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**Controlled Technical Report**

**Rapport technique contrôlé**

**1987 / 11**

**CTR-ENG-015**

**NOISE PROPAGATION TESTS OF A CF-18 AIRCRAFT  
AT OTTAWA INTERNATIONAL AIRPORT**

**N.G. Ball**

**Division of  
Mechanical Engineering**

**Division de  
génie mécanique**



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NOISE PROPAGATION TESTS OF A CF-18 AIRCRAFT  
AT OTTAWA INTERNATIONAL AIRPORT

DES ESSAIS SUR LA PROPAGATION DE BRUIT D'UN AÉRONEF CF-18  
L'AÉROPORT INTERNATIONAL D'OTTAWA

N.G. Ball

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Technical Report

1987/11

Rapport technique  
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CTR-ENG-015

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## ABSTRACT

Noise levels in the communities surrounding Ottawa International Airport were monitored during static engine runups of a CF-18 aircraft parked on an airport taxiway. The tests were designed to validate an acoustic propagation model developed for a proposed outdoor engine test facility to be located adjacent to the airport. The results support the model but show the strong influence of the atmosphere on the propagation of sound. The noise of the aircraft engine exceeded background levels at downwind sites at distances of 2 and 4 km.

## RÉSUMÉ

On a contrôlé les niveaux de bruit dans les collectivités voisines de l'aéroport international d'Ottawa pendant la marche des réacteurs d'un CF-18 garé sur une voie de circulation de l'aérodrome. Les essais avaient pour but de valider un modèle de propagation acoustique élaboré en vue de l'implantation proposée d'un banc d'essai extérieur pour réacteurs à proximité de l'aéroport. Les résultats confirment le modèle mais mettent en évidence la forte influence de l'atmosphère sur la propagation du bruit. Le bruit produit par les réacteurs du chasseur a dépassé les niveaux du bruit de fond à des points sous le vent à des distances de 2 km et 4 km.

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## NOISE PROPAGATION TESTS OF A CF-18 AIRCRAFT AT OTTAWA INTERNATIONAL AIRPORT

### 1.0 INTRODUCTION

On June 30, 1987 the Engine Laboratory of the Division of Mechanical Engineering measured the noise radiation from a CF-18 aircraft during static engine runups at Ottawa International Airport. The tests were performed to aid in the assessment of the noise impact from a proposed outdoor gas turbine engine test facility to be built adjacent to the airport. The primary purpose was to confirm the theoretical predictions of the noise levels in the surrounding community made by Davis Engineering Limited, 1987. A secondary purpose of the test was to note the community response to the noise of these tests.

Additional studies of the near and far-field noise of the GE-404-400 engine, the type used in the CF-18 aircraft, can be found in References Franklin et al., 1979, General Electric Aircraft Engine Group, 1975, and Powell 1979.

### 2.0 DESCRIPTION OF TESTS

#### 2.1 Noise Source

The CF-18 aircraft was parked on the taxiway of the Uplands Airport, as shown in Figure 1, with the nose of the aircraft pointing into the west wind which aligned the aircraft at approximately 20 degrees to the taxiway. The position and orientation of the aircraft remained fixed throughout all of the tests.

The tests were designed to measure the noise radiation from a single engine at two power levels, military power and with full afterburner, but the operational procedures for the aircraft required that the second engine remain at idle power at all times. The small increment to the total noise from the idling second engine was not considered significant. The engine runup sequence was as follows: 5 minutes at an idle power setting, 5 minutes at military power, 3 minutes with full afterburner, 10 minutes at idle, 5 minutes at military power, 3 minutes with afterburner, and a final 5 minutes at idle. The first sequence ran the right engine at the higher throttle settings and the left engine for the second. The second runup sequence was terminated 90 seconds after the start of the final period of afterburner because of fuel shortage onboard the aircraft. The one hour interval between tests was used to move the noise measurement equipment to new locations for the second engine runup sequence.

