Low Flight Speed Fan Noise from a Supersonic Inlet

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A model supersonic inlet with auxiliary inlet doors and boundary-layer bleeds was acoustically tested in simulated low speed flight up to Mach 0 2 in the NASA Lewis 9 × 15 anechoic wind tunnel and statically in the NASA Lewis anechoic chamber A JT8D refan model was used as the noise source. Data were also taken for a CTOL inlet and an annular inlet with simulated centerbody support struts Inlet operation with open auxiliary doors increased the blade passage tone by about 10 dB relative to the closed door configuration although noise radiation was primarily through the main inlet rather than the doors. Numerous strong spikes in the noise spectra were associated with the bleed system and were strongly affected by the centerbody location. The supersonic inlet appeared to suppress multiple pure tones (MPTs) at or near the fan source Inlet length and the presence of support struts were shown not to cause this MPT suppression

Introduction

POSSIBLE future use of supersonic transports may affect the surrounding airport community adversely with excess noise There is concern about the fan noise radiated from supersonic inlets during takeoff and approach. This noise will also be affected by the required variable geometry of the inlet assembly These assemblies may require auxiliary inlet flow area in the form of doors or annular slots Little is known about the effects of these auxiliary doors on either the generation of fan noise or its propagation In addition, these inlets employ a variable inlet area mechanism, such as a translating centerbody, to adjust inflow conditions Centerbody and cowl bleeds are features that are included primarily to help control shock generated boundary layer separation at supersonic cruise conditions Thus the supersonic inlet assembly has several geometric features which could complicate forward radiated noise

References 1 and 2 present static aeroacoustic results for a supersonic inlet with auxiliary doors bleeds and a translating centerbody The test vehicle was a YF-12 aircraft operated statically Results show that all of the variable geometry components affected noise generation

The present study is an effort to define the aeroacoustic properties of a supersonic inlet operating in two controlled test environments The test inlet designated the "P-inlet,"[3,4] was tested in simulated low speed flight up to Mach 0 2 in the NASA Lewis anechoic wind tunnel [5,6] and statically in the NASA Lewis anechoic chamber [7] Acoustic results are presented for far-field microphones as well as for internal pressure sensors located on the inlet duct walls Corresponding aerodynamic results for the anechoic tunnel tests are presented in Ref 8 Baseline acoustic data for a conventional flight contoured inlet (CTOL inlet) on the JT8D refan are included for comparison The acoustic effect of long support struts was investigated using an annular inlet with simulated struts which approximated those found in the P-inlet This inlet was also tested with the struts removed

Apparatus

Anechoic Tunnel Installation

Figure 1 shows a cross sectional view of the P-inlet as it was tested in the Lewis anechoic wind tunnel A JT8D refan model[9] was mated to the inlet for this test series This fan, which has inlet guide vanes and operates at high tip speed was selected as having characteristics representative of the fan noise expected from future supersonic transport engines Design parameters for the JT8D refan model are given in Table 1 Results presented for the anechoic wind tunnel installation are for a 0 2 tunnel Mach number except where otherwise noted The inlet in the tunnel had sharp lips at the highlight and door openings typical of a flight configuration

Auxiliary inlet doors are required on a supersonic inlet to allow sufficient airflow to reach the fan during takeoff conditions, where relatively low forward flight speed and high airflow requirements prevail A primary purpose of this investigation was to assess the acoustic impact of opening these auxiliary doors with their additional noise path and circumferential flow distortion The P-inlet was run with 40%, 20%, and closed door configurations as shown in Fig 1 The percent door opening was calculated as the ratio of the door throat area to the disk area projected by the inlet cowl lip The closed door configuration was achieved by covering only the door outer surface Each of the four doors extended circumferentially over a 50 deg arc Four axially aligned centerbody support struts (length/height = 4) were located midway between the doors in the horizontal and vertical directions

The P-inlet assembly cowl and centerbody walls have porous surfaces in the throat region consisting of many small holes (1 6 mm diameter) which, in flight remove wall boundary layers and exhaust the low velocity air to the atmosphere This inlet bleed system is intended to prevent terminal shock/boundary layer separation at design speeds and provide some margin of inlet subcritical operating stability [10,11] The cowl and centerbody bleed holes were always open to the internal airflow The closed bleed tests were performed by taping the bleed exit louvers on the outside of the inlet The centerbody bleed had a complicated path (see Fig 1) connecting the outside bleed louvers to the centerbody orifices through the hollow support struts and the fixed centerbody cylinder [3] The cylinder connects to selected cavities behind bleed holes in the concentric translating centerbody depending on centerbody position At high flight speeds the lower pressure at the external bleed exits compared to the internal pressures results in positive bleed flow from

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inside to outside. However, reverse bleed flow did occur under static conditions and at the 0 2 Mach number simulated flight speed of the tunnel The actual magnitude of the bleed flow was not measured in the current tests

The JT8D refan model was driven by a multistage air turbine in the tunnel installation The turbine exhaust exited on the inside of the translating cone which acted as the fan stage plug nozzle The aerodynamic survey rakes[8] (Fig 1) were found not to affect the acoustic results, and thus were left installed for all tests

The plan view of this tunnel installation is shown in Fig. 2 The auxiliary door and cowl lip microphones were mounted on the inlet assembly about 2 5 cm from the surface. All microphones were 0 64 cm in diameter oriented to point upstream, and equipped with aerodynamic nose cones with side openings to minimize airflow induced noise In addition to the microphones, there were a number of dynamic pressure transducers located in the flow passages to allow diagnostic study of the internal noise field Acoustic calibration of the anechoic wind tunnel has shown the test section to be anechoic at frequencies above 1000 Hz [6]

