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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-ft^2 ($205.1 \text{ kgm/sec-m}^2$) 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 by 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 giving 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 ± 3 ksi ($\pm 20.7 \times 10^6 \text{ N/m}^2$) for the rotor blades and ± 4.5 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 that 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

$\frac{N}{\sqrt{\sigma}}$ ($N/\sqrt{\sigma}$) _{des}	Reading	$\frac{W/\sqrt{\sigma}}{(W/\sqrt{\sigma})}$ _{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	0.818
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	0.828	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

$\frac{N}{N_{des}}$ (N_{des})	Reading	$\frac{W\sqrt{z}/s}{(W\sqrt{z}/s)_{des}}$	$\frac{T_{T12}-T_{T5}}{T_{T5}}$	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	0.780	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	0.867	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	$\frac{W\sqrt{c/l}}{(W\sqrt{c/l})_{des}}$	$\frac{T_{T12}-T_{T5}}{T_{T5}}$	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	0.85	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.

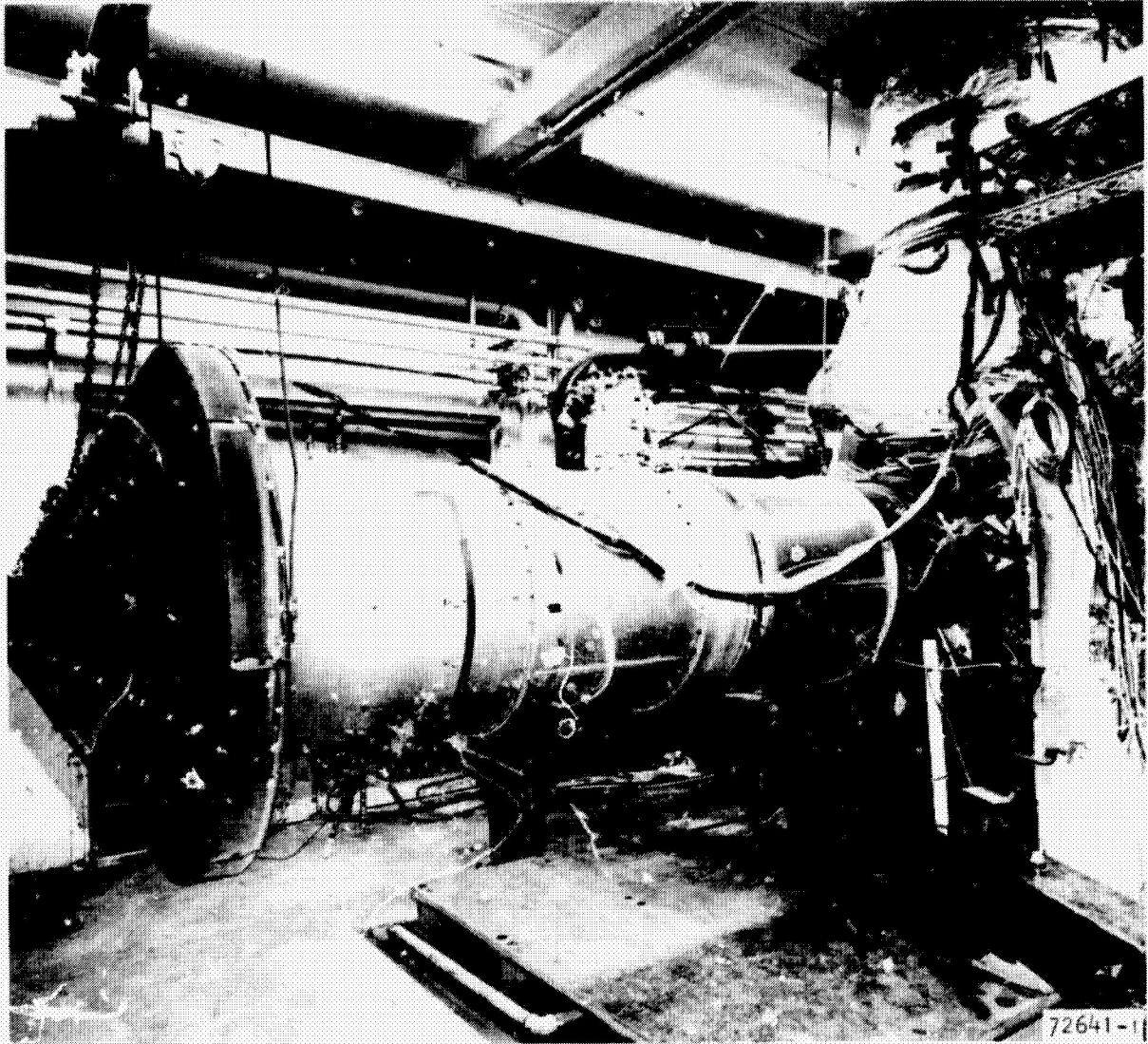
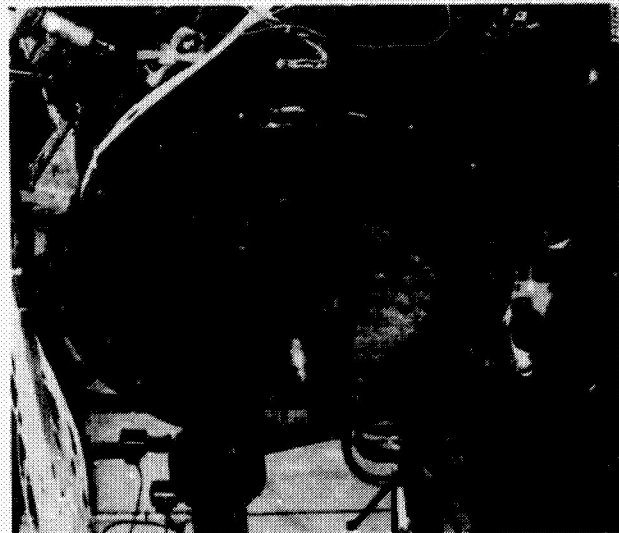
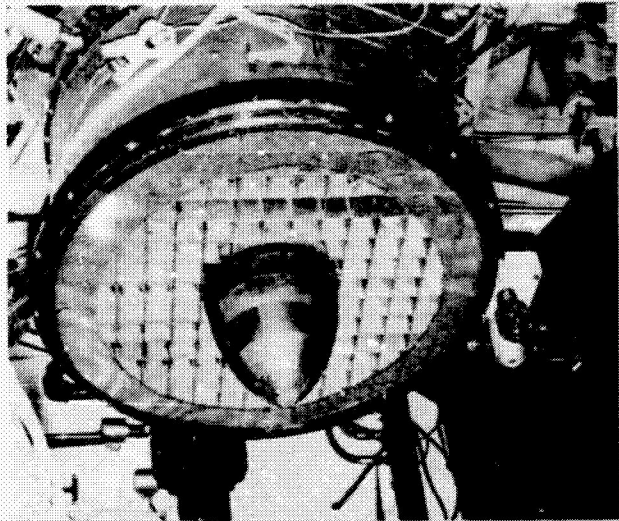


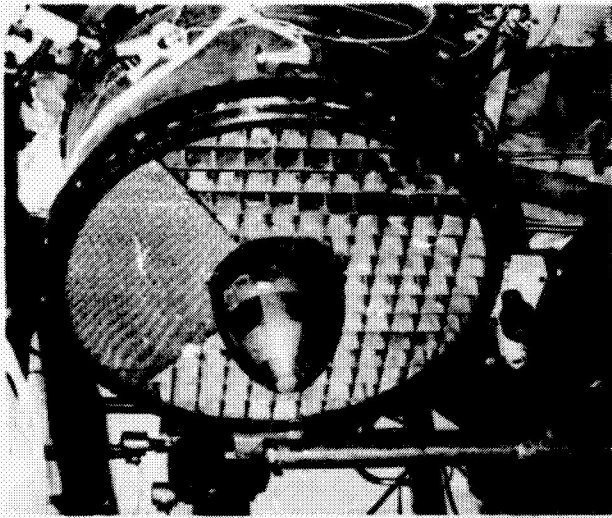
Figure 1.--Sea Level Compressor Test Cell.



(a) Hub-radial distortion screen.

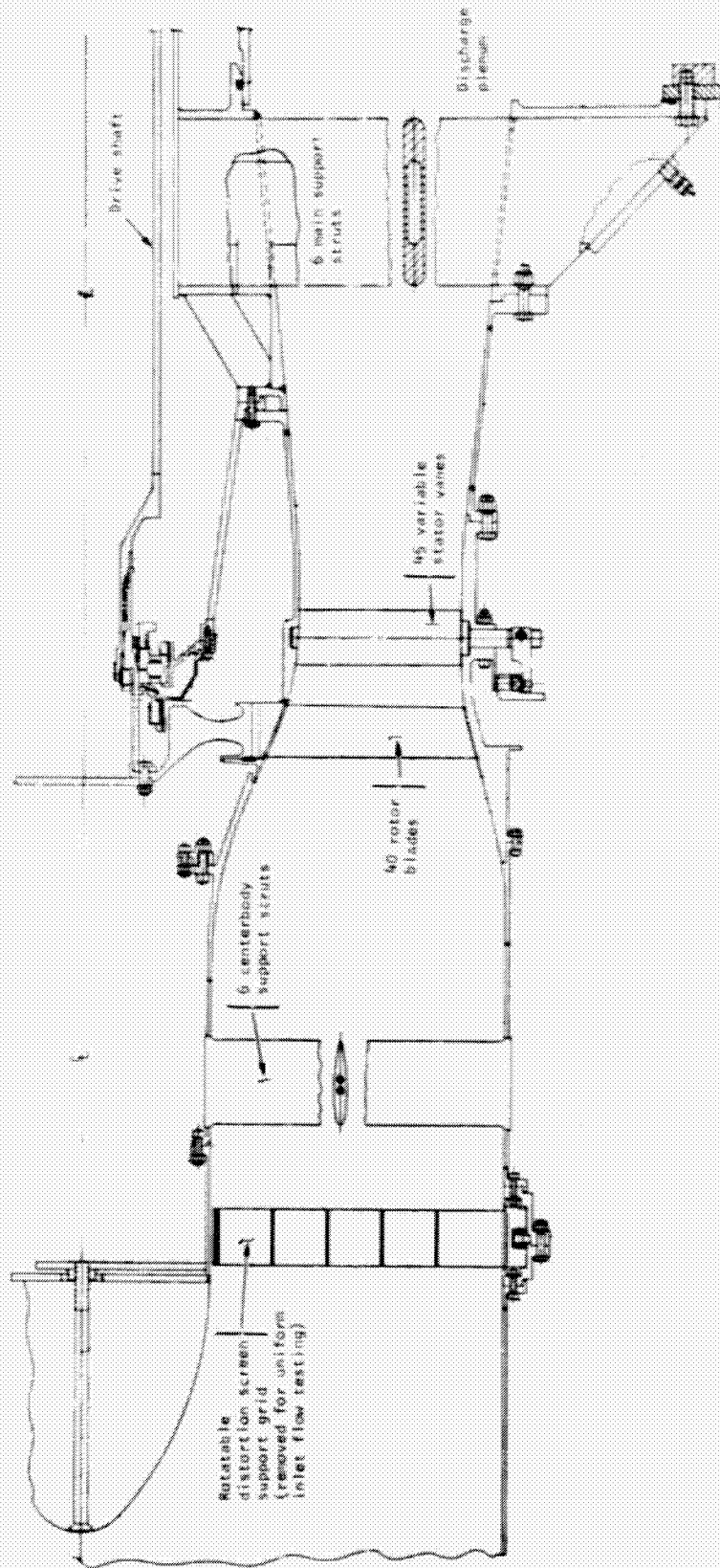


(b) Tip-radial distortion screen.



(c) Circumferential distortion screen. F-18625

Figure 2.--Distortion Screens.



S-82862

Figure 3.--Fan Cross Section.

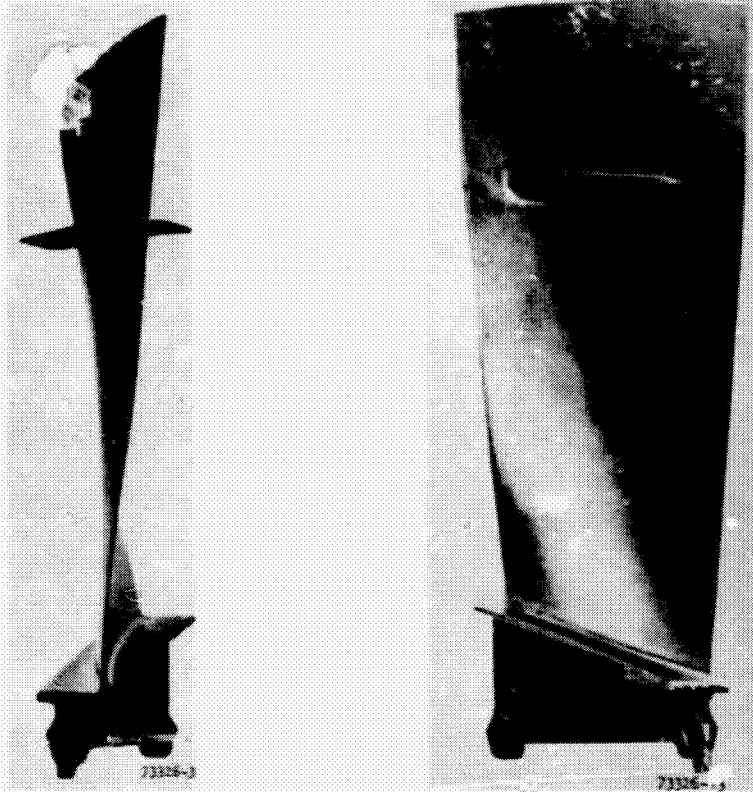
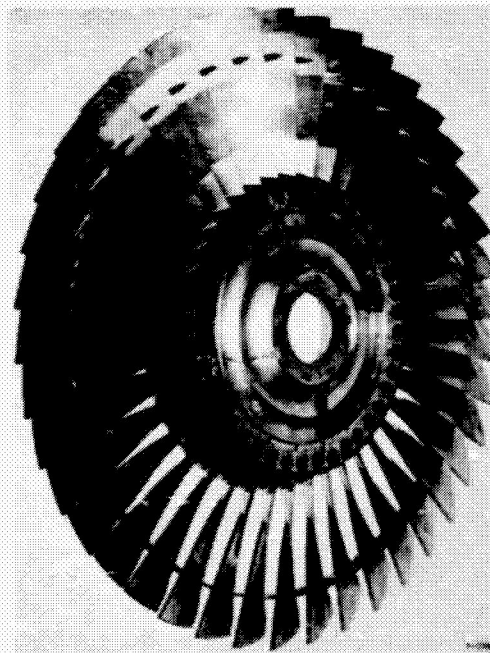


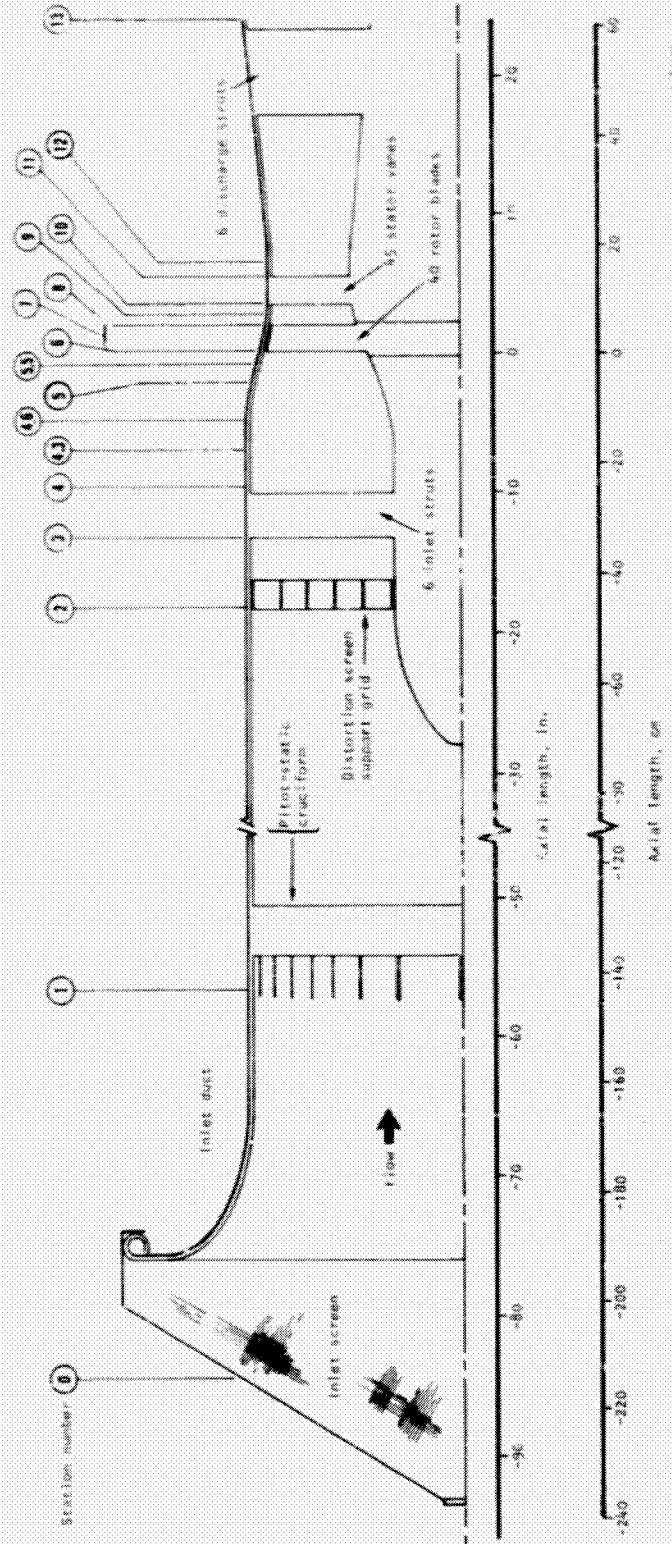
Figure 4.--Rotor Blade.



F-19102

Figure 5.--Bladed Disc Assembly.

Note: Station 10 is the inlet station diameter of station 11.



Station number	Location	Station number	Location
0	Inlet bellmouth screen	7	Rotor casing instrumentation
1	Bellmouth instrumentation plane	8	Rotor leading edge
2	Distortion screen plane	9	Rotor exit traverse plane
3, 4, 4.3, 4.6	Inlet dust instrumentation	10	Stator leading edge
5	Rotor inlet instrumentation plane	11	Stator trailing edge
5.5	Rotor inlet traverse plane	12	Stage exit instrumentation plane
6	Rotor leading edge	13	Plenum inlet plane

Figure 6.--Axial Station Designations.

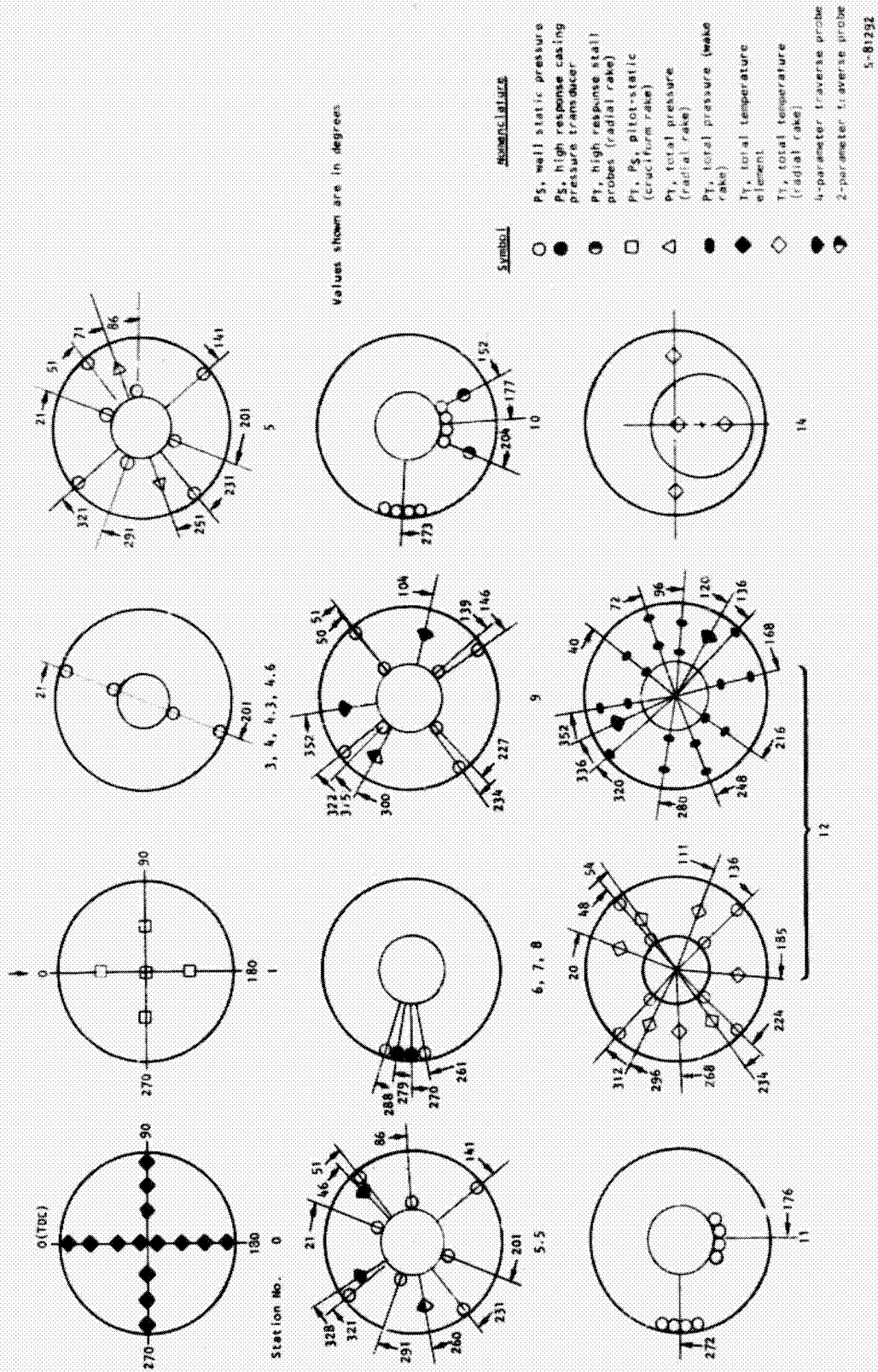
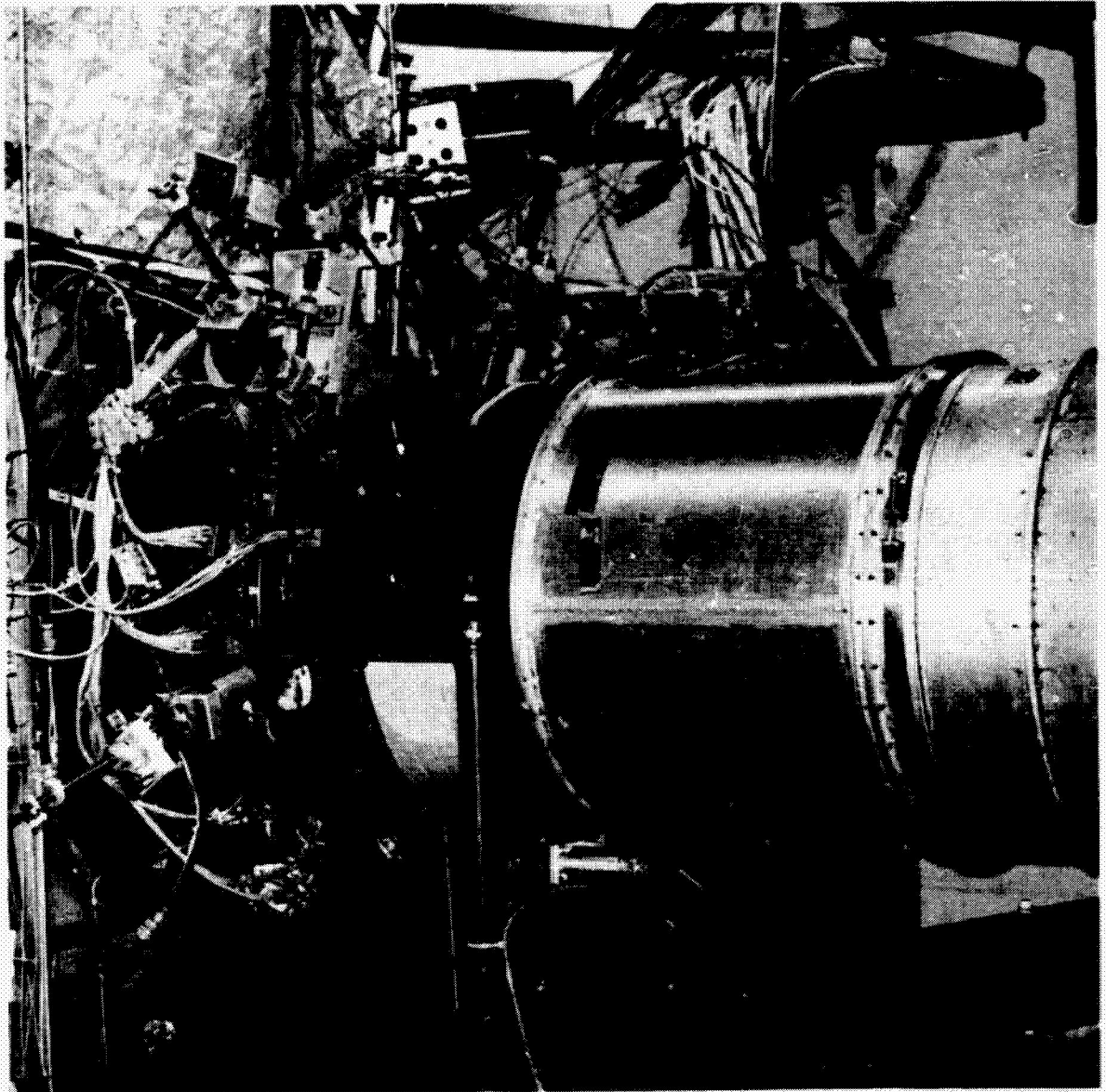
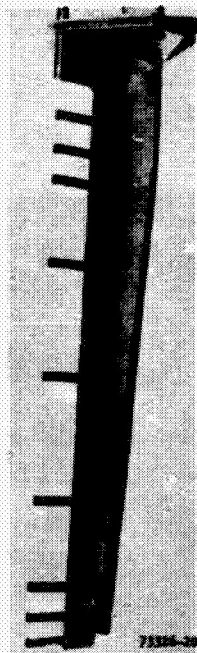


Figure 7.--Circumferential Position of Instrumentation Viewed Aft, Looking Forward.

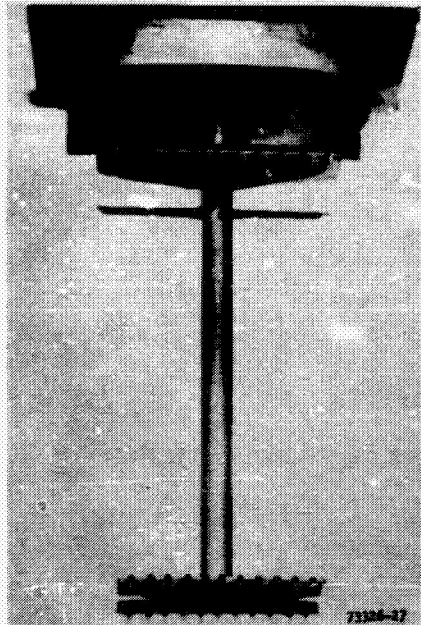


F-18623

Figure 8.--Instrumented Test Compressor.

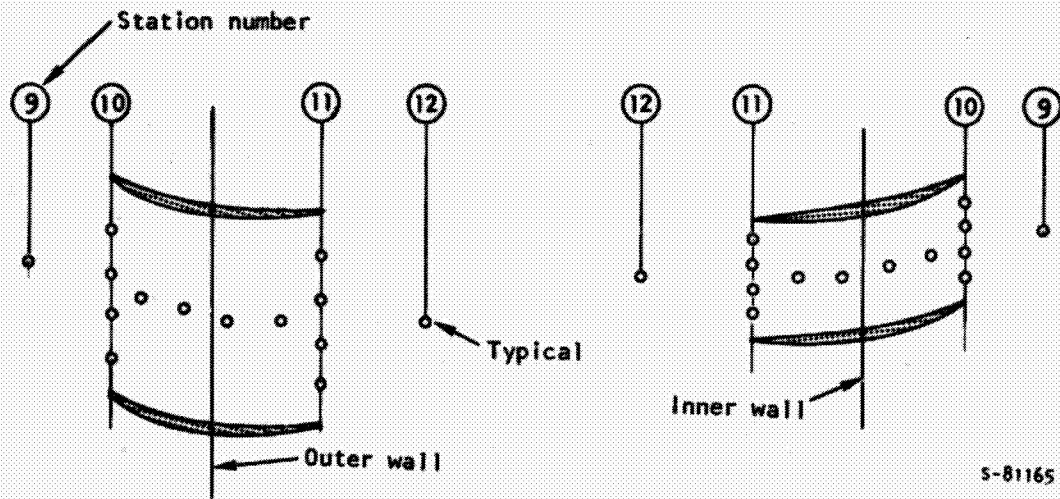


(a) Temperature Rake.



(b) Total Pressure Rake.

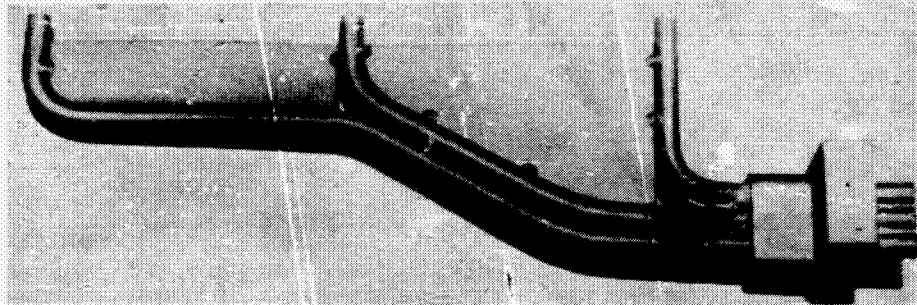
Figure 9.--Stage Exit Temperature and Total Pressure Rakes.



S-81165

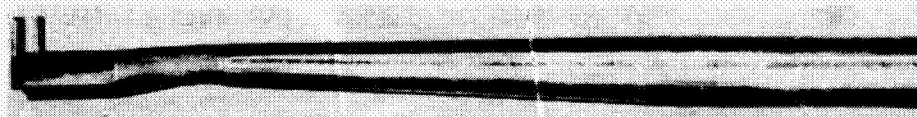
F-19137

Figure 10.--Stator Channel Static Pressure Schematic.



(a) Stall Sensing Radial Rake.

73326-21



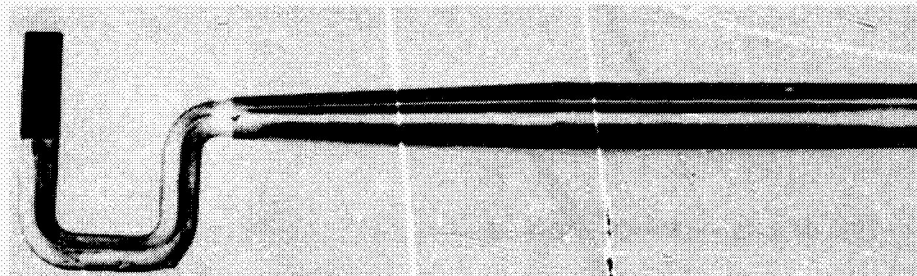
(b) 60-Deg Wedge Probe.

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.

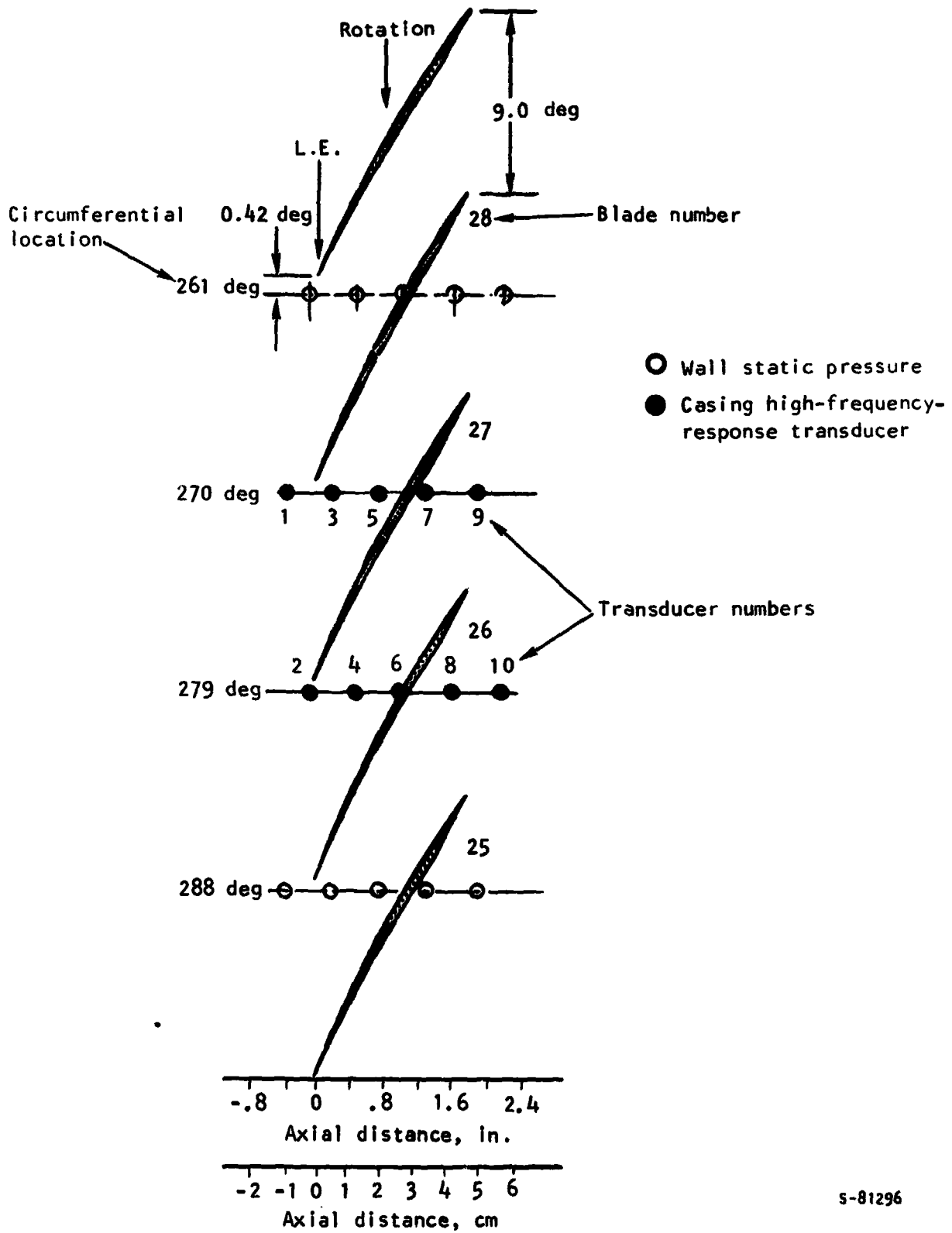
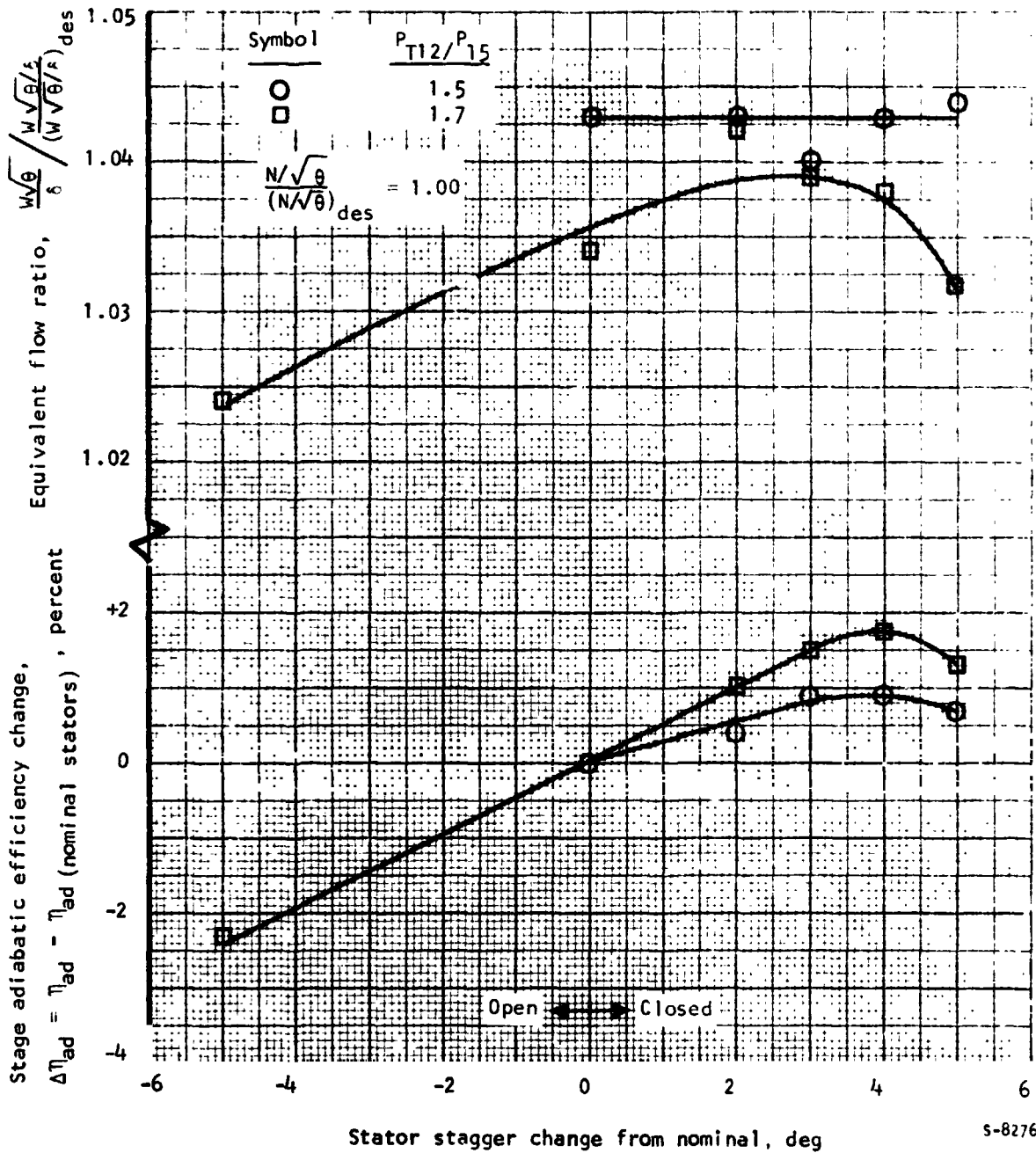


Figure 12.--High-Response Casing Pressure Transducer Locations.



S-82760

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

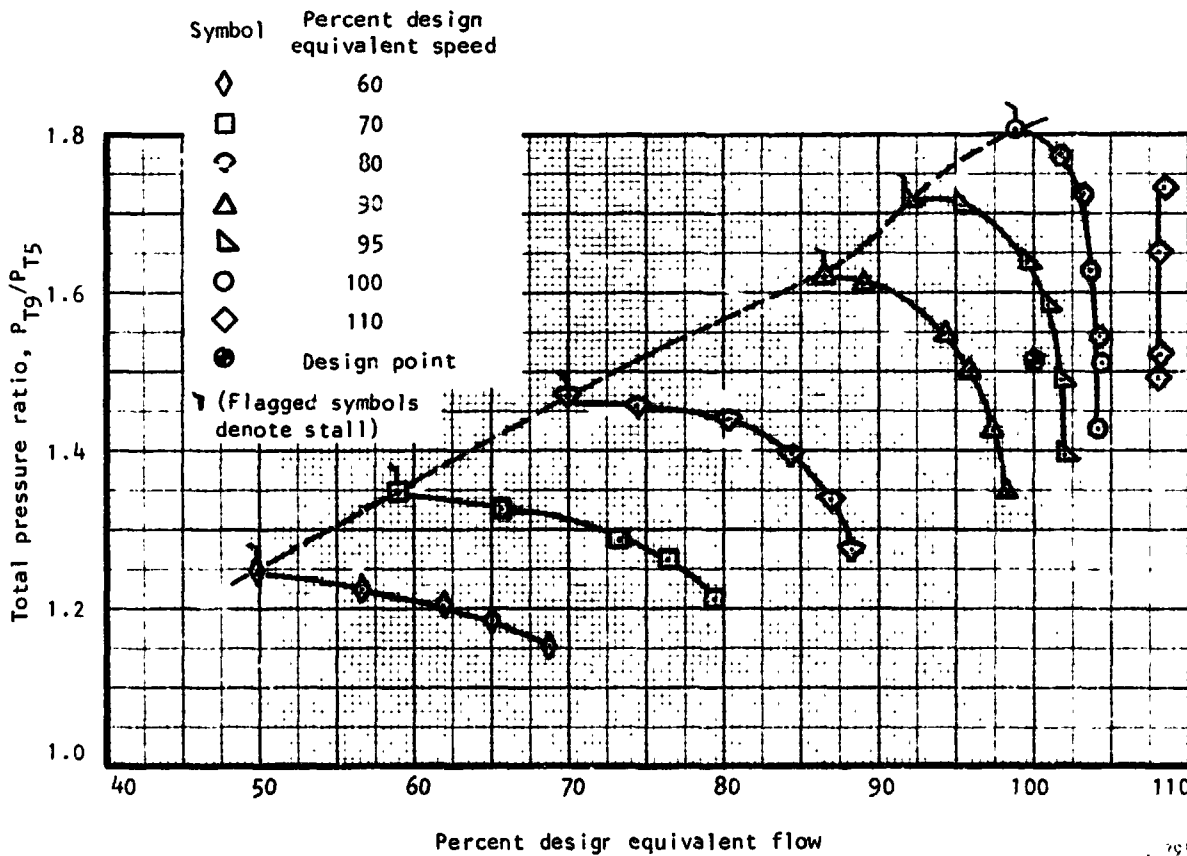
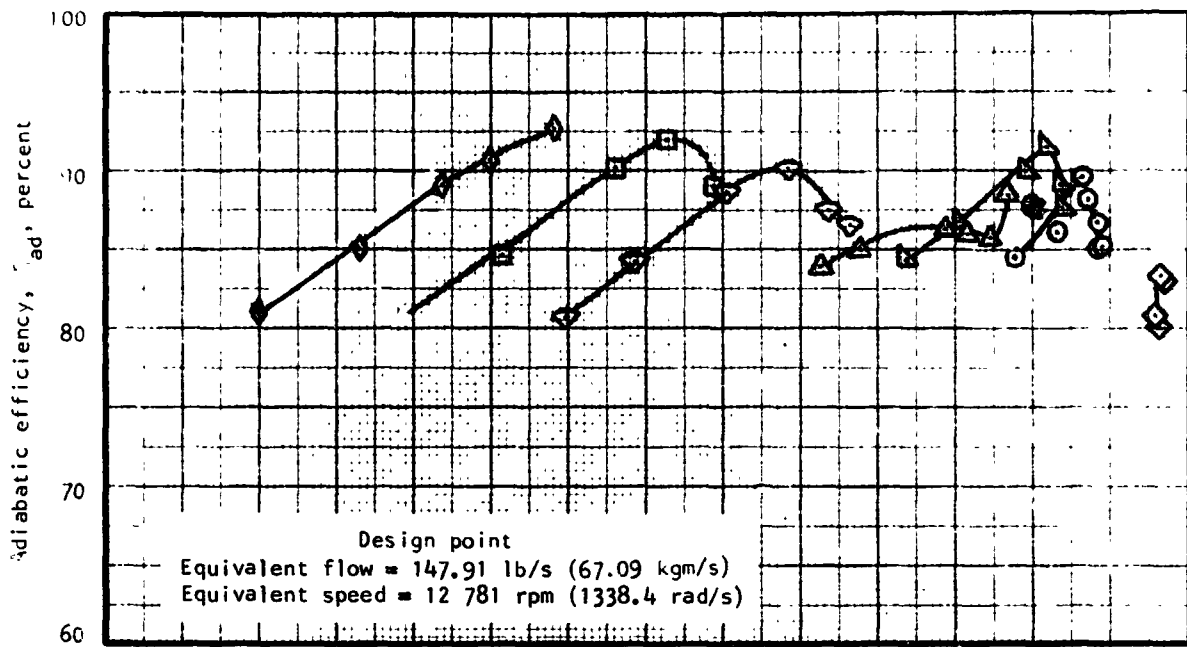
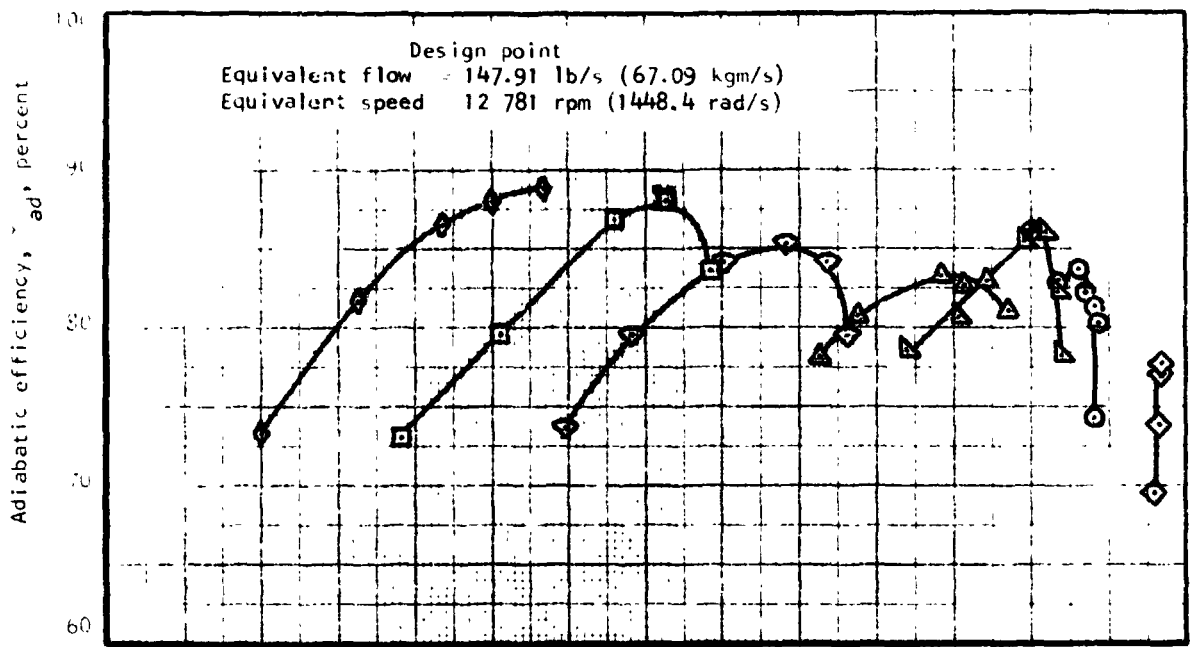


Figure 14.--Rotor Performance, Uniform Inlet Flow.



Symbol	Percent design equivalent speed
◇	60
□	70
◇	80
△	90
▷	95
○	100
◇	110
●	Design point

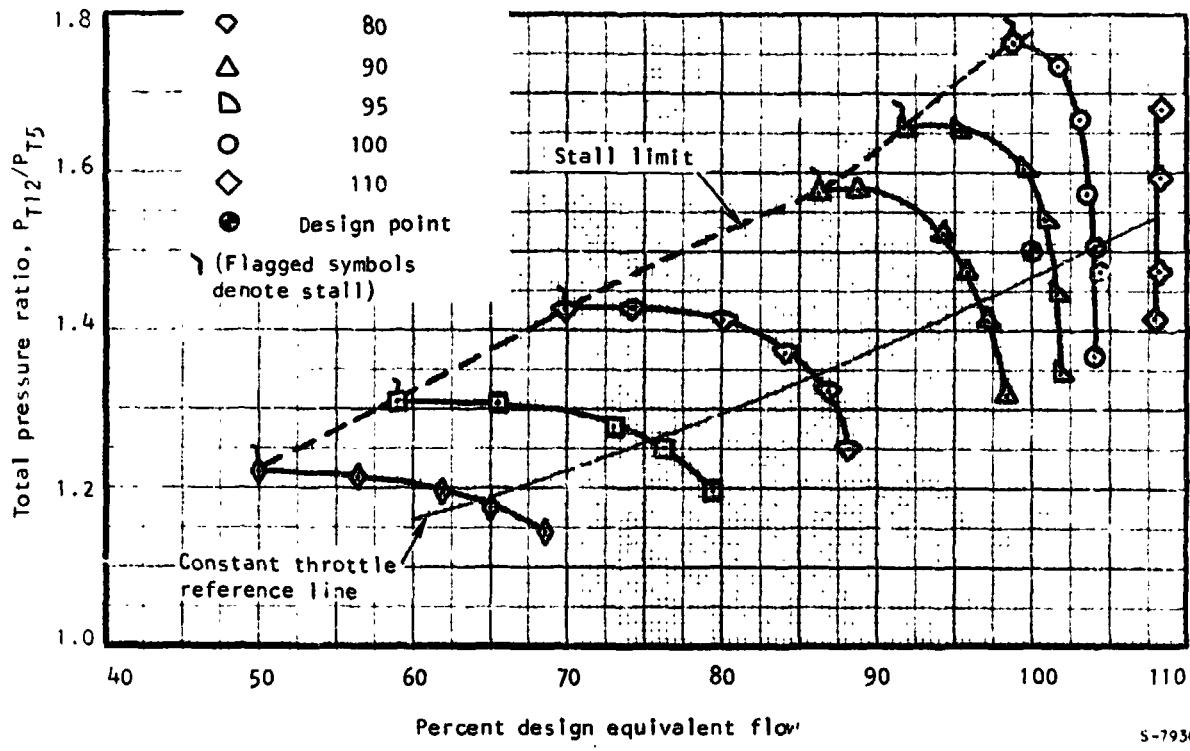
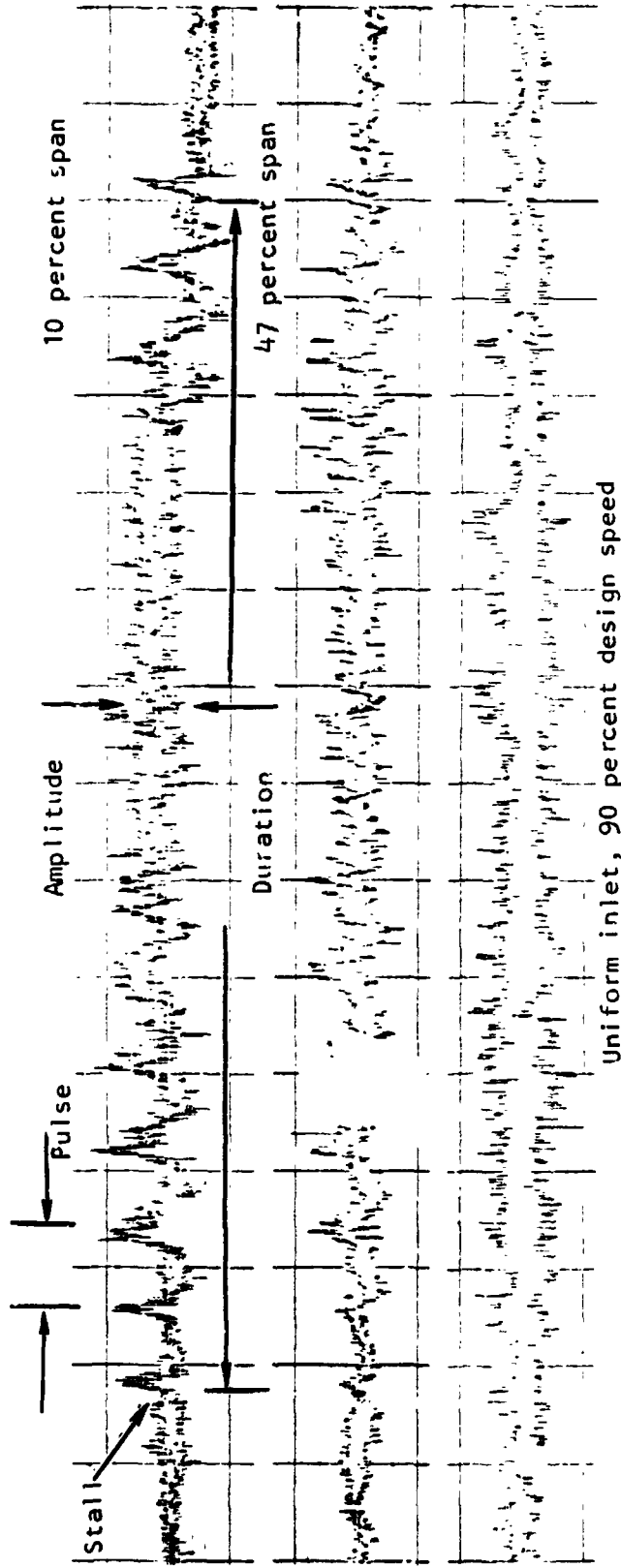


Figure 15.--Stage Performance, Uniform Inlet Flow.

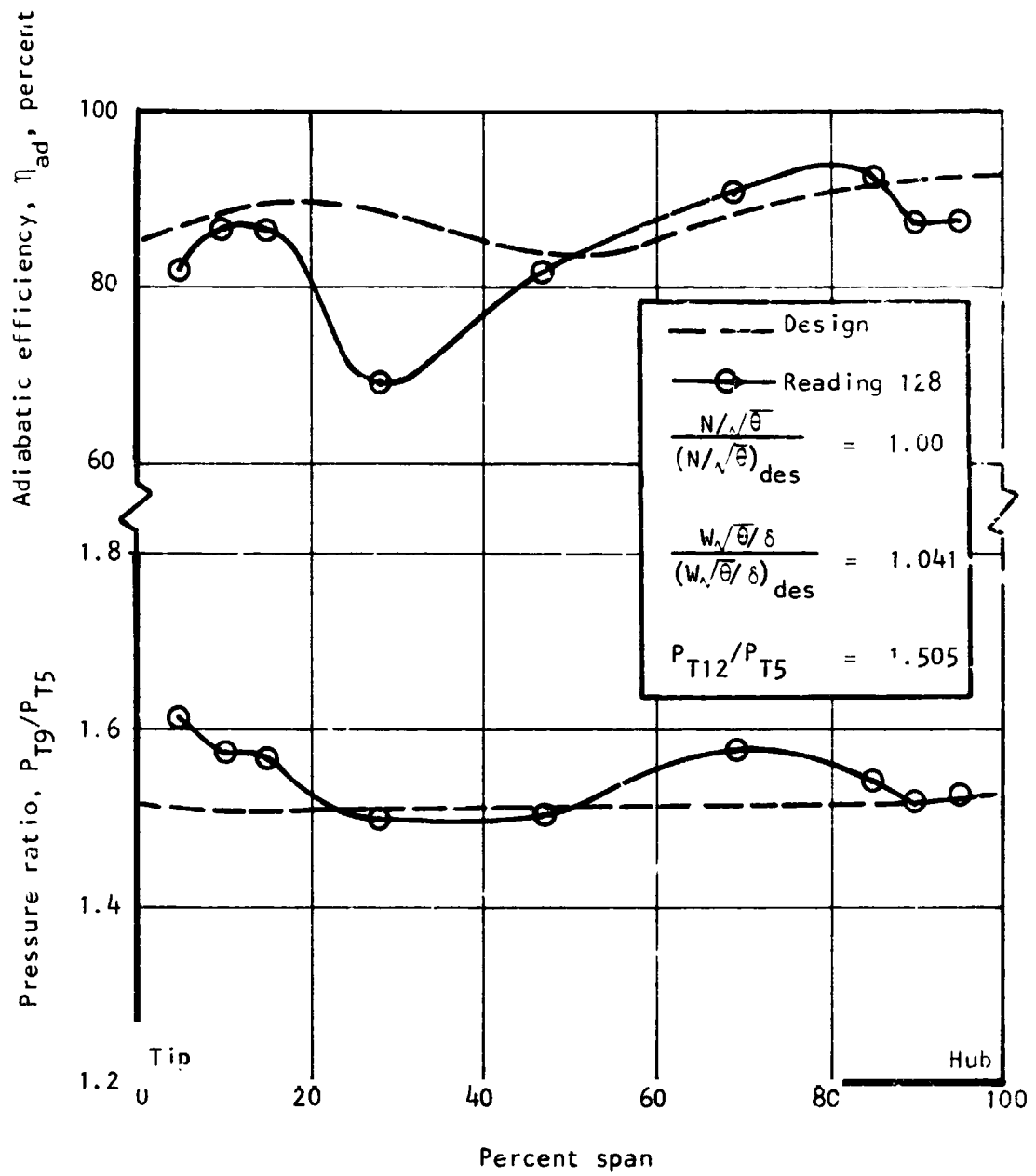
S-79306



Uniform inlet, 90 percent design speed

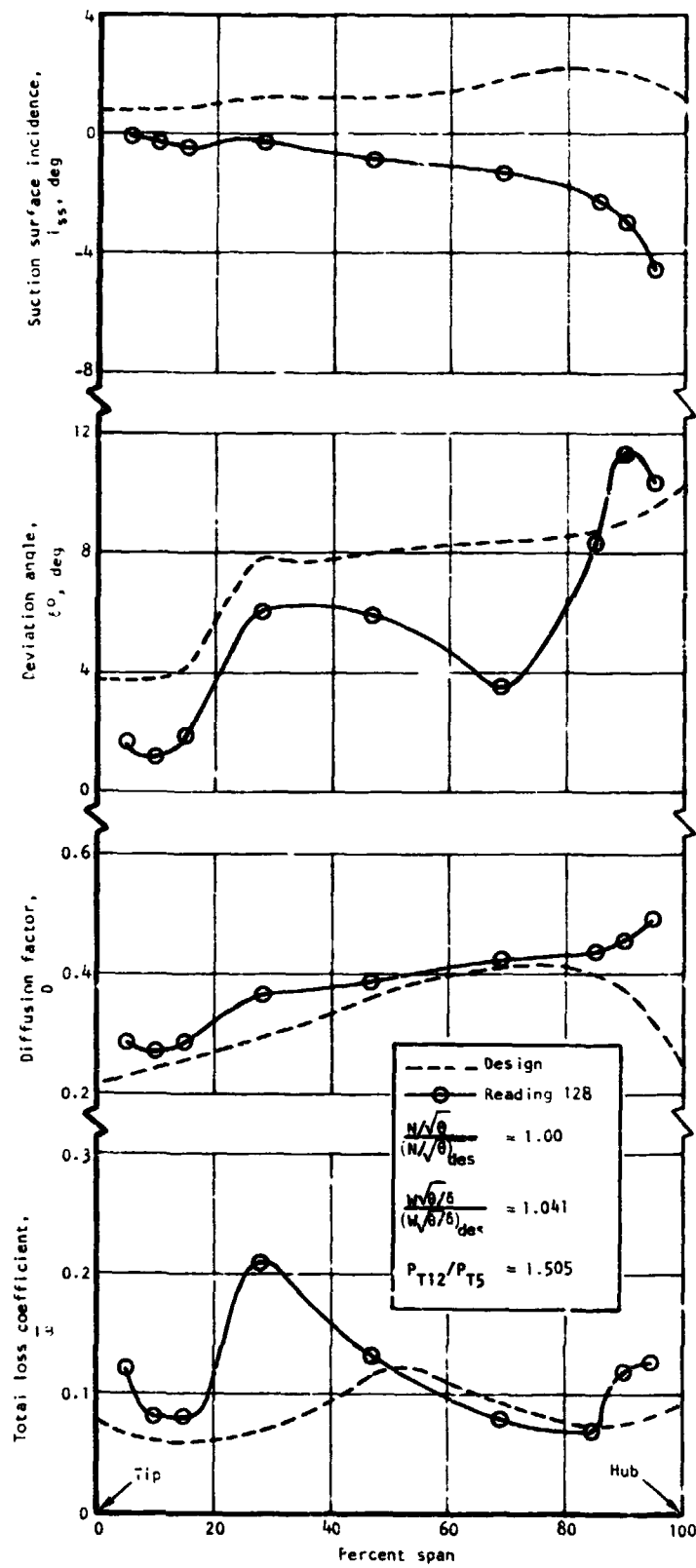
S-85364

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



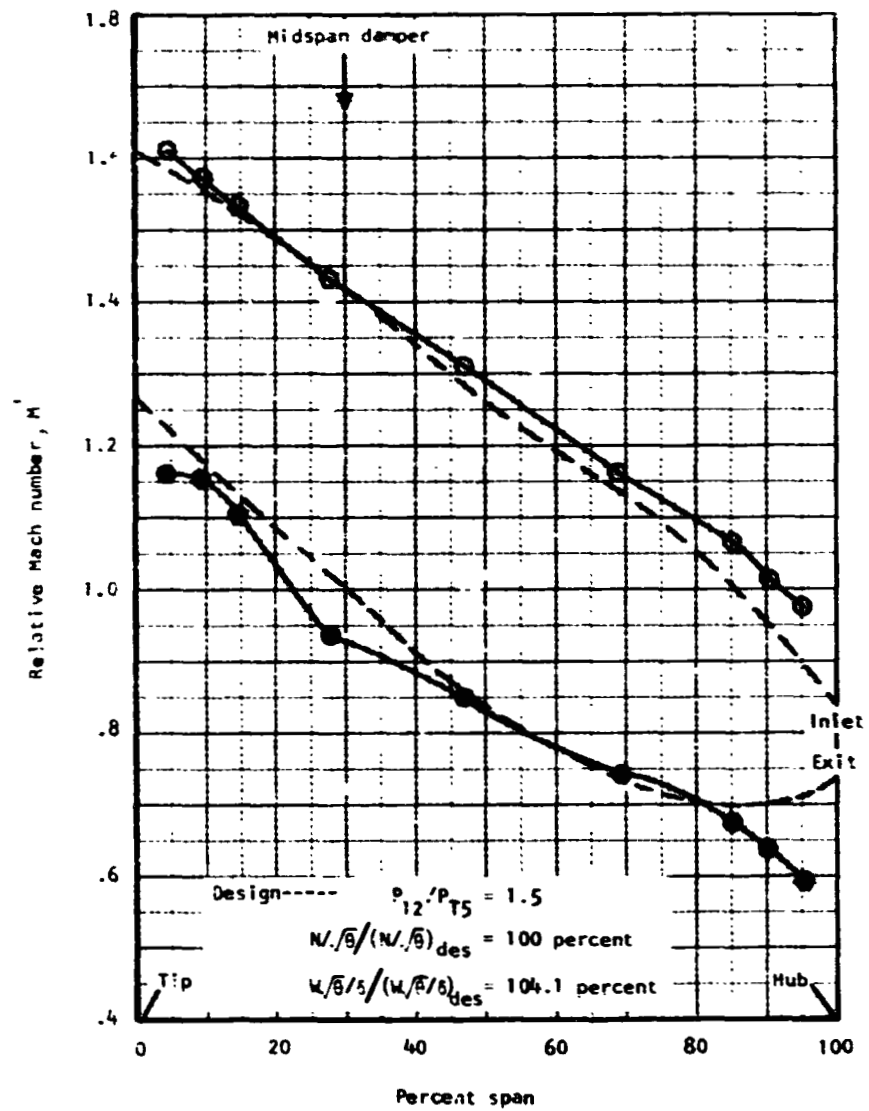
S-81627

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.

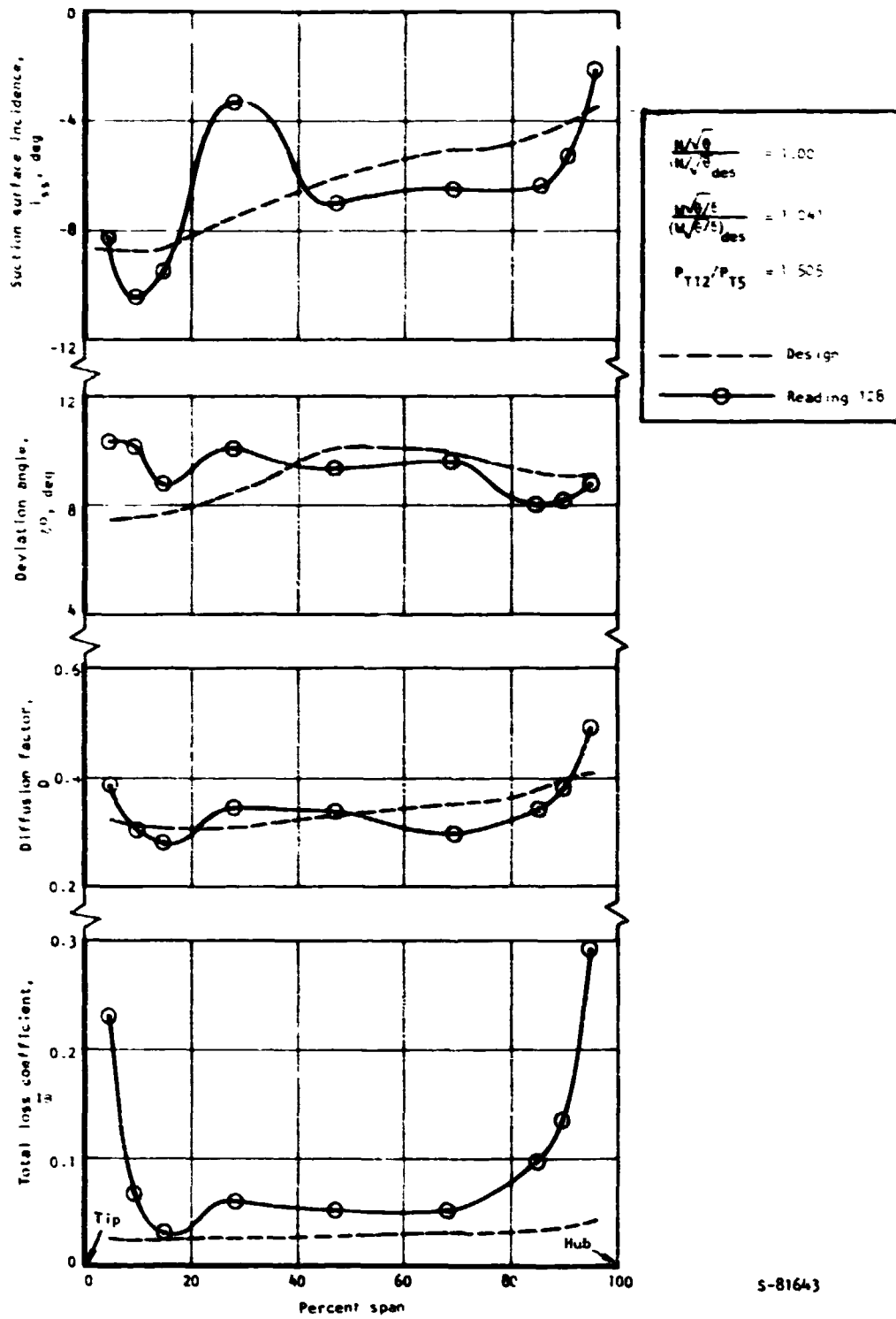


Figure 20.--Stator Vane Element Performance, Uniform Inlet Flow.

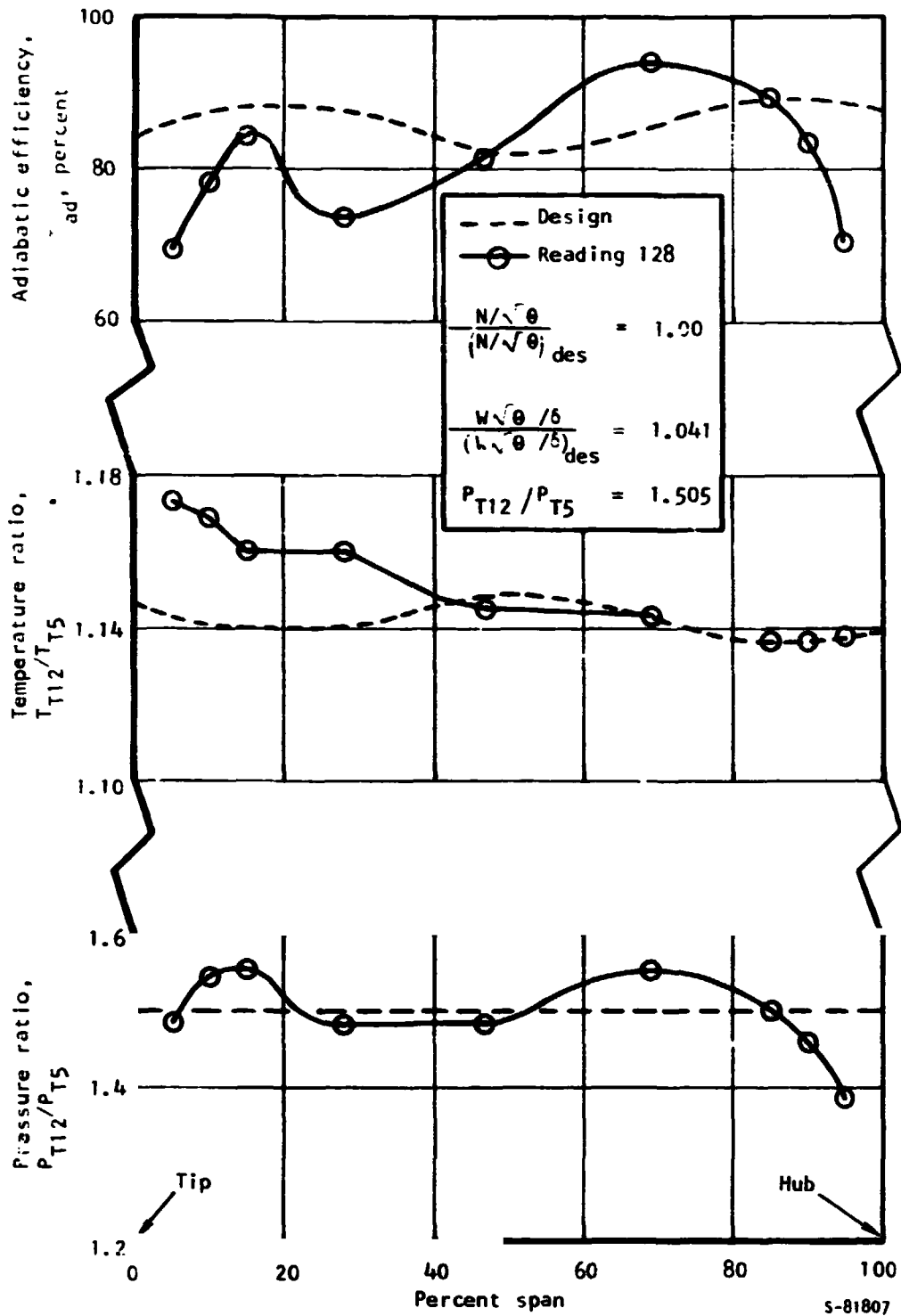


Figure 21.-- Stage Element Performance, Uniform Inlet Flow.

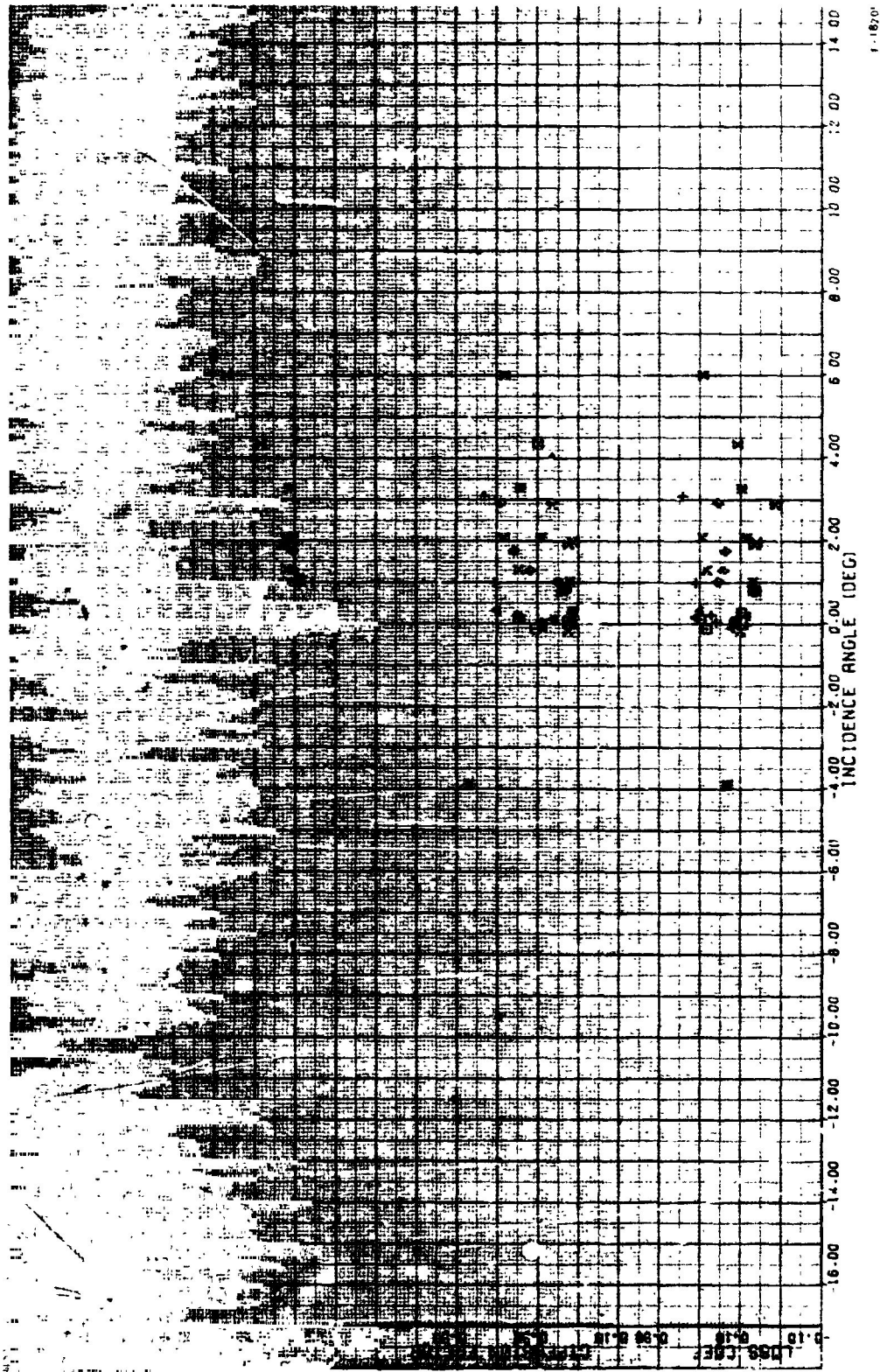


Figure 22a.--Rotor Blade Element Performance, Uniform Inlet Flow,
5 Percent Span from Tip.

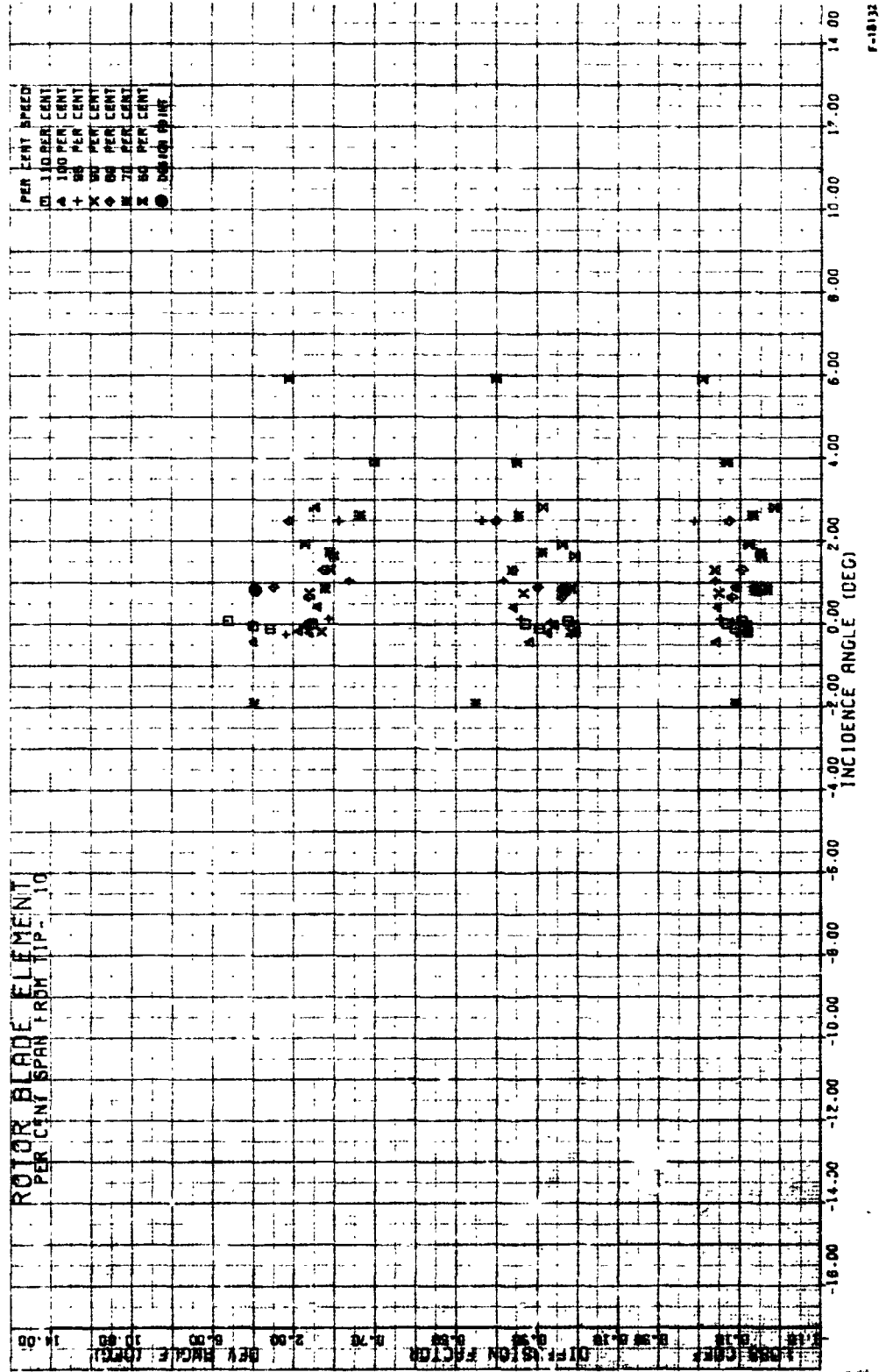


Figure 22b.--Rotor Blade Element Performance, Uniform Inlet Flow,
10 Percent Span from Tip.

