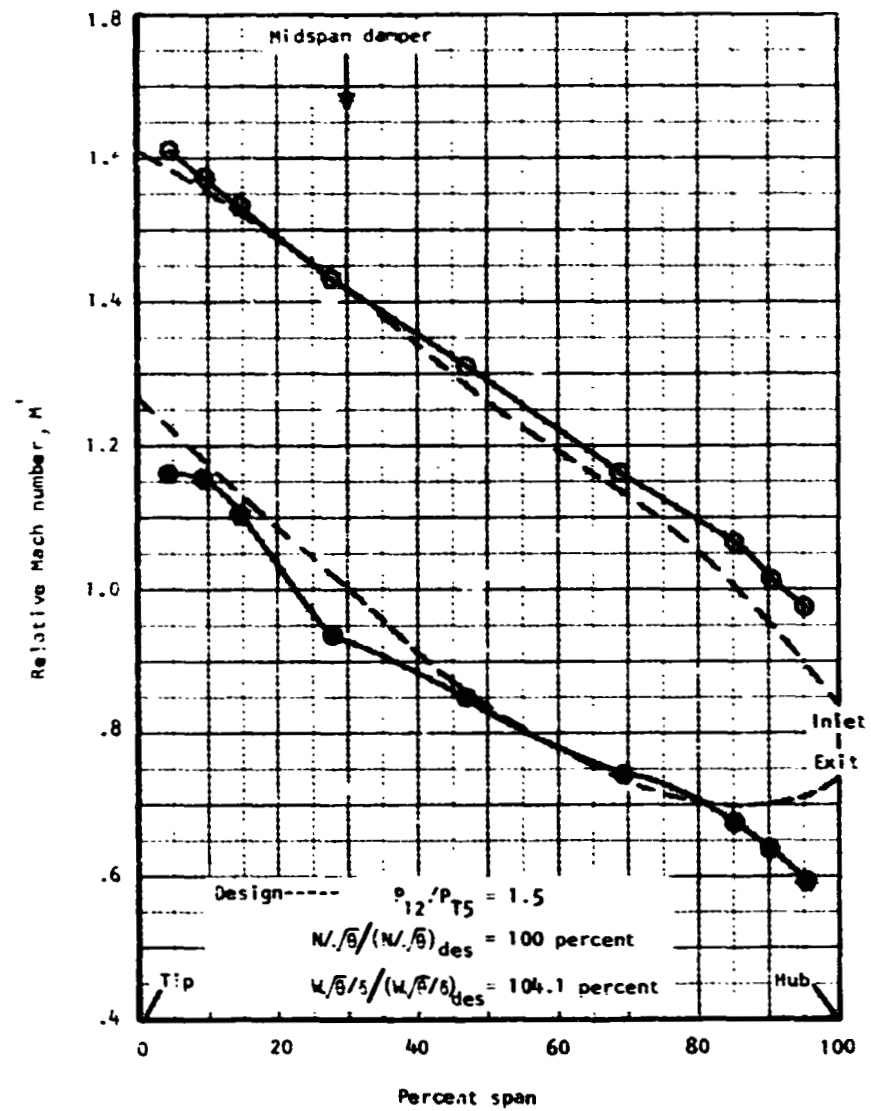
S-81627

Figure 17.--Rotor Blade Element Performance, Uniform Inlet Flow.



S-81736

Figure 18.--Rotor Blade Element Performance, Uniform Inlet Flow.



5-82136

Figure 19.--Rotor Relative Mach Number, Design Speed and Design Pressure Ratio.

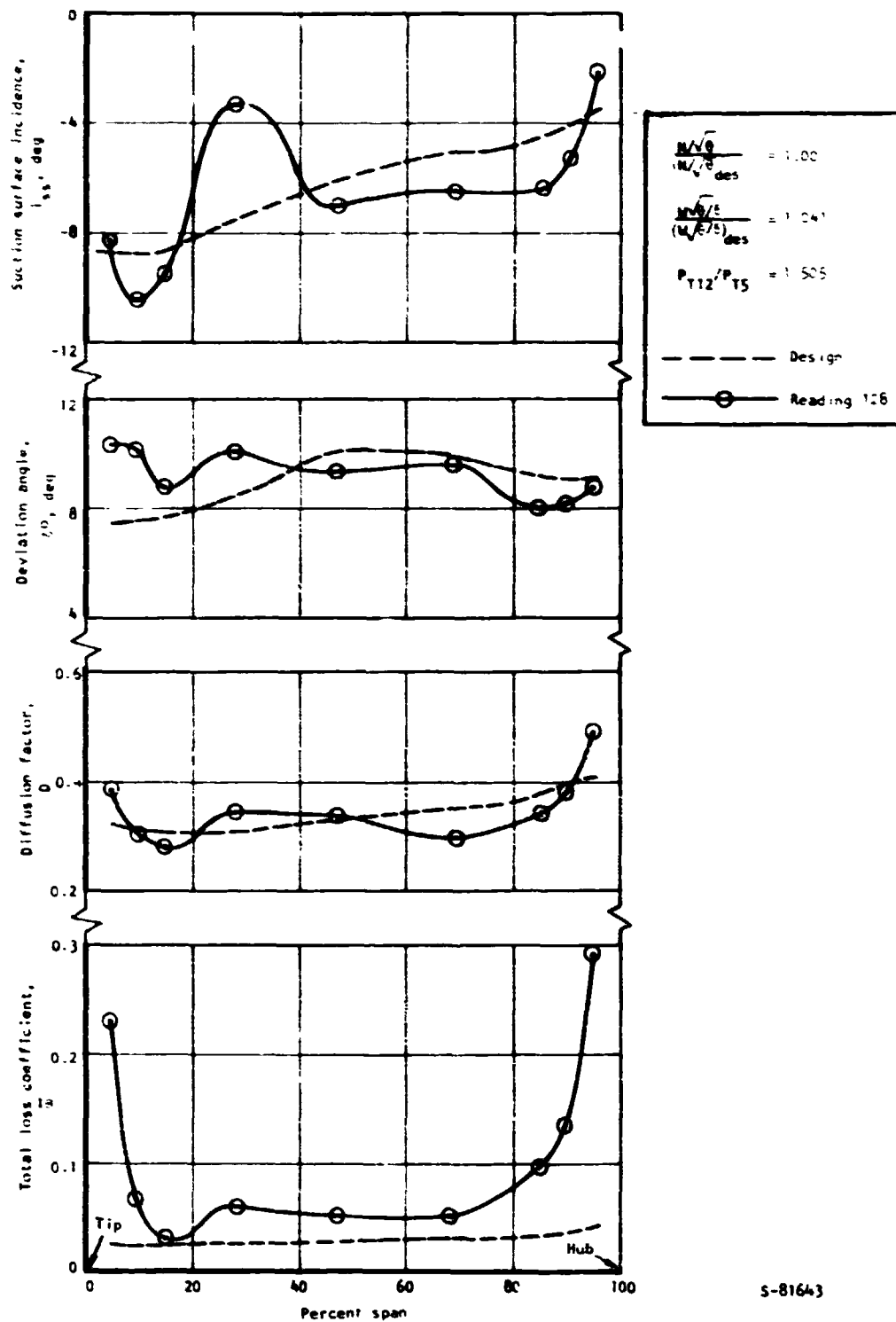


Figure 20.--Stator Vane Element Performance, Uniform Inlet Flow.

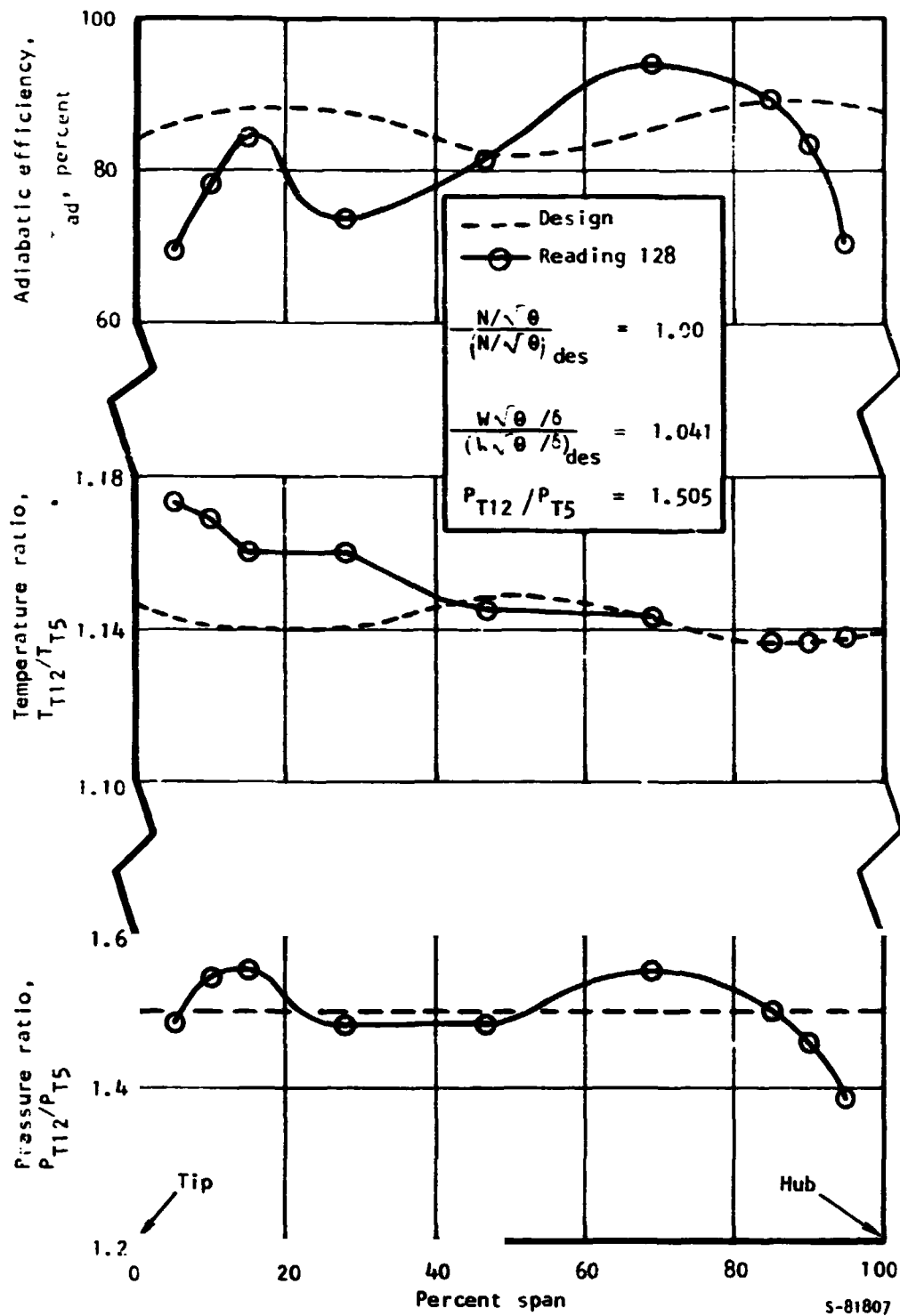


Figure 21. -- Stage Element Performance, Uniform Inlet Flow.

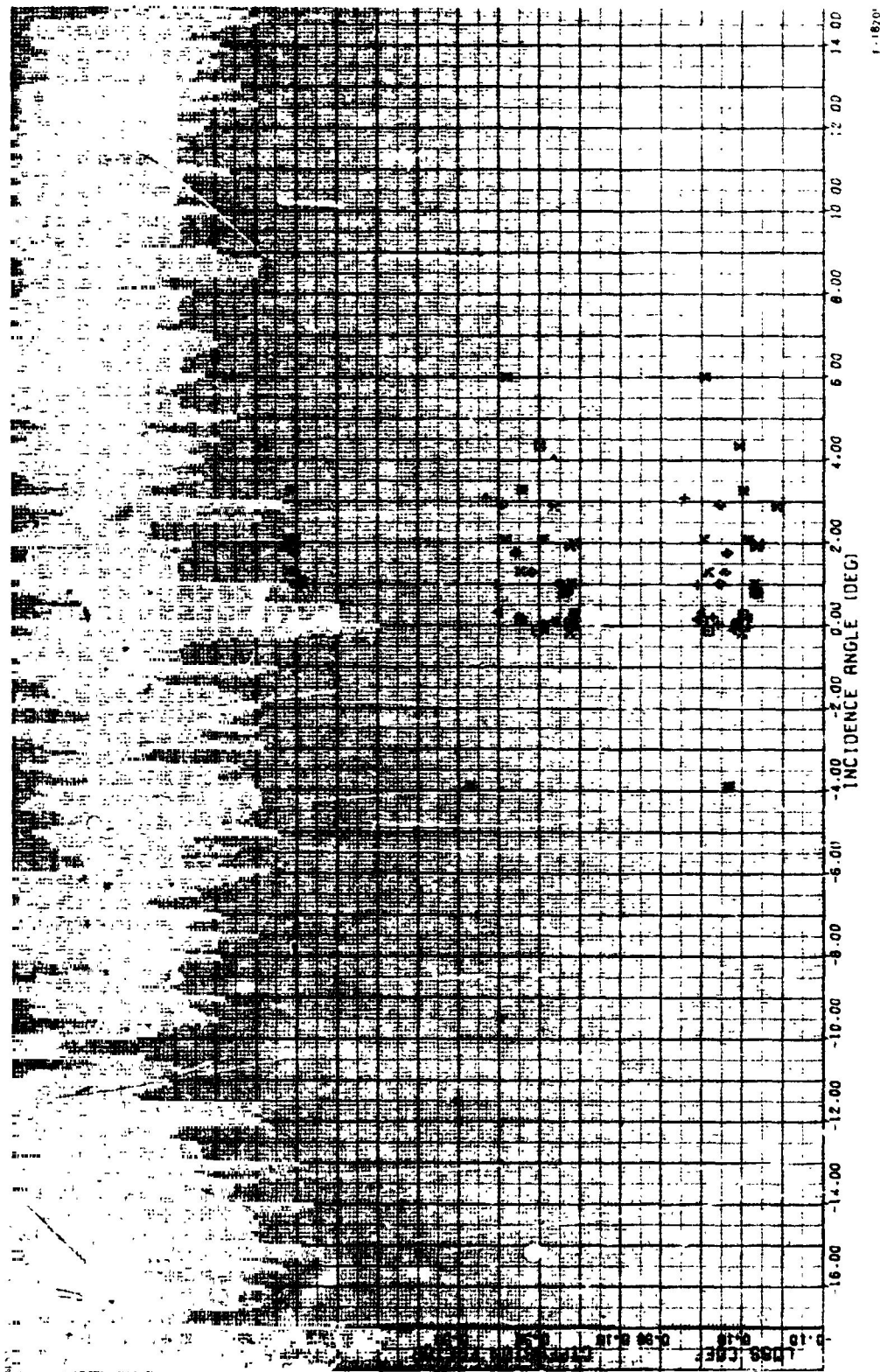


Figure 22a.--Rotor Blade Element Performance, Uniform Inlet Flow,
5 Percent Span from Tip.

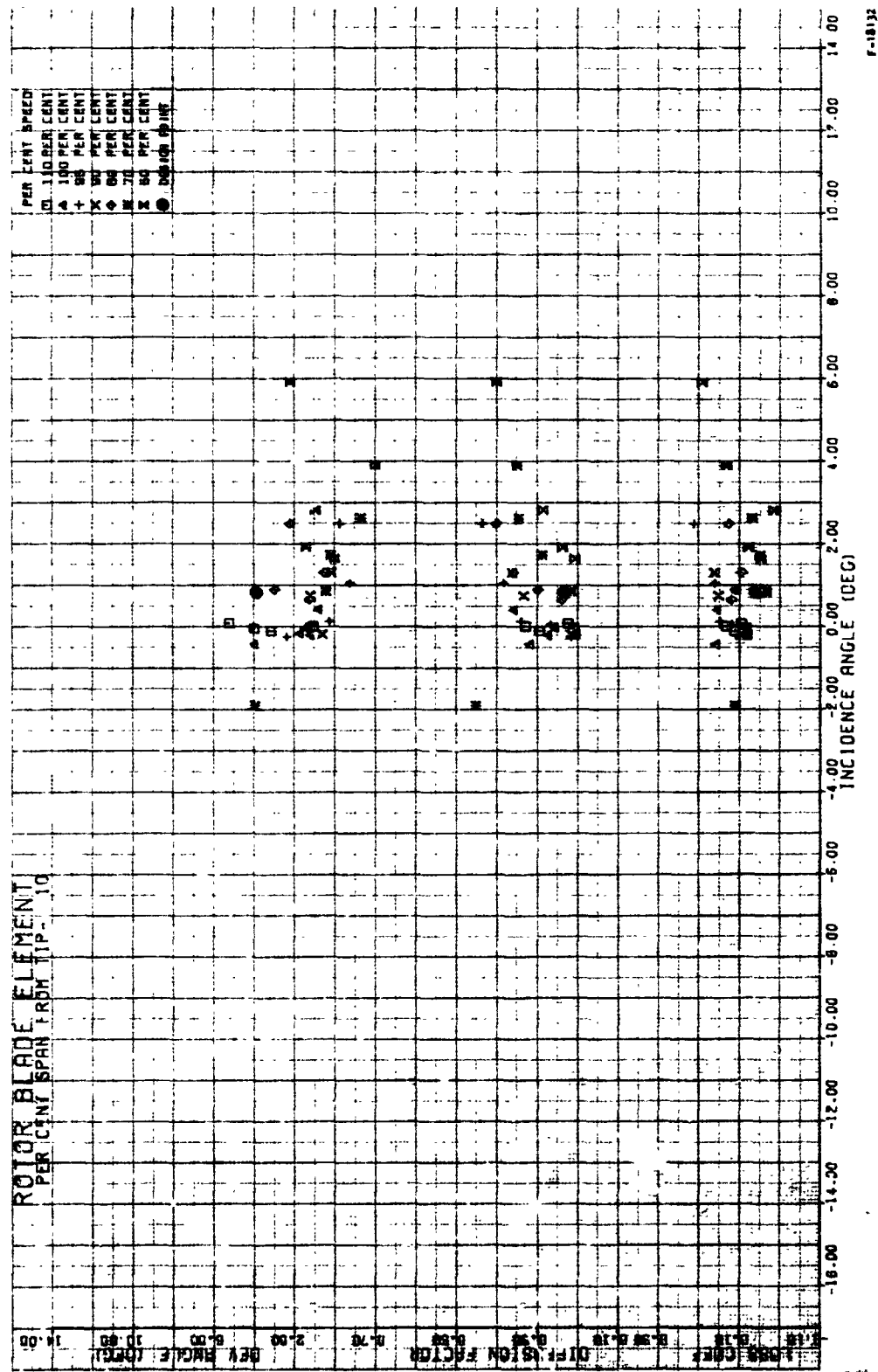


Figure 22b.--Rotor Blade Element Performance, Uniform Inlet Flow,
10 Percent Span from Tip.

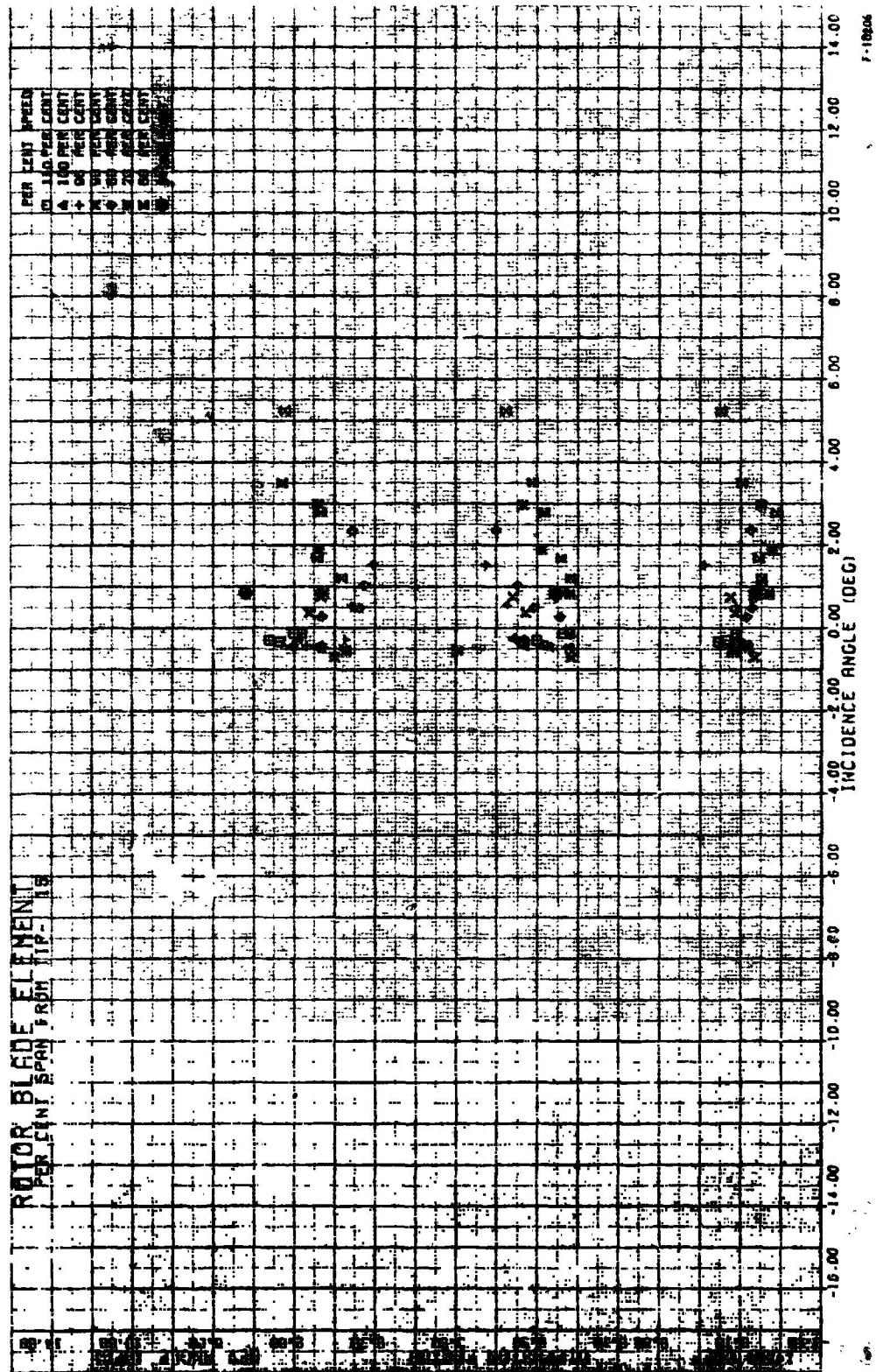


Figure 22c.--Rotor Blade Element Performance, Uniform Inlet Flow,
15 Percent Span from Tip.

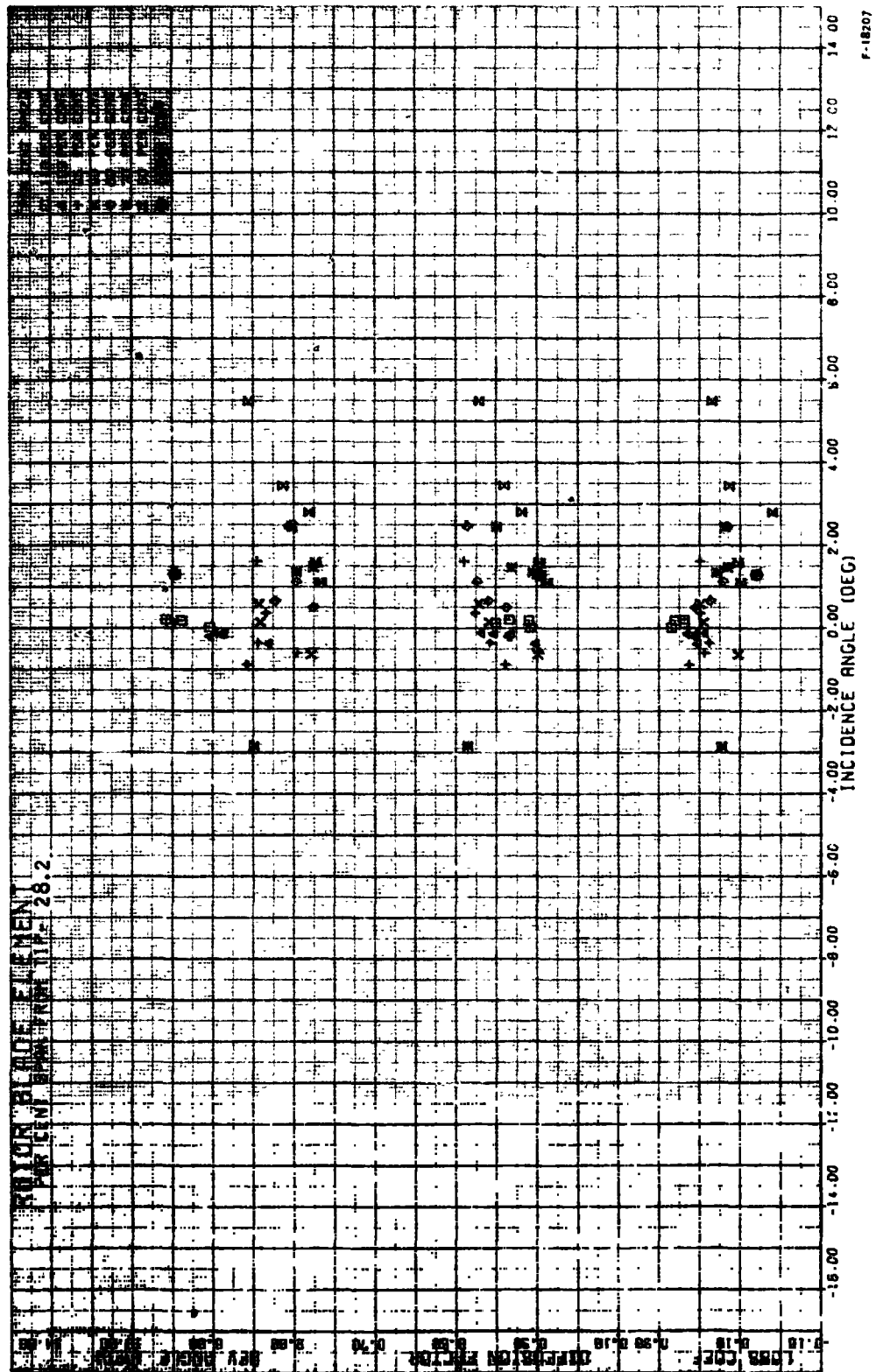


Figure 22d.--Rotor Blade Element Performance, Uniform Inlet Flow,
28.2 Percent Span from Tip.

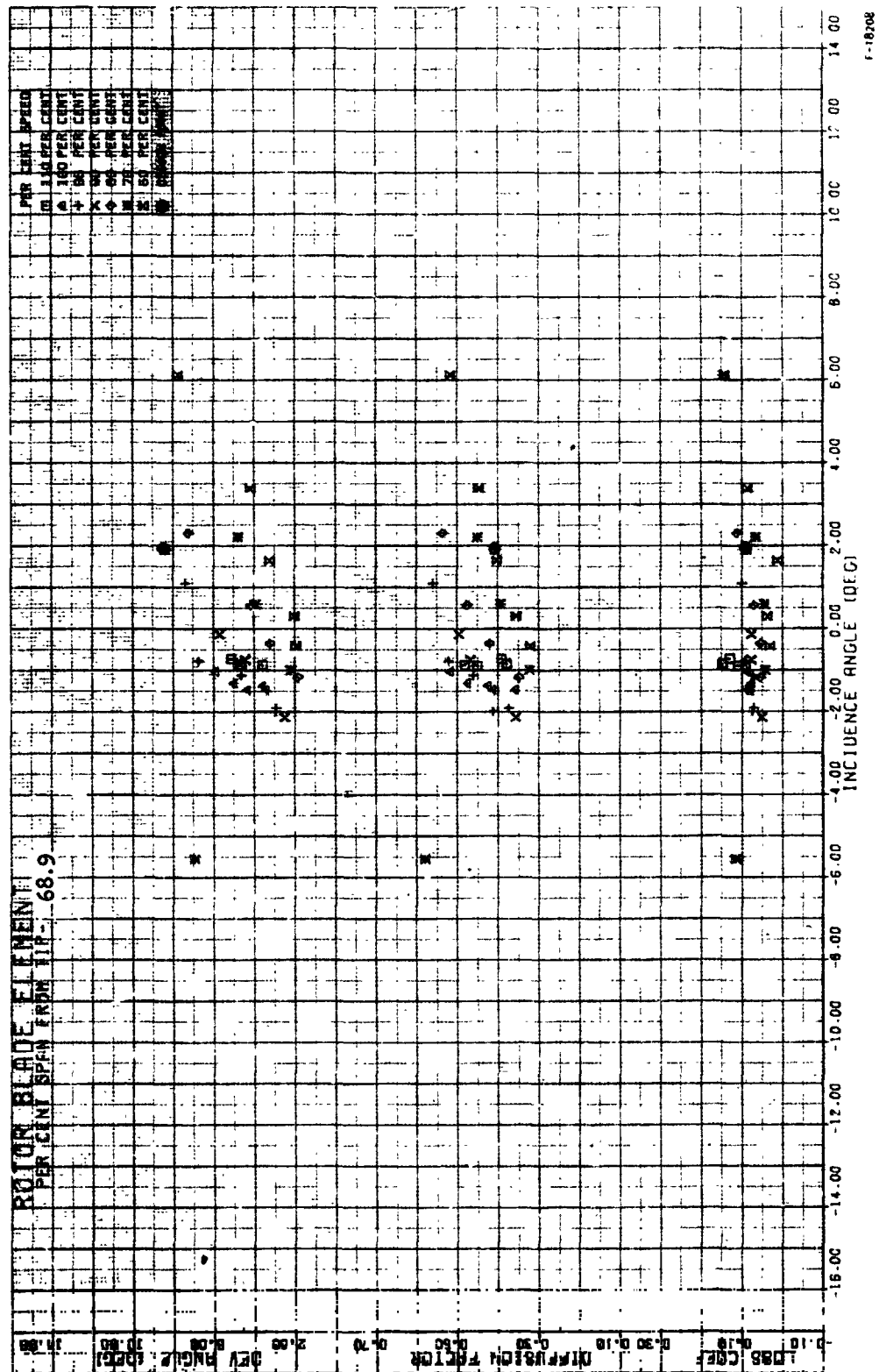


Figure 22f.--Rotor Blade Element Performance, Uniform Inlet Flow,
68.9 Percent Span from Tip.

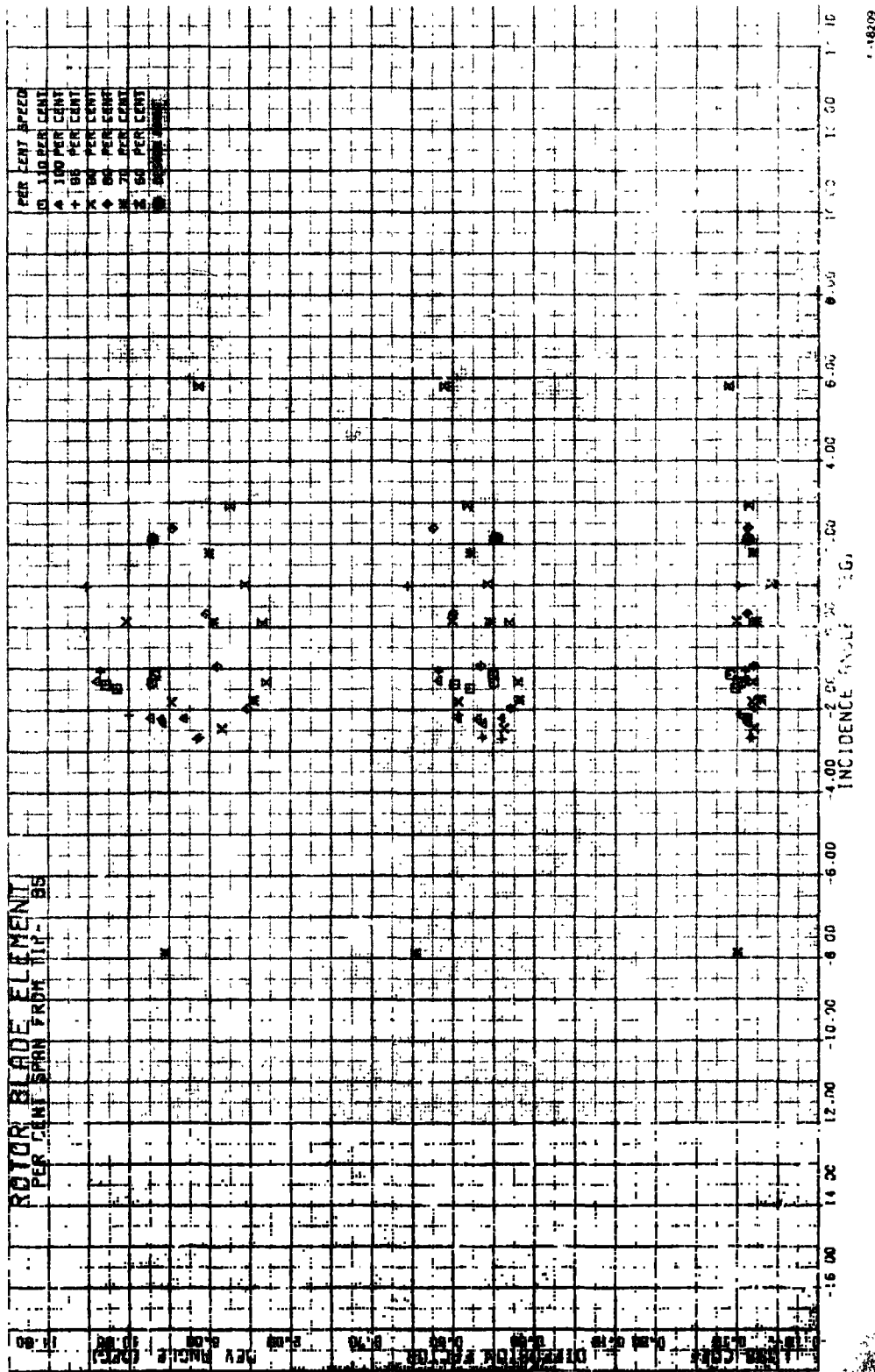


Figure 22g.--Rotor Blade Element Performance, Uniform Inlet Flow,
85 Percent Span from Tip.

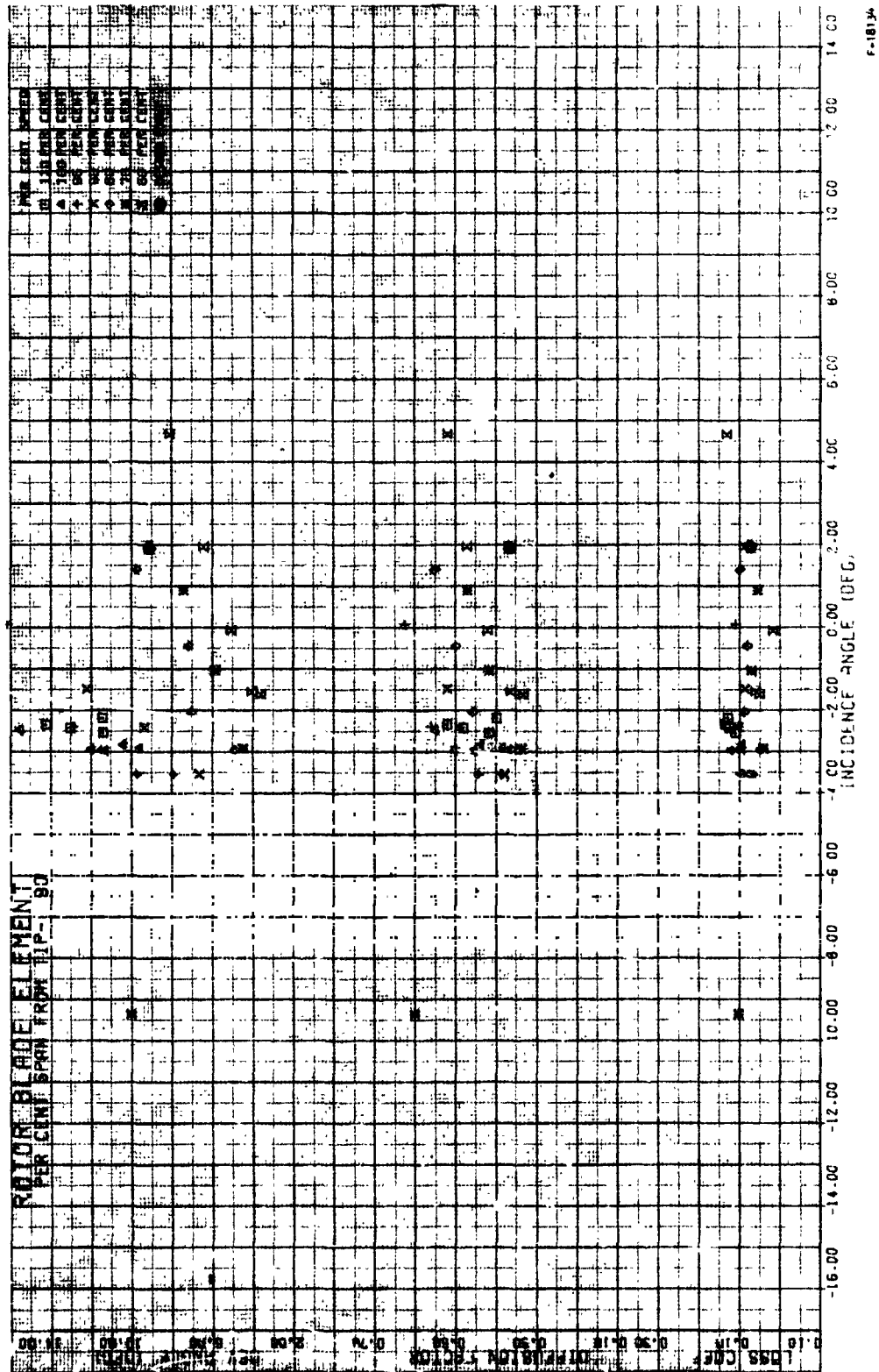


Figure 22i.--Rotor Blade Element Performance, Uniform Inlet Flow, 90 Percent Span from Tip.

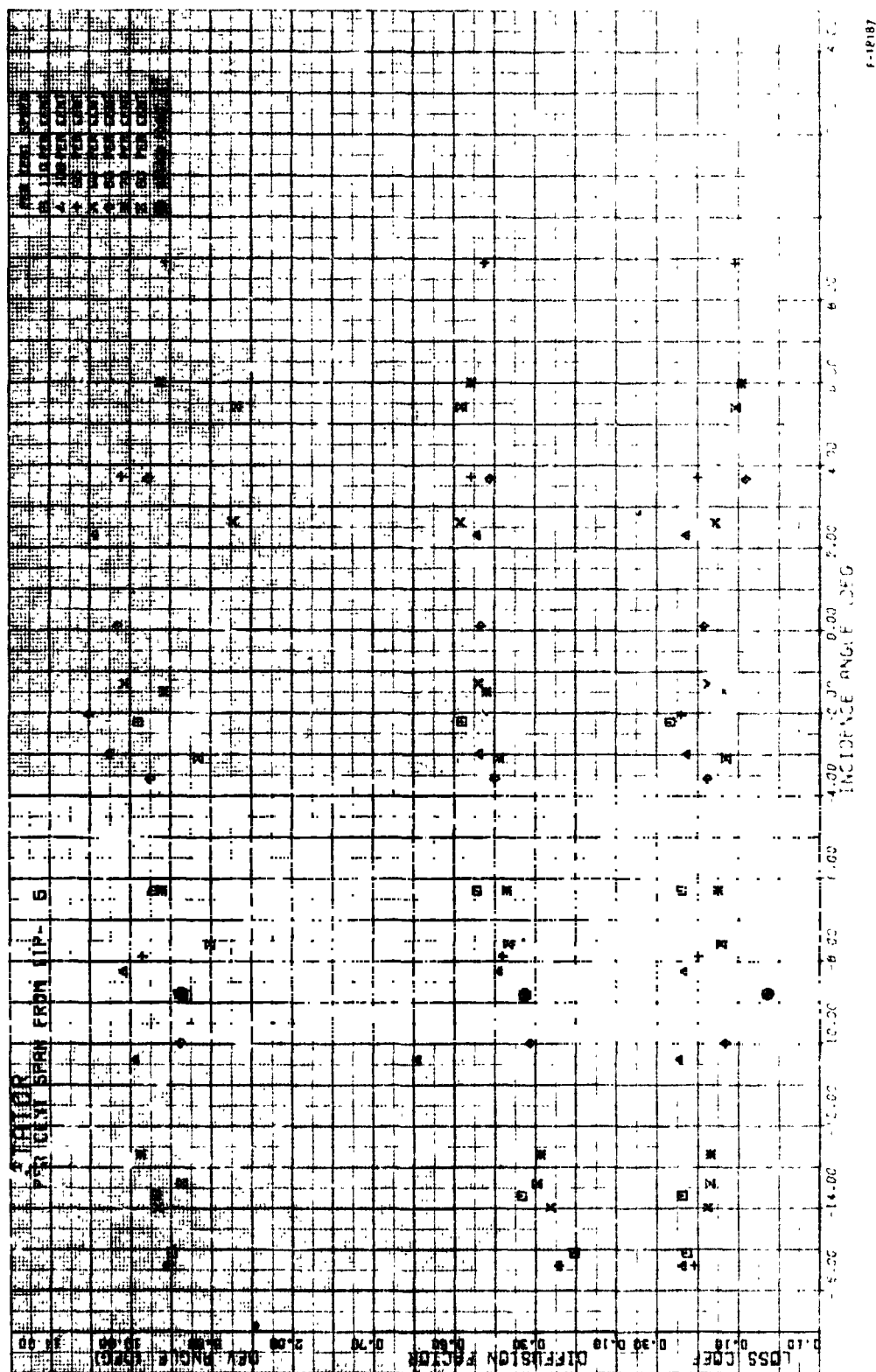


Figure 22i.--Rotor Blade Element Performance, Uniform Inlet Flow, 93.7 Percent Span from Tip.

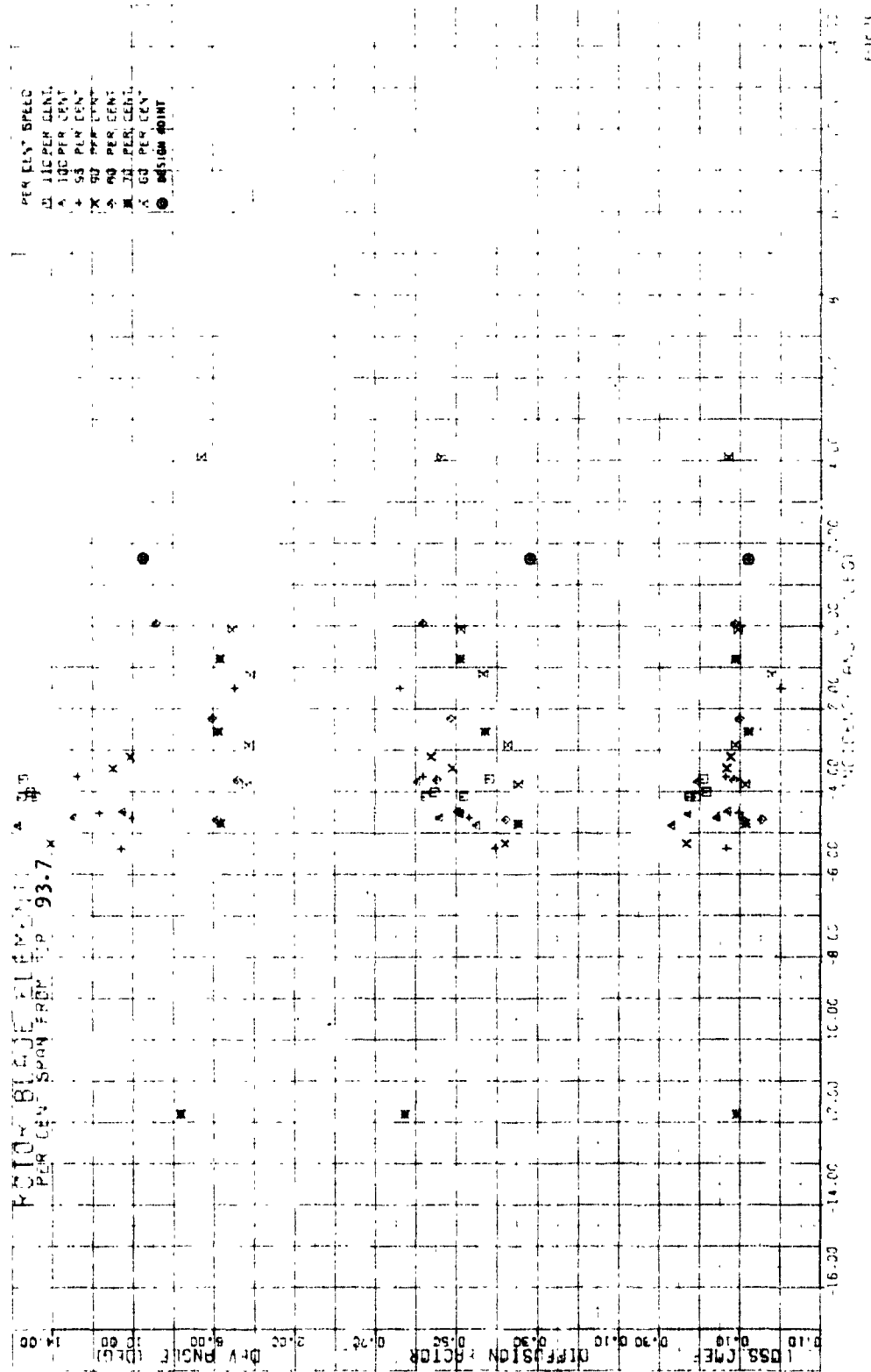


Figure 23a.---Stator Vane Element Performance, Uniform Inlet Flow,
5 Percent Span from Tip.

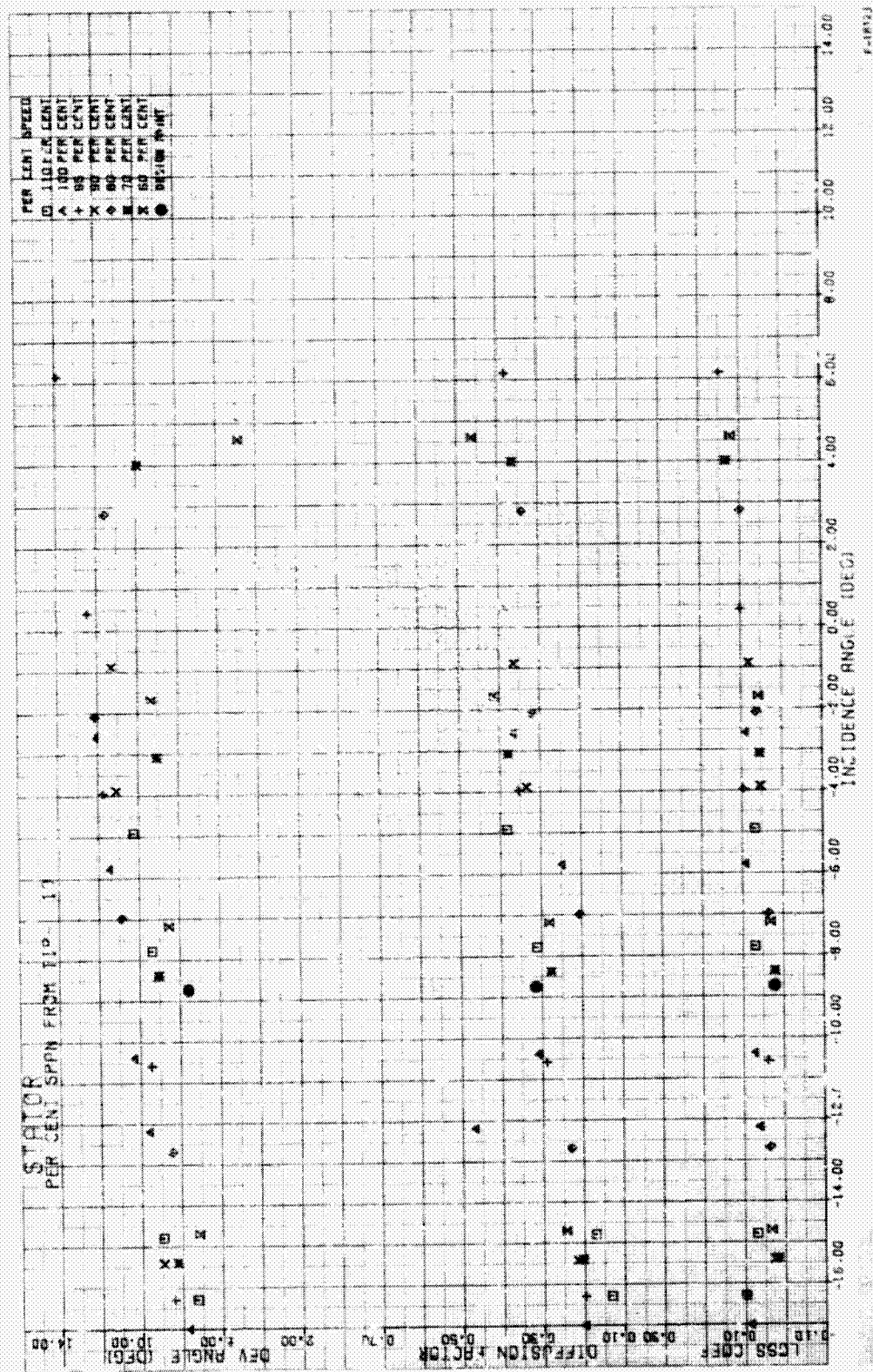


Figure 23b.--Stator Vane Element Performance, Uniform Inlet Flow,
10 Percent Span from Tip.

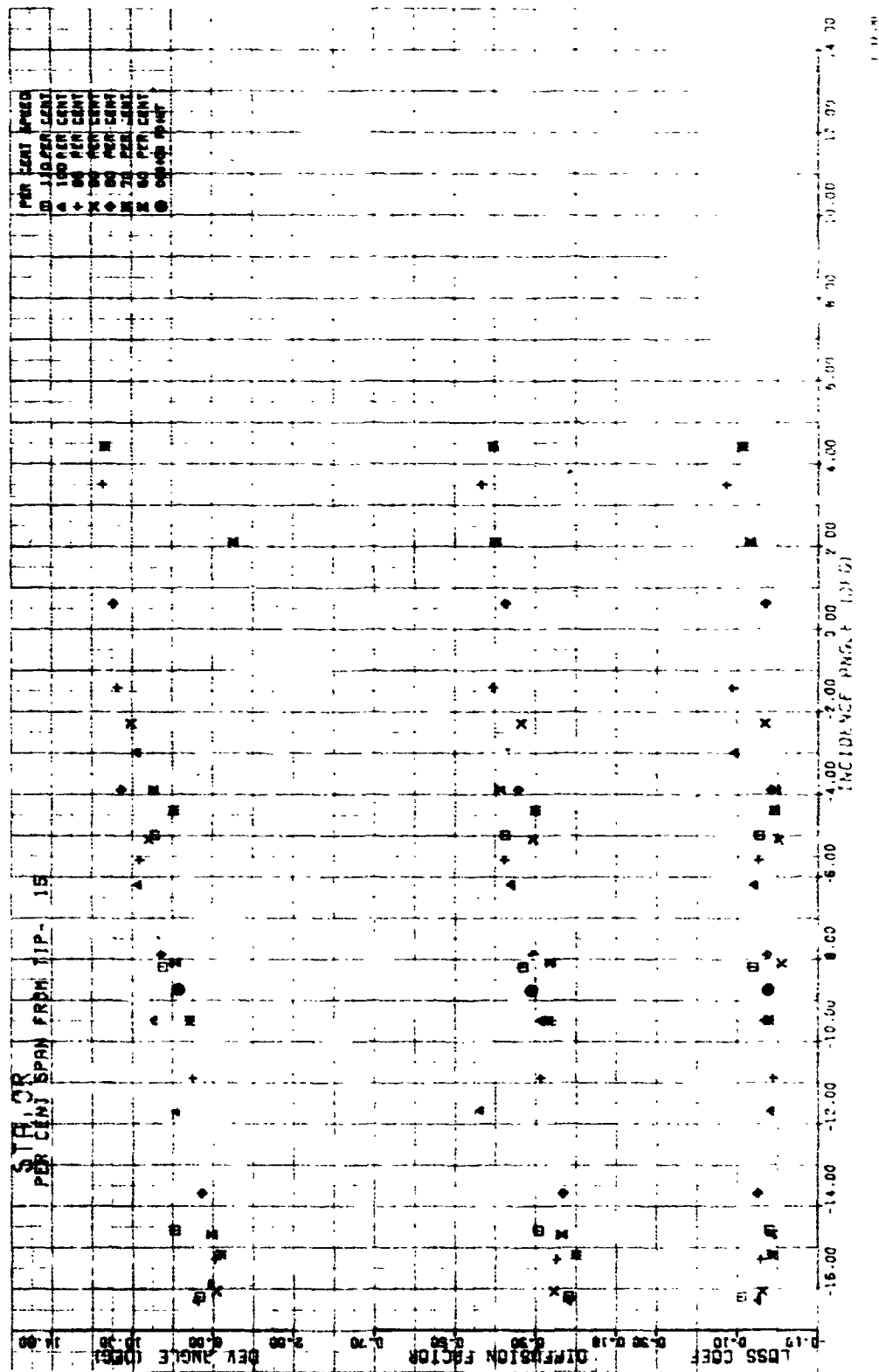


Figure 23c.---Stator Vane Element Performance, Uniform Inlet Flow,
15 Percent Span from Tip.

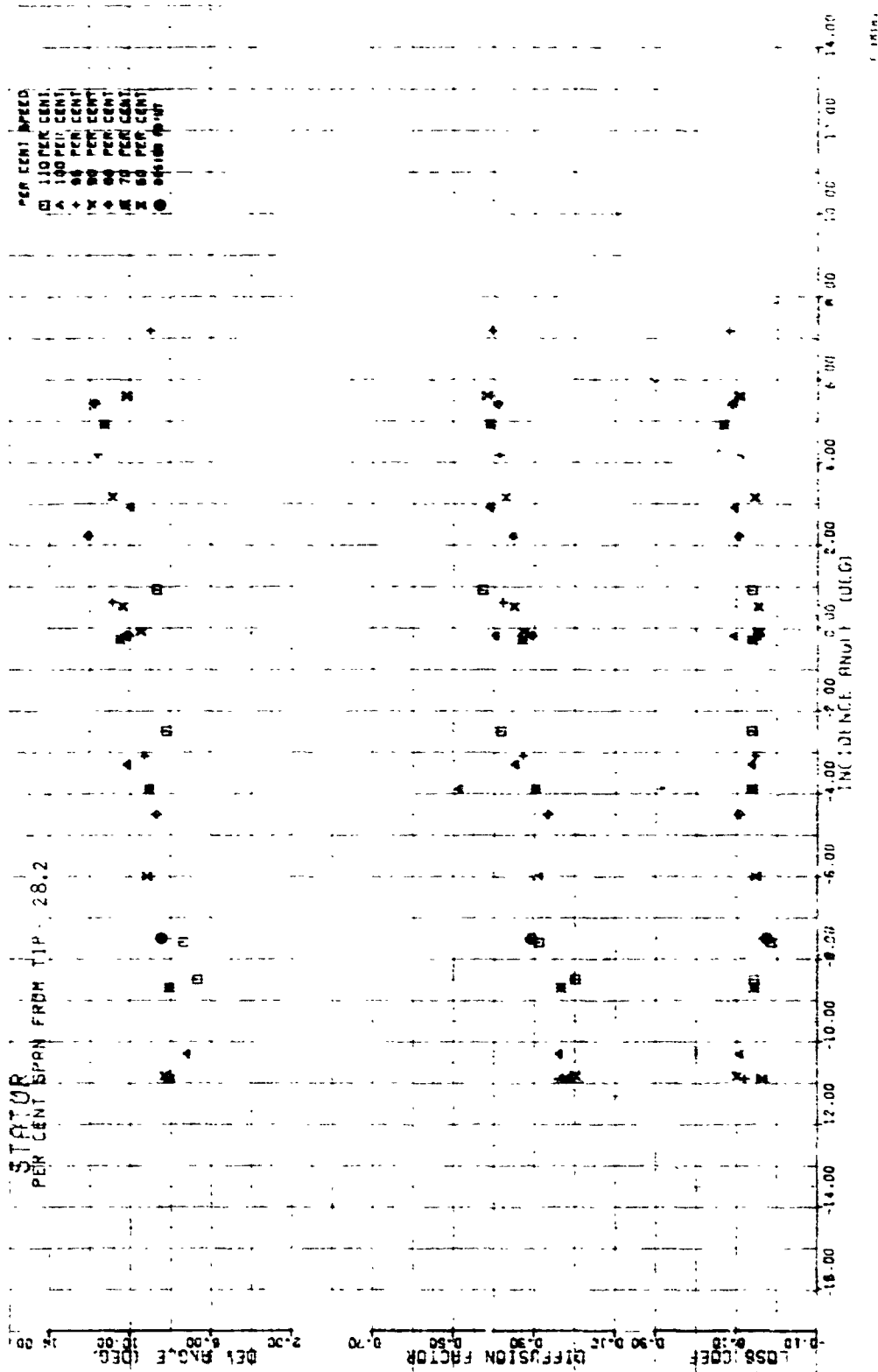


Figure 23d.--Stator Vane Element Performance, Uniform Inlet Flow,
28.2 Percent Span from Tip.

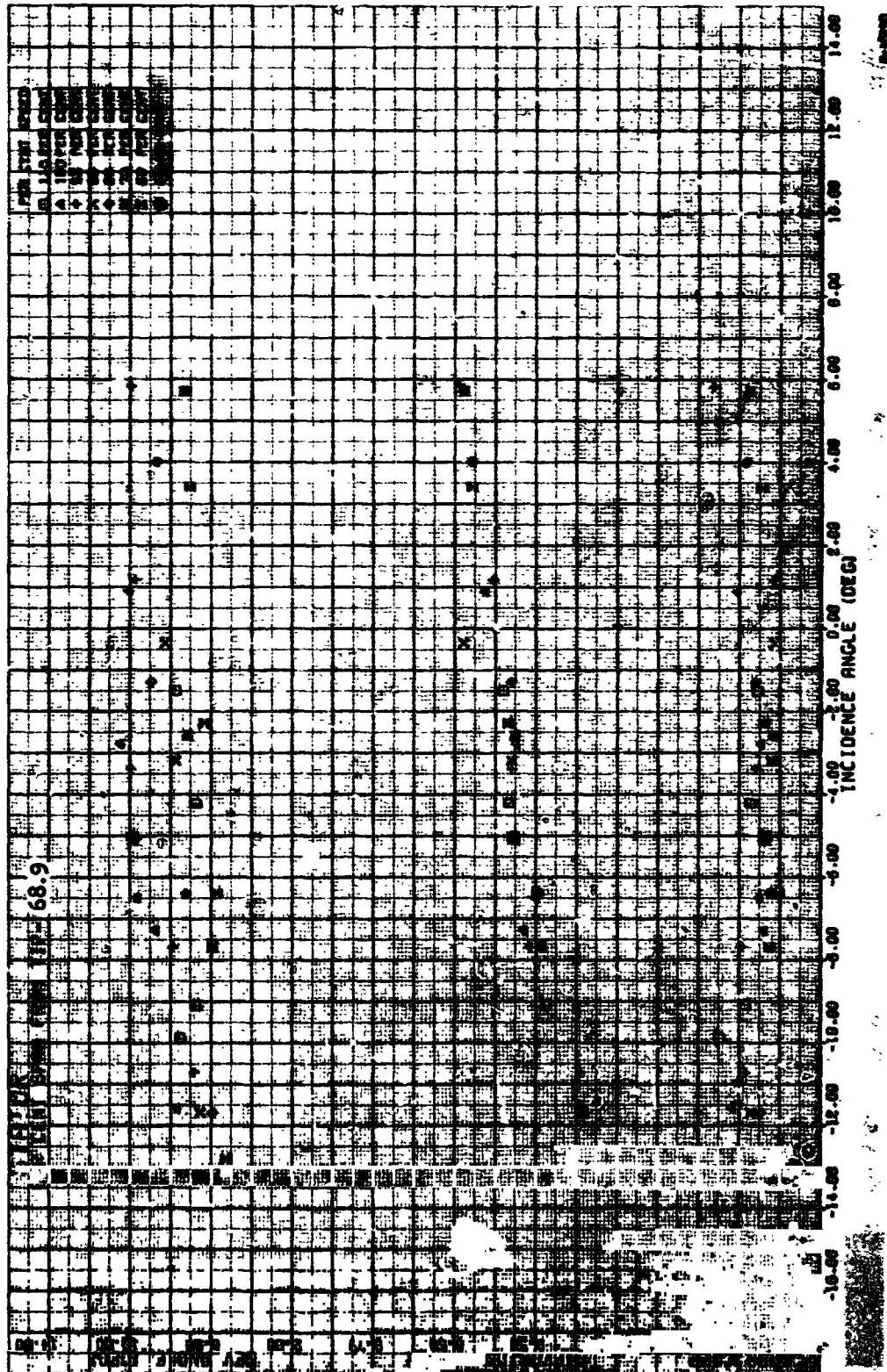


Figure 23f.--Stator Vane Element Performance, Uniform Inlet Flow,
68.9 Percent Span from Tip.

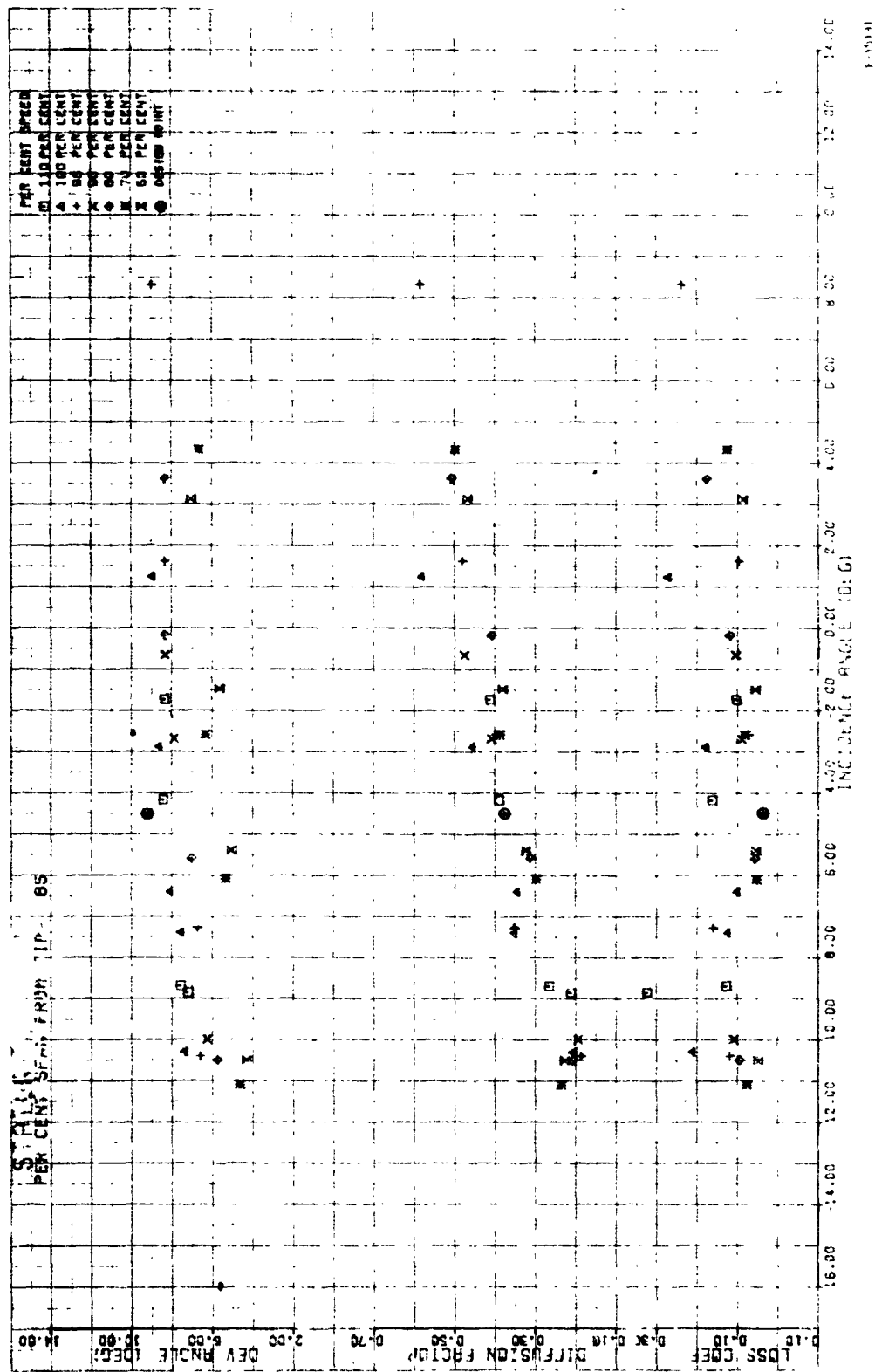


Figure 23g.--Stator Vane Element Performance, Uniform Inlet Flow,
85 Percent Span from Tip.

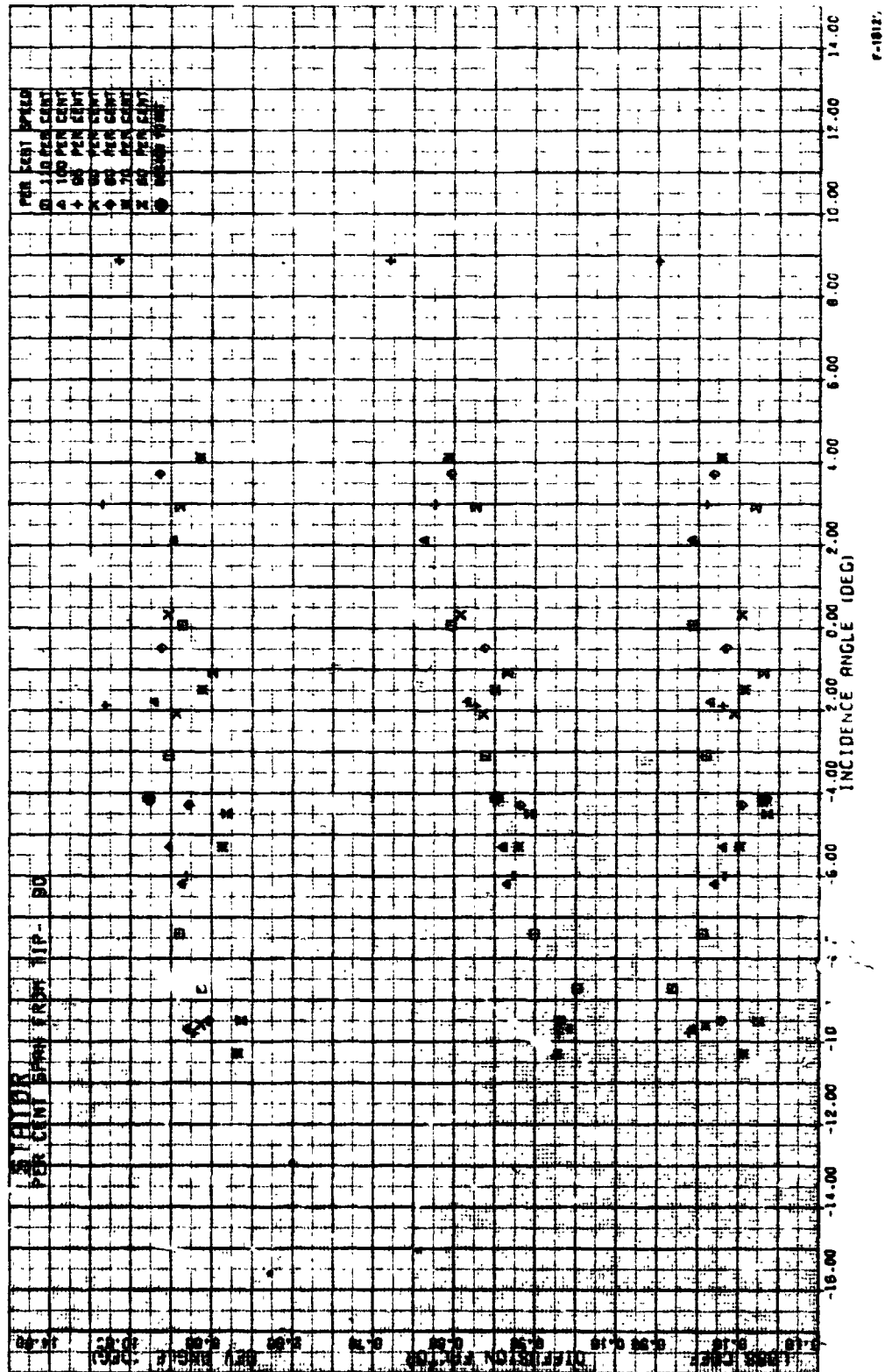


Figure 23h.--Stator Vane Element Performance, Uniform Inlet Flow,
90 Percent Span from Tip.

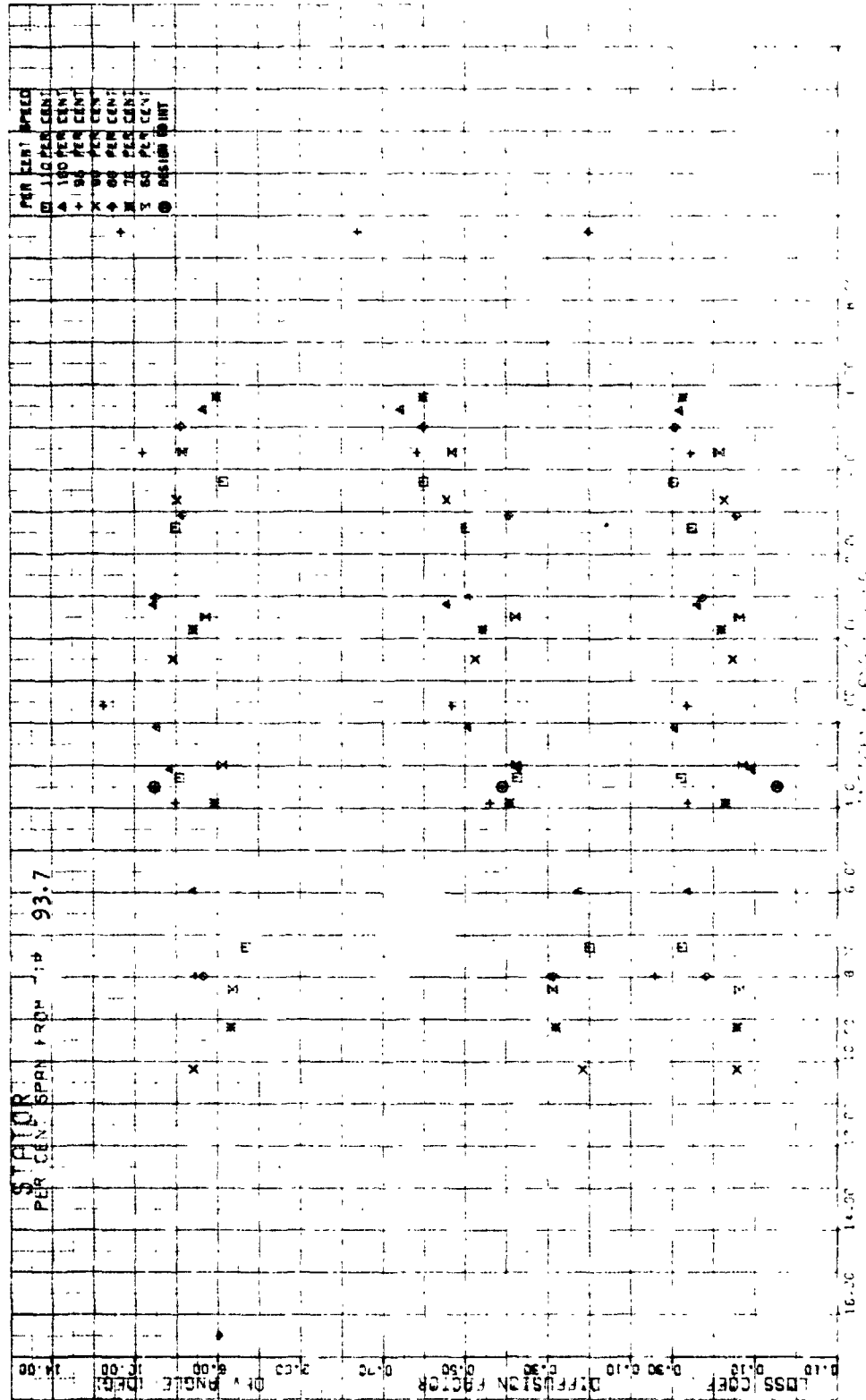


Figure 23i.--Stator Vane Element Performance, Uniform Inlet Flow, 93.7 Percent Span from Tip.

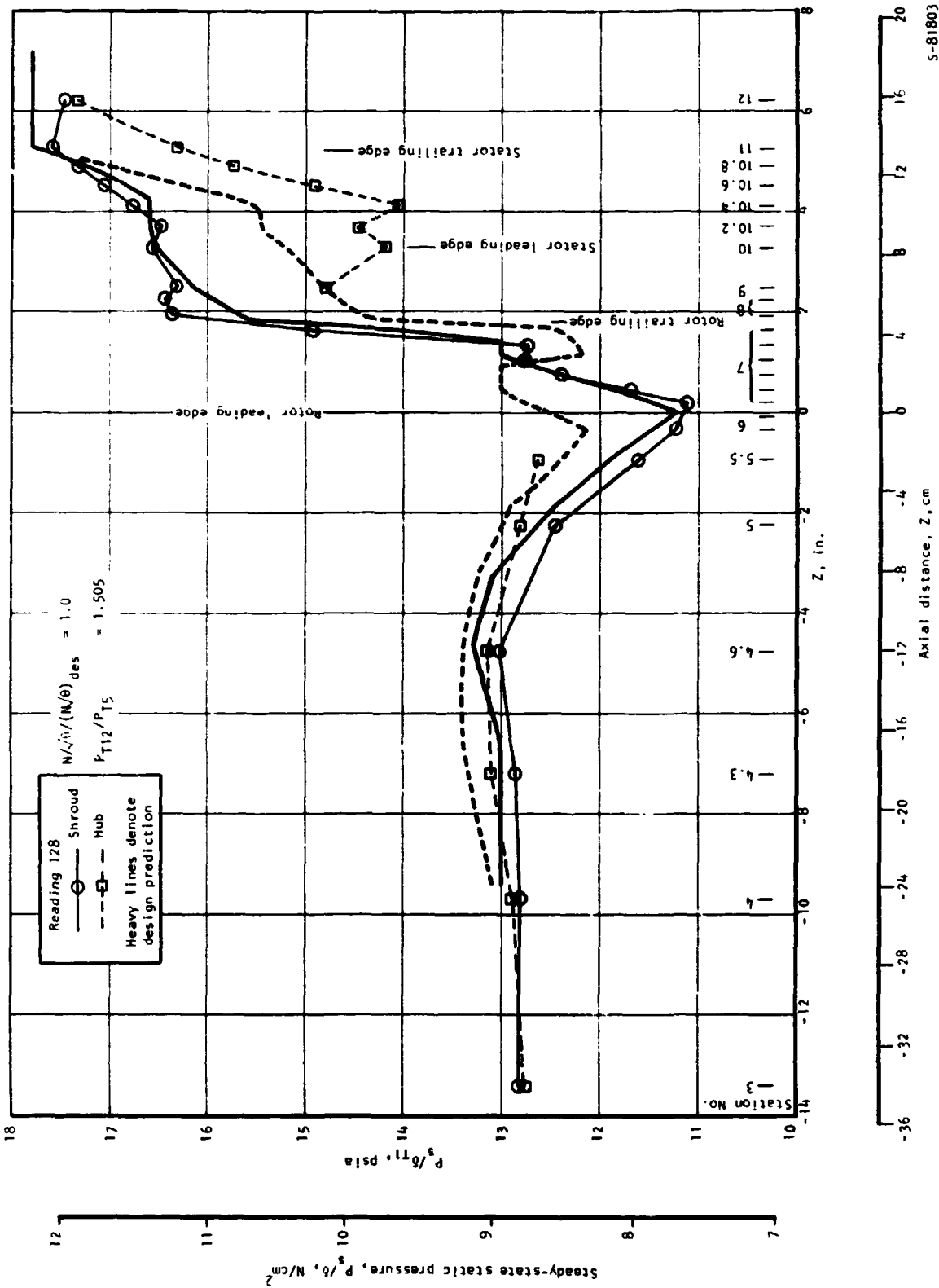


Figure 24. Axial Static Pressure Distribution, Uniform Inlet Flow.