Anechoic Chamber Installation

The P-inlet assembly with the JT8D refan model was also tested in the Lewis anechoic chamber The inlet and auxiliary doors had bellmouth lips to simulate flight airflow better for these static tests. In addition, an inflow control device (ICD) was attached to the inlet to help establish flight quality air flow into the inlet [12] It was not possible to treat the airflow entering the auxiliary doors similarly

The JT8D refan model was driven remotely by an electric motor in the anechoic chamber installation The fan airflow exited into an exhaust collector and out of the facility Far field (0 64 cm diam) microphones were located in 10 deg increments from 0 to 90 deg from the inlet axis There were no microphones located adjacent to the inlet assembly; however, the same internal pressure transducers were used in the chamber installation as in the tunnel installation Only the forward radiated noise (including door radiated noise) was

measured in the chamber, unlike the tunnel where there was a possibility for aft radiated noise contamination Acoustic calibration of the anechoic chamber has shown it to be anechoic at frequencies above 200 Hz

The JT8D refan was also tested in the anechoic chamber with a CTOL inlet for baseline noise comparisons with the P-inlet. As shown in Fig 3, the same ICD was installed on the CTOL inlet as was used for the P-inlet chamber installation The far field microphone array was adjusted to keep the same radius centered on the inlet plane for the shorter CTOL inlet The CTOL inlet installation had limited internal pressure transducers for diagnostic purposes

Acoustic Data Reduction

The acoustic data were recorded on magnetic tapes for later 50 Hz constant bandwidth spectral analysis Using a computer data reduction program, narrow bandwidth sound power level (PWL) spectra were generated for the forward quadrant (0 90 deg from the fan inlet axis) for the chamber results

Results and Discussion

Aerodynamic Results

Detailed aerodynamic results for the P-inlet test are reported in Ref 8 Table 1 shows selected fan stage design parameters. The fan's performance was similar in all installations Data were taken for fan operation from 50 to 90% design speed

Acoustic Results

The acoustic results are presented in two groups The first group is for lower fan speeds where the spectra are charac terized by tones at the blade passing frequency and its har monics, while the second group is for higher fan speeds where shaft order tones dominate the noise spectra
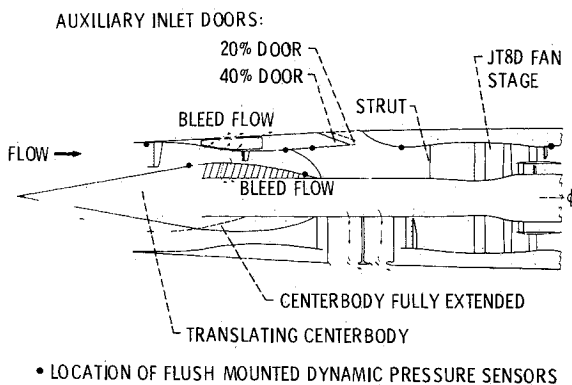

Fig 1   Cross sectional view of P inlet assembly as tested in 9 × 15 anechoic wind tunnel (Shown with centerbody fully retracted)

Table 1   JT8D refan stage design parameters

Inlet guide vanes	23
Rotor blades	34
Bypass stator vanes	84
Core stator vanes	56
Rotor tip diameter cm (in)	50 8 (20)
Rotor tip speed m/s (ft/s)	488 (1600)
Inlet weight flow kg/s (lbm/s)	35 (77)
Bypass ratio	2 032
Bypass stage total pressure ratio	1 67

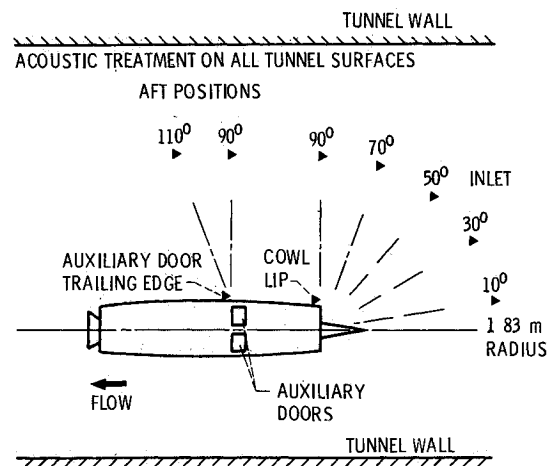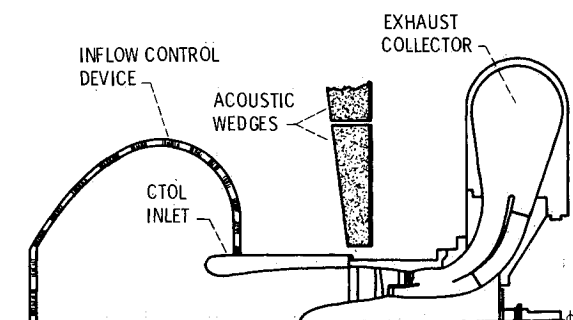Fig 2   Plan view of anechoic tunnel test section.