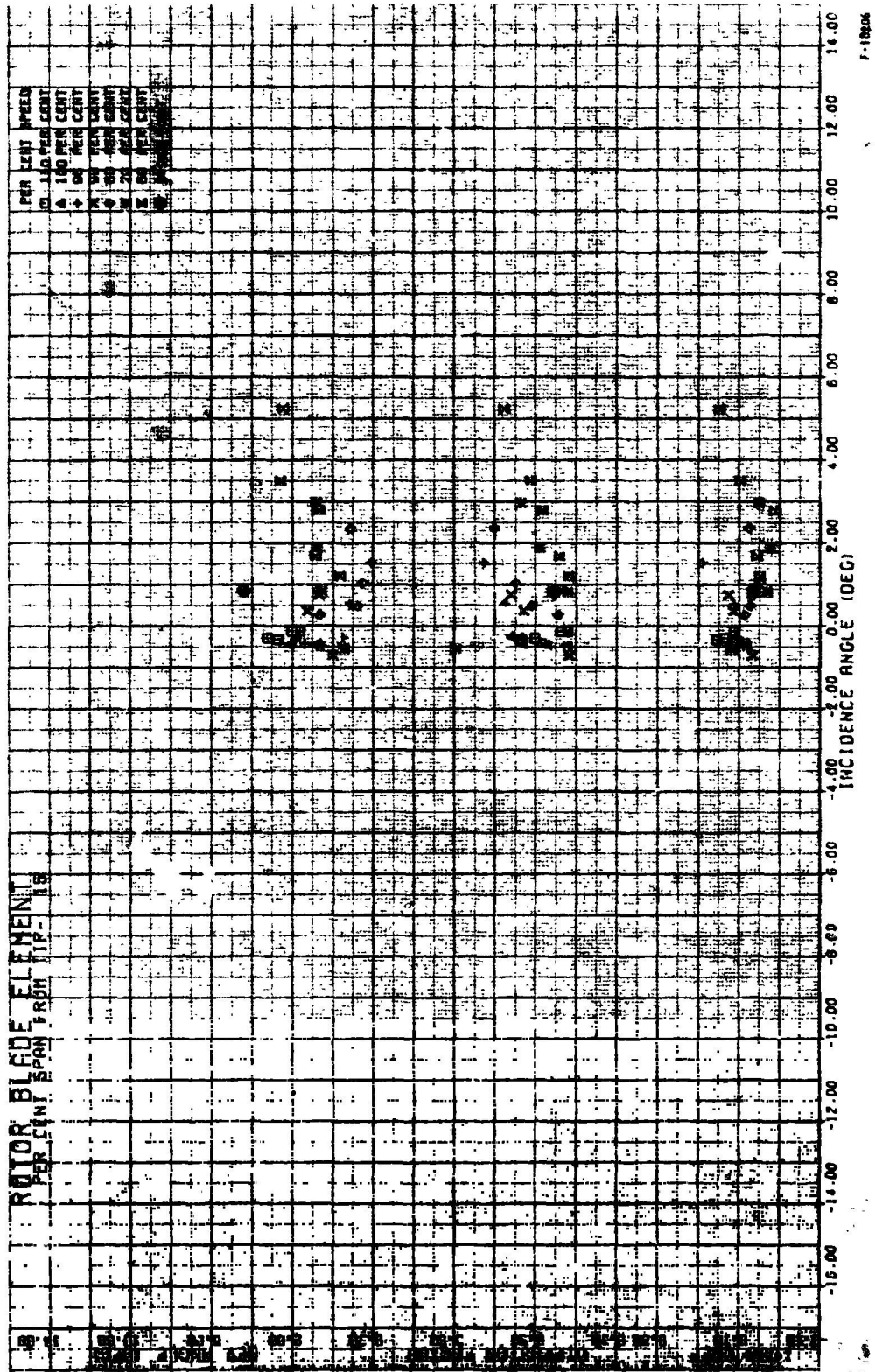


Figure 22c.--Rotor Blade Element Performance, Uniform Inlet Flow, 15 Percent Span from Tip.

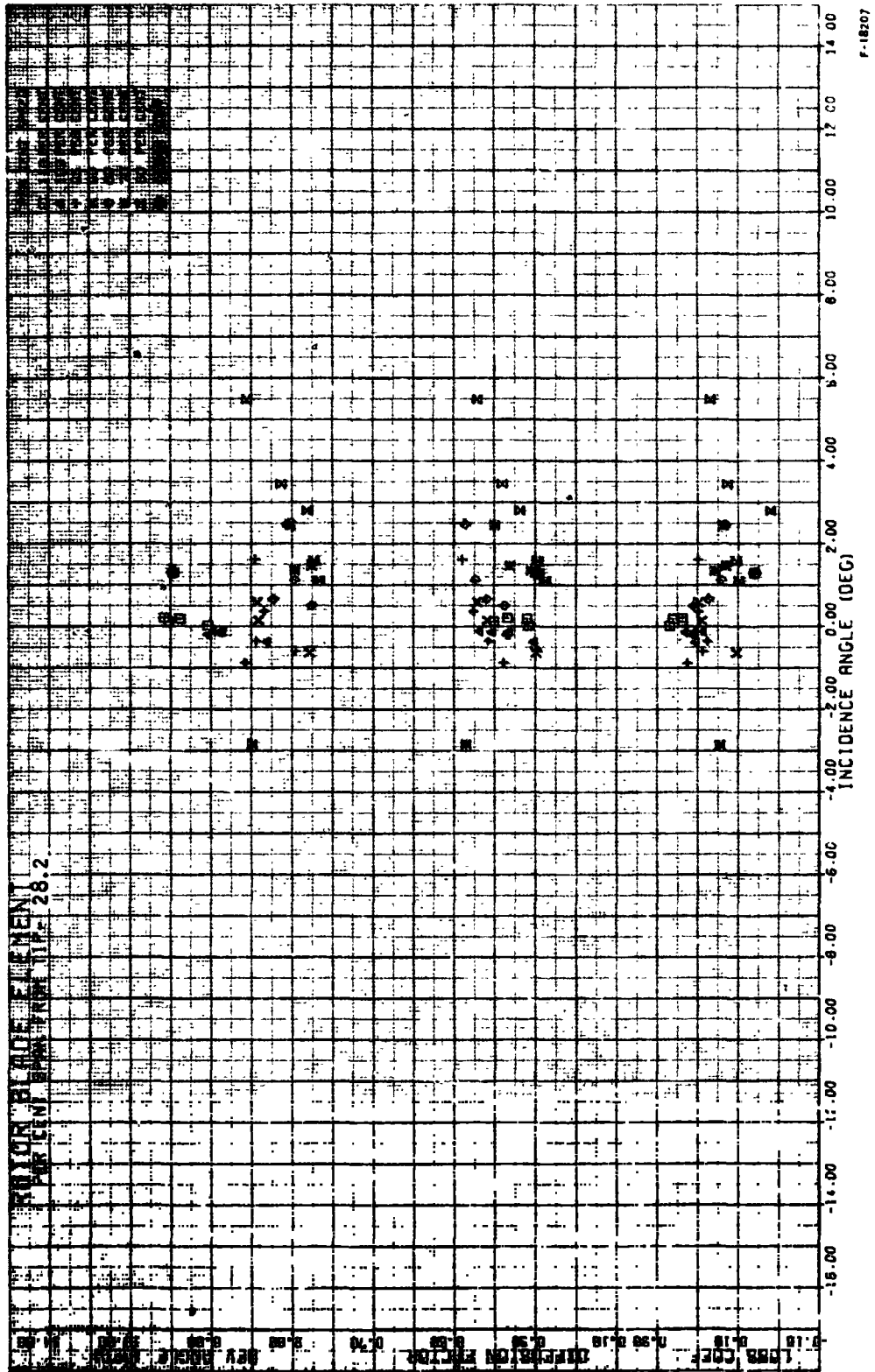
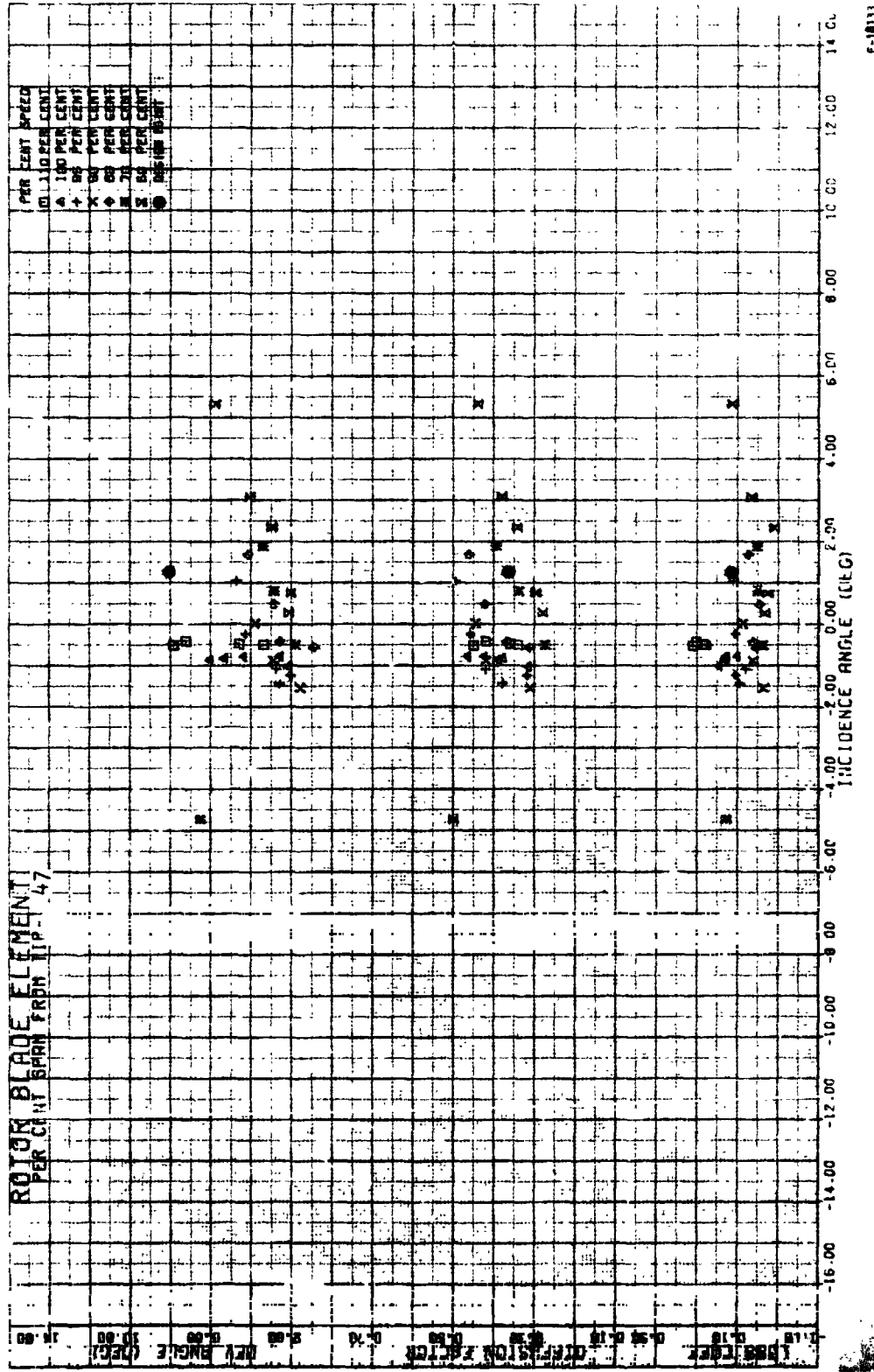


Figure 22d.--Rotor Blade Element Performance, Uniform Inlet Flow, 28.2 Percent Span from Tip.



P-18133

Figure 22e.--Rotor Blade Element Performance, Uniform Inlet Flow, 47 Percent Span from Tip.

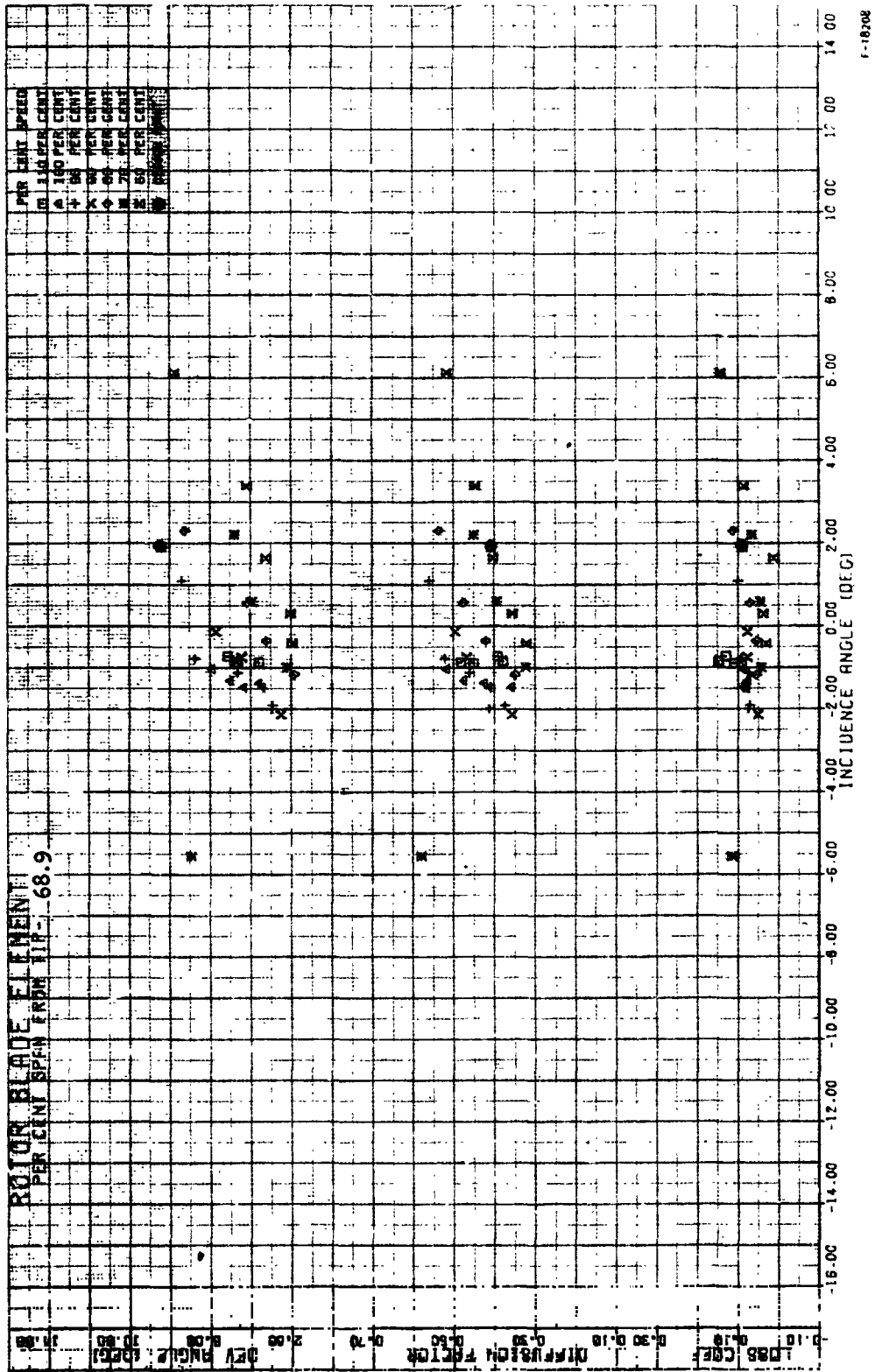


Figure 22f.--Rotor Blade Element Performance, Uniform Inlet Flow, 68.9 Percent Span from Tip.

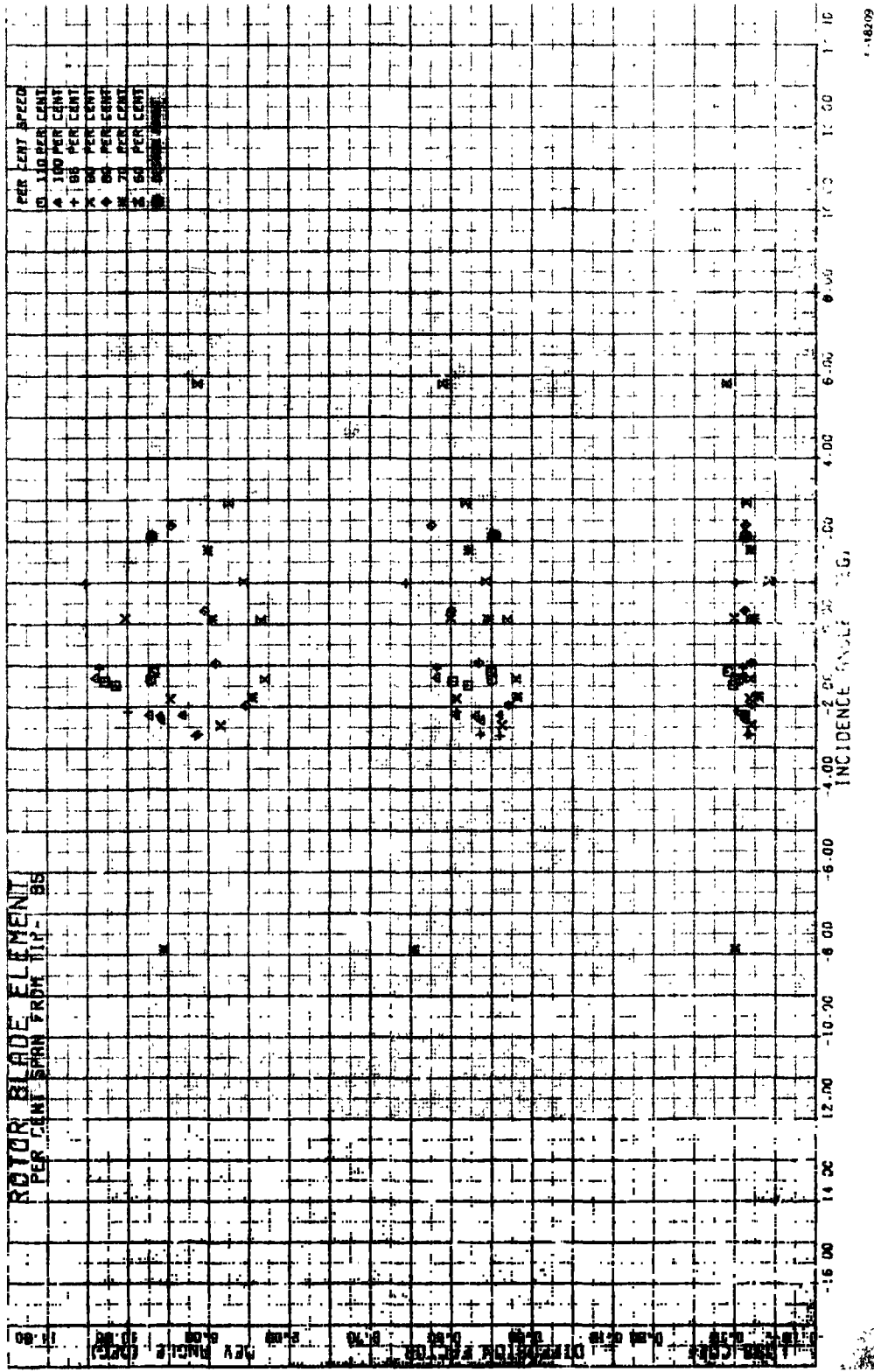


Figure 22g.--Rotor Blade Element Performance, Uniform Inlet Flow, 85 Percent Span from Tip.

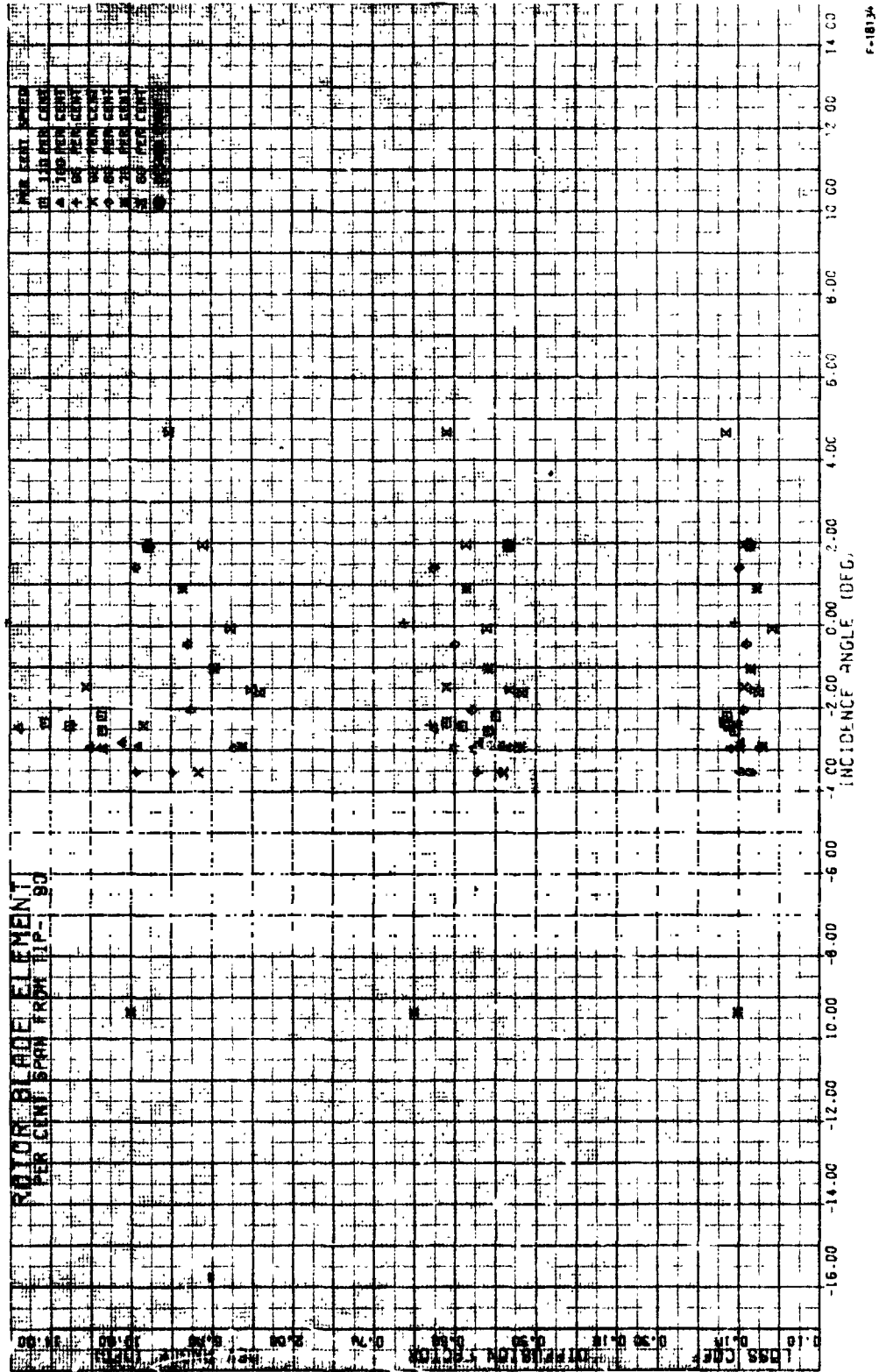


Figure 22i.--Rotor Blade Element Performance, Uniform Inlet Flow, 90 Percent Span from Tip.

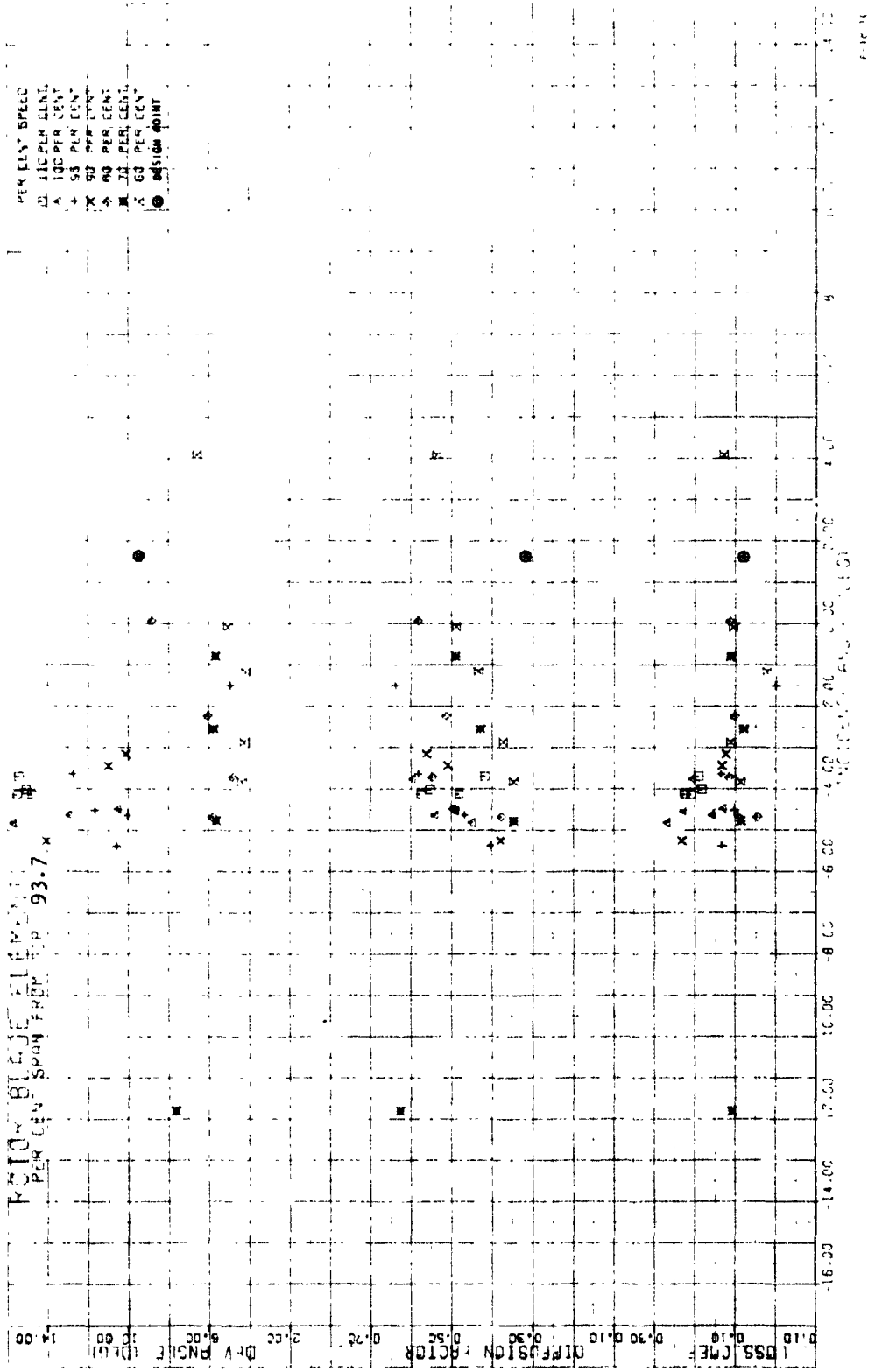


Figure 23a.---Stator Vane Element Performance, Uniform Inlet Flow, 5 Percent Span from Tip.

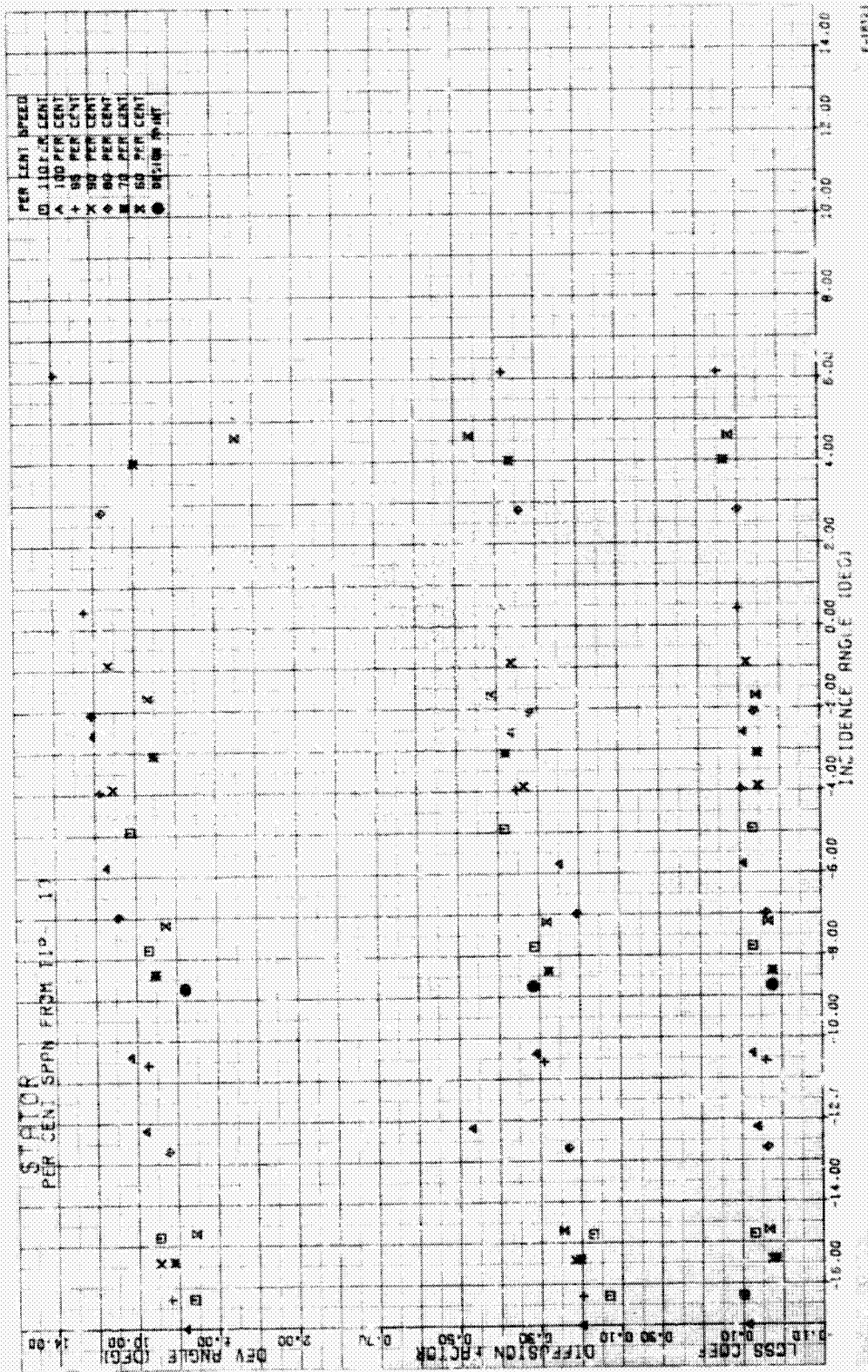


Figure 23b.--Stator Vane Element Performance, Uniform Inlet Flow, 10 Percent Span from Tip.

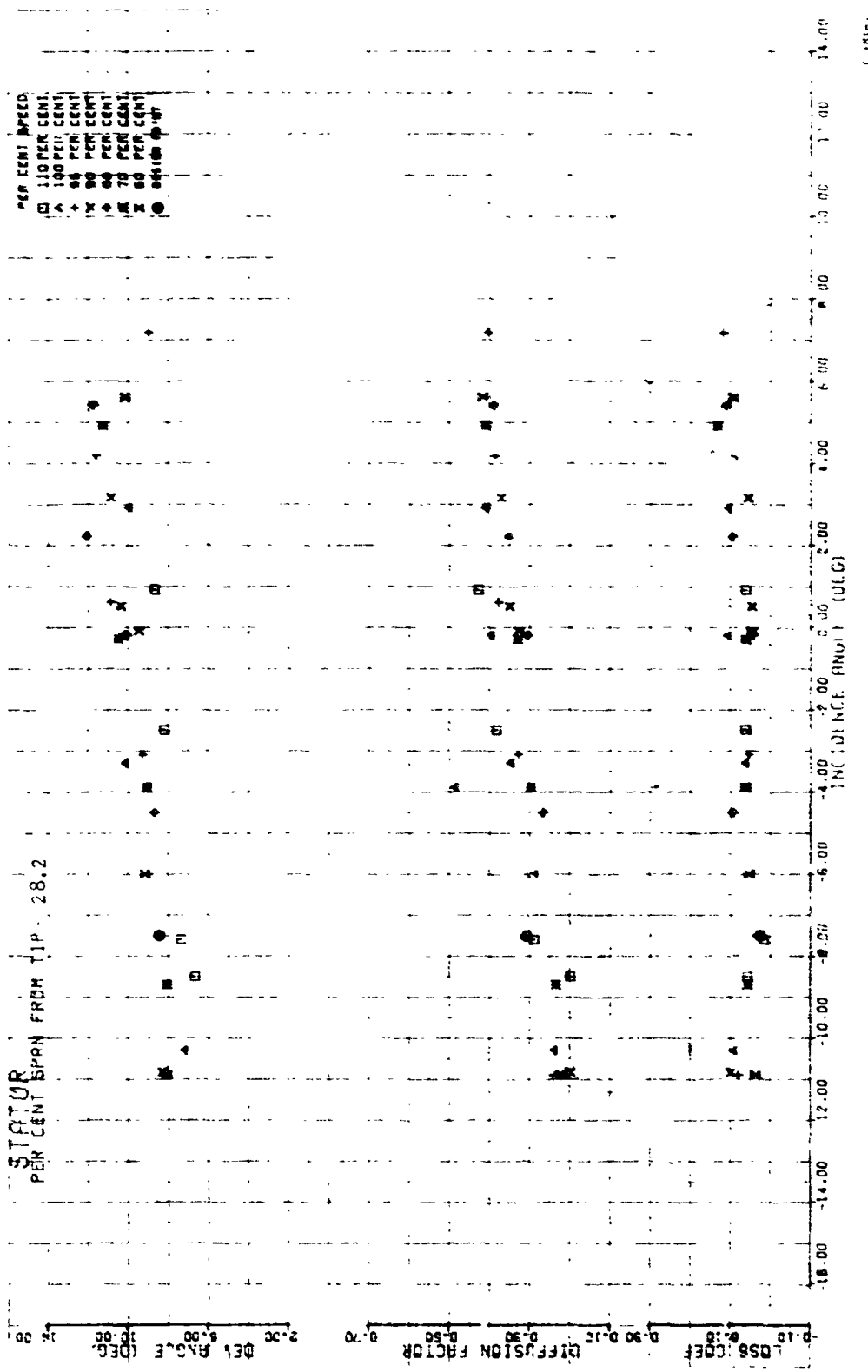
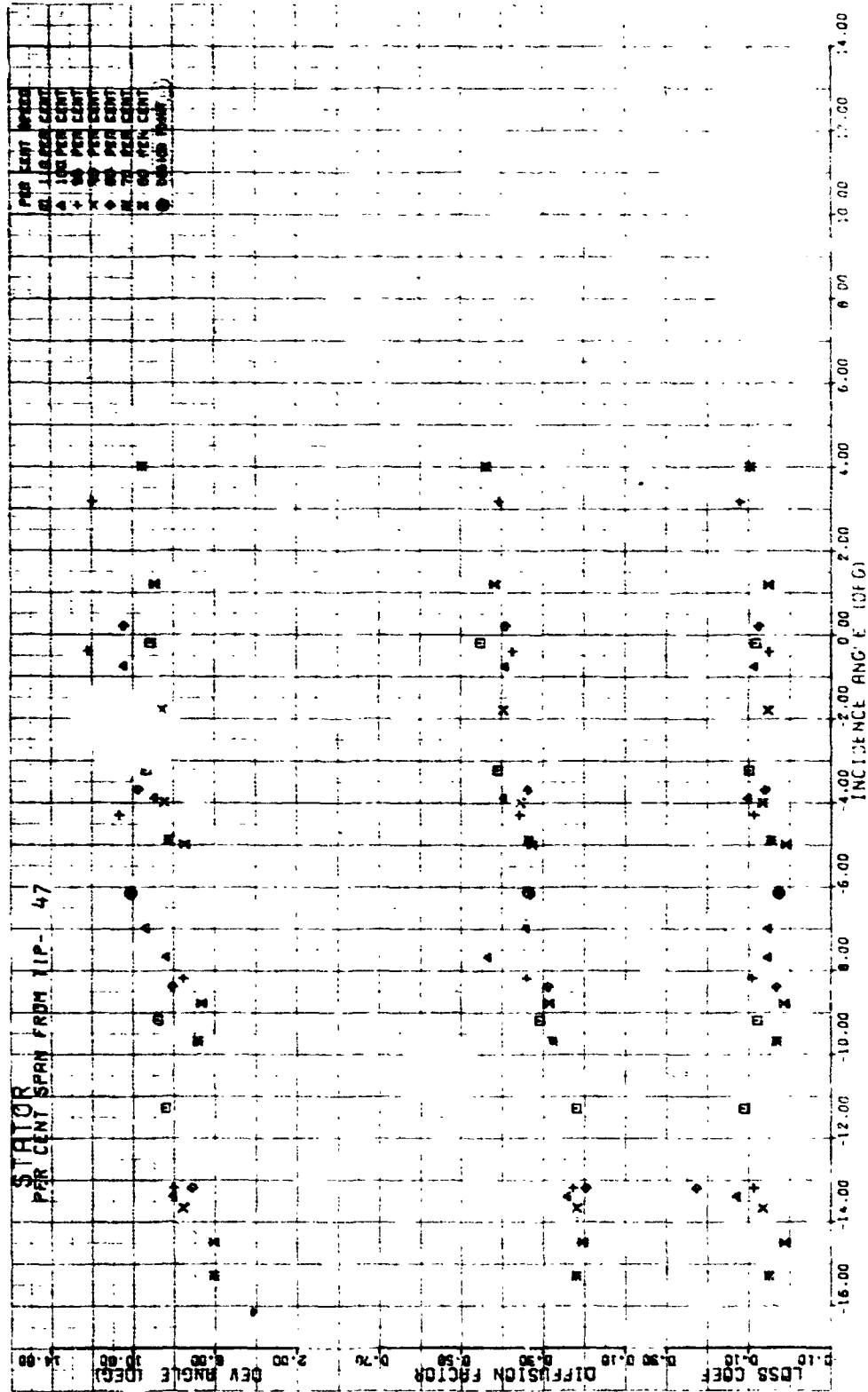


Figure 23d.--Stator Vane Element Performance, Uniform Inlet Flow, 28.2 Percent Span from Tip.



F-1812

Figure 23e.--Stator Vane Element Performance, Uniform Inlet Flow, 47 Percent Span from Tip.

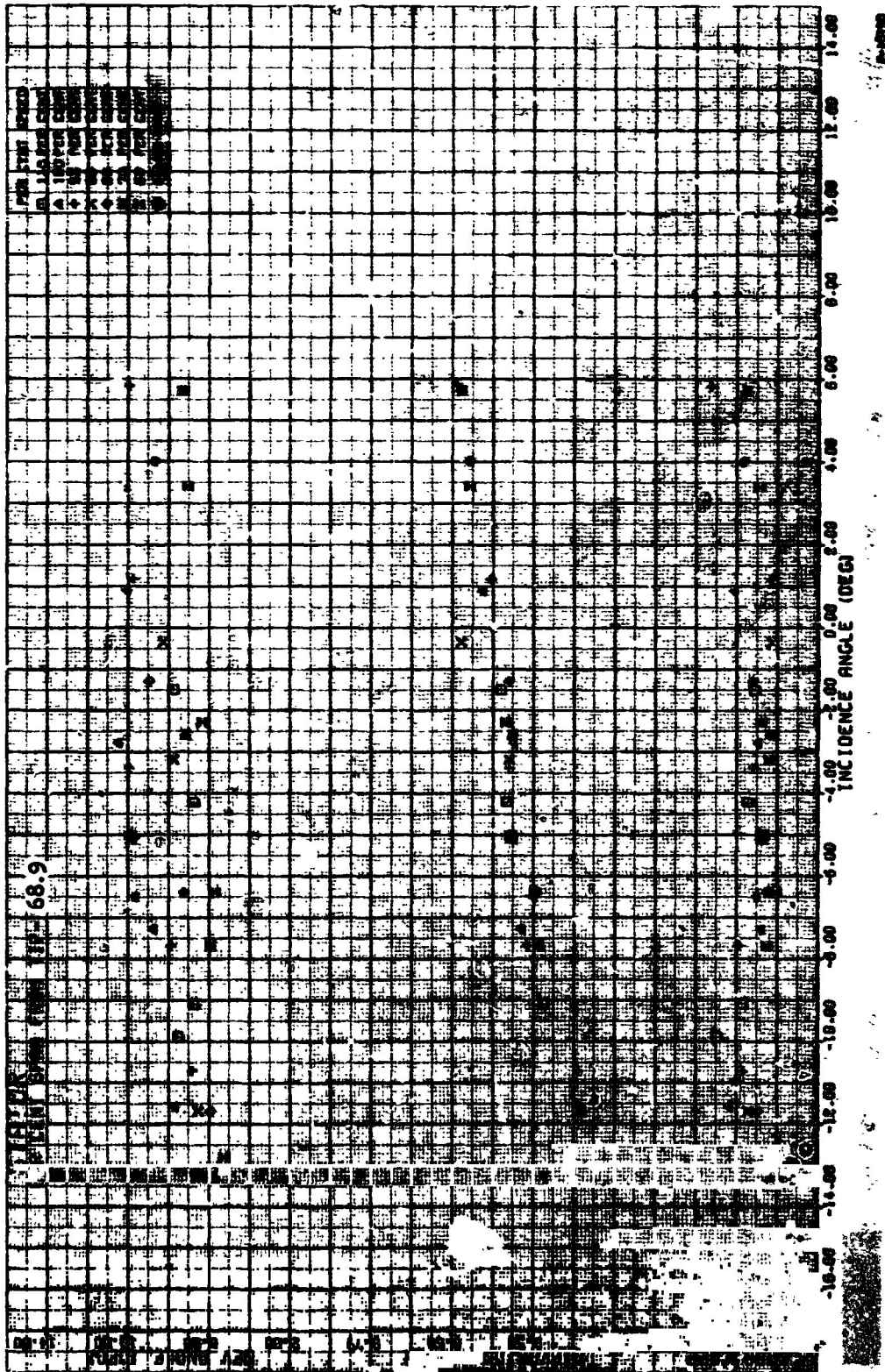


Figure 23f.--Stator Vane Element Performance, Uniform Inlet Flow,
68.9 Percent Span from Tip.

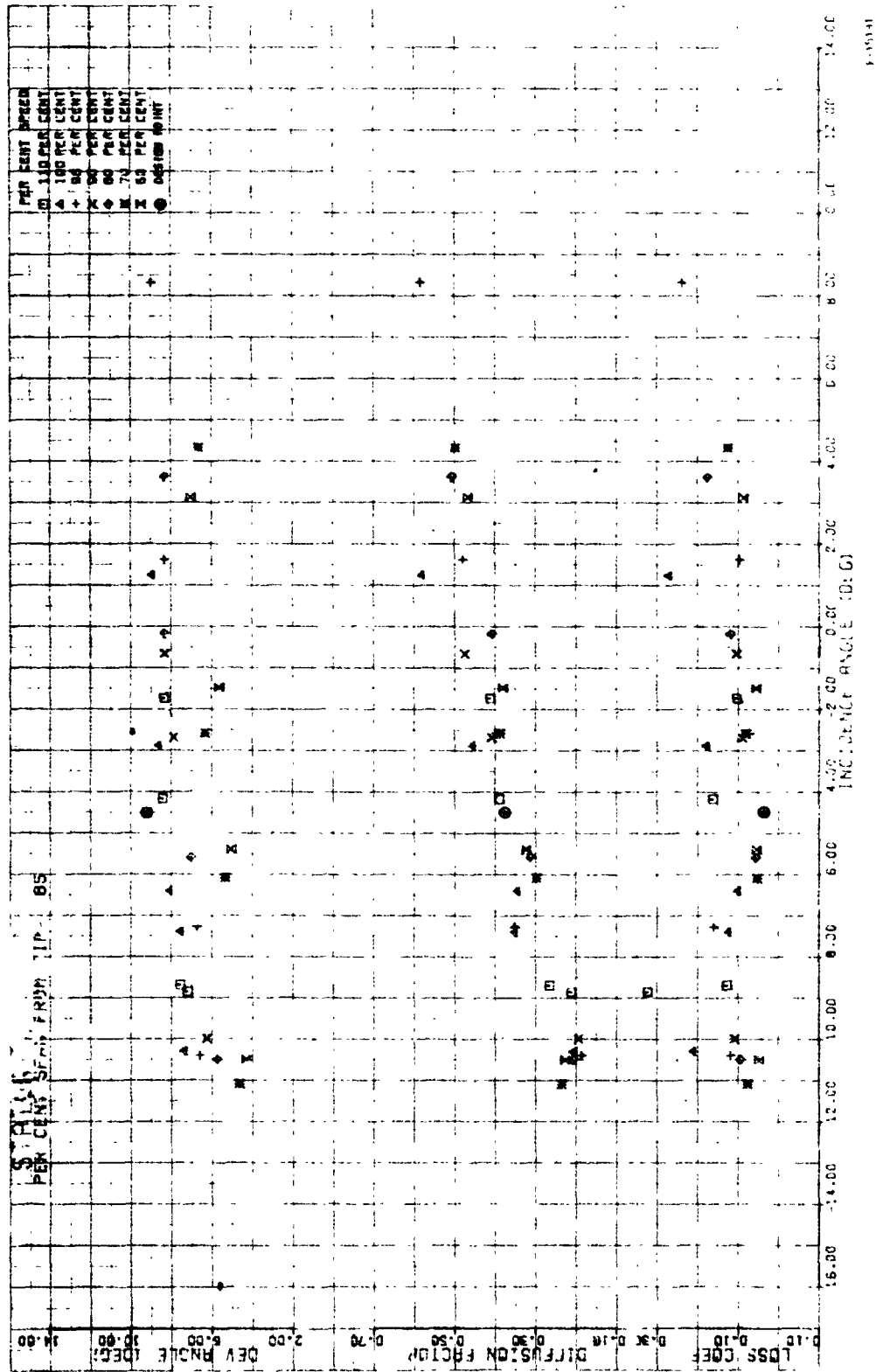
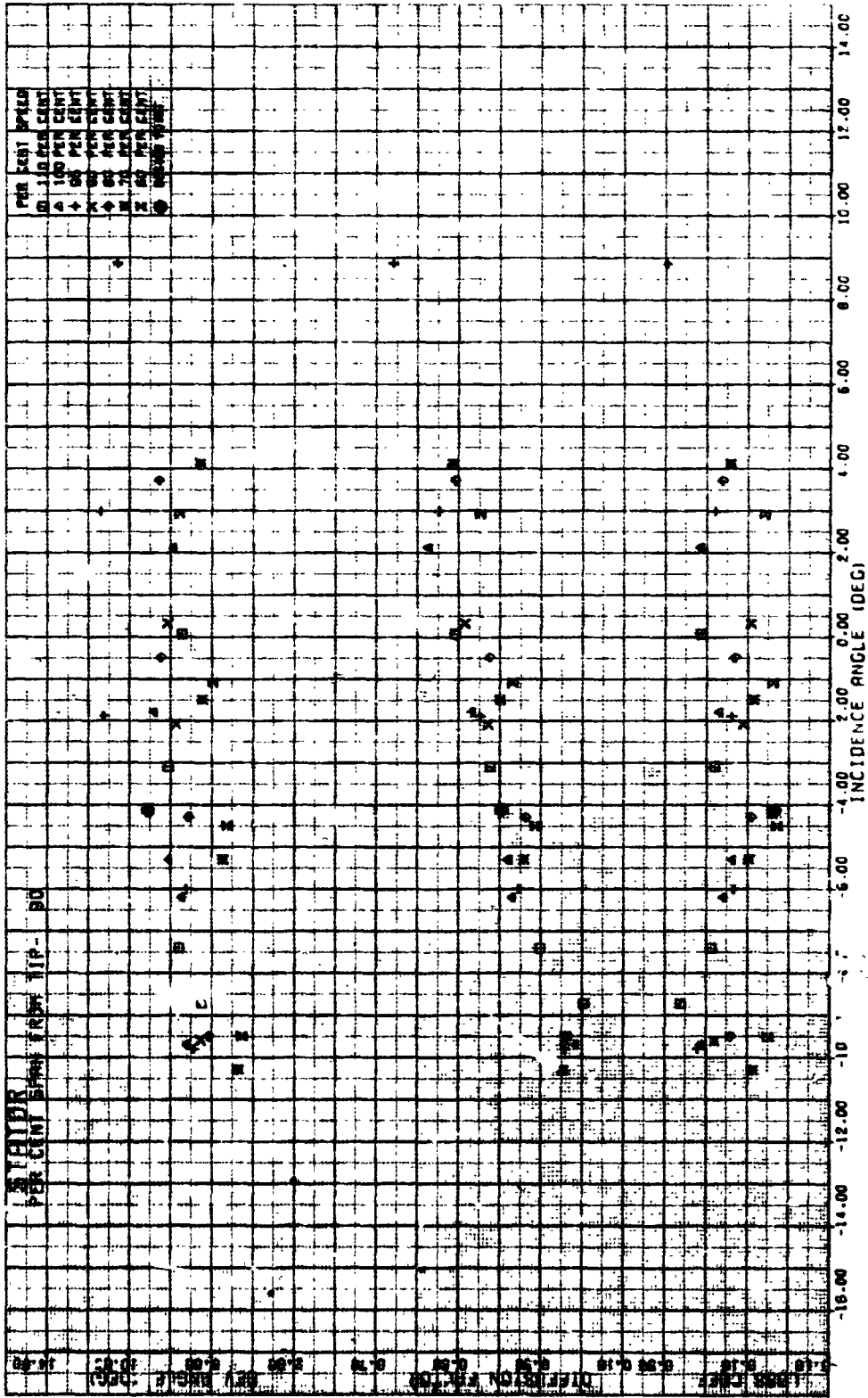
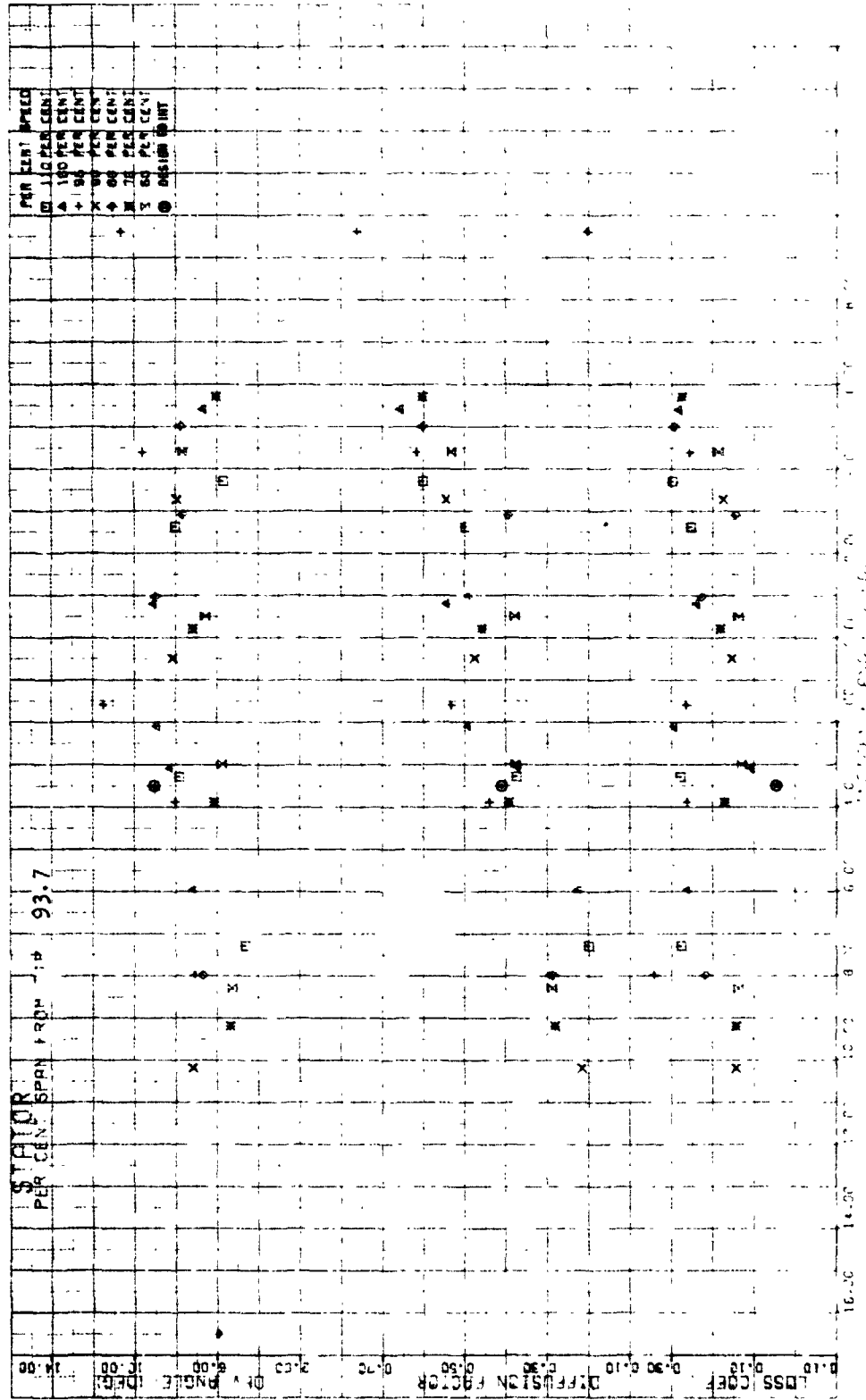


Figure 23g.--Stator Vane Element Performance, Uniform Inlet Flow, 85 Percent Span from Tip.



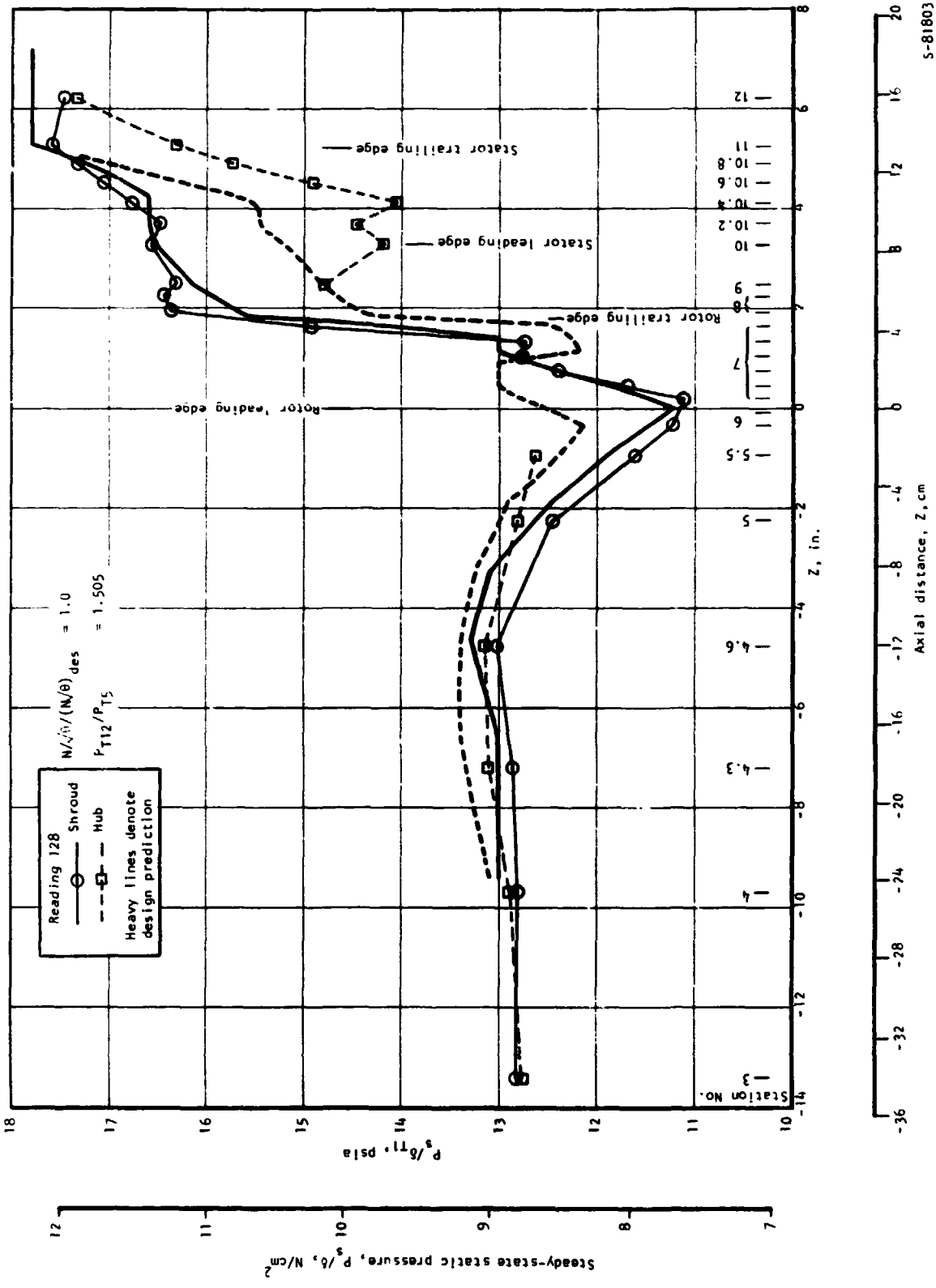
r-10127

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



1-16-97

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



S-81803

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

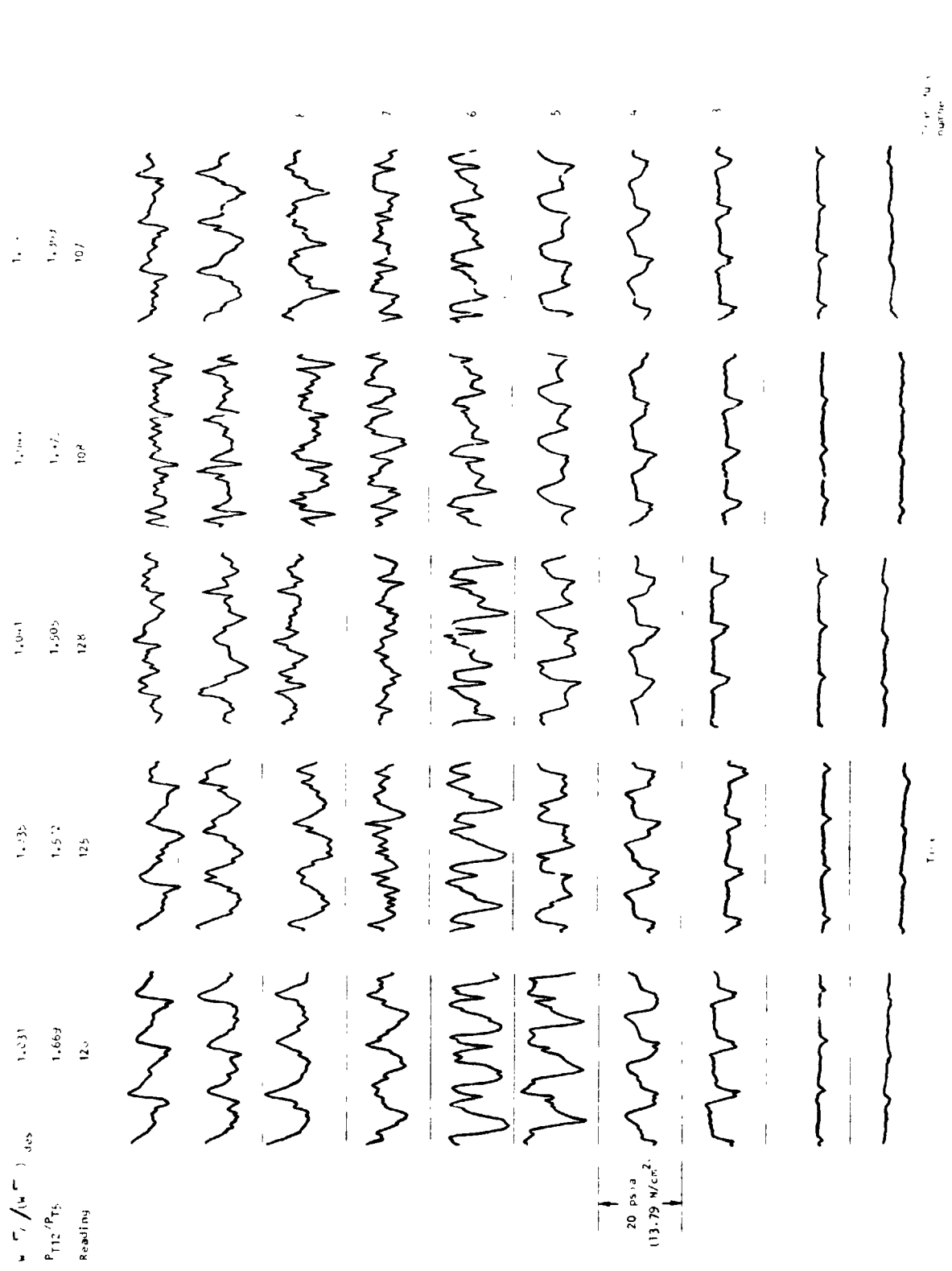
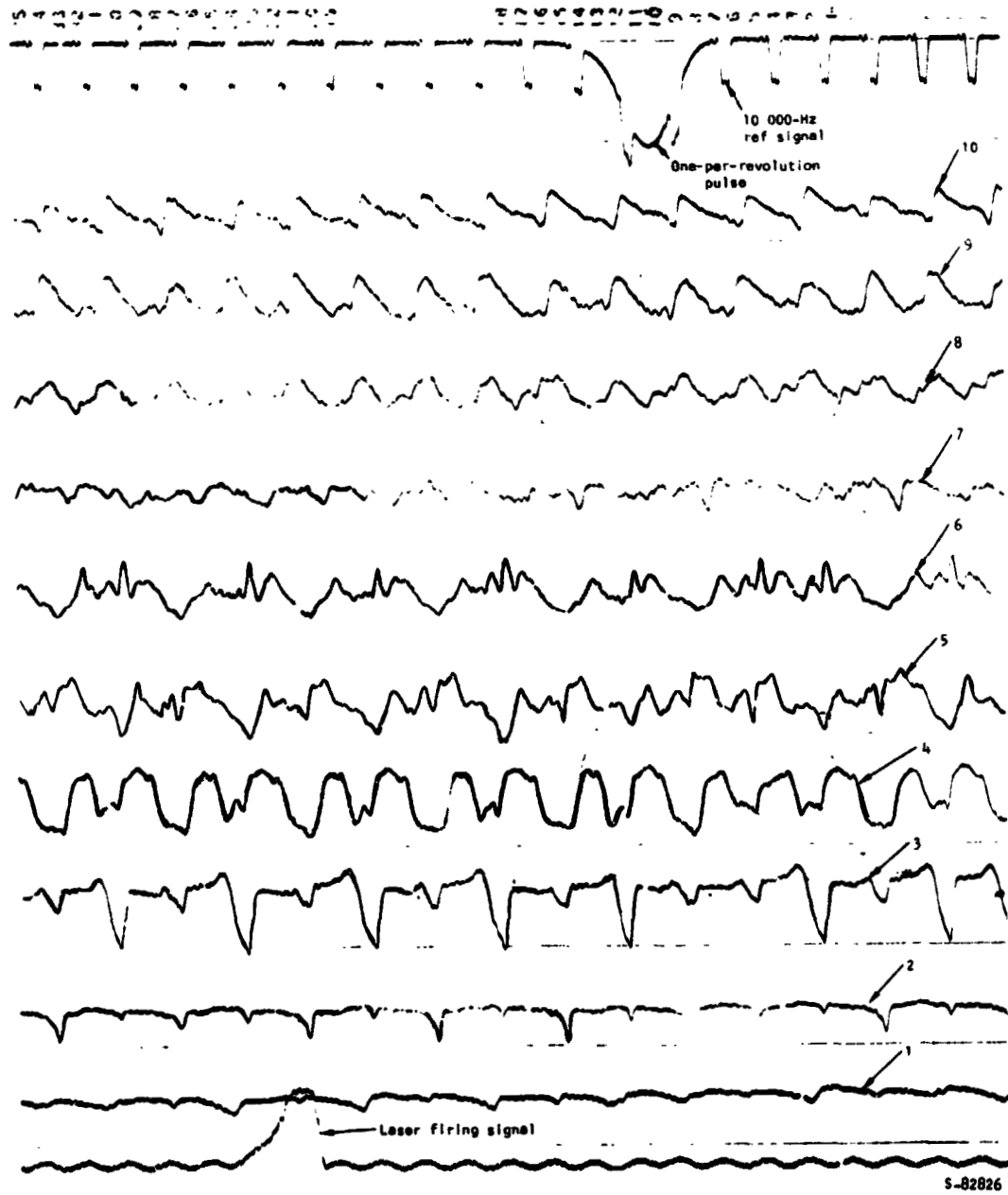
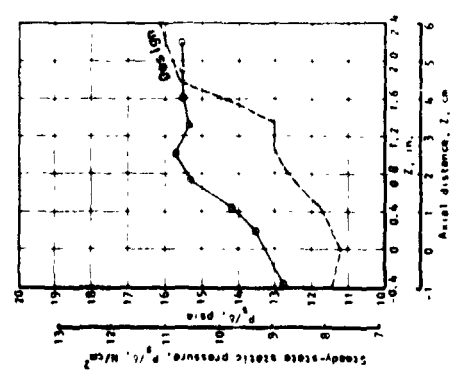
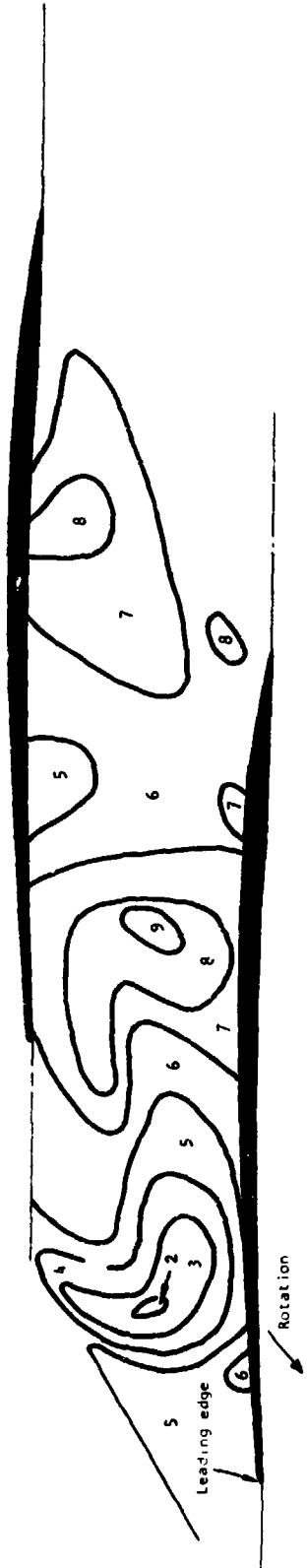


Figure 25.--Typical Rotor Casing High-Frequency-Response Oscillograph Traces at Design Speed.



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

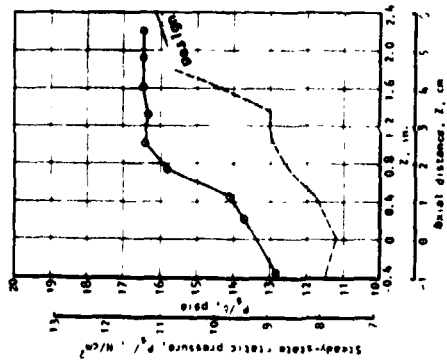
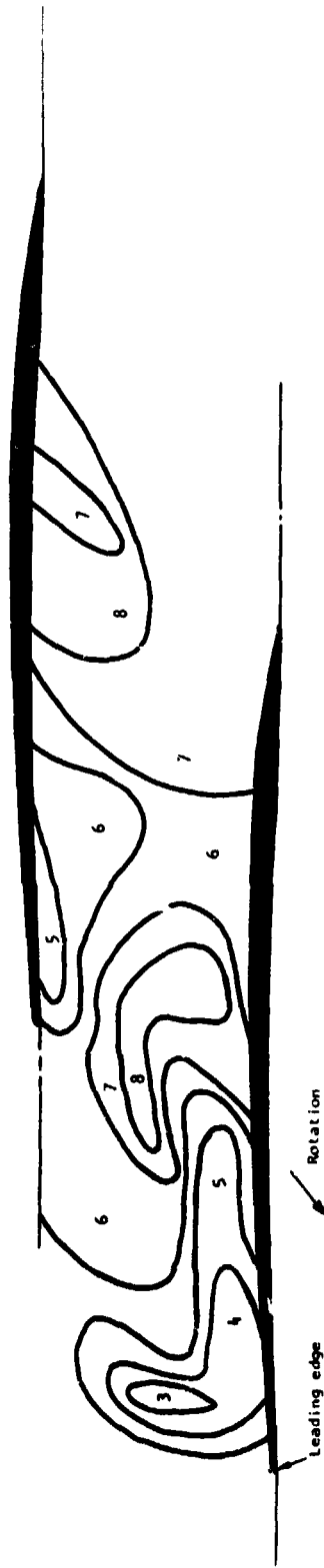


Reading 75
 $\frac{M/\delta}{M/\delta_{des}} = 0.80$
 $\frac{M/\delta/\delta}{M/\delta/\delta_{des}} = 0.869$
 $P_{T12}/P_{T5} = 1.324$

Contour number	Static pressure contour code	
	ps.	N/cm ²
1	3 to 5	0.7 to 1.45
2	5 to 7	3.45 to 8.3
3	7 to 9	4.3 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 13.1
9	19 to 21	13.1 to 14.48
10	21 to 23	14.48 to 15.86
11	23 to 25	15.86 to 17.24

S-81876

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



Reading 80

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

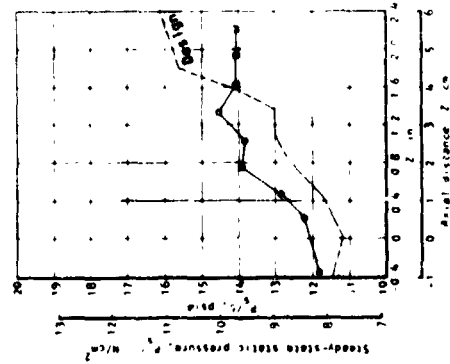
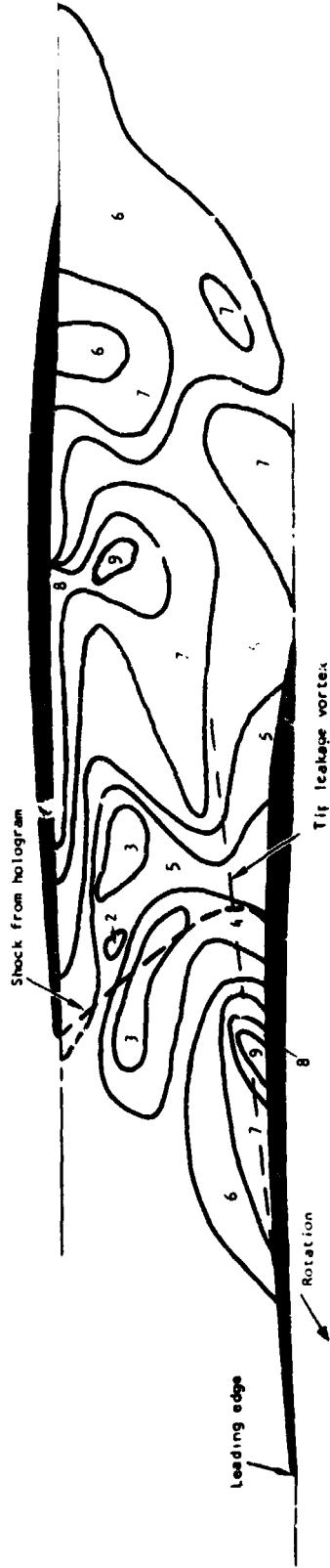
$$\frac{M/\delta}{M/\delta_{des}} = 0.842$$

$$P_{112}/P_{15} = 1.371$$

Code number	Static pressure contour code	
	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

S-81877

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



Reading 103

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

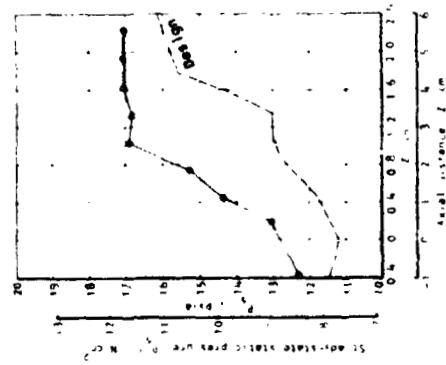
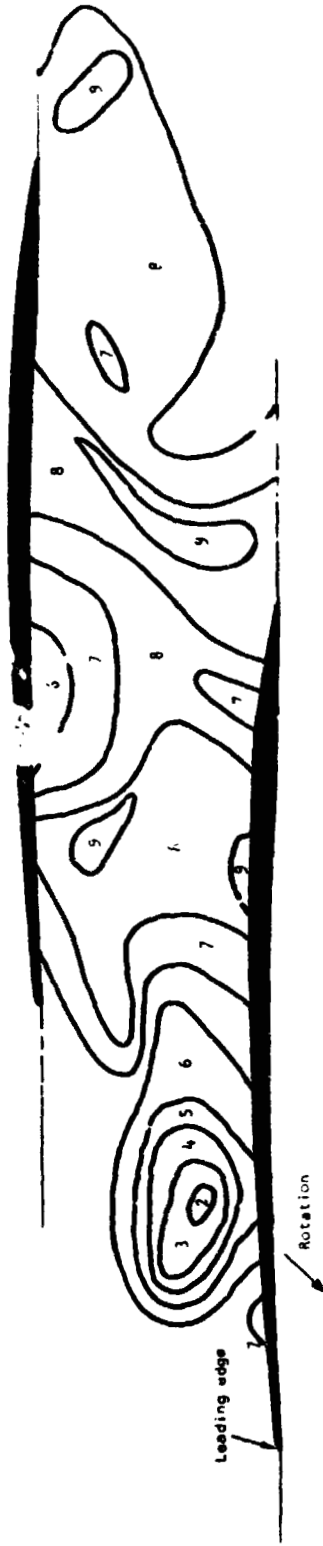
$$\frac{N/\delta}{N/\delta_{des}} = 0.984$$

$$P_{T12}/P_{T5} = 1.320$$

Code number	Static pressure contour, low	
	pt. #	Static pressure range, 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 7.59
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

S-81P80

Figure 29.--Rotor Blade Tip Static Pressure Contours, 90 Percent Design Speed, Pressure Ratio 1.320.

