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Abstract

A full scale engine wing shielding investigation was conducted at the Lewis Research Center using a 97,900-N (22,000 lb) thrust turbofan engine and a simulated wing section sized around a conventional-take-off type four-engine narrow body airplane. Sound data were obtained for the wing placed at seven positions in a plane parallel to the engine axis, and were compared to data obtained without the wing at both take off and approach power. In addition the engine was operated with and without extensive acoustic treatment including a sonic inlet in order to evaluate wing shielding effectiveness with a highly suppressed engine. The wing shielding effectiveness was also calibrated using an 3.8 cm diam air nozzle as a sound source. Results indicated that even though about 10 dB broad band shielding was achieved, the equivalent flyover noise reduction was less than 3.0 EPNdB for most configurations.

Introduction

Some current CTOL aircraft have the engines located on the fuselage in a plane above the wing. Future aircraft may have their engines mounted on and above the wing proper. The wing in either case can act as a sound reflector and redirect the engine sound skyward thus shielding the engine noise from the ground during takeoff and approach. Wing shielding can thus offer a reduction in flyover noise without the attendant expense and performance loss involved in conventional acoustic suppression methods.

Experimental work to evaluate the effectiveness of wing shielding has been done, but mostly with small scale jet nozzles in powered lift investigations. The results,[1] with nozzles of 5 and 33 cm in diameter, indicated that up to 10 Perceived Noise decibels (PNdB) of shielding effectiveness may be realized. However, a series of flyover tests[2] conducted on two different models of the same tri-jet airplane (B727) indicated that a 10 PNdB wing shielding benefit may result in practically no change in effective perceived noise level (EPNL). This occurs for this particular airplane due to the narrow shielded angle that the wing produces in relation to the engine inlets with the result that the time duration of the flyover signal is not reduced. Another full scale wing shielding investigation was reported[3] which presented design charts for nozzle shielding where the nozzle was within one diameter of the wing's surface. It should be noted that in most airplane installations it is impossible to shield both the inlet and exhaust of the engine with the wing.

A full scale single engine wing shielding investigation was conducted at the Lewis Research Center using a 97,900-N (22,000 lb) thrust turbofan engine and a simulated wing section sized around a conventional-take-off type four-engine narrow body airplane. Sound data were obtained for the wing placed at seven positions in a plane parallel to the engine axis. Comparisons of noise measurements made on the engine alone with those of each wing position at both takeoff and approach power settings are presented herein. The results, though static tests, should be credible and indicate directly the effect of wing shielding on the airplane flyover noise. Results from Ref. 3 indicated that as long as no flow surface interaction occurs that effects of forward velocity on noise shielding are minimal. In addition the engine was operated with and without extensive acoustic treatment including a sonic inlet as described in Ref. 4 in order to evaluate this effect on wing shielding.

The wing shielding effectiveness was also calibrated using a 3.8 cm diam air nozzle as a sound source. The purpose was to compare the shielding using a single, concentrated, high intensity noise source with the results from a large distributed source, such as the turbofan engine used in this investigation.

Engine, Wing, and Test Facility

Wing

Since the full scale high bypass engine (Quiet Engine "C") used for the experiment existed, the wing size had to be scaled to the engine. A four-engine narrow body transport of the DC-8 or B707 class was selected as a model because a study[5] conducted by the McDonnell-Douglas Aircraft Company indicated that retrofitting the DC8-61 with this engine was mechanically and aerodynamically viable. So a wing section from a DC-8 airplane could provide a reasonable full scale model. Wing dimensions of both the DC-8 and Boeing 707 (military KC-135) were taken from Ref. 6. The two wings were so similar in size that one mockup would simulate both. When the area was divided by the span a mean aerodynamic chord of 6.4 m (21 ft) was calculated. An average thickness of 12 percent or 0.76 m (30 in.) was somewhat arbitrarily chosen. For experimental simplicity a constant chord was also chosen. It was believed that 7.3 m (24 ft) of span would be adequate for the experiment.

The wing was mounted on a movable dolly such that its fore and aft position could be readily changed. The closest practical spacing between the engine and wing centers was 3.2 m (10.5 ft). The actual arrangement of the engine and wing as tested is shown in Fig. 1. The engine is shown with bellmouth inlet.

Simulating the acoustical transmission properties of a real wing was impossible and a real wing for the test was also not available. Therefore, the only property used for the mockup was the weight per unit of projected area. From Ref. 7 a target of 80 kg/m^2 was chosen.

A cross section of the wing showing the type of construction is given in Fig. 2. The wing was simply constructed of triangles and rectangles since no air was to flow over it. It was built with steel plates and plywood and fastened to a structural steel framework. The finished average weight of the wing was 80.5 kg/m^2 (16.6 lb/ft^2).

Engine and Facility

The engine used in the investigation was designated Quiet Engine-C. It was a high bypass (5:1) turbofan engine which developed 97,900 N (22,000 lb) of thrust at takeoff power. It used a single stage fan with no inlet guide vanes or damping shrouds. The fan was considered to be of high tip speed design, 477 m/sec (1565 fps). As shown in Fig 1 the inlet was fitted with a bellmouth and contained no acoustic treatment. The fan exhaust duct was of medium length and it contained no acoustic treatment. For part of the investigation, the engine was equipped with sonic inlets and massive aft fan suppression treatment as described in Ref. 4. A photograph of this configuration is shown without the wing in Fig. 3. The contour of the takeoff sonic inlet is shown in Fig. 4 and both the frame treatment configuration and the fully suppressed configuration are detailed in Fig. 5. The frame treatment configuration consisted of acoustic treatment in the fan frame and core compressor inlet passages with an untreated cylindrical inlet and untreated straight fan exhaust duct.

The engine was mounted on a static thrust stand which held the engine 4.1 m (13.5 ft) above the ground. The engine stand was located in the center of a circular microphone arena. A plot plan of the arena is shown in Fig. 6. The microphone circle was 45.7 m (150 ft) radius with its origin approximately at the engine center.

All 17 of the microphone signals were transmitted over low impedance lines to individual amplifiers. The amplifier outputs then fed into two 14 channel frequency modulated tape recorders. The tapes were then replayed off-line into a 1/3-octave band analyzer which digitized the signals over a 4 second average time. The digital signals were recorded on tape and fed into a comprehensive computing program using standardized procedures[8] which produced the results presented in this report.

The microphone and amplifiers were pre-run and post-run calibrated with piston phones. The accuracy of the measured sound pressure levels was ±0.5 dB.

Calibration Nozzle

A single jet nozzle 3.8 cm diam was located on the center of the microphone circle in place of the engine. The nozzle (Fig. 7) was pointed upward to provide a circular noise directivity pattern to the microphones. The nozzle discharge was located at the microphone horizontal plane.

Air at 524,000 n/m^2 (76 psi) gauge pressure at ambient temperature was discharged through the nozzle. Thus the flow was "choked" to yield a noise source containing nearly white noise with a pure tone.

A 1/3-octave band spectrum of the noise sound pressure level is shown in Fig. 8. The overall sound pressure level (OASPL) measured at the 45.7 m radius was about 103 dB.

Procedure

To obtain the shielding effectiveness over a wide range of wing positions the wing was moved to seven locations in a plane parallel to the engine axis. The locations are defined by the placement of the 0.4 chord point of the wing. The positions are illustrated on Fig. 9. There are three basic positions and the wing was simply moved ±3.05 m (10 ft) from the basic forward and aft positions to define the seven positions. The basic forward position was defined by a line drawn from the center of the bellmouth inlet through the 0.4 chord point of the wing to the 60° microphone. The basic side position was established by placing the 0.4 chord point on the 90° microphone radius. The basic aft position was set by aligning the wing leading edge with the fan discharge plane.

Noise measurements were made at each wing position while the engine was operated at both takeoff and approach powers. Engine parameters at both power settings are given in Table I. These data were taken from previous aerodynamic measurements made on the engine in this facility.

Results and Discussion

The wing shielding effectiveness calibration with the small jet nozzle will first be presented in terms of 1/3-octave band sound pressure level difference (ΔSPL), and then in terms of ΔOASPL for various angles. The wing shielding effectiveness is defined as the difference between the SPL's (OASPL's or PNL's) measured with and without the wing.

The baseline engine characteristics without the wing are then discussed in terms of 1/3-octave band SPL and perceived noise level (PNL) directivity at both approach and takeoff power.

The wing shielding effectiveness with the engine is then presented; first with the engine with frame treatment only, then with frame treatment and aft suppressor and finally with the fully suppressed engine (sonic inlet and aft suppressor). These results are presented in terms of 1/3-octave band ΔSPL and ΔPNL. ΔSPL shielding effectiveness on tones is also shown for the engine with frame treatment. Flyover time histories for both takeoff and approach conditions are discussed and finally the jet shielding configurations are compared to a jet shielding correlation.[9]

Wing Shielding Effectiveness Calibration with a Small Jet Nozzle

The 1/3-octave band shielding effectiveness is presented in Fig. 10 for the wing in a basic side position and for angles from 80° to 110° (measured from where the engine inlet would normally be if the engine were installed) which are in the wing's shadow. An average of 8 dB of shielding was realized for frequencies from 315 to 2000 Hz. At frequencies above 2500 Hz the shielding, was greater, reaching values above 20 dB at frequencies above 12,500 Hz. Inspection of the narrow bands showed that a tone did exist at 2500 Hz which was not shielded as well as the broad band noise. At frequencies below 315 Hz, there is no evidence of shielding. In fact there are some positive values possibly caused by reflections of the low frequency waves from instrumentation boxes and the truck cab. (see Fig. 7).

Inspection of Fig. 11 shows the angular extent of the ΔOASPL wing shielding for the wing in three basic positions. As might be expected the angular extent of the shielding is much greater for the wing in a basic side position than for the wing in the other two positions. The angular region where the wing geometrically shields the nozzle from the microphones, the "shadow," subtends about twice as great an angle (~100°) for the wing in the side position as for the wing in the other two positions.

The average wing shielding effectiveness is also greater for the wing in the side position (~12 dB) compared to the other two positions (~9.5 dB). The single compact noise source shielding discussed in this section is much simpler than the shielding of the engine which has three major noise source locations which span the length of the engine. The noise characteristics of the basic engine configurations are discussed next.

Baseline Engine Configuration Noise Characteristics, Without Wing

Presented in Fig. 12 are comparisons of front and aft baseline spectra at takeoff power for the three basic engine configurations without the wing. At 60° from the inlet (Fig. 12(a)) the spectra for the frame treatment and for the aft suppressor at takeoff power are dominated by the forward radiated fan machinery noise. The sonic inlet configuration reduces these noise sources and forward radiated jet noise becomes dominant.