## 2.2 Far-Field Noise Measurements

### 2.2.1 Measurement Sites

The far-field noise levels were monitored at eight locations equally spaced around a circle of 2 km radius during the first engine runup sequence. The radius was increased to 4 km for the second sequence. When the measurement sites were selected, it was assumed that the aircraft would be aligned with the taxiway and sites were chosen at 45 degree intervals from the taxiway. However, for the tests the aircraft was parked at 20 degrees to the taxiway to face the aircraft into the wind with the consequence that no measurement sites were located on the jet axis. The precise locations of the measurements are shown on Figure 1. In general, the sites were on flat, open, grass-covered terrain with the microphones set 1.8 metres above the ground.

Two types of measurements were made in the acoustic far-field of the engine. The A-weighted average sound pressure levels ( $L_{eq}$ ) were measured at all sixteen sites, and at six of the sites the noise was recorded for subsequent spectral analysis for comparison with the assumptions of the theoretical model.

### 2.2.2 Instrumentation

At all of the locations the noise levels were monitored throughout an entire engine runup sequence, at 2 km distance during the first and 4 km during the second. The instrumentation (Metrosonics Metrologgers model dB-301) stored the average sound pressure level (A-weighted  $L_{eq}$ ) for one minute intervals. By coordinating the starting time of the data acquisition and the time of the engine running, the noise levels for each of the engine power settings was determined. The operators at each of the sites noted the subjective level of the engine noise relative to the background noise. Any significant acoustic events that occurred during the measurement period were logged so that data contaminated by extraneous noise could be eliminated.

At six of the sites (A90, A135, A225, B90, B135, and B225) [shown on Figure 1] the sound of the engine was recorded with sound level meters and tape recorders (Bruel and Kjaer types 2209 and 7003). These tapes were later analyzed for spectral content with an octave band real-time analyzer (Bruel and Kjaer type 2131).

## 2.3 Near-Field Measurements

Noise measurements close to the aircraft were made by R. Westley of the National Aeronautical Establishment. These values were used to ensure that the sound power of the engine during the tests was the same as that used in the theoretical predictions. The overall sound pressure levels were measured along a line normal to the jet axis in the plane of the exhaust nozzle, at a height of approximately 1.8 metres.

## 2.4 Atmospheric Conditions

The propagation of sound through air can be greatly affected by the atmosphere. Meteorological conditions during the test were provided by the weather office of Ottawa International Airport. The first runup sequence started at 10:44 and the second sequence ended at 12:58. At 11:00 the temperature was 23° C, the winds were from the west at 22 kph gusting to 40 kph, and the humidity was 57%. At 13:00 the temperature and wind were unchanged but the humidity had dropped to 44%. During the period of the test the weather office reported a 'normal' temperature profile (adiabatic lapse rate).

## 3.0 OBSERVATIONS

### 3.1 Near-Field Sound Pressure Levels

The sound pressure levels of the engine measured close to the aircraft are shown in Figure 2 and are compared with data given by the engine manufacturer [General Electric Aircraft Engine Group, 1975]. While it is recognized that the sound pressure levels change with the angle from the jet axis, the good agreement at this one angle indicates that the sound power of the engines during the tests was close to the sound power stated by the manufacturer.

### 3.2 Far-Field Noise Levels

The noise levels at both 2 and 4 km distance from the aircraft showed a strong angular dependence. Jet noise characteristically has the highest sound pressure levels at approximately 40 degrees from the jet axis. While this trend is apparent in the data, it is also clear that the atmospheric conditions and ground properties greatly affected the sound propagation.

Table 1 shows the average A-weighted noise levels for both military and afterburner power settings for a 2 and 4 km radius, based on the one minute equivalent sound level readings. At 2 and 4 km, the observed levels were as high as 70 dBA and 61 dBA respectively. Care was taken, when examining the one minute levels, to exclude any data which was contaminated by extraneous noise sources. Figure 3 shows a sample of the output from the noise monitors. Each of the values is the one minute average of the A-weighted noise at the site. A clear correlation is evident between the engine power setting and the noise level at this site. At some of the sites, the observers reported that the engine noise was inaudible or below the background noise levels. For these sites no estimate of the engine noise was possible. The background noise level varied greatly between sites and because of the short duration of the sampling, no accurate estimates of average noise levels for the community are possible from this data. The scant data that were available show levels in the range of 45-55 dBA typical of residential areas.