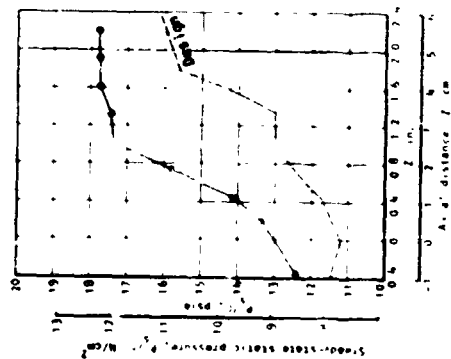
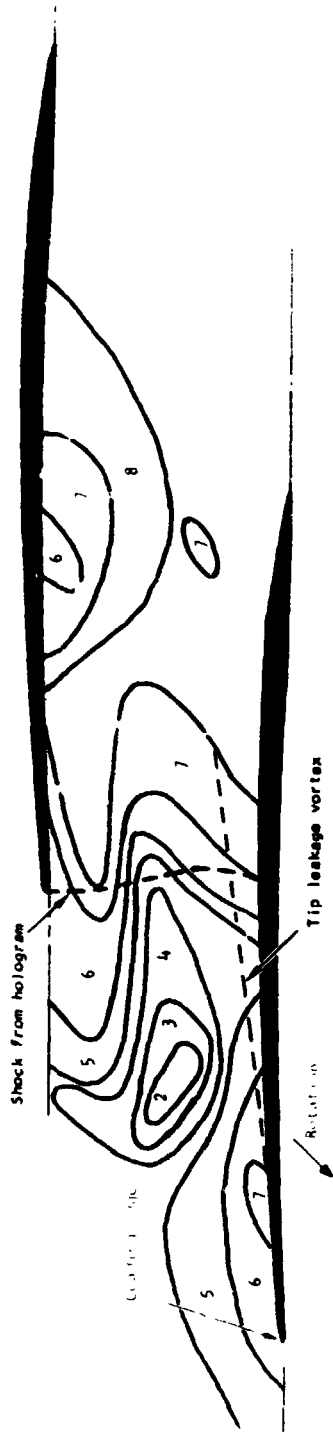


Reading 101
 $\frac{M_1/\beta}{M_2/\beta_{des}} = 1.1$
 $\frac{M_1/\beta}{M_2/\beta_{des}} = 0.557$
 $P_{112}/P_{15} = 1.479$

Code number	Static pressure contours lines	
	Static pressure, psia	Static pressure range, N/cm ²
1	3.105	2.01 to 3.45
2	5.107	3.45 to 4.83
3	7.109	4.83 to 7.1
4	9.111	6.21 to 7.58
5	11.113	7.58 to 8.96
6	13.115	8.96 to 10.34
7	15.117	10.34 to 11.72
8	17.119	11.72 to 13.1
9	19.121	13.1 to 14.48
10	21.123	14.48 to 15.86
11	23.125	15.86 to 17.24

5-81878

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

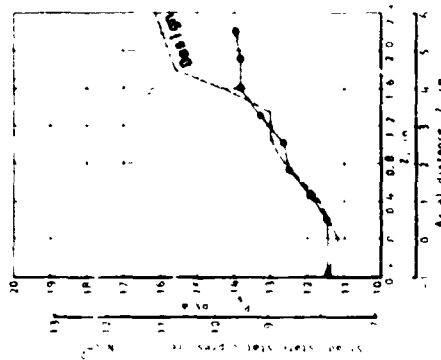
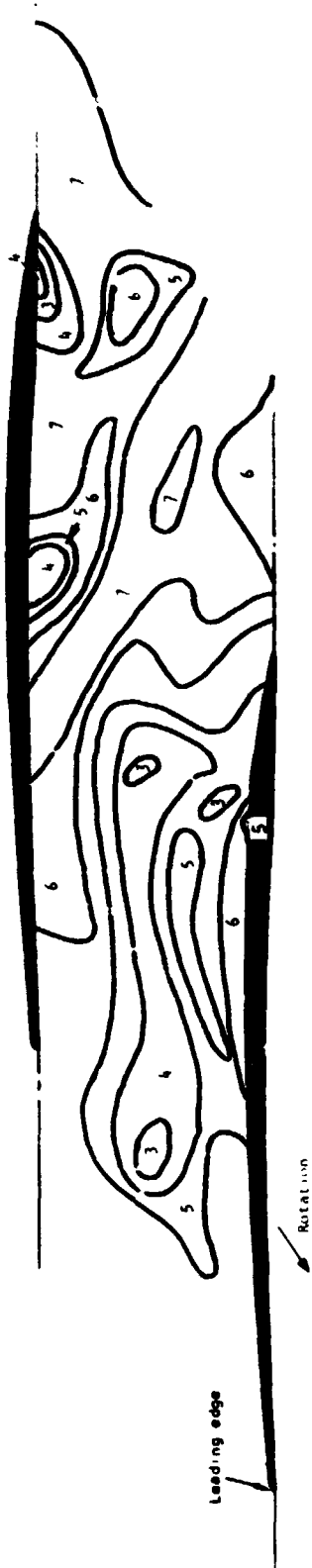


Reading	106
$\frac{M \sqrt{\rho}}{M \sqrt{\rho}}_{des}$	0.710
$\frac{M \sqrt{\rho}}{M \sqrt{\rho}}_{des}$	0.142
P_{T12} / P_{T5}	1.511

Code number	Static pressure contour line	
	Static pressure range	Value
1	3 to 5	2.01 to 3.04
2	5 to 7	3.51 to 4.81
3	7 to 9	4.81 to 7.21
4	9 to 11	7.21 to 10.8
5	11 to 13	10.8 to 16.2
6	13 to 15	16.2 to 24.3
7	15 to 17	24.3 to 36.4
8	17 to 19	36.4 to 54.6
9	19 to 21	54.6 to 81.9
10	21 to 23	81.9 to 122.8
11	23 to 25	122.8 to 184.2

S-81879

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



Reading 104

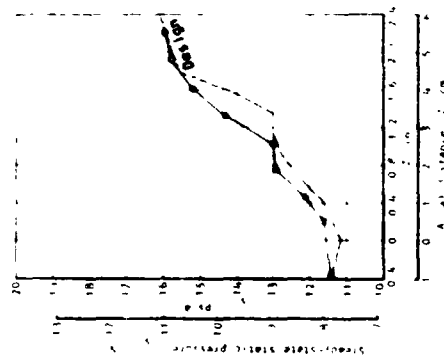
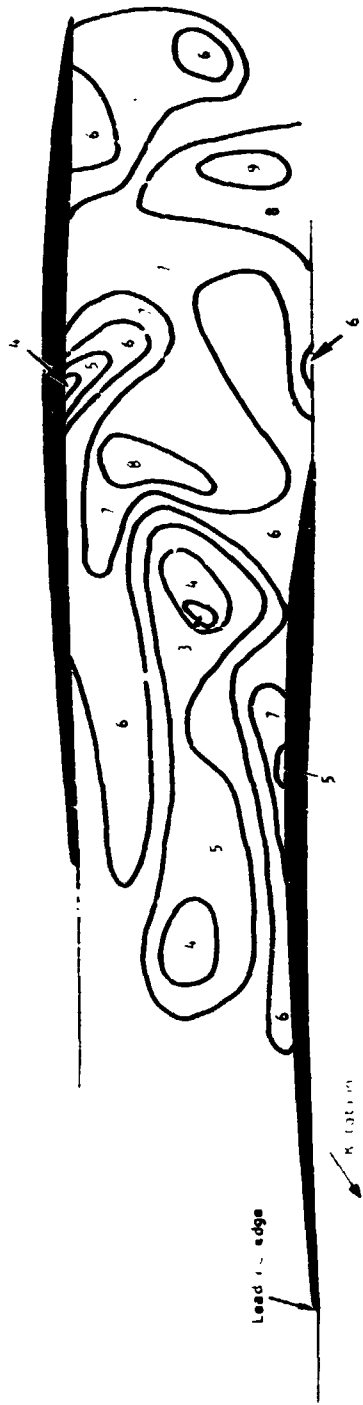
$$\frac{M_{tip}}{M_{des}} = 0.95$$

$$\frac{M_{tip}}{M_{des}} = 1.019$$

$$P_{tip}/P_{des} = 1.348$$

Cont. number	Static pressure contour, mm Hg	
	Static pressure, range	M/c ²
1	1 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 7.58
5	11 to 13	7.58 to 8.94
6	13 to 15	8.94 to 10.34
7	15 to 17	10.34 to 11.77
8	17 to 19	11.77 to 13.22
9	19 to 21	13.22 to 14.69
10	21 to 23	14.69 to 16.18
11	23 to 25	16.18 to 17.69

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

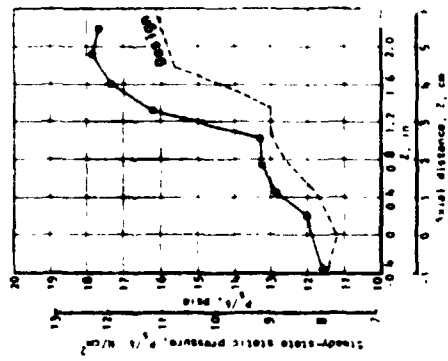


Reading	105
$\frac{N/A}{N/A}$ des	0.95
$\frac{N/A}{N/A}$ des	1.016
$\frac{P_{112}/P_{15}}$	1.449

Code number	Static pressure (psia)	
	1	2
1	18.5	17.5
2	17.5	16.5
3	16.5	15.5
4	15.5	14.5
5	14.5	13.5
6	13.5	12.5
7	12.5	11.5
8	11.5	10.5
9	10.5	9.5
10	9.5	8.5
11	8.5	7.5

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

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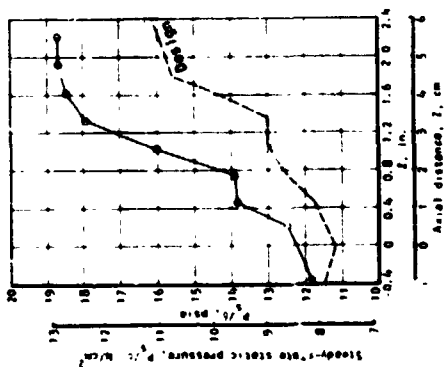
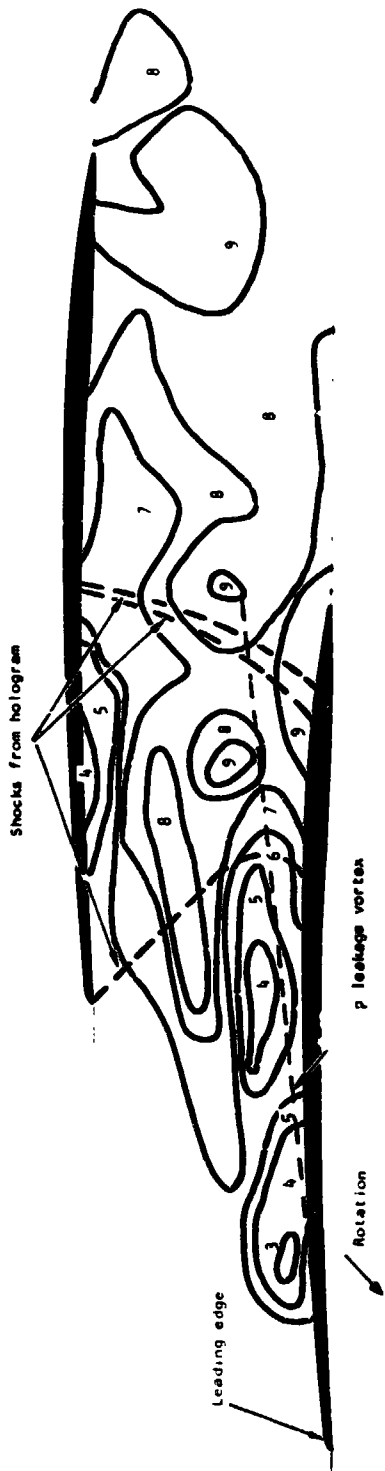


Reading 117
 $\frac{M_{tip}}{M_{tip, des}} = 0.95$
 $\frac{M_{TS}}{M_{TS, des}} = 1.008$
 $P_{T12}/P_{TS} = 1.540$

Code Number	Static pressure contour code		W/m ²
	g-h	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 7.58	
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 vs. Axial Distance at Design Speed, Pressure Ratio 1.540.



Reading 118

$\frac{M_{118}^2}{M_{des}^2} = 0.95$

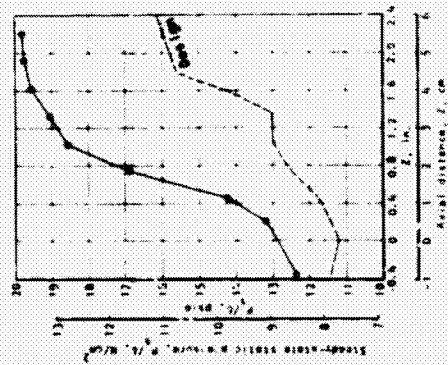
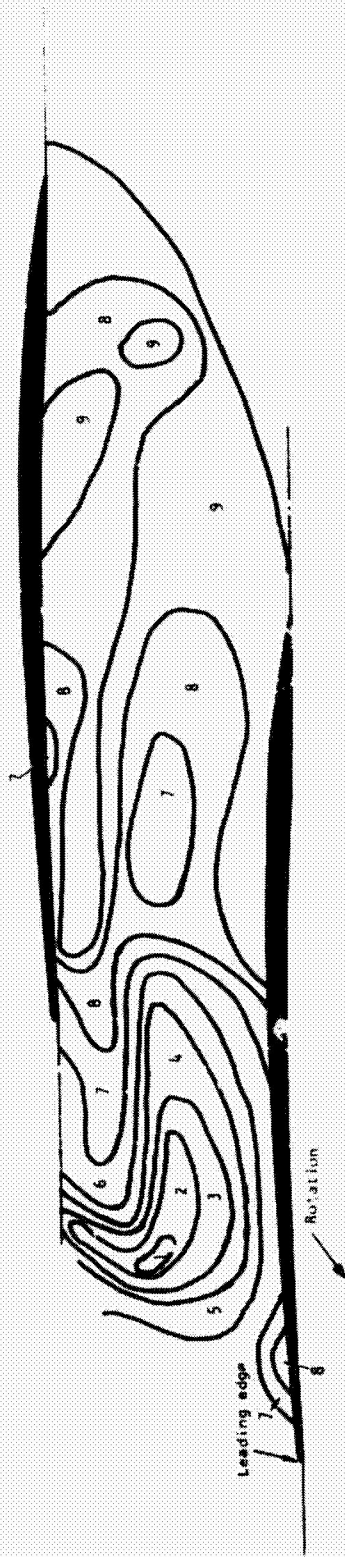
$\frac{M_{118}^2}{M_{des}^2} = 0.995$

$P_{112}/P_{15} = 1.604$

Code number	Static pressure contour code	
	Static pressure range	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

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

S-61875

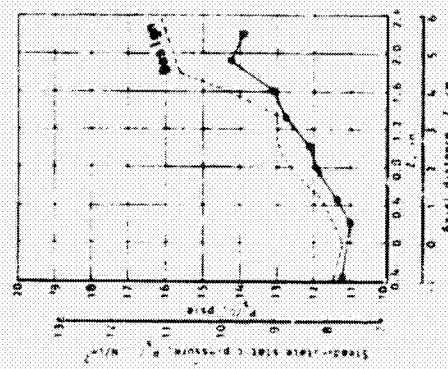
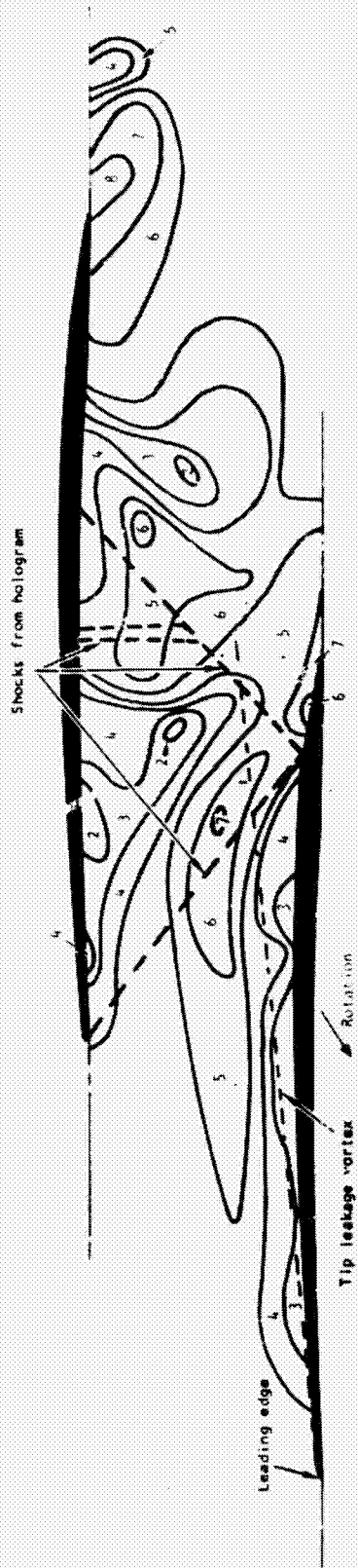


Reading 119
 $\frac{M_{tip}}{M_{tip, des}} = 0.95$
 $\frac{M_{tip}}{M_{tip, des}} = 0.952$
 $P_{T12}/P_{T5} = 1.656$

Code number	Static pressure contour no.	
	Static pressure range	P/P_{∞}
1	3 to 5	7.07 to 1.45
2	5 to 7	3.5 to 0.83
3	7 to 9	0.83 to 0.21
4	9 to 11	1.1 to 0.58
5	11 to 13	1.05 to 0.44
6	13 to 15	0.44 to 0.36
7	15 to 17	0.36 to 0.27
8	17 to 19	0.27 to 0.19
9	19 to 21	0.19 to 0.14
10	21 to 23	0.14 to 0.10
11	23 to 25	0.10 to 0.07

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



Reedir 107

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

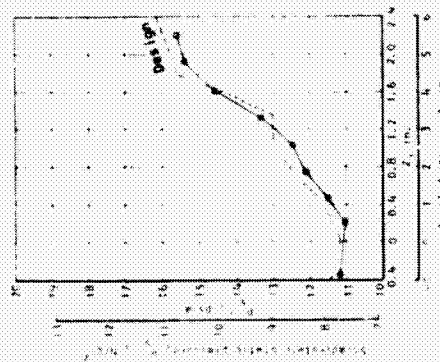
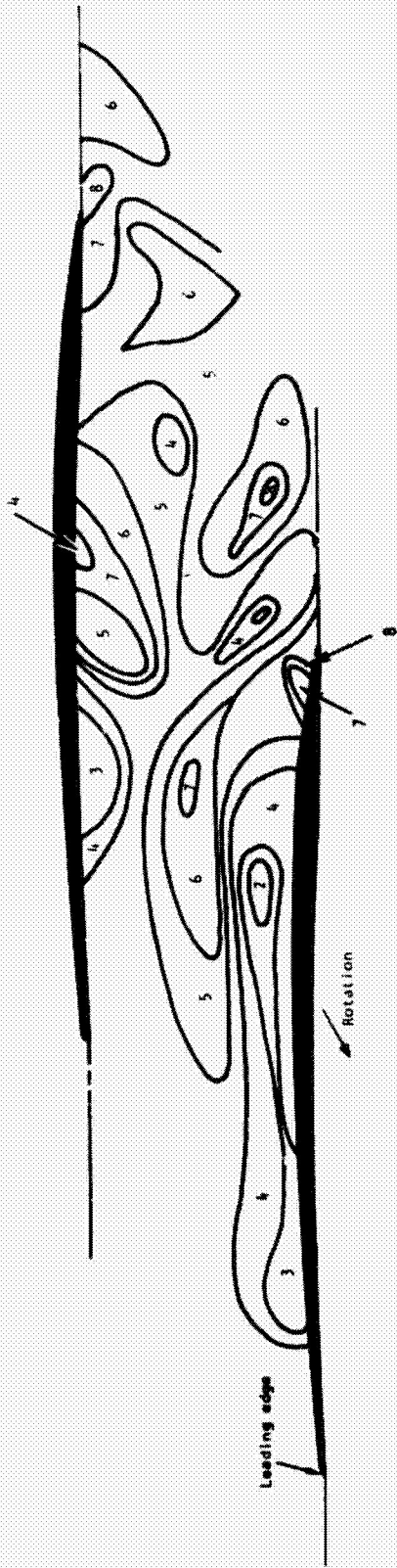
$$\frac{M_{\infty}}{M_{\infty}^*} = 1.040$$

$$P_{112}/P_{125} = 1.369$$

Cont. number	Static pressure, comp.	
	p/ρc²	h/ρc²
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

$$\frac{M_{108}/0}{M_{108}/0}_{des} = 1.00$$

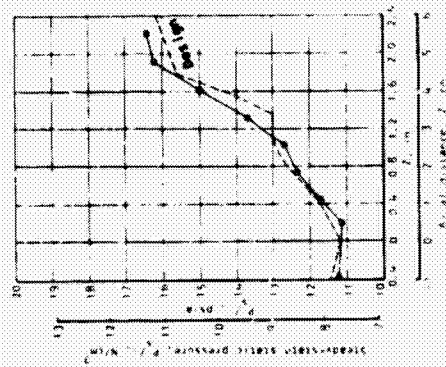
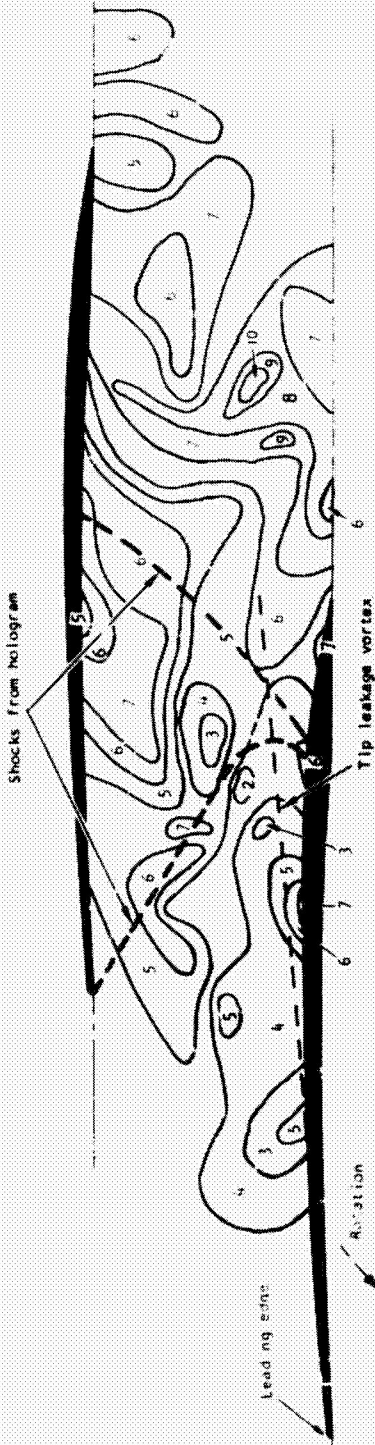
$$\frac{M_{112}/0}{M_{112}/0}_{des} = 1.044$$

$$P_{112}/P_{108} = 1.475$$

Code number	Static pressure range	
	psia	mmHg
1	3 to 5	2.07 to 3.45
2	5 to 7	3.45 to 5.28
3	7 to 9	5.28 to 7.11
4	9 to 11	7.11 to 8.94
5	11 to 13	8.94 to 10.77
6	13 to 15	10.77 to 12.60
7	15 to 17	12.60 to 14.43
8	17 to 19	14.43 to 16.26
9	19 to 21	16.26 to 18.09
10	21 to 23	18.09 to 19.92
11	23 to 25	19.92 to 21.75

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



Reading 128

$$\frac{M_1^2/6}{M_2^2/6} = 1.00$$

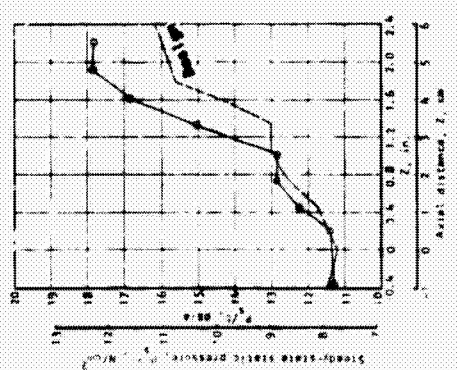
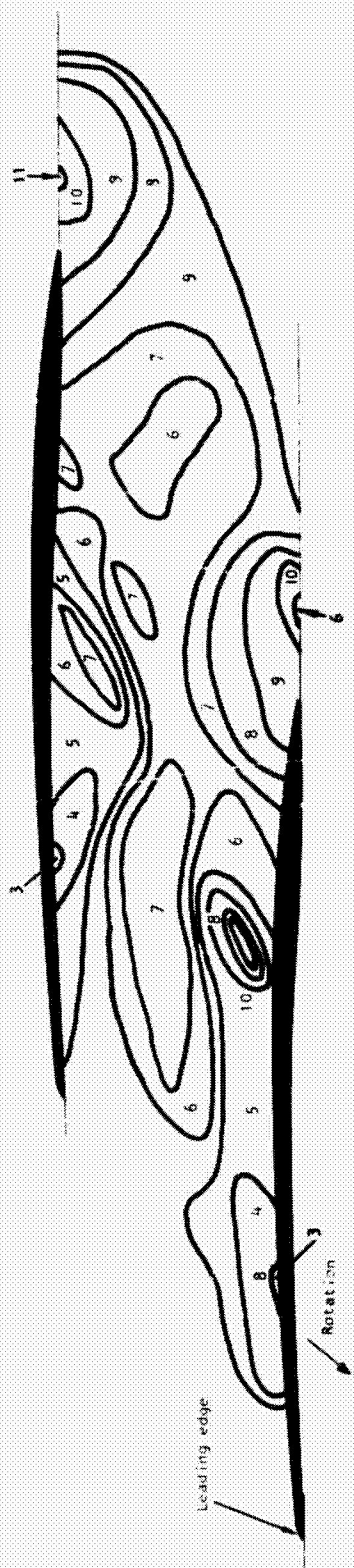
$$\frac{M_1^2/5}{M_2^2/5} = 1.041$$

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

Code number	Steady-state static pressure range	
	psia	mmHg
1	1.505	2.0710-3.4
2	5.107	3.4530-4.83
3	7.165	5.8330-7.21
4	9.183	7.2130-8.59
5	11.163	8.5930-9.97
6	13.165	9.9730-11.35
7	15.167	11.3530-12.73
8	17.169	12.7330-14.11
9	19.171	14.1130-15.49
10	21.173	15.4930-16.87
11	23.175	16.8730-18.25

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



Reading 125

$$\frac{M/\beta}{M/\beta_{des}} = 1.00$$

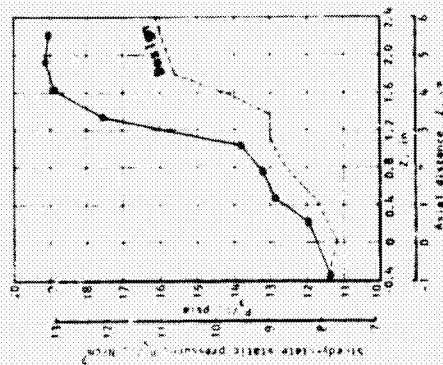
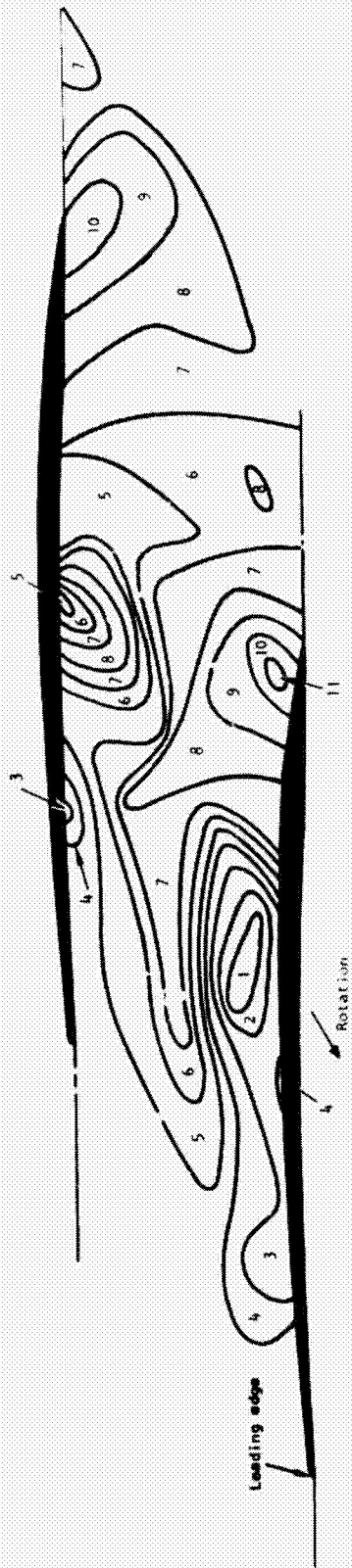
$$\frac{M/\beta_{15}}{M/\beta_{des}} = 1.035$$

$$P_{T12}/P_{T15} = 1.663$$

Code number	Steady pressure contour code	
	psia	N/cm²
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 40.--Rotor Blade Tip Static Pressure Contours, Design Speed, Pressure Ratio 1.623.

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Reading 126

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

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

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

Contour number	Static pressure contour code	
	Static pressure range	lbf/in ²
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 13.12
9	19 to 21	13.12 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 41.--Rotor Blade Tip Static Pressure Contours, Design Speed, Pressure Ratio 1.669.

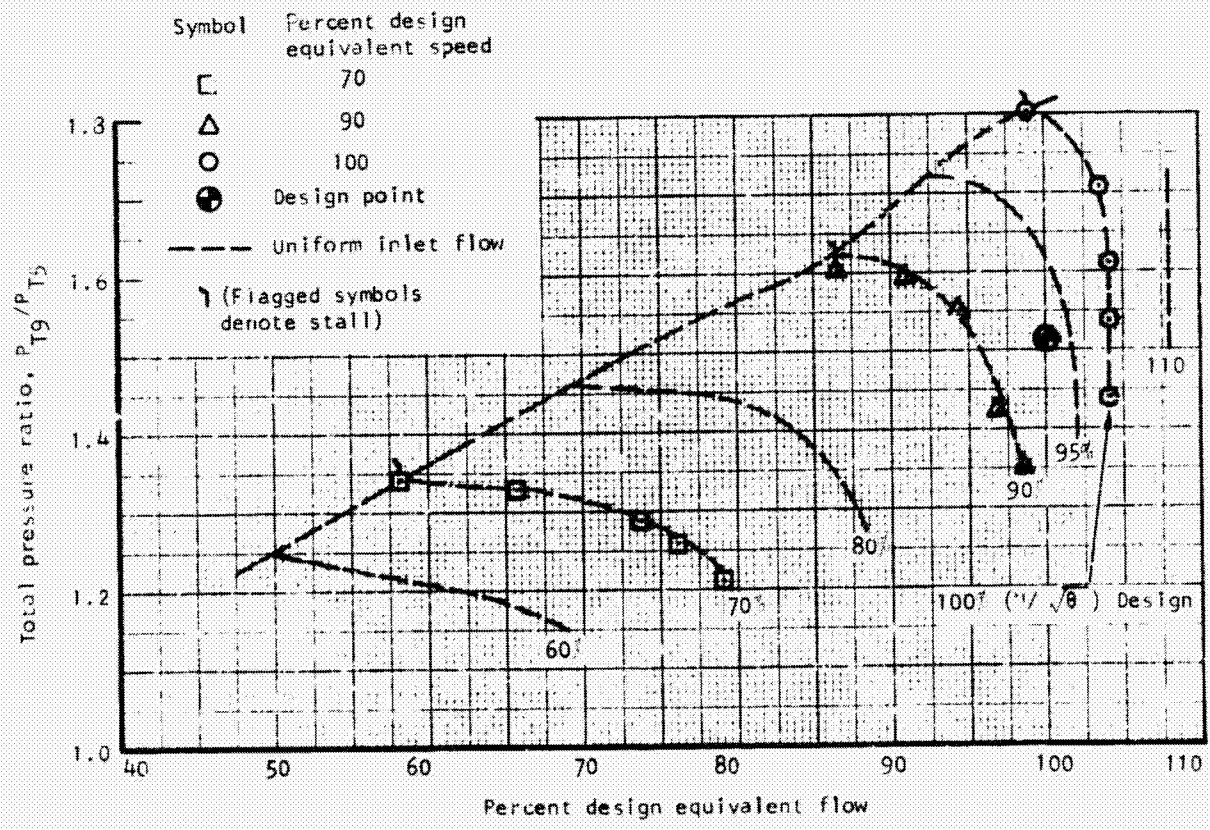
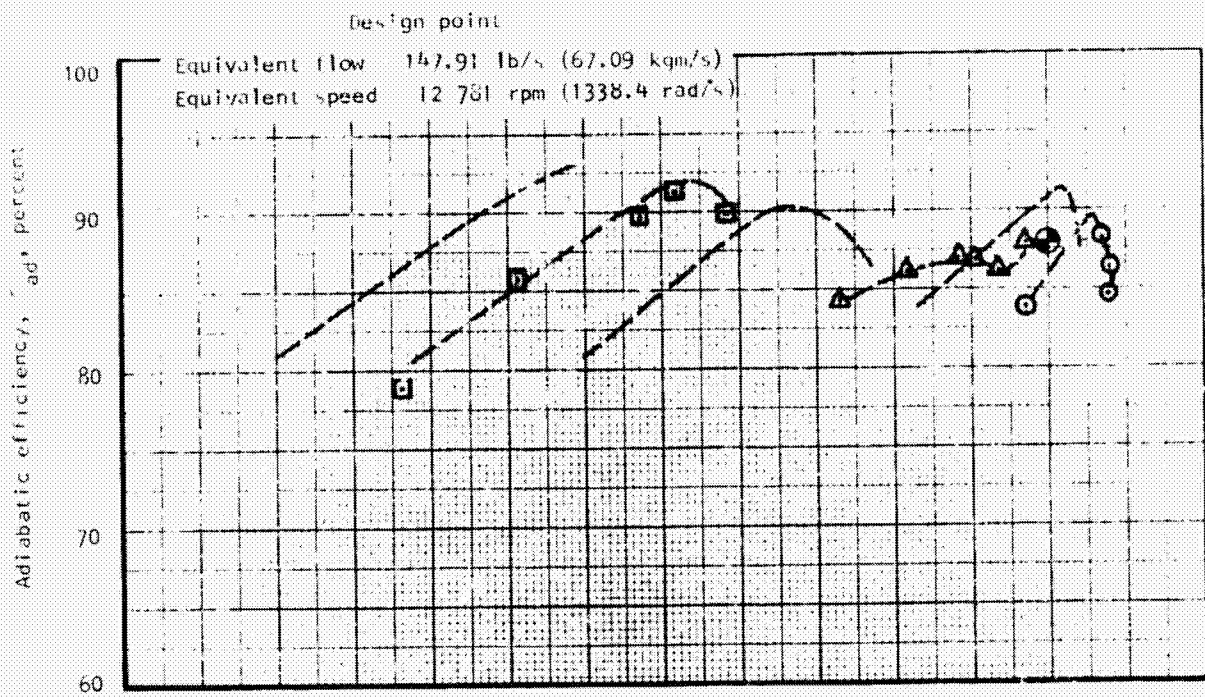


Figure 42.--Rotor Performance, Predistortion Baseline.

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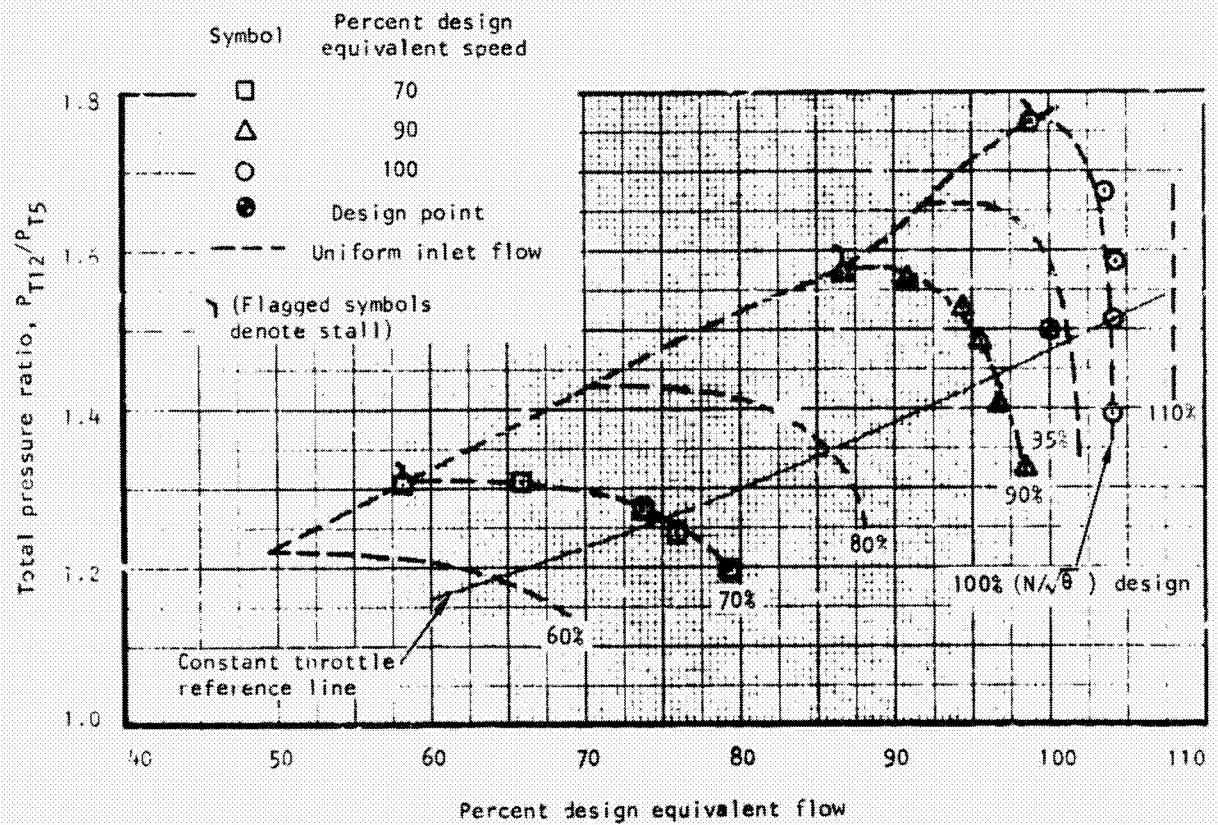
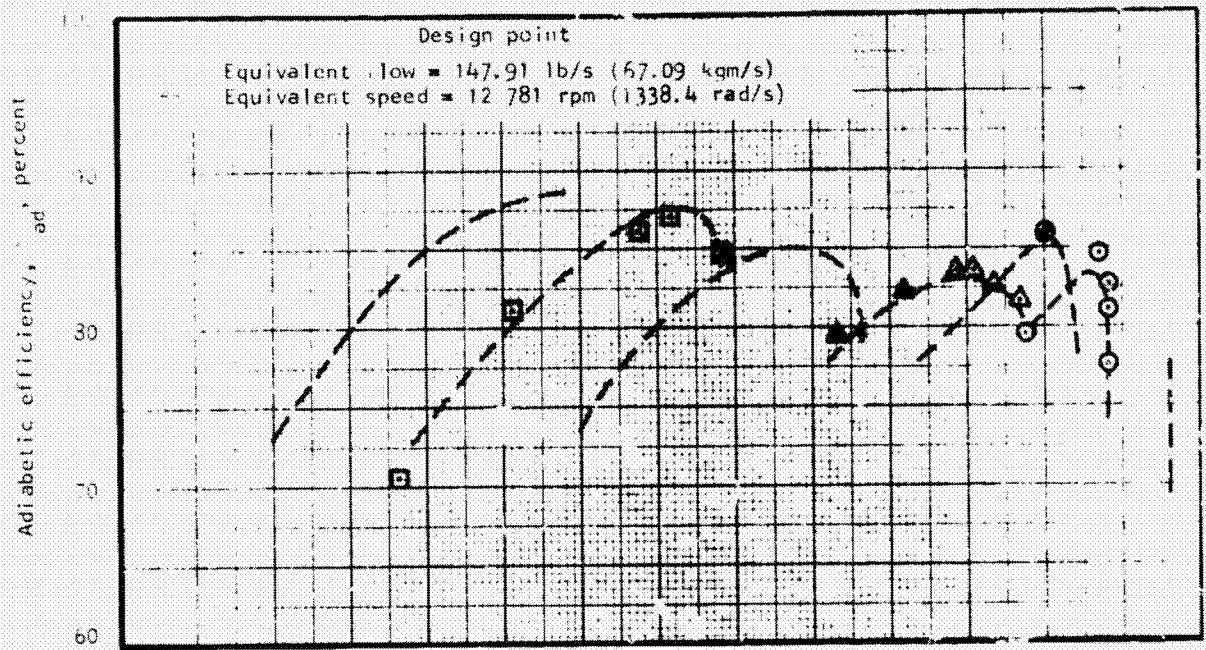


Figure 43.--Stage Performance, Predistortion Baseline.

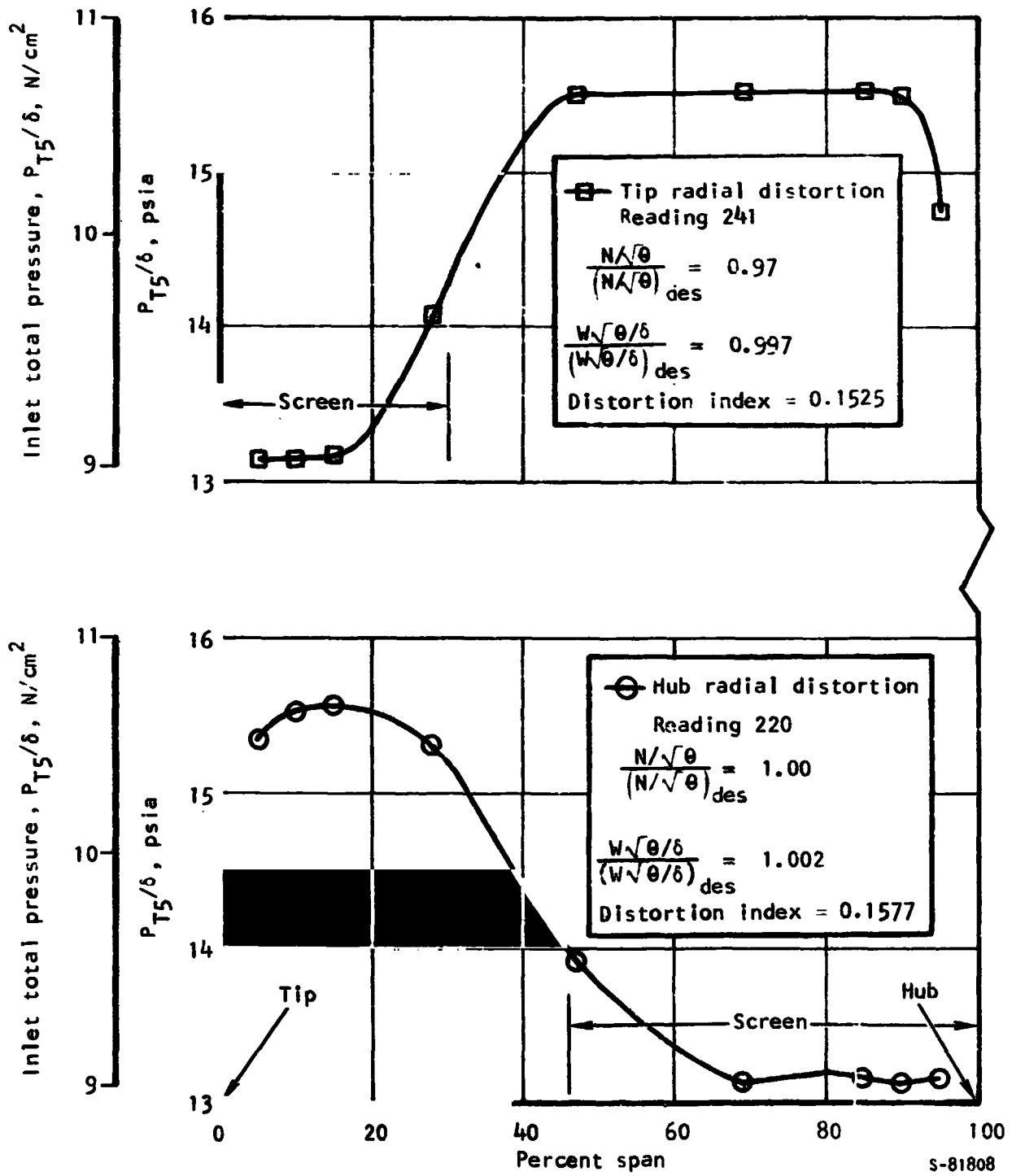


Figure 44.--Radial Distortion Total Pressure Profiles for Design Equivalent Flow.

2

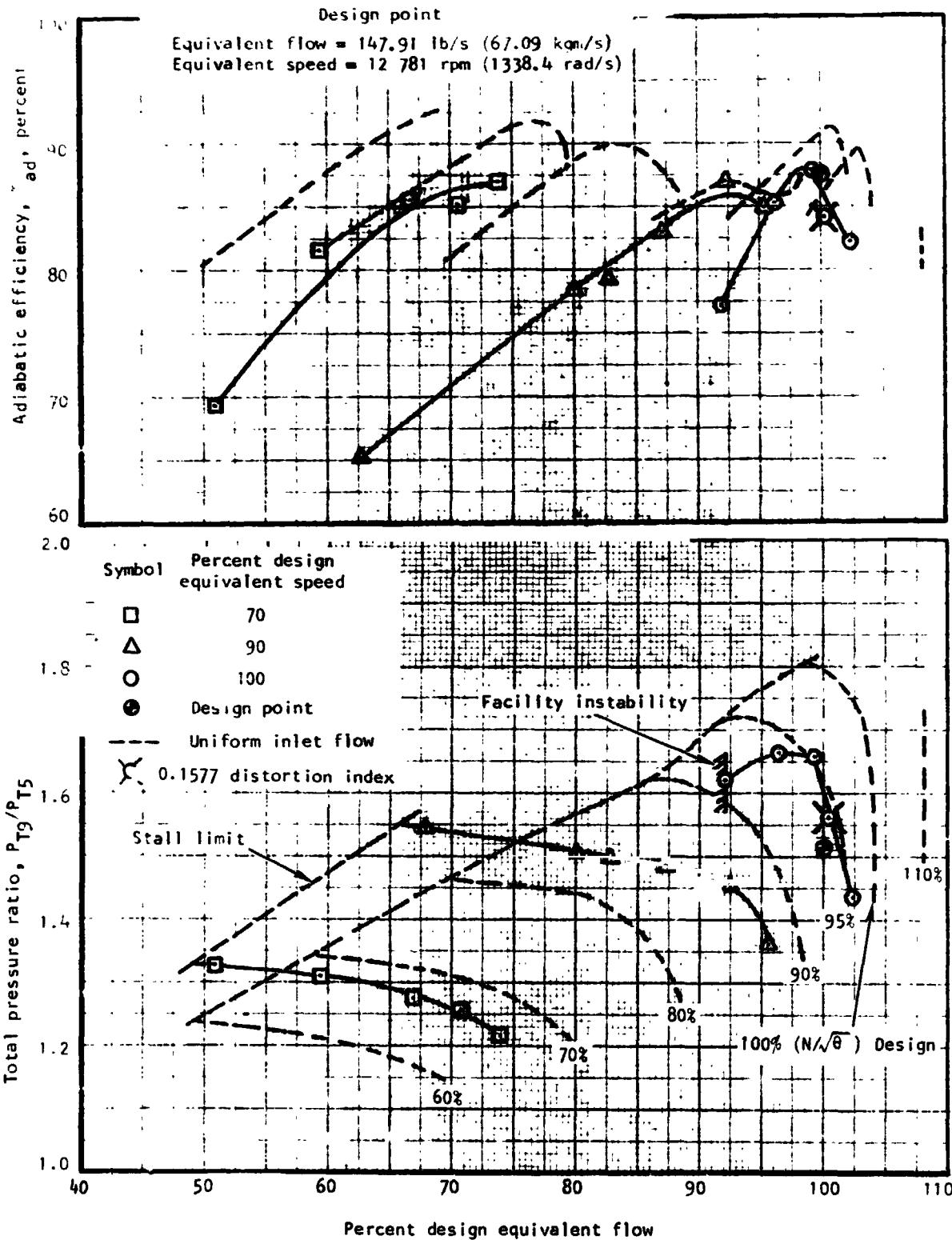


Figure 45.--Rotor Performance, Hub-Radial Distortion.

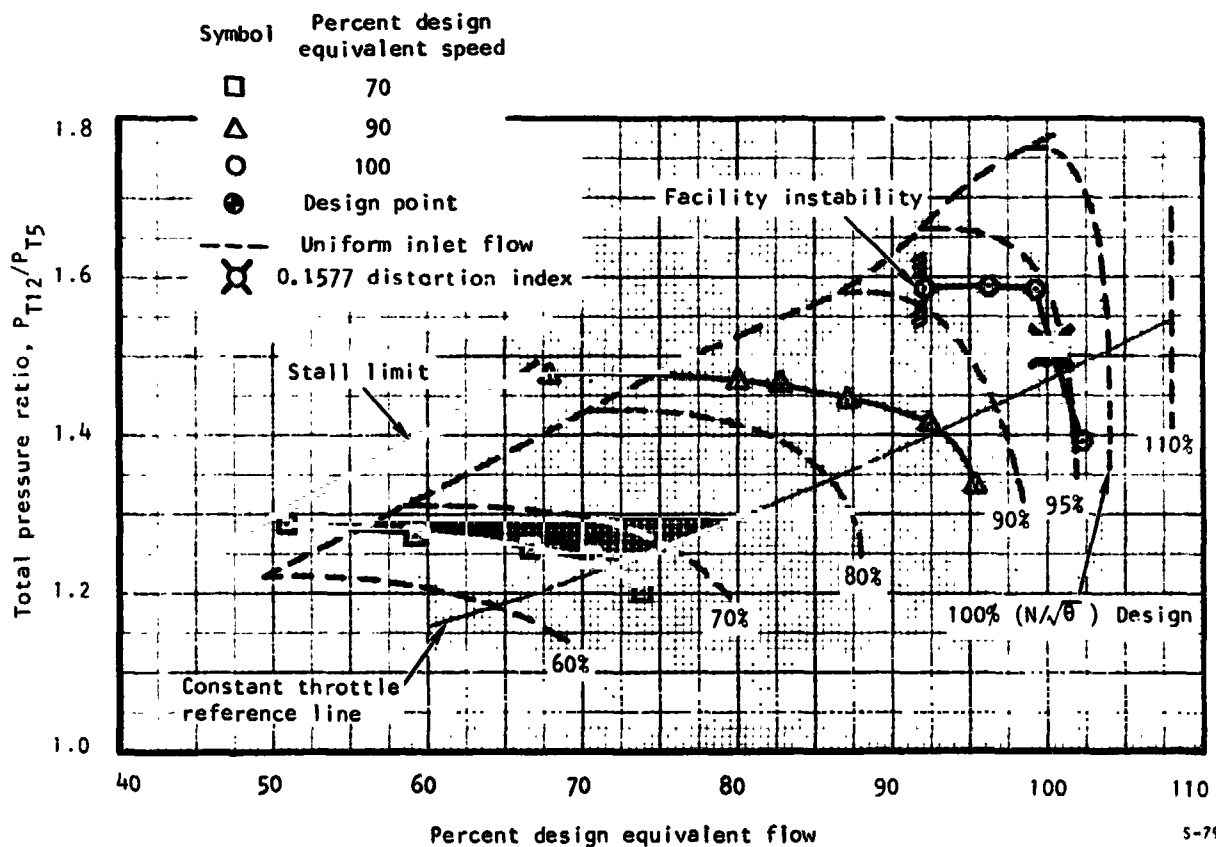
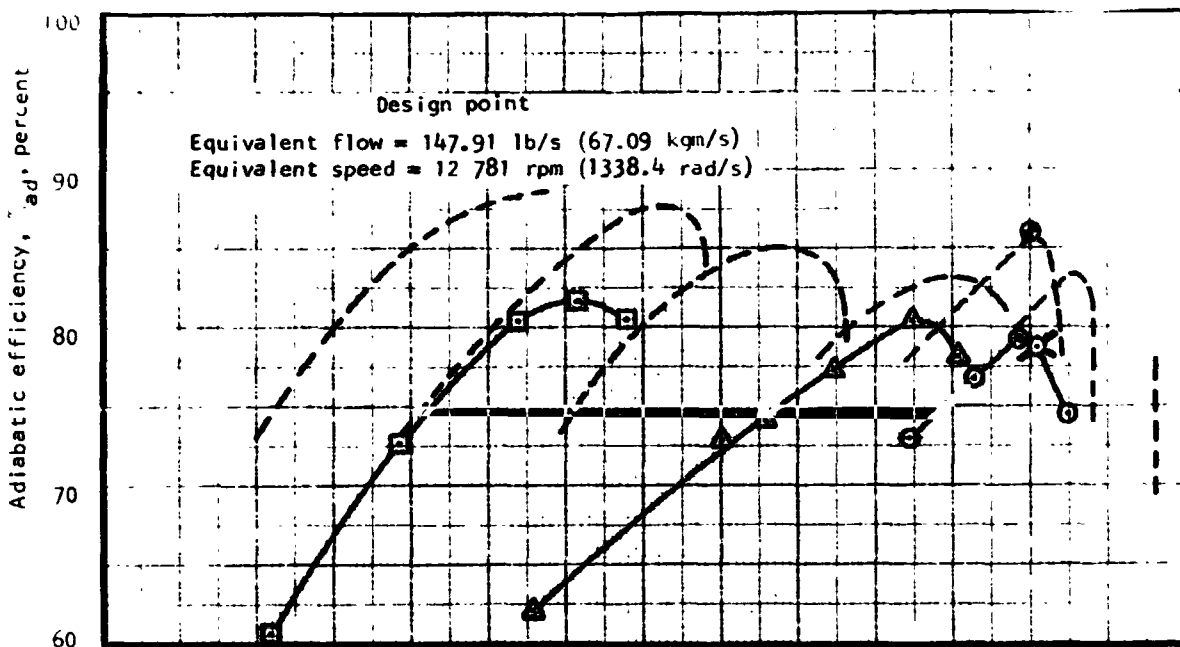


Figure 46.--Stage Performance, Hub-Radial Distortion.

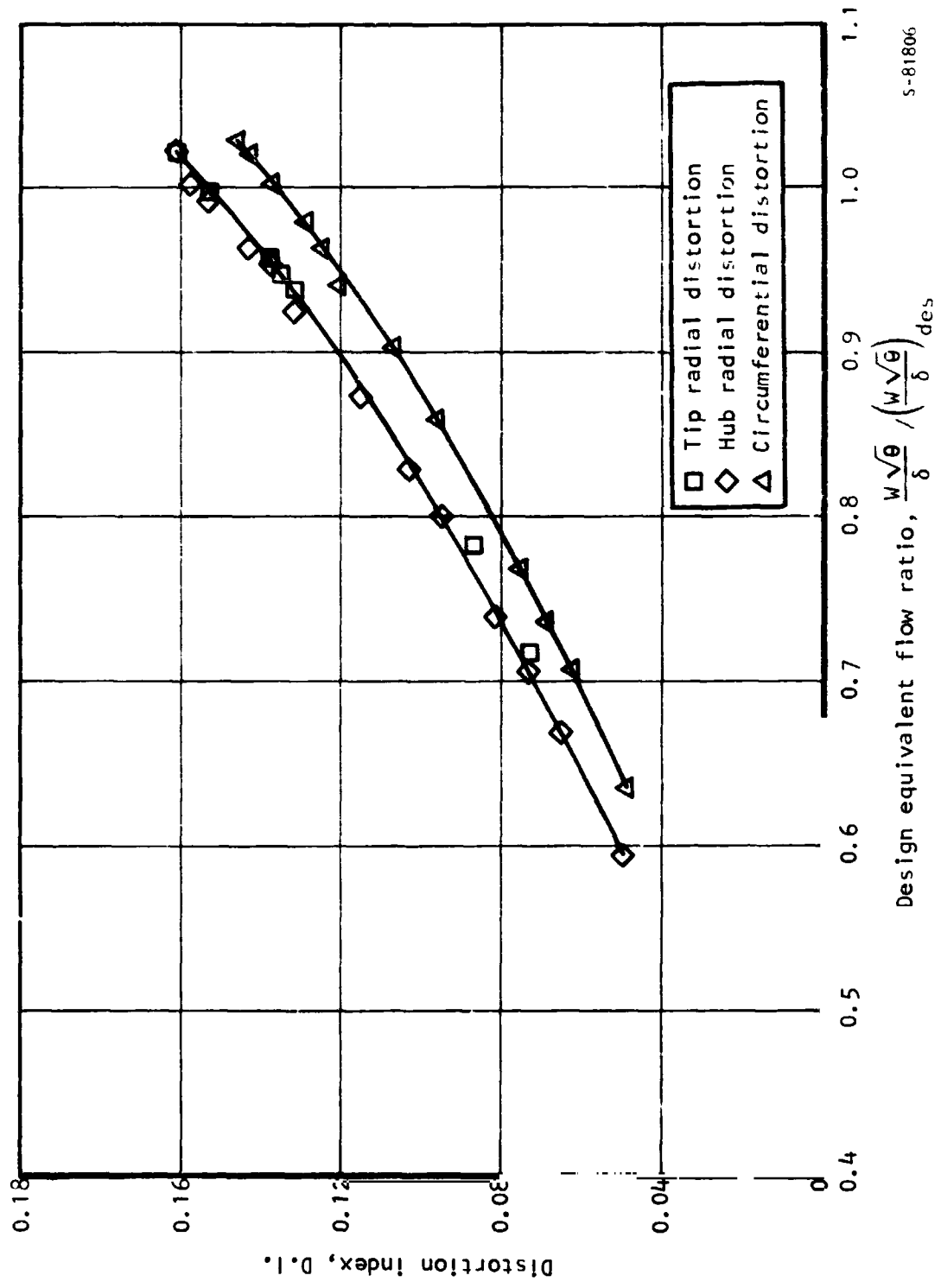
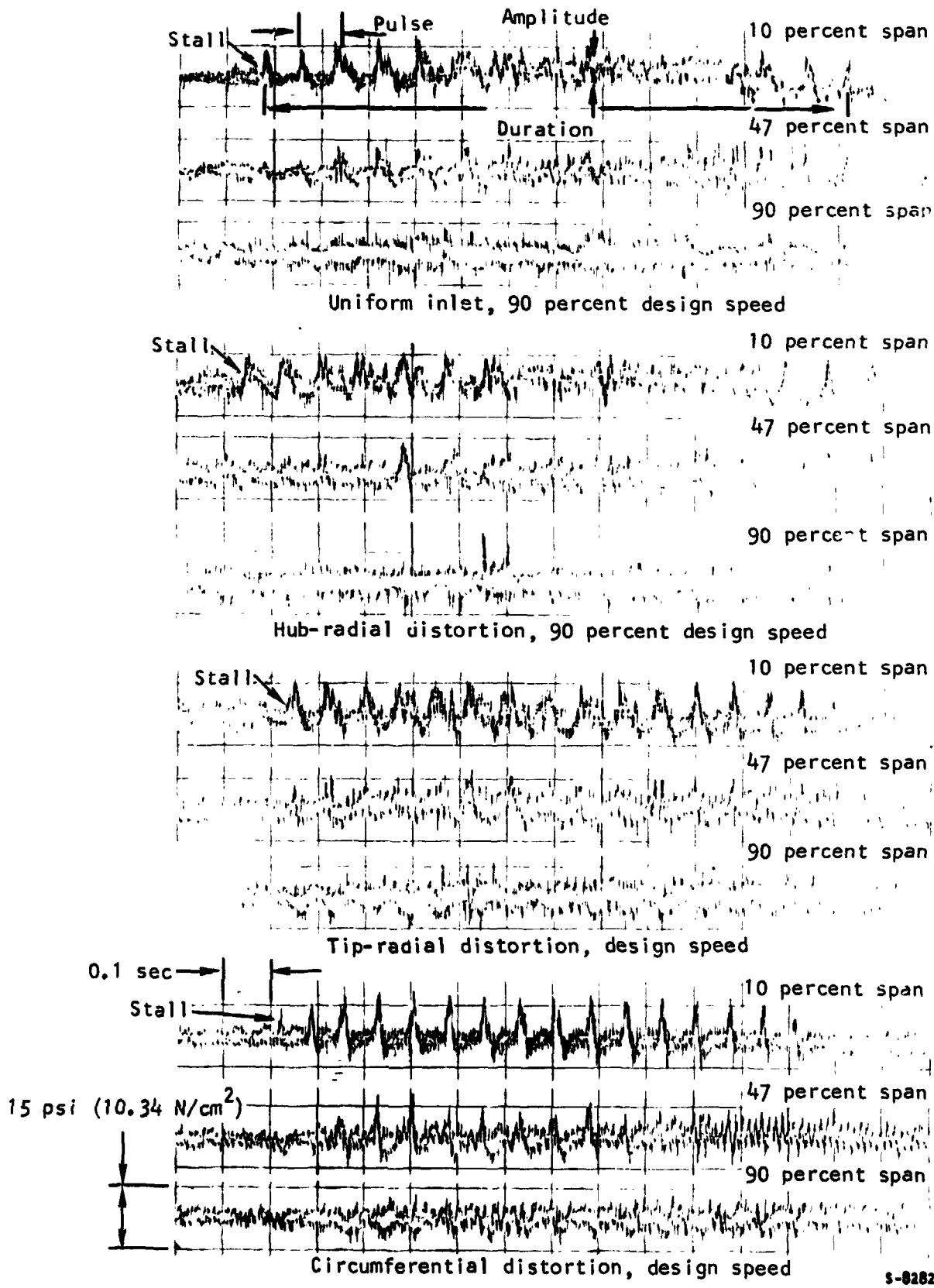


Figure 47.--Distortion Index vs Design Equivalent Flow Ratio.



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

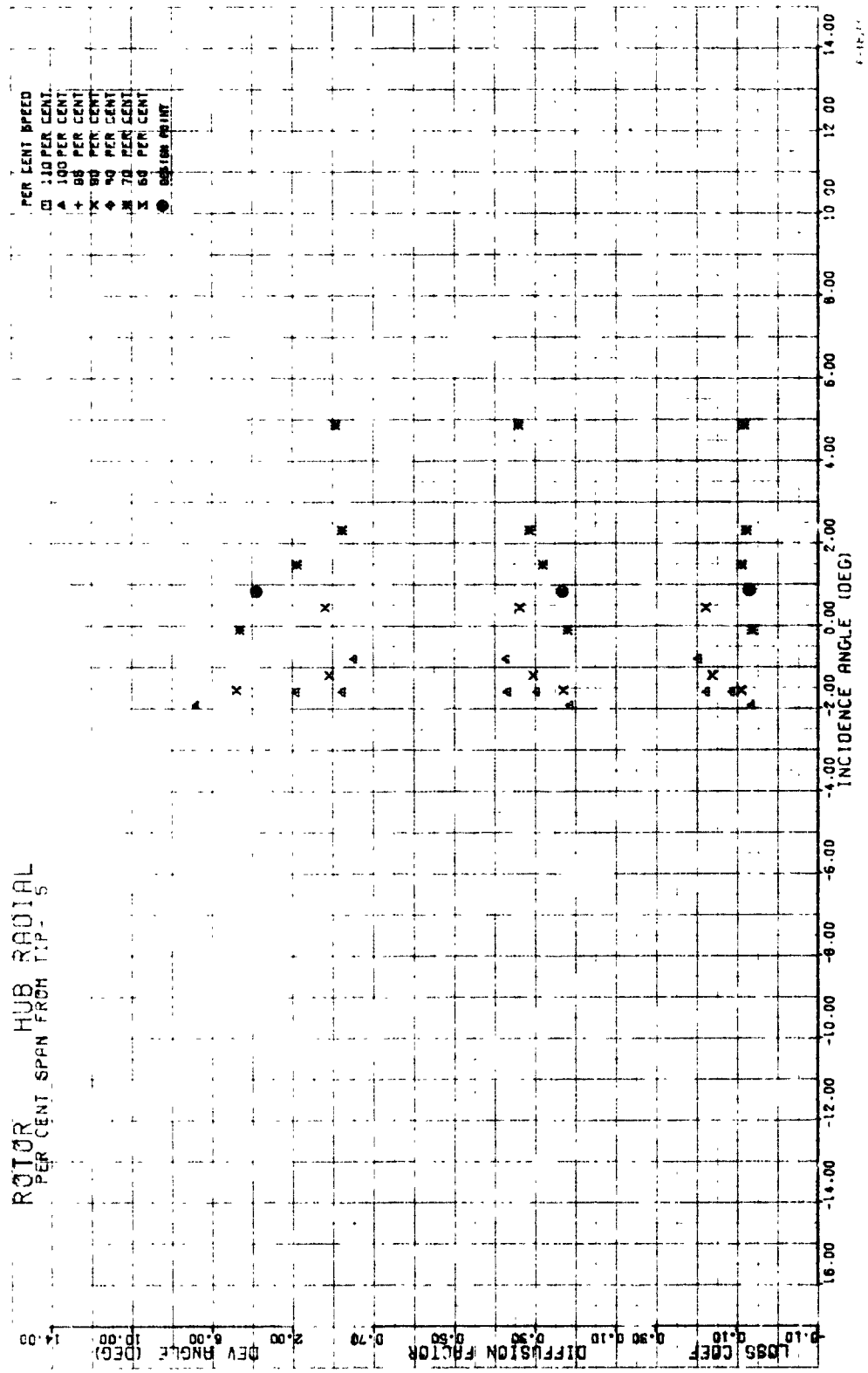


Figure 49a.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 5 Percent Span from Tip.

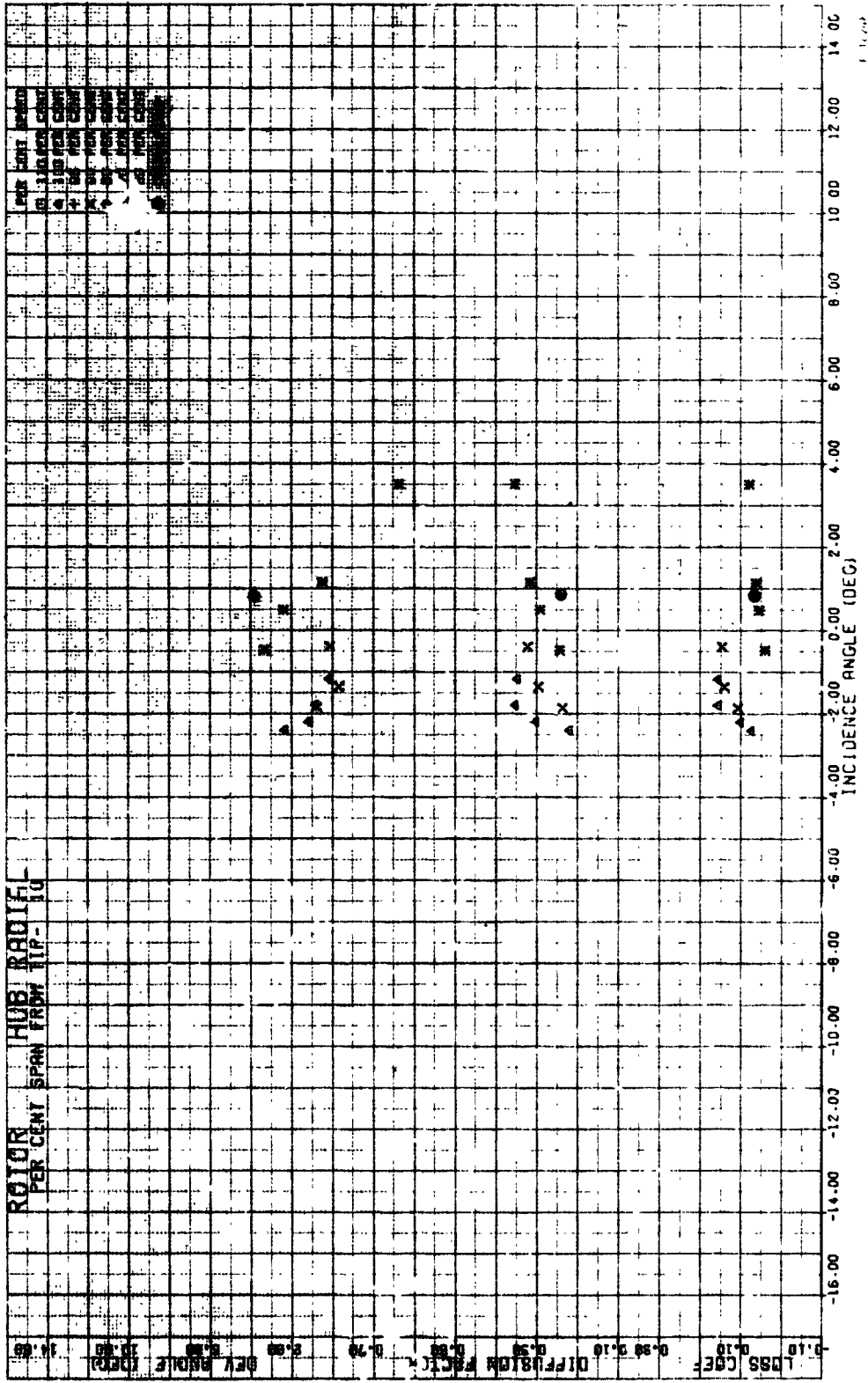


Figure 49b.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 10 Percent Span from Tip.

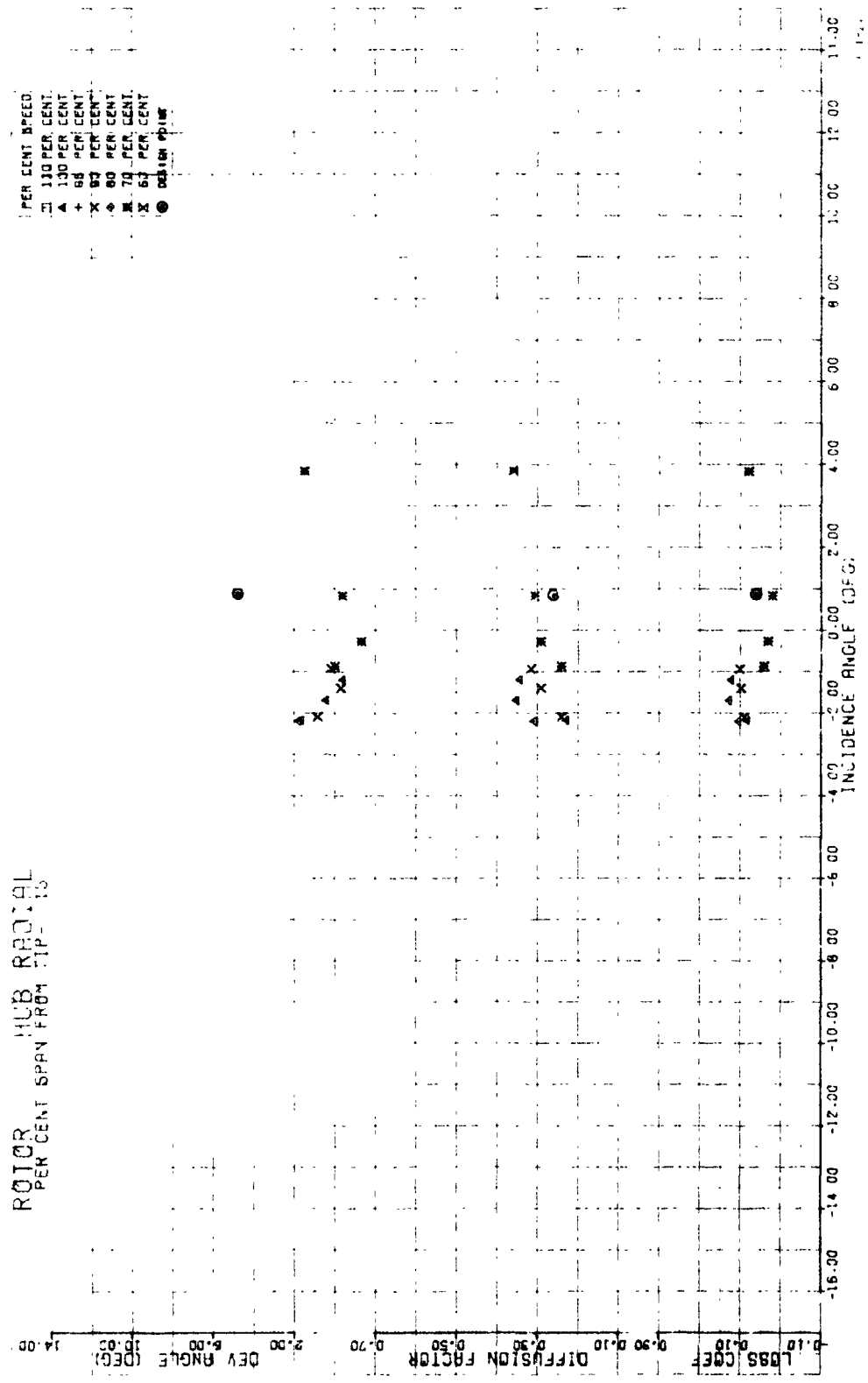


Figure 49c.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 15 Percent Span from Tip.

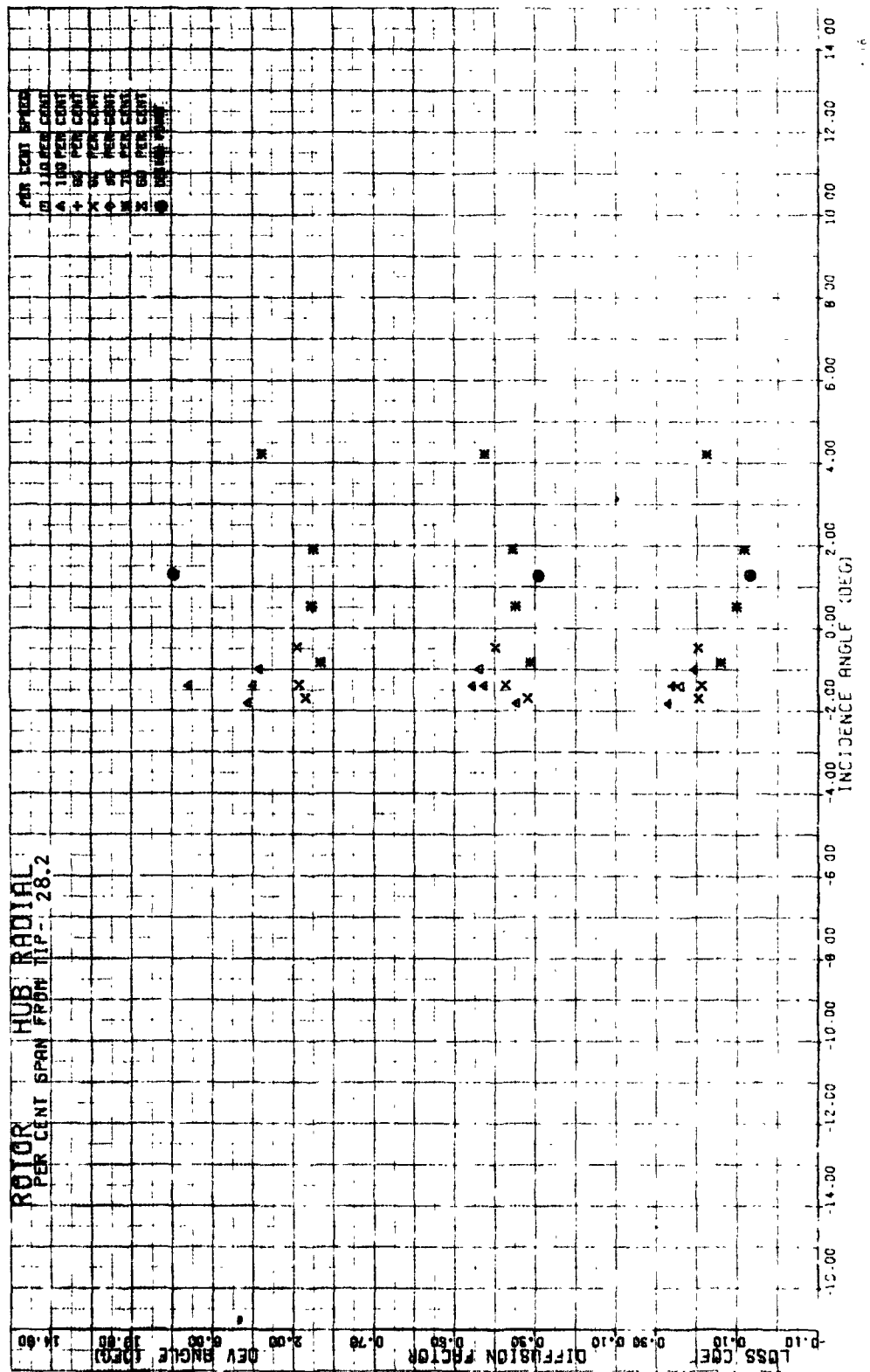


Figure 49d.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 28.2 Percent Span from Tip.

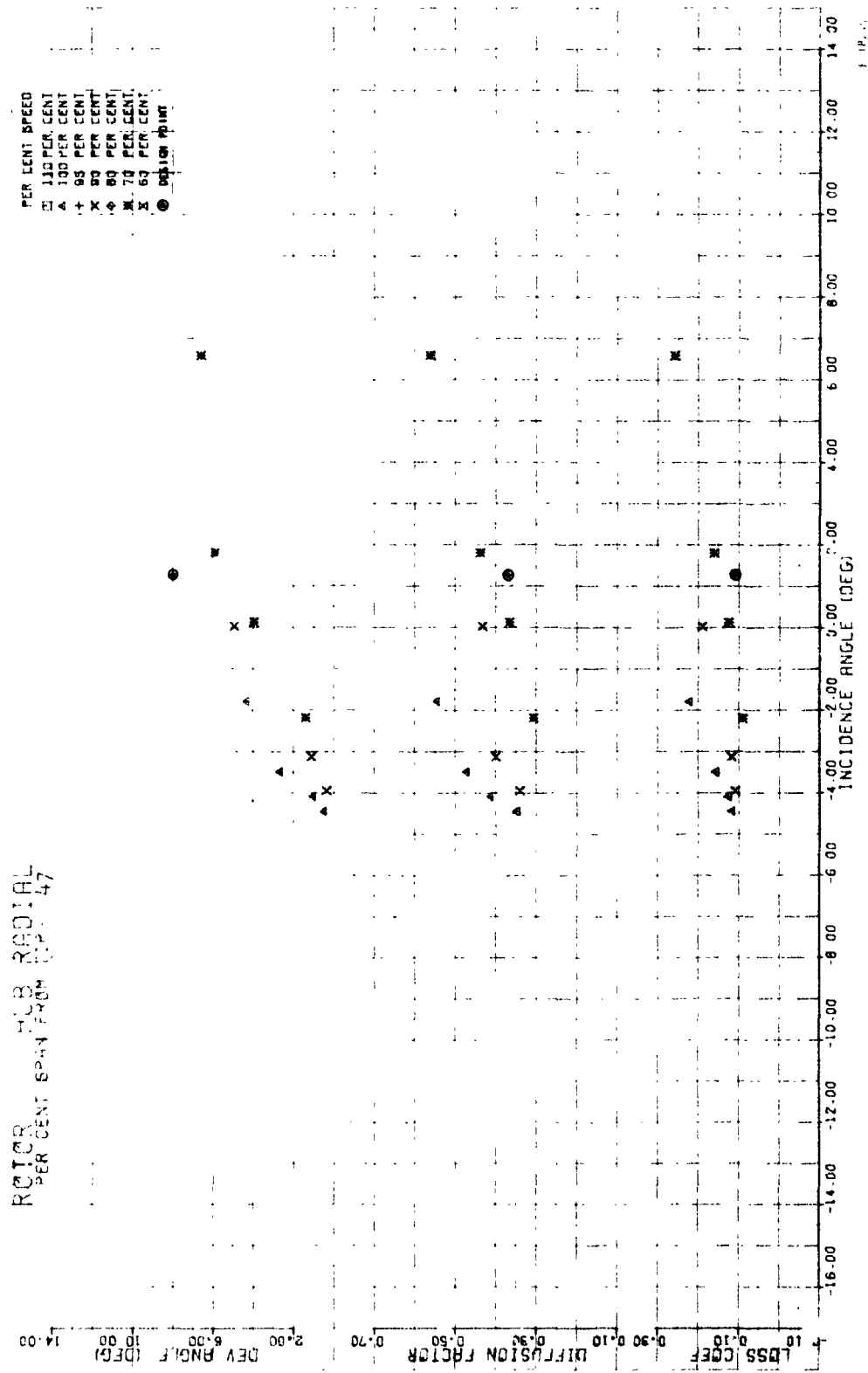


Figure 49e.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 47 Percent Span from Tip.

