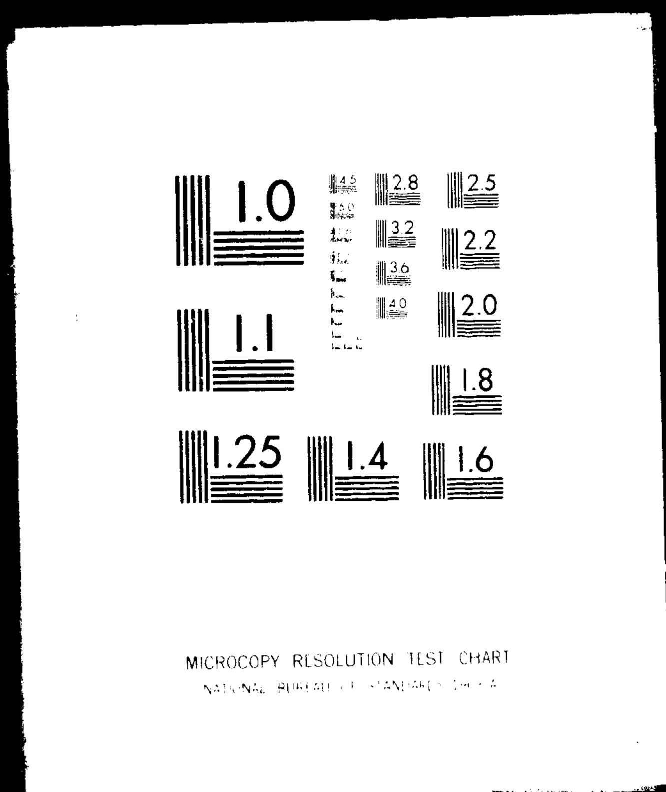
N79 27093 UNCLAS



NASA Technical Memorandum 79176

(NASA-TM-79176) PERFORMANCE OF A V/STOL TILT NACELLE INLET WITH BLOWING BOUNDARY LAYER CONTROL (NASA) 13 p HC A02/MF A01 CSCL 01A

N79-27093

Unclas
G3/02 29271

PERFORMANCE OF A V/STOL TILT NACELLE INLET WITH BLOWING BOUNDARY LAYER CONTROL

Albert L. Johns and Robert C. Williams
Lewis Research Center
Cleveland, Ohio

and

H. C. Potonides
Grumman Aerospace Corporation
Bethpage, New York 11714

Prepared for the
Fifteenth Joint Propulsion Conference
cosponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers
Las Vegas, Nevada, June 18-20, 1979

PERFORMANCE OF A V/STOL TILT NACELLE INLET

WITH BLOWING BOUNDARY LAYER CONTROL

by Albert L. Johns and Robert C. Williams
Lewis Research Center
Cleveland, Ohio 44135

and

H. C. Potonides
Grumman Aerospace Corporation
Bethpage, New York 11714

E-043

INTRODUCTION

The propulsion system for tilt nacelle V/STOL aircraft must operate efficiently and smoothly over a wide range of flight speeds, engine weight flows and incidence angles. For example, during the approach to landing (fig. 1), the nacelles rotate from the normal horizontal position to an angle of 90°. Rotating the nacelles to these high angles results in correspondingly high angles of flow incidence at the inlets.

If the fan is to perform satisfactorily, the inlet must meet the requirements listed in figure 2. For high thrust and engine efficiency, the inlet pressure recovery must be high and the inlet flow distortion low. These two requirements are usually met simultaneously. For the fan blade stresses to be low, the distortion must be low. For acceptable airplane handling qualities and control, any variations in the pressure recovery and distortion that do occur must be smooth, that is, not discontinuous. Generally, an inlet with attached flow will satisfy the above requirements. There are however some levels and degrees of separation that may be acceptable for certain engines.

SYMBOLS

Blg. P.R.	Blowing pressure ratio, P_p/P_∞
CR	inlet area contraction ratio $(R_{hL}/R_t)^2$
D_f	fan face diameter 50.8 cm (20.00 in.)
D_{hL}	hilite diameter 53.87 cm (21.208 in.)
L	inlet axial length 30.63 cm (12.059 in.)
M_t	inlet throat Mach number
N	fan rotational speed
P_p	blowing plenum pressure
P_∞	free stream total pressure
$\bar{P}_2/P_\infty$	fan face area weighted total pressure recovery
R_t	local throat radius, cm (in.)