Table 2 shows a comparison of the noise levels observed at the military power setting with those predicted by Davis Engineering Limited, 1987. The theoretical values include only the effects of

geometrical spreading and molecular absorption and do not include the effects of wind, ground impedance or temperature gradients. These values were interpolated from the noise level contours of Figure 5-6 from Davis Engineering Limited, 1987 and correspond to the values expected for the same angles as the measurement sites relative to the aircraft.

### 3.3 Engine Noise Spectra

The spectrum of the engine noise greatly affects the propagation of sound through the atmosphere. The A-weighted octave band spectra of the recorded engine noise at military and afterburner power settings from sites A135 and B135 are shown in Figure 4. Included in the same Figure are three of the spectra for a typical aero engine as defined by Davis Engineering Limited, 1987 [Figure 5-3].

### 3.4 Community Response

The noise level and duration of these tests would be comparable to the noise of a typical engine test program. The airport authorities occasionally receive noise complaints from the normal operation of the airport but no complaints were received from the residential communities during the static running of the aircraft engines.

## 4.0 INTERPRETATION OF TEST DATA

### 4.1 Atmospheric Influences

The Far-field noise levels are strongly influenced by atmospheric conditions. The 'normal' vertical temperature profile causes the sound rays to be refracted upwards, away from the surface of the earth. This effect reduces the sound pressure levels observed close to the ground. Similarly, sound rays propagating upwind tend to be refracted upwards and away from the ground by the velocity gradients near the surface. Both of these effects tend to create an acoustic 'shadow region' near the surface of the ground where the sound levels are much lower than would be expected in calm air with no temperature gradients. It must be noted that these favourable temperature profiles typically do not exist at night or during thermal inversions. Sound rays propagating downwind tend to be refracted downward toward the surface of the earth. This downwind effect would tend to negate the favourable effects of a 'normal' temperature profile.

Additional reduction of the sound pressure levels near the ground can arise from the acoustic properties of the surface of the earth.

### 4.2 Comparison of Predicted and Observed Far-Field Levels

In general, the far-field levels were 15 to 20 dBA below those predicted by the theory of Davis Engineering Limited, 1987 which included only molecular absorption and geometrical spreading. This difference is reasonable when allowance is made for the effects of wind

and thermal gradients. This report asserts that attenuations as high as 20 to 30 dBA are possible with favourable atmospheric conditions. The only locations where this large difference was not observed are at the sites downwind of the aircraft. For two of these sites the observed levels were only 1 to 2 dBA below theoretical predictions. For these sites there was a cancellation of the favourable thermal effects by the adverse downwind propagation effects.

The great difference between the theoretical and experimental values shows the importance of the atmospheric effects on the propagation of sound and the difficulty of accurately predicting outdoor sound propagation.

#### 4.3 Far-Field Spectral Shape

The spectra of the noise measured in the far-field differ from those of the typical aero engine presented by Davis Engineering Limited, 1987. The marked difference in overall levels is probably the result of the atmospheric effects which are not included in the predicted levels. The measured spectra have peaks in the 500 or 1000 Hz octave band and are flatter than the theoretical curves above these spectral peaks. A direct comparison of the spectral shapes is difficult because the spectral shape of the engine noise varies with the angle relative to the engine axis and the simplified model of Davis Engineering Limited, 1987 does not include this effect. However the difference between the measured and theoretical engine noise spectral shape would not greatly affect the overall noise levels observed in the community.

