OVERALL AND BLADE ELEMENT PERFORMANCE
OF A 1.20 PRESSURE RATIO FAN STAGE
WITH ROTOR BLADES RESET -7°

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A 51-cm-diam model of a fan stage for short-haul-type aircraft was tested in the Lewis single-stage compressor research facility. This stage was designed and built on contract by the Hamilton Standard Division of United Technologies Corporation. In the present study the rotor blades were set 7° toward the axial direction (opened) from the design setting angle. Surveys of the air flow conditions ahead of the rotor, between the rotor and stator, and behind the stator were made over the stable operating range of the stage. At the design speed and a weight flow of 30.9 kg/sec, the stage pressure ratio and efficiency were 1.205 and 0.85, respectively. The design speed rotor peak efficiency of 0.90 occurred at a flow rate of 32.5 kg/sec.
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SUMMARY

A 51-centimeter-diameter model of a fan stage for short-haul aircraft was tested in a single-stage compressor research facility at Lewis. This stage was designed and built on contract by the Hamilton Standard Division of United Technologies Corporation. In the present study the rotor blades, which were adjustable through axial position, were set $7^\circ$ toward the axial direction (opened) from design setting angle. Surveys of the air flow conditions ahead of the rotor, between the rotor and stator, and behind the stator were made over the stable operating range of the stage. At the design speed of 213.3 meters per second and weight flow of 30.9 kilograms per second, the stage pressure ratio was 1.205 and the efficiency was 0.85. The design speed rotor peak efficiency of 0.90 occurred at a flow rate of 32.5 kilograms per second.

INTRODUCTION

NASA is currently evaluating short-haul aircraft for commercial application. These aircraft must have an efficient and reliable propulsion system satisfying the low-noise requirements for urban communities. The aircraft engines must be capable of a variety of operating conditions: take-off, cruise, approach, and thrust reversal on landing.

In support of this program the Lewis Research Center is investigating a variety of fan compressor inlet stages. These stages provide the potential for high bypass flows in aircraft engines. The Hamilton Standard Division of United Technologies Corporation has designed a fan stage under contract from which two stages were built with adjustable rotor blades: a 197-centimeter-diameter version for acoustic studies (ref. 1) and a 51-centimeter-diameter stage for aerodynamic studies. Overall performance for this
stage at three rotor blade setting angles was reported in reference 2. Results indicated that the overall performance changed with rotor blade setting angle. The overall and blade-element performances at design and design $-5^\circ$ rotor blade setting angles were presented in references 3 and 4, respectively. This report presents the overall and blade-element performance results for the stage with rotor blades set at design $-7^\circ$. Data are presented over the stable operating range at 3 speeds: 80, 90, and 100 percent of design speed. The data in this report are presented in plotted and in tabular form. The symbols and equations are defined in appendixes A and B. The tests were conducted in the single-stage compressor test facility at Lewis.

APPARATUS AND PROCEDURE

Compressor Test Facility

The compressor stage was tested in the single-stage compressor facility, which is described in detail in reference 5 and shown schematically in figure 1. Atmospheric air enters the test facility at an inlet located on the roof of the building, passes through the flow measuring orifice and into the plenum chamber upstream of the test stage. The air then passes through the experimental compressor stage into the collector and is exhausted to the atmosphere. Weight flow is controlled by a sleeve valve located in the discharge collector.

The adjustable rotor blade test stage was designed and built by Hamilton Standard. A detailed description of the aerodynamic design was presented in reference 3. The design tables are presented herein (tables I to V) for convenience, and the flow path is shown in figure 2. The definitions and units used for the tabular data are presented in appendix C. Briefly, the fan stage was designed for a pressure ratio of 1.20, a rotor tip speed of 213.3 meters per second, and a weight flow per unit annulus area of 195.3 kilograms per second per square meter. For the present test the rotor blades were opened $7^\circ$, and this configuration is designated stage 55B–55. The design tables do not reflect the $7^\circ$ reset.

Instrumentation

The compressor weight flow was determined from measurements on a calibrated thin-plate orifice. The orifice temperature was determined from an average of two Chromel–Constantan thermocouples. Orifice pressures were measured by calibrated transducers.
Radial surveys of the flow were made upstream of the rotor, between the rotor and stator, and downstream of the stator (see fig. 2 for axial location). Total pressure, total temperature, and flow angle were measured with the combination probe (fig. 3(a)), and the static pressure was measured with a $8^\circ$ C-shaped wedge probe (fig. 3(b)). Each probe was equipped with a null-balancing, control system. The thermocouple material was Chromel-Constantan. Two combination probes and two wedge static probes were used at each of the three measuring stations.