$\left(\frac{P_{max} - P_{min}}{\overline{P}}\right)_2$	fan face area weighted total pressure distortion
V_t	one dimensional throat velocity
V_∞	free stream velocity
α	angle-of-attack, deg
θ	circumferential angle, deg (=0° in windward plane)
σ	fan blade vibratory stress
σ_{max}	maximum allowable fan blade vibratory stress 2.4×10^8 N/m^2 p-p (3.5×10^4 lb/in^2 p-p)

APPARATUS

At NASA Lewis Research Center several concepts have been evaluated that would extend the tilt nacelle/inlet attached flow operating range. (Thick lips, scarf inlets, centerbody location, etc.). These concepts are discussed in the references.

This paper presents the experimental results of a Grumman Aerospace Corporation/Lewis V/STOL inlet with blowing boundary layer control which was tested in the NASA Lewis 9×15 ft Low Speed Wind Tunnel (fig. 3). This is approximately a 1/3 scale model of a fixed geometry inlet designed by Grumman Aerospace Corporation for a tilt nacelle V/STOL aircraft. The inlet/nacelle model was tested with an existing (20 in.) 30.48 cm diameter fan. This is a single stage fan which has a pressure ratio and a tip speed representative of a V/STOL aircraft application.

The goal was to ascertain the inlet/fan performance over the low speed inlet operating envelope ($0 \leq V_o \leq 64$ m/sec (125 knots), $0^\circ \leq \alpha \leq 120^\circ$). The model rotates in the horizontal plane about the vertical support post. This post also provides the passage for the high pressure turbine drive air. (The windward plane is labeled in the slide.)

The blowing air supply line comes from the top of the tunnel and is mounted with a swivel joint. A portion of the adajcent vertical wall was removed to allow the fan and turbine exhaust to pass through during high angles of attack.

Figure 4 shows the inlet details and instrumentation. The inlet is an asymmetric design with a windward-side contraction ratio of 1.69 and a leeward-side contraction ratio of 1.32. The contraction ratio is defined as $(R_{hL}/R_t)^2$.

The blowing slot was located slightly downstream of the inlet throat and extends 120°, from -60° to $+60^\circ$ about the windward plane. The slot height was ≈0.012 inches. The blowing direction was tangent to the inlet surface. The diffuser wall angle was 12°, maximum.

The fan face diameter was 30.48 cm (20 in.) and the inlet length ratio (L/D_f) was 0.603. Rakes were located ahead of the fan. These rakes were used to measure the fan face total pressure recovery and distortion. A wall static and the lower total probe were used to determine fan face separation.

Data were taken from $0 \leq V_o \leq 64$ m/sec (125 knots), $0^o \leq \alpha \leq 120^o$ and blowing pressure ratios from $0.99 \leq P_p/P_o \leq 2.00$.

RESULTS AND DISCUSSION

What can a small amount of blowing do for the inlet angle-of-attack (α) operating range?

Figure 5 answers this question. Shown is the inlet angle-of-attack plotted against the throat-to-freestream velocity ratio for both the non-blowing and blowing inlets. The blowing inlet had a blowing pressure ratio (P_p/P_∞) of 1.40 (5% of inlet mass flow). Separation-free (attached) flow is to the right of each curve.

With no blowing, at a velocity ratio of 2.5, the maximum α of separation-free flow is $\approx 61^o$. However, with blowing the maximum angle-of-attack is 110^o. This result applies to the low speed, 31 m/sec (60 knots). This is a tremendous improvement in the separation-free operation of the inlet.

The blowing curve includes points for four freestream velocities. The data tends to correlate with the throat-to-freestream velocity ratio (V_t/V_∞) in the region where compressibility effect is not a factor.

Figure 6 shows the inlet operating range from part-to-full throttle. In this particular figure, the inlet separations bounds have been compared to the fan operating range. The right hand curve represents full-throttle (100% fan speed) and the left hand curve is part-throttle (40% fan speed). These curves represent a range of freestream velocities. In general, with blowing the inlet would operate in the attached flow region over the operating range from part to full throttle.