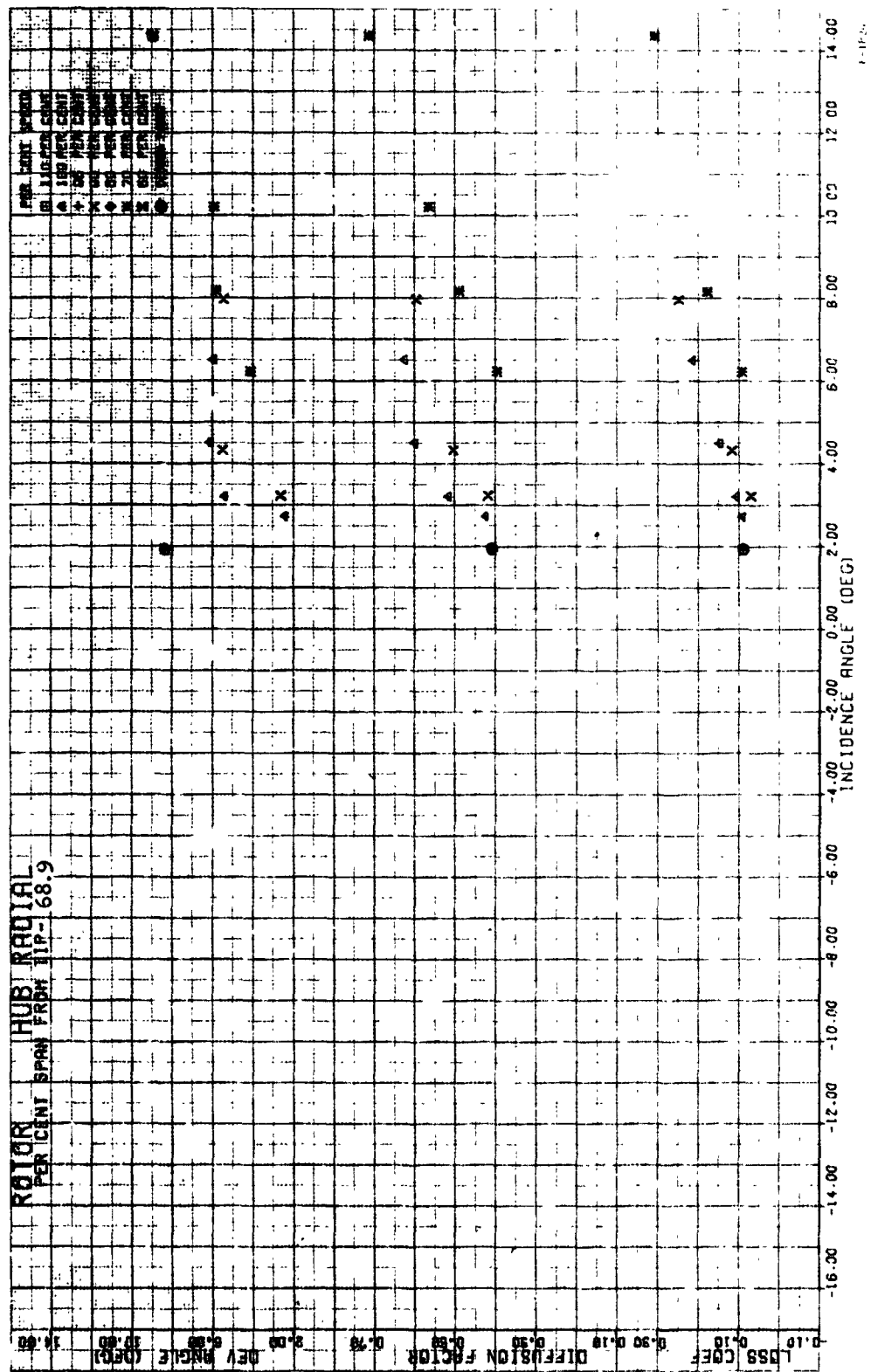


Figure 49f.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 68.9 Percent Span from Tip.

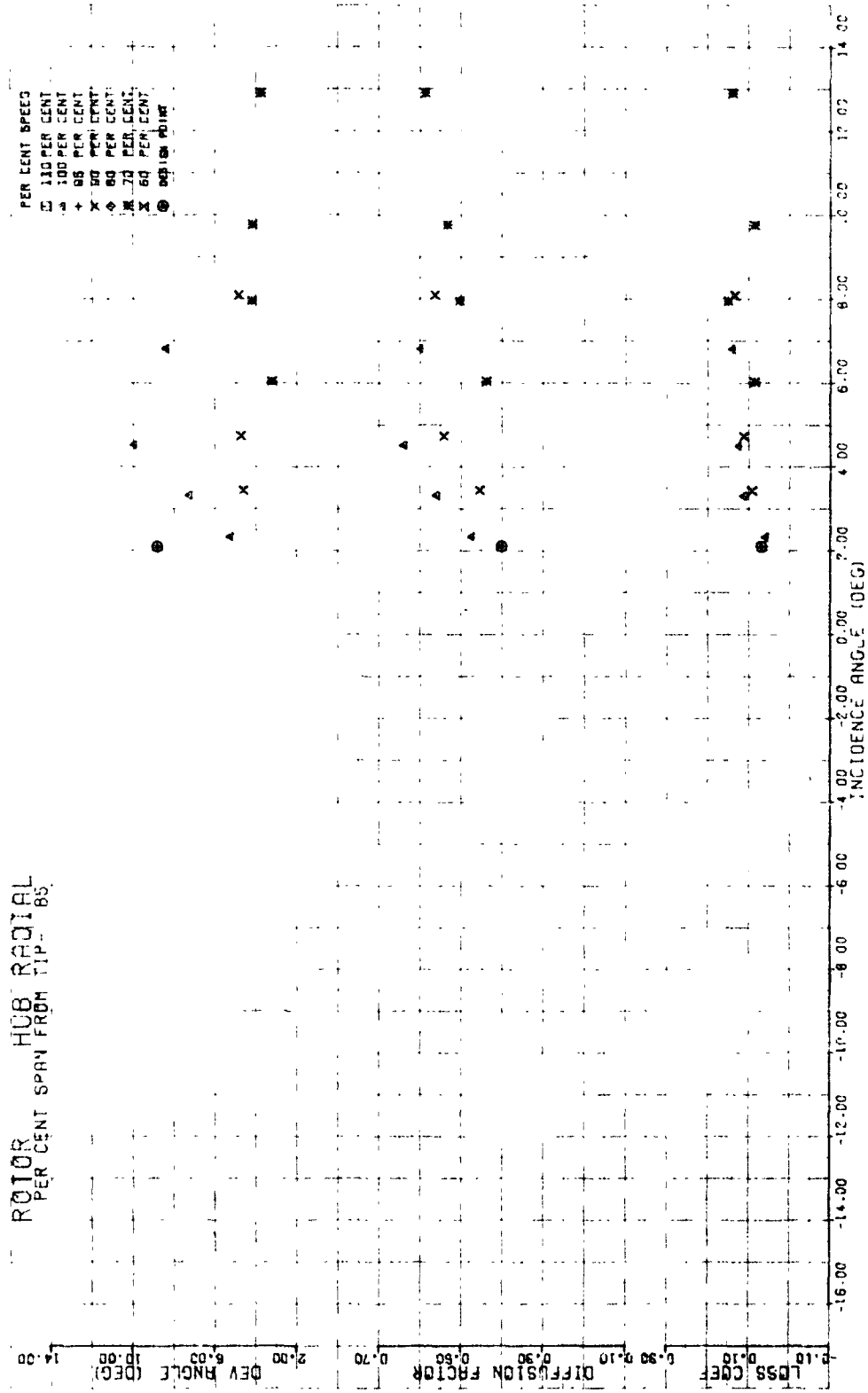


Figure 499.---Rotor Blade Clement Performance, Hub-Radially Distorted Inlet Flow, 85 Percent Span from Tip.

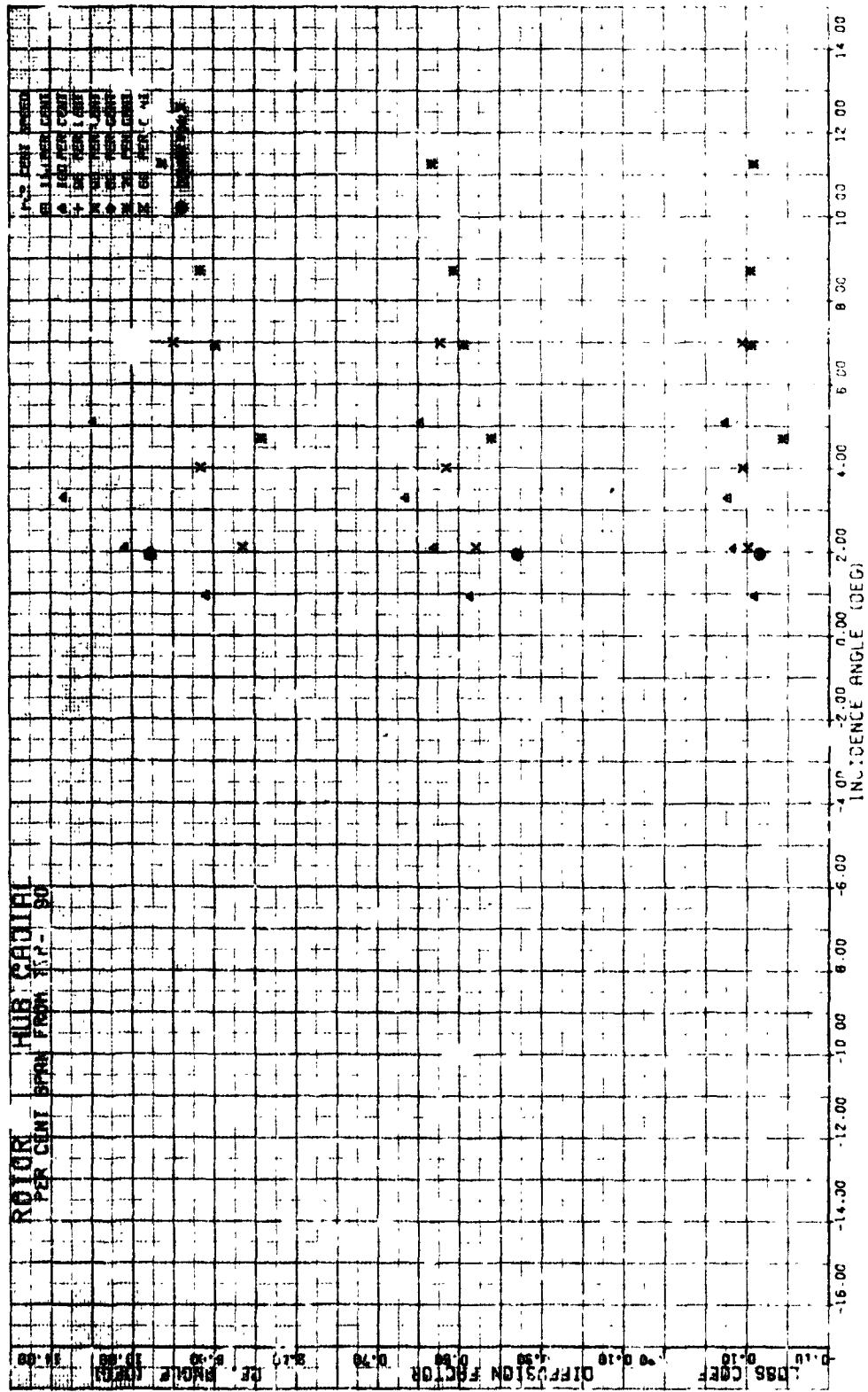


Figure 49h.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 90 Percent Span from Tip.

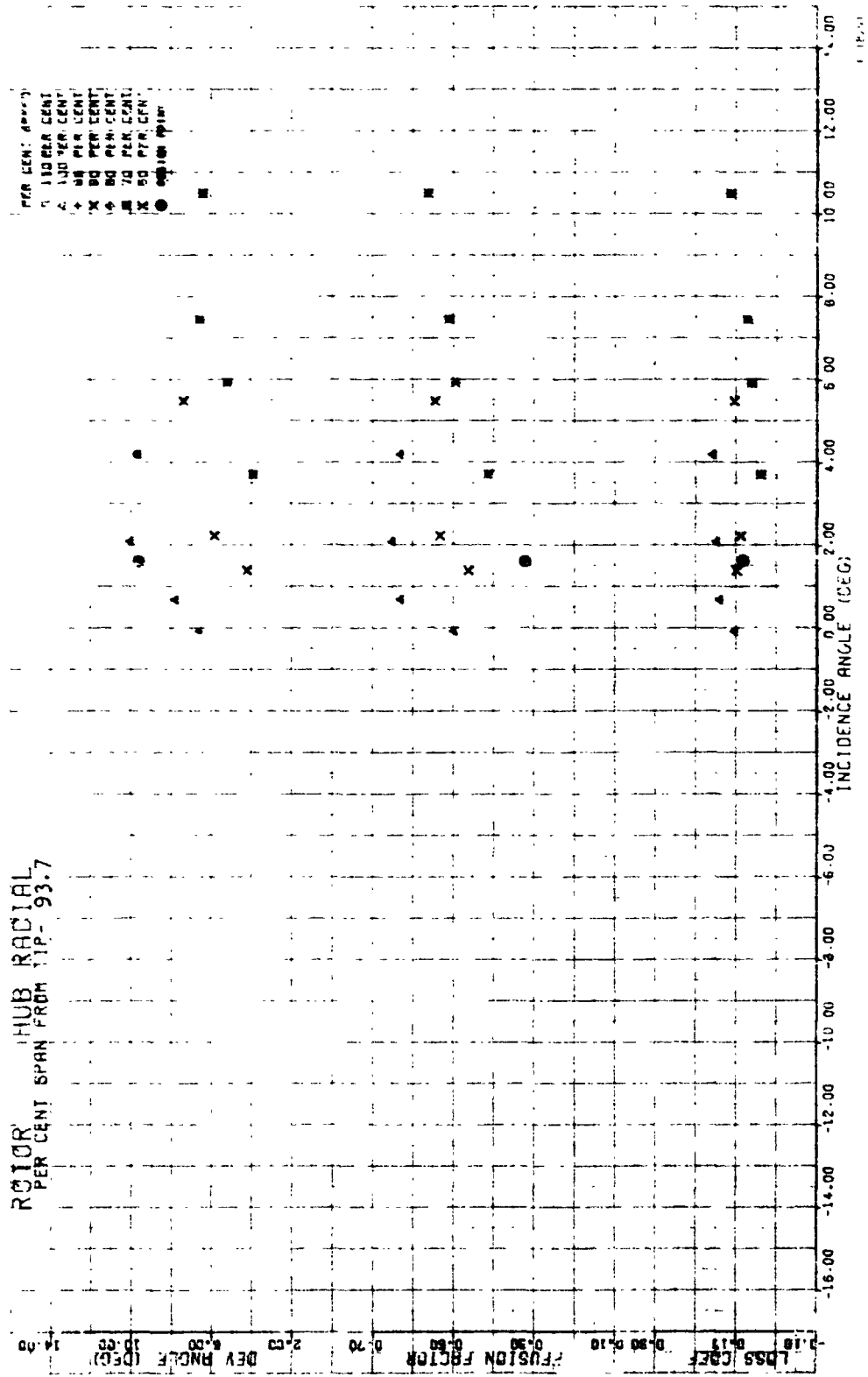


Figure 49i.--Rotor Blade Element Performance, Hub-Radially Distorted Inlet Flow, 93.7 Percent Span from Tip.

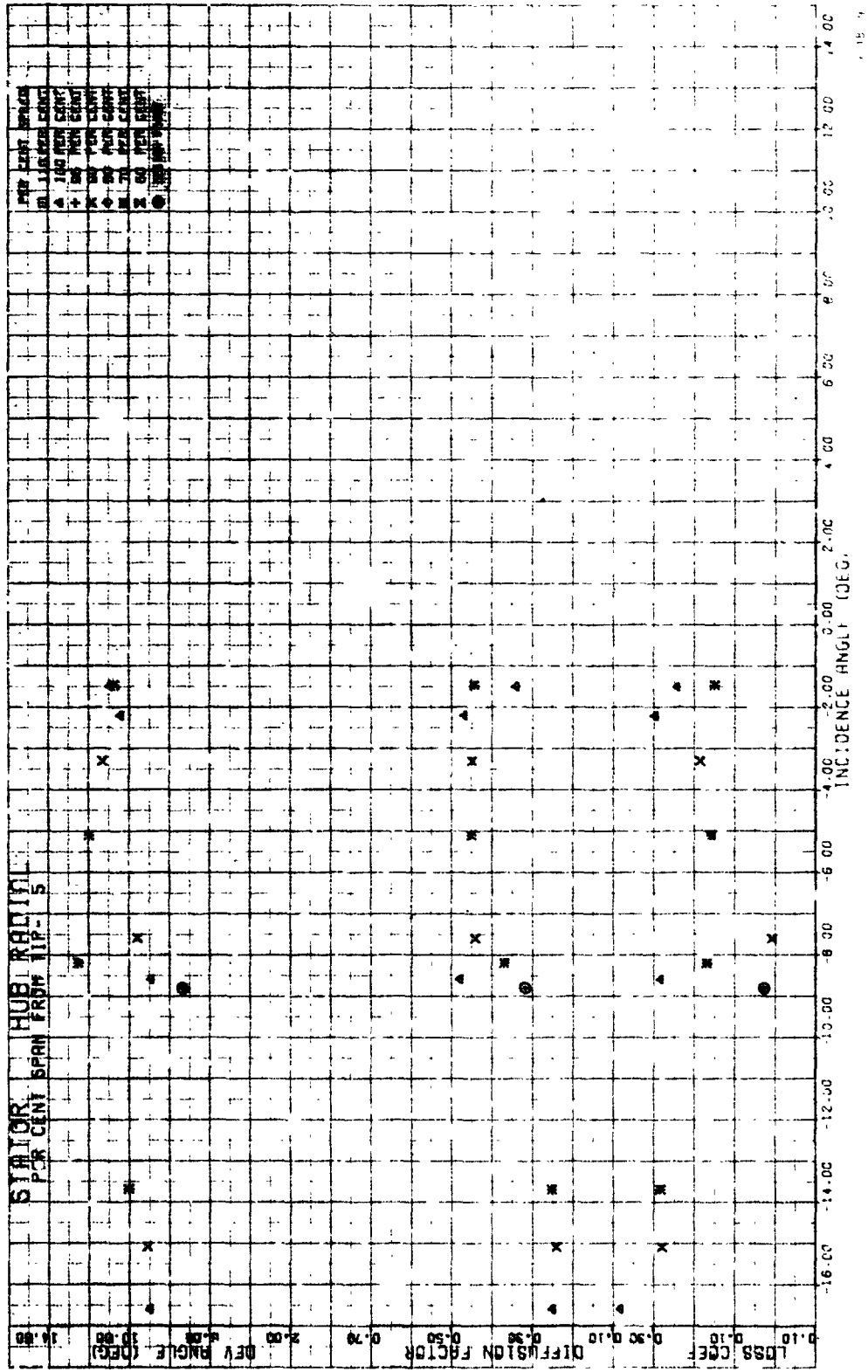


Figure 50a.--Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 5 Percent Span from Tip.

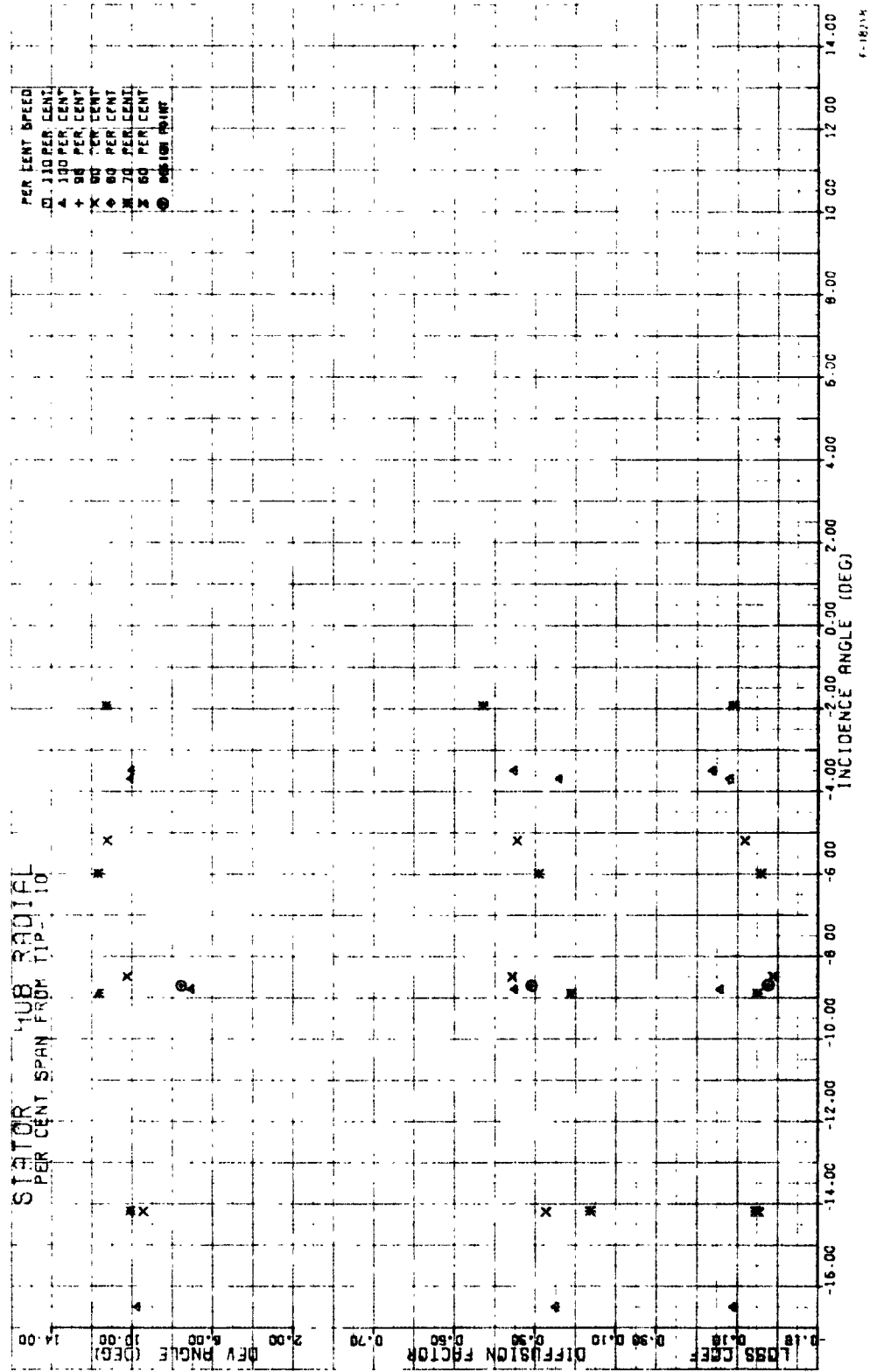


Figure 50b.---Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 10 Percent Span from Tip.

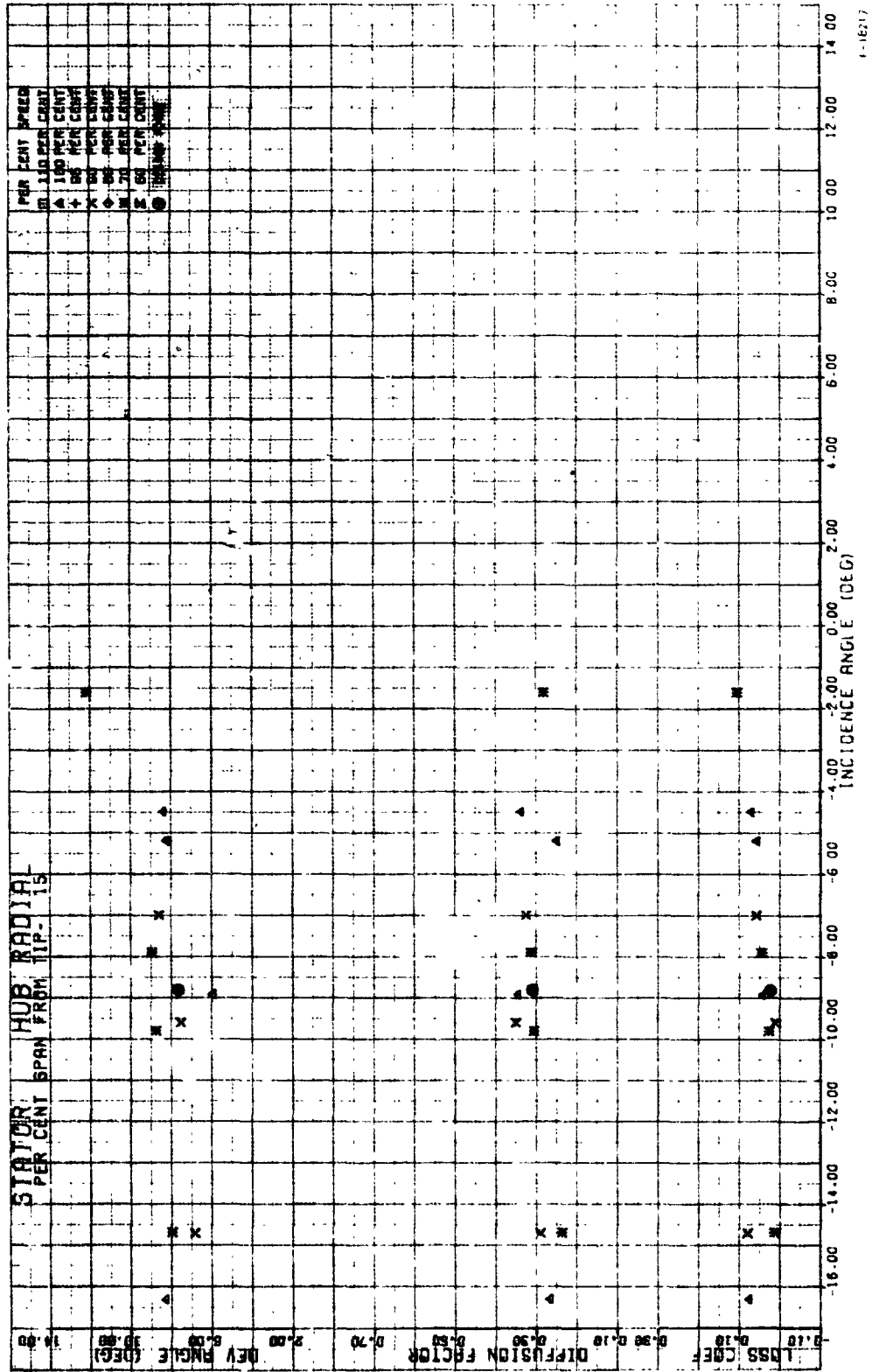


Figure 50c.--Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 15 Percent Span from Tip.

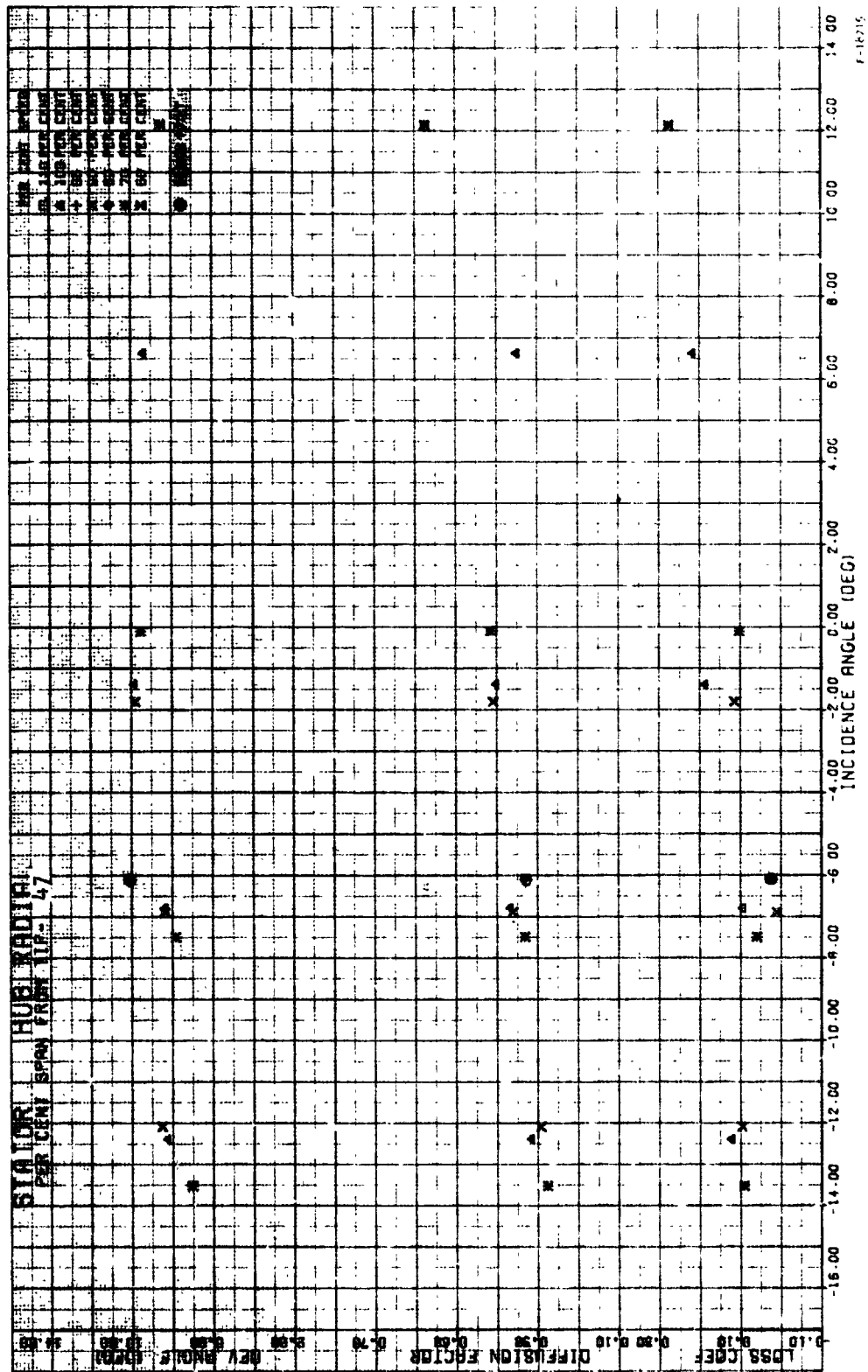


Figure 50e.--Stator Vane Element Performance, Hub-Radiially Distorted Inlet Flow, 47 Percent Span from Tip.

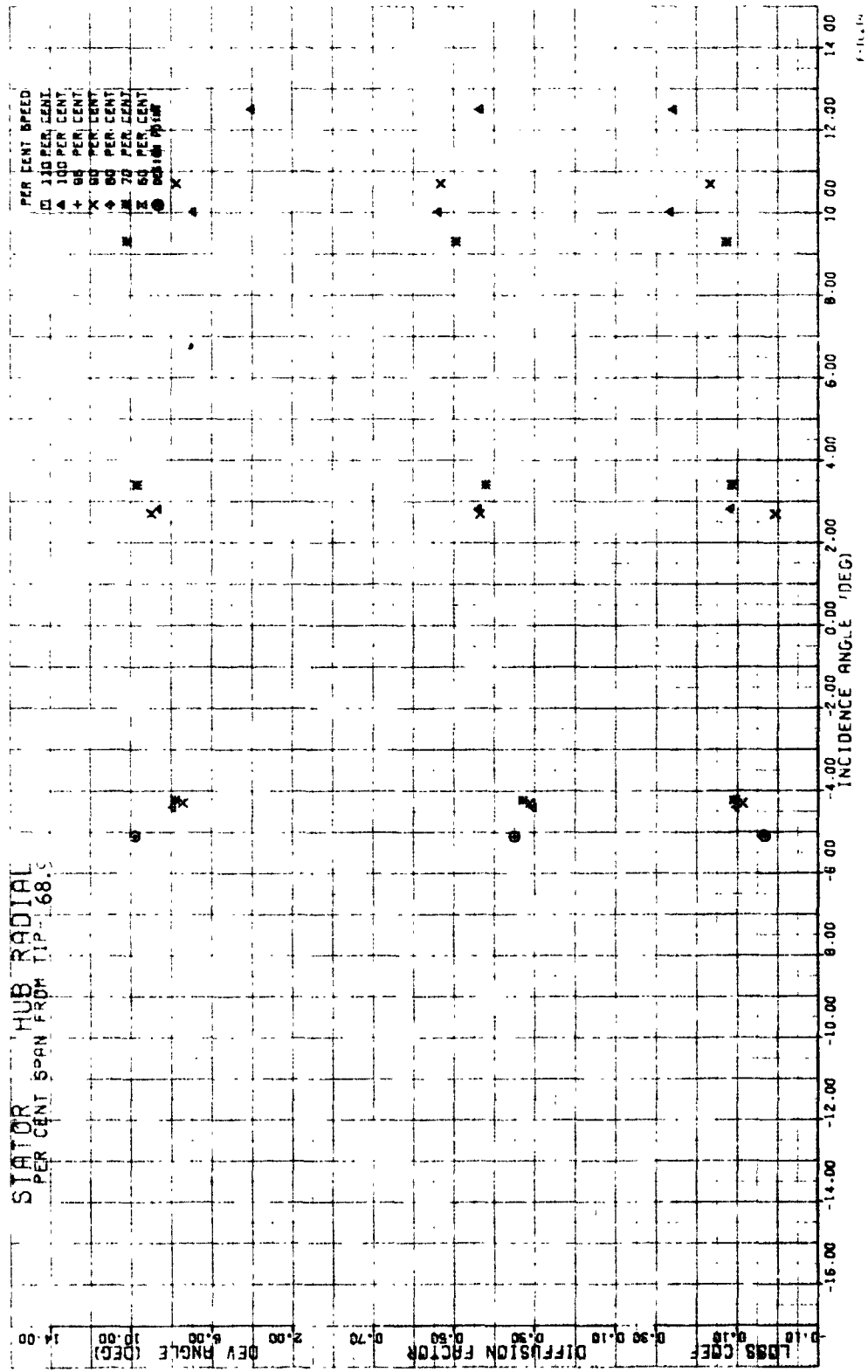


Figure 50f. --Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 68.9 Percent Span from Tip.

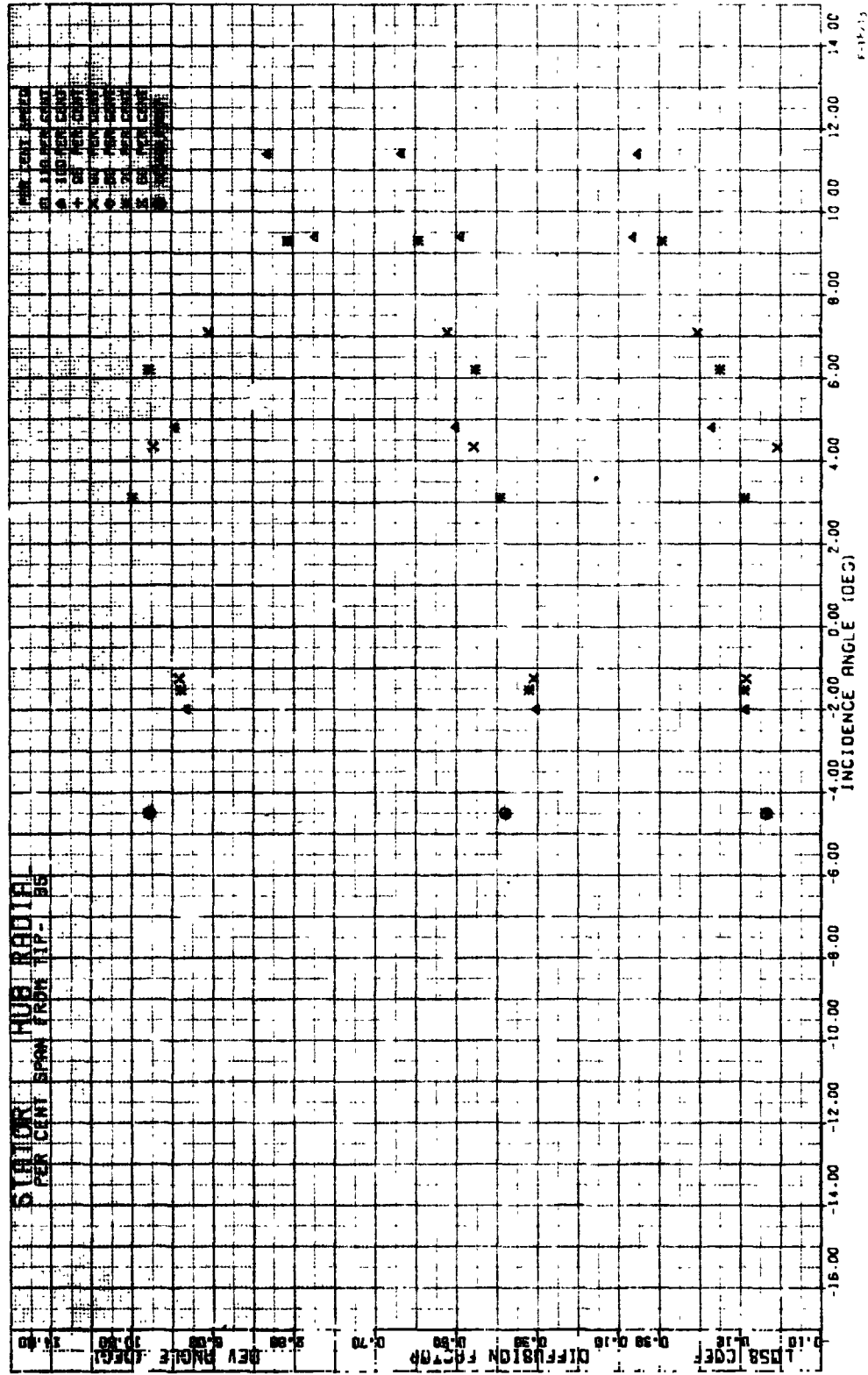
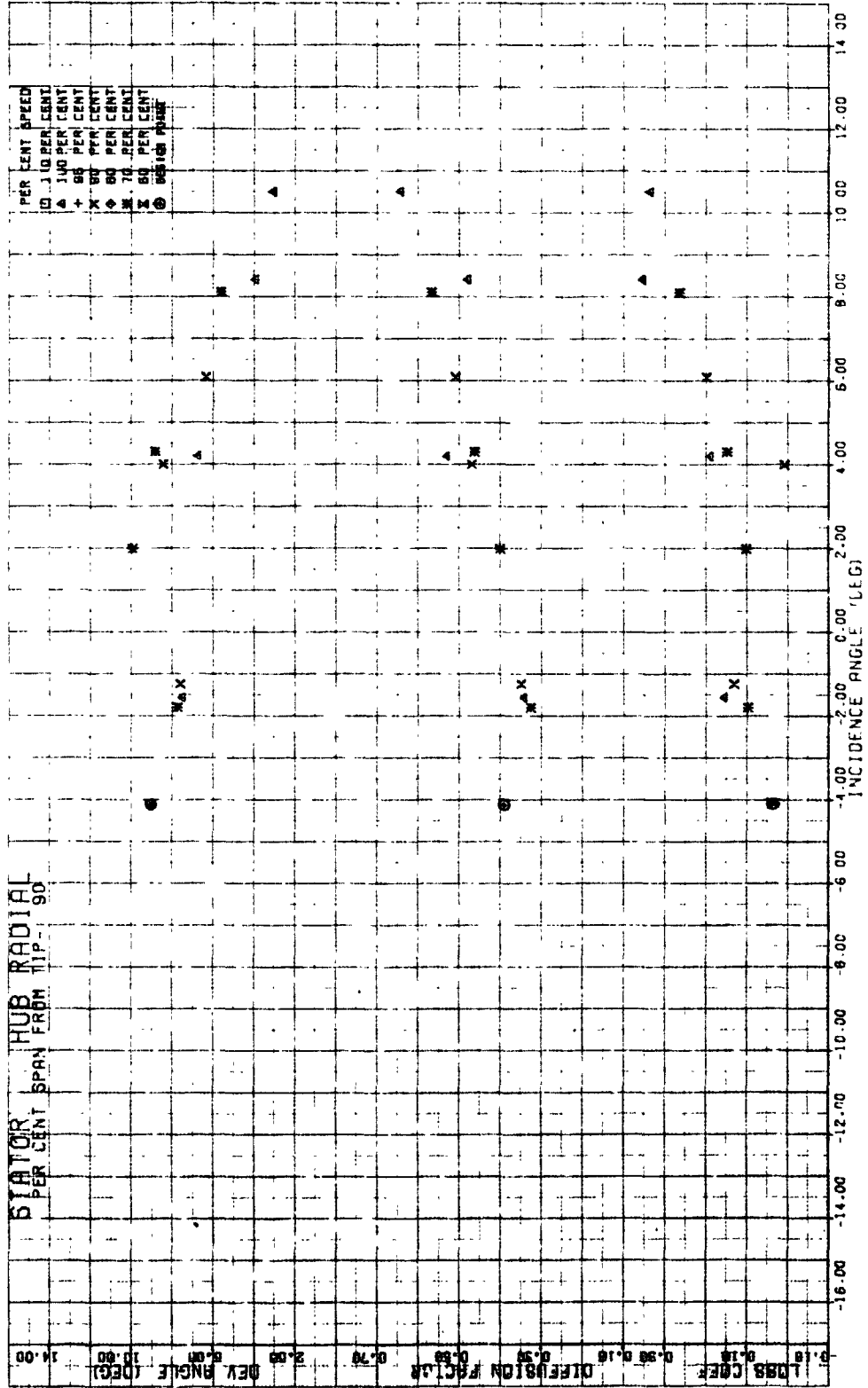


Figure 50g.--Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 85 Percent Span from Tip.



F 10-17

Figure 50h.--Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 90 Percent Span from Tip.

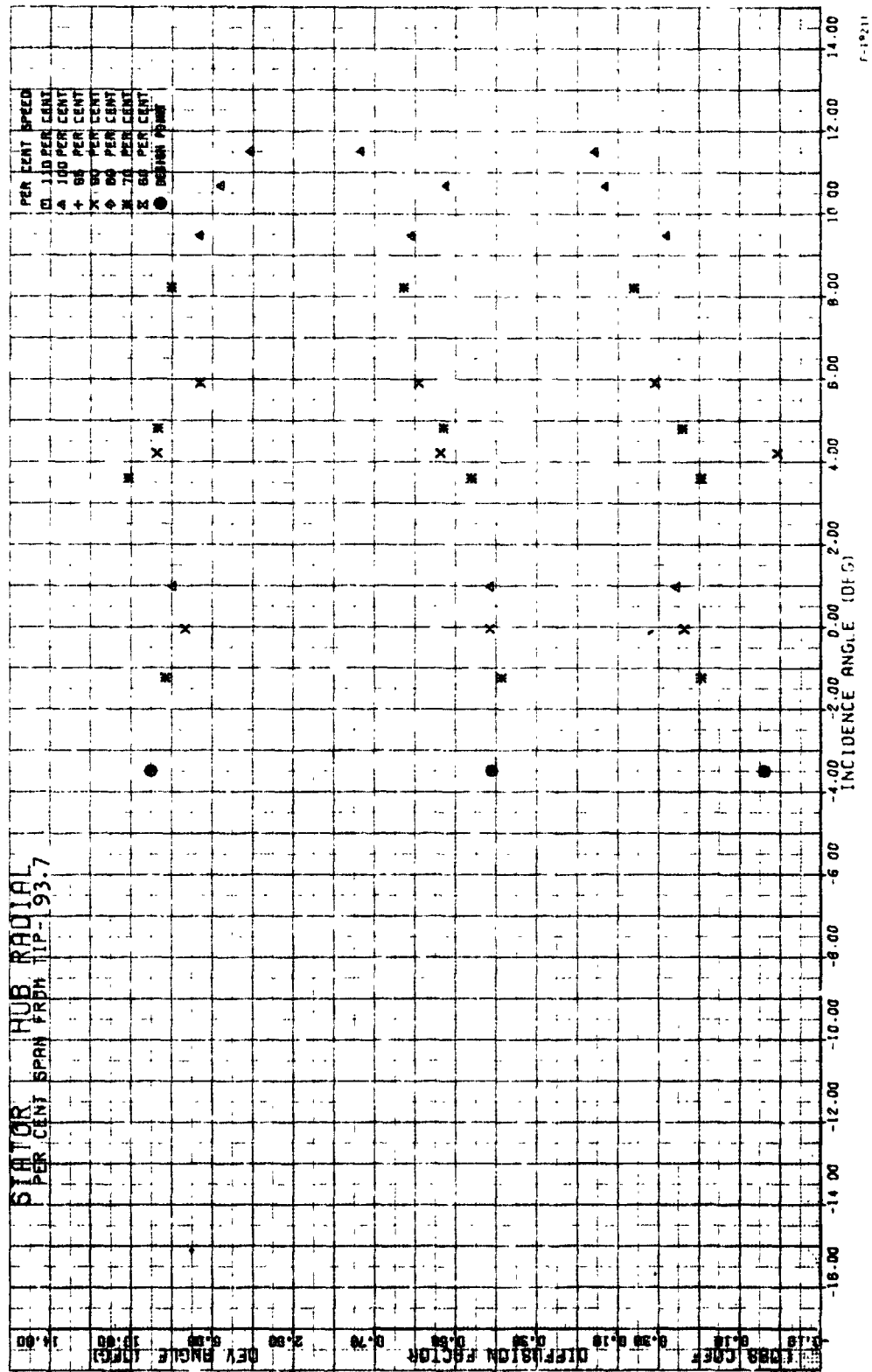
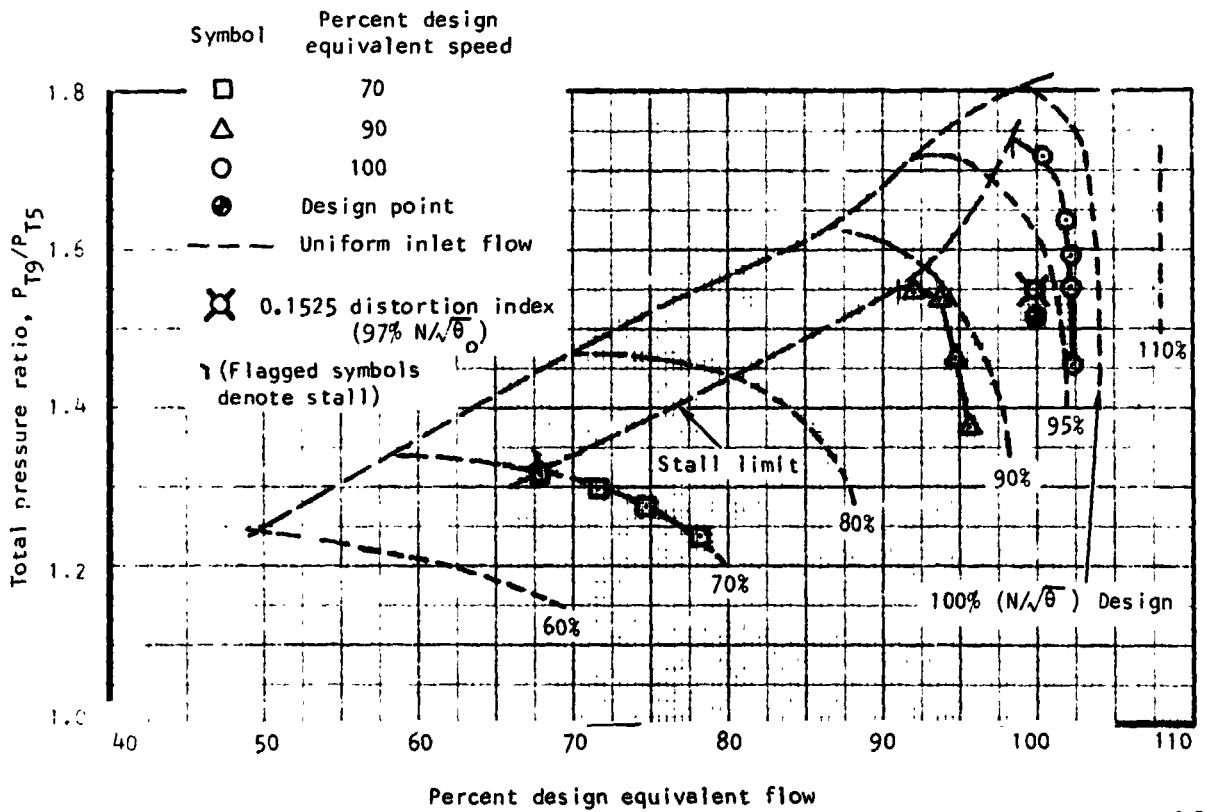
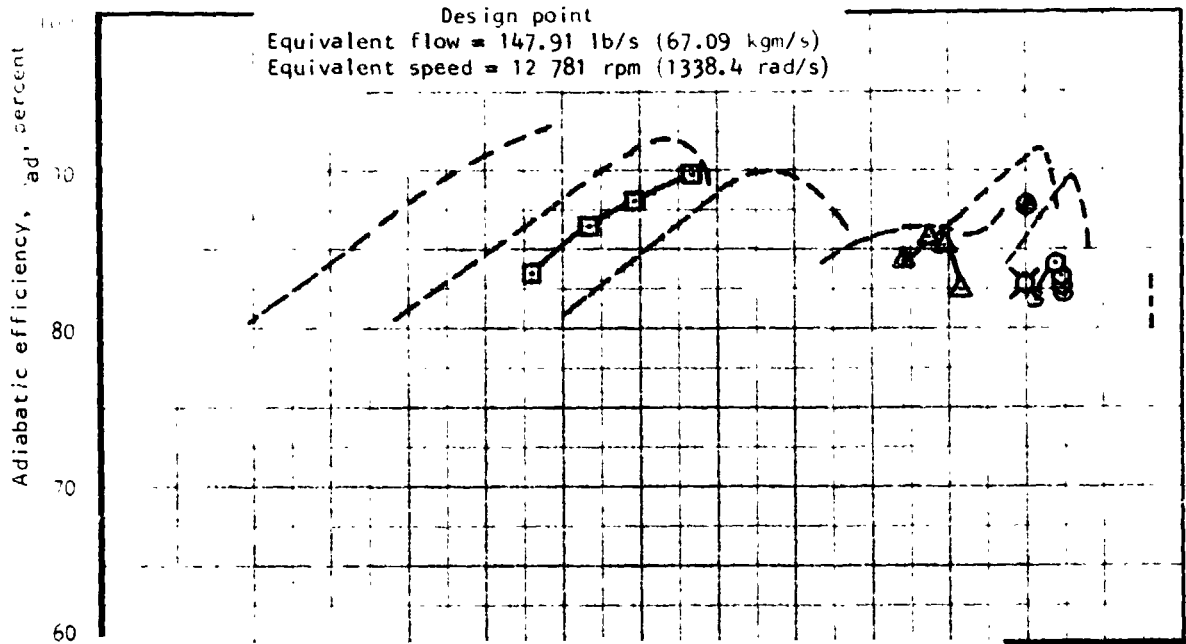
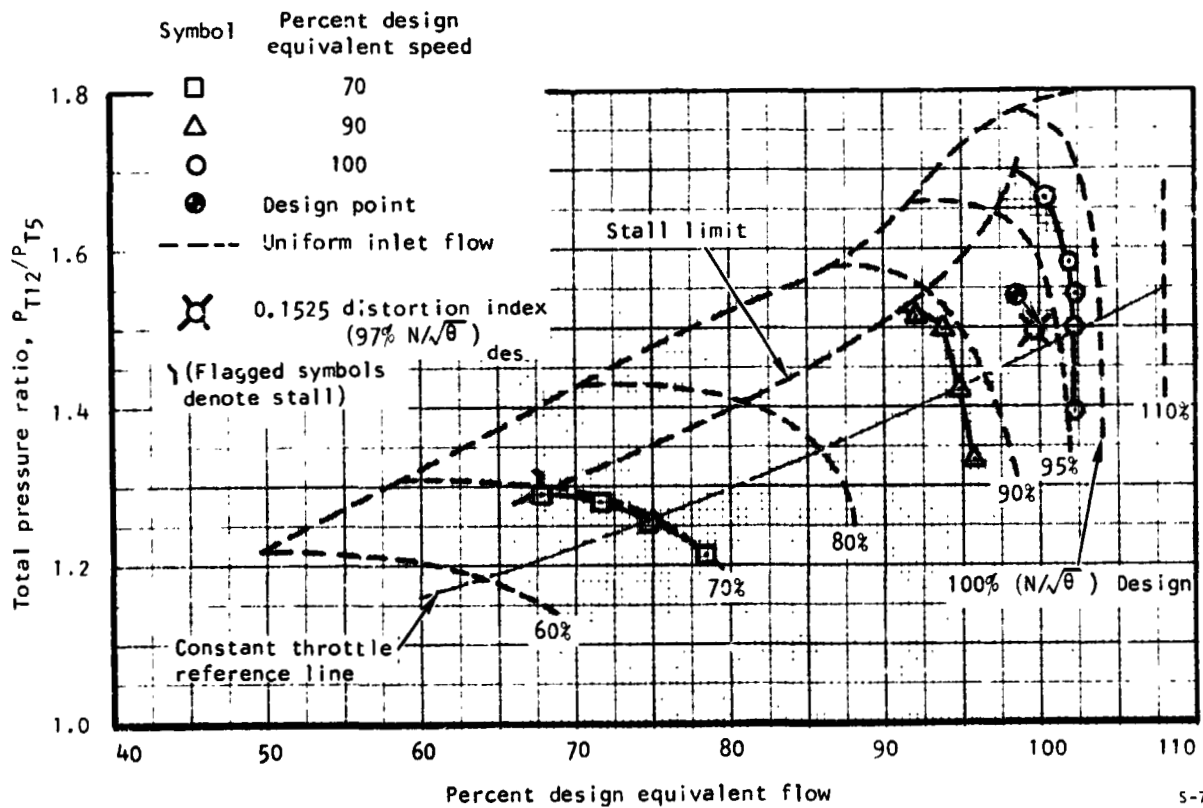
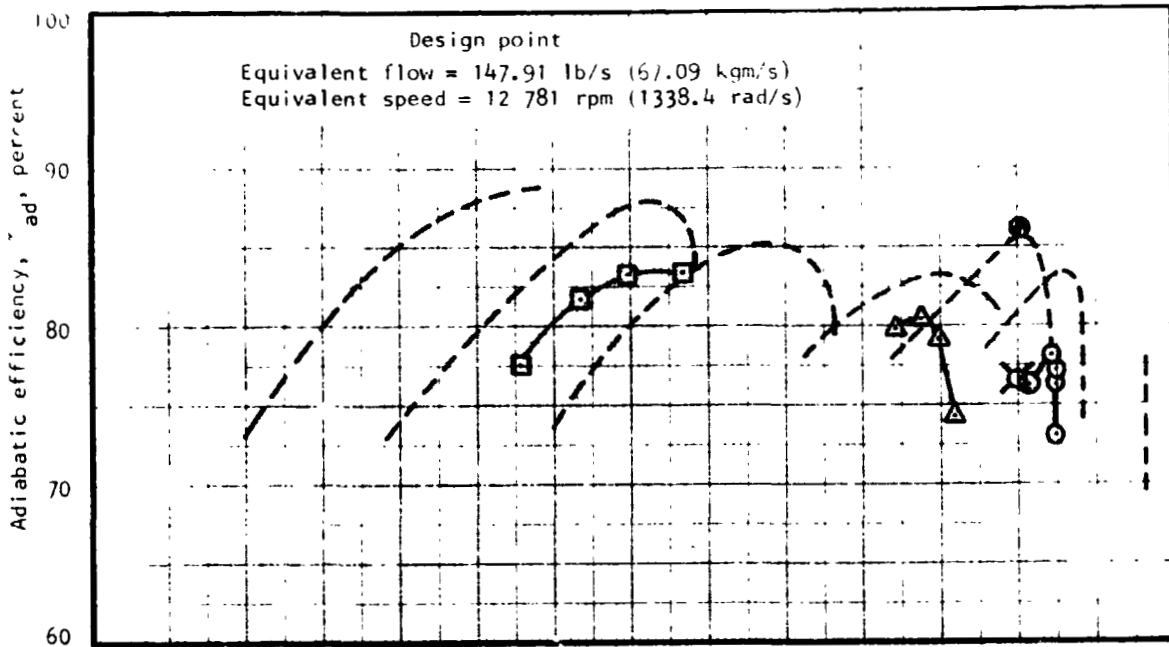


Figure 501. --Stator Vane Element Performance, Hub-Radially Distorted Inlet Flow, 93.7 Percent Span from Tip.



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



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

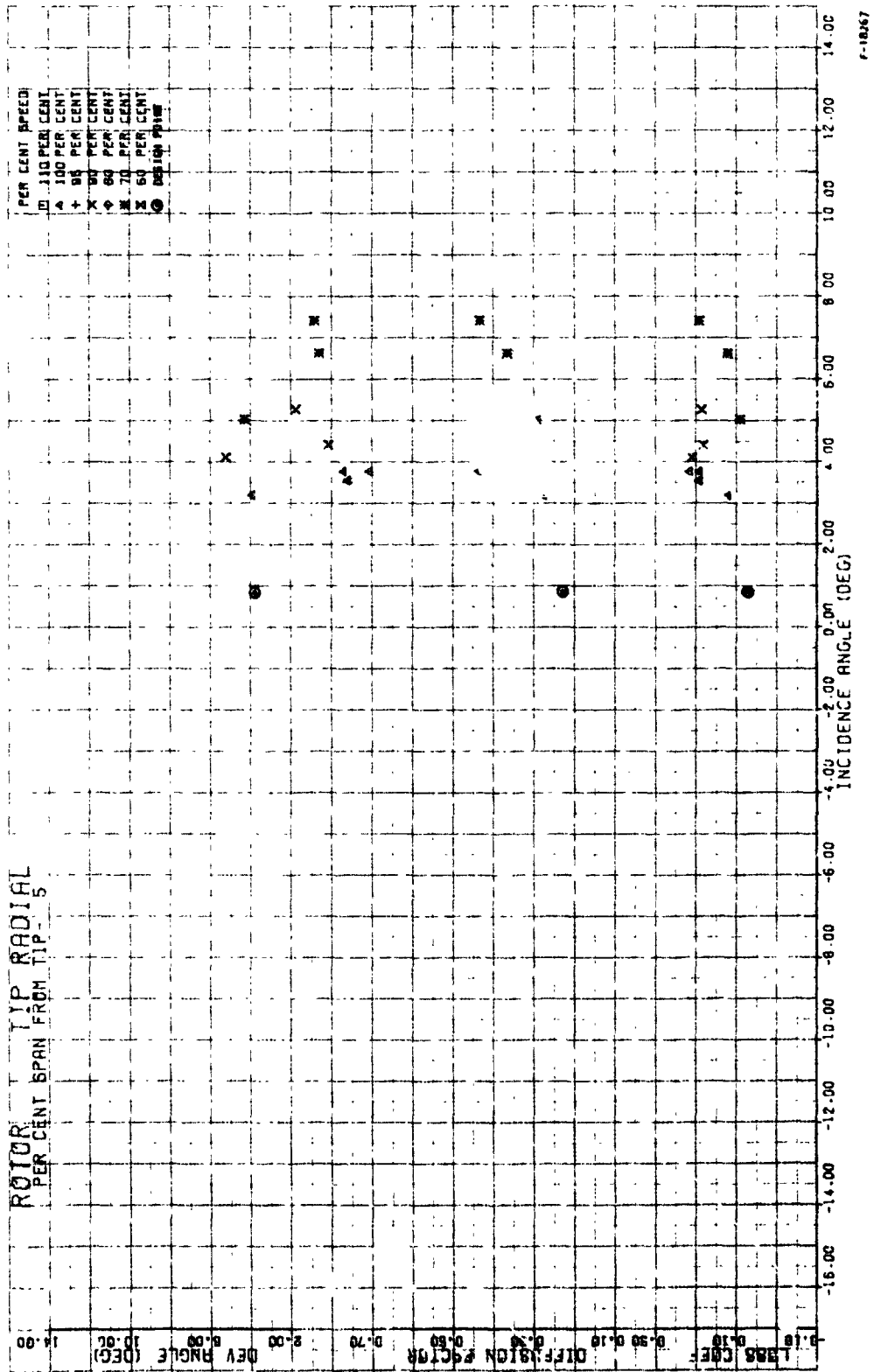


Figure 53a.--Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 5 Percent Span from Tip.

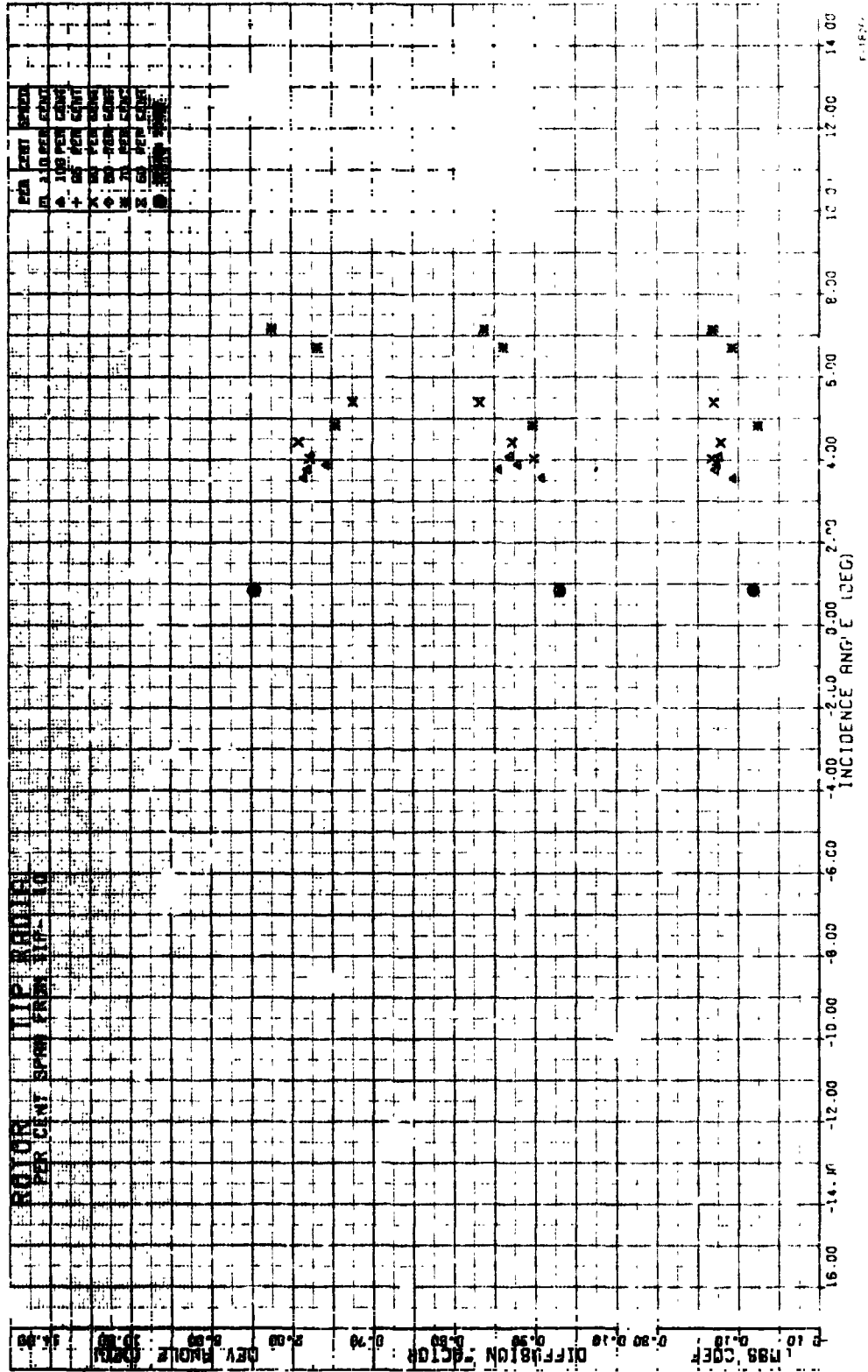


Figure 53b.---Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 10 Percent Span from Tip.

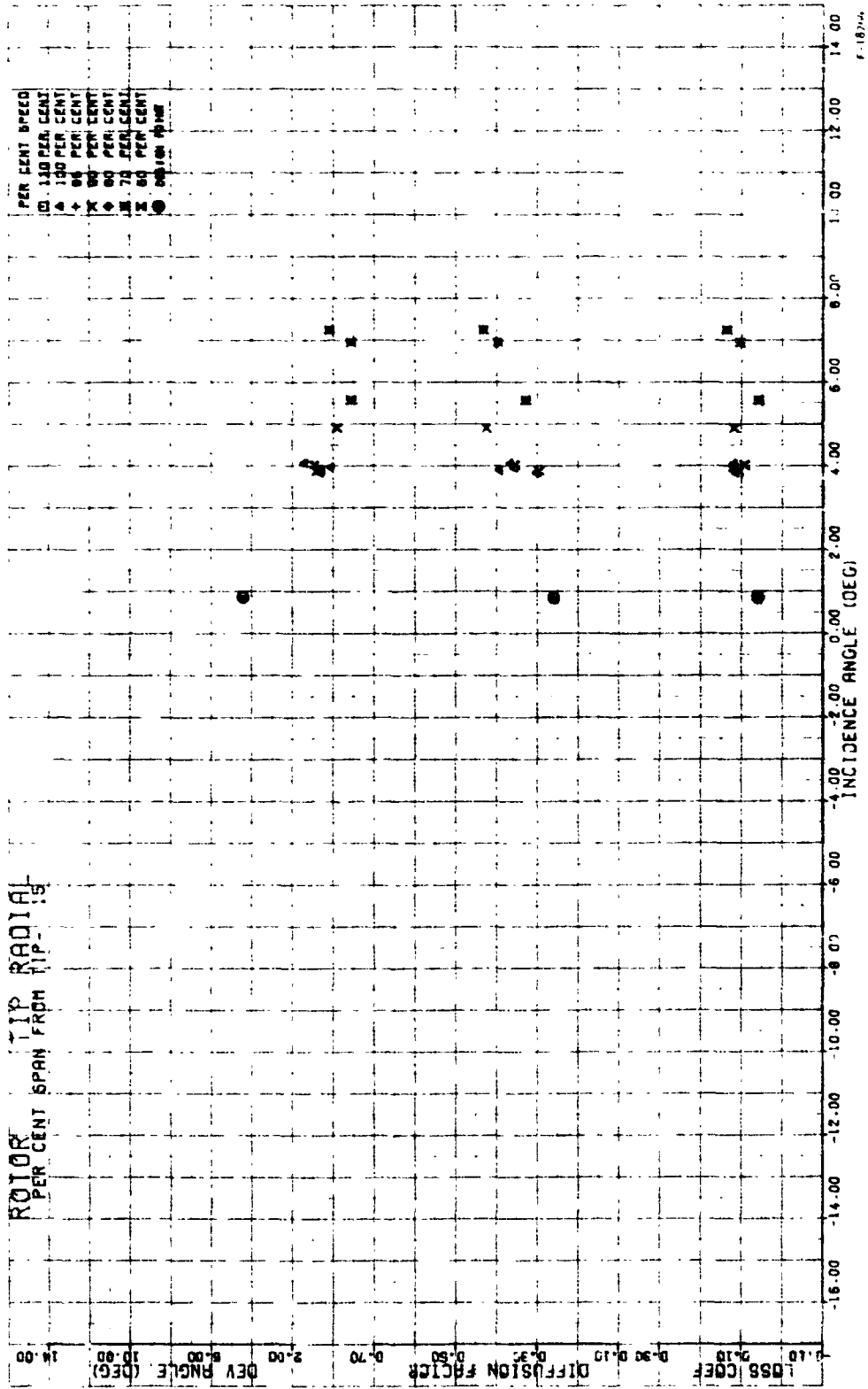


Figure 53c.--Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 15 Percent Span from Tip.

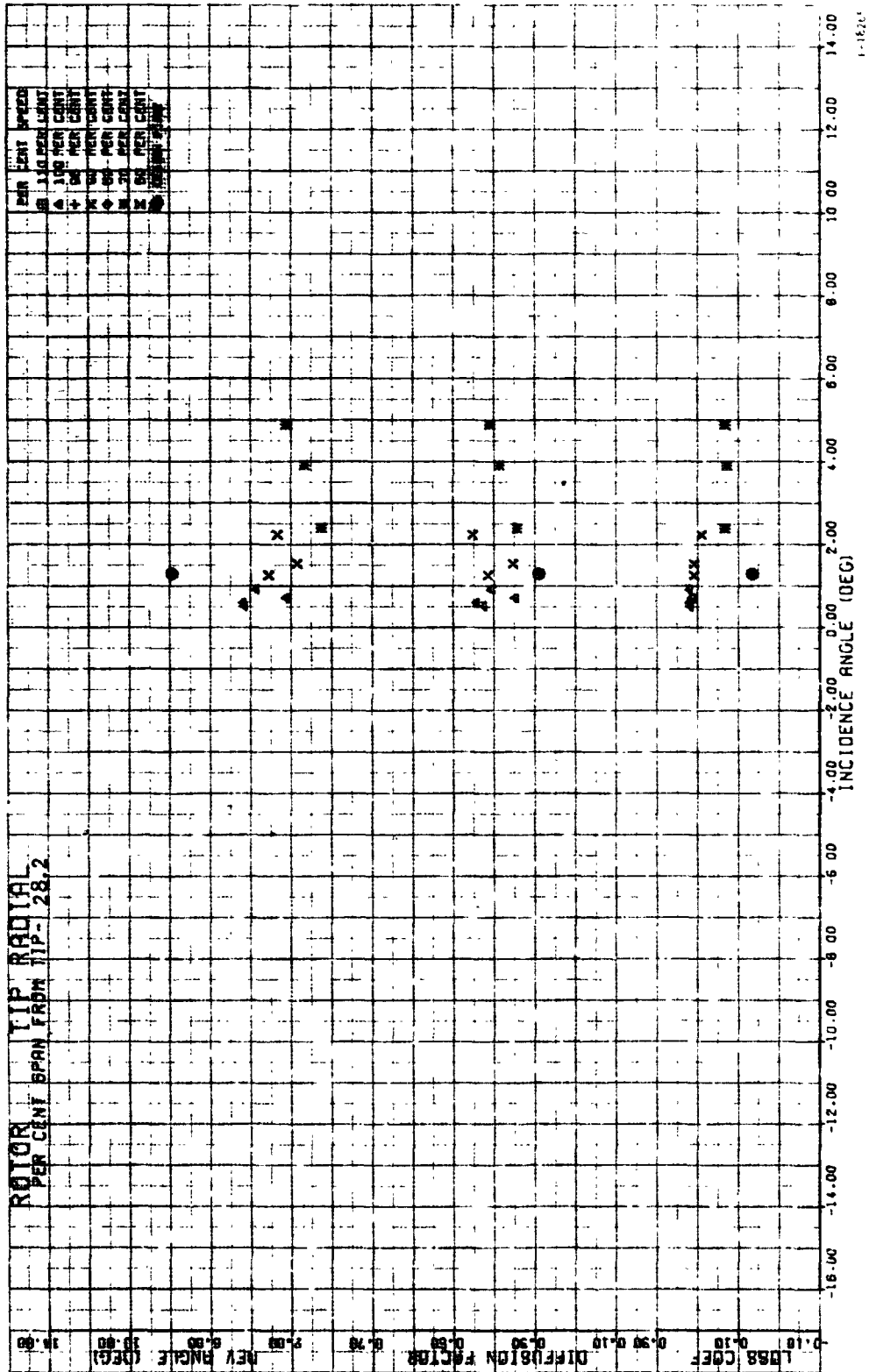


Figure 53d.--Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 28.2 Percent Span from Tip.

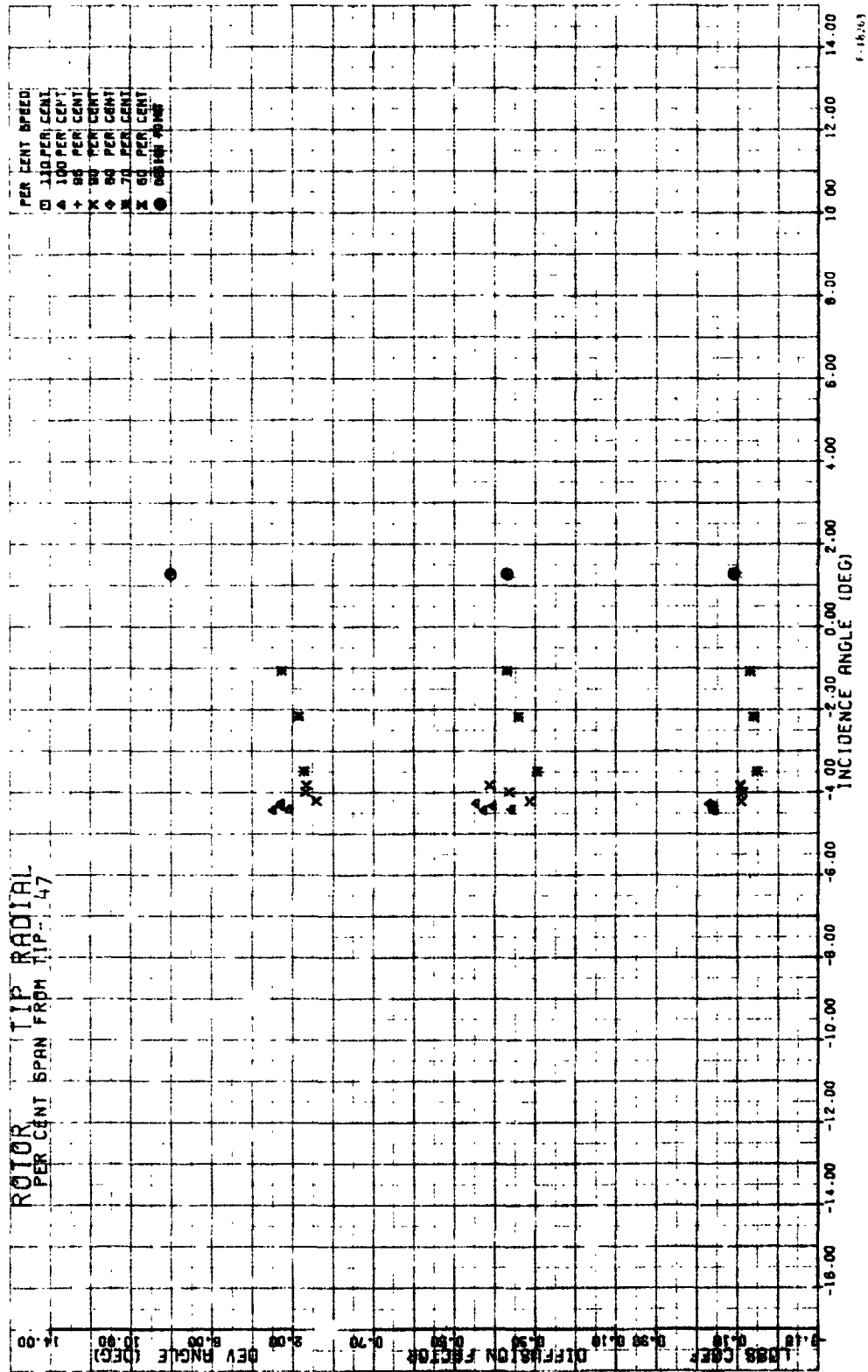


Figure 53e.--Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 47 Percent Span from Tip.

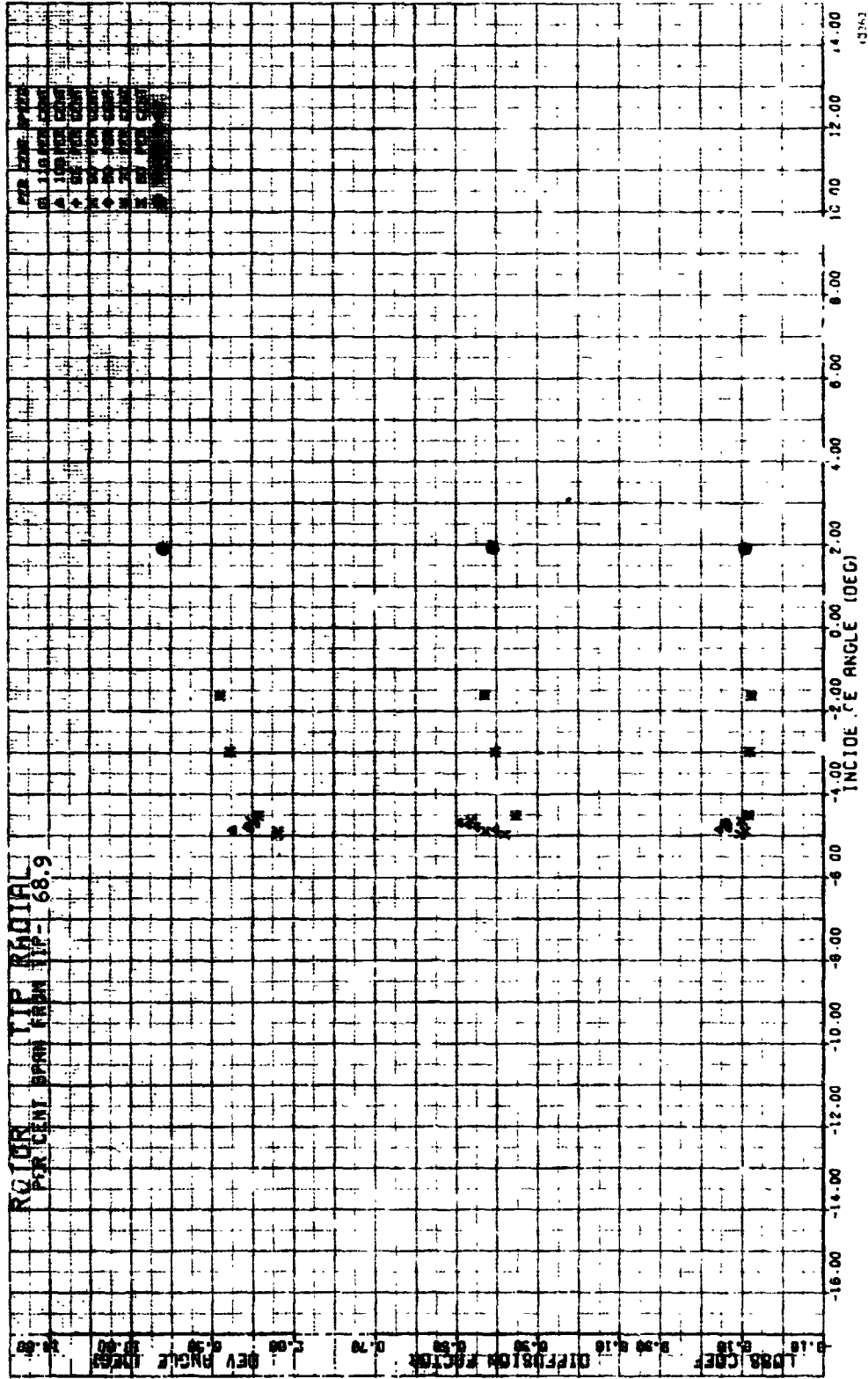


Figure 53f.--Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 68.9 Percent Span from Tip.