Inner and outer wall static-pressure taps were located at the same axial stations as the survey probes. The circumferential locations of both types of survey probes along with inner and outer wall static-pressure taps are shown in figure 4. An electronic speed counter, in conjunction with a magnetic pickup, was used to measure rotative speed (rpm). The estimated errors of the data, based on inherent accuracies of the instrumentation and recording systems, are as follows:

- Flow, kg/sec: ±0.3
- Rotative speed, rpm: ±30
- Flow angle, deg: ±1
- Temperature, K: ±0.6
- Rotor-inlet total pressure, N/cm$^2$: ±0.01
- Rotor-outlet total pressure, N/cm$^2$: ±0.10
- Stator-outlet total pressure, N/cm$^2$: ±0.10
- Rotor-inlet static pressure, N/cm$^2$: ±0.04
- Rotor-outlet static pressure, N/cm$^2$: ±0.07
- Stator-outlet static pressure, N/cm$^2$: ±0.07

Test Procedure

The stage survey data were taken over a range of weight flow from maximum flow to the near-stall conditions. At 80, 90, and 100 percent of design speed, radial surveys were taken at five weight flows. Data were recorded at nine radial positions for each speed and weight flow.

At each radial position the two combination probes behind the stator were circumferentially traversed to nine different locations across the stator gap. The wedge probes were set at midgap because preliminary studies showed that the static pressure across the stator gap was constant. Values of total pressure, total temperature, and flow angle were recorded at each circumferential position. At the last circumferential position, values of pressure, temperature, and flow angle were also recorded at stations 1 and 2. All probes were then moved to the next radial position, and the circumferential traverse procedure repeated.
Stall was determined at each rotative speed by closing the sleeve valve in the collector until an abrupt drop in total-pressure ratio occurred. Survey data were obtained at a weight flow within 1/2 kilogram of actual stall weight flow.

Calculation Procedure

Measured total temperatures and total pressures were corrected for Mach number and streamline slope. These corrections were based on the instrument probe calibrations given in reference 6. The stream static pressure was corrected for Mach number and streamline slope based on an average calibration for the type of probe used.

Because of the physical construction of the C-shaped static-pressure wedges, it was not possible to obtain static-pressure measurements at 5, 10, and 95 percent of span from the rotor tip. The static pressure at 95 percent span was obtained by assuming a linear variation in static pressure between the values at the inner wall and the probe measurement at 90 percent span. A similar variation was assumed between the static-pressure measurements at the outer wall and the 15-percent span position to obtain the static pressure at 5 and 10 percent spans positions.

At each radial position averaged values of the nine circumferential measurements of total pressure, temperature, and flow angle downstream of the stator (station 3) were obtained. The nine values of total temperature were mass averaged to obtain the stage total-temperature rise. The nine values of total pressure were energy averaged. The measured values of pressure, temperature, and flow angle were used to calculate axial and tangential velocities at each circumferential position. The flow angles presented for each radial position are calculated based on the mass-average of the axial and tangential velocities. To obtain the overall performance, the radial values of total temperature were mass averaged, and the values of total pressure were energy averaged. At each measuring station the integrated weight flow was computed based on the radial survey data. The data, measured at the three measuring stations, have been translated to planes approximating the blade leading and trailing edges by the method presented in reference 7.

Orifice weight flow, total pressures, static pressures, and temperatures were all corrected to sea-level standard-day conditions based on the rotor inlet conditions.

RESULTS AND DISCUSSION

The results from this investigation will be presented in three main sections. The overall performances for the rotor and the stage are given first. Radial distributions
of several performance parameters are then presented for the rotor and stator followed by the blade-element data. The data presented are computer plotted, and occasionally a data point will be omitted because it falls outside the range of the parameters shown in the figure. A brief discussion of the results is included.

All the plotted data, together with some additional performance parameters, are listed in tabular form. The overall performance data are presented in table VI. The blade-element data are given first for the rotor and then for the stator in tables VII and VIII. The abbreviations and units used for the tabular data are defined in appendix C.