Fig 3   Cross sectional view of JT8D refan with CTOL inlet as tested in anechoic chamber

Flight Effect

Figure 4 shows the effect of simulated flight in the anechoic wind tunnel The SPL spectra are for the fan operating at 60% design speed, which, for this inlet configuration (fully extended centerbody, 40% open auxiliary doors, and closed bleeds), gives an inlet throat Mach number of about 0 38 and an auxiliary inlet door Mach number of about 0 4 (The door Mach numbers were calculated from a static tap near the door throat and should be considered only as approximate values) Forward speed propagation effects would tend to distort the far field directivity toward the aft angles This angular distortion would be about 10 deg for a Mach 0 2 tunnel. These distortion effects have been disregarded for this discussion since most comparisons are for common Mach 0 2 data The data are for the microphone at 70 deg from the inlet axis These spectra show a reduced "skirting" of the blade passage tone (BPF) with increasing tunnel flow, indicating improved airflow at the sharp inlet lip The actual level of the BPF tone shows little change with flight showing that internal noise mechanisms, such as inlet guide vane rotor interaction, control the tone level The absence of higher tone harmonics (2 × BPF and 3 × BPF) when there is no tunnel flow remains unexplained The spectrum for the fan at windmill (about 15% design fan speed) with the tunnel at Mach number 0 2 shows that the tunnel background noise level has no effect on the test results above 1000 Hz

Test Facility Effects

Figure 5 shows a spectral comparison for the P-inlet in the two test facilities For reference a spectrum of the refan noise with the CTOL inlet is also shown The SPL spectra are at 70 deg from the inlet axis with the fan operating at 60% design speed The anechoic chamber data are adjusted to the 1 83 m radius of the tunnel microphone The P-inlet was operated with 40% open auxiliary doors and closed bleeds The P-inlet centerbody spike was extended 50% in the tunnel, while in the chamber it was extended 40% The P-inlet throat Mach numbers were about 0 42 in both installations, while the door Mach numbers were about 0 35 The CTOL inlet throat Mach number was slightly lower

The fundamental tone levels (BPF) for the P-inlet are about the same in both installations, indicating that these tones are controlled by sources other than installation effects Likewise, there is good agreement for the P-inlet overtone levels The strong tones between the fundamental and first overtone are resonant tones which seem to be associated with the inlet bleed systems These tones, which appear to be quite sensitive to inlet configuration and centerbody position, will be discussed in detail in a later section of this report The P-inlet results for the tunnel installation typically showed a higher level in the 1 4 kHz range than did the corresponding chamber results The reason for this difference is unknown, but seems to relate to the tunnel airflow

There was good agreement in broadband noise between the CTOL and P-inlet results However, the fundamental tone and the second overtone (3 × BPF) for the CTOL inlet are considerably higher than the corresponding P-inlet tones Earlier investigators (see Ref 1) have shown that the in stallation of a supersonic inlet may reduce the fan noise levels relative to those for a CTOL inlet. However, in Ref 1, the fan was operating in the supersonic tip speed range rather than subsonically as for Fig 5, and the entire spectral noise level, rather than just the fundamental tone and its harmonics, was reduced with installation of the supersonic inlet

Inlet Mach Number Effect

The sound attenuation effects of near sonic flow at an inlet throat have been reported in the literature [13] This effect in the P-inlet data from the anechoic chamber is shown in Fig 6 where the overall sound power level (OAPWL, 1 20 kHz) is plotted as a function of inlet throat Mach number The inlet
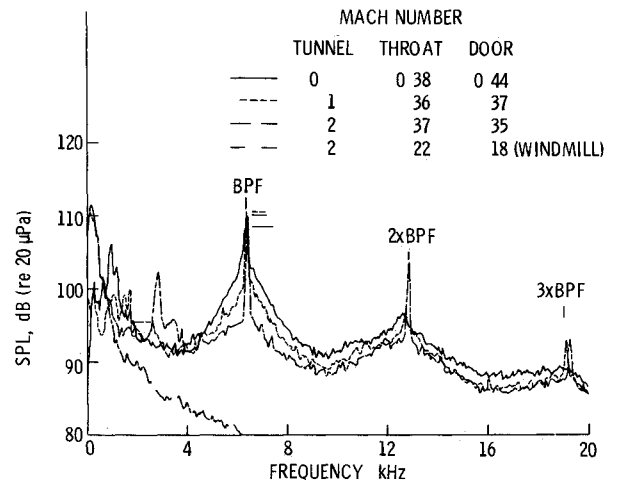

Fig 4 Effect of tunnel Mach number on far field spectra (60% of design fan speed; 70 deg from inlet axis; centerbody fully extended; 40% open doors; both bleeds closed)
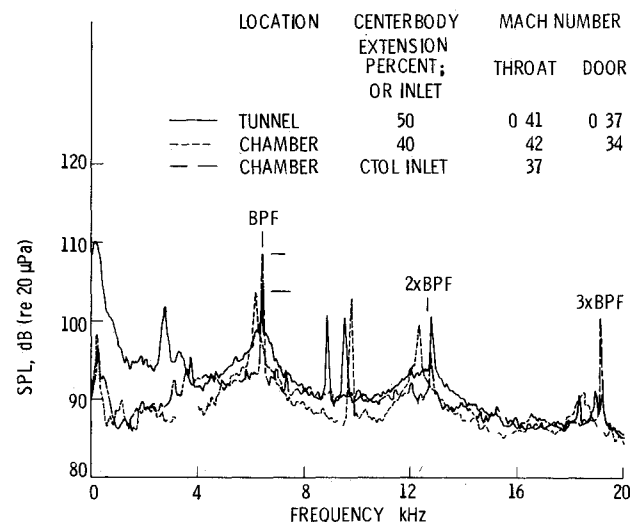

Fig 5 Comparison of SPL spectra for tunnel and chamber facilities (60% of design fan speed; 70 deg from inlet axis; 40% open doors; both bleeds closed; tunnel Mach number 0 2; data adjusted for 1 83 m radius)
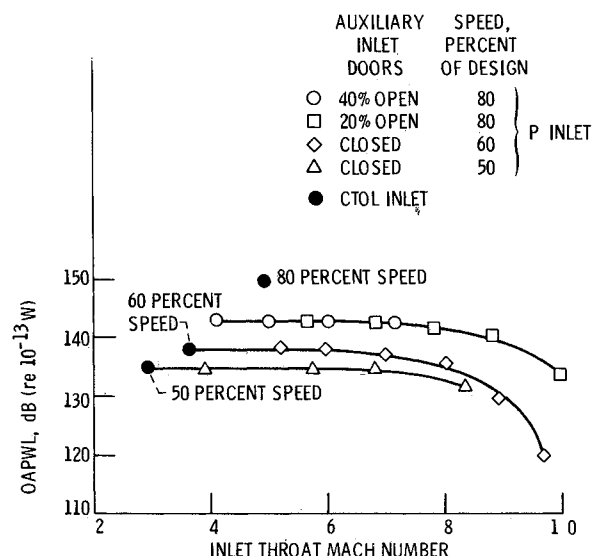