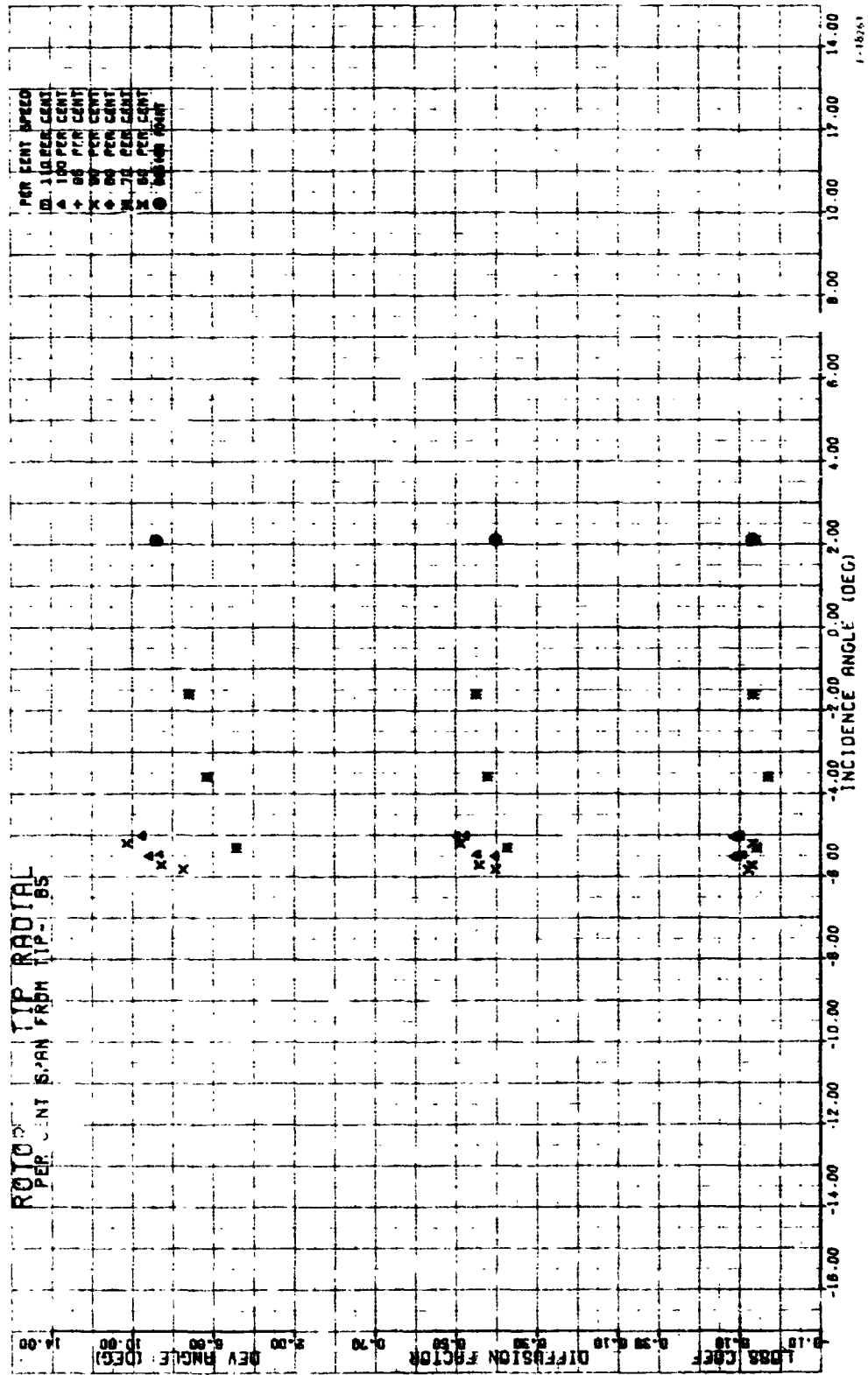


Figure 539.---Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 85 Percent Span from Tip.

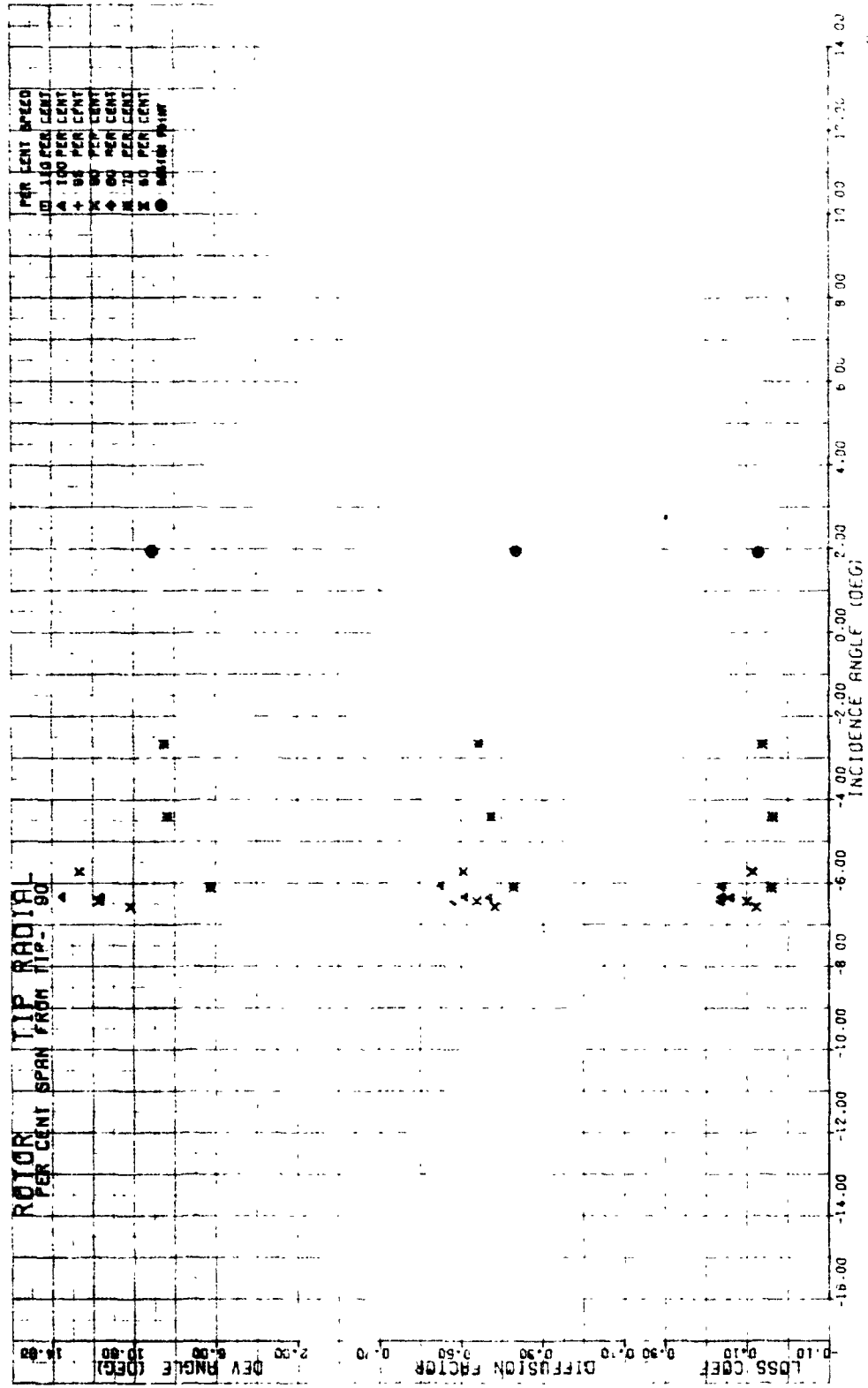


Figure 53h.--Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 90 Percent Span from Tip.

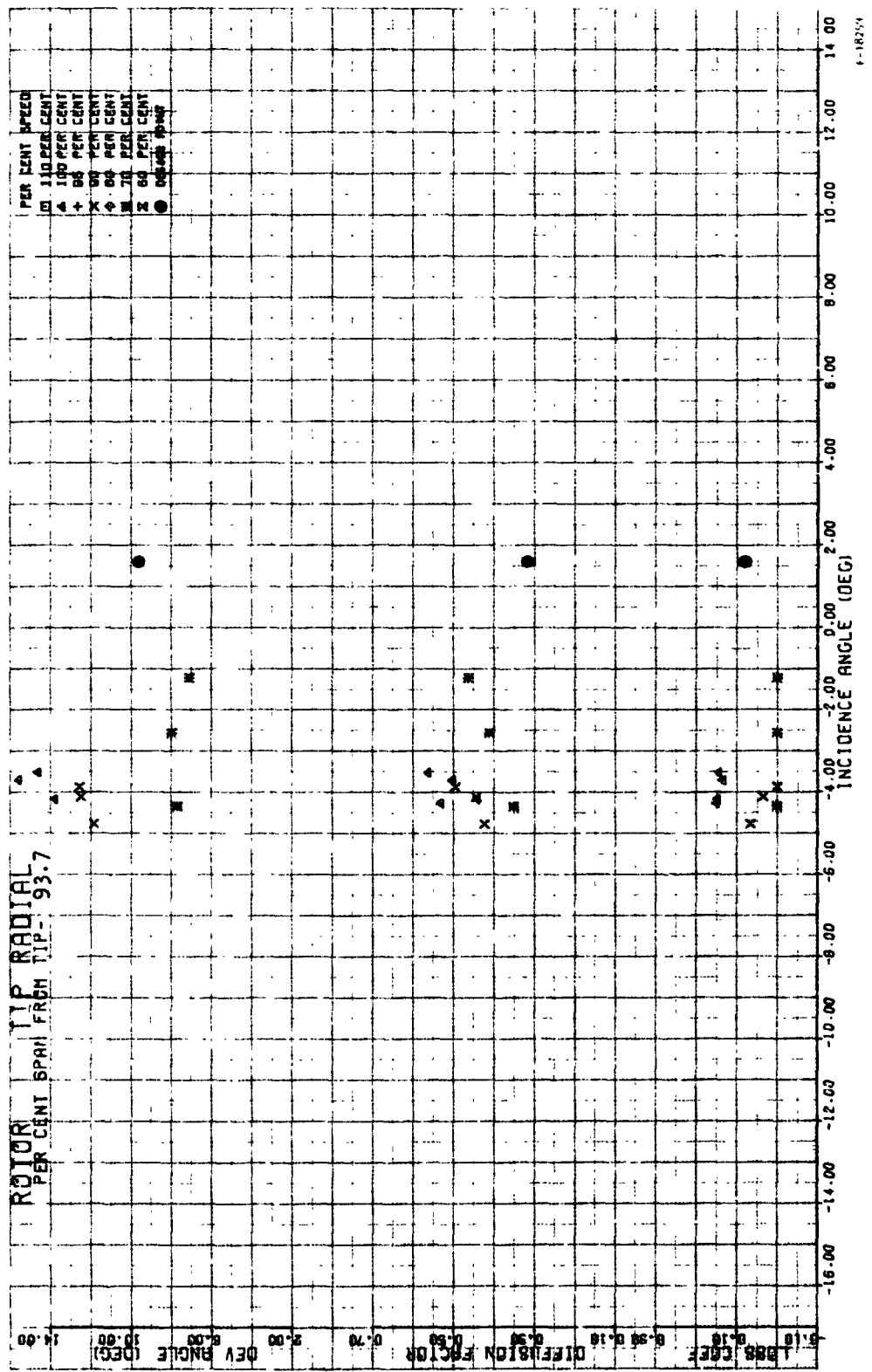
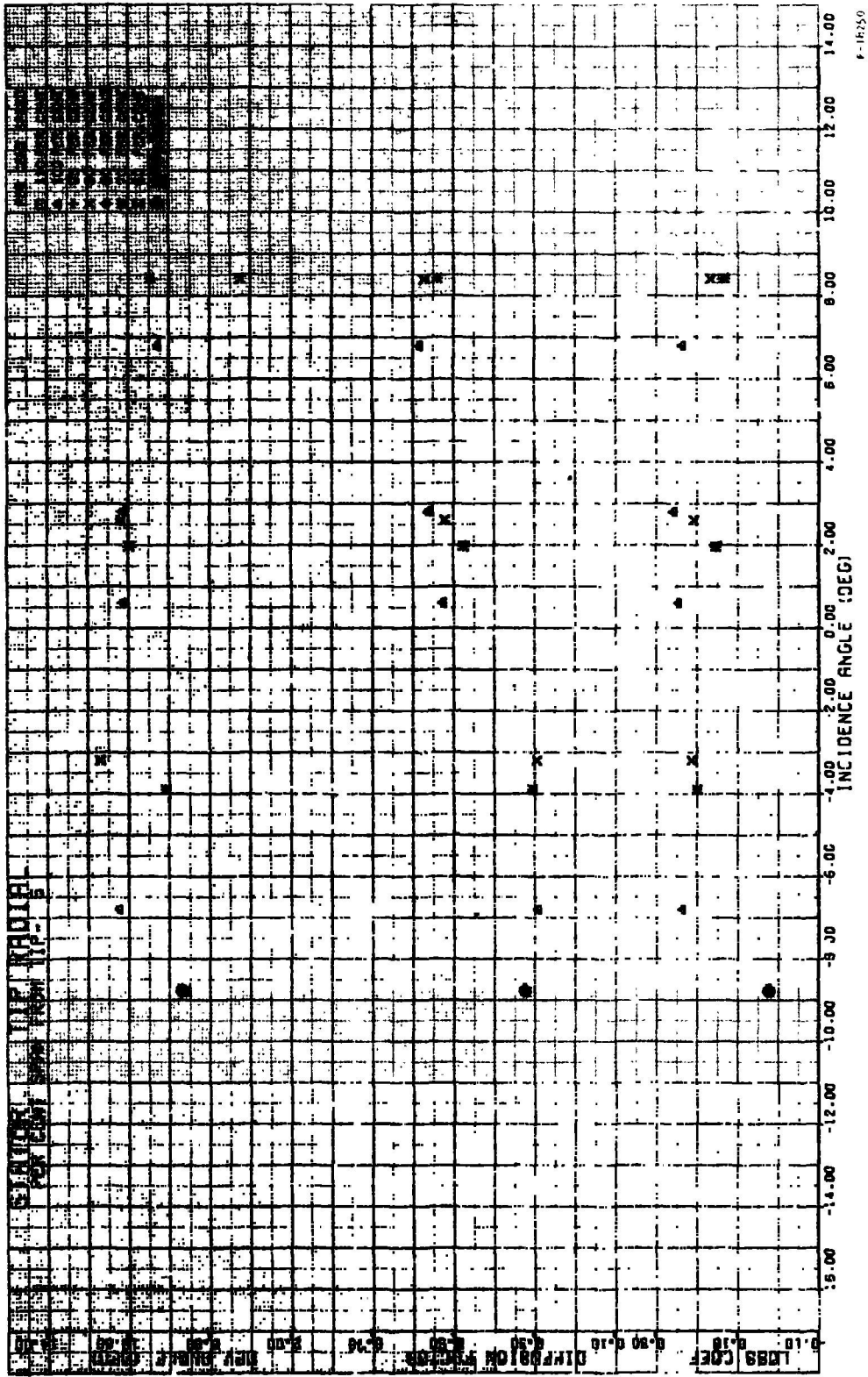


Figure 53i.--Rotor Blade Element Performance, Tip-Radially Distorted Inlet Flow, 93.7 Percent Span from Tip.



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

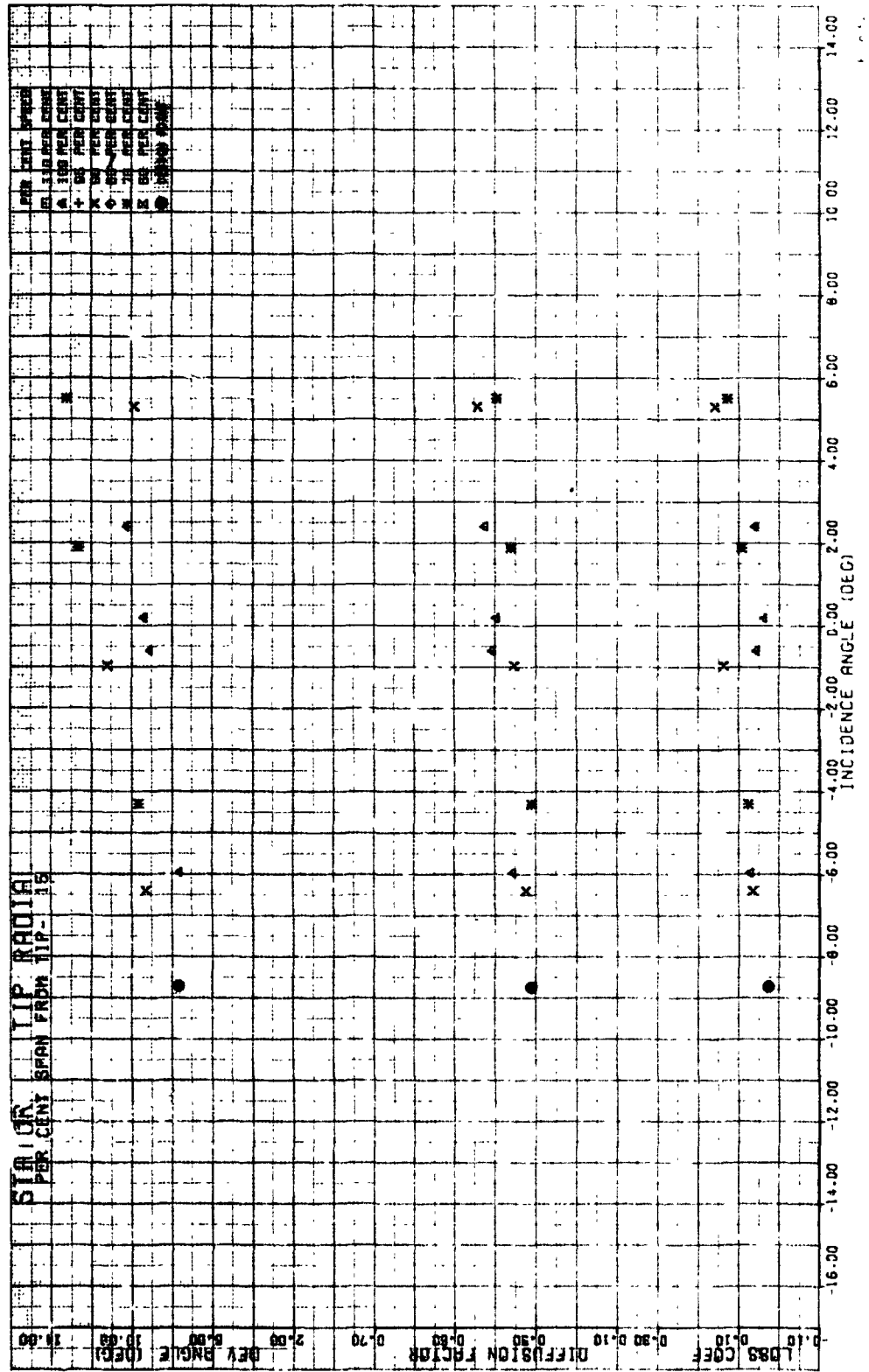
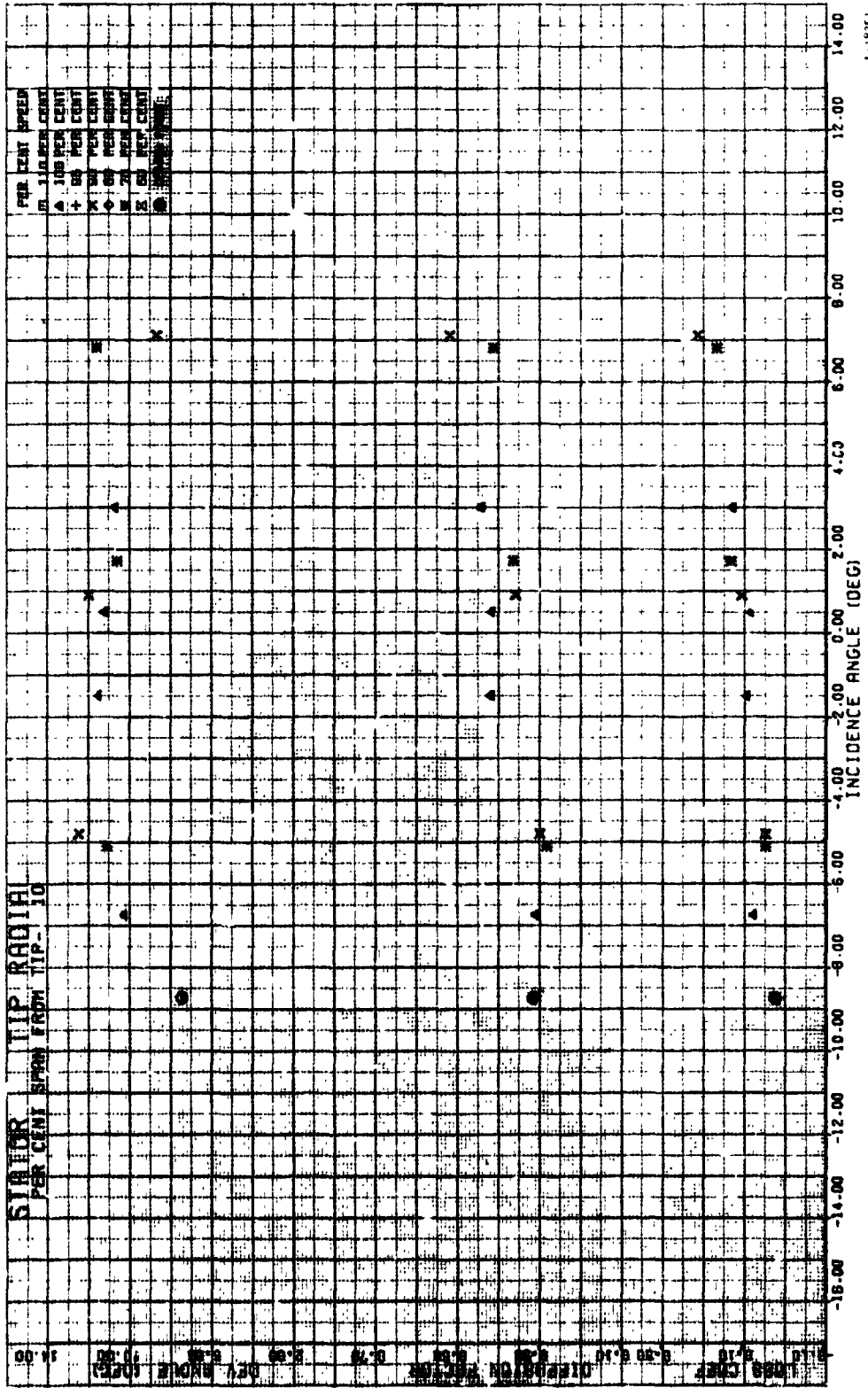


Figure 54b.--Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 10 Percent Span from Tip.



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

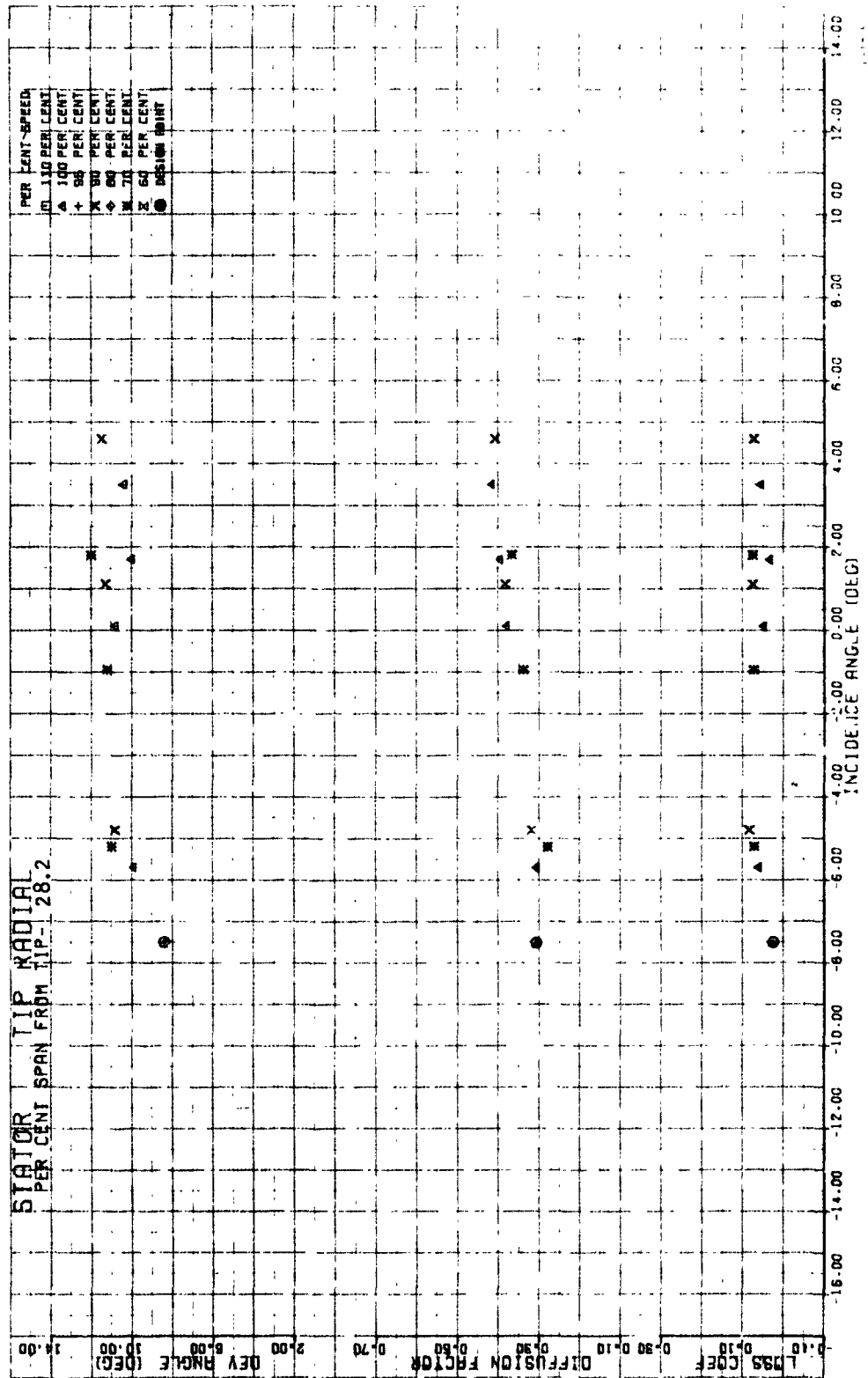


Figure 54d.--Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 28.2 Percent Span from Tip.

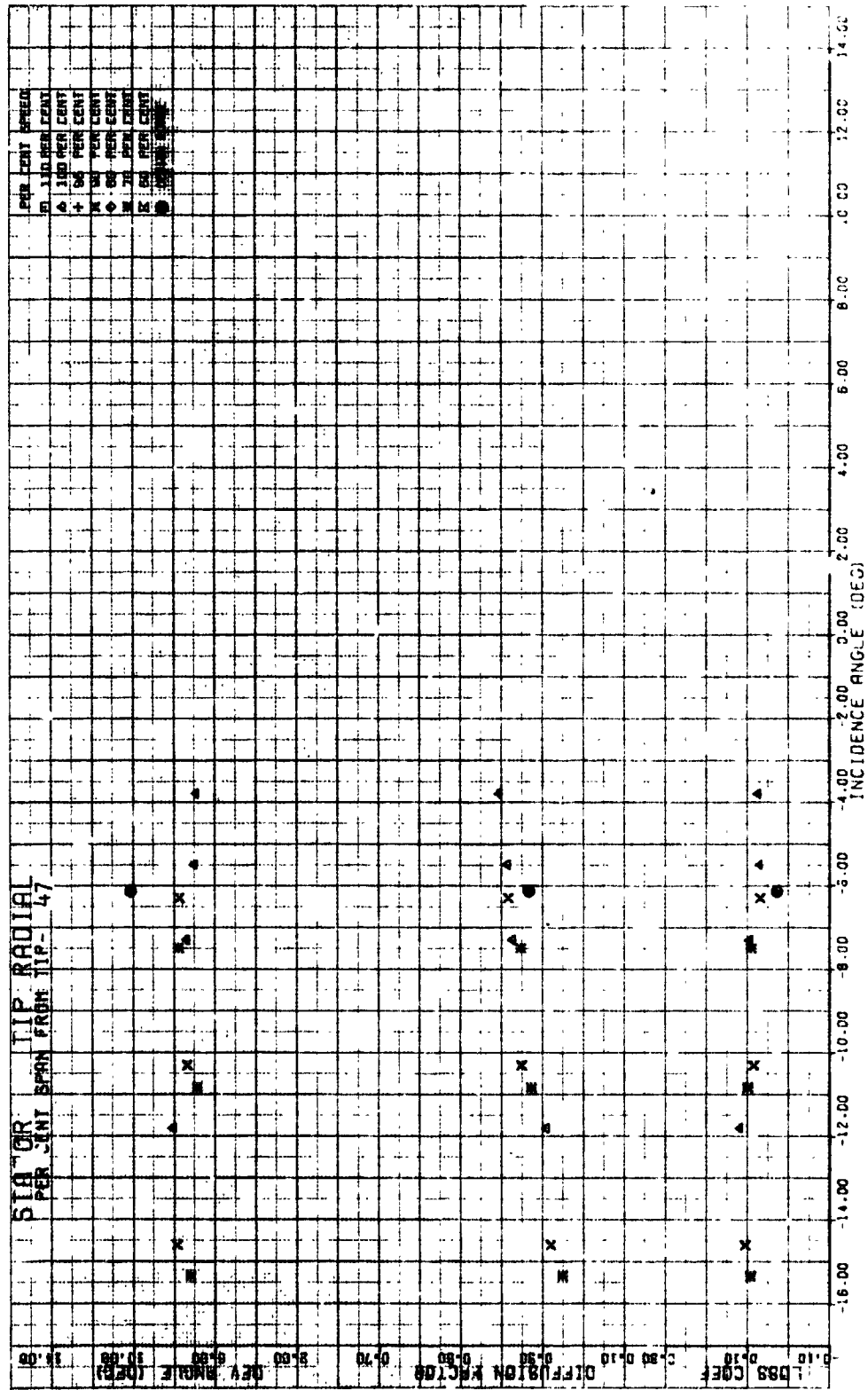


Figure 54e.--Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 47 Percent Span from Tip.

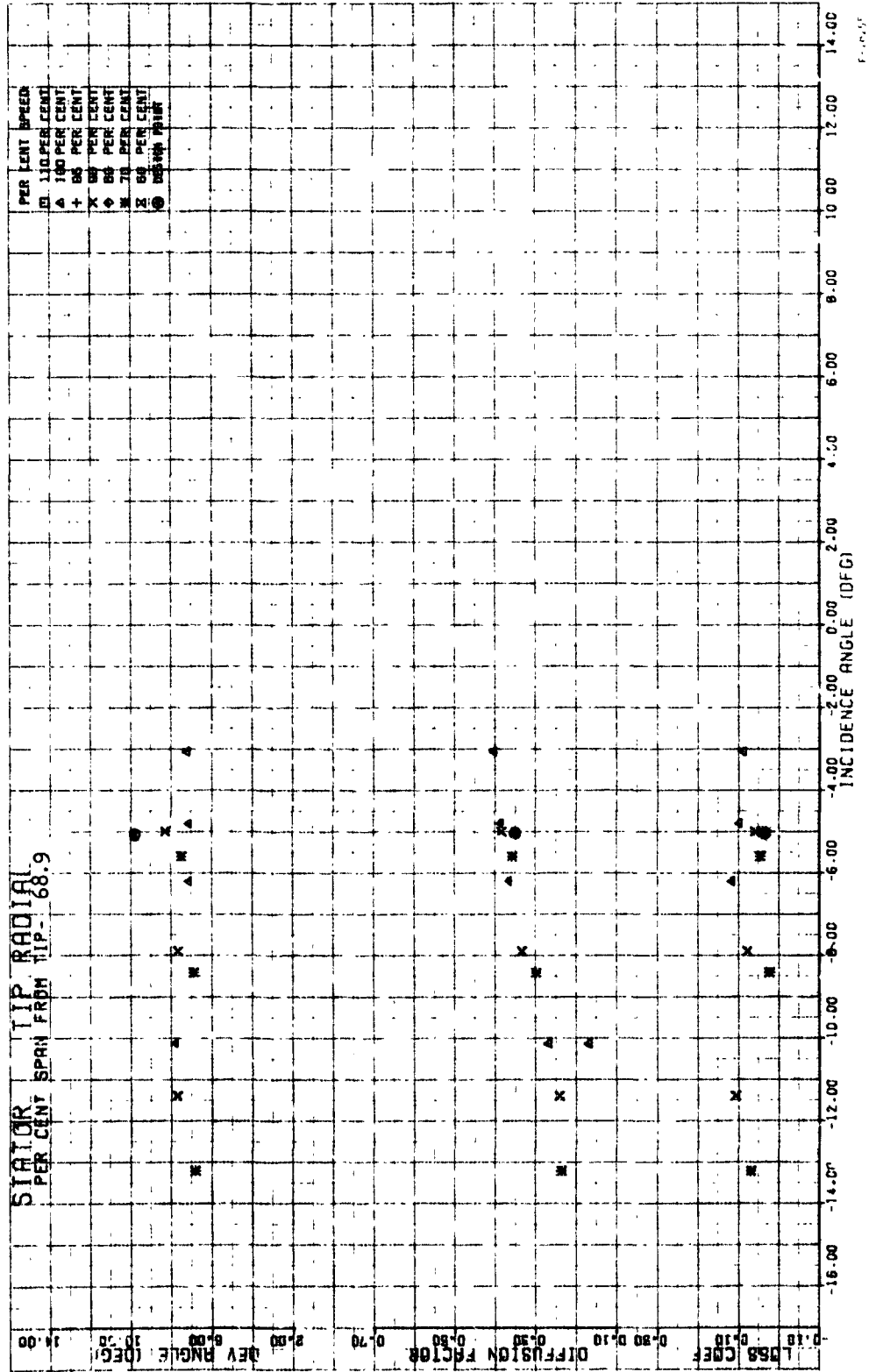


Figure 54f.--Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 68.9 Percent Span from Tip.

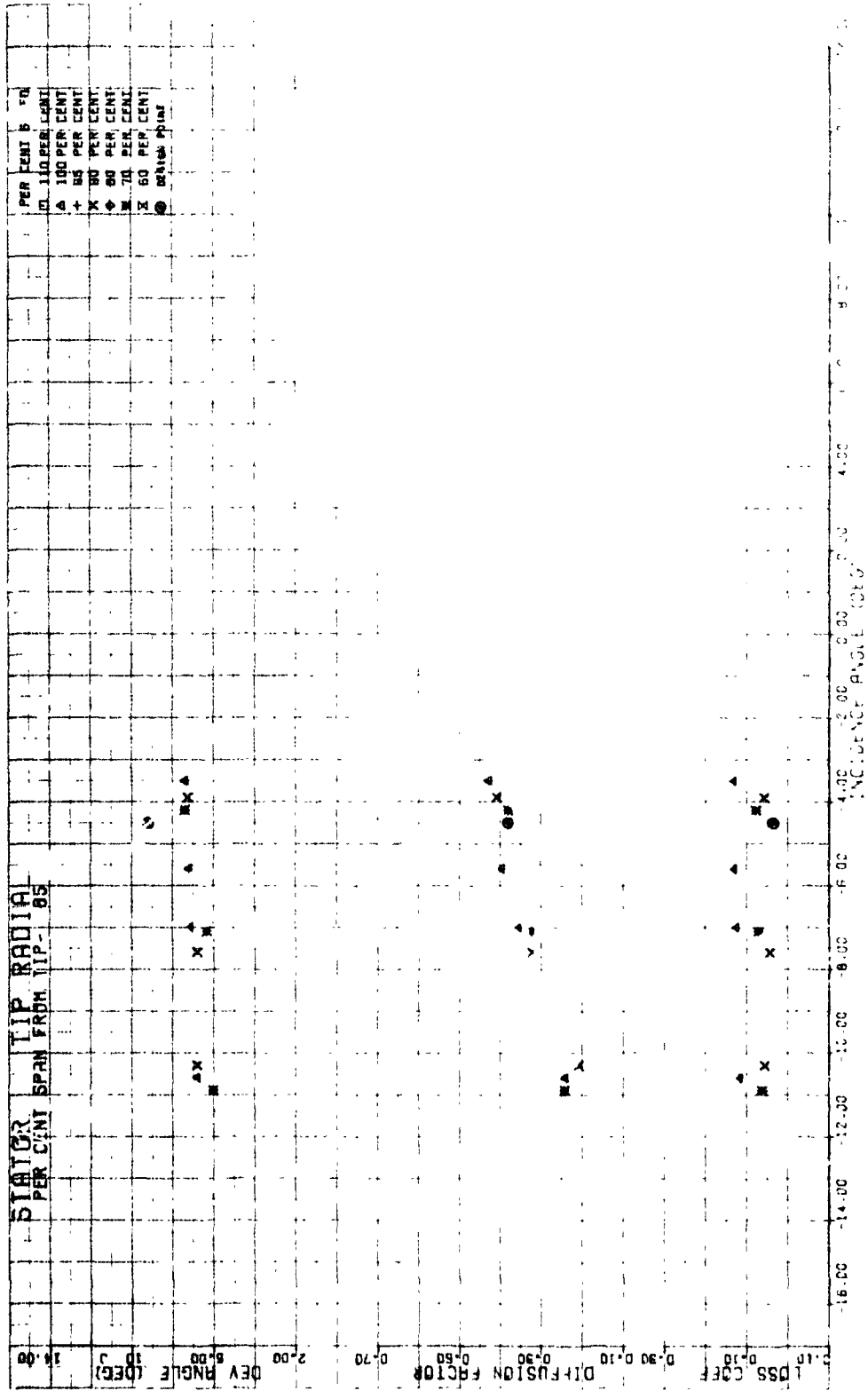


Figure 54g.---Stator Vane Element Performance, Tip-Radially Distorted Inlet Flow, 85 Percent Span from Tip.

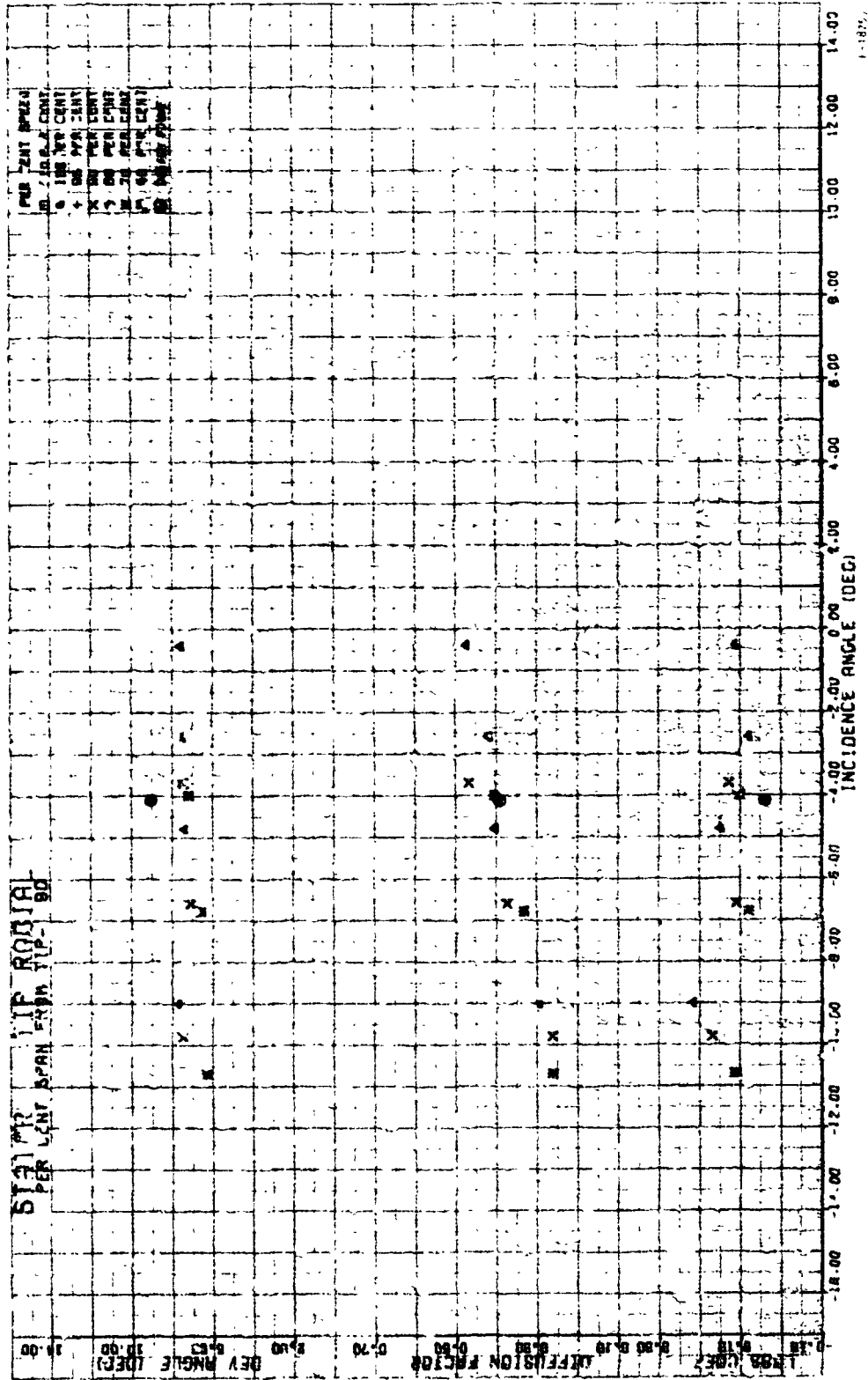


Figure 54h.--Stator Vane Element Performance, Tip-Radially Distorted
Inlet Flow, 90 Percent Span from Tip.

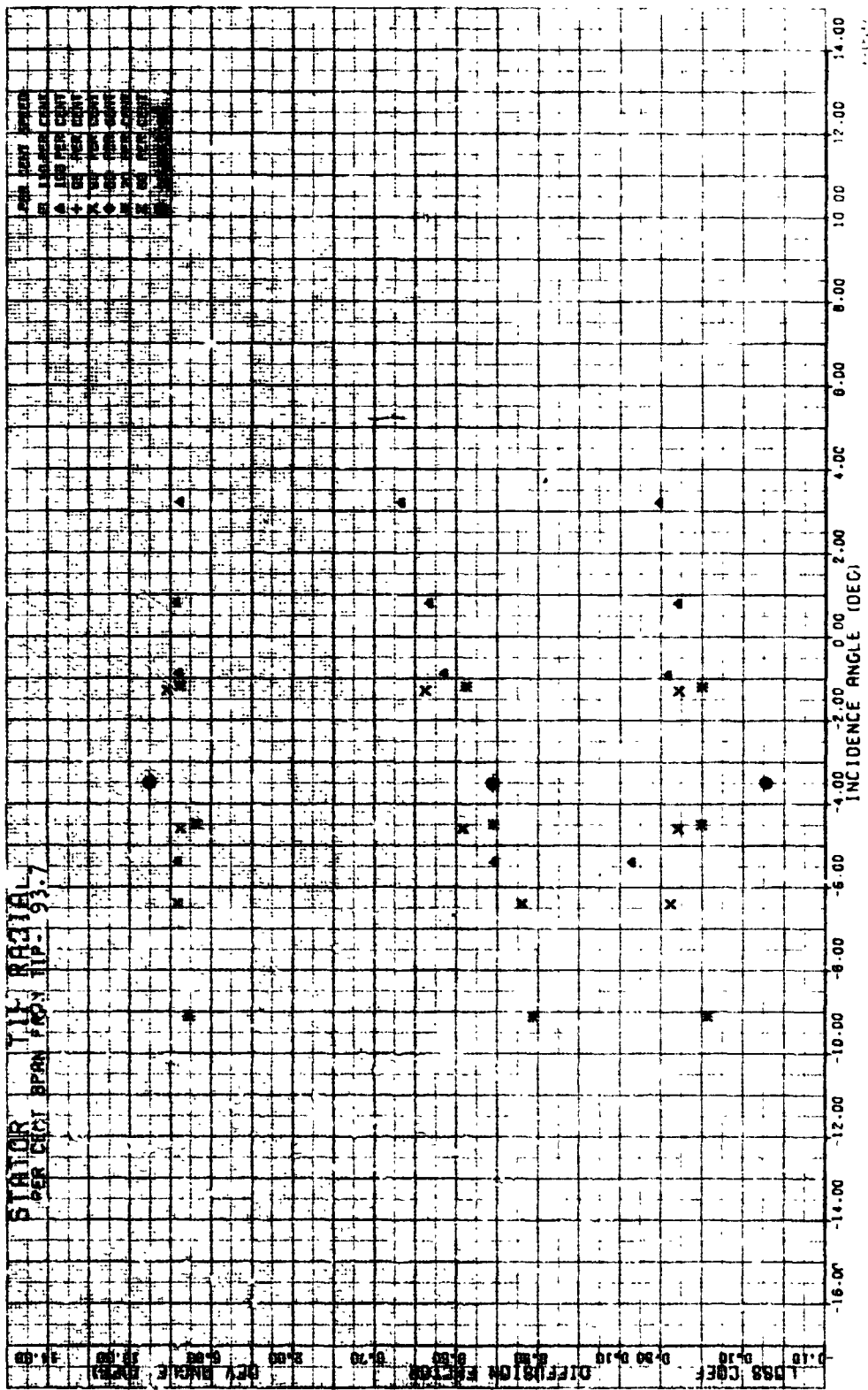
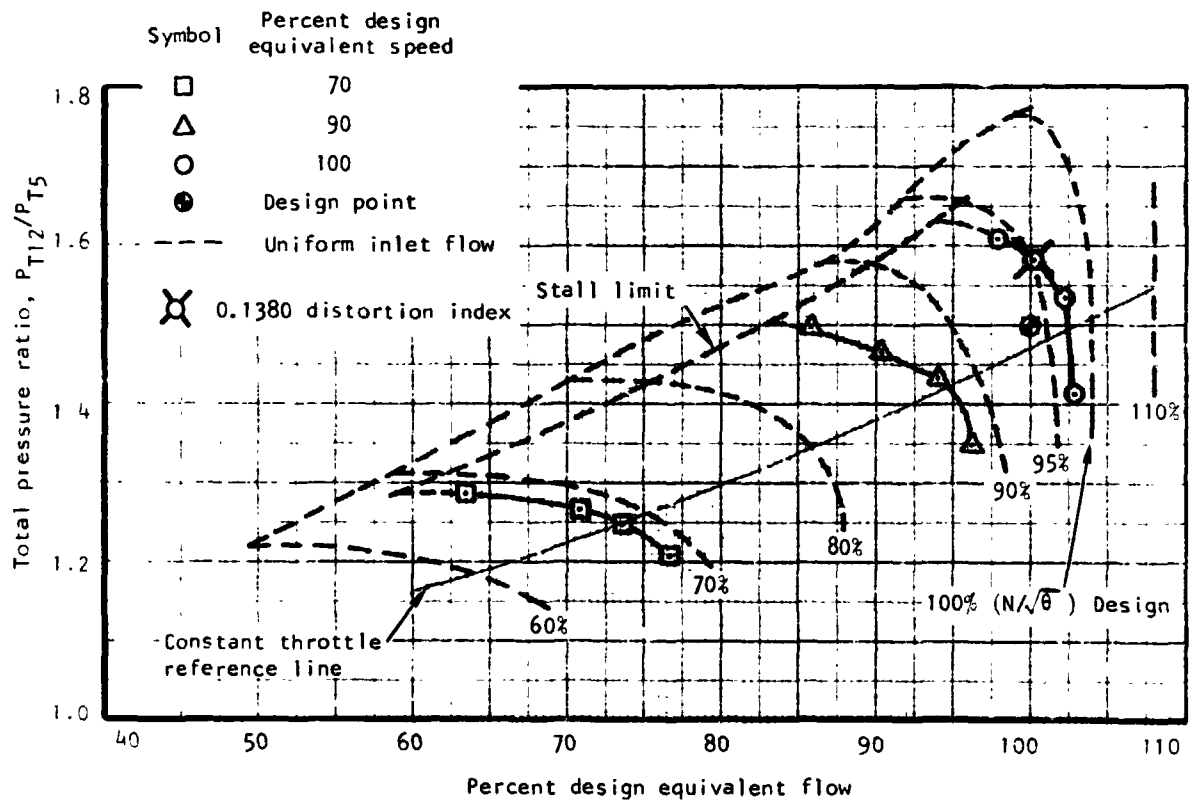
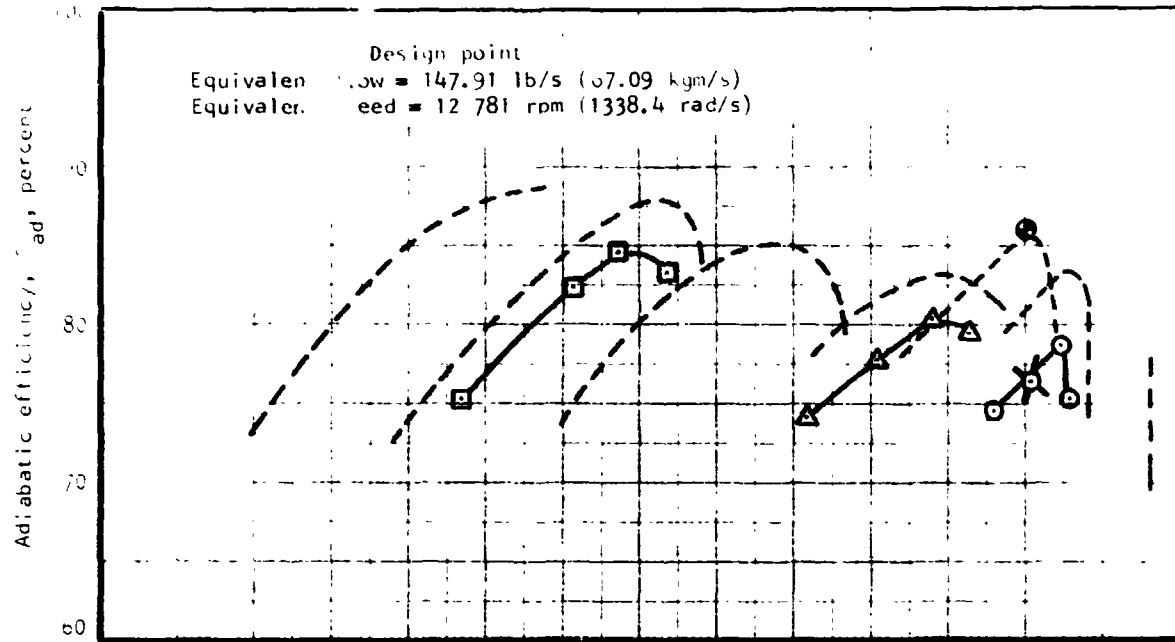


Figure 54i.---Stator Vane Element Performance, Tip-Radiially Distorted
Inlet Flow, 93.7 Percent Span from Tip.



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

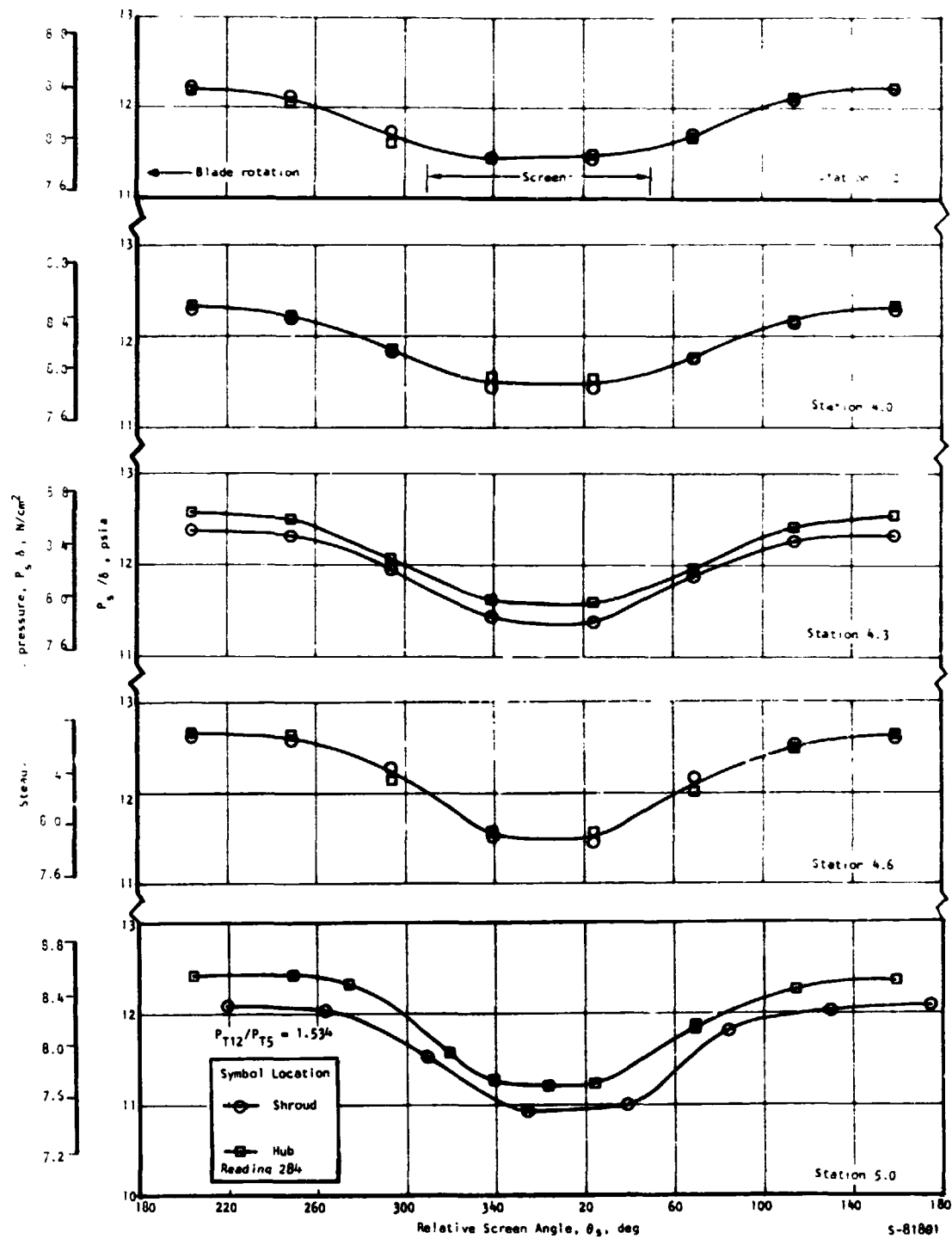


Figure 56.--Circumferential Distribution of Rotor Upstream Static Pressures at Design Speed with Circumferential Inlet Distortion.

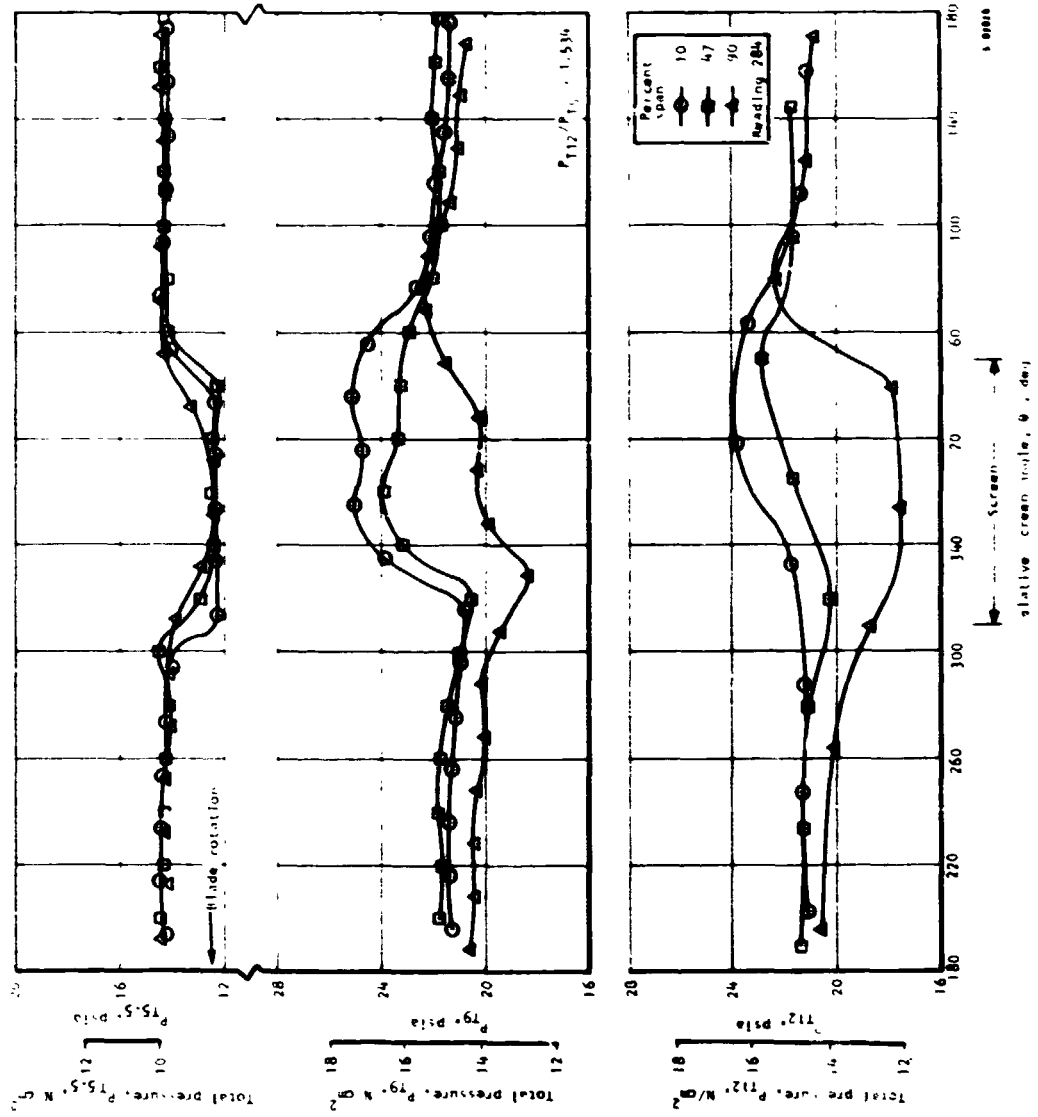


Figure 57.--Circumferential Distribution of Total Pressure at Design Speed with Circumferential Inlet Distortion.

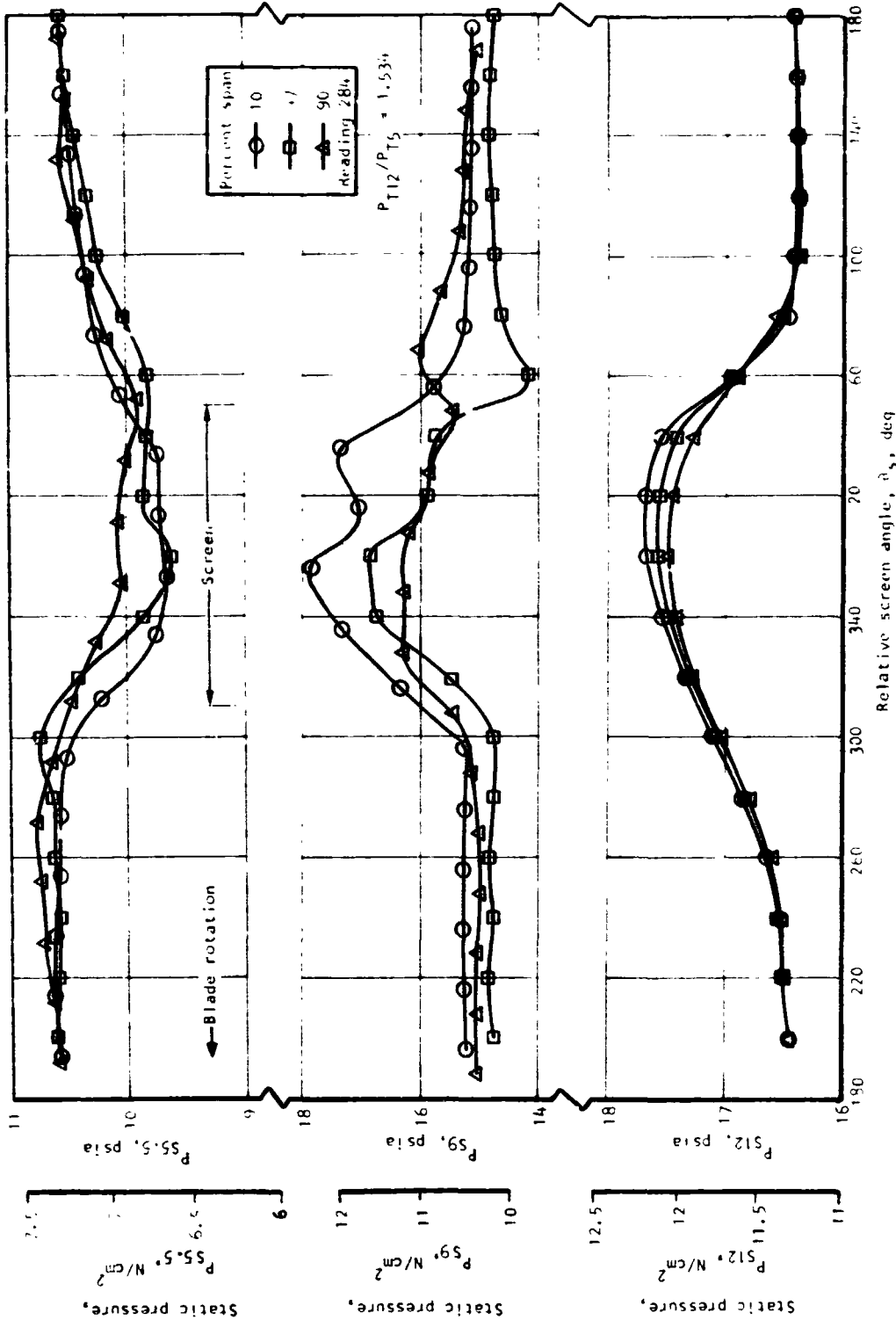


Figure 58.--Circumferential Distribution of Static Pressure at Design Speed with Circumferential Inlet Distortion.

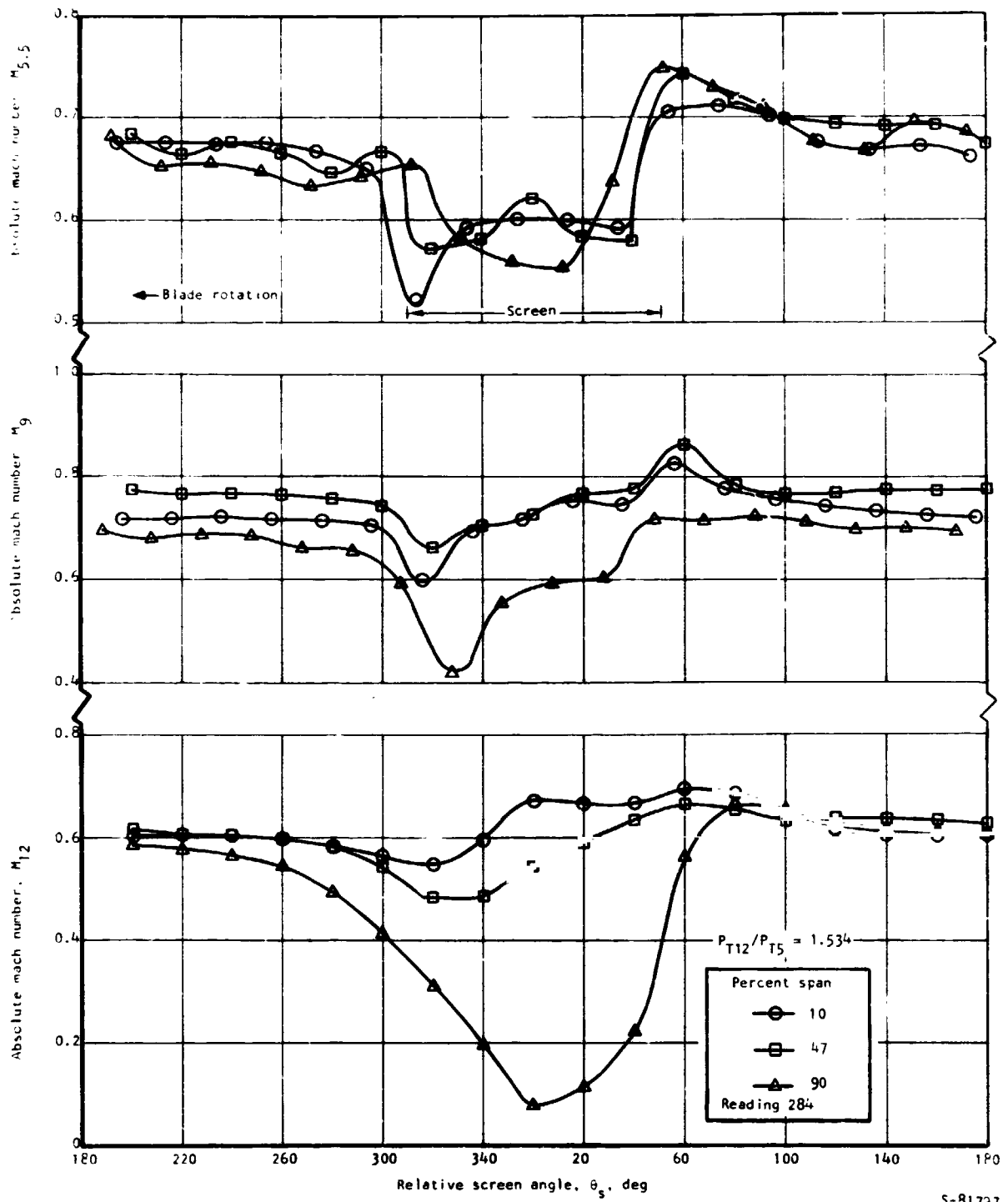


Figure 59.--Circumferential Distribution of Absolute Mach Number at Design Speed with Circumferential Inlet Distortion.

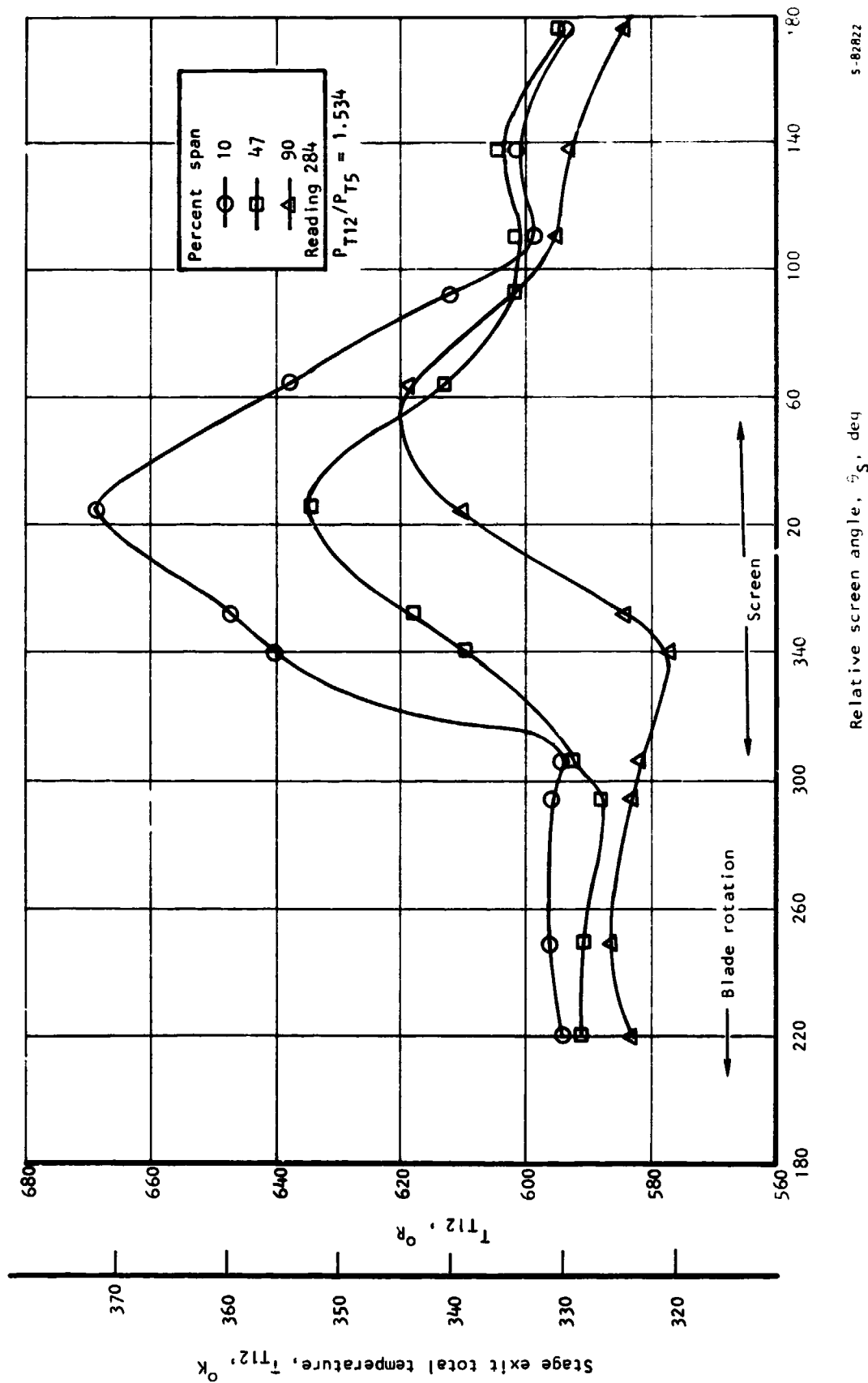


Figure 60.--Circumferential Distribution of Stage Exit Total Temperature at Design Speed with Circumferential Inlet Distortion.

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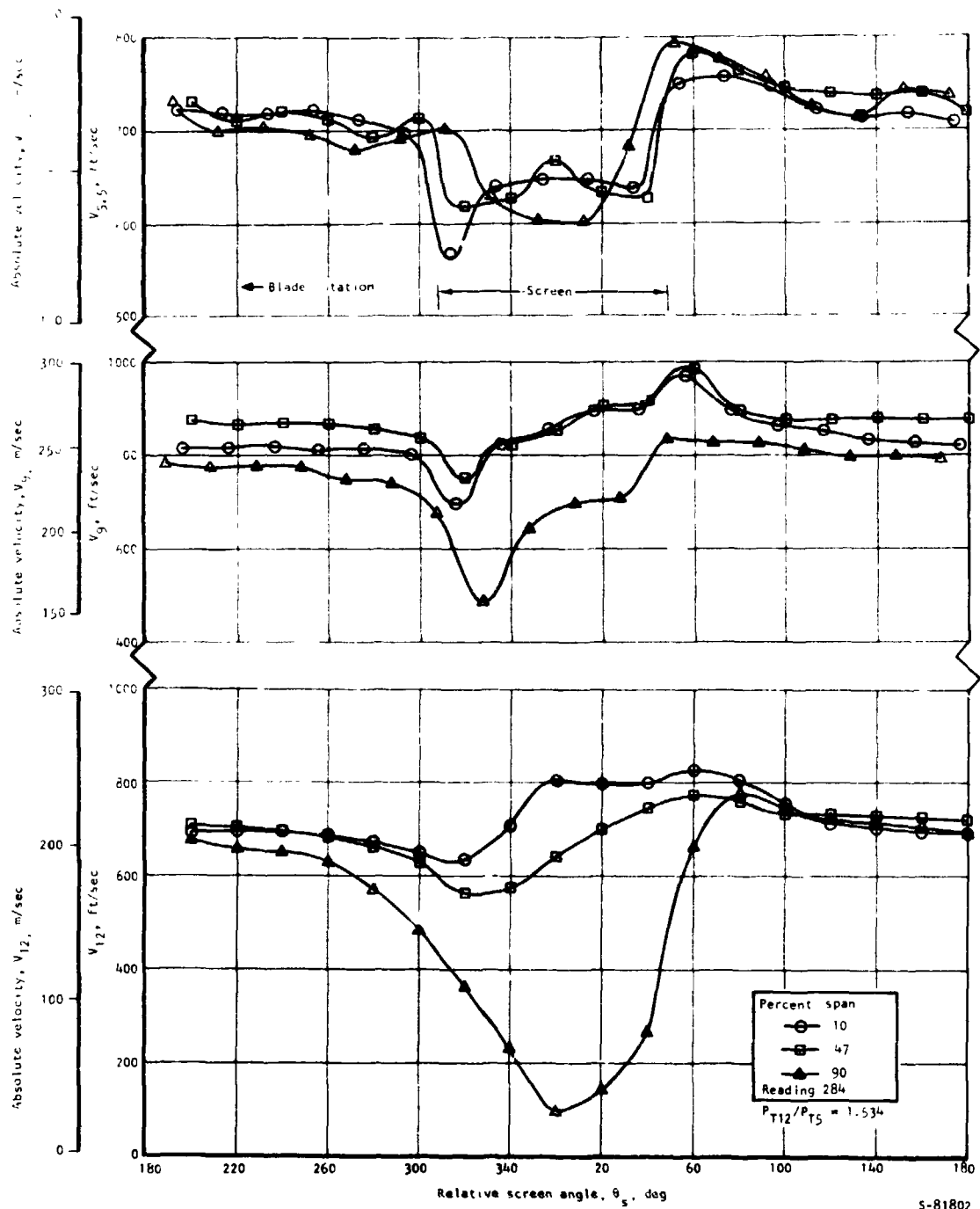


Figure 61.--Circumferential Distribution of Absolute Mach Number at Design Speed with Circumferential Inlet Distortion.

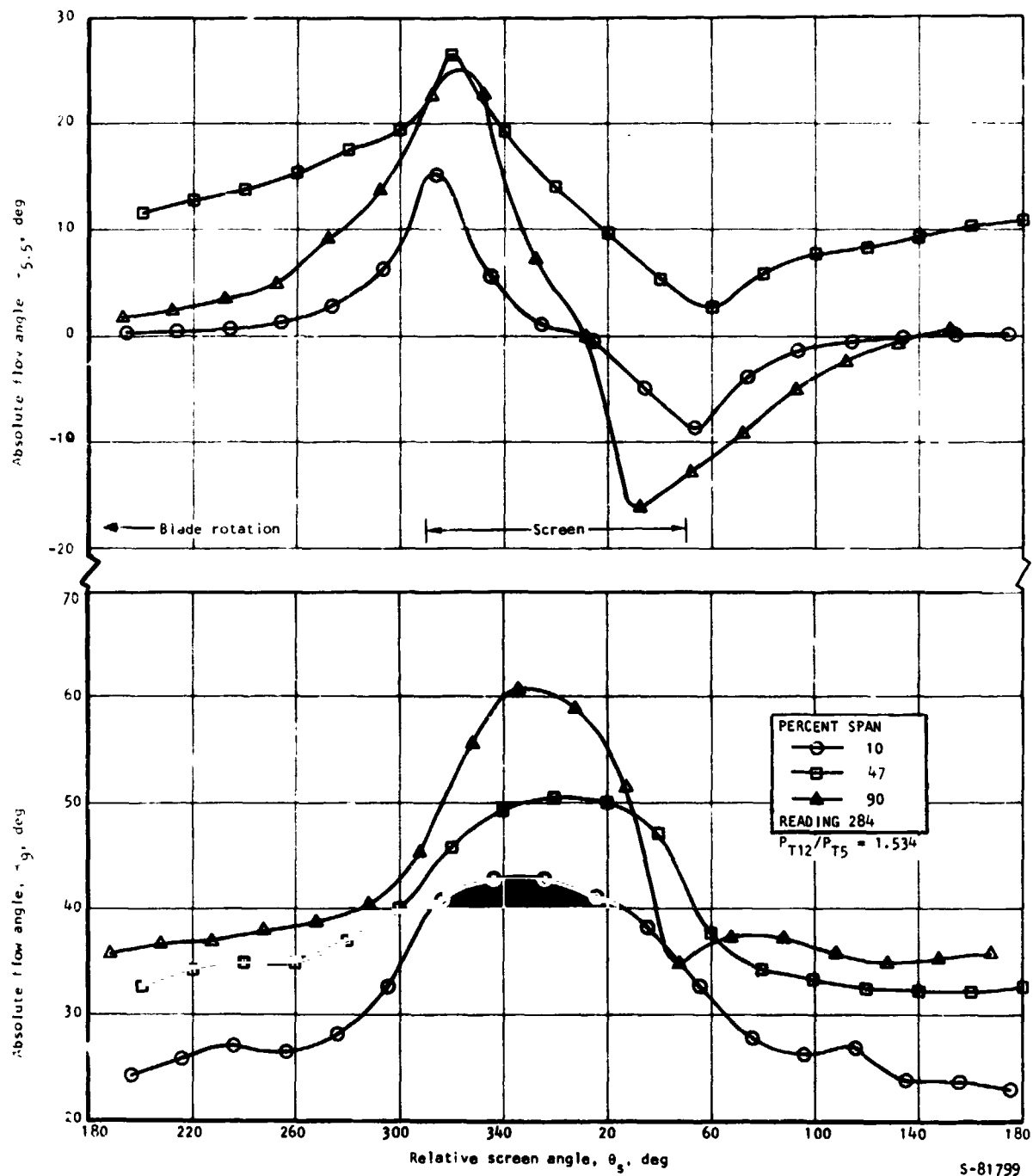


Figure 62.--Circumferential Distribution of Absolute Flow Angle at Design Speed with Circumferential Inlet Distortion.