At 120° from the inlet (Fig. 12(b)) the aft suppressor partially reduces the aft radiated fan machinery noise from the fan nozzle but the fan machinery noise coming from the inlet holds up the noise floor at the frequencies above 300 Hz. The sonic inlet configuration eliminates this noise source and the core jet noise becomes dominant.

At approach power the dominant noises are somewhat different from takeoff. At the front angle of 60° (Fig. 13(a)) the blade passing frequency (BPF) peak is dominant. No multiple pure tones (MPT's) exist at this lower fan speed because the tip relative Mach number is subsonic. The sonic inlet operated at approach power absorbs some front end noise. At the aft angle of 120° (Fig. 13(b)) broadband fan machinery noise and turbine noise are the main noise sources. The sonic inlet at approach power did not reduce the aft noise below the aft suppressor configuration noise.

The PNL directivities on a 305 m sideline for the baseline configurations (without the wing) are presented in Fig. 14. At takeoff power (Fig. 14(a)) the configurations with frame treatment and aft suppressor have PNL peaks of 104 and 105 PNdB at 60°. The aft suppressor reduces the aft peak noise (120°) of the frame treatment configuration from 102 to 97 PNdB. Adding the sonic inlet reduces the

front quadrant noise at 60° to 89.5 dB leaving the aft peak noise at 120° which is about 96 PNdB. At approach power (Fig. 14(b)) the frame treatment configuration has a front peak noise of 99 PNdB and a rear peak of about 102 PNdB. The aft suppressor configuration cuts the rear peak noise down to about 97 PNdB while the front peak noise is about the same as for the frame treatment. The sonic inlet at approach power reduces the front peak noise about 3 PNdB while the aft peak noise remains about the same as for the apt suppressor, as expected.

Wing Shielding Results

Engine with frame treatment. The wing shielding effectiveness on an SPL basis is presented in Fig. 15 for four wing positions; front forward, basic forward, basic side and basic aft. Only the microphones which are in the "shadow" of the wing are presented. Since the engine with frame treatment is front noise dominated as shown earlier the results for the forward wing locations show good shielding values. The average decrease in SPL due to shielding (Fig. 15(a)) is about 10 dB for frequencies between 2000 and 16,000 Hz for angles of 30°, 40°, and 50° from the engine inlet.

For the basic forward wing position (Fig. 15(b)) the decrease in SPL due to shielding at 50° from the engine inlet is also about 10 dB (which is maximum) at frequencies above 1000 Hz. For the wing in the basic side position (Fig. 15(c)) neither the front nor the aft noise sources are shielded by the wing and therefore, little noise reduction results. For the wing in the aft position (Fig. 15(d)) the core jet and the fan exhaust are well shielded by the wing and the ΔSPL for three angles from the engine inlet (100°, 110°, and 120°) average about 10 dB for frequencies above 3150 Hz.

At approach power (Fig. 16) the results are about the same as for takeoff power. The basic side position offers little or no noise reduction and the front forward and aft positions yield noise reductions over 10 dB at frequencies over 2000 Hz.

Shielding effectiveness on a perceived noise basis is presented in Fig. 17. Generally the wing shielding is more impressive at takeoff power than at approach power for front shielding. Recall from Figs. 13 and 14 that the engine at takeoff power is front noise dominated while at approach power aft noise is more dominant. Shielding of front noise then should be more effective at takeoff power since relatively lower aft noise would not encroach on the front quadrant. This is evident from Figs. 17(a) to (c).

The maximum ΔPNL of 10 dB occurs at the 50° forward angle for the wing in front forward position at takeoff power. The angular extent of the shielding (about 60°) with the wing in the front forward position is greater than for any other wing position tested. The shielding with the wing in the basic side position (Fig. 17(d)) is negligible as would be expected since neither the front or aft sources are well shielded. For the aft shielding positions (Figs. 17(e) to (g)), basic aft is the most effective. About 5 PNdB of shielding at takeoff power is shown for angles from 100 through 120° (Fig. 17(f)). Approach power shielding is even more effective for the reason mentioned previously. Approximately 9 PNdB of shielding is accomplished at angles of 110° and 120° from the engine inlet. Outside the wing's shadow the ΔPNL's are positive for the approach power condition. Reflections off the wing back to the engine and thrust stand and thence to the far-field could cause this behavior.

The effect of wing shielding on tones is presented in Fig. 18. The blade passing frequency (1250 Hz, 1/3-octave bandwidth) at approach power and the largest amplitude multiple pure tone (500 Hz, 1/3-octave bandwidth) at takeoff power were selected for the wing in the basic and front forward positions. At takeoff power the MPT was reduced by about 15 dB at the peak forward angle of 50° from the engine inlet. At approach power, the peak forward BPF was reduced by about 11 dB at 50° from the engine inlet.

Engine with aft suppressor. These results are presented for the wing in the basic and front forward positions since the engine noise for the aft suppressor configuration is front noise dominated. Shown in Fig. 19 are the wing shielding results at 50° from the engine inlet for takeoff and approach power conditions on an SPL basis. The results, as expected are almost exactly the same as for the frame treatment configuration (Figs. 15(a) and (b) and 16(a) and (b)). An average of about 10 dB reduction is achieved at takeoff power for frequencies above 500 Hz and about 11 dB above 1000 Hz for approach power.

Likewise, the wing shielding results on a PNL basis for takeoff and approach power presented in Fig. 20 are almost the same as those presented in Figs. 17(a) and (b) for the frame treatment configuration. A maximum forward peak angle ΔPNL equal to about 10 PNdB was achieved at takeoff power. At approach power, the PNL at the forward angle of 50° is about 8 PNdB. The extent of the wing shielding "shadow" is about 60° for both wing positions at both power settings.

Engine with sonic inlet and aft suppressor. Since this configuration was aft noise dominated (Fig. 14(a)) at takeoff power by core jet noise, wing shielding results are presented for the wing in the three aft positions. On an SPL basis (Fig. 21), the wing shielding effectiveness was greatest at an angle of 80° for the wing in the front aft position and 110° for the wing in the basic and back aft positions. Shielding varied from a nominal 2 dB at 200 Hz to as much as 17 dB at 10,000 Hz for the wing in a basic and front aft position These losses translated into about 5 dB on a PNL basis (Fig. 22) for the basic and front aft wing positions and into only about 3.5 dB for the wing in the back aft position. Table II summarizes the maximum wing shielding in terms of PNdB for engine configurations and wing positions reported herein. The takeoff sonic inlet and aft suppressor configuration was not run at approach power with wing shielding and therefore, does not appear in the table.

Effect of Wing Shielding on Flyover Noise

These data were calculated from the far field measured noise data assuming a four engine B707/DC8 type of takeoff and approach. The flyover parameters used in the calculations are summarized in Table III.

The tone corrected perceived noise level (PNLT) results are plotted as a function of time in relation to an observer standing at either the takeoff or approach FAR 36 specified points. Shown in Fig. 23 is a comparison of the takeoff time histories for the baseline (no wing) and the basic and front forward wing positions for the frame treated engine. The effect of the wing shielding was to lower the effective perceived noise level (EPNL) from 104.2 to 102.7 EPNdB for the basic forward and to 101.9 EPNdB for the front forward positions at takeoff. At approach (Fig. 24), for the front forward wing position, the EPNL was reduced from 101.3 EPNdB for the baseline engine without wing to 99.8 EPNdB. With the wing in the basic forward position, the calculated EPNL actually increased from 101.3 to 101.5 EPNdB. The wing shielding was effective until the 0 second time where the peak PNLT actually increased and resulted in a slight increase in the calculated EPNL.

Presented in Fig. 25 are time histories for the engine equipped with aft suppressors at takeoff. Without the wing the EPNL was 102.5 EPNdB. With the wing in either the basic or front forward position the EPNL was lowered by about 4 EPNdB.

Shown in Fig. 26 are time histories for the engine with aft suppressor and sonic inlet. The baseline EPNL without wing shielding is 94.5 EPNdB. With the wing in the aft positions shielding the jet noise of this very low noise configuration, the reductions in EPNL were substantial, about 2.5 EPNdB. For the front aft location of the wing, the reduction in EPNL was about 2 EPNdB.

A tabular presentation of all the calculated time histories is presented in Table IV. For the engine with frame treatment and the wing located in its most favorable location for approach conditions, the maximum reduction in EPNL from the baseline was 1.5 EPNdB. For takeoff conditions, the maximum reduction ranged from 2.3 EPNdB for the frame treatment configuration to 4.3 EPNdB for the aft suppressor configuration. The total EPNL reduction for the combined effect of shielding and engine suppression at takeoff power can be obtained by subtracting the EPNL for the quietest configuration (Sonic inlet and aft suppressor for the wing in the basic aft position (91.8 EPNdB) from the baseline frame treatment configuration with no wing shielding (104.2 EPNdB) which equals 12.4 EPNdB.

Jet Shielding Correlation

For the sonic inlet configuration at takeoff the dominant engine noise remaining was attributed to the core jet. With the wing shielding this source, the data were compared to the jet noise correlation developed in Ref. 9. The correlation parameter Z takes into account directivity, size of source (nozzle diameter), length of shield, and frequency.

Presented in Fig. 27 are data from directivity angles shielded by the wing in the basic aft position compared to the correlation represented by the solid line. As can be seen, the data agree with the correlation within ±3 dB. The agreement is better at low values of Z, which correspond to low frequency, than at high values of Z.

Summary of Results

1. Calibration of the wing shielding using the small air nozzle as a sound source showed that about 10 dB of broad band wing shielding effectiveness could be achieved in the shadow region. On an OASPL basis the maximum suppression amounted to about 14 dB at 90° from the engine inlet with the wing in a side position.

2. Shielding of the engine with frame treatment at approach power (BPF dominated) yielded a maximum broad band suppression of about 10 dB with the wing in a basic or front forward position. The BPF tone (1200 Hz) was suppressed about 11 dB. The maximum suppression of 9 PNdB occurred at an angle of 40° on a 114 m (375 ft) sideline.

3. Shielding of the engine with frame treatment at takeoff power (multiple pure tone and jet noise dominated) also yielded about 10 dB broad band suppression with the wing in the basic or front forward position. The peak MPT noise was suppressed 16 dB at 50°. The maximum shielding on a perceived noise basis amounted to 10 PNdB at an angle of 50° on a 305 m (1000 ft) sideline. The engine aft noise sources were not shielded in this position. Putting the wing in the aft position provided 5.0 PNdB suppression.