Fig 6 Effect of throat Mach number on overall sound power level (0 90 deg 1 20 kHz) in anechoic chamber (P-inlet bleeds closed)

bleeds are closed The inlet throat Mach number for a par ticular auxiliary door configuration was changed by axially translating the inlet centerbody The attenuation produced by increasing Mach number is evident at about 0 7 throat Mach number There is a considerable noise attenuation toward Mach unity for the closed auxiliary doors configuration, showing the sonic inlet behavior The lesser attenuation for the open door configurations with increasing Mach number suggests that some noise may be radiating through the auxiliary doors It is possible that noise "leakage" from the covered auxiliary door or bleed vents may have contaminated the data in Fig 6 tending to limit the noise reductions near choke Directivity results for the 60% speed points in Fig 6 showed the noise reduction near choke to be roughly the same at all angles from 0 to 90 deg.

The results for the CTOL inlet are similar to the P-inlet results at the subsonic (50% and 60% design) fan speeds However, the CTOL inlet results are about 6 dB higher than those for the P inlet at 80% design fan speed where MPT noise can occur. Thus the P-inlet appears to prevent or at tenuate the far field radiation of MPT noise in a region of relatively low throat Mach number Again, the nature of the MPT noise of the refan with the P-inlet will be discussed in more detail in a later section of this report

Auxiliary Door Effect

For takeoff, and possibly approach, it may be necessary to open the auxiliary doors to provide sufficient fan airflow With open door operation there is a clear possibility that nonuniform airflow will reach the fan Also, open doors provide an additional path for acoustic radiation Finally, opening the doors reduces the inlet throat Mach number All of these effects could lead to an increase in the radiated noise

The fundamental tone directivity results of Fig 7 show a tone level increase at all angles with open auxiliary doors that is typical of this inlet The cowl and centerbody bleeds were closed for the investigation of the auxiliary door effect. In Fig 7 the tone level increases almost 10 dB at all forward angles with 40% open doors relative to the results with closed doors The difference between levels for 40 and 20% open doors becomes less toward the aft angles

The data for the 90 and 110 deg aft positions relative to the auxiliary doors show little effect of door opening This unexpected result suggests that the door induced noise is radiated primarily through the inlet mouth rather than through the door openings or, if through the doors is radiated forward Another possibility is that the levels at these two angles are controlled by aft radiating noise

Narrow bandwidth spectra are presented in Fig 8 for the 70 data of Fig 7 These results show a weak tone increase as the doors are opened The lower broadband level for the closed door configuration above 10 kHz is unexplained but may be related to the lower throat Mach number Several resonance tone spikes are seen in the spectrum of Fig 8

As an aid to separating source and propagation effects it is useful to look at the internal pressure spectra Figure 9 shows spectra corresponding to the conditions of Fig 12 but measured at a location on the outer flow passage wall between the auxiliary door opening and the refan stage inlet guide vane Again, there is a tone level increase associated with open door operation This clearly shows that the tone level increase which was observed in the far field is a source effect associated with the auxiliary door inflow The broadband level for the closed door configuration in Fig 9 may relate to the higher throat Mach number and consequent scrubbing noise potential for this configuration

Bleed Effect

Throat region boundary layer bleeds are used to help prevent terminal shock/boundary layer separation at design speeds and to increase inlet subcritical operating stability It is
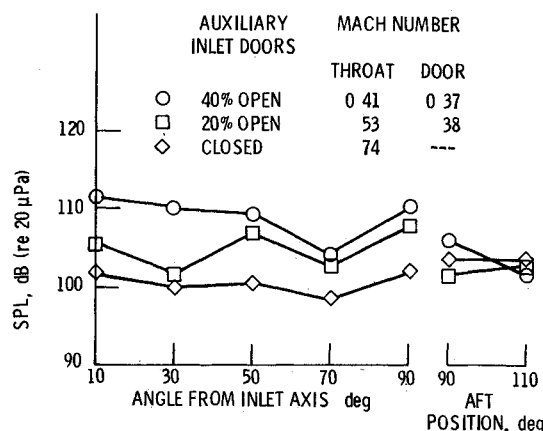
Fig 7 **Blade passage tone directivity for tunnel facility (60% of design fan speed; centerbody 50% extended; both bleeds closed; 1 83 m radius)**
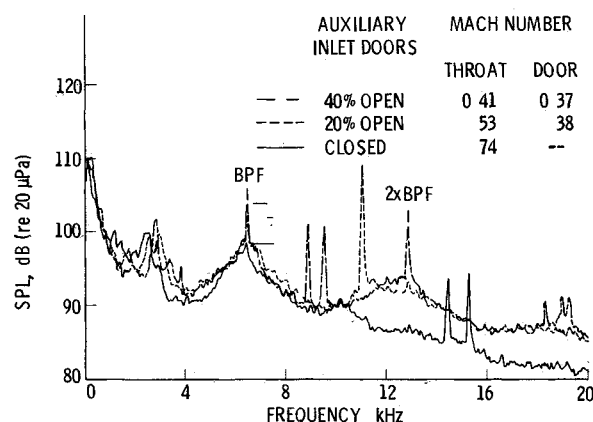
Fig 8 **Effect of auxiliary door opening on far-field spectra with bleeds closed. (60% of design fan speed; 70 deg from inlet axis; centerbody 50% extended; tunnel Mach number 0 2)**

desirable to leave the inlet bleed system open at all times for simplicity of operation However little is known of the acoustic effects of the bleed system The P-inlet had both cowl and centerbody bleed systems (see Fig 1) which were ducted to the outer surface of the inlet The centerbody bleed system was especially complicated Depending on centerbody position, different translating centerbody cavities were opened to the hollow centerbody The bleed airflow also travels through passages in the centerbody supports struts to external exhaust ports At high flight Mach numbers the lower pressure at these exit ports compared to the internal pressures would insure positive bleed flow However, at low forward flight speed (Mach 0 2) and during static operation these bleed systems experienced reverse flow No measurements of the bleed flow magnitude were made during these tests The bleeds were closed by taping over the external duct openings leaving some internal bleed cavities open to the internal flow.