S-81803

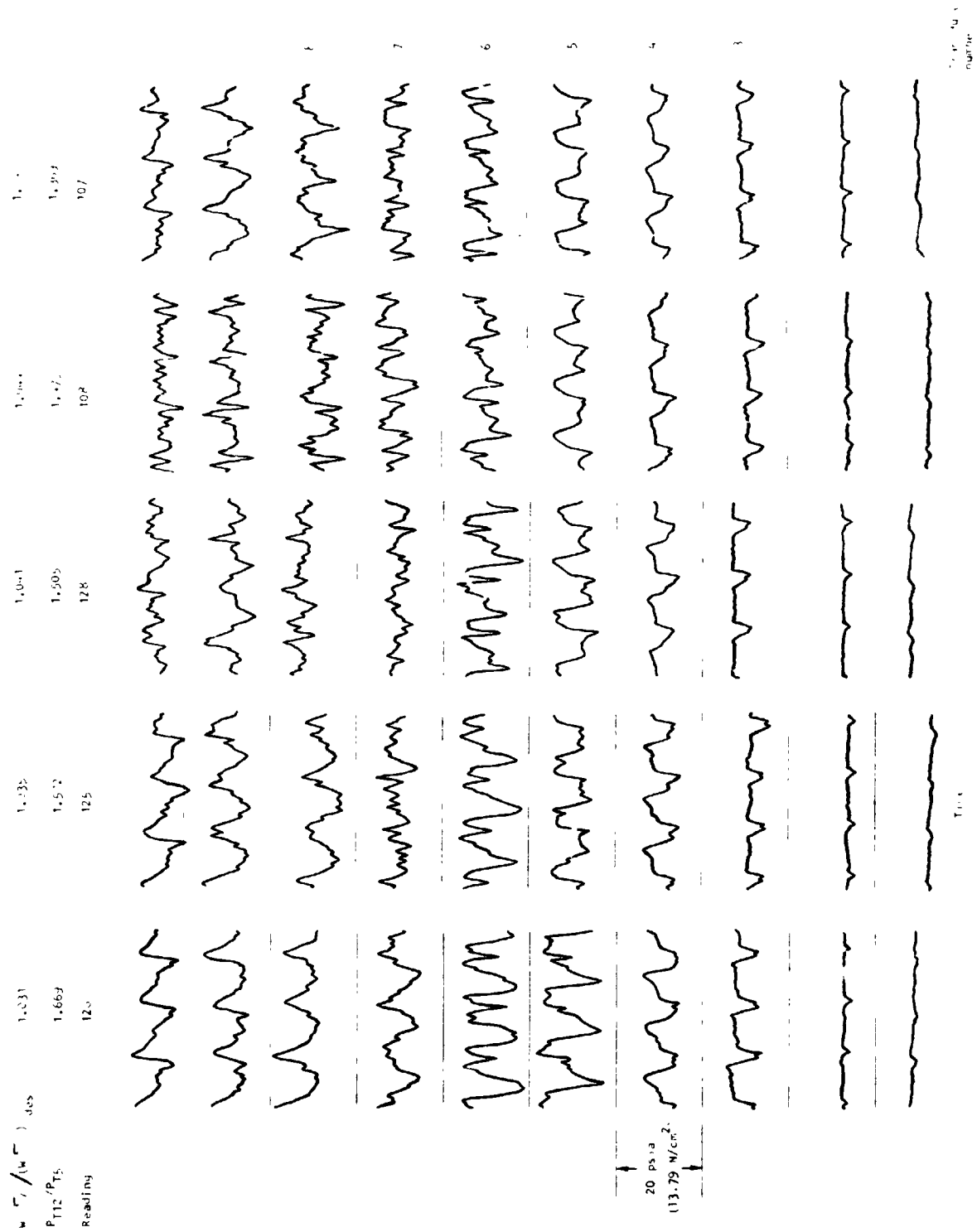


Figure 25.--Typical Rotor Casing High-Frequency-Response Oscillograph Traces at Design Speed.

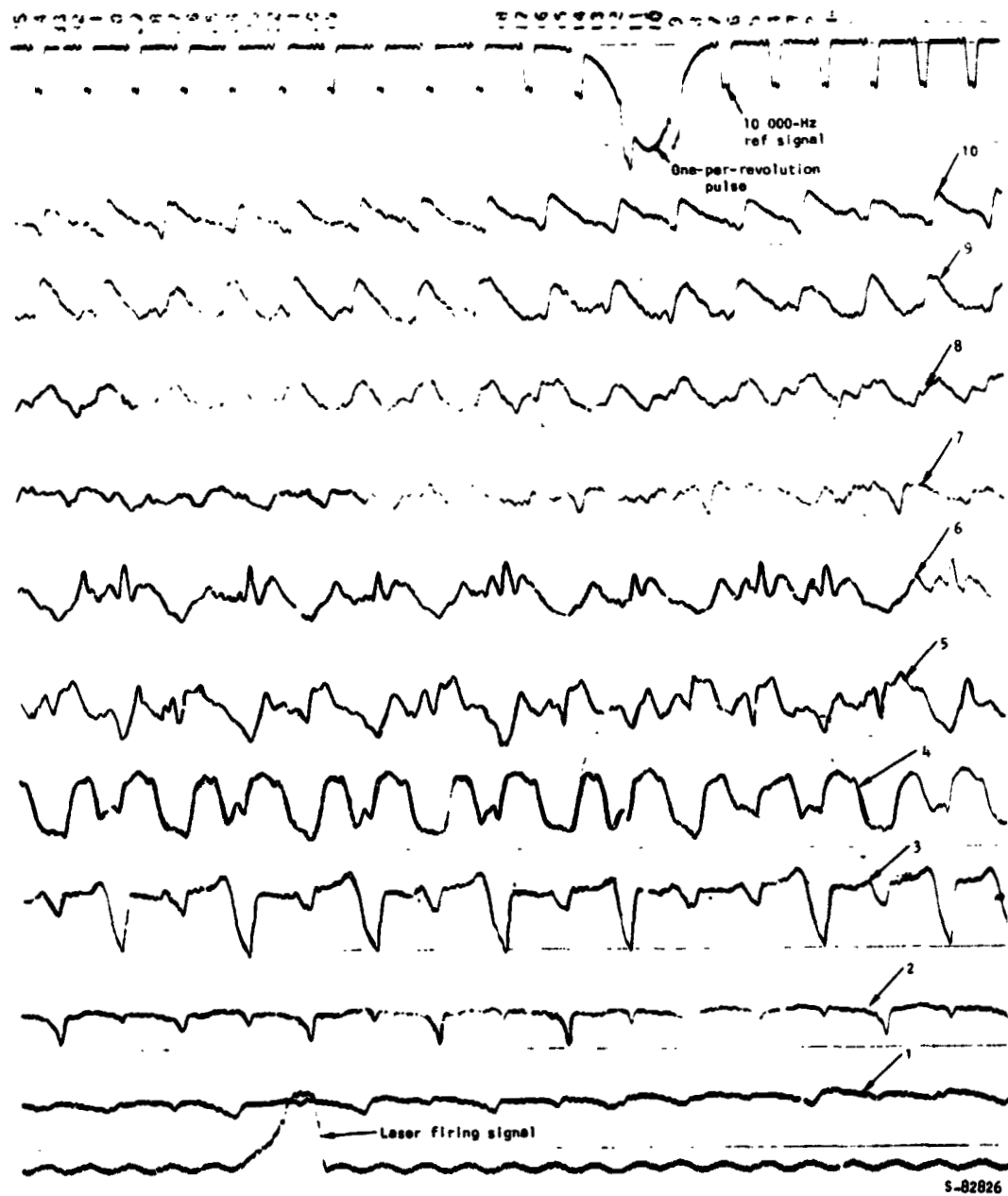
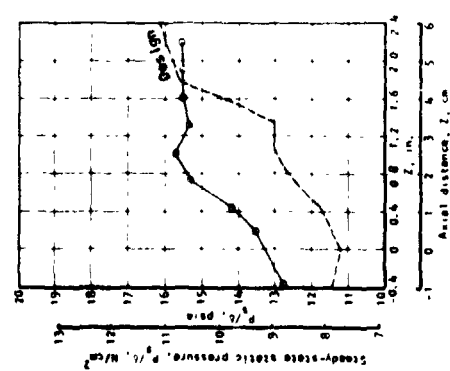
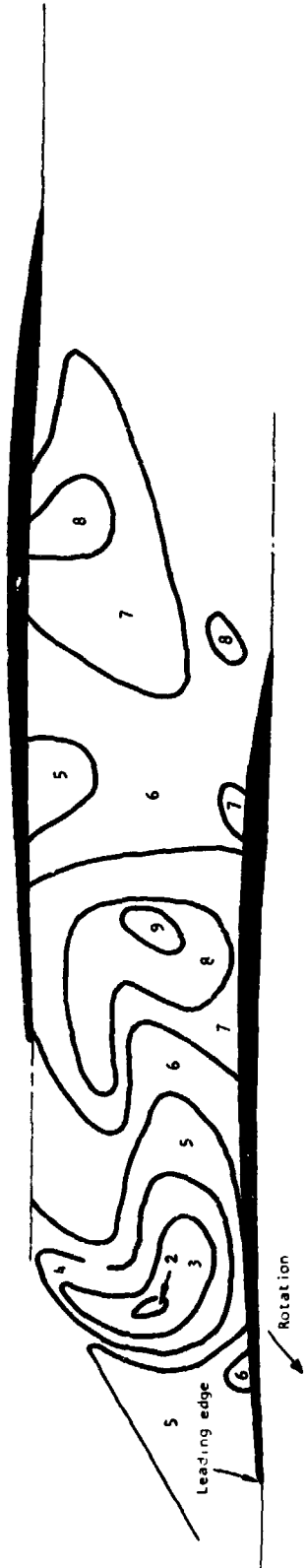


Figure 25.--Rotor Casing High-Frequency-Response Oscillograph
Traces at 90 Percent of Design Speed Showing Transition
from Started to Unstarted Conditions.



Reading 75

$$\frac{M/\delta}{M/\delta_{des}} = 0.80$$

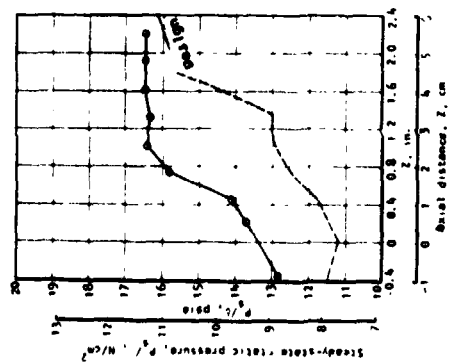
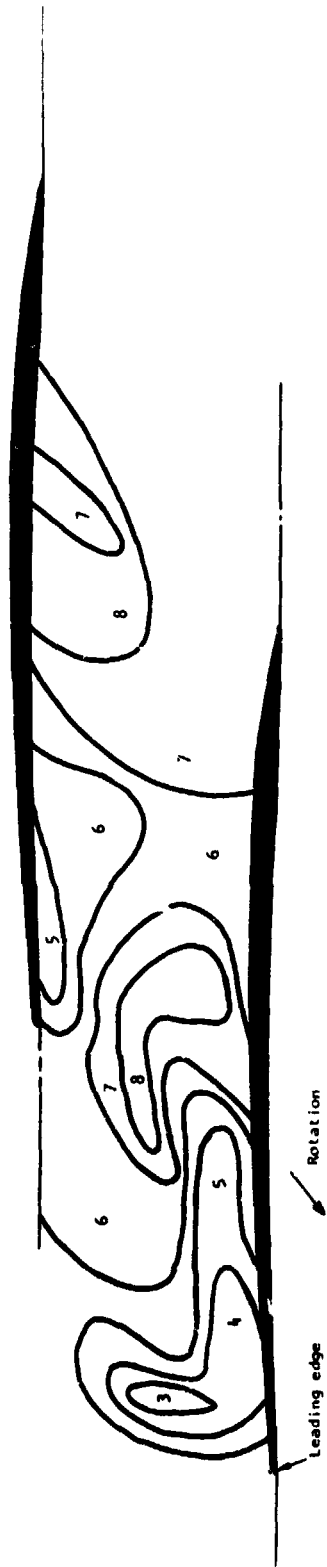
$$\frac{M/\delta}{M/\delta_{des}} = 0.869$$

$$P_{T12}/P_{T5} = 1.324$$

Contour number	Static pressure contour code	
	psf	N/cm ²
1	3 to 5	0.7 to 3.45
2	5 to 7	3.45 to 8.3
3	7 to 9	8.3 to 15.2
4	9 to 11	15.2 to 21.1
5	11 to 13	21.1 to 27.5
6	13 to 15	27.5 to 34.9
7	15 to 17	34.9 to 43.2
8	17 to 19	43.2 to 52.4
9	19 to 21	52.4 to 62.5
10	21 to 23	62.5 to 73.6
11	23 to 25	73.6 to 85.8

S-81376

Figure 27.--Rotor Blade Tip Static Pressure Contours, 80 Percent Design Speed, Pressure Ratio 1.324.



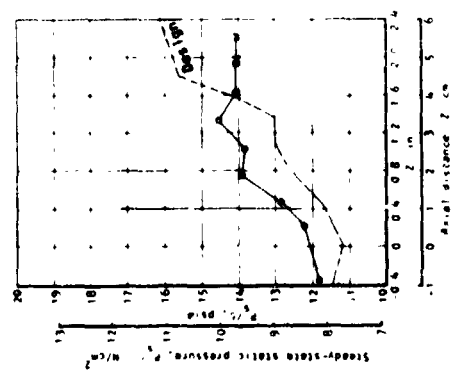
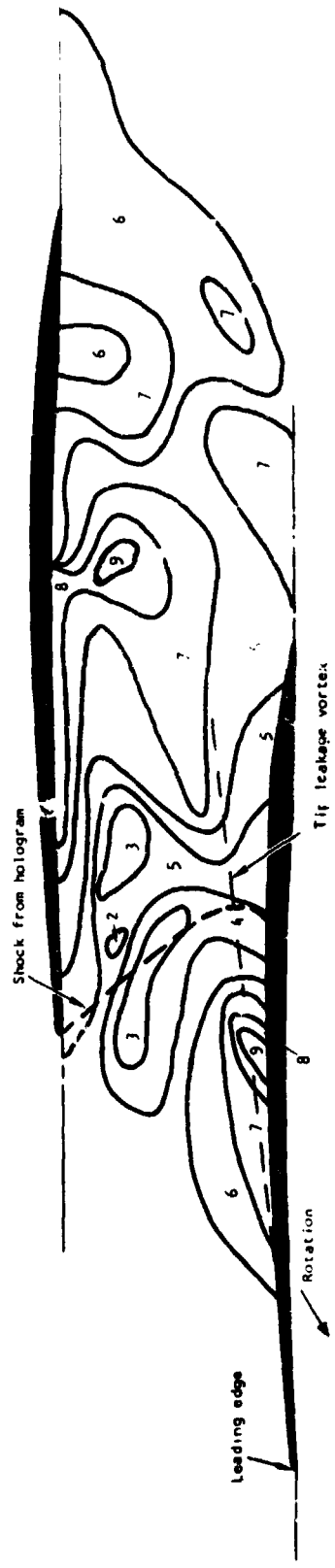
Reading 80

$$\frac{M/\sqrt{\theta}}{M/\sqrt{\theta}}_{\text{des}} = 0.80$$
$$\frac{M/\sqrt{\theta}}{M/\sqrt{\theta}}_{\text{des}} = 0.842$$
$$P_{112}/P_{15} = 1.371$$

Static pressure contour code		
Code number	Static pressure range	
	psia	N/cm ²
1	3 to 5	2.07 to 3.45
2	5 to 7	3.45 to 8.1
3	7 to 9	4.83 to 6.21
4	9 to 11	6.21 to 7.58
5	11 to 13	7.58 to 8.96
6	13 to 15	8.96 to 10.34
7	15 to 17	10.34 to 11.72
8	17 to 19	11.72 to 13.10
9	19 to 21	13.10 to 14.48
10	21 to 23	14.48 to 15.86
11	23 to 25	15.86 to 17.24

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Figure 28.--Rotor Blade Tip Static Pressure Contours, 80 Percent Design Speed, Pressure Ratio 1.371.



Reading 103

$$\frac{N/\delta}{N/\delta_{des}} = 0.90$$

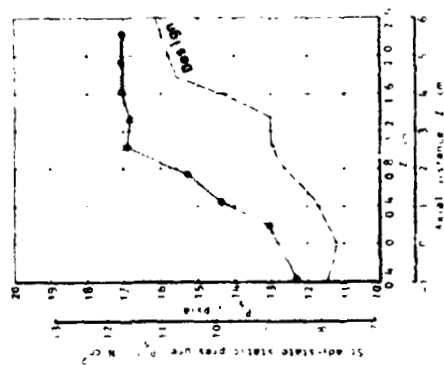
$$\frac{N/\delta}{N/\delta_{des}} = 0.984$$

$$P_{112}/P_{T5} = 1.320$$

Code number	Static pressure contour code	
	Static pressure range	Static pressure range
1	3 to 5	2.07 to 3.45
2	5 to 7	3.45 to 4.83
3	7 to 9	4.83 to 6.21
4	9 to 11	6.21 to 7.59
5	11 to 13	7.59 to 8.96
6	13 to 15	8.96 to 10.34
7	15 to 17	10.34 to 11.72
8	17 to 19	11.72 to 13.10
9	19 to 21	13.10 to 14.48
10	21 to 23	14.48 to 15.86
11	23 to 25	15.86 to 17.24

Figure 29.--Rotor Blade Tip Static Pressure Contours, 10 Percent Design Speed, Pressure Ratio 1.320.

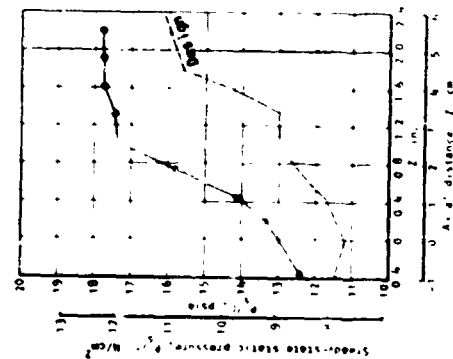
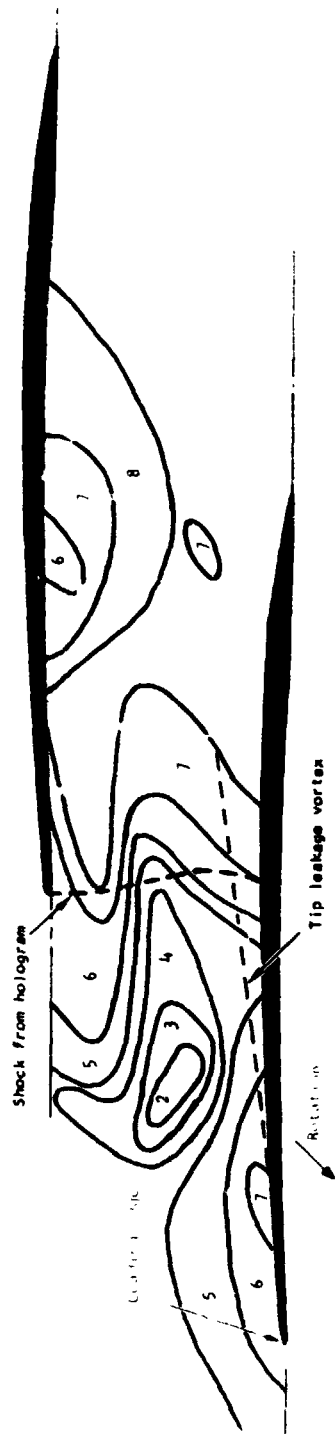
S-81p80



$Q_{\text{reading}} = 101$
 $\frac{N}{N_{\text{des}}} = \dots$
 $\frac{N}{N_{\text{des}}} = 0.57$
 $P_{T12}/P_{T5} = 1.479$

Code number	Static pressure contour lines	
	Static pressure range	N/cm ²
1	3 to 5	2.01 to 3.45
2	5 to 7	3.45 to 4.83
3	7 to 9	4.83 to 7.1
4	9 to 11	7.1 to 9.58
5	11 to 13	9.58 to 12.96
6	13 to 15	12.96 to 17.34
7	15 to 17	17.34 to 21.72
8	17 to 19	21.72 to 26.1
9	19 to 21	26.1 to 30.48
10	21 to 23	30.48 to 34.86
11	23 to 25	34.86 to 39.24

Figure 30.--Rotor Blade Tip Static Pressure Contours, 90 Percent Design Speed, Pressure Ratio 1.479.

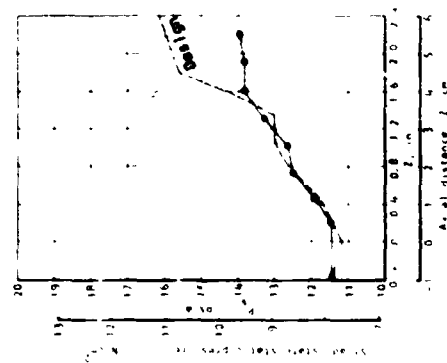
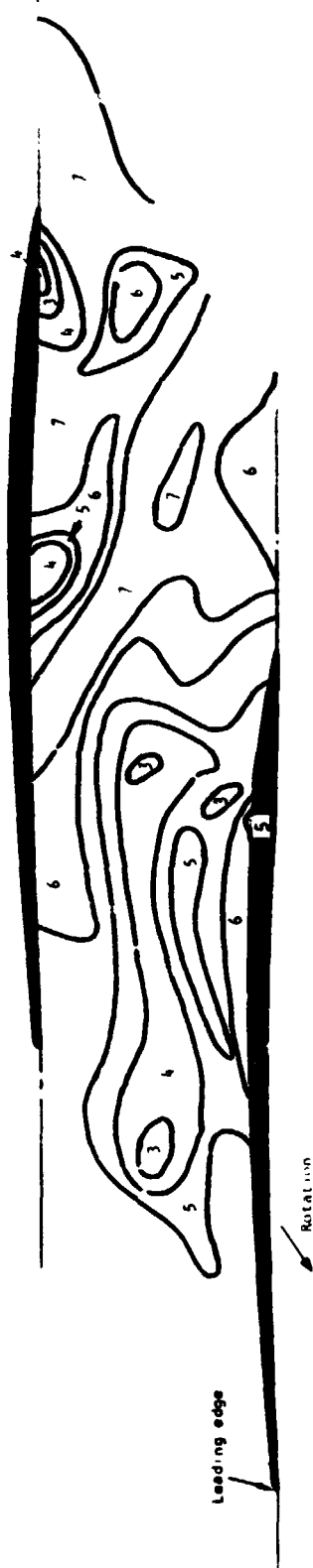


Reading	106
$\frac{M\sqrt{\rho}}{M_0\sqrt{\rho_0}}_{des}$	0.710
$\frac{M\sqrt{\rho}}{M_0\sqrt{\rho_0}}_{des}$	0.742
$P_{T12} P_{T5}$	1.5 +

Code number	Static pressure contour line	
	Static pressure range	Value
1	3 to 5	2.01 to 3.45
2	5 to 7	3.5 to 4.83
3	7 to 9	4.83 to 6.21
4	9 to 11	6.21 to 7.58
5	11 to 13	7.58 to 8.96
6	13 to 15	8.96 to 10.34
7	15 to 17	10.34 to 11.72
8	17 to 19	11.72 to 13.10
9	19 to 21	13.10 to 14.48
10	21 to 23	14.48 to 15.86
11	23 to 25	15.86 to 17.24

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Figure 31.--Rotor Blade Tip Static Pressure Contours, 90 Percent Design Speed, Pressure Ratio 1.524.



Reading 104

$$\frac{M\sqrt{\rho}}{W\sqrt{\rho_{des}}} = 0.95$$

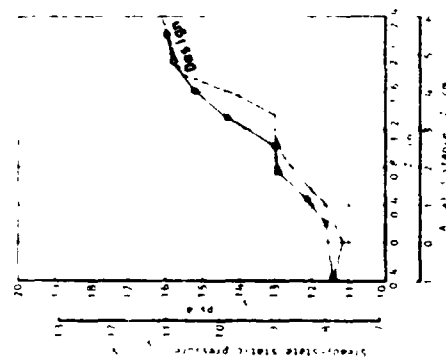
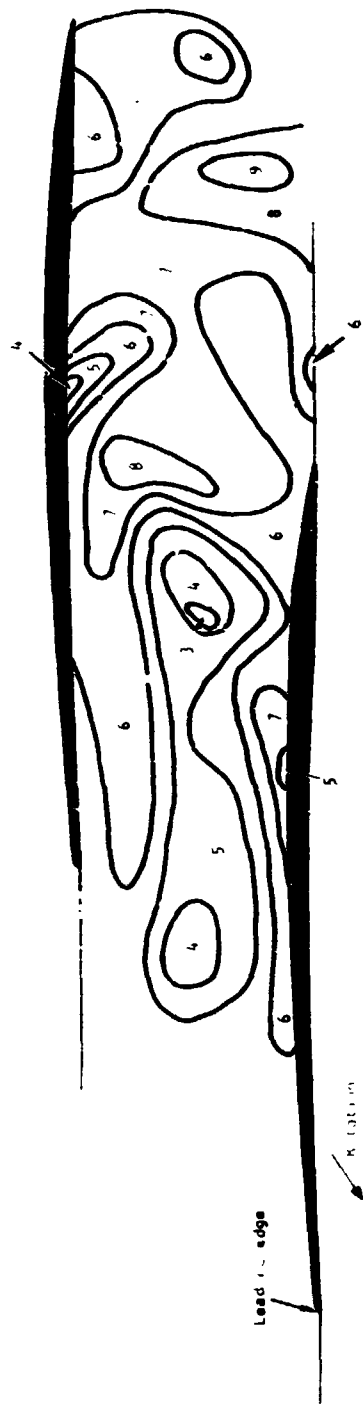
$$\frac{M\sqrt{\rho}}{W\sqrt{\rho_{des}}} = 1.019$$

$$P_{T12}/P_{T5} = 1.348$$

Cont. number	Static pressure contour, mm	
	Static pressure, range	W/10 ³
1	3 to 5	2.27 to 3.45
2	5 to 7	3.45 to 4.81
3	7 to 9	4.81 to 6.21
4	9 to 11	6.21 to 7.68
5	11 to 13	7.68 to 9.34
6	13 to 15	9.34 to 10.34
7	15 to 17	10.34 to 11.7
8	17 to 19	11.7 to 13.1
9	19 to 21	13.1 to 14.8
10	21 to 23	14.8 to 16.5
11	23 to 25	16.5 to 18.1

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Figure 32.--Rotor Blade Tip Static Pressure Contours, 95 Percent Design Speed, Pressure Ratio 1.348.

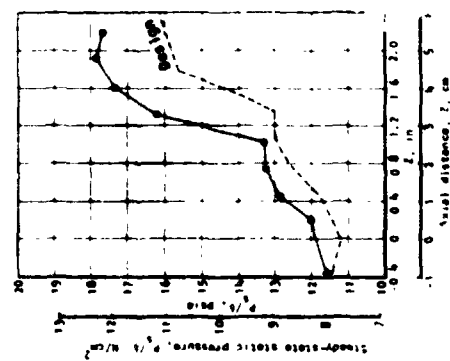
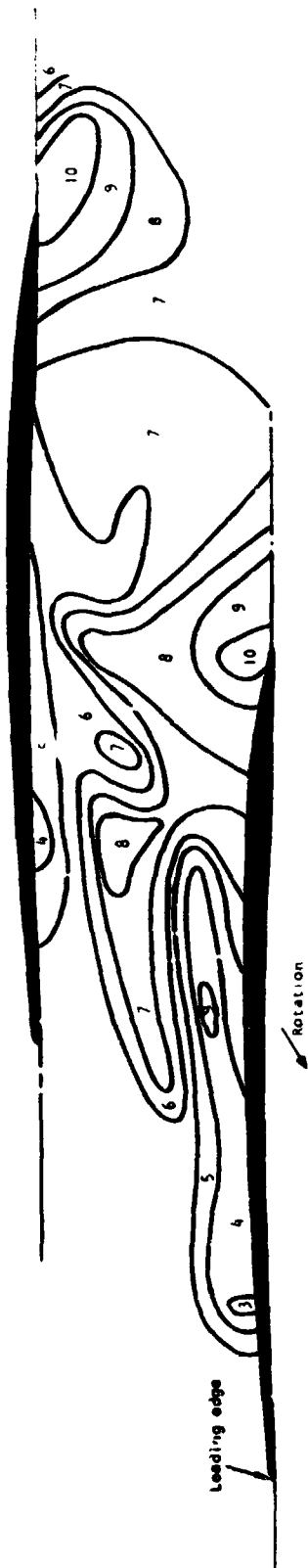


Reading	105
$\frac{N}{N_{des}}$	0.95
$\frac{N}{N_{des}}$	1.016
$\frac{P_{112}}{P_{15}}$	1.449

Code number	Static pressure, p	
	p, in	p, in
1	1.005	1.005
2	1.017	1.017
3	1.029	1.029
4	1.041	1.041
5	1.053	1.053
6	1.065	1.065
7	1.077	1.077
8	1.089	1.089
9	1.101	1.101
10	1.113	1.113
11	1.125	1.125

S-81882

Figure 33.--Rotor Blade Tip Static Pressure Contours, 95 Percent Design Speed, Pressure Ratio 1.449.



Reading 117

$$\frac{M_{\infty}^2}{M_{\infty}^2} \frac{\rho}{\rho_{\infty}} = 0.95$$

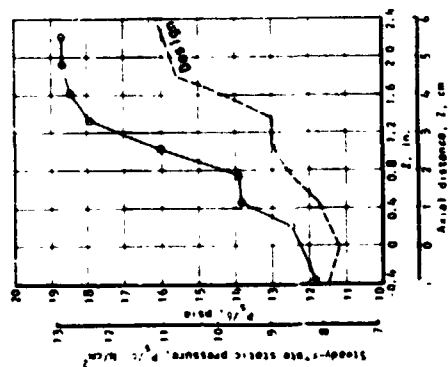
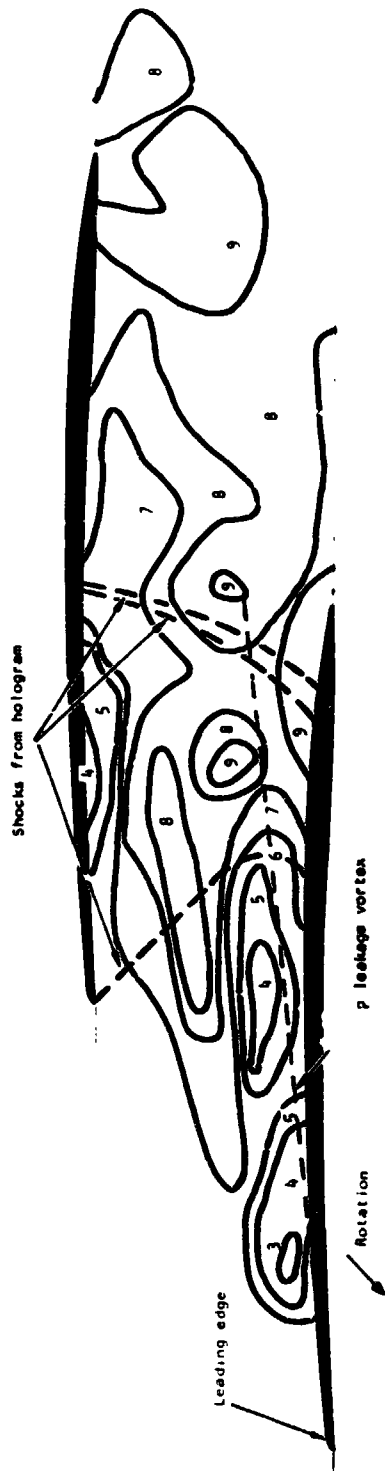
$$\frac{M_{\infty}^2}{M_{\infty}^2} \frac{\rho}{\rho_{\infty}} = 1.008$$

$$P_{T12}/P_{T5} = 1.540$$

Code Number	Static pressure contour code	
	Static pressure range	g/cm ²
1	3 to 5	2.07 to 3.45
2	5 to 7	3.45 to 4.83
3	7 to 9	4.83 to 6.21
4	9 to 11	6.21 to 7.58
5	11 to 13	7.58 to 8.96
6	13 to 15	8.96 to 10.34
7	15 to 17	10.34 to 11.72
8	17 to 19	11.72 to 13.10
9	19 to 21	13.10 to 14.48
10	21 to 23	14.48 to 15.86
11	23 to 25	15.86 to 17.24

S-81883

Figure 34.--Rotor Blade Tip Static Pressure Contour Plot
Speed, Pressure Ratio 1.540.



Reading 118

$$\frac{M_{\infty}^2}{M_{\infty}^2} = 0.95$$

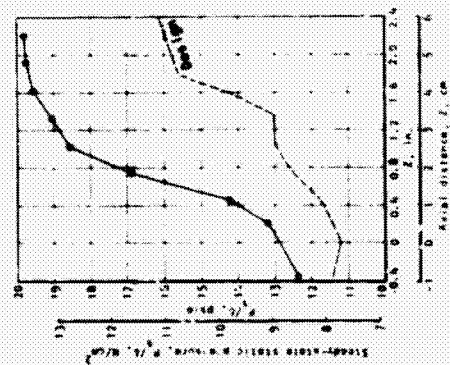
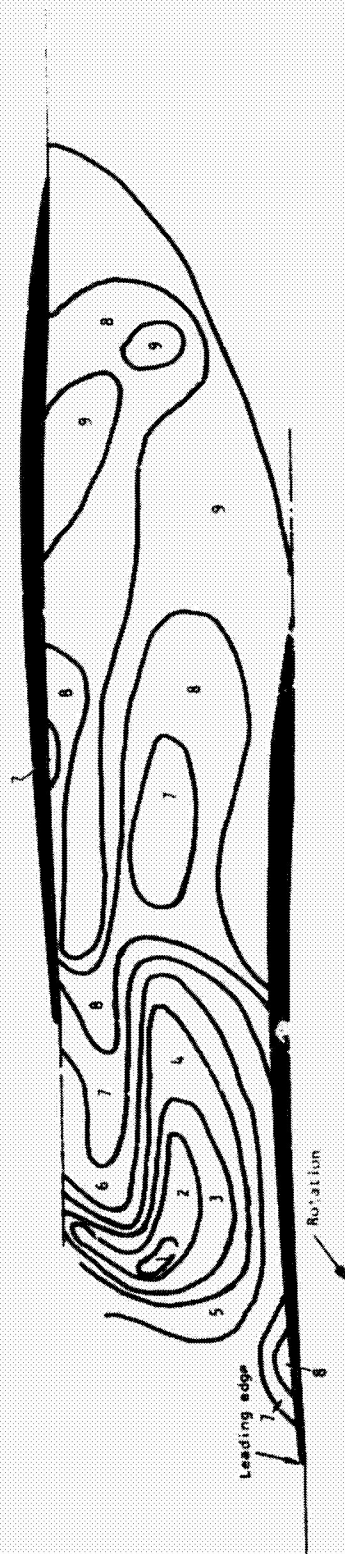
$$\frac{M_{\infty}^2}{M_{\infty}^2} = 0.995$$

$$P_{s12}/P_{s15} = 1.604$$

Code number	Static pressure contour code	
	psia	in. Hg
1	3 to 5	2.07 to 3.45
2	5 to 7	3.45 to 4.83
3	7 to 9	4.83 to 6.21
4	9 to 11	6.21 to 7.58
5	11 to 13	7.58 to 8.96
6	13 to 15	8.96 to 10.34
7	15 to 17	10.34 to 11.72
8	17 to 19	11.72 to 13.10
9	19 to 21	13.10 to 14.48
10	21 to 23	14.48 to 15.86
11	23 to 25	15.86 to 17.24

Figure 35.--Rotor Blade Tip Static Pressure Contours, 95 Percent Design Speed, Pressure Ratio 1.604.

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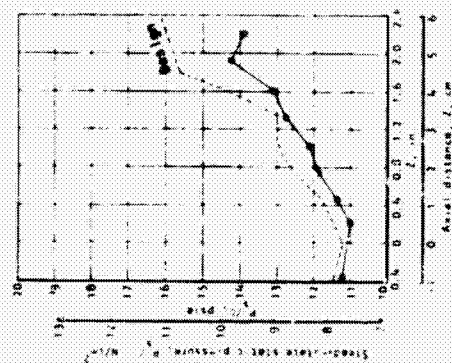
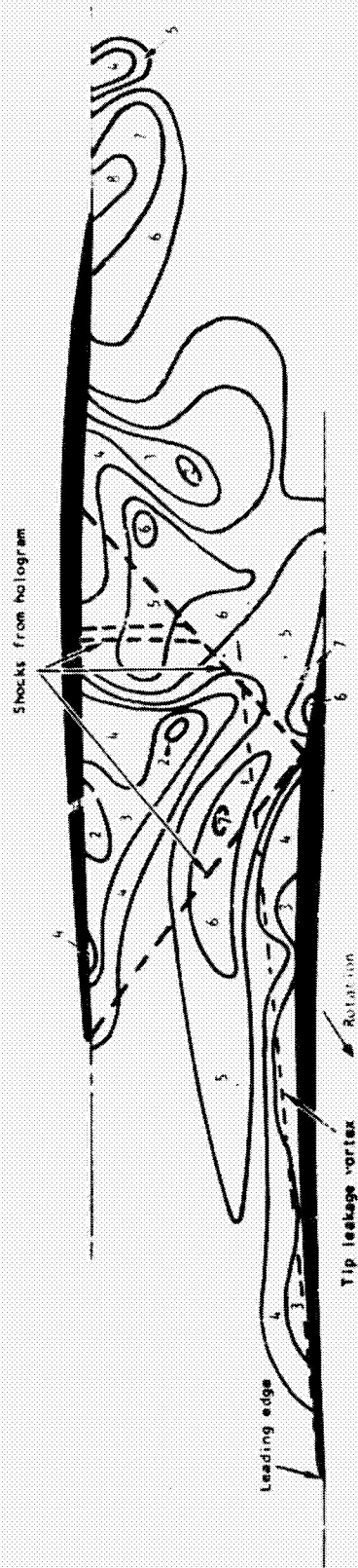


Reading	119
$\frac{M_0}{M_\infty} \frac{P_0}{P_\infty}$	0.95
$\frac{M_0}{M_\infty} \frac{P_0}{P_\infty}$	0.952
P_{T12}/P_{T5}	1.656

Code number	Static pressure contour line	
	Static pressure range	h/m
1	1 to 5	2.07 to 3.45
2	5 to 7	3.45 to 4.83
3	7 to 9	4.83 to 6.21
4	9 to 11	6.21 to 7.59
5	11 to 13	7.59 to 8.97
6	13 to 15	8.97 to 10.35
7	15 to 17	10.35 to 11.73
8	17 to 19	11.73 to 13.11
9	19 to 21	13.11 to 14.49
10	21 to 23	14.49 to 15.87
11	23 to 25	15.87 to 17.25

S-81884

Figure 36.--Rotor Blade Tip Static Pressure Contours, 95 Percent Design Speed, Pressure Ratio 1.656.



Reading 107

$$\frac{M_{\infty}^2}{M_{\infty}^2} = 1.00$$

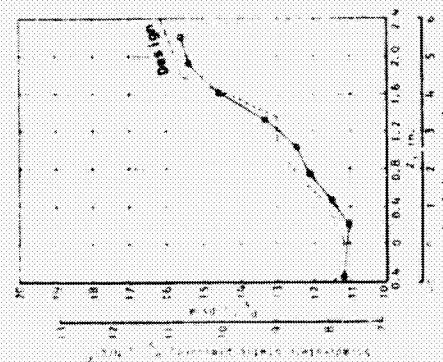
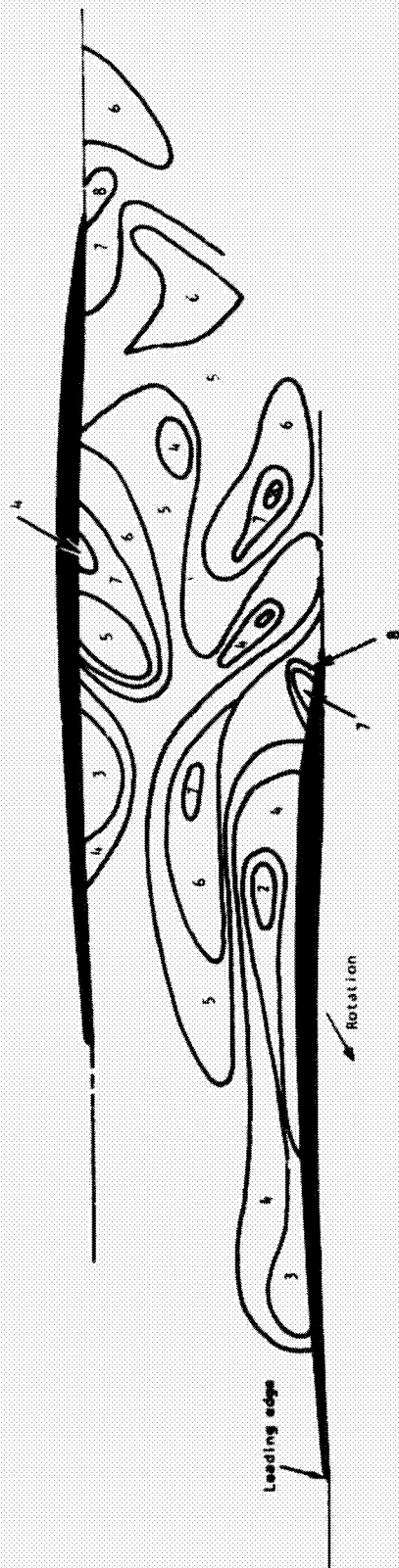
$$\frac{M_{\infty}^2}{M_{\infty}^2} = 1.040$$

$$P_{112}/P_{15} = 1.369$$

Cont. number	Static pressure range	
	psia	in. H ₂ O
1	3 to 5	2.07 to 3.45
2	5 to 7	3.45 to 4.83
3	7 to 9	4.83 to 6.21
4	9 to 11	6.21 to 7.58
5	11 to 13	7.58 to 8.96
6	13 to 15	8.96 to 10.34
7	15 to 17	10.34 to 11.72
8	17 to 19	11.72 to 13.10
9	19 to 21	13.10 to 14.48
10	21 to 23	14.48 to 15.86
11	23 to 25	15.86 to 17.24

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Figure 37.--Rotor Blade Tip Static Pressure Contours, Design Speed, Pressure Ratio 1.369.



Reading 108

$$\frac{N_{112}}{N_{112}^{\text{des}}} = 1.00$$

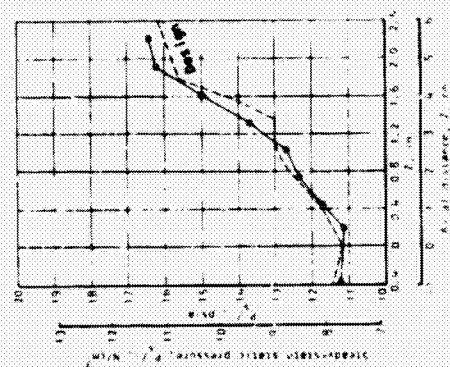
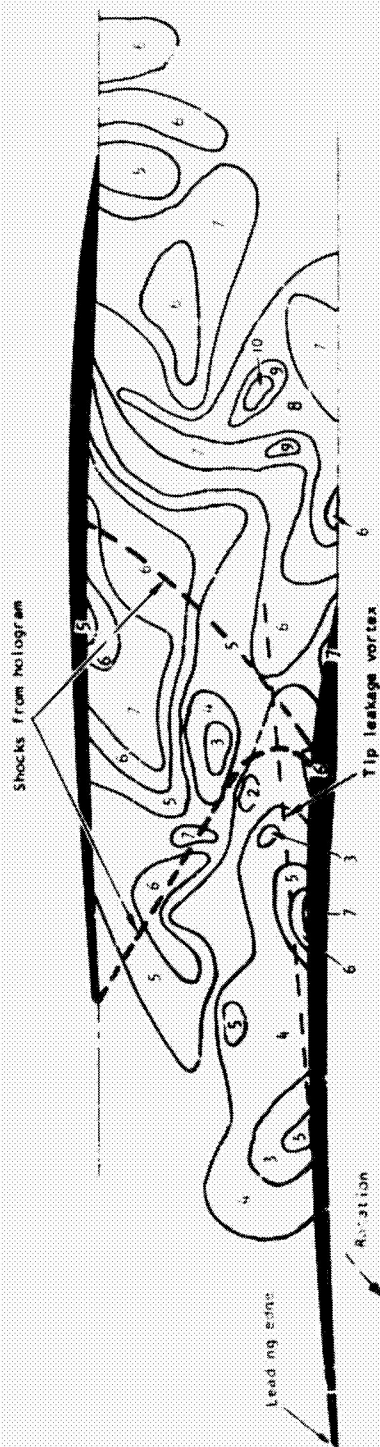
$$\frac{M_{112}}{M_{112}^{\text{des}}} = 1.044$$

$$P_{112}/P_{15} = 1.475$$

Code number	Static pressure range	
	psia	mm Hg
1	3 to 5	2.07 to 3.45
2	5 to 7	3.45 to 4.84
3	7 to 9	4.84 to 6.23
4	9 to 11	6.23 to 7.62
5	11 to 13	7.62 to 9.01
6	13 to 15	9.01 to 10.40
7	15 to 17	10.40 to 11.79
8	17 to 19	11.79 to 13.18
9	19 to 21	13.18 to 14.57
10	21 to 23	14.57 to 15.96
11	23 to 25	15.96 to 17.35

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Figure 38.--Rotor Blade Tip Static Pressure Contours, Design Speed, Pressure Ratio 1.475.



Reading 128

$$\frac{M/\sqrt{\theta}}{M/\sqrt{\theta}}_{\text{des}} = 1.00$$

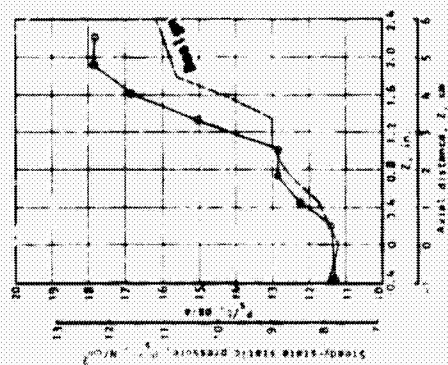
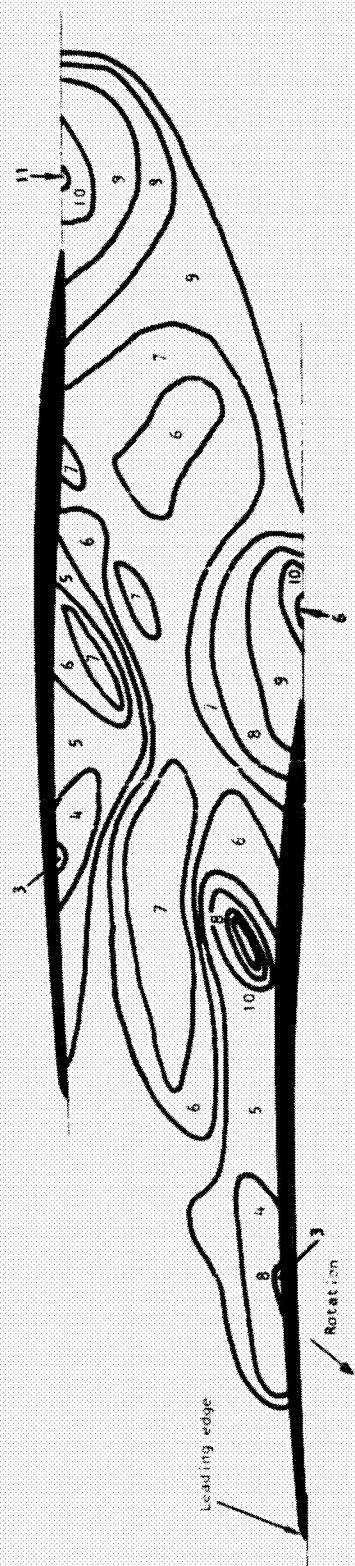
$$\frac{M/\sqrt{\theta}}{M/\sqrt{\theta}}_{\text{des}} = 1.041$$

$$P_{T12}/P_{T5} = 1.505$$

Code number	Static pressure contour map	
	Static pressure range	Static pressure range
1	3.40-5	2.07 to 3.40
2	5.10-7	3.40 to 5.10
3	7.10-9	5.10 to 7.10
4	9.10-11	7.10 to 9.10
5	11.10-13	9.10 to 11.10
6	13.10-15	11.10 to 13.10
7	15.10-17	13.10 to 15.10
8	17.10-19	15.10 to 17.10
9	19.10-21	17.10 to 19.10
10	21.10-23	19.10 to 21.10
11	23.10-25	21.10 to 23.10

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Figure 39.--Rotor Blade Tip Static Pressure Contours, Design Speed, Pressure Ratio 1.505.



Reading 125

$$\frac{M/\delta}{M/\delta_{des}} = 1.00$$

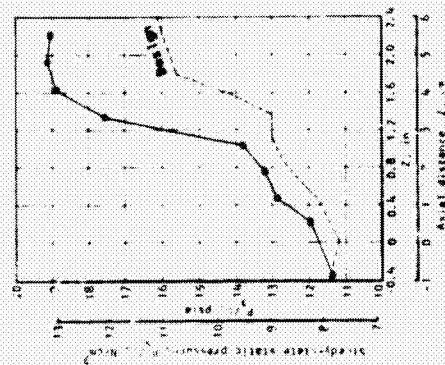
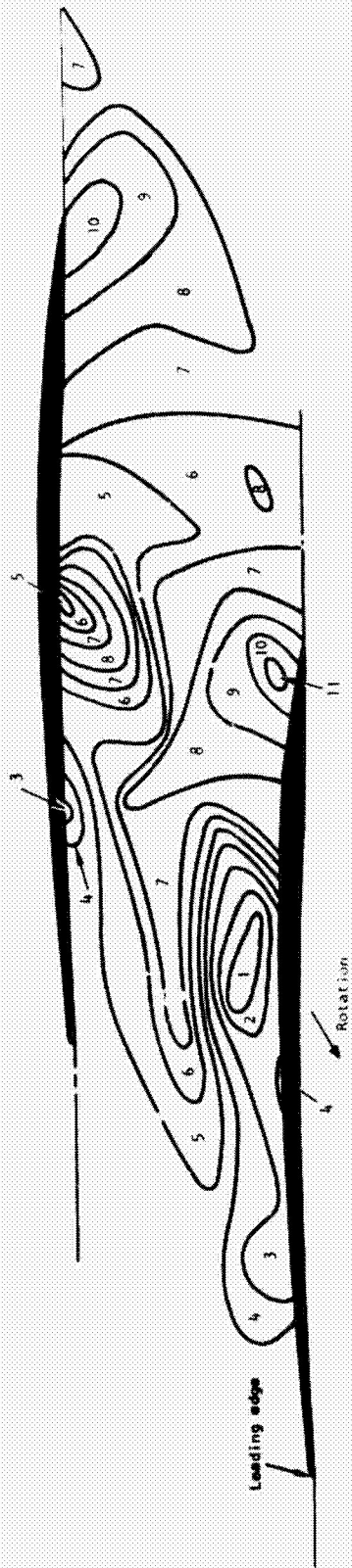
$$\frac{M/\delta}{M/\delta_{des}} = 1.035$$

$$P_{T12}/P_{T5} = 1.673$$

Code number	Static pressure contour code	
	psi-a	N/cm ²
1	3 to 5	2.07 to 3.45
2	5 to 7	3.45 to 4.83
3	7 to 9	4.83 to 6.21
4	9 to 11	6.21 to 7.58
5	11 to 13	7.58 to 8.96
6	13 to 15	8.96 to 10.34
7	15 to 17	10.34 to 11.72
8	17 to 19	11.72 to 13.10
9	19 to 21	13.10 to 14.48
10	21 to 23	14.48 to 15.86
11	23 to 25	15.86 to 17.24

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Figure 40.--Rotor Blade Tip Static Pressure Contours, Design Speed, Pressure Ratio 1.623.



Reading 126

$$\frac{M\sqrt{\rho}}{N\sqrt{\rho}}_{des} = 1.00$$

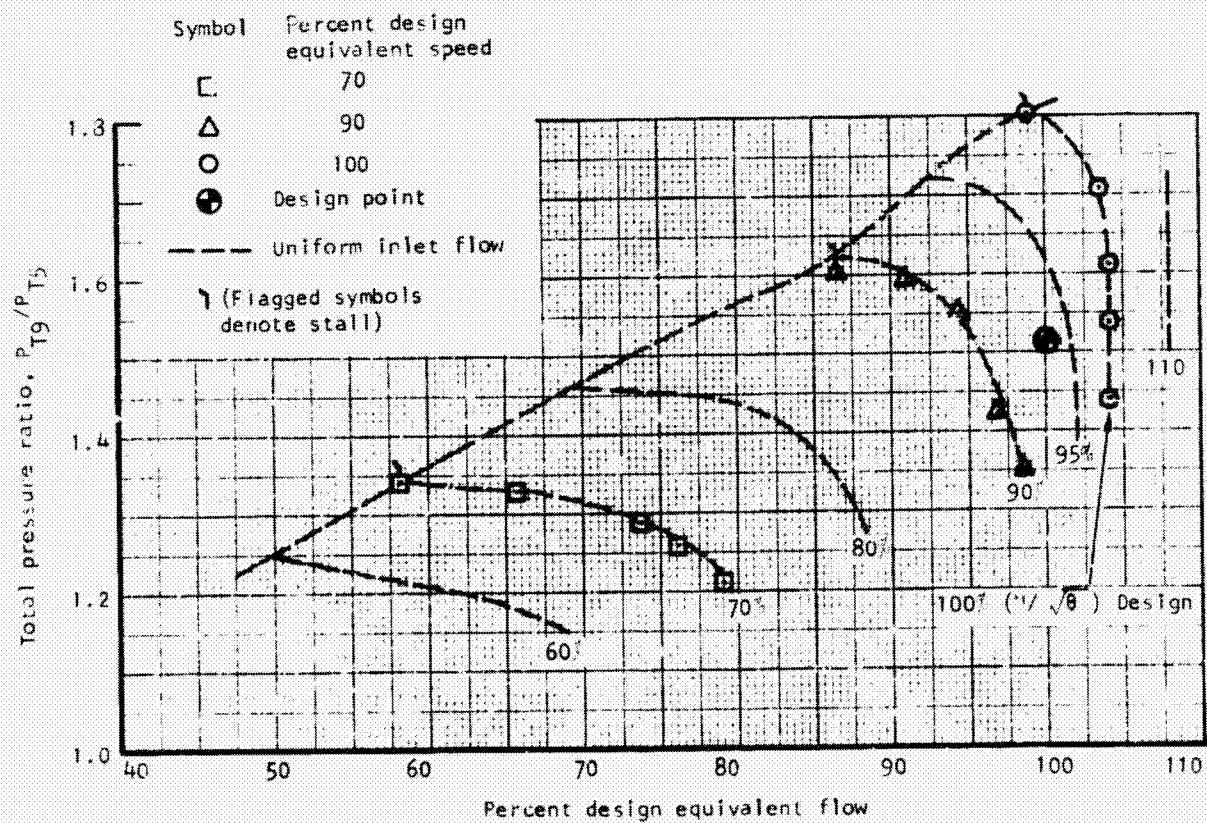
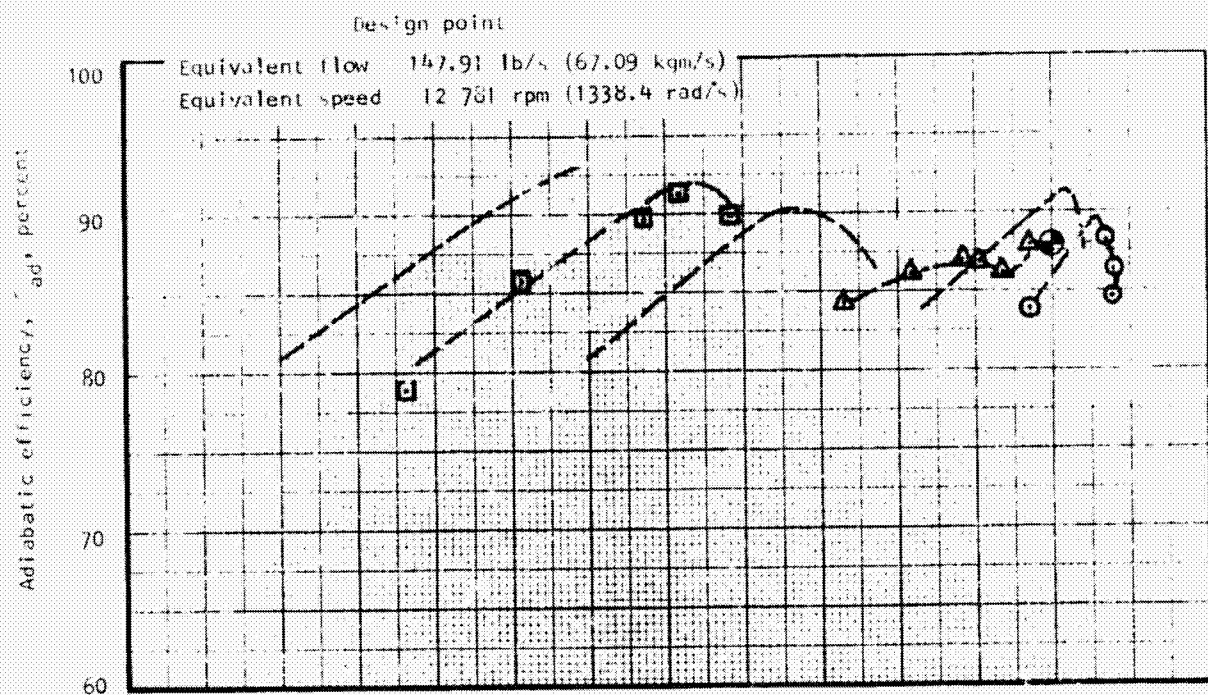
$$\frac{M\sqrt{\rho}}{N\sqrt{\rho}}_{des} = 1.031$$

$$P_{T12}/P_{T5} = 1.669$$

Cont. number	Static pressure contour code	
	Static pressure range	psi
1	3 to 5	1.07 to 3.45
2	5 to 7	3.45 to 4.81
3	7 to 9	4.81 to 6.21
4	9 to 11	6.21 to 7.58
5	11 to 13	7.58 to 8.96
6	13 to 15	8.96 to 10.34
7	15 to 17	10.34 to 11.72
8	17 to 19	11.72 to 13.10
9	19 to 21	13.10 to 14.48
10	21 to 23	14.48 to 15.86
11	23 to 25	15.86 to 17.24

S-8188c

Figure 41.--Rotor Blade Tip Static Pressure Contours, Design Speed, Pressure Ratio 1.669.



S-81149

Figure 42.--Rotor Performance, Predistortion Baseline.

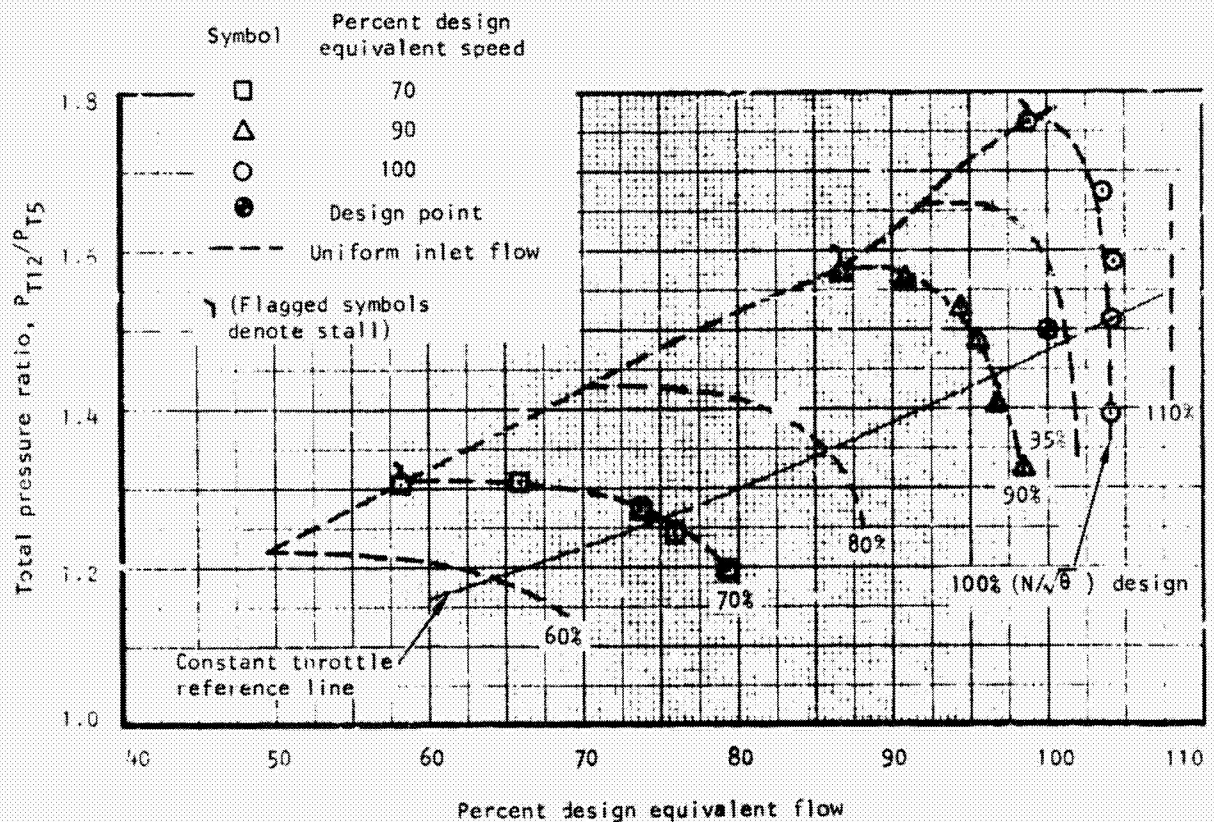
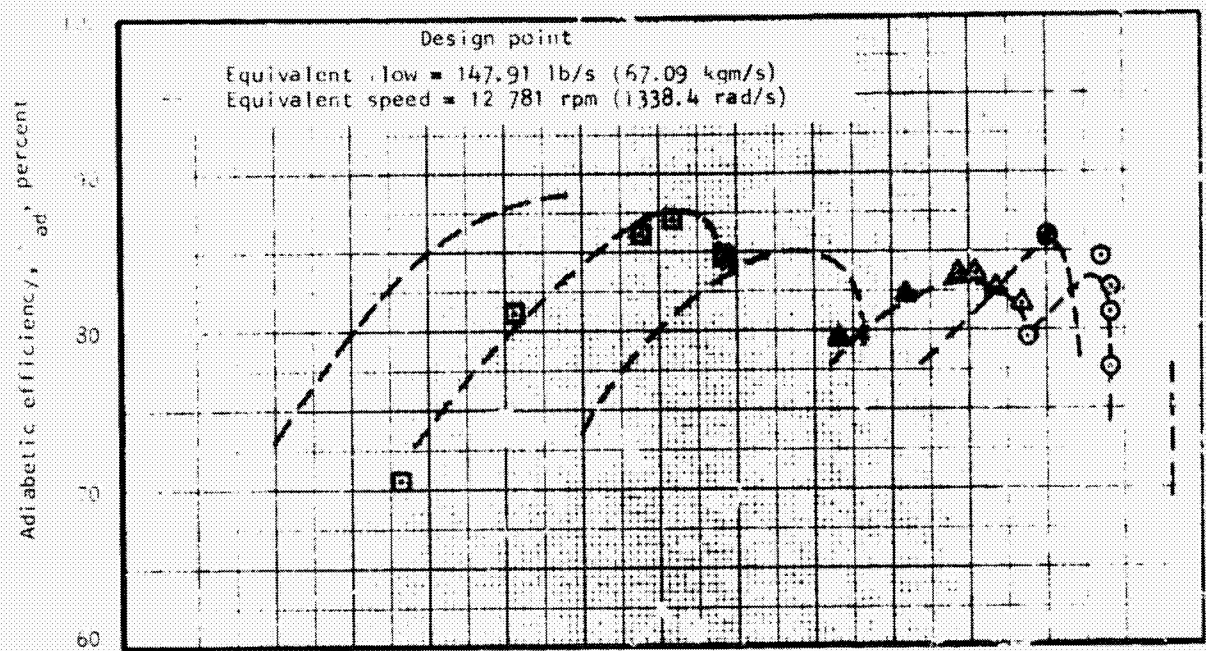


Figure 43.--Stage Performance, Predistortion Baseline.

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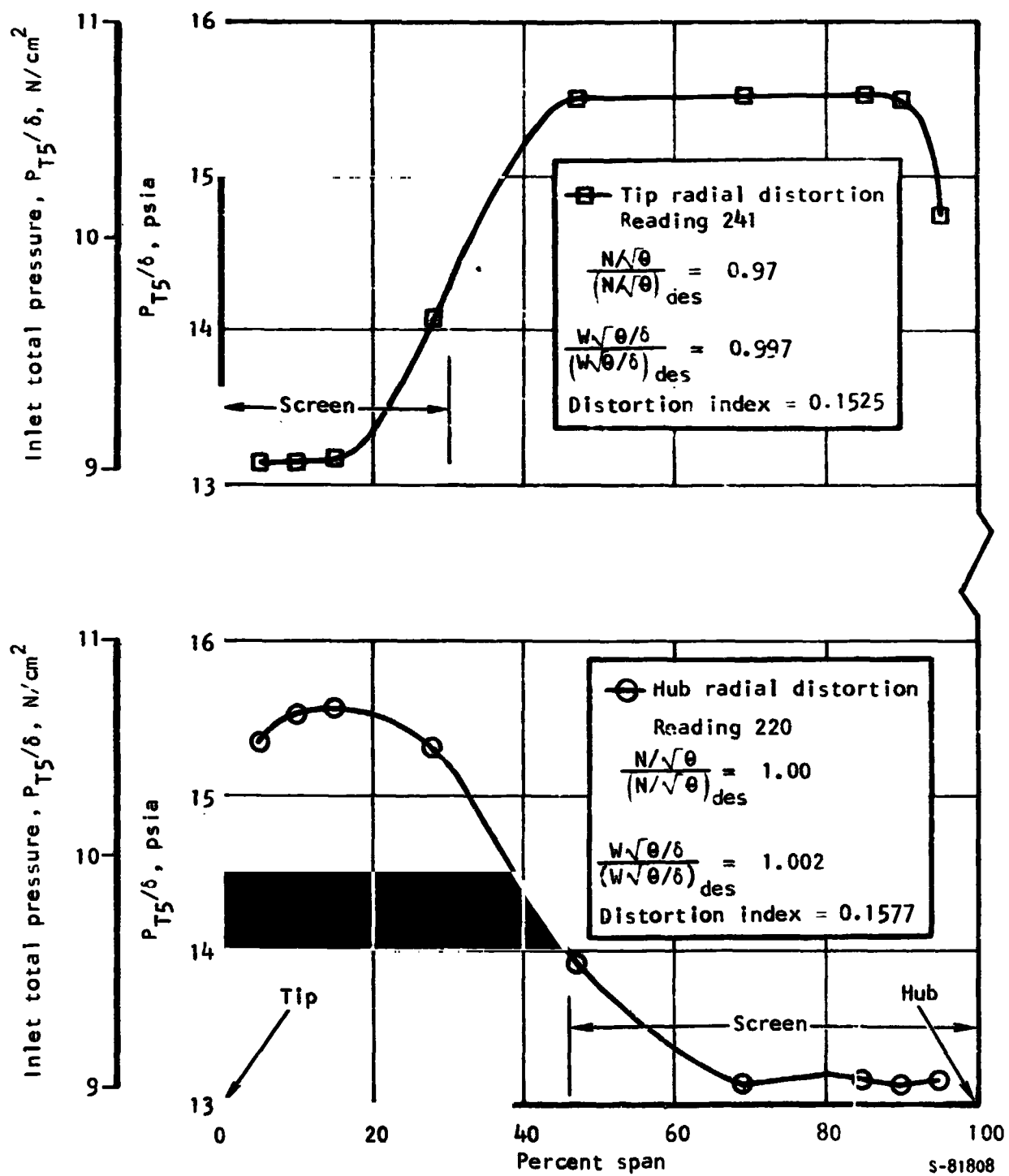
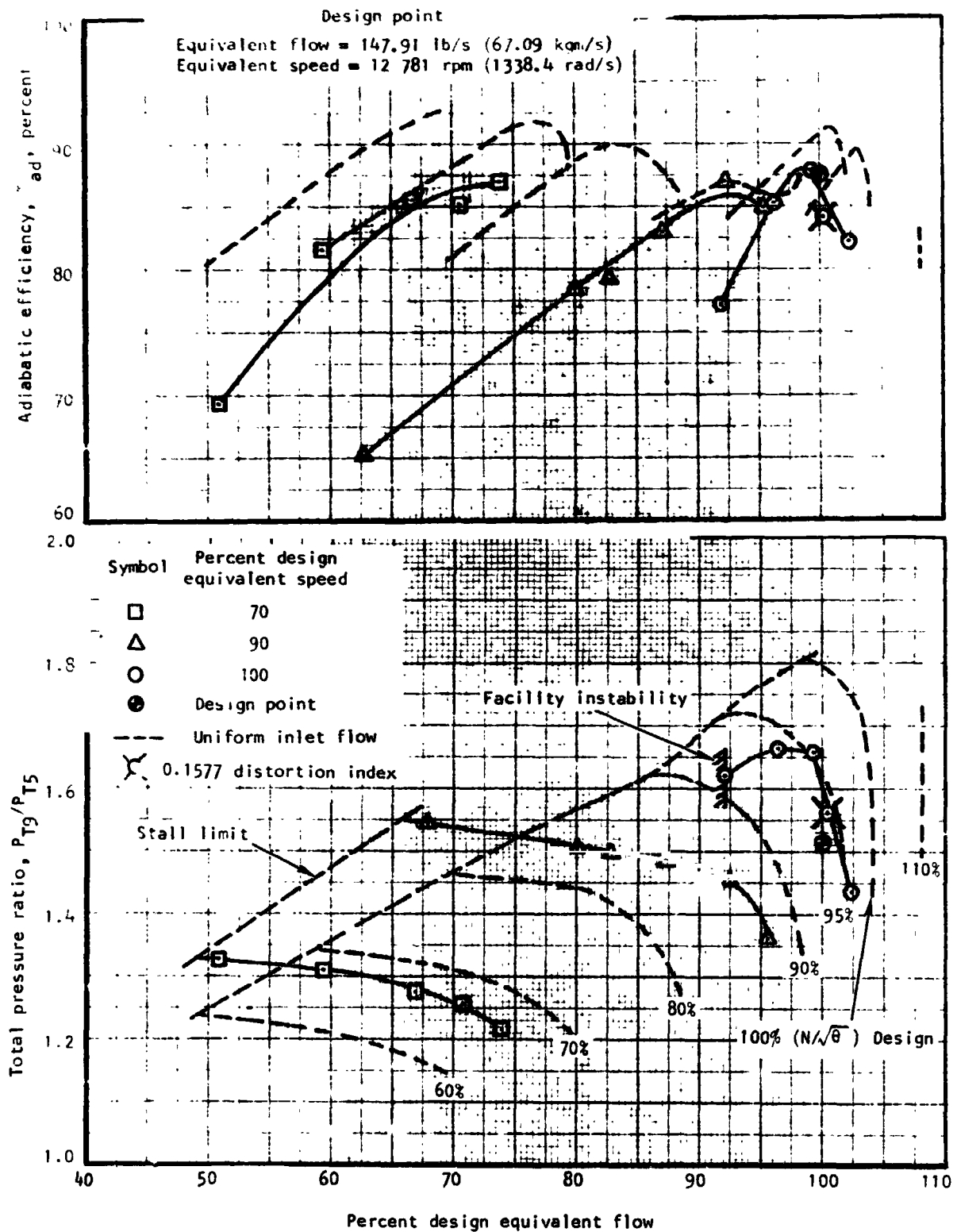


Figure 44.--Radial Distortion Total Pressure Profiles for Design Equivalent Flow.



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Figure 45.--Rotor Performance, Hub-Radial Distortion.