Typical attachment/separation occurring with blowing is shown in figure 7. Total pressure recovery and distortion at the fan face is plotted versus the one-dimensional inlet throat Mach number. The data is shown for V_∞ of 41 m/sec (80 knots) and α of 75^o. Attachment occurs with increasing M_t (rpm). Separation occurs with decreasing M_t (rpm). The solid symbols denote separated flow.

With decreasing throat Mach number, the flow separation occurred at a significantly lower throat Mach number than it attached with increasing throat Mach number. This is a stable hysteresis which was typical with blowing. However, the baseline (nonblowing) inlet had negligible hysteresis.

The fan face distortion also exhibited a stable hysteresis. As throat Mach number (rpm) increased the fan face distortion increased (responding to separated flow) and decreased when the flow attached. However, with decreasing throat Mach number (rpm) the flow remains attached to a lower throat Mach number with a corresponding lower fan face distortion.

For a particular set of inlet condition (V_∞, α = const. with rpm varying from maximum to minimum) the following occurs:

(a) From maximum rpm to (rpm) separation, the pressure recovery increases and distortion decreases.

(b) From (rpm) separation to rpm where separated flow occurs over a small part of the fan face, the pressure recovery decreases and distortion increases.

(c) When the inlet is completely separated both pressure recovery and distortion decrease.

It is interesting to note, that when attachment or separation occurs there is an abrupt change in the pressure recovery and distortion. Data pertaining to the separation point (decreasing rpm) will be the topic of the remaining discussion.

Figure 8 shows the effect of blowing pressure ratio on inlet separation. This figure shows: the total pressure recovery and fan face distortion versus throat Mach number (M_t) at $V_\infty = 41$ m/sec (80 knots) and $\alpha = 75^o$, the same condition as the previous figure. Data for the baseline (nonblowing) inlet are given by the symbols. Solid symbols denotes separated flow. The baseline (nonblowing) inlet was separated from a throat Mach number of 0.15 to 0.375. There is also a region from 0.250 to 0.325 where the inlet flow and fan rpm are unstable.

For the blowing inlet, blowing pressure ratios of 1.2, 1.4 and 1.7 are shown. The blowing pressure ratio is defined as P_p/P_∞. A large incremental gain in the attached flow throat Mach number range occurred with a blowing pressure ratio of 1.2 (maximum of 4.3% inlet flow). However, the higher blowing pressure ratios do modestly increase the level of recovery and the range of attached flow.

As a result of the separation point occurring at lower throat Mach number the region of smooth thrust modulation is increased with blowing. Blowing also resulted in a reduction in fan face distortion which is analogous to the pressure recovery increase.

Figure 9 shows the effect of blowing on fan blade stresses for $V_\infty = 64$ m/sec (125 knots), $\alpha = 55^o$. The first, flatwise bending mode stress signature is shown as a percentage of the maximum allowable stress versus the fan rotational speed (N).

The stress signature can be characterized as having two components: a broadband level superimposed on which are a series of discrete narrow speed band peaks. With the baseline configuration these discrete narrow peaks correspond to integral numbers of blade vibration cycles per revolution (ViB/REV).

With the nonblowing inlet the 3, 4, and 5 vibration per rev. were of a significant level. Of particular concern was the 4 vib. per rev. which was near 100% of the allowable stress. However, with the 120° blowing (Blg. P.R. of 1.4 ~ 5% of inlet mass flow) the blade stress peaks were eradicated.

SUMMARY

The major effects of blowing on boundary layer control of a tilt-nacelle V/STOL inlet are:

1. Angle-of-attack range increased.
2. Blade stresses significantly reduced.
3. Fan face distortion reduced.

REFERENCES

1. Shaw, R. J., Williams, R. C., and Koncsek, J. L., "V/STOL Tilt Nacelle Aerodynamics and its Relation to Fan Blade Stresses," NASA TM-78899, 1978.

2. Abbott, J. M., "Aerodynamics Performance of Scarf Inlets," NASA TM-79055, 1979.

3. Burley, R. R., "Effect of Lip and Centerbody Geometry on Aerodynamic Performance of Inlets for Tilting-Nacelle VTOL Aircraft," NASA TM-79056, 1979.

4. Potonides, H. C., Cea, R. A., and Nelson, T. F., "Design and Experimental Studies of a Type "A" V/STOL Inlet," AIAA Paper 78-956, July 1978.