4. Forward shielding of the engine equipped with an aft suppressor yielded reductions in front noise approximately equal to the results with the frame treated engine at both approach and takeoff power. At approach the ΔPNL at a 50° angle from the inlet was about 8 PNdB. At takeoff power, about 10 PNdB shielding was achieved.

5. Aft shielding of the engine equipped with sonic inlet and aft suppressor (jet noise dominated) at takeoff power produced about 5 PNdB of suppression. The data generally agreed with the jet noise shielding correlation of Ref. 9.

6. Flyover noise results showed a maximum 1.5 EPNdB reduction was achieved by shielding the frame treated engine at approach. For takeoff, the maximum reduction was 2.7 to 4.3 EPNdB, depending on the engine configuration.

Concluding Remarks

The implications for CTOL wing shielding are that, since the wing chord is not sufficiently large in most cases to shield both ends of a turbofan engine, it would be a good compromise to acoustically treat one end of the engine and to shield the other end. The effect of this has been shown with the quietest configuration tested at takeoff power. The total reduction in flyover noise at takeoff power with the sonic inlet and aft suppressor configuration and the wing in the basic aft location was 12.4 EPNdB. Of this total noise reduction wing shielding of the aft radiated jet noise contributed 2.7 EPNdB.

References

1. Reshotko, M., Goodykoontz, J. H., and Dorsch, R. G., "Engine-over-the-Wing Noise Research," NASA TM X-68246, 1973.

2. Hodge, C. G., Winslow, L. J., and Wood, S. K., "The Effect of Inlet Noise Suppression on Propulsion System Design," AIAA Paper 73-1294, Nov. 1973.

3. Conticelli, V. M., Di Blasi, A., and O'Keefe, J. V., "Noise Shielding Effects for Engine-Over-Wing Installations," AIAA Paper 75-474, Mar. 1975.

4. Bloomer, H. E. and Schaefer, J. W., "Aerodynamic and Acoustic Performance of a Contracting Cowl High Throat Mach Number Inlet Installed on NASA Quiet Engine 'C'," AIAA Paper 76-540, July 1976.

5. "The Integration of Quiet Engines with Subsonic Transport Aircraft," Douglas Aircraft Co., Inc., Long Beach, Calif., DAC-68510A, Aug. 1969. (NASA CR-72548).

6. Taylor, J. W. R., ed., Jane's All the World's Aircraft, 1972-73, McGraw-Hill, New York, 1972.

7. Harris, C. M., ed., Handbook of Noise Control, McGraw-Hill, New York, 1957.

8. Montegani, F. J., "Some Propulsion System Noise Data Handling Conventions and Computer Programs Used at the Lewis Research Center," NASA TM X-3013, 1974.

9. vonGlahn, U., Groesbeck, D., and Reshotko, M., "Geometry Considerations for Jet Noise Shielding with CTOL Engine-over-the-Wing Concept," NASA TM X-71562, 1974.

TABLE I. - QUIET ENGINE "C" OPERATING PARAMETERS AND ENGINE DIMENSIONS

[Fan diam, m, 1.737; core discharge diam, m, 0.747; fan discharge o.d., m, 1.838; number of fan rotor blades, 26; number of fan exhaust guide vanes, 60.]

Engine parameter	Takeoff	Approach
Corrected fan speed, rpm	4620	3080
Corrected core speed,[a] rpm	8290	7655
Corrected total airflow, kg/sec	358	220
Bypass ratio	4.63	5.24
Corrected core jet velocity, m/sec	362.7	192.0
Corrected fan jet velocity, m/sec	268.2	167.6
Fan bypass pressure ratio	1.48	1.18
Corrected net thrust, N	97,900	37,380
Engine pressure ratio	3.96	2.04

[a]Corrected to fan core discharge

TABLE II. - MAXIMUM WING SHIELDING EFFECTIVENESS IN TERMS OF ΔPNdB

Wing position	Pwr. sett.	Engine configuration					
		Frame treatment		Aft suppressor		Sonic inlet and aft suppressor	
		θ°	ΔPNdB	θ°	ΔPNdB	θ°	ΔPNdB
Front forward	T.O.	50	-10	60	-10		
Basic forward	↓	50 and 60	-9.5	60	-10.5		
Back forward	↓	70	-6				
Basic side	↓	100	-3				
Front aft	↓	100	-4			80	-5
Basic aft	↓	100	-5			110	-5
Back aft	↓	110	-1.5			110	-3.5
Front forward	App.	40	-9	50	-8.5		
Basic forward	↓	40 and 50	-8	50	-8		
Back forward	↓	70	-3.5				
Basic side	↓	80 and 90	-3				
Front aft	↓	90 and 100	-5				
Basic aft	↓	110 and 120	-9				
Back aft	↓	140	-3.5				

TABLE III. - FLYOVER CONDITIONS FOR B707/DC-8 TYPE AIRPLANE

WITH $4 \cdot 10^5$ NEWTON[a] ENGINES

	Altitude, m	Airplane velocity, m/sec	Thrust angle	Average jet velocity, m/sec	Airplane gross weight, kg
Takeoff	451	72	6° up	330	147,500
Landing	104	71	3° down	183	102,000

[a]Nominal sea level static thrust

TABLE IV. - COMPARISON OF EPNL FOR VARIOUS ENGINE

AND WING CONFIGURATIONS

[Four-engine DC-8 type airplane.]

Engine with frame treatment								
	Wind positions							
	No wing	Side	Basic fwd	Front[a] fwd	Back fwd	Basic aft	Front aft	Back aft
T.O.	104.2	103.8	102.7	101.9	104.7	103.4	103.1	104.5
App.	101.3	102.2	101.5	99.8	101.6	100.7	102.0	101.0

Aft suppressor			
	Wing positions		
	No wing	Front[a] fwd	Basic fwd
T.O.	102.5	98.2	98.4

Sonic inlet and aft suppressor				
	Wing positions			
	No wing	Front aft	Basic[a] aft	Back aft
T.O.	94.5	92.7	91.8	92.1

[a]Wing positions having greatest wing shielding effectiveness.

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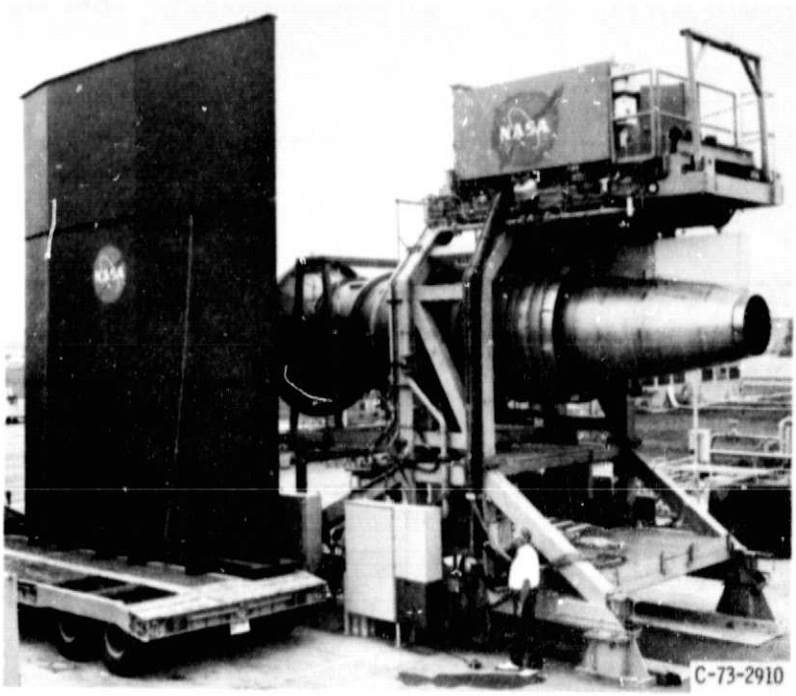

Figure 1. - Quiet engine and wing as tested with bellmouth and engine frame treatment.

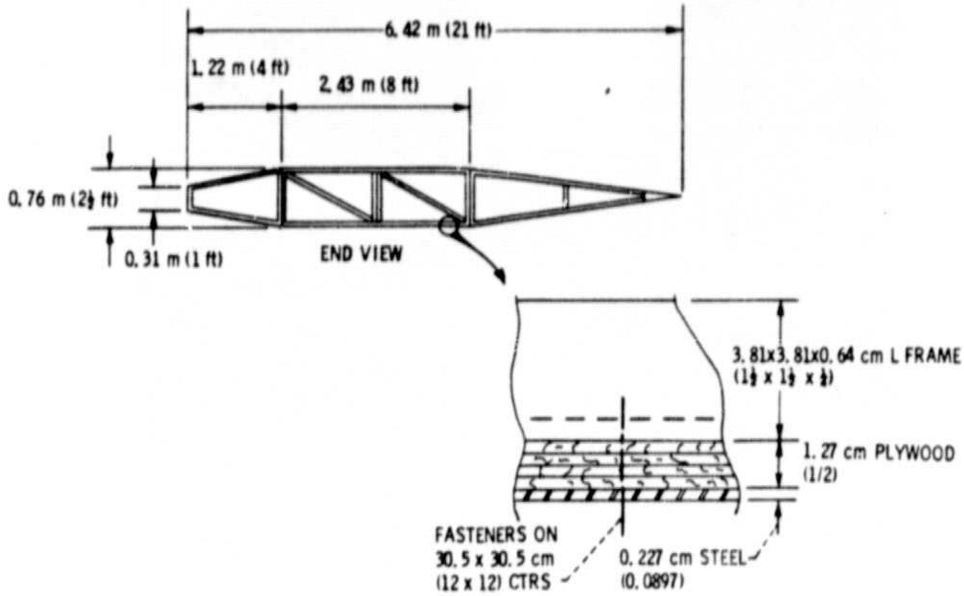

Figure 2. - Wing construction.