Overall Performance

The overall performance for rotor 55B and stage 55B-55 are presented in figures 5 and 6, respectively. Data are presented for 80, 90, and 100 percent of design speed. At each speed line data were taken at five values of weight flow from choke to the near-stall conditions. Design-point values for the original design blade setting angle are shown as solid symbols in both figures for reference purposes and assessment of test results.

**Rotor.** - The peak efficiency for rotor 55B at design speed was 0.90 and occurred at a weight flow of 32.5 kilograms per second (203 (kg/sec)/m² annulus area). Corresponding values of total-pressure ratio and total-temperature ratio are 1.220 and 1.065, respectively. A peak rotor efficiency of 0.933 occurs at 80 percent of design speed.

**Stage.** - The peak efficiency for stage 55B-55 at design speed was 0.85 and occurred at a pressure ratio of 1.205 and a weight flow of 30.9 kilograms per second. Peak stage efficiency of 0.91 occurred at 80 percent of design speed.

Radial Distributions

The radial distributions of several parameters are presented at design speed in figure 7 for rotor 55B and in figure 8 for stator 55. In each figure data are presented for three weight flows: near maximum, peak efficiency, and near stall. Temperature-rise efficiency, temperature ratio, pressure ratio, mean incidence angle, meridional velocity ratio, deviation angle, total-loss parameter, total-loss coefficient, and diffusion factor are presented as functions of percent span from the blade tip. The design values for the original stage are shown as solid symbols and are included for reference only. A line is drawn through the data for the peak efficiency weight flow of 30.9 kilograms per second.
**Rotor.** - At design speed and a weight flow of 30.9 kilograms per second, the energy input was slightly greater than reference values at all span locations, and the pressure ratio is greater except at the 10 and 15 percent spans where reference and measured values are close or equal. At this weight flow the blading is operating at a high incidence angle and the total-pressure loss coefficients are high at all radial stations as compared with the reference values. At the near stall weight flow of 27.8 kilograms per second, high total-pressure loss coefficients and loading is measured from the rotor tip through 30 percent span.

**Stator.** - At design speed and stage peak efficiency flow (fig. 8) the stator losses are high from the blade tip to the 30 percent span, comparable to reference at 50 and 70 percent spans, and low from 85 percent span to the hub. Incidence angles across the span are higher than the reference values. Blade loading is greater than reference values at the blade tip region and lower in the hub region. With decreasing weight flow greater loading occurs across the blade span and losses decrease from the tip to 15 percent span and increase from 30 percent span to the hub.

**Variations With Incidence Angle**

The variations of blade-element performance parameters with incidence angle are shown in figure 9 for rotor 55B and in figure 10 for stator 55. The data are presented for 80 and 100 percent of design speed at blade elements located at 5, 10, 30, 50, 70, 90, and 95 percent of blade span as measured from the rotor outlet blade tip. Referenced values are indicated by solid symbols.

**Rotor.** - The 7° reset shifts the rotor incidence angle to higher positive values than reference for both 80 and 100 percent speeds. Design speed energy addition equalled or exceeded the referenced value over the entire incidence angle range. The total-pressure ratio also equalled or exceeded the reference values at all span locations except at the 5 and 10 percent spans where pressure ratio fell off at the maximum and minimum incidence angle. Minimum total-pressure loss coefficient occurs near or at minimum incidence angle at the 5, 10, and 30 percent spans. The total-pressure loss coefficients are low and indicate little change with incidence angle at the 50 and 70 percent span. At the hub (90 and 95 percent span) total-pressure loss coefficients are high at low incidence angle and decrease with increasing incidence angle.

**Stator.** - The stator performance with incidence angle is presented in figure 10 for 80 and 100 percent of design speeds. The highest total-pressure loss coefficients occurred at the 5 percent span at maximum flow for both speeds, and this loss coefficient decreased rapidly with increasing incidence angle at the 5, 10, and 30 percent spans.
At 90 and 95 percent spans total-pressure loss coefficients are lower than reference values over the incidence angle range.

SUMMARY OF RESULTS

This report presents the aerodynamic design, the overall performance, and blade-element performance of 51-centimeter-diameter fan stage suitable for application in short-haul aircraft. Radial surveys of the flow conditions at the rotor inlet, rotor outlet, and stator outlet were made over the stable operating flow range of the stage at equivalent rotative speeds from 80 to 100 percent of design speed. Weight flow and performance parameters were calculated across nine selected blade elements. The following principle results were obtained:

1. The stage design speed peak efficiency of 0.85 was obtained at a weight flow of 30.9 kilograms per second and a pressure ratio of 1.20. Peak design speed rotor efficiency of 0.90 occurs at 32.5 kilograms per second and at a pressure ratio of 1.220.