Strong resonance tones related to the bleed system geometry were observed in the P-inlet results The number, frequency, and magnitude of these tones were sensitive to fan speed, centerbody location and the bleed system configuration Curiously, in the far field results, these strong resonance tones were restricted almost entirely to the angles from 50 to 90 deg Also, the occurrence of these resonance tones was greatest at the lower fan speeds and for the midrange cen terbody positions The spectra in Fig 10 are for the tunnel installation at 50% design fan speed and 70% from the inlet axis, and a 50% centerbody extension Various resonance tones appear in response to the opening of different bleed

ducts The one exception is that with the centerbody bleed open to flow and the cowl bleed closed there were no ob servable resonance tones in the spectrum It should be noted that these resonance tones have no frequency relationship to the rotor interaction tones and their harmonics Retracting the centerbody to the 25% extended position (not shown) results in an entirely different set of resonance tones being generated The different set of resonance tones for the 40% open door, closed bleed configuration in Fig 8 shows how fan speed may affect these tones The frequency of these spikes does not correspond to either cavity resonance frequency or the Strouhal frequency for vortex shedding from the orifices as they are usually calculated; however, predictions are un certain due to the complexity of the P-inlet bleed system passages Thus the generating mechanism of the spikes was not identified

As mentioned previously, these resonance tones were restricted largely to the 70-deg microphone position results Directivities for three of the typical resonance tones are presented in Fig 11 While the tone levels clearly peak at 70 deg, the corresponding broadband level tends to dip at the same angular position This irregular broadband behavior is not normally observed in fan noise directivity results and remains unexplained

References 14 and 15 present data for another supersonic inlet which was tested in the Lewis 10×10 supersonic wind tunnel In this test lower frequency resonance tones were found to be generated by bypass door cavities Installation of a blade cascade at the entrance to the cavities eliminated these tones. In addition, the resonance tones were reduced when airflow passed through the cavities Although a different region of the inlet internal flow path produced resonance in this reference, there is the similarity that cavity flow, such as centerbody bleed flow in the present study, tended to reduce the resonance tone levels

Combination Auxiliary Door and Bleed Effects

In an earlier section it was shown that opening the auxiliary doors will increase the fan fundamental tone level The results presented in that section were for both bleeds closed Figure 12 shows how the blade passage tone directivity is affected by opening both bleeds As in the earlier section, the data are for the tunnel installation at Mach number 0 2, with the fan operating at 60% design speed and 50% centerbody ex tension Open bleeds have little effect on the fundamental tone level (except for a single point at 90 deg forward arc) with 20% open doors (Fig 12a) With 40% open doors (Fig 12b)

opening the bleeds increases the fundamental tone level by 5 to 7 dB in the 30 and 70 deg ranges The bleed effect is slightly reversed at the forward arc 10 and 90 deg positions As in Fig 7, no clear data trends are seen in the aft 90 and 110 deg results

Data from the internal pressure transducers can be an effective tool in isolating the fan inlet noise mechanisms Figure 13 shows internal pressure spectra at a number of locations in the P-inlet for the anechoic tunnel installation Spectra for the external microphones at the cowl lip and auxiliary door lip are also shown These data are for the fan operating at 60% design speed, centerbody 50% extended 40% open auxiliary doors, and both bleeds closed Figure 13 clearly shows the development of the resonance tones. These tones are especially strong along the centerbody and outer cowl just upstream of the bleed openings The resonance tones become weaker toward the fan stage, and are not at all present just downstream of the fan stage These data support the idea that the resonance tones originate in the bleed system, and especially in the centerbody bleed system This idea is rein forced by the observation that the resonance tone structure varies with centerbody position The corresponding internal data for the anechoic chamber installation of the P-inlet was similar to the data of Fig 13.

