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7/ELASTICS/3

REVIEW OF NOISE PROBLEMS ON ARROW AIRCRAFT Mk. 1 & 2

Feb/58

H.W.F. Naylor

February, 1958

Report Number 7/ELASTICS/3

REVIEW OF NOISE PROBLEMS
ON ARROW AIRCRAFT Mk. 1 &2

Compiled by ....
H.F.W. NAYLOR

Approved by ....
A. Thomann

FORM 1749 A

AIRCRAFT:		PREPARED BY	DATE
Arrow Mk. 1 & 2		H.F. Naylor	February/58
		CHECKED BY	DATE

INTRODUCTION

This report discusses the various noise producing elements associated with the Arrow Aircraft and the effect of these on personnel, equipment and structure. Several problems are shown to exist and methods of treatment are suggested. The overall problem, except for the community reaction situation, appears soluble with little resulting penalty to the aircraft.

CONTENTS

1. DISTRIBUTION OF NOISE OUTSIDE THE AIRCRAFT

1.1 Far Field Jet Noise

The Pratt and Whitney formula (6) estimates the total acoustic power radiated by an engine when the thrust, mass flow and nozzle area are known. The J-57 series of engines produce a distribution of noise around these engines which peaks at 35° from the exhaust axis at 150' at a value of approximately 44 db below the total acoustic power level. This present work compares several engines (2,4,6,7) to that of the Iroquois 2, the difference in total acoustic power then becomes a scaling factor which is applied to the known noise fields to estimate the Iroquois 2 noise field. The noise field of the Orenda 11-R has been scaled up to give estimated Iroquois 2 levels at 150' at 35° to be 136 $\pm$ 2 db; measurements of the B-47 Iroquois showed 140 db at this location. Total noise comparisons of the scaled up engine noise levels are shown in figures 1,2,3, and 4.

1.2 Near Field Jet Noise

The noise level scale factors determined above also apply to the near field distribution but near field distances are measured in nozzle diameters to allow for scale effect near the source. The Iroquois 2 near noise field is shown in Figures 5 and 6 based on Orenda 11-R data for one and two engines, afterburners on and off. The rudder is seen to be in a 148 to 155 db sound pressure level field, the wing controls are in a 143 db field and the sting experiences 165-170 db. These total sound pressure correspond to maximum engine conditions, which produce the greatest noise. These noise levels are shown broken down into frequency distributions for comparison with structural natural frequencies, the frequency being scaled by the Strouhal number ratio comparable to the Orenda 11-R and the Iroquois 2. See Figures 7,8,9 and 10.

1.3 Boundary Layer Noise

The pressure fluctuations in each eddy of a turbulent boundary layer are estimated (8) to be less than 1% of the stream stagnation pressure but the total effect of a sheet of these eddies washing a skin panel can induce pronounced effects both in transmitted sound to the interior and in direct effect to the skin structure. These pressure fluctuations are termed pseudo-sound (8) because they cannot be directly heard; they must first vibrate structure which then radiates audible noise.

A qualitative picture of the boundary layer "noise" is necessary. Consider each eddy as a source radiating pressure fluctuations to the local area of skin adjacent to it, like a small piston connected to the skin: there may be hundreds of such eddies over a typical skin panel. At one instant of time, these eddies are radomly distributed over the panel so that each element of panel is generally being loaded at a different pressure, frequency and phase from every other element. At the next instant of time, the whole sheet of eddies has moved as a body some distance downstream where they may be simply assumed to have not changed their relative positions to each other. The ability of this running load to deflect the panel depends on how the eddies are distributed over the panel, the speed at which the mass of them traverse it and, of course on the panel characteristics. The running ripples induced in the skin panel by the boundary layer move along the skin until they reach a discontinuity of the structure, say a frame or stringer, which reflects them back into the panel. A series of such reflections may store up vibrational energy in the panel in the form of standing waves and it is these waves that radiate the sound energy. Above certain supersonic flight speeds, the aformentioned running ripples move supersonically across the panel and also radiate sound energy as they do, this adding to the noise from the standing waves.

This motion of the panel under boundary layer excitation is not panel flutter; this phenomenon arises from the interaction of the panel with the flow, while in the present case the boundary layer is assumed independent of the panel motion.

The size and associated pressure of the eddies depends chiefly on altitude, boundary layer thickness and the effective boundary layer traversing speed (about 0.7 of the flight speed). The boundary layer turbulence on a db scale plotted against speed and altitude is shown in Figure 11.

It is opportune to compare the effects on a skin panel of boundary layer pseudo-sound and jet noise. As shown above, the boundary layer induces running ripples in the skin which travel with the boundary layer.

The jet noise, on the other hand, pounds the whole panel uniformly over its area. The resulting deflections bear no relationship to each other and therefore the results of panel tests under jet noise conditions cannot to be expected to predict the effects on a panel due to the same boundary layer pseudo-sound levels.

1.4 Shock Noise

As with boundary layer noise, shock noise must be classified as pseudo-sound as only its effects can be heard. The random oscillations of an unsteady shock terminating at a surface can appreciably deflect that surface and so radiate noise to the interior. The motion of the lambda shock on the 1/6 scale Arrow 1 intake ramp has been broken down into discrete frequencies components, Figure12, the chief contribution being at low frequencies, quite remote from any natural frequency of the sturcture. The measured model frequency was brought to full ~~scale~~ via the Strouhal Number equality.

The shock structure over the canopy is unkown but its proximity to the intakes suggests a complex structure with possible instabilities which are energy sources that excite the structure and so radiate noise into the cockpits. This subject bears further investigation.

2. NOISE INSIDE THE AIRCRAFT

The vibrations of structure and components are the sources of internal noise generation. The structure responds to external excitations from jet noise, turbulent boundary layer pseudo-sound and shock instabilities as discussed earlier in Section 1, while accessories and equipment may themselves be direct sources of noise.

2.1 A rough estimate of this structure produced noise can be made by assuming that the structure attenuates the source noise level by from 10-20 db; the order of the approximation allows this to be applied to both the boundary layer and jet sources of noise. More accurate estimates may be made from Refs. 8 and 18, respectively, for the above two noise sources and Ribner's work may be enlarged (19) to include noise radiated by shock-induced skin vibrations.

These works determine the response of a panel to the different kinds of disturbances; the response being very dependent on the exciting media as well as on the panel structural parameters. For example, the attenuation of the boundary layer noise transmitted through a given panel to the interior varies with flight condition and position on the aircraft.

2.2 The internal noise from internal sources may be estimated from test measurements of the equipment (neglecting reverberance) to give the order of the expected levels of the installed equipment.

Discounting engine vibration, the most disturbing internal noise generator in the Arrow 1 is the turbo-compressor of the air conditioning unit which produces 124 db one foot from it, the spectum being quite flat at 117 db, Figure 13.

These levels were measured at the test rig and are not for peak performance where the noise could conceivably be 5 or 10 db higher, say from 130-135 db total pressure level. The air conditioning ducting is designed to maintain the flow below M = 0.4 but this speed can be considered a possible noise source as the flow is turbulent. Also the outlets to the air-condtioned cockpits will radiate any compressor and turbulence noise with very little attenuation.

3. EFFECT OF NOISE

Much recent discussion summarized in references 4, 7 and 14 describes the present feelings on the physiological, psychological and legal reactions to noise on human beings. The effects are mentioned here, Figure 14 showing a tentative display of varying degrees of damaging noise levels and suggested protection requirements.

3.1 The crew and ground support personnel are directly exposed for relatively long times to the Arrow's noise field and require protection against hearing loss. Taking 110 db as a liberal maximum allowable level for long-time exposure without protection, no one should continually approach closer to the Arrow than 300' in front or 1200' off the rear quadrant (based on Ref. 11 data attenuated by Ref. 6 data). The present rear cockpit levels require reduction to protect the crew during taxiing and at takeoff. The jet's contribution to the cockpit noise is negligible shortly after take-off when the air conditioning becomes the chief source. Boundary layer noise in the cockpit is expected to be transmitted through the side walls which are some 10 feet aft of the nose; the flow over the canopy being laminar or near so should produce no noise.

A refined estimate of the boundary layer effects has not been made nor has the shock structure been investigated in theis direction. The wall attenuation characteristics appear to be the only protection as the boundary layer characteristics are not controllable. The present 3/4" thermal blanket probably exerts an attenuation of 10 db below 1 kc which increases to 20 db at higher frequencies.

The noise level on the ground from a low flying aircraft may be roughly estimated by reducing the levels from ground run-up by the effect of the decrease in relative speed of jet to the surrounding air. Assuming the noise output is proportional to the relative velocity to the 9th power(22), the correction becomes

$$-90 \log_{10} \left(1 + \frac{V_F}{V_J}\right) \text{ db}$$

V_F = Flight Speed
V_J = Jet Exhaust Speed

Figure 15 shows this correction for V_J = 3000 fps, a characteristic velocity for the Iroquois 2 with afterburner, for various flight speeds. From this and the contours for ground running (Figure 2) we may estimate the maximum noise level of the Arrow flying at different heights and speeds, Figure 16.

This is rough but qualitative.

The noise level inside a building may be attenuated by 40 db if the walls are heavy and the openings are double and sealed, (hardly a common situation in a family dwelling). These moderatley large levels of 120 db for the aircraft flying at 1000' occur for only several seconds at a time but the levels are above the "vigorous legal action" range (2) and therefore a problem exists, which must be either solved or circumvented.