2. The energy input across the rotor span exceeds the reference values at design speed and weight flow. The total-pressure loss coefficient at this condition is larger than the reference values across the span.

3. Design speed stator total-pressure loss coefficients are high at low incidence angles at the 5, 10, and 30 percent spans and decrease rapidly with increasing incidence angle. Losses in the hub region are generally lower than the reference values.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, October 2, 1975,
505-04.
APPENDIX A

SYMBOLS

\( A_{an} \)  annulus area at rotor leading edge
\( A_f \)  frontal area at rotor leading edge
\( C_p \)  specific heat at constant pressure
\( c \)  aerodynamic chord, cm
\( D \)  diffusion factor
\( i_{mc} \)  mean incidence angle, angle between inlet air direction and line tangent to blade mean camber line at leading edge, deg
\( N \)  rotative speed, rpm
\( P \)  total pressure, \( \text{N/cm}^2 \)
\( P \)  static pressure, \( \text{N/cm}^2 \)
\( r \)  radius, cm
\( t \)  total temperature, K
\( U \)  wheel speed, m/sec
\( V \)  air velocity, m/sec
\( W \)  weight flow, kg/sec
\( Z \)  axial distance references from rotor blade hub leading edge, cm
\( \alpha_c \)  cone angle, deg
\( \alpha_s \)  slope of streamline, deg
\( \beta \)  air angle, angle between air velocity and axial direction, deg
\( \beta'_c \)  relative meridional air angle based on cone angle,
\[ \arctan \left( \frac{\tan \beta'_m \cos \alpha_c}{\cos \alpha_s} \right), \text{ deg} \]
\( \gamma \)  ratio of specific heats
\( \delta \)  ratio of rotor inlet total pressure to standard pressure of 10.13 \( \text{N/m}^2 \)
\( \delta^0 \)  deviation angle, angle between exit air direction and tangent to blade mean camber line at trailing edge, deg
\( \theta \)  ratio of rotor inlet total temperature to standard temperature of 288.2 K
\( \eta \)  efficiency
\( \kappa_{mc} \)  
angle between the blade mean camber line and the meridional plane, deg

\( \sigma \)  
solidity, ratio of chord to spacing

\( \bar{\omega} \)  
total loss coefficient

\( \bar{\omega}_p \)  
profile loss coefficient

\( \bar{\omega}_s \)  
shock loss coefficient

Subscripts:

ad  
adiabatic (temperature rise)

id  
ideal

LE  
blade leading edge

m  
meridional direction

mom  
momentum rise

p  
polytropic

TE  
blade trailing edge

z  
axial direction

\( \theta \)  
tangential direction

1  
instrumentation plane upstream of rotor

2  
instrumentation plane between rotor and stator

3  
instrumentation plane downstream of stator

Superscript:

'  
relative to blade
APPENDIX B

EQUATIONS

Performance parameters are defined as follows:

Mean incidence angle

\[ i_{mc} = (\beta_{c}^{'})_{LE} - (\kappa_{mc})_{LE} \]  \hspace{1cm} (B1)

Deviation angle

\[ \delta^0 = (\beta_{c}^{'})_{TE} - (\kappa_{mc})_{TE} \]  \hspace{1cm} (B2)

Diffusion factor

\[ D = 1 - \frac{V_{TE}^{'}}{V_{LE}^{'}} \left[ \frac{(rV_{\theta})_{TE} - (rV_{\theta})_{LE}}{(r_{TE} + r_{LE})\sigma(V_{LE}^{'})} \right] \]  \hspace{1cm} (B3)

Total loss coefficient

\[ \overline{\omega} = \frac{(P_{id})_{TE} - (P_{id})_{TE}}{p_{LE}^{'}, p_{LE}} \]  \hspace{1cm} (B4)

Profile loss coefficient

\[ \overline{\omega}_{p} = \overline{\omega} - \overline{\omega}_{s} \]  \hspace{1cm} (B5)

Total loss parameter

\[ \frac{\overline{\omega} \cos (\beta_{m}^{'})_{TE}}{2\sigma} \]  \hspace{1cm} (B6)