Fig 10 Effect of inlet bleed configuration on resonance tones in far field (50% of design fan speed; 70 deg from inlet axis; centerbody 50% extended; doors closed)
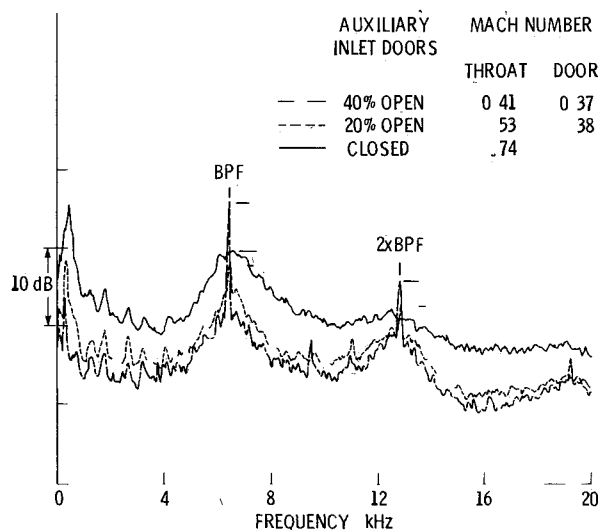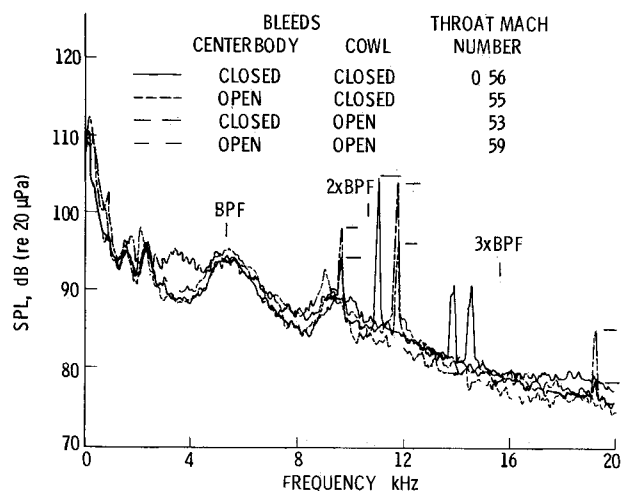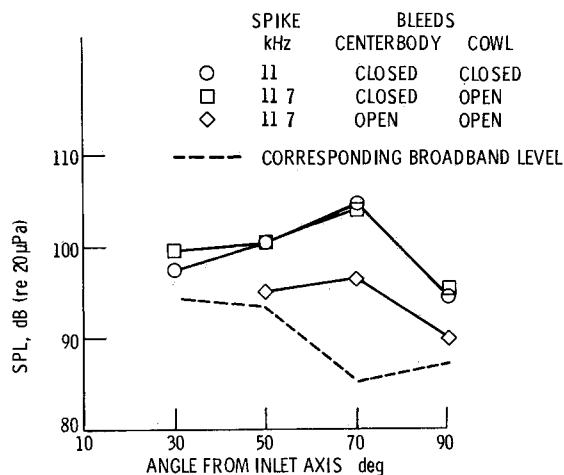

Fig 9 Effect of auxiliary door opening on internal pressure spectra with bleeds closed (60% of design fan speed; internal duct outside diameter just downstream of doors; centerbody 50% extended)

Fig 11 Resonant tone directivity (50% of design fan speed; cen terbody 50% extended; doors closed)

a) 20% open doors; Mach numbers: throat 0 53; door 0 38

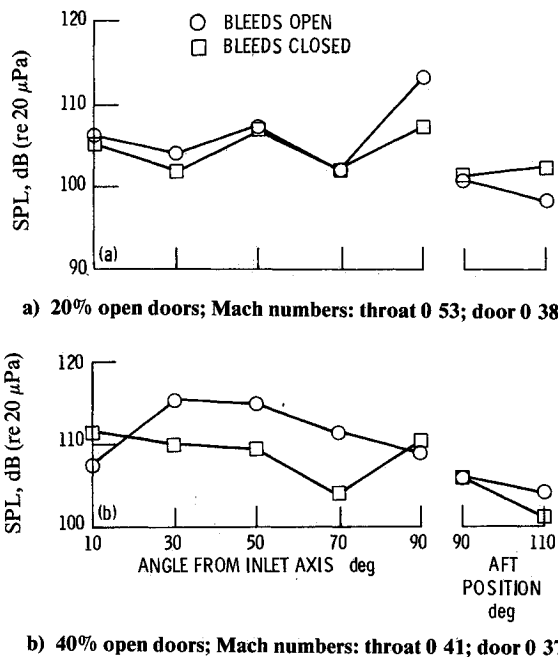b) 40% open doors; Mach numbers: throat 0 41; door 0 37

Fig 12 Effect of bleed and door configurations on blade passage tone directivity (60% of design fan speed; centerbody 50% extended)
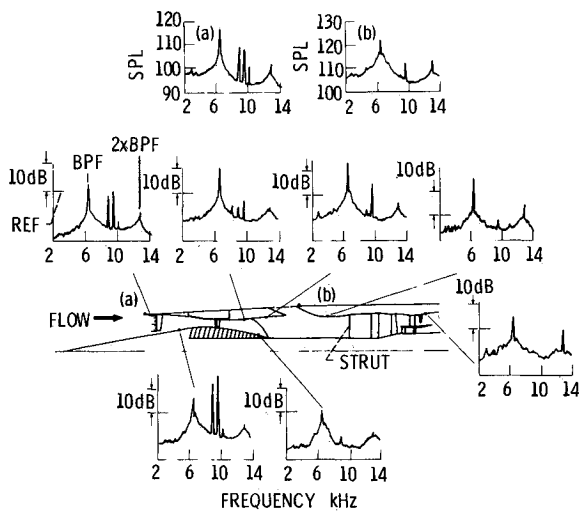

Fig 13 Internal pressure spectra for wind tunnel facility (60% of design fan speed; centerbody 50% extended; 40% open doors; both bleeds closed; Mach numbers: throat, 0 41; door, 0 37) a) Cowl lip microphone. b) Auxiliary door microphone

Fig 14 Effect of fan speed on overall sound power level (0-90 deg 1 20kHz) in anechoic chamber (P-inlet: 40% open doors; centerbody nominally 50% extended; bleeds closed)

Fig 15 Power level spectra for P-inlet and CTOL inlet with JT8D refan in anechoic chamber (80% of design fan speed)

Multiple Pure Tone Attenuation

An unexpected observation from earlier supersonic inlet tests has been the apparent attenuation of fan multiple pure tones (MPTs) even though the inlet throat Mach number was too low to expect acoustic choking effects [1] In the present investigation internal sound measurements show that the P-inlet somehow causes a reduction in the actual MPTs at or near the fan source