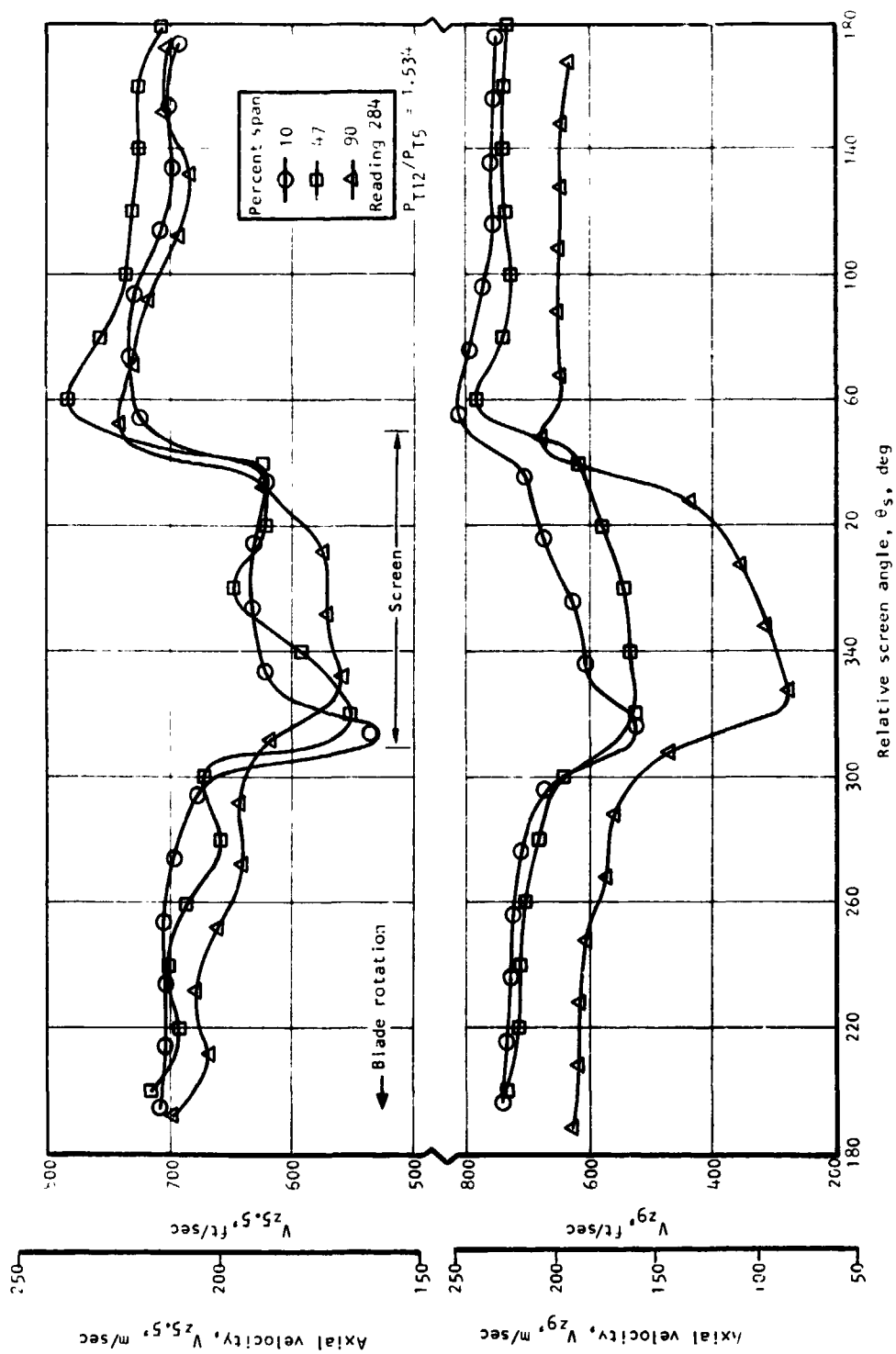
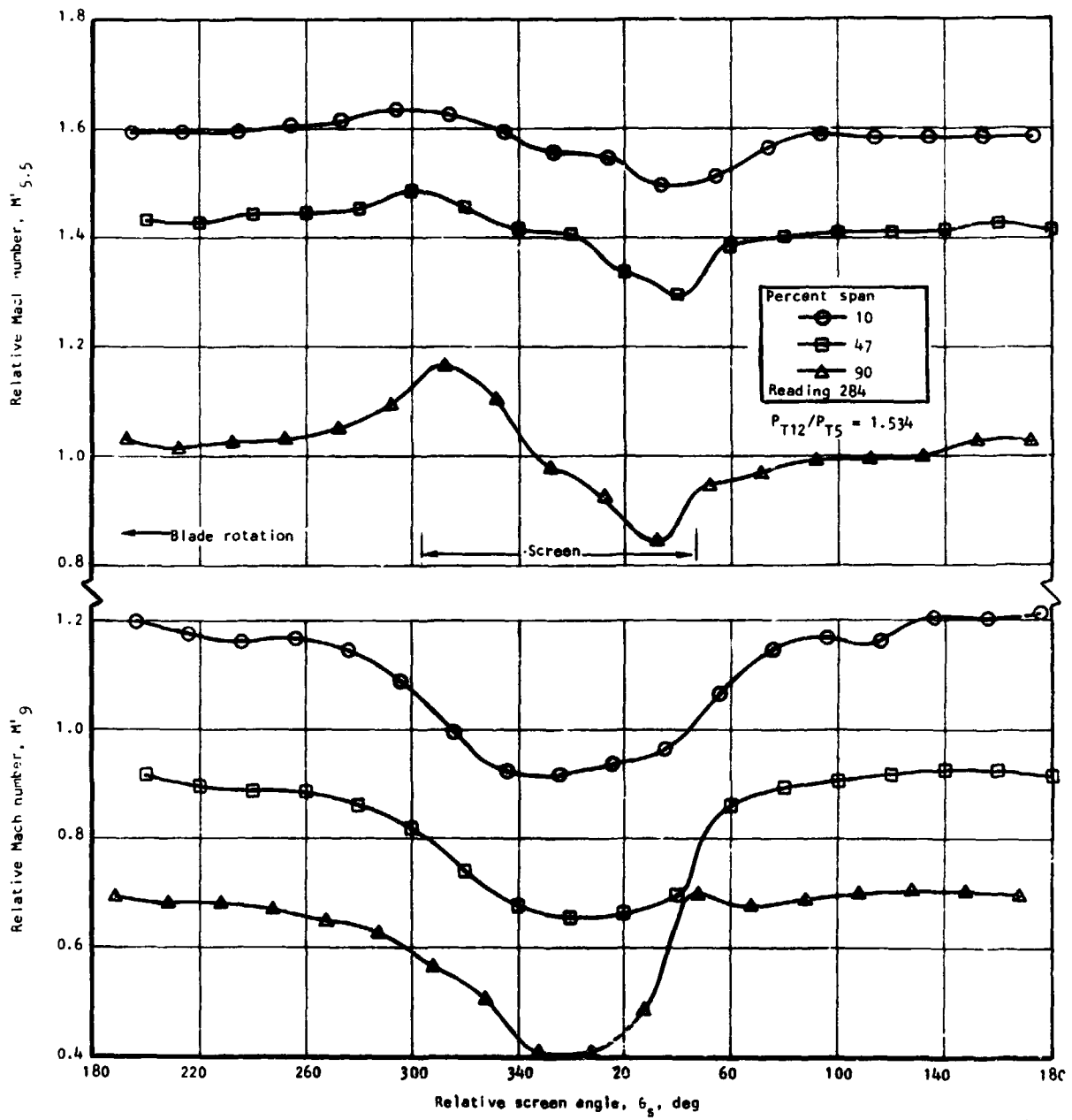


Figure 63.--Circumferential Distribution of Axial Velocity at Design Speed with Circumferential Inlet Distortion.



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

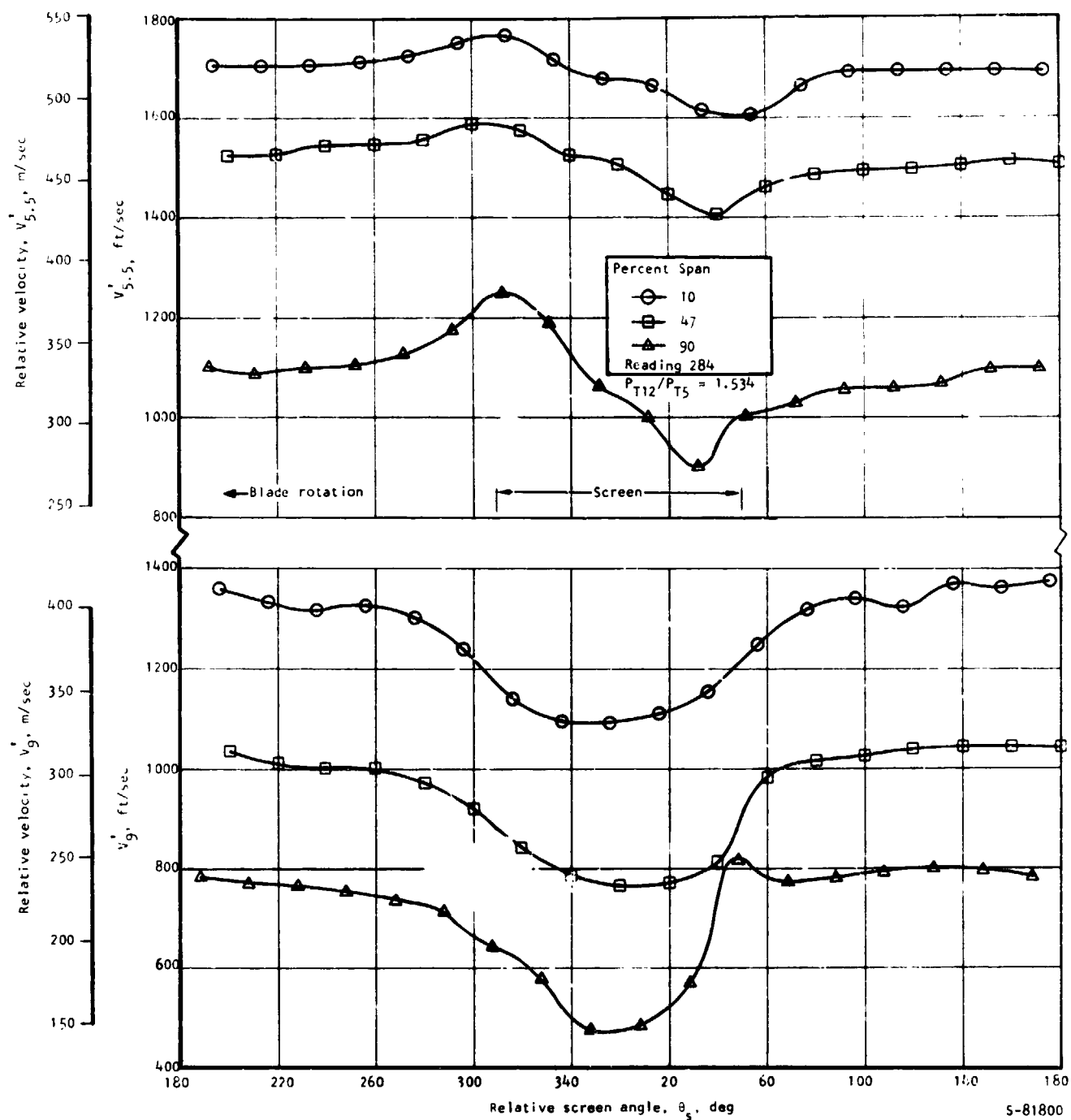


Figure 65.--Circumferential Distribution of Relative Velocity at Design Speed with Circumferential Inlet Distortion.

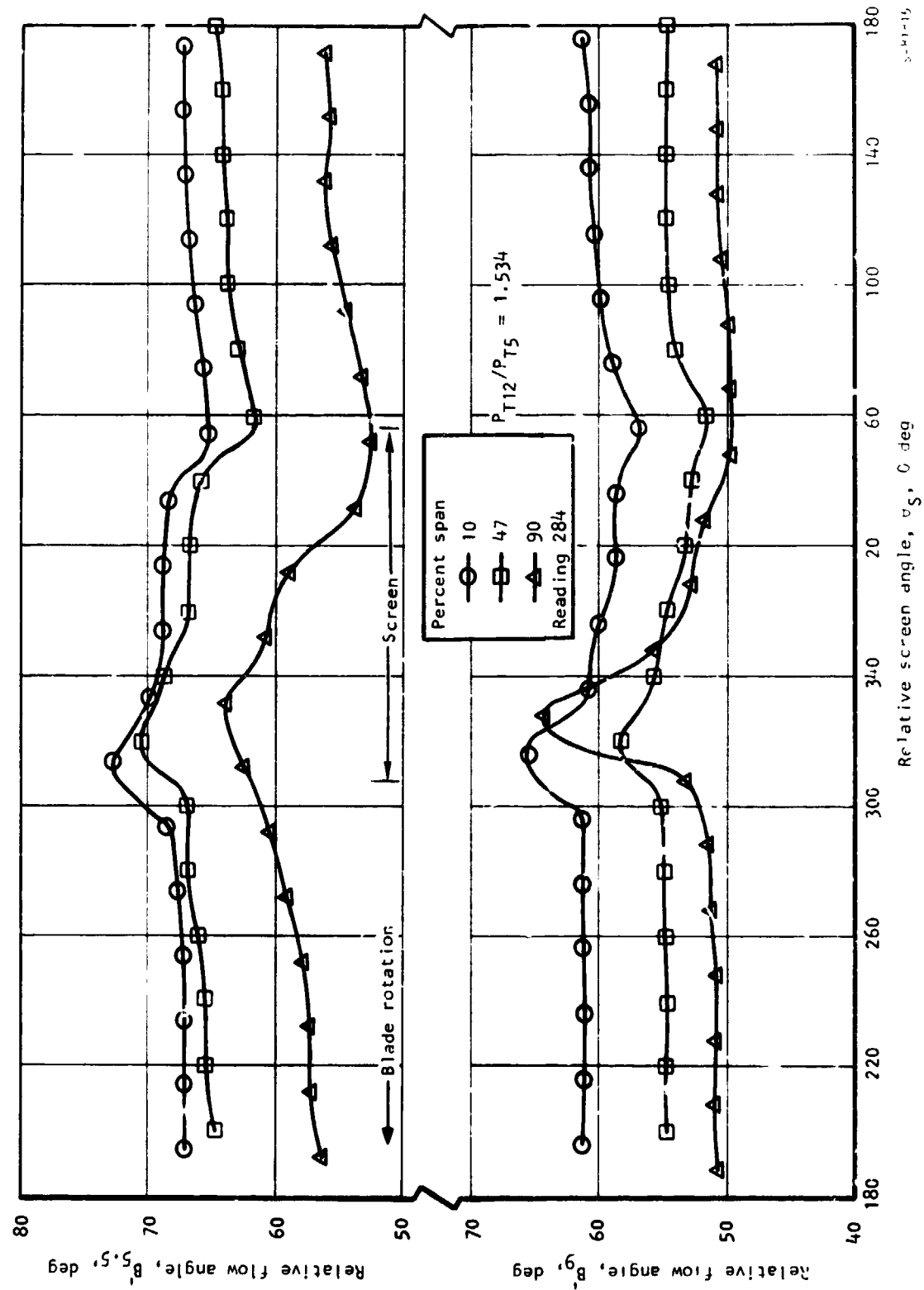


Figure 66.--Circumferential Distribution of Relative Flow Angle at Design Speed with Circumferential Inlet Distortion.

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**

$P_{T1} = 14.696 \text{ psia} = 10.133 \text{ N/cm}^2$
 $T_{T1} = 518.69 \text{ }^\circ\text{R} = 288.16 \text{ }^\circ\text{K}$
 $N/\phi = 12,781 \text{ rpm} = 1338.4 \text{ rad/sec}$
 $M/\phi = 147.91 \text{ lbm/s} = 67.09 \text{ kg/sec}$
 $U_{T1} = 1603.0 \text{ ft/sec} = 486.594 \text{ m/sec}$
 $r_{T1} = 14.370 \text{ in} = 36.50 \text{ cm}$

Blockage factor = 0.450

inlet (station 0)

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_T/P_{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
T_T/T_{T0}	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_θ/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	7.53	13.76	23.30
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	0.3374
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	0.3374
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
ϵ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MCL	2.791	2.797	2.839	3.130	3.675	3.623	3.670	3.908	4.341	5.266	5.856	6.086
l_{sc}	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/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
δ	0.851	0.875	0.891	0.893	0.887	0.867	0.841	0.837	0.870	0.900	0.920	0.928
τ	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_T/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/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_θ/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
ϵ	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
l^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.	14.370	13.800	13.100	12.750	12.400	12.000	11.700	11.000	10.300	9.600	8.900	8.200	7.500	6.642
	cm	36.500	35.052	33.274	32.385	31.496	30.480	29.718	27.940	26.162	24.384	22.606	20.828	19.050	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_C^* 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_B^* 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
Prebend		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_C^* 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_B^* 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.	3.660	3.577	3.477	3.421	3.351	3.274	3.194	3.026	2.882	2.728	2.558	2.414	2.303	2.191
	cm	9.296	9.086	8.832	8.689	8.512	8.316	8.113	7.886	7.320	6.929	6.497	6.132	5.850	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	0.0032	0.0054	0.0074	0.0035	0.0034	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 ROTOR AIRFOIL COORDINATES
RADIUS 14.570 IN. (36,500 CM.)

SUCTION SURFACE		PERFORE SURFACE		PERFORE SURFACE		PERFORE SURFACE	
X.IN.	Y.IN.	X.CM.	Y.CM.	X.IN.	Y.IN.	X.CM.	Y.CM.
-.820	-1.7139	-2.2404	-4.3534	-.820	-1.7159	-2.2404	-4.3534
-.820	-1.7135	-2.2404	-4.3523	-.818	-1.7160	-2.2398	-4.3527
-.817	-1.7106	-2.2394	-4.3449	-.810	-1.7179	-2.2374	-4.3587
-.807	-1.7075	-2.2370	-4.3371	-.808	-1.7190	-2.2346	-4.3635
-.807	-1.6668	-2.1963	-4.2317	-.801	-1.7192	-2.2303	-4.3688
-.813	-1.5579	-2.0861	-3.9572	-.802	-1.7185	-2.2255	-4.3650
-.779	-1.4908	-1.9758	-3.6651	-.804	-1.7169	-2.2205	-4.3610
-.7345	-1.3454	-1.8656	-3.4174	-.803	-1.7110	-2.2105	-4.3458
-.6911	-1.2420	-1.7554	-3.1547	-.802	-1.6773	-2.1698	-4.2605
-.6477	-1.1407	-1.6452	-2.8474	-.809	-1.5866	-2.0597	-4.0500
-.6043	-1.0413	-1.5350	-2.6449	-.807	-1.4958	-1.9497	-3.7994
-.5609	-.9433	-1.4248	-2.4390	-.805	-1.4050	-1.8396	-3.5687
-.5174	-.8464	-1.3146	-2.2349	-.809	-1.3142	-1.7295	-3.3581
-.4742	-.7502	-1.2044	-2.0324	-.807	-1.2235	-1.6195	-3.1677
-.4308	-.6587	-1.0942	-1.8330	-.803	-1.1324	-1.5094	-2.9779
-.3874	-.5604	-.9840	-1.6224	-.809	-.9520	-1.3994	-2.8076
-.3440	-.4671	-.8738	-1.4105	-.803	-.8618	-1.2893	-2.6401
-.3006	-.3747	-.7636	-1.2016	-.803	-.7718	-1.1792	-2.4800
-.2572	-.2824	-.6534	-1.0009	-.803	-.6821	-1.0692	-2.3280
-.2138	-.1917	-.5432	-.8069	-.803	-.5924	-.9592	-2.1734
-.1705	-.1011	-.4330	-.6268	-.803	-.5026	-.8491	-2.0152
-.1271	-.0113	-.3228	-.4604	-.803	-.4124	-.7390	-1.8588
-.0837	-.0779	-.2126	-.3199	-.803	-.3226	-.6290	-1.7029
-.0403	-.1664	-.1024	-.2226	-.803	-.2326	-.5189	-1.5481
-.0031	-.2541	-.0076	-.1655	-.803	-.1426	-.4088	-1.3934
-.045	-.3413	-.1181	-.1068	-.803	-.0524	-.2987	-1.2384
-.089	-.4277	-.2282	-.0484	-.803	-.0321	-.1887	-1.0834
-.132	-.5135	-.3385	-.0103	-.803	-.0235	-.0787	-.9286
-.176	-.5987	-.4487	-.0206	-.803	-.0195	-.0314	-.7731
-.220	-.6831	-.5589	-.0352	-.803	-.0144	-.1414	-.6179
-.2634	-.7669	-.6691	-.0480	-.803	-.0090	-.2515	-.4623
-.3068	-.8500	-.7793	-.0589	-.803	-.0036	-.3615	-.3068
-.3502	-.9323	-.8895	-.0681	-.803	-.0000	-.4716	-.1519
-.3936	-1.0139	-.9997	-.0754	-.803	-.0000	-.5817	-.0000
-.4370	-1.0915	1.1099	-.0815	-.803	-.0000	-.6917	1.5509
-.4804	-1.1625	1.2201	-.0827	-.803	-.0000	-.8018	1.7551
-.5237	-1.2288	1.3303	-.0821	-.803	-.0000	-.9118	1.9566
-.5671	-1.2941	1.4405	-.0803	-.803	-.0000	1.0219	2.1553
-.6105	-1.3586	1.5507	-.0766	-.803	-.0000	1.1320	2.3504
-.6539	-1.4224	1.6609	-.0718	-.803	-.0000	1.2420	2.5437
-.6973	-1.4854	1.7711	-.0660	-.803	-.0000	1.3521	2.7379
-.7407	-1.5476	1.8813	-.0593	-.803	-.0000	1.4621	2.9326
-.7835	-1.6097	1.9915	-.0517	-.803	-.0000	1.5722	3.1271
-.8264	-1.6715	2.1017	-.0432	-.803	-.0000	1.6822	3.3216
-.8693	-1.7328	2.2119	-.0338	-.803	-.0000	1.7923	3.5161
-.9121	-1.7935	2.3221	-.0235	-.803	-.0000	1.9024	3.7106
-.9550	-1.8537	2.4323	-.0123	-.803	-.0000	2.0125	3.9051
-.9979	-1.9134	2.5425	-.0000	-.803	-.0000	2.1226	4.1000
-1.0408	-1.9726	2.6527	-.0123	-.803	-.0000	2.2327	4.2945
-1.0837	-2.0313	2.7629	-.0235	-.803	-.0000	2.3428	4.4890
-1.1266	-2.0895	2.8731	-.0347	-.803	-.0000	2.4529	4.6835
-1.1695	-2.1472	2.9833	-.0460	-.803	-.0000	2.5630	4.8780
-1.2124	-2.2045	3.0935	-.0572	-.803	-.0000	2.6731	5.0725
-1.2553	-2.2613	3.2037	-.0684	-.803	-.0000	2.7832	5.2670
-1.2982	-2.3176	3.3139	-.0796	-.803	-.0000	2.8933	5.4615
-1.3411	-2.3735	3.4241	-.0908	-.803	-.0000	3.0034	5.6560
-1.3840	-2.4289	3.5343	-.1020	-.803	-.0000	3.1135	5.8505
-1.4269	-2.4838	3.6445	-.1132	-.803	-.0000	3.2236	6.0450
-1.4698	-2.5382	3.7547	-.1244	-.803	-.0000	3.3337	6.2395
-1.5127	-2.5921	3.8649	-.1356	-.803	-.0000	3.4438	6.4340
-1.5556	-2.6455	3.9751	-.1468	-.803	-.0000	3.5539	6.6285
-1.5985	-2.6984	4.0853	-.1580	-.803	-.0000	3.6640	6.8230
-1.6414	-2.7508	4.1955	-.1692	-.803	-.0000	3.7741	7.0175
-1.6843	-2.8027	4.3057	-.1804	-.803	-.0000	3.8842	7.2120
-1.7272	-2.8541	4.4159	-.1916	-.803	-.0000	3.9943	7.4065
-1.7701	-2.9050	4.5261	-.2028	-.803	-.0000	4.1044	7.6010
-1.8130	-2.9554	4.6363	-.2140	-.803	-.0000	4.2145	7.7955
-1.8559	-3.0053	4.7465	-.2252	-.803	-.0000	4.3246	7.9900
-1.8988	-3.0547	4.8567	-.2364	-.803	-.0000	4.4347	8.1845
-1.9417	-3.1036	4.9669	-.2476	-.803	-.0000	4.5448	8.3790
-1.9846	-3.1520	5.0771	-.2588	-.803	-.0000	4.6549	8.5735
-2.0275	-3.2000	5.1873	-.2700	-.803	-.0000	4.7650	8.7680
-2.0704	-3.2475	5.2975	-.2812	-.803	-.0000	4.8751	8.9625
-2.1133	-3.2945	5.4077	-.2924	-.803	-.0000	4.9852	9.1570
-2.1562	-3.3410	5.5179	-.3036	-.803	-.0000	5.0953	9.3515
-2.1991	-3.3870	5.6281	-.3148	-.803	-.0000	5.2054	9.5460
-2.2420	-3.4325	5.7383	-.3260	-.803	-.0000	5.3155	9.7405
-2.2849	-3.4775	5.8485	-.3372	-.803	-.0000	5.4256	9.9350
-2.3278	-3.5220	5.9587	-.3484	-.803	-.0000	5.5357	10.1295
-2.3707	-3.5660	6.0689	-.3596	-.803	-.0000	5.6458	10.3240
-2.4136	-3.6095	6.1791	-.3708	-.803	-.0000	5.7559	10.5185
-2.4565	-3.6525	6.2893	-.3820	-.803	-.0000	5.8660	10.7130
-2.4994	-3.6950	6.3995	-.3932	-.803	-.0000	5.9761	10.9075
-2.5423	-3.7370	6.5097	-.4044	-.803	-.0000	6.0862	11.1020
-2.5852	-3.7785	6.6199	-.4156	-.803	-.0000	6.1963	11.2965
-2.6281	-3.8195	6.7301	-.4268	-.803	-.0000	6.3064	11.4910
-2.6710	-3.8600	6.8403	-.4380	-.803	-.0000	6.4165	11.6855
-2.7139	-3.8995	6.9505	-.4492	-.803	-.0000	6.5266	11.8800
-2.7568	-3.9385	7.0607	-.4604	-.803	-.0000	6.6367	12.0745
-2.7997	-3.9770	7.1709	-.4716	-.803	-.0000	6.7468	12.2690
-2.8426	-4.0150	7.2811	-.4828	-.803	-.0000	6.8569	12.4635
-2.8855	-4.0525	7.3913	-.4940	-.803	-.0000	6.9670	12.6580
-2.9284	-4.0895	7.5015	-.5052	-.803	-.0000	7.0771	12.8525
-2.9713	-4.1260	7.6117	-.5164	-.803	-.0000	7.1872	13.0470
-3.0142	-4.1620	7.7219	-.5276	-.803	-.0000	7.2973	13.2415
-3.0571	-4.1975	7.8321	-.5388	-.803	-.0000	7.4074	13.4360
-3.1000	-4.2325	7.9423	-.5500	-.803	-.0000	7.5175	13.6305
-3.1429	-4.2670	8.0525	-.5612	-.803	-.0000	7.6276	13.8250
-3.1858	-4.2995	8.1627	-.5724	-.803	-.0000	7.7377	14.0195
-3.2287	-4.3310	8.2729	-.5836	-.803	-.0000	7.8478	14.2140
-3.2716	-4.3615	8.3831	-.5948	-.803	-.0000	7.9579	14.4085
-3.3145	-4.3910	8.4933	-.6060	-.803	-.0000	8.0680	14.6030
-3.3574	-4.4195	8.6035	-.6172	-.803	-.0000	8.1781	14.7975
-3.4003	-4.4470	8.7137	-.6284	-.803	-.0000	8.2882	14.9920
-3.4432	-4.4735	8.8239	-.6396	-.803	-.0000	8.3983	15.1865
-3.4861	-4.4990	8.9341	-.6508	-.803	-.0000	8.5084	15.3810
-3.5290	-4.5235	9.0443	-.6620	-.803	-.0000	8.6185	15.5755
-3.5719	-4.5470	9.1545	-.6732	-.803	-.0000	8.7286	15.7700
-3.6148	-4.5695	9.2647	-.6844	-.803	-.0000	8.8387	15.9645
-3.6577	-4.5910	9.3749	-.6956	-.803	-.0000	8.9488	16.1590
-3.7006	-4.6115	9.4851	-.7068	-.803	-.0000	9.0589	16.3535
-3.7435	-4.6305	9.5953	-.7180	-.803	-.0000	9.1690	16.5480
-3.7864	-4.6485	9.7055	-.7292	-.803	-.0000	9.2791	16.7425
-3.8293	-4.6655	9.8157	-.7404	-.803	-.0000	9.3892	16.9370
-3.8722	-4.6815	9.9259	-.7516	-.803	-.0000	9.4993	17.1315
-3.9151	-4.6965	10.0361	-.7628	-.803	-.0000	9.6094	17.3260
-3.9580	-4.7105	10.1463	-.7740	-.803	-.0000	9.7195	17.5205
-4.0009	-4.7235	10.2565	-.7852	-.803	-.0000	9.8296	17.7150
-4.0438	-4.7355	10.3667	-.7964	-.803	-.0000	9.9397	17.9095
-4.0867	-4.7465	10.4769	-.8076	-.803	-.0000	10.0498	18.1040
-4.1296	-4.7565	10.5871	-.8188	-.803	-.0000	10.1599	18.2985
-4.1725	-4.7655	10.6973	-.8300	-.803	-.0000	10.2700	18.4930
-4.2154	-4.7735	10.8075	-.8412	-.803	-.0000	10.3801	18.6875
-4.2583	-4.7805	10.9177	-.8524	-.803	-.0000	10.4902	18.8820
-4.3012	-4.7865	11.0279	-.8636	-.803	-.0000	10.6003	19.0765
-4.3441	-4.7915	11.1381	-.8748	-.803	-.0000	10.7104	19.2710
-4.3870	-4.7955	11.2483	-.8860	-.803	-.0000	10.8205	19.4655
-4.4299	-4.7985	11.3585	-.8972	-.803	-.0000	10.9306	19.6600
-4.4728	-4.8005	11.4687	-.9084	-.803	-.0000	11.0407	19.8545
-4.5157	-4.8015	11.5789	-.9196	-.803	-.0000	11.1508	20.0490
-4.5586	-4.8015	11.6891	-.9308	-.803	-.0000	11.2609	20.2435
-4.6015	-4.8005	11.7993	-.9420	-.803	-.0000	11.3710	20.4380
-4.6444	-4.7985	11.9095	-.9532	-.803	-.0000	11.4811	20.6325
-4.6873	-4.7955	12.0197	-.9644	-.803	-.0000	11.5912	20.8270
-4.7302	-4.7915	12.1299	-.9756	-.803	-.0000	11.7013	21.0215
-4.7731	-4.7865	12.2401	-.9868	-.803	-.0000</		

TABLE A-3.--Continued

ROTOR AIRFOIL COORDINATES
SECTION NO. 2 RADIUS 13.000 IN. (33.052 CM.)

SECTION SURFACE		PRESSURE SURFACE		SECTION SURFACE		PRESSURE SURFACE	
X IN.	Y IN.	X CM.	Y CM.	X IN.	Y IN.	X CM.	Y CM.
.9345	-1.6420	-2.3736	-4.1708	.9345	-1.6420	-2.3736	-4.1708
.9344	-1.6009	-2.3735	-4.1679	.9344	-1.6040	-2.3735	-4.1744
.9330	-1.6376	-2.3720	-4.1599	.9336	-1.6457	-2.3714	-4.1802
.9326	-1.6345	-2.3689	-4.1517	.9323	-1.6470	-2.3680	-4.1834
.9158	-1.5976	-2.3260	-4.0983	.9305	-1.6473	-2.3635	-4.1844
.9246	-1.6093	-2.2102	-3.8083	.9284	-1.6467	-2.3581	-4.1825
.9709	-1.6021	-2.0944	-3.5014	.9261	-1.6451	-2.3524	-4.1785
.9733	-1.6061	-1.9785	-3.3176	.9215	-1.6387	-2.3405	-4.1622
.9777	-1.6215	-1.8627	-3.0172	.9186	-1.6307	-2.3340	-4.0835
.9421	-1.6114	-1.7469	-2.8040	.9159	-1.6239	-2.3276	-3.8707
.9365	-1.6267	-1.6310	-2.6077	.9135	-1.6199	-2.3262	-3.6574
.9304	-1.6359	-1.5152	-2.4171	.9109	-1.6158	-2.3250	-3.4437
.9253	-1.6457	-1.3994	-2.2324	.9079	-1.6158	-2.3240	-3.2297
.9203	-1.6550	-1.2835	-2.0482	.9041	-1.6271	-2.3230	-3.0155
.9153	-1.6644	-1.1677	-1.8632	.9013	-1.6102	-2.3220	-2.8013
.9103	-1.6738	-1.0519	-1.6781	.8987	-1.6185	-2.3210	-2.5871
.9053	-1.6832	-9360	-1.4930	.8960	-1.6342	-2.3200	-2.3729
.9003	-1.6926	-8202	-1.3082	.8934	-1.6503	-2.3190	-2.1591
.8953	-1.7020	-7044	-1.1234	.8907	-1.6664	-2.3180	-1.9455
.8903	-1.7114	-5886	-9383	.8881	-1.6825	-2.3170	-1.7324
.8853	-1.7208	-4728	-8224	.8854	-1.7000	-2.3160	-1.5197
.8803	-1.7302	-3570	-7066	.8828	-1.7175	-2.3150	-1.3076
.8753	-1.7396	-2412	-5908	.8801	-1.7350	-2.3140	-1.0941
.8703	-1.7490	-1254	-4750	.8775	-1.7525	-2.3130	-.8804
.8653	-1.7584	-93	-3592	.8749	-1.7700	-2.3120	-.6664
.8603	-1.7678	93	-2434	.8723	-1.7875	-2.3110	-.4523
.8553	-1.7772	177	-1276	.8697	-1.8050	-2.3100	-.2382
.8503	-1.7866	261	-1118	.8671	-1.8225	-2.3090	-.0241
.8453	-1.7960	345	-960	.8645	-1.8400	-2.3080	.1900
.8403	-1.8054	429	-802	.8619	-1.8575	-2.3070	.3759
.8353	-1.8148	513	-644	.8593	-1.8750	-2.3060	.5618
.8303	-1.8242	597	-486	.8567	-1.8925	-2.3050	.7477
.8253	-1.8336	681	-328	.8541	-1.9100	-2.3040	.9336
.8203	-1.8430	765	-170	.8515	-1.9275	-2.3030	1.1195
.8153	-1.8524	849	-12	.8489	-1.9450	-2.3020	1.3054
.8103	-1.8618	933	86	.8463	-1.9625	-2.3010	1.4913
.8053	-1.8712	1017	170	.8437	-1.9800	-2.3000	1.6772
.8003	-1.8806	1101	254	.8411	-1.9975	-2.2990	1.8631
.7953	-1.8900	1185	338	.8385	-2.0150	-2.2980	2.0490
.7903	-1.8994	1269	422	.8359	-2.0325	-2.2970	2.2349
.7853	-1.9088	1353	506	.8333	-2.0500	-2.2960	2.4208
.7803	-1.9182	1437	590	.8307	-2.0675	-2.2950	2.6067
.7753	-1.9276	1521	674	.8281	-2.0850	-2.2940	2.7926
.7703	-1.9370	1605	758	.8255	-2.1025	-2.2930	2.9785
.7653	-1.9464	1689	842	.8229	-2.1200	-2.2920	3.1644
.7603	-1.9558	1773	926	.8203	-2.1375	-2.2910	3.3503
.7553	-1.9652	1857	1010	.8177	-2.1550	-2.2900	3.5362
.7503	-1.9746	1941	1094	.8151	-2.1725	-2.2890	3.7221
.7453	-1.9840	2025	1178	.8125	-2.1900	-2.2880	3.9080
.7403	-1.9934	2109	1262	.8099	-2.2075	-2.2870	4.0939
.7353	-2.0028	2193	1346	.8073	-2.2250	-2.2860	4.2798
.7303	-2.0122	2277	1430	.8047	-2.2425	-2.2850	4.4657
.7253	-2.0216	2361	1514	.8021	-2.2600	-2.2840	4.6516
.7203	-2.0310	2445	1598	.7995	-2.2775	-2.2830	4.8375
.7153	-2.0404	2529	1682	.7969	-2.2950	-2.2820	5.0234
.7103	-2.0498	2613	1766	.7943	-2.3125	-2.2810	5.2093
.7053	-2.0592	2697	1850	.7917	-2.3300	-2.2800	5.3952
.7003	-2.0686	2781	1934	.7891	-2.3475	-2.2790	5.5811
.6953	-2.0780	2865	2018	.7865	-2.3650	-2.2780	5.7670
.6903	-2.0874	2949	2102	.7839	-2.3825	-2.2770	5.9529
.6853	-2.0968	3033	2186	.7813	-2.4000	-2.2760	6.1388
.6803	-2.1062	3117	2270	.7787	-2.4175	-2.2750	6.3247
.6753	-2.1156	3201	2354	.7761	-2.4350	-2.2740	6.5106
.6703	-2.1250	3285	2438	.7735	-2.4525	-2.2730	6.6965
.6653	-2.1344	3369	2522	.7709	-2.4700	-2.2720	6.8824
.6603	-2.1438	3453	2606	.7683	-2.4875	-2.2710	7.0683
.6553	-2.1532	3537	2690	.7657	-2.5050	-2.2700	7.2542
.6503	-2.1626	3621	2774	.7631	-2.5225	-2.2690	7.4401
.6453	-2.1720	3705	2858	.7605	-2.5400	-2.2680	7.6260
.6403	-2.1814	3789	2942	.7579	-2.5575	-2.2670	7.8119
.6353	-2.1908	3873	3026	.7553	-2.5750	-2.2660	8.0000
.6303	-2.2002	3957	3110	.7527	-2.5925	-2.2650	8.1881
.6253	-2.2096	4041	3194	.7501	-2.6100	-2.2640	8.3762
.6203	-2.2190	4125	3278	.7475	-2.6275	-2.2630	8.5643
.6153	-2.2284	4209	3362	.7449	-2.6450	-2.2620	8.7524
.6103	-2.2378	4293	3446	.7423	-2.6625	-2.2610	8.9405
.6053	-2.2472	4377	3530	.7397	-2.6800	-2.2600	9.1286
.6003	-2.2566	4461	3614	.7371	-2.6975	-2.2590	9.3167
.5953	-2.2660	4545	3698	.7345	-2.7150	-2.2580	9.5048
.5903	-2.2754	4629	3782	.7319	-2.7325	-2.2570	9.6929
.5853	-2.2848	4713	3866	.7293	-2.7500	-2.2560	9.8810
.5803	-2.2942	4797	3950	.7267	-2.7675	-2.2550	10.0691
.5753	-2.3036	4881	4034	.7241	-2.7850	-2.2540	10.2572
.5703	-2.3130	4965	4118	.7215	-2.8025	-2.2530	10.4453
.5653	-2.3224	5049	4202	.7189	-2.8200	-2.2520	10.6334
.5603	-2.3318	5133	4286	.7163	-2.8375	-2.2510	10.8215
.5553	-2.3412	5217	4370	.7137	-2.8550	-2.2500	11.0096
.5503	-2.3506	5301	4454	.7111	-2.8725	-2.2490	11.1977
.5453	-2.3600	5385	4538	.7085	-2.8900	-2.2480	11.3858
.5403	-2.3694	5469	4622	.7059	-2.9075	-2.2470	11.5739
.5353	-2.3788	5553	4706	.7033	-2.9250	-2.2460	11.7620
.5303	-2.3882	5637	4790	.7007	-2.9425	-2.2450	11.9501
.5253	-2.3976	5721	4874	.6981	-2.9600	-2.2440	12.1382
.5203	-2.4070	5805	4958	.6955	-2.9775	-2.2430	12.3263
.5153	-2.4164	5889	5042	.6929	-2.9950	-2.2420	12.5144
.5103	-2.4258	5973	5126	.6903	-3.0125	-2.2410	12.7025
.5053	-2.4352	6057	5210	.6877	-3.0300	-2.2400	12.8906
.5003	-2.4446	6141	5294	.6851	-3.0475	-2.2390	13.0787
.4953	-2.4540	6225	5378	.6825	-3.0650	-2.2380	13.2668
.4903	-2.4634	6309	5462	.6799	-3.0825	-2.2370	13.4549
.4853	-2.4728	6393	5546	.6773	-3.1000	-2.2360	13.6430
.4803	-2.4822	6477	5630	.6747	-3.1175	-2.2350	13.8311
.4753	-2.4916	6561	5714	.6721	-3.1350	-2.2340	14.0192
.4703	-2.5010	6645	5798	.6695	-3.1525	-2.2330	14.2073
.4653	-2.5104	6729	5882	.6669	-3.1700	-2.2320	14.3954
.4603	-2.5198	6813	5966	.6643	-3.1875	-2.2310	14.5835
.4553	-2.5292	6897	6050	.6617	-3.2050	-2.2300	14.7716
.4503	-2.5386	6981	6134	.6591	-3.2225	-2.2290	14.9597
.4453	-2.5480	7065	6218	.6565	-3.2400	-2.2280	15.1478
.4403	-2.5574	7149	6302	.6539	-3.2575	-2.2270	15.3359
.4353	-2.5668	7233	6386	.6513	-3.2750	-2.2260	15.5240
.4303	-2.5762	7317	6470	.6487	-3.2925	-2.2250	15.7121
.4253	-2.5856	7401	6554	.6461	-3.3100	-2.2240	15.9002
.4203	-2.5950	7485	6638	.6435	-3.3275	-2.2230	16.0883
.4153	-2.6044	7569	6722	.6409	-3.3450	-2.2220	16.2764
.4103	-2.6138	7653	6806	.6383	-3.3625	-2.2210	16.4645
.4053	-2.6232	7737	6890	.6357	-3.3800	-2.2200	16.6526
.4003	-2.6326	7821	6974	.6331	-3.3975	-2.2190	16.8407
.3953	-2.6420	7905	7058	.6305	-3.4150	-2.2180	17.0288
.3903	-2.6514	7989	7142	.6279	-3.4325	-2.2170	17.2169
.3853	-2.6608	8073	7226	.6253	-3.4500	-2.2160	17.4050
.3803	-2.6702	8157	7310	.6227	-3.4675	-2.2150	17.5931
.3753	-2.6796	8241	7394	.6201	-3.4850	-2.2140	17.7812
.3703	-2.6890	8325	7478	.6175	-3.5025	-2.2130	17.9693
.3653	-2.6984	8409	7562	.6149	-3.5200	-2.2120	18.1574
.3603	-2.7078	8493	7646	.6123	-3.5375	-2.2110	18.3455
.3553	-2.7172	8577	7730	.6097	-3.5550	-2.2100	18.5336
.3503	-2.7266	8661	7814	.6071	-3.5725	-2.2090	18.7217
.3453	-2.7360	8745	7898	.6045	-3.5900	-2.2080	18.9098
.3403	-2.7454	8829	7982	.6019	-3.6075	-2.2070	19.0979
.3353	-2.7548	8913	8066	.5993	-3.6250	-2.2060	19.2860
.3303	-2.7642	8997	8150	.5967	-3.6425	-2.2050	19.4741
.3253	-2.7736	9081	8234	.5941	-3.6600	-2.2040	19.6622
.3203	-2.7830	9165	8318	.5915	-3.6775	-2.2030	19.8503
.3153	-2.7924	9249	8402	.5889	-3.6950	-2.2020	20.0384
.3103	-2.8018	9333	8486	.5863	-3.7125	-2.2010	20.2265
.3053	-2.8112	9417	8570	.5837	-3.7300	-2.2000	20.4146
.3003	-2.8206	9501	8654	.5811	-3.7475	-2.1990	20.6027
.2953	-2.8300	9585	8738	.5785	-3.7650	-2.1980	20.7908
.2903	-2.8394	9669	8822	.5759	-3.7825	-2.1970	20.9789
.2853	-2.8488	9753	8906	.5733	-3.8000	-2.1960	2

TABLE A-3.--Continued

SECTION NO. 3 RADIUS 13.100 IN. (33.274 CM.)

AIRFOIL COORDINATES

SUCTION SURFACE			PRESSURE SURFACE		
X.IN.	Y.IN.	X.CM.	Y.IN.	X.IN.	Y.CM.
-.9574	-1.5712	-2.4319	-1.5712	-.9574	-3.9908
-.9595	-1.5317	-2.4317	-1.5737	-.9573	-3.9867
-.9566	-1.5859	-2.4297	-1.5752	-.9565	-3.9774
-.9551	-1.5622	-2.4259	-1.5767	-.9550	-3.9679
-.9389	-1.5293	-2.3848	-1.5771	-.9530	-3.9683
-.8458	-1.4353	-2.2666	-1.5764	-.9505	-3.9457
-.7993	-1.3425	-2.1484	-1.5746	-.9478	-3.9100
-.7528	-1.2509	-2.0302	-1.5672	-.9421	-3.8773
-.7062	-1.1606	-1.9120	-1.5594	-.9260	-3.8480
-.6597	-1.0718	-1.7936	-1.5530	-.8795	-3.7224
-.6131	-0.9841	-1.6756	-1.5476	-.8330	-2.9997
-.5666	-0.8972	-1.5574	-1.5498	-.7865	-2.2792
-.5201	-0.8110	-1.4392	-1.5202	-.7400	-2.0600
-.4735	-0.7251	-1.3210	-1.4407	-.6936	-1.8417
-.4270	-0.6396	-1.2028	-1.4013	-.6471	-1.6230
-.3805	-0.5551	-1.0846	-.8822	-.6006	-1.4100
-.3339	-0.4711	-.9664	-.9033	-.5541	-1.1965
-.2874	-0.3875	-.8482	-.8245	-.5076	-.9841
-.2409	-0.3043	-.7300	-.7450	-.4612	-.7720
-.1943	-0.2216	-.6118	-.6676	-.4147	-.5628
-.1478	-0.1393	-.4935	-.5895	-.3682	-.3539
-.1012	-0.0576	-.3753	-.5117	-.3217	-.1464
-.0547	-.0196	-.2571	-.4342	-.2752	-.0602
-.0082	-.0825	-.1389	-.3569	-.2287	-.2658
-.0009	-.0384	-.0207	-.2800	-.1823	-.4705
-.1314	-.3454	-.2157	-.2034	-.1358	-.6743
-.1780	-.5843	-.3339	-.1272	-.0893	-.8773
-.2245	-.8233	-.4521	-.0244	-.0428	1.0794
-.2711	-1.0621	-.5703	-.0997	-.0037	1.2808
-.3176	-1.3006	-.6885	-.1746	-.0501	1.4816
-.3641	-1.5396	-.8067	-.2491	-.0966	1.6817
-.4107	-1.7786	-.9249	-.3233	-.1431	1.8811
-.4572	-2.0175	1.0431	-.3971	-.1896	2.0773
-.5037	-2.2565	1.1613	-.4704	-.2361	2.2600
-.5503	-2.4953	1.2795	-.5438	-.2826	2.4304
-.5968	-2.7343	1.3977	-.6178	-.3290	2.5977
-.6434	-2.9733	1.5159	-.6900	-.3755	2.7643
-.6899	-3.2123	1.6341	-.7602	-.4220	2.9305
-.7364	-3.4513	1.7523	-.8300	-.4685	3.0963
-.7830	-3.6903	1.8706	-.8996	-.5150	3.2617
-.8295	-3.9293	1.9881	-.9696	-.5615	3.4267
-.8761	-4.1683	2.1050	1.0583	-.6079	3.5912
-.9226	-4.4073	2.2225	1.1461	-.6544	3.7542
-.9691	-4.6463	2.3400	1.2332	-.7009	3.9172
-.0156	-4.8853	2.4575	1.3193	-.7474	4.0801
-.0621	-5.1243	2.5750	1.4046	-.7939	4.2431
-.1086	-5.3633	2.6925	1.4113	-.7976	4.4061
-.1551	-5.6023	2.8100	1.4157	-.7996	4.5691
-.2016	-5.8413	2.9275	1.4193	-.8004	4.7321
-.2481	-6.0803	3.0450	1.4207	-.8005	4.8951
-.2946	-6.3193	3.1625	1.4207		
-.3411	-6.5583	3.2800			
-.3876	-6.7973	3.3975			
-.4341	-7.0363	3.5150			
-.4806	-7.2753	3.6325			
-.5271	-7.5143	3.7500			
-.5736	-7.7533	3.8675			
-.6201	-7.9923	3.9850			
-.6666	-8.2313	4.1025			
-.7131	-8.4703	4.2200			
-.7596	-8.7093	4.3375			
-.8061	-8.9483	4.4550			
-.8526	-9.1873	4.5725			
-.8991	-9.4263	4.6900			
-.9456	-9.6653	4.8075			
-.9921	-9.9043	4.9250			
-1.0386	-10.1433	5.0425			
-1.0851	-10.3823	5.1600			
-1.1316	-10.6213	5.2775			
-1.1781	-10.8603	5.3950			
-1.2246	-11.0993	5.5125			
-1.2711	-11.3383	5.6300			
-1.3176	-11.5773	5.7475			
-1.3641	-11.8163	5.8650			
-1.4106	-12.0553	5.9825			
-1.4571	-12.2943	6.1000			
-1.5036	-12.5333	6.2175			
-1.5501	-12.7723	6.3350			
-1.5966	-13.0113	6.4525			
-1.6431	-13.2503	6.5700			
-1.6896	-13.4893	6.6875			
-1.7361	-13.7283	6.8050			
-1.7826	-13.9673	6.9225			
-1.8291	-14.2063	7.0400			
-1.8756	-14.4453	7.1575			
-1.9221	-14.6843	7.2750			
-1.9686	-14.9233	7.3925			
-2.0151	-15.1623	7.5100			
-2.0616	-15.4013	7.6275			
-2.1081	-15.6403	7.7450			
-2.1546	-15.8793	7.8625			
-2.2011	-16.1183	7.9800			
-2.2476	-16.3573	8.0975			
-2.2941	-16.5963	8.2150			
-2.3406	-16.8353	8.3325			
-2.3871	-17.0743	8.4500			
-2.4336	-17.3133	8.5675			
-2.4801	-17.5523	8.6850			
-2.5266	-17.7913	8.8025			
-2.5731	-18.0303	8.9200			
-2.6196	-18.2693	9.0375			
-2.6661	-18.5083	9.1550			
-2.7126	-18.7473	9.2725			
-2.7591	-18.9863	9.3900			
-2.8056	-19.2253	9.5075			
-2.8521	-19.4643	9.6250			
-2.8986	-19.7033	9.7425			
-2.9451	-19.9423	9.8600			
-2.9916	-20.1813	9.9775			
-3.0381	-20.4203	10.0950			
-3.0846	-20.6593	10.2125			
-3.1311	-20.8983	10.3300			
-3.1776	-21.1373	10.4475			
-3.2241	-21.3763	10.5650			
-3.2706	-21.6153	10.6825			
-3.3171	-21.8543	10.8000			
-3.3636	-22.0933	10.9175			
-3.4101	-22.3323	11.0350			
-3.4566	-22.5713	11.1525			
-3.5031	-22.8103	11.2700			
-3.5496	-23.0493	11.3875			
-3.5961	-23.2883	11.5050			
-3.6426	-23.5273	11.6225			
-3.6891	-23.7663	11.7400			
-3.7356	-24.0053	11.8575			
-3.7821	-24.2443	11.9750			
-3.8286	-24.4833	12.0925			
-3.8751	-24.7223	12.2100			
-3.9216	-24.9613	12.3275			
-3.9681	-25.2003	12.4450			
-4.0146	-25.4393	12.5625			
-4.0611	-25.6783	12.6800			
-4.1076	-25.9173	12.7975			
-4.1541	-26.1563	12.9150			
-4.2006	-26.3953	13.0325			
-4.2471	-26.6343	13.1500			
-4.2936	-26.8733	13.2675			
-4.3401	-27.1123	13.3850			
-4.3866	-27.3513	13.5025			
-4.4331	-27.5903	13.6200			
-4.4796	-27.8293	13.7375			
-4.5261	-28.0683	13.8550			
-4.5726	-28.3073	13.9725			
-4.6191	-28.5463	14.0900			
-4.6656	-28.7853	14.2075			
-4.7121	-29.0243	14.3250			
-4.7586	-29.2633	14.4425			
-4.8051	-29.5023	14.5600			
-4.8516	-29.7413	14.6775			
-4.8981	-29.9803	14.7950			
-4.9446	-30.2193	14.9125			
-4.9911	-30.4583	15.0300			
-5.0376	-30.6973	15.1475			
-5.0841	-30.9363	15.2650			
-5.1306	-31.1753	15.3825			
-5.1771	-31.4143	15.5000			
-5.2236	-31.6533	15.6175			
-5.2701	-31.8923	15.7350			
-5.3166	-32.1313	15.8525			
-5.3631	-32.3703	15.9700			
-5.4096	-32.6093	16.0875			
-5.4561	-32.8483	16.2050			
-5.5026	-33.0873	16.3225			
-5.5491	-33.3263	16.4400			
-5.5956	-33.5653	16.5575			
-5.6421	-33.8043	16.6750			
-5.6886	-34.0433	16.7925			
-5.7351	-34.2823	16.9100			
-5.7816	-34.5213	17.0275			
-5.8281	-34.7603	17.1450			
-5.8746	-35.0000	17.2625			
-5.9211	-35.2388	17.3800			
-5.9676	-35.4778	17.4975			
-6.0141	-35.7168	17.6150			
-6.0606	-35.9558	17.7325			
-6.1071	-36.1948	17.8500			
-6.1536	-36.4338	17.9675			
-6.2001	-36.6728	18.0850			
-6.2466	-36.9118	18.2025			
-6.2931	-37.1508	18.3200			
-6.3396	-37.3898	18.4375			
-6.3861	-37.6288	18.5550			
-6.4326	-37.8678	18.6725			
-6.4791	-38.1068	18.7900			
-6.5256	-38.3458	18.9075			
-6.5721	-38.5848	19.0250			
-6.6186	-38.8238	19.1425			
-6.6651	-39.0628	19.2600			
-6.7116	-39.3018	19.3775			
-6.7581	-39.5408	19.4950			
-6.8046	-39.7798	19.6125			
-6.8511	-40.0188	19.7300			
-6.8976	-40.2578	19.8475			
-6.9441	-40.4968	19.9650			
-6.9906	-40.7358	20.0825			
-7.0371	-40.9748	20.2000			
-7.0836	-41.2138	20.3175			
-7.1301	-41.4528	20.4350			
-7.1766	-41.6918	20.5525			
-7.2231	-41.9308	20.6700			
-7.2696	-42.1698	20.7875			
-7.3161	-42.4088	20.9050			
-7.3626	-42.6478	21.0225			
-7.4091	-42.8868	21.1400			
-7.4556	-43.1258	21.2575			
-7.5021	-43.3648	21.3750			
-7.5486	-43.6038	21.4925			
-7.5951	-43.8428	21.6100			
-7.6416	-44.0818	21.7275			
-7.6881	-44.3208	21.8450			
-7.7346	-44.5598	21.9625			
-7.7811	-44.7988	22.0800			
-7.8276	-45.0378	22.1975			
-7.8741	-45.2768	22.3150			
-7.9206	-45.5158	22.4325			
-7.9671	-45.7548	22.5500			
-8.0136	-45.9938	22.6675			
-8.0601	-46.2328	22.7850			
-8.1066	-46.4718	22.9025			

TABLE A-3.--Continued

ROTOR AIRFOIL COORDINATES
SECTION NO. 4 RADIUS 12.750 IN. (32.385 CM.)

SUCTION SURFACE		PRESSURE SURFACE		SUCTION SURFACE		PRESSURE SURFACE	
X IN.	Y IN.	X IN.	Y IN.	X IN.	Y IN.	X IN.	Y IN.
.9700	-1.5335	-2.4792	-3.8951	.9740	-1.5335	-2.4792	-3.8951
.9759	-1.5314	-2.4788	-3.8897	.9759	-1.5351	-2.4789	-3.8943
.9789	-1.5273	-2.4763	-3.8788	.9750	-1.5361	-2.4766	-3.9007
.9731	-1.5227	-2.4717	-3.8676	.9733	-1.5399	-2.4722	-3.9113
.9572	-1.4914	-2.4314	-3.7881	.9708	-1.5404	-2.4659	-3.9120
.9097	-1.3983	-2.3107	-3.5510	.9679	-1.5396	-2.4584	-3.9100
.8622	-1.3064	-2.1900	-3.3184	.9647	-1.5376	-2.4504	-3.9054
.8147	-1.2157	-2.0694	-3.0878	.9578	-1.5288	-2.4328	-3.8833
.7672	-1.1261	-1.9487	-2.8604	.9419	-1.5026	-2.3925	-3.8166
.7197	-1.0378	-1.8280	-2.6361	.9344	-1.4739	-2.3717	-3.8167
.6722	-.9506	-1.7073	-2.4186	.9268	-1.4454	-2.3508	-3.8173
.6247	-.8643	-1.5866	-2.2019	.9192	-1.4171	-2.3295	-3.82185
.5771	-.7787	-1.4659	-1.9780	.9116	-1.3892	-2.3082	-3.8205
.5296	-.6930	-1.3453	-1.7524	.9041	-1.3615	-2.2867	-3.8233
.4821	-.6079	-1.2246	-1.5281	.8965	-1.3342	-2.2652	-3.8268
.4346	-.5227	-1.1039	-1.3037	.8889	-1.3072	-2.2437	-3.8313
.3871	-.4374	-.9832	-1.0794	.8814	-.2805	-2.2222	-3.8360
.3396	-.3521	-.8625	-.8550	.8738	-.2538	-2.2007	-3.8407
.2921	-.2668	-.7418	-.6282	.8662	-.2271	-2.1792	-3.8454
.2445	-.1815	-.6212	-.4014	.8587	-.2004	-2.1577	-3.8501
.1970	-.0962	-.5005	-.1746	.8511	-.1737	-2.1362	-3.8548
.1495	.0000	-.3798	.0511	.8435	-.1470	-2.1147	-3.8595
.1020	.0847	-.2591	.2244	.8359	-.1203	-2.0932	-3.8642
.0545	.1694	-.1384	.3989	.8283	-.0936	-2.0717	-3.8689
.0070	.2541	-.0178	.5734	.8207	-.0669	-2.0502	-3.8736
.0405	.3388	.1029	.7479	.8131	-.0402	-2.0287	-3.8783
.0830	.4235	.2236	.9224	.8055	-.0135	-2.0072	-3.8830
.1255	.5082	.3443	1.0969	.7979	.0132	-1.9857	-3.8877
.1680	.5929	.4650	1.2714	.7903	.0400	-1.9642	-3.8924
.2105	.6776	.5857	1.4459	.7827	.0667	-1.9427	-3.8971
.2530	.7623	.7064	1.6204	.7751	.0934	-1.9212	-3.9018
.2955	.8470	.8271	1.7949	.7675	.1201	-1.8997	-3.9065
.3380	.9317	.9478	1.9694	.7600	.1468	-1.8782	-3.9112
.3805	1.0164	1.0685	2.1439	.7524	.1735	-1.8567	-3.9159
.4230	1.1011	1.1892	2.3184	.7448	.2002	-1.8352	-3.9206
.4655	1.1858	1.3099	2.4929	.7373	.2269	-1.8137	-3.9253
.5080	1.2705	1.4306	2.6674	.7297	.2536	-1.7922	-3.9300
.5505	1.3552	1.5513	2.8419	.7222	.2803	-1.7707	-3.9347
.5930	1.4399	1.6720	3.0164	.7146	.3070	-1.7492	-3.9394
.6355	1.5246	1.7927	3.1909	.7071	.3337	-1.7277	-3.9441
.6780	1.6093	1.9134	3.3654	.7000	.3604	-1.7062	-3.9488
.7205	1.6940	2.0341	3.5399	.6924	.3871	-1.6847	-3.9535
.7630	1.7787	2.1548	3.7144	.6849	.4138	-1.6632	-3.9582
.8055	1.8634	2.2755	3.8889	.6773	.4405	-1.6417	-3.9629
.8480	1.9481	2.3962	4.0634	.6700	.4672	-1.6202	-3.9676
.8905	2.0328	2.5169	4.2379	.6624	.4939	-1.5987	-3.9723
.9330	2.1175	2.6376	4.4124	.6549	.5206	-1.5772	-3.9770
.9755	2.2022	2.7583	4.5869	.6473	.5473	-1.5557	-3.9817
1.0180	2.2869	2.8790	4.7614	.6400	.5740	-1.5342	-3.9864
1.0605	2.3716	2.9997	4.9359	.6324	.6007	-1.5127	-3.9911
1.1030	2.4563	3.1204	5.1104	.6249	.6274	-1.4912	-3.9958
1.1455	2.5410	3.2411	5.2849	.6173	.6541	-1.4697	-4.0005
1.1880	2.6257	3.3618	5.4594	.6100	.6808	-1.4482	-4.0052
1.2305	2.7104	3.4825	5.6339	.6024	.7075	-1.4267	-4.0099
1.2730	2.7951	3.6032	5.8084	.5949	.7342	-1.4052	-4.0146
1.3155	2.8798	3.7239	5.9829	.5873	.7609	-1.3837	-4.0193
1.3580	2.9645	3.8446	6.1574	.5800	.7876	-1.3622	-4.0240
1.4005	3.0492	3.9653	6.3319	.5724	.8143	-1.3407	-4.0287
1.4430	3.1339	4.0860	6.5064	.5649	.8410	-1.3192	-4.0334
1.4855	3.2186	4.2067	6.6809	.5573	.8677	-1.2977	-4.0381
1.5280	3.3033	4.3274	6.8554	.5500	.8944	-1.2762	-4.0428
1.5705	3.3880	4.4481	7.0299	.5424	.9211	-1.2547	-4.0475
1.6130	3.4727	4.5688	7.2044	.5349	.9478	-1.2332	-4.0522
1.6555	3.5574	4.6895	7.3789	.5273	.9745	-1.2117	-4.0569
1.6980	3.6421	4.8102	7.5534	.5200	1.0012	-1.1902	-4.0616
1.7405	3.7268	4.9309	7.7279	.5124	1.0279	-1.1687	-4.0663
1.7830	3.8115	5.0516	7.9024	.5049	1.0546	-1.1472	-4.0710
1.8255	3.8962	5.1723	8.0769	.4973	1.0813	-1.1257	-4.0757
1.8680	3.9809	5.2930	8.2514	.4900	1.1080	-1.1042	-4.0804
1.9105	4.0656	5.4137	8.4259	.4824	1.1347	-1.0827	-4.0851
1.9530	4.1503	5.5344	8.6004	.4749	1.1614	-1.0612	-4.0898
1.9955	4.2350	5.6551	8.7749	.4673	1.1881	-1.0397	-4.0945
2.0380	4.3197	5.7758	8.9494	.4600	1.2148	-1.0182	-4.0992
2.0805	4.4044	5.8965	9.1239	.4524	1.2415	-0.9967	-4.1039
2.1230	4.4891	6.0172	9.2984	.4449	1.2682	-0.9752	-4.1086
2.1655	4.5738	6.1379	9.4729	.4373	1.2949	-0.9537	-4.1133
2.2080	4.6585	6.2586	9.6474	.4300	1.3216	-0.9322	-4.1180
2.2505	4.7432	6.3793	9.8219	.4224	1.3483	-0.9107	-4.1227
2.2930	4.8279	6.5000	9.9964	.4149	1.3750	-0.8892	-4.1274
2.3355	4.9126	6.6207	10.1709	.4073	1.4017	-0.8677	-4.1321
2.3780	4.9973	6.7414	10.3454	.4000	1.4284	-0.8462	-4.1368
2.4205	5.0820	6.8621	10.5199	.3924	1.4551	-0.8247	-4.1415
2.4630	5.1667	6.9828	10.6944	.3849	1.4818	-0.8032	-4.1462
2.5055	5.2514	7.1035	10.8689	.3773	1.5085	-0.7817	-4.1509
2.5480	5.3361	7.2242	11.0434	.3700	1.5352	-0.7602	-4.1556
2.5905	5.4208	7.3449	11.2179	.3624	1.5619	-0.7387	-4.1603
2.6330	5.5055	7.4656	11.3924	.3549	1.5886	-0.7172	-4.1650
2.6755	5.5902	7.5863	11.5669	.3473	1.6153	-0.6957	-4.1697
2.7180	5.6749	7.7070	11.7414	.3400	1.6420	-0.6742	-4.1744
2.7605	5.7596	7.8277	11.9159	.3324	1.6687	-0.6527	-4.1791
2.8030	5.8443	7.9484	12.0904	.3249	1.6954	-0.6312	-4.1838
2.8455	5.9290	8.0691	12.2649	.3173	1.7221	-0.6097	-4.1885
2.8880	6.0137	8.1898	12.4394	.3100	1.7488	-0.5882	-4.1932
2.9305	6.0984	8.3105	12.6139	.3024	1.7755	-0.5667	-4.1979
2.9730	6.1831	8.4312	12.7884	.2949	1.8022	-0.5452	-4.2026
3.0155	6.2678	8.5519	12.9629	.2873	1.8289	-0.5237	-4.2073
3.0580	6.3525	8.6726	13.1374	.2800	1.8556	-0.5022	-4.2120
3.1005	6.4372	8.7933	13.3119	.2724	1.8823	-0.4807	-4.2167
3.1430	6.5219	8.9140	13.4864	.2649	1.9090	-0.4592	-4.2214
3.1855	6.6066	9.0347	13.6609	.2573	1.9357	-0.4377	-4.2261
3.2280	6.6913	9.1554	13.8354	.2500	1.9624	-0.4162	-4.2308
3.2705	6.7760	9.2761	14.0099	.2424	1.9891	-0.3947	-4.2355
3.3130	6.8607	9.3968	14.1844	.2349	2.0158	-0.3732	-4.2402
3.3555	6.9454	9.5175	14.3589	.2273	2.0425	-0.3517	-4.2449
3.3980	7.0301	9.6382	14.5334	.2200	2.0692	-0.3302	-4.2496
3.4405	7.1148	9.7589	14.7079	.2124	2.0959	-0.3087	-4.2543
3.4830	7.1995	9.8796	14.8824	.2049	2.1226	-0.2872	-4.2590
3.5255	7.2842	9.9999	15.0569	.2000	2.1493	-0.2657	-4.2637
3.5680	7.3689	10.1206	15.2314	.1924	2.1760	-0.2442	-4.2684
3.6105	7.4536	10.2413	15.4059	.1849	2.2027	-0.2227	-4.2731
3.6530	7.5383	10.3620	15.5804	.1773	2.2294	-0.2012	-4.2778
3.6955	7.6230	10.4827	15.7549	.1700	2.2561	-0.1797	-4.2825
3.7380	7.7077	10.6034	15.9294	.1624	2.2828	-0.1582	-4.2872
3.7805	7.7924	10.7241	16.1039	.1549	2.3095	-0.1367	-4.2919
3.8230	7.8771	10.8448	16.2784	.1473	2.3362	-0.1152	-4.2966
3.8655	7.9618	10.9655	16.4529	.1400	2.3629	-0.0937	-4.3013
3.9080	8.0465	11.0862	16.6274	.1324	2.3896	-0.0722	-4.3060
3.9505	8.1312	11.2069	16.8019	.1249	2.4163	-0.0507	-4.3107
3.9930	8.2159	11.3276	16.9764	.1173	2.4430	-0.0292	-4.3154
4.0355	8.3006	11.4483	17.1509	.1100	2.4697	-0.0077	-4.3201
4.0780	8.3853	11.5690	17.3254	.1024	2.4964	.0138	-4.3248
4.1205	8.4700	11.6897	17.4999	.0949	2.5231	.0353	-4.3295
4.1630	8.5547	11.8104	17.6744	.0873	2.5498	.0568	-4.3342
4.2055	8.6394	11.9311	17.8489	.0800	2.5765	.0783	-4.3389
4.2480	8.7241	12.0518	18.0234	.0724	2.6032	.1000	-4.3436
4.2905	8.8088	12.1725	18.1979	.0649	2.6299	.1215	-4.3483
4.3330	8.8935	12.2932	18.3724	.0573	2.6566	.1430	-4.3530
4.3755	8.9782	12.4139	18.5469	.0500	2.6833	.1645	-4.3577
4.4180	9.0629	12.5346	18.7214	.0424	2.7100	.1860	-4.3624
4.4605	9.1476	12.6553	18.8959	.0349	2.7367	.2075	-4.3671
4.5030	9.2323	12.7760	19.0704	.0273	2.7634	.2290	-4.3718
4.5455	9.3170	12.8967	19.2449	.0200	2.7901	.2505	-4.3765
4.5880	9.4017	13.0174	19.4194	.0124	2.8168	.2720	-4.3812
4.6305	9.4864	13.1381	19.5939	.0049	2.8435	.2935	-4.3859
4.6730	9.5711	13.2588	19.7684	.0000	2.8702	.3150	-4.3906</

TABLE A-3.--Continued

SECTION NO. 5 NOTCH RADIUS 12.400 IN. (31.496 CM.)

SUCTION SURFACE		SECTION NO. 5 NOTCH RADIUS 12.400 IN. (31.496 CM.)		PRESSURE SURFACE	
X, IN.	Y, IN.	X, IN.	Y, IN.	X, IN.	Y, IN.
.9921	-1.4070	.9921	-1.4070	.9921	-1.4070
.9919	-1.4041	.9920	-1.4049	.9920	-1.4049
.9905	-1.4066	.9909	-1.4026	.9909	-1.4026
.9891	-1.4729	.9886	-1.4950	.9886	-1.4950
.9729	-1.4035	.9855	-1.4957	.9855	-1.4957
.9245	-1.3513	.9817	-1.4948	.9817	-1.4948
.8762	-1.2802	.9776	-1.4922	.9776	-1.4922
.8279	-1.1702	.9686	-1.4813	.9686	-1.4813
.7794	-1.0813	.9533	-1.4569	.9533	-1.4569
.7313	-.9916	.9408	-1.3795	.9408	-1.3795
.6830	-.9049	.9263	-1.3025	.9263	-1.3025
.6347	-.8212	.9077	-1.2260	.9077	-1.2260
.5864	-.7365	.8792	-1.1498	.8792	-1.1498
.5380	-.6527	.7107	-1.0741	.7107	-1.0741
.4897	-.5700	.6621	-.9989	.6621	-.9989
.4414	-.4881	.6136	-.9241	.6136	-.9241
.3931	-.4071	.5651	-.8498	.5651	-.8498
.3448	-.3269	.5165	-.7760	.5165	-.7760
.2965	-.2476	.4680	-.7027	.4680	-.7027
.2482	-.1691	.4195	-.6299	.4195	-.6299
.1999	-.0914	.3709	-.5576	.3709	-.5576
.1516	-.0140	.3224	-.4859	.3224	-.4859
.1032	.0619	.2739	-.4147	.2739	-.4147
.0549	.1375	.2254	-.3440	.2254	-.3440
.0066	.2124	.1768	-.2739	.1768	-.2739
.0000	.2867	.1283	-.2044	.1283	-.2044
.0900	.3603	.0798	-.1354	.0798	-.1354
.1363	.4335	.0312	-.0670	.0312	-.0670
.1866	.5061	.0173	.0008	.0173	.0008
.2369	.5778	.0050	.0681	.0050	.0681
.2833	.6467	.1144	.1347	.1144	.1347
.3316	.7067	.1629	.2008	.1629	.2008
.3799	.7658	.2114	.2662	.2114	.2662
.4282	.8245	.2599	.3310	.2599	.3310
.4765	.8830	.3085	.3952	.3085	.3952
.5248	.9412	.3570	.4588	.3570	.4588
.5731	.9991	.4055	.5217	.4055	.5217
.6214	1.0568	.4541	.5865	.4541	.5865
.6698	1.1143	.5026	.6510	.5026	.6510
.7181	1.1716	.5511	.7163	.5511	.7163
.7664	1.2286	.5997	.7819	.5997	.7819
.8147	1.2859	.6482	.8482	.6482	.8482
.8630	1.3430	.6967	.9142	.6967	.9142
.9112	1.4000	.7453	.9800	.7453	.9800
.9595	1.4568	.7938	1.0454	.7938	1.0454
1.0078	1.5134	.8423	1.1104	.8423	1.1104
1.0561	1.5699	.8908	1.1754	.8908	1.1754
1.1044	1.6263	.9393	1.2404	.9393	1.2404
1.1527	1.6826	.9878	1.3054	.9878	1.3054
1.2010	1.7388	1.0363	1.3704	1.0363	1.3704
1.2493	1.7949	1.0848	1.4354	1.0848	1.4354
1.2976	1.8509	1.1333	1.5004	1.1333	1.5004
1.3459	1.9068	1.1818	1.5654	1.1818	1.5654
1.3942	1.9626	1.2303	1.6304	1.2303	1.6304
1.4425	2.0184	1.2788	1.6954	1.2788	1.6954
1.4908	2.0741	1.3273	1.7604	1.3273	1.7604
1.5391	2.1299	1.3758	1.8254	1.3758	1.8254
1.5874	2.1856	1.4243	1.8904	1.4243	1.8904
1.6357	2.2413	1.4728	1.9554	1.4728	1.9554
1.6840	2.2970	1.5213	2.0204	1.5213	2.0204
1.7323	2.3527	1.5698	2.0854	1.5698	2.0854
1.7806	2.4084	1.6183	2.1504	1.6183	2.1504
1.8289	2.4641	1.6668	2.2154	1.6668	2.2154
1.8772	2.5198	1.7153	2.2804	1.7153	2.2804
1.9255	2.5755	1.7638	2.3454	1.7638	2.3454
1.9738	2.6312	1.8123	2.4104	1.8123	2.4104
2.0221	2.6869	1.8608	2.4754	1.8608	2.4754
2.0704	2.7426	1.9093	2.5404	1.9093	2.5404
2.1187	2.7983	1.9578	2.6054	1.9578	2.6054
2.1670	2.8540	2.0063	2.6704	2.0063	2.6704
2.2153	2.9097	2.0548	2.7354	2.0548	2.7354
2.2636	2.9654	2.1033	2.8004	2.1033	2.8004
2.3119	3.0211	2.1518	2.8654	2.1518	2.8654
2.3602	3.0768	2.2003	2.9304	2.2003	2.9304
2.4085	3.1325	2.2488	2.9954	2.2488	2.9954
2.4568	3.1882	2.2973	3.0604	2.2973	3.0604
2.5051	3.2439	2.3458	3.1254	2.3458	3.1254
2.5534	3.2996	2.3943	3.1904	2.3943	3.1904
2.6017	3.3553	2.4428	3.2554	2.4428	3.2554
2.6500	3.4110	2.4913	3.3204	2.4913	3.3204
2.6983	3.4667	2.5398	3.3854	2.5398	3.3854
2.7466	3.5224	2.5883	3.4504	2.5883	3.4504
2.7949	3.5781	2.6368	3.5154	2.6368	3.5154
2.8432	3.6338	2.6853	3.5804	2.6853	3.5804
2.8915	3.6895	2.7338	3.6454	2.7338	3.6454
2.9398	3.7452	2.7823	3.7104	2.7823	3.7104
2.9881	3.8009	2.8308	3.7754	2.8308	3.7754
3.0364	3.8566	2.8793	3.8404	2.8793	3.8404
3.0847	3.9123	2.9278	3.9054	2.9278	3.9054
3.1330	3.9680	2.9763	3.9704	2.9763	3.9704
3.1813	4.0237	3.0248	4.0354	3.0248	4.0354
3.2296	4.0794	3.0733	4.1004	3.0733	4.1004
3.2779	4.1351	3.1218	4.1654	3.1218	4.1654
3.3262	4.1908	3.1703	4.2304	3.1703	4.2304
3.3745	4.2465	3.2188	4.2954	3.2188	4.2954
3.4228	4.3022	3.2673	4.3604	3.2673	4.3604
3.4711	4.3579	3.3158	4.4254	3.3158	4.4254
3.5194	4.4136	3.3643	4.4904	3.3643	4.4904
3.5677	4.4693	3.4128	4.5554	3.4128	4.5554
3.6160	4.5250	3.4613	4.6204	3.4613	4.6204
3.6643	4.5807	3.5098	4.6854	3.5098	4.6854
3.7126	4.6364	3.5583	4.7504	3.5583	4.7504
3.7609	4.6921	3.6068	4.8154	3.6068	4.8154
3.8092	4.7478	3.6553	4.8804	3.6553	4.8804
3.8575	4.8035	3.7038	4.9454	3.7038	4.9454
3.9058	4.8592	3.7523	5.0104	3.7523	5.0104
3.9541	4.9149	3.8008	5.0754	3.8008	5.0754
4.0024	4.9706	3.8493	5.1404	3.8493	5.1404
4.0507	5.0263	3.8978	5.2054	3.8978	5.2054
4.0990	5.0820	3.9463	5.2704	3.9463	5.2704
4.1473	5.1377	3.9948	5.3354	3.9948	5.3354
4.1956	5.1934	4.0433	5.4004	4.0433	5.4004
4.2439	5.2491	4.0918	5.4654	4.0918	5.4654
4.2922	5.3048	4.1403	5.5304	4.1403	5.5304
4.3405	5.3605	4.1888	5.5954	4.1888	5.5954
4.3888	5.4162	4.2373	5.6604	4.2373	5.6604
4.4371	5.4719	4.2858	5.7254	4.2858	5.7254
4.4854	5.5276	4.3343	5.7904	4.3343	5.7904
4.5337	5.5833	4.3828	5.8554	4.3828	5.8554
4.5820	5.6390	4.4313	5.9204	4.4313	5.9204
4.6303	5.6947	4.4798	5.9854	4.4798	5.9854
4.6786	5.7504	4.5283	6.0504	4.5283	6.0504
4.7269	5.8061	4.5768	6.1154	4.5768	6.1154
4.7752	5.8618	4.6253	6.1804	4.6253	6.1804
4.8235	5.9175	4.6738	6.2454	4.6738	6.2454
4.8718	5.9732	4.7223	6.3104	4.7223	6.3104
4.9201	6.0289	4.7708	6.3754	4.7708	6.3754
4.9684	6.0846	4.8193	6.4404	4.8193	6.4404
5.0167	6.1403	4.8678	6.5054	4.8678	6.5054
5.0650	6.1960	4.9163	6.5704	4.9163	6.5704
5.1133	6.2517	4.9648	6.6354	4.9648	6.6354
5.1616	6.3074	5.0133	6.7004	5.0133	6.7004
5.2099	6.3631	5.0618	6.7654	5.0618	6.7654
5.2582	6.4188	5.1103	6.8304	5.1103	6.8304
5.3065	6.4745	5.1588	6.8954	5.1588	6.8954
5.3548	6.5302	5.2073	6.9604	5.2073	6.9604
5.4031	6.5859	5.2558	7.0254	5.2558	7.0254
5.4514	6.6416	5.3043	7.0904	5.3043	7.0904
5.4997	6.6973	5.3528	7.1554	5.3528	7.1554
5.5480	6.7530	5.4013	7.2204	5.4013	7.2204
5.5963	6.8087	5.4498	7.2854	5.4498	7.2854
5.6446	6.8644	5.4983	7.3504	5.4983	7.3504
5.6929	6.9201	5.5468	7.4154	5.5468	7.4154
5.7412	6.9758	5.5953	7.4804	5.5953	7.4804
5.7895	7.0315	5.6438	7.5454	5.6438	7.5454
5.8378	7.0872	5.6923	7.6104	5.6923	7.6104
5.8861	7.1429	5.7408	7.6754	5.7408	7.6754
5.9344	7.1986	5.7893	7.7404	5.7893	7.7404
5.9827	7.2543	5.8378	7.8054	5.8378	7.8054
6.0310	7.3100	5.8863	7.8704	5.8863	7.8704
6.0793	7.3657	5.9348	7.9354	5.9348	7.9354
6.1276	7.4214	5.9833	8.0004	5.9833	8.0004
6.1759	7.4771	6.0318	8.0654	6.0318	8.0654
6.2242	7.5328	6.0803	8.1304	6.0803	8.1304
6.2725	7.5885	6.1288	8.1954	6.1288	8.1954
6.3208	7.6442	6.1773	8.2604	6.1773	8.2604
6.3691	7.7000	6.2258	8.3254	6.2258	8.3254
6.4174	7.7557	6.2743	8.3904	6.2743	8.3904
6.4657	7.8114	6.3228	8.4554	6.3228	8.4554
6.5140	7.8671	6.3713	8.5204	6.3713	8.5204
6.5623	7.9228	6.4198	8.5854	6.4198	8.5854
6.6106	7.9785	6.4683	8.6504	6.4683	8.6504
6.6589	8.0342	6.5168	8.7154	6.5168	8.7154
6.7072	8.0900	6.5653	8.7804	6.5653	8.7804
6.7555	8.1457	6.6138	8.8454	6.6138	8.8454
6.8038	8.2014	6.6623	8.9104	6.6623	8.9104
6.8521	8.2571	6.7108	8.9754	6.7108	8.9754
6.9004	8.3128	6.7593	9.0404	6.7593	9.0404
6.9487	8.3685	6.8078	9.1054	6.8078	9.1054
7.0000	8.4242	6.8563	9.1704	6.8563	9.1704
7.0500	8.4800	6.9048	9.2354	6.9048	9.2354
7.1000	8.5357	6.9533	9.3004	6.9533	9.3004
7.1500	8.5914	7.0018	9.3654	7.0018	9.3654
7.2000	8.6471	7.0503	9.4304	7.0503	9.4304
7.2500	8.7028	7.0988	9.4954	7.0988	9.4954
7.3000	8.7585	7.1473	9.5604	7.1473	9.5604
7.3500	8.8142	7.1958	9.6254	7.19	

TABLE A-3.--Continued

SECTION NO. 6 ROTOR AIRFOIL COORDINATES
RADIUS 12.000 IN. (30.480 CM.)