Profile loss parameter

\[ \frac{\overline{\omega}_{p} \cos (\beta_{m}^{'})_{TE}}{2\sigma} \]  \hspace{1cm} (B7)
Adiabatic (temperature-rise) efficiency

\[ \eta_{ad} = \frac{\left( \frac{P_{TE}}{P_{LE}} \right)^{(\gamma-1)/\gamma} - 1}{\frac{T_{TE}}{T_{LE}} - 1} \]  

Momentum-rise efficiency

\[ \eta_{mom} = \frac{\left( \frac{P_{TE}}{P_{LE}} \right)^{(\gamma-1)/\gamma} - 1}{\frac{(U\theta)_{TE}}{T_{TE}} - \frac{(U\theta)_{LE}}{T_{LE}C_p}} \]  

Equivalent weight flow

\[ \frac{W\sqrt{\theta}}{\delta} \]  

Equivalent rotative speed

\[ \frac{N}{\sqrt{\theta}} \]  

Weight flow per unit annulus area

\[ \frac{\left( \frac{W\sqrt{\theta}}{\delta} \right)}{A_{an}} \]  

Weight flow per unit frontal area

\[ \frac{\left( \frac{W\sqrt{\theta}}{\delta} \right)}{A_f} \]
Head-rise coefficient

$$\frac{C_P T_{LE}}{U_{tip}^2} \left[ \left( \frac{P_{TE}}{P_{LE}} \right)^{(\gamma - 1)/\gamma} - 1 \right]$$  \hspace{1cm} (B14)

Flow coefficient

$$\left( \frac{V_z}{U_{tip}/LE} \right)$$  \hspace{1cm} (B15)

Polytropic efficiency

$$\eta_p = \frac{\ln \left( \frac{P_{TE}}{P_{LE}} \right)^{(\gamma - 1)/\gamma}}{\ln \left( \frac{T_{TE}}{T_{LE}} \right)}$$  \hspace{1cm} (B16)
### APPENDIX C

#### DEFINITIONS AND UNITS USED IN TABLES

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS</td>
<td>absolute</td>
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<tr>
<td>AERO CHORD</td>
<td>straight line between blade leading and trailing edges along design streamline, cm</td>
</tr>
<tr>
<td>AREA RATIO</td>
<td>ratio of actual flow area to critical area (where local Mach number is one)</td>
</tr>
<tr>
<td>BETAM</td>
<td>meridional air angle, deg</td>
</tr>
<tr>
<td>CONE ANGLE</td>
<td>angle between axial direction and conical surface representing blade element, deg</td>
</tr>
<tr>
<td>DEV</td>
<td>deviation angle (defined by eq. (B2)), deg</td>
</tr>
<tr>
<td>D-FACT</td>
<td>diffusion factor (defined by eq. (B3))</td>
</tr>
<tr>
<td>EFF</td>
<td>adiabatic efficiency (defined by eq. (B8))</td>
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<tr>
<td>IN</td>
<td>inlet (leading edge of blade)</td>
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<tr>
<td>INCIDENCE</td>
<td>incidence angle (mean defined by eq. (B1)), deg</td>
</tr>
<tr>
<td>KIC</td>
<td>angle between blade mean camber line at leading edge and meridional plane, deg</td>
</tr>
<tr>
<td>KOC</td>
<td>angle between blade mean camber line at trailing edge and meridional plane, deg</td>
</tr>
<tr>
<td>KTC</td>
<td>angle between blade mean camber line at transition point and meridional plane, deg</td>
</tr>
<tr>
<td>LOSS COEFF</td>
<td>loss coefficient (total defined by eq. (B4) and profile defined by eq. (B5))</td>
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<tr>
<td>LOSS PARAM</td>
<td>loss parameter (total defined by eq. (B6) and profile defined by eq. (B7))</td>
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<tr>
<td>MERID</td>
<td>meridional</td>
</tr>
<tr>
<td>MERID VEL R</td>
<td>meridional velocity ratio</td>
</tr>
<tr>
<td>OUT</td>
<td>outlet (trailing edge of blade)</td>
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<tr>
<td>PERCENT SPAN</td>
<td>percent of blade span from tip at rotor outlet</td>
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<tr>
<td>PHISS</td>
<td>suction surface camber ahead of assumed shock location, deg</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------------------------</td>
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<tr>
<td>PRESS</td>
<td>pressure, ( \text{N/cm}^2 )</td>
</tr>
<tr>
<td>PROF</td>
<td>profile</td>
</tr>
<tr>
<td>RADII</td>
<td>radius, cm</td>
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<tr>
<td>REL</td>
<td>relative to the blade</td>
</tr>
<tr>
<td>RI</td>
<td>inlet radius (leading edge of blade), cm</td>
</tr>
<tr>
<td>RO</td>
<td>outlet radius (trailing edge of blade), cm</td>
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<td>RP</td>
<td>radial position</td>
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<tr>
<td>RPM</td>
<td>equivalent rotative speed, rpm</td>
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<td>SETTING ANGLE</td>
<td>angle between aerodynamic chord and meridional plane, deg</td>
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<tr>
<td>SOLIDITY</td>
<td>ratio of aerodynamic chord to blade spacing</td>
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<td>SPEED</td>
<td>speed, m/sec</td>
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<td>SS</td>
<td>suction surface</td>
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<td>STREAMLINE SLOPE</td>
<td>slope of streamline, deg</td>
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<td>tangential</td>
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<tr>
<td>TEMP</td>
<td>temperature, K</td>
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<td>TI</td>
<td>thickness of blade at leading edge, cm</td>
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<tr>
<td>TM</td>
<td>thickness of blade at maximum thickness, cm</td>
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<tr>
<td>TO</td>
<td>thickness of blade at trailing edge, cm</td>
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<td>TOT</td>
<td>total</td>
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<tr>
<td>TOTAL CAMBER</td>
<td>difference between inlet and outlet blade mean camber lines, deg</td>
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<td>VEL</td>
<td>velocity, m/sec</td>
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<td>WT FLOW</td>
<td>equivalent weight flow, kg/sec</td>
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<td>X FACTOR</td>
<td>ratio of suction surface camber ahead of assumed shock location of multiple circular arc blade section to that of double circular arc blade section</td>
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<tr>
<td>ZIC</td>
<td>axial distance to blade leading edge from inlet, cm</td>
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<td>ZMC</td>
<td>axial distance to blade maximum thickness point from inlet, cm</td>
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<td>ZOC</td>
<td>axial distance to blade trailing edge from inlet, cm</td>
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<td>ZTC</td>
<td>axial distance to transition point from inlet, cm</td>
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REFERENCES