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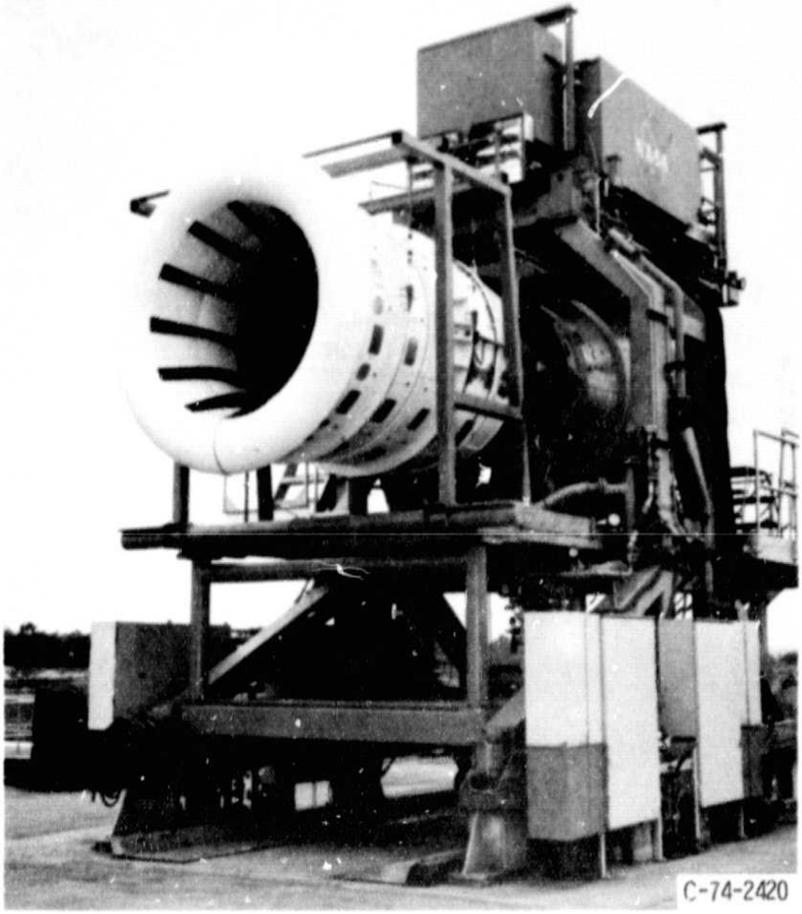


Figure 3. - Quiet engine as tested with sonic inlet and aft suppressor. Wing not shown.

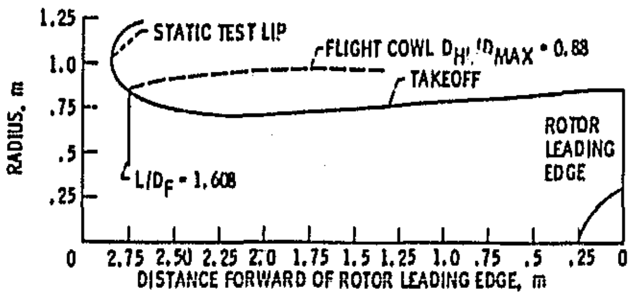
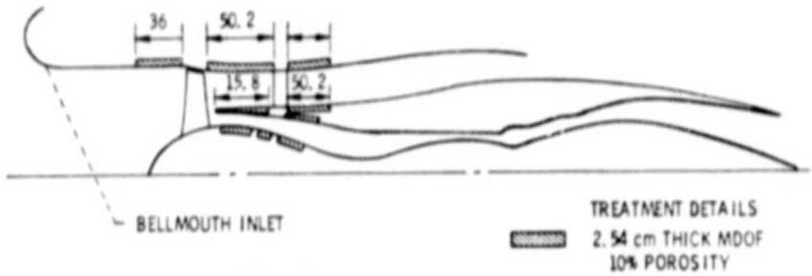
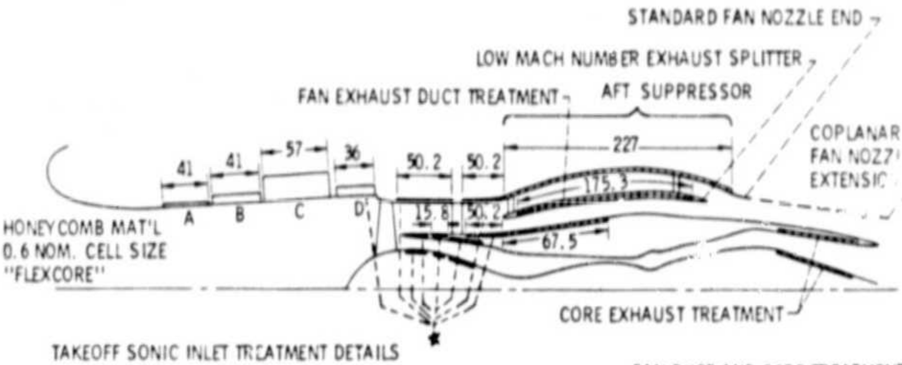


Figure 4. - Sonic inlet showing the take-off contour and the static test lip utilized for performance evaluation.



(a) CROSS SECTION OF FRAME-TREATED CONFIGURATION.



TAKEOFF SONIC INLET TREATMENT DETAILS

	B'KING DEPTH	FACING SHEET		
		THICKNESS	HOLE DIAM.	% OPEN
A	0.76	0.08	0.14	7.3
B	2.54	.08	.14	10.0
C	7.19	.08	.14	2.5
D	2.79	.13	.13	7.0

NOTE: ALL DIMENSIONS ARE IN CM.

FAN DUCT AND CORE TREATMENT DETAILS

2.54 THICK MDOF 10% POROSITY

0.64 THICK SDOF 7% POROSITY

2.54 THICK SCOTTFELT

★ FRAME TREATMENT

(b) CROSS SECTION OF FULLY SUPPRESSED CONFIGURATION WITH FRAME TREATMENT, SONIC INLET AND AFT SUPPRESSOR.

Figure 5. - Quiet engine "C".

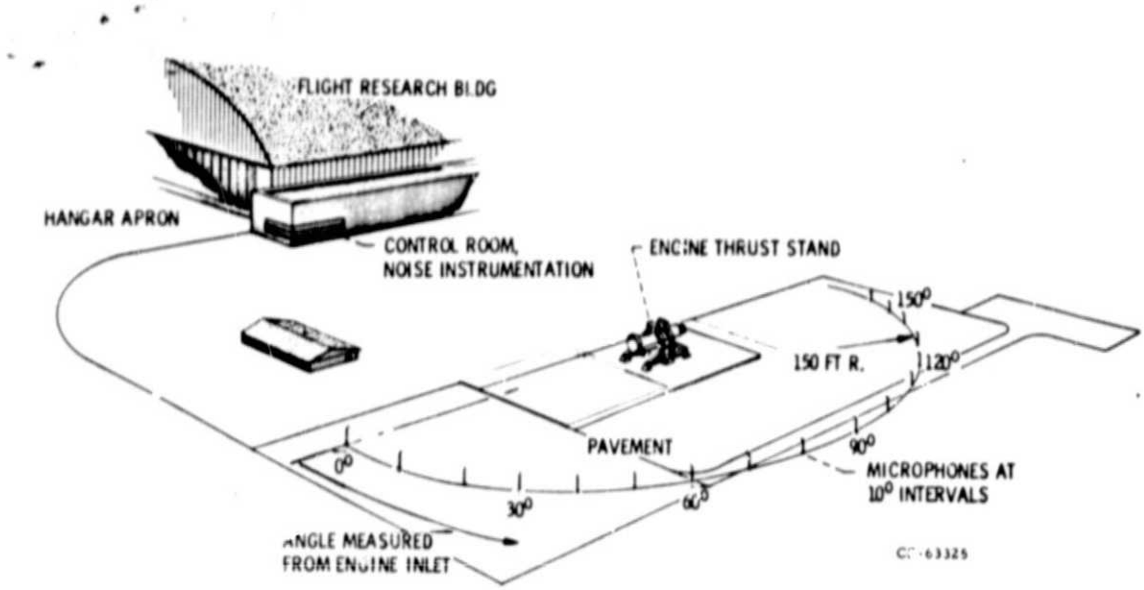


Figure 6. - Engine Noise Test Facility plot plan showing thrust stand, microphone array, control and noise instrumentation rooms.

Figure 7. - Jet nozzle location relative to wing for wing calibration tests.

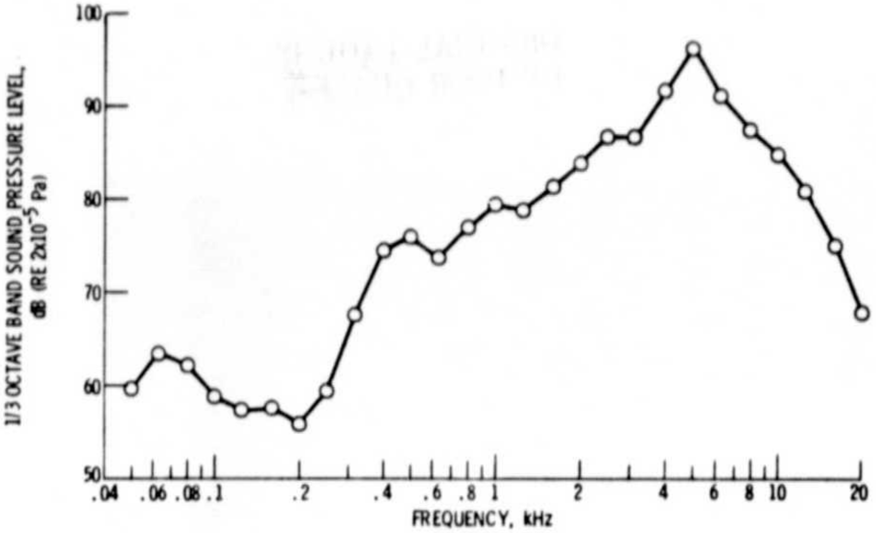


Figure 8. - 1/3 octave band spectrum produced by small jet. Angle from engine inlet if engine were installed, 90°. (Refer to fig. 6.) No wing in place.

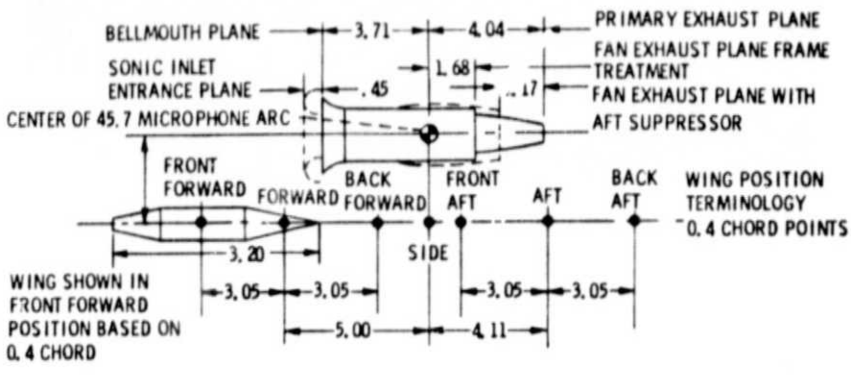


Figure 9. - Wing positions relative to the engine.