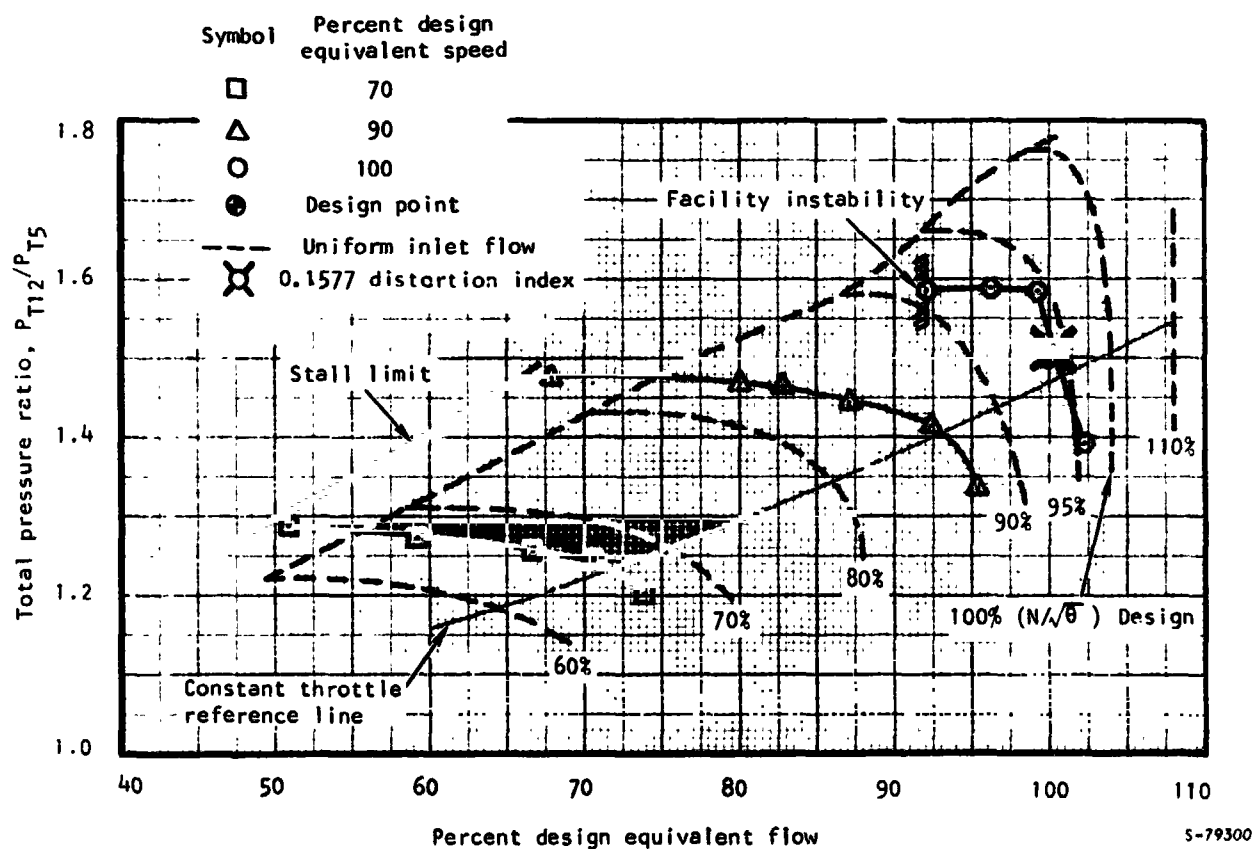
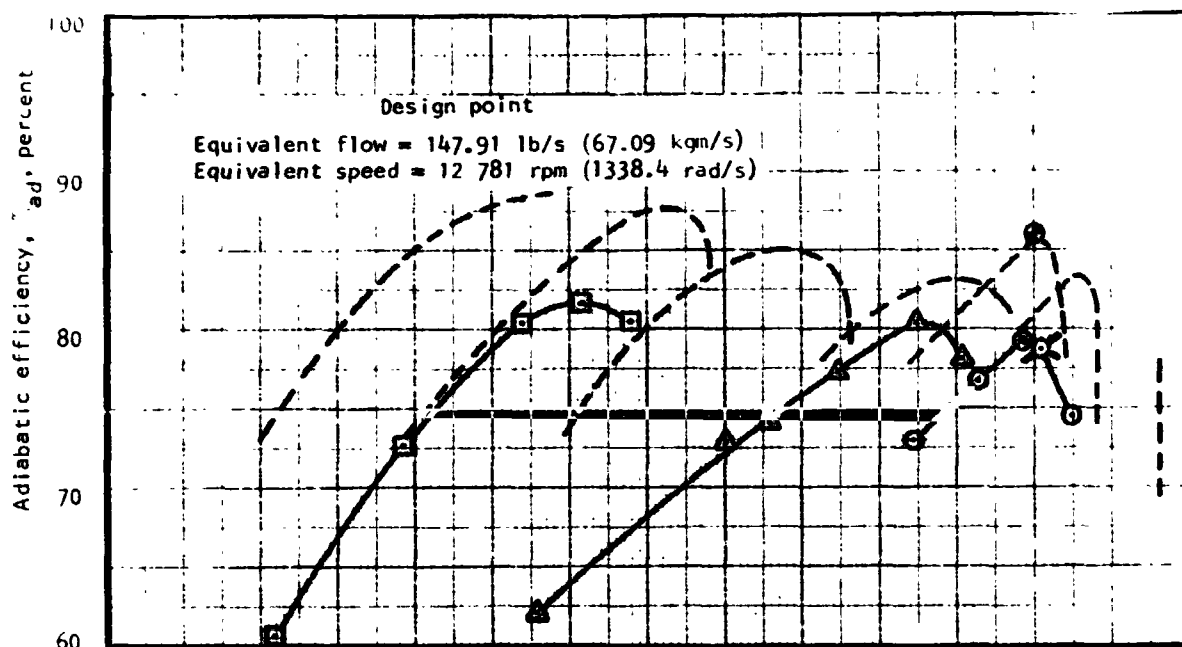
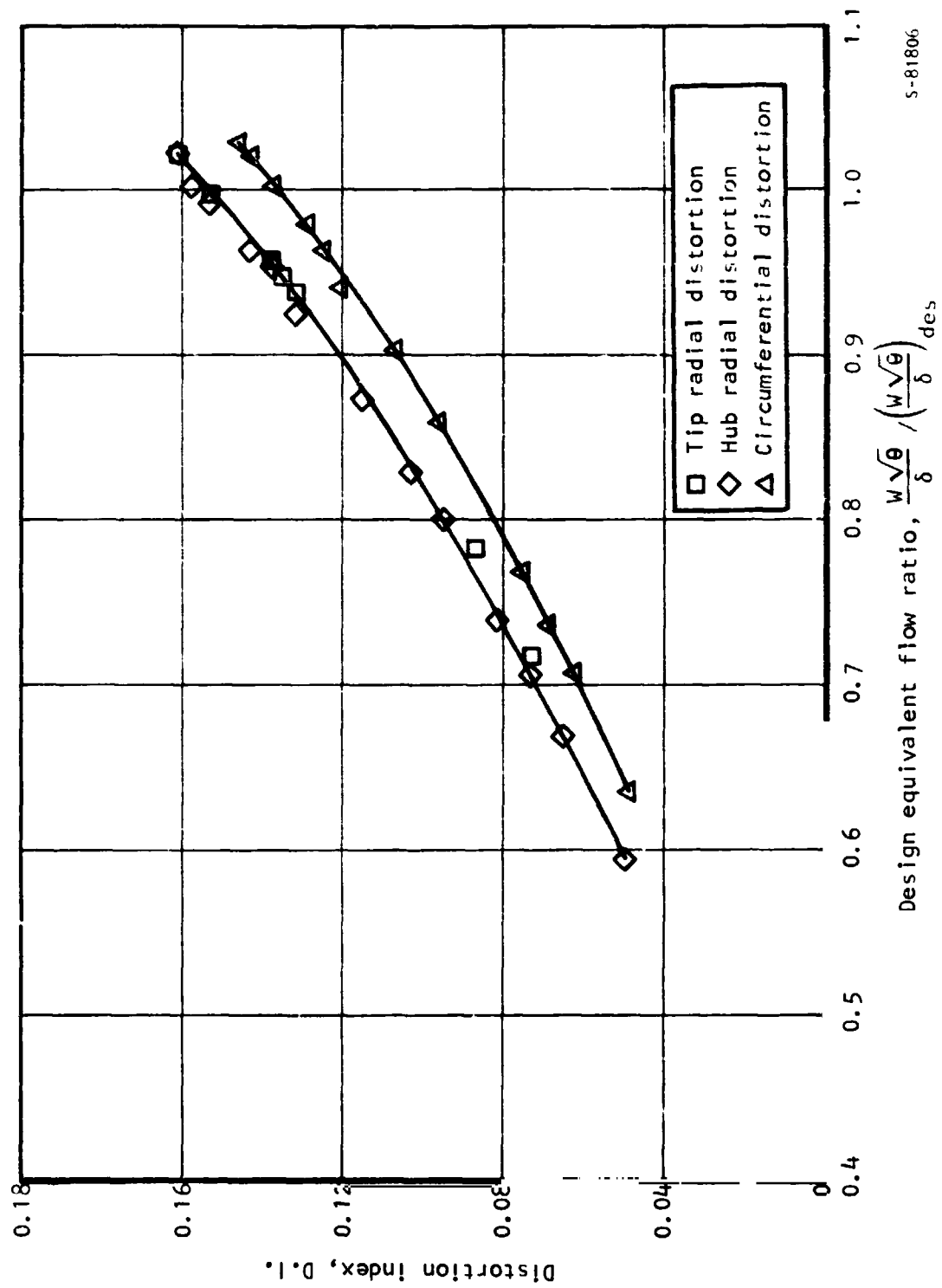


Figure 46.--Stage Performance, Hub-Radial Distortion.



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Figure 47.--Distortion Index vs Design Equivalent Flow Ratio.

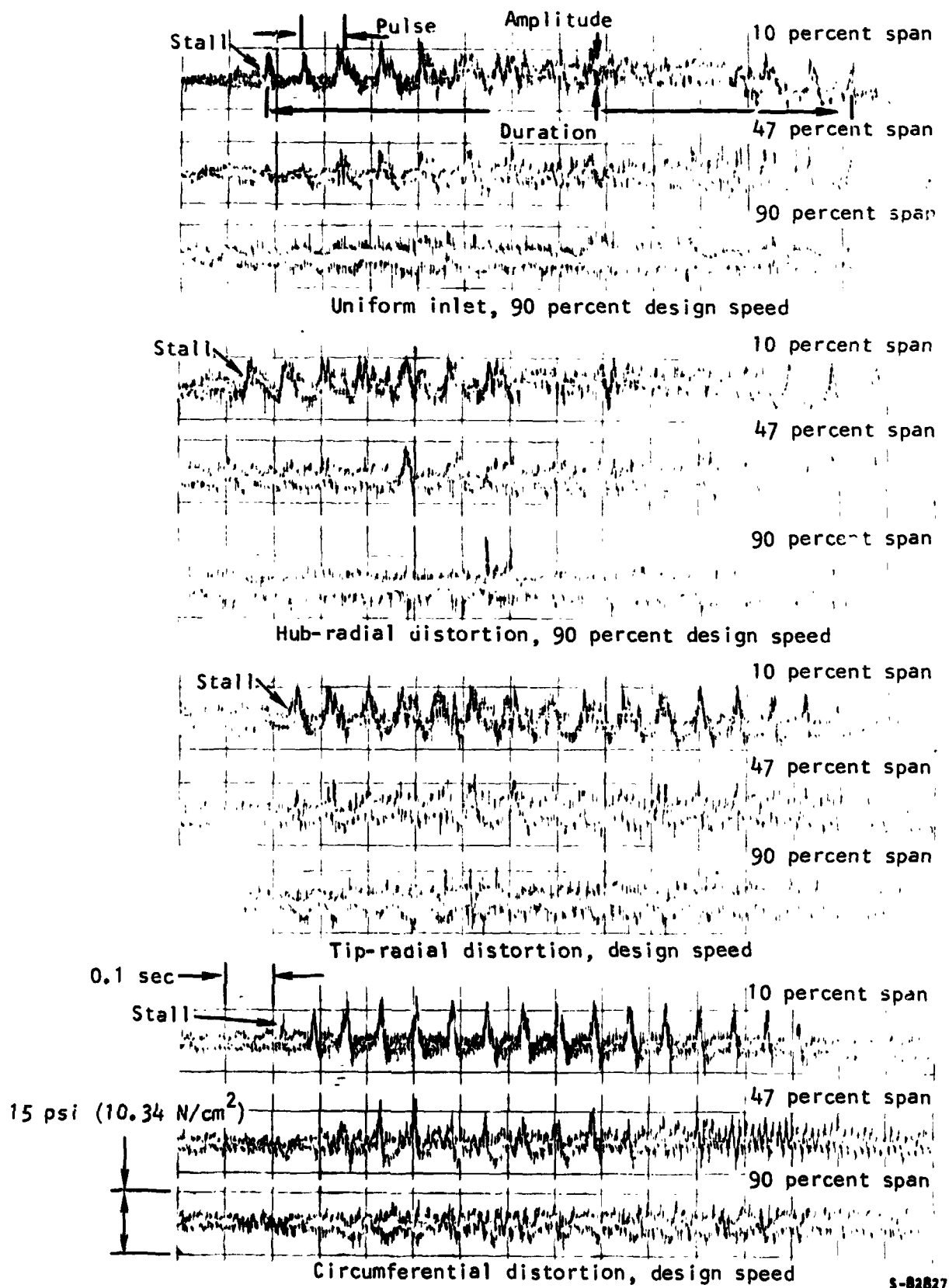


Figure 48.--Distorted Inlet Flow Stall Oscillograph Traces.

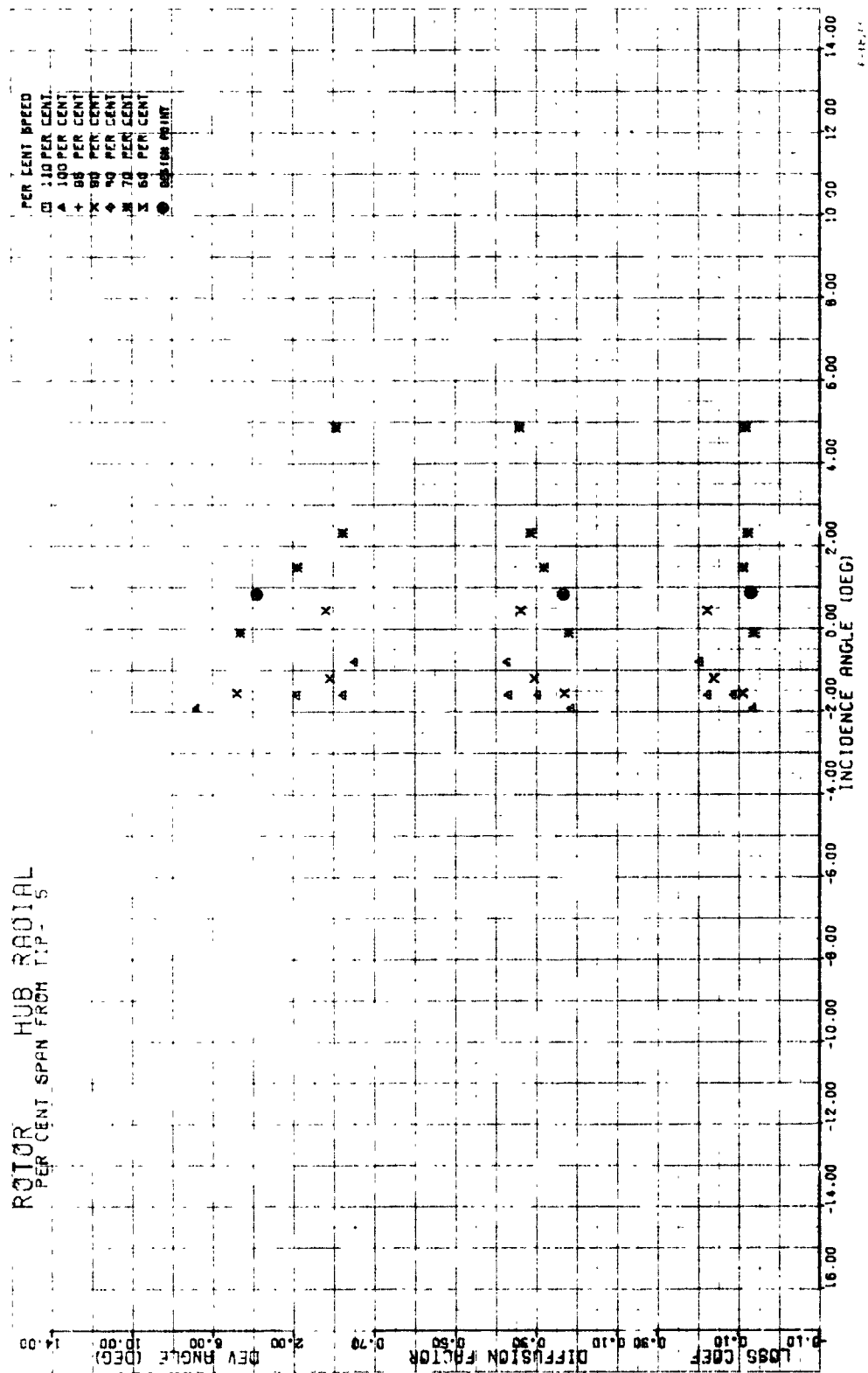


Figure 49a.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 5 Percent Span from Tip.

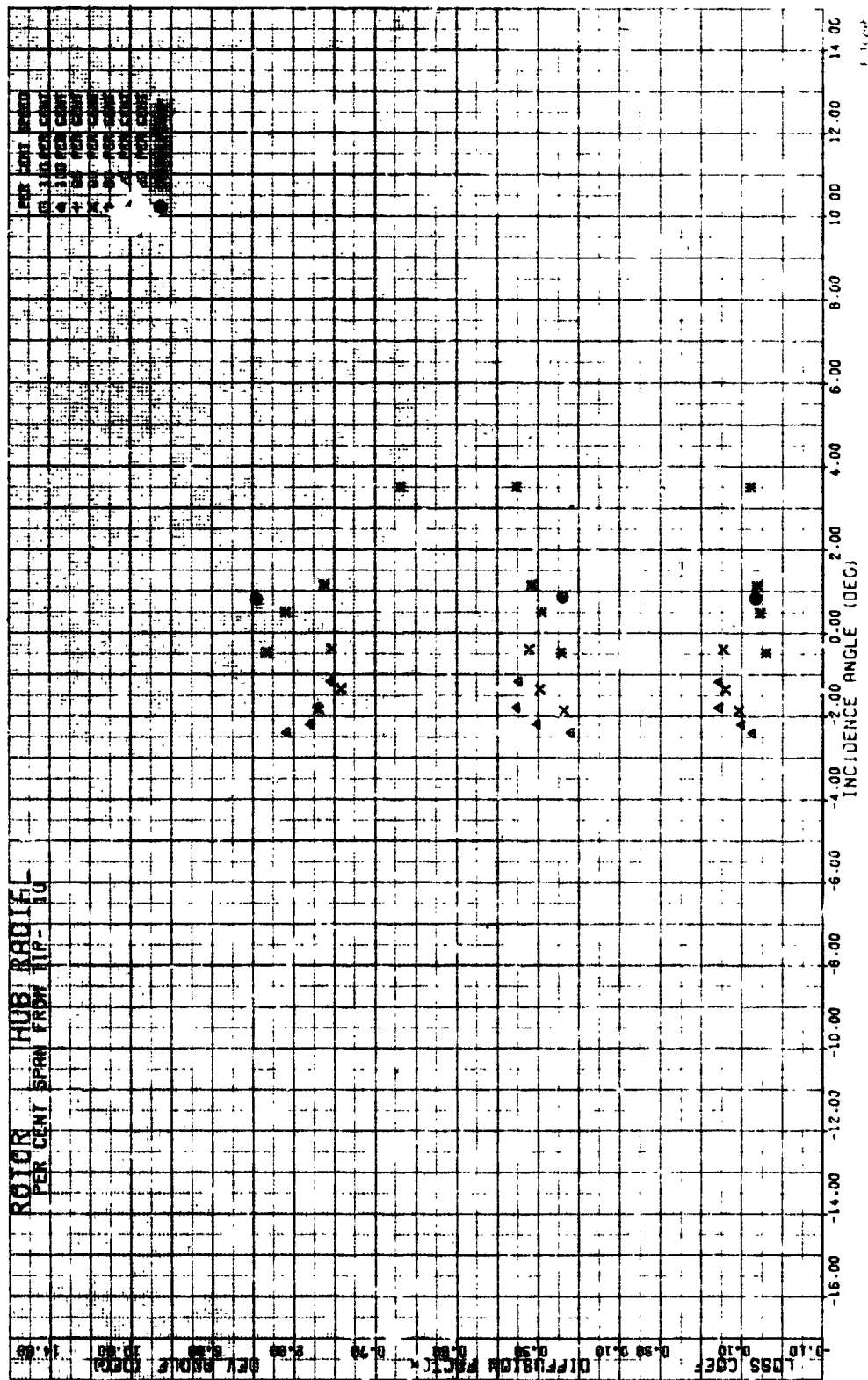


Figure 49b.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 10 Percent Span from Tip.

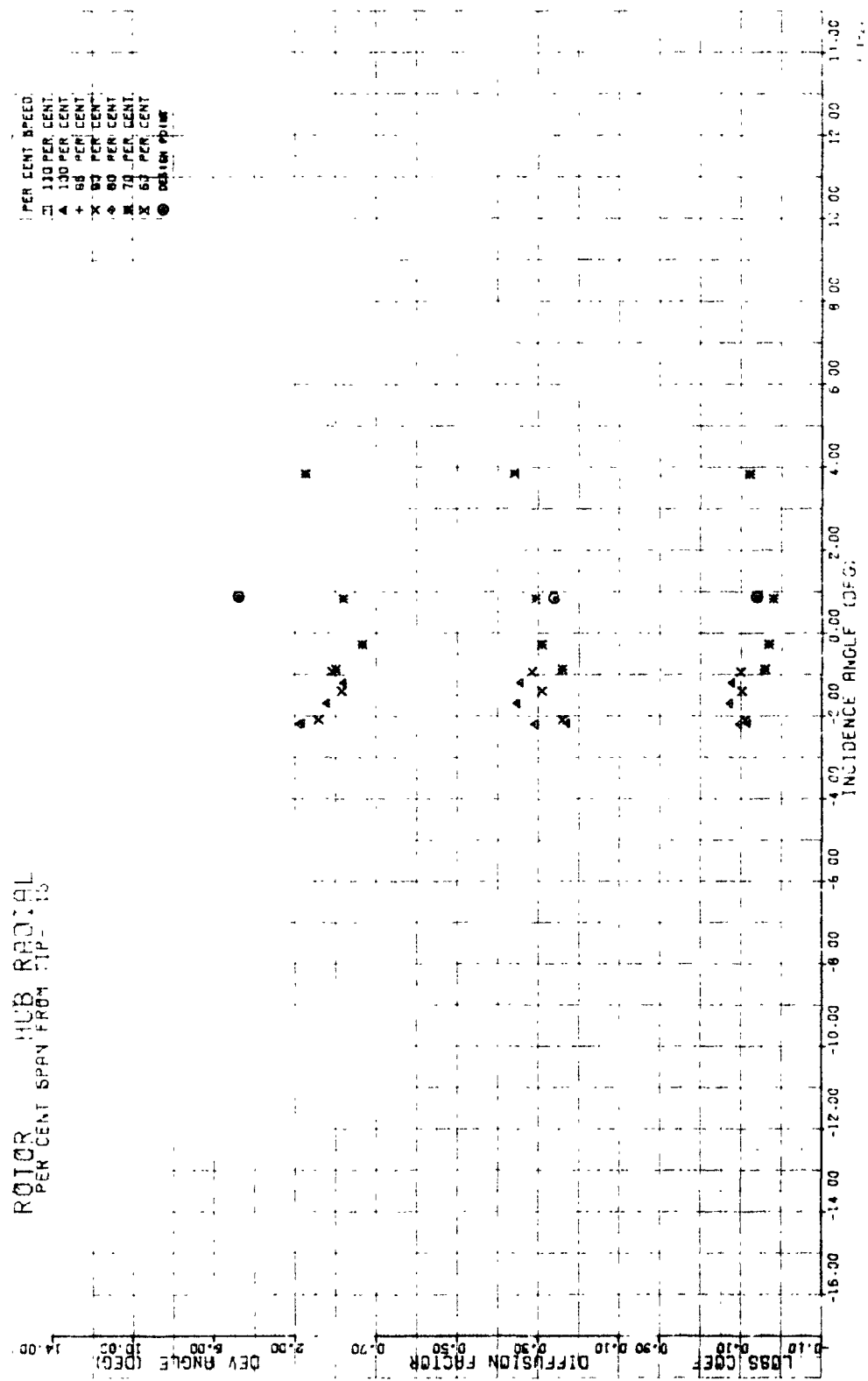


Figure 49c.--Rotor Blade Element Performance, Hub-Radially Distorted
Inlet Flow, 15 Percent Span from Tip.

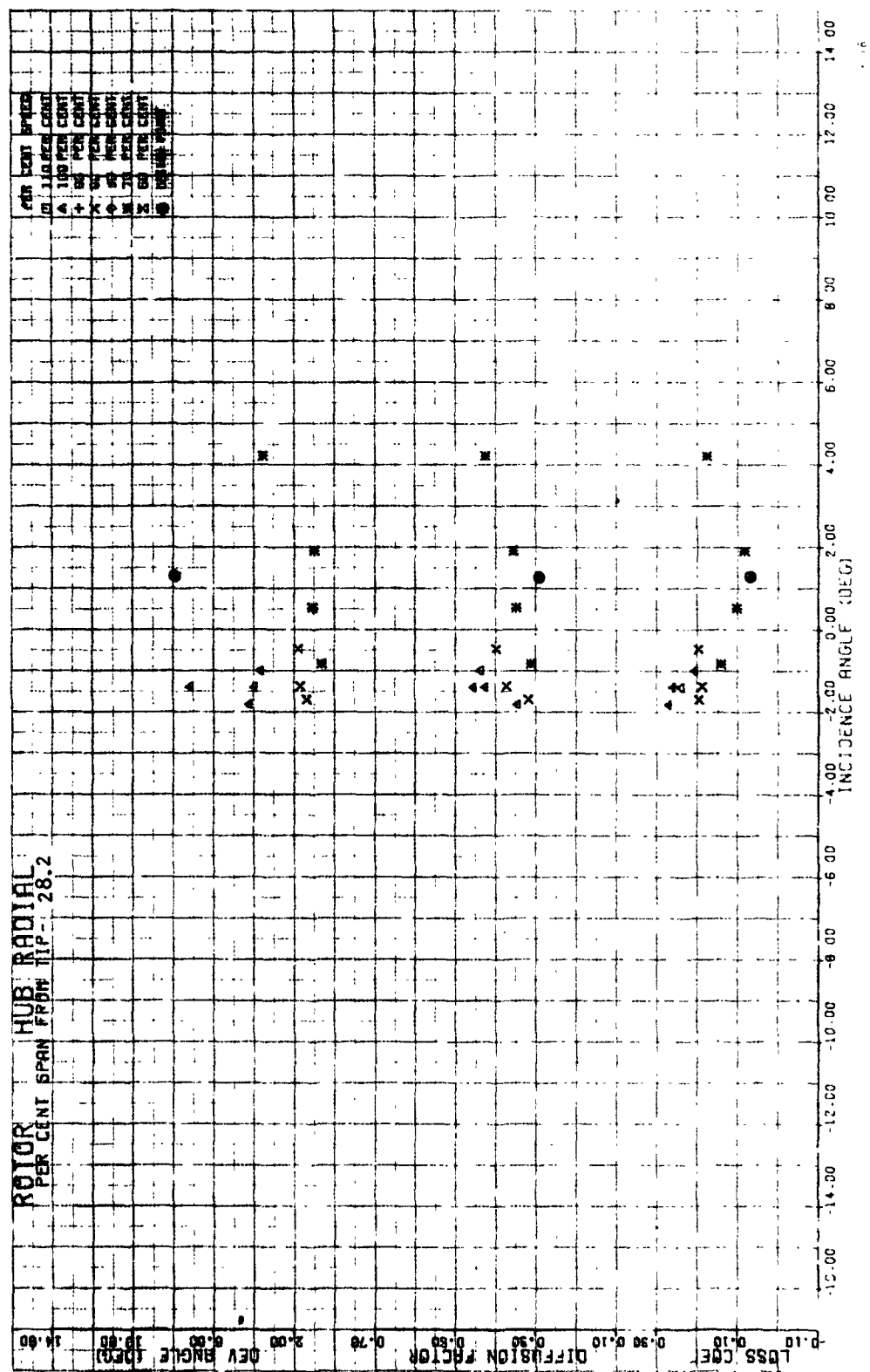


Figure 49d.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 28.2 Percent Span from Tip.

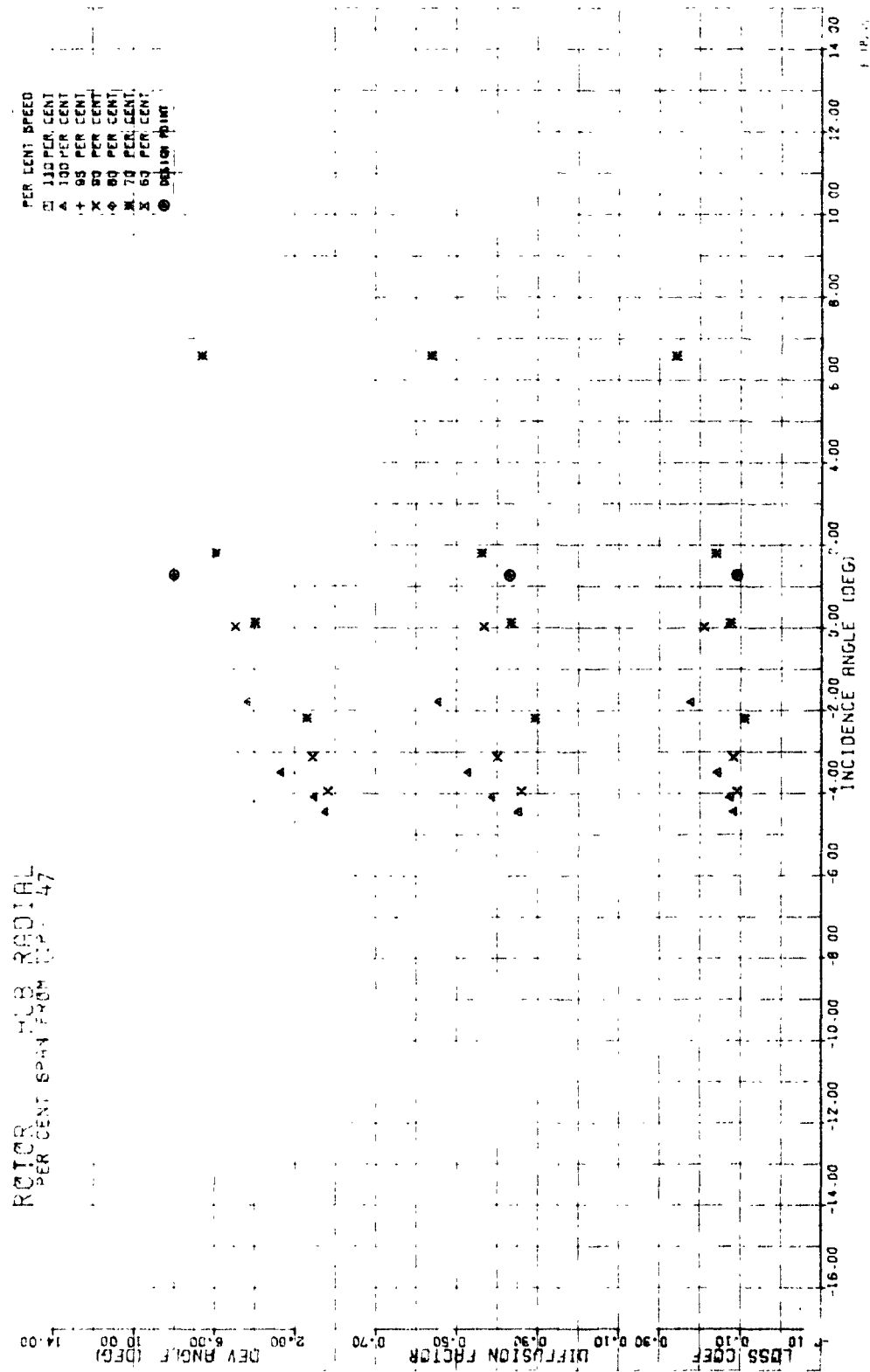


Figure 49e.--Rotor Blade Element Performance, Hub-Radially Distorted
Inlet Flow, 47 Percent Span from Tip.

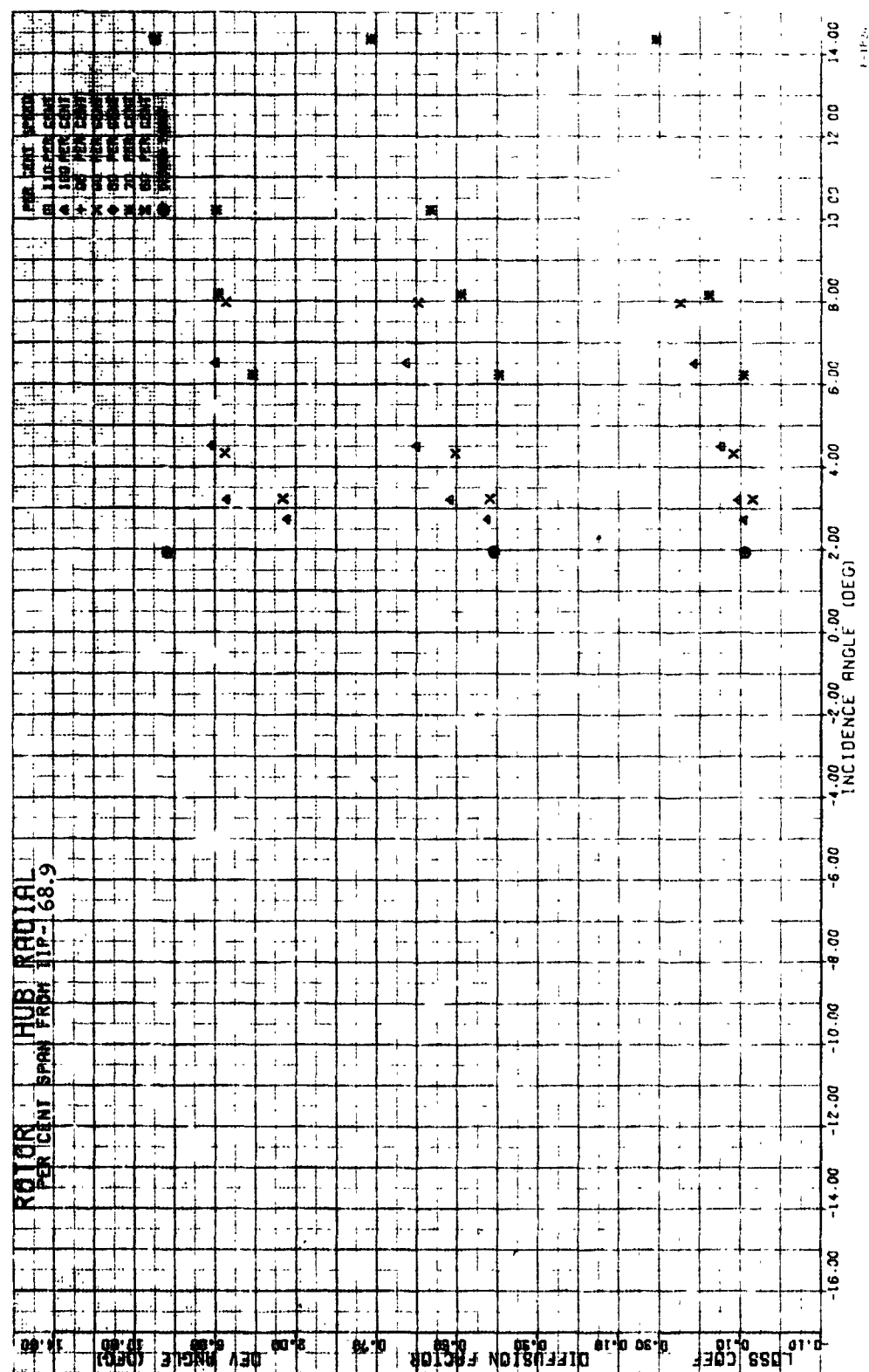


Figure 49f.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 68.9 Percent Span from Tip.

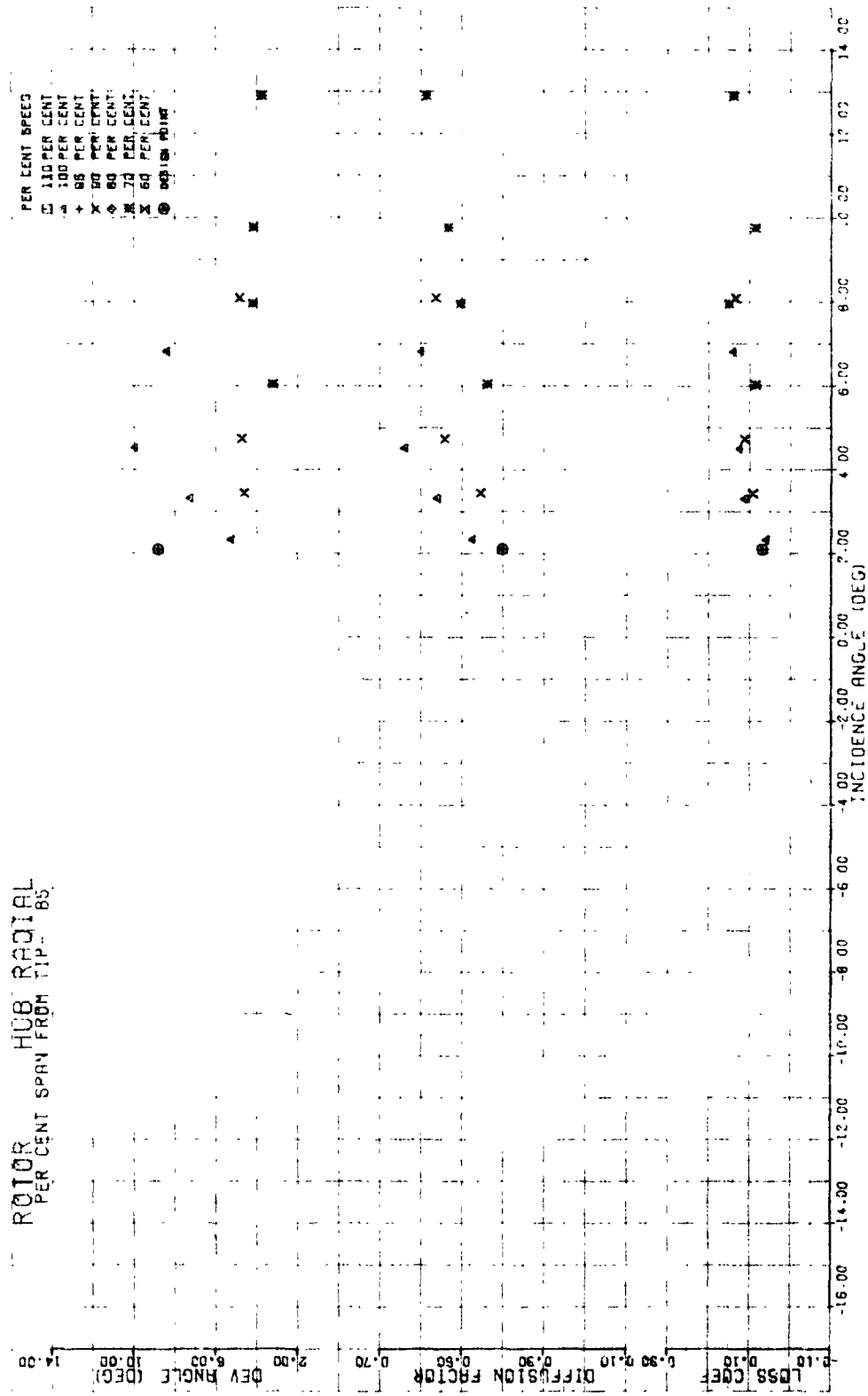


Figure 49g.--Rotor Blade Clement Performance, Hub-Radially Distorted Inlet Flow, 85 Percent Span from Tip.

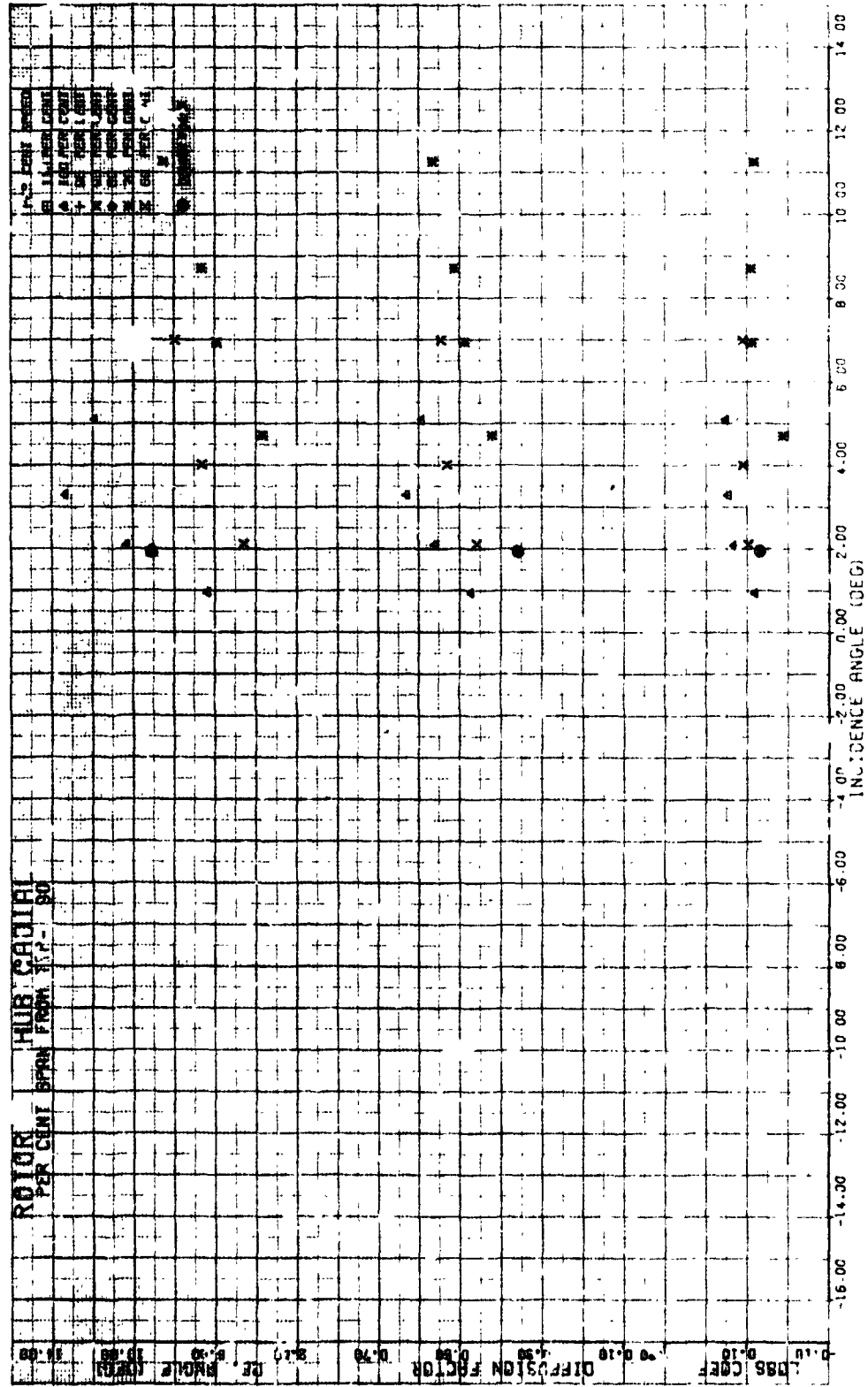


Figure 49h.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 90 Percent Span from Tip.

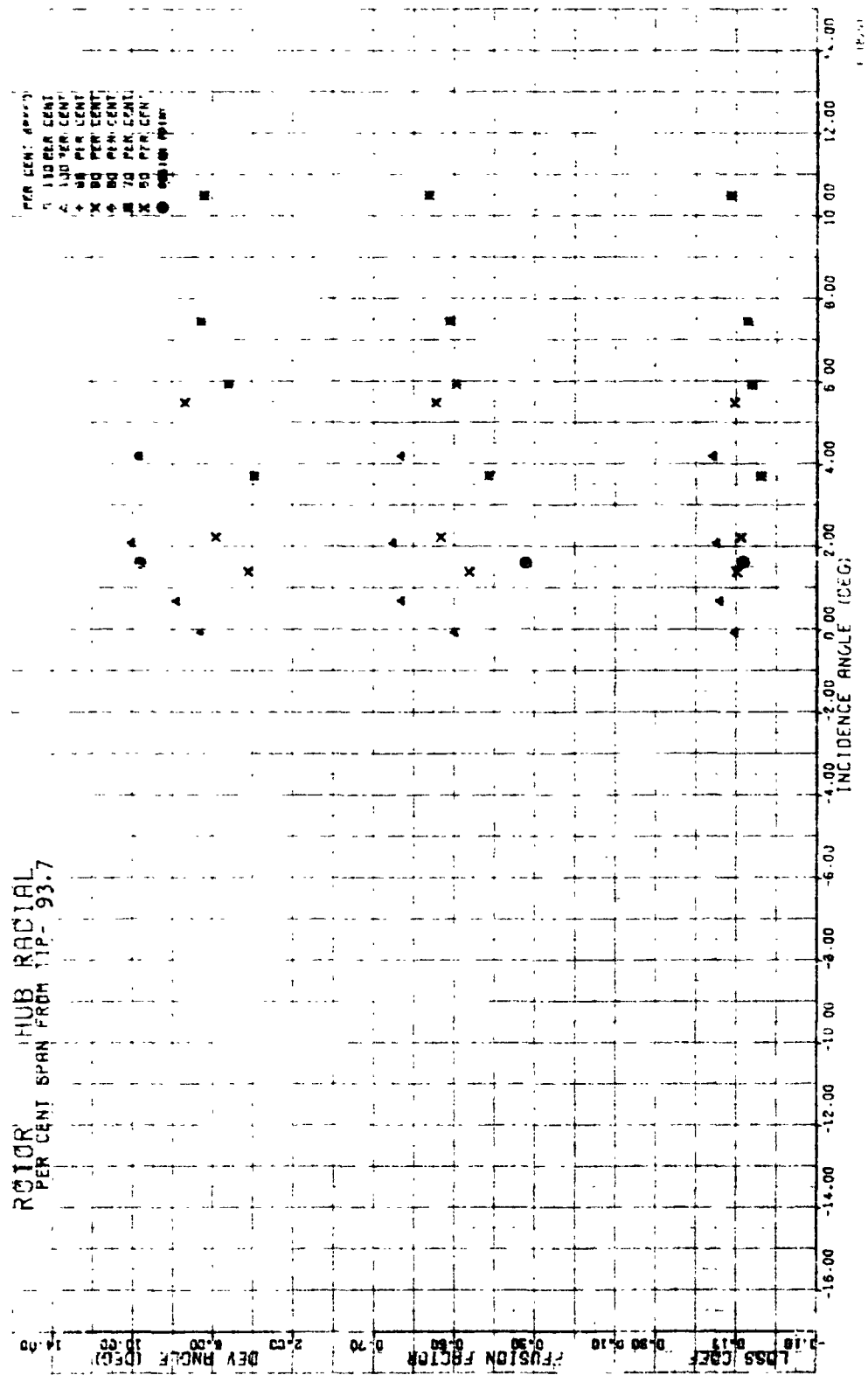


Figure 49i.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 93.7 Percent Span from Tip.

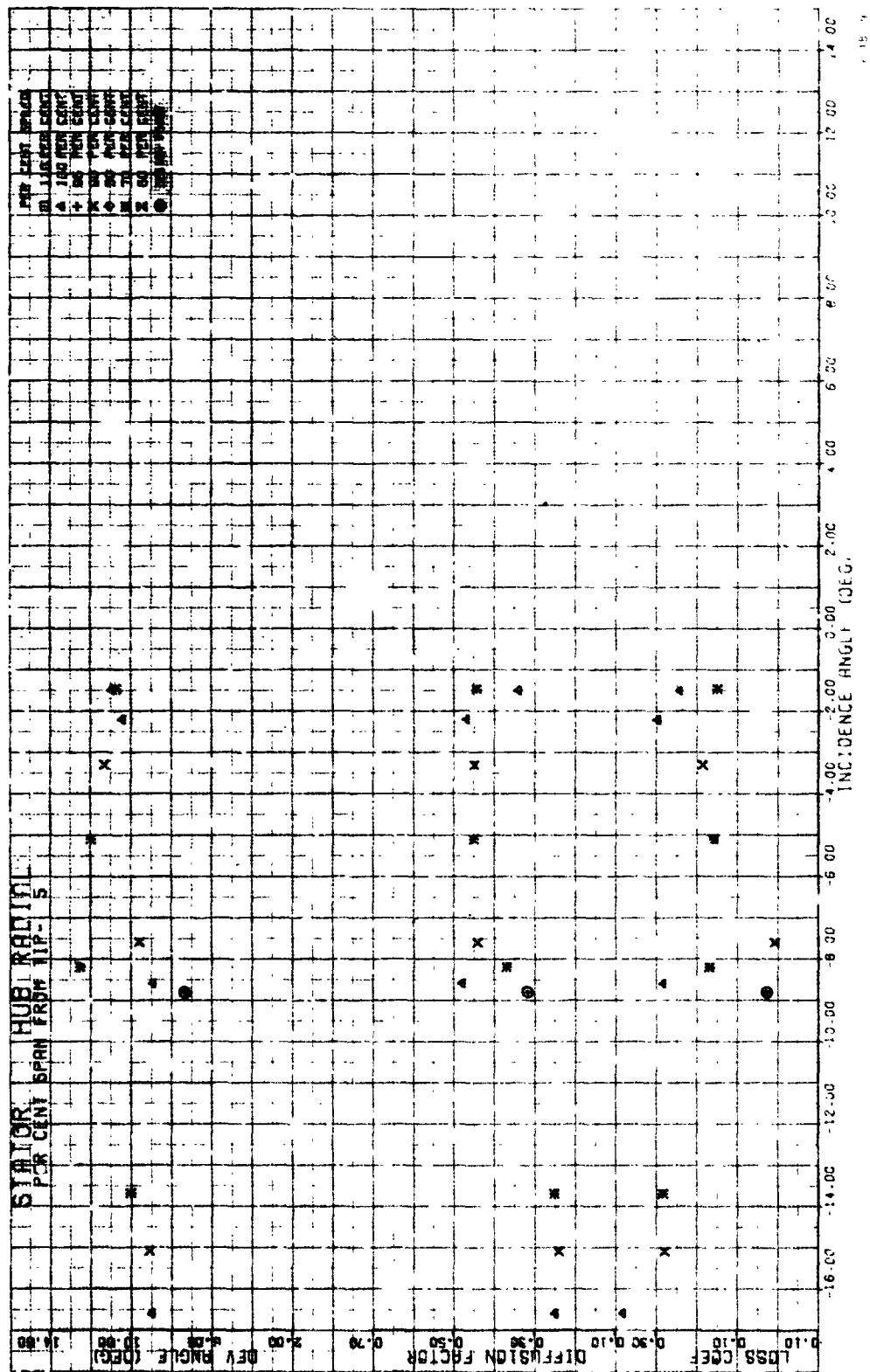


Figure 50a.--Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 5 Percent Span from Tip.

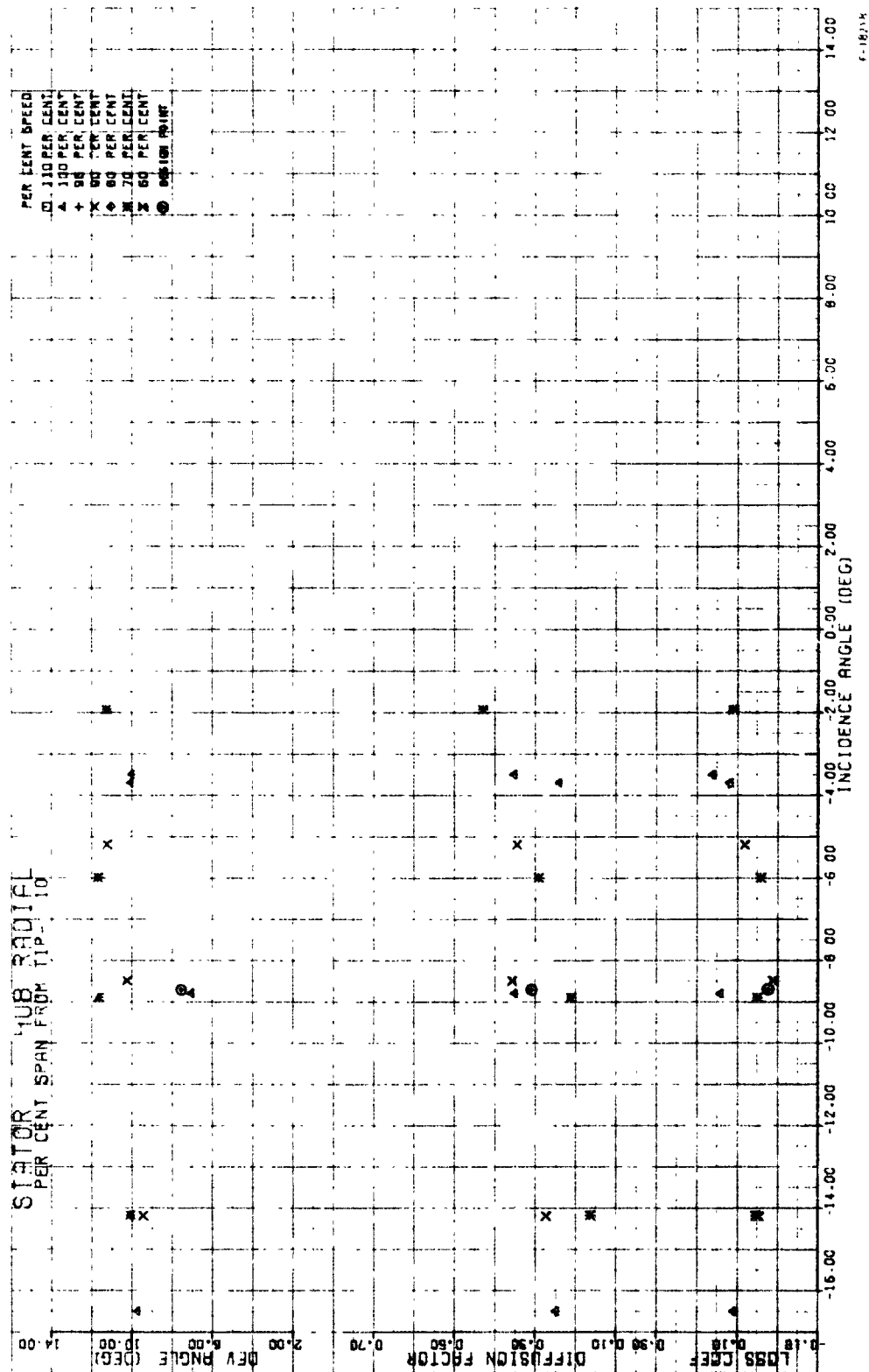


Figure 50b.---Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 10 Percent Span from Tip.

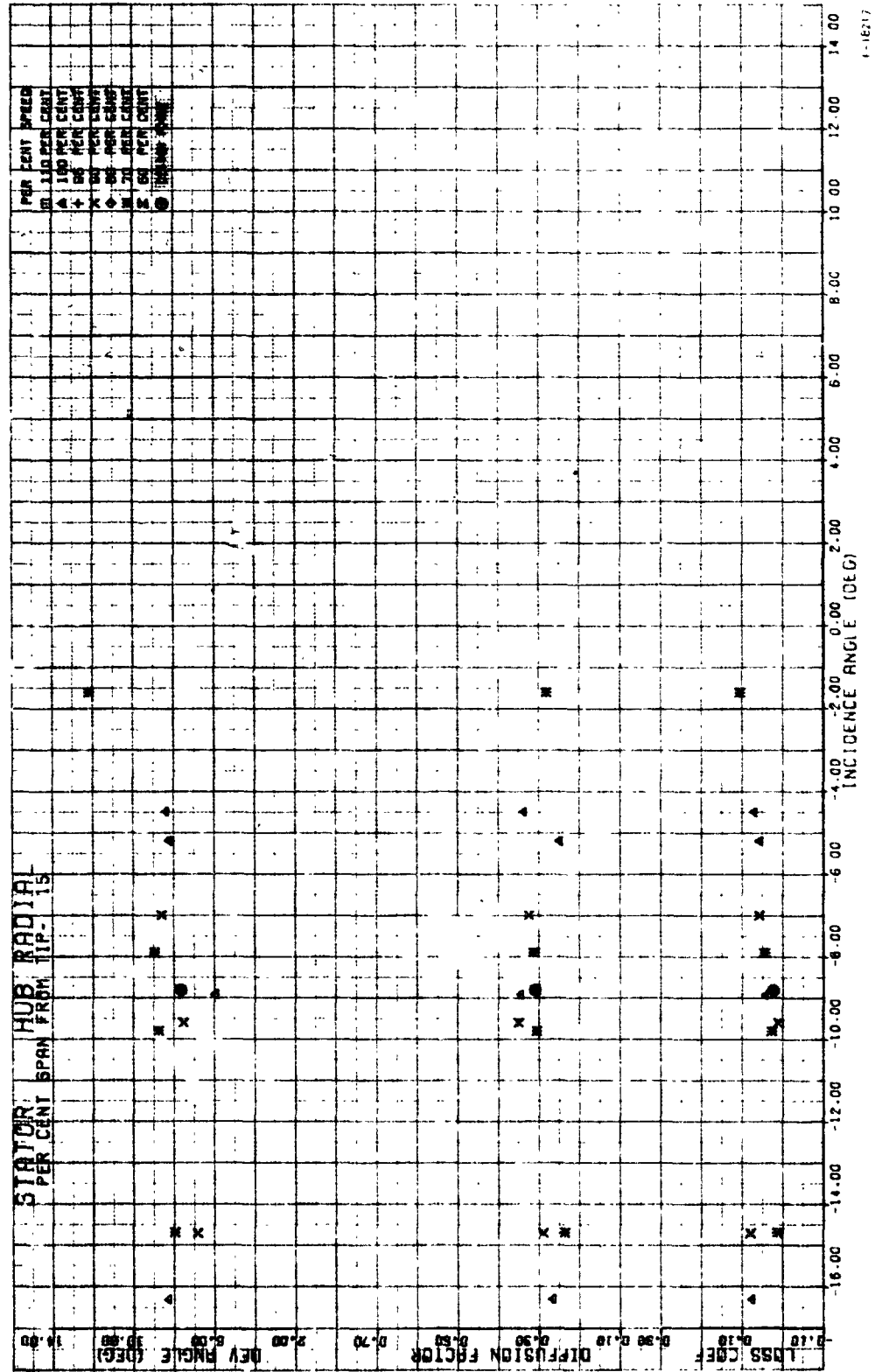


Figure 50c.--Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 15 Percent Span from Tip.

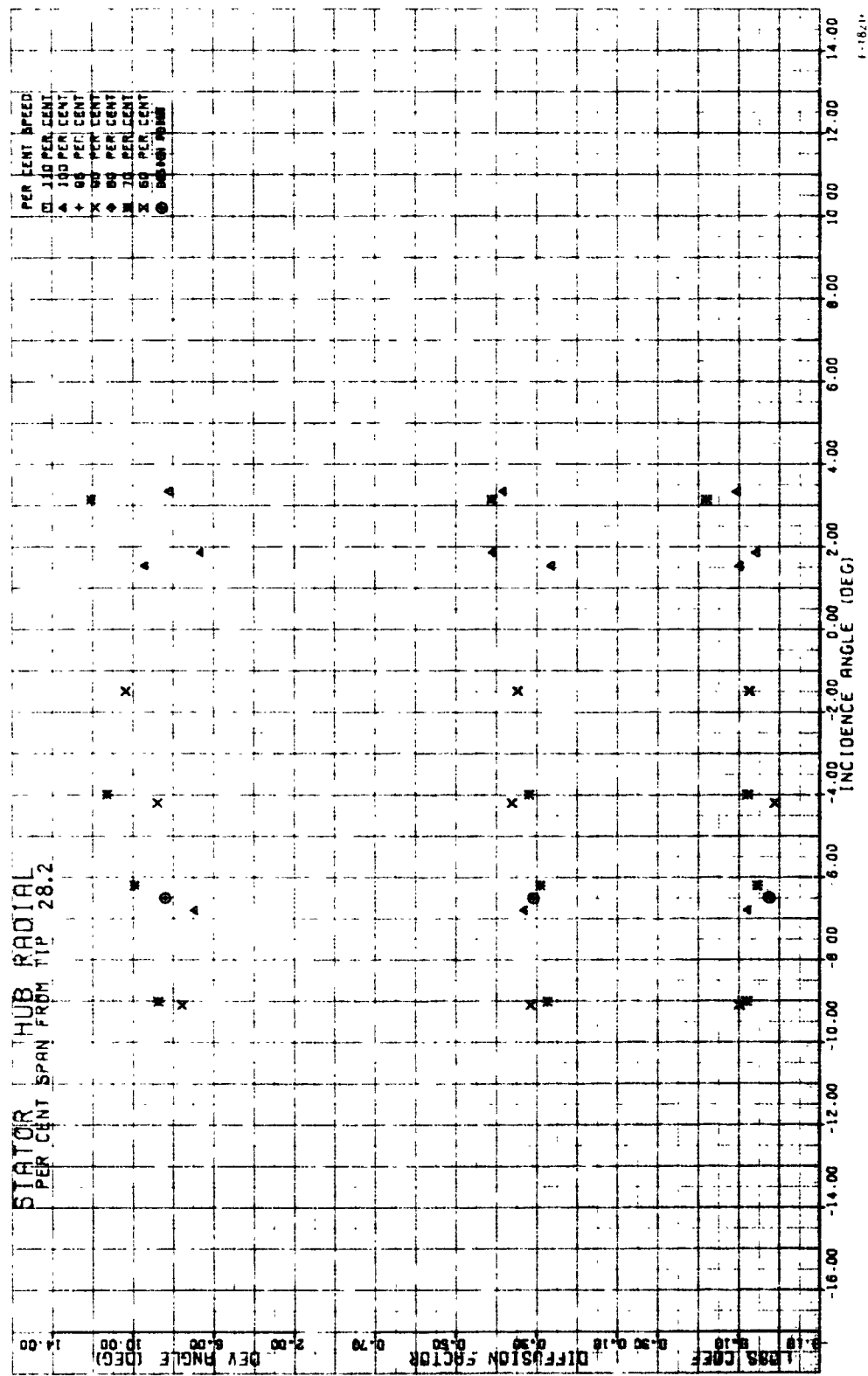


Figure 50d.--Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 28.2 Percent Span from Tip.

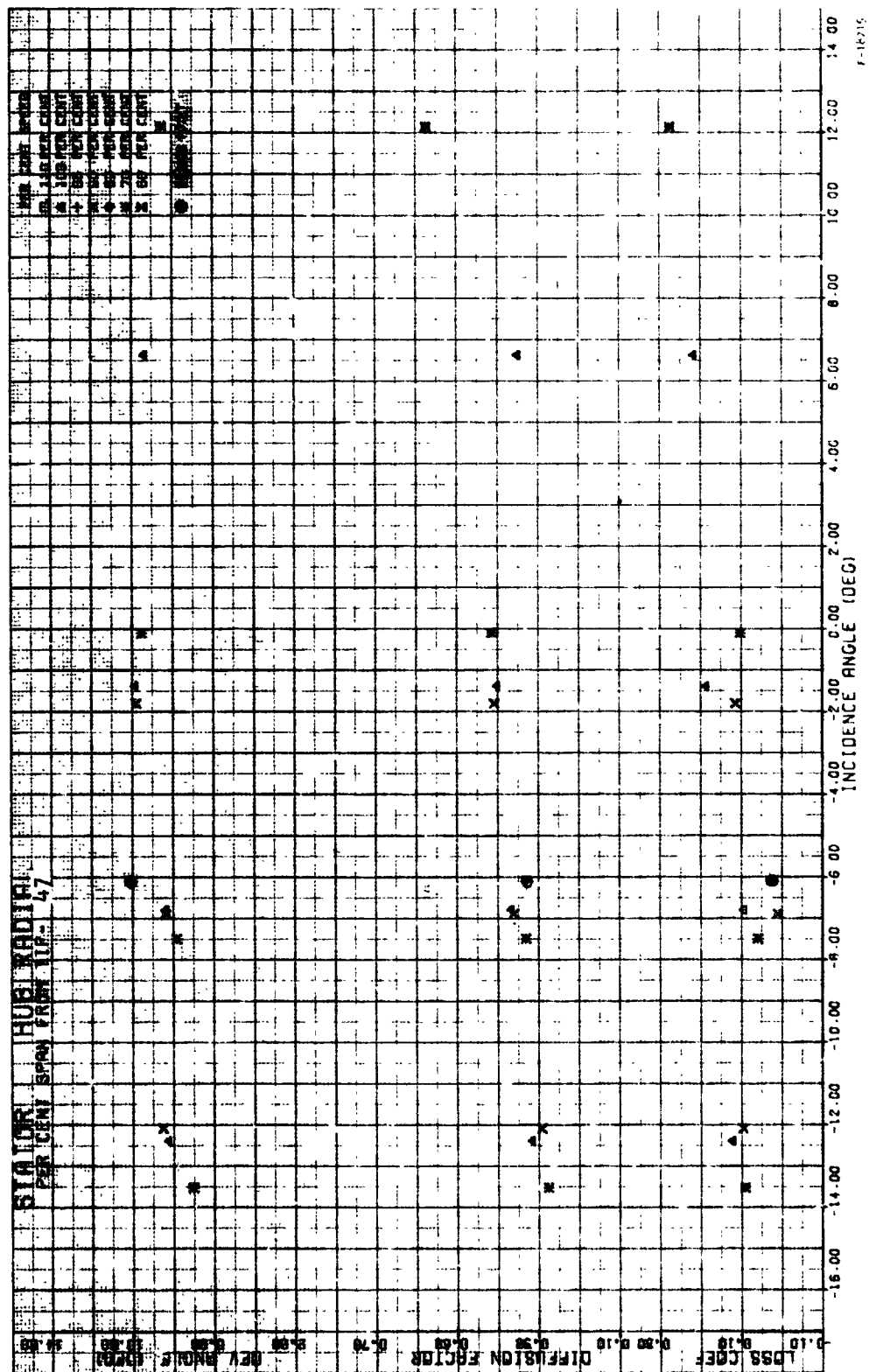


Figure 50e.--Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 47 Percent Span from Tip.

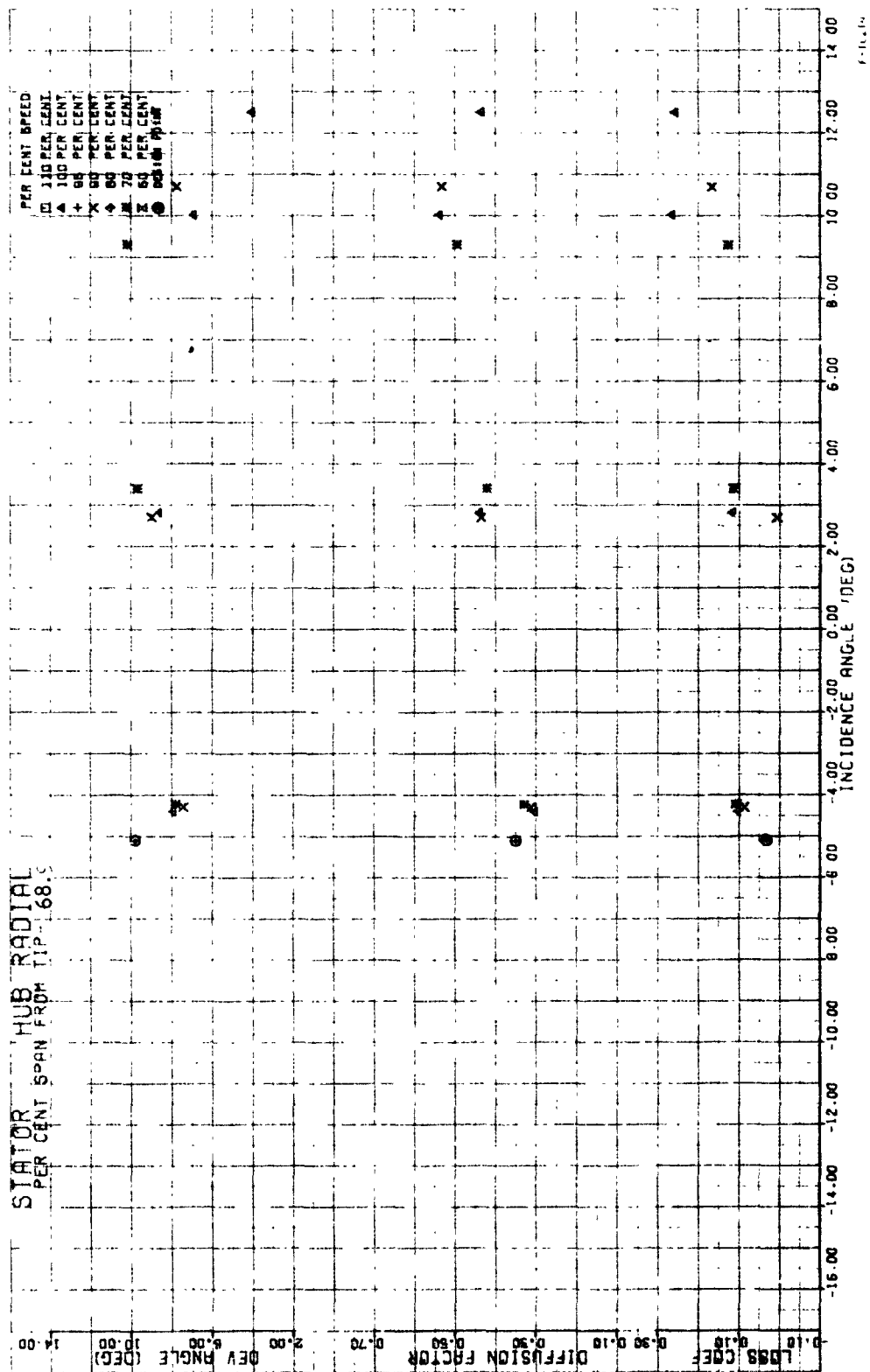


Figure 50f. --Stator Vane Element Performance, Hub-Radially Distorted
Inlet Flow, 68.9 Percent Span from Tip.

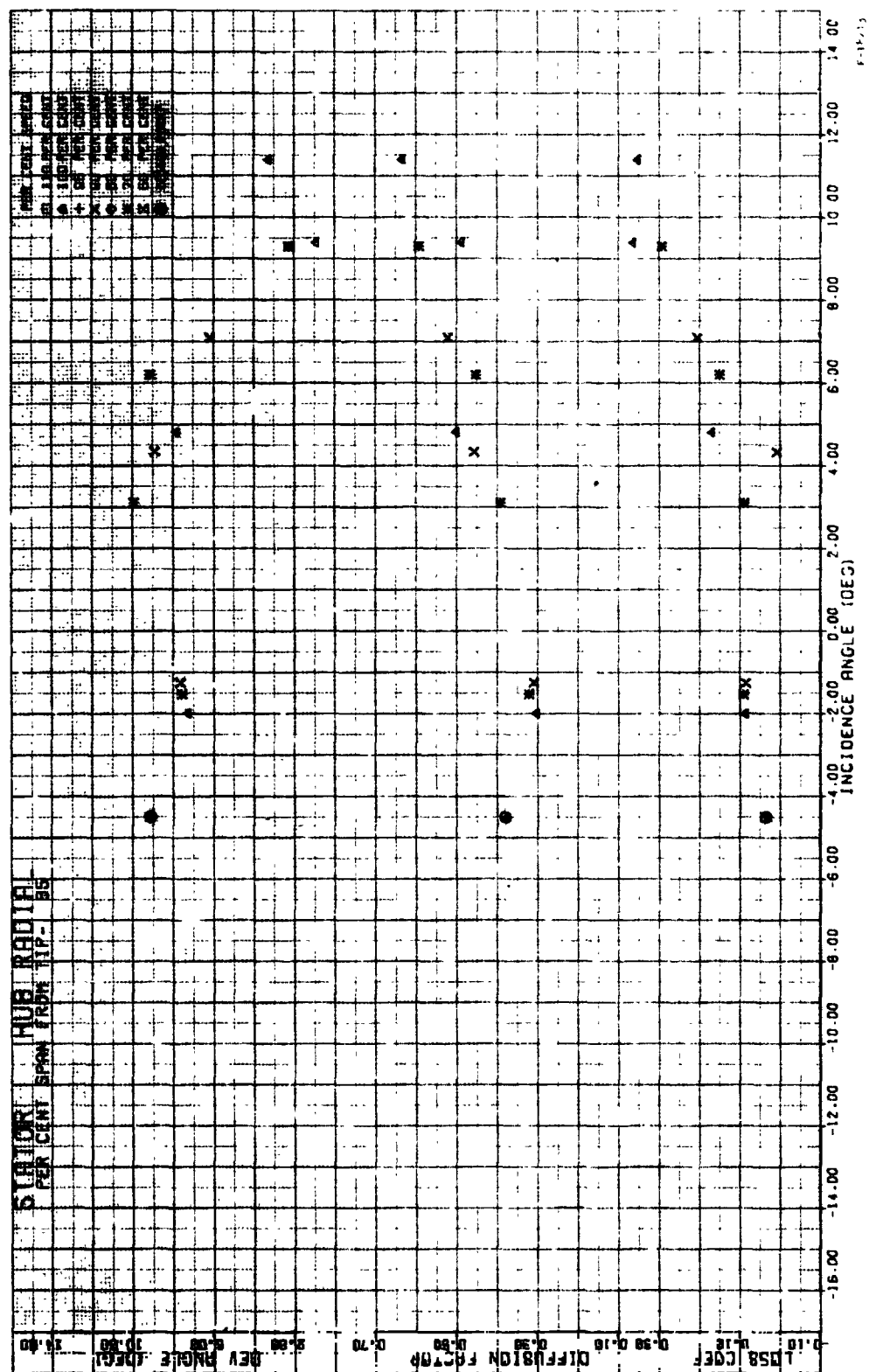
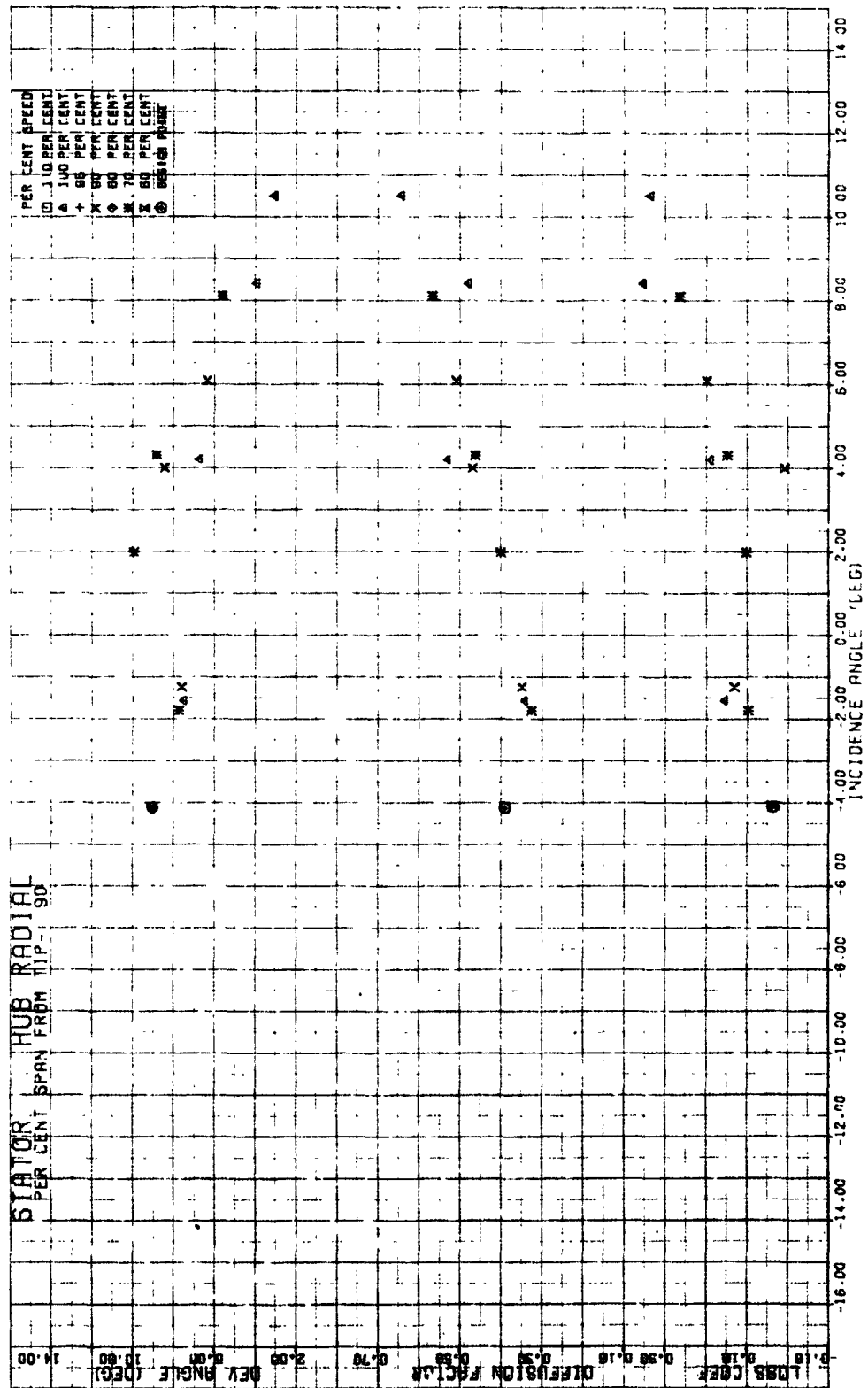


Figure 50g.--Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 85 Percent Span from Tip.