#### 5.0 CONCLUSIONS

The tests with the CF-18 aircraft confirmed that the model of the F404 engine noise used in the noise predictions by Davis Engineering Limited, 1987 accurately represent the noise of the engine. Furthermore, the predictions of the noise propagation into the community are valid under the assumed atmospheric conditions. However, the tests clearly show the strong influence of the atmosphere on the observed noise levels in the surrounding community.

The observed levels of 70 dBA in the downwind direction at 2 km distance, are well above the background noise levels and, with less favourable atmospheric conditions, the levels observed in other directions could have been as much as 10 to 20 dBA above the measured levels. Running the outdoor engine test facility with an engine equivalent to the GE-404-400 will generate noise levels in excess of the existing background levels. While no complaints from the residential communities were received by the airport during the tests with the CF-18 aircraft, the elevated noise levels could easily produce complaints, particularly during prolonged testing, under adverse atmospheric conditions or, during periods when the existing background noise is low.

## 6.0 REFERENCES

Davis Engineering Limited. 1987. Project Definition Documentation for the Outdoor Gas Turbine Test Facility at Ottawa International Airport.

FRANKLIN, C.P., E.O. McCann. 1979. F404-GE-400 Qualification Test Phase - Noise Survey Test. Rep. No R79AEG058, General Electric Aircraft Engines Group, Lynn Massachusetts.

General Electric Aircraft Engine Group. 1975. Model Specifications for the F404-GE-400 Turbofan Engine, Specification #CP45K0006.

POWELL, R.G. 1979. USAF Bioenvironmental Noise Data Handbook. Vol. 141, F/A-18 Aircraft, Far-Field Noise. Report AMRL-TR-75-50-Vol-141.

