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(NASA-TM-78917) DESIGN OF AN AIR EJECTOR FOR BOUNDARY-LAYER BLEED OF AN ACOUSTICALLY TREATED TURBOFAN ENGINE INLET DURING GROUND TESTING (NASA) 21 p HC A02/MF A01 CSCL 14B

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DESIGN OF AN AIR EJECTOR FOR BOUNDARY-LAYER BLEED OF AN ACOUSTICALLY TREATED TURBOFAN ENGINE INLET DURING GROUND TESTING

AUG 1978
FACILITY

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SUMMARY

An air ejector was designed and built to remove the boundary-layer air from the inlet of a turbofan engine during an acoustic ground test program. The test program objective was to evaluate an acoustically treated inlet and to determine the effect of the boundary layer on the acoustic properties of this inlet. This report describes (1) how the ejector was sized to meet the required 6.35 kilogram per second (14 lb/sec) bleed flow rate, (2) how the ejector performed during the acoustic test program, and (3) the performance of a scale-model ejector built and tested to verify the design. The noise output of the ejector was reduced to a minimum of 10 decibels below that of the engine for most test conditions by wrapping the ejector with acoustic insulation and exhausting into a muffler. Consequently, the ejector system proved to be an effective way of reducing the boundary layer thickness in the inlet of the tested turbofan engine.

INTRODUCTION

Noise research on turbofan engines has led to using acoustic treatment on the inlet walls to attenuate fan noise. A test program on attenuating turbofan engine noise by using inlet acoustic treatment was conducted at the Lewis Research Center. This treatment was specially designed to reduce the noise produced by the acoustic propagation of various spinning modes in the inlet which are produced by fan rotor-stator and inlet distortion-rotor interactions. Also investigated was the effect of the turbulent boundary layer on the attenuation characteristics of the inlet acoustic treatment. A third objective of this test program was to determine the effect of the boundary layer on fan source noise. In order to evaluate the effect of the boundary layer in this test program, a method of varying this boundary-layer thickness was required. Several methods were considered, and an air ejector was selected.

The test program was performed at the vertical lift facility (VLF), an outdoor acoustic test facility at the Lewis Research Center. A Lycoming YF-102 turbofan engine rated at a thrust of 32 470 newtons (7300 lb) was used. The boundary-layer bleed airflow requirement was approximately 6.35 kilograms per second (14 lb/sec) maximum from an inlet air pressure of 87 600 newtons per square meter (12.7 psia).

This report describes the procedures used in designing an air ejector to remove this boundary-layer air, and it shows how the actual performance of the ejector compares with the predicted design performance. It also describes how effective the ejector was in reducing the boundary-layer thickness during the test program. A major concern in using an air ejector at an acoustic test facility is whether the ejector noise can be suppressed enough so that it will not interfere with the acoustic measurements being taken of the engine. A description of the noise suppression techniques used to reduce the ejector noise is included, and a comparison of the noise difference between the suppressed ejector and the engine was made. A scale model of the ejector was built and tested to verify the adequacy of the design process before fabricating the full-scale ejector. An evaluation of this scaling is also presented. The effect of boundary-layer thickness on fan noise and inlet acoustic attenuation is not included in this report.

SYMBOLS

A ejector mixing tube area

A_t ejector primary nozzle throat area

C nozzle flow coefficient

D_N distance from wall of tube N

d ejector mixing tube diameter

d_t ejector primary nozzle throat diameter

P static pressure

ΔP pressure drop through ejector primary nozzle

P_o total pressure

P_p ejector primary air pressure

P_d ejector discharge pressure

P_s ejector suction pressure

T suction air temperature

T_p primary air total temperature

V_F free-stream velocity

V_N velocity at tube N

$\bar{V}_1$ specific volume of fluid at inlet to nozzle

Y expansion factor for compressible flow

δ^* boundary-layer displacement thickness

ω_p ejector primary flow rate

ω_s ejector suction flow rate

DESIGN

Ejector Requirements

The maximum boundary-layer bleed flow requirement for the test program was 6.35 kilograms per second (14 lb/sec) or approximately 10 percent of the total engine flow at maximum power. This bleed flow which would be drawn from a minimum inlet pressure of 87 600 newtons per square meter (12.7 psia) was to be varied from essentially zero to the maximum obtainable during a particular test run of the engine. The design of the inlet bleed ring required that the ejector be connected to the bleed ring through six 10.16-centimeter-(4-in.-) diameter flexible hoses (fig. 1). Each of these lines was approximately 7.62 meters (25 ft) long because of certain facility restrictions requiring the positioning of the ejector some distance from the engine (fig. 2). The bleed ring was constructed of perforated aluminum sheet with a pressure drop of approximately 3447 newtons per square meter (0.5 psig) for the maximum flow rate of 6.35 kilograms per second (14 lb/sec). In order to obtain the required airflow with these line losses, it was determined that the ejector suction pressure should be approximately 0.5 atmosphere or 55 158 newtons per square meter absolute (8.0 psia). Therefore, the basic ejector design requirement was a maximum flow rate of 6.35 kilograms per second (14 lb/sec) at a suction pressure of 55 158 newtons per square meter absolute (8.0 psia). Throttling the suction flow would be accomplished by varying the ejector primary airflow. Another very important requirement was that the noise produced by the ejector would have to be a minimum of 10 decibels below that produced by the engine in order to obtain valid acoustic data during the test.