5. Lewis, G. W., Jr., and Tysl, E. R., "Overall and Blade-Element Performance of a 1.20-Pressure-Ratio Fan Stage at Design Blade Setting Angle," NASA TM X-3101, 1974.

Figure 1. - Representative landing approach for tilt-narcelle VTOL aircraft

INLET REQUIREMENTS

HIGH PRESSURE RECOVERY

LOW DISTORTION LEVELS

LOW BLADE STRESSES

SMOOTH THRUST VARIATIONS

Figure 2. - Inlet requirements.

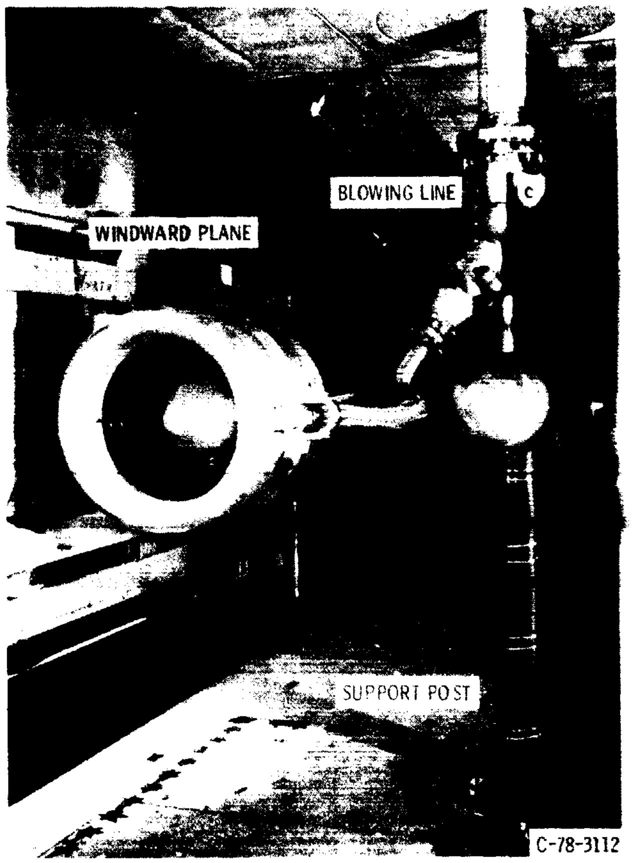


Figure 3. - Model installation in 9x15 foot wind tunnel.

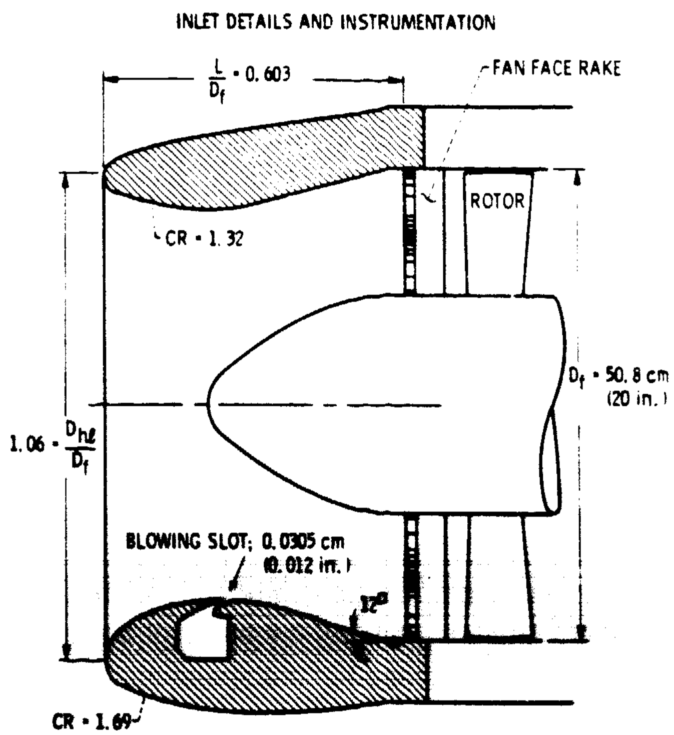


Figure 4. - Inlet details and instrumentation.