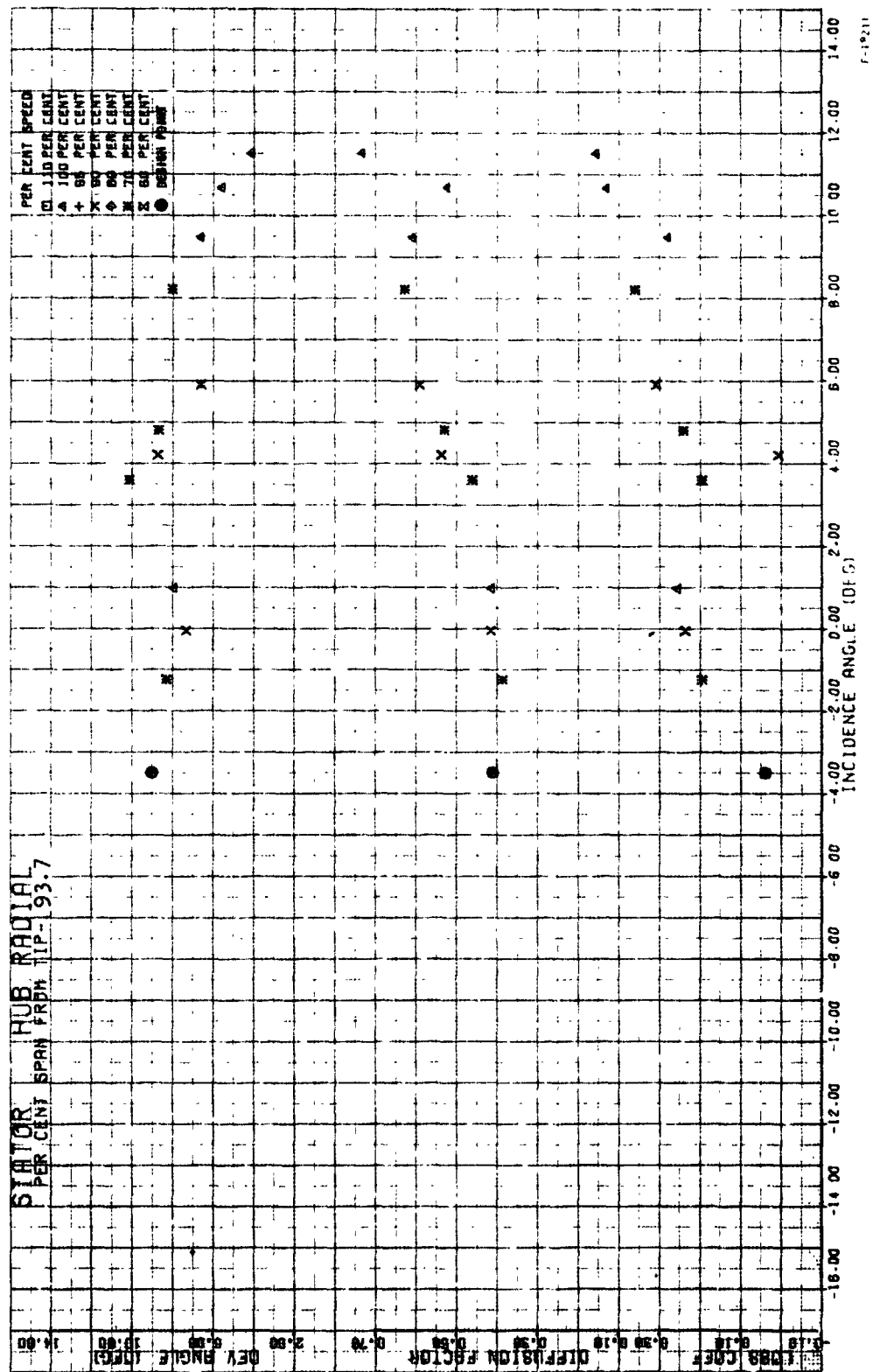
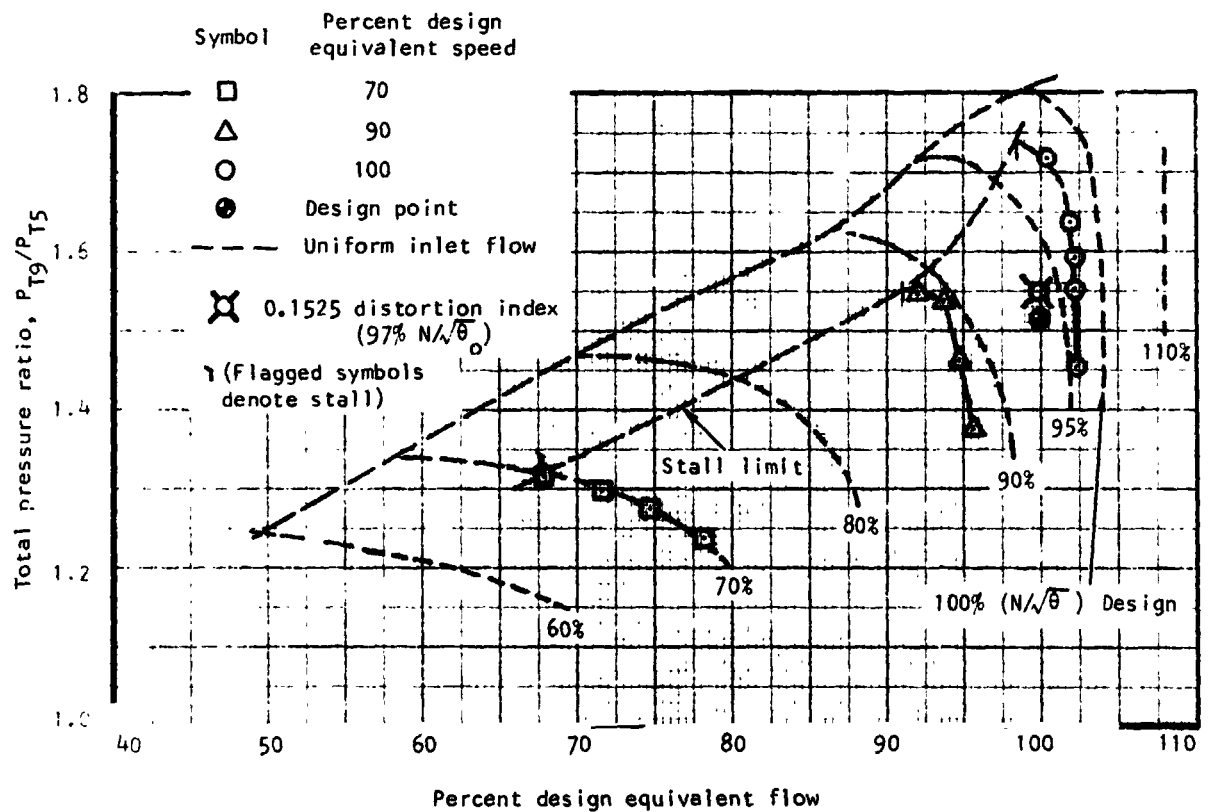
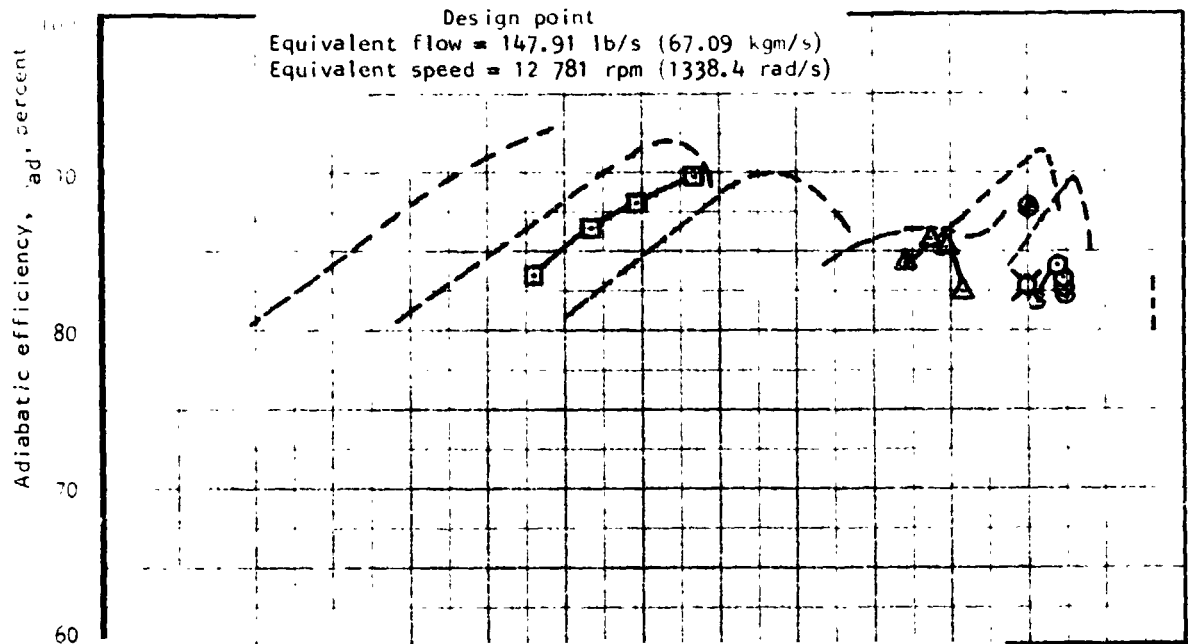
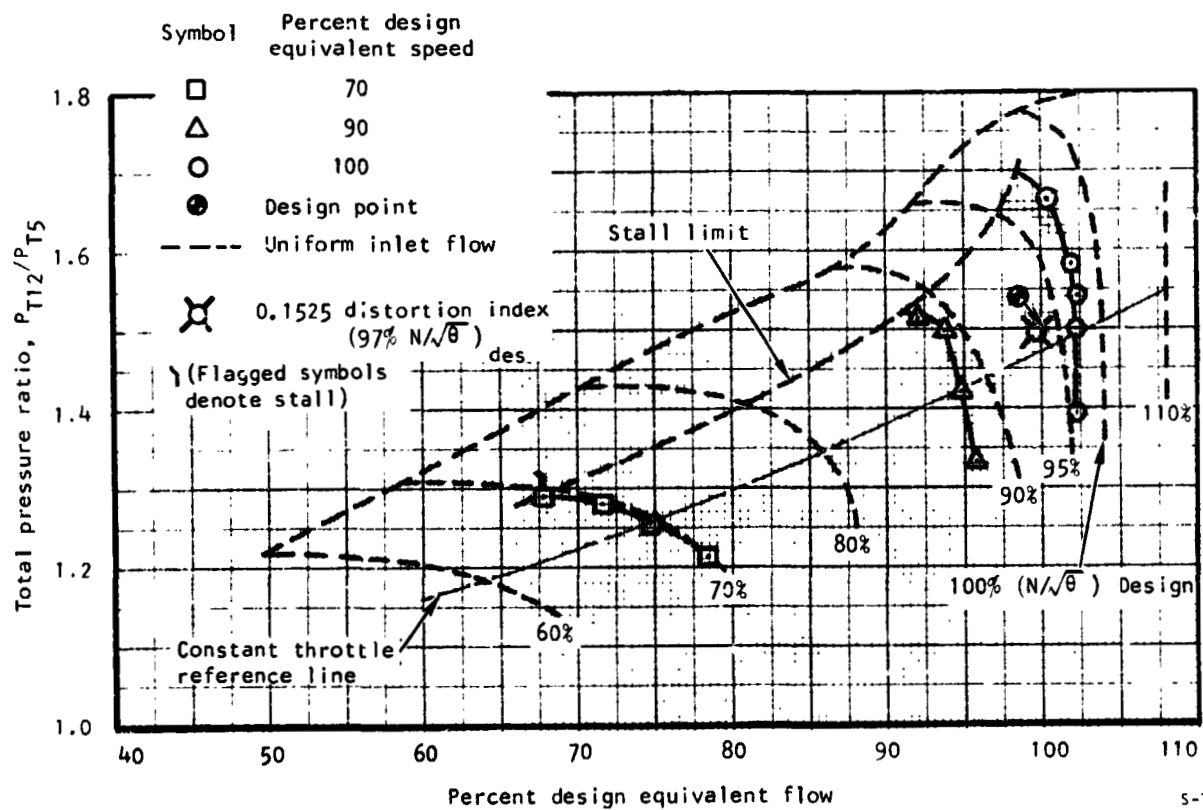
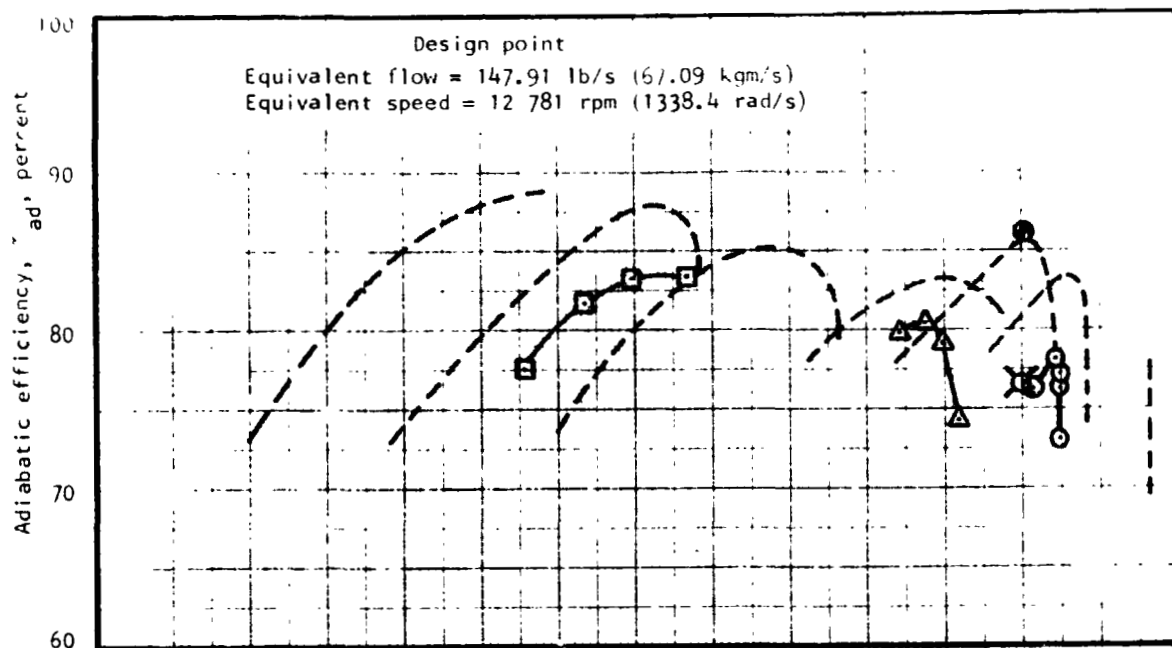


Figure 50i.--Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 93.7 Percent Span from Tip.



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Figure 51.--Rotor Performance, Tip-Radial Distortion.



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Figure 52.--Stage Performance, Tip-Radial Distortion.

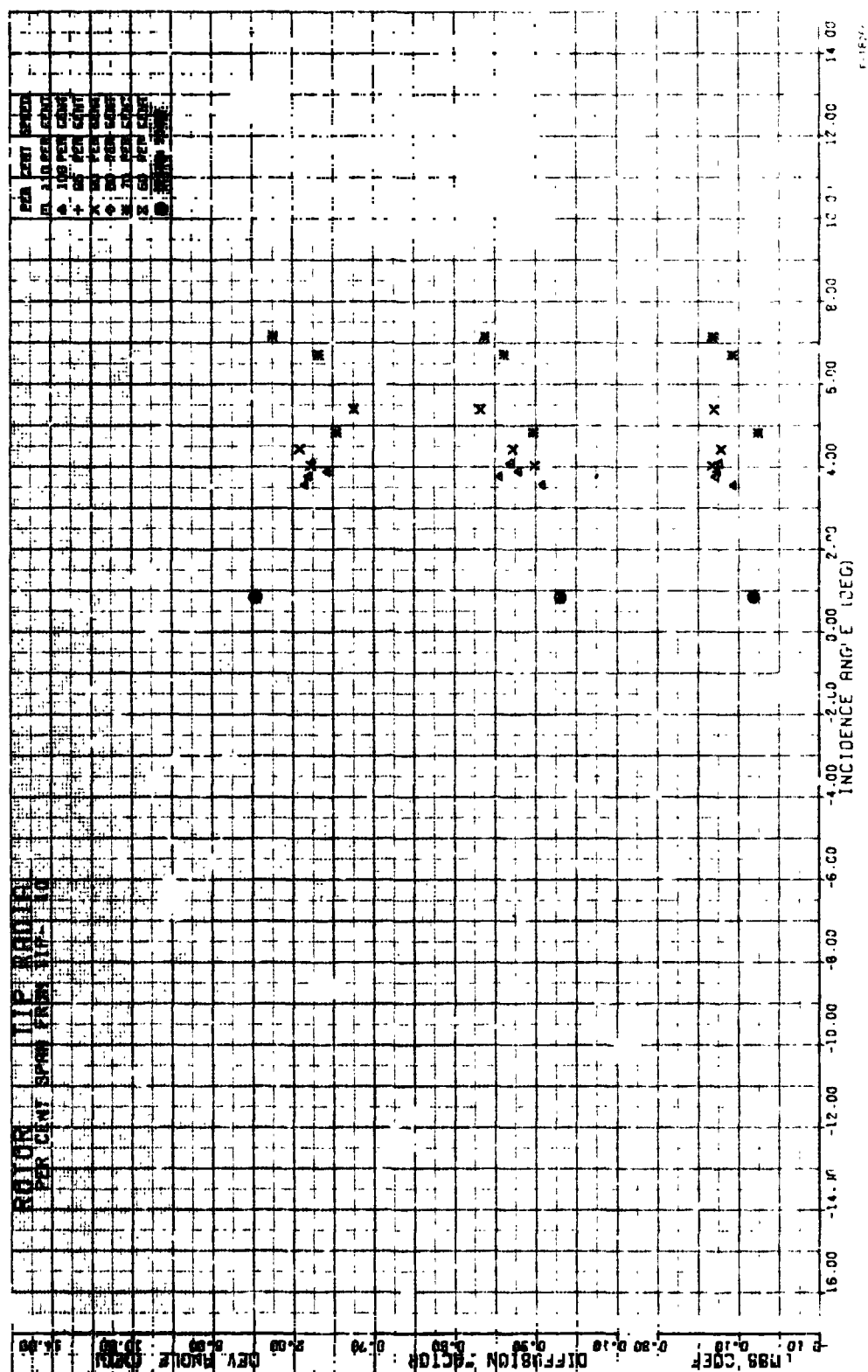


Figure 53b.---Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 10 Percent Span from Tip.

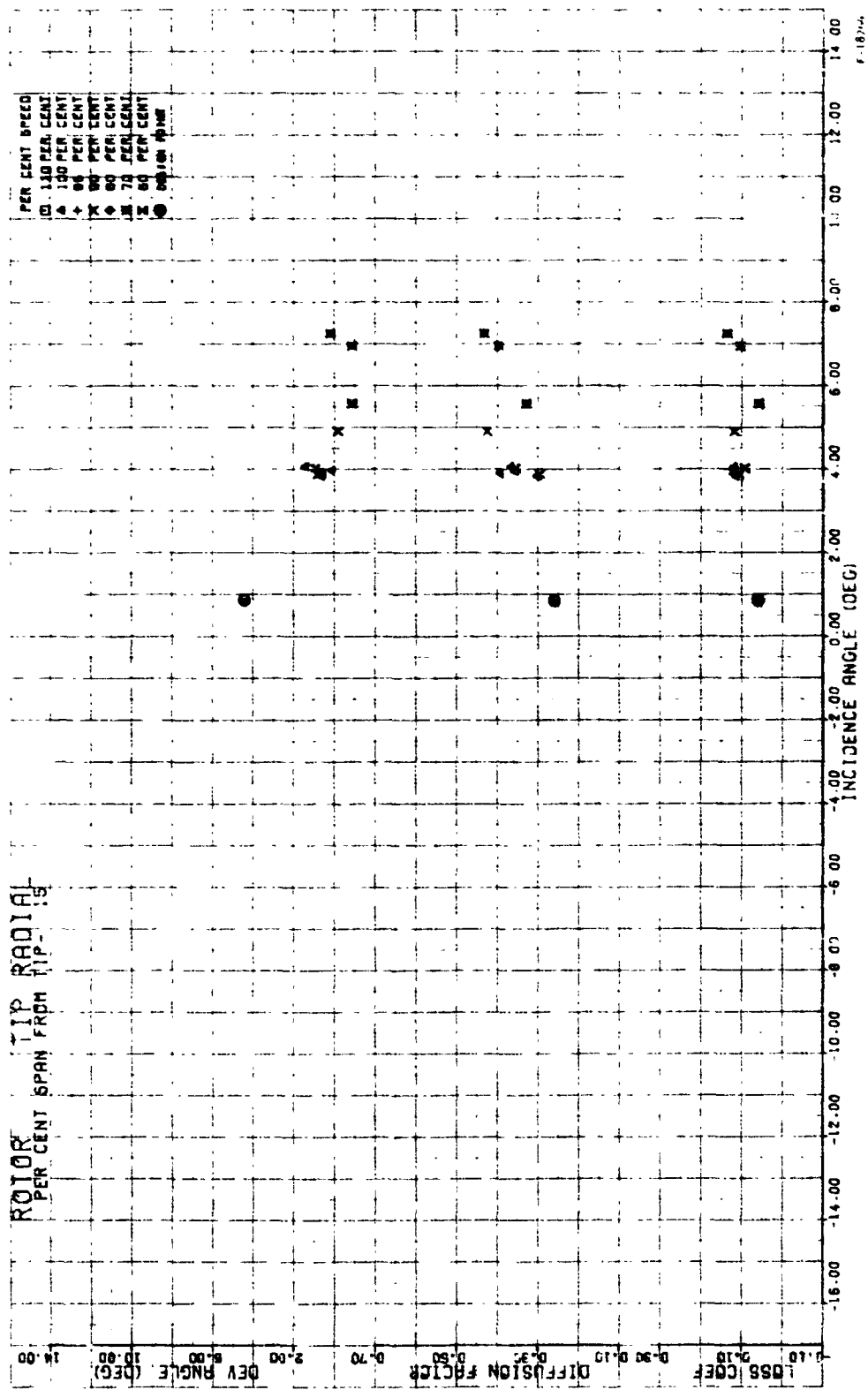


Figure 53c.--Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 15 Percent Span from Tip.

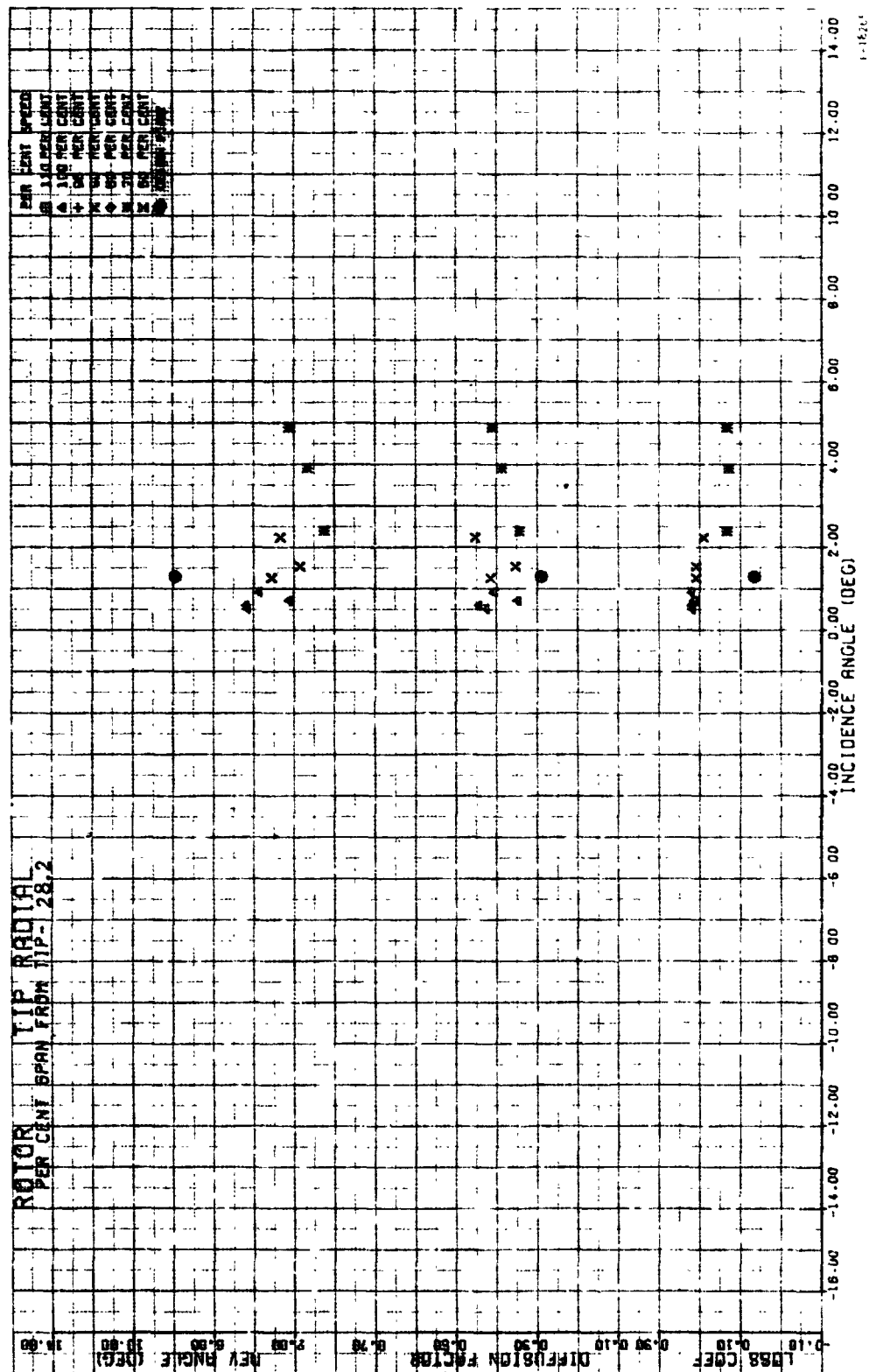


Figure 53d.--Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 28.2 Percent Span from Tip.

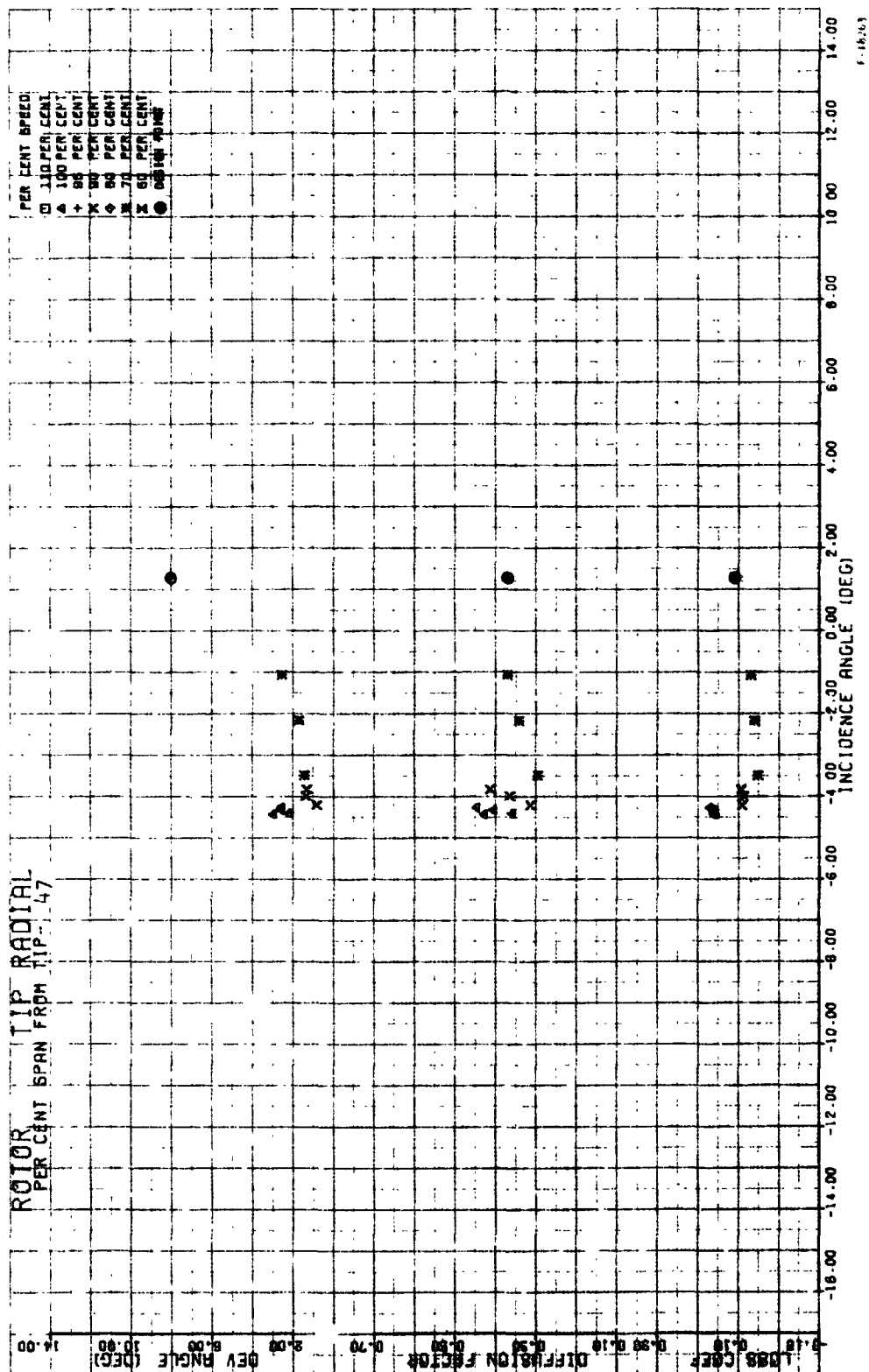


Figure 53e.--Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 47 Percent Span from Tip.

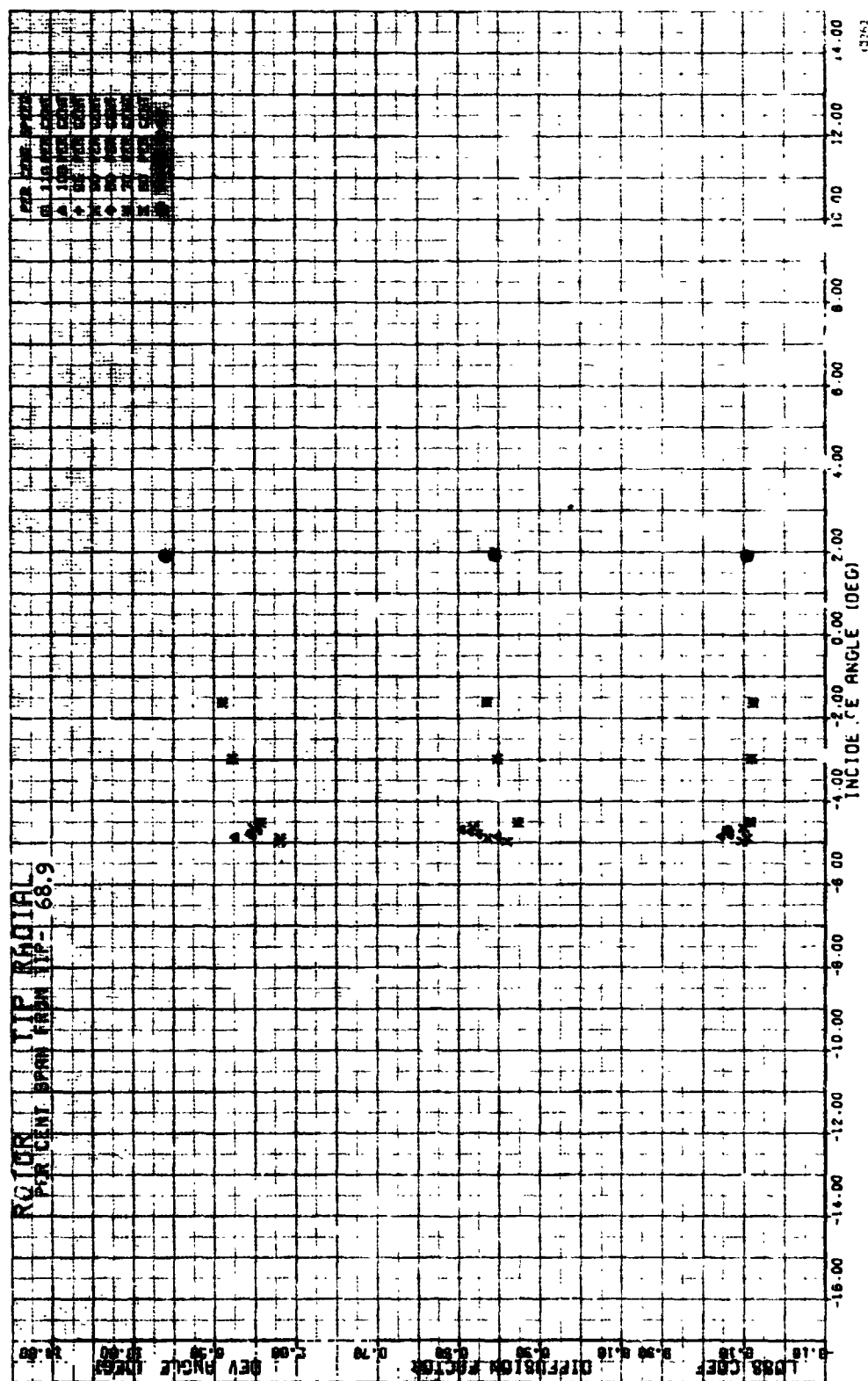


Figure 53f.--Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 68.9 Percent Span from Tip.

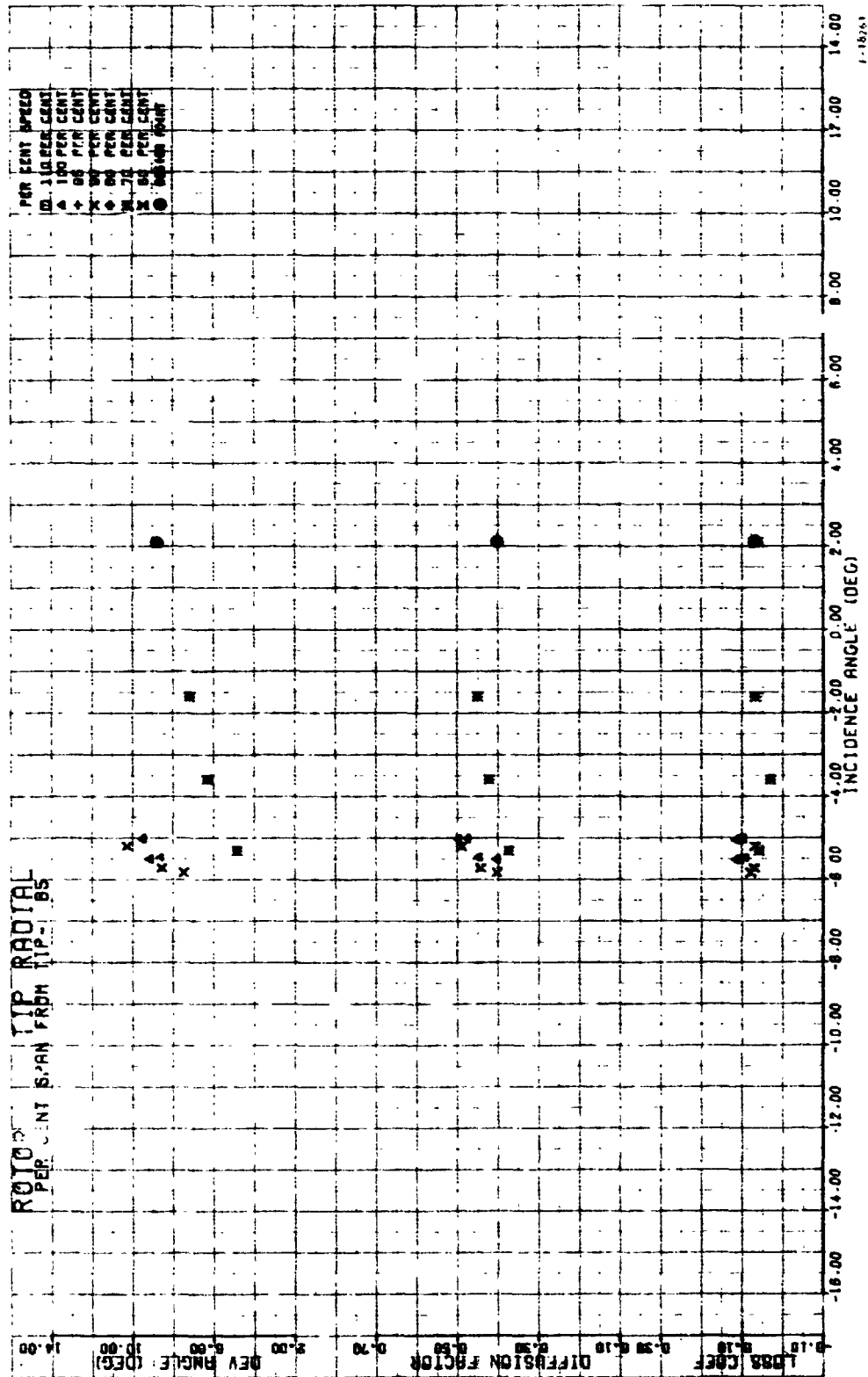


Figure 53g.---Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 85 Percent Span from Tip.

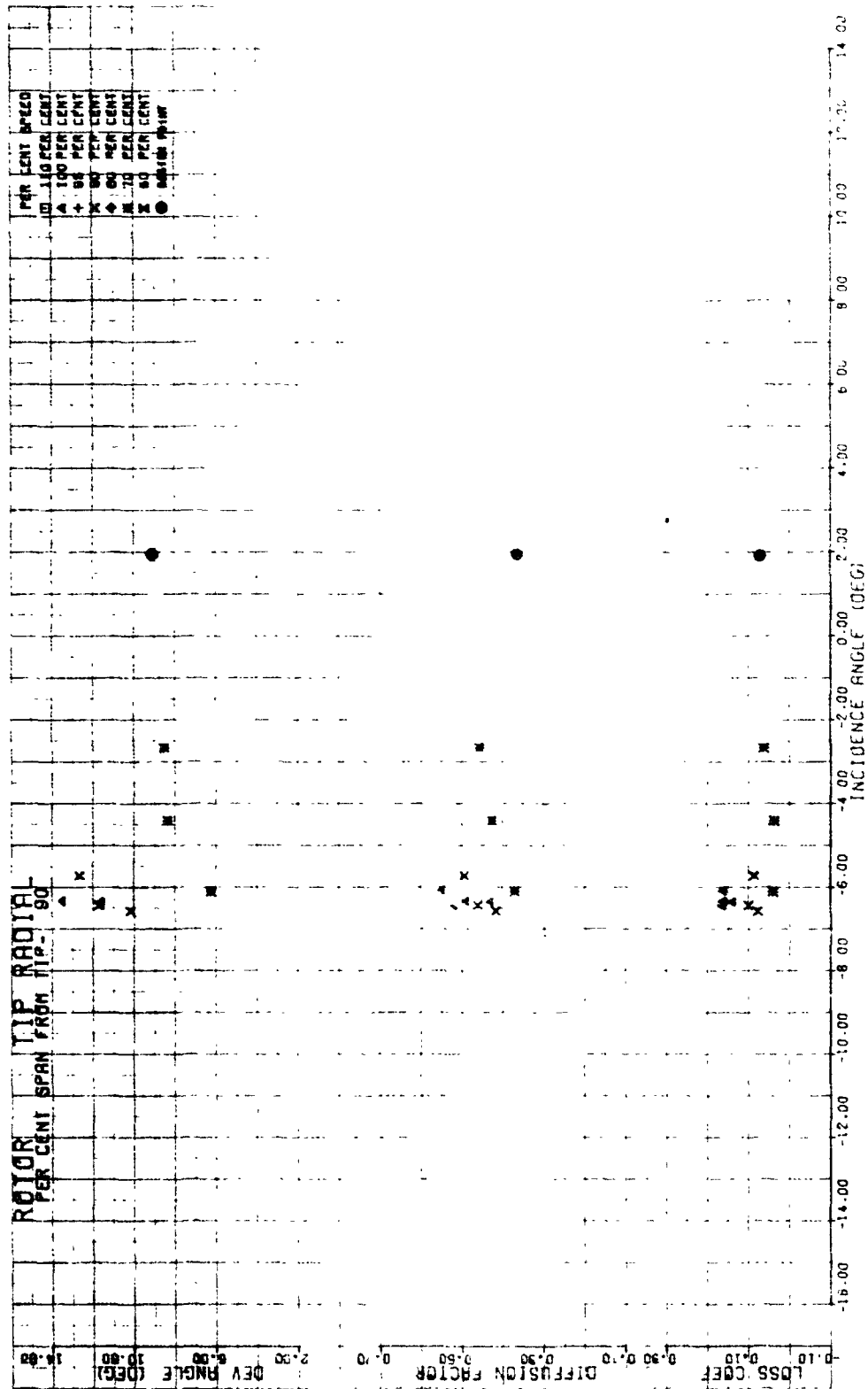


Figure 53h.--Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 90 Percent Span from Tip.

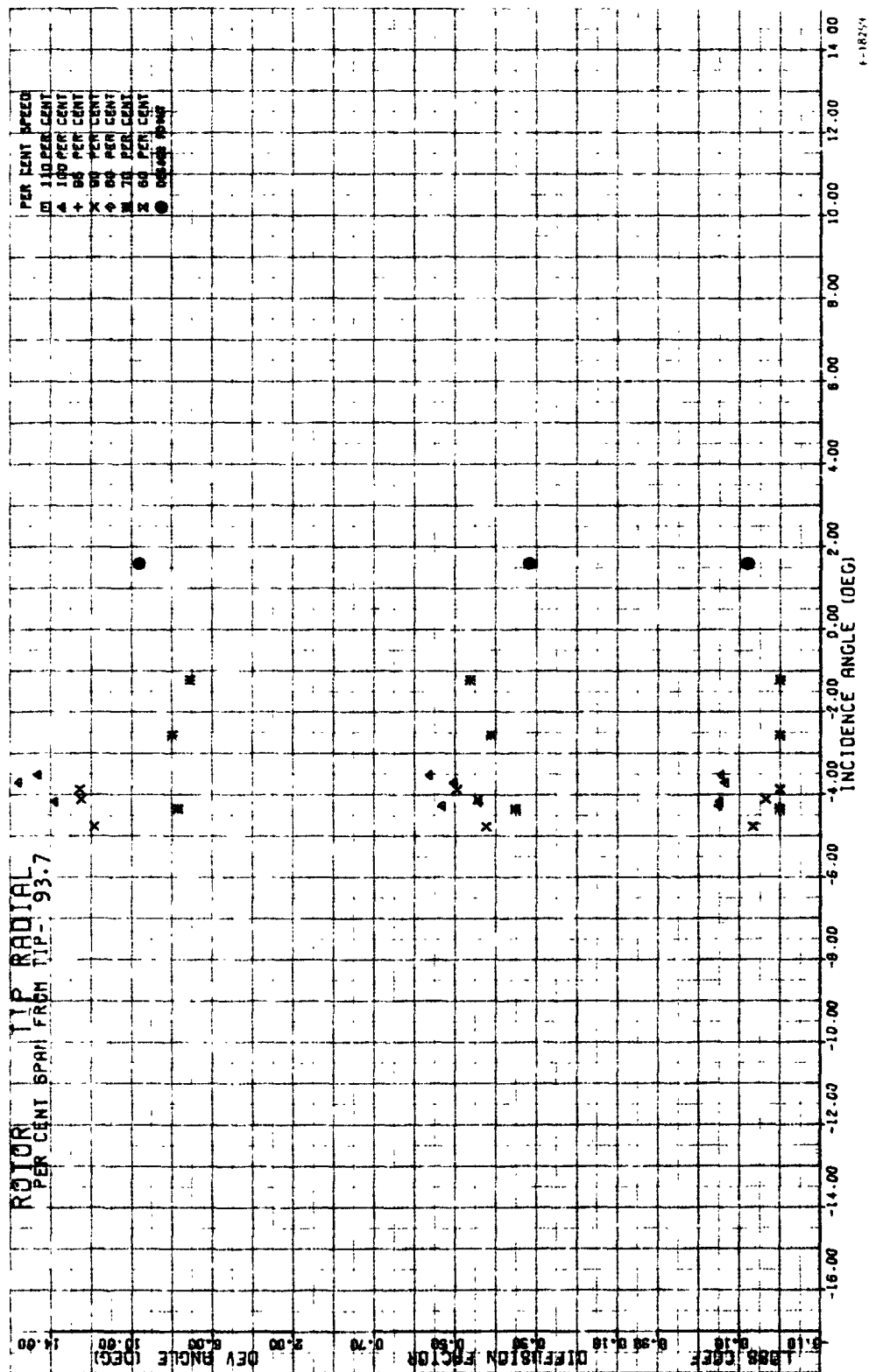


Figure 53i.--Rotor Blade Element Performance, Tip-Radially Distorted
Inlet Flow, 93.7 Percent Span from Tip.

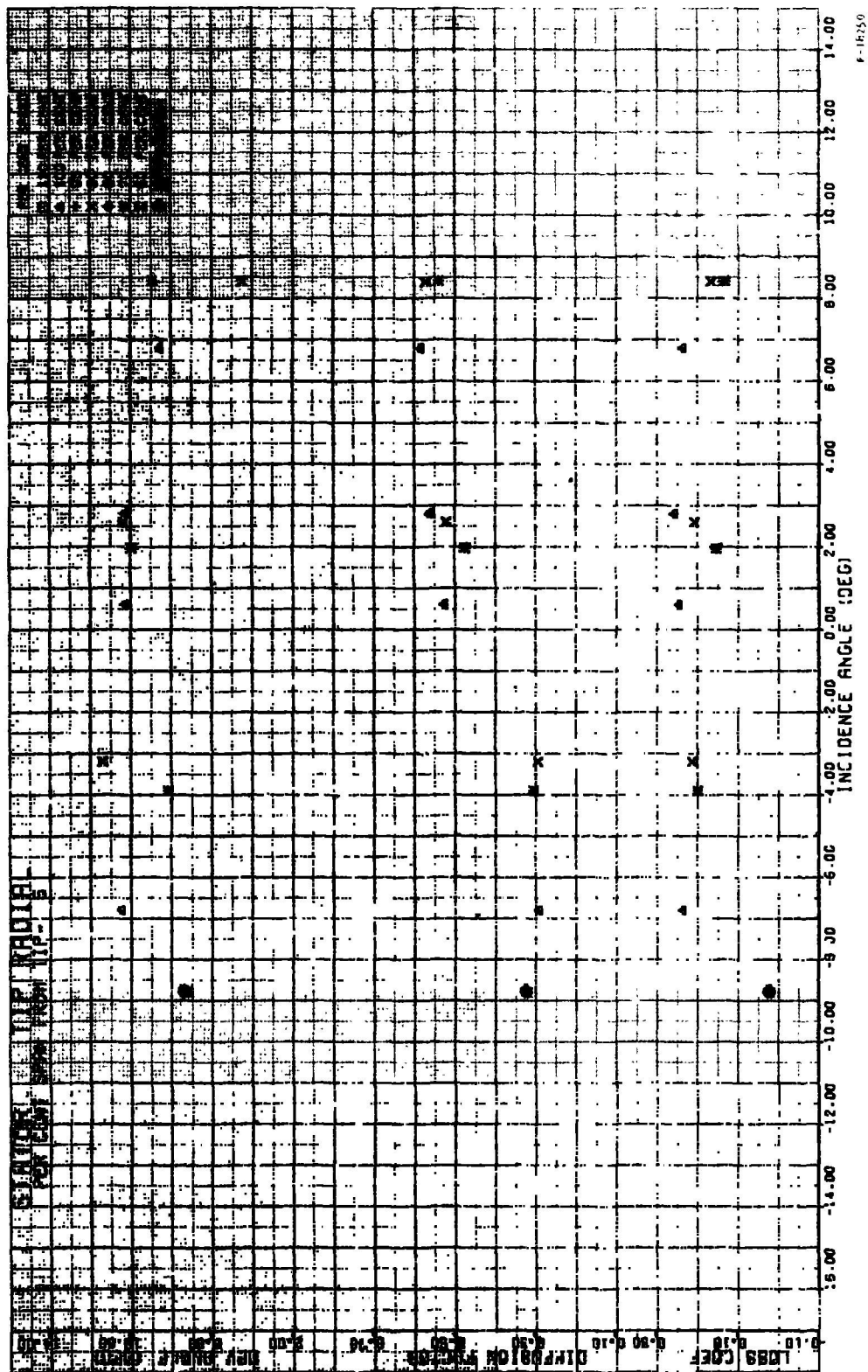


Figure 54a.--Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 5 Percent Span from Tip.

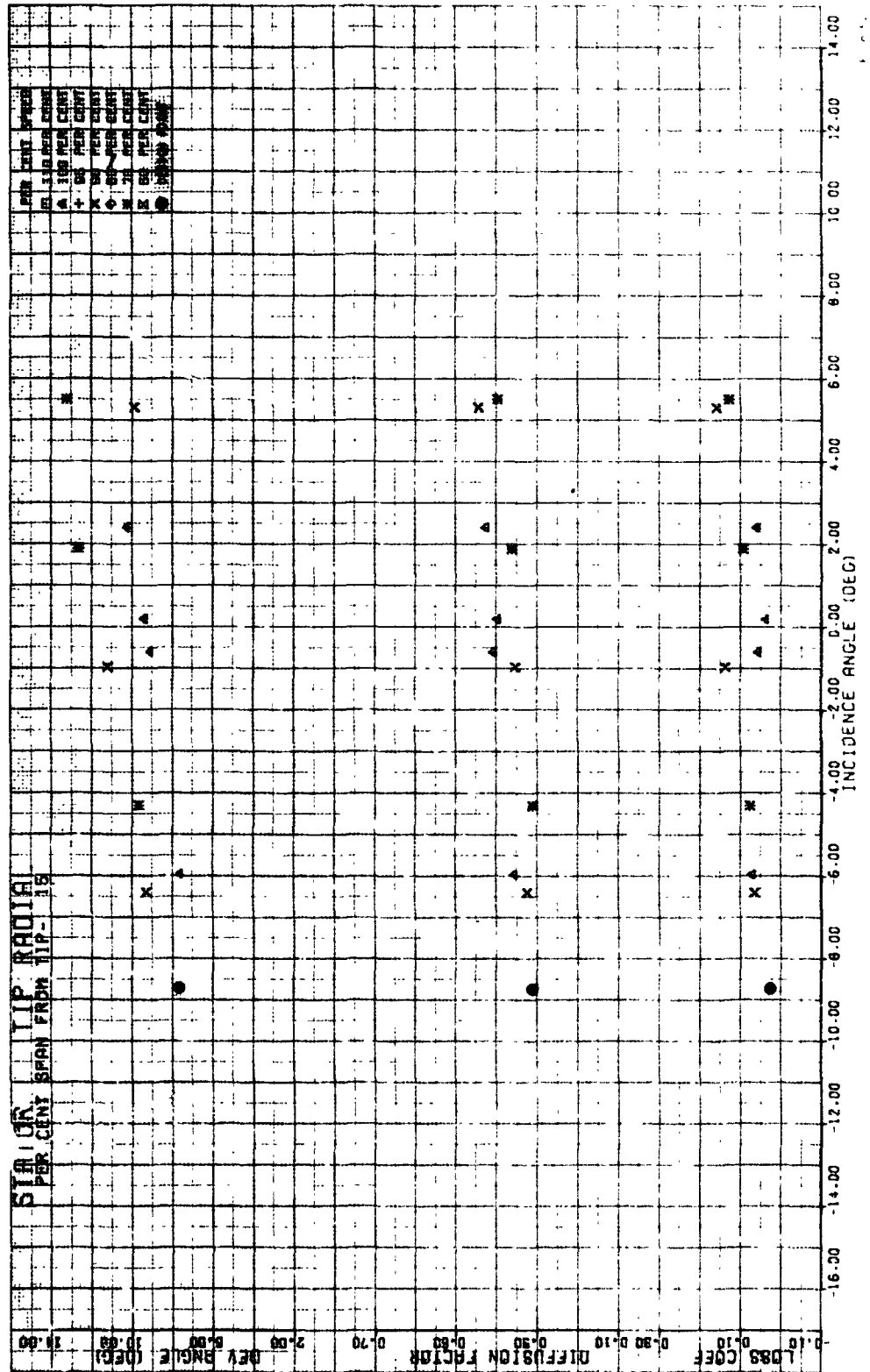


Figure 54b.--Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 10 Percent Span from Tip.

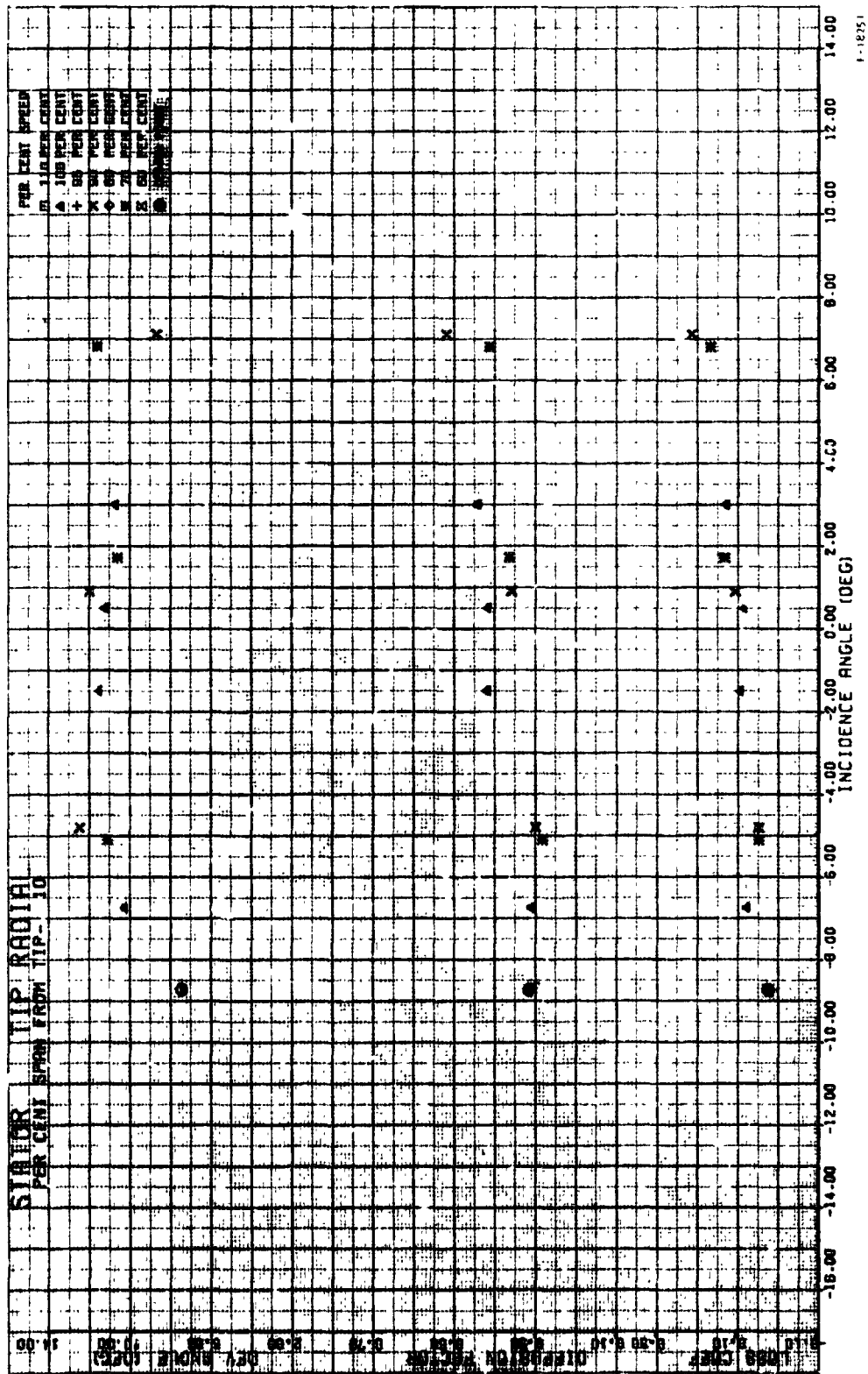


Figure 54c.--Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 15 Percent Span from Tip.

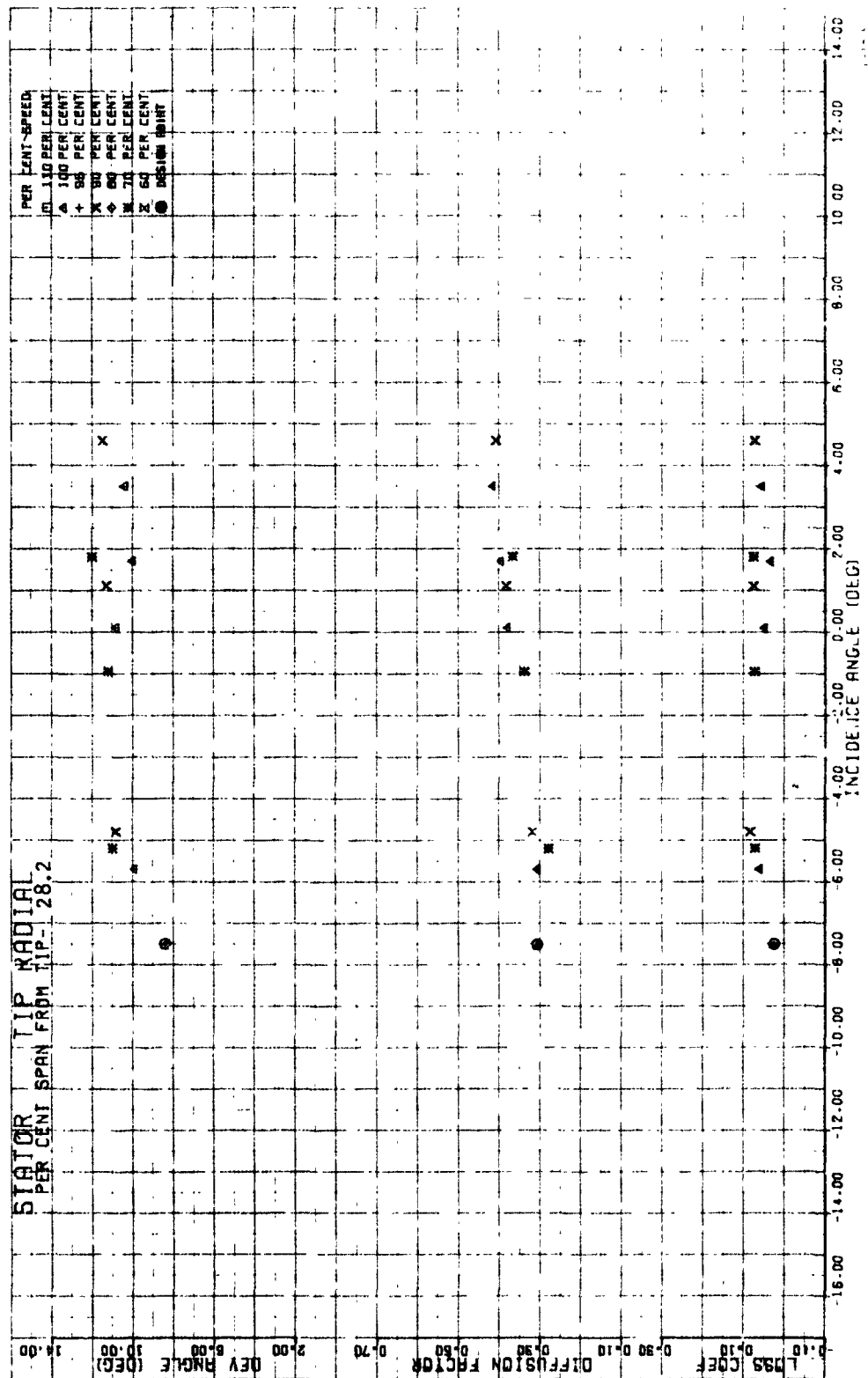


Figure 54d.--Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 28.2 Percent Span from Tip.

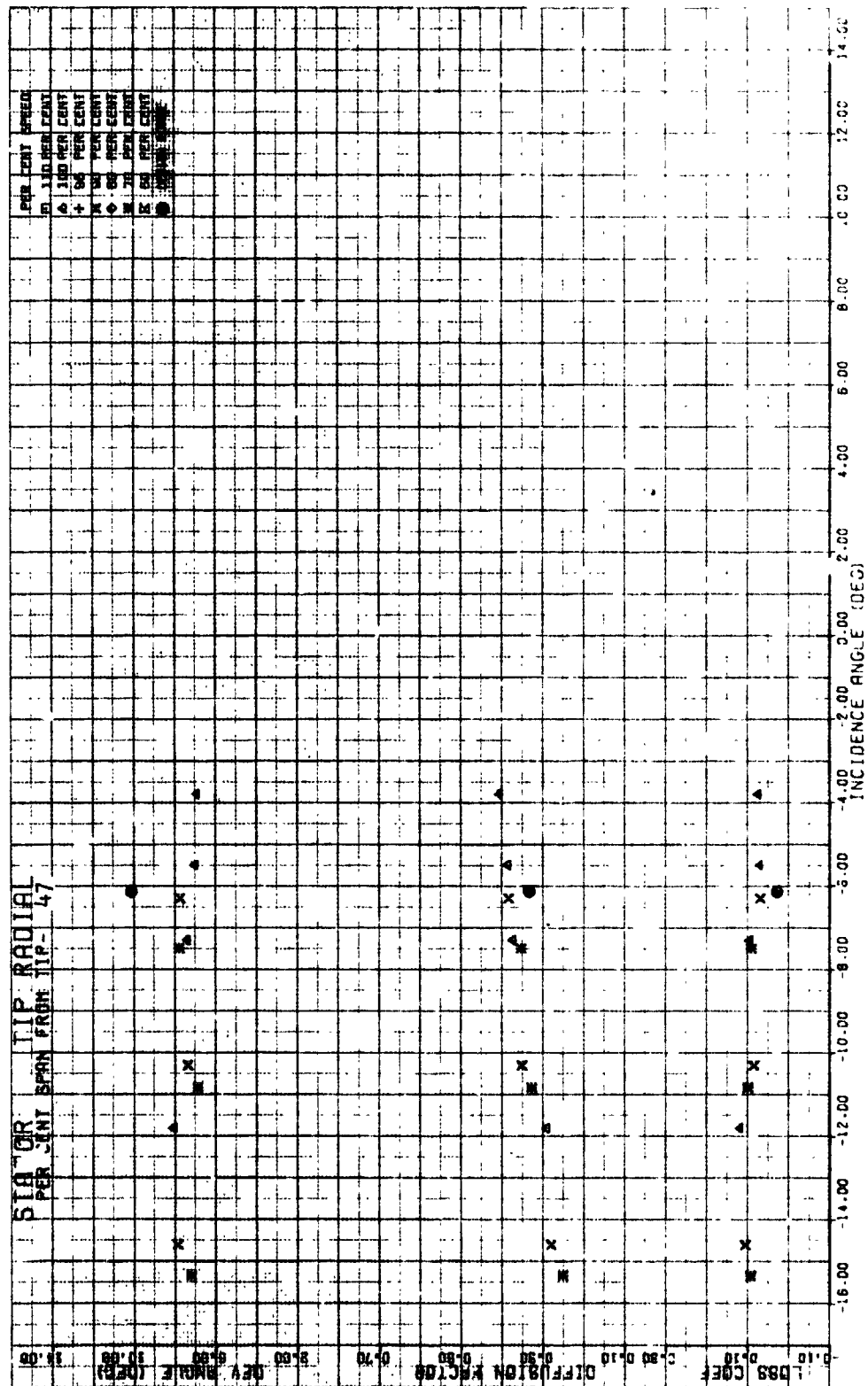


Figure 54e.--Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 47 Percent Span from Tip.

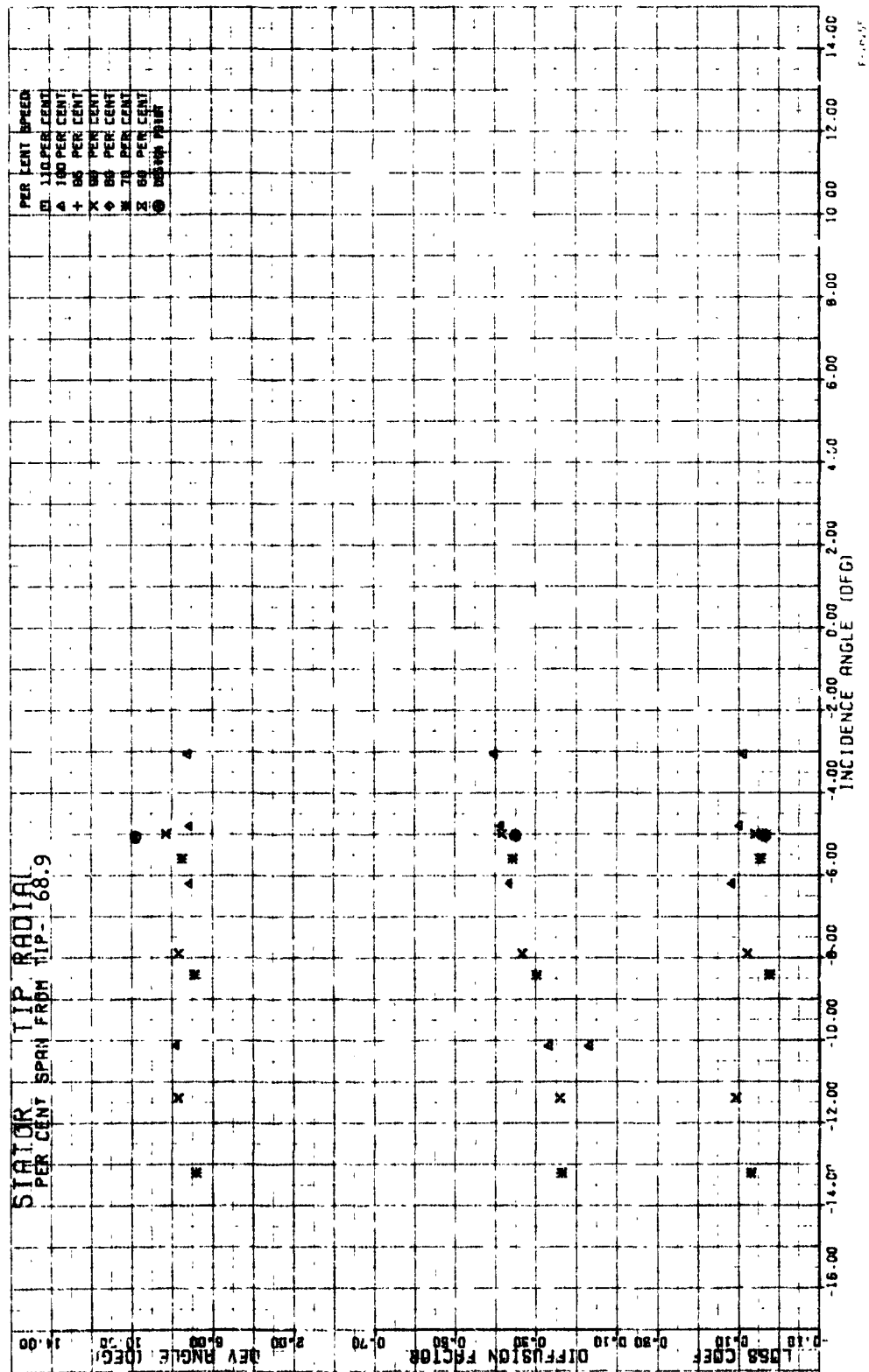


Figure 54f.--Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 68.9 Percent Span from Tip.

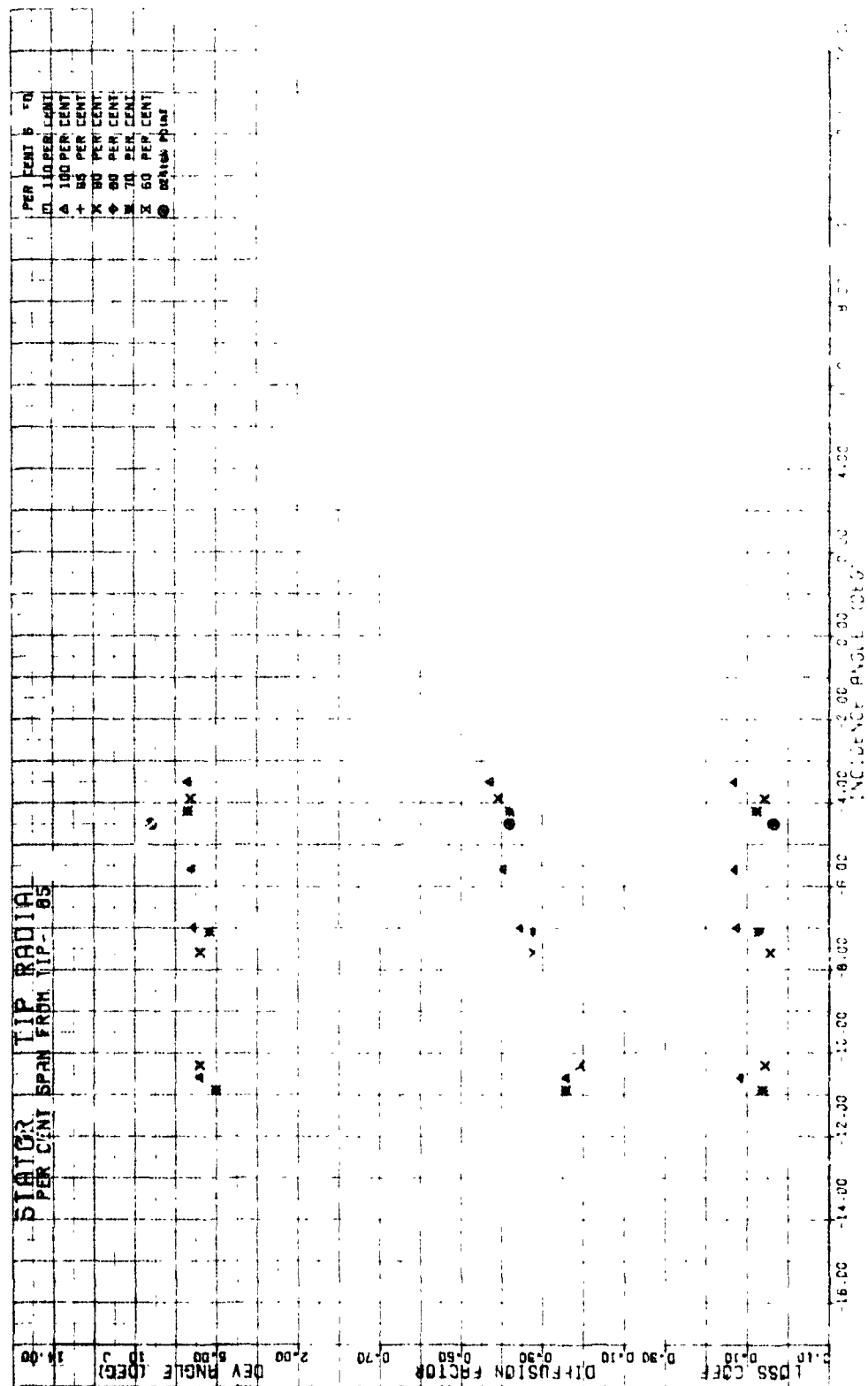


Figure 54g.---Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 85 Percent Span from Tip.

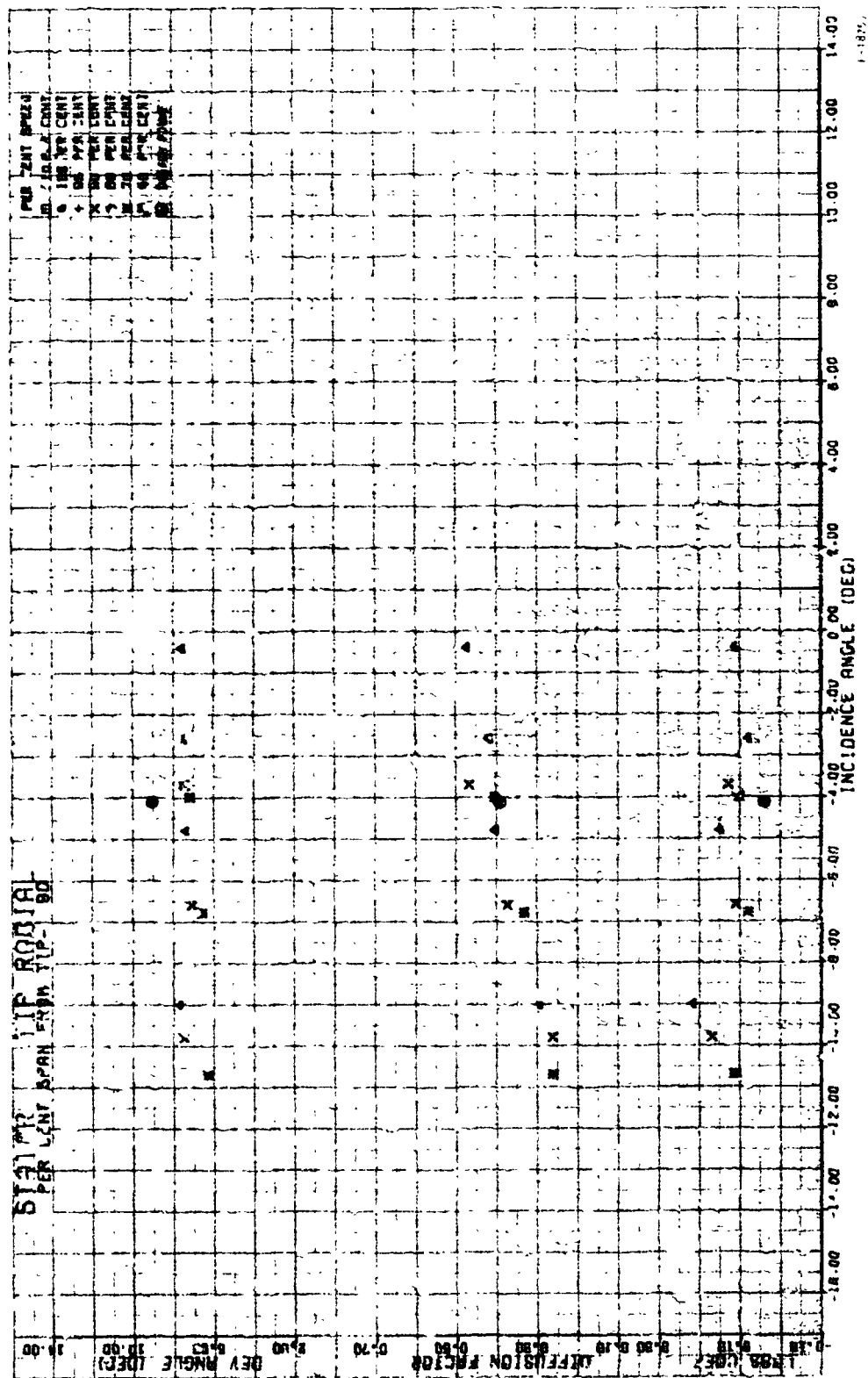


Figure 54h.--Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 90 Percent Span from Tip.