Ejector Sizing

One of the prime considerations in sizing the ejector is the available pressure and flow capabilities of the primary air supply. the VLF facility at Lewis is supplied with 1 035 000 newtons per square meter (150 psig) of air at a 454 kilogram per second (100 lb/sec) maximum through a 61-centimeter (24-in.) line. The location of this line together with the need to be able to position the movable shelter required extending the air supply line approximately 30.5 meters (100 ft) through several bends to reach the ejector nozzle as shown in figure 3. The maximum available primary nozzle pressure for the required 20.3-centimeter-(8-in.-) diameter pipe with a shutoff and flow control valve was calculated to be approximately 689 476 newtons per square meter absolute (100 psia). The 20.3-centimeter-(8-in.-) diameter pipe was chosen as a practical size for both installation purposes and flow capacity. The ejector was to exhaust to atmosphere through a muffler for noise suppression. The ejector was sized according to the methods described in references 1 and 2. The final design curve shown in figure 4 was produced by the procedure described in reference 1. The design curve consists of two curves, one showing the ejector pressure ratio and the other the mass flow entrainment ratio; both of these curves are functions of the ratio of suction to motive pressure. The design, for an area ratio (A/A_t) of 15, was picked from a family of curves with varying area ratios (ref. 1). It was chosen because it gave initial values of motive gas pressure and flow entrainment ratio that were the most compatible with the requirements, and it also allowed for a reasonable ejector size for the facility. The sizing procedure for the ejector begins by entering the curve at the required ejector pressure ratio of 1.83 and reading the ratio of suction to motive pressure of 0.072 and entrainment ratio of 0.40. To achieve a suction to motive pressure ratio of 0.072 requires a motive gas pressure of 758 000 newtons per square meter (111 psia), which is very close to the available facility air pressure of 689 476 newtons per square meter (100 psia). With an entrainment ratio of 0.4, the required primary nozzle flow rate is 15.9 kilograms per second (35 lb/sec). As a safety factor to insure that the ejector suction flow rate would not be marginal, it was sized for a required flow rate of 9.07 kilograms per second (20 lb/sec) instead of 6.35 kilograms per second (14 lb/sec); this resulted in a primary nozzle flow of 22.7 kilograms per second (50 lb/sec). This safety factor was included to account for flow losses which might occur because of small deviations in the required flow areas resulting from the use of standard size piping, slight inaccuracies in the flow equations and the design curves used, and losses anticipated in the bleed ring and flexlines between the ejector and the engine inlet. The next step was to determine the primary nozzle size that would pass a flow of 22.7 kilograms per second (50 lb/sec) with a nozzle pressure of 689 476 newtons per square meter absolute (100 psia). It was assumed that the nozzle would be exhausting to atmospheric pressure in the ejector mixing tube. A nozzle diameter d_t of 13.21 centimeters (5.2 in.) was calculated from equation (1)(ref. 3):

$$\omega_p = 0.525\ Y d_t^2 C \sqrt{\frac{\Delta P}{\bar{V}_1}} \tag{1}$$

The nozzle exit area was sized for a supersonic nozzle with an exit Mach number of 2.0 (ref. 2). The mixing tube diameter was then calculated for an area ratio of 15 as follows:

$$\frac{A}{A_t} = \frac{d^2}{d_t^2} = 15$$

where

$$d = \sqrt{15\ d_t^2} = 51.2\ \text{cm}\ (20.1\ \text{in.})$$

For ease of fabrication, the nozzle throat diameter and the mixing tube diameter were changed to the closest standard pipe sizes of 12.82 and 49.53 centimeters (5.047 and 19.5 in.). The area ratio was then recalculated at

$$\frac{A}{A_t} = \frac{(49.53)^2}{(12.82)^2} = 14.95 \cong 15$$

For this area ratio, the flow through the primary nozzle is 20.4 kilograms per second (45 lb/sec) and the expected suction flow is 8.16 kilograms per second (18 lb/sec).

A mixing tube length to diameter (L/D) ratio of 10 was recommended in reference 2 for optimum ejector performance. However, because of limited space at the test facility the actual mixing tube L/D ratio was 8.6. The mixing tube flow exhausted through a short diffuser section into the acoustic muffler which exhausted to atmosphere. The total length of the complete ejector and muffler system was 17.7 meters (58 ft). Figure 5 shows the full-scale ejector flow path geometry.

A 1/200 scale model of the ejector (fig. 6) was built and tested to verify the adequacy of the design. The model was built from stainless steel tubing and fittings with several sizes of contoured inlet nozzles made from lucite. A metal plate with six holes simulating the six-tube inlet to the ejector was also tested.

Noise Considerations

The ejector was exhausted into a large muffler (fig. 3) capable of a 35-decibel reduction in sound power level at frequencies from 500 to 8000 hertz. The muffler, which was approximately 5.49 meters (18 ft) in length by 2.13 meters (7 ft) in diameter, was capable of handling 2832 cubic meters (100 000 actual ft^3) of air per minute. The maximum total design airflow for the ejector system was 1555 cubic meters (54 895 ft^3) per minute.

All the primary air piping that was above the ground plane was wrapped with a foam-lead acoustic insulation. The insulation contained three separate layers of acoustic treatment: A lead barrier with a density of 16.02 kilograms per cubic meter (1 lb/ft^3) was sandwiched between 2.54-centimeter-(1-in.-) thick foam absorption layer and a 1.27-centimeter-(½-in.-) thick foam insulation layer. This material was also used to wrap the complete ejector assembly up to the exhaust muffler. Sound attenuation through this insulation was expected to be 20 to 35 decibels in the 500- to 4000-hertz frequency range.

FACILITY AND TEST HARDWARE

Facility

The vertical lift facility (fig. 7) is an outdoor acoustic test facility capable of testing turbofan engines up to a maximum thrust level of 133 440 newtons (30 000 lb). The large tripod structure supports the cantilevered, overhead, thrust-measuring engine mount; the engine centerline is 2.9 meters (9.5 ft) above ground. The area around the test stand is paved with concrete to provide a flat, consistent ground surface for acoustic measurements. The engine support and thrust measuring system can be rotated to allow the movable shelter to be rolled in place over the test stand. For this test program, a large engine muffler (fig. 2) was used to suppress engine exhaust noise in order to properly evaluate the effectiveness of the acoustic inlet.

The engine and ejector were operated from the control room located approximately 120 meters (394 ft) from the engine test stand. The ejector primary nozzle flow was controlled by two valves in the 20.3-centimeter-(8-in.-) diameter feedline, a motor-operated gate valve and an air-operated butterfly valve. The butterfly valve had a position controller that allowed it to be set at any desired opening through an electrical to pneumatic transducer operated from the control room. The gate valve was used only as a snutoff valve. Various ejector parameters (fig. 8) were monitored in the control room on digital panel meters and analog chart recorders. A digital data acquisition system capable of recording pressures, temperatures, and other engine parameters and connected with a computer system prints out engineering units in the control room.