<table>
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<td>Tip Speed</td>
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### TABLE II. DESIGN BLADE-ELEMENT PARAMETERS FOR ROTOR 55

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<th>RP</th>
<th>IN</th>
<th>OUT</th>
<th>IN</th>
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<th>TOTAL TEMP</th>
<th>TOTAL PRESS</th>
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<td>TIP</td>
<td>25.400</td>
<td>25.400</td>
<td>0.276</td>
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<td>1.063</td>
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<tr>
<td>1</td>
<td>24.750</td>
<td>24.714</td>
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<td>2</td>
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17
### TABLE III. - DESIGN BLADE-ELEMENT PARAMETERS FOR STATOR 55

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19
# Table V. Blade Geometry for Stator 55

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## Blade Thicknesses

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## Aero Setting Total X

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### (b) 90 Percent of Design Speed

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### (c) 100 Percent of Design Speed

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TABLE VII. - BLADE-ELEMENT DATA AT BLADE EDGES FOR ROTOR 55B

(a) 80 Percent of design speed; reading 1638

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(b) 80 Percent of design speed; reading 1639

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(e) 80 Percent of design speed; reading 1642

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(i) 90 Percent of design speed; reading 1636

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(g) 90 Percent of design speed; reading 1637

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TABLE VII. – Continued.

(h) 90 Percent of design speed; reading 1632

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TABLE VII. - Continued.

(j) 90 Percent of design speed; reading 1634

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31
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TABLE VII. – Continued.

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(m) 100 Percent of design speed; reading 1627

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TABLE VII. - Continued.

(n) 100 Percent of design speed; reading 1628

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(b) 80 Percent of design speed; reading 1639

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(c) 80 Percent of design speed; reading 1640

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## ABS VEL REL VEL MERID VEL TANG VEL WHEEL SPEED

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TABLE VIII. - Continued.