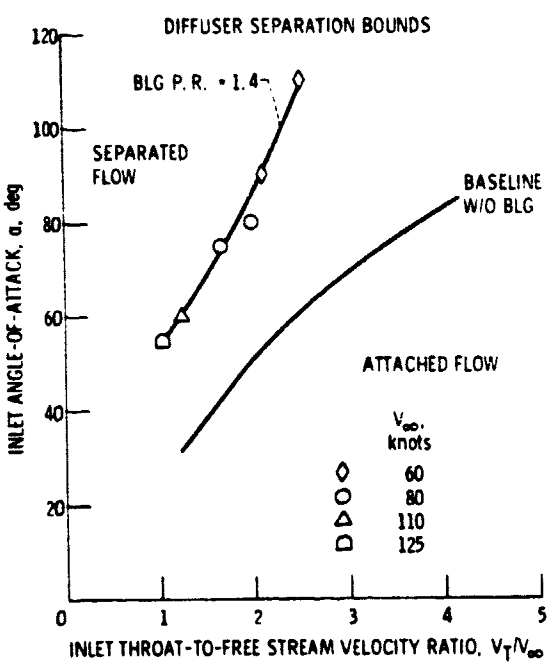


Figure 5. - Diffuser separation bounds (effect of diffuser blowing).

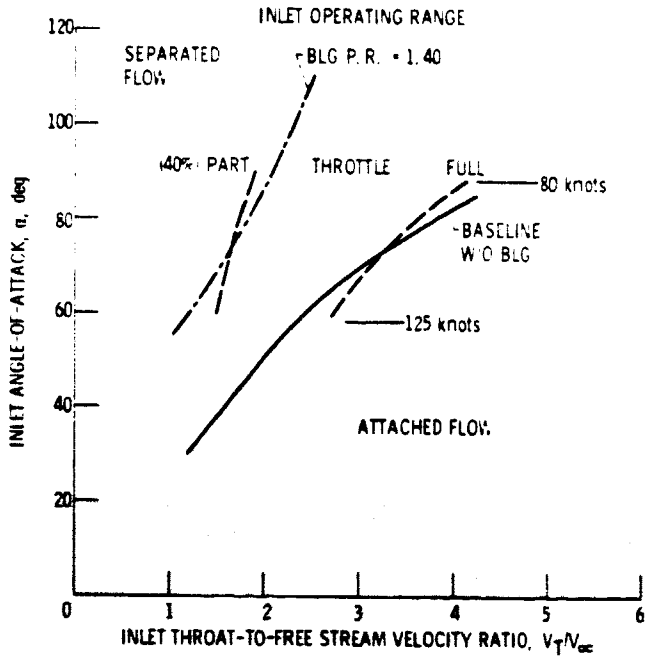


Figure 6. - Inlet operating range.

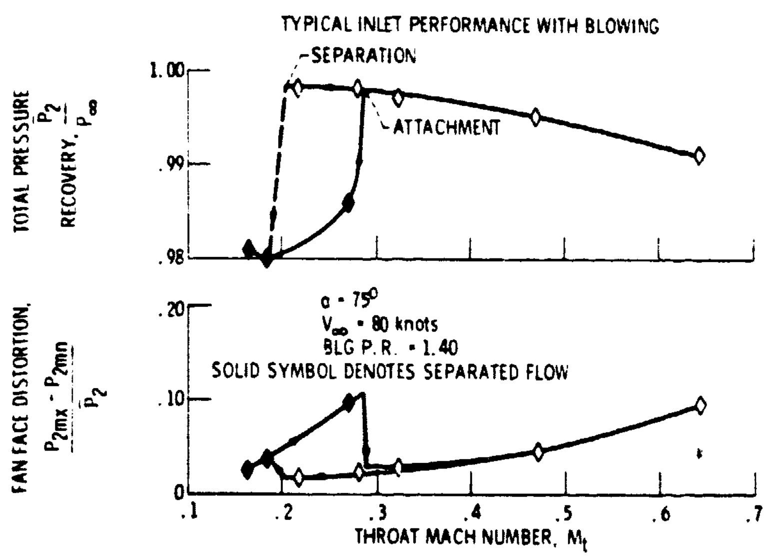


Figure 7. - Typical attachment/separation occurring with blowing.