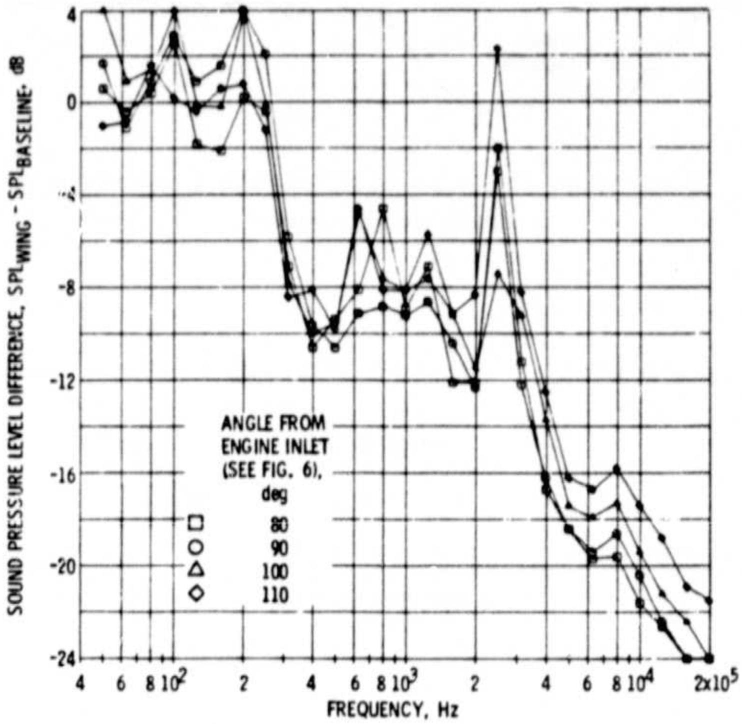


Figure 10. - Wing shielding effectiveness with a small jet nozzle as a sound source. Wing position, basic side.

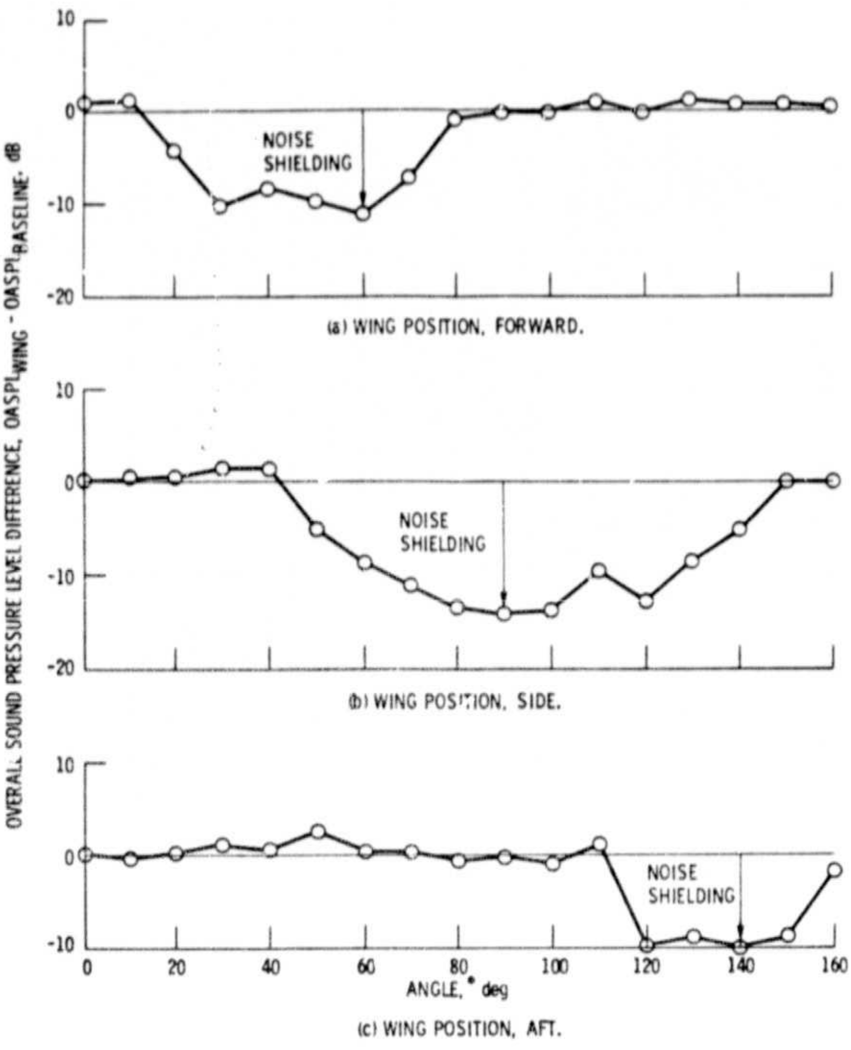


Figure 11. - Wing shielding effectiveness on an OASPL basis with a small jet nozzle as a sound source.

*REFER TO FIG. 6.

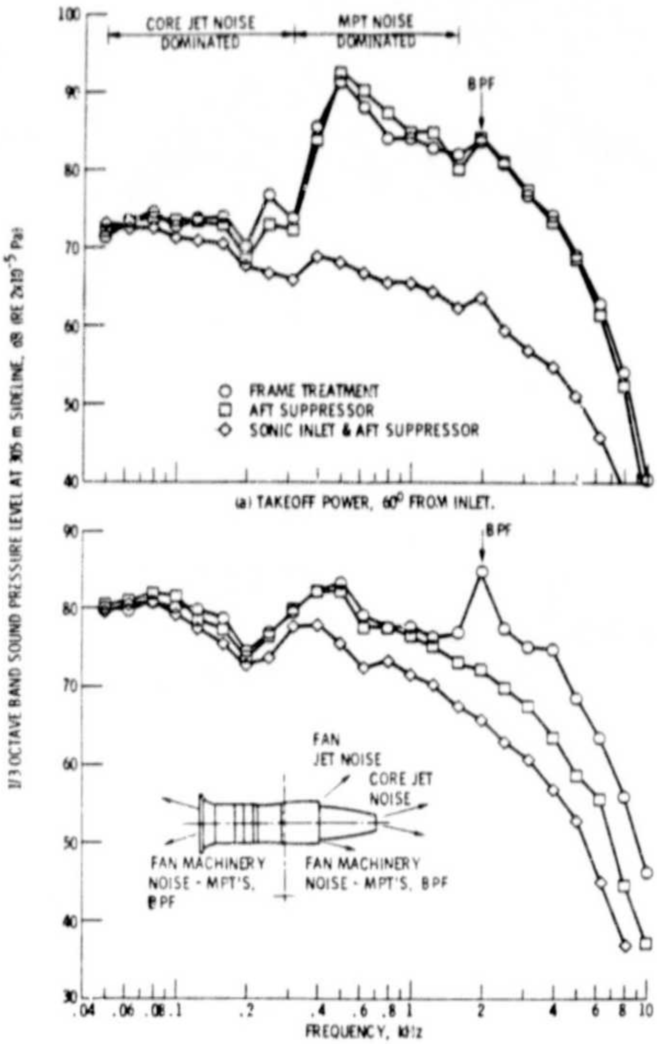


Figure 12. - Comparison of baseline spectra without wing.

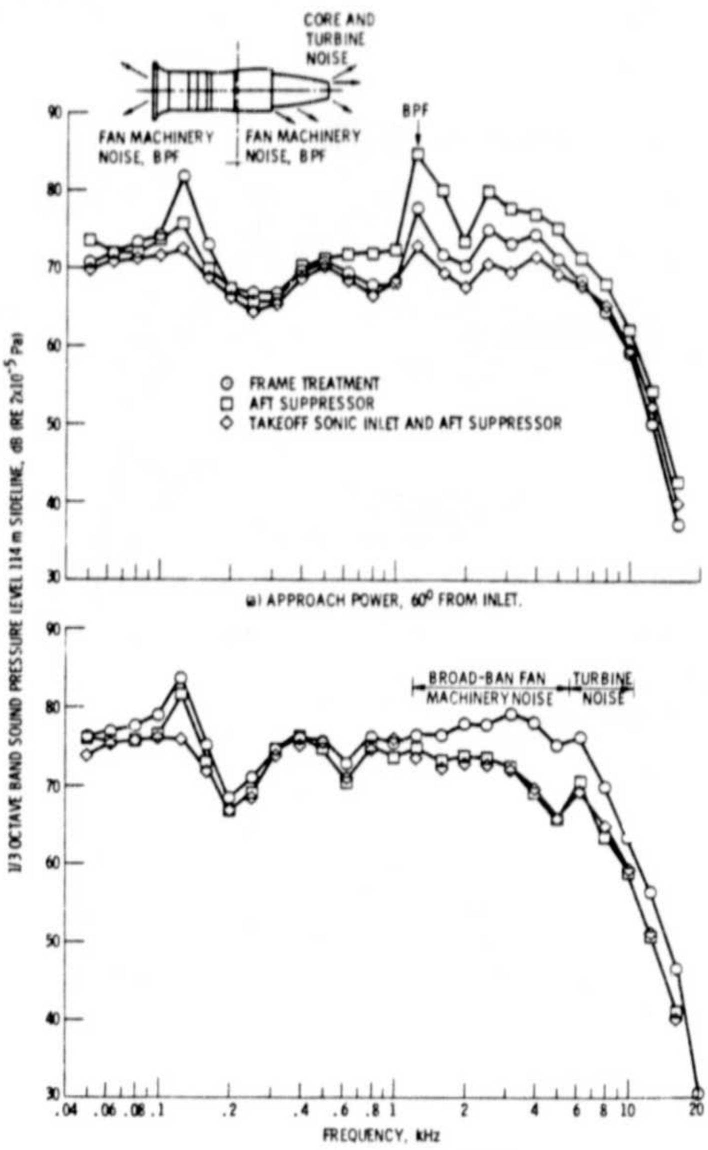


Figure 13. - Comparison of baseline spectra without wing.