3.2 EFFECT ON EQUIPMENT

Electronic equipment is prone to failure from acute vibration by the nature of the delicacy of its components. Grids and filaments resonate and progressively "microphone", alter the tube characteristics and completely deteriorate the tube, culminating in plysical fatigue failure. Little design recommendations are available but reference 17 has found the subminiature vacuum tubes have been unaffected by 140 db at 10 kc. However, if the noise environment contains a component at the resonant frequency of a component then trouble exists. Vibration isolation is most important to subminature tubes; maximum allowable accelerations decrease from 10g to 100 cps to 1.0g at 350 cps. Relays and other fin-clearance equipment can be forced to close their contacts with these vibrations and suitable protection is mandatory for trouble-free operation.

For its successful operation, the Arrow relies on correct, continuous operation of much electronic and related equipment; a failure could be disastrous. Most of this equipment is housed in the dorsal fairing just forward of the fin and in the electronics equipment bay just aft of the nose undercarriage well. Taking a liberal wall attenuation of 20 db, the maximum noise levels could be 125 db and 120 db from ground running in the dorsal and equipment bay compartments respectively, and 130 db in both from the boundary layer at 720 knots flight speed.

The effects of these noise levels is unkown and the reliablility of these components should therefore be checked under representative conditions to ensure their effective operation.

3.3 EFFECT ON STRUCTURE

The deflections of a skin panel in its response to acoustic excitation produce proportional bending stresses which oscillate about the existing static stress of the overall structural loading. For estimating fatigue life, the problem lies in determining the stress history of the deflected panel. The deflections are discussed in Section 1 but the few known criteria for fatigue failure are complex and are not discussed here and simple approaches are used.

JET NOISE

A simplified treatment (13) of the aft structure of the Arrow gives the maximum pressure oscillating at the panel's first natural frequency that produces the bending stress for infinite life. This frequency and pressure level can be compared to the frequency spectrum of the engine jet noise level on the particular structural portion considered, showing the severity of the problem; figures 7, 8, 9 and 10 show this. The stainless steel sting appears to be 20 db overloaded (1 to 10 minute life), the magnesium rudder is 12 db overloaded, (1 to 10 min life), the elevator is marginal and the elevator is free. These life estimates are sensitively dependent upon the sound-pressure level applied to the panel and may radically change if the shape of noise spectrum (frequency distribution) changes.

BOUNDARY LAYER NOISE

The response of a typical skin panel to boundary layer excitation has been investigated by Ribner (Ref. 19) and the stresses arising from these deflections are shown to be quite small (100 psi) and relatively unaffected by flight speed. The structural affect of boundary layer noise may then be neglected.

SHOCK NOISE

The oscillations of an unsteady shock terminating at a skin panel set up an oscillating bending moment in the skin which gives rise to bending stresses whose magnitude depends upon the response of the panel to this excitation. The unsteady lambda shock on the intake ramp of the Arrow gives rise to moderate stresses only because the natural frequency of the panel is so far above the dominant frequency of the shock motion (9), However, if resonance had occurred, the stresses could have quickly failed the skin.

4. CONCLUSIONS

The sources of noise and their effect on personnel, equipment and structure have been discussed, and some methods of alleviating each situation have been put forward. The whole problem will now be discussed to ascertain the possiblility and magnitude of these solutions.

4.1 Equipment

The electronic equipment must function faithfully to make the aircraft successful. The estimated overall noise levels (from the boundary layer) reach 130 db in these equipment compartments but the effect of these levels is not known. Therefore only adhoc testing of this delicate equipment under the true noise field is acceptable. The delicate equipment in the air conditioning compartment will be subjected to 130 db from the turbo-compressor and a source of trouble may also exist here.

4.2 Structure

The structure is affected solely by ground running of the unmuffled engines. The stainless steel sting is 20 db overloaded giving it a life of 1 to 10 minutes, the magnesium rudder is 12 db overloaded also having a 1 to 10 minute life, the elevator is marginal and the elevator is free. The situation is comparable to that of the CF-100 Mk. 6 which was solved by careful re-design and therefore the Arrow problem appears quite soluble.

The boundary layer noise, while producing high interior levels, does not heavily stress the skin and does not appear as structural problem.

The oscillating shock on the intake ramp reduces low stresses in the ramp skin and this particular problem does not appear. However, other shocks over the structure of the aircraft may meet a structure which will resonate at the low frequencies of the shock's oscillation which can cuase rapid failure. All-in-all, the structural problems are soluble with a probably small penalty.

It should be noted here that any testing must be done in the true environment that the part meets in service due to the variety of ways each environment excites the part: i.e. compare the running load of the boundary layer, the pounding uniform load from the jet noise and the local oscillating bending moment applied by an unsteady shock wave.

4.3 Personnel

The protection of the flying crew is achieved by directly muffling the air conditioner and its cockpit outlets. Engine noise will be negligible at all flying speeds and bounday layer noise levels will be attenuated 20-35 db by the wall and insulating blanket and another 20-40 db by the crews' headgear; giving a net reduction of from 40-75 db. Any shock noise will be chiefly of low frequency and though inaudible may introduce uhpleasant vibrations which are difficult to remove.

The ground support personnel may be protected by well sealed run-up mufflers (14 db attenuation) and good ear protectors (20-40 db). These attenuate the high frequencies but the chest-surging, low frequencies still exist and danger areas around the A/C exist and must be clearly marked.

The response of the community is based on annoyance rather than on physical damage, the level for vigorous legal action being about 40-50 db below the level for pain. The object of the problem is now reversed and it is the aircraft which now must be protected from the listeners.

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MALTON - ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT: Arrow Mk. 1 and 2	REPORT NO. 7/ELASTICS/3	SHEET NO. 19
	PREPARED BY: H. Naylor	DATE: February/58
	CHECKED BY	DATE

REFERENCES

	AUTHOR	TITLE	REPORT NUMBER
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2.	W.L. Howes H.R. Mull	Near Noise Field of a Jet Engine Exhaust	NACA TN 3763
3.	W.B. McCarter	"Aerodynamic Noise Generated on the Surfaces of the CF-105"	P/POWER/83
4.	W. MacNamara	"Noise Level Measurements on the Near Field of the CF-100 Mk. 6	AVRO ATR No. 2782 /10
5.	Richards -E.J. Prof.	Noise Research in U.K. Ref: CAI Journal December 1957 (J.R.Ae. Soc. May 1953)	
6.		"Method of Handling the Jet Engine Noise Data" Ref: Pratt and Whitney G.T. Information Letter No. 14	
7.	G.R. Gibson	"Noise Level Measurements With and Without A/B CF-100 Aircraft 18279" Ref: October 1956 Flight Note Papers C-100-25-2-1 and 2	
8.	H.S. Ribner	"Boundary Layer Induced Noise in the Interior of A/C"	UTIA RPT 37
9.	K. Vriend	Oscillating Effects on Intake Ramp Structure	AVRO Thermo-Elastics Report P6-S4/4

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	AUTHOR	TITLE	REPORT NUMBER
10.	O.M. Phillips	"Surface Noise from a Plane Turbulent b.l."	ARC 16963
11.	J.W. Wilde	"B-47 Iroquois Noise Levels" Ref: Avro Plant Eng's December 10/57	
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13.	A. Thomann	"Estimation of Life of Flat Skin Panels under Random Noise Loading"	Avro Report P6-S4/1 Thermoelastics
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15.	Lippert	Limitations to Noise and Vibration Control Ref: Douglas A/C Corp. Misc. Number 4.	
16.	J.W. Wilde	Air Conditioner Noise Measurements Ref: Avro Plant Engineering February, 1957	
17.		"How to Prevent Tube Failures from Noise and Vibration" Ref: Aviation Age, Feb. 1957 page 82	

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	AUTHOR	TITLE	REPORT NUMBER
18.		MIT Summer Course in Noise Control 1957	
19.	H.S. Ribner	Effects of Boundary Layer Noise and Oscillating Shock Waves on Skin Panels April 30, 1957 Unpublished report	
20.	Corcos and Liepman	On the Contribution of Turbulent Boundary Layers to the Noise Inside a Fuselage	NACA TM 1420
21.		Portions on Measured Noise Levels Ref: Avro Experimental Department ATR's 5 and 13	PDS 742
22.	Greatrex	"Jet Noise" Ref: IAS pp.559	
23.	Rosenblith and Stevens	"Noise and Man"	WADC TR 52-204