Twelve 1.27-centimeter-(0.5-in.-) condenser microphones were used to measure far field noise. These microphones at ground level were spaced 10° apart, starting at 10° from the engine inlet centerline on a 30.5-meter (100-ft) radius from the engine.

Test Hardware

Engine. - The Avco Lycoming YF-102 engine used for this test is a two-spool turbofan engine with a bypass ratio of 6 and a rated thrust of 32 470 newtons (7300 lb). The engine core consists of an eight stage compressor, a reverse flow annular combustor, and a four stage turbine. The compressor, which consists of seven axial and one centrifugal stage, is driven by the first two (high pressure) stages of the turbine. The 102-centimeter-(40.0-in.-) diameter fan and one supercharger stage are driven through a 2.3 to 1 speed reduction gear by the last two (low pressure) turbine stages.

A confluent flow nozzle arrangement carries both the fan and core exhaust through a muffler transition pipe into the muffler. Figure 9 shows the complete engine, confluent nozzle, and muffler extension pipe wrapped with acoustic insulation to further attenuate any engine and exhaust noise.

Acoustic inlet. - The acoustic inlet is made up of several aluminum cylindrical sections (fig. 10) and a fiberglass bellmouth. There are two spacers, four sections which accept acoustic liners, a boundary-layer bleed ring, and a seal section which uncouples the weight load of the inlet from the engine. The inlet is supported from the facility thrust structure. The acoustic liners used during the test program were of aluminum honeycomb sandwich construction. The honeycomb is bonded on one side to an aluminum backing sheet and on the other to an aluminum perforated sheet. These liners are bolted into the four cylindrical acoustic sections as required during the test program. The boundary-layer bleed ring has six 10.16-centimeter-(4-in.-) diameter openings which receive the boundary-layer air after it passes through a perforated aluminum skin with a 20-percent open area. Six 10.16-centimeter-(4-in.-) diameter flex hoses are attached to the bleed ring at one end and the ejector at the other. The overall length of the complete acoustic inlet assembly is 371 centimeters (146 in.) with an inside flow diameter of 102 centimeters (40 in.). The inlet was instrumented to measure static pressures and inlet air temperatures; it also had provisions for installing boundary-layer total pressure rakes to determine the thickness of the boundary layer.

TEST PROCEDURE

Ejector and Engine

First, several engine tests were run to evaluate the performance of the various acoustic treatment sections installed in the engine inlet. Next, the ejector was used to vary the boundary-layer thickness on the treated sections. To measure the boundary-layer thickness a boundary-layer rake with 10 total-pressure tubes was installed in the middle of the first acoustic ring downstream of the bleed ring. An online computer program calculated the boundary-layer thickness from the total-pressure readings on the rake and printed the results in the control room.

The ejector was always started before the engine to avoid a back flow of air from the ejector into the engine inlet. The engine was started with the ejector at a low suction flow rate and suction pressure. As the engine was brought up to the desired power setting, the ejector primary flow was increased to keep a slight positive suction flow at all times during engine operation. Data were taken at three engine fan speeds, 7070, 5900, and 4500 rpm. Three boundary-layer bleed flow settings were used at each engine speed. These were near zero flow (as close to zero as practical without getting reverse flow), maximum flow, and one intermediate flow.

Ejector

To determine ejector alone performance, the ejector was tested without the engine running. Three configurations were tested. The first was the basic ejector with the six 10.16-centimeter-(4-in.-) diameter tubes on the inlet of the suction tube open to the atmosphere. The second was with the flex lines connected from the ejector to the bleed ring - the same as for testing with the engine running. For the third test, the holes in the perforated sheet of the bleed ring were taped; this effectively deadheaded the ejector suction flow. For each of the test conditions the ejector was run from minimum to maximum flow by varying the primary air pressure from 172 370 to 689 476 newtons per square meter absolute (25 to 100 psia). All of the ejector performance parameters listed in figure 8 were recorded. For the second test configuration, acoustic data were taken to evaluate the acoustic performance of the ejector.

Scale Model

The 1/200 scale-model ejector was bench tested using 1 034 214 newtons per square meter (150 psig) nitrogen as the primary nozzle driving medium. Four different inlet nozzles were used, three ASME long radius inlets and a 6-hole inlet which simulated the flow area of the tubes on the inlet of the full-scale suction tube. The model was also run with the suction tube deadheaded. The primary pressure was varied from a minimum to approximately 827 376 newtons per square meter absolute (120 psia), and all ejector parameters were recorded at each nozzle pressure.

RESULTS AND DISCUSSION

There are two full-scale ejector configurations which will be referred to in the discussion of results. The first is the ejector alone (not connected to the engine bleed ring) which will be called the ejector. The second is the basic ejector connected to the engine bleed ring through the six flex lines which will be called the ejector system. All of the scale-model ejector performance data were obained in the ejector configuration.

Ejector Performance

A comparison of full-scale ejector performance with design and scale-model data is shown in figure 4. The full-scale ejector performed very close to that predicted by the design curves. The compression ratio fell right on the design curve at 1.83, and the flow entrainment ratio was 0.38 as compared to 0.40 for the design point. For off-design conditions, the compression ratio curve followed the design throughout a large range of suction to motive pressure ratio values, while the entrainment ratio fell off considerably from the design curve at higher suction to motive pressure ratios.

This deviation from the design performance at off-design operation is explained in reference 1. In theory each point on the design curve is associated with an optimum ejector for the operating conditions in question. Adjacent points on this design curve represent theoretically different ejectors; that is, for each value of the suction to motive pressure ratio, there is an optimum area for the exit of the motive gas nozzle. The performance curves for the full-scale ejector then show the deviation from the design condition with a variation in the suction to motive pressure ratio both above and below the design value. This performance deviation did not hinder the test since the ejector was designed for a maximum required flow. Suction flow rates less than this maximum were easily obtained as the ejector was throttled down in flow to achieve the variation in boundary-layer bleed.