Figure 14 shows how the overall sound power level (OAPWL) (1 20 kHz 0 90 deg) varies with fan speed for the refan with the CTOL inlet and with the P-inlet in the anechoic chamber The P inlet was run with 40% open auxiliary doors and closed bleeds The centerbody was 50% extended Open doors are necessary with P-inlet operation above 70% design fan speed to avoid hard choking at the inlet throat Above 70% design fan speed, strong MPT generation controls the OAPWL level for the CTOL inlet The OAPWL for the P-
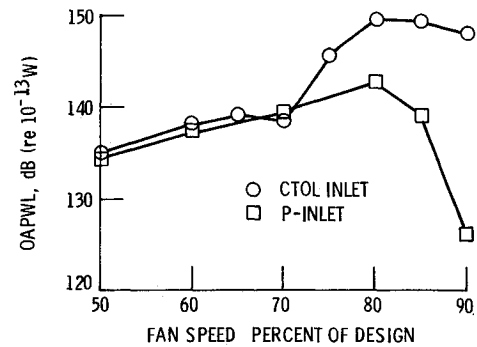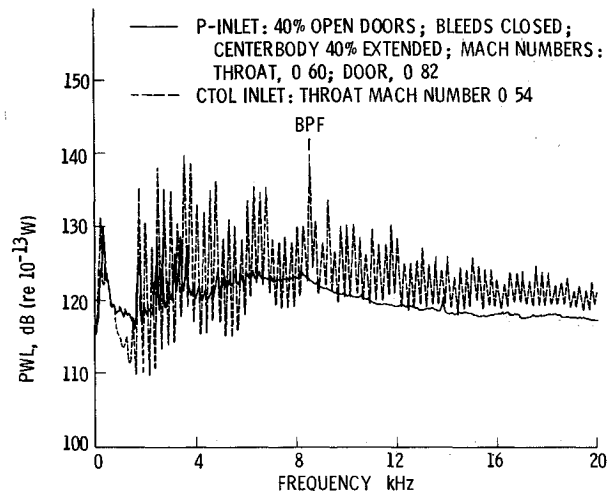
inlet shows a modest increase at 80% speed, then decreases rapidly at higher fan speeds At 90% design fan speed the P-inlet throat Mach number for this configuration is only 0.70 and the door Mach number is 0.56 So, from Fig 6, acoustic choking effects are unlikely

Figure 15 compares the PWL spectra at 80% fan speed for the two inlet configurations of Fig 14. As seen in this figure, the MPT content for the P-inlet is much less than for the CTOL inlet where the entire spectrum consists of MPTs In addition, the fundamental rotor alone tone, which is clearly evident for the CTOL inlet, is essentially missing in the P-inlet results At 80% fan speed the MPT content and fundamental rotor alone tone level for the P-inlet increase somewhat with additional centerbody extension However, at higher fan speeds translating the centerbody has little effect on the MPTs

Internal spectra provide an insight into the MPT generation mechanism The internal spectra for the CTOL inlet with the refan operating at 80% design speed (Fig 16) show strong MPT content throughout the inlet There is even evidence of weak MPTs downstream of the fan

In contrast, only modest MPT levels are seen in the corresponding internal spectra for the P-inlet in the tunnel installation (Fig 17) Likewise, corresponding internal data for the P-inlet in the chamber showed little MPT content, and were quite similar to the data of Fig 16

Similar results were seen at 90% design fan speed and the same P-inlet configuration The strong internal MPTs in the CTOL inlet were essentially not present in the P inlet At 75% design speed it was possible to operate the P inlet with the
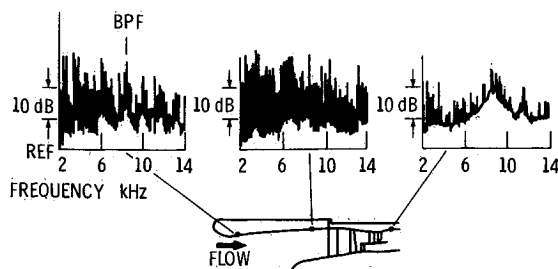
Fig 16 Internal pressure spectra for JT8D refan in anechoic chamber (80% of design fan speed; throat Mach number 0 54)
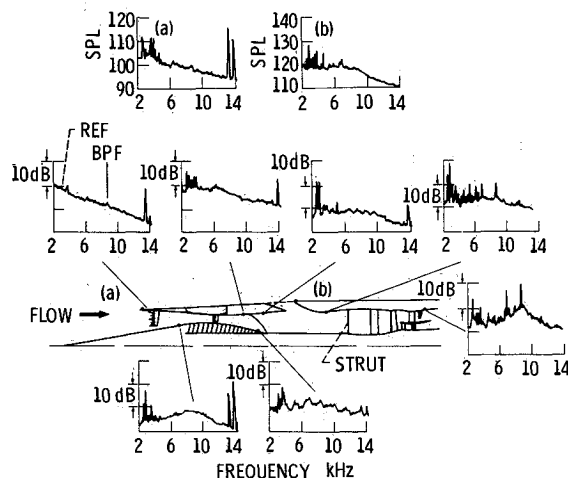

Fig 17 Internal pressure spectra for wind tunnel facility. (80% of design fan speed; centerbody 50% extended; 40% open doors; both bleeds closed; Mach numbers: throat, 0.58; door, 0 54) a) Cowl lip microphone b) Auxiliary door microphone

Fig 18 Effect of inlet configuration on overall sound power level (0 90 deg, 1 20 kHz)

Fig 19 Effect of inlet configuration on far field SPL spectra (60% of design fan speed; 70 deg from inlet axis; 7 6 m radius)

doors closed and centerbody fully extended Again, for this choked inlet throat condition there was no MPT evidence in the internal SPL spectra near the fan face; although, there were strong MPTs in the corresponding spectra for the CTOL inlet.