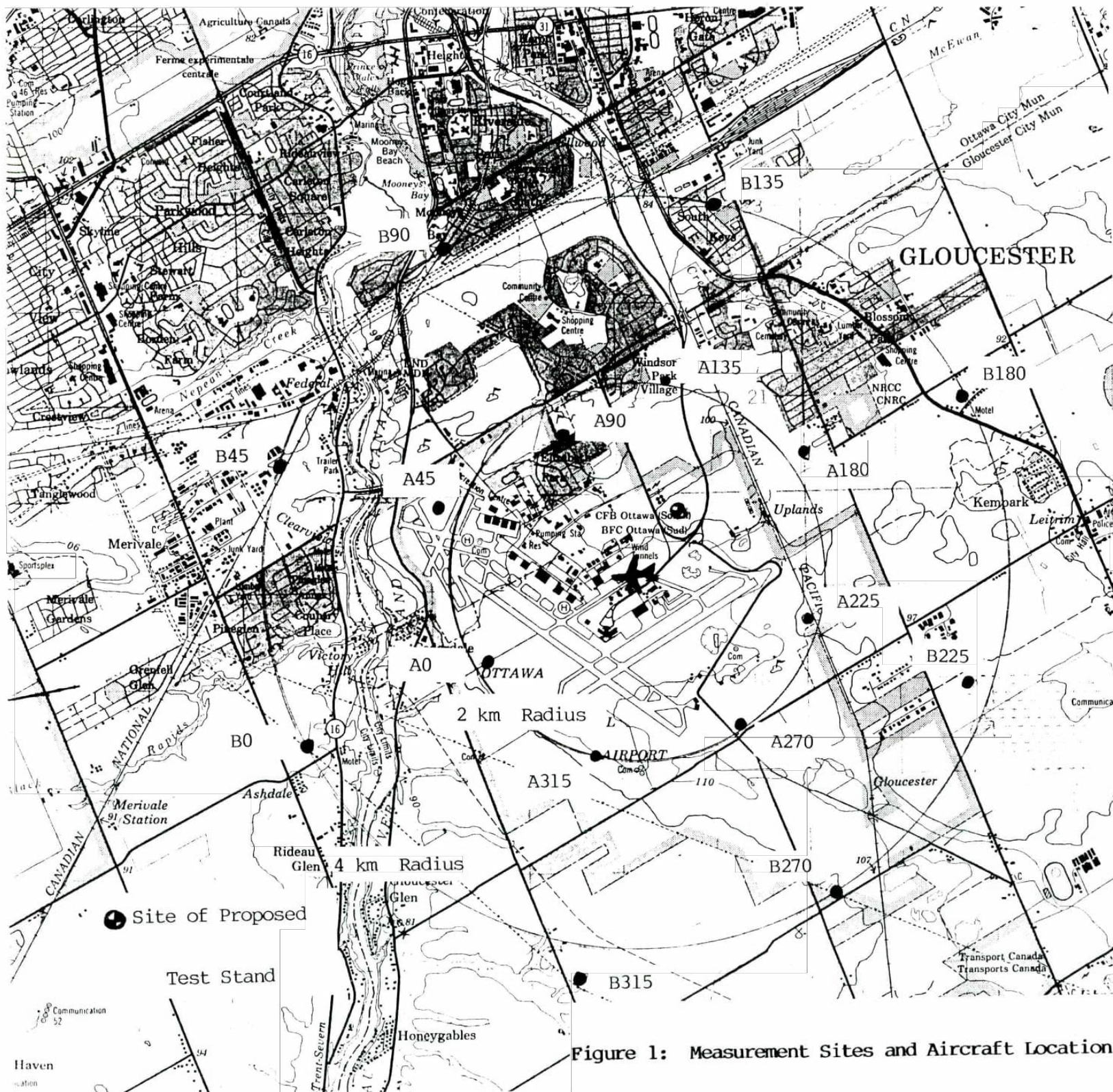


Figure 1: Measurement Sites and Aircraft Location