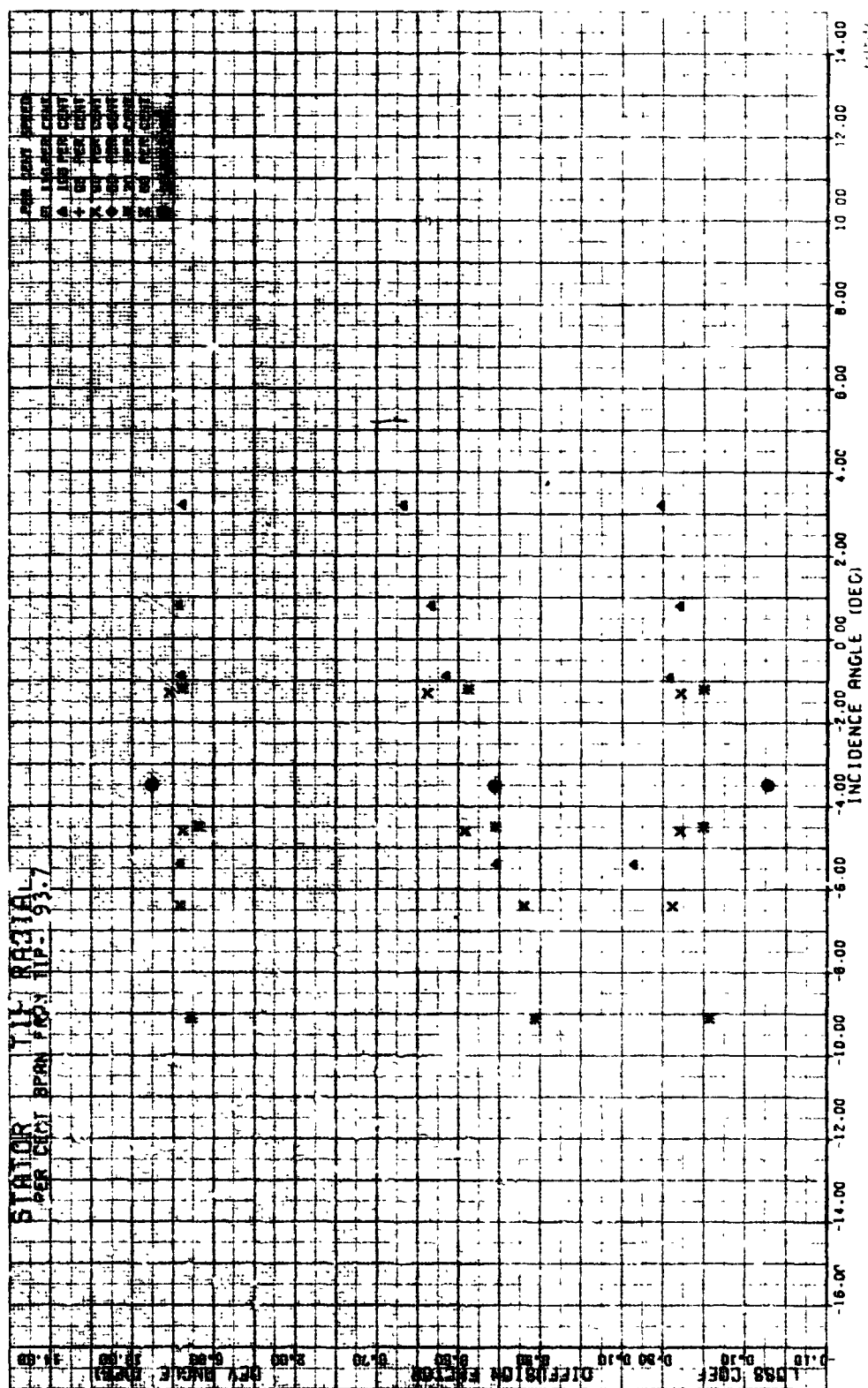
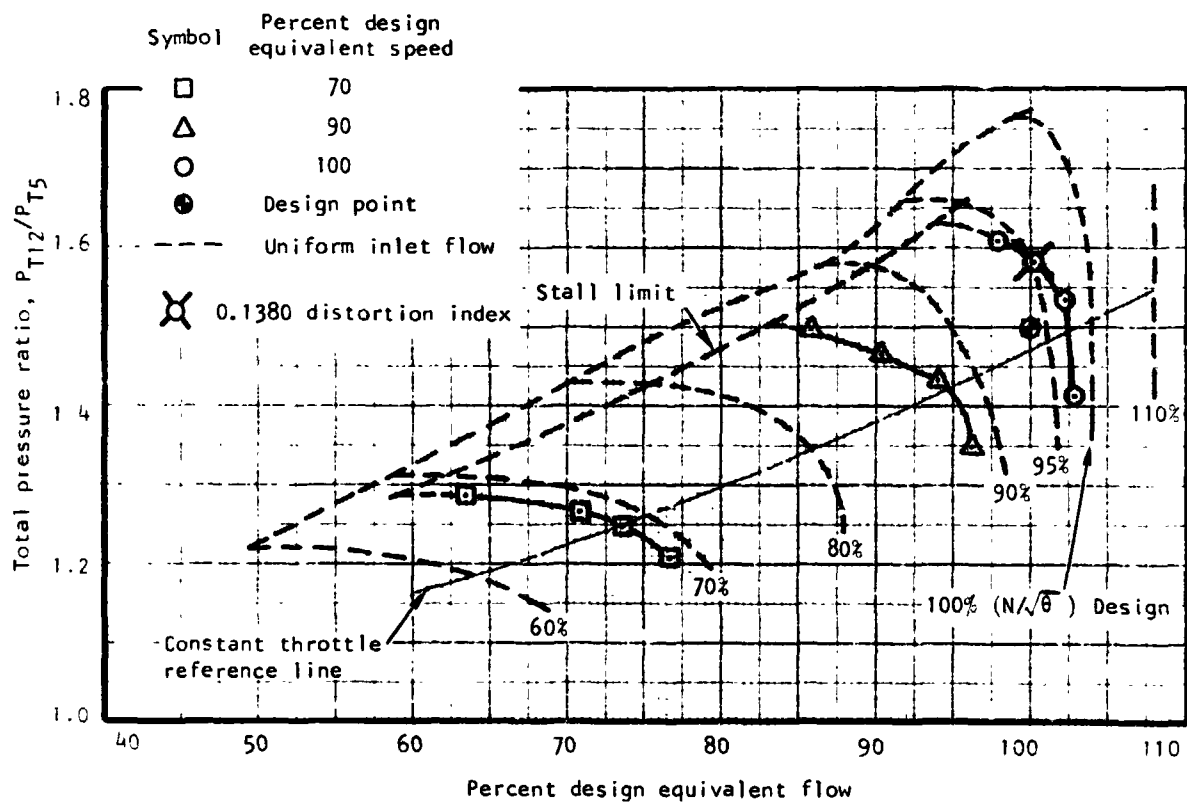
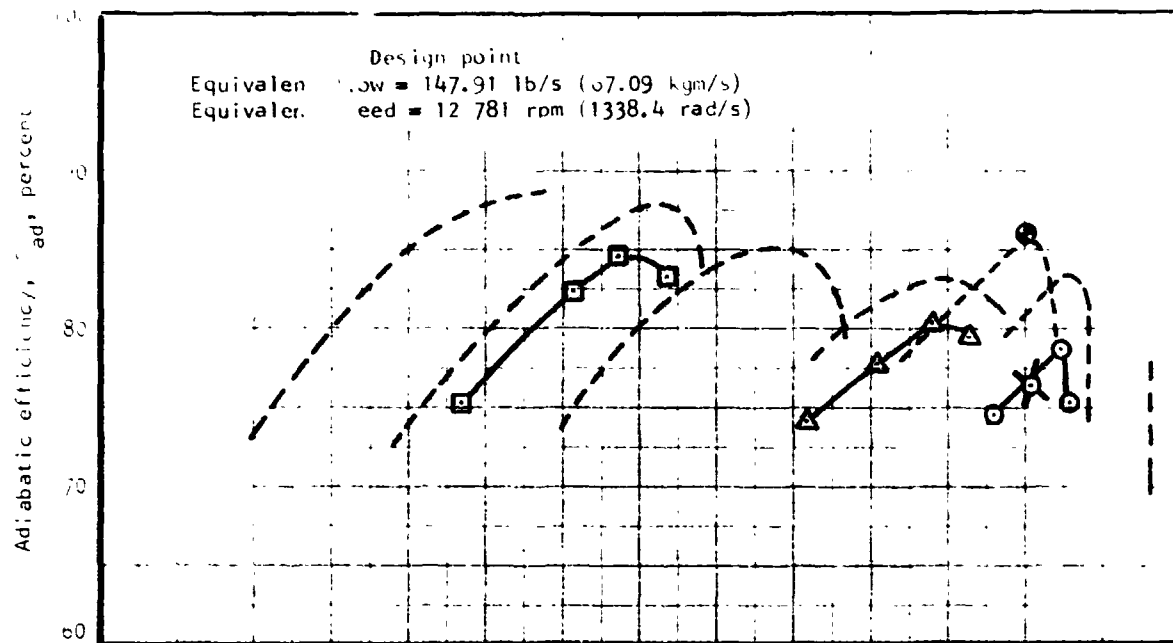


Figure 54i.---Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 93.7 Percent Span from Tip.



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Figure 55.--Stage Performance, Circumferential Inlet Distortion.

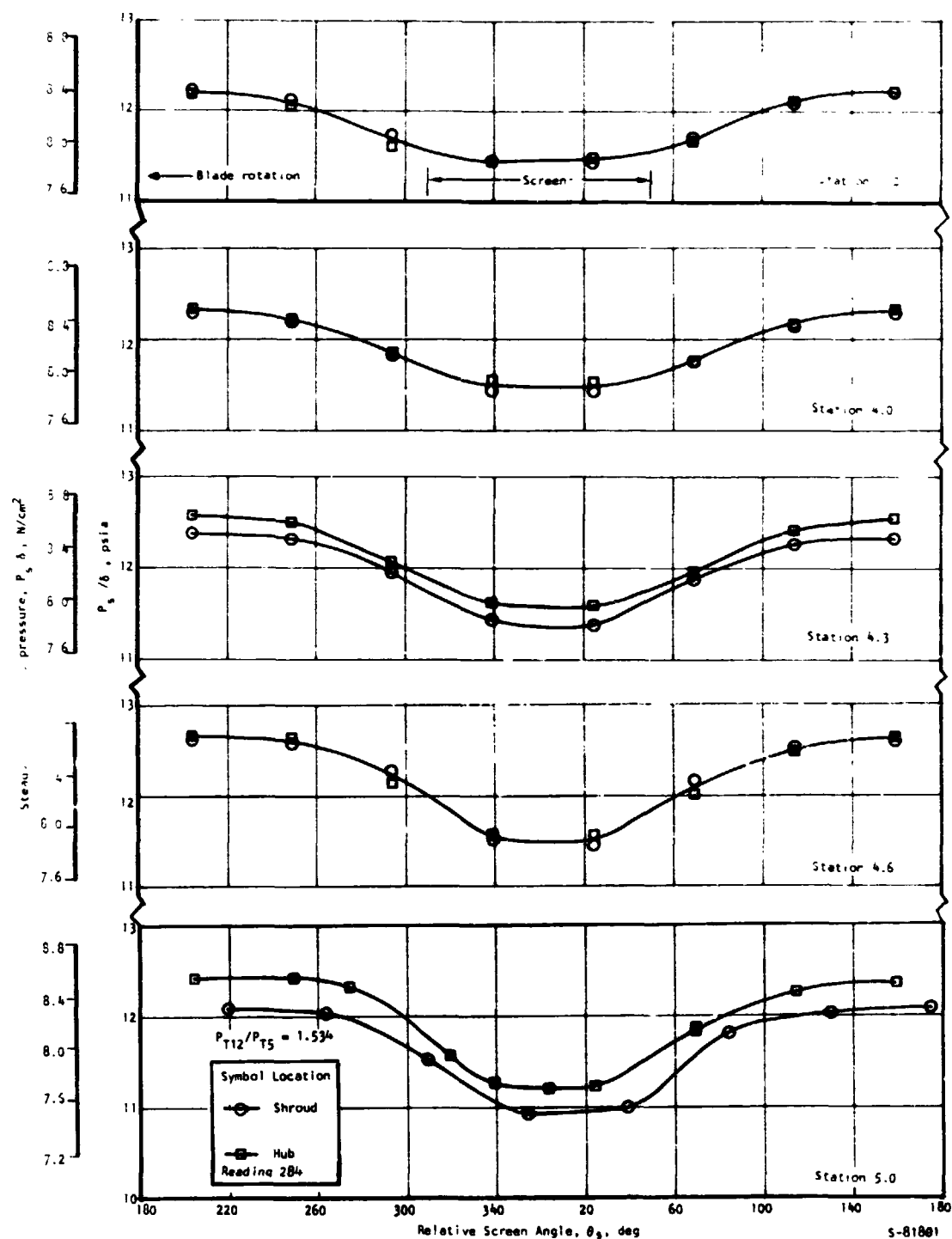


Figure 56.--Circumferential Distribution of Rotor Upstream Static Pressures at Design Speed with Circumferential Inlet Distortion.

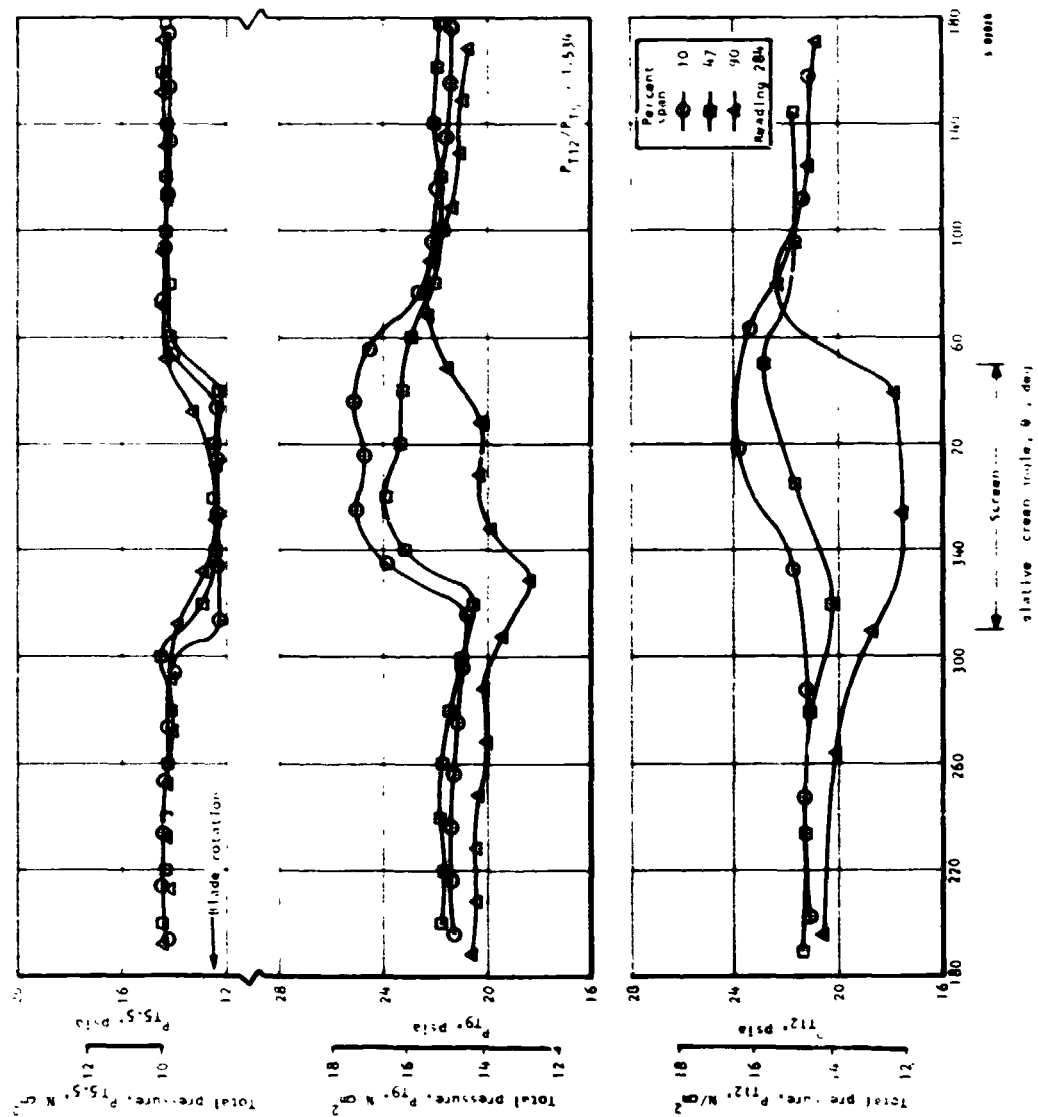


Figure 57.---Circumferential Distribution of Total Pressure at Design Speed with Circumferential Inlet Distortion.

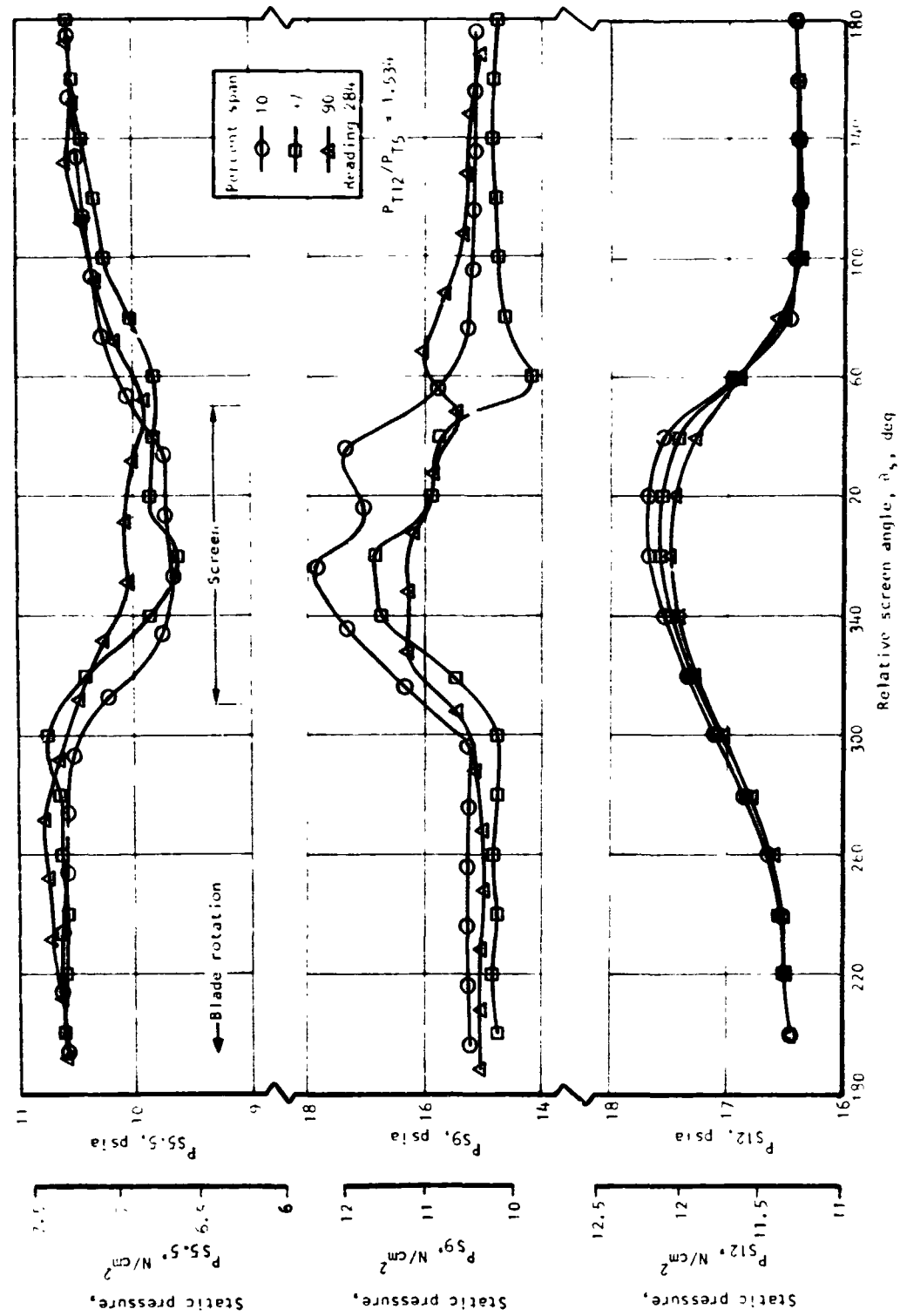
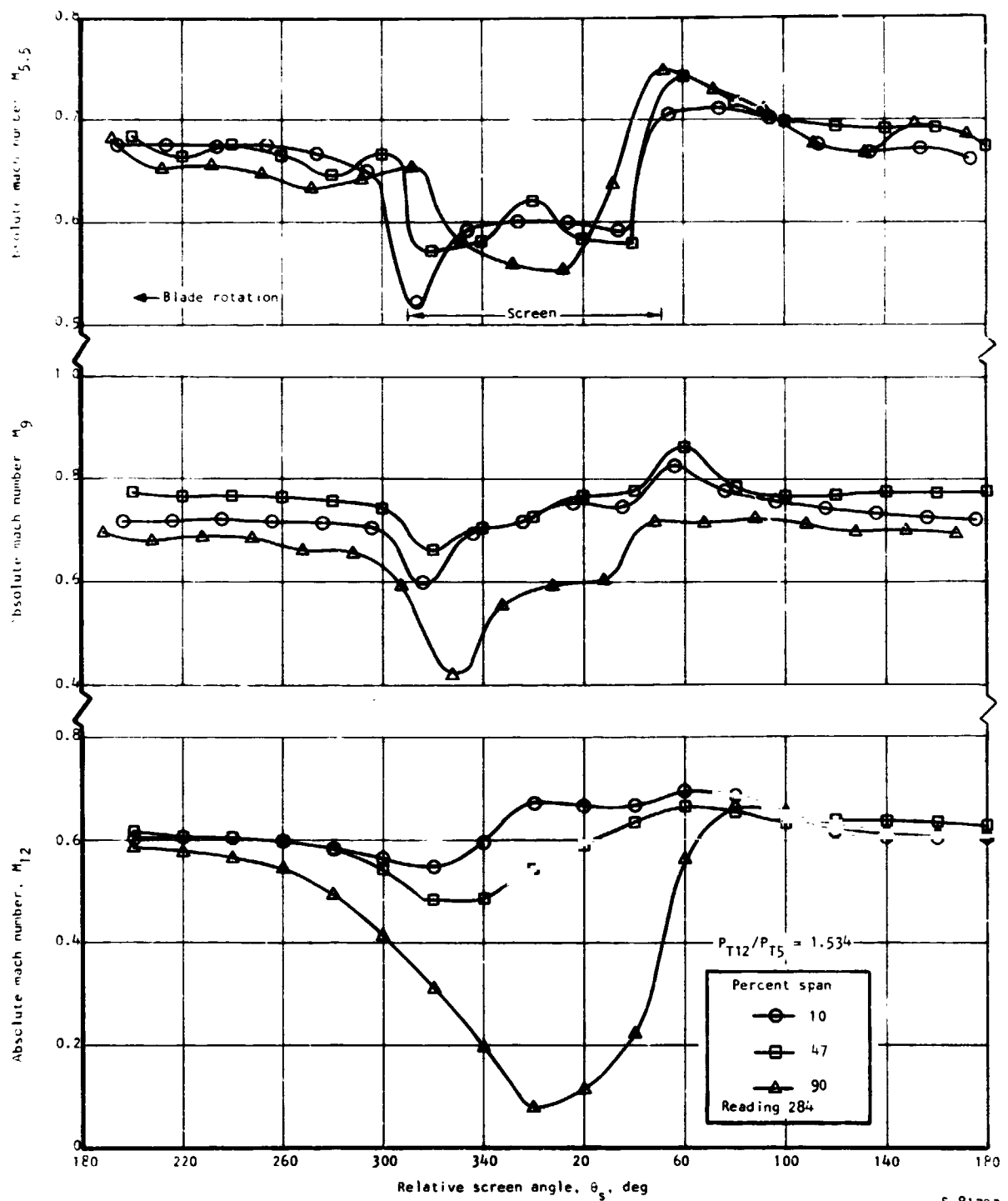


Figure 58.--Circumferential Distribution of Static Pressure at Design Speed with Circumferential Inlet Distortion.



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Figure 59.--Circumferential Distribution of Absolute Mach Number at Design Speed with Circumferential Inlet Distortion.

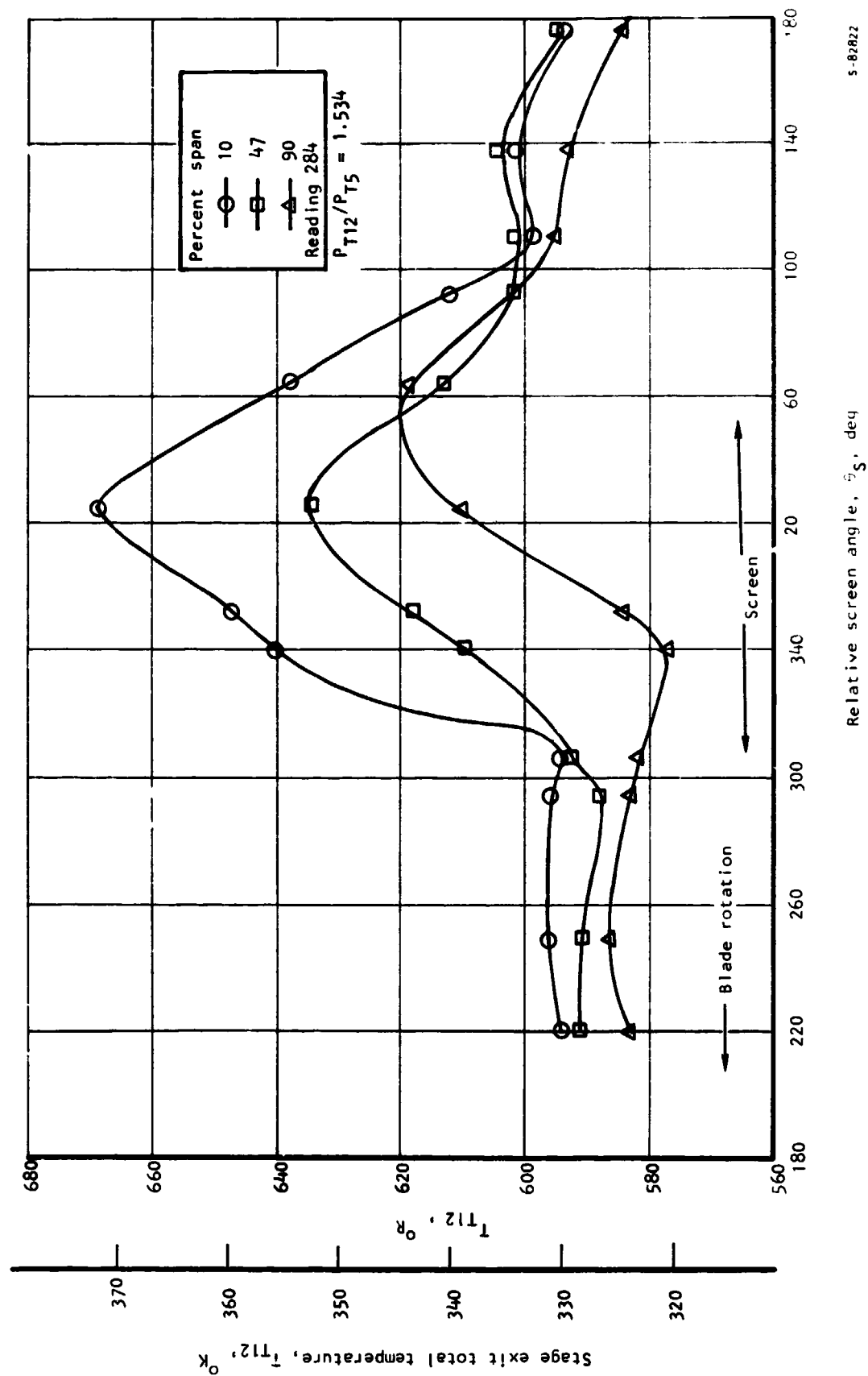


Figure 60.--Circumferential Distribution of Stage Exit Total Temperature at Design Speed with Circumferential Inlet Distortion.

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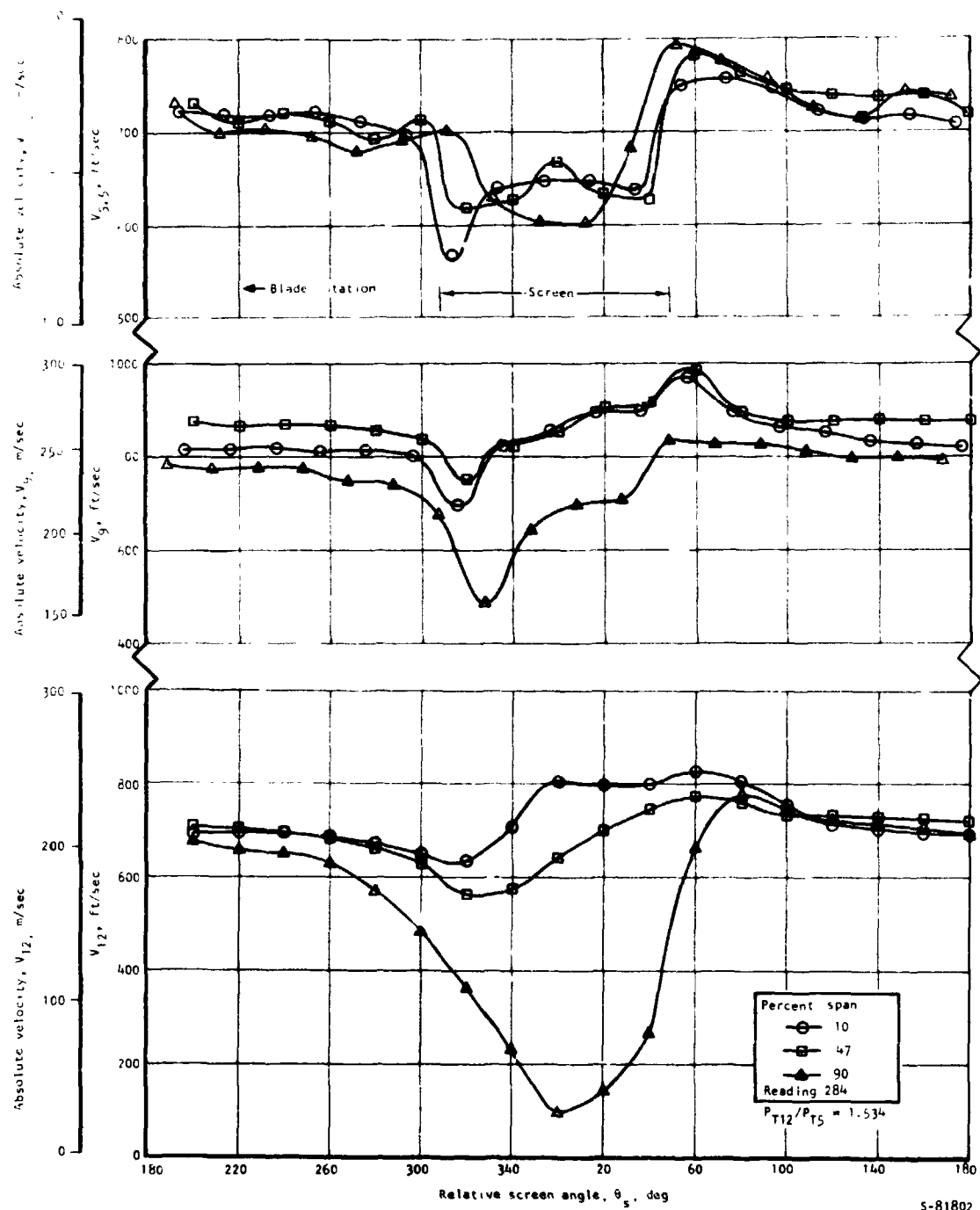


Figure 61.--Circumferential Distribution of Absolute Mach Number at Design Speed with Circumferential Inlet Distortion.

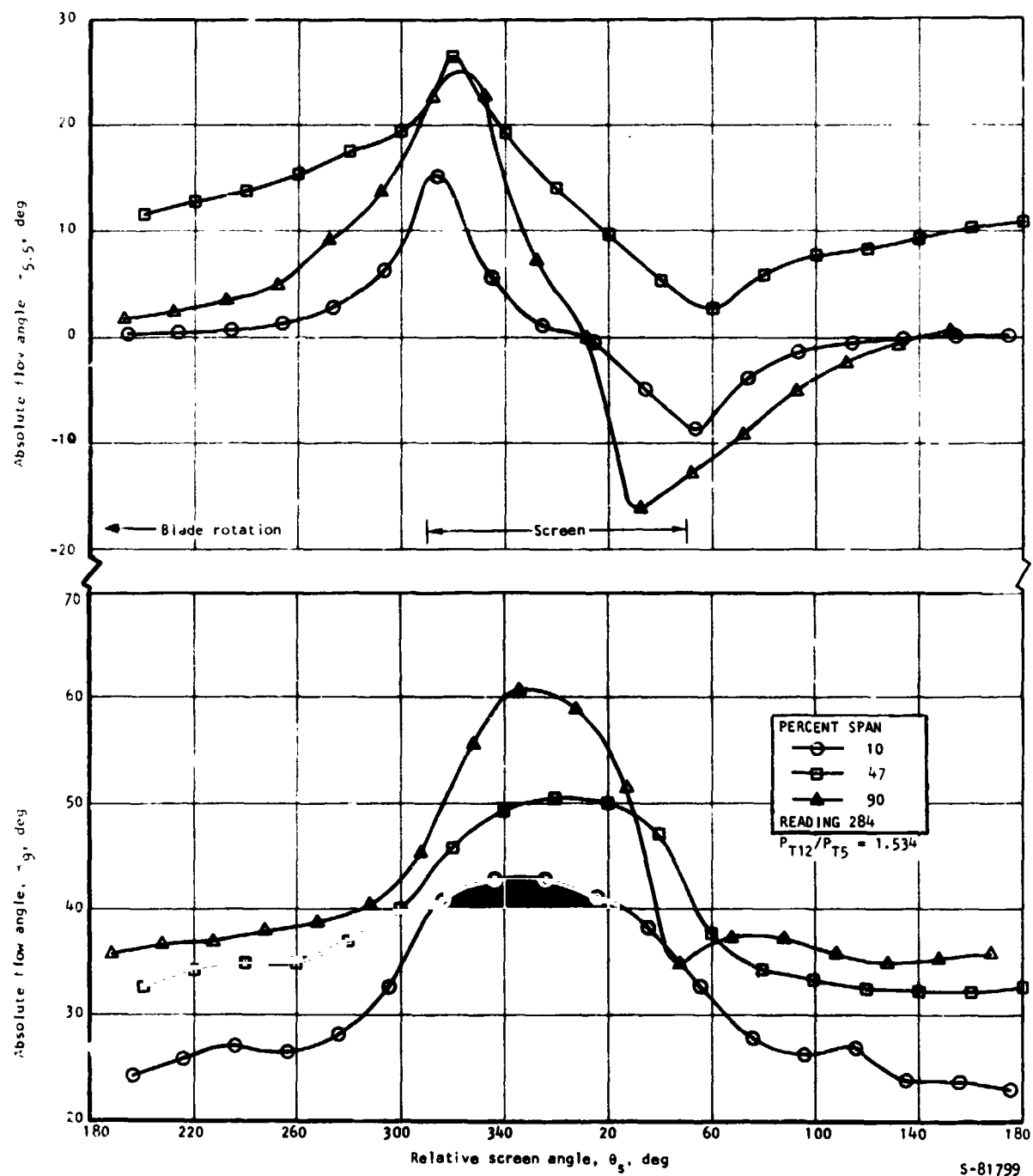


Figure 62.--Circumferential Distribution of Absolute Flow Angle at Design Speed with Circumferential Inlet Distortion.

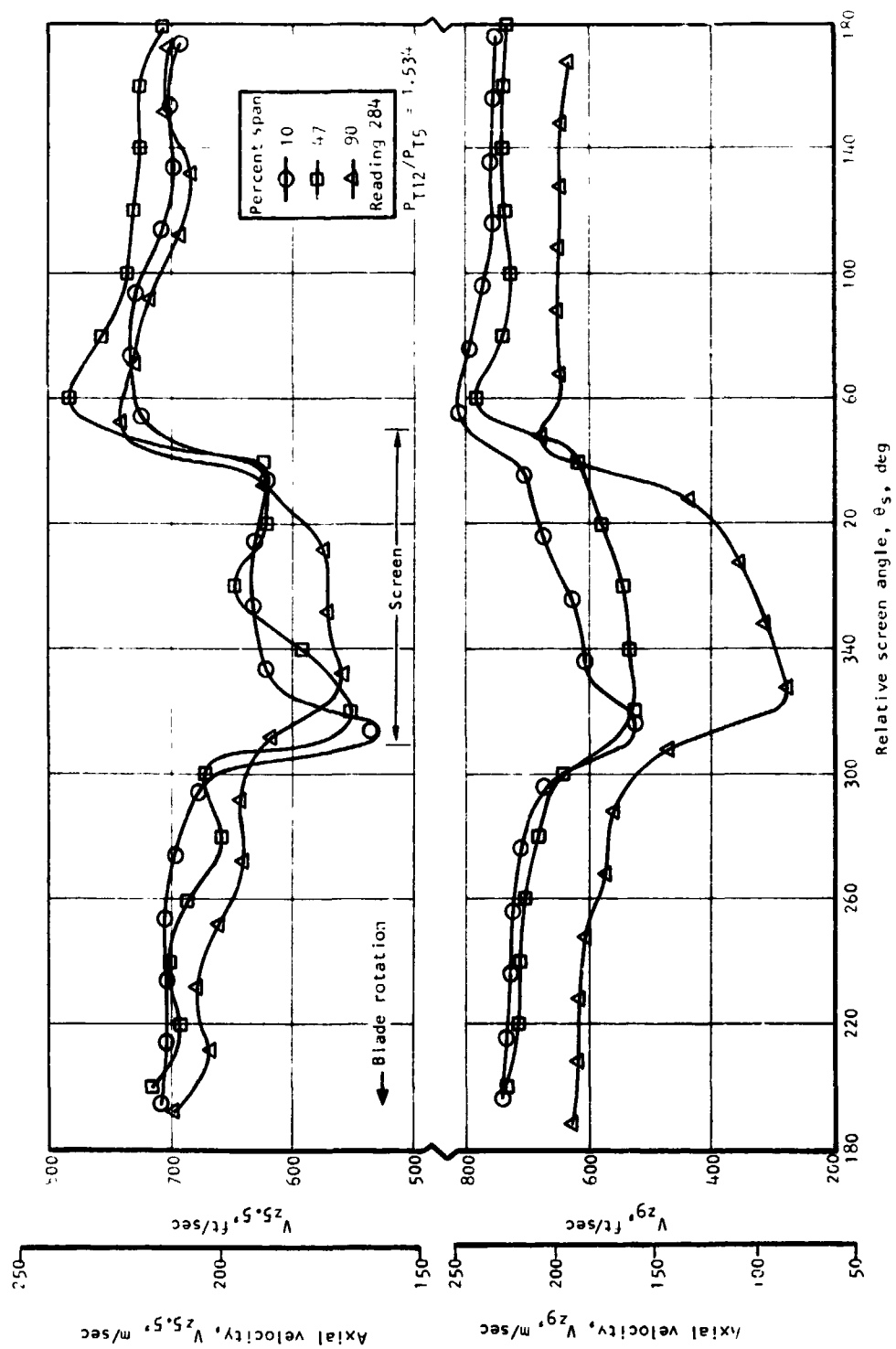
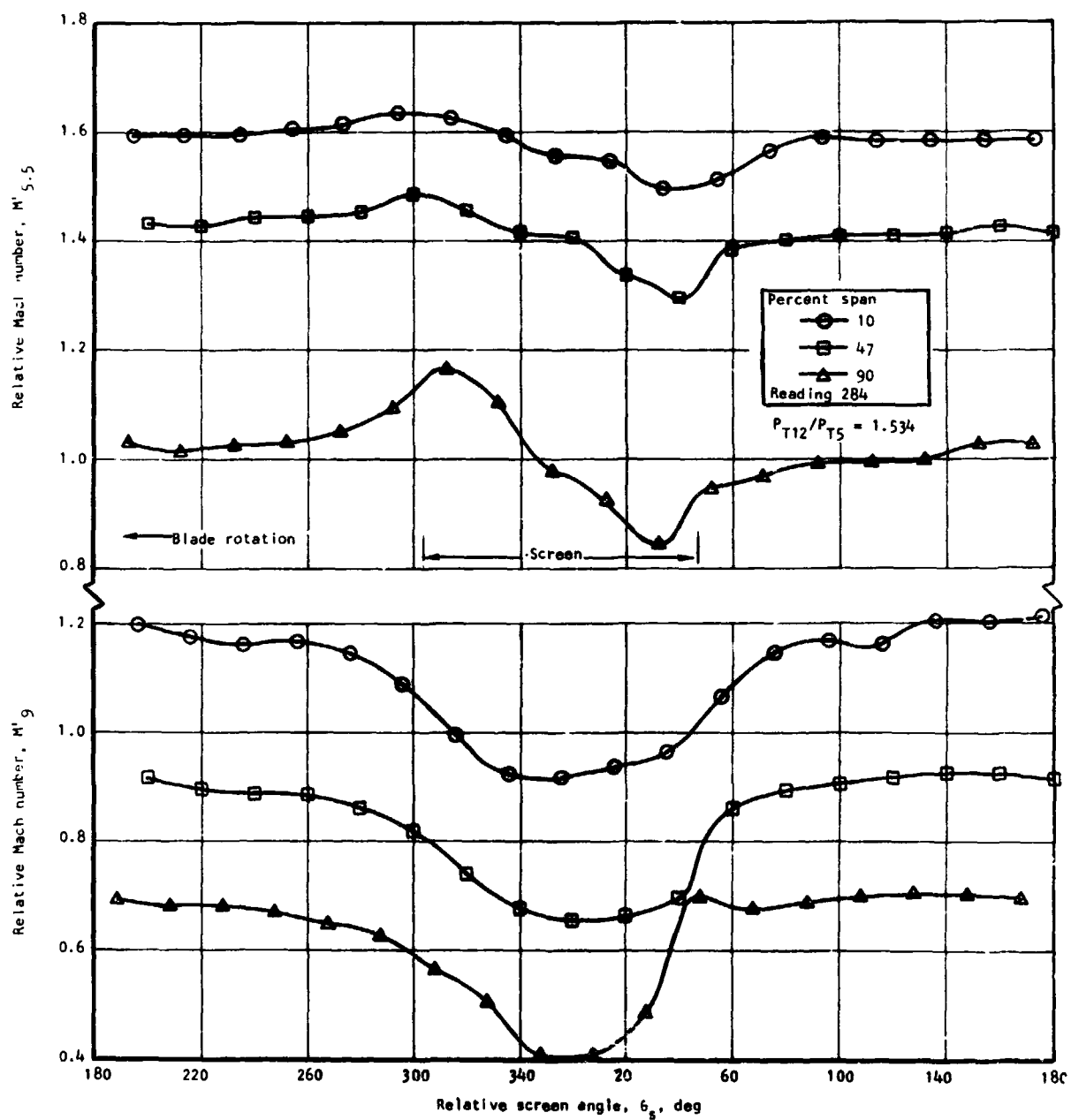


Figure 63.--Circumferential Distribution of Axial Velocity at Design Speed with Circumferential Inlet Distortion.



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Figure 64.--Circumferential Distribution of Relative Mach Number at Design Speed with Circumferential Inlet Distortion.

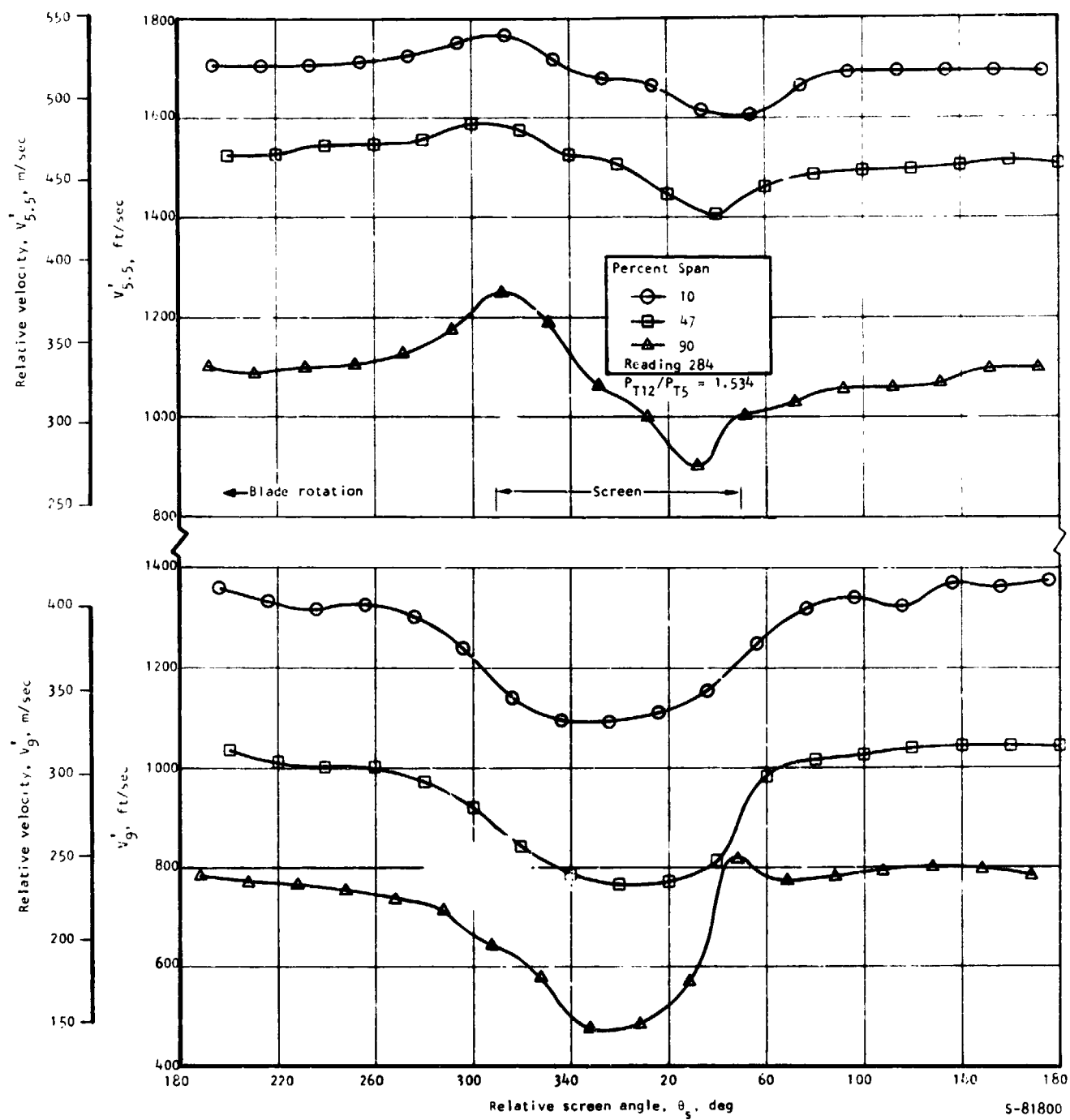


Figure 65.--Circumferential Distribution of Relative Velocity at Design Speed with Circumferential Inlet Distortion.

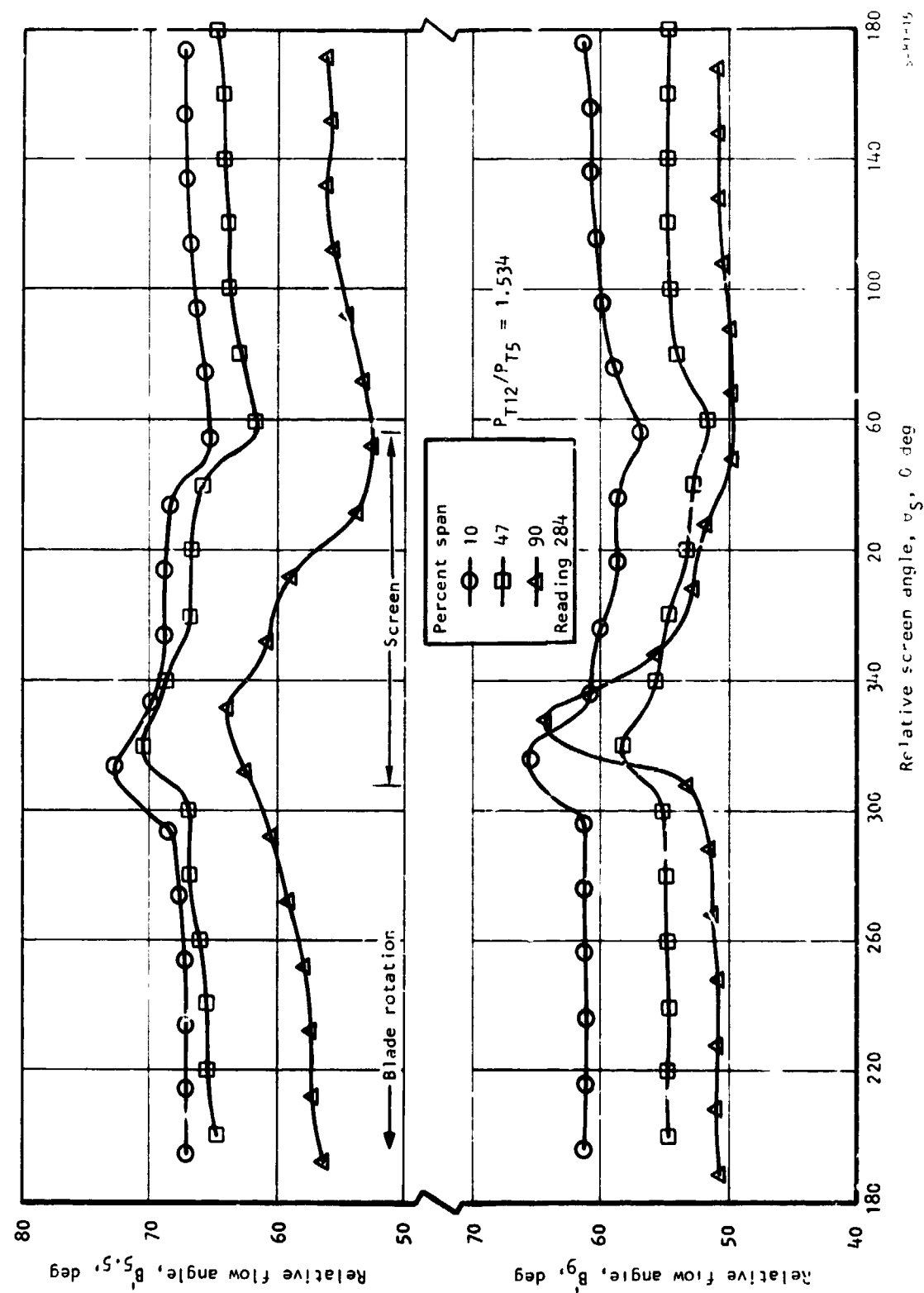


Figure 66.---Circumferential Distribution of Relative Flow Angle at Design Speed with Circumferential Inlet Distortion.

APPENDIX A

REDESIGNED ROTOR FOR TRANSONIC FAN STAGE

The original design detailed in ref. 1 exhibited an aerodynamic instability phenomenon (flutter), which resulted in high cycle fatigue failure of the mid-span dampers during initial testing to 110 percent of design speed. The flutter phenomenon was concluded to be a coupled bending-torsion mode instability. The performance data obtained at design speed from this test were encouraging, and it was felt that modifications to the midspan dampers (thickness, contact angle, and contact surface shape) would be sufficient to relieve the structural problem. However, to further ensure structural integrity of the redesigned rotor without sacrificing the original aerodynamic features, the torsional flutter parameter was increased by thickening blade sections immediately adjacent to the damper.

Aerodynamic

The redesign of the rotor followed the procedures detailed in ref. 1, which consist of sequential running of the axisymmetric stream filament computer program for velocity diagrams, the blade design calculation program for blade sections on conical surfaces, and the blade stacking program for definition of sections on cylindrical surface tangent planes. The original stage design objectives were retained.

Overall total pressure ratio	1.5
Flow per unit annulus area	42 lb/sec-ft ² (205.1 kgm/sec-m ²)
Equivalent total flow	148 lb/sec (67.1 kgm/sec)
Equivalent tip speed	1600 ft/sec (488.6 m/sec)
Equivalent speed	12 781 rpm (1338.4 rad/sec)
Adiabatic efficiency	86 percent

Also retained from the original design were the flow path, streamline work and loss distributions, number of blades, and approximately the same solidity distribution and aspect ratio. The redesign was initiated by revising the axisymmetric stream filament computer program to reflect the blade thickness distribution of fig. A-1 as dictated by mechanical design requirements. The resulting velocities and angles at the blade inlet and outlet are shown in table A-1 as a function of streamline number. The incidence angle rules used for the original design were maintained for the supersonic and transonic region of the redesigned blade. The incidence angles of the subsonic (inboard) sections of the original blade were thought to be low, however, and were increased for the redesign. The deviation rules applied to the redesigned blade were the same as those used for the original blade. The resulting incidence angles, deviation angles, and Carter's rule additive are tabulated in table A-1.

The blade design program does not provide a precise quantitative definition of the input changes required to generate a blade of the desired thickness. The effective, available methods of implementing thickness changes required an increase in both the leading and trailing edge radii as shown in fig. A-2, coupled with an increase in trailing edge shock strength via the specification of an increase in D-shock (the trailing edge shock strength minus the leading edge shock strength) as shown in fig. A-3. The resulting conical developments for typical streamlines 1, 3, 5, 7, and 12 are shown in fig. A-4. Streamline 5 is the closest streamline to the midspan damper and is where the greatest increase in thickness from the original design was required.

The 12 conical blade sections resulting from the blade design program were then used to establish the 14 manufacturing section coordinates as described in the paragraphs that follow.

Mechanical

A geometric summary of the redesigned rotor blade is presented in table A-2. The rotor airfoil coordinates of the resulting 14 rotor blade sections incorporating both axial and tangential tilt and allowance for blade untwist are presented in table A-3. The coordinates are plane blade sections defined by the intersection of the blade with planes tangent to the cylindrical surfaces. A typical section is presented in fig. A-5. The materials selected for the critical components have not changed from the original design. The fan blade and disc material is Ti-6Al-4V (AMS 4928), and the stator vane material is 17-4 PH (AMS 5643).

The fan blade thickness was increased by approximately 45 percent at the midspan damper to increase the blade natural frequency, thereby raising the flutter parameter to a more stable regime. Both torsional flutter and coupled flexural torsional flutter modes were examined. Fig. A-6 shows the torsional flutter parameter ($\omega_T C_T / V_T$) versus rotor speed for the original and redesigned blade, where ω_T is the torsional natural frequency, C_T is the blade tip chord and V_T is the relative fluid velocity at the blade tip. The redesigned blade shows a 45 percent increase in the torsional flutter parameter over the original. From an analysis of the data obtained with the original rotor blade, the threshold of flutter, as indicated in fig. A-6, was thought to occur at approximately 93 percent of design speed. At 110 percent of design speed, the redesigned blade has a 20 percent margin over the value of the flutter parameter at which the original blade fluttered at 93 percent of design speed.

A flutter parameter for coupled flexural-torsional flutter, based on the stability criteria established in ref. 7 is shown in fig. A-7. Using the theoretical approach outlined in Ref. 7, the stability boundary was located based on the results of the original test. Fig. A-7 compares this coupled flutter parameter ($V_T / C_T f_B$) (arbitrary scale) with the rotation-to-translation ratio ($\phi_T C_T / 2h_T$) for both the original and redesigned blade, where f_B is the first flexure natural frequency of the blade, h_T is the relative deflection (translation) of the blade tip midchord point in the first flexural mode, and ϕ_T is the relative angular deflection of the blade tip in the first flexural mode.

The redesigned blade is well within the stable region and should be aeroelastically stable, with respect to this mode of flutter, over the operating speed range.

The blade natural frequencies were calculated using a finite element program in which the blade is modeled as a curved variable thickness plate. The blade was assumed to be built-in (clamped at the root and supported in the axial and tangential directions at the midspan damper. The damper is assumed to be locked up at zero speed for nominal blade dimensions. The first three natural frequencies are shown as a function of rotor speed on the excitation diagram given in fig. A-8. No serious resonant conditions are shown in the operating range.

The first three mode shapes at zero speed are shown in fig. A-9. The location of the maximum vibratory stress in each mode, as well as the relative values (in percent) of the vibratory stress at other critical points, also are shown.

Fig. A-10 is a modified Goodman diagram showing the allowable vibratory stress as a function of steady stress. The allowable vibratory stress is 50 percent of the 10^7 cycle endurance strength. The airfoil mid-chord at the midspan damper has been chosen as a critical point for vibratory stress. The allowable vibratory stress at this location is ± 30 ksi (207×10^6 N/m²) at design speed.

The airfoil was tilted 0.010 in./in. (cm/cm) in the tangential direction and 0.0035 in./in. (cm/cm) in the axial direction to allow centrifugal loads to counteract the aerodynamic loads. The airfoil suction and pressure surface design speed stress distributions due to centrifugal, untwist, and aerodynamic loads are shown in fig. A-11. The steady stresses at 110 percent speed will be 1.21 times those shown. Thus, the maximum equivalent calculated airfoil stress at 110 percent speed is 78.6 ksi (543×10^6 N/m²).

The airfoil will untwist due to both centrifugal and aerodynamic loads. The untwist versus radius at the design point is shown in fig. A-12. The untwist at the midspan damper is approximately 0.5 deg. The nominal midspan damper blade-to-blade spacing will increase with speed and thereby allow the midspan damper to untwist the 0.5 deg at design speed.

The midspan damper stress distribution is shown in fig. A-13. The redesigned damper has a smaller interface angle (15 deg) and has no grind relief notch, which was the origin of failure on the original blade. The maximum midspan damper equivalent stress is 80 ksi (551×10^6 N/m²) and is very localized. This stress is slightly less than the allowable 82 ksi (566×10^6 N/m²).

The disc stresses with the redesigned blade are slightly higher than those in the original design because of the small increase in blade weight. The disc tangential and radial stresses at critical locations at 110 percent design speed are listed on the next page.

Location	Type of Stress	Calculated Stress		Allowable Stress	
		Ksi	(N/m ²)	Ksi	(N/m ²)
Disc	Avg. tangential	67.6	(465 x 10 ⁶)	67.5	(465 x 10 ⁶)
Bore	Max. tangential	88.0	(607 x 10 ⁶)	91.0	(926 x 10 ⁶)
Web	Max. radial	30.0	(207 x 10 ⁶)	85.5	(590 x 10 ⁶)

The bore and web stresses are within the allowables. The average tangential stress is equal to the allowable, indicating the burst criteria has just been met.

The minimum shedding speeds for the airfoil and dovetail were determined using 90 percent of the minimum natural ultimate stress at the maximum temperature conditions.

Blade airfoil	18 090 rpm (1892 rad/sec)
Blade shank	21 900 rpm (2295 rad/sec)
Disc shank	17 800 rpm (1864 rad/sec)
Disc burst	17 600 rpm (1843 rad/sec)

The minimum burst and shedding speed is 17 600 rpm (1843.1 rad/sec), which is 138 percent of the design speed.

The dovetail stresses in the blade and disc are slightly higher than those of the original design because of the heavier airfoil and midspan damper on the redesigned blade. The neck, tang, and combined stresses at 110 percent speed are listed in table A-4 along with the allowable stresses. All margins of safety are positive. The combined fillet stress is a combination of tang bending and neck tension, excluding the stress concentration effects. The maximum fillet stress, which determines the low-cycle fatigue life of the attachment, includes the stress concentration factor. All calculated stresses show a positive margin of safety.

TABLE A-1
ROTOR AERODYNAMIC SUMMARY

$P_{T1} = 14.696 \text{ psia} = 10.133 \text{ N/cm}^2$
 $T_{T1} = 518.69^\circ\text{R} = 288.16^\circ\text{K}$
 $\omega = 12,781 \text{ rpm} = 1338.4 \text{ rad/sec}$
 $U/\omega = 147.91 \text{ lbm/s} = 67.09 \text{ kg/sec}$
 $U_{T1} = 1603.0 \text{ ft/sec} = 488.594 \text{ m/sec}$
 $r_{T1} = 14.370 \text{ in} = 36.50 \text{ cm}$

Blockage factor = 0.460

Inlet (station 6)

Streamline	1	2	3	4	5	6	7	8	9	10	11	12
r/r_{T6}	1.0000	0.9638	0.9274	0.8897	0.8501	0.8081	0.7638	0.7161	0.6644	0.6077	0.5432	0.4622
P/P_{T1}	0.0	9.09	18.18	27.27	36.36	45.45	54.55	63.64	72.73	81.82	90.91	100.00
T/T_{T1}	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
U/U_{T6}	1.0000	0.9638	0.9274	0.8897	0.8501	0.8081	0.7638	0.7161	0.6644	0.6077	0.5432	0.4622
V_0/U_{T6}	1.0000	0.9638	0.9274	0.8897	0.8501	0.8081	0.7638	0.7161	0.6644	0.6077	0.5432	0.4622
θ	-13.00	-9.26	-5.42	-2.29	-0.63	-0.05	2.03	3.17	4.36	5.53	6.76	7.93
V/U_{T6}	0.4318	0.4567	0.4594	0.4555	0.4486	0.4440	0.4406	0.4313	0.4242	0.4170	0.3955	0.3314
V'/U_{T6}	0.4318	0.4567	0.4594	0.4555	0.4486	0.4440	0.4406	0.4313	0.4242	0.4170	0.3955	0.3314
S'	66.64	64.64	63.64	62.88	62.17	61.21	60.01	58.93	57.44	55.54	53.94	54.35
z	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
θ_{CL}	2.791	2.797	2.839	3.130	3.675	3.623	3.670	3.908	4.341	5.266	5.856	6.086
θ_{CL}	0.721	0.801	0.847	1.000	1.300	1.220	1.216	1.355	1.620	2.136	2.100	1.160
M	1.619	1.593	1.547	1.493	1.434	1.374	1.313	1.243	1.170	1.093	0.992	0.837
M	0.642	0.682	0.687	0.681	0.669	0.662	0.656	0.641	0.630	0.618	0.584	0.485

Overall parameters

r/r_{T6}	0.9848	0.9523	0.9187	0.8835	0.8461	0.8063	0.7638	0.7180	0.6685	0.6151	0.5565	0.4883
T/T_{T0}	0.1470	0.1419	0.1400	0.1400	0.1410	0.1439	0.1485	0.1499	0.1439	0.1400	0.1369	0.1390
T	0.0785	0.0642	0.0596	0.0620	0.0688	0.0840	0.1096	0.1202	0.0978	0.0831	0.0714	0.0910
D	0.2150	0.2340	0.2520	0.2685	0.2903	0.3191	0.3558	0.3879	0.4033	0.4126	0.3878	0.2410
θ	0.851	0.875	0.891	0.893	0.887	0.867	0.841	0.837	0.870	0.900	0.920	0.928
θ	1.622	1.644	1.668	1.675	1.693	1.706	1.724	1.752	1.781	1.805	1.885	2.098

Exit (station 8)

Blockage factor = 0.955

r/r_{T6}	0.9694	0.9407	0.9101	0.8771	0.8421	0.8041	0.7635	0.7199	0.6724	0.6224	0.5696	0.5144
P/P_{T1}	1.512	1.510	1.509	1.509	1.509	1.510	1.511	1.512	1.513	1.514	1.517	1.528
T/T_{T0}	1.147	1.142	1.140	1.140	1.141	1.144	1.149	1.150	1.144	1.140	1.137	1.139
U/U_{T6}	0.9694	0.9407	0.9101	0.8771	0.8421	0.8041	0.7635	0.7199	0.6724	0.6224	0.5696	0.5144
V_0/U_{T6}	0.7835	0.7554	0.7217	0.6824	0.6375	0.5850	0.5251	0.4649	0.4097	0.3475	0.2742	0.1840
V_H/U_{T6}	0.4666	0.4371	0.4129	0.3954	0.3805	0.3692	0.3600	0.3543	0.3590	0.3729	0.4078	0.4807
θ	-11.50	-9.69	-8.42	-7.79	-6.22	-3.54	-2.15	-1.18	3.19	7.96	12.99	17.70
V/U_{T6}	0.5024	0.4746	0.4538	0.4408	0.4320	0.4294	0.4319	0.4364	0.4449	0.4633	0.5036	0.5832
V'/U_{T6}	0.9114	0.8727	0.8315	0.7885	0.7423	0.6918	0.6359	0.5845	0.5447	0.5097	0.4915	0.5147
S'	59.21	59.95	60.22	59.90	59.16	57.74	55.57	52.69	48.77	42.98	33.92	20.95
z	21.75	22.93	24.51	26.24	28.26	30.71	33.54	35.72	36.21	36.40	35.91	34.50
M'	1.275	1.217	1.156	1.094	1.028	0.956	0.878	0.807	0.755	0.710	0.691	0.736
M	0.703	0.662	0.631	0.612	0.598	0.594	0.596	0.602	0.617	0.645	0.708	0.834
θ^0	3.778	3.788	3.933	5.753	7.869	7.727	7.930	8.191	8.370	8.533	8.914	10.277
x	3.14	3.01	3.09	4.80	6.74	5.96	5.40	5.31	5.50	5.43	4.81	2.49

TABLE A-2
ROTOR GEOMETRIC SUMMARY

[Blade sections, defined by the intersection of the blade with planes tangent to cylindrical surfaces]

Blade height = 7.728 in. (19.63 cm) Number of blades = 40
Hub tip ratio = 0.462 Aspect ratio = 2.76

L = plane radius	in. cm	14.370 36.500	13.800 35.052	13.100 33.274	12.750 32.385	12.400 31.496	12.000 30.480	11.700 29.718	11.000 27.940	10.300 26.162	9.600 24.384	8.900 22.606	8.200 20.828	7.500 19.050	6.642 16.871
Blade height from tip, percent		0	7.7	16.7	20.9	25.4	30.6	34.8	44.0	52.9	61.9	71.0	80.0	89.0	100.0
β_6^* design		65.01	62.43	61.01	60.30	59.54	58.41	57.92	56.65	55.42	53.88	51.89	50.23	48.87	49.85
β_8^* design		56.91	57.09	56.89	56.20	54.24	51.59	50.54	48.20	44.82	40.35	34.06	24.11	10.08	-4.26
β_H design		62.02	60.36	58.85	57.51	55.82	54.06	53.48	52.06	49.77	46.38	41.70	36.11	30.85	25.43
Protwist		1.050	0.960	0.860	0.740	0.750	1.030	0.810	0.830	0.980	0.900	0.500	0.160	0.0	0.0
β_6^* static		66.06	63.39	61.87	61.04	60.29	58.44	58.73	57.48	56.40	54.78	52.39	50.39	48.87	49.85
β_8^* static		57.96	58.05	57.75	56.94	54.99	52.62	51.35	49.03	45.80	44.26	34.56	24.27	10.08	-4.26
β_H static		63.05	61.32	59.71	58.25	56.57	55.09	54.29	52.89	50.75	47.28	42.20	36.27	30.65	25.48
Camber		8.10	5.34	4.12	4.10	5.30	6.82	7.38	8.45	10.60	13.52	17.83	26.12	38.79	54.11
Chord	in. cm	3.640 9.296	3.577 9.086	3.477 8.832	3.421 8.689	3.351 8.512	3.274 8.316	3.194 8.113	3.026 7.686	2.882 7.320	2.728 6.929	2.558 6.497	2.414 6.132	2.303 5.850	2.191 5.565
Solidity		1.650	1.650	1.690	1.708	1.720	1.737	1.738	1.751	1.781	1.809	1.830	1.874	1.955	2.100
T_{max}/C		0.0235	0.0264	0.0324	0.0412	0.0520	0.0567	0.0545	0.0532	-0.0560	0.0611	0.0679	0.0740	0.0803	0.0875
$r_{LE}/C(a)$		0.0015	0.0017	0.0020	0.0024	0.0032	0.0036	0.0032	0.0029	0.0032	0.0037	0.0044	0.0052	0.0059	0.0065
$r_{TE}/C(a)$		0.0014	0.0016	0.0019	0.0022	0.0024	0.0024	0.0024	0.0024	0.0035	0.0042	0.0052	0.0063	0.0072	0.0080

^aLeading and trailing edge radii are defined to be the semi-minor axes of 2-to-1 ellipses.