(d) 80 Percent of design speed; reading 1641

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| 1 | 5.00 | -4.5 | 13.4 | 0.518 | 0.0 | 0.105 | 0.105 | 0.072 | 0.072 |
| 2 | 10.00 | -7.1 | 13.2 | 0.478 | 0.0 | 0.084 | 0.084 | 0.056 | 0.056 |
| 3 | 15.00 | -7.6 | 12.5 | 0.473 | 0.0 | 0.083 | 0.083 | 0.053 | 0.053 |
| 4 | 30.00 | -7.5 | 11.3 | 0.443 | 0.0 | 0.046 | 0.046 | 0.027 | 0.027 |
| 5 | 50.00 | -5.6 | 10.5 | 0.421 | 0.0 | 0.034 | 0.034 | 0.018 | 0.018 |
| 6 | 70.00 | -4.4 | 10.7 | 0.402 | 0.0 | 0.050 | 0.050 | 0.023 | 0.023 |
| 7 | 85.00 | -3.0 | 8.2 | 0.395 | 0.0 | 0.051 | 0.051 | 0.021 | 0.021 |
| 8 | 90.00 | -2.1 | 5.3 | 0.413 | 0.0 | 0.038 | 0.038 | 0.015 | 0.015 |
| 9 | 95.00 | -1.1 | 3.3 | 0.434 | 0.0 | 0.066 | 0.066 | 0.024 | 0.024 |

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TABLE VIII. - Continued.

(e) 80 Percent of design speed; reading 1642

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(f) 90 Percent of design speed; reading 1636

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(h) 90 Percent of design speed; reading 1632

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TABLE VIII. – Continued.

(j) 90 Percent of design speed; reading 1634

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### TABLE VIII. - Continued.

(k) 100 Percent of design speed; reading 1625

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TABLE VIII. - Continued.

(6) 100 Percent of design speed; reading 1626

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TABLE VIII. - Continued.

(m) 100 Percent design speed; reading 1627

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### TABLE VIII. - Continued.

(n) 100 Percent of design speed, reading 1628

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| 3   | 15.00 | -5.9 |
| 4   | 30.00 | -6.9 |
| 5   | 50.00 | -4.4 |
| 6   | 70.00 | -4.0 |
| 7   | 85.00 | -2.3 |
| 8   | 90.00 | -1.5 |
| 9   | 95.00 | -0.7 |

| 1   | 0.098 | 0.098 |
| 2   | 0.100 | 0.100 |
| 3   | 0.095 | 0.095 |
| 4   | 0.058 | 0.058 |
| 5   | 0.024 | 0.024 |
| 6   | 0.068 | 0.068 |
| 7   | 0.057 | 0.057 |
| 8   | 0.036 | 0.036 |
| 9   | 0.095 | 0.095 |
TABLE VIII. – Concluded.

(o) 100 Percent of design speed; reading 1629

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51
Figure 1. - Single-stage compressor facility.

Figure 2. - Fan stage 55 flow path.
Figure 3. - Survey probes.

(a) Combination total pressure, total temperature, and flow angle probe.
(b) Static-pressure probe; $8^\circ$ C-shaped wedge.

Figure 4. - Circumferential location of survey instrumentation at each station looking downstream.

- Wall static pressure
- C-shaped static probe
- Combination total pressure, total temperature, and angle probe

Station 1
Station 2
Station 3
FIGURE 5. - OVERALL PERFORMANCE FOR ROTOR 55B.

FIGURE 6. - OVERALL PERFORMANCE FOR STAGE 55B-55.
Figure 7. - Radial distribution of performance for rotor 55B. 100 percent of design speed.
Figure 9. - Blade Element Performance for Rotor SSP.
Figure 9. - Continued. Blade-element performance for rotor 550.
TOTAL LOSS PARAMETER

TOTAL LOSS COEFFICIENT

DIFFUSION FACTOR

(c) 30.0 PERCENT SPAN.

FIGURE 9. - CONTINUED. BLADE-ELEMENT PERFORMANCE FOR ROTOR 55R.
(E) 70.0 PERCENT SPAN.

FIGURE 9. - CONTINUED. BLADE-ELEMENT PERFORMANCE FOR ROTOR 55B.
Figure 9. - CONCLUDED. BLADE-ELEMENT PERFORMANCE FOR ROTOR 55P.
FIGURE 10. - PLANE-ELEMENT PERFORMANCE FOR STATOR 55.
Figure 10. - Continued. Blade-element performance for stator 55.
FIGURE 10. - CONTINUED. BLADE-ELEMENT PERFORMANCE FOR STATOR 55.
FIGURE 10, CONTINUED. BLADE-ELEMENT PERFORMANCE FOR STATOR 55.
FIGURE 10. - CONCLUDED. BLADE-ELEMENT PERFORMANCE FOR STATOR 55.
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