The primary and suction flow rates obtained over the complete operating range are shown in figure 11. The maximum extrapolated ejector primary and suction flow rates of 21.5 and 7.94 kilograms per second (47.5 and 17.5 lb/sec), respectively, compare very well with our calculated design flow rates of 20.4 and 8.16 kilograms per second (45 and 18 lb/sec). The ejector primary flow rate was calculted from the isentropic flow relations for a perfect gas through a sonic nozzle ($\omega_p = 0.532\ A_t P_p/\sqrt{T_p}$). The ejector suction flow rate was measured with a commercial flowmeter element sized for the suction tube diameter and expected flow rate. Two pressure transducers, one for a low flow range and one for a high range, were connected to the flow sensing elements.

Scale-Model Ejector Performance

The results from the scale-model ejector tests are compared to the full-scale ejector performance and design in figure 4. The flow entrainment ratio curve for the scale model shows good agreement at the design point and falls between the design curve and the full-scale data at higher suction to motive pressure ratios. The compression ratio curve shows good agreement with design and full-scale data over most of the range of suction to motive pressure ratios. At the design suction to motive pressure ratio of 0.072 the compression ratio is 1.58 as compared to the 1.83

required. Therefore, the expected suction pressure would be 64 121 newtons per square meter (9.3 psia) compared to the desired 55 158 newtons per square meter (8.0 psia). The results of the scale-model tests verified the adequacy of the design process to continue the fabrication of the full-scale ejector as originally designed.

Ejector System Performance

Ejector system performance data were taken without the engine operating. The results shown in figure 12 clearly indicate a drop in the ejector system flow entrainment ratio throughout the complete range of suction to motive pressures, while the compression ratio is slightly higher then the basic ejector. This expected decrease in performance is a result of the losses in the flex lines and the perforated sheet of the bleed ring. As a result, the maximum suction flow for the ejector bleed system without the engine running was approximately 4.3 kilograms per second (9.5 lb/sec) compared to the expected 6.35 kilograms per second (14 lb/sec).

Even though the maximum suction flow was somewhat less than was planned for, it was still enough to produce significant reductions in the boundary-layer thickness as shown in figure 13. The displacement thickness was reduced from 1.9 millimeters (0.075 in.) at zero bleed flow to 0.74 millimeter (0.029 in.) at maximum bleed flow; this is a 61-percent reduction in displacement thickness. Displacement thickness is a calculated value by which the flow streamlines are shifted away from the wall owing to the boundary layer. Equation (2) was used to calculate the displacement thickness δ^* from the total-pressure data taken near the wall of the inlet with a boundary-layer total-pressure rake:

$$\delta^* = \sum_{N=1}^{N=10} \left(1 - \frac{V_N}{V_F}\right) D_N \qquad (2)$$

Acoustic Comparison of Ejector and Engine

If an ejector is to be usable in an acoustic evaluation of the effect of boundary-layer bleed on jet engine fan noise, it should be at least 10 decibels quieter than the engine. Since the predominant fan noise occurs at a frequency called blade passage frequency, the ejector must meet this 10-decibel requirement mainly at that frequency. Also, since this test was to evaluate fan noise, the data from the forward quadrant of the microphone array is the most significant and is used in the comparison. The noise difference between the engine operating alone and the ejector system operating alone is shown in figure 14. Acoustic data from two engine fan speeds are compared with data from the maximum ejector suction flow condition. At an engine fan speed of 7070 rpm, which was the maximum speed reached in the test program, the ejector was considerably quieter than the 10 decibels required through the complete 120° microphone array. At the minimum engine fan speed tested (4465 rpm), the noise difference was less than the required 10 decibels at microphone angles greater than 70° from the engine inlet. Even so, the acoustic performance of the ejector system, wrapped with acoustic insulation and exhausting into a muffler, was considered adequate (especially at the higher engine speeds) to properly evaluate the effect of boundary-layer thickness on the engine fan noise and the inlet acoustic treatment. It seems probable that with additional acoustic insulation and a muffler designed specifically for this test, the ejector noise could be suppressed even further, especially at the rear quadrant angles.

CONCLUDING REMARKS

An air ejector was designed and built to remove boundary-layer air from the inlet of a jet engine during performance testing of an acoustic inlet. The performance of the ejector was predicted very well by the design curves used in sizing the ejector. A scale model of the ejector was built to verify ejector performance.

Test results indicated that the ejector design would be adequate. The ejector was wrapped with acoustic insulation and exhausted into a muffler to reduce the noise output to a minimum of 10 decibels below that of the engine for most test conditions. As a result, the ejector system proved to be an effective way of reducing the boundary-layer thickness in the inlet of the test turbofan engine in order to obtain the desired acoustic test conditions.

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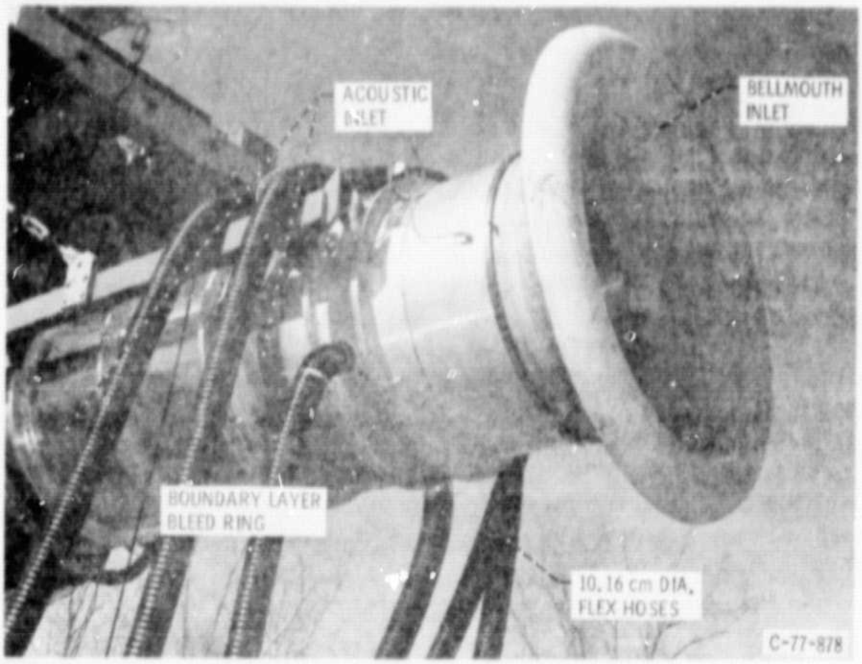

Figure 1. - Boundary layer bleed ring and flex hoses.