TABLE A-3
ROTOR AIRFOIL COORDINATES

SECTION NO. 1 RADIUS 14.570 IN. (36.500 CM.)					
X.IN.	SUCTION SURFACE		Y.CM.	PRESSURE SURFACE	
	Y.IN.	X.CM.		Y.IN.	Y.CM.
-0.020	-1.7139	-2.2404	-4.3534	-1.7159	-2.2404
-0.020	-1.7135	-2.2404	-4.3523	-1.7160	-2.2396
-0.017	-1.7106	-2.2394	-4.3449	-1.7179	-2.2374
-0.007	-1.7075	-2.2370	-4.3371	-1.7190	-2.2346
-0.007	-1.6668	-2.1963	-4.3317	-1.7192	-2.2303
-0.013	-1.5579	-2.0861	-3.9572	-1.7185	-2.2255
-1.0900	-1.4950	-1.9750	-3.6051	-1.7169	-2.2205
-1.2420	-1.3454	-1.8656	-3.4174	-1.7110	-2.2105
-1.1407	-1.2420	-1.7554	-3.1547	-1.6773	-2.1698
-1.0413	-1.1407	-1.6452	-2.7474	-1.5866	-2.0597
-0.9413	-1.0413	-1.5350	-2.6449	-1.4958	-1.9497
-0.8413	-0.9413	-1.4248	-2.4390	-1.4050	-1.8396
-0.7413	-0.8413	-1.3146	-2.1499	-1.3142	-1.7295
-0.6413	-0.7413	-1.2044	-1.8054	-1.2235	-1.6195
-0.5413	-0.6413	-1.0942	-1.4830	-1.1329	-1.5094
-0.4413	-0.5413	-0.9840	-1.1424	-1.0424	-1.3994
-0.3413	-0.4413	-0.8738	-1.1405	-0.9520	-1.2893
-0.2413	-0.3413	-0.7636	-0.9514	-0.8618	-1.1792
-0.1413	-0.2413	-0.6534	-0.7106	-0.7718	-1.0692
-0.0413	-0.1413	-0.5432	-0.4809	-0.6821	-0.9592
-0.0413	-0.0413	-0.4330	-0.2508	-0.5926	-0.8491
-0.1413	-0.1413	-0.3228	-0.0204	-0.5034	-0.7390
-0.2413	-0.2413	-0.2126	0.1979	-0.4145	-0.6290
-0.3413	-0.3413	-0.1024	0.4226	-0.3260	-0.5189
-0.4413	-0.4413	0.0078	0.6455	-0.2379	-0.4089
-0.5413	-0.5413	0.1181	0.8668	-0.1503	-0.2988
-0.6413	-0.6413	0.2283	1.0884	-0.0631	-0.1887
-0.7413	-0.7413	0.3385	1.3093	0.0235	-0.0787
-0.8413	-0.8413	0.4487	1.5206	0.0995	0.0314
-0.9413	-0.9413	0.5589	1.7352	0.1949	0.1414
-1.0413	-1.0413	0.6691	1.9480	0.2794	0.2515
-1.1413	-1.1413	0.7793	2.1589	0.3636	0.3615
-1.2413	-1.2413	0.8895	2.3681	0.4468	0.4716
-1.3413	-1.3413	0.9997	2.5754	0.5292	0.5817
-1.4413	-1.4413	1.1099	2.7725	0.6106	0.6917
-1.5413	-1.5413	1.2201	2.9527	0.6910	0.8018
-1.6413	-1.6413	1.3303	3.1211	0.7703	0.9118
-1.7413	-1.7413	1.4405	3.2870	0.8485	1.0219
-1.8413	-1.8413	1.5507	3.4508	0.9293	1.1320
-1.9413	-1.9413	1.6609	3.6128	1.0172	1.2420
-2.0413	-2.0413	1.7711	3.7730	1.1094	1.3521
-2.1413	-2.1413	1.8813	3.9310	1.1995	1.4621
-2.2413	-2.2413	1.9915	4.0866	1.2878	1.5722
-2.3413	-2.3413	2.1017	4.2403	1.3742	1.6822
-2.4413	-2.4413	2.2119	4.3925	1.4584	1.7923
-2.5413	-2.5413	2.3221	4.5448	1.5405	1.9024
-2.6413	-2.6413	2.4323	4.6971	1.6208	2.0125
-2.7413	-2.7413	2.5425	4.8494	1.7000	2.1226
-2.8413	-2.8413	2.6527	4.9997	1.7792	2.2327
-2.9413	-2.9413	2.7629	5.1499	1.8584	2.3428
-3.0413	-3.0413	2.8731	5.2997	1.9376	2.4529
-3.1413	-3.1413	2.9833	5.4494	2.0168	2.5630
-3.2413	-3.2413	3.0935	5.5997	2.0960	2.6731
-3.3413	-3.3413	3.2037	5.7494	2.1752	2.7832
-3.4413	-3.4413	3.3139	5.8997	2.2544	2.8933
-3.5413	-3.5413	3.4241	6.0494	2.3336	3.0034
-3.6413	-3.6413	3.5343	6.1997	2.4128	3.1135
-3.7413	-3.7413	3.6445	6.3494	2.4920	3.2236
-3.8413	-3.8413	3.7547	6.4997	2.5712	3.3337
-3.9413	-3.9413	3.8649	6.6494	2.6504	3.4438
-4.0413	-4.0413	3.9751	6.7997	2.7296	3.5539
-4.1413	-4.1413	4.0853	6.9494	2.8088	3.6640
-4.2413	-4.2413	4.1955	7.0997	2.8880	3.7741
-4.3413	-4.3413	4.3057	7.2494	2.9672	3.8842
-4.4413	-4.4413	4.4159	7.3997	3.0464	3.9943
-4.5413	-4.5413	4.5261	7.5494	3.1256	4.1044
-4.6413	-4.6413	4.6363	7.6997	3.2048	4.2145
-4.7413	-4.7413	4.7465	7.8494	3.2840	4.3246
-4.8413	-4.8413	4.8567	7.9997	3.3632	4.4347
-4.9413	-4.9413	4.9669	8.1494	3.4424	4.5448
-5.0413	-5.0413	5.0771	8.2997	3.5216	4.6549
-5.1413	-5.1413	5.1873	8.4494	3.6008	4.7650
-5.2413	-5.2413	5.2975	8.5997	3.6800	4.8751
-5.3413	-5.3413	5.4077	8.7494	3.7592	4.9852
-5.4413	-5.4413	5.5179	8.8997	3.8384	5.0953
-5.5413	-5.5413	5.6281	9.0494	3.9176	5.2054
-5.6413	-5.6413	5.7383	9.1997	4.0000	5.3155
-5.7413	-5.7413	5.8485	9.3494	4.0800	5.4256
-5.8413	-5.8413	5.9587	9.4997	4.1600	5.5357
-5.9413	-5.9413	6.0689	9.6494	4.2400	5.6458
-6.0413	-6.0413	6.1791	9.7997	4.3200	5.7559
-6.1413	-6.1413	6.2893	9.9494	4.4000	5.8660
-6.2413	-6.2413	6.3995	10.0997	4.4800	5.9761
-6.3413	-6.3413	6.5097	10.2494	4.5600	6.0862
-6.4413	-6.4413	6.6199	10.3997	4.6400	6.1963
-6.5413	-6.5413	6.7301	10.5494	4.7200	6.3064
-6.6413	-6.6413	6.8403	10.6997	4.8000	6.4165
-6.7413	-6.7413	6.9505	10.8494	4.8800	6.5266
-6.8413	-6.8413	7.0607	10.9997	4.9600	6.6367
-6.9413	-6.9413	7.1709	11.1494	5.0400	6.7468
-7.0413	-7.0413	7.2811	11.2997	5.1200	6.8569
-7.1413	-7.1413	7.3913	11.4494	5.2000	6.9670
-7.2413	-7.2413	7.5015	11.5997	5.2800	7.0771
-7.3413	-7.3413	7.6117	11.7494	5.3600	7.1872
-7.4413	-7.4413	7.7219	11.8997	5.4400	7.2973
-7.5413	-7.5413	7.8321	12.0494	5.5200	7.4074
-7.6413	-7.6413	7.9423	12.1997	5.6000	7.5175
-7.7413	-7.7413	8.0525	12.3494	5.6800	7.6276
-7.8413	-7.8413	8.1627	12.4997	5.7600	7.7377
-7.9413	-7.9413	8.2729	12.6494	5.8400	7.8478
-8.0413	-8.0413	8.3831	12.7997	5.9200	7.9579
-8.1413	-8.1413	8.4933	12.9494	6.0000	8.0680
-8.2413	-8.2413	8.6035	13.0997	6.0800	8.1781
-8.3413	-8.3413	8.7137	13.2494	6.1600	8.2882
-8.4413	-8.4413	8.8239	13.3997	6.2400	8.3983
-8.5413	-8.5413	8.9341	13.5494	6.3200	8.5084
-8.6413	-8.6413	9.0443	13.6997	6.4000	8.6185
-8.7413	-8.7413	9.1545	13.8494	6.4800	8.7286
-8.8413	-8.8413	9.2647	13.9997	6.5600	8.8387
-8.9413	-8.9413	9.3749	14.1494	6.6400	8.9488
-9.0413	-9.0413	9.4851	14.2997	6.7200	9.0589
-9.1413	-9.1413	9.5953	14.4494	6.8000	9.1690
-9.2413	-9.2413	9.7055	14.5997	6.8800	9.2791
-9.3413	-9.3413	9.8157	14.7494	6.9600	9.3892
-9.4413	-9.4413	9.9259	14.8997	7.0400	9.4993
-9.5413	-9.5413	10.0361	15.0494	7.1200	9.6094
-9.6413	-9.6413	10.1463	15.1997	7.2000	9.7195
-9.7413	-9.7413	10.2565	15.3494	7.2800	9.8296
-9.8413	-9.8413	10.3667	15.4997	7.3600	9.9397
-9.9413	-9.9413	10.4769	15.6494	7.4400	10.0498
-10.0413	-10.0413	10.5871	15.7997	7.5200	10.1599
-10.1413	-10.1413	10.6973	15.9494	7.6000	10.2700
-10.2413	-10.2413	10.8075	16.0997	7.6800	10.3801
-10.3413	-10.3413	10.9177	16.2494	7.7600	10.4902
-10.4413	-10.4413	11.0279	16.3997	7.8400	10.6003
-10.5413	-10.5413	11.1381	16.5494	7.9200	10.7104
-10.6413	-10.6413	11.2483	16.6997	8.0000	10.8205
-10.7413	-10.7413	11.3585	16.8494	8.0800	10.9306
-10.8413	-10.8413	11.4687	16.9997	8.1600	11.0407
-10.9413	-10.9413	11.5789	17.1494	8.2400	11.1508
-11.0413	-11.0413	11.6891	17.2997	8.3200	11.2609
-11.1413	-11.1413	11.7993	17.4494	8.4000	11.3710
-11.2413	-11.2413	11.9095	17.5997	8.4800	11.4811
-11.3413	-11.3413	12.0197	17.7494	8.5600	11.5912
-11.4413	-11.4413	12.1299	17.8997	8.6400	11.7013
-11.5413	-11.5413	12.2401	18.0494	8.7200	11.8114
-11.6413	-11.6413	12.3503	18.1997	8.8000	11.9215
-11.7413	-11.7413	12.4605	18.3494	8.8800	12.0316
-11.8413	-11.8413	12.5707	18.4997	8.9600	12.1417
-11.9413	-11.9413	12.6809	18.6494	9.0400	12.2518
-12.0413	-12.0413	12.7911	18.7997	9.1200	12.3619
-12.1413	-12.1413	12.9013	18.9494	9.2000	12.4720
-12.2413	-12.2413	13.0115	19.0997	9.2800	12.5821
-12.3413	-12.3413	13.1217	19.2494	9.3600	12.6922
-12.4413	-12.4413	13.2319	19.3997	9.4400	12.8023
-12.5413	-12.5413	13.3421	19.5494	9.5200	12.9124
-12.6413	-12.6413	13.4523	19.6997	9.6000	13.0225
-12.7413	-12.7413	13.5625	19.8494	9.6800	13.1326
-12.8413	-12.8413	13.6727	19.9997	9.7600	13.2427
-12.9413	-12.9413	13.7829	20.1494	9.8400	13.3528
-13.0413	-13.0413	13.8931	20.2997	9.9200	13.4629
-13.1413	-13.1413	14.0033	20.4494	10.0000	13.5730
-13.2413	-13.2413	14.1135	20.5997	10.0800	13.6831
-13.3413	-13.3413	14.2237	20.7494	10.1600	13.7932
-13.4413	-13.4413	14.3339	20.8997	10.2400	13.9033
-13.5413	-13.5413	14.4441	21.0494	10.3200	14.0134
-13.6413	-13.6413	14.5543	21.1997	10.4000	14.1235
-13.7413	-13.7413	14.6645	21.3494	10.4800	14.2336
-13.8413	-13.8413	14.7747	21.4997	10.5600	14.3437
-13.9413	-13.9413	14.8849	21.6494	10.6400	14.4538
-14.0413	-14.0413	14.9951	21.7997	10.7200	14.5639
-14.1413	-14.1413	15.1053	21.9494	10.8000	14.6740
-14.2413	-14.2413	15.2155	22.0997	10.8800	14.7841
-14.3413	-14.3413	15.3257	22.2494	10.9600	14.8942
-14.4413	-14.4413	15.4359	22.3997	11.0400	15.0043
-14.5413	-14.5413	15.5461	22.5494	11.1200	15.1144

TABLE A-3.--Continued

ROTOR AIRFOIL COORDINATES SECTION NO. 2 RADIUS 13.000 IN. (35.052 CM.)					
SUCTION SURFACE		PRESSURE SURFACE			
X IN.	Y IN.	X IN.	Y IN.	X IN.	Y IN.
-0.945	-1.6420	-0.945	-1.6420	-2.3730	-4.1700
-0.944	-1.6009	-0.944	-1.6437	-2.3735	-4.1749
-0.930	-1.6370	-0.936	-1.6457	-2.3714	-4.1802
-0.926	-1.6345	-0.923	-1.6470	-2.3680	-4.1834
-0.9150	-1.5970	-0.905	-1.6473	-2.3635	-4.1842
-0.902	-1.4993	-0.884	-1.6467	-2.3581	-4.1825
-0.8246	-1.4021	-0.841	-1.6451	-2.3524	-4.1785
-0.7709	-1.3061	-0.815	-1.6387	-2.3405	-4.1622
-0.7333	-1.2115	-0.8046	-1.6377	-2.3276	-4.0835
-0.6877	-1.1104	-0.8590	-1.6323	-2.3189	-3.8707
-0.6421	-1.0267	-0.9135	-1.6399	-2.3062	-3.6374
-0.5965	-0.9350	-0.9679	-1.6358	-2.2905	-3.4337
-0.5509	-0.8457	-1.0224	-1.62715	-2.2715	-3.2297
-0.5053	-0.7550	-1.0760	-1.6182	-2.2501	-3.0155
-0.4597	-0.6644	-1.127	-1.6034	-2.2269	-2.8013
-0.4141	-0.5780	-1.1759	-1.6185	-2.2017	-2.5871
-0.3685	-0.4900	-1.2246	-1.6342	-2.1720	-2.3729
-0.3229	-0.4025	-1.2724	-1.6500	-2.1391	-2.1591
-0.2773	-0.3155	-1.3199	-1.6663	-2.1046	-1.9455
-0.2317	-0.2289	-1.3674	-1.6820	-2.0689	-1.7324
-0.1861	-0.1427	-1.4147	-1.6983	-2.0323	-1.5197
-0.1405	-0.0570	-1.4617	-1.7140	-1.9942	-1.3076
-0.0949	-0.0203	-1.5086	-1.7297	-1.9575	-1.0941
-0.0493	-0.1131	-1.5554	-1.7454	-1.9201	-0.8854
-0.0037	-0.1976	-1.6021	-1.7611	-1.8826	-0.6754
0.0410	0.2817	-1.6486	-1.7768	-1.8451	-0.4663
0.0875	0.3654	-1.6951	-1.7925	-1.8076	-0.2582
0.1331	0.4486	-1.7416	-1.8082	-1.7701	-0.0511
0.1787	0.5317	-1.7881	-1.8239	-1.7326	0.1549
0.2243	0.6143	-1.8346	-1.8396	-1.6951	0.3599
0.2699	0.6968	-1.8811	-1.8553	-1.6576	0.5637
0.3155	0.7791	-1.9276	-1.8710	-1.6201	0.7662
0.3611	0.8611	-1.9741	-1.8867	-1.5826	0.9674
0.4067	0.9401	-2.0206	-1.9024	-1.5451	1.1670
0.4523	1.0161	-2.0671	-1.9181	-1.5076	1.3649
0.4980	1.0902	-2.1136	-1.9338	-1.4701	1.5611
0.5436	1.1530	-2.1601	-1.9495	-1.4326	1.7553
0.5892	1.2195	-2.2066	-1.9652	-1.3951	1.9544
0.6348	1.2854	-2.2531	-1.9809	-1.3576	2.1710
0.6804	1.3510	-2.2996	-1.9966	-1.3201	2.4045
0.7260	1.4160	-2.3461	-2.0123	-1.2826	2.6350
0.7716	1.4806	-2.3926	-2.0280	-1.2451	2.8625
0.8172	1.5449	-2.4391	-2.0437	-1.2076	3.0970
0.8628	1.6091	-2.4856	-2.0594	-1.1701	3.3302
0.9084	1.6734	-2.5321	-2.0751	-1.1326	3.5626
0.9540	1.7376	-2.5786	-2.0908	-1.0951	3.7405
1.0000	1.8019	-2.6251	-2.1065	-1.0576	3.9150
1.0460	1.8661	-2.6716	-2.1222	-1.0201	4.0850
1.0920	1.9304	-2.7181	-2.1379	-0.9826	4.2550
1.1380	2.0000	-2.7646	-2.1536	-0.9451	4.4250
1.1840	2.0696	-2.8111	-2.1693	-0.9076	4.5950
1.2300	2.1392	-2.8576	-2.1850	-0.8701	4.7650
1.2760	2.2088	-2.9041	-2.2007	-0.8326	4.9350
1.3220	2.2784	-2.9506	-2.2164	-0.7951	5.1050
1.3680	2.3480	-3.0000	-2.2321	-0.7576	5.2750
1.4140	2.4176	-3.0465	-2.2478	-0.7201	5.4450
1.4600	2.4872	-3.0930	-2.2635	-0.6826	5.6150
1.5060	2.5568	-3.1395	-2.2792	-0.6451	5.7850
1.5520	2.6264	-3.1860	-2.2949	-0.6076	5.9550
1.5980	2.6960	-3.2325	-2.3106	-0.5701	6.1250
1.6440	2.7656	-3.2790	-2.3263	-0.5326	6.2950
1.6900	2.8352	-3.3255	-2.3420	-0.4951	6.4650
1.7360	2.9048	-3.3720	-2.3577	-0.4576	6.6350
1.7820	2.9744	-3.4185	-2.3734	-0.4201	6.8050
1.8280	3.0440	-3.4650	-2.3891	-0.3826	6.9750
1.8740	3.1136	-3.5115	-2.4048	-0.3451	7.1450
1.9200	3.1832	-3.5580	-2.4205	-0.3076	7.3150
1.9660	3.2528	-3.6045	-2.4362	-0.2701	7.4850
2.0120	3.3224	-3.6510	-2.4519	-0.2326	7.6550
2.0580	3.3920	-3.6975	-2.4676	-0.1951	7.8250
2.1040	3.4616	-3.7440	-2.4833	-0.1576	7.9950
2.1500	3.5312	-3.7905	-2.4990	-0.1201	8.1650
2.1960	3.6008	-3.8370	-2.5147	-0.0826	8.3350
2.2420	3.6704	-3.8835	-2.5304	-0.0451	8.5050
2.2880	3.7400	-3.9300	-2.5461	-0.0076	8.6750
2.3340	3.8096	-3.9765	-2.5618	0.0301	8.8450
2.3800	3.8792	-4.0230	-2.5775	0.0676	9.0150
2.4260	3.9488	-4.0695	-2.5932	0.1051	9.1850
2.4720	4.0184	-4.1160	-2.6089	0.1426	9.3550
2.5180	4.0880	-4.1625	-2.6246	0.1801	9.5250
2.5640	4.1576	-4.2090	-2.6403	0.2176	9.6950
2.6100	4.2272	-4.2555	-2.6560	0.2551	9.8650
2.6560	4.2968	-4.3020	-2.6717	0.2926	10.0350
2.7020	4.3664	-4.3485	-2.6874	0.3301	10.2050
2.7480	4.4360	-4.3950	-2.7031	0.3676	10.3750
2.7940	4.5056	-4.4415	-2.7188	0.4051	10.5450
2.8400	4.5752	-4.4880	-2.7345	0.4426	10.7150
2.8860	4.6448	-4.5345	-2.7502	0.4801	10.8850
2.9320	4.7144	-4.5810	-2.7659	0.5176	11.0550
2.9780	4.7840	-4.6275	-2.7816	0.5551	11.2250
3.0240	4.8536	-4.6740	-2.7973	0.5926	11.3950
3.0700	4.9232	-4.7205	-2.8130	0.6301	11.5650
3.1160	4.9928	-4.7670	-2.8287	0.6676	11.7350
3.1620	5.0624	-4.8135	-2.8444	0.7051	11.9050
3.2080	5.1320	-4.8600	-2.8601	0.7426	12.0750
3.2540	5.2016	-4.9065	-2.8758	0.7801	12.2450
3.3000	5.2712	-4.9530	-2.8915	0.8176	12.4150
3.3460	5.3408	-5.0000	-2.9072	0.8551	12.5850
3.3920	5.4104	-5.0465	-2.9229	0.8926	12.7550
3.4380	5.4800	-5.0930	-2.9386	0.9301	12.9250
3.4840	5.5496	-5.1395	-2.9543	0.9676	13.0950
3.5300	5.6192	-5.1860	-2.9700	1.0051	13.2650
3.5760	5.6888	-5.2325	-2.9857	1.0426	13.4350
3.6220	5.7584	-5.2790	-3.0014	1.0801	13.6050
3.6680	5.8280	-5.3255	-3.0171	1.1176	13.7750
3.7140	5.8976	-5.3720	-3.0328	1.1551	13.9450
3.7600	5.9672	-5.4185	-3.0485	1.1926	14.1150
3.8060	6.0368	-5.4650	-3.0642	1.2301	14.2850
3.8520	6.1064	-5.5115	-3.0799	1.2676	14.4550
3.8980	6.1760	-5.5580	-3.0956	1.3051	14.6250
3.9440	6.2456	-5.6045	-3.1113	1.3426	14.7950
3.9900	6.3152	-5.6510	-3.1270	1.3801	14.9650
4.0360	6.3848	-5.6975	-3.1427	1.4176	15.1350
4.0820	6.4544	-5.7440	-3.1584	1.4551	15.3050
4.1280	6.5240	-5.7905	-3.1741	1.4926	15.4750
4.1740	6.5936	-5.8370	-3.1898	1.5301	15.6450
4.2200	6.6632	-5.8835	-3.2055	1.5676	15.8150
4.2660	6.7328	-5.9300	-3.2212	1.6051	15.9850
4.3120	6.8024	-5.9765	-3.2369	1.6426	16.1550
4.3580	6.8720	-6.0230	-3.2526	1.6801	16.3250
4.4040	6.9416	-6.0695	-3.2683	1.7176	16.4950
4.4500	7.0112	-6.1160	-3.2840	1.7551	16.6650
4.4960	7.0808	-6.1625	-3.2997	1.7926	16.8350
4.5420	7.1504	-6.2090	-3.3154	1.8301	17.0050
4.5880	7.2200	-6.2555	-3.3311	1.8676	17.1750
4.6340	7.2896	-6.3020	-3.3468	1.9051	17.3450
4.6800	7.3592	-6.3485	-3.3625	1.9426	17.5150
4.7260	7.4288	-6.3950	-3.3782	1.9801	17.6850
4.7720	7.4984	-6.4415	-3.3939	2.0176	17.8550
4.8180	7.5680	-6.4880	-3.4096	2.0551	18.0250
4.8640	7.6376	-6.5345	-3.4253	2.0926	18.1950
4.9100	7.7072	-6.5810	-3.4410	2.1301	18.3650
4.9560	7.7768	-6.6275	-3.4567	2.1676	18.5350
5.0020	7.8464	-6.6740	-3.4724	2.2051	18.7050
5.0480	7.9160	-6.7205	-3.4881	2.2426	18.8750
5.0940	7.9856	-6.7670	-3.5038	2.2801	19.0450
5.1400	8.0552	-6.8135	-3.5195	2.3176	19.2150
5.1860	8.1248	-6.8600	-3.5352	2.3551	19.3850
5.2320	8.1944	-6.9065	-3.5509	2.3926	19.5550
5.2780	8.2640	-6.9530	-3.5666	2.4301	19.7250
5.3240	8.3336	-7.0000	-3.5823	2.4676	19.8950
5.3700	8.4032	-7.0465	-3.5980	2.5051	20.0650
5.4160	8.4728	-7.0930	-3.6137	2.5426	20.2350
5.4620	8.5424	-7.1395	-3.6294	2.5801	20.4050
5.5080	8.6120	-7.1860	-3.6451	2.6176	20.5750
5.5540	8.6816	-7.2325	-3.6608	2.6551	20.7450
5.6000	8.7512	-7.2790	-3.6765	2.6926	20.9150
5.6460	8.8208	-7.3255	-3.6922	2.7301	21.0850
5.6920	8.8904	-7.3720	-3.7079	2.7676	21.2550
5.7380	8.9600	-7.4185	-3.7236	2.8051	21.4250
5.7840	9.0296	-7.4650	-3.7393	2.8426	21.5950
5.8300	9.0992	-7.5115	-3.7550	2.8801	21.7650
5.8760	9.1688	-7.5580	-3.7707	2.9176	21.9350
5.9220	9.2384	-7.6045	-3.7864	2.9551	22.1050
5.9680	9.3080	-7.6510	-3.8021	2.9926	22.2750
6.0140	9.3776	-7.6975	-3.8178	3.0301	22.4450
6.0600	9.4472	-7.7440	-3.8335	3.0676	22.6150
6.1060	9.5168	-7.7905	-3.8492	3.1051	22.7850
6.1520	9.5864	-7.8370	-3.8649	3.1426	22.9550
6.1980	9.6560	-7.8835	-3.8806	3.1801	23.1250
6.2440	9.7256	-7.9300	-3.8963	3.2176	23.2950
6.2900	9.7952	-7.9765	-3.9120	3.2551	23.4650
6.3360	9.8648	-8.0230	-3.9277	3.2926	23.6350
6.3820	9.9344	-8.0695	-3.9434	3.3301	23.8050
6.4280	10.0040	-8.1160	-3.9591	3.3676	23.9750
6.4740	10.0736	-8.1625	-3.9748	3.4051	24.1450
6.5200	10.1432	-8.209			

TABLE A-3.--Continued

SECTION NO. 3 RADIUS 13.100 IN. (33.274 CM.)									
SUCTION SURFACE			PRESSURE SURFACE						
X.IN.	Y.IN.	X.CM.	Y.CM.	X.IN.	Y.IN.	X.CM.	Y.CM.	X.IN.	Y.IN.
-0.9574	-1.5712	-2.4319	-3.9908	-0.9574	-1.5712	-2.4319	-3.9908	-0.9574	-1.5712
-0.9573	-1.5695	-2.4317	-3.9867	-0.9573	-1.5737	-2.4316	-3.9947	-0.9573	-1.5737
-0.9566	-1.5659	-2.4297	-3.9774	-0.9565	-1.5752	-2.4296	-4.0010	-0.9565	-1.5752
-0.9551	-1.5622	-2.4259	-3.9679	-0.9550	-1.5767	-2.4258	-4.0048	-0.9550	-1.5767
-0.9389	-1.5293	-2.3848	-3.8843	-0.9530	-1.5771	-2.4258	-4.0058	-0.9530	-1.5771
-0.8924	-1.4353	-2.2666	-3.6457	-0.9505	-1.5764	-2.4245	-4.0040	-0.9505	-1.5764
-0.8458	-1.3425	-2.1484	-3.4100	-0.9478	-1.5746	-2.4275	-3.9996	-0.9478	-1.5746
-0.7993	-1.2509	-2.0302	-3.1773	-0.9421	-1.5672	-2.3930	-3.9807	-0.9421	-1.5672
-0.7528	-1.1606	-1.9120	-2.9480	-0.9260	-1.5394	-2.3520	-3.9101	-0.9260	-1.5394
-0.7062	-1.0718	-1.7938	-2.7224	-0.8795	-1.4594	-2.2339	-3.7070	-0.8795	-1.4594
-0.6597	-0.9841	-1.6756	-2.4997	-0.8330	-1.3796	-2.1159	-3.5041	-0.8330	-1.3796
-0.6131	-0.8972	-1.5574	-2.2742	-0.7865	-1.2998	-1.9978	-3.3015	-0.7865	-1.2998
-0.5666	-0.8110	-1.4392	-2.0490	-0.7400	-1.2202	-1.8797	-3.0992	-0.7400	-1.2202
-0.5201	-0.7251	-1.3210	-1.8247	-0.6936	-1.1407	-1.7617	-2.8973	-0.6936	-1.1407
-0.4735	-0.6398	-1.2028	-1.6000	-0.6471	-1.0613	-1.6438	-2.6958	-0.6471	-1.0613
-0.4270	-0.5551	-1.0846	-1.3750	-0.6006	-0.9822	-1.5255	-2.4948	-0.6006	-0.9822
-0.3805	-0.4711	-0.9664	-1.1495	-0.5541	-0.9033	-1.4075	-2.2943	-0.5541	-0.9033
-0.3339	-0.3875	-0.8482	-0.9241	-0.5076	-0.8245	-1.2894	-2.0943	-0.5076	-0.8245
-0.2874	-0.3033	-0.7300	-0.7728	-0.4612	-0.7450	-1.1713	-1.8948	-0.4612	-0.7450
-0.2409	-0.2216	-0.6118	-0.5628	-0.4147	-0.6676	-1.0533	-1.6958	-0.4147	-0.6676
-0.1943	-0.1393	-0.4935	-0.3539	-0.3682	-0.5895	-0.9352	-1.4974	-0.3682	-0.5895
-0.1478	-0.0576	-0.3753	-0.1464	-0.3217	-0.5117	-0.8171	-1.2997	-0.3217	-0.5117
-0.1012	0.0237	-0.2571	-0.0602	-0.2752	-0.4342	-0.6991	-1.1028	-0.2752	-0.4342
-0.0547	0.1046	-0.1389	0.2658	-0.2287	-0.3569	-0.5810	-0.9068	-0.2287	-0.3569
-0.0082	0.1852	-0.0207	0.4705	-0.1823	-0.2800	-0.4629	-0.7113	-0.1823	-0.2800
0.0384	0.2655	0.0975	0.6743	-0.1358	-0.2034	-0.3449	-0.5167	-0.1358	-0.2034
0.0849	0.3454	0.2157	0.8773	-0.0893	-0.1272	-0.2268	-0.3230	-0.0893	-0.1272
0.1314	0.4250	0.3339	1.0794	-0.0428	-0.0512	-0.1087	-0.1111	-0.0428	-0.0512
0.1780	0.5043	0.4521	1.2808	0.0037	0.0244	0.0093	0.0621	0.0037	0.0244
0.2245	0.5833	0.5703	1.4816	0.0501	0.0987	0.0501	0.2531	0.0501	0.0987
0.2711	0.6621	0.6885	1.6817	0.0966	0.1746	0.0966	0.4434	0.0966	0.1746
0.3176	0.7406	0.8067	1.8811	0.1431	0.2491	0.1431	0.6328	0.1431	0.2491
0.3641	0.8198	0.9249	2.0773	0.1896	0.3233	0.1896	0.8212	0.1896	0.3233
0.4107	0.8996	1.0431	2.2600	0.2361	0.3971	0.2361	1.0085	0.2361	0.3971
0.4572	0.9799	1.1613	2.4304	0.2826	0.4704	0.2826	1.1944	0.2826	0.4704
0.5037	1.0627	1.2795	2.5977	0.3290	0.5438	0.3290	1.3801	0.3290	0.5438
0.5503	1.1463	1.3977	2.7643	0.3755	0.6178	0.3755	1.5693	0.3755	0.6178
0.5968	1.2337	1.5159	2.9305	0.4220	0.6900	0.4220	1.7781	0.4220	0.6900
0.6434	1.3219	1.6341	3.0963	0.4685	0.7602	0.4685	2.0070	0.4685	0.7602
0.6899	1.4101	1.7523	3.2617	0.5150	0.8301	0.5150	2.2356	0.5150	0.8301
0.7364	1.4991	1.8706	3.4267	0.5615	0.9006	0.5615	2.4628	0.5615	0.9006
0.7830	1.5888	1.9888	3.5912	0.6079	1.0583	0.6079	2.6880	0.6079	1.0583
0.8295	1.6786	2.1071	3.7557	0.6544	1.1461	0.6544	2.9111	0.6544	1.1461
0.8760	1.7684	2.2259	3.9202	0.7009	1.2332	0.7009	3.1323	0.7009	1.2332
0.9225	1.8582	2.3441	4.0847	0.7474	1.3193	0.7474	3.3511	0.7474	1.3193
0.9690	1.9480	2.4629	4.2492	0.7939	1.4046	0.7939	3.5677	0.7939	1.4046
1.0155	2.0378	2.5817	4.4137	0.8404	1.4911	0.8404	3.7844	0.8404	1.4911
1.0620	2.1276	2.7005	4.5782	0.8869	1.5776	0.8869	4.0011	0.8869	1.5776
1.1085	2.2174	2.8193	4.7427	0.9334	1.6641	0.9334	4.2178	0.9334	1.6641
1.1550	2.3072	2.9381	4.9072	0.9799	1.7506	0.9799	4.4345	0.9799	1.7506
1.2015	2.3970	3.0569	5.0717	1.0264	1.8371	1.0264	4.6512	1.0264	1.8371
1.2480	2.4868	3.1757	5.2362	1.0729	1.9236	1.0729	4.8679	1.0729	1.9236
1.2945	2.5766	3.2945	5.4007	1.1194	2.0101	1.1194	5.0846	1.1194	2.0101
1.3410	2.6664	3.4133	5.5652	1.1659	2.0966	1.1659	5.3013	1.1659	2.0966
1.3875	2.7562	3.5321	5.7297	1.2124	2.1831	1.2124	5.5180	1.2124	2.1831
1.4340	2.8460	3.6509	5.8942	1.2589	2.2696	1.2589	5.7347	1.2589	2.2696
1.4805	2.9358	3.7697	6.0587	1.3054	2.3561	1.3054	5.9514	1.3054	2.3561
1.5270	3.0256	3.8885	6.2232	1.3519	2.4426	1.3519	6.1681	1.3519	2.4426
1.5735	3.1154	4.0073	6.3877	1.3984	2.5291	1.3984	6.3848	1.3984	2.5291
1.6200	3.2052	4.1261	6.5522	1.4449	2.6156	1.4449	6.6015	1.4449	2.6156
1.6665	3.2950	4.2449	6.7167	1.4914	2.7021	1.4914	6.8182	1.4914	2.7021
1.7130	3.3848	4.3637	6.8812	1.5379	2.7886	1.5379	7.0349	1.5379	2.7886
1.7595	3.4746	4.4825	7.0457	1.5844	2.8751	1.5844	7.2516	1.5844	2.8751
1.8060	3.5644	4.6013	7.2102	1.6309	2.9616	1.6309	7.4683	1.6309	2.9616
1.8525	3.6542	4.7201	7.3747	1.6774	3.0481	1.6774	7.6850	1.6774	3.0481
1.8990	3.7440	4.8389	7.5392	1.7239	3.1346	1.7239	7.9017	1.7239	3.1346
1.9455	3.8338	4.9577	7.7037	1.7704	3.2211	1.7704	8.1184	1.7704	3.2211
1.9920	3.9236	5.0765	7.8682	1.8169	3.3076	1.8169	8.3351	1.8169	3.3076
2.0385	4.0134	5.1953	8.0327	1.8634	3.3941	1.8634	8.5518	1.8634	3.3941
2.0850	4.1032	5.3141	8.1972	1.9099	3.4806	1.9099	8.7685	1.9099	3.4806
2.1315	4.1930	5.4329	8.3617	1.9564	3.5671	1.9564	8.9852	1.9564	3.5671
2.1780	4.2828	5.5517	8.5262	2.0029	3.6536	2.0029	9.2019	2.0029	3.6536
2.2245	4.3726	5.6705	8.6907	2.0494	3.7401	2.0494	9.4186	2.0494	3.7401
2.2710	4.4624	5.7893	8.8552	2.0959	3.8266	2.0959	9.6353	2.0959	3.8266
2.3175	4.5522	5.9081	9.0197	2.1424	3.9131	2.1424	9.8520	2.1424	3.9131
2.3640	4.6420	6.0269	9.1842	2.1889	4.0000	2.1889	10.0687	2.1889	4.0000
2.4105	4.7318	6.1457	9.3487	2.2354	4.0865	2.2354	10.2854	2.2354	4.0865
2.4570	4.8216	6.2645	9.5132	2.2819	4.1730	2.2819	10.5021	2.2819	4.1730
2.5035	4.9114	6.3833	9.6777	2.3284	4.2595	2.3284	10.7188	2.3284	4.2595
2.5500	5.0012	6.5021	9.8422	2.3749	4.3460	2.3749	10.9355	2.3749	4.3460
2.5965	5.0910	6.6209	10.0067	2.4214	4.4325	2.4214	11.1522	2.4214	4.4325
2.6430	5.1808	6.7397	10.1712	2.4679	4.5190	2.4679	11.3689	2.4679	4.5190
2.6895	5.2706	6.8585	10.3357	2.5144	4.6055	2.5144	11.5856	2.5144	4.6055
2.7360	5.3604	6.9773	10.5002	2.5609	4.6920	2.5609	11.8023	2.5609	4.6920
2.7825	5.4502	7.0961	10.6647	2.6074	4.7785	2.6074	12.0190	2.6074	4.7785
2.8290	5.5400	7.2149	10.8292	2.6539	4.8650	2.6539	12.2357	2.6539	4.8650
2.8755	5.6298	7.3337	10.9937	2.7004	4.9515	2.7004	12.4524	2.7004	4.9515
2.9220	5.7196	7.4525	11.1582	2.7469	5.0380	2.7469	12.6691	2.7469	5.0380
2.9685	5.8094	7.5713	11.3227	2.7934	5.1245	2.7934	12.8858	2.7934	5.1245
3.0150	5.8992	7.6901	11.4872	2.8399	5.2110	2.8399	13.1025	2.8399	5.2110
3.0615	5.9890	7.8089	11.6517	2.8864	5.2975	2.8864	13.3192	2.8864	5.2975
3.1080	6.0788	7.9277	11.8162	2.9329	5.3840	2.9329	13.5359	2.9329	5.3840
3.1545	6.1686	8.0465	11.9807	2.9794	5.4705	2.9794	13.7526	2.9794	5.4705
3.2010	6.2584	8.1653	12.1452	3.0259	5.5570	3.0259	13.9693	3.0259	5.5570
3.2475	6.3482	8.2841	12.3097	3.0724	5.6435	3.0724	14.1860	3.0724	5.6435
3.2940	6.4380	8.4029	12.4742	3.1189	5.7300	3.1189	14.4027	3.1189	5.7300
3.3405	6.5278	8.5217	12.6387	3.1654	5.8165	3.1654	14.6194	3.1654	5.8165
3.3870	6.6176	8.6405	12.8032	3.2119	5.9030	3.2119	14.8361	3.2119	5.9030
3.4335	6.7074	8.7593	12.9677	3.2584	5.9895	3.2584	15.0528	3.2584	5.9895
3.4800	6.7972	8.8781	13.1322	3.3049	6.0760	3.3049	15.2695	3.3049	6.0760
3.5265	6.8870	8.9969	13.2967	3.3514	6.1625	3.3514	15.4862	3.3514	6.1625
3.5730	6.9768	9.1157	13.4612	3.3979	6.2490	3.3979	15.7029	3.3979	6.2490
3.6195	7.0666	9.2345	13.6257	3.4444	6.3355	3.4444	15.9196	3.4444	6.3355
3.6660	7.1564	9.3533	13.7902	3.4909	6.4220	3.4909	16.1363	3.4909	6.4220

TABLE A-3.--Continued

SECTION NO. 4 ROTOR AIRFOIL COORDINATES RADIUS 12.750 IN. (32.385 CM.)					
SUCTION SURFACE		PRESSURE SURFACE		T.C.M.	
X-IN.	Y-IN.	X-IN.	Y-IN.	X-IN.	Y-IN.
.9700	-1.5335	.9740	-1.5335	.9740	-1.5335
.9759	-1.5314	.9759	-1.5351	.9759	-1.5351
.9749	-1.5271	.9750	-1.5361	.9750	-1.5361
.9731	-1.5227	.9733	-1.5399	.9733	-1.5399
.9572	-1.4914	.9708	-1.5404	.9708	-1.5404
.9097	-1.3983	.9679	-1.5356	.9679	-1.5356
.8622	-1.3064	.9647	-1.5376	.9647	-1.5376
.8147	-1.2157	.9578	-1.5288	.9578	-1.5288
.7672	-1.1261	.9419	-1.5026	.9419	-1.5026
.7197	-1.0378	.8944	-1.4239	.8944	-1.4239
.6722	-.9506	.8468	-1.3454	.8468	-1.3454
.6247	-.8643	.7992	-1.2671	.7992	-1.2671
.5771	-.7787	.7516	-1.1892	.7516	-1.1892
.5296	-.6939	.7041	-1.1115	.7041	-1.1115
.4821	-.6099	.6565	-1.0382	.6565	-1.0382
.4346	-.5267	.6089	-.9572	.6089	-.9572
.3871	-.4443	.5614	-.8805	.5614	-.8805
.3396	-.3624	.5138	-.8053	.5138	-.8053
.2921	-.2812	.4662	-.7284	.4662	-.7284
.2445	-.2006	.4187	-.6529	.4187	-.6529
.1970	-.1287	.3711	-.5777	.3711	-.5777
.1495	-.0514	.3235	-.5030	.3235	-.5030
.1020	.0374	.2759	-.4287	.2759	-.4287
.0545	.1156	.2284	-.3549	.2284	-.3549
.0070	.1934	.1808	-.2814	.1808	-.2814
.0405	.2707	.1332	-.2084	.1332	-.2084
.0880	.3475	.0856	-.1358	.0856	-.1358
.1355	.4239	.0381	-.0637	.0381	-.0637
.1831	.5000	.0095	.0079	.0095	.0079
.2306	.5757	.0571	.0792	.0571	.0792
.2781	.6511	.1046	.1499	.1046	.1499
.3256	.7282	.1522	.2202	.1522	.2202
.3731	.7920	.1998	.2900	.1998	.2900
.4206	.8556	.2474	.3593	.2474	.3593
.4681	.9183	.2949	.4281	.2949	.4281
.5157	.9809	.3425	.4985	.3425	.4985
.5632	1.0434	.3901	.5687	.3901	.5687
.6107	1.1058	.4377	.6397	.4377	.6397
.6582	1.1682	.4852	.7254	.4852	.7254
.7057	1.2305	.5328	.8137	.5328	.8137
.7532	1.2929	.5804	.9020	.5804	.9020
.8007	1.3552	.6279	.9905	.6279	.9905
.8482	1.4174	.6755	1.0785	.6755	1.0785
.8957	1.4797	.7231	1.1660	.7231	1.1660
.9433	1.5419	.7706	1.2532	.7706	1.2532
.9908	1.6042	.8182	1.3398	.8182	1.3398
.0383	1.6665	.8658	1.4270	.8658	1.4270
.0858	1.7288	.9134	1.5141	.9134	1.5141
.1333	1.7911	.9610	1.6012	.9610	1.6012
.1808	1.8534	.0086	1.6883	.0086	1.6883
.2283	1.9157	.0562	1.7754	.0562	1.7754
.2758	1.9780	.1038	1.8625	.1038	1.8625
.3233	2.0403	.1514	1.9496	.1514	1.9496
.3708	2.1026	.1990	2.0367	.1990	2.0367
.4183	2.1649	.2466	2.1238	.2466	2.1238
.4658	2.2272	.2942	2.2109	.2942	2.2109
.5133	2.2895	.3418	2.2980	.3418	2.2980
.5608	2.3518	.3894	2.3851	.3894	2.3851
.6083	2.4141	.4370	2.4722	.4370	2.4722
.6558	2.4764	.4846	2.5593	.4846	2.5593
.7033	2.5387	.5322	2.6464	.5322	2.6464
.7508	2.6010	.5798	2.7335	.5798	2.7335
.7983	2.6633	.6274	2.8206	.6274	2.8206
.8458	2.7256	.6750	2.9077	.6750	2.9077
.8933	2.7879	.7226	2.9948	.7226	2.9948
.9408	2.8502	.7702	3.0819	.7702	3.0819
.9883	2.9125	.8178	3.1690	.8178	3.1690
.0358	2.9748	.8654	3.2561	.8654	3.2561
.0833	3.0371	.9130	3.3432	.9130	3.3432
.1308	3.0994	.9606	3.4303	.9606	3.4303
.1783	3.1617	.0082	3.5174	.0082	3.5174
.2258	3.2240	.0558	3.6045	.0558	3.6045
.2733	3.2863	.1034	3.6916	.1034	3.6916
.3208	3.3486	.1510	3.7787	.1510	3.7787
.3683	3.4109	.1986	3.8658	.1986	3.8658
.4158	3.4732	.2462	3.9529	.2462	3.9529
.4633	3.5355	.2938	4.0400	.2938	4.0400
.5108	3.5978	.3414	4.1271	.3414	4.1271
.5583	3.6601	.3890	4.2142	.3890	4.2142
.6058	3.7224	.4366	4.3013	.4366	4.3013
.6533	3.7847	.4842	4.3884	.4842	4.3884
.7008	3.8470	.5318	4.4755	.5318	4.4755
.7483	3.9093	.5794	4.5626	.5794	4.5626
.7958	3.9716	.6270	4.6497	.6270	4.6497
.8433	4.0339	.6746	4.7368	.6746	4.7368
.8908	4.0962	.7222	4.8239	.7222	4.8239
.9383	4.1585	.7698	4.9110	.7698	4.9110
.9858	4.2208	.8174	5.0000	.8174	5.0000
.0333	4.2831	.8650	5.0890	.8650	5.0890
.0808	4.3454	.9126	5.1780	.9126	5.1780
.1283	4.4077	.9602	5.2670	.9602	5.2670
.1758	4.4700	.0078	5.3560	.0078	5.3560
.2233	4.5323	.0554	5.4450	.0554	5.4450
.2708	4.5946	.1030	5.5340	.1030	5.5340
.3183	4.6569	.1506	5.6230	.1506	5.6230
.3658	4.7192	.1982	5.7120	.1982	5.7120
.4133	4.7815	.2458	5.8010	.2458	5.8010
.4608	4.8438	.2934	5.8900	.2934	5.8900
.5083	4.9061	.3410	5.9790	.3410	5.9790
.5558	4.9684	.3886	6.0680	.3886	6.0680
.6033	5.0307	.4362	6.1570	.4362	6.1570
.6508	5.0930	.4838	6.2460	.4838	6.2460
.6983	5.1553	.5314	6.3350	.5314	6.3350
.7458	5.2176	.5790	6.4240	.5790	6.4240
.7933	5.2799	.6266	6.5130	.6266	6.5130
.8408	5.3422	.6742	6.6020	.6742	6.6020
.8883	5.4045	.7218	6.6910	.7218	6.6910
.9358	5.4668	.7694	6.7800	.7694	6.7800
.9833	5.5291	.8170	6.8690	.8170	6.8690
.0308	5.5914	.8646	6.9580	.8646	6.9580
.0783	5.6537	.9122	7.0470	.9122	7.0470
.1258	5.7160	.9598	7.1360	.9598	7.1360
.1733	5.7783	.0074	7.2250	.0074	7.2250
.2208	5.8406	.0550	7.3140	.0550	7.3140
.2683	5.9029	.1026	7.4030	.1026	7.4030
.3158	5.9652	.1502	7.4920	.1502	7.4920
.3633	6.0275	.1978	7.5810	.1978	7.5810
.4108	6.0898	.2454	7.6700	.2454	7.6700
.4583	6.1521	.2930	7.7590	.2930	7.7590
.5058	6.2144	.3406	7.8480	.3406	7.8480
.5533	6.2767	.3882	7.9370	.3882	7.9370
.6008	6.3390	.4358	8.0260	.4358	8.0260
.6483	6.4013	.4834	8.1150	.4834	8.1150
.6958	6.4636	.5310	8.2040	.5310	8.2040
.7433	6.5259	.5786	8.2930	.5786	8.2930
.7908	6.5882	.6262	8.3820	.6262	8.3820
.8383	6.6505	.6738	8.4710	.6738	8.4710
.8858	6.7128	.7214	8.5600	.7214	8.5600
.9333	6.7751	.7690	8.6490	.7690	8.6490
.9808	6.8374	.8166	8.7380	.8166	8.7380
.0283	6.8997	.8642	8.8270	.8642	8.8270
.0758	6.9620	.9118	8.9160	.9118	8.9160
.1233	7.0243	.9594	9.0050	.9594	9.0050
.1708	7.0866	.0070	9.0940	.0070	9.0940
.2183	7.1489	.0546	9.1830	.0546	9.1830
.2658	7.2112	.1022	9.2720	.1022	9.2720
.3133	7.2735	.1498	9.3610	.1498	9.3610
.3608	7.3358	.1974	9.4500	.1974	9.4500
.4083	7.3981	.2450	9.5390	.2450	9.5390
.4558	7.4604	.2926	9.6280	.2926	9.6280
.5033	7.5227	.3402	9.7170	.3402	9.7170
.5508	7.5850	.3878	9.8060	.3878	9.8060
.5983	7.6473	.4354	9.8950	.4354	9.8950
.6458	7.7096	.4830	9.9840	.4830	9.9840
.6933	7.7719	.5306	10.0730	.5306	10.0730
.7408	7.8342	.5782	10.1620	.5782	10.1620
.7883	7.8965	.6258	10.2510	.6258	10.2510
.8358	7.9588	.6734	10.3400	.6734	10.3400
.8833	8.0211	.7210	10.4290	.7210	10.4290
.9308	8.0834	.7686	10.5180	.7686	10.5180
.9783	8.1457	.8162	10.6070	.8162	10.6070
.0258	8.2080	.8638	10.6960	.8638	10.6960
.0733	8.2703	.9114	10.7850	.9114	10.7850
.1208	8.3326	.9590	10.8740	.9590	10.8740
.1683	8.3949	.0066	10.9630	.0066	10.9630
.2158	8.4572	.0542	11.0520	.0542	11.0520
.2633	8.5195	.1018	11.1410	.1018	11.1410
.3108	8.5818	.1494	11.2300	.1494	11.2300
.3583	8.6441	.1970	11.3190	.1970	11.3190
.4058	8.7064	.2446	11.4080	.2446	11.4080
.4533	8.7687	.2922	11.4970	.2922	11.4970
.5008	8.8310	.3398	11.5860	.3398	11.5860
.5483	8.8933	.3874	11.6750	.3874	11.6750
.5958	8.9556	.4350	11.7640	.4350	11.7640
.6433	9.0179	.4826	11.8530	.4826	11.8530
.6908	9.0802	.5302	11.9420	.5302	11.9420
.7383	9.1425	.5778	12.0310	.5778	12.0310
.7858	9.2048	.6254	12.1200	.6254	12.1200
.8333	9.2671	.6730	12.2090	.6730	12.2090
.8808	9.3294	.7206	12.2980	.7206	12.2980
.9283	9.3917	.7682	12.3870	.7682	12.3870
.9758	9.4540	.8158	12.4760	.8158	12.4760
.0233	9.5163	.8634	12.5650	.8634	12.5650
.0708	9.5786	.9110	12.6540	.9110	12.6540
.1183	9.6409	.9586	12.7430	.9586	12.7430
.1658	9.7032	.0062	12.8320	.0062	12.8320
.2133	9.7655	.0538	12.9210	.0538	12.9210
.2608	9.8278	.1014	13.0100	.1014	13.0100
.3083	9.8901	.1490	13.0990	.1490	13.0990
.3558	9.9524	.1966	13.1880	.1966	13.1880
.4033	10.0147	.2442	13.2770	.2442	13.2770
.4508	10.0770	.2918	13.3660	.2918	13.3660
.4983	10.1393	.3394	13.4550	.3394	13.4550
.5458	10.				

TABLE A-3.--Continued

SECTION NO. 5 RADIUS 12.400 IN. (31.496 CM.)						
SUCTION SURFACE		MOTION		PRESSURE SURFACE		
X, IN.	Y, IN.	X, CM.	Y, CM.	X, IN.	Y, IN.	Y, CM.
-0.921	-1.4070	-2.3149	-3.7770	-0.921	-1.4070	-2.5199
-0.919	-1.4041	-2.3193	-3.7795	-0.920	-1.4069	-2.5196
-0.905	-1.4066	-2.3160	-3.7756	-0.909	-1.4026	-2.5168
-0.901	-1.4729	-2.5099	-3.7412	-0.906	-1.4950	-2.5111
-0.879	-1.4035	-2.4711	-3.6666	-0.905	-1.4957	-2.5031
-0.825	-1.3513	-2.3404	-3.4324	-0.917	-1.4948	-2.4934
-0.822	-1.2802	-2.2256	-3.2010	-0.976	-1.4822	-2.4830
-0.879	-1.1702	-2.1029	-2.9723	-0.906	-1.4813	-2.4802
-0.776	-1.0813	-1.9802	-2.7466	-0.933	-1.4569	-2.4214
-0.733	-0.9936	-1.8575	-2.5238	-0.908	-1.3795	-2.2982
-0.630	-0.9069	-1.7348	-2.3036	-0.863	-1.3025	-2.1749
-0.537	-0.8212	-1.6121	-2.0860	-0.807	-1.2260	-2.0516
-0.504	-0.7365	-1.4894	-1.8707	-0.792	-1.1498	-1.9284
-0.530	-0.6527	-1.3666	-1.6579	-0.707	-1.0741	-1.8051
-0.487	-0.5700	-1.2439	-1.4477	-0.621	-0.9989	-1.6818
-0.444	-0.4881	-1.1212	-1.2399	-0.6136	-0.9241	-1.5588
-0.391	-0.4071	-0.9985	-1.0341	-0.5651	-0.8498	-1.4353
-0.348	-0.3260	-0.8758	-0.8304	-0.5165	-0.7760	-1.3120
-0.295	-0.2476	-0.7531	-0.6288	-0.4680	-0.7027	-1.1887
-0.242	-0.1691	-0.6304	-0.4294	-0.4195	-0.6299	-1.0655
-0.199	-0.0914	-0.5076	-0.2321	-0.3709	-0.5576	-0.9422
-0.156	-0.0140	-0.3849	-0.0366	-0.3224	-0.4859	-0.8189
-0.103	0.0619	-0.2622	0.1572	-0.2739	-0.4147	-0.6957
-0.054	0.1375	-0.1395	0.3491	-0.2254	-0.3400	-0.5724
-0.006	0.2124	0.0168	0.5394	-0.1768	-0.2739	-0.4491
0.047	0.2867	0.1059	0.7281	-0.1283	-0.2044	-0.3259
0.090	0.3603	0.2206	0.9153	-0.0798	-0.1354	-0.2026
0.133	0.4335	0.3513	1.1011	-0.0312	-0.0670	-0.0793
0.186	0.5061	0.4741	1.2855	0.0173	0.0008	0.0439
0.239	0.5778	0.5960	1.4676	0.0658	0.0681	0.1672
0.283	0.6487	0.7195	1.6376	0.1144	0.1347	0.2905
0.316	0.7067	0.8422	1.7949	0.1629	0.2008	0.4137
0.379	0.7658	0.9649	1.9451	0.2114	0.2662	0.5370
0.422	0.8245	1.0876	2.0943	0.2599	0.3310	0.6603
0.475	0.8830	1.2103	2.2428	0.3085	0.3952	0.7835
0.528	0.9412	1.3330	2.3905	0.3570	0.4588	0.9068
0.571	0.9991	1.4558	2.5377	0.4055	0.5217	1.0301
0.624	1.0568	1.5785	2.6842	0.4541	0.5865	1.1533
0.668	1.1143	1.7012	2.8303	0.5026	0.6510	1.2766
0.711	1.1716	1.8239	2.9759	0.5511	0.7163	1.3999
0.764	1.2288	1.9466	3.1212	0.5997	0.7819	1.5231
0.817	1.2859	2.0693	3.2662	0.6482	0.8482	1.6464
0.870	1.3430	2.1921	3.4112	0.6967	0.9142	1.7697
0.923	1.3993	2.3148	3.5563	0.7453	1.0000	1.8930
0.976	1.4566	2.4375	3.7014	0.7938	1.0754	2.0162
1.029	1.5139	2.5602	3.8465	0.8423	1.1504	2.1395
1.082	1.5712	2.6829	3.9916	0.8908	1.2254	2.2628
1.135	1.6285	2.8056	4.1367	0.9393	1.2999	2.3861
1.188	1.6858	2.9283	4.2818	0.9878	1.3744	2.5094
1.241	1.7431	3.0510	4.4269	1.0363	1.4489	2.6327
1.294	1.8004	3.1737	4.5720	1.0848	1.5234	2.7560
1.347	1.8577	3.2964	4.7171	1.1333	1.5979	2.8793
1.400	1.9150	3.4191	4.8622	1.1818	1.6724	3.0026
1.453	1.9723	3.5418	5.0073	1.2303	1.7469	3.1259
1.506	2.0296	3.6645	5.1524	1.2788	1.8214	3.2492
1.559	2.0869	3.7872	5.2975	1.3273	1.8959	3.3725
1.612	2.1442	3.9099	5.4426	1.3758	1.9704	3.4958
1.665	2.2015	4.0326	5.5877	1.4243	2.0449	3.6191
1.718	2.2588	4.1553	5.7328	1.4728	2.1194	3.7424
1.771	2.3161	4.2780	5.8779	1.5213	2.1939	3.8657
1.824	2.3734	4.3997	6.0230	1.5698	2.2684	3.9890
1.877	2.4307	4.5214	6.1681	1.6183	2.3429	4.1123
1.930	2.4880	4.6431	6.3132	1.6668	2.4174	4.2356
1.983	2.5453	4.7648	6.4583	1.7153	2.4919	4.3589
2.036	2.6026	4.8865	6.6034	1.7638	2.5664	4.4822
2.089	2.6599	5.0082	6.7485	1.8123	2.6409	4.6055
2.142	2.7172	5.1299	6.8936	1.8608	2.7154	4.7288
2.195	2.7745	5.2516	7.0387	1.9093	2.7899	4.8521
2.248	2.8318	5.3733	7.1838	1.9578	2.8644	4.9754
2.301	2.8891	5.4950	7.3289	2.0063	2.9389	5.0987
2.354	2.9464	5.6167	7.4740	2.0548	3.0134	5.2220
2.407	3.0037	5.7384	7.6191	2.1033	3.0879	5.3453
2.460	3.0610	5.8601	7.7642	2.1518	3.1624	5.4686
2.513	3.1183	5.9818	7.9093	2.2003	3.2369	5.5919
2.566	3.1756	6.1035	8.0544	2.2488	3.3114	5.7152
2.619	3.2329	6.2252	8.1995	2.2973	3.3859	5.8385
2.672	3.2902	6.3469	8.3446	2.3458	3.4604	5.9618
2.725	3.3475	6.4686	8.4897	2.3943	3.5349	6.0851
2.778	3.4048	6.5903	8.6348	2.4428	3.6094	6.2084
2.831	3.4621	6.7120	8.7799	2.4913	3.6839	6.3317
2.884	3.5194	6.8337	8.9250	2.5398	3.7584	6.4550
2.937	3.5767	6.9554	9.0701	2.5883	3.8329	6.5783
2.990	3.6340	7.0771	9.2152	2.6368	3.9074	6.7016
3.043	3.6913	7.2000	9.3603	2.6853	3.9819	6.8249
3.096	3.7486	7.3227	9.5054	2.7338	4.0564	6.9482
3.149	3.8059	7.4454	9.6505	2.7823	4.1309	7.0715
3.202	3.8632	7.5681	9.7956	2.8308	4.2054	7.1948
3.255	3.9205	7.6908	9.9407	2.8793	4.2799	7.3181
3.308	3.9778	7.8135	10.0858	2.9278	4.3544	7.4414
3.361	4.0351	7.9362	10.2309	2.9763	4.4289	7.5647
3.414	4.0924	8.0589	10.3760	3.0248	4.5034	7.6880
3.467	4.1497	8.1816	10.5211	3.0733	4.5779	7.8113
3.520	4.2070	8.3043	10.6662	3.1218	4.6524	7.9346
3.573	4.2643	8.4270	10.8113	3.1703	4.7269	8.0579
3.626	4.3216	8.5497	10.9564	3.2188	4.8014	8.1812
3.679	4.3789	8.6724	11.1015	3.2673	4.8759	8.3045
3.732	4.4362	8.7951	11.2466	3.3158	4.9504	8.4278
3.785	4.4935	8.9178	11.3917	3.3643	5.0249	8.5511
3.838	4.5508	9.0405	11.5368	3.4128	5.0994	8.6744
3.891	4.6081	9.1632	11.6819	3.4613	5.1739	8.7977
3.944	4.6654	9.2859	11.8270	3.5098	5.2484	8.9210
3.997	4.7227	9.4086	11.9721	3.5583	5.3229	9.0443
4.050	4.7800	9.5313	12.1172	3.6068	5.3974	9.1676
4.103	4.8373	9.6540	12.2623	3.6553	5.4719	9.2909
4.156	4.8946	9.7767	12.4074	3.7038	5.5464	9.4142
4.209	4.9519	9.8994	12.5525	3.7523	5.6209	9.5375
4.262	5.0092	10.0221	12.6976	3.8008	5.6954	9.6608
4.315	5.0665	10.1448	12.8427	3.8493	5.7699	9.7841
4.368	5.1238	10.2675	12.9878	3.8978	5.8444	9.9074
4.421	5.1811	10.3902	13.1329	3.9463	5.9189	10.0307
4.474	5.2384	10.5129	13.2780	3.9948	5.9934	10.1540
4.527	5.2957	10.6356	13.4231	4.0433	6.0679	10.2773
4.580	5.3530	10.7583	13.5682	4.0918	6.1424	10.4006
4.633	5.4103	10.8810	13.7133	4.1403	6.2169	10.5239
4.686	5.4676	11.0037	13.8584	4.1888	6.2914	10.6472
4.739	5.5249	11.1264	14.0035	4.2373	6.3659	10.7705
4.792	5.5822	11.2491	14.1486	4.2858	6.4404	10.8938
4.845	5.6395	11.3718	14.2937	4.3343	6.5149	11.0171
4.898	5.6968	11.4945	14.4388	4.3828	6.5894	11.1404
4.951	5.7541	11.6172	14.5839	4.4313	6.6639	11.2637
5.004	5.8114	11.7399	14.7290	4.4798	6.7384	11.3870
5.057	5.8687	11.8626	14.8741	4.5283	6.8129	11.5103
5.110	5.9260	11.9853	15.0192	4.5768	6.8874	11.6336
5.163	5.9833	12.1080	15.1643	4.6253	6.9619	11.7569
5.216	6.0406	12.2307	15.3094	4.6738	7.0364	11.8802
5.269	6.0979	12.3534	15.4545	4.7223	7.1109	12.0035
5.322	6.1552	12.4761	15.5996	4.7708	7.1854	12.1268
5.375	6.2125	12.5988	15.7447	4.8193	7.2599	12.2501
5.428	6.2698	12.7215	15.8898	4.8678	7.3344	12.3734
5.481	6.3271	12.8442	16.0349	4.9163	7.4089	12.4967
5.534	6.3844	12.9669	16.1800	4.9648	7.4834	12.6200
5.587	6.4417	13.0896	16.3251	5.0133	7.5579	12.7433
5.640	6.4990	13.2123	16.4702	5.0618	7.6324	12.8666
5.693	6.5563	13.3350	16.6153	5.1103	7.7069	12.9899
5.746	6.6136	13.4577	16.7604	5.1588	7.7814	13.1132
5.799	6.6709	13.5804	16.9055	5.2073	7.8559	13.2365
5.852	6.7282	13.7031	17.0506	5.2558	7.9304	13.3598
5.905	6.7855	13.8258	17.1957	5.3043	8.0049	13.4831
5.958	6.8428	13.9485	17.3408	5.3528	8.0794	13.6064
6.011	6.8991	14.0712	17.4859	5.4013	8.1539	13.7297
6.064	6.9564	14.1939	17.6310	5.4498	8.2284	13.8530
6.117	7.0137	14.3166	17.7761	5.4983	8.3029	13.9763
6.170	7.0710	14.4393	17.9212	5.5468	8.3774	14.0996
6.223	7.1283	14.5620	18.0663	5.5953	8.4519	14.2229
6.276	7.1856	14.6847	18.2114	5.6438	8.5264	14.3462
6.329	7.2429	14.8074	18.3565	5.6923	8.6009	14.4695
6.382	7.3002	14.9301	18.5016	5.7408	8.6754	14.5928
6.435	7.3575	15.0528	18.6			

TABLE A-3.--Continued

SECTION NO. 6 RADIUS 12.000 IN. (30.480 CM.)						
SUCTION SURFACE		X.C.M.		Y.C.M.		Y.C.M.
X.IN.	Y.IN.	X.C.M.	Y.C.M.	X.IN.	Y.IN.	
-1.0030	-1.4452	-2.5476	-3.6707	-1.0030	-1.4452	-2.5476
-1.0027	-1.4416	-2.5469	-3.6617	-1.0029	-1.4410	-2.5474
-1.0022	-1.4355	-2.5430	-3.6662	-1.0017	-1.4312	-2.5444
-9984	-1.4293	-2.5360	-3.6304	-9993	-1.4253	-2.5382
-9836	-1.4021	-2.4988	-3.5612	-9958	-1.4047	-2.5294
-9351	-1.3121	-2.3753	-3.3329	-9916	-1.4537	-2.5164
-8865	-1.2231	-2.2517	-3.1066	-9870	-1.4509	-2.5069
-8379	-1.1349	-2.1282	-2.8826	-9748	-1.4389	-2.4810
-7892	-1.0475	-2.0046	-2.6607	-9621	-1.4162	-2.4436
-7406	-9609	-1.8811	-2.4408	-9431	-1.3408	-2.3193
-6919	-8753	-1.7575	-2.2233	-8641	-1.2656	-2.1947
-6433	-7906	-1.6340	-2.0082	-8150	-1.1912	-2.0702
-5946	-7066	-1.5104	-1.7957	-7660	-1.1171	-1.9457
-5460	-6242	-1.3849	-1.5855	-7170	-1.0435	-1.8211
-4974	-5425	-1.2613	-1.3779	-6676	-9704	-1.6966
-4487	-4616	-1.1398	-1.1726	-6189	-8978	-1.5721
-4001	-3810	-1.0162	-9697	-5699	-8257	-1.4475
-3514	-3029	-8927	-7693	-5209	-7541	-1.3230
-3028	-2250	-7691	-5714	-4718	-6831	-1.1984
-2542	-1480	-6456	-3758	-4226	-6125	-1.0734
-2055	-0718	-5220	-1824	-3738	-5424	-9494
-1569	0035	-3985	0009	-3247	-4732	-8248
-1082	0780	-2749	1781	-2757	-4044	-7003
-0596	1517	-1514	3852	-2267	-3361	-5757
0109	2245	-0270	5703	-1776	-2684	-4512
0377	2964	0957	7533	-1286	-2013	-3267
0633	3679	2193	9345	-0796	-1348	-2021
0830	4394	3428	11135	0006	-0689	-0776
1036	5048	4664	12822	0185	0036	0470
1242	5699	5899	14371	0675	0610	1715
1448	6320	7135	15823	1165	1250	2960
1654	6952	8370	17253	1656	1883	4204
1860	7593	9606	18669	2146	2510	5451
2066	8233	10841	20073	2636	3129	6696
2272	8850	12077	21463	3127	3741	7946
2478	9453	13312	22841	3617	4366	9187
2684	10064	14548	24207	4107	4982	10433
2890	10674	15783	25562	4598	5594	11678
3096	11284	17019	26905	5088	6179	12924
3302	11894	18254	28237	5578	6925	14169
3508	12504	19490	29558	6069	7746	15414
3714	13114	20725	30870	6559	8563	16660
3920	13724	21960	32186	7049	9377	17905
4126	14334	23196	33426	7539	10190	19150
4332	14944	24432	34666	8030	11000	20396
4538	15554	25668	35906	8520	11807	21641
4744	16164	26904	37146	9010	12614	22886
4950	16774	28140	38386	9500	13421	24131
5156	17384	29376	39626	10000	14228	25376
5362	17994	30612	40866	10500	15035	26621
5568	18604	31848	42106	11000	15842	27866
5774	19214	33084	43346	11500	16649	29111
5980	19824	34320	44586	12000	17456	30356
6186	20434	35556	45826	12500	18263	31601
6392	21044	36792	47066	13000	19070	32846
6598	21654	38028	48306	13500	19877	34091
6804	22264	39264	49546	14000	20684	35336
7010	22874	40500	50786	14500	21491	36581
7216	23484	41736	52026	15000	22298	37826
7422	24094	42972	53266	15500	23105	39071
7628	24704	44208	54506	16000	23912	40316
7834	25314	45444	55746	16500	24719	41561
8040	25924	46680	56986	17000	25526	42806
8246	26534	47916	58226	17500	26333	44051
8452	27144	49152	59466	18000	27140	45296
8658	27754	50388	60706	18500	27947	46541
8864	28364	51624	61946	19000	28754	47786
9070	28974	52860	63186	19500	29561	49031
9276	29584	54096	64426	20000	30368	50276
9482	30194	55332	65666	20500	31175	51521
9688	30804	56568	66906	21000	31982	52766
9894	31414	57804	68146	21500	32789	54011
10100	32024	59040	69386	22000	33596	55256
10306	32634	60276	70626	22500	34403	56501
10512	33244	61512	71866	23000	35210	57746
10718	33854	62748	73106	23500	36017	58991
10924	34464	63984	74346	24000	36824	60236
11130	35074	65220	75586	24500	37631	61481
11336	35684	66456	76826	25000	38438	62726
11542	36294	67692	78066	25500	39245	63971
11748	36904	68928	79306	26000	40052	65216
11954	37514	70164	80546	26500	40859	66461
12160	38124	71400	81786	27000	41666	67706
12366	38734	72636	83026	27500	42473	68951
12572	39344	73872	84266	28000	43280	70196
12778	39954	75108	85506	28500	44087	71441
12984	40564	76344	86746	29000	44894	72686
13190	41174	77580	87986	29500	45701	73931
13396	41784	78816	89226	30000	46508	75176
13602	42394	80052	90466	30500	47315	76421
13808	43004	81288	91706	31000	48122	77666
14014	43614	82524	92946	31500	48929	78911
14220	44224	83760	94186	32000	49736	80156
14426	44834	84996	95426	32500	50543	81401
14632	45444	86232	96666	33000	51350	82646
14838	46054	87468	97906	33500	52157	83891
15044	46664	88704	99146	34000	52964	85136
15250	47274	89940	100386	34500	53771	86381
15456	47884	91176	101626	35000	54578	87626
15662	48494	92412	102866	35500	55385	88871
15868	49104	93648	104106	36000	56192	90116
16074	49714	94884	105346	36500	57000	91361
16280	50324	96120	106586	37000	57807	92606
16486	50934	97356	107826	37500	58614	93851
16692	51544	98592	109066	38000	59421	95096
16898	52154	99828	110306	38500	60228	96341
17104	52764	101064	111546	39000	61035	97586
17310	53374	102300	112786	39500	61842	98831
17516	53984	103536	114026	40000	62649	100076
17722	54594	104772	115266	40500	63456	101321
17928	55204	106008	116506	41000	64263	102566
18134	55814	107244	117746	41500	65070	103811
18340	56424	108480	118986	42000	65877	105056
18546	57034	109716	120226	42500	66684	106301
18752	57644	110952	121466	43000	67491	107546
18958	58254	112188	122706	43500	68298	108791
19164	58864	113424	123946	44000	69105	110036
19370	59474	114660	125186	44500	69912	111281
19576	60084	115896	126426	45000	70719	112526
19782	60694	117132	127666	45500	71526	113771
19988	61304	118368	128906	46000	72333	115016
20194	61914	119604	130146	46500	73140	116261
20400	62524	120840	131386	47000	73947	117506
20606	63134	122076	132626	47500	74754	118751
20812	63744	123312	133866	48000	75561	119996
21018	64354	124548	135106	48500	76368	121241
21224	64964	125784	136346	49000	77175	122486
21430	65574	127020	137586	49500	77982	123731
21636	66184	128256	138826	50000	78789	124976
21842	66794	129492	140066	50500	79596	126221
22048	67404	130728	141306	51000	80403	127466
22254	68014	131964	142546	51500	81210	128711
22460	68624	133200	143786	52000	82017	129956
22666	69234	134436	145026	52500	82824	131201
22872	69844	135672	146266	53000	83631	132446
23078	70454	136908	147506	53500	84438	133691
23284	71064	138144	148746	54000	85245	134936
23490	71674	139380	149986	54500	86052	136181
23696	72284	140616	151226	55000	86859	137426
23902	72894	141852	152466	55500	87666	138671
24108	73504	143088	153706	56000	88473	139916
24314	74114	144324	154946	56500	89280	141161
24520	74724	145560	156186	57000	90087	142406
24726	75334	146796	157426	57500	90894	143651
24932	75944	148032	158666	58000	91701	144896
25138	76554	149268	159906	58500	92508	146141
25344	77164	150504	161146	59000	93315	147386
25550	77774	151740	162386	59500	94122	148631
25756	78384	152976	163626	60000	94929	149876
25962	78994	154212	164866	60500	95736	151121
26168	79604	155448	166106	61000	96543	152366
26374	80214	156684	167346	61500	97350	153611
26580	80824	157920	168586	62000	98157	154856
26786	81434	159156	169826	62500	98964	156101
26992	82044	160392	171066	63000	99771	157346
27198	82654	161628	172306	63500	100578	158591
27404	83264	162864	173546	64000	101385	159836
27610	83874	164100	174786	64500	102192	

TABLE A-3.--Continued

 ROUGH AIRFOIL COORDINATES
 SECTION NO. 7 RADIUS 11.700 IN. (29.718 CM.)