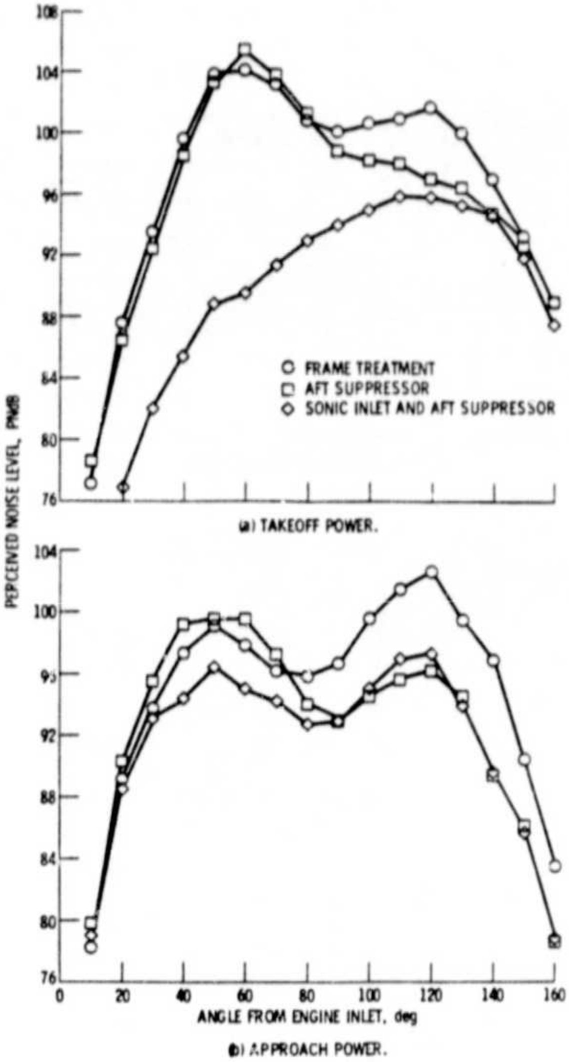


Figure 14. - Comparison of PNL directivities for base line configurations without wing.

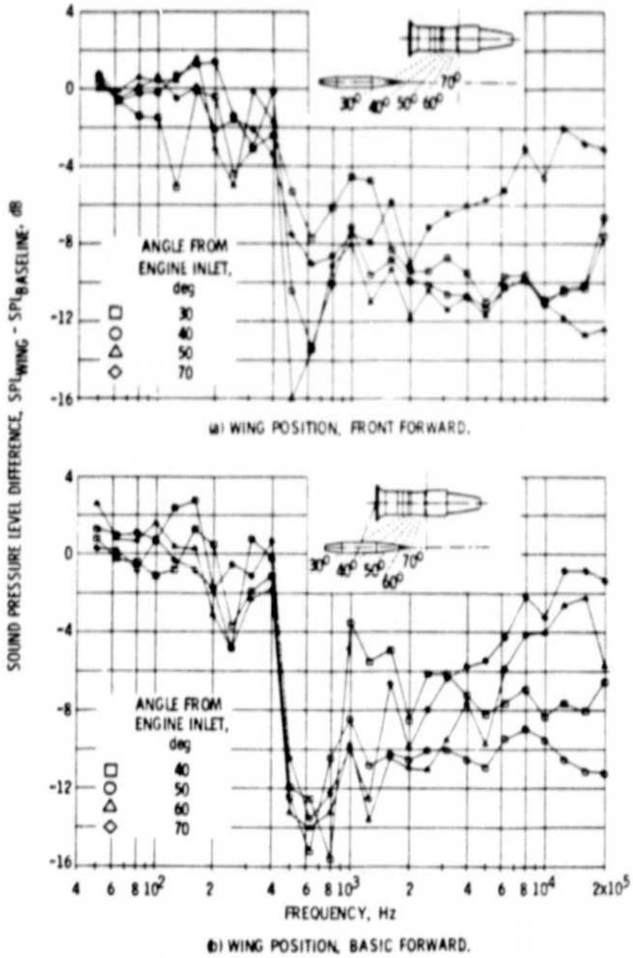


Figure 15. - Wing shielding effectiveness with engine frame treatment configuration at takeoff power.

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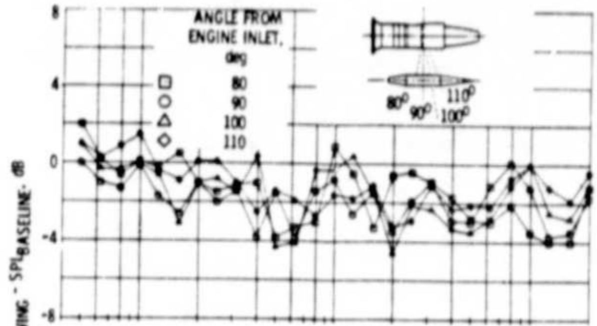
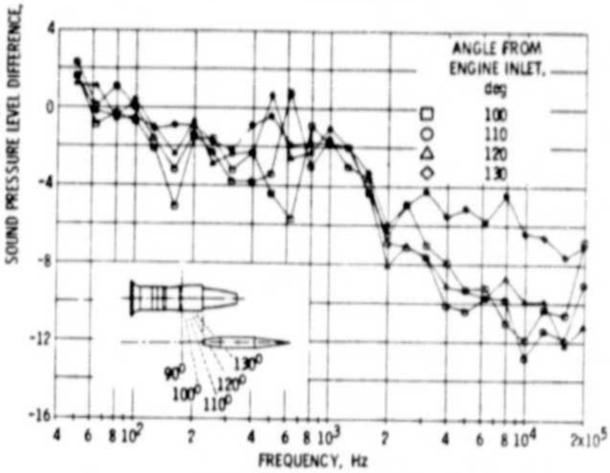
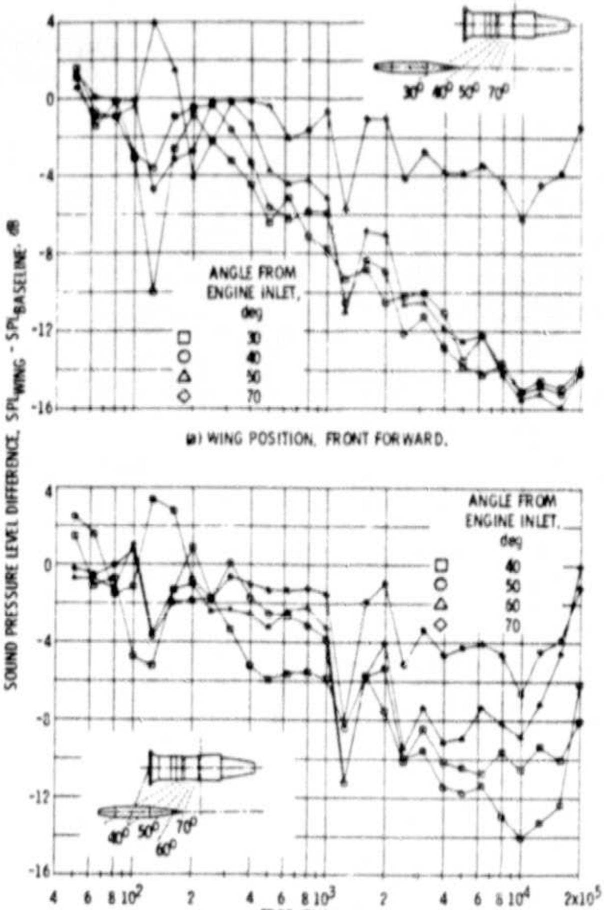


(c) WING POSITION, BASIC SIDE.



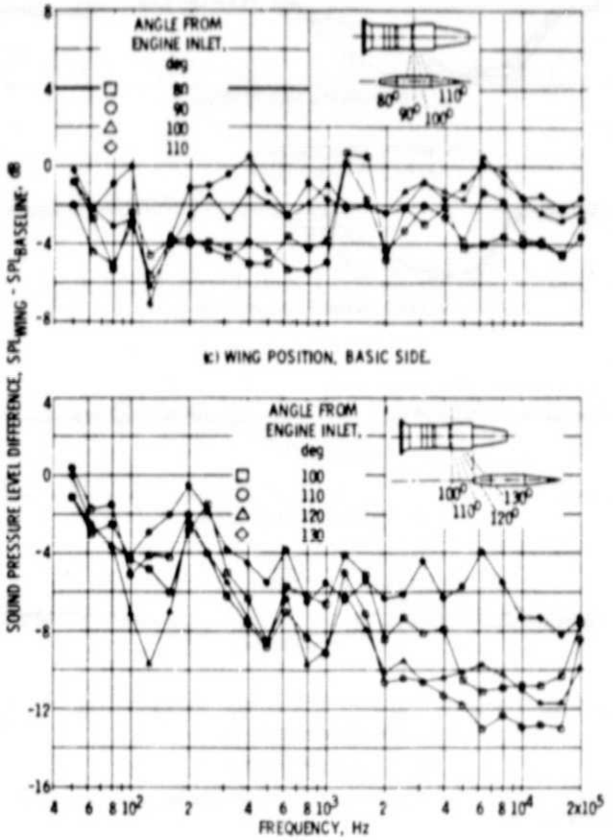
(d) WING POSITION, BASIC AFT.

Figure 15. - Concluded.



(b) WING POSITION, BASIC FORWARD.

Figure 16. - Wing shielding effectiveness with engine frame treatment configuration at approach power.



(c) WING POSITION, BASIC SIDE.

(d) WING POSITION, BASIC AFT.

Figure 16. - Concluded.