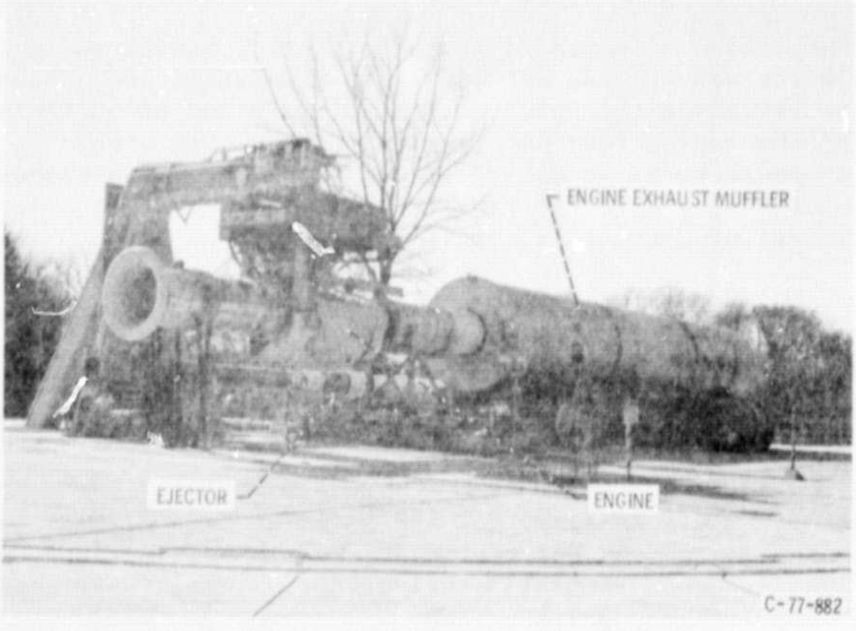

Figure 2. - Engine and ejector installation at the vertical lift facility.

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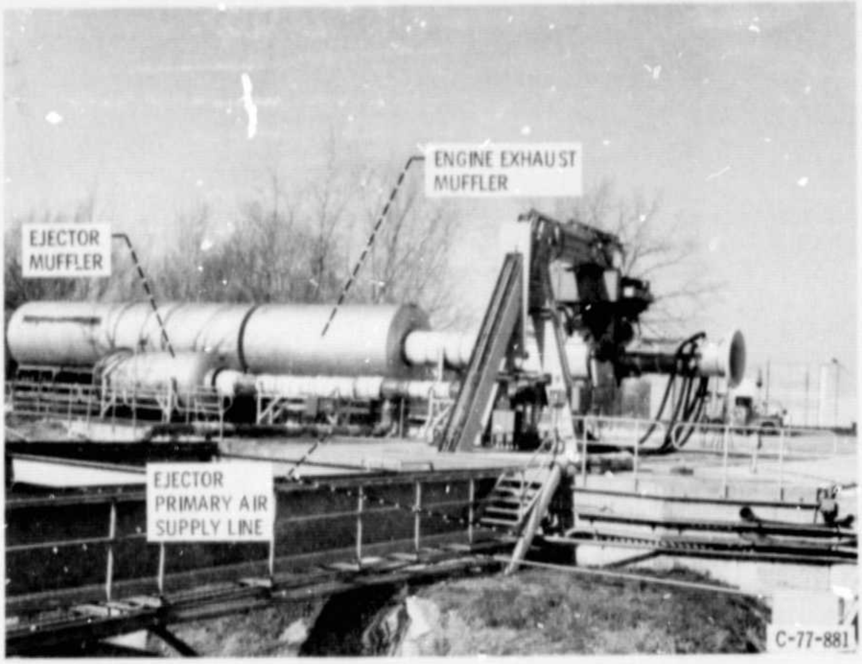

Figure 3. - Ejector muffler and primary air supply line.

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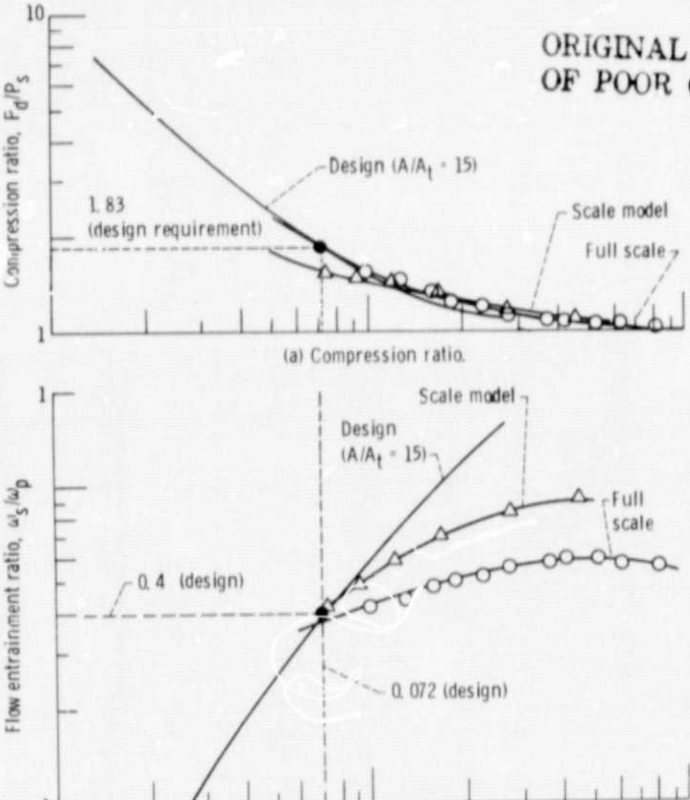

Figure 4. - Comparison of full-scale ejector performance with design and scale-model data.