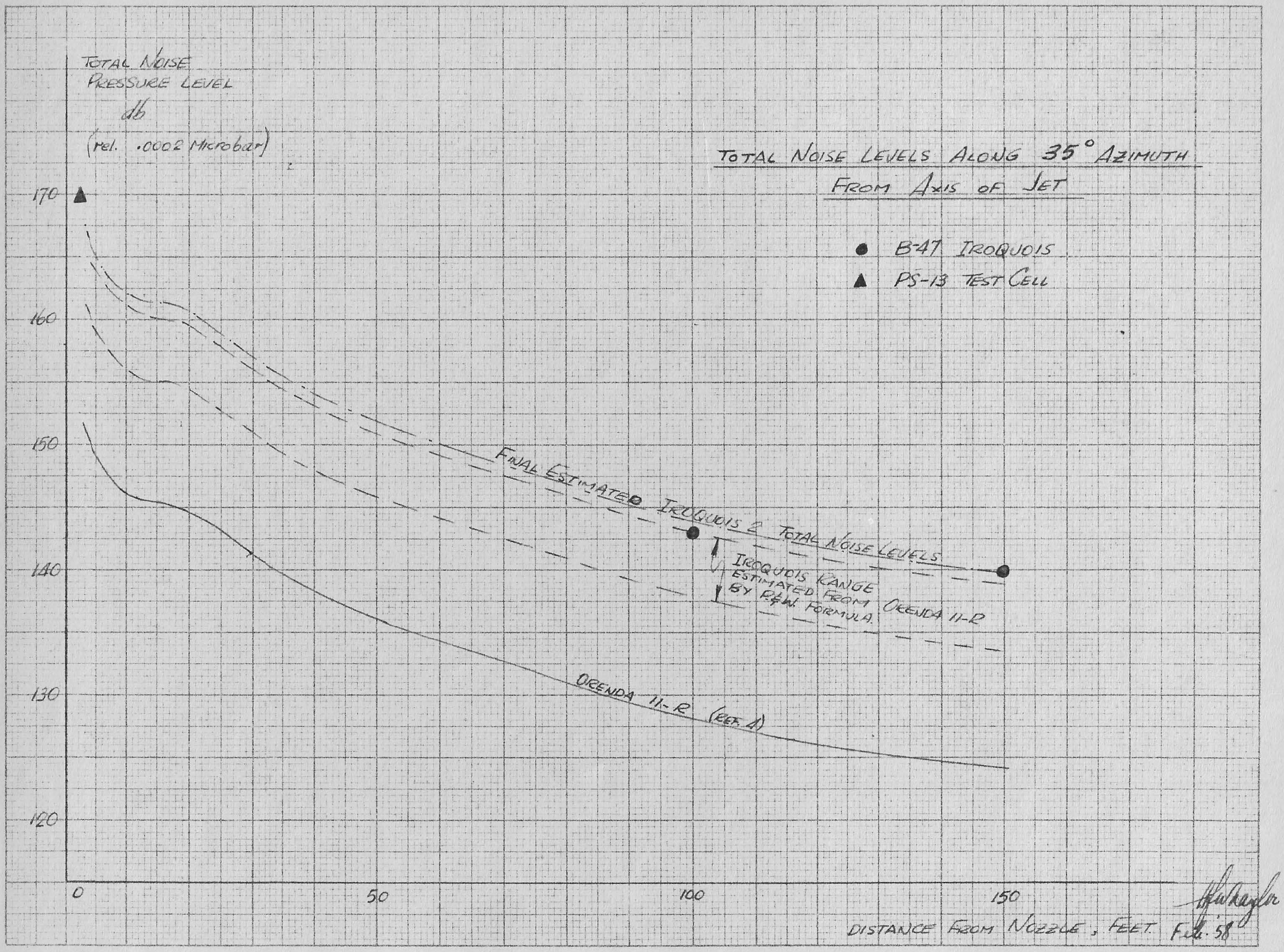
TOTAL NOISE LEVELS ALONG 35° AZIMUTH FROM AXIS OF JET
TOTAL NOISE PRESSURE LEVEL db (rel. .0002 Microbar)
170
160
150
140
130
120
0
50
100
150
DISTANCE FROM NOZZLE, FEET
● B-47 IROQUOIS
▲ PS-13 TEST CELL
FINAL ESTIMATED IROQUOIS 2 TOTAL NOISE LEVELS
IROQUOIS RANGE ESTIMATED FROM ORENDA 11-R BY P&W. FORMULA
ORENDA 11-R (REF. 4)
Feb. 58

FIGURE 1

FIGURE 2

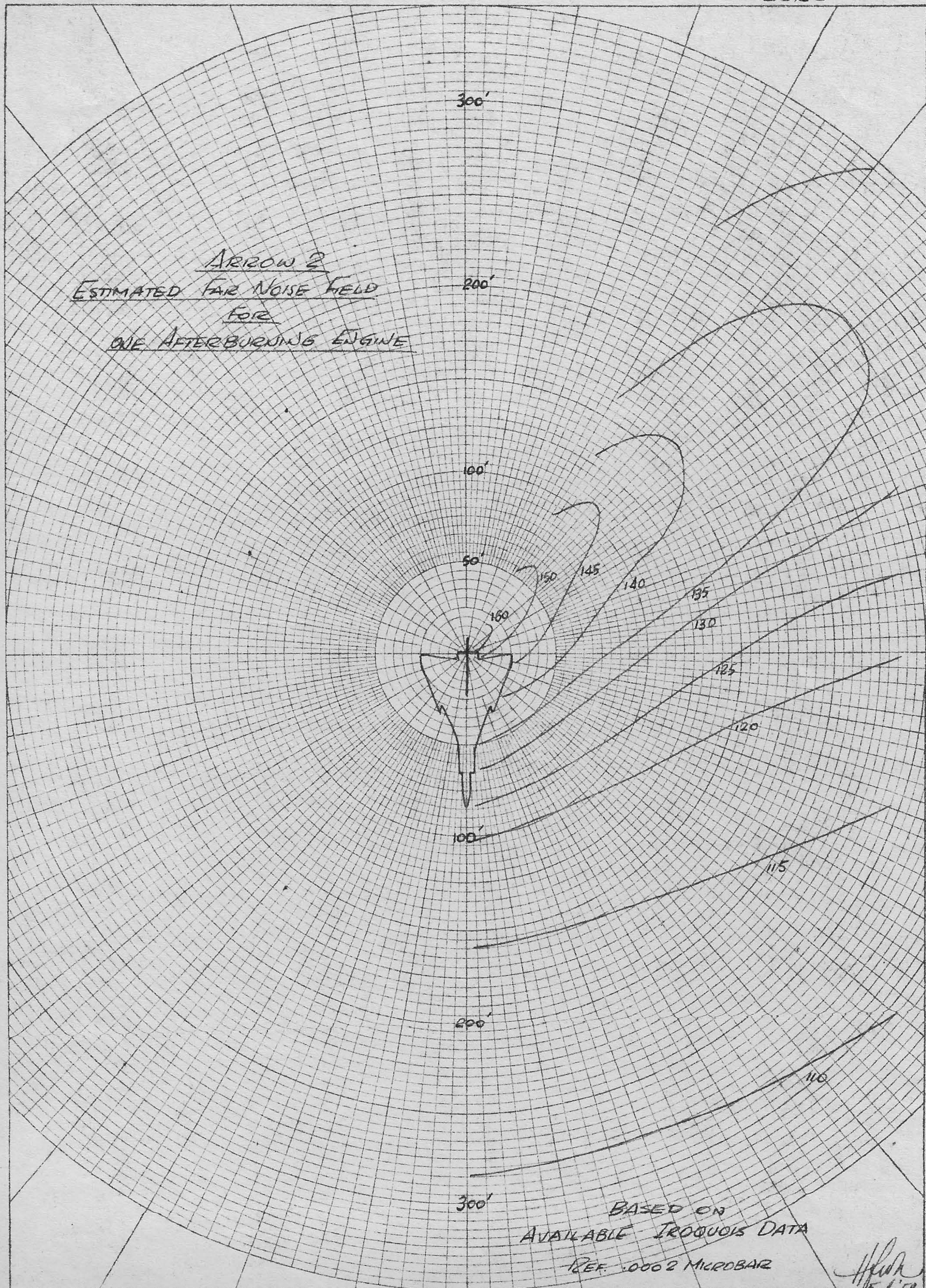
ARROW 2
ESTIMATED FAR NOISE FIELD
FOR
ONE AFTERBURNING ENGINE
300'
200'
100'
50'
160
150
145
140
135
130
125
120
115
110
100'
200'
300'
BASED ON
AVAILABLE IROQUOIS DATA
REF. .0002 MICROBAR
Feb '58

FIGURE 3

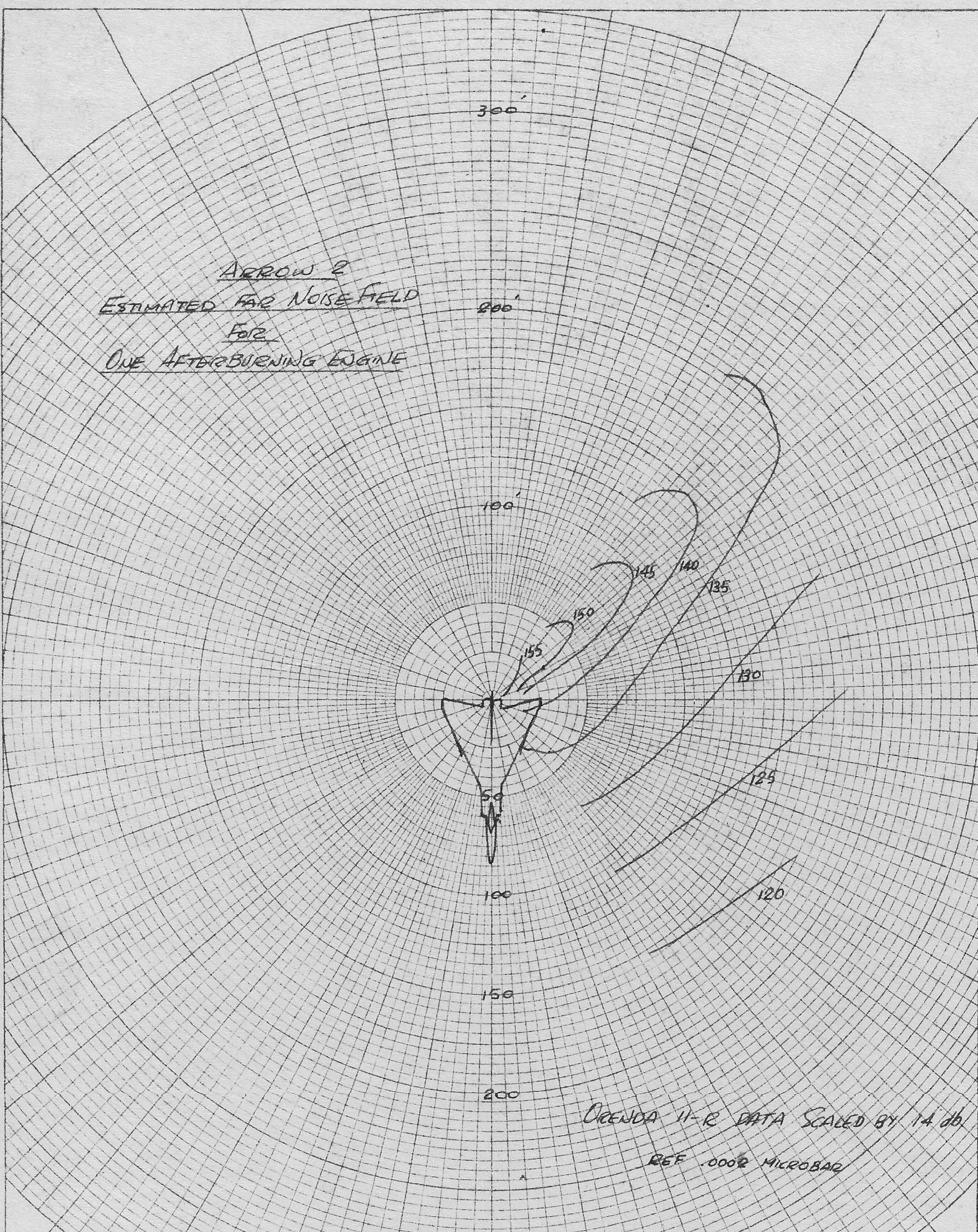
ARROW 2
ESTIMATED FAR NOISE FIELD
FOR
ONE AFTERBURNING ENGINE
300'
200'
100'
50
100
150
200
155
150
145
140
135
130
125
120
ORENDA 11-R DATA SCALED BY 14 db
REF .0002 MICROBAR