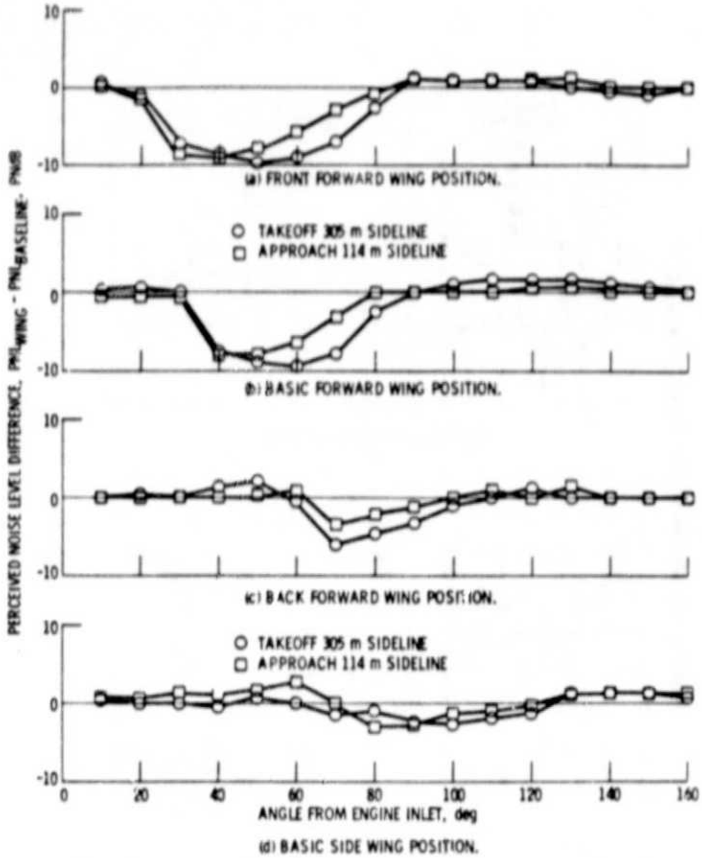
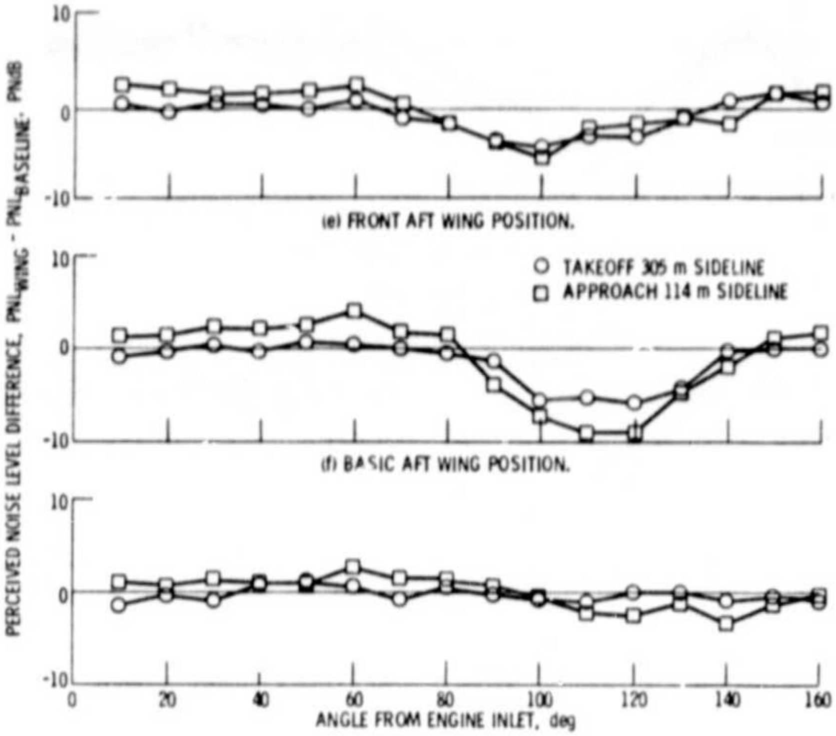


Figure 17. - Wing shielding effectiveness on a perceived noise level basis. Engine with frame treatment.



(g) BACK AFT WING POSITION.

Figure 17. - Concluded.

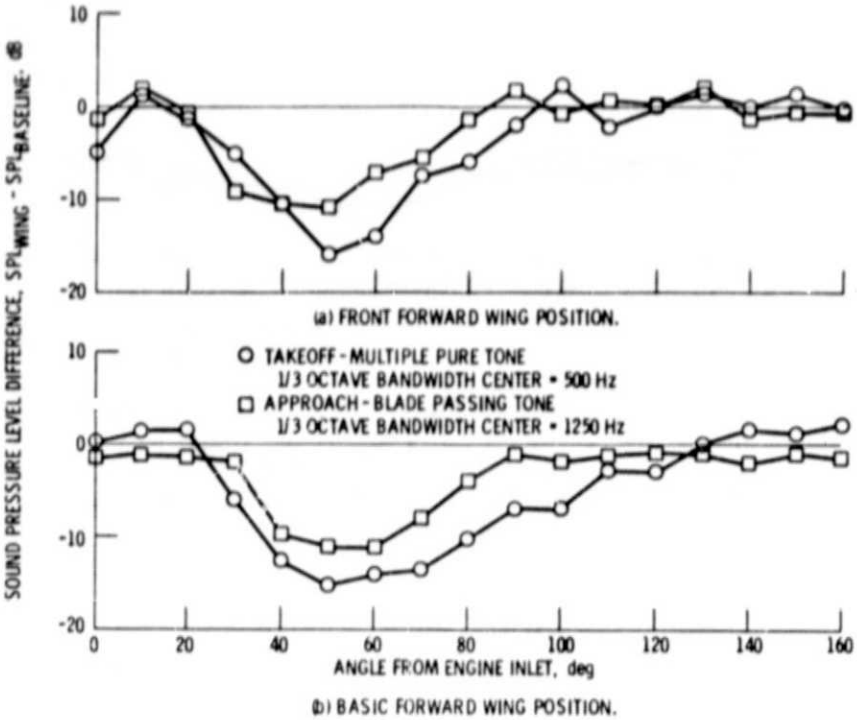


Figure 18. - Wing shielding effectiveness on tones. Engine with frame treatment.

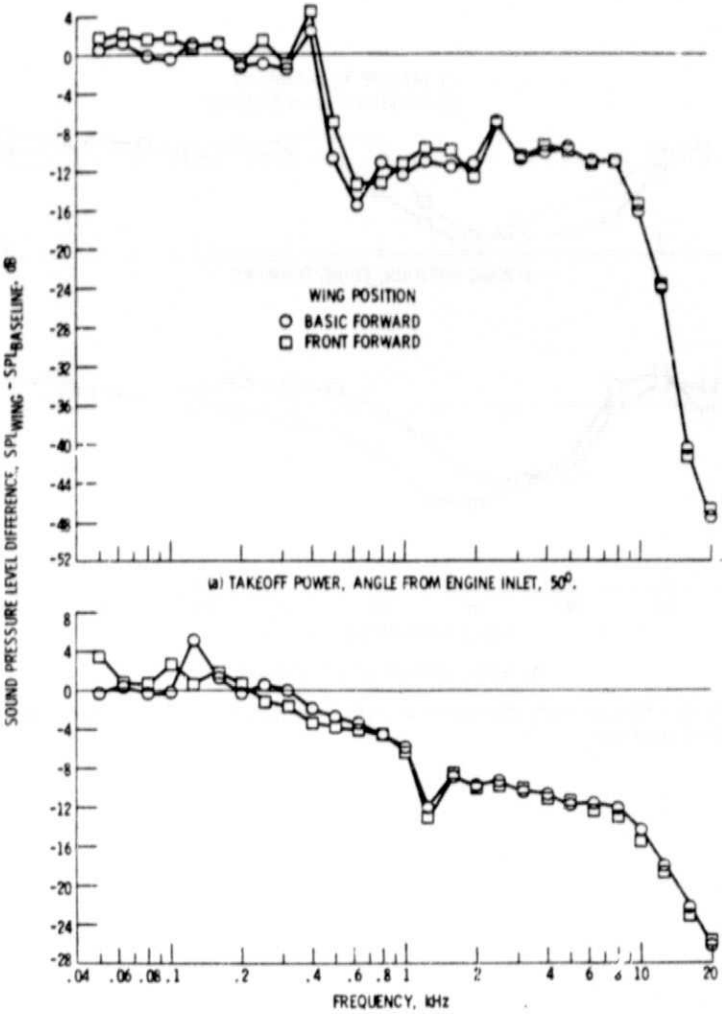


Figure 19. - Wing shielding effectiveness on a sound pressure level basis. Engine equipped with aft suppressor.

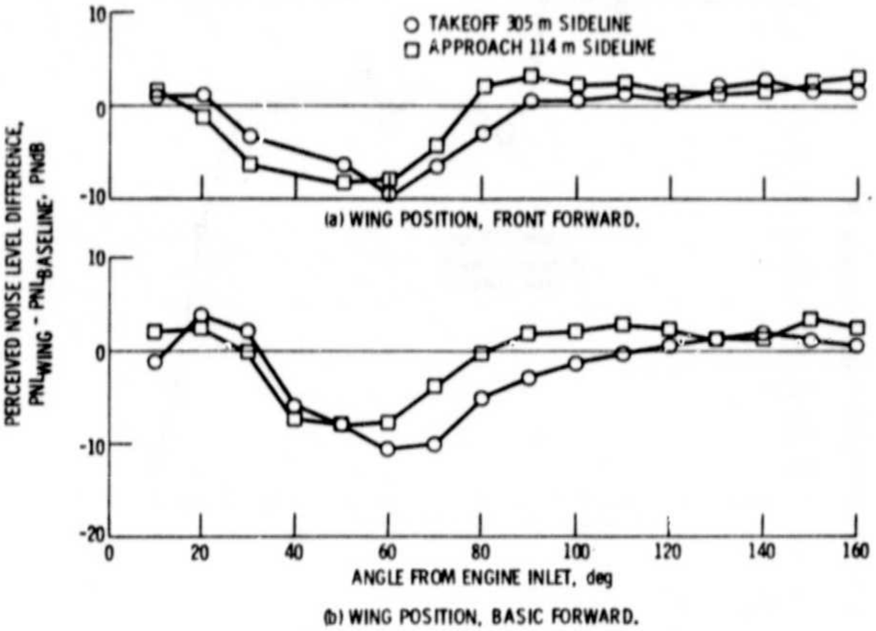


Figure 20. - Wing shielding effectiveness on a perceived noise level basis. Engine equipped with aft suppressor.