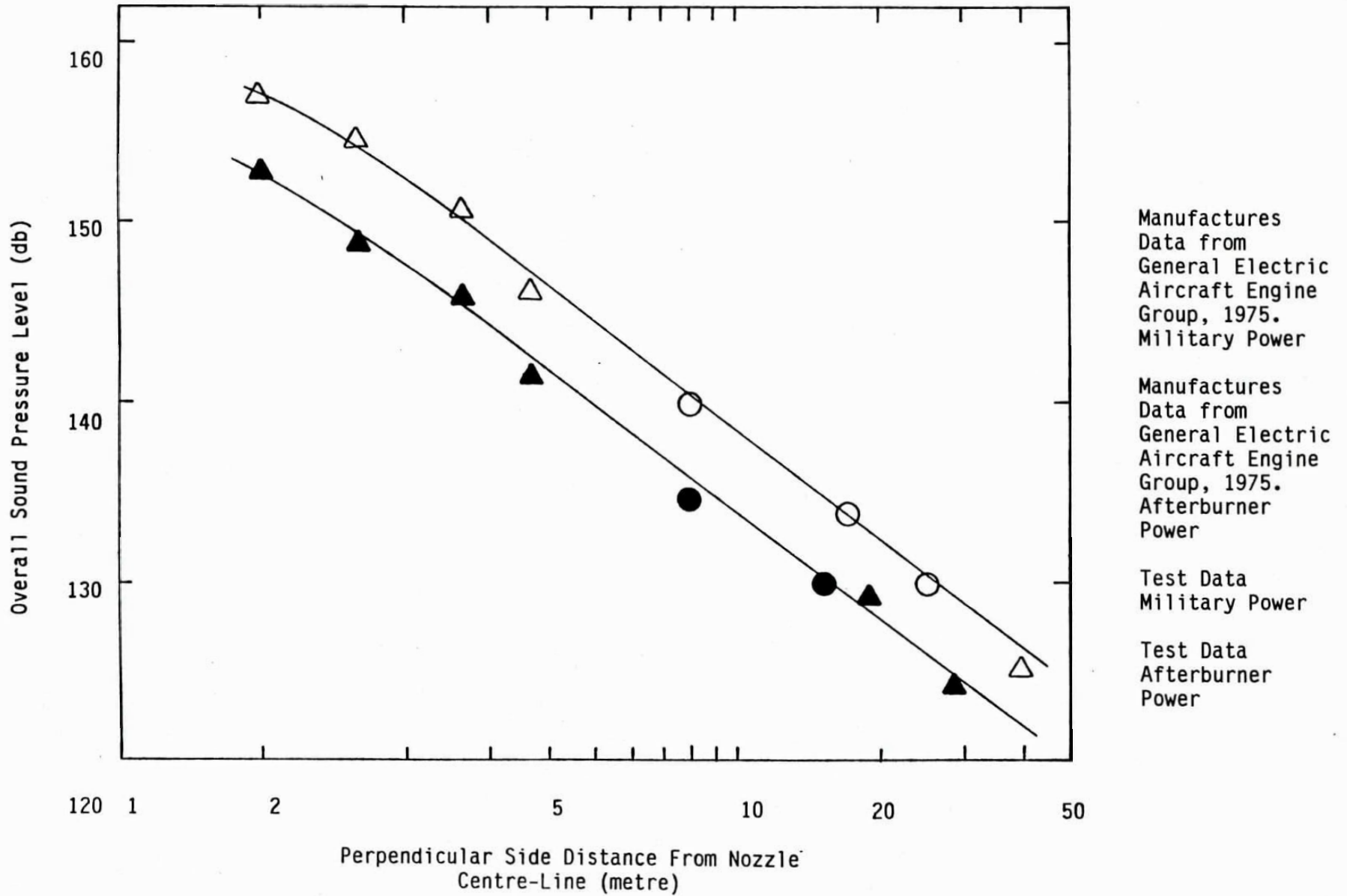
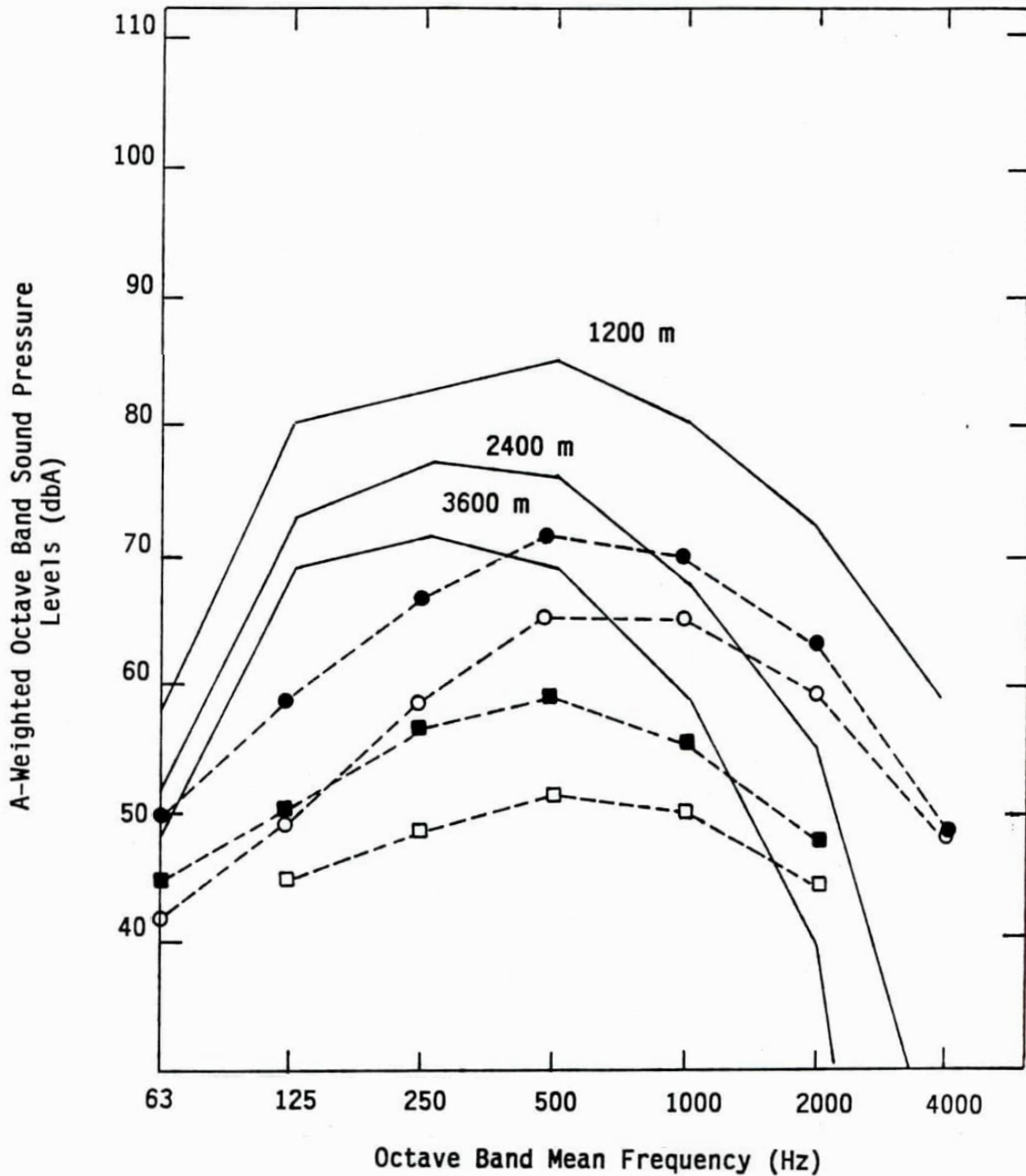