FIGURE 4

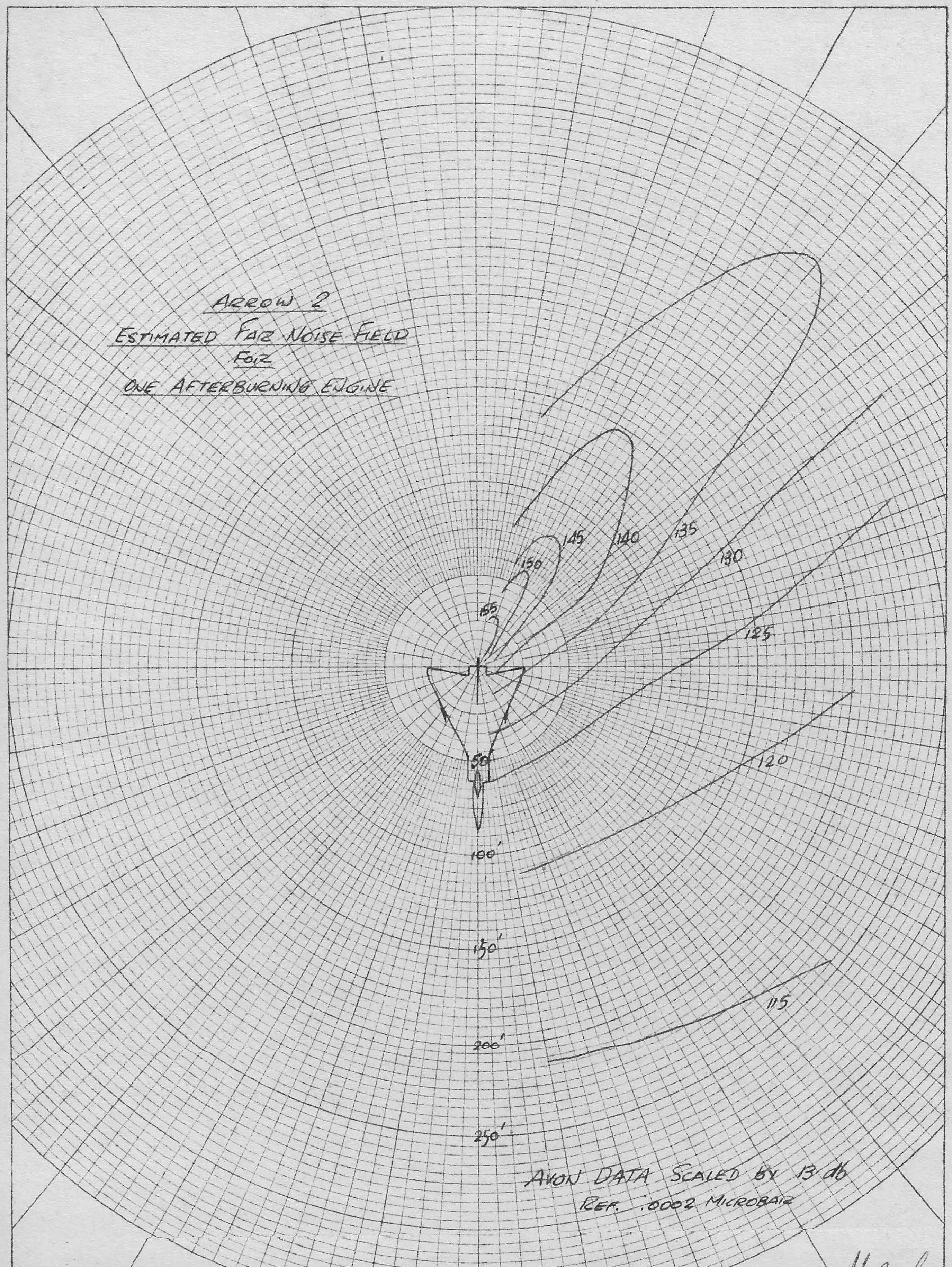
ARROW 2
ESTIMATED FAR NOISE FIELD
FOR
ONE AFTERBURNING ENGINE
155
150
145
140
135
130
125
120
115
150
100'
150'
200'
250'
AVON DATA SCALED BY 13 db
REF. .0002 MICROBAR
Feb. '58

FIGURE 5

AVRO AIRCRAFT LIMITED
MALTON ONTARIO

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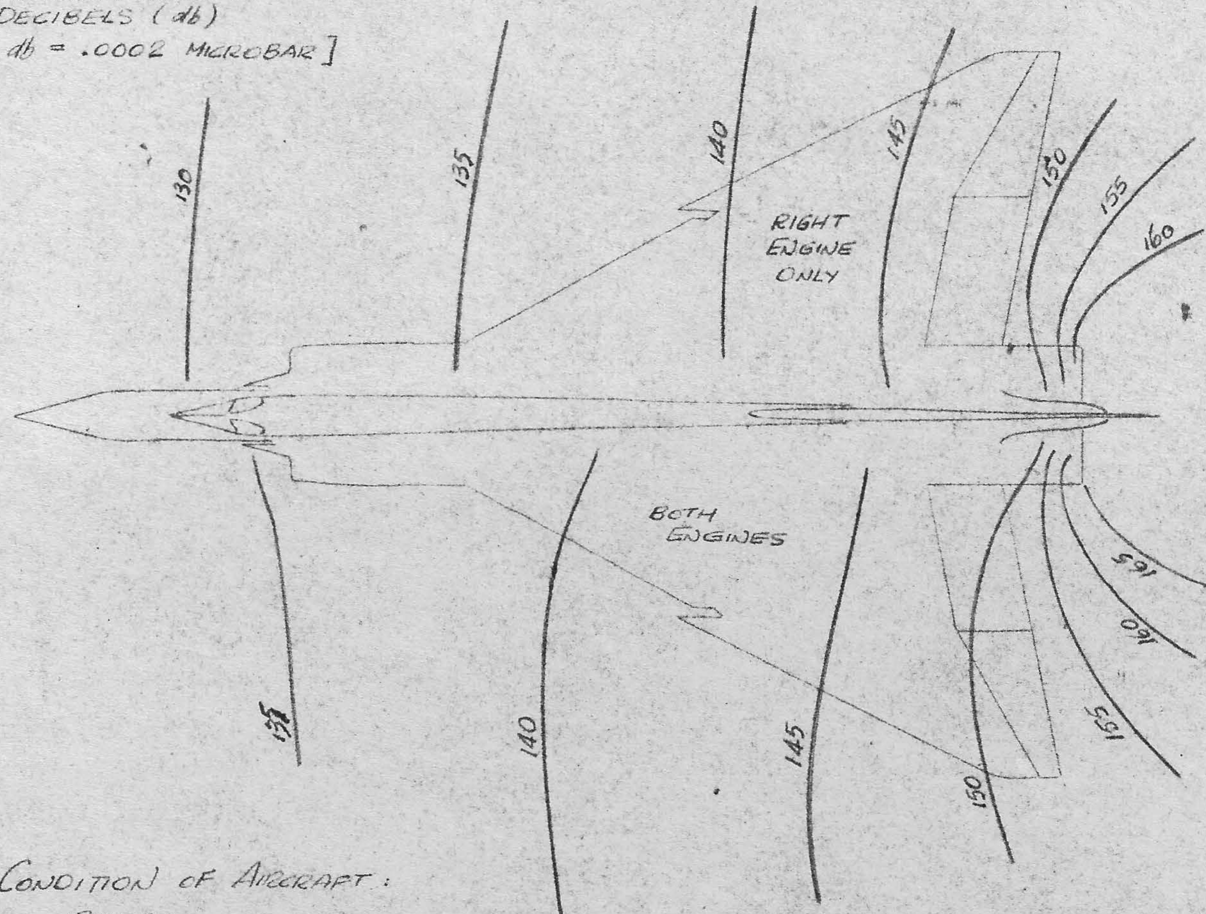
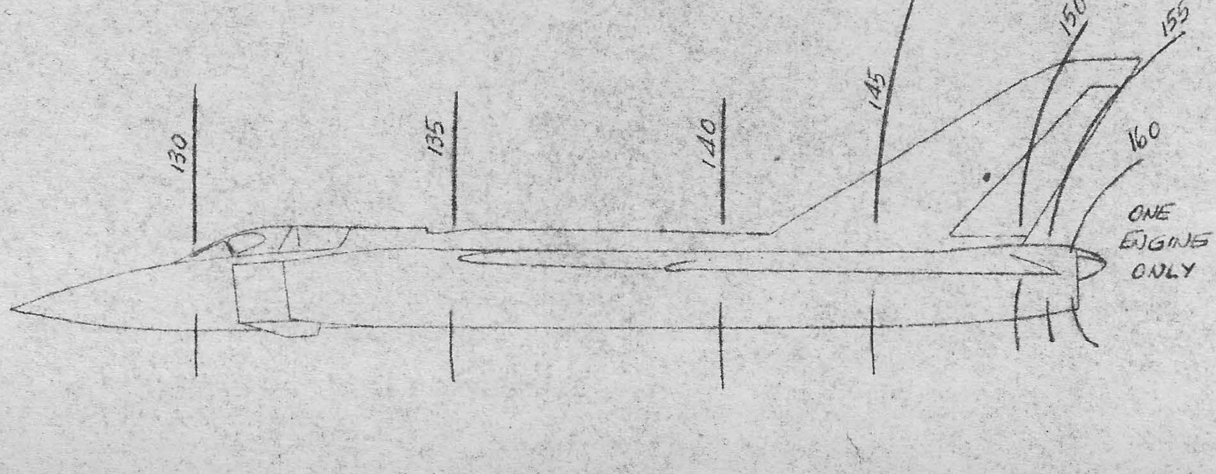
AIRCRAFT		REPORT NO.	
		SHEET NO.	
		PREPARED BY	DATE
ARROW MK. 2	NOISE FIELDS FOR ONE AND TWO ENGINES AT FULL AFTERBURNER OPERATION	HFW. NAYLOR	DEC. 1957.
		CHECKED BY	DATE