SUCTION SURFACE		PRESSURE SURFACE			
X, IN.	Y, IN.	X, CM.	Y, CM.	X, IN.	Y, IN.
-1.0030	-1.4452	-2.5476	-3.6707	-1.0030	-1.4452
-1.0027	-1.4416	-2.5469	-3.6617	-1.0029	-1.4470
-1.0012	-1.4335	-2.5430	-3.6662	-1.0017	-1.4512
-9984	-1.4293	-2.5360	-3.6304	-9993	-1.4530
-9836	-1.4021	-2.4988	-3.5612	-9958	-1.4547
-9351	-1.3321	-2.3753	-3.3329	-9916	-1.4537
-8865	-1.2231	-2.2517	-3.1066	-9870	-1.4509
-8379	-1.1369	-2.1282	-2.8826	-9768	-1.4369
-7892	-1.0475	-2.0046	-2.6607	-9621	-1.4162
-7406	-9509	-1.8811	-2.4408	-9431	-1.3408
-6919	-8753	-1.7575	-2.2233	-8641	-1.2656
-6433	-7966	-1.6340	-2.0082	-8150	-1.1912
-5946	-7099	-1.5104	-1.7957	-7660	-1.1171
-5460	-6242	-1.3869	-1.5855	-7170	-1.0435
-4974	-5423	-1.2633	-1.3779	-6679	-0.9704
-4487	-4616	-1.1398	-1.1726	-6189	-0.8978
-4001	-3810	-1.0162	-0.9697	-5699	-0.8257
-3514	-3020	-0.8927	-0.7693	-5209	-0.7541
-3028	-2230	-0.7691	-0.5714	-4718	-0.6831
-2542	-1480	-0.6456	-0.3758	-4228	-0.6125
-2055	-0.718	-0.5220	-0.1824	-3738	-0.5424
-1569	0.035	-0.3985	0.009	-3247	-0.4732
-1082	0.780	-0.2749	0.181	-2757	-0.4044
-0596	1.517	-0.1514	0.3852	-2267	-0.3361
0109	2.245	-0.0278	0.5703	-1776	-0.2684
0623	2.964	0.0957	0.7533	-1286	-0.2013
1136	3.679	0.2193	0.9345	-0.796	-0.1348
1650	4.394	0.3428	1.1135	0.0306	-0.0689
2164	5.108	0.4664	1.2822	0.0185	0.0036
2678	5.823	0.5899	1.4371	0.0675	0.0610
3192	6.538	0.7135	1.5823	0.1165	0.1250
3706	7.252	0.8370	1.7253	0.1656	0.1893
4220	7.967	0.9606	1.8669	0.2146	0.2510
4734	8.681	1.0841	2.0073	0.2636	0.3129
5248	9.396	1.2077	2.1463	0.3127	0.3741
5762	10.110	1.3312	2.2841	0.3617	0.4366
6276	10.825	1.4548	2.4207	0.4107	0.4982
6790	11.539	1.5783	2.5562	0.4598	0.5593
7304	12.254	1.7019	2.6905	0.5088	0.6179
7818	12.968	1.8254	2.8237	0.5578	0.6725
8332	13.683	1.9490	2.9558	0.6069	0.7246
8846	14.397	2.0725	3.0870	0.6559	0.7766
9360	15.111	2.1960	3.2183	0.7049	0.8286
9874	15.826	2.3196	3.3496	0.7539	0.8806
10388	16.540	2.4431	3.4809	0.8030	0.9326
10902	17.254	2.5666	3.6122	0.8520	0.9846
11416	17.968	2.6901	3.7435	0.9010	1.0366
11930	18.682	2.8136	3.8748	0.9500	1.0886
12444	19.396	2.9371	4.0061	1.0000	1.1406
12958	20.110	3.0606	4.1374	1.0500	1.1926
13472	20.824	3.1841	4.2687	1.1000	1.2446
13986	21.538	3.3076	4.4000	1.1500	1.2966
14500	22.252	3.4311	4.5313	1.2000	1.3486
15014	22.966	3.5546	4.6626	1.2500	1.4006
15528	23.680	3.6781	4.7939	1.3000	1.4526
16042	24.394	3.8016	4.9252	1.3500	1.5046
16556	25.108	3.9251	5.0565	1.4000	1.5566
17070	25.822	4.0486	5.1878	1.4500	1.6086
17584	26.536	4.1721	5.3191	1.5000	1.6606
18098	27.250	4.2956	5.4504	1.5500	1.7126
18612	27.964	4.4191	5.5817	1.6000	1.7646
19126	28.678	4.5426	5.7130	1.6500	1.8166
19640	29.392	4.6661	5.8443	1.7000	1.8686
20154	30.106	4.7896	5.9756	1.7500	1.9206
20668	30.820	4.9131	6.1069	1.8000	1.9726
21182	31.534	5.0366	6.2382	1.8500	2.0246
21696	32.248	5.1601	6.3695	1.9000	2.0766
22210	32.962	5.2836	6.5008	1.9500	2.1286
22724	33.676	5.4071	6.6321	2.0000	2.1806
23238	34.390	5.5306	6.7634	2.0500	2.2326
23752	35.104	5.6541	6.8947	2.1000	2.2846
24266	35.818	5.7776	7.0260	2.1500	2.3366
24780	36.532	5.9011	7.1573	2.2000	2.3886
25294	37.246	6.0246	7.2886	2.2500	2.4406
25808	37.960	6.1481	7.4199	2.3000	2.4926
26322	38.674	6.2716	7.5512	2.3500	2.5446
26836	39.388	6.3951	7.6825	2.4000	2.5966
27350	40.102	6.5186	7.8138	2.4500	2.6486
27864	40.816	6.6421	7.9451	2.5000	2.7006
28378	41.530	6.7656	8.0764	2.5500	2.7526
28892	42.244	6.8891	8.2077	2.6000	2.8046
29406	42.958	7.0126	8.3390	2.6500	2.8566
29920	43.672	7.1361	8.4703	2.7000	2.9086
30434	44.386	7.2596	8.6016	2.7500	2.9606
30948	45.100	7.3831	8.7329	2.8000	3.0126
31462	45.814	7.5066	8.8642	2.8500	3.0646
31976	46.528	7.6301	8.9955	2.9000	3.1166
32490	47.242	7.7536	9.1268	2.9500	3.1686
33004	47.956	7.8771	9.2581	3.0000	3.2206
33518	48.670	8.0006	9.3894	3.0500	3.2726
34032	49.384	8.1241	9.5207	3.1000	3.3246
34546	50.098	8.2476	9.6520	3.1500	3.3766
35060	50.812	8.3711	9.7833	3.2000	3.4286
35574	51.526	8.4946	9.9146	3.2500	3.4806
36088	52.240	8.6181	10.0459	3.3000	3.5326
36602	52.954	8.7416	10.1772	3.3500	3.5846
37116	53.668	8.8651	10.3085	3.4000	3.6366
37630	54.382	8.9886	10.4398	3.4500	3.6886
38144	55.096	9.1121	10.5711	3.5000	3.7406
38658	55.810	9.2356	10.7024	3.5500	3.7926
39172	56.524	9.3591	10.8337	3.6000	3.8446
39686	57.238	9.4826	10.9650	3.6500	3.8966
40200	57.952	9.6061	11.0963	3.7000	3.9486
40714	58.666	9.7296	11.2276	3.7500	4.0006
41228	59.380	9.8531	11.3589	3.8000	4.0526
41742	60.094	9.9766	11.4902	3.8500	4.1046
42256	60.808	10.1001	11.6215	3.9000	4.1566
42770	61.522	10.2236	11.7528	3.9500	4.2086
43284	62.236	10.3471	11.8841	4.0000	4.2606
43798	62.950	10.4706	12.0154	4.0500	4.3126
44312	63.664	10.5941	12.1467	4.1000	4.3646
44826	64.378	10.7176	12.2780	4.1500	4.4166
45340	65.092	10.8411	12.4093	4.2000	4.4686
45854	65.806	10.9646	12.5406	4.2500	4.5206
46368	66.520	11.0881	12.6719	4.3000	4.5726
46882	67.234	11.2116	12.8032	4.3500	4.6246
47396	67.948	11.3351	12.9345	4.4000	4.6766
47910	68.662	11.4586	13.0658	4.4500	4.7286
48424	69.376	11.5821	13.1971	4.5000	4.7806
48938	70.090	11.7056	13.3284	4.5500	4.8326
49452	70.804	11.8291	13.4597	4.6000	4.8846
49966	71.518	11.9526	13.5910	4.6500	4.9366
50480	72.232	12.0761	13.7223	4.7000	4.9886
50994	72.946	12.2001	13.8536	4.7500	5.0406
51508	73.660	12.3236	13.9849	4.8000	5.0926
52022	74.374	12.4471	14.1162	4.8500	5.1446
52536	75.088	12.5706	14.2475	4.9000	5.1966
53050	75.802	12.6941	14.3788	4.9500	5.2486
53564	76.516	12.8176	14.5101	5.0000	5.3006
54078	77.230	12.9411	14.6414	5.0500	5.3526
54592	77.944	13.0646	14.7727	5.1000	5.4046
55106	78.658	13.1881	14.9040	5.1500	5.4566
55620	79.372	13.3116	15.0353	5.2000	5.5086
56134	80.086	13.4351	15.1666	5.2500	5.5606
56648	80.800	13.5586	15.2979	5.3000	5.6126
57162	81.514	13.6821	15.4292	5.3500	5.6646
57676	82.228	13.8056	15.5605	5.4000	5.7166
58190	82.942	13.9291	15.6918	5.4500	5.7686
58704	83.656	14.0526	15.8231	5.5000	5.8206
59218	84.370	14.1761	15.9544	5.5500	5.8726
59732	85.084	14.3001	16.0857	5.6000	5.9246
60246	85.798	14.4236	16.2170	5.6500	5.9766
60760	86.512	14.5471	16.3483	5.7000	6.0286
61274	87.226	14.6706	16.4796	5.7500	6.0806
61788	87.940	14.7941	16.6109	5.8000	6.1326
62302	88.654	14.9176	16.7422	5.8500	6.1846
62816	89.368	15.0411	16.8735	5.9000	6.2366
63330	90.082	15.1646	17.0048	5.9500	6.2886
63844	90.796	15.2881	17.1361	6.0000	6.3406
64358	91.510	15.4116	17.2674	6.0500	6.3926
64872	92.224	15.5351	17.3987	6.1000	6.4446
65386	92.938	15.6586	17.5300	6.1500	6.4966
65900	93.652	15.7821	17.6613	6.2000	6.5486
66414	94.366	15.9056	17.7926	6.2500	6.6006
66928	95.080	16.0291	17.9239	6.3000	6.6526
67442	95.794	16.1526	18.0552	6.3500	6.7046
67956	96.508	16.2761	18.1865	6.4000	6.7566
68470	97.222	16.4001	18.3178	6.4500	6.8086
68984	97.936	16.5236	18.4491	6.5000	6.8606
69498	98.650	16.6471	18.5804	6.5500	6.9126
70012	99.364	16.7706	18.7117	6.6000	6.9646
70526	100.078	16.8941	18.8430	6.6500	7.0166
71040	100.792	17.0176	18.9743	6.7000	7.0686
71554	101.506	17.1411	19.1056	6.7500	7.1206
72068	102.220	17.2646	19.2369	6.8000	7.1726
72582	102.934	17.3881	19.3682	6.8500	7.2246
73096	103.648	17.5116	19.4995	6.9000	7.2766
73610	104.362	17.6351	19.6308	6.9500	7.3286
74124	105.076	17.7586	19.7621	7.0000	7.3806
74638	105.790	17.8821	19.8934	7.0500	7.4326
75152	106.504	18.0056	20.0247	7.1000	7.4846
75666	107.218	18.1291	20.1560	7.1500	7.5366
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TABLE A-3.--Continued

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

SUCTION SURFACE		PRESSURE SURFACE			
X IN.	Y IN.	X IN.	Y IN.	X IN.	Y IN.
-1.0005	-1.4010	-2.5413	-3.5285	-1.0005	-1.4010
-1.0002	-1.3977	-2.5406	-3.5201	-1.0004	-1.4024
-9988	-1.3924	-2.5369	-3.5166	-9995	-1.4061
-9963	-1.3869	-2.5308	-3.5128	-9973	-1.4084
-9822	-1.3815	-2.4949	-3.4581	-9943	-1.4092
-9836	-1.3740	-2.3712	-3.2360	-9906	-1.4084
-9849	-1.3673	-2.2476	-3.0157	-9865	-1.4060
-9362	-1.3613	-2.1280	-2.7974	-9773	-1.3955
-7876	-1.3560	-2.0004	-2.5807	-9633	-1.3743
-7389	-1.3515	-1.8768	-2.3659	-9143	-1.3011
-6902	-1.3477	-1.7532	-2.1533	-8654	-1.2284
-6416	-1.3450	-1.6296	-1.9431	-8164	-1.1582
-5929	-1.3432	-1.5060	-1.7354	-7675	-1.0846
-5442	-1.3423	-1.3824	-1.5299	-7186	-1.0134
-4956	-1.3423	-1.2587	-1.3268	-6696	-9429
-4469	-1.3433	-1.1351	-1.1261	-6207	-8728
-3982	-1.3453	-1.0115	-9278	-5717	-8032
-3496	-1.3482	-8879	-7321	-5228	-7342
-3009	-1.3521	-7643	-5387	-4739	-6656
-2522	-1.3569	-6407	-3476	-4249	-5976
-2036	-1.3625	-5171	-1588	-3760	-5300
-1549	-1.3688	-3935	-978	-3270	-4629
-1062	-1.3758	-2699	2123	-2781	-3963
-576	-1.3834	-1463	3946	-2291	-3302
100	-1.3915	-227	5749	-1802	-2645
588	-1.3999	1010	7531	-1313	-1993
1071	-1.4084	2246	9290	-823	-1345
1558	-1.4171	3482	10941	-334	-702
2044	-1.4259	4718	12457	156	-1064
2529	-1.4347	5954	13878	645	1639
3014	-1.4435	7190	15278	1134	2482
3499	-1.4522	8426	16663	1624	3425
3984	-1.4609	9662	18033	2113	4368
4469	-1.4696	10898	19399	2603	5311
4954	-1.4782	12135	20731	3092	6254
5439	-1.4868	13371	22060	3582	7197
5924	-1.4954	14607	23375	4071	8140
6409	-1.5039	15843	24677	4560	9083
6894	-1.5123	17079	25966	5050	10026
7379	-1.5206	18315	27242	5539	10969
7864	-1.5288	19551	28505	6029	11912
8349	-1.5369	20787	29756	6518	12855
8834	-1.5449	21992	30991	7007	13798
9319	-1.5528	23170	32208	7497	14741
9804	-1.5606	24322	33407	7986	15684
10289	-1.5683	25456	34581	8476	16627
10774	-1.5759	26574	35731	8965	17570
11259	-1.5834	27678	36856	9454	18513
11744	-1.5908	28769	37966	9943	19456
12229	-1.5981	29847	39061	10432	20400
12714	-1.6053	30912	40141	10921	21343
13199	-1.6125	31965	41206	11410	22286
13684	-1.6196	33007	42256	11900	23229
14169	-1.6266	34039	43291	12390	24172
14654	-1.6335	35062	44311	12880	25115
15139	-1.6403	36076	45326	13370	26058
15624	-1.6471	37081	46336	13860	27001
16109	-1.6538	38078	47341	14350	27944
16594	-1.6604	39067	48341	14840	28887
17079	-1.6669	40049	49336	15330	29830
17564	-1.6733	41024	50326	15820	30773
18049	-1.6796	41992	51311	16310	31716
18534	-1.6858	42953	52291	16800	32659
19019	-1.6919	43907	53266	17290	33602
19504	-1.6979	44854	54236	17780	34545
19989	-1.7038	45794	55201	18270	35488
20474	-1.7096	46728	56161	18760	36431
20959	-1.7153	47657	57116	19250	37374
21444	-1.7209	48581	58066	19740	38317
21929	-1.7264	49501	59011	20230	39260
22414	-1.7318	50417	59951	20720	40203
22899	-1.7371	51329	60886	21210	41146
23384	-1.7423	52237	61816	21700	42089
23869	-1.7474	53142	62741	22190	43032
24354	-1.7524	54044	63661	22680	43975
24839	-1.7573	54943	64576	23170	44918
25324	-1.7621	55839	65486	23660	45861
25809	-1.7668	56732	66391	24150	46804
26294	-1.7714	57623	67291	24640	47747
26779	-1.7759	58511	68186	25130	48690
27264	-1.7803	59397	69076	25620	49633
27749	-1.7846	60281	69961	26110	50576
28234	-1.7888	61162	70841	26600	51519
28719	-1.7929	62040	71716	27090	52462
29204	-1.7969	62916	72586	27580	53405
29689	-1.8008	63791	73451	28070	54348
30174	-1.8046	64664	74311	28560	55291
30659	-1.8083	65535	75166	29050	56234
31144	-1.8119	66404	76016	29540	57177
31629	-1.8154	67271	76861	30030	58120
32114	-1.8188	68136	77701	30520	59063
32599	-1.8221	69000	78536	31010	60006
33084	-1.8253	69863	79366	31500	60949
33569	-1.8284	70724	80191	31990	61892
34054	-1.8314	71583	81011	32480	62835
34539	-1.8343	72440	81826	32970	63778
35024	-1.8371	73295	82636	33460	64721
35509	-1.8398	74149	83441	33950	65664
35994	-1.8424	75002	84241	34440	66607
36479	-1.8449	75854	85036	34930	67550
36964	-1.8473	76705	85826	35420	68493
37449	-1.8496	77555	86611	35910	69436
37934	-1.8518	78404	87391	36400	70379
38419	-1.8539	79252	88166	36890	71322
38904	-1.8559	80099	88936	37380	72265
39389	-1.8578	80945	89701	37870	73208
39874	-1.8596	81790	90461	38360	74151
40359	-1.8613	82634	91216	38850	75094
40844	-1.8629	83477	91966	39340	76037
41329	-1.8644	84319	92711	39830	76980
41814	-1.8658	85160	93451	40320	77923
42299	-1.8671	85999	94186	40810	78866
42784	-1.8683	86837	94916	41300	79809
43269	-1.8694	87674	95641	41790	80752
43754	-1.8704	88510	96361	42280	81695
44239	-1.8713	89345	97076	42770	82638
44724	-1.8721	90179	97786	43260	83581
45209	-1.8728	91012	98491	43750	84524
45694	-1.8734	91844	99191	44240	85467
46179	-1.8739	92675	99886	44730	86410
46664	-1.8743	93505	100576	45220	87353
47149	-1.8746	94334	101261	45710	88296
47634	-1.8748	95162	101941	46200	89239
48119	-1.8749	95989	102616	46690	90182
48604	-1.8749	96816	103286	47180	91125
49089	-1.8747	97642	103951	47670	92068
49574	-1.8744	98467	104611	48160	93011
50059	-1.8739	99292	105266	48650	93954
50544	-1.8732	100116	105916	49140	94897
51029	-1.8724	100939	106561	49630	95840
51514	-1.8714	101761	107201	50120	96783
51999	-1.8703	102583	107836	50610	97726
52484	-1.8690	103404	108466	51100	98669
52969	-1.8676	104225	109091	51590	99612
53454	-1.8661	105046	109711	52080	100555
53939	-1.8645	105867	110326	52570	101498
54424	-1.8628	106688	110936	53060	102441
54909	-1.8610	107509	111541	53550	103384
55394	-1.8591	108330	112141	54040	104327
55879	-1.8571	109151	112736	54530	105270
56364	-1.8550	109972	113326	55020	106213
56849	-1.8528	110793	113911	55510	107156
57334	-1.8505	111614	114491	56000	108099
57819	-1.8481	112435	115066	56490	109042
58304	-1.8456	113256	115636	56980	110000
58789	-1.8430	114077	116201	57470	110957
59274	-1.8403	114898	116761	57960	111914
59759	-1.8375	115719	117316	58450	112871
60244	-1.8346	116540	117866	58940	113828
60729	-1.8316	117361	118411	59430	114785
61214	-1.8285	118182	118951	59920	115742
61699	-1.8253	119003	119486	60410	116699
62184	-1.8220	119824	120016	60900	117656
62669	-1.8186	120645	120541	61390	118613
63154	-1.8151	121466	121061	61880	119570
63639	-1.8115	122287	121576	62370	120527
64124	-1.8078	123108	122086	62860	121484
64609	-1.8040	123929	122591	63350	122441
65094	-1.8001	124750	123091	63840	123398
65579	-1.7961	125571	123586	64330	124355
66064	-1.7920	126392	124076	64820	125312
66549	-1.7878	127213	124561	65310	126269
67034	-1.7835	128034	125041	65800	127226
67519	-1.7791	128855	125516	66290	128183
68004	-1.7746	129676	125986	66780	129140
68489	-1.7700	130497	126451	67270	130097
68974	-1.7653	131318	126911	67760	131054
69459	-1.7606	132139	127366	68250	132011
69944	-1.7558	132960	127816	68740	132968
70429	-1.7509	133781	128261	69230	133925
70914	-1.7459	134602	128701	69720	134882
71399	-1.7408	135423	129136	70210	135839
71884	-1.7356	136244	129566	70700	136796
72369	-1.7303	137065	129991	71190	137753
72854	-1.7249	137886	130411	71680	138710
73339	-1.7194	138707	130826	72170	139667
73824	-1.7138	139528	131236	72660	140624
74309	-1.7081	140349	131641	73150	141581
74794	-1.7023	141170	132041	73640	142538
75279	-1.6964	142000	132436	74130	143495
75764	-1.6904	142829	132826	74620	144452
76249	-1.6843	143659	133211	75110	145409
76734	-1.6781	144488	133591	75	

TABLE A-3.--Continued

MOTON AIRFOIL COORDINATES
SECTION NO. 8 RADIUS 11.000 IN. (27.940 CM.)

SUCTION SURFACE		PRESSURE SURFACE		Y.C.P.	
X.IN.	Y.IN.	X.IN.	Y.IN.	X.C.P.	Y.C.P.
-.9866	-1.3093	-.6568	-1.3193	-2.5064	-3.3256
-.9864	-1.3062	-.6567	-1.3102	-2.5056	-3.3279
-.9852	-1.3016	-.6560	-1.3133	-2.5043	-3.3350
-.9830	-1.2972	-.6542	-1.3153	-2.4999	-3.3409
-.9785	-1.2957	-.6517	-1.3160	-2.4954	-3.3428
-.9723	-1.1930	-.6485	-1.3154	-2.4854	-3.3412
-.8740	-1.1109	-.6450	-1.3135	-2.4766	-3.3363
-.8258	-1.0293	-.6413	-1.3107	-2.4563	-3.3139
-.7775	-.9483	-.6374	-1.2869	-2.4246	-3.2886
-.7293	-.8679	-.6334	-1.2103	-2.3022	-3.0945
-.6810	-.7884	-.6292	-1.1503	-2.1798	-2.9218
-.6328	-.7096	-.6250	-1.0829	-2.0573	-2.7505
-.5846	-.6315	-.6208	-1.0140	-1.9348	-2.5807
-.5363	-.5543	-.6166	-.9497	-1.8124	-2.4123
-.4881	-.4781	-.6125	-.8859	-1.6900	-2.2451
-.4395	-.4030	-.6083	-.8233	-1.5675	-2.0792
-.3916	-.3288	-.6041	-.7617	-1.4451	-1.9145
-.3436	-.2537	-.6000	-.7007	-1.3228	-1.7510
-.2951	-.1795	-.5958	-.6404	-1.2002	-1.5888
-.2469	-.1022	-.5917	-.5819	-1.0777	-1.4272
-.1984	-.0218	-.5876	-.5248	-.9553	-1.2669
-.1504	-.0277	-.5835	-.4681	-.8328	-1.1075
-.1022	-.0964	-.5795	-.4116	-.7104	-.9490
-.0539	-.1682	-.5755	-.3551	-.5880	-.7914
-.0057	-.2395	-.5714	-.2986	-.4655	-.6345
-.0426	-.2895	-.5673	-.2421	-.3431	-.4785
-.0906	-.3448	-.5632	-.1856	-.2206	-.3230
-.1390	-.3943	-.5592	-.1291	-.0982	-.1683
-.1873	-.4511	-.5552	-.0726	-.0243	-.0141
-.2355	-.5032	-.5511	-.0471	.0969	.1395
-.2836	-.5582	-.5470	.1278	.2092	.3027
-.3320	-.6050	-.5429	.1892	.3516	.4454
-.3803	-.6502	-.5389	.2506	.5180	.5977
-.4285	-.6960	-.5348	.3121	.6365	.7497
-.4767	-.7400	-.5307	.3736	.7590	.9013
-.5250	-.7840	-.5266	.4351	.8814	1.0526
-.5732	-.8282	-.5225	.4966	1.0038	1.2039
-.6215	-.8999	-.5184	.5581	1.1263	1.3560
-.6697	-.9470	-.5143	.6196	1.2487	1.5144
-.7179	-.9937	-.5102	.6811	1.3712	1.6607
-.7662	1.0396	-.5061	.7426	1.4936	1.8013
-.8144	1.0854	-.5020	.8041	1.6161	2.0223
-.8621	1.0826	-.5000	.8656	1.7385	2.1940
-.9103	1.0963	-.5000	.9271	1.8610	2.3662
-.9585	1.0987	-.5000	.9886	1.9834	2.5391
-.9830	1.0992	-.5000	1.0501	2.1058	2.7127
-.9843	1.0972	-.5000	1.0646	2.1453	2.7403
-.9823	1.0938	-.5000	1.0895	2.1340	2.7546
-.9824	1.0930	-.5000	1.0930	2.1196	2.7674
-.9824	1.0930	-.5000	1.0930	2.1196	2.7761

TABLE A-3.--Continued

MIDCH AIRFOIL COORDINATES
SECTION NO. 9 RADIUS 10.300 IN. (26.162 CM.)

SUCTION SURFACE		Y CM.		X IN.		PRESSURE SURFACE		Y IN.		X CM.	
X IN.	Y IN.	X CM.	Y CM.	X IN.	Y IN.	X CM.	Y CM.	X IN.	Y IN.	X CM.	Y CM.
-0.752	-1.2190	-2.4770	-3.0962	-0.752	-1.2190	-2.4770	-3.0962	-0.752	-1.2190	-2.4770	-3.0962
-0.740	-1.2155	-2.4760	-3.0873	-0.752	-1.2190	-2.4770	-3.0962	-0.752	-1.2190	-2.4770	-3.0962
-0.754	-1.2108	-2.4724	-3.0754	-0.744	-1.2155	-2.4760	-3.0873	-0.752	-1.2190	-2.4770	-3.0962
-0.710	-1.2080	-2.4662	-3.0632	-0.726	-1.2108	-2.4724	-3.0754	-0.752	-1.2190	-2.4770	-3.0962
-0.601	-1.1881	-2.4368	-3.0177	-0.699	-1.1881	-2.4368	-3.0177	-0.726	-1.2108	-2.4724	-3.0754
-0.636	-1.1085	-2.3164	-2.8154	-0.666	-1.1085	-2.3164	-2.8154	-0.699	-1.1881	-2.4368	-3.0177
-0.636	-1.0296	-2.1940	-2.6152	-0.628	-1.0296	-2.1940	-2.6152	-0.666	-1.1085	-2.3164	-2.8154
-0.6156	-0.9512	-2.0715	-2.4111	-0.561	-0.9512	-2.0715	-2.4111	-0.628	-1.0296	-2.1940	-2.6152
-0.7474	-0.8734	-1.9491	-2.2185	-0.533	-0.8734	-1.9491	-2.2185	-0.561	-0.9512	-2.0715	-2.4111
-0.719	-0.7963	-1.8267	-2.0227	-0.4952	-0.7963	-1.8267	-2.0227	-0.533	-0.8734	-1.9491	-2.2185
-0.6710	-0.7199	-1.7053	-1.8285	-0.471	-0.7199	-1.7053	-1.8285	-0.4952	-0.7963	-1.8267	-2.0227
-0.6228	-0.6440	-1.5819	-1.6337	-0.440	-0.6440	-1.5819	-1.6337	-0.471	-0.7199	-1.7053	-1.8285
-0.5766	-0.5689	-1.4595	-1.4450	-0.409	-0.5689	-1.4595	-1.4450	-0.440	-0.6440	-1.5819	-1.6337
-0.5264	-0.4951	-1.3371	-1.2576	-0.378	-0.4951	-1.3371	-1.2576	-0.409	-0.5689	-1.4595	-1.4450
-0.4782	-0.4225	-1.2147	-1.0713	-0.347	-0.4225	-1.2147	-1.0713	-0.378	-0.4951	-1.3371	-1.2576
-0.4301	-0.3511	-1.0923	-0.8919	-0.316	-0.3511	-1.0923	-0.8919	-0.347	-0.4225	-1.2147	-1.0713
-0.3819	-0.2809	-0.9699	-0.7134	-0.285	-0.2809	-0.9699	-0.7134	-0.316	-0.3511	-1.0923	-0.8919
-0.3337	-0.2117	-0.8475	-0.5377	-0.254	-0.2117	-0.8475	-0.5377	-0.285	-0.2809	-0.9699	-0.7134
-0.2855	-0.1436	-0.7251	-0.3608	-0.223	-0.1436	-0.7251	-0.3608	-0.254	-0.2117	-0.8475	-0.5377
-0.2373	-0.0766	-0.6027	-0.1897	-0.192	-0.0766	-0.6027	-0.1897	-0.223	-0.1436	-0.7251	-0.3608
-0.1891	-0.0107	-0.4803	0.0271	-0.161	-0.0107	-0.4803	0.0271	-0.192	-0.0766	-0.6027	-0.1897
-0.1409	0.0537	-0.3579	0.2077	-0.130	0.0537	-0.3579	0.2077	-0.161	-0.0107	-0.4803	0.0271
-0.0927	0.1132	-0.2355	0.3946	-0.100	0.1132	-0.2355	0.3946	-0.130	0.0537	-0.3579	0.2077
-0.0445	0.1681	-0.1131	0.5806	-0.070	0.1681	-0.1131	0.5806	-0.100	0.1132	-0.2355	0.3946
0.0037	0.2199	-0.0093	0.7680	-0.040	0.2199	-0.0093	0.7680	-0.070	0.1681	-0.1131	0.5806
0.0518	0.2709	0.1317	0.9561	0.010	0.2709	0.1317	0.9561	-0.040	0.2199	-0.0093	0.7680
0.1000	0.3212	0.2541	1.1428	0.040	0.3212	0.2541	1.1428	0.010	0.2709	0.1317	0.9561
0.1482	0.3707	0.3765	1.3284	0.070	0.3707	0.3765	1.3284	0.040	0.3212	0.2541	1.1428
0.1966	0.4195	0.4889	1.5109	0.100	0.4195	0.4889	1.5109	0.070	0.3707	0.3765	1.3284
0.2446	0.4676	0.5915	1.6892	0.130	0.4676	0.5915	1.6892	0.100	0.4195	0.4889	1.5109
0.2928	0.5150	0.6861	1.8628	0.160	0.5150	0.6861	1.8628	0.130	0.4676	0.5915	1.6892
0.3402	0.5617	0.7805	2.0314	0.190	0.5617	0.7805	2.0314	0.160	0.5150	0.6861	1.8628
0.3874	0.6076	0.8805	2.1954	0.220	0.6076	0.8805	2.1954	0.190	0.5617	0.7805	2.0314
0.4354	0.6532	1.1109	2.3543	0.250	0.6532	1.1109	2.3543	0.220	0.6076	0.8805	2.1954
0.4836	0.6980	1.2333	2.5082	0.280	0.6980	1.2333	2.5082	0.250	0.6532	1.1109	2.3543
0.5317	0.7422	1.3557	2.6574	0.310	0.7422	1.3557	2.6574	0.280	0.6980	1.2333	2.5082
0.5800	0.7857	1.4781	2.8020	0.340	0.7857	1.4781	2.8020	0.310	0.7422	1.3557	2.6574
0.6281	0.8287	1.6005	2.9419	0.370	0.8287	1.6005	2.9419	0.340	0.7857	1.4781	2.8020
0.6763	0.8710	1.7229	3.0764	0.400	0.8710	1.7229	3.0764	0.370	0.8287	1.6005	2.9419
0.7245	0.9128	1.8453	3.2054	0.430	0.9128	1.8453	3.2054	0.400	0.8710	1.7229	3.0764
0.7727	0.9540	1.9677	3.3292	0.460	0.9540	1.9677	3.3292	0.430	0.9128	1.8453	3.2054
0.8209	0.9947	2.0901	3.4481	0.490	0.9947	2.0901	3.4481	0.460	0.9540	1.9677	3.3292
0.8691	1.0322	2.2129	3.5624	0.520	1.0322	2.2129	3.5624	0.490	0.9947	2.0901	3.4481
0.9172	1.0655	2.3360	3.6724	0.550	1.0655	2.3360	3.6724	0.520	1.0322	2.2129	3.5624
0.9654	1.0976	2.4594	3.7774	0.580	1.0976	2.4594	3.7774	0.550	1.0655	2.3360	3.6724
1.0136	1.0076	2.5827	3.8774	0.610	1.0076	2.5827	3.8774	0.580	1.0976	2.4594	3.7774
1.0617	1.0055	2.7060	3.9724	0.640	1.0055	2.7060	3.9724	0.610	1.0136	1.0076	2.5827
1.1098	1.0055	2.8292	4.0624	0.670	1.0055	2.8292	4.0624	0.640	1.0617	1.0055	2.7060
1.1578	1.0022	2.9524	4.1474	0.700	1.0022	2.9524	4.1474	0.670	1.1098	1.0055	2.8292
1.2058	1.0022	3.0756	4.2274	0.730	1.0022	3.0756	4.2274	0.700	1.1578	1.0022	2.9524
1.2537	1.0022	3.1988	4.3024	0.760	1.0022	3.1988	4.3024	0.730	1.2058	1.0022	3.0756
1.3016	1.0022	3.3220	4.3724	0.790	1.0022	3.3220	4.3724	0.760	1.2537	1.0022	3.1988
1.3494	1.0022	3.4452	4.4374	0.820	1.0022	3.4452	4.4374	0.790	1.3016	1.0022	3.3220
1.3972	1.0022	3.5684	4.5024	0.850	1.0022	3.5684	4.5024	0.820	1.3494	1.0022	3.4452
1.4450	1.0022	3.6916	4.5624	0.880	1.0022	3.6916	4.5624	0.850	1.3972	1.0022	3.5684
1.4928	1.0022	3.8148	4.6174	0.910	1.0022	3.8148	4.6174	0.880	1.4450	1.0022	3.6916
1.5406	1.0022	3.9380	4.6674	0.940	1.0022	3.9380	4.6674	0.910	1.4928	1.0022	3.8148
1.5884	1.0022	4.0612	4.7124	0.970	1.0022	4.0612	4.7124	0.940	1.5406	1.0022	3.9380
1.6362	1.0022	4.1844	4.7524	1.000	1.0022	4.1844	4.7524	0.970	1.5884	1.0022	4.0612
1.6840	1.0022	4.3076	4.7874	1.030	1.0022	4.3076	4.7874	1.000	1.6362	1.0022	4.1844
1.7318	1.0022	4.4308	4.8174	1.060	1.0022	4.4308	4.8174	1.030	1.6840	1.0022	4.3076
1.7796	1.0022	4.5540	4.8424	1.090	1.0022	4.5540	4.8424	1.060	1.7318	1.0022	4.4308
1.8274	1.0022	4.6772	4.8624	1.120	1.0022	4.6772	4.8624	1.090	1.7796	1.0022	4.5540
1.8752	1.0022	4.8004	4.8774	1.150	1.0022	4.8004	4.8774	1.120	1.8274	1.0022	4.6772
1.9230	1.0022	4.9236	4.8874	1.180	1.0022	4.9236	4.8874	1.150	1.8752	1.0022	4.8004
1.9708	1.0022	5.0468	4.8924	1.210	1.0022	5.0468	4.8924	1.180	1.9230	1.0022	4.9236
2.0186	1.0022	5.1700	4.8924	1.240	1.0022	5.1700	4.8924	1.210	1.9708	1.0022	5.0468
2.0664	1.0022	5.2932	4.8874	1.270	1.0022	5.2932	4.8874	1.240	2.0186	1.0022	5.1700
2.1142	1.0022	5.4164	4.8774	1.300	1.0022	5.4164	4.8774	1.270	2.0664	1.0022	5.2932
2.1620	1.0022	5.5396	4.8624	1.330	1.0022	5.5396	4.8624	1.300	2.1142	1.0022	5.4164
2.2098	1.0022	5.6628	4.8424	1.360	1.0022	5.6628	4.8424	1.330	2.1620	1.0022	5.5396
2.2576	1.0022	5.7860	4.8174	1.390	1.0022	5.7860	4.8174	1.360	2.2098	1.0022	5.6628
2.3054	1.0022	5.9092	4.7874	1.420	1.0022	5.9092	4.7874	1.390	2.2576	1.0022	5.7860
2.3532	1.0022	6.0324	4.7524	1.450	1.0022	6.0324	4.7524	1.420	2.3054	1.0022	5.9092
2.4010	1.0022	6.1556	4.7124	1.480	1.0022	6.1556	4.7124	1.450	2.3532	1.0022	6.0324
2.4488	1.0022	6.2788	4.6674	1.510	1.0022	6.2788	4.6674	1.480	2.4010	1.0022	6.1556
2.4966	1.0022	6.4020	4.6174	1.540	1.0022	6.4020	4.6174	1.510	2.4488	1.0022	6.2788
2.5444	1.0022	6.5252	4.5624	1.570	1.0022	6.5252	4.5624	1.540	2.4966	1.0022	6.4020
2.5922	1.0022	6.6484	4.5024	1.600	1.0022	6.6484	4.5024	1.570	2.5444	1.0022	6.5252
2.6400	1.0022	6.7716	4.4374	1.630	1.0022	6.7716	4.4374	1.600	2.5922	1.0022	6.6484
2.6878	1.0022	6.8948	4.3724	1.660	1.0022	6.8948	4.3724	1.630	2.6400	1.0022	6.7716
2.7356	1.0022	7.0180	4.3024	1.690	1.0022	7.0180	4.3024	1.660	2.6878	1.0022	6.8948
2.7834	1.0022	7.1412	4.2274	1.720	1.0022	7.1412	4.2274	1.690	2.7356	1.0022	7.0180
2.8312	1.0022	7.2644	4.1474	1.750	1.0022	7.2644	4.1474	1.720	2.7834	1.0022	7.1412
2.8790	1.0022	7.3876	4.0624	1.780	1.0022	7.3876	4.0624	1.750	2.8312	1.0022	7.2644
2.9268	1.0022	7.5108	3.9724	1.810	1.0022	7.5108	3.9724	1.780	2.8790	1.0022	7.3876
2.9746	1.0022	7.6340	3.8774	1.840	1.0022	7.6340	3.8774	1.810	2.9268	1.0022	7.5108
3.0224	1.0022	7.7572	3.7774	1.870	1.0022	7.7572	3.7774	1.840	2.9746	1.0022	7.6340
3.0702	1.0022	7.8804	3.6724	1.900	1.0022	7.8804	3.6724	1.870	3.0224	1.0022	7.7572
3.1180	1.0022	8.0036	3.5624	1.930	1.0						

TABLE A-3.--Continued

ROTOR AIRFOIL COORDINATES
SECTION NO. 10 RADIUS 9.600 IN. (25.384 CM.)

SUCTION SURFACE		PRESSURE SURFACE		Y.C.M.	
X.IN.	Y.IN.	X.IN.	Y.IN.	X.C.M.	Y.C.M.
.0027	-1.1152	-2.4962	-1.1152	-2.4962	-2.0327
.0032	-1.1110	-2.4949	-1.1156	-2.4949	-2.0316
.0035	-1.1059	-2.4905	-1.1192	-2.4905	-2.0429
.0037	-1.1001	-2.4835	-1.1217	-2.4895	-2.0490
.0039	-1.0961	-2.4784	-1.1227	-2.4821	-2.0516
.0040	-1.0910	-2.4717	-1.1221	-2.4727	-2.0502
.0042	-1.0874	-2.4624	-1.1201	-2.4622	-2.0481
.0042	-1.0818	-2.4503	-1.1182	-2.45371	-2.0499
.0043	-1.0770	-2.4367	-1.0981	-2.4330	-2.07091
.0043	-1.0726	-2.4219	-1.0749	-2.42066	-2.0712
.0043	-1.0639	-2.4062	-1.0359	-2.41641	-2.0761
.0043	-1.0534	-2.3898	.0020	-2.4150	-2.07240
.0043	-1.0435	-2.3717	.0038	.0020	-2.07192
.0043	-1.0317	-2.3535	.0070	.0020	-2.07907
.0043	-1.0199	-2.3353	.0080	.0020	-2.08274
.0043	-1.0082	-2.3177	.0084	.0020	-2.08827
.0043	-0.9968	-2.3000	.0084	.0020	-2.09494
.0043	-0.9854	-2.2822	.0084	.0020	-2.10264
.0043	-0.9740	-2.2645	.0070	.0020	-2.11133
.0043	-0.9626	-2.2468	.0051	.0020	-2.12173
.0043	-0.9512	-2.2290	.0031	.0020	-2.13403
.0043	-0.9398	-2.2113	.0011	.0020	-2.14833
.0043	-0.9284	-2.1935	.0000	.0020	-2.16463
.0043	-0.9170	-2.1757	.0000	.0020	-2.18303
.0043	-0.9056	-2.1579	.0000	.0020	-2.20353
.0043	-0.8942	-2.1401	.0000	.0020	-2.22603
.0043	-0.8828	-2.1223	.0000	.0020	-2.25053
.0043	-0.8714	-2.1045	.0000	.0020	-2.27703
.0043	-0.8600	-2.0867	.0000	.0020	-2.30553
.0043	-0.8486	-2.0689	.0000	.0020	-2.33603
.0043	-0.8372	-2.0511	.0000	.0020	-2.36853
.0043	-0.8258	-2.0333	.0000	.0020	-2.40303
.0043	-0.8144	-2.0155	.0000	.0020	-2.43953
.0043	-0.8030	-1.9977	.0000	.0020	-2.47803
.0043	-0.7916	-1.9800	.0000	.0020	-2.51853
.0043	-0.7802	-1.9622	.0000	.0020	-2.56103
.0043	-0.7688	-1.9444	.0000	.0020	-2.60553
.0043	-0.7574	-1.9266	.0000	.0020	-2.65203
.0043	-0.7460	-1.9088	.0000	.0020	-2.70053
.0043	-0.7346	-1.8910	.0000	.0020	-2.75103
.0043	-0.7232	-1.8732	.0000	.0020	-2.80353
.0043	-0.7118	-1.8554	.0000	.0020	-2.85803
.0043	-0.7004	-1.8376	.0000	.0020	-2.91453
.0043	-0.6890	-1.8198	.0000	.0020	-2.97303
.0043	-0.6776	-1.8020	.0000	.0020	-3.03353
.0043	-0.6662	-1.7842	.0000	.0020	-3.09603
.0043	-0.6548	-1.7664	.0000	.0020	-3.16053
.0043	-0.6434	-1.7486	.0000	.0020	-3.22703
.0043	-0.6320	-1.7308	.0000	.0020	-3.29553
.0043	-0.6206	-1.7130	.0000	.0020	-3.36603
.0043	-0.6092	-1.6952	.0000	.0020	-3.43853
.0043	-0.5978	-1.6774	.0000	.0020	-3.51303
.0043	-0.5864	-1.6596	.0000	.0020	-3.58953
.0043	-0.5750	-1.6418	.0000	.0020	-3.66803
.0043	-0.5636	-1.6240	.0000	.0020	-3.74853
.0043	-0.5522	-1.6062	.0000	.0020	-3.83103
.0043	-0.5408	-1.5884	.0000	.0020	-3.91553
.0043	-0.5294	-1.5706	.0000	.0020	-4.00203
.0043	-0.5180	-1.5528	.0000	.0020	-4.09053
.0043	-0.5066	-1.5350	.0000	.0020	-4.18103
.0043	-0.4952	-1.5172	.0000	.0020	-4.27353
.0043	-0.4838	-1.4994	.0000	.0020	-4.36803
.0043	-0.4724	-1.4816	.0000	.0020	-4.46453
.0043	-0.4610	-1.4638	.0000	.0020	-4.56303
.0043	-0.4496	-1.4460	.0000	.0020	-4.66353
.0043	-0.4382	-1.4282	.0000	.0020	-4.76603
.0043	-0.4268	-1.4104	.0000	.0020	-4.87053
.0043	-0.4154	-1.3926	.0000	.0020	-4.97703
.0043	-0.4040	-1.3748	.0000	.0020	-5.08553
.0043	-0.3926	-1.3570	.0000	.0020	-5.19603
.0043	-0.3812	-1.3392	.0000	.0020	-5.30853
.0043	-0.3698	-1.3214	.0000	.0020	-5.42303
.0043	-0.3584	-1.3036	.0000	.0020	-5.53953
.0043	-0.3470	-1.2858	.0000	.0020	-5.65803
.0043	-0.3356	-1.2680	.0000	.0020	-5.77853
.0043	-0.3242	-1.2502	.0000	.0020	-5.90103
.0043	-0.3128	-1.2324	.0000	.0020	-6.02553
.0043	-0.3014	-1.2146	.0000	.0020	-6.15203
.0043	-0.2900	-1.1968	.0000	.0020	-6.28053
.0043	-0.2786	-1.1790	.0000	.0020	-6.41103
.0043	-0.2672	-1.1612	.0000	.0020	-6.54353
.0043	-0.2558	-1.1434	.0000	.0020	-6.67803
.0043	-0.2444	-1.1256	.0000	.0020	-6.81453
.0043	-0.2330	-1.1078	.0000	.0020	-6.95303
.0043	-0.2216	-1.0900	.0000	.0020	-7.09353
.0043	-0.2102	-1.0722	.0000	.0020	-7.23603
.0043	-0.1988	-1.0544	.0000	.0020	-7.38053
.0043	-0.1874	-1.0366	.0000	.0020	-7.52703
.0043	-0.1760	-1.0188	.0000	.0020	-7.67553
.0043	-0.1646	-1.0010	.0000	.0020	-7.82603
.0043	-0.1532	-0.9832	.0000	.0020	-7.97853
.0043	-0.1418	-0.9654	.0000	.0020	-8.13303
.0043	-0.1304	-0.9476	.0000	.0020	-8.28953
.0043	-0.1190	-0.9298	.0000	.0020	-8.44803
.0043	-0.1076	-0.9120	.0000	.0020	-8.60853
.0043	-0.0962	-0.8942	.0000	.0020	-8.77103
.0043	-0.0848	-0.8764	.0000	.0020	-8.93553
.0043	-0.0734	-0.8586	.0000	.0020	-9.10203
.0043	-0.0620	-0.8408	.0000	.0020	-9.27053
.0043	-0.0506	-0.8230	.0000	.0020	-9.44103
.0043	-0.0392	-0.8052	.0000	.0020	-9.61353
.0043	-0.0278	-0.7874	.0000	.0020	-9.78803
.0043	-0.0164	-0.7696	.0000	.0020	-9.96453
.0043	-0.0050	-0.7518	.0000	.0020	-10.14303
.0043	0.0064	-0.7340	.0000	.0020	-10.32353
.0043	0.0178	-0.7162	.0000	.0020	-10.50603
.0043	0.0292	-0.6984	.0000	.0020	-10.69053
.0043	0.0406	-0.6806	.0000	.0020	-10.87703
.0043	0.0520	-0.6628	.0000	.0020	-11.06553
.0043	0.0634	-0.6450	.0000	.0020	-11.25603
.0043	0.0748	-0.6272	.0000	.0020	-11.44853
.0043	0.0862	-0.6094	.0000	.0020	-11.64303
.0043	0.0976	-0.5916	.0000	.0020	-11.83953
.0043	0.1090	-0.5738	.0000	.0020	-12.03803
.0043	0.1204	-0.5560	.0000	.0020	-12.23853
.0043	0.1318	-0.5382	.0000	.0020	-12.44103
.0043	0.1432	-0.5204	.0000	.0020	-12.64553
.0043	0.1546	-0.5026	.0000	.0020	-12.85203
.0043	0.1660	-0.4848	.0000	.0020	-13.06053
.0043	0.1774	-0.4670	.0000	.0020	-13.27103
.0043	0.1888	-0.4492	.0000	.0020	-13.48353
.0043	0.2002	-0.4314	.0000	.0020	-13.69803
.0043	0.2116	-0.4136	.0000	.0020	-13.91453
.0043	0.2230	-0.3958	.0000	.0020	-14.13303
.0043	0.2344	-0.3780	.0000	.0020	-14.35353
.0043	0.2458	-0.3602	.0000	.0020	-14.57603
.0043	0.2572	-0.3424	.0000	.0020	-14.80053
.0043	0.2686	-0.3246	.0000	.0020	-15.02703
.0043	0.2800	-0.3068	.0000	.0020	-15.25553
.0043	0.2914	-0.2890	.0000	.0020	-15.48603
.0043	0.3028	-0.2712	.0000	.0020	-15.71853
.0043	0.3142	-0.2534	.0000	.0020	-15.95303
.0043	0.3256	-0.2356	.0000	.0020	-16.18953
.0043	0.3370	-0.2178	.0000	.0020	-16.42803
.0043	0.3484	-0.2000	.0000	.0020	-16.66853
.0043	0.3598	-0.1822	.0000	.0020	-16.91103
.0043	0.3712	-0.1644	.0000	.0020	-17.15553
.0043	0.3826	-0.1466	.0000	.0020	-17.40203
.0043	0.3940	-0.1288	.0000	.0020	-17.65053
.0043	0.4054	-0.1110	.0000	.0020	-17.90103
.0043	0.4168	-0.0932	.0000	.0020	-18.15353
.0043	0.4282	-0.0754	.0000	.0020	-18.40803
.0043	0.4396	-0.0576	.0000	.0020	-18.66453
.0043	0.4510	-0.0398	.0000	.0020	-18.92303
.0043	0.4624	-0.0220	.0000	.0020	-19.18353
.0043	0.4738	-0.0042	.0000	.0020	-19.44603
.0043	0.4852	0.0136	.0000	.0020	-19.71053
.0043	0.4966	0.0314	.0000	.0020	-19.97703
.0043	0.5080	0.0496	.0000	.0020	-20.24553
.0043	0.5194	0.0682	.0000	.0020	-20.51603
.0043	0.5308	0.0874	.0000	.0020	-20.78853
.0043	0.5422	0.1072	.0000	.0020	-21.06303
.0043	0.5536	0.1276	.0000	.0020	-21.33953
.0043	0.5650	0.1486	.0000	.0020	-21.61803
.0043	0.5764	0.1702	.0000	.0020	-21.89853
.0043	0.5878	0.1924	.0000	.0020	-22.18103
.0043	0.5992	0.2152	.0000	.0020	-22.46553
.0043	0.6106	0.2386	.0000	.0020	-22.75203
.0043	0.6220	0.2626	.0000	.0020	-23.04053
.0043	0.6334	0.2872	.0000	.0020	-23.33103
.0043	0.6448	0.3124	.0000	.0020	-23.62353
.0043	0.6562	0.3382	.0000	.0020	-23.91803
.0043	0.6676	0.3646	.0000	.0020	-24.21453
.0043	0.6790	0.3916	.0000	.0020	-24.51303
.0043	0.6904	0.4192	.0000	.0020	-24.81353
.0043	0.7018	0.4474	.0000	.0020	-25.11603
.0043	0.7132	0.4762	.0000	.0020	-25.42053
.0043	0.7246	0.5056	.0000	.0020	-25.72703
.0043	0.7360	0.5356	.0000	.0020	-26.03553
.0043	0.7474	0.5662	.0000	.0020	-26.34603
.0043	0.7588	0.5974	.0000	.0020	-26.65853
.0043	0.7702	0.6292	.0000	.0020	-26.97303
.0043	0.7816	0.6616	.0000	.0020	-27.28953
.0043	0.7930	0.6946	.0000	.0020	-27.60803
.0043	0.8044	0.7282	.0000	.0020	-27.92853
.0043	0.8158	0.7624	.0000	.0020	-28.25103
.0043	0.8272	0.7972	.0000	.0020	-28.57553
.0043	0.8386	0.8326	.0000	.0020	-28.90203
.0043	0.8500	0.8686	.0000	.0020	-29.23053
.0043	0.8614	0.9052	.0000	.0020	-29.56103
.0043	0.8728	0.9424	.0000	.0020	-29.89353
.0043	0.8842	0.9802	.0000		

TABLE A-3.--Continued

SECTION NO. 11 RADIUS 8.900 IN. (22.806 CM.)

ROTOR ATMFOIL COORDINATES

SUCTION SURFACE		PRESSURE SURFACE		Y.C.M.	
X.IN.	Y.IN.	X.IN.	Y.IN.	X.C.M.	Y.C.M.
-0.976	-0.9789	-2.5340	-2.4063	-0.976	-2.5340
-0.976	-0.9787	-2.5340	-2.4059	-0.976	-2.5340
-0.969	-0.9737	-2.5320	-2.4051	-0.970	-2.5223
-0.968	-0.9681	-2.5267	-2.4050	-0.955	-2.5272
-0.9615	-0.9625	-2.5184	-2.4048	-0.918	-2.5064
-0.9440	-0.9443	-2.5079	-2.4044	-0.877	-2.5053
-0.9466	-0.9273	-2.2773	-2.2716	-0.830	-2.5002
-0.9491	-0.7418	-2.1568	-1.9344	-0.715	-2.4730
-0.9017	-0.6909	-2.0362	-1.7702	-0.624	-2.4474
-0.7582	-0.6334	-1.9157	-1.6087	-0.533	-2.4216
-0.7068	-0.5707	-1.7952	-1.4495	-0.445	-2.3959
-0.6593	-0.5092	-1.6746	-1.2933	-0.355	-2.3702
-0.6110	-0.4493	-1.5581	-1.1411	-0.268	-2.3446
-0.5684	-0.3909	-1.4438	-0.9928	-0.183	-2.3189
-0.5169	-0.3339	-1.3330	-0.8882	-0.100	-2.2932
-0.4695	-0.2786	-1.2255	-0.8076	-0.020	-2.2675
-0.4220	-0.2246	-1.1219	-0.7505	0.063	-2.2418
-0.3746	-0.1728	-1.0318	-0.7070	0.147	-2.2161
-0.3271	-0.1209	-0.9509	-0.6771	0.231	-2.1904
-0.2797	-0.0785	-0.8801	-0.6581	0.314	-2.1647
-0.2322	-0.0268	-0.8198	-0.6492	0.398	-2.1390
-0.1847	0.0163	-0.7692	-0.6503	0.481	-2.1133
-0.1373	0.0586	-0.7287	-0.6614	0.565	-2.0876
-0.0898	0.0987	-0.6882	-0.6825	0.648	-2.0619
-0.0424	0.1384	-0.6467	-0.7136	0.731	-2.0362
0.0051	0.1772	-0.6049	-0.7549	0.813	-2.0105
0.0525	0.2149	-0.5630	-0.8063	0.896	-1.9848
0.1000	0.2517	-0.5200	-0.8676	0.978	-1.9591
0.1475	0.2876	-0.4761	-0.9389	1.060	-1.9334
0.1949	0.3226	-0.4311	-1.0202	1.141	-1.9077
0.2424	0.3567	-0.3851	-1.1115	1.222	-1.8820
0.2898	0.3899	-0.3381	-1.2128	1.303	-1.8563
0.3373	0.4223	-0.2901	-1.3241	1.384	-1.8306
0.3847	0.4538	-0.2411	-1.4454	1.464	-1.8049
0.4322	0.4846	-0.1901	-1.5767	1.544	-1.7792
0.4796	0.5145	-0.1371	-1.7180	1.624	-1.7535
0.5271	0.5437	-0.0821	-1.8693	1.704	-1.7278
0.5746	0.5721	-0.0251	-2.0306	1.784	-1.7021
0.6220	0.5998	0.0319	-2.1919	1.864	-1.6764
0.6695	0.6266	0.0887	-2.3532	1.944	-1.6507
0.7169	0.6526	0.1455	-2.5145	2.024	-1.6250
0.7644	0.6779	0.2023	-2.6758	2.104	-1.6000
0.8118	0.7027	0.2591	-2.8371	2.184	-1.5743
0.8593	0.7261	0.3159	-3.0000	2.264	-1.5486
0.9068	0.7481	0.3727	-3.1639	2.344	-1.5229
0.9542	0.7687	0.4295	-3.3288	2.424	-1.4972
1.0017	0.7879	0.4863	-3.4947	2.504	-1.4715
1.0491	0.8057	0.5431	-3.6616	2.584	-1.4458
1.0966	0.8221	0.6000	-3.8295	2.664	-1.4201
1.1440	0.8371	0.6568	-4.0000	2.744	-1.3944
1.1915	0.8507	0.7137	-4.1729	2.824	-1.3687
1.2390	0.8629	0.7705	-4.3488	2.904	-1.3430
1.2864	0.8738	0.8274	-4.5277	2.984	-1.3173
1.3339	0.8834	0.8843	-4.7096	3.064	-1.2916
1.3814	0.8917	0.9412	-4.8945	3.144	-1.2659
1.4289	0.8987	0.9981	-5.0824	3.224	-1.2402
1.4764	0.9044	1.0550	-5.2733	3.304	-1.2145
1.5239	0.9088	1.1119	-5.4672	3.384	-1.1888
1.5714	0.9119	1.1688	-5.6641	3.464	-1.1631
1.6189	0.9137	1.2257	-5.8640	3.544	-1.1374
1.6664	0.9142	1.2826	-6.0669	3.624	-1.1117
1.7139	0.9134	1.3395	-6.2728	3.704	-1.0860
1.7614	0.9113	1.3964	-6.4817	3.784	-1.0603
1.8089	0.9079	1.4533	-6.6936	3.864	-1.0346
1.8564	0.9032	1.5102	-6.9085	3.944	-1.0089
1.9039	0.8972	1.5671	-7.1264	4.024	-0.9832
1.9514	0.8899	1.6240	-7.3483	4.104	-0.9575
1.9989	0.8813	1.6809	-7.5742	4.184	-0.9318
2.0464	0.8714	1.7378	-7.8041	4.264	-0.9061
2.0939	0.8602	1.7947	-8.0380	4.344	-0.8804
2.1414	0.8477	1.8516	-8.2759	4.424	-0.8547
2.1889	0.8339	1.9085	-8.5178	4.504	-0.8290
2.2364	0.8188	1.9654	-8.7637	4.584	-0.8033
2.2839	0.8024	2.0223	-9.0136	4.664	-0.7776
2.3314	0.7847	2.0792	-9.2675	4.744	-0.7519
2.3789	0.7657	2.1361	-9.5254	4.824	-0.7262
2.4264	0.7454	2.1930	-9.7873	4.904	-0.7005
2.4739	0.7238	2.2500	-10.0532	4.984	-0.6748
2.5214	0.7009	2.3070	-10.3231	5.064	-0.6491
2.5689	0.6767	2.3640	-10.5970	5.144	-0.6234
2.6164	0.6512	2.4210	-10.8749	5.224	-0.5977
2.6639	0.6243	2.4780	-11.1568	5.304	-0.5720
2.7114	0.5960	2.5350	-11.4427	5.384	-0.5463
2.7589	0.5663	2.5920	-11.7326	5.464	-0.5206
2.8064	0.5352	2.6490	-12.0265	5.544	-0.4949
2.8539	0.5027	2.7060	-12.3244	5.624	-0.4692
2.9014	0.4689	2.7630	-12.6263	5.704	-0.4435
2.9489	0.4338	2.8200	-12.9322	5.784	-0.4178
2.9964	0.3974	2.8770	-13.2421	5.864	-0.3921
3.0439	0.3597	2.9340	-13.5560	5.944	-0.3664
3.0914	0.3207	2.9910	-13.8739	6.024	-0.3407
3.1389	0.2804	3.0480	-14.1958	6.104	-0.3150
3.1864	0.2388	3.1050	-14.5217	6.184	-0.2893
3.2339	0.1959	3.1620	-14.8516	6.264	-0.2636
3.2814	0.1517	3.2190	-15.1855	6.344	-0.2379
3.3289	0.1062	3.2760	-15.5234	6.424	-0.2122
3.3764	0.0594	3.3330	-15.8653	6.504	-0.1865
3.4239	0.0113	3.3900	-16.2112	6.584	-0.1608
3.4714	-0.0371	3.4470	-16.5611	6.664	-0.1351
3.5189	-0.0848	3.5040	-16.9150	6.744	-0.1094
3.5664	-0.1325	3.5610	-17.2729	6.824	-0.0837
3.6139	-0.1802	3.6180	-17.6348	6.904	-0.0580
3.6614	-0.2279	3.6750	-18.0007	6.984	-0.0323
3.7089	-0.2756	3.7320	-18.3706	7.064	-0.0066
3.7564	-0.3233	3.7890	-18.7445	7.144	0.0191
3.8039	-0.3710	3.8460	-19.1224	7.224	0.0448
3.8514	-0.4187	3.9030	-19.5043	7.304	0.0705
3.8989	-0.4664	3.9600	-19.8902	7.384	0.0962
3.9464	-0.5141	4.0170	-20.2801	7.464	0.1219
3.9939	-0.5618	4.0740	-20.6740	7.544	0.1476
4.0414	-0.6095	4.1310	-21.0719	7.624	0.1733
4.0889	-0.6572	4.1880	-21.4738	7.704	0.1990
4.1364	-0.7049	4.2450	-21.8797	7.784	0.2247
4.1839	-0.7526	4.3020	-22.2896	7.864	0.2504
4.2314	-0.7993	4.3590	-22.7035	7.944	0.2761
4.2789	-0.8460	4.4160	-23.1214	8.024	0.3018
4.3264	-0.8927	4.4730	-23.5433	8.104	0.3275
4.3739	-0.9394	4.5300	-23.9692	8.184	0.3532
4.4214	-0.9861	4.5870	-24.4001	8.264	0.3789
4.4689	-1.0328	4.6440	-24.8360	8.344	0.4046
4.5164	-1.0795	4.7010	-25.2769	8.424	0.4303
4.5639	-1.1262	4.7580	-25.7228	8.504	0.4560
4.6114	-1.1729	4.8150	-26.1737	8.584	0.4817
4.6589	-1.2196	4.8720	-26.6296	8.664	0.5074
4.7064	-1.2663	4.9290	-27.0905	8.744	0.5331
4.7539	-1.3130	4.9860	-27.5564	8.824	0.5588
4.8014	-1.3597	5.0430	-28.0273	8.904	0.5845
4.8489	-1.4064	5.1000	-28.5032	8.984	0.6102
4.8964	-1.4531	5.1570	-28.9841	9.064	0.6359
4.9439	-1.4998	5.2140	-29.4700	9.144	0.6616
4.9914	-1.5465	5.2710	-29.9609	9.224	0.6873
5.0389	-1.5932	5.3280	-30.4568	9.304	0.7130
5.0864	-1.6399	5.3850	-30.9577	9.384	0.7387
5.1339	-1.6866	5.4420	-31.4636	9.464	0.7644
5.1814	-1.7333	5.4990	-31.9745	9.544	0.7901
5.2289	-1.7790	5.5560	-32.4904	9.624	0.8158
5.2764	-1.8257	5.6130	-33.0113	9.704	0.8415
5.3239	-1.8724	5.6700	-33.5372	9.784	0.8672
5.3714	-1.9191	5.7270	-34.0681	9.864	0.8929
5.4189	-1.9658	5.7840	-34.6040	9.944	0.9186
5.4664	-2.0125	5.8410	-35.1459	10.024	0.9443
5.5139	-2.0592	5.8980	-35.6938	10.104	0.9700
5.5614	-2.1059	5.9550	-36.2477	10.184	0.9957
5.6089	-2.1526	6.0120	-36.8076	10.264	1.0214
5.6564	-2.1993	6.0690	-37.3735	10.344	1.0471
5.7039	-2.2460	6.1260	-37.9454	10.424	1.0728
5.7514	-2.2927	6.1830	-38.5233	10.504	1.0985
5.7989	-2.3394	6.2400	-39.1072	10.584	1.1242
5.8464	-2.3861	6.2970	-39.6971	10.664	1.1500
5.8939	-2.4328	6.3540	-40.2930	10.744	1.1757
5.9414	-2.4795	6.4110	-40.8949	10.824	1.2014
5.9889	-2.5262	6.4680	-41.5028	10.904	1.2271
6.0364	-2.5729	6.5250	-42.1167	10.984	1.2528
6.0839	-2.6196	6.5820	-42.7366	11.064	1.2785
6.1314	-2.6663	6.6390	-43.3625	11.144	1.3042
6.1789	-2.7130	6.6960	-43.9944	11.224	1.3300
6.2264	-2.7597	6.7530	-44.6323	11.304	1.3557
6.2739	-2.8064	6.8100	-45.2762	11.384	1.3814
6.3214	-2.8531	6.8670	-45.9261	11.464	1.4071
6.3689	-2.8998	6.9240	-46.5820	11.544	1.4328
6.4164	-2.9465	6.9810	-47.2439	11.624	1.4585
6.4639	-2.9932	7.0380	-47.9118	11.704	1.4842
6.5114	-3.0399	7.0950	-48.5857	11.784	1.5100
6.5589	-3.0866	7.1520	-49.2656	11.864	1.5357
6.6064	-3.1333	7.2090	-49.9515	11.944	1.5614
6.6539	-3.1790	7.2660	-50.6434	12.024	1.5871
6.7014	-3.2257	7.3230	-51.3413	12.104	1.6128
6.7489	-3.2724	7.3800	-52.0452	12.184	1.6385
6.7964	-3.3191	7.4370	-52.7551	12.264	1.6642
6.8439	-3.3658	7.4940	-53.4710	12.344	1.6900
6.8914	-3.4125	7.5510	-54.1929	12.424	1.715

TABLE A-3.--Continued

MOION AIRFOIL COORDINATES
SECTION NO. 12 RADIUS R=200 IN. (20,000 CM.)

SUCTION SURFACE		PRESSURE SURFACE		Y.C.M.		X.I.N.	
Y.I.N.	X.C.M.	Y.I.N.	X.C.M.	Y.I.N.	X.I.N.	Y.I.N.	X.I.N.
-1.0131	-2.5732	-0.8549	-2.1731	-1.0131	-0.8550	-2.1731	-1.0131
-1.0131	-2.5732	-0.8549	-2.1716	-1.0125	-0.8594	-2.5717	-2.1629
-1.0121	-2.5707	-0.8495	-2.1577	-1.0104	-0.8625	-2.5663	-2.1508
-1.0099	-2.5684	-0.8435	-2.1425	-1.0069	-0.8660	-2.5578	-2.1446
-1.0059	-2.5549	-0.8375	-2.1272	-1.0024	-0.8697	-2.5481	-2.1354
-0.9573	-2.4316	-0.7720	-1.9808	-0.9972	-0.8616	-2.5340	-2.1084
-0.9068	-2.3083	-0.7084	-1.7994	-0.9842	-0.8508	-2.4999	-2.1011
-0.8602	-2.1849	-0.6469	-1.6431	-0.9756	-0.8417	-2.4761	-2.1374
-0.8116	-2.0616	-0.5872	-1.4915	-0.9261	-0.7899	-2.3524	-2.0480
-0.7631	-1.9383	-0.5292	-1.3442	-0.8762	-0.7391	-2.2285	-1.9172
-0.7145	-1.8149	-0.4729	-1.2012	-0.8263	-0.6899	-2.0988	-1.7523
-0.6660	-1.6916	-0.4183	-1.0625	-0.7764	-0.6423	-1.9720	-1.6213
-0.6174	-1.5683	-0.3654	-0.9281	-0.7264	-0.5960	-1.8452	-1.5140
-0.5689	-1.4450	-0.3142	-0.7980	-0.6765	-0.5512	-1.7184	-1.4001
-0.5203	-1.3216	-0.2645	-0.6718	-0.6266	-0.5077	-1.5916	-1.2896
-0.4718	-1.1983	-0.2163	-0.5493	-0.5767	-0.4655	-1.4647	-1.1823
-0.4232	-1.0750	-0.1694	-0.4303	-0.5267	-0.4244	-1.3374	-1.0781
-0.3747	-0.9516	-0.1241	-0.3151	-0.4768	-0.3845	-1.2111	-0.9740
-0.3261	-0.8283	-0.0804	-0.2051	-0.4269	-0.3456	-1.0844	-0.8714
-0.2775	-0.7050	-0.0349	-0.1007	-0.3770	-0.3076	-0.9576	-0.7617
-0.2290	-0.5816	0.0006	0.0017	-0.3271	-0.2706	-0.8306	-0.6674
-0.1804	-0.4583	0.0367	0.0932	-0.2771	-0.2348	-0.7034	-0.5963
-0.1319	-0.3350	0.0727	0.1846	-0.2272	-0.1995	-0.5771	-0.5460
-0.0833	-0.2117	0.1073	0.2726	-0.1773	-0.1650	-0.4503	-0.4191
-0.0348	-0.0883	0.1407	0.3574	-0.1474	-0.1312	-0.3235	-0.3231
0.0130	0.0350	0.1726	0.4390	-0.0775	-0.0979	-0.1967	-0.2487
0.0237	0.1583	0.2037	0.5175	-0.0275	-0.0652	-0.0700	-0.1656
0.1109	0.2335	0.2620	0.5930	0.0224	-0.0330	0.0589	-0.0837
0.1595	0.2895	0.2820	0.6555	0.0723	-0.0011	0.1837	0.0024
0.2560	0.3159	0.2800	0.7125	0.1222	0.0304	0.3105	0.0771
0.3051	0.3422	0.2687	0.7687	0.1722	0.0616	0.4373	0.1565
0.3537	0.3655	0.2483	0.8263	0.2221	0.0927	0.5641	0.2354
0.4022	0.3887	0.2217	0.8833	0.2720	0.1237	0.6909	0.3142
0.4508	0.4109	0.1945	0.9437	0.3219	0.1548	0.8177	0.3933
0.4993	0.4320	0.1674	1.0074	0.3716	0.1862	0.9445	0.4730
0.5479	0.4522	0.1406	1.0746	0.4218	0.2176	1.0713	0.5534
0.5964	0.4714	0.1135	1.1466	0.4717	0.2496	1.1981	0.6331
0.6450	0.4896	0.0864	1.2235	0.5216	0.2817	1.3249	0.7155
0.6936	0.5068	0.0594	1.3072	0.5715	0.3139	1.4517	0.7974
0.7421	0.5231	0.0324	1.3966	0.6214	0.3464	1.5785	0.8799
0.7907	0.5384	0.0054	1.4926	0.6714	0.3791	1.7053	0.9626
0.8396	0.5529	0.0000	1.5959	0.7213	0.4119	1.8321	1.0463
0.8906	0.5670	0.0000	1.7072	0.7712	0.4450	1.9589	1.1303
0.9412	0.5809	0.0000	1.8267	0.8211	0.4782	2.0857	1.2147
0.9925	0.5949	0.0000	1.9544	0.8710	0.5117	2.2125	1.2996
1.0432	0.6089	0.0000	2.0904	0.9210	0.5453	2.3393	1.3850
1.0944	0.6230	0.0000	2.2348	0.9715	0.5784	2.4661	1.4711
1.1456	0.6370	0.0000	2.3788	1.0220	0.6116	2.5929	1.5580
1.1968	0.6510	0.0000	2.5224	1.0725	0.6450	2.7197	1.6454
1.2480	0.6650	0.0000	2.6656	1.1230	0.6784	2.8465	1.7334
1.2992	0.6790	0.0000	2.8082	1.1735	0.7118	2.9733	1.8219
1.3504	0.6930	0.0000	2.9503	1.2240	0.7452	3.1001	1.9104
1.4016	0.7070	0.0000	3.0919	1.2745	0.7786	3.2269	2.0000
1.4528	0.7210	0.0000	3.2330	1.3250	0.8120	3.3537	2.0906
1.5040	0.7350	0.0000	3.3736	1.3755	0.8454	3.4805	2.1822
1.5552	0.7490	0.0000	3.5137	1.4260	0.8788	3.6073	2.2748
1.6064	0.7630	0.0000	3.6533	1.4765	0.9122	3.7341	2.3674
1.6576	0.7770	0.0000	3.7924	1.5270	0.9456	3.8609	2.4600
1.7088	0.7910	0.0000	3.9310	1.5775	0.9790	3.9877	2.5526
1.7600	0.8050	0.0000	4.0691	1.6280	1.0124	4.1145	2.6452
1.8112	0.8190	0.0000	4.2067	1.6785	1.0458	4.2413	2.7378
1.8624	0.8330	0.0000	4.3438	1.7290	1.0792	4.3681	2.8304
1.9136	0.8470	0.0000	4.4804	1.7795	1.1126	4.4949	2.9230
1.9648	0.8610	0.0000	4.6165	1.8300	1.1460	4.6217	3.0156
2.0160	0.8750	0.0000	4.7521	1.8805	1.1794	4.7485	3.1082
2.0672	0.8890	0.0000	4.8872	1.9310	1.2128	4.8753	3.2008
2.1184	0.9030	0.0000	5.0218	1.9815	1.2462	5.0021	3.2934
2.1696	0.9170	0.0000	5.1559	2.0320	1.2796	5.1289	3.3860
2.2208	0.9310	0.0000	5.2895	2.0825	1.3130	5.2557	3.4786
2.2720	0.9450	0.0000	5.4226	2.1330	1.3464	5.3825	3.5712
2.3232	0.9590	0.0000	5.5552	2.1835	1.3798	5.5093	3.6638
2.3744	0.9730	0.0000	5.6873	2.2340	1.4132	5.6361	3.7564
2.4256	0.9870	0.0000	5.8189	2.2845	1.4466	5.7629	3.8490
2.4768	1.0010	0.0000	5.9500	2.3350	1.4800	5.8897	3.9416
2.5280	1.0150	0.0000	6.0806	2.3855	1.5134	6.0165	4.0342
2.5792	1.0290	0.0000	6.2107	2.4360	1.5468	6.1433	4.1268
2.6304	1.0430	0.0000	6.3403	2.4865	1.5802	6.2701	4.2194
2.6816	1.0570	0.0000	6.4694	2.5370	1.6136	6.3969	4.3120
2.7328	1.0710	0.0000	6.5980	2.5875	1.6470	6.5237	4.4046
2.7840	1.0850	0.0000	6.7261	2.6380	1.6804	6.6505	4.4972
2.8352	1.0990	0.0000	6.8537	2.6885	1.7138	6.7773	4.5898
2.8864	1.1130	0.0000	6.9808	2.7390	1.7472	6.9041	4.6824
2.9376	1.1270	0.0000	7.1074	2.7895	1.7806	7.0309	4.7750
2.9888	1.1410	0.0000	7.2335	2.8400	1.8140	7.1577	4.8676
3.0400	1.1550	0.0000	7.3591	2.8905	1.8474	7.2845	4.9602
3.0912	1.1690	0.0000	7.4842	2.9410	1.8808	7.4113	5.0528
3.1424	1.1830	0.0000	7.6088	2.9915	1.9142	7.5381	5.1454
3.1936	1.1970	0.0000	7.7329	3.0420	1.9476	7.6649	5.2380
3.2448	1.2110	0.0000	7.8565	3.0925	1.9810	7.7917	5.3306
3.2960	1.2250	0.0000	7.9796	3.1430	2.0144	7.9185	5.4232
3.3472	1.2390	0.0000	8.1022	3.1935	2.0478	8.0453	5.5158
3.3984	1.2530	0.0000	8.2243	3.2440	2.0812	8.1721	5.6084
3.4496	1.2670	0.0000	8.3459	3.2945	2.1146	8.2989	5.7010
3.5008	1.2810	0.0000	8.4670	3.3450	2.1480	8.4257	5.7936
3.5520	1.2950	0.0000	8.5876	3.3955	2.1814	8.5525	5.8862
3.6032	1.3090	0.0000	8.7077	3.4460	2.2148	8.6793	5.9788
3.6544	1.3230	0.0000	8.8273	3.4965	2.2482	8.8061	6.0714
3.7056	1.3370	0.0000	8.9464	3.5470	2.2816	8.9329	6.1640
3.7568	1.3510	0.0000	9.0650	3.5975	2.3150	9.0597	6.2566
3.8080	1.3650	0.0000	9.1831	3.6480	2.3484	9.1865	6.3492
3.8592	1.3790	0.0000	9.3007	3.6985	2.3818	9.3133	6.4418
3.9104	1.3930	0.0000	9.4178	3.7490	2.4152	9.4401	6.5344
3.9616	1.4070	0.0000	9.5344	3.7995	2.4486	9.5669	6.6270
4.0128	1.4210	0.0000	9.6505	3.8500	2.4820	9.6937	6.7196
4.0640	1.4350	0.0000	9.7661	3.9005	2.5154	9.8205	6.8122
4.1152	1.4490	0.0000	9.8812	3.9510	2.5488	9.9473	6.9048
4.1664	1.4630	0.0000	9.9958	4.0015	2.5822	10.0741	6.9974
4.2176	1.4770	0.0000	10.1100	4.0520	2.6156	10.2009	7.0900
4.2688	1.4910	0.0000	10.2237	4.1025	2.6490	10.3277	7.1826
4.3200	1.5050	0.0000	10.3369	4.1530	2.6824	10.4545	7.2752
4.3712	1.5190	0.0000	10.4496	4.2035	2.7158	10.5813	7.3678
4.4224	1.5330	0.0000	10.5618	4.2540	2.7492	10.7081	7.4604
4.4736	1.5470	0.0000	10.6735	4.3045	2.7826	10.8349	7.5530
4.5248	1.5610	0.0000	10.7847	4.3550	2.8160	10.9617	7.6456
4.5760	1.5750	0.0000	10.8954	4.4055	2.8494	11.0885	7.7382
4.6272	1.5890	0.0000	11.0056	4.4560	2.8828	11.2153	7.8308
4.6784	1.6030	0.0000	11.1153	4.5065	2.9162	11.3421	7.9234
4.7296	1.6170	0.0000	11.2245	4.5570	2.9496	11.4689	8.0160
4.7808	1.6310	0.0000	11.3332	4.6075	2.9830	11.5957	8.1086
4.8320	1.6450	0.0000	11.4414	4.6580	3.0164	11.7225	8.2012
4.8832	1.6590	0.0000	11.5491	4.7085	3.0498	11.8493	8.2938
4.9344	1.6730	0.0000	11.6563	4.7590	3.0832	11.9761	8.3864
4.9856	1.6870	0.0000	11.7630	4.8095	3.1166	12.1029	8.4790
5.0368	1.7010	0.0000	11.8692	4.8600	3.1500	12.2297	8.5716
5.0880	1.7150	0.0000	11.9749	4.9105	3.1834	12.3565	8.6642
5.1392	1.7290	0.0000	12.0801	4.9610	3.2168	12.4833	8.7568
5.1904	1.7430	0.0000	12.1848	5.0115	3.2502	12.6101	8.8494
5.2416	1.7570	0.0000	12.2890	5.0620	3.2836	12.7369	8.9420
5.2928	1.7710	0.0000	12.3927	5.1125	3.3170	12.8637	9.0346
5.3440	1.7850	0.00					

TABLE A-3.--Continued

SECTION NO. 13 ROTOM AIR-OIL COORDINATES
 HORIZ. RADIUS 7.500 IN. (19.050 CM.)