Figure 2: Near-Field Noise Data

<u>Time</u>		<u>Power Setting</u>
	53	
	53	
	55	
	56	OFF
	59	
10:45	59	
	54	
	56	
	59	IDLE
10:50	54	
	54	
	70	
	70	
	73	MILITARY
	72	
10:55	67	
	71	
	71	AFTERBURNER
10:58	71	
	58	
	57	
	58	
	57	IDLE
	58	
	57	
	59	
	57	
	54	
11:08	62	
	72	
	71	
	71	MILITARY
	69	
11:13	68	
	69	
	68	AFTERBURNER
11:16	70	
	63	
	52	
	58	IDLE
	67	
11:21	66	
	83	
	79	
	71	OFF
	71	

NOTE: Output is time history of 1 minute equivalent noise levels from site A225. Higher levels are displaced to the right to resemble a strip chart recording.

Figure 3: Sample Output of Noise Monitor



- Predicted Spectra at 1200, 2400, & 3600 metre [Davis Engineering Ltd., 1987]
- Site A135, (2 km) Afterburner Power
- Site A135, (2 km) Military Power
- Site B135, (4 km) Afterburner Power
- Site B135, (4 km) Military Power

Figure 4: Engine Noise Spectra

MEASUREMENT SITE

2 km	Distance	A0	A45	A90	A135	A180	A225	A270	A315
	Military Power	-	-	55	66	69	70	68	58
	Afterburner	-	57	58	76	71	70	77	62

4 km	Distance	A0	A45	A90	A135	A180	A225	A270	A315
	Military Power	-	-	-	55	53	61	55	-
	Afterburner	-	-	50	63	55	65	64	-

(-) Engine noise below background levels

Table 1: Far-Field A-Weighted Sound Pressure Levels (dBA)

2 km	Measurement Site	A0	A45	A90	A135	A180	A225	A270	A315
	Observation	-	-	55	66	69	70	68	58
	Theory	82	77	81	85	70	80	87	78
	Difference	-	-	-16	-19	-1	-10	-19	-20

4 km	Measurement Site	A0	A45	A90	A135	A180	A225	A270	A315
	Observation	-	-	-	55	53	61	55	-
	Theory	64	64	60	73	55	70	72	57
	Difference	-	-	-	-18	-2	-9	-17	-

Theory is that developed by Davis Engineering Ltd., 1987.

Measurements are based on the average of 2 engine runups.

Table 2: Comparison of Theoretical and Observed Sound Pressure Levels (dBA) at Military Power Setting

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