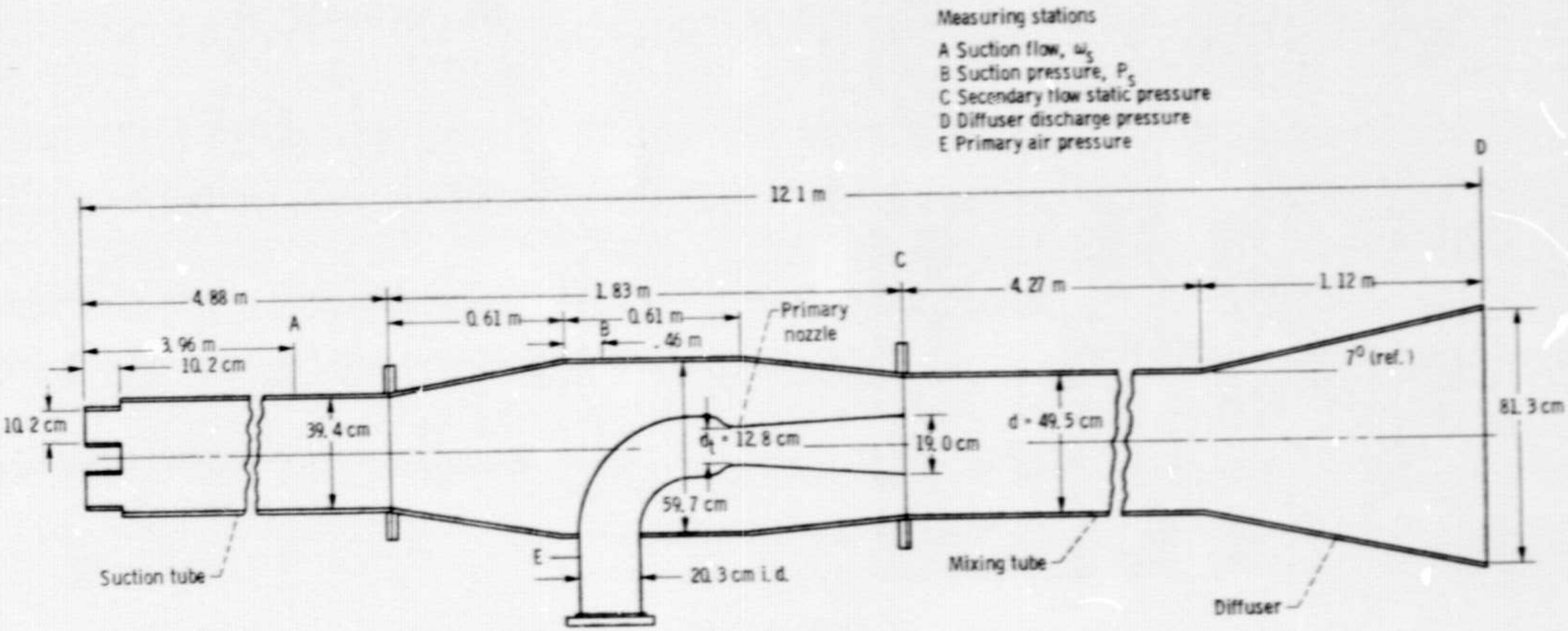

Figure 5. - Full-scale ejector flow path geometry.

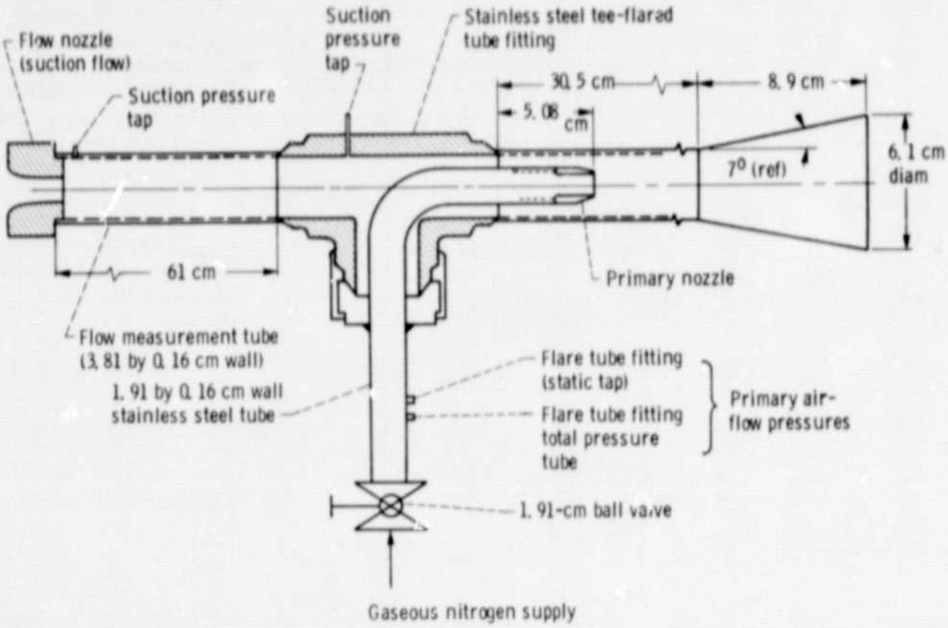

Figure 6. - Scale model (1/200) ejector.

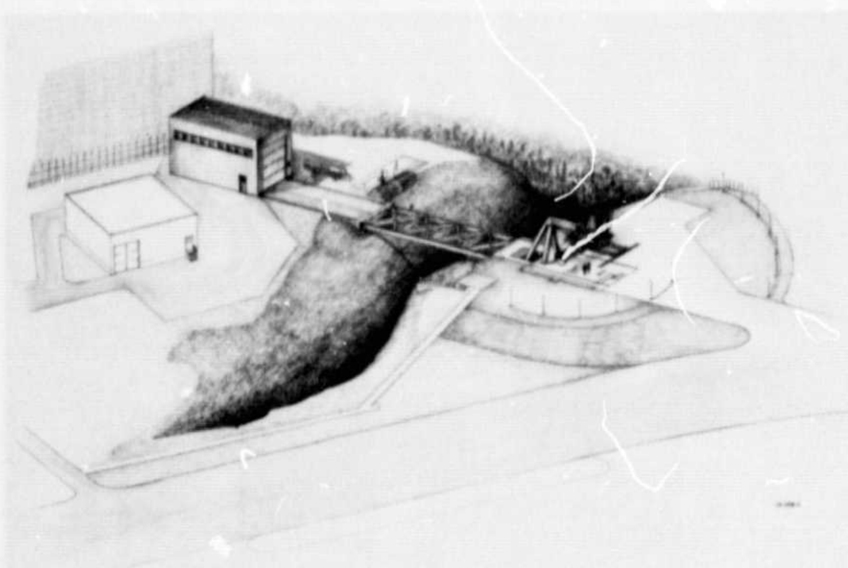

Figure 7. - Perspective view of NASA Lewis test facility.