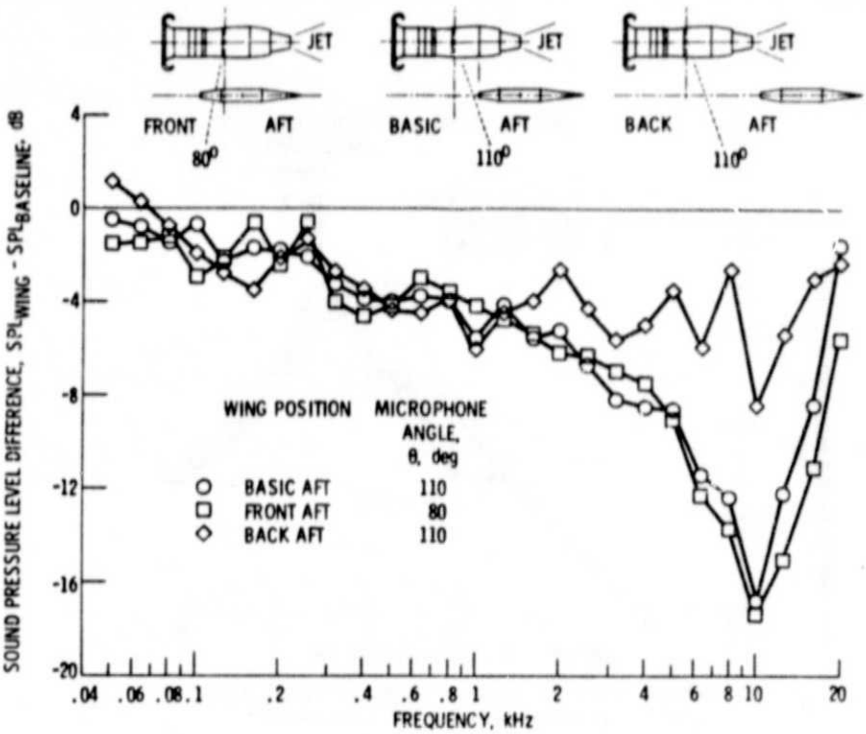


Figure 21. - 1/3 octave band transmission loss spectra through wing with the engine equipped with sonic inlet at takeoff power.

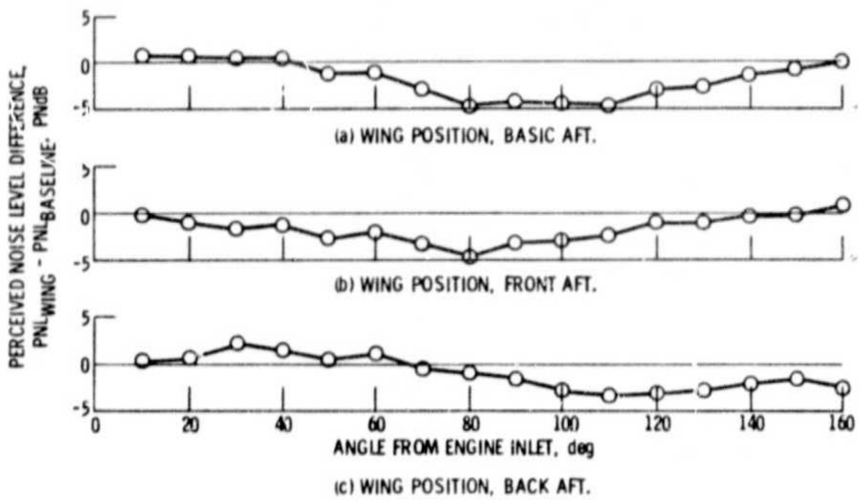


Figure 22. - Wing shielding effectiveness on a perceived noise level basis engine with sonic inlet and aft suppressor. Takeoff power. Data shown for 305 m sideline.

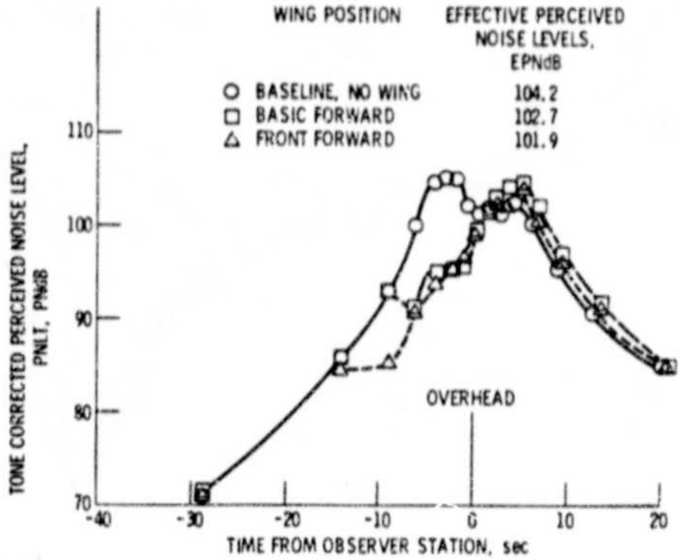


Figure 23. - Takeoff time histories (flyover noise) of four engine (DC8/B707 type) airplane. Engines with frame treatment.

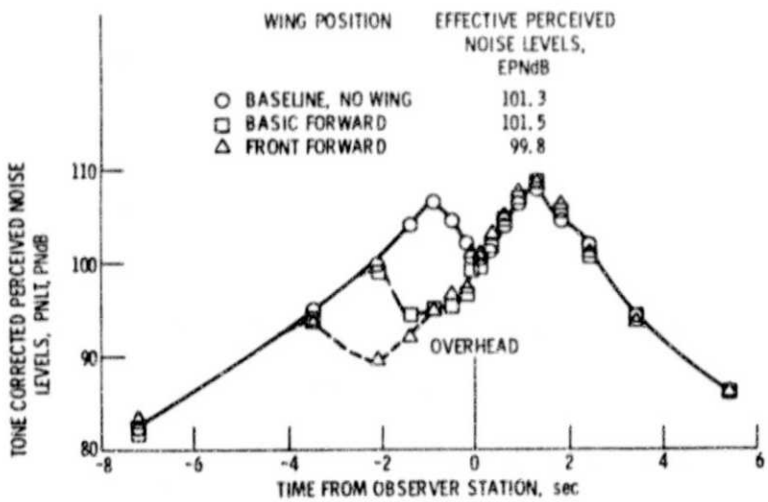


Figure 24. - Landing time histories (flyover noise) of four engine (DC8/B707 type) airplane. Engines with frame treatment.

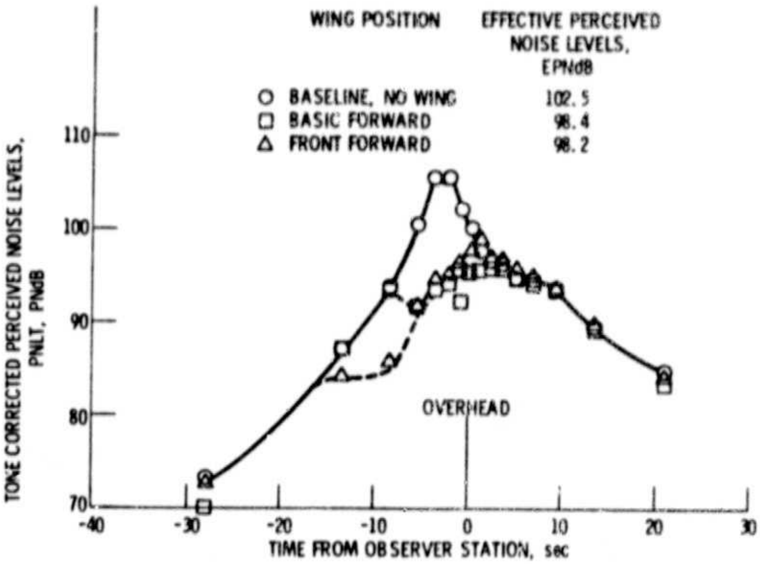


Figure 25. - Takeoff time histories (flyover noise) of four engine (DC8/B707 type) airplane. Engine equipped with aft suppressors.

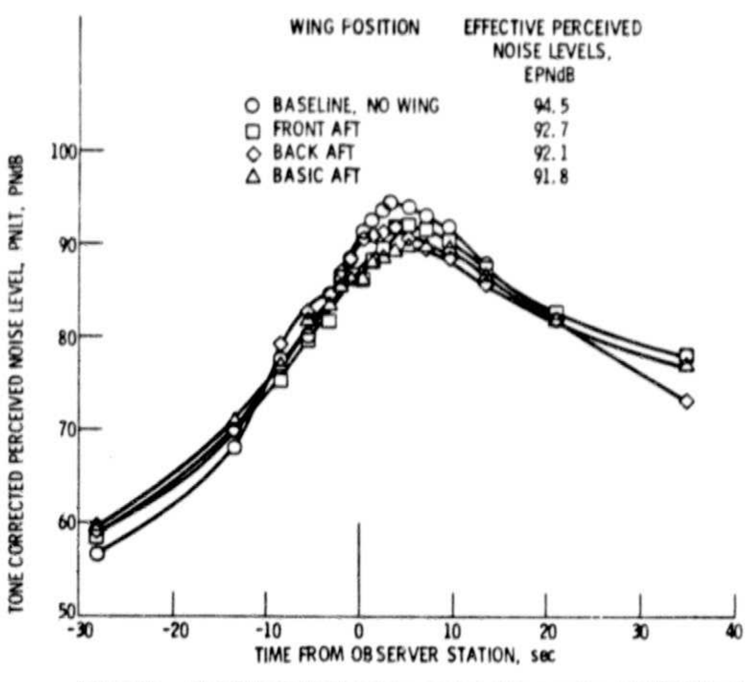


Figure 26. - Takeoff time histories (flyover noise) of four engine (DC8/B707 type) airplane. Engines equipped with sonic inlets and aft suppressors.

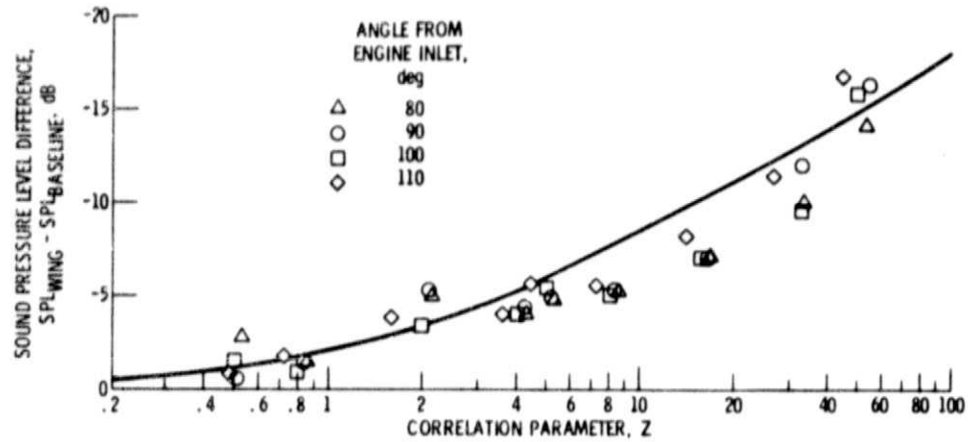


Figure 27. - Comparison of quiet engine "C" jet noise shielding data to correlation developed in reference 9. (Sonic inlet configuration.)