SUCTION SURFACE		PRESSURE SURFACE		Y.C.M.	
X.IN.	Y.IN.	X.C.M.	Y.C.M.	X.IN.	Y.IN.
-1.0067	-.7599	-2.5570	-1.9301	-1.0067	-.7599
-1.0055	-.7531	-2.5540	-1.9277	-1.0061	-.7637
-1.0028	-.7405	-2.5471	-1.9130	-1.0040	-.7671
-1.0007	-.7327	-2.5367	-1.8989	-1.0003	-.7688
-.9927	-.6806	-2.4199	-1.8008	-.9935	-.7666
-.8007	-.6228	-2.3031	-1.7287	-.9756	-.7550
-.6147	-.5671	-2.1863	-1.6405	-.9672	-.7472
-.4288	-.5135	-2.0694	-1.5303	-.9512	-.7350
-.2428	-.4617	-1.9526	-1.4126	-.9350	-.7204
-.0568	-.4117	-1.8358	-1.2850	-.9190	-.7025
-.1288	-.3635	-1.7190	-.9234	-.9034	-.6835
-.3008	-.3169	-1.6022	-.8099	-.8882	-.6635
-.4728	-.2719	-1.4854	-.6906	-.8734	-.6423
-.6448	-.2284	-1.3685	-.5802	-.8590	-.6200
-.8168	-.1864	-1.2517	-.4735	-.8451	-.5967
-.9888	-.1450	-1.1349	-.3704	-.8317	-.5725
-1.1608	-.1067	-1.0181	-.2709	-.8189	-.5477
-1.3328	-.0691	-.9013	-.1755	-.8066	-.5225
-1.5048	-.0332	-.7844	-.0828	-.7949	-.4969
-1.6768	-.0010	-.6676	-.0028	-.7839	-.4709
-1.8488	.0335	-.5508	.0850	-.7734	-.4445
-2.0208	.0645	-.4340	.1639	-.7633	-.4177
-2.1928	.0942	-.3172	.2392	-.7536	-.3905
-2.3648	.1222	-.2003	.3110	-.7443	-.3631
-2.5368	.1494	-.0835	.3793	-.7354	-.3355
-2.7088	.1750	.0333	.4444	-.7269	-.3079
-2.8808	.1992	.1501	.5060	-.7188	-.2803
-3.0528	.2222	.2669	.5645	-.7111	-.2527
-3.2248	.2440	.3830	.6197	-.7038	-.2251
-3.3968	.2644	.5000	.6717	-.6969	-.1975
-3.5688	.2837	.6174	.7205	-.6904	-.1700
-3.7408	.3017	.7342	.7663	-.6843	-.1425
-3.9128	.3185	.8510	.8099	-.6785	-.1150
-4.0848	.3340	.9679	.8505	-.6730	-.0875
-4.2568	.3480	1.0847	.8850	-.6678	-.0600
-4.4288	.3610	1.2015	.9104	-.6629	-.0325
-4.6008	.3735	1.3183	.9297	-.6583	-.0050
-4.7728	.3852	1.4351	.9430	-.6540	.0225
-4.9448	.3960	1.5520	.9510	-.6500	.0500
-5.1168	.4050	1.6688	.9540	-.6463	.0775
-5.2888	.4120	1.7856	.9520	-.6429	.1050
-5.4608	.4180	1.9024	.9460	-.6400	.1325
-5.6328	.4230	2.0192	.9360	-.6375	.1600
-5.8048	.4270	2.1360	.9220	-.6355	.1875
-5.9768	.4300	2.2528	.9050	-.6340	.2150
-6.1488	.4320	2.3696	.8850	-.6330	.2425
-6.3208	.4330	2.4864	.8620	-.6325	.2700
-6.4928	.4330	2.6032	.8360	-.6325	.2975
-6.6648	.4320	2.7200	.8080	-.6330	.3250
-6.8368	.4300	2.8368	.7780	-.6340	.3525
-7.0088	.4270	2.9536	.7460	-.6355	.3800
-7.1808	.4230	3.0704	.7130	-.6375	.4075
-7.3528	.4180	3.1872	.6790	-.6400	.4350
-7.5248	.4120	3.3040	.6440	-.6429	.4625
-7.6968	.4050	3.4208	.6080	-.6463	.4900
-7.8688	.3960	3.5376	.5710	-.6500	.5175
-8.0408	.3850	3.6544	.5330	-.6540	.5450
-8.2128	.3730	3.7712	.4940	-.6583	.5725
-8.3848	.3590	3.8880	.4540	-.6629	.6000
-8.5568	.3440	4.0048	.4130	-.6678	.6275
-8.7288	.3280	4.1216	.3710	-.6729	.6550
-8.9008	.3110	4.2384	.3280	-.6783	.6825
-9.0728	.2930	4.3552	.2840	-.6840	.7100
-9.2448	.2750	4.4720	.2390	-.6900	.7375
-9.4168	.2560	4.5888	.1930	-.6963	.7650
-9.5888	.2360	4.7056	.1460	-.7029	.7925
-9.7608	.2150	4.8224	.0990	-.7100	.8200
-9.9328	.1930	4.9392	.0510	-.7175	.8475
-10.1048	.1700	5.0560	.0030	-.7255	.8750
-10.2768	.1460	5.1728	-.0450	-.7340	.9025
-10.4488	.1210	5.2896	-.0970	-.7429	.9300
-10.6208	.0950	5.4064	-.1490	-.7523	.9575
-10.7928	.0680	5.5232	-.2010	-.7621	.9850
-10.9648	.0400	5.6400	-.2530	-.7723	.1025
-11.1368	.0120	5.7568	-.3050	-.7829	.1300
-11.3088	-.0160	5.8736	-.3570	-.7939	.1575
-11.4808	-.0440	5.9904	-.4090	-.8053	.1850
-11.6528	-.0720	6.1072	-.4610	-.8171	.2125
-11.8248	-.1000	6.2240	-.5130	-.8293	.2400
-11.9968	-.1280	6.3408	-.5650	-.8419	.2675
-12.1688	-.1560	6.4576	-.6170	-.8549	.2950
-12.3408	-.1840	6.5744	-.6690	-.8683	.3225
-12.5128	-.2120	6.6912	-.7210	-.8821	.3500
-12.6848	-.2400	6.8080	-.7730	-.8963	.3775
-12.8568	-.2680	6.9248	-.8250	-.9109	.4050
-13.0288	-.2960	7.0416	-.8770	-.9259	.4325
-13.2008	-.3240	7.1584	-.9290	-.9413	.4600
-13.3728	-.3520	7.2752	-.9810	-.9571	.4875
-13.5448	-.3800	7.3920	-.1030	-.9733	.5150
-13.7168	-.4080	7.5088	-.1550	-.9900	.5425
-13.8888	-.4360	7.6256	-.2070	-.1000	.5700
-14.0608	-.4640	7.7424	-.2590	-.1100	.5975
-14.2328	-.4920	7.8592	-.3110	-.1200	.6250
-14.4048	-.5200	7.9760	-.3630	-.1300	.6525
-14.5768	-.5480	8.0928	-.4150	-.1400	.6800
-14.7488	-.5760	8.2096	-.4670	-.1500	.7075
-14.9208	-.6040	8.3264	-.5190	-.1600	.7350
-15.0928	-.6320	8.4432	-.5710	-.1700	.7625
-15.2648	-.6600	8.5600	-.6230	-.1800	.7900
-15.4368	-.6880	8.6768	-.6750	-.1900	.8175
-15.6088	-.7160	8.7936	-.7270	-.2000	.8450
-15.7808	-.7440	8.9104	-.7790	-.2100	.8725
-15.9528	-.7720	9.0272	-.8310	-.2200	.9000
-16.1248	-.8000	9.1440	-.8830	-.2300	.9275
-16.2968	-.8280	9.2608	-.9350	-.2400	.9550
-16.4688	-.8560	9.3776	-.9870	-.2500	.9825
-16.6408	-.8840	9.4944	-.1030	-.2600	.1000
-16.8128	-.9120	9.6112	-.1550	-.2700	.1275
-16.9848	-.9400	9.7280	-.2070	-.2800	.1550
-17.1568	-.9680	9.8448	-.2590	-.2900	.1825
-17.3288	-.9960	9.9616	-.3110	-.3000	.2100
-17.5008	-.1020	10.0784	-.3630	-.3100	.2375
-17.6728	-.1280	10.1952	-.4150	-.3200	.2650
-17.8448	-.1540	10.3120	-.4670	-.3300	.2925
-18.0168	-.1800	10.4288	-.5190	-.3400	.3200
-18.1888	-.2060	10.5456	-.5710	-.3500	.3475
-18.3608	-.2320	10.6624	-.6230	-.3600	.3750
-18.5328	-.2580	10.7792	-.6750	-.3700	.4025
-18.7048	-.2840	10.8960	-.7270	-.3800	.4300
-18.8768	-.3100	11.0128	-.7790	-.3900	.4575
-19.0488	-.3360	11.1296	-.8310	-.4000	.4850
-19.2208	-.3620	11.2464	-.8830	-.4100	.5125
-19.3928	-.3880	11.3632	-.9350	-.4200	.5400
-19.5648	-.4140	11.4800	-.9870	-.4300	.5675
-19.7368	-.4400	11.5968	-.1030	-.4400	.5950
-19.9088	-.4660	11.7136	-.1550	-.4500	.6225
-20.0808	-.4920	11.8304	-.2070	-.4600	.6500
-20.2528	-.5180	11.9472	-.2590	-.4700	.6775
-20.4248	-.5440	12.0640	-.3110	-.4800	.7050
-20.5968	-.5700	12.1808	-.3630	-.4900	.7325
-20.7688	-.5960	12.2976	-.4150	-.5000	.7600
-20.9408	-.6220	12.4144	-.4670	-.5100	.7875
-21.1128	-.6480	12.5312	-.5190	-.5200	.8150
-21.2848	-.6740	12.6480	-.5710	-.5300	.8425
-21.4568	-.7000	12.7648	-.6230	-.5400	.8700
-21.6288	-.7260	12.8816	-.6750	-.5500	.8975
-21.8008	-.7520	12.9984	-.7270	-.5600	.9250
-21.9728	-.7780	13.1152	-.7790	-.5700	.9525
-22.1448	-.8040	13.2320	-.8310	-.5800	.9800
-22.3168	-.8300	13.3488	-.8830	-.5900	.1075
-22.4888	-.8560	13.4656	-.9350	-.6000	.1350
-22.6608	-.8820	13.5824	-.9870	-.6100	.1625
-22.8328	-.9080	13.6992	-.1030	-.6200	.1900
-23.0048	-.9340	13.8160	-.1550	-.6300	.2175
-23.1768	-.9600	13.9328	-.2070	-.6400	.2450
-23.3488	-.9860	14.0496	-.2590	-.6500	.2725
-23.5208	-.1020	14.1664	-.3110	-.6600	.3000
-23.6928	-.1280	14.2832	-.3630	-.6700	.3275
-23.8648	-.1540	14.4000	-.4150	-.6800	.3550
-24.0368	-.1800	14.5168	-.4670	-.6900	.3825
-24.2088	-.2060	14.6336	-.5190	-.7000	.4100
-24.3808	-.2320	14.7504	-.5710	-.7100	.4375
-24.5528	-.2580	14.8672	-.6230	-.7200	.4650
-24.7248	-.2840	14.9840	-.6750	-.7300	.4925
-24.8968	-.3100	15.1008	-.7270	-.7400	.5200
-25.0688	-.3360	15.2176	-.7790	-.7500	.5475
-25.2408	-.3620	15.3344	-.8310	-.7600	.5750
-25.4128	-.3880	15.4512	-.8830	-.7700	.6025
-25.5848	-.4140	15.5680	-.9350	-.7800	.6300
-25.7568	-.4400	15.6848	-.9870	-.7900	.6575
-25.9288	-.4660	15.8016	-.1030	-.8000	.6850
-26.1008	-.4920	15.9184	-.1550	-.8100	.7125
-26.2728	-.5180	16.0352	-.2070	-.8200	.7400
-26.4448	-.5440	16.1520	-.2590	-.8300	.7675
-26.6168	-.5700	16.2688	-.3110	-.8400	.7950
-26.7888	-.5960	16.3856	-.3630	-.8500	.8225
-26.9608	-.6220	16.5024	-.4150	-.8600	.8500
-27.1328	-.6480	16.6192	-.4670	-.8700	.8775
-27.3048	-.6740	16.7360	-.5190	-.8800	.9050
-27.4768	-.7000	16.8528	-.5710	-.8900	.9325
-27.6488	-.7260	16.9696	-.6230	-.9000	.9600
-27.8208	-.7520	17.0864	-.6750	-.9100	.9875
-27.9928	-.7780	17.2032	-.7270	-.9200	.1050
-28.1648	-.8040	17.3200	-.7790	-.9300	.1325
-28.3368	-.8300	17.4368	-.8310	-.9400	.1600
-28.5088	-.8560	17.5536	-.8830	-.9500	.1875
-28.6808	-.8820	17.6704	-.9350	-.9600	.2150
-28.8528	-.9080	17.7872	-.9870	-.9700	.2425
-29.0248	-.9340	17.9040	-.1030	-.9800	.2700
-29.1968	-.9600	18.0208	-.1550	-.9900	.2975
-29.3688	-.9860	18.1376	-.2070	-.1000	.3250
-29.5408	-.1020	18.2544	-.2590	-.1100	.3525
-29.712					

TABLE A-3.--Concluded

ROTOR AIRFOIL COORDINATES
SECTION NO. 14 RADIUS 6.642 IN. (16.871 CM.)

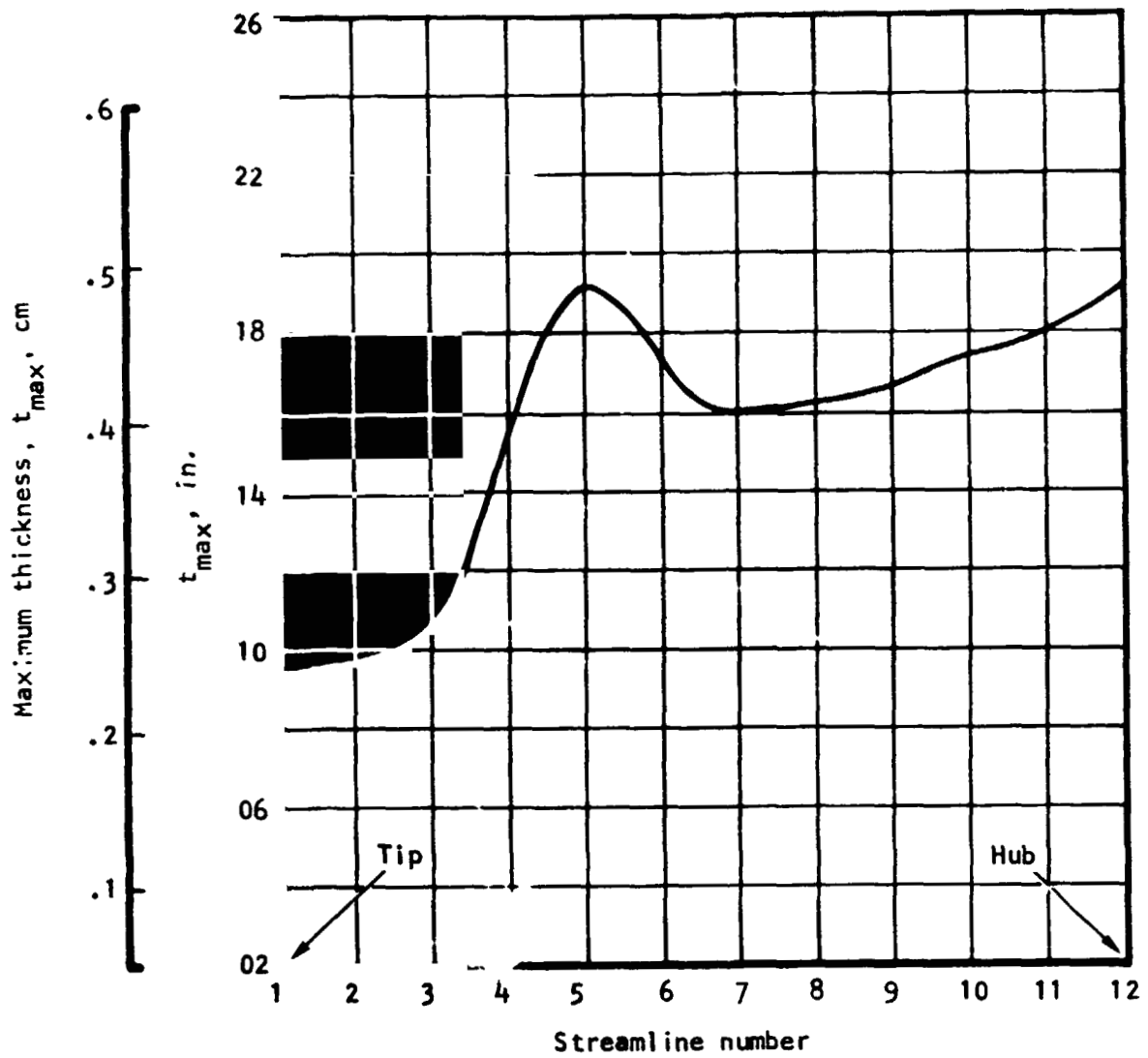
SUCTION SURFACE		PRESSURE SURFACE		PRESSURE SURFACE	
X IN.	Y IN.	X IN.	Y IN.	X IN.	Y IN.
-0.750	-0.639	-2.4765	-1.7372	-0.750	-0.639
-0.750	-0.634	-2.474	-1.7360	-0.743	-0.6843
-0.740	-0.675	-2.4780	-1.7210	-0.720	-0.6917
-0.714	-0.6775	-2.4674	-1.7044	-0.682	-0.6934
-0.674	-0.684	-2.4573	-1.6876	-0.633	-0.6952
-0.626	-0.609	-2.3408	-1.5264	-0.577	-0.6913
-0.575	-0.5403	-2.2243	-1.3723	-0.436	-0.6005
-0.526	-0.4826	-2.1078	-1.2257	-0.356	-0.6724
-0.480	-0.4276	-1.9913	-1.0861	-0.276	-0.6256
-0.431	-0.3752	-1.8748	-0.9529	-0.197	-0.5780
-0.382	-0.3253	-1.7583	-0.8263	-0.123	-0.5323
-0.334	-0.2779	-1.6418	-0.7058	-0.053	-0.4863
-0.285	-0.2327	-1.5253	-0.5910	-0.008	-0.4461
-0.236	-0.1898	-1.4088	-0.4821	-0.056	-0.4056
-0.188	-0.1491	-1.2923	-0.3834	-0.169	-0.3669
-0.140	-0.1106	-1.1758	-0.2909	-0.297	-0.3297
-0.170	-0.0741	-1.0593	-0.2083	-0.420	-0.2942
-0.212	-0.0396	-0.9427	-0.1307	-0.543	-0.2602
-0.253	-0.0070	-0.8263	-0.0578	-0.666	-0.2278
-0.294	-0.0238	-0.7098	-0.0095	-0.789	-0.1968
-0.336	-0.0524	-0.5932	-0.345	-0.912	-0.1672
-0.377	-0.0804	-0.4766	-0.693	-1.035	-0.1391
-0.418	-0.1063	-0.3602	-0.700	-1.158	-0.1123
-0.460	-0.1305	-0.2437	-0.315	-1.270	-0.0868
-0.501	-0.1531	-0.1272	-0.090	-0.763	-0.0626
-0.542	-0.042	-0.0107	-0.425	-0.256	-0.0397
-0.583	-0.1742	-0.1050	-0.921	-0.251	-0.0179
-0.624	-0.1938	-0.223	-0.758	-0.227	-0.027
-0.665	-0.2253	-0.338	-0.265	-0.221	-0.046
-0.706	-0.2569	-0.453	-0.181	-0.406	-0.221
-0.747	-0.2890	-0.5718	-0.279	-0.581	-0.4501
-0.788	-0.3210	-0.6803	-0.633	-0.750	-0.5769
-0.829	-0.3527	-0.789	-0.914	-0.914	-0.7077
-0.870	-0.3842	-0.898	-1.103	-1.073	-0.8345
-0.911	-0.4156	-1.007	-1.300	-1.225	-0.9653
-0.952	-0.4466	-1.116	-1.507	-1.370	-1.0941
-0.993	-0.4775	-1.225	-1.714	-1.517	-1.2229
-1.034	-0.5084	-1.334	-1.921	-1.664	-1.3517
-1.075	-0.5393	-1.443	-2.128	-1.811	-1.4804
-1.116	-0.5702	-1.552	-2.335	-1.958	-1.6092
-1.157	-0.6011	-1.661	-2.542	-2.105	-1.7380
-1.198	-0.6320	-1.770	-2.749	-2.252	-1.8668
-1.239	-0.6629	-1.879	-2.956	-2.400	-1.9956
-1.280	-0.6938	-1.988	-3.163	-2.547	-2.1244
-1.321	-0.7247	-2.097	-3.370	-2.694	-2.2532
-1.362	-0.7556	-2.206	-3.577	-2.841	-2.3820
-1.403	-0.7865	-2.315	-3.784	-2.988	-2.5108
-1.444	-0.8174	-2.424	-3.991	-3.135	-2.6396
-1.485	-0.8483	-2.533	-4.198	-3.282	-2.7684
-1.526	-0.8792	-2.642	-4.405	-3.429	-2.8972
-1.567	-0.9101	-2.751	-4.612	-3.576	-3.0260
-1.608	-0.9410	-2.860	-4.819	-3.723	-3.1548
-1.649	-0.9719	-2.969	-5.026	-3.870	-3.2836
-1.690	-1.0028	-3.078	-5.233	-4.017	-3.4124
-1.731	-1.0337	-3.187	-5.440	-4.164	-3.5412
-1.772	-1.0646	-3.296	-5.647	-4.311	-3.6700
-1.813	-1.0955	-3.405	-5.854	-4.458	-3.7988
-1.854	-1.1264	-3.514	-6.061	-4.605	-3.9276
-1.895	-1.1573	-3.623	-6.268	-4.752	-4.0564
-1.936	-1.1882	-3.732	-6.475	-4.899	-4.1852
-1.977	-1.2191	-3.841	-6.682	-5.046	-4.3140
-2.018	-1.2500	-3.950	-6.889	-5.193	-4.4428
-2.059	-1.2809	-4.059	-7.096	-5.340	-4.5716
-2.100	-1.3118	-4.168	-7.303	-5.487	-4.7004
-2.141	-1.3427	-4.277	-7.510	-5.634	-4.8292
-2.182	-1.3736	-4.386	-7.717	-5.781	-4.9580
-2.223	-1.4045	-4.495	-7.924	-5.928	-5.0868
-2.264	-1.4354	-4.604	-8.131	-6.075	-5.2156
-2.305	-1.4663	-4.713	-8.338	-6.222	-5.3444
-2.346	-1.4972	-4.822	-8.545	-6.369	-5.4732
-2.387	-1.5281	-4.931	-8.752	-6.516	-5.6020
-2.428	-1.5590	-5.040	-8.959	-6.663	-5.7308
-2.469	-1.5899	-5.149	-9.166	-6.810	-5.8596
-2.510	-1.6208	-5.258	-9.373	-6.957	-5.9884
-2.551	-1.6517	-5.367	-9.580	-7.104	-6.1172
-2.592	-1.6826	-5.476	-9.787	-7.251	-6.2460
-2.633	-1.7135	-5.585	-9.994	-7.398	-6.3748
-2.674	-1.7444	-5.694	-10.201	-7.545	-6.5036
-2.715	-1.7753	-5.803	-10.408	-7.692	-6.6324
-2.756	-1.8062	-5.912	-10.615	-7.839	-6.7612
-2.797	-1.8371	-6.021	-10.822	-7.986	-6.8900
-2.838	-1.8680	-6.130	-11.029	-8.133	-7.0188
-2.879	-1.8989	-6.239	-11.236	-8.280	-7.1476
-2.920	-1.9298	-6.348	-11.443	-8.427	-7.2764
-2.961	-1.9607	-6.457	-11.650	-8.574	-7.4052
-3.002	-1.9916	-6.566	-11.857	-8.721	-7.5340
-3.043	-2.0225	-6.675	-12.064	-8.868	-7.6628
-3.084	-2.0534	-6.784	-12.271	-9.015	-7.7916
-3.125	-2.0843	-6.893	-12.478	-9.162	-7.9204
-3.166	-2.1152	-7.002	-12.685	-9.309	-8.0492
-3.207	-2.1461	-7.111	-12.892	-9.456	-8.1780
-3.248	-2.1770	-7.220	-13.099	-9.603	-8.3068
-3.289	-2.2079	-7.329	-13.306	-9.750	-8.4356
-3.330	-2.2388	-7.438	-13.513	-9.897	-8.5644
-3.371	-2.2697	-7.547	-13.720	-10.044	-8.6932
-3.412	-2.3006	-7.656	-13.927	-10.191	-8.8220
-3.453	-2.3315	-7.765	-14.134	-10.338	-8.9508
-3.494	-2.3624	-7.874	-14.341	-10.485	-9.0796
-3.535	-2.3933	-7.983	-14.548	-10.632	-9.2084
-3.576	-2.4242	-8.092	-14.755	-10.779	-9.3372
-3.617	-2.4551	-8.201	-14.962	-10.926	-9.4660
-3.658	-2.4860	-8.310	-15.169	-11.073	-9.5948
-3.699	-2.5169	-8.419	-15.376	-11.220	-9.7236
-3.740	-2.5478	-8.528	-15.583	-11.367	-9.8524
-3.781	-2.5787	-8.637	-15.790	-11.514	-9.9812
-3.822	-2.6096	-8.746	-16.000	-11.661	-10.1100
-3.863	-2.6405	-8.855	-16.207	-11.808	-10.2388
-3.904	-2.6714	-8.964	-16.414	-11.955	-10.3676
-3.945	-2.7023	-9.073	-16.621	-12.102	-10.4964
-3.986	-2.7332	-9.182	-16.828	-12.249	-10.6252
-4.027	-2.7641	-9.291	-17.035	-12.396	-10.7540
-4.068	-2.7950	-9.400	-17.242	-12.543	-10.8828
-4.109	-2.8259	-9.509	-17.449	-12.690	-11.0116
-4.150	-2.8568	-9.618	-17.656	-12.837	-11.1404
-4.191	-2.8877	-9.727	-17.863	-12.984	-11.2692
-4.232	-2.9186	-9.836	-18.070	-13.131	-11.3980
-4.273	-2.9495	-9.945	-18.277	-13.278	-11.5268
-4.314	-2.9804	-10.054	-18.484	-13.425	-11.6556
-4.355	-3.0113	-10.163	-18.691	-13.572	-11.7844
-4.396	-3.0422	-10.272	-18.898	-13.719	-11.9132
-4.437	-3.0731	-10.381	-19.105	-13.866	-12.0420
-4.478	-3.1040	-10.490	-19.312	-14.013	-12.1708
-4.519	-3.1349	-10.599	-19.519	-14.160	-12.2996
-4.560	-3.1658	-10.708	-19.726	-14.307	-12.4284
-4.601	-3.1967	-10.817	-19.933	-14.454	-12.5572
-4.642	-3.2276	-10.926	-20.140	-14.601	-12.6860
-4.683	-3.2585	-11.035	-20.347	-14.748	-12.8148
-4.724	-3.2894	-11.144	-20.554	-14.895	-12.9436
-4.765	-3.3203	-11.253	-20.761	-15.042	-13.0724
-4.806	-3.3512	-11.362	-20.968	-15.189	-13.2012
-4.847	-3.3821	-11.471	-21.175	-15.336	-13.3300
-4.888	-3.4130	-11.580	-21.382	-15.483	-13.4588
-4.929	-3.4439	-11.689	-21.589	-15.630	-13.5876
-4.970	-3.4748	-11.798	-21.796	-15.777	-13.7164
-5.011	-3.5057	-11.907	-22.003	-15.924	-13.8452
-5.052	-3.5366	-12.016	-22.210	-16.071	-13.9740
-5.093	-3.5675	-12.125	-22.417	-16.218	-14.1028
-5.134	-3.5984	-12.234	-22.624	-16.365	-14.2316
-5.175	-3.6293	-12.343	-22.831	-16.512	-14.3604
-5.216	-3.6602	-12.452	-23.038	-16.659	-14.4892
-5.257	-3.6911	-12.561	-23.245	-16.806	-14.6180
-5.298	-3.7220	-12.670	-23.452	-16.953	-14.7468
-5.339	-3.7529	-12.779	-23.659	-17.100	-14.8756
-5.380	-3.7838	-12.888	-23.866	-17.247	-15.0044
-5.421	-3.8147	-12.997	-24.073	-17.394	-15.1332
-5.462	-3.8456	-13.106	-24.280	-17.541	-15.2620
-5.503	-3.8765	-13.215	-24.487	-17.688	-15.3908
-5.544	-3.9074	-13.324	-24.694	-17.835	-15.5196
-5.585	-3.9383	-13.433	-24.901	-17.982	-15.6484
-5.626	-3.9692	-13.542	-25.108	-18.129	-15.7772
-5.667	-4.0001	-13.651	-25.315	-18.276	-15.9060
-5.708	-4.0310	-13.760	-25.522	-18.423	-16.0348
-5.749	-4.0619	-13.869	-25.729	-18.570	-16.1636
-5.790	-4.0928	-13.978	-25.936	-18.717	-16.2924
-5.831	-4.1237	-14.087	-26.143	-18.864	-16.4212
-5.872	-4.1546	-14.196	-26.350	-19.011	-16.5500
-5.913	-4.1855	-14.305	-26.557	-19.158	-16.6788
-5.954	-4.2164	-14.414	-26.764	-19.305	-16.8076
-5.995	-4.2473	-14.523	-26.971	-19.452	-16.9364
-6.036	-4.2782	-14.632	-27.178	-19.599	-17.0652
-6.077	-4.3091	-14.741	-27.385	-19.746	-17.1940
-6.118	-4.3400	-14.850	-27.592	-19.893	-17.3228
-6.159	-4.3709	-14.959	-27.799	-20.040	-17.4516
-6.200	-4.4018	-15.068	-28.006	-20.187	-17.5804
-6.241	-4.4327	-15.177	-28.213	-20.334	-17.7092
-6.282	-4.4636	-15.286	-28.420	-20.481	-17.8380
-6.323	-4.4945	-15.395	-28.627	-20.628	-17.9668
-6.364	-4.5254	-15.504	-28.834	-20.775	-18.0956
-6.405	-4.5563	-15.613	-29.041	-20.922	-18.2244
-6.446	-4.5872	-15.722	-29.248	-21.069	-18.3532
-6.487	-4.6181	-15.831	-29.455	-21.216	-18.4820
-6.528	-4.6490	-15.940	-29.662	-21.363	-18.6108
-6.569	-4.6799	-16.049	-29.869	-21.510	-18.7396
-6.610	-4.7108	-16.158	-30.076	-21.657	-18.8684
-6.651	-4.7417	-16.267	-30.283	-21.804	-18.9972
-6.69					

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

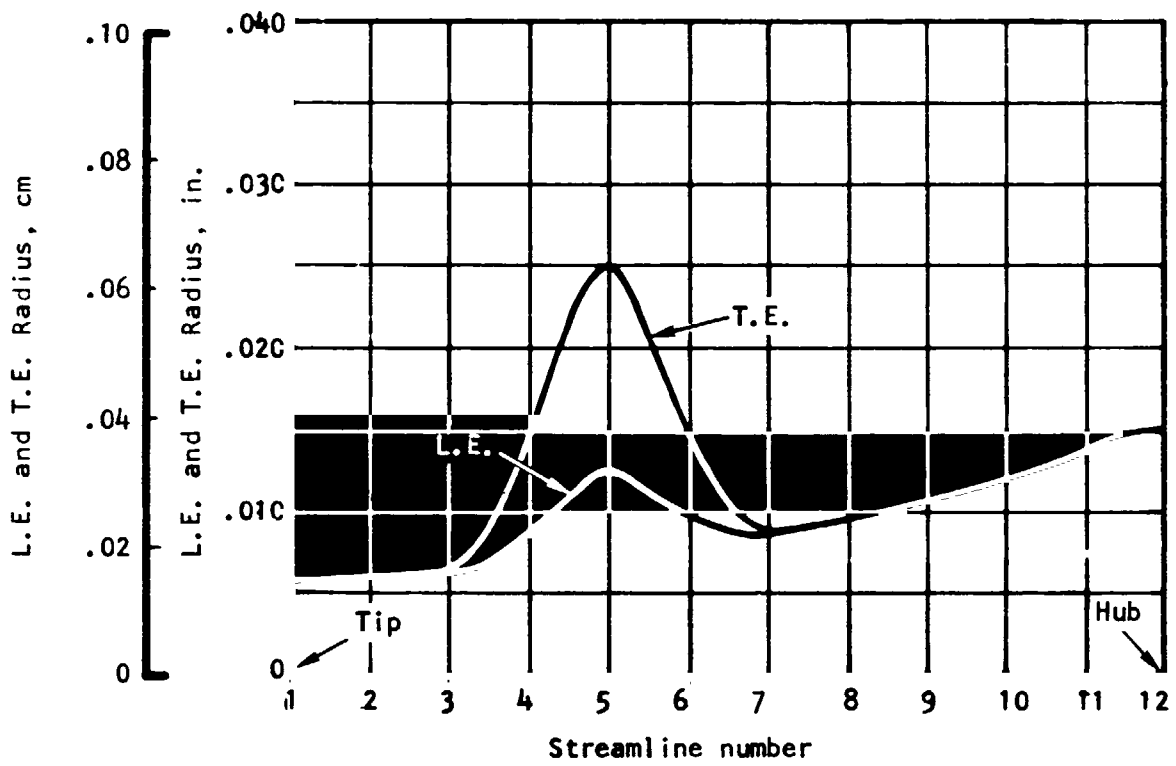
Notes:

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.



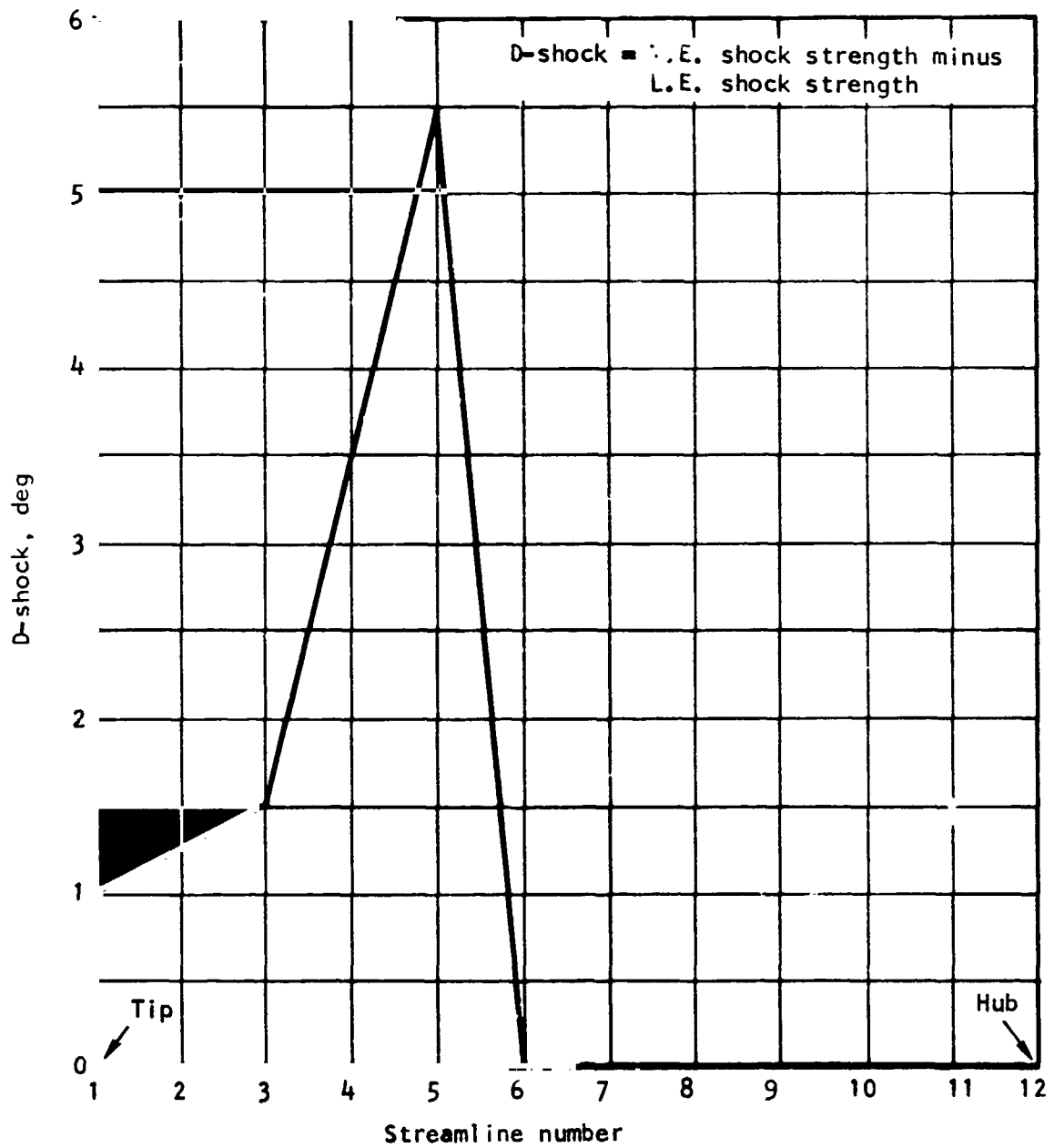
S-80697

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



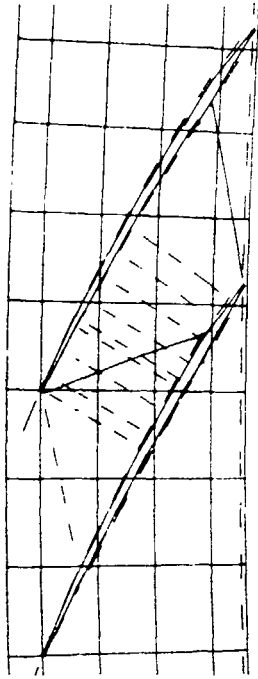
S-80561

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

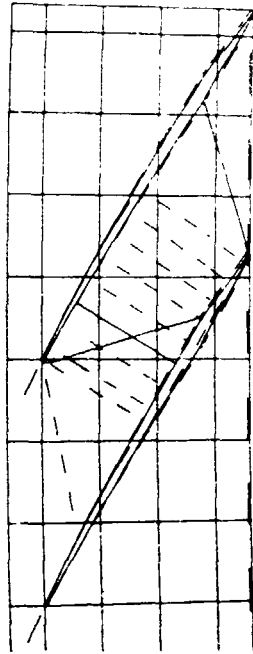


S-80558

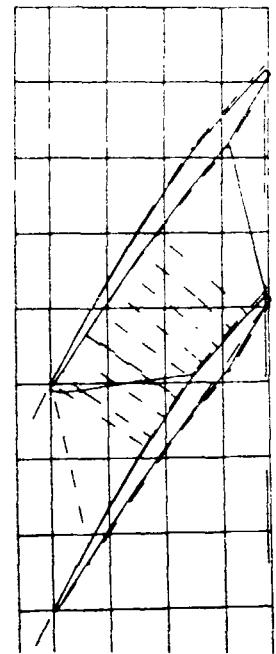
Figure A-3.--Rotor Blade Trailing-Edge Shock Strength Minus Leading-Edge Shock Strength.



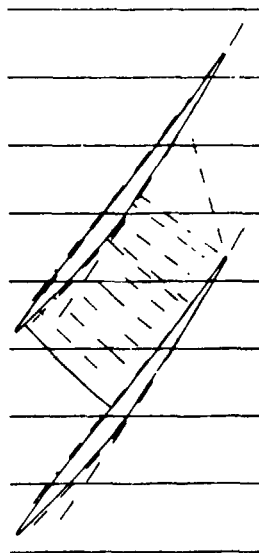
Streamline 1



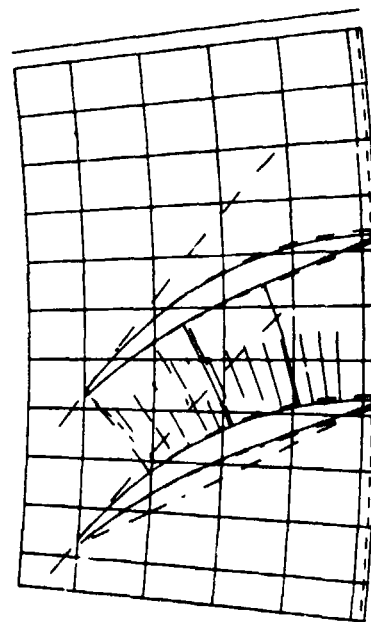
Streamline 3



Streamline 5



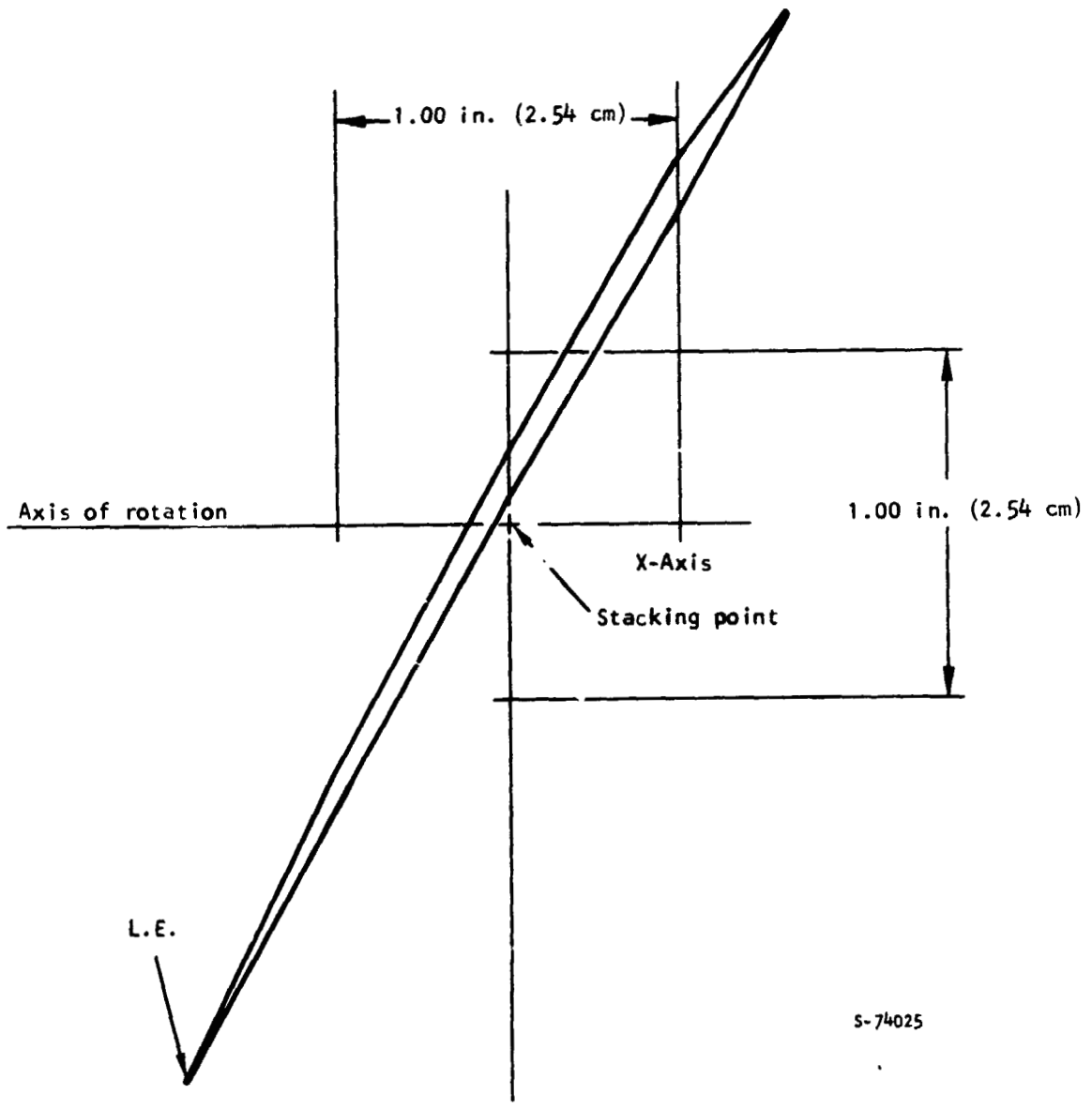
Streamline 7



Streamline 12

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



S-74025

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

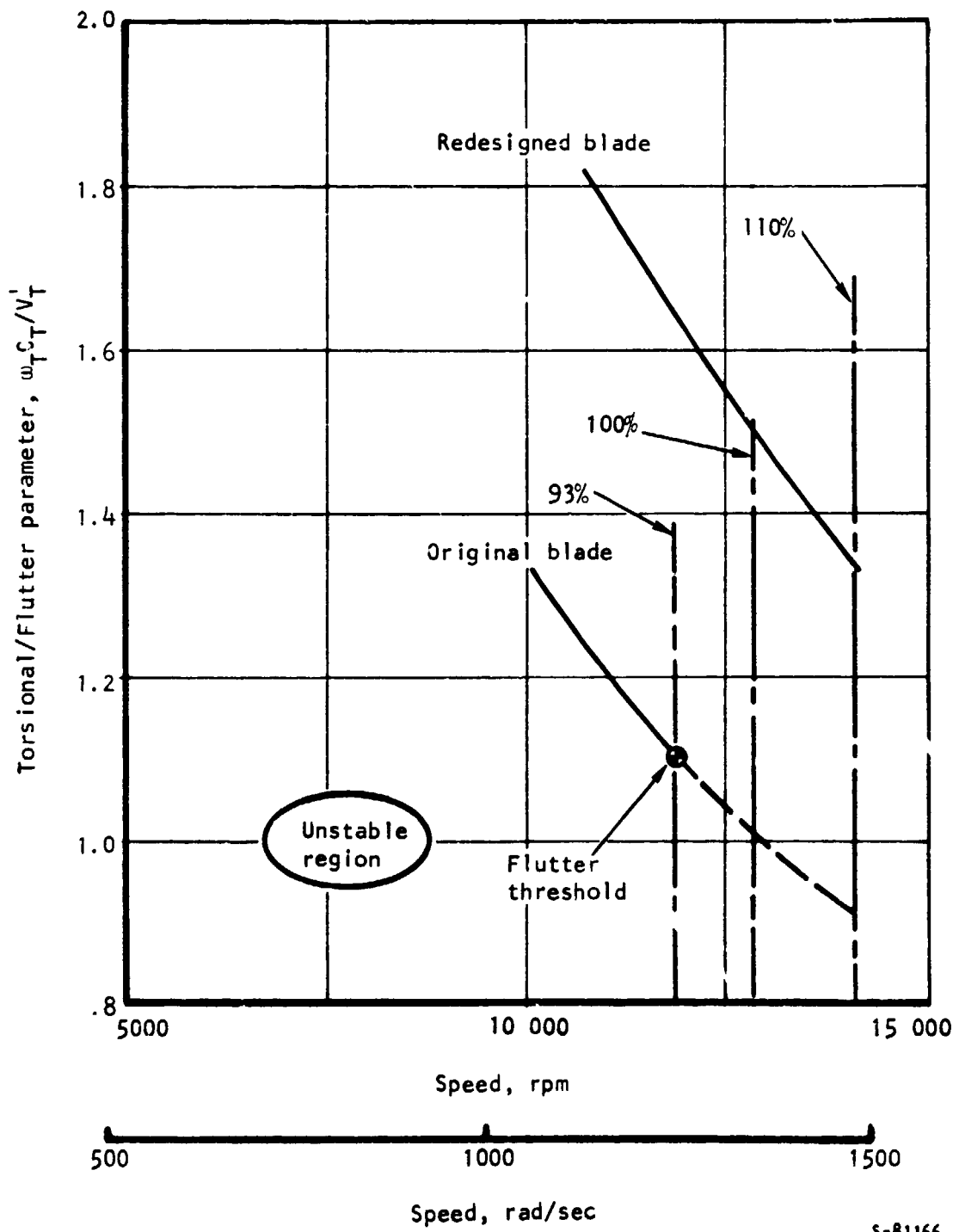
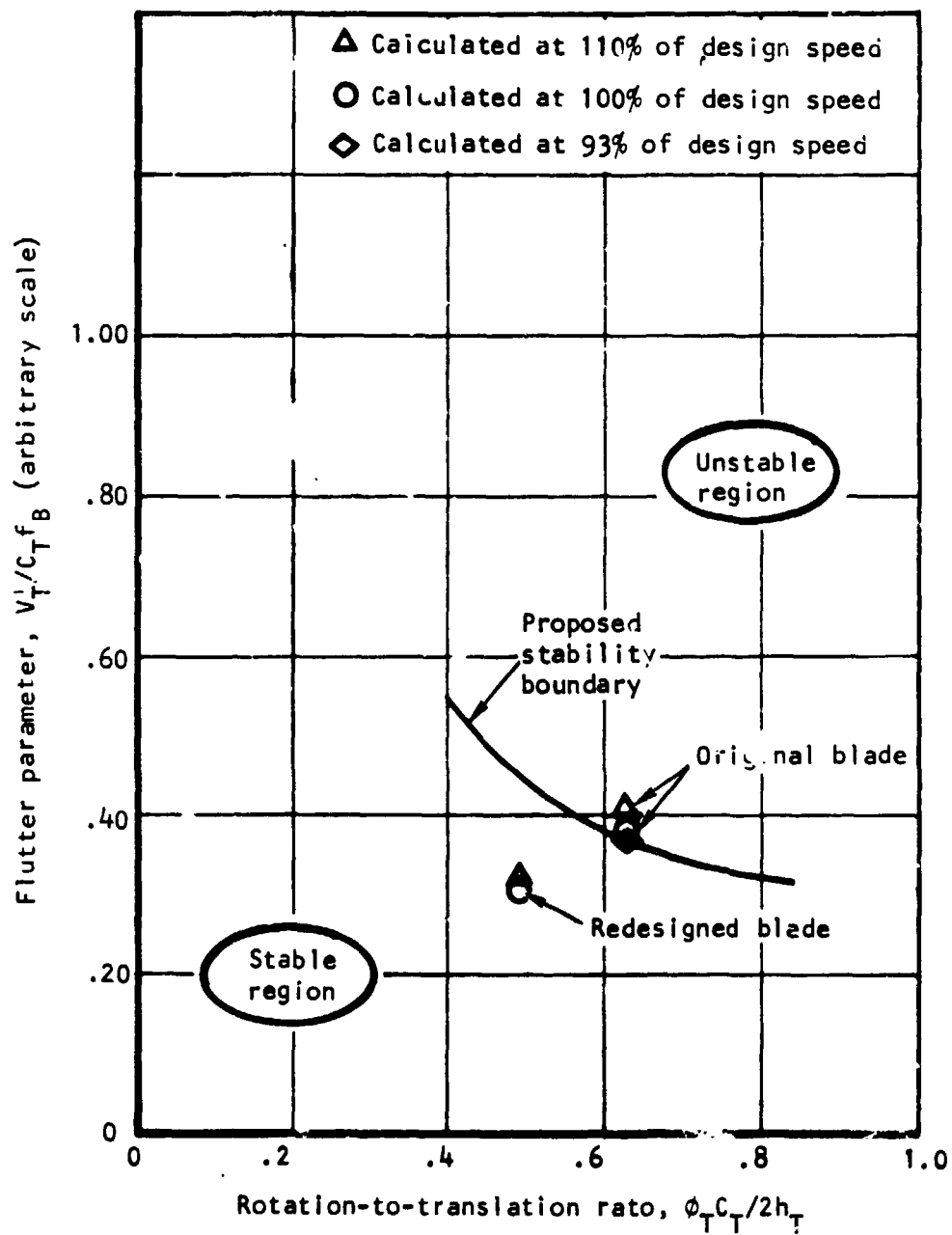


Figure A-6.--Fan Blade Torsional Flutter Parameter.



S-80629

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

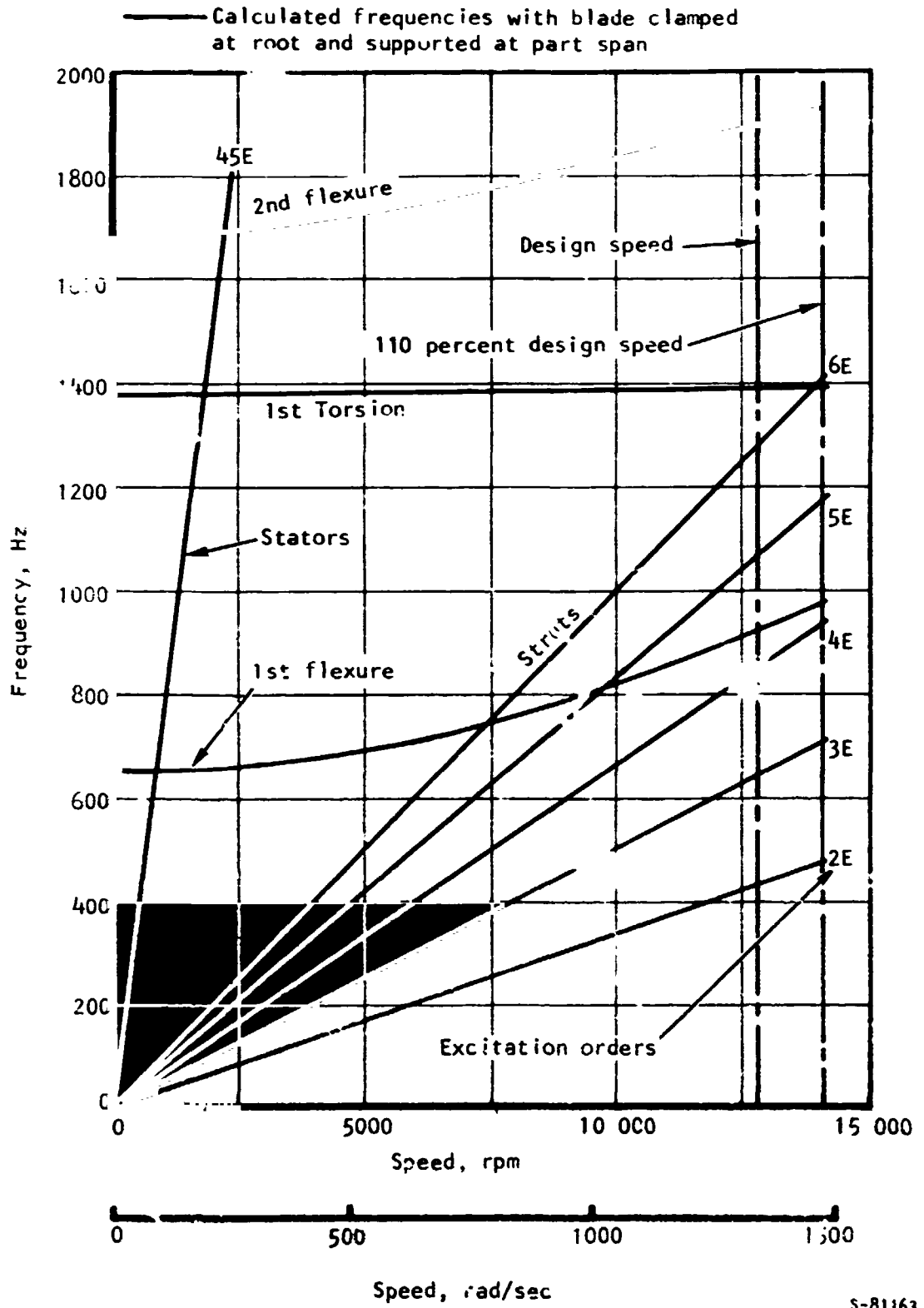
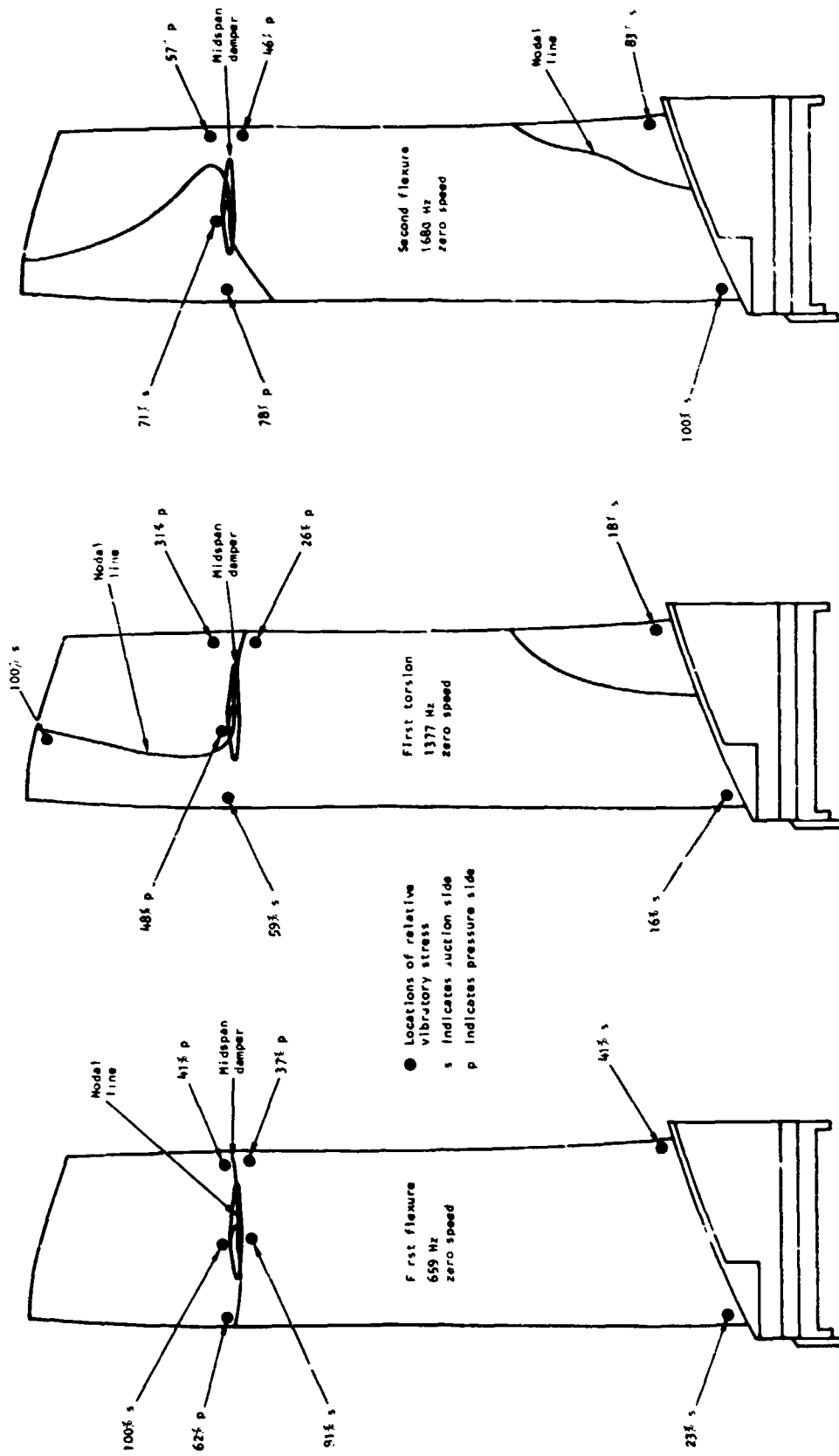
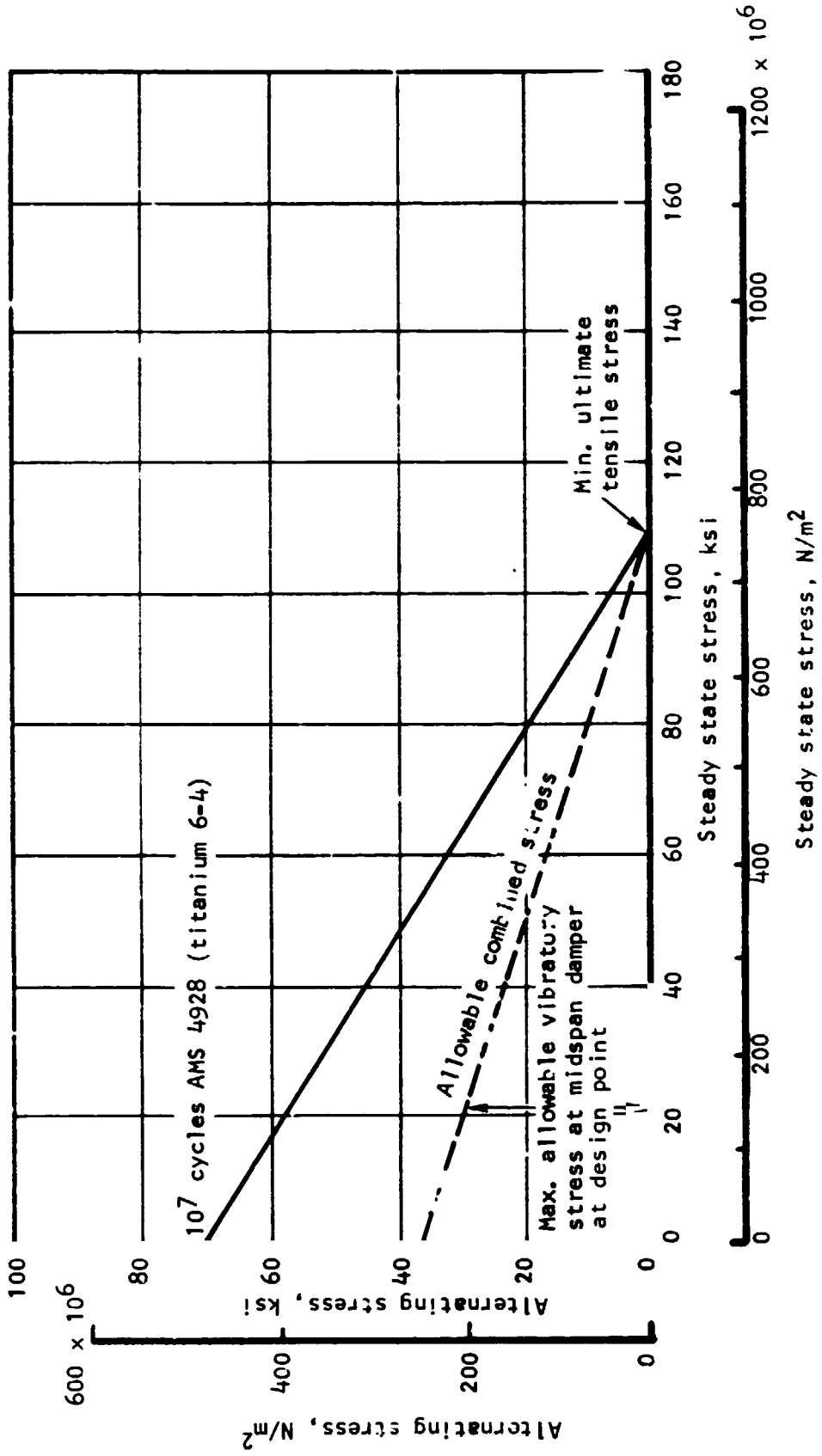


Figure A-8.--Fan Blade Excitation Diagram.



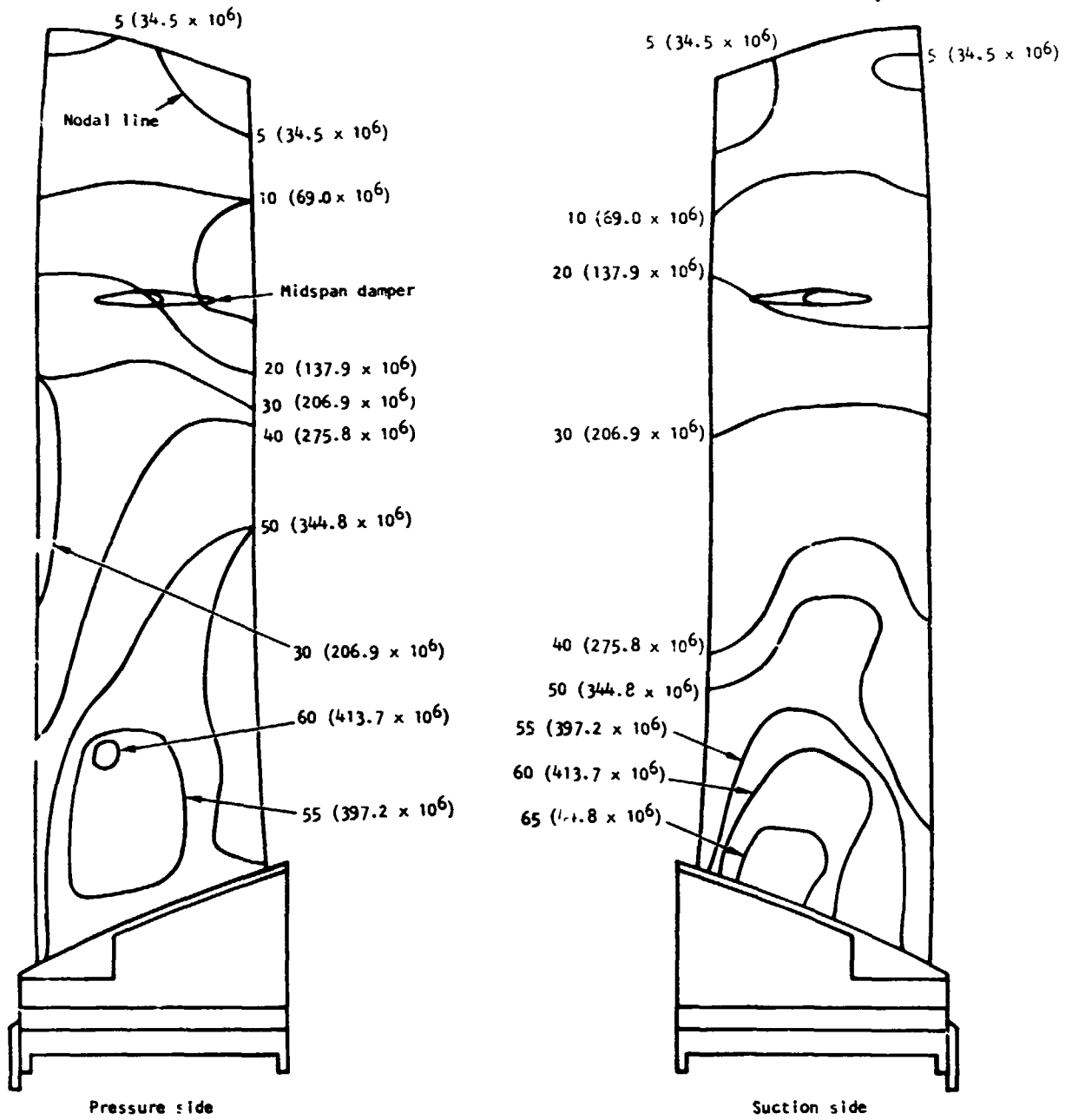
S-84112

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



S-80644

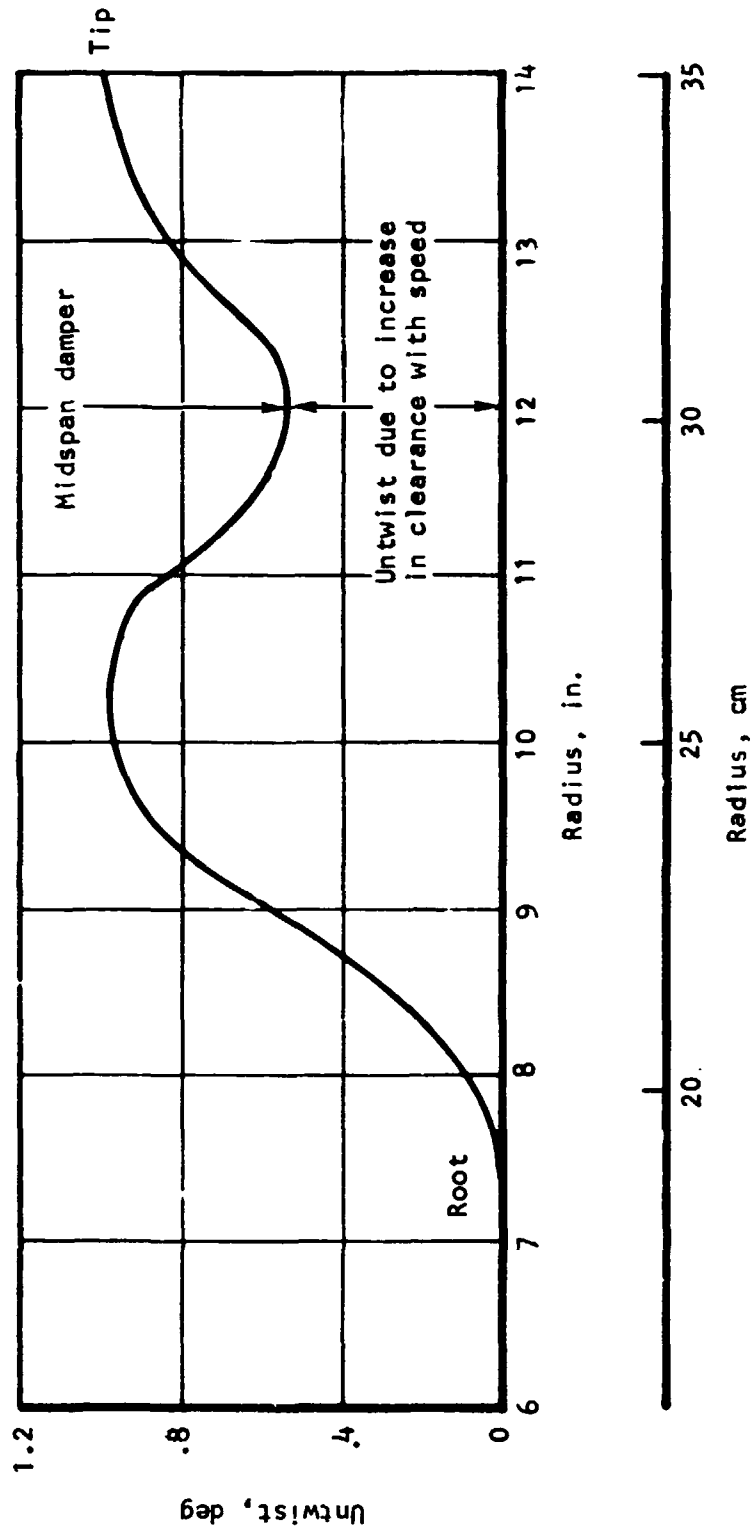
Figure A-10.--Blade Goodman-Solderburg Diagram.



Stresses in ksi (N/m^2)
 $N = 12\ 800\ rpm\ (1340.5\ rad/sec)$
 (100%)
 Aerodynamic design point loads included

S-1157

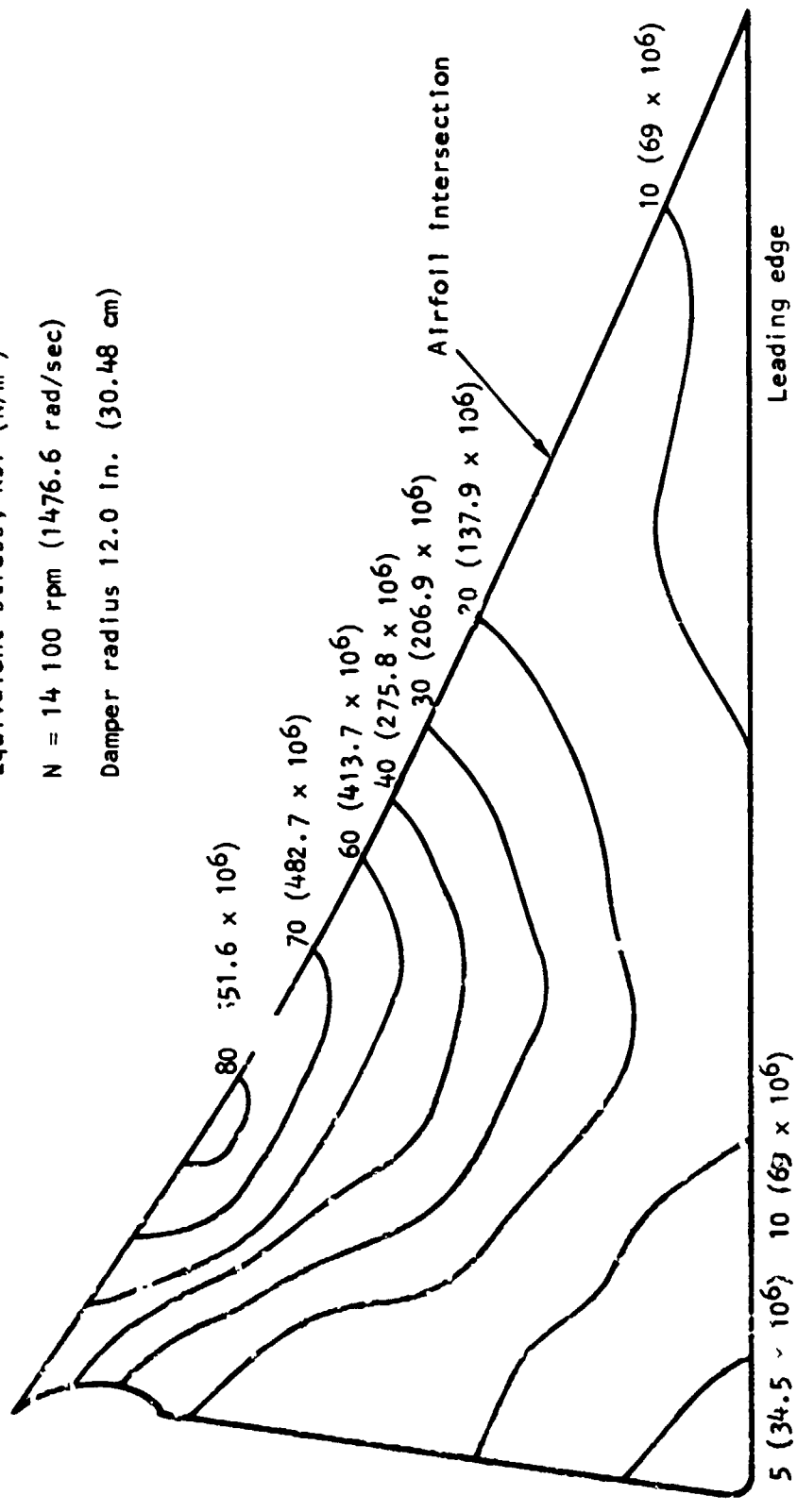
Figure A-11.--Fan Blade Equivalent Steady Stress Distribution.



S-80653

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

Equivalent stress, ksi (N/m²)
 N = 14 100 rpm (1476.6 rad/sec)
 Damper radius 12.0 in. (30.48 cm)



S-80517

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

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 (rotor)

$$\delta^0 = \beta_8' - \beta_8'^*$$

$$\delta^0 = \beta_{11} - \beta_{11}^*$$

(stator)

D diffusion factor (rotor)

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

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

(stator)

$\bar{\omega}$ loss coefficient (rotor)

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

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

$$\bar{\omega} = \frac{P_{10} - P_{11}}{P_{10} - p_{10}}$$

(stator)

loss parameter (rotor)

$$\frac{\bar{\omega} \cos \beta_8'}{2\sigma}$$

$$\frac{\bar{\omega} \cos \beta_{11}}{2\sigma}$$

(stator)

η_{poly} polytropic efficiency

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

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

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

η_{ad} adiabatic efficiency

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

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

SM

stall margin

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

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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