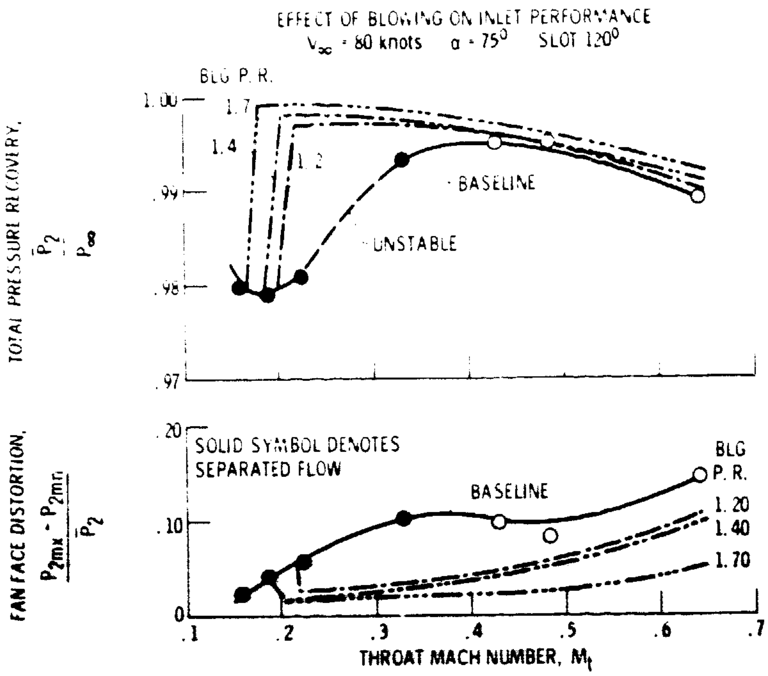


Figure 8. - Effect of diffuser blowing on inlet performance.

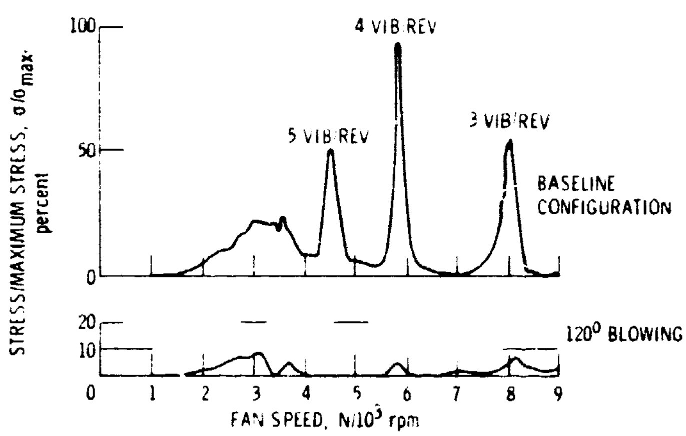


Figure 9. - Effect of blowing on fan blade stress (first flatwise bending mode), at V_0 = 64 m/sec (125 knots) and α = 55°, blowing pressure ratio = 1.40.

1. Report No. NASA TM-79176	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle PERFORMANCE OF A V/STOL TILT NACELLE INLET WITH BLOWING BOUNDARY LAYER CONTROL		5. Report Date
		6. Performing Organization Code
7. Author(s) Albert L. Johns and Robert C. Williams, Lewis Research Center; H. C. Potonides, Grumman Aerospace Corporation, Bethpage, New York 11714		8. Performing Organization Report No. E-043
9. Performing Organization Name and Address National Aeronautics and Space Administration Lewis Research Center Cleveland, Ohio 44135		10. Work Unit No.
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Technical Memorandum
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

A scale model of a V/STOL tilt nacelle fitted to a 0.508 m single stage fan was tested in the NASA Lewis 9×15 ft Low Speed Wind Tunnel to determine the effect of diffuser blowing on the inlet aerodynamics and aeromechanical performance. The test was conducted over a range of freestream speeds (up to 120 knots) and angles-of-attack (up to 120°). In general, diffuser blowing had a beneficial affect on all performance parameters. That is, the angle-of-attack range for separation-free flow substantially increased, and the fan face distortion significantly reduced with a corresponding increase in total pressure recovery. Discrete narrow band blade stress peaks which were common to the nonblowing (baseline) configuration were eradicated with diffuser blowing.

17. Key Words (Suggested by Author(s)) Wind tunnel tests; Inlet aerodynamics; V/STOL; Boundary layer control; Diffuser blowing		18. Distribution Statement Unclassified - unlimited STAR Category 02	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price*

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

END

DATE

FILMED

SEP 11 1979