X IN.	SECTION SURFACE		PRESSURE SURFACE		Y IN.
	Y IN.	X CM.	Y CM.	X CM.	Y CM.
-1.0005	-1.4010	-2.5413	-3.5585	-1.0005	-1.4010
-1.0002	-1.3977	-2.5406	-3.5501	-1.0004	-1.4024
-9988	-1.3924	-2.5369	-3.5366	-.9995	-1.4061
-9963	-1.3869	-2.5308	-3.5228	-.9973	-1.4084
-9822	-1.3615	-2.4949	-3.4581	-.9943	-1.4092
-9336	-1.2740	-2.3712	-3.2360	-.9906	-1.4084
-8849	-1.1673	-2.2476	-3.0157	-.9865	-1.4060
-8362	-1.1013	-2.1280	-2.7974	-.9773	-1.3955
-7876	-1.0160	-2.0004	-2.5807	-.9633	-1.3743
-7389	-.9315	-1.8768	-2.3659	-.9143	-1.3011
-6902	-.8477	-1.7532	-2.1533	-.8654	-1.2284
-6416	-.7650	-1.6296	-1.9431	-.8164	-1.1502
-5929	-.6832	-1.5060	-1.7354	-.7675	-1.0846
-5442	-.6023	-1.3826	-1.5299	-.7186	-1.0134
-4956	-.5223	-1.2587	-1.3268	-.6696	-.9429
-4469	-.4433	-1.1351	-1.1261	-.6207	-.8728
-3982	-.3653	-1.0115	-.9278	-.5717	-.8032
-3496	-.2882	-.8879	-.7321	-.5228	-.7342
-3009	-.2121	-.7643	-.5387	-.4739	-.6656
-2522	-.1369	-.6407	-.3476	-.4249	-.5976
-2036	-.0625	-.5171	-.1568	-.3760	-.5300
-1549	-.0110	-.3935	-.0278	-.3270	-.4629
-1062	.0836	-.2699	.2123	-.2781	-.3963
-.9576	.1554	-.1463	.3946	-.2291	-.3302
-.8489	.2263	-.0227	.5749	-.1802	-.2645
-.7398	.2965	.1010	.7531	-.1313	-.1993
-.6304	.3658	.2246	.9290	-.0823	-.1345
-.5211	.4307	.3482	1.0941	-.0334	-.0702
-.4118	.4904	.4718	1.2457	.0156	-.0064
-.3021	.5464	.5954	1.3878	.0645	.0570
-.1923	.6015	.7190	1.5278	.1134	.1200
-.0824	.6560	.8426	1.6663	.1624	.1825
.0271	.7100	.9662	1.8033	.2113	.2445
.1371	.7634	1.0898	1.9369	.2603	.3060
.2477	.8162	1.2135	2.0731	.3092	.3671
.3584	.8685	1.3371	2.2060	.3582	.4277
.4691	.9203	1.4607	2.3375	.4071	.4877
.5797	.9715	1.5843	2.4677	.4560	.5473
.6904	1.0223	1.7079	2.5966	.5050	.6094
.8011	1.0725	1.8315	2.7242	.5539	.6747
.9118	1.1222	1.9551	2.8505	.6029	.7357
1.0225	1.1715	2.0787	2.9756	.6518	.7954
1.1332	1.2200	2.2022	3.1008	.7007	.8544
1.2439	1.2684	2.3257	3.2251	.7497	.9134
1.3546	1.3169	2.4492	3.3494	.7986	.9724
1.4653	1.3654	2.5727	3.4737	.8476	1.0314
1.5760	1.4139	2.6962	3.5980	.8965	1.0904
1.6867	1.4624	2.8197	3.7223	.9455	1.1494
1.7974	1.5109	2.9432	3.8466	.9944	1.2084
1.9081	1.5594	3.0667	3.9709	1.0434	1.2674
2.0188	1.6079	3.1902	4.0952	1.0924	1.3264
2.1295	1.6564	3.3137	4.2195	1.1414	1.3854
2.2402	1.7049	3.4372	4.3438	1.1904	1.4444
2.3509	1.7534	3.5607	4.4681	1.2394	1.5034
2.4616	1.8019	3.6842	4.5924	1.2884	1.5624
2.5723	1.8504	3.8077	4.7167	1.3374	1.6214
2.6830	1.8989	3.9312	4.8410	1.3864	1.6804
2.7937	1.9474	4.0547	4.9653	1.4354	1.7394
2.9044	2.0000	4.1782	5.0896	1.4844	1.7984
3.0151	2.0526	4.3017	5.2139	1.5334	1.8574
3.1258	2.1052	4.4252	5.3382	1.5824	1.9164
3.2365	2.1578	4.5487	5.4625	1.6314	1.9754
3.3472	2.2104	4.6722	5.5868	1.6804	2.0344
3.4579	2.2630	4.7957	5.7111	1.7294	2.0934
3.5686	2.3156	4.9192	5.8354	1.7784	2.1524
3.6793	2.3682	5.0427	5.9597	1.8274	2.2114
3.7900	2.4208	5.1662	6.0840	1.8764	2.2704
3.9007	2.4734	5.2897	6.2083	1.9254	2.3294
4.0114	2.5260	5.4132	6.3326	1.9744	2.3884
4.1221	2.5786	5.5367	6.4569	2.0234	2.4474
4.2328	2.6312	5.6602	6.5812	2.0724	2.5064
4.3435	2.6838	5.7837	6.7055	2.1214	2.5654
4.4542	2.7364	5.9072	6.8298	2.1704	2.6244
4.5649	2.7890	6.0307	6.9541	2.2194	2.6834
4.6756	2.8416	6.1542	7.0784	2.2684	2.7424
4.7863	2.8942	6.2777	7.2027	2.3174	2.8014
4.8970	2.9468	6.4012	7.3270	2.3664	2.8604
5.0077	3.0000	6.5247	7.4513	2.4154	2.9194
5.1184	3.0526	6.6482	7.5756	2.4644	2.9784
5.2291	3.1052	6.7717	7.6999	2.5134	3.0374
5.3398	3.1578	6.8952	7.8242	2.5624	3.0964
5.4505	3.2104	7.0187	7.9485	2.6114	3.1554
5.5612	3.2630	7.1422	8.0728	2.6604	3.2144
5.6719	3.3156	7.2657	8.1971	2.7094	3.2734
5.7826	3.3682	7.3892	8.3214	2.7584	3.3324
5.8933	3.4208	7.5127	8.4457	2.8074	3.3914
6.0040	3.4734	7.6362	8.5700	2.8564	3.4504
6.1147	3.5260	7.7597	8.6943	2.9054	3.5094
6.2254	3.5786	7.8832	8.8186	2.9544	3.5684
6.3361	3.6312	8.0067	8.9429	3.0034	3.6274
6.4468	3.6838	8.1302	9.0672	3.0524	3.6864
6.5575	3.7364	8.2537	9.1915	3.1014	3.7454
6.6682	3.7890	8.3772	9.3158	3.1504	3.8044
6.7789	3.8416	8.5007	9.4401	3.1994	3.8634
6.8896	3.8942	8.6242	9.5644	3.2484	3.9224
6.9903	3.9468	8.7477	9.6887	3.2974	3.9814
7.1010	4.0000	8.8712	9.8130	3.3464	4.0404
7.2117	4.0526	8.9947	9.9373	3.3954	4.0994
7.3224	4.1052	9.1182	10.0616	3.4444	4.1584
7.4331	4.1578	9.2417	10.1859	3.4934	4.2174
7.5438	4.2104	9.3652	10.3102	3.5424	4.2764
7.6545	4.2630	9.4887	10.4345	3.5914	4.3354
7.7652	4.3156	9.6122	10.5588	3.6404	4.3944
7.8759	4.3682	9.7357	10.6831	3.6894	4.4534
7.9866	4.4208	9.8592	10.8074	3.7384	4.5124
8.0973	4.4734	9.9827	10.9317	3.7874	4.5714
8.2080	4.5260	10.1062	11.0560	3.8364	4.6304
8.3187	4.5786	10.2297	11.1803	3.8854	4.6894
8.4294	4.6312	10.3532	11.3046	3.9344	4.7484
8.5401	4.6838	10.4767	11.4289	3.9834	4.8074
8.6508	4.7364	10.6002	11.5532	4.0324	4.8664
8.7615	4.7890	10.7237	11.6775	4.0814	4.9254
8.8722	4.8416	10.8472	11.8018	4.1304	4.9844
8.9829	4.8942	10.9707	11.9261	4.1794	5.0434
9.0936	4.9468	11.0942	12.0504	4.2284	5.1024
9.2043	5.0000	11.2177	12.1747	4.2774	5.1614
9.3150	5.0526	11.3412	12.2990	4.3264	5.2204
9.4257	5.1052	11.4647	12.4233	4.3754	5.2794
9.5364	5.1578	11.5882	12.5476	4.4244	5.3384
9.6471	5.2104	11.7117	12.6719	4.4734	5.3974
9.7578	5.2630	11.8352	12.7962	4.5224	5.4564
9.8685	5.3156	11.9587	12.9205	4.5714	5.5154
9.9792	5.3682	12.0822	13.0448	4.6204	5.5744
10.0899	5.4208	12.2057	13.1691	4.6694	5.6334
10.2006	5.4734	12.3292	13.2934	4.7184	5.6924
10.3113	5.5260	12.4527	13.4177	4.7674	5.7514
10.4220	5.5786	12.5762	13.5420	4.8164	5.8104
10.5327	5.6312	12.6997	13.6663	4.8654	5.8694
10.6434	5.6838	12.8232	13.7906	4.9144	5.9284
10.7541	5.7364	12.9467	13.9149	4.9634	5.9874
10.8648	5.7890	13.0702	14.0392	5.0124	6.0464
10.9755	5.8416	13.1937	14.1635	5.0614	6.1054
11.0862	5.8942	13.3172	14.2878	5.1104	6.1644
11.1969	5.9468	13.4407	14.4121	5.1594	6.2234
11.3076	6.0000	13.5642	14.5364	5.2084	6.2824
11.4183	6.0526	13.6877	14.6607	5.2574	6.3414
11.5290	6.1052	13.8112	14.7850	5.3064	6.4004
11.6397	6.1578	13.9347	14.9093	5.3554	6.4594
11.7504	6.2104	14.0582	15.0336	5.4044	6.5184
11.8611	6.2630	14.1817	15.1579	5.4534	6.5774
11.9718	6.3156	14.3052	15.2822	5.5024	6.6364
12.0825	6.3682	14.4287	15.4065	5.5514	6.6954
12.1932	6.4208	14.5522	15.5308	5.6004	6.7544
12.3039	6.4734	14.6757	15.6551	5.6494	6.8134
12.4146	6.5260	14.7992	15.7794	5.6984	6.8724
12.5253	6.5786	14.9227	15.9037	5.7474	6.9314
12.6360	6.6312	15.0462	16.0280	5.7964	6.9904
12.7467	6.6838	15.1697	16.1523	5.8454	7.0494
12.8574	6.7364	15.2932	16.2766	5.8944	7.1084
12.9681	6.7890	15.4167	16.4009	5.9434	7.1674
13.0788	6.8416	15.5402	16.5252	5.9924	7.2264
13.1895	6.8942	15.6637	16.6495	6.0414	7.2854
13.3002	6.9468	15.7872	16.7738	6.0904	7.3444
13.4109	7.0000	15.9107	16.8981	6.1394	7.4034
13.5216	7.0526	16.0342	17.0224	6.1884	7.4624
13.6323	7.1052	16.1577	17.1467	6.2374	7.5214
13.7430	7.1578	16.2812	17.2710	6.2864	7.5804
13.8537	7.2104	16.4047	17.3953	6.3354	7.6394
13.9644	7.2630	16.5282	17.5196	6.3844	7.6984
14.0751	7.3156	16.6517	17.6439	6.4334	7.7574
14.1858	7.3682	16.7752	17.7682	6.4824	7.8164
14.2965	7.4208	16.8987	17.8925	6.5314	7.8754
14.4072	7.4734	17.0222	18.0168	6.5804	7.9344
14.5179	7.5260	17.1457	18.1411	6.6294	7.9934
14.6286	7.5786	17.2692	18.2654	6.6784	8.0524
14.7393	7.6312	17.3927	18.3897	6.7274	8.1114
14.8500	7.6838	17.5162	18.5140	6.7764	8.1704
14.9607	7.7364	17.6397	18.6383	6.8254	8.2294
15.0714	7.7890	17.7632	18.7626	6.8744	8.2884
15.1821	7.8416	17.8867	18.8869	6.9234	8.3474
15.2928	7.8942	18.0102	19.0112	6.9724	8.4064
15.4035	7.9468	18.1337	19.1355		

TABLE A-3.--Continued

SECTION NO. 8 RADIUS 11.000 IN. (27.940 CM.)					
SUCTION SURFACE			PRESSURE SURFACE		
X IN.	Y IN.	X CM.	Y IN.	X IN.	Y CM.
-0.066	-1.3093	-2.5064	-3.3256	-1.3093	-3.3256
-0.064	-1.3062	-2.5056	-3.3178	-1.3102	-3.3279
-0.052	-1.3018	-2.5023	-3.3105	-1.3133	-3.3350
-0.030	-1.2972	-2.4967	-3.2949	-1.3153	-3.3409
-0.005	-1.2957	-2.4951	-3.2404	-1.3160	-3.3428
-0.223	-1.1930	-2.3425	-3.0302	-1.3154	-3.3412
-0.070	-1.1109	-2.2200	-2.8216	-1.3135	-3.3363
-0.258	-1.0293	-2.0975	-2.6145	-1.3047	-3.3139
-0.773	-0.9483	-1.9750	-2.4087	-1.2869	-3.2886
-0.723	-0.8679	-1.8524	-2.2046	-1.2683	-3.2644
-0.610	-0.7884	-1.7299	-2.0025	-1.2503	-3.2422
-0.328	-0.7096	-1.6073	-1.8024	-1.2303	-3.2198
-0.506	-0.6315	-1.4848	-1.6041	-1.2029	-3.1957
-0.536	-0.5543	-1.3623	-1.4079	-1.1747	-3.1705
-0.681	-0.4781	-1.2397	-1.2143	-1.1451	-3.1445
-0.439	-0.4030	-1.1172	-1.0235	-1.1145	-3.1185
-0.396	-0.3288	-0.9947	-0.8353	-1.0829	-3.0925
-0.346	-0.2537	-0.8722	-0.6495	-1.0503	-3.0664
-0.293	-0.1835	-0.7496	-0.4660	-1.0179	-3.0402
-0.249	-0.1125	-0.6271	-0.2850	-0.9853	-3.0140
-0.194	-0.0418	-0.5045	-0.1061	-0.9523	-2.9878
-0.154	-0.0277	-0.3820	-0.0704	-0.9193	-2.9616
-0.102	-0.0964	-0.2595	-0.2448	-0.8863	-2.9354
-0.039	-0.1682	-0.1370	-0.4170	-0.8533	-2.9092
-0.057	-0.2395	-0.0144	-0.5830	-0.8203	-2.8830
-0.026	-0.2895	-0.1081	-0.7352	-0.7873	-2.8568
-0.006	-0.3448	-0.2107	-0.8759	-0.7543	-2.8306
-0.130	-0.3943	-0.3532	-1.0116	-0.7213	-2.8044
-0.103	-0.4511	-0.4757	-1.1457	-0.6883	-2.7782
-0.355	-0.5232	-0.5982	-1.2782	-0.6553	-2.7520
-0.320	-0.6058	-0.7206	-1.4092	-0.6223	-2.7258
-0.303	-0.6962	-0.8433	-1.5387	-0.5893	-2.6996
-0.285	-0.7660	-0.9659	-1.6667	-0.5563	-2.6734
-0.467	-0.8553	-1.0884	-1.7933	-0.5233	-2.6472
-0.520	-0.9440	-1.2109	-1.9185	-0.4903	-2.6210
-0.572	-1.0322	-1.3334	-2.0423	-0.4573	-2.5948
-0.615	-1.1200	-1.4567	-2.1647	-0.4243	-2.5686
-0.657	-1.2077	-1.5785	-2.2857	-0.3913	-2.5424
-0.719	-1.2953	-1.7010	-2.4055	-0.3583	-2.5162
-0.762	-1.3830	-1.8236	-2.5239	-0.3253	-2.4900
-0.814	-1.4706	-1.9461	-2.6410	-0.2923	-2.4638
-0.821	-1.5582	-2.0687	-2.7569	-0.2593	-2.4376
-0.827	-1.6458	-2.1912	-2.8745	-0.2263	-2.4114
-0.835	-1.7334	-2.3137	-2.9933	-0.1933	-2.3852
-0.830	-1.8210	-2.4362	-3.1123	-0.1603	-2.3590
-0.843	-1.9086	-2.5587	-3.2313	-0.1273	-2.3328
-0.823	-1.9962	-2.6812	-3.3503	-0.0943	-2.3066
-0.824	-2.0838	-2.8037	-3.4693	-0.0613	-2.2804
-0.824	-2.1714	-2.9262	-3.5883	-0.0283	-2.2542
-0.824	-2.2590	-3.0487	-3.7073	0.0047	-2.2280
-0.824	-2.3466	-3.1712	-3.8263	0.0317	-2.2018
-0.824	-2.4342	-3.2937	-3.9453	0.0587	-2.1756
-0.824	-2.5218	-3.4162	-4.0643	0.0857	-2.1494
-0.824	-2.6094	-3.5387	-4.1833	0.1127	-2.1232
-0.824	-2.6970	-3.6612	-4.3023	0.1397	-2.0970
-0.824	-2.7846	-3.7837	-4.4213	0.1667	-2.0708
-0.824	-2.8722	-3.9062	-4.5403	0.1937	-2.0446
-0.824	-2.9598	-4.0287	-4.6593	0.2207	-2.0184
-0.824	-3.0474	-4.1512	-4.7783	0.2477	-1.9922
-0.824	-3.1350	-4.2737	-4.8973	0.2747	-1.9660
-0.824	-3.2226	-4.3962	-5.0163	0.3017	-1.9398
-0.824	-3.3102	-4.5187	-5.1353	0.3287	-1.9136
-0.824	-3.3978	-4.6412	-5.2543	0.3557	-1.8874
-0.824	-3.4854	-4.7637	-5.3733	0.3827	-1.8612
-0.824	-3.5730	-4.8862	-5.4923	0.4097	-1.8350
-0.824	-3.6606	-5.0087	-5.6113	0.4367	-1.8088
-0.824	-3.7482	-5.1312	-5.7303	0.4637	-1.7826
-0.824	-3.8358	-5.2537	-5.8493	0.4907	-1.7564
-0.824	-3.9234	-5.3762	-5.9683	0.5177	-1.7302
-0.824	-4.0110	-5.4987	-6.0873	0.5447	-1.7040
-0.824	-4.0986	-5.6212	-6.2063	0.5717	-1.6778
-0.824	-4.1862	-5.7437	-6.3253	0.5987	-1.6516
-0.824	-4.2738	-5.8662	-6.4443	0.6257	-1.6254
-0.824	-4.3614	-5.9887	-6.5633	0.6527	-1.5992
-0.824	-4.4490	-6.1112	-6.6823	0.6797	-1.5730
-0.824	-4.5366	-6.2337	-6.8013	0.7067	-1.5468
-0.824	-4.6242	-6.3562	-6.9203	0.7337	-1.5206
-0.824	-4.7118	-6.4787	-7.0393	0.7607	-1.4944
-0.824	-4.7994	-6.6012	-7.1583	0.7877	-1.4682
-0.824	-4.8870	-6.7237	-7.2773	0.8147	-1.4420
-0.824	-4.9746	-6.8462	-7.3963	0.8417	-1.4158
-0.824	-5.0622	-6.9687	-7.5153	0.8687	-1.3896
-0.824	-5.1498	-7.0912	-7.6343	0.8957	-1.3634
-0.824	-5.2374	-7.2137	-7.7533	0.9227	-1.3372
-0.824	-5.3250	-7.3362	-7.8723	0.9497	-1.3110
-0.824	-5.4126	-7.4587	-7.9913	0.9767	-1.2848
-0.824	-5.5002	-7.5812	-8.1103	1.0037	-1.2586
-0.824	-5.5878	-7.7037	-8.2293	1.0307	-1.2324
-0.824	-5.6754	-7.8262	-8.3483	1.0577	-1.2062
-0.824	-5.7630	-7.9487	-8.4673	1.0847	-1.1800
-0.824	-5.8506	-8.0712	-8.5863	1.1117	-1.1538
-0.824	-5.9382	-8.1937	-8.7053	1.1387	-1.1276
-0.824	-6.0258	-8.3162	-8.8243	1.1657	-1.1014
-0.824	-6.1134	-8.4387	-8.9433	1.1927	-1.0752
-0.824	-6.2010	-8.5612	-9.0623	1.2197	-1.0490
-0.824	-6.2886	-8.6837	-9.1813	1.2467	-1.0228
-0.824	-6.3762	-8.8062	-9.3003	1.2737	-0.9966
-0.824	-6.4638	-8.9287	-9.4193	1.3007	-0.9704
-0.824	-6.5514	-9.0512	-9.5383	1.3277	-0.9442
-0.824	-6.6390	-9.1737	-9.6573	1.3547	-0.9180
-0.824	-6.7266	-9.2962	-9.7763	1.3817	-0.8918
-0.824	-6.8142	-9.4187	-9.8953	1.4087	-0.8656
-0.824	-6.9018	-9.5412	-10.0143	1.4357	-0.8394
-0.824	-6.9894	-9.6637	-10.1333	1.4627	-0.8132
-0.824	-7.0770	-9.7862	-10.2523	1.4897	-0.7870
-0.824	-7.1646	-9.9087	-10.3713	1.5167	-0.7608
-0.824	-7.2522	-10.0312	-10.4903	1.5437	-0.7346
-0.824	-7.3398	-10.1537	-10.6093	1.5707	-0.7084
-0.824	-7.4274	-10.2762	-10.7283	1.5977	-0.6822
-0.824	-7.5150	-10.3987	-10.8473	1.6247	-0.6560
-0.824	-7.6026	-10.5212	-10.9663	1.6517	-0.6298
-0.824	-7.6902	-10.6437	-11.0853	1.6787	-0.6036
-0.824	-7.7778	-10.7662	-11.2043	1.7057	-0.5774
-0.824	-7.8654	-10.8887	-11.3233	1.7327	-0.5512
-0.824	-7.9530	-11.0112	-11.4423	1.7597	-0.5250
-0.824	-8.0406	-11.1337	-11.5613	1.7867	-0.4988
-0.824	-8.1282	-11.2562	-11.6803	1.8137	-0.4726
-0.824	-8.2158	-11.3787	-11.7993	1.8407	-0.4464
-0.824	-8.3034	-11.5012	-11.9183	1.8677	-0.4202
-0.824	-8.3910	-11.6237	-12.0373	1.8947	-0.3940
-0.824	-8.4786	-11.7462	-12.1563	1.9217	-0.3678
-0.824	-8.5662	-11.8687	-12.2753	1.9487	-0.3416
-0.824	-8.6538	-11.9912	-12.3943	1.9757	-0.3154
-0.824	-8.7414	-12.1137	-12.5133	2.0027	-0.2892
-0.824	-8.8290	-12.2362	-12.6323	2.0297	-0.2630
-0.824	-8.9166	-12.3587	-12.7513	2.0567	-0.2368
-0.824	-9.0042	-12.4812	-12.8703	2.0837	-0.2106
-0.824	-9.0918	-12.6037	-12.9893	2.1107	-0.1844
-0.824	-9.1794	-12.7262	-13.1083	2.1377	-0.1582
-0.824	-9.2670	-12.8487	-13.2273	2.1647	-0.1320
-0.824	-9.3546	-12.9712	-13.3463	2.1917	-0.1058
-0.824	-9.4422	-13.0937	-13.4653	2.2187	-0.0796
-0.824	-9.5298	-13.2162	-13.5843	2.2457	-0.0534
-0.824	-9.6174	-13.3387	-13.7033	2.2727	-0.0272
-0.824	-9.7050	-13.4612	-13.8223	2.2997	0.0010
-0.824	-9.7926	-13.5837	-13.9413	2.3267	0.0272
-0.824	-9.8802	-13.7062	-14.0603	2.3537	0.0534
-0.824	-9.9678	-13.8287	-14.1793	2.3807	0.0796
-0.824	-10.0554	-13.9512	-14.2983	2.4077	0.1058
-0.824	-10.1430	-14.0737	-14.4173	2.4347	0.1320
-0.824	-10.2306	-14.1962	-14.5363	2.4617	0.1582
-0.824	-10.3182	-14.3187	-14.6553	2.4887	0.1844
-0.824	-10.4058	-14.4412	-14.7743	2.5157	0.2106
-0.824	-10.4934	-14.5637	-14.8933	2.5427	0.2368
-0.824	-10.5810	-14.6862	-15.0123	2.5697	0.2630
-0.824	-10.6686	-14.8087	-15.1313	2.5967	0.2892
-0.824	-10.7562	-14.9312	-15.2503	2.6237	0.3154
-0.824	-10.8438	-15.0537	-15.3693	2.6507	0.3416
-0.824	-10.9314	-15.1762	-15.4883	2.6777	0.3678
-0.824	-11.0190	-15.2987	-15.6073	2.7047	0.3940
-0.824	-11.1066	-15.4212	-15.7263	2.7317	0.4202
-0.824	-11.1942	-15.5437	-15.8453	2.7587	0.4464
-0.824	-11.2818	-15.6662	-15.9643	2.7857	0.4726
-0.824	-11.3694	-15.7887	-16.0833	2.8127	0.4988
-0.824	-11.4570	-15.9112	-16.2023	2.8397	0.5250
-0.824	-11.5446	-16.0337	-16.3213	2.8667	0.5512
-0.824	-11.6322	-16.1562	-16.4403	2.8937	0.5774
-0.824	-11.7198	-16.2787	-16.5593	2.9207	0.6036
-0.824	-11.8074	-16.4012	-16.6783	2.9477	0.6298
-0.824	-11.8950	-16.5237	-16.7973	2.9747	0.6560
-0.824	-11.9826	-16.6462	-16.9163	3.0017	0.6822
-0.824	-12.0702	-16.7687	-17.0353	3.0287	0.7084
-0.824	-12.1578	-16.8912	-17.1543	3.0557	0.7346
-0.824	-12.2454	-17.0137	-17.2733	3.0827	0.7608
-0.824	-12.3330	-17.1362	-17.3923	3.1097	0.7870
-0.824	-12.4206	-17.2587	-17.5113	3.1367	0.8132
-0.824	-12.5082	-17.3812	-17.6303	3.1637	0.8394
-0.824	-12.5958	-17.5037	-17.7493	3.1907	0.8656
-0.824	-12.6834	-17.6262	-17.8683	3.2177	0.8918
-0.824	-12.7710	-17.7487	-17.9873	3.2447	0.9180
-0.824					

TABLE A-3.--Continued

SECTION NO. 9 RADIUS 10.300 IN. (26.162 CM.)					
SUCTION SURFACE		Y CM.		PRESSURE SURFACE	
X IN.	Y IN.	X CM.	Y CM.	X IN.	Y IN.
-0.752	-1.2190	-2.4770	-3.0962	-0.752	-1.2190
-0.740	-1.2155	-2.4760	-3.0873	-0.740	-1.2155
-0.734	-1.2108	-2.4724	-3.0754	-0.734	-1.2108
-0.710	-1.2060	-2.4662	-3.0632	-0.710	-1.2060
-0.681	-1.1981	-2.4398	-3.0177	-0.681	-1.1981
-0.614	-1.1085	-2.3164	-2.8154	-0.614	-1.1085
-0.638	-1.0296	-2.1900	-2.6152	-0.638	-1.0296
-0.5156	-0.9512	-2.0715	-2.4111	-0.5156	-0.9512
-0.7474	-0.8734	-1.9491	-2.2185	-0.7474	-0.8734
-0.7192	-0.7963	-1.8267	-2.0227	-0.7192	-0.7963
-0.6710	-0.7199	-1.7043	-1.8285	-0.6710	-0.7199
-0.6228	-0.6440	-1.5819	-1.6337	-0.6228	-0.6440
-0.5746	-0.5689	-1.4595	-1.4350	-0.5746	-0.5689
-0.5264	-0.4951	-1.3371	-1.2374	-0.5264	-0.4951
-0.4782	-0.4225	-1.2147	-1.0413	-0.4782	-0.4225
-0.4301	-0.3511	-1.0923	-0.8419	-0.4301	-0.3511
-0.3819	-0.2809	-0.9699	-0.7134	-0.3819	-0.2809
-0.3337	-0.2117	-0.8475	-0.5371	-0.3337	-0.2117
-0.2855	-0.1436	-0.7251	-0.3608	-0.2855	-0.1436
-0.2373	-0.0766	-0.6027	-0.1847	-0.2373	-0.0766
-0.1891	-0.0107	-0.4803	-0.0271	-0.1891	-0.0107
-0.1409	-0.0537	-0.3579	-0.1364	-0.1409	-0.0537
-0.0927	-0.1132	-0.2355	-0.2977	-0.0927	-0.1132
-0.0445	-0.1681	-0.1131	-0.4269	-0.0445	-0.1681
-0.037	-0.2199	-0.0093	-0.5386	-0.037	-0.2199
-0.0516	-0.2709	-0.1317	-0.6081	-0.0516	-0.2709
-0.0000	-0.3212	-0.2541	-0.6137	-0.0000	-0.3212
-0.0482	-0.3707	-0.3765	-0.6164	-0.0482	-0.3707
-0.0968	-0.4195	-0.4989	-0.6055	-0.0968	-0.4195
-0.1446	-0.4676	-0.6215	-0.5877	-0.1446	-0.4676
-0.1928	-0.5150	-0.7437	-0.5619	-0.1928	-0.5150
-0.2410	-0.5617	-0.8661	-0.5288	-0.2410	-0.5617
-0.2892	-0.6078	-0.9885	-0.4890	-0.2892	-0.6078
-0.3374	-0.6532	-1.1109	-0.4393	-0.3374	-0.6532
-0.3856	-0.6980	-1.2333	-0.3790	-0.3856	-0.6980
-0.4337	-0.7422	-1.3557	-0.3094	-0.4337	-0.7422
-0.4819	-0.7857	-1.4781	-0.2308	-0.4819	-0.7857
-0.5301	-0.8287	-1.6005	-0.1469	-0.5301	-0.8287
-0.5783	-0.8710	-1.7229	-0.0597	-0.5783	-0.8710
-0.6265	-0.9128	-1.8453	-0.0714	-0.6265	-0.9128
-0.6747	-0.9540	-1.9677	-0.0777	-0.6747	-0.9540
-0.7229	-0.9947	-2.0901	-0.0785	-0.7229	-0.9947
-0.7711	-1.0022	-2.1129	-0.0739	-0.7711	-1.0022
-0.8193	-1.0055	-2.1200	-0.0639	-0.8193	-1.0055
-0.8675	-1.0076	-2.1360	-0.0494	-0.8675	-1.0076
-0.9157	-1.0084	-2.1472	-0.0312	-0.9157	-1.0084
-0.9639	-1.0076	-2.1557	-0.0094	-0.9639	-1.0076
-1.0121	-1.0055	-2.1612	-0.0254	-1.0121	-1.0055
-1.0603	-1.0022	-2.1632	-0.0457	-1.0603	-1.0022
-1.1085	-1.0020	-2.1632	-0.0517	-1.1085	-1.0020
-1.1567	-0.9999	-2.1616	-0.0510	-1.1567	-0.9999
-1.2049	-0.9978	-2.1584	-0.0474	-1.2049	-0.9978
-1.2531	-0.9957	-2.1544	-0.0428	-1.2531	-0.9957
-1.3013	-0.9927	-2.1494	-0.0372	-1.3013	-0.9927
-1.3495	-0.9897	-2.1444	-0.0306	-1.3495	-0.9897
-1.3977	-0.9867	-2.1394	-0.0230	-1.3977	-0.9867
-1.4459	-0.9837	-2.1344	-0.0144	-1.4459	-0.9837
-1.4941	-0.9807	-2.1294	-0.0048	-1.4941	-0.9807
-1.5423	-0.9777	-2.1244	-0.0042	-1.5423	-0.9777
-1.5905	-0.9747	-2.1194	-0.0036	-1.5905	-0.9747
-1.6387	-0.9717	-2.1144	-0.0030	-1.6387	-0.9717
-1.6869	-0.9687	-2.1094	-0.0024	-1.6869	-0.9687
-1.7351	-0.9657	-2.1044	-0.0018	-1.7351	-0.9657
-1.7833	-0.9627	-2.0994	-0.0012	-1.7833	-0.9627
-1.8315	-0.9597	-2.0944	-0.0006	-1.8315	-0.9597
-1.8797	-0.9567	-2.0894	-0.0000	-1.8797	-0.9567
-1.9279	-0.9537	-2.0844	-0.0004	-1.9279	-0.9537
-1.9761	-0.9507	-2.0794	-0.0008	-1.9761	-0.9507
-2.0243	-0.9477	-2.0744	-0.0012	-2.0243	-0.9477
-2.0725	-0.9447	-2.0694	-0.0016	-2.0725	-0.9447
-2.1207	-0.9417	-2.0644	-0.0020	-2.1207	-0.9417
-2.1689	-0.9387	-2.0594	-0.0024	-2.1689	-0.9387
-2.2171	-0.9357	-2.0544	-0.0028	-2.2171	-0.9357
-2.2653	-0.9327	-2.0494	-0.0032	-2.2653	-0.9327
-2.3135	-0.9297	-2.0444	-0.0036	-2.3135	-0.9297
-2.3617	-0.9267	-2.0394	-0.0040	-2.3617	-0.9267
-2.4099	-0.9237	-2.0344	-0.0044	-2.4099	-0.9237
-2.4581	-0.9207	-2.0294	-0.0048	-2.4581	-0.9207
-2.5063	-0.9177	-2.0244	-0.0052	-2.5063	-0.9177
-2.5545	-0.9147	-2.0194	-0.0056	-2.5545	-0.9147
-2.6027	-0.9117	-2.0144	-0.0060	-2.6027	-0.9117
-2.6509	-0.9087	-2.0094	-0.0064	-2.6509	-0.9087
-2.6991	-0.9057	-2.0044	-0.0068	-2.6991	-0.9057
-2.7473	-0.9027	-2.0000	-0.0072	-2.7473	-0.9027
-2.7955	-0.8997	-1.9950	-0.0076	-2.7955	-0.8997
-2.8437	-0.8967	-1.9900	-0.0080	-2.8437	-0.8967
-2.8919	-0.8937	-1.9850	-0.0084	-2.8919	-0.8937
-2.9401	-0.8907	-1.9800	-0.0088	-2.9401	-0.8907
-2.9883	-0.8877	-1.9750	-0.0092	-2.9883	-0.8877
-3.0365	-0.8847	-1.9700	-0.0096	-3.0365	-0.8847
-3.0847	-0.8817	-1.9650	-0.0100	-3.0847	-0.8817
-3.1329	-0.8787	-1.9600	-0.0104	-3.1329	-0.8787
-3.1811	-0.8757	-1.9550	-0.0108	-3.1811	-0.8757
-3.2293	-0.8727	-1.9500	-0.0112	-3.2293	-0.8727
-3.2775	-0.8697	-1.9450	-0.0116	-3.2775	-0.8697
-3.3257	-0.8667	-1.9400	-0.0120	-3.3257	-0.8667
-3.3739	-0.8637	-1.9350	-0.0124	-3.3739	-0.8637
-3.4221	-0.8607	-1.9300	-0.0128	-3.4221	-0.8607
-3.4703	-0.8577	-1.9250	-0.0132	-3.4703	-0.8577
-3.5185	-0.8547	-1.9200	-0.0136	-3.5185	-0.8547
-3.5667	-0.8517	-1.9150	-0.0140	-3.5667	-0.8517
-3.6149	-0.8487	-1.9100	-0.0144	-3.6149	-0.8487
-3.6631	-0.8457	-1.9050	-0.0148	-3.6631	-0.8457
-3.7113	-0.8427	-1.9000	-0.0152	-3.7113	-0.8427
-3.7595	-0.8397	-1.8950	-0.0156	-3.7595	-0.8397
-3.8077	-0.8367	-1.8900	-0.0160	-3.8077	-0.8367
-3.8559	-0.8337	-1.8850	-0.0164	-3.8559	-0.8337
-3.9041	-0.8307	-1.8800	-0.0168	-3.9041	-0.8307
-3.9523	-0.8277	-1.8750	-0.0172	-3.9523	-0.8277
-4.0005	-0.8247	-1.8700	-0.0176	-4.0005	-0.8247
-4.0487	-0.8217	-1.8650	-0.0180	-4.0487	-0.8217
-4.0969	-0.8187	-1.8600	-0.0184	-4.0969	-0.8187
-4.1451	-0.8157	-1.8550	-0.0188	-4.1451	-0.8157
-4.1933	-0.8127	-1.8500	-0.0192	-4.1933	-0.8127
-4.2415	-0.8097	-1.8450	-0.0196	-4.2415	-0.8097
-4.2897	-0.8067	-1.8400	-0.0200	-4.2897	-0.8067
-4.3379	-0.8037	-1.8350	-0.0204	-4.3379	-0.8037
-4.3861	-0.8007	-1.8300	-0.0208	-4.3861	-0.8007
-4.4343	-0.7977	-1.8250	-0.0212	-4.4343	-0.7977
-4.4825	-0.7947	-1.8200	-0.0216	-4.4825	-0.7947
-4.5307	-0.7917	-1.8150	-0.0220	-4.5307	-0.7917
-4.5789	-0.7887	-1.8100	-0.0224	-4.5789	-0.7887
-4.6271	-0.7857	-1.8050	-0.0228	-4.6271	-0.7857
-4.6753	-0.7827	-1.8000	-0.0232	-4.6753	-0.7827
-4.7235	-0.7797	-1.7950	-0.0236	-4.7235	-0.7797
-4.7717	-0.7767	-1.7900	-0.0240	-4.7717	-0.7767
-4.8199	-0.7737	-1.7850	-0.0244	-4.8199	-0.7737
-4.8681	-0.7707	-1.7800	-0.0248	-4.8681	-0.7707
-4.9163	-0.7677	-1.7750	-0.0252	-4.9163	-0.7677
-4.9645	-0.7647	-1.7700	-0.0256	-4.9645	-0.7647
-5.0127	-0.7617	-1.7650	-0.0260	-5.0127	-0.7617
-5.0609	-0.7587	-1.7600	-0.0264	-5.0609	-0.7587
-5.1091	-0.7557	-1.7550	-0.0268	-5.1091	-0.7557
-5.1573	-0.7527	-1.7500	-0.0272	-5.1573	-0.7527
-5.2055	-0.7497	-1.7450	-0.0276	-5.2055	-0.7497
-5.2537	-0.7467	-1.7400	-0.0280	-5.2537	-0.7467
-5.3019	-0.7437	-1.7350	-0.0284	-5.3019	-0.7437
-5.3501	-0.7407	-1.7300	-0.0288	-5.3501	-0.7407
-5.3983	-0.7377	-1.7250	-0.0292	-5.3983	-0.7377
-5.4465	-0.7347	-1.7200	-0.0296	-5.4465	-0.7347
-5.4947	-0.7317	-1.7150	-0.0300	-5.4947	-0.7317
-5.5429	-0.7287	-1.7100	-0.0304	-5.5429	-0.7287
-5.5911	-0.7257	-1.7050	-0.0308	-5.5911	-0.7257
-5.6393	-0.7227	-1.7000	-0.0312	-5.6393	-0.7227
-5.6875	-0.7197	-1.6950	-0.0316	-5.6875	-0.7197
-5.7357	-0.7167	-1.6900	-0.0320	-5.7357	-0.7167
-5.7839	-0.7137	-1.6850	-0.0324	-5.7839	-0.7137
-5.8321	-0.7107	-1.6800	-0.0328	-5.8321	-0.7107
-5.8803	-0.7077	-1.6750	-0.0332	-5.8803	-0.7077
-5.9285	-0.7047	-1.6700	-0.0336	-5.9285	-0.7047
-5.9767	-0.7017	-1.6650	-0.0340	-5.9767	-0.7017
-6.0249	-0.6987	-1.6600	-0.0344	-6.0249	-0.6987
-6.0731	-0.6957	-1.6550	-0.0348	-6.0731	-0.6957
-6.1213	-0.6927	-1.6500	-0.0352	-6.1213	-0.6927
-6.1695	-0.6897	-1.6450	-0.0356	-6.1695	-0.6897
-6.2177	-0.6867	-1.6400	-0.0360	-6.2177	-0.6867
-6.2659	-0.6837	-1.6350	-0.0364	-6.2659	-0.6837
-6.3141	-0.6807	-1.6300	-0.0368	-6.3141	-0.6807
-6.3623	-0.6777	-1.6250	-0.0372	-6.3623	-0.6777
-6.4105	-0.6747	-1.6200	-0.0376	-6.4105	-0.6747
-6.4587	-0.6717	-1.6150	-0.0380	-6.4587	-0.6717
-6.5069	-0.6687	-1.6100	-0.0384	-6.5069	-0.6687
-6.5551	-0.6657	-1.6050	-0.0388	-6.5551	-0.6657
-6.6033	-0.6627	-1.6000	-0.0392	-6.6033	-0.6627
-6.6515	-0.6597	-1.5950	-0.0396	-6.6515	-0.6597
-6.6997	-0.6567	-1.5900	-0.0400	-6.6997	-0.6567
-6.7479	-0.6537	-1.5850	-0.0404	-6.7479	-0.6537
-6.7961	-0.6507	-1.5800	-0.0408	-6.7961	-0.6507
-6.8443	-0.6477	-1.5750	-0.0412	-6.8443	-0.6477
-6.8925	-0.6447	-1.5700	-0.0416	-6.8925	-0.6447
-6.9407	-0.6417	-1.5650	-0.0420	-6.9407</	

TABLE A-3.--Continued

SECTION NO. 10 ROTOR AIRFOIL COORDINATES (20.384 CH.)							
SUCTION SURFACE		Y.C.M.		PRESSURE SURFACE		Y.C.M.	
X.IN.	Y.IN.	X.C.M.	Y.C.M.	X.IN.	Y.IN.	X.C.M.	Y.C.M.
-0.027	-1.1152	-2.4962	-2.0327	-0.027	-1.1152	-2.4962	-2.0327
-0.022	-1.1110	-2.4949	-2.0320	-0.027	-1.1152	-2.4962	-2.0327
-0.005	-1.1059	-2.4905	-2.0301	-0.020	-1.1192	-2.4943	-2.0316
-0.077	-1.1000	-2.4835	-2.0260	-0.001	-1.1217	-2.4895	-2.0299
-0.083	-1.0961	-2.4854	-2.0254	-0.072	-1.1227	-2.4821	-2.0310
-0.219	-1.0130	-2.3417	-2.0751	-0.735	-1.1221	-2.4727	-2.0302
-0.756	-0.9424	-2.2240	-2.3938	-0.904	-1.1201	-2.4622	-2.0481
-0.842	-0.8710	-2.1063	-2.5213	-0.995	-1.1102	-2.4371	-2.0199
-0.729	-0.8018	-1.9883	-2.6367	-0.958	-1.0981	-2.4130	-2.0709
-0.736	-0.7326	-1.8708	-2.7365	-0.910	-1.0859	-2.3886	-2.0312
-0.639	-0.6639	-1.7531	-2.8402	-0.850	-1.0749	-2.3641	-2.0461
-0.538	-0.5956	-1.6354	-2.9434	-0.838	-1.0550	-2.3396	-2.0320
-0.5975	-0.5289	-1.5177	-3.0435	-0.790	-1.0361	-2.3152	-2.0719
-0.5512	-0.4633	-1.3999	-3.1438	-0.700	-1.0170	-2.2907	-2.0274
-0.5048	-0.3988	-1.2822	-3.2441	-0.640	-0.9982	-2.2662	-1.9827
-0.4585	-0.3356	-1.1645	-3.3444	-0.600	-0.9791	-2.2417	-1.9403
-0.421	-0.2737	-1.0468	-3.4447	-0.580	-0.9599	-2.2173	-1.8996
-0.3658	-0.2130	-0.9291	-3.5450	-0.5092	-0.9393	-2.1928	-1.8613
-0.3194	-0.1536	-0.8113	-3.6453	-0.460	-0.9185	-2.1683	-1.8240
-0.2731	-0.0953	-0.6936	-3.7456	-0.410	-0.8976	-2.1438	-1.7867
-0.2267	-0.0382	-0.5759	-3.8459	-0.360	-0.8767	-2.1193	-1.7494
-0.1804	0.0110	-0.4582	-3.9462	-0.310	-0.8558	-2.0948	-1.7121
-0.1340	0.0591	-0.3404	-4.0465	-0.260	-0.8349	-2.0703	-1.6748
-0.0877	0.1054	-0.2227	-4.1468	-0.210	-0.8140	-2.0458	-1.6375
-0.0413	0.1514	-0.1050	-4.2471	-0.160	-0.7931	-2.0213	-1.5999
-0.0050	0.1962	0.0127	-4.3474	-0.110	-0.7722	-1.9968	-1.5626
0.0313	0.2402	0.1300	-4.4477	-0.060	-0.7513	-1.9723	-1.5253
0.0777	0.2834	0.2482	-4.5480	0.010	-0.7304	-1.9478	-1.4880
0.1241	0.3258	0.3659	-4.6483	0.060	-0.7095	-1.9233	-1.4507
0.1704	0.3674	0.4836	-4.7486	0.110	-0.6886	-1.8988	-1.4134
0.2167	0.4082	0.6013	-4.8489	0.160	-0.6677	-1.8743	-1.3761
0.2631	0.4483	0.7190	-4.9492	0.210	-0.6468	-1.8498	-1.3388
0.3094	0.4874	0.8368	-5.0495	0.260	-0.6259	-1.8253	-1.3015
0.3558	0.5261	0.9545	-5.1498	0.310	-0.6050	-1.8008	-1.2642
0.4021	0.5640	1.0722	-5.2501	0.360	-0.5841	-1.7763	-1.2269
0.4485	0.6011	1.1899	-5.3504	0.410	-0.5632	-1.7518	-1.1896
0.4948	0.6375	1.3077	-5.4507	0.460	-0.5423	-1.7273	-1.1523
0.5412	0.6732	1.4254	-5.5510	0.510	-0.5214	-1.7028	-1.1150
0.5875	0.7083	1.5431	-5.6513	0.560	-0.5005	-1.6783	-1.0777
0.6339	0.7427	1.6608	-5.7516	0.610	-0.4796	-1.6538	-1.0404
0.6802	0.7764	1.7785	-5.8519	0.660	-0.4587	-1.6293	-1.0031
0.7266	0.8095	1.8963	-5.9522	0.710	-0.4378	-1.6048	-0.9658
0.7730	0.8419	2.0140	-6.0525	0.760	-0.4169	-1.5803	-0.9285
0.8194	0.8736	2.1317	-6.1528	0.810	-0.3960	-1.5558	-0.8912
0.8658	0.9046	2.2494	-6.2531	0.860	-0.3751	-1.5313	-0.8539
0.9121	0.9347	2.3671	-6.3534	0.910	-0.3542	-1.5068	-0.8166
0.9585	0.9637	2.4848	-6.4537	0.960	-0.3333	-1.4823	-0.7793
1.0048	0.9917	2.6025	-6.5540	1.010	-0.3124	-1.4578	-0.7420
1.0512	1.0187	2.7202	-6.6543	1.060	-0.2915	-1.4333	-0.7047
1.0975	1.0447	2.8379	-6.7546	1.110	-0.2706	-1.4088	-0.6674
1.1439	1.0697	2.9556	-6.8549	1.160	-0.2497	-1.3843	-0.6301
1.1902	1.0937	3.0733	-6.9552	1.210	-0.2288	-1.3598	-0.5928
1.2365	1.1167	3.1910	-7.0555	1.260	-0.2079	-1.3353	-0.5555
1.2829	1.1387	3.3087	-7.1558	1.310	-0.1870	-1.3108	-0.5182
1.3292	1.1597	3.4264	-7.2561	1.360	-0.1661	-1.2863	-0.4809
1.3755	1.1797	3.5441	-7.3564	1.410	-0.1452	-1.2618	-0.4436
1.4218	1.1987	3.6618	-7.4567	1.460	-0.1243	-1.2373	-0.4063
1.4681	1.2167	3.7795	-7.5570	1.510	-0.1034	-1.2128	-0.3690
1.5144	1.2337	3.8972	-7.6573	1.560	-0.0825	-1.1883	-0.3317
1.5607	1.2497	4.0149	-7.7576	1.610	-0.0616	-1.1638	-0.2944
1.6070	1.2647	4.1326	-7.8579	1.660	-0.0407	-1.1393	-0.2571
1.6533	1.2787	4.2503	-7.9582	1.710	-0.0198	-1.1148	-0.2198
1.6996	1.2917	4.3680	-8.0585	1.760	0.0011	-1.0903	-0.1825
1.7459	1.3037	4.4857	-8.1588	1.810	0.0220	-1.0658	-0.1452
1.7922	1.3147	4.6034	-8.2591	1.860	0.0429	-1.0413	-0.1079
1.8385	1.3247	4.7211	-8.3594	1.910	0.0638	-1.0168	-0.0706
1.8848	1.3337	4.8388	-8.4597	1.960	0.0847	-0.9923	-0.0333
1.9311	1.3417	4.9565	-8.5599	2.010	0.1056	-0.9678	0.0040
1.9774	1.3487	5.0742	-8.6602	2.060	0.1265	-0.9433	0.0207
2.0237	1.3547	5.1919	-8.7605	2.110	0.1474	-0.9188	0.0374
2.0699	1.3597	5.3096	-8.8608	2.160	0.1683	-0.8943	0.0541
2.1162	1.3637	5.4273	-8.9611	2.210	0.1892	-0.8698	0.0708
2.1625	1.3667	5.5450	-9.0614	2.260	0.2101	-0.8453	0.0875
2.2088	1.3687	5.6627	-9.1617	2.310	0.2310	-0.8208	0.1042
2.2551	1.3697	5.7804	-9.2620	2.360	0.2519	-0.7963	0.1209
2.3014	1.3697	5.8981	-9.3623	2.410	0.2728	-0.7718	0.1376
2.3477	1.3687	6.0158	-9.4626	2.460	0.2937	-0.7473	0.1543
2.3940	1.3667	6.1335	-9.5629	2.510	0.3146	-0.7228	0.1710
2.4403	1.3637	6.2512	-9.6632	2.560	0.3355	-0.6983	0.1877
2.4866	1.3597	6.3689	-9.7635	2.610	0.3564	-0.6738	0.2044
2.5329	1.3547	6.4866	-9.8638	2.660	0.3773	-0.6493	0.2211
2.5792	1.3487	6.6043	-9.9641	2.710	0.3982	-0.6248	0.2378
2.6255	1.3417	6.7220	-10.0644	2.760	0.4191	-0.6003	0.2545
2.6718	1.3337	6.8397	-10.1647	2.810	0.4400	-0.5758	0.2712
2.7181	1.3247	6.9574	-10.2650	2.860	0.4609	-0.5513	0.2879
2.7644	1.3147	7.0751	-10.3653	2.910	0.4818	-0.5268	0.3046
2.8107	1.3037	7.1928	-10.4656	2.960	0.5027	-0.5023	0.3213
2.8570	1.2917	7.3105	-10.5659	3.010	0.5236	-0.4778	0.3380
2.9033	1.2787	7.4282	-10.6662	3.060	0.5445	-0.4533	0.3547
2.9496	1.2647	7.5459	-10.7665	3.110	0.5654	-0.4288	0.3714
3.0000	1.2497	7.6636	-10.8668	3.160	0.5863	-0.4043	0.3881
3.0503	1.2337	7.7813	-10.9671	3.210	0.6072	-0.3798	0.4048
3.1006	1.2167	7.8990	-11.0674	3.260	0.6281	-0.3553	0.4215
3.1509	1.1987	8.0167	-11.1677	3.310	0.6490	-0.3308	0.4382
3.2012	1.1797	8.1344	-11.2680	3.360	0.6700	-0.3063	0.4549
3.2515	1.1597	8.2521	-11.3683	3.410	0.6909	-0.2818	0.4716
3.3018	1.1387	8.3698	-11.4686	3.460	0.7118	-0.2573	0.4883
3.3521	1.1167	8.4875	-11.5689	3.510	0.7327	-0.2328	0.5050
3.4024	1.0937	8.6052	-11.6692	3.560	0.7536	-0.2083	0.5217
3.4527	1.0697	8.7229	-11.7695	3.610	0.7745	-0.1838	0.5384
3.5030	1.0447	8.8406	-11.8698	3.660	0.7954	-0.1593	0.5551
3.5533	1.0187	8.9583	-11.9701	3.710	0.8163	-0.1348	0.5718
3.6036	0.9917	9.0760	-12.0704	3.760	0.8372	-0.1103	0.5885
3.6539	0.9637	9.1937	-12.1707	3.810	0.8581	-0.0858	0.6052
3.7042	0.9347	9.3114	-12.2710	3.860	0.8790	-0.0613	0.6219
3.7545	0.9047	9.4291	-12.3713	3.910	0.9000	-0.0368	0.6386
3.8048	0.8736	9.5468	-12.4716	3.960	0.9209	-0.0123	0.6553
3.8551	0.8416	9.6645	-12.5719	4.010	0.9418	0.0122	0.6720
3.9054	0.8086	9.7822	-12.6722	4.060	0.9627	0.0367	0.6887
3.9557	0.7746	9.8999	-12.7725	4.110	0.9836	0.0612	0.7054
4.0060	0.7396	10.0176	-12.8728	4.160	1.0045	0.0857	0.7221
4.0563	0.7036	10.1353	-12.9731	4.210	1.0254	0.1102	0.7388
4.1066	0.6666	10.2530	-13.0734	4.260	1.0463	0.1347	0.7555
4.1569	0.6286	10.3707	-13.1737	4.310	1.0672	0.1592	0.7722
4.2072	0.5896	10.4884	-13.2740	4.360	1.0881	0.1837	0.7889
4.2575	0.5496	10.6061	-13.3743	4.410	1.1090	0.2082	0.8056
4.3078	0.5086	10.7238	-13.4746	4.460	1.1299	0.2327	0.8223
4.3581	0.4666	10.8415	-13.5749	4.510	1.1508	0.2572	0.8390
4.4084	0.4236	10.9592	-13.6752	4.560	1.1717	0.2817	0.8557
4.4587	0.3796	11.0769	-13.7755	4.610	1.1926	0.3062	0.8724
4.5090	0.3346	11.1946	-13.8758	4.660	1.2135	0.3307	0.8891
4.5593	0.2886	11.3123	-13.9761	4.710	1.2344	0.3552	0.9058
4.6096	0.2416	11.4300	-14.0764	4.760	1.2553	0.3797	0.9225
4.6599	0.1936	11.5477	-14.1767	4.810	1.2762	0.4042	0.9392
4.7102	0.1446	11.6654	-14.2770	4.860	1.2971	0.4287	0.9559
4.7605	0.0946	11.7831	-14.3773	4.910	1.3180	0.4532	0.9726
4.8108	0.0436	11.9008	-14.4776	4.960	1.3389	0.4777	0.9893
4.8611	-0.0084	12.0185	-14.5779	5.010	1.3598	0.5022	1.0060
4.9114	-0.0594	12.1362	-14.6782	5.060	1.3807	0.5267	1.0227
4.9617	-0.1094	12.2539	-14.7785	5.110	1.4016	0.5512	1.0394

TABLE A-3.--Continued

SECTION NO. 11 ROTOM AIRFOIL COORDINATES RADIUS 8.900 IN. (22.866 CM.)									
SUCTION SURFACE			PRESSURE SURFACE						
X IN.	Y IN.	X CM.	Y CM.	X IN.	Y IN.	A CL.	A CL.	Y CM.	
-.9976	-.9789	-2.5340	-2.4863	-.9976	-.9784	-2.5340		-2.4863	
-.9976	-.9787	-2.5340	-2.4859	-.9970	-.9780	-2.5340		-2.4859	
-.9969	-.9737	-2.5320	-2.4731	-.9950	-.9755	-2.5272		-2.4731	
-.9948	-.9681	-2.5267	-2.4590	-.9918	-.9708	-2.5191		-2.4590	
-.9915	-.9625	-2.5184	-2.4448	-.9877	-.9663	-2.5087		-2.4448	
-.9840	-.8943	-2.3979	-2.2716	-.9830	-.9643	-2.4968		-2.4968	
-.8966	-.8273	-2.2773	-2.1014	-.9715	-.9739	-2.4677		-2.4730	
-.8491	-.7416	-2.1568	-1.9344	-.9624	-.9635	-2.4451		-2.4474	
-.8017	-.6969	-2.0362	-1.7702	-.9133	-.9069	-2.3197		-2.3036	
-.7582	-.6334	-1.9157	-1.6087	-.8645	-.8525	-2.1959		-2.1853	
-.7068	-.5707	-1.7952	-1.4895	-.8158	-.7993	-2.0721		-2.0303	
-.6593	-.5092	-1.6746	-1.3741	-.7671	-.7475	-1.9484		-1.8987	
-.6118	-.4493	-1.5581	-1.2581	-.7183	-.6969	-1.8248		-1.7701	
-.5684	-.3909	-1.4336	-.9928	-.6696	-.6474	-1.7008		-1.6445	
-.5169	-.3339	-1.3130	-.8882	-.6209	-.5991	-1.5771		-1.5216	
-.4695	-.2786	-1.1925	-.7876	-.5722	-.5517	-1.4533		-1.4014	
-.4220	-.2246	-1.0719	-.6705	-.5234	-.5054	-1.3295		-1.2836	
-.3746	-.1728	-.9514	-.5370	-.4787	-.4599	-1.2058		-1.1681	
-.3271	-.1209	-.8309	-.4071	-.4260	-.4153	-1.0820		-1.0548	
-.2797	-.0725	-.7103	-.2773	-.3714	-.3517	-.9582		-.9334	
-.2322	-.0269	-.5898	-.1481	-.3205	-.3082	-.8344		-.8130	
-.1847	.0163	-.4692	-.0413	-.2798	-.2658	-.7107		-.7258	
-.1373	.0580	-.3487	.1474	-.2311	-.2438	-.5864		-.5193	
-.0898	.0987	-.2282	.2508	-.1823	-.2044	-.4631		-.3142	
-.0424	.1384	-.1076	.3516	-.1334	-.1615	-.3394		-.2102	
.0051	.1772	.0129	.4500	-.0849	-.1210	-.2158		-.1072	
.0525	.2149	.1335	.5459	-.0362	-.0807	-.0916		-.2051	
.1000	.2517	.2540	.6393	.0126	-.0408	.0319		-.1036	
.1475	.2876	.3745	.7305	.0613	-.0010	.1557		-.0027	
.1949	.3226	.4951	.8193	.1100	.0386	.2795		.0980	
.2424	.3567	.6156	.9059	.1587	.0781	.4032		.1985	
.2898	.3899	.7361	.9903	.2075	.1177	.5270		.2990	
.3373	.4223	.8567	1.0726	.2562	.1574	.6501		.3997	
.3847	.4538	.9772	1.1527	.3047	.1972	.7745		.5009	
.4322	.4846	1.0978	1.2308	.3537	.2374	.8983		.6031	
.4796	.5145	1.2183	1.3069	.4024	.2781	1.0221		.7065	
.5271	.5437	1.3389	1.3810	.4511	.3193	1.1458		.8110	
.5746	.5721	1.4594	1.4532	.4998	.3610	1.2698		.9149	
.6220	.5998	1.5799	1.5235	.5486	.4031	1.3934		1.0240	
.6695	.6266	1.7005	1.5917	.5973	.4459	1.5171		1.1325	
.7169	.6526	1.8210	1.6577	.6460	.4891	1.6409		1.2423	
.7644	.6779	1.9416	1.7218	.6948	.5328	1.7647		1.3534	
.8119	.7287	2.0619	1.8509	.7435	.5770	1.8885		1.4657	
.8594	.7541	2.2253	1.9647	.7922	.6217	2.0122		1.5791	
.9069	.7797	2.3417	2.0712	.8409	.6669	2.1360		1.6938	
.9544	.8054	2.4570	2.1741	.8897	.7125	2.2598		1.8098	
.9976	.8311	2.5723	2.2799	.9384	.7584	2.3836		1.9246	
.9976	.8568	2.6876	2.3846	.9868	.8041	2.5074		2.0394	
.9976	.8825	2.8029	2.4893	.9999	.8498	2.6312		2.1542	
.9976	.9082	2.9182	2.5940	.9999	.8955	2.7550		2.2690	
.9976	.9339	3.0335	2.6987	.9999	.9412	2.8788		2.3838	
.9976	.9596	3.1488	2.8034	.9999	.9869	3.0026		2.4986	
.9976	.9853	3.2641	2.9081	.9999	.9999	3.1264		2.6134	
.9976	.9976	3.3794	3.0128	.9999	.9999	3.2502		2.7282	
.9976	.9976	3.4947	3.1175	.9999	.9999	3.3740		2.8430	
.9976	.9976	3.6099	3.2222	.9999	.9999	3.4978		2.9578	
.9976	.9976	3.7252	3.3269	.9999	.9999	3.6216		3.0726	
.9976	.9976	3.8405	3.4316	.9999	.9999	3.7454		3.1874	
.9976	.9976	3.9558	3.5363	.9999	.9999	3.8692		3.3022	
.9976	.9976	4.0711	3.6410	.9999	.9999	3.9930		3.4170	
.9976	.9976	4.1864	3.7457	.9999	.9999	4.1168		3.5318	
.9976	.9976	4.3017	3.8504	.9999	.9999	4.2406		3.6466	
.9976	.9976	4.4170	3.9551	.9999	.9999	4.3644		3.7614	
.9976	.9976	4.5323	4.0598	.9999	.9999	4.4882		3.8762	
.9976	.9976	4.6476	4.1645	.9999	.9999	4.6120		3.9910	
.9976	.9976	4.7629	4.2692	.9999	.9999	4.7358		4.1058	
.9976	.9976	4.8782	4.3739	.9999	.9999	4.8596		4.2206	
.9976	.9976	4.9935	4.4786	.9999	.9999	4.9834		4.3354	
.9976	.9976	5.1088	4.5833	.9999	.9999	5.1072		4.4502	
.9976	.9976	5.2241	4.6880	.9999	.9999	5.2310		4.5650	
.9976	.9976	5.3394	4.7927	.9999	.9999	5.3548		4.6798	
.9976	.9976	5.4547	4.8974	.9999	.9999	5.4786		4.7946	
.9976	.9976	5.5700	4.9999	.9999	.9999	5.6024		4.9094	
.9976	.9976	5.6853	5.1046	.9999	.9999	5.7262		5.0242	
.9976	.9976	5.8006	5.2093	.9999	.9999	5.8500		5.1390	
.9976	.9976	5.9159	5.3140	.9999	.9999	5.9738		5.2538	
.9976	.9976	6.0312	5.4187	.9999	.9999	6.0976		5.3686	
.9976	.9976	6.1465	5.5234	.9999	.9999	6.2214		5.4834	
.9976	.9976	6.2618	5.6281	.9999	.9999	6.3452		5.5982	
.9976	.9976	6.3771	5.7328	.9999	.9999	6.4690		5.7130	
.9976	.9976	6.4924	5.8375	.9999	.9999	6.5928		5.8278	
.9976	.9976	6.6077	5.9422	.9999	.9999	6.7166		5.9426	
.9976	.9976	6.7230	6.0469	.9999	.9999	6.8404		6.0574	
.9976	.9976	6.8383	6.1516	.9999	.9999	6.9642		6.1722	
.9976	.9976	6.9536	6.2563	.9999	.9999	7.0880		6.2870	
.9976	.9976	7.0689	6.3610	.9999	.9999	7.2118		6.4018	
.9976	.9976	7.1842	6.4657	.9999	.9999	7.3356		6.5166	
.9976	.9976	7.2995	6.5704	.9999	.9999	7.4594		6.6314	
.9976	.9976	7.4148	6.6751	.9999	.9999	7.5832		6.7462	
.9976	.9976	7.5301	6.7798	.9999	.9999	7.7070		6.8610	
.9976	.9976	7.6454	6.8845	.9999	.9999	7.8308		6.9758	
.9976	.9976	7.7607	6.9892	.9999	.9999	7.9546		7.0906	
.9976	.9976	7.8760	7.0939	.9999	.9999	8.0784		7.2054	
.9976	.9976	7.9913	7.1986	.9999	.9999	8.2022		7.3202	
.9976	.9976	8.1066	7.3033	.9999	.9999	8.3260		7.4350	
.9976	.9976	8.2219	7.4080	.9999	.9999	8.4498		7.5498	
.9976	.9976	8.3372	7.5127	.9999	.9999	8.5736		7.6646	
.9976	.9976	8.4525	7.6174	.9999	.9999	8.6974		7.7794	
.9976	.9976	8.5678	7.7221	.9999	.9999	8.8212		7.8942	
.9976	.9976	8.6831	7.8268	.9999	.9999	8.9450		8.0090	
.9976	.9976	8.7984	7.9315	.9999	.9999	9.0688			
.9976	.9976	8.9137	8.0362	.9999	.9999	9.1926			
.9976	.9976	9.0290	8.1409	.9999	.9999	9.3164			
.9976	.9976	9.1443	8.2456	.9999	.9999	9.4402			
.9976	.9976	9.2596	8.3503	.9999	.9999	9.5640			
.9976	.9976	9.3749	8.4550	.9999	.9999	9.6878			
.9976	.9976	9.4902	8.5597	.9999	.9999	9.8116			
.9976	.9976	9.6055	8.6644	.9999	.9999	9.9354			
.9976	.9976	9.7208	8.7691	.9999	.9999	10.0592			
.9976	.9976	9.8361	8.8738	.9999	.9999	10.1830			
.9976	.9976	9.9514	8.9785	.9999	.9999	10.3068			
.9976	.9976	10.0667	9.0832	.9999	.9999	10.4306			
.9976	.9976	10.1820	9.1879	.9999	.9999	10.5544			
.9976	.9976	10.2973	9.2926	.9999	.9999	10.6782			
.9976	.9976	10.4126	9.3973	.9999	.9999	10.8020			
.9976	.9976	10.5279	9.5020	.9999	.9999	10.9258			
.9976	.9976	10.6432	9.6067	.9999	.9999	11.0496			
.9976	.9976	10.7585	9.7114	.9999	.9999	11.1734			
.9976	.9976	10.8738	9.8161	.9999	.9999	11.2972			
.9976	.9976	10.9891	9.9208	.9999	.9999	11.4210			
.9976	.9976	11.1044	10.0255	.9999	.9999	11.5448			
.9976	.9976	11.2197	10.1302	.9999	.9999	11.6686			
.9976	.9976	11.3350	10.2349	.9999	.9999	11.7924			
.9976	.9976	11.4503	10.3396	.9999	.9999	11.9162			
.9976	.9976	11.5656	10.4443	.9999	.9999	12.0400			
.9976	.9976	11.6809	10.5490	.9999	.9999	12.1638			
.9976	.9976	11.7962	10.6537	.9999	.9999	12.2876			
.9976	.9976	11.9115	10.7584	.9999	.9999	12.4114			
.9976	.9976	12.0268	10.8631	.9999	.9999	12.5352			
.9976	.9976	12.1421	10.9678	.9999	.9999	12.6590			
.9976	.9976	12.2574	11.0725	.9999	.9999	12.7828</			

TABLE A-3.--Continued

SECTION NO. 12 RADIUS R=200 IN. (20,828 CM.)						
SUCTION SURFACE		Y-CH.		Y-CM.		X-IN.
Y-IN.		Y-CH.		Y-CM.		
PRESSURE SURFACE						
Y-IN.						
-1.0131	-.0559	-2.5732	-2.1731	-1.0131	-.0559	-2.5732
-1.0131	-.0549	-2.5732	-2.1716	-1.0125	-.0594	-2.5717
-1.0121	-.0645	-2.5707	-2.1577	-1.0104	-.0605	-2.5663
-1.0099	-.0635	-2.5684	-2.1425	-1.0069	-.0600	-2.5579
-1.0059	-.0375	-2.5549	-2.1272	-1.0024	-.0637	-2.5481
-.9573	-.7720	-2.4316	-1.9808	-.9972	-.0616	-2.5340
-.9068	-.7084	-2.3083	-1.7994	-.9842	-.0508	-2.4999
-.8602	-.6469	-2.1849	-1.6431	-.9756	-.08417	-2.4781
-.8116	-.5872	-2.0616	-1.4915	-.9661	-.07899	-2.4524
-.7631	-.5292	-1.9383	-1.3442	-.9562	-.7391	-1.0172
-.7145	-.4729	-1.8149	-1.2012	-.9463	-.0899	-2.0168
-.6660	-.4183	-1.6916	-1.0625	-.9364	-.08720	-1.6213
-.6174	-.3654	-1.5683	-.9281	-.9264	-.05960	-1.6452
-.5689	-.3142	-1.4450	-.7980	-.9165	-.5512	-1.4001
-.5203	-.2645	-1.3216	-.6718	-.9066	-.5077	-1.2596
-.4718	-.2163	-1.1983	-.5493	-.8967	-.0655	-1.1023
-.4232	-.1694	-1.0750	-.4303	-.8868	-.4244	-1.0781
-.3747	-.1241	-.9516	-.3151	-.8768	-.3645	-.9740
-.3261	-.0806	-.8283	-.2051	-.8669	-.3456	-.0174
-.2775	-.0396	-.7050	-.1007	-.8570	-.3076	-.7617
-.2290	-.0006	-.5816	-.0017	-.8471	-.2706	-.0874
-.1804	-.0367	-.4583	-.0932	-.8372	-.2348	-.5963
-.1319	-.0727	-.3350	-.1846	-.8272	-.1995	-.5060
-.0833	-.1073	-.2117	-.2726	-.8173	-.1650	-.4503
-.0348	-.1407	-.0883	-.3574	-.8075	-.1312	-.3235
-.023	-.1726	-.0350	-.4390	-.7975	-.0979	-.2487
-.1109	-.2037	-.0183	-.5175	-.7875	-.0652	-.1656
-.1595	-.2335	-.0507	-.5930	-.7772	-.0330	-.0837
-.2080	-.2620	-.0850	-.6655	-.7672	-.0011	-.0024
-.2560	-.2895	-.117	-.7352	-.7572	-.0304	-.0771
-.3051	-.3159	-.1486	-.8067	-.7472	-.0416	-.1565
-.3537	-.3412	-.1750	-.8667	-.7372	-.0927	-.2554
-.4022	-.3655	-.2017	-.9283	-.7272	-.1237	-.3142
-.4508	-.3887	-.2283	-.9873	-.7172	-.1548	-.3933
-.4993	-.4109	-.2550	1.0437	-.7072	-.1862	-.4730
-.5479	-.4320	-.2813	1.0974	-.6972	-.2176	-.5534
-.5964	-.4522	-.3079	1.1486	-.6872	-.2490	-.6321
-.6450	-.4714	-.3346	1.1973	-.6772	-.2817	-.7155
-.6936	-.4896	-.3613	1.2435	-.6672	-.3139	-.7974
-.7421	-.5068	-.3880	1.2872	-.6572	-.3464	-.8799
-.7907	-.5231	-.4146	1.3286	-.6472	-.3791	-.9626
-.8392	-.5384	-.4413	1.3675	-.6372	-.4119	1.0453
-.8878	-.5509	-.4680	1.4050	-.6272	-.4450	1.1303
-.9364	-.5720	-.4947	1.4429	-.6172	-.4782	1.2147
-.9850	-.5933	-.5214	1.4803	-.6072	-.5117	1.2996
1.0336	-.6146	-.5481	1.5177	-.5972	-.5453	1.3850
1.0822	-.6359	-.5748	1.5550	-.5872	-.5784	1.4701
1.1308	-.6572	-.6015	1.5924	-.5772	-.6115	1.5554
1.1794	-.6785	-.6282	1.6298	-.5672	-.6446	1.6411
1.2280	-.6998	-.6549	1.6672	-.5572	-.6777	1.7264
1.2766	-.7211	-.6816	1.7046	-.5472	-.7108	1.8111
1.3252	-.7424	-.7083	1.7420	-.5372	-.7439	1.8958
1.3738	-.7637	-.7350	1.7794	-.5272	-.7770	1.9805
1.4224	-.7850	-.7617	1.8168	-.5172	-.8101	2.0652
1.4710	-.8063	-.7884	1.8542	-.5072	-.8432	2.1499
1.5196	-.8276	-.8151	1.8916	-.4972	-.8763	2.2346
1.5682	-.8489	-.8418	1.9290	-.4872	-.9094	2.3193
1.6168	-.8702	-.8685	1.9664	-.4772	-.9425	2.4040
1.6654	-.8915	-.8952	2.0038	-.4672	-.9756	2.4887
1.7140	-.9128	-.9219	2.0412	-.4572	-.1.0087	2.5734
1.7626	-.9341	-.9486	2.0786	-.4472	-.1.0418	2.6581
1.8112	-.9554	-.9753	2.1160	-.4372	-.1.0749	2.7428
1.8598	-.9767	-.1.0020	2.1534	-.4272	-.1.1080	2.8275
1.9084	-.9980	-.1.0287	2.1908	-.4172	-.1.1411	2.9122
1.9570	-.1.0193	-.1.0554	2.2282	-.4072	-.1.1742	2.9969
2.0056	-.1.0406	-.1.0821	2.2656	-.3972	-.1.2073	3.0816
2.0542	-.1.0619	-.1.1088	2.3030	-.3872	-.1.2404	3.1663
2.1028	-.1.0832	-.1.1355	2.3404	-.3772	-.1.2735	3.2510
2.1514	-.1.1045	-.1.1622	2.3778	-.3672	-.1.3066	3.3357
2.2000	-.1.1258	-.1.1889	2.4152	-.3572	-.1.3397	3.4204
2.2486	-.1.1471	-.1.2156	2.4526	-.3472	-.1.3728	3.5051
2.2972	-.1.1684	-.1.2423	2.4900	-.3372	-.1.4059	3.5898
2.3458	-.1.1897	-.1.2690	2.5274	-.3272	-.1.4390	3.6745
2.3944	-.1.2110	-.1.2957	2.5648	-.3172	-.1.4721	3.7592
2.4430	-.1.2323	-.1.3224	2.6022	-.3072	-.1.5052	3.8439
2.4916	-.1.2536	-.1.3491	2.6396	-.2972	-.1.5383	3.9286
2.5402	-.1.2749	-.1.3758	2.6770	-.2872	-.1.5714	4.0133
2.5888	-.1.2962	-.1.4025	2.7144	-.2772	-.1.6045	4.0980
2.6374	-.1.3175	-.1.4292	2.7518	-.2672	-.1.6376	4.1827
2.6860	-.1.3388	-.1.4559	2.7892	-.2572	-.1.6707	4.2674
2.7346	-.1.3601	-.1.4826	2.8266	-.2472	-.1.7038	4.3521
2.7832	-.1.3814	-.1.5093	2.8640	-.2372	-.1.7369	4.4368
2.8318	-.1.4027	-.1.5360	2.9014	-.2272	-.1.7700	4.5215
2.8804	-.1.4240	-.1.5627	2.9388	-.2172	-.1.8031	4.6062
2.9290	-.1.4453	-.1.5894	2.9762	-.2072	-.1.8362	4.6909
2.9776	-.1.4666	-.1.6161	3.0136	-.1972	-.1.8693	4.7756
3.0262	-.1.4879	-.1.6428	3.0510	-.1872	-.1.9024	4.8603
3.0748	-.1.5092	-.1.6695	3.0884	-.1772	-.1.9355	4.9450
3.1234	-.1.5305	-.1.6962	3.1258	-.1672	-.1.9686	5.0297
3.1720	-.1.5518	-.1.7229	3.1632	-.1572	-.2.0017	5.1144
3.2206	-.1.5731	-.1.7496	3.2006	-.1472	-.2.0348	5.1991
3.2692	-.1.5944	-.1.7763	3.2380	-.1372	-.2.0679	5.2838
3.3178	-.1.6157	-.1.8030	3.2754	-.1272	-.2.1010	5.3685
3.3664	-.1.6370	-.1.8297	3.3128	-.1172	-.2.1341	5.4532
3.4150	-.1.6583	-.1.8564	3.3502	-.1072	-.2.1672	5.5379
3.4636	-.1.6796	-.1.8831	3.3876	-.0972	-.2.2003	5.6226
3.5122	-.1.7009	-.1.9098	3.4250	-.0872	-.2.2334	5.7073
3.5608	-.1.7222	-.1.9365	3.4624	-.0772	-.2.2665	5.7920
3.6094	-.1.7435	-.1.9632	3.4998	-.0672	-.2.2996	5.8767
3.6580	-.1.7648	-.1.9899	3.5372	-.0572	-.2.3327	5.9614
3.7066	-.1.7861	-.1.0166	3.5746	-.0472	-.2.3658	6.0461
3.7552	-.1.8074	-.1.0433	3.6120	-.0372	-.2.3989	6.1308
3.8038	-.1.8287	-.1.0700	3.6494	-.0272	-.2.4320	6.2155
3.8524	-.1.8500	-.1.0967	3.6868	-.0172	-.2.4651	6.2999
3.9010	-.1.8713	-.1.1234	3.7242	-.0072	-.2.4982	6.3846
3.9496	-.1.8926	-.1.1501	3.7616	-.0000	-.2.5313	6.4693
4.0000	-.1.9139	-.1.1768	3.7990	-.0000	-.2.5644	6.5540
4.0504	-.1.9352	-.1.2035	3.8364	-.0000	-.2.5975	6.6387
4.1008	-.1.9565	-.1.2302	3.8738	-.0000	-.2.6306	6.7234
4.1512	-.1.9778	-.1.2569	3.9112	-.0000	-.2.6637	6.8081
4.2016	-.1.9991	-.1.2836	3.9486	-.0000	-.2.6968	6.8928
4.2520	-.1.0204	-.1.3103	3.9860	-.0000	-.2.7299	6.9775
4.3024	-.1.0417	-.1.3370	4.0234	-.0000	-.2.7630	7.0622
4.3528	-.1.0630	-.1.3637	4.0608	-.0000	-.2.7961	7.1469
4.4032	-.1.0843	-.1.3904	4.0982	-.0000	-.2.8292	7.2316
4.4536	-.1.1056	-.1.4171	4.1356	-.0000	-.2.8623	7.3163
4.5040	-.1.1269	-.1.4438	4.1730	-.0000	-.2.8954	7.4010
4.5544	-.1.1482	-.1.4705	4.2104	-.0000	-.2.9285	7.4857
4.6048	-.1.1695	-.1.4972	4.2478	-.0000	-.2.9616	7.5704
4.6552	-.1.1908	-.1.5239	4.2852	-.0000	-.3.0000	7.6551
4.7056	-.1.2121	-.1.5506	4.3226	-.0000	-.3.0375	7.7398
4.7560	-.1.2334	-.1.5773	4.3600	-.0000	-.3.0750	7.8245
4.8064	-.1.2547	-.1.6040	4.3974	-.0000	-.3.1125	7.9092
4.8568	-.1.2760	-.1.6307	4.4348	-.0000	-.3.1500	8.0000
4.9072	-.1.2973	-.1.6574	4.4722	-.0000	-.3.1875	8.0908
4.9576	-.1.3186	-.1.6841	4.5096	-.0000	-.3.2250	8.1816
5.0080	-.1.3399	-.1.7108	4.5470	-.0000	-.3.2625	8.2724
5.0584	-.1.3612	-.1.7375	4.5844	-.0000	-.3.3000	8.3632
5.1088	-.1.3825	-.1.7642	4.6218	-.0000	-.3.3375	8.4540
5.1592	-.1.4038	-.1.7909	4.6592	-.0000	-.3.3750	8.5448
5.2096	-.1.4251	-.1.8176	4.6966	-.0000	-.3.4125	8.6356
5.2600	-.1.4464	-.1.8443	4.7340	-.0000	-.3.4500	8.7264
5.3104	-.1.4677	-.1.8710	4.7714	-.0000	-.3.4875	8.8172
5.3608	-.1.4890	-.1.8977	4.8088	-.0000	-.3.5250	8.9079
5.4112	-.1.51031					