TOTAL SOUND PRESSURE LEVELS IN DECIBELS (db)
[ZERO db = .0002 MICROBAR]



CONDITION OF AIRCRAFT:
STATIC
NO WIND
NO SILENCERS
FULL A/B.



NOTE: FOR ARROW 1 (J-75) REDUCE ABOVE VALUES BY 2 db.

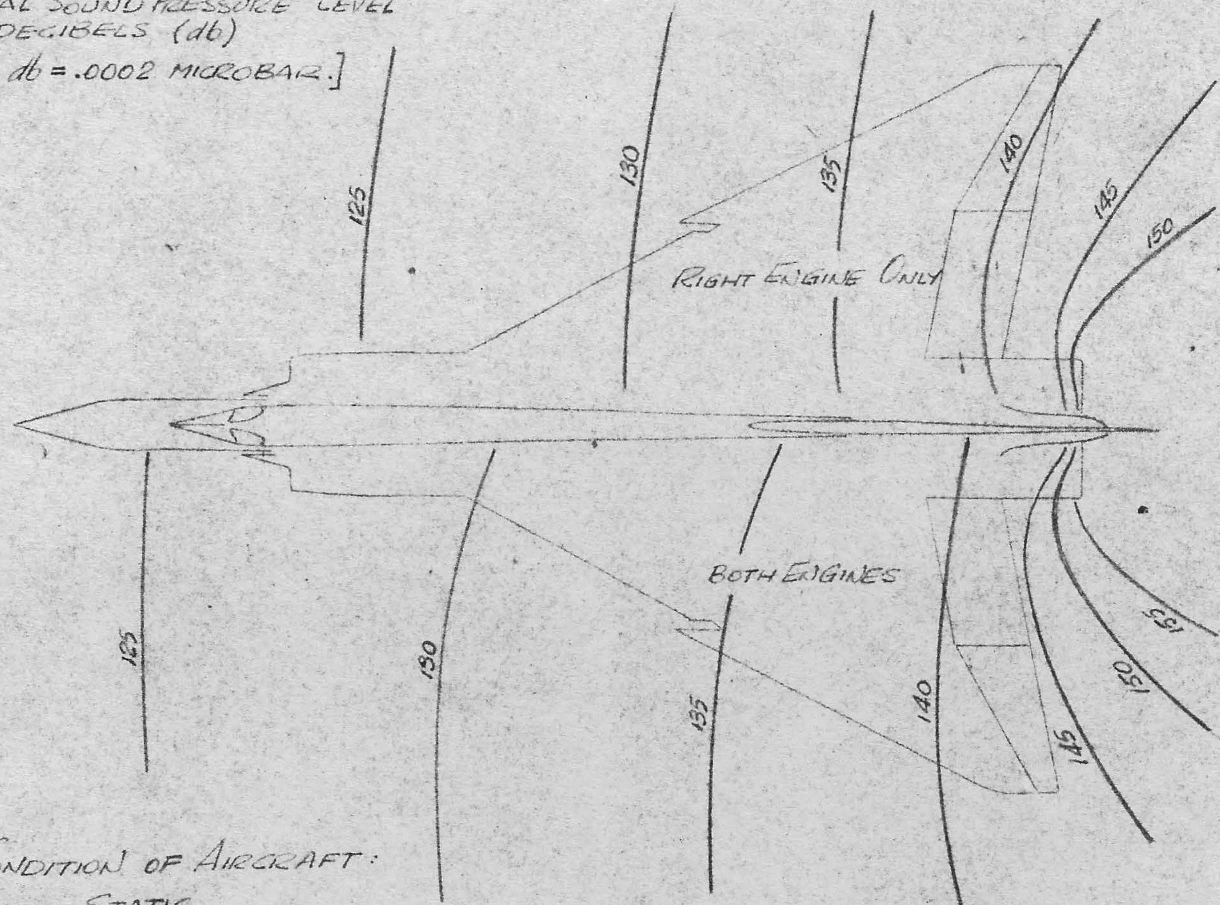
FIGURE 6

AVRO AIRCRAFT LIMITED
MALTON ONTARIO

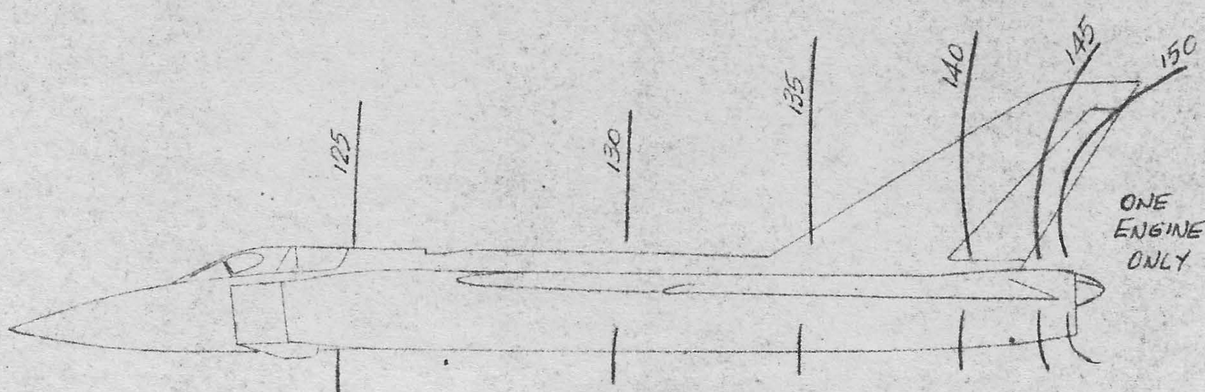
TECHNICAL DEPARTMENT

AIRCRAFT:		REPORT NO.	
		SHEET NO.	
ARROW MK. 2	NOISE FIELDS FOR ONE AND TWO ENGINES AT 100% MIL. RPM. AFTERBURNER OFF	PREPARED BY: HFW. NAYLOR	DATE: DEC. 1957
		CHECKED BY	DATE