This analysis of the internal spectra for the CTOL and P-inlet clearly shows that the nature of the P-inlet is to suppress the actual generation of MPTs at fan speeds which would otherwise result in strong MPT spectral content Reference 1 reported a significant MPT and fundamental BPF tone reduction with a YF 12 supersonic inlet, and suggested that the axial centerbody support struts may be responsible for the noise reduction Tests were conducted with the JT8D refan in the anechoic chamber to investigate possible inlet strut effects on the radiated noise

For these tests a long annular duct with a bellmouth like lip was fitted to the JT8D refan The inlet had a cylindrical centerbody with a rounded nose Four equally spaced thin axial struts were located in the annular duct These struts had L/H ratios from 1 to 8, and a "no strut" case was run by using thin upstream wires to support the centerbody The inlet lip was fitted with the same inflow control device as was used for the P-inlet tests in the chamber

Figure 18 shows the effect of fan speed on the overall sound power level (1 20 kHz, 0-90 deg) for the baseline CTOL inlet and the long annular inlet The long inlet results shown are for the struts removed and for a strut L/H = 4, which was the case for the P-inlet support struts The results for the long inlet show essentially no acoustic effect due to the struts There are however, some apparent differences between the two inlets due to duct length. The far field SPL spectra likewise showed the long inlet struts to have little acoustic effect For
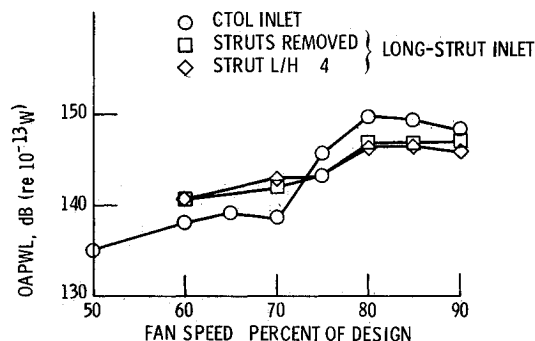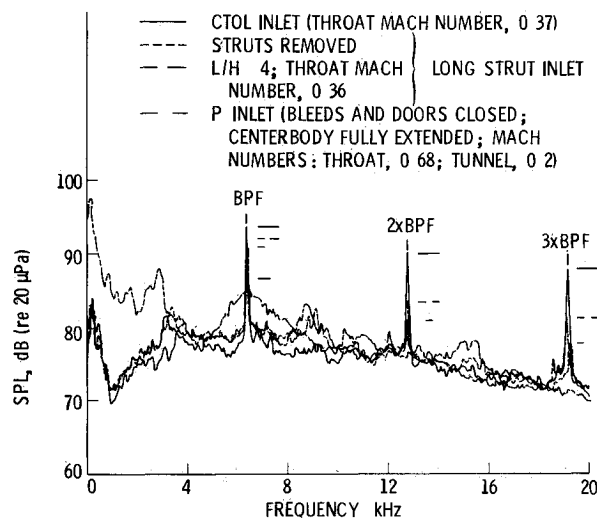
example, at 80% design fan speed and 70 deg from the inlet axis, the spectra for the L/H=4 struts and for the struts removed were similar, with strong MPT content in both spectra

Figure 19 shows the effect of all three inlet configurations at 60% design fan speed, where the fan spectra are charac terized by prominent fan fundamental and overtones, with no MPTs The tone levels at 70 deg from the fan inlet axis are highest with the CTOL inlet With the long strut inlet the fundamental tone is reduced only slightly, although the overtones show greater reductions It is interesting to note that the tone levels are slightly higher with the L/H=4 struts than with the struts removed—presumably a strut rotor in-teraction effect With the P-inlet (tunnel data) the fun damental tone level is greatly reduced relative to the levels for the other inlets, and the overtones are not detectable in the spectrum Thus the observed rotor tone reduction for the P-inlet is not associated with the inlet struts, and is only partially related to inlet length The total reason for the observed rotor tone and MPT reduction for the P-inlet remains unexplained

Summary of Results

A supersonic inlet, designated the P-inlet, was tested at a Mach 0 2 forward flight speed in the Lewis 9 × 15 anechoic tunnel and statically in the Lewis anechoic chamber using a JT8D refan model as the fan source Internal and far field acoustic data were taken Baseline data using the refan with a conventional CTOL inlet were also taken in the anechoic chamber This test program was conducted to investigate the

acoustic impact of opening auxiliary inlet doors which are required on a supersonic inlet to provide additional fan airflow at low flight speeds The acoustic effect of opening internal boundary layer bleed systems required for more stable internal airflow and the effect of struts was also in vestigated

Significant results of this investigation are as follows.

1) At subsonic fan tip speeds P-inlet operation with open auxiliary doors results in a significant increase in the fan fundamental tone SPL Internal pressure spectra show that this tone increase occurs at the fan source and is most likely due to changes in fan inflow uniformity caused by the open doors There is no clear indication that the open doors present a significant additional acoustic radiation pathway However corresponding fundamental tone levels for the CTOL inlet were greater than those for any P inlet configuration

2) The P-inlet appears to suppress fan multiple pure tones greatly at or near the fan source Tests with a long annular inlet with axial struts showed that the inlet support struts, of themselves are not the sound suppression mechanism The reason for this suppression remains unexplained

3) Numerous strong tones in the spectra were associated with the bleed system. These tones were not fan related and were strongly affected by the centerbody location The far field directivity of these tones is highly directional, with a peak at about 70 deg from the inlet axis Internal SPL spectra suggest that the centerbody bleed system is primarily responsible for these tones

4) Operation with open bleeds has no effect on the fan fundamental tone level for the closed and 20% open auxiliary door configurations However, the tone was increased significantly with open bleeds for the 40% open auxiliary door configuration.

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