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Location	Range	Function
A	6894 N/m^2 ΔP	Suction flow rate (high)
	689.4 N/m^2 ΔP	Suction flow rate (low)
	172 500 N/m^2	Suction flow static pressure (absolute)
	Chromel - Alumel	Suction flow temperature
B	± 68940 N/m^2	Suction pressure (4 wall statics); manifold
C	Chromel - Alumel	Suction air temperature (1 T.C.)
	172 500 N/m^2	Secondary flow: total pressure (absolute)
	172 500 N/m^2	Secondary flow; static pressure (absolute)
D	± 68940 N/m^2	Diffuser discharge pressure
E	Chromel - Alumel	Primary air temperature (total)
	1 035 000 N/m^2	Primary air total pressure (absolute)
	1 035 000 N/m^2	Primary air static pressure (absolute)

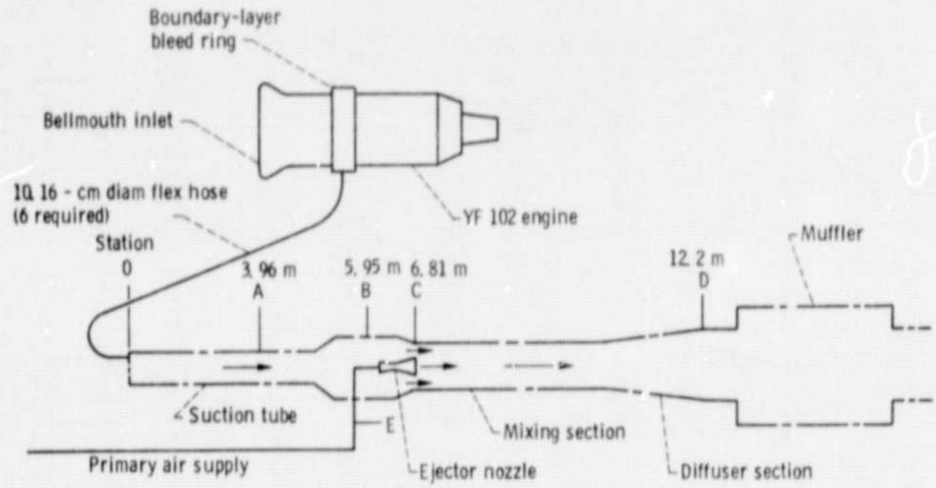

Figure 8. - Ejector instrumentation.

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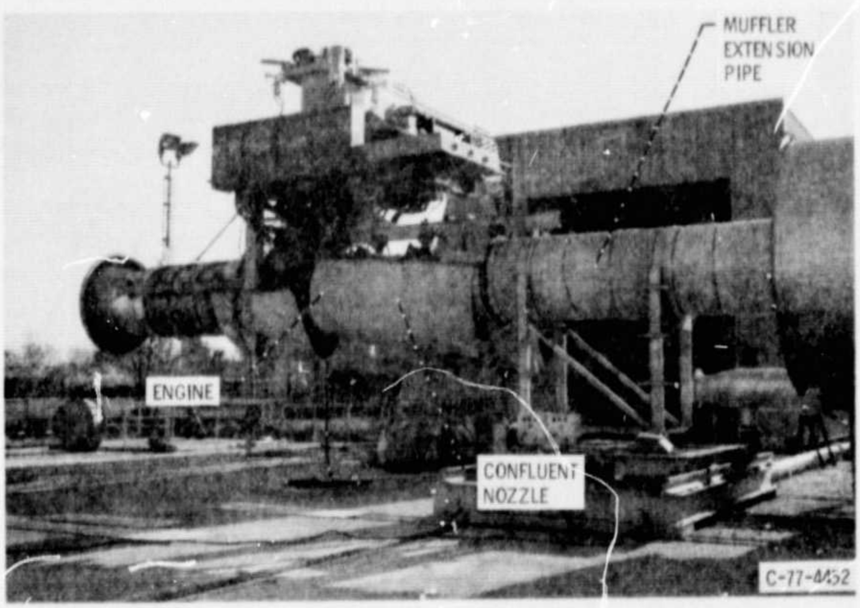

Figure 9. - Engine, nozzle and muffler extension pipe with acoustic wrap.

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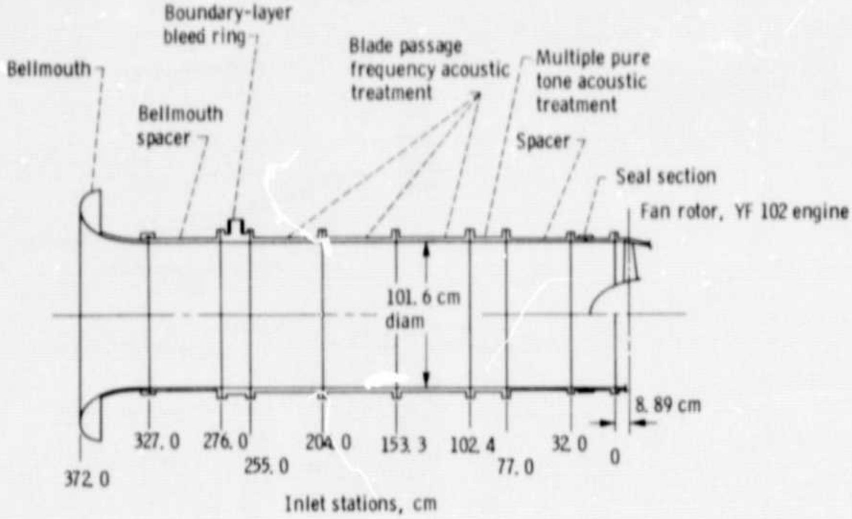

Figure 10. - Inlet acoustic treatment configuration.