TABLE A-3.--Continued

SECTION NO. 13 WATERSHIP 7,500 IN. (19,050 CM.)									
SUCTION SURFACE		Y.C.M.		Y.C.M.		PRESSURE SURFACE		Y.C.M.	
X IN.	Y IN.	X CM.	Y CM.	X IN.	Y IN.	X IN.	Y IN.	X CM.	Y CM.
-1.0067	-1.7599	-2.5570	-1.9301	-1.0067	-1.7599	-2.5570	-1.9301	-1.9301	-1.9301
-1.0067	-1.7599	-2.5570	-1.9301	-1.0067	-1.7599	-2.5570	-1.9301	-1.9301	-1.9301
-1.0055	-1.7531	-2.5540	-1.9130	-1.0040	-1.7471	-2.5501	-1.9130	-1.9130	-1.9130
-1.0028	-1.7468	-2.5471	-1.8969	-1.0003	-1.7408	-2.5408	-1.8969	-1.8969	-1.8969
-1.0007	-1.7405	-2.5367	-1.8808	-0.9935	-1.7345	-2.5308	-1.8808	-1.8808	-1.8808
-0.9927	-1.7327	-2.5249	-1.8649	-0.9867	-1.7287	-2.5185	-1.8649	-1.8649	-1.8649
-0.9867	-1.7248	-2.5131	-1.8489	-0.9798	-1.7227	-2.5125	-1.8489	-1.8489	-1.8489
-0.9807	-1.7169	-2.5013	-1.8330	-0.9729	-1.7167	-2.5060	-1.8330	-1.8330	-1.8330
-0.9747	-1.7090	-2.4894	-1.8170	-0.9660	-1.7107	-2.4997	-1.8170	-1.8170	-1.8170
-0.9687	-1.7011	-2.4776	-1.8011	-0.9591	-1.7047	-2.4934	-1.8011	-1.8011	-1.8011
-0.9627	-1.6932	-2.4657	-1.7852	-0.9522	-1.6983	-2.4871	-1.7852	-1.7852	-1.7852
-0.9567	-1.6853	-2.4538	-1.7693	-0.9453	-1.6923	-2.4808	-1.7693	-1.7693	-1.7693
-0.9507	-1.6774	-2.4419	-1.7534	-0.9384	-1.6863	-2.4745	-1.7534	-1.7534	-1.7534
-0.9447	-1.6695	-2.4300	-1.7375	-0.9315	-1.6803	-2.4682	-1.7375	-1.7375	-1.7375
-0.9387	-1.6616	-2.4181	-1.7216	-0.9246	-1.6743	-2.4619	-1.7216	-1.7216	-1.7216
-0.9327	-1.6537	-2.4062	-1.7057	-0.9177	-1.6683	-2.4556	-1.7057	-1.7057	-1.7057
-0.9267	-1.6458	-2.3943	-1.6898	-0.9108	-1.6623	-2.4493	-1.6898	-1.6898	-1.6898
-0.9207	-1.6379	-2.3824	-1.6739	-0.9039	-1.6563	-2.4430	-1.6739	-1.6739	-1.6739
-0.9147	-1.6300	-2.3705	-1.6580	-0.8970	-1.6503	-2.4367	-1.6580	-1.6580	-1.6580
-0.9087	-1.6221	-2.3586	-1.6421	-0.8901	-1.6443	-2.4304	-1.6421	-1.6421	-1.6421
-0.9027	-1.6142	-2.3467	-1.6262	-0.8832	-1.6383	-2.4241	-1.6262	-1.6262	-1.6262
-0.8967	-1.6063	-2.3348	-1.6103	-0.8763	-1.6323	-2.4178	-1.6103	-1.6103	-1.6103
-0.8907	-1.5984	-2.3229	-1.5944	-0.8694	-1.6263	-2.4115	-1.5944	-1.5944	-1.5944
-0.8847	-1.5905	-2.3110	-1.5785	-0.8625	-1.6203	-2.4052	-1.5785	-1.5785	-1.5785
-0.8787	-1.5826	-2.2991	-1.5626	-0.8556	-1.6143	-2.3989	-1.5626	-1.5626	-1.5626
-0.8727	-1.5747	-2.2872	-1.5467	-0.8487	-1.6083	-2.3926	-1.5467	-1.5467	-1.5467
-0.8667	-1.5668	-2.2753	-1.5308	-0.8418	-1.6023	-2.3863	-1.5308	-1.5308	-1.5308
-0.8607	-1.5589	-2.2634	-1.5149	-0.8349	-1.5963	-2.3800	-1.5149	-1.5149	-1.5149
-0.8547	-1.5510	-2.2515	-1.4990	-0.8280	-1.5903	-2.3737	-1.4990	-1.4990	-1.4990
-0.8487	-1.5431	-2.2396	-1.4831	-0.8211	-1.5843	-2.3674	-1.4831	-1.4831	-1.4831
-0.8427	-1.5352	-2.2277	-1.4672	-0.8142	-1.5783	-2.3611	-1.4672	-1.4672	-1.4672
-0.8367	-1.5273	-2.2158	-1.4513	-0.8073	-1.5723	-2.3548	-1.4513	-1.4513	-1.4513
-0.8307	-1.5194	-2.2039	-1.4354	-0.8004	-1.5663	-2.3485	-1.4354	-1.4354	-1.4354
-0.8247	-1.5115	-2.1920	-1.4195	-0.7935	-1.5603	-2.3422	-1.4195	-1.4195	-1.4195
-0.8187	-1.5036	-2.1801	-1.4036	-0.7866	-1.5543	-2.3359	-1.4036	-1.4036	-1.4036
-0.8127	-1.4957	-2.1682	-1.3877	-0.7797	-1.5483	-2.3296	-1.3877	-1.3877	-1.3877
-0.8067	-1.4878	-2.1563	-1.3718	-0.7728	-1.5423	-2.3233	-1.3718	-1.3718	-1.3718
-0.8007	-1.4799	-2.1444	-1.3559	-0.7659	-1.5363	-2.3170	-1.3559	-1.3559	-1.3559
-0.7947	-1.4720	-2.1325	-1.3400	-0.7590	-1.5303	-2.3107	-1.3400	-1.3400	-1.3400
-0.7887	-1.4641	-2.1206	-1.3241	-0.7521	-1.5243	-2.3044	-1.3241	-1.3241	-1.3241
-0.7827	-1.4562	-2.1087	-1.3082	-0.7452	-1.5183	-2.2981	-1.3082	-1.3082	-1.3082
-0.7767	-1.4483	-2.0968	-1.2923	-0.7383	-1.5123	-2.2918	-1.2923	-1.2923	-1.2923
-0.7707	-1.4404	-2.0849	-1.2764	-0.7314	-1.5063	-2.2855	-1.2764	-1.2764	-1.2764
-0.7647	-1.4325	-2.0730	-1.2605	-0.7245	-1.5003	-2.2792	-1.2605	-1.2605	-1.2605
-0.7587	-1.4246	-2.0611	-1.2446	-0.7176	-1.4943	-2.2729	-1.2446	-1.2446	-1.2446
-0.7527	-1.4167	-2.0492	-1.2287	-0.7107	-1.4883	-2.2666	-1.2287	-1.2287	-1.2287
-0.7467	-1.4088	-2.0373	-1.2128	-0.7038	-1.4823	-2.2603	-1.2128	-1.2128	-1.2128
-0.7407	-1.4009	-2.0254	-1.1969	-0.6969	-1.4763	-2.2540	-1.1969	-1.1969	-1.1969
-0.7347	-1.3930	-2.0135	-1.1810	-0.6900	-1.4703	-2.2477	-1.1810	-1.1810	-1.1810
-0.7287	-1.3851	-2.0016	-1.1651	-0.6831	-1.4643	-2.2414	-1.1651	-1.1651	-1.1651
-0.7227	-1.3772	-1.9897	-1.1492	-0.6762	-1.4583	-2.2351	-1.1492	-1.1492	-1.1492
-0.7167	-1.3693	-1.9778	-1.1333	-0.6693	-1.4523	-2.2288	-1.1333	-1.1333	-1.1333
-0.7107	-1.3614	-1.9659	-1.1174	-0.6624	-1.4463	-2.2225	-1.1174	-1.1174	-1.1174
-0.7047	-1.3535	-1.9540	-1.1015	-0.6555	-1.4403	-2.2162	-1.1015	-1.1015	-1.1015
-0.6987	-1.3456	-1.9421	-1.0856	-0.6486	-1.4343	-2.2099	-1.0856	-1.0856	-1.0856
-0.6927	-1.3377	-1.9302	-1.0697	-0.6417	-1.4283	-2.2036	-1.0697	-1.0697	-1.0697
-0.6867	-1.3298	-1.9183	-1.0538	-0.6348	-1.4223	-2.1973	-1.0538	-1.0538	-1.0538
-0.6807	-1.3219	-1.9064	-1.0379	-0.6279	-1.4163	-2.1910	-1.0379	-1.0379	-1.0379
-0.6747	-1.3140	-1.8945	-1.0220	-0.6210	-1.4103	-2.1847	-1.0220	-1.0220	-1.0220
-0.6687	-1.3061	-1.8826	-1.0061	-0.6141	-1.4043	-2.1784	-1.0061	-1.0061	-1.0061
-0.6627	-1.2982	-1.8707	-0.9902	-0.6072	-1.3983	-2.1721	-0.9902	-0.9902	-0.9902
-0.6567	-1.2903	-1.8588	-0.9743	-0.6003	-1.3923	-2.1658	-0.9743	-0.9743	-0.9743
-0.6507	-1.2824	-1.8469	-0.9584	-0.5934	-1.3863	-2.1595	-0.9584	-0.9584	-0.9584
-0.6447	-1.2745	-1.8350	-0.9425	-0.5865	-1.3803	-2.1532	-0.9425	-0.9425	-0.9425
-0.6387	-1.2666	-1.8231	-0.9266	-0.5796	-1.3743	-2.1469	-0.9266	-0.9266	-0.9266
-0.6327	-1.2587	-1.8112	-0.9107	-0.5727	-1.3683	-2.1406	-0.9107	-0.9107	-0.9107
-0.6267	-1.2508	-1.7993	-0.8948	-0.5658	-1.3623	-2.1343	-0.8948	-0.8948	-0.8948
-0.6207	-1.2429	-1.7874	-0.8789	-0.5589	-1.3563	-2.1280	-0.8789	-0.8789	-0.8789
-0.6147	-1.2350	-1.7755	-0.8630	-0.5520	-1.3503	-2.1217	-0.8630	-0.8630	-0.8630
-0.6087	-1.2271	-1.7636	-0.8471	-0.5451	-1.3443	-2.1154	-0.8471	-0.8471	-0.8471
-0.6027	-1.2192	-1.7517	-0.8312	-0.5382	-1.3383	-2.1091	-0.8312	-0.8312	-0.8312
-0.5967	-1.2113	-1.7398	-0.8153	-0.5313	-1.3323	-2.1028	-0.8153	-0.8153	-0.8153
-0.5907	-1.2034	-1.7279	-0.7994	-0.5244	-1.3263	-2.0965	-0.7994	-0.7994	-0.7994
-0.5847	-1.1955	-1.7160	-0.7835	-0.5175	-1.3203	-2.0902	-0.7835	-0.7835	-0.7835
-0.5787	-1.1876	-1.7041	-0.7676	-0.5106	-1.3143	-2.0839	-0.7676	-0.7676	-0.7676
-0.5727	-1.1797	-1.6922	-0.7517	-0.5037	-1.3083	-2.0776	-0.7517	-0.7517	-0.7517
-0.5667	-1.1718	-1.6803	-0.7358	-0.4968	-1.3023	-2.0713	-0.7358	-0.7358	-0.7358
-0.5607	-1.1639	-1.6684	-0.7199	-0.4899	-1.2963	-2.0650	-0.7199	-0.7199	-0.7199
-0.5547	-1.1560	-1.6565	-0.7040	-0.4830	-1.2903	-2.0587	-0.7040	-0.7040	-0.7040
-0.5487	-1.1481	-1.6446	-0.6881	-0.4761	-1.2843	-2.0524	-0.6881	-0.6881	-0.6881
-0.5427	-1.1402	-1.6327	-0.6722	-0.4692	-1.2783	-2.0461	-0.6722	-0.6722	-0.6722
-0.5367	-1.1323	-1.6208	-0.6563	-0.4623	-1.2723	-2.0398	-0.6563	-0.6563	-0.6563
-0.5307	-1.1244	-1.6089	-0.6404	-0.4554	-1.2663	-2.0335	-0.6404	-0.6404	-0.6404
-0.5247	-1.1165	-1.5970	-0.6245	-0.4485	-1.2603	-2.0272	-0.6245	-0.6245	-0.6245
-0.5187	-1.1086	-1.5851	-0.6086	-0.4416	-1.2543	-2.0209	-0.6086	-0.6086	-0.6086
-0.5127	-1.1007	-1.5732	-0.5927	-0.4347	-1.2483	-2.0146	-0.5927	-0.5927	-0.5927
-0.5067	-1.0928	-1.5613	-0.5768	-0.4278	-1.2423	-2.0083	-0.5768	-0.5768	-0.5768
-0.5007	-1.0849	-1.5494	-0.5609	-0.4209	-1.2363	-2.0020	-0.5609	-0.5609	-0.5609
-0.4947	-1.0770	-1.5375	-0.5450	-0.4140	-1.2303	-1.9957	-0.5450	-0.5450	-0.5450
-0.4887	-1.0691	-1.5256	-0.5291	-0.4071	-1.2243	-1.9894	-0.5291	-0.5291	-0.5291
-0.4827	-1.0612	-1.5137	-0.5132	-0.4002	-1.2183	-1.9831	-0.5132	-0.5132	-0.5132
-0.4767	-1.0533	-1.5018	-0.4973	-0.3933	-1.2123	-1.9768	-0.4973	-0.4973	-0.4973
-0.4707	-1.0454	-1.4899	-0.4814	-0.3864	-1.2063	-1.9705	-0.4814	-0.4814	-0.4814
-0.4647	-1.0375	-1.4780	-0.4655	-0.3795	-1.2003	-1.9642	-0.4655	-0.4655	-0.4655
-0.4587	-1.0296	-1.4661	-0.4496	-0.3726	-1.1943	-1.9579	-0.4496	-0.4496	-0.4496
-0.4527	-1.0217	-1.4542	-0.4337	-0.3657	-1.1883	-1.9516	-0.4337	-0.4337	-0.4337
-0.4467	-1.0138	-1.4423	-0.4178	-0.3588	-1.1823	-1.9453	-0.4178	-0.4178	-0.4178
-0.4407	-1.0059	-1.4304	-0.4019	-0.3519	-1.1763	-1.9390	-0.4019	-0.4019	-0.4019
-0.4347	-0.9980	-1.4185	-0.3860	-0.3450	-1.1703	-1.9327	-0.3860	-0.3860	-0.3860
-0.4287	-0.9901	-1.4066	-0.3701	-0.3381	-1.1643	-1.9264	-0.3701	-0.3701	-0.3701
-0.4227	-0.9822	-1.3947	-0.3542	-0.3312	-1.1583	-1.9201	-0.3542	-0.3542	-0.3542
-0.4167	-0.9743	-1.3828	-0.3383	-0.3243	-1.1523	-1.9138	-0.3383	-0.3383	-0.3383
-0.4107	-0.9664	-1.3709	-0.3224	-0.3174	-1.1463	-1.9075	-0.3224	-0.3224	-0.3224
-0.4047	-0.9585	-1.3590	-0.3065	-0.3105	-1.1403	-1.9012	-0.3065	-0.3065	-0.3065
-0.3987	-0.9506	-1							

TABLE A-3.--Concluded

ROTOR AIRFOIL COORDINATES SECTION NO. 14 RADIUS 6.642 IN. (16.871 CM.)									
SUCTION SURFACE			PRESSURE SURFACE						
X IN.	Y IN.	X CM.	Y CM.	X IN.	Y IN.	X CM.	Y CM.	A CM.	Y CM.
-0.9750	-0.6039	-2.4765	-1.7372	-0.9750	-0.6039	-2.4765	-1.7372		-1.7372
-0.9750	-0.6034	-2.4764	-1.7360	-0.9743	-0.6033	-2.4763	-1.7360		-1.7403
-0.9740	-0.6775	-2.4780	-1.7210	-0.9720	-0.6917	-2.4684	-1.7069		-1.7569
-0.9710	-0.6710	-2.4674	-1.7084	-0.9682	-0.6934	-2.4693	-1.7012		-1.7612
-0.9714	-0.6644	-2.4573	-1.6876	-0.9633	-0.6432	-2.4469	-1.7004		-1.7604
-0.9216	-0.6009	-2.3408	-1.5264	-0.9577	-0.6413	-2.4326	-1.7559		-1.7559
-0.9757	-0.5403	-2.2243	-1.3723	-0.9438	-0.6005	-2.3472	-1.7284		-1.7284
-0.9298	-0.4826	-2.1078	-1.2257	-0.9356	-0.6724	-2.3764	-1.7078		-1.7078
-0.9840	-0.4276	-1.9913	-1.0861	-0.8876	-0.6236	-2.2546	-1.5890		-1.5890
-0.9361	-0.3752	-1.8748	-0.9529	-0.8369	-0.5780	-2.1258	-1.4682		-1.4682
-0.9222	-0.3253	-1.7583	-0.8263	-0.7862	-0.5323	-1.9970	-1.3514		-1.3514
-0.8464	-0.2779	-1.6418	-0.7058	-0.7355	-0.4863	-1.8682	-1.2403		-1.2403
-0.8005	-0.2327	-1.5253	-0.5910	-0.6868	-0.4461	-1.7394	-1.1331		-1.1331
-0.7546	-0.1898	-1.4088	-0.4821	-0.6361	-0.4056	-1.6106	-1.0303		-1.0303
-0.7088	-0.1491	-1.2923	-0.3787	-0.5834	-0.3669	-1.4818	-0.9318		-0.9318
-0.6429	-0.1106	-1.1758	-0.2809	-0.5327	-0.3297	-1.3530	-0.8375		-0.8375
-0.5170	-0.0741	-1.0593	-0.1883	-0.4820	-0.2942	-1.2242	-0.7472		-0.7472
-0.3712	-0.0396	-0.9427	-0.1007	-0.4313	-0.2602	-1.0954	-0.6604		-0.6604
-0.3253	-0.0070	-0.8263	-0.0178	-0.3806	-0.2278	-0.9666	-0.5785		-0.5785
-0.2794	-0.0238	-0.7098	-0.0695	-0.3299	-0.1968	-0.8378	-0.4998		-0.4998
-0.2336	-0.0524	-0.5932	-0.1345	-0.2792	-0.1672	-0.7090	-0.4248		-0.4248
-0.1877	-0.0804	-0.4768	-0.2043	-0.2285	-0.1391	-0.5803	-0.3533		-0.3533
-0.1410	-0.1063	-0.3602	-0.2700	-0.1777	-0.1123	-0.4515	-0.2853		-0.2853
-0.0960	-0.1305	-0.2437	-0.3315	-0.1270	-0.0868	-0.3227	-0.2206		-0.2206
-0.0501	-0.1531	-0.1272	-0.3890	-0.0763	-0.0626	-0.1919	-0.1591		-0.1591
-0.0042	-0.1742	-0.0107	-0.4425	-0.0256	-0.0397	-0.0651	-0.1008		-0.1008
-0.0416	-0.1938	-0.1058	-0.4921	-0.0251	-0.0179	-0.0637	-0.0456		-0.0456
-0.0875	-0.2118	-0.2233	-0.5379	-0.0758	-0.0227	-0.027	-0.0068		-0.0068
-0.1334	-0.2283	-0.3388	-0.5799	-0.1265	-0.0221	-0.0213	-0.0062		-0.0062
-0.1792	-0.2433	-0.4523	-0.6181	-0.1772	-0.0406	-0.4501	-0.1031		-0.1031
-0.2251	-0.2569	-0.5718	-0.6525	-0.2279	-0.0581	-0.5769	-0.1477		-0.1477
-0.2710	-0.2690	-0.6803	-0.6833	-0.2786	-0.0750	-0.7077	-0.1908		-0.1908
-0.3168	-0.2797	-0.7848	-0.7103	-0.3293	-0.0914	-0.8365	-0.2324		-0.2324
-0.3627	-0.2869	-0.8893	-0.7337	-0.3800	-0.1073	-0.9653	-0.2725		-0.2725
-0.4086	-0.2966	-1.0378	-0.7534	-0.4307	-0.1225	-1.0941	-0.3112		-0.3112
-0.4564	-0.3029	-1.1543	-0.7694	-0.4814	-0.1370	-1.2229	-0.3480		-0.3480
-0.5003	-0.3078	-1.2708	-0.7817	-0.5321	-0.1508	-1.3517	-0.3831		-0.3831
-0.5462	-0.3112	-1.3873	-0.7903	-0.5828	-0.1639	-1.4804	-0.4183		-0.4183
-0.5920	-0.3131	-1.5036	-0.7952	-0.6336	-0.1761	-1.6092	-0.4474		-0.4474
-0.6379	-0.3135	-1.6203	-0.7964	-0.6843	-0.1876	-1.7380	-0.4764		-0.4764
-0.6838	-0.3125	-1.7368	-0.7938	-0.7350	-0.1981	-1.8668	-0.5032		-0.5032
-0.7298	-0.3100	-1.8533	-0.7873	-0.7857	-0.2077	-1.9958	-0.5277		-0.5277
-0.7558	-0.2952	-1.9737	-0.7698	-0.8364	-0.2164	-2.1244	-0.5497		-0.5497
-0.7997	-0.2717	-2.0930	-0.7498	-0.8871	-0.2241	-2.2532	-0.5691		-0.5691
-0.8244	-0.2684	-2.2122	-0.7303	-0.9378	-0.2307	-2.3820	-0.5860		-0.5860
-0.8906	-0.2656	-2.3312	-0.7107	-0.9885	-0.2370	-2.5108	-0.6020		-0.6020
-0.9973	-0.2618	-2.4502	-0.6911	-0.9957	-0.2438	-2.6390	-0.6184		-0.6184
1.0019	-0.2574	-2.5690	-0.6717	1.0009	-0.2435	-2.7672	-0.6296		-0.6296
1.0042	-0.2526	-2.6880	-0.6417	1.0038	-0.2479	-2.8954	-0.6372		-0.6372
1.0043	-0.2509	-2.8070	-0.6172	1.0043	-0.2509	-3.0236	-0.6432		-0.6432

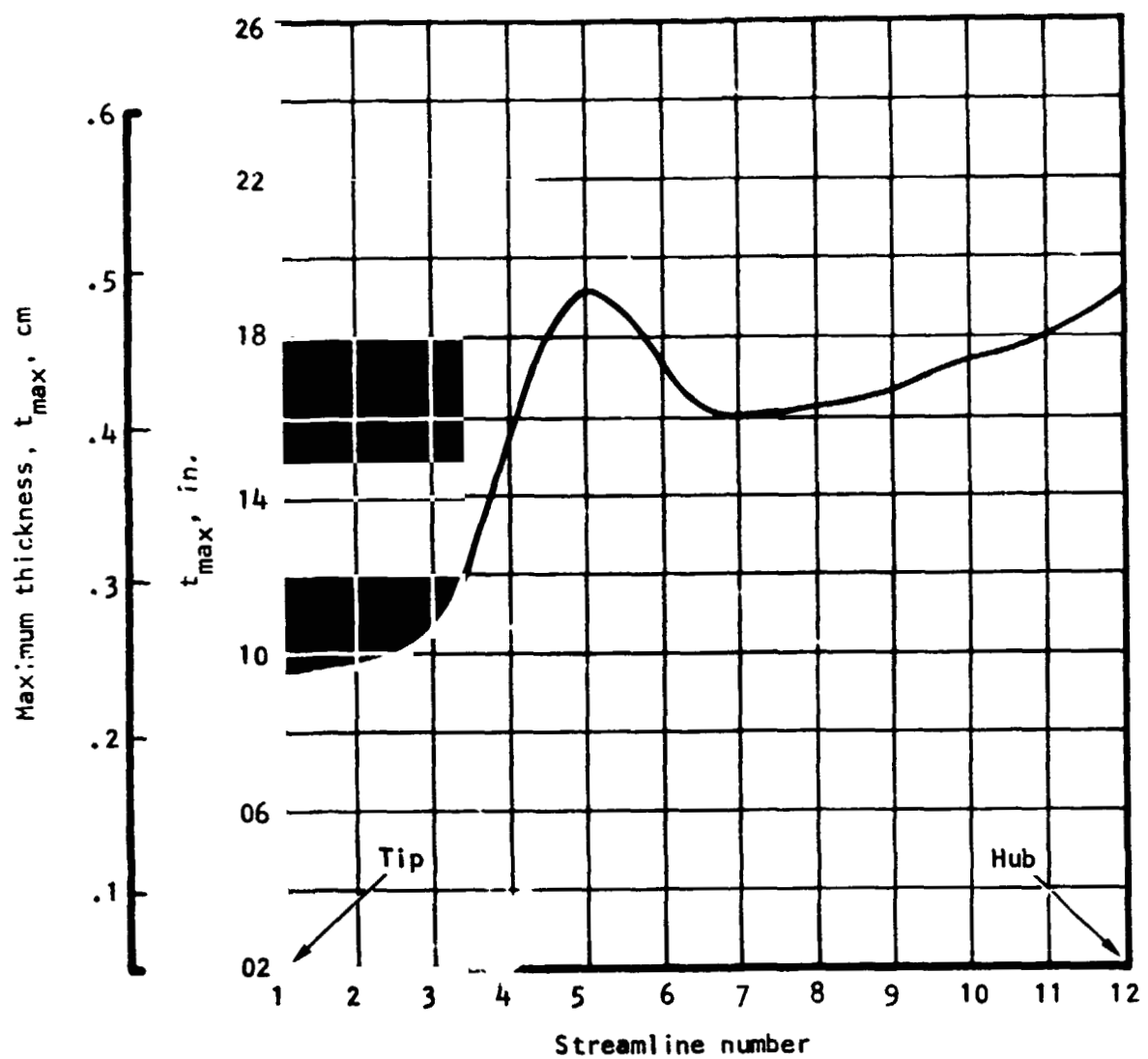
1--MIN.

TABLE A-4
BLADE-TO-DISC ATTACHMENT STRESSES

	Blade				Disc			
	Allowable	Nominal	Peak	Margin of safety	Allowable	Nominal	Peak	Margin of safety
Neck tension or tang bending	87.4 (603x10 ⁶)	39.9 (275x10 ⁶)	50.7 (350x10 ⁶)	0.72	87.4 (603x10 ⁶)	66.2 (457x10 ⁶)	82.8 (571x10 ⁶)	0.06
Combined fillet	127.6 (875x10 ⁶)	75.7 (522x10 ⁶)	94.7 (654x10 ⁶)	0.35	127.6 (875x10 ⁶)	102.7 (708x10 ⁶)	124.2 (857x10 ⁶)	0.02
Maximum fillet	130.0 (897x10 ⁶)	0. (0.)	139.3 (961x10 ⁶)	0.87	130.0 (897.106)	0. (0.)	192.0 (1325x10 ⁶)	0.35
Bearing	121.3 (838x10 ⁶)	52.2 (360x10 ⁶)	78.6 (542x10 ⁶)	0.54	121.3 (838x10 ⁶)	51.8 (357x10 ⁶)	77.9 (537x10 ⁶)	0.56
Shear	50.7 (350x10 ⁶)	25.3 (174x10 ⁶)	29.6 (204x10 ⁶)	0.67	50.7 (350x10 ⁶)	23.8 (164x10 ⁶)	27.8 (192x10 ⁶)	0.77

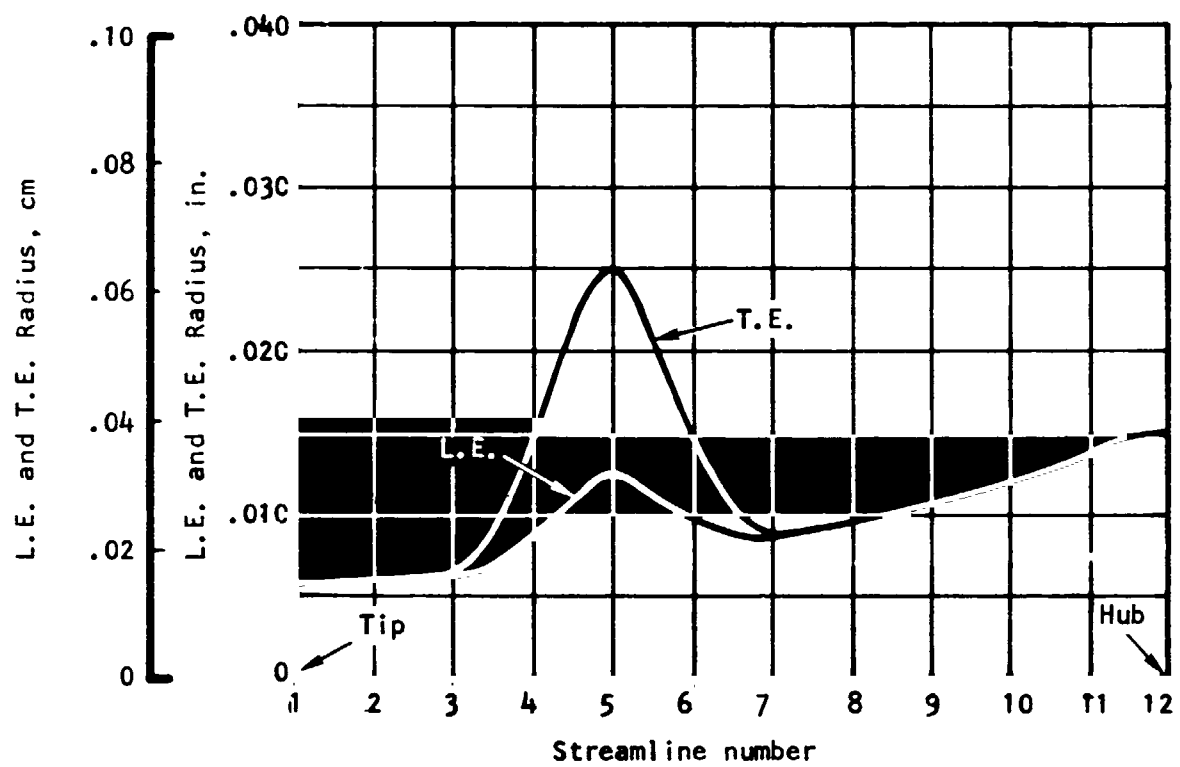
Notes:

1. All stresses are in ksi (N/m²).
2. All stresses are calculated at 110 percent design speed (14 100 rpm or 1477 rad/sec).
3. Margin of safety is based on the larger of 1.2 times the nominal stress or the calculated peak stress.
4. Margin of safety = (allowable stress/calculated stress) - 1.
5. Allowable stresses include:
 - 5 percent reduction for surface finish and loading rate (except for combined fillet).
 - 4.5 percent reduction for broach angle.
6. Allowable maximum fillet stress is 1/2 amplitude equivalent elastic stress.



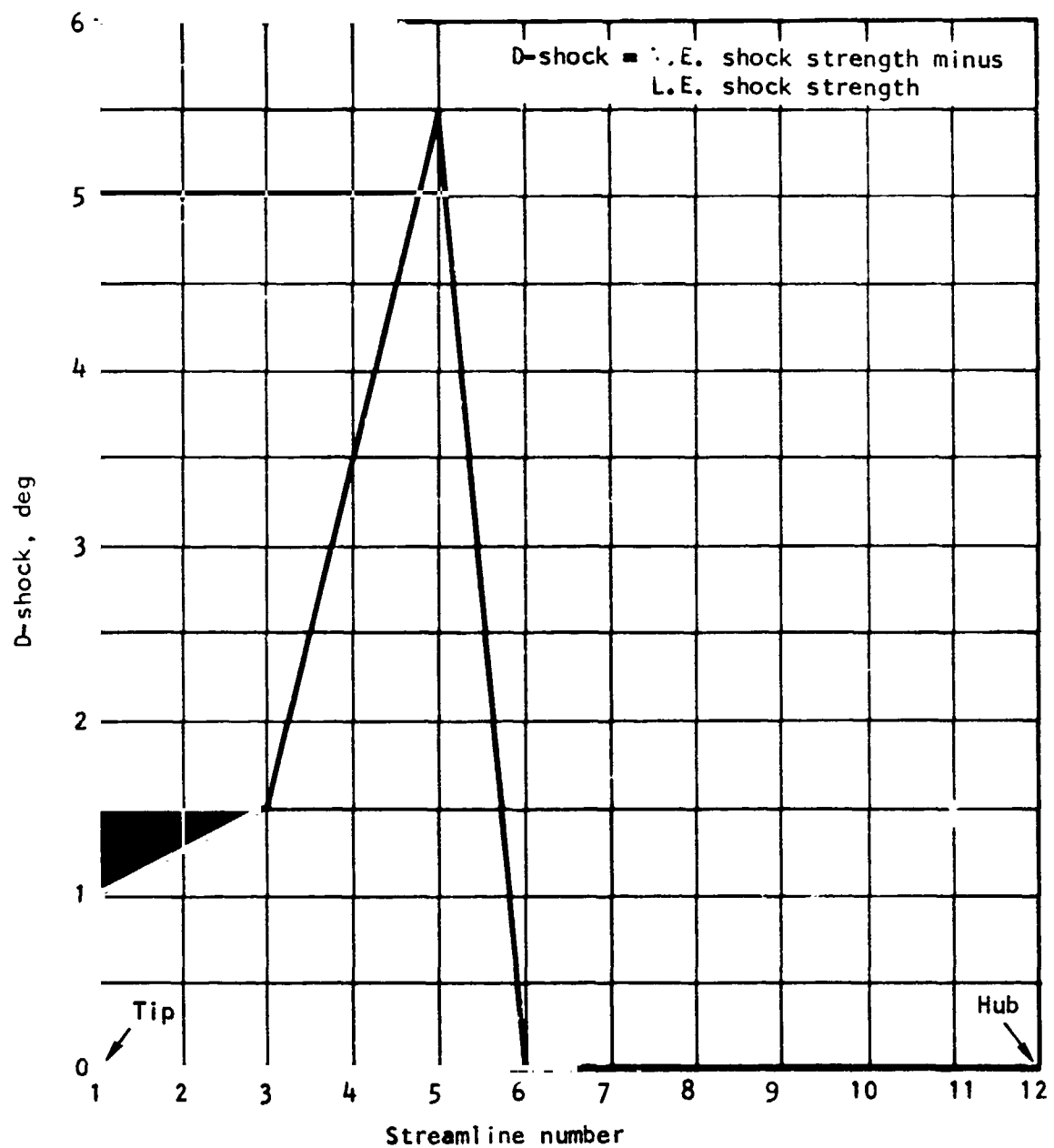
S-80697

Figure A-1.--Rotor Blade Maximum Thickness Distribution.



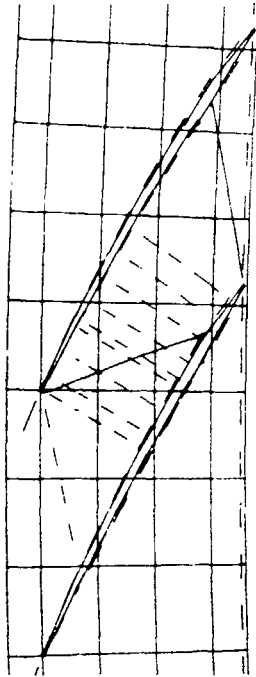
S-80561

Figure A-2.--Rotor Blade Leading- and Trailing-Edge Radii.

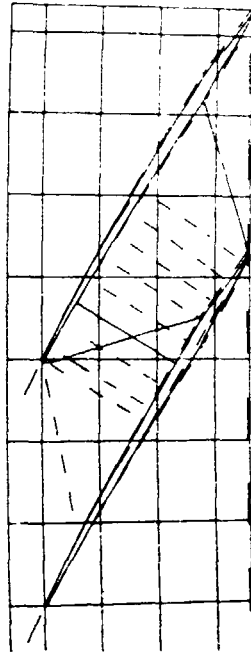


S-80558

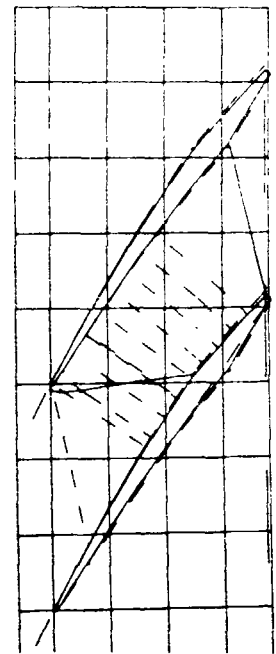
Figure A-3.--Rotor Blade Trailing-Edge Shock Strength Minus
Leading-Edge Shock Strength.



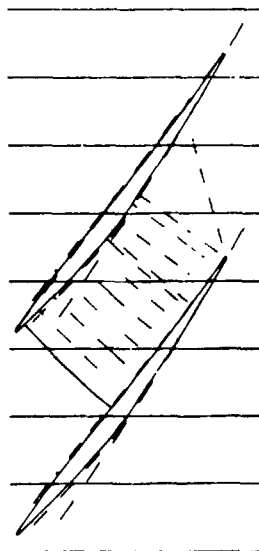
Streamline 1



Streamline 3



Streamline 5



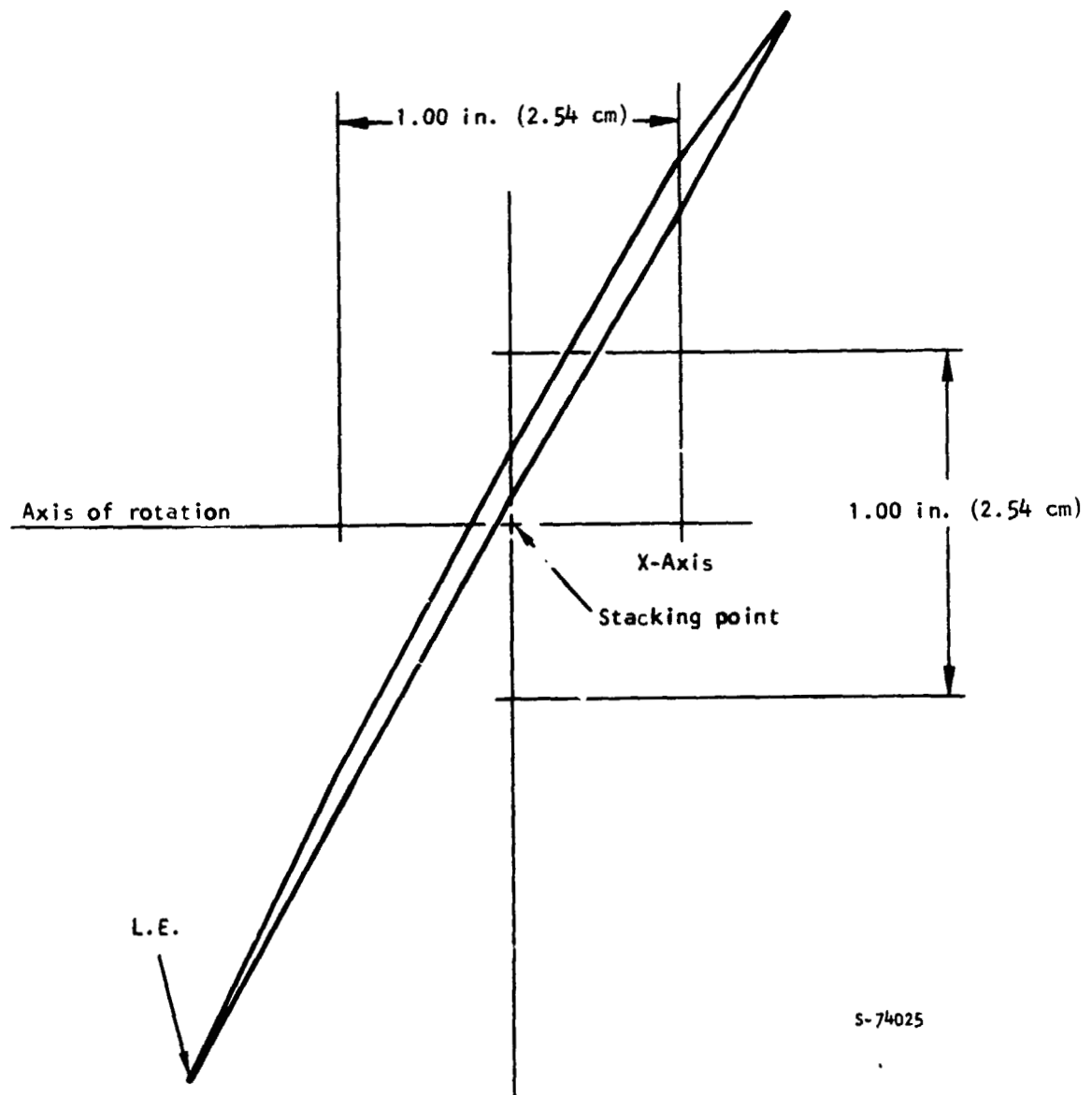
Streamline 7



Streamline 12

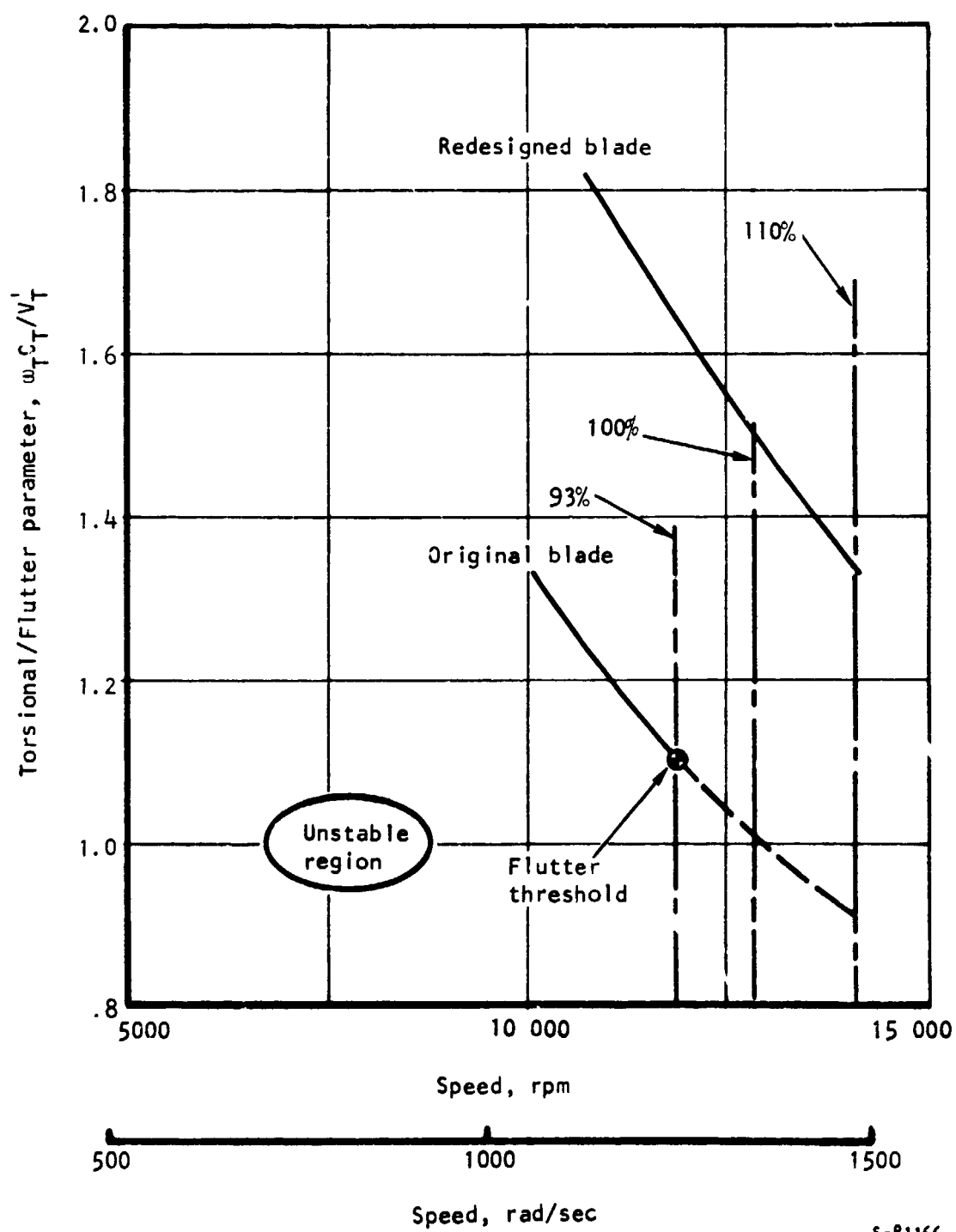
S-82824

Figure A-4.--Rotor Blade Conical Development.



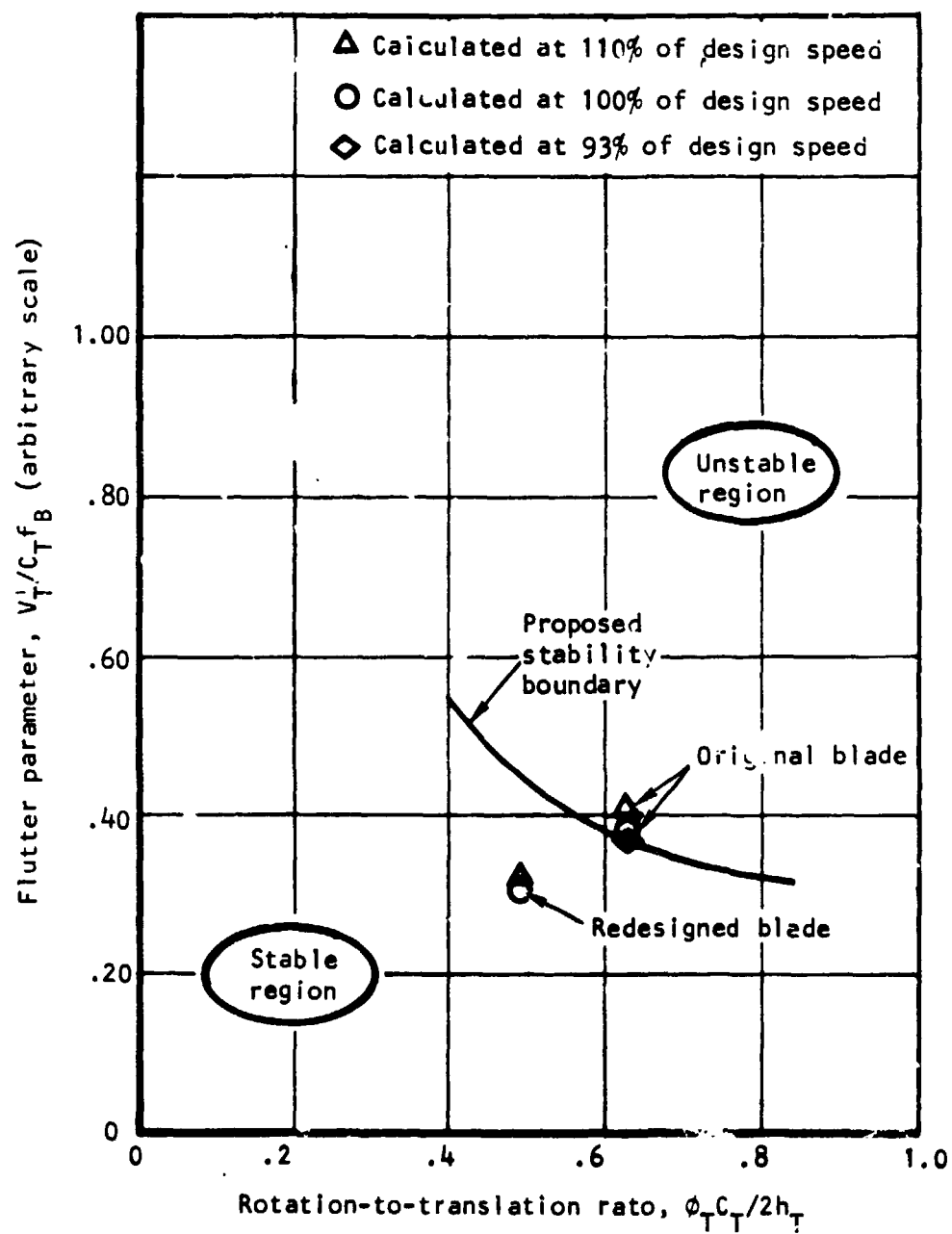
S-74025

Figure A-5.--Typical Rotor Blade Section.



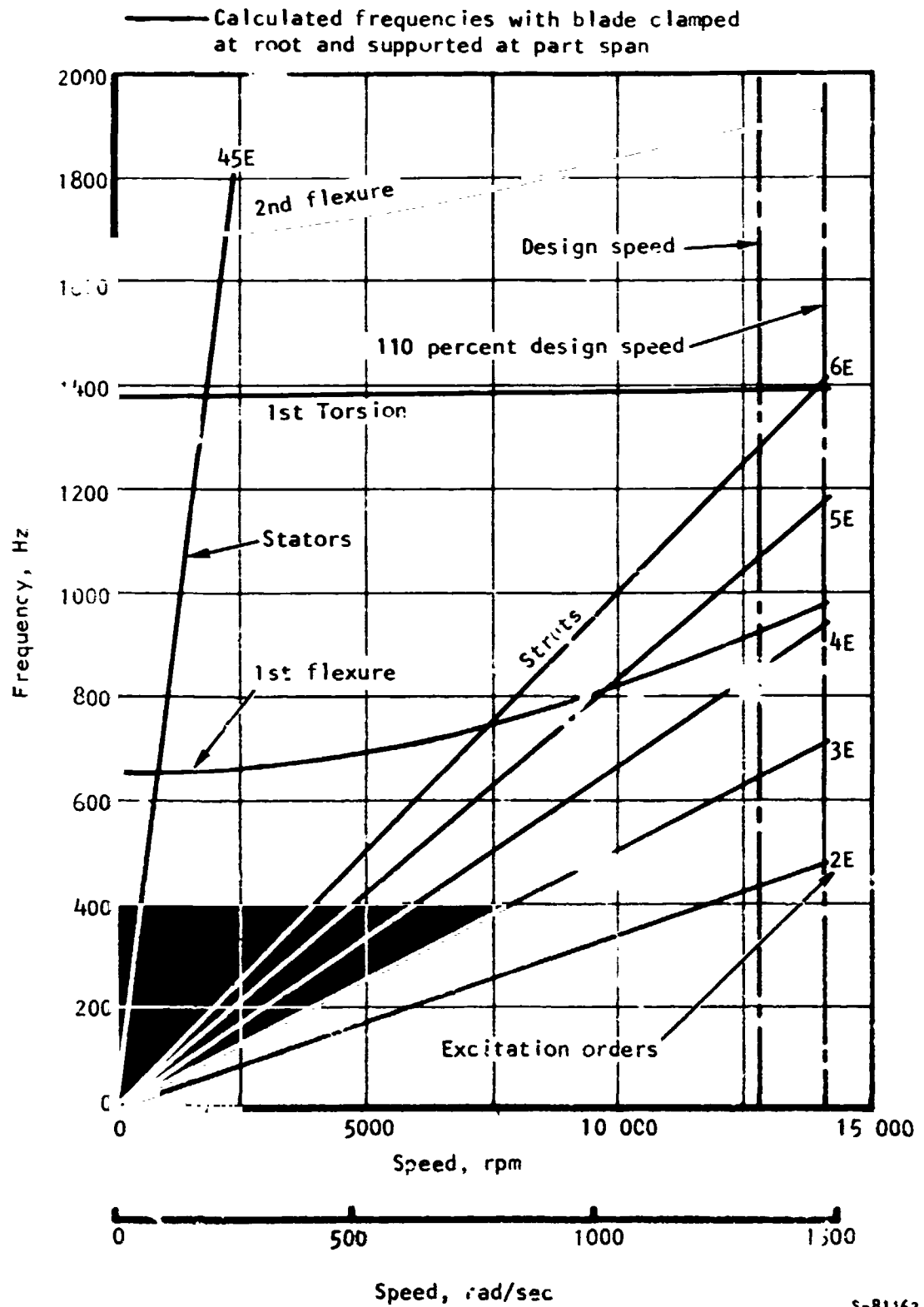
S-81166

Figure A-6.--Fan Blade Torsional Flutter Parameter.



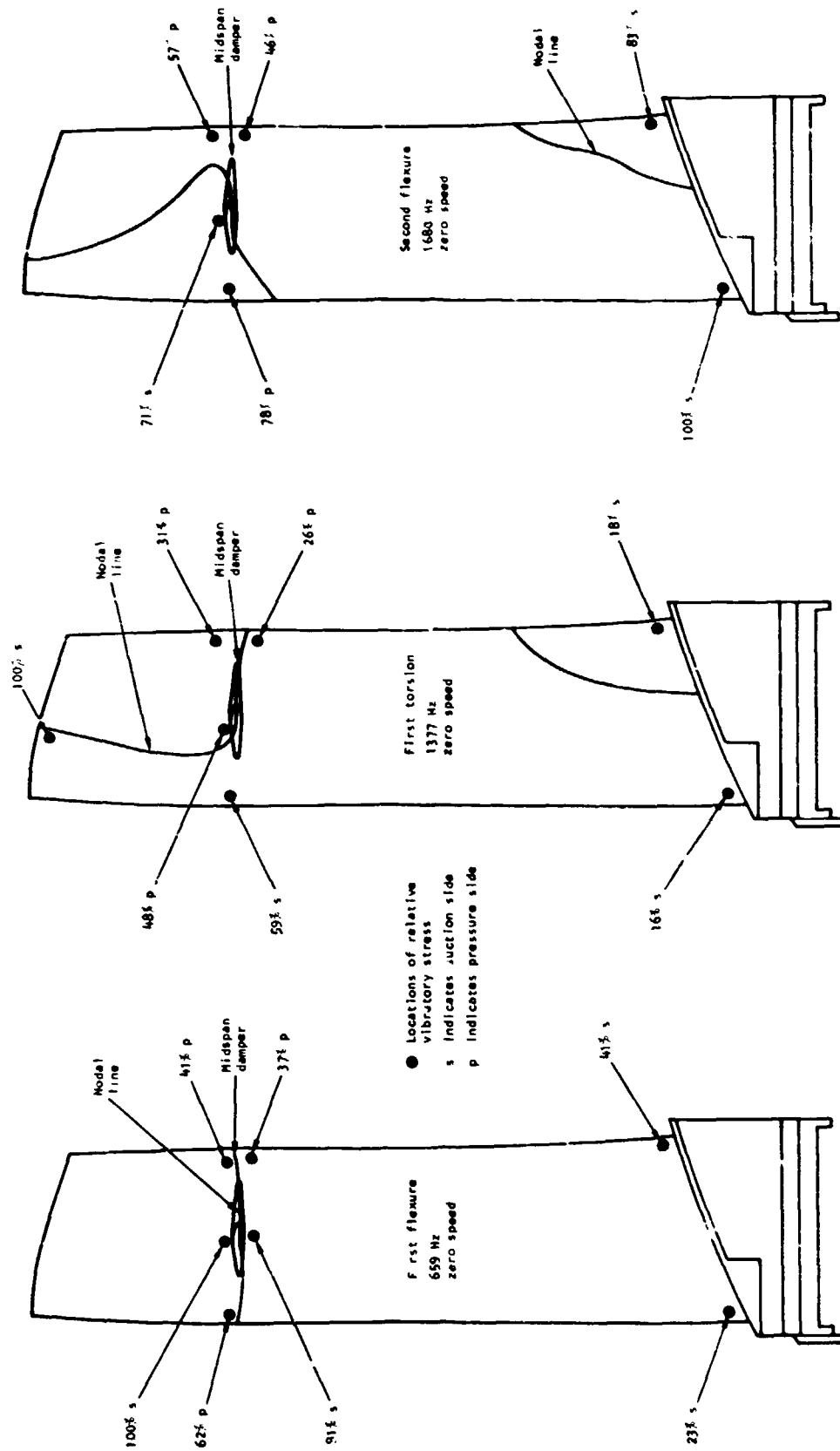
S-80629

Figure A-7.--Fan Blade Coupled Flexural-Torsional Flutter Parameter.



S-81163

Figure A-8.--Fan Blade Excitation Diagram.



S-84112

Figure A-9.--Fan Blade Mode Shapes and Relative Vibratory Stress.

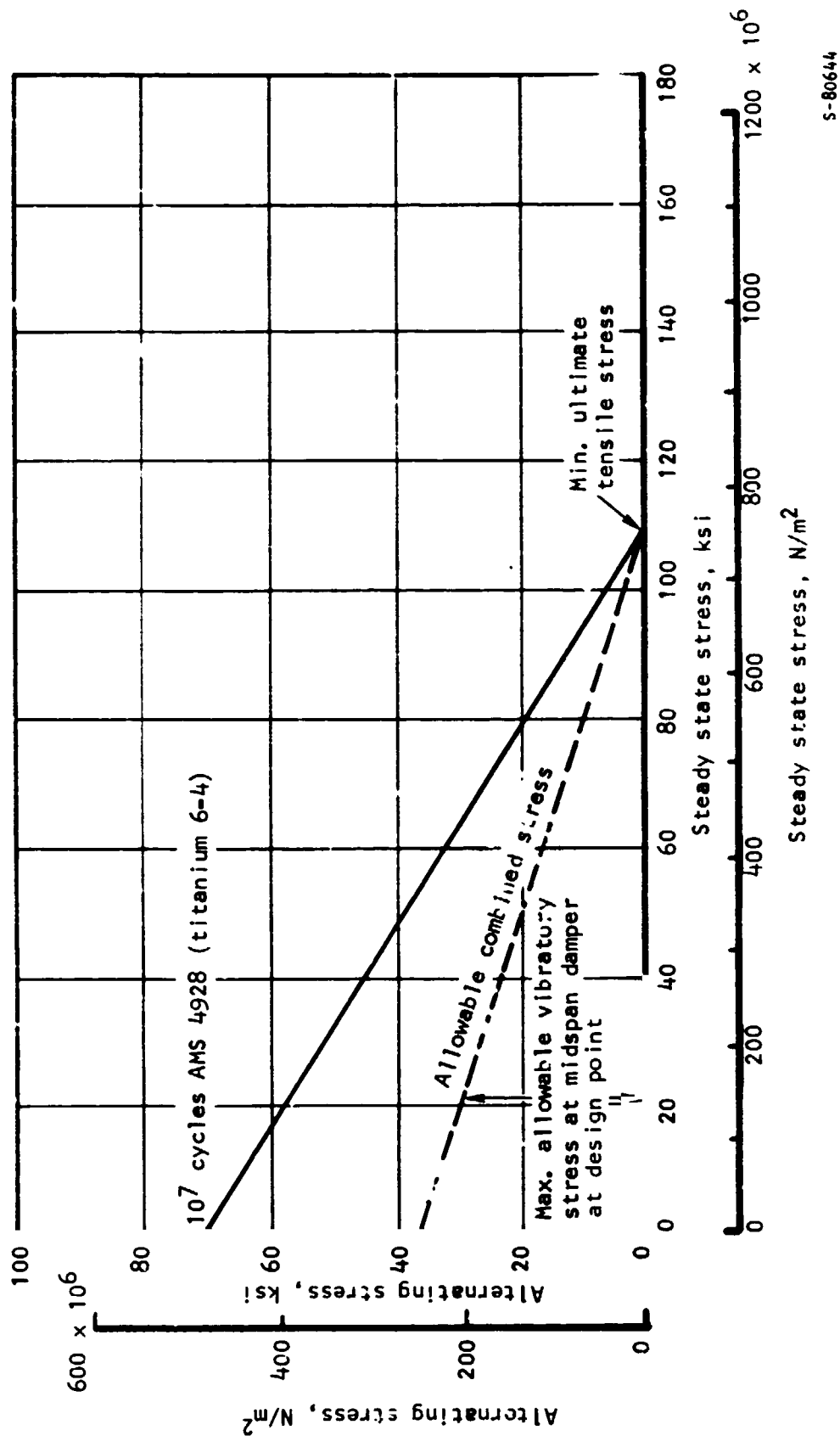
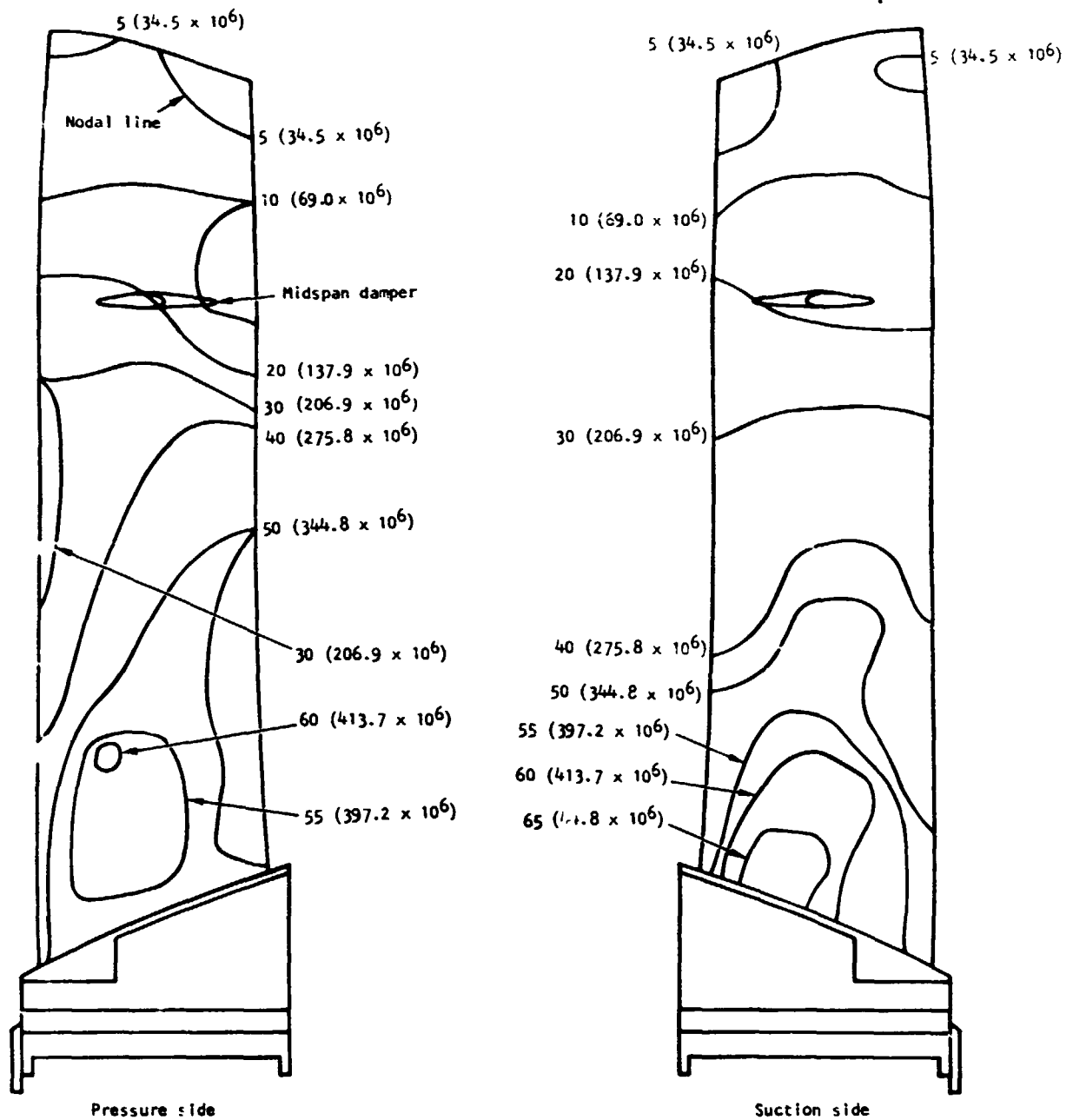
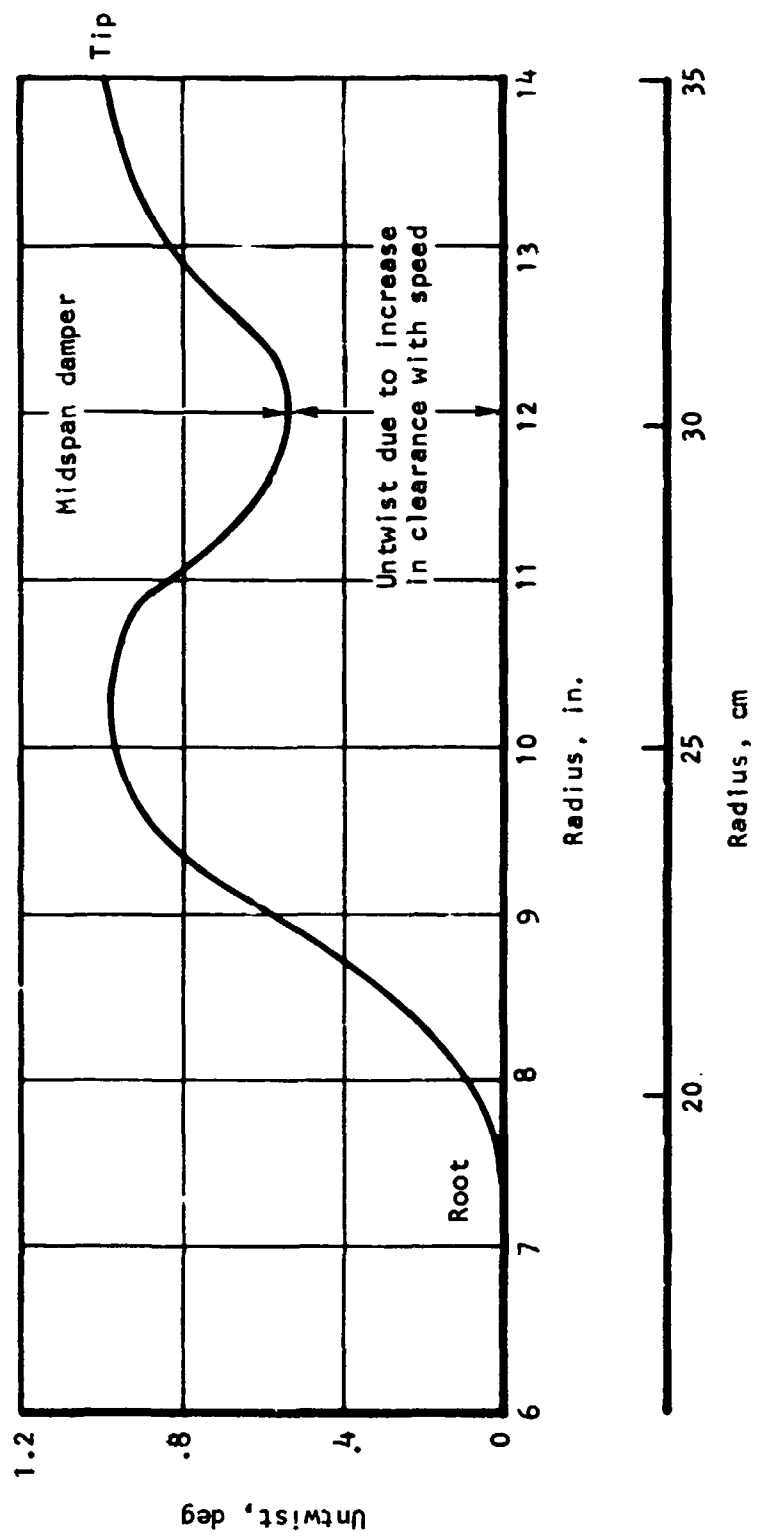


Figure A-10.--Blade Goodman-Solderburg Diagram.



S-1157

Figure A-11.--Fan Blade Equivalent Steady Stress Distribution.



S-80653

Figure A-12.--Airfoil Untwist at Design Speed.

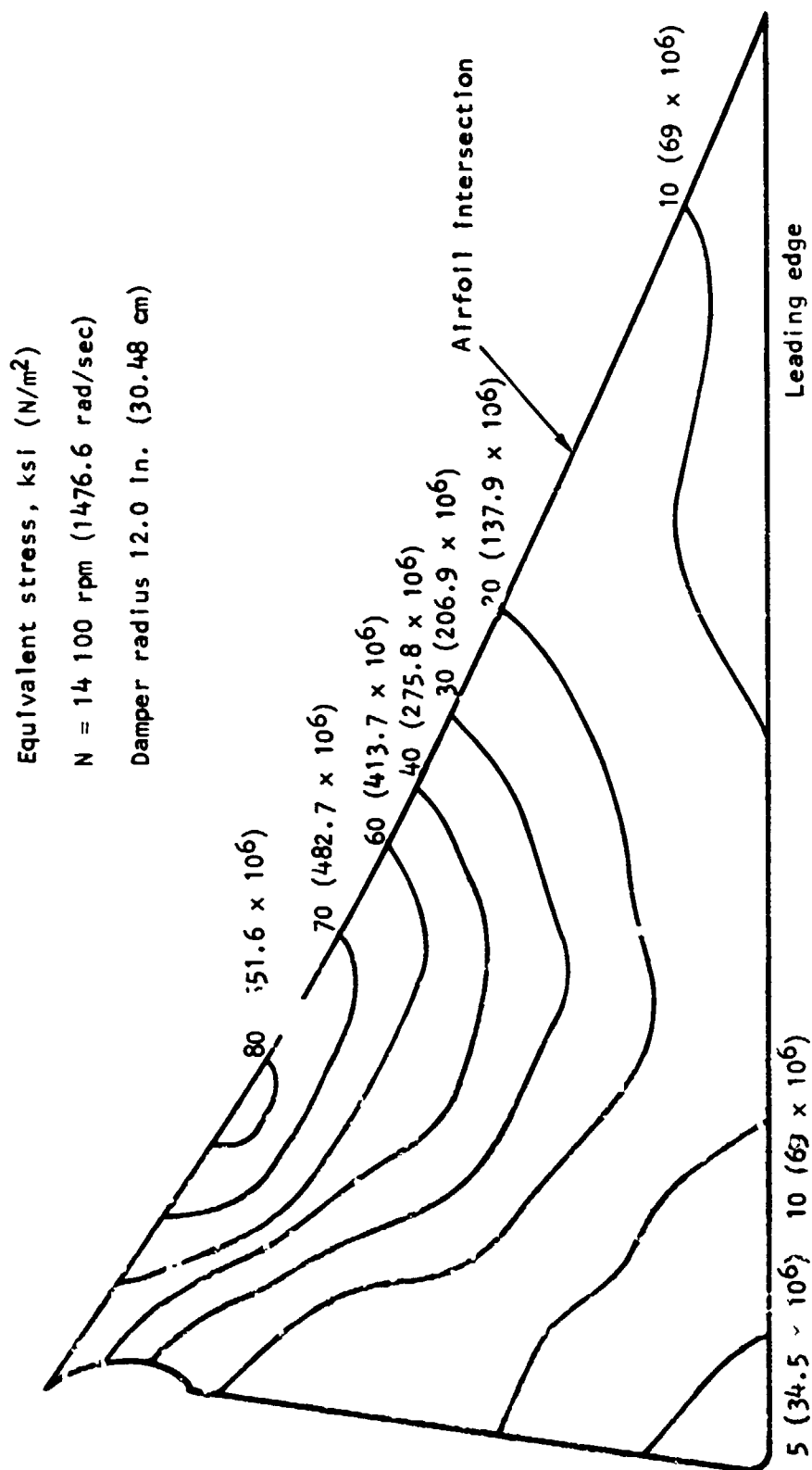


Figure A-13.--Midspan Damper Stress Distribution.

S-80517

APPENDIX B
SYMBOLS AND PERFORMANCE PARAMETER DEFINITIONS

Symbols

AR	aspect ratio
c	chord, in. (cm)
C_T	blade tip chord, in. (cm)
D	diffusion factor
D-shock	T.E. shock strength - L.E. shock strength, deg
D.I.	distortion index, $(P_{Tmax} - P_{Tmin})/P_{Tmax}$
f_B	first flexure natural frequency, Hz
h_T	relative deflection (translation) of the blade tip mid-chord point in the first flexural mode
i	incidence angle, angle between inlet air direction and line tangent to blade or vane at leading edge, deg
M	Mach number
N	rotational speed, rpm (rad/sec)
P	total pressure, psia (N/cm ²)
p	static pressure, psia (N/cm ²)
r	radius, in. (cm)
SL	streamline number
SM	stall margin, percent
T	total temperature, °R (°K)
t	static temperature, °R (°K)
t_{max}	blade maximum thickness, in. (cm)
U	rotor speed, ft/sec (m/sec)
V	air velocity, ft/sec (m/sec)
V_T'	relative fluid velocity at blade tip, ft/sec (m/sec)

W	weight flow rate, lbm/sec (kg/sec)
X	Carter's rule additive to deviation angle, deg
Z	axial distance, in. (cm)
β	air angle $\left[\cot^{-1}(V_m/V_\theta) \right]$, deg
β^*	metal angle on conical surface between tangent to mean camber line and axial direction at leading and trailing edge, deg
β_M	stagger or chord angle, angle between a chord line and axial direction (measured in a plane parallel to Z-axis), deg
$\Delta\beta$	camber or turning angle, deg
γ	ratio of specific heats for air
δ	ratio of mass average inlet total pressure to standard pressure of 14.696 psia (10.133 N/cm ²)
δ°	deviation angle, angle between exit air direction and tangent to blade mean camber line at trailing edge, deg
η	efficiency, percent
θ	ratio of inlet total temperature to standard temperature of 518.69°R (288.16°K)
θ_s	circumferential distortion screen relative angle, deg
σ	solidity, ratio of chord to spacing
ϕ	angle between tangent to streamline projected on meridional plane and axial direction, deg
ϕ_T	relative angular deflection of blade tip in first flexural mode, rad
$\bar{\omega}$	total pressure loss coefficient
ω_T	blade tip torsional natural frequency, Hz

Superscripts:

'	relative to moving blades
*	designates blade metal angle

Subscripts:

ad	adiabatic
id	ideal

L.E.	leading edge
M	meridional component
max	maximum
MCL	mean camber line
min	minimum
poly	polytropic
r	radial direction
ss	suction surface
T	denotes stagnation conditions
T.E.	trailing edge
Z	axial direction
θ	tangential component
0	inlet bellmouth screen plane
1	bellmouth instrumentation plane
5	rotor inlet instrumentation plane
5.5	rotor inlet traverse plane
6	rotor leading edge
8	rotor trailing edge
9	rotor exit traverse plane
10	stator leading edge
11	stator trailing edge
12	stage exit plane

Performance Parameter Definitions

i_m incidence angle based on mean camber line

$$i_m = \beta'_6 - \beta'^*_6 \quad (\text{rotor})$$

$$i_m = \beta_{10} - \beta^*_{10} \quad (\text{stator})$$

δ^0 deviation

$$\delta^0 = \beta_8' - \beta_8'^* \quad (\text{rotor})$$

$$\delta^0 = \beta_{11} - \beta_{11}^* \quad (\text{stator})$$

D diffusion factor

$$D = 1 - \frac{V_8'}{V_6'} + \frac{r_8 V_{\theta 8} - r_6 V_{\theta 6}}{(r_6 + r_8) \sigma V_6'} \quad (\text{rotor})$$

$$D = 1 - \frac{V_{11}}{V_{10}} + \frac{r_{10} V_{\theta 10} - r_{11} V_{\theta 11}}{(r_{10} + r_{11}) \sigma V_{10}} \quad (\text{stator})$$

$\bar{\omega}$ loss coefficient

$$\bar{\omega} = \frac{(P_8')_{id} - P_8'}{P_6' - p_6} \quad (\text{rotor})$$

$$\text{where } (P_8')_{id} = P_6' \left\{ \left[1 + \left(\frac{\gamma - 1}{2} \right) \left(\frac{u_8^2}{a_{01}^2} \right) \right] \left[1 - \left(\frac{r_6}{r_8} \right)^2 \right] \right\}^{\gamma/(\gamma-1)}$$

and a_{01} = upstream total acoustic velocity

$$\bar{\omega} = \frac{P_{10} - P_{11}}{P_{10} - p_{10}} \quad (\text{stator})$$

loss parameter

$$\frac{\bar{\omega} \cos \beta_8'}{2\sigma} \quad (\text{rotor})$$

$$\frac{\bar{\omega} \cos \beta_{11}}{2\sigma} \quad (\text{stator})$$

η_{poly} polytropic efficiency

$$\eta_{poly} = \frac{\frac{\gamma - 1}{\gamma} \ln \left[\frac{P_8}{P_6} \right]}{\ln \left[\frac{T_8}{T_6} \right]} \quad (\text{rotor})$$

$$\eta_{poly} = \frac{\frac{\gamma - 1}{\gamma} \ln \left[\frac{P_{11}}{P_{10}} \right]}{\ln \left[\frac{t_{11}}{t_{10}} \right]} \quad (\text{stator})$$

$$\eta_{poly} = \frac{\frac{\gamma - 1}{\gamma} \ln \left[\frac{P_{12}}{P_5} \right]}{\ln \left[\frac{T_{12}}{T_5} \right]} \quad (\text{stage})$$

η_{ad} adiabatic efficiency

$$\eta_{ad} = \frac{\left[\frac{P_8}{P_6} \right]^{\frac{\gamma-1}{\gamma}} - 1}{\left[\frac{T_8}{T_6} \right] - 1} \quad (\text{rotor})$$

$$\eta_{ad} = \frac{\left[\frac{P_{12}}{P_5} \right]^{\frac{\gamma-1}{\gamma}} - 1}{\left[\frac{T_{12}}{T_5} \right] - 1} \quad (\text{stage})$$

SM

stall margin

$$SM = \left[\left(\frac{\frac{P_{12}}{P_5}}{\frac{W\sqrt{\theta}}{\delta}} \right)_{\text{at stall}} \left(\frac{\frac{W\sqrt{\theta}}{\delta}}{\frac{P_{12}}{P_5}} \right)_{\text{at reference point}} - 1 \right] \times 100\% \quad N/\sqrt{\theta} = \text{constant}$$

For absolute values of stall margin, the reference point at any speed and inlet flow condition (whether uniform or distorted) is defined as the intersection of a particular speed line with the constant throttle line passing through design pressure ratio at design speed obtained with uniform inlet flow.

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