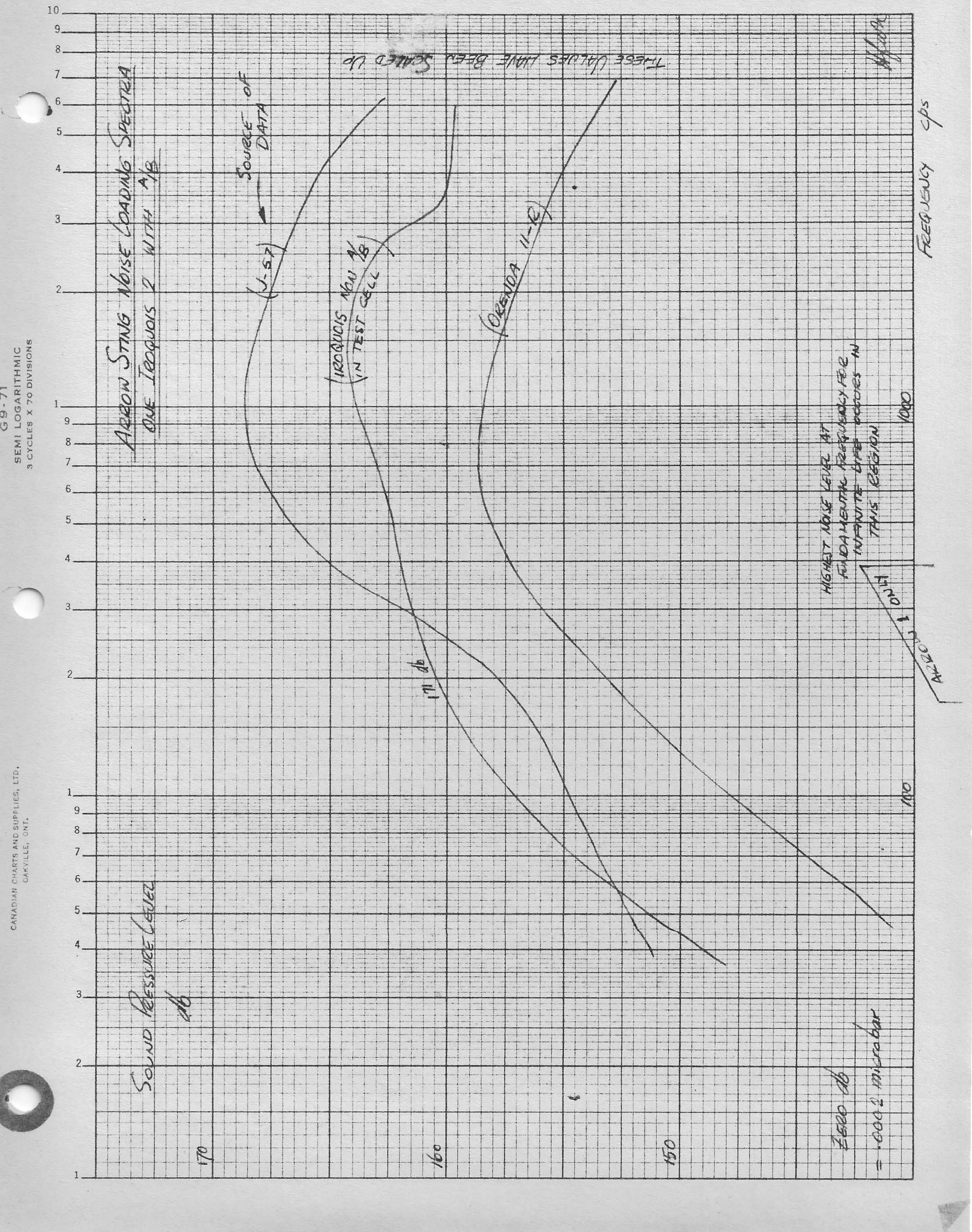
TOTAL SOUND PRESSURE LEVEL IN DECIBELS (db)
[ZERO db = .0002 MICROBAR.]



CONDITION OF AIRCRAFT:
STATIC
NO SILENCERS
NO WIND
NO A/B



NOTE: FOR ARROW 1 (J-75), REDUCE ABOVE VALUES BY 2 db.



ARROW STING NOISE LOADING SPECTRA
ONE IROQUOIS 2 WITH A/B
SOURCE OF DATA
(J-57)
(IROQUOIS NON A/B IN TEST CELL)
(ORENDA 11-R)
THESE VALUES HAVE BEEN SCALED UP
171 db
FREQUENCY cps
1000
100
HIGHEST NOISE LEVEL AT FUNDAMENTAL FREQUENCY FOR INFINITE LIFE OCCURS IN THIS REGION
ARROW 1 ONLY
SOUND PRESSURE LEVEL db
170
160
150
ZERO db = .0002 microbar
G9-71
SEMI LOGARITHMIC
3 CYCLES X 70 DIVISIONS
CANADIAN CHARTS AND SUPPLIES, LTD.
OAKVILLE, ONT.

FIGURE 1

FIGURE 8

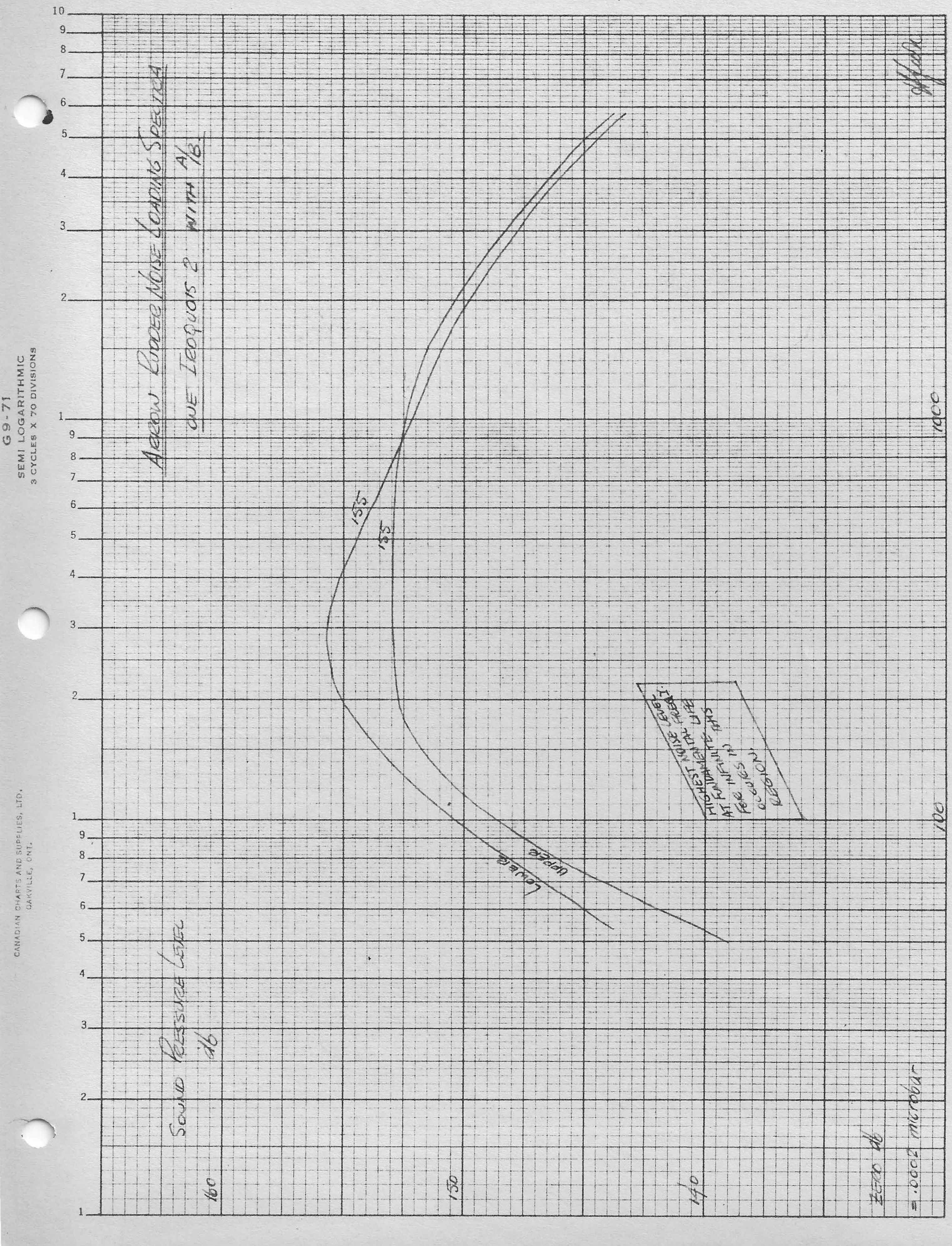

ARROW RUDDER NOISE LOADING SPECTRA
ONE IROQUOIS 2 WITH A/B
SOUND PRESSURE LEVEL
db
155
155
UPPER
LOWER
HIGHEST NOISE LEVEL AT FUNDAMENTAL FREQ. FOR INFINITE LIFE OCCURS IN THIS REGION
160
150
140
100
1000
ZERO db
= .0002 microbar
G9-71
SEMI LOGARITHMIC
3 CYCLES X 70 DIVISIONS
CANADIAN CHARTS AND SUPPLIES, LTD.
OAKVILLE, ONT.

FIGURE 9

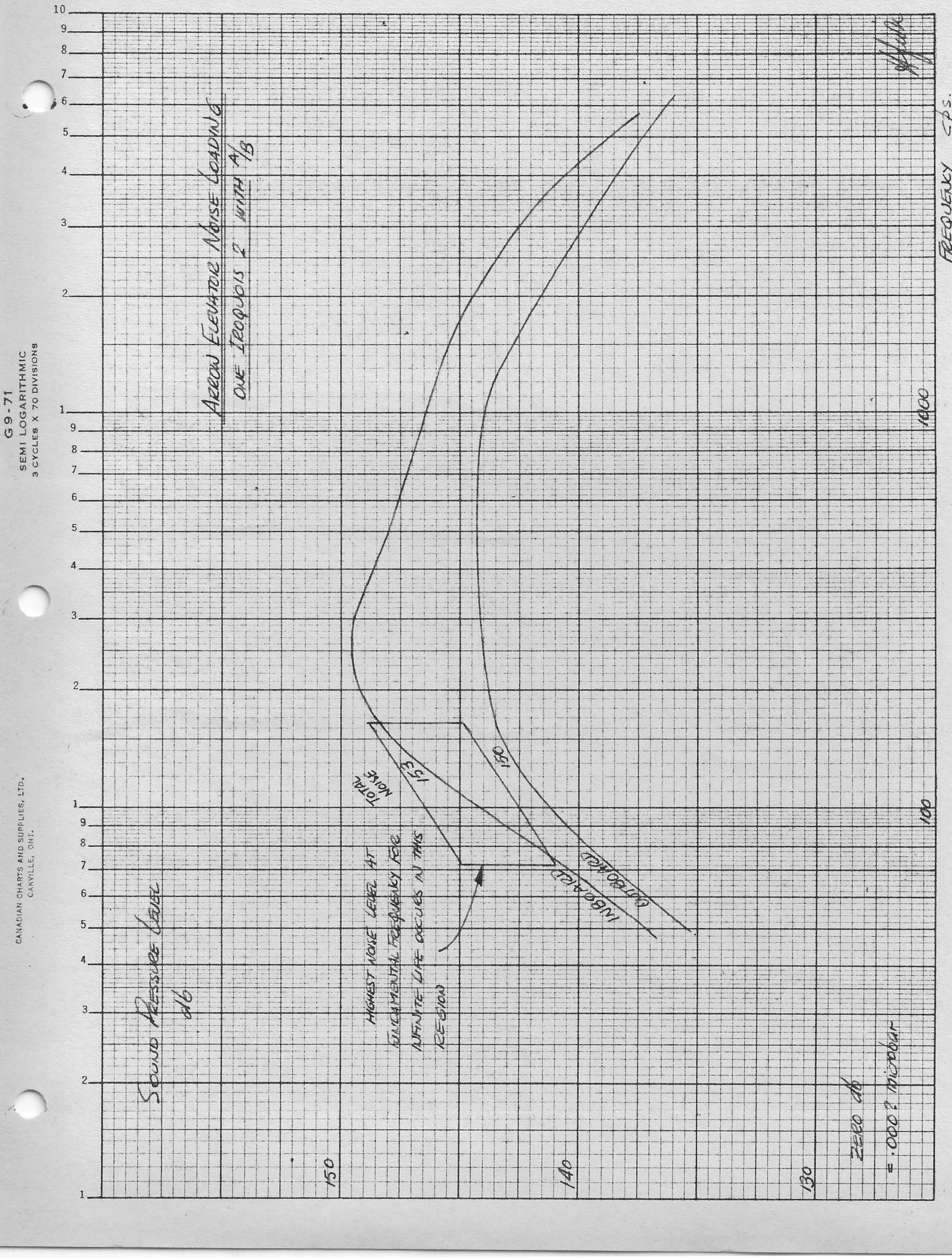
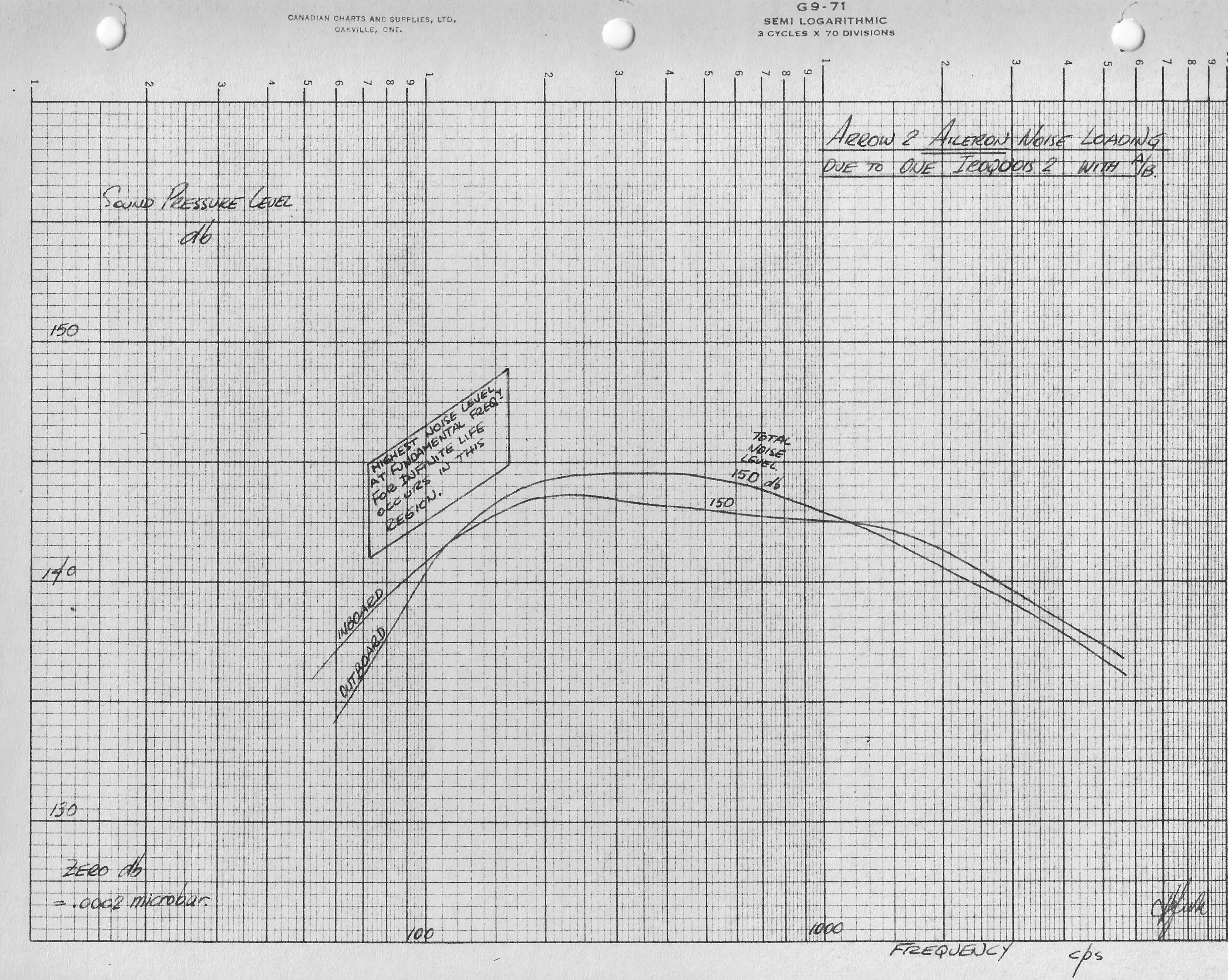
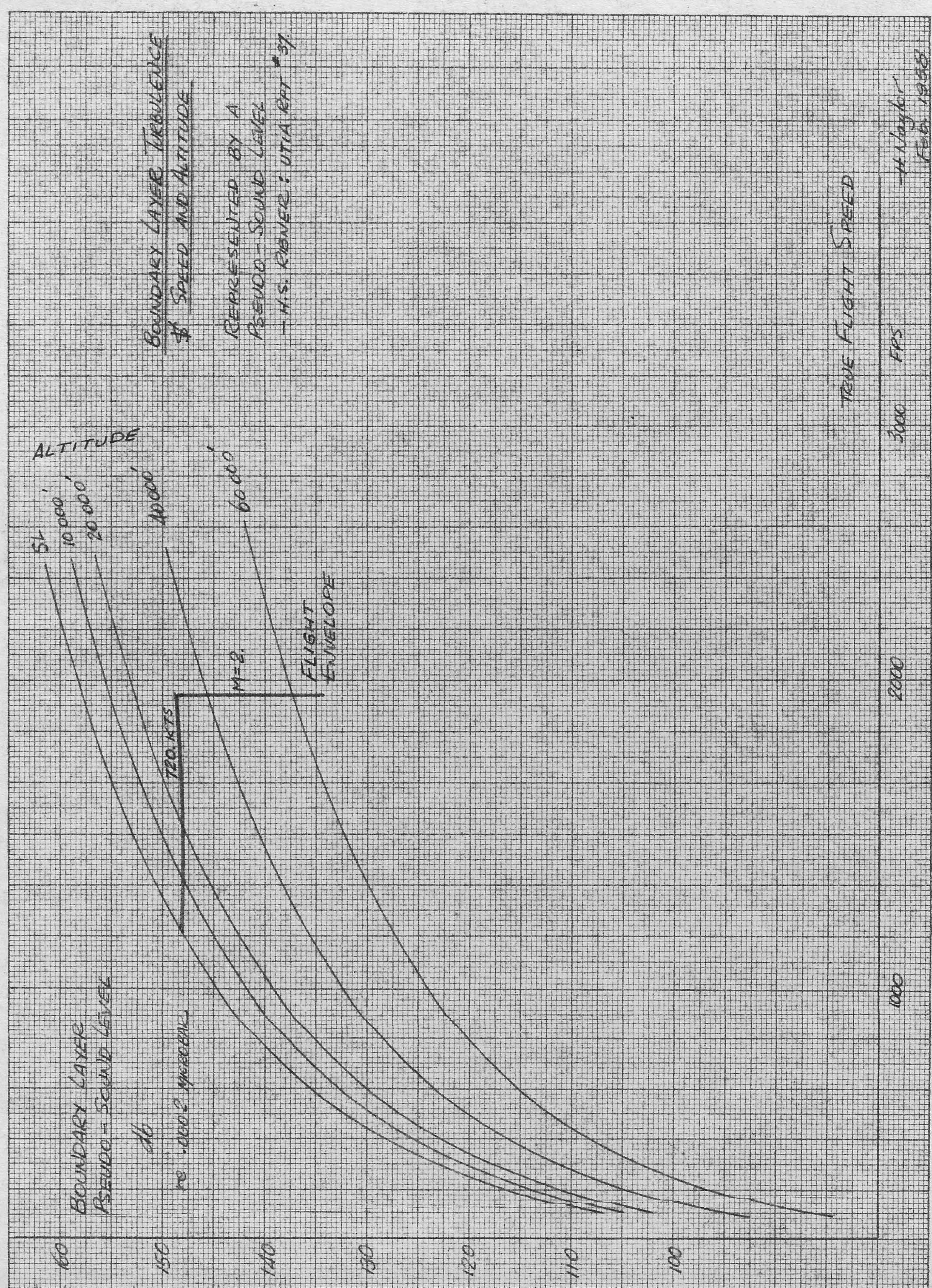

ARROW ELEVATOR NOISE LOADING
ONE IROQUOIS 2 WITH A/B
FREQUENCY cps.
1000
100
SOUND PRESSURE LEVEL
db
150
140
130
ZERO db
= .0002 microbar
TOTAL NOISE
153
150
INBOARD
OUTBOARD
HIGHEST NOISE LEVEL AT FUNDAMENTAL FREQUENCY FOR INFINITE LIFE OCCURS IN THIS REGION
G9-71
SEMI LOGARITHMIC
3 CYCLES X 70 DIVISIONS
CANADIAN CHARTS AND SUPPLIES, LTD.
OAKVILLE, ONT.

FIGURE 10



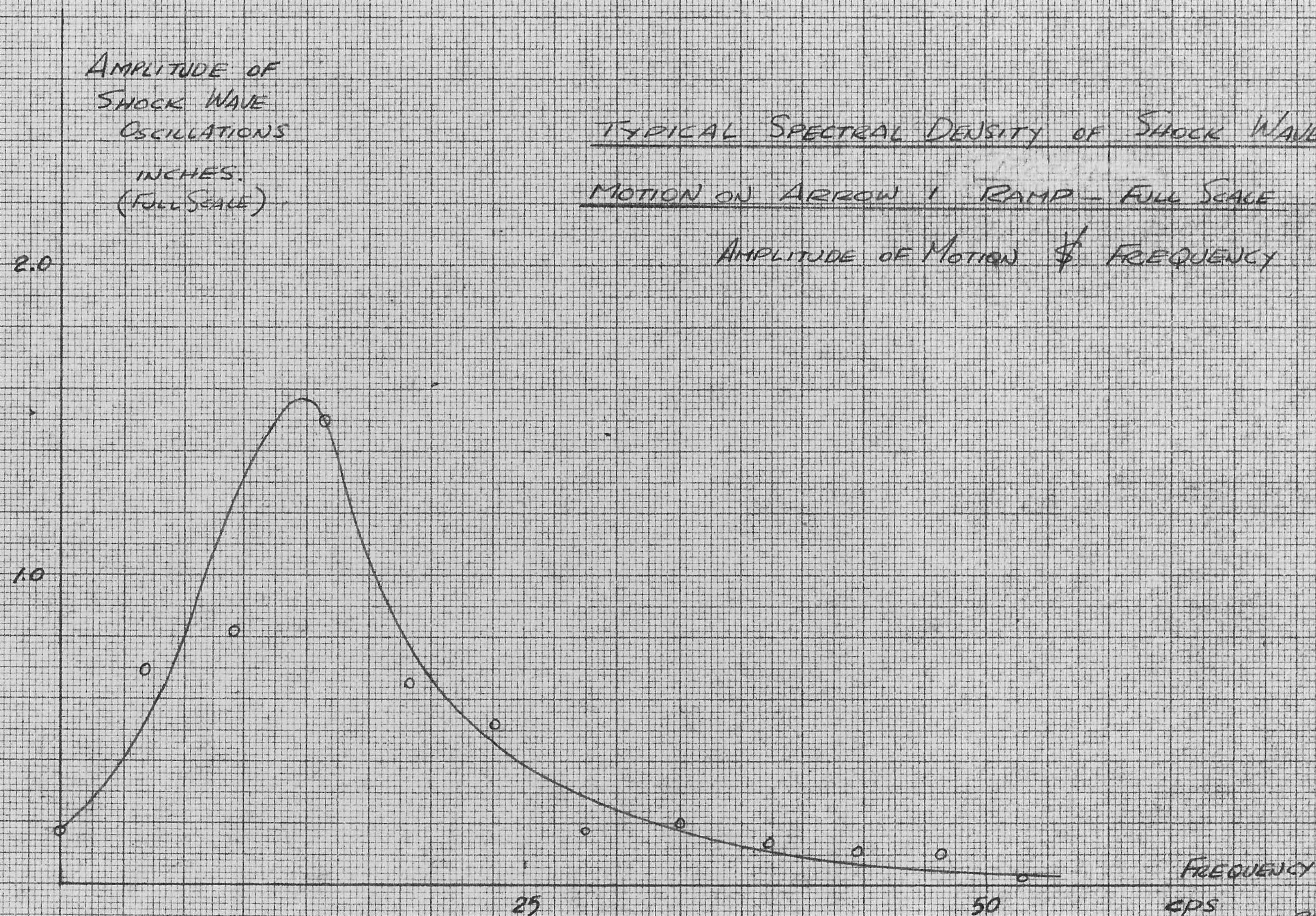
CANADIAN CHARTS AND SUPPLIES, LTD.
OAKVILLE, ONT.
G9-71
SEMI LOGARITHMIC
3 CYCLES X 70 DIVISIONS
ARROW 2 AILERON NOISE LOADING
DUE TO ONE IROQUOIS 2 WITH A/B.
SOUND PRESSURE LEVEL
db
150
140
130
ZERO db
= .0002 microbar.
HIGHEST NOISE LEVEL AT FUNDAMENTAL FREQ! FOR INFINITE LIFE OCCURS IN THIS REGION.
TOTAL NOISE LEVEL 150 db
150
INBOARD
OUTBOARD
100
1000
FREQUENCY cps

FIGURE 11


BOUNDARY LAYER TURBULENCE
vs SPEED AND ALTITUDE
REPRESENTED BY A
PSEUDO-SOUND LEVEL
— H.S. RIBNER: UTIA RPT #37
BOUNDARY LAYER
PSEUDO-SOUND LEVEL
db
re .0002 MICROBAR
ALTITUDE
SL
10,000'
20,000'
40,000'
60,000'
FLIGHT ENVELOPE
M=2.
720 KTS
160
150
140
130
120
110
100
1000
2000
3000
FPS
TRUE FLIGHT SPEED
Feb. 1958

TYPICAL SPECTRAL DENSITY OF SHOCK WAVE MOTION ON ARROW I RAMP – FULL SCALE

AMPLITUDE OF MOTION VS FREQUENCY



REF. 9

H. F. W. Naylor
Feb. 1958

FIGURE 12

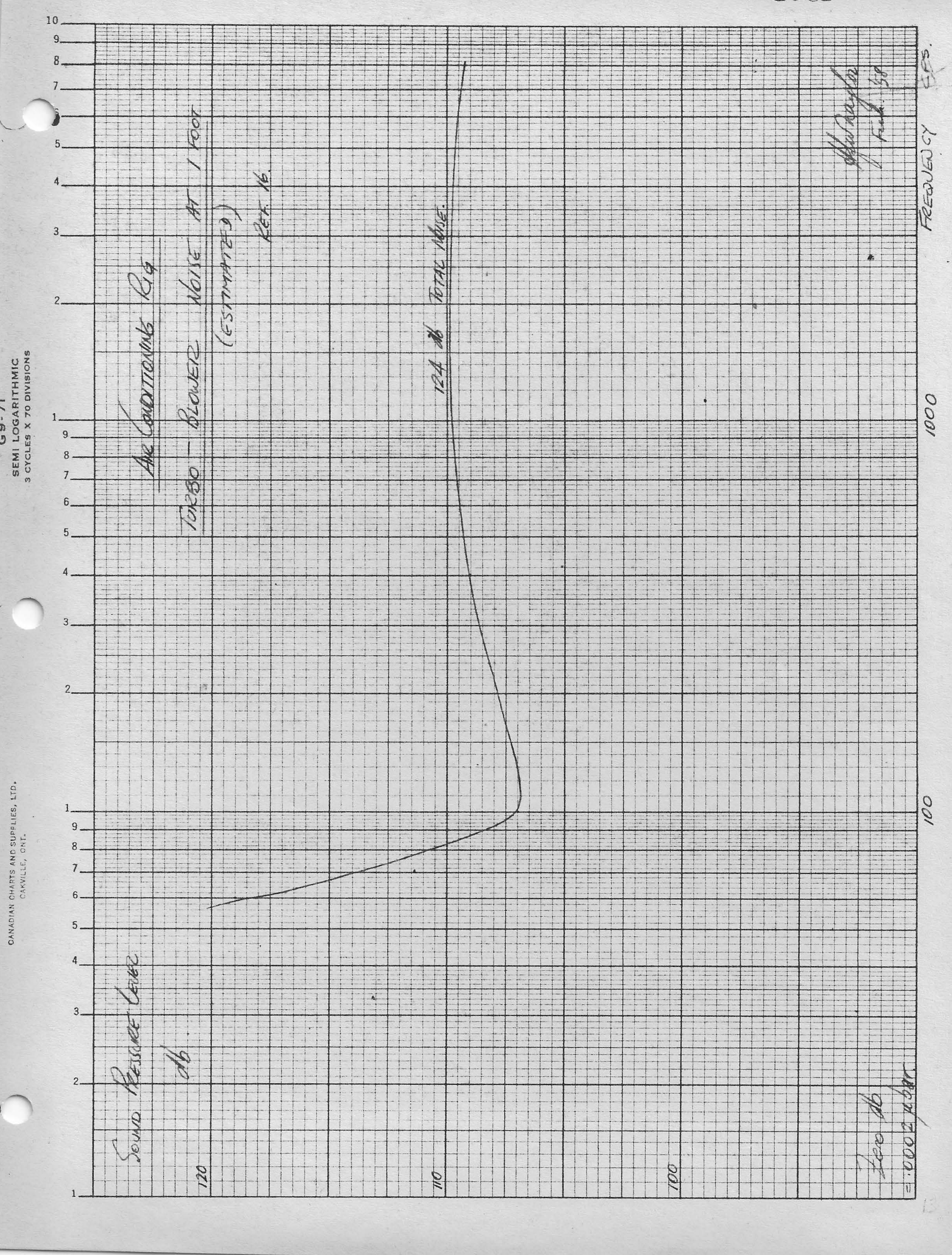