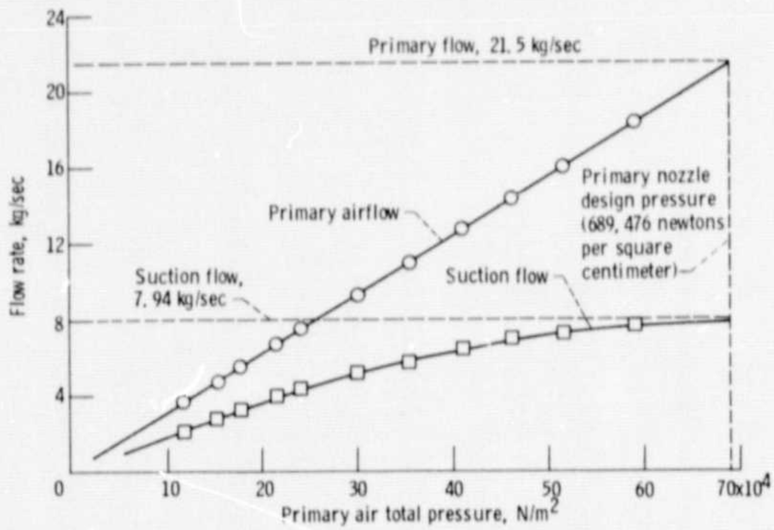

Figure 11. - Full-scale ejector airflow rates.

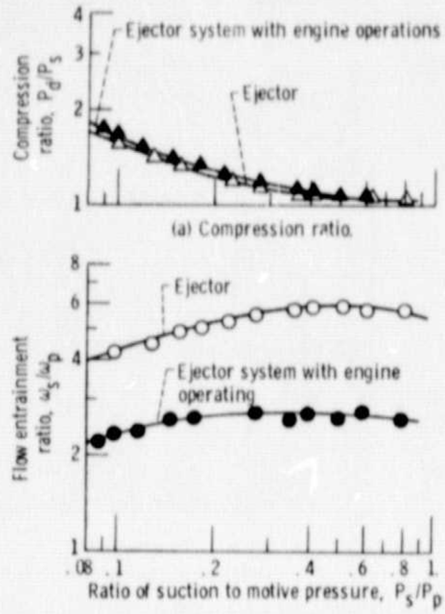

Figure 12. - Effect of suction lines and bleed ring on ejector system performance.

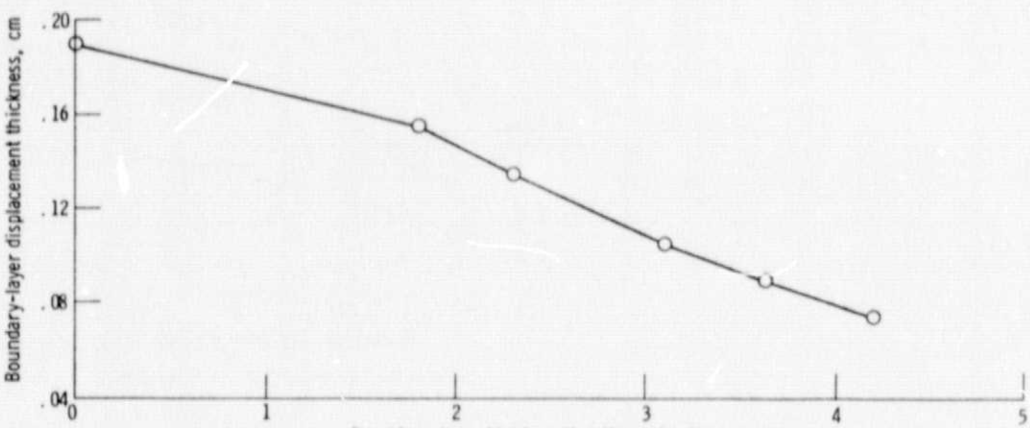

Figure 13. - Effect of bleed flow on boundary layer displacement thickness at an engine fan speed of 7070 RPM.

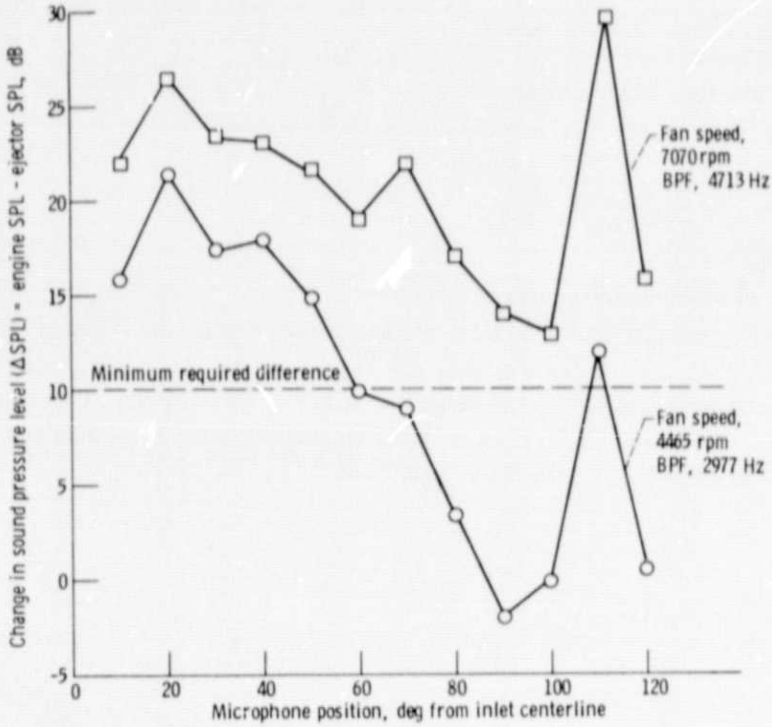

Figure 14. - Difference in noise level at blade passage frequency (BPF) between engine and ejector at maximum ejector suction flow.

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15. Supplementary Notes

16. Abstract

An air ejector was designed and built to remove the boundary-layer air from the inlet of a turbofan engine during an acoustic ground test program. This report describes (1) how the ejector was sized, (2) how the ejector performed, and (3) the performance of a scale-model ejector built and tested to verify the design. With proper acoustic insulation, the ejector was effective in reducing boundary-layer thickness in the inlet of the turbofan engine while obtaining the desired acoustic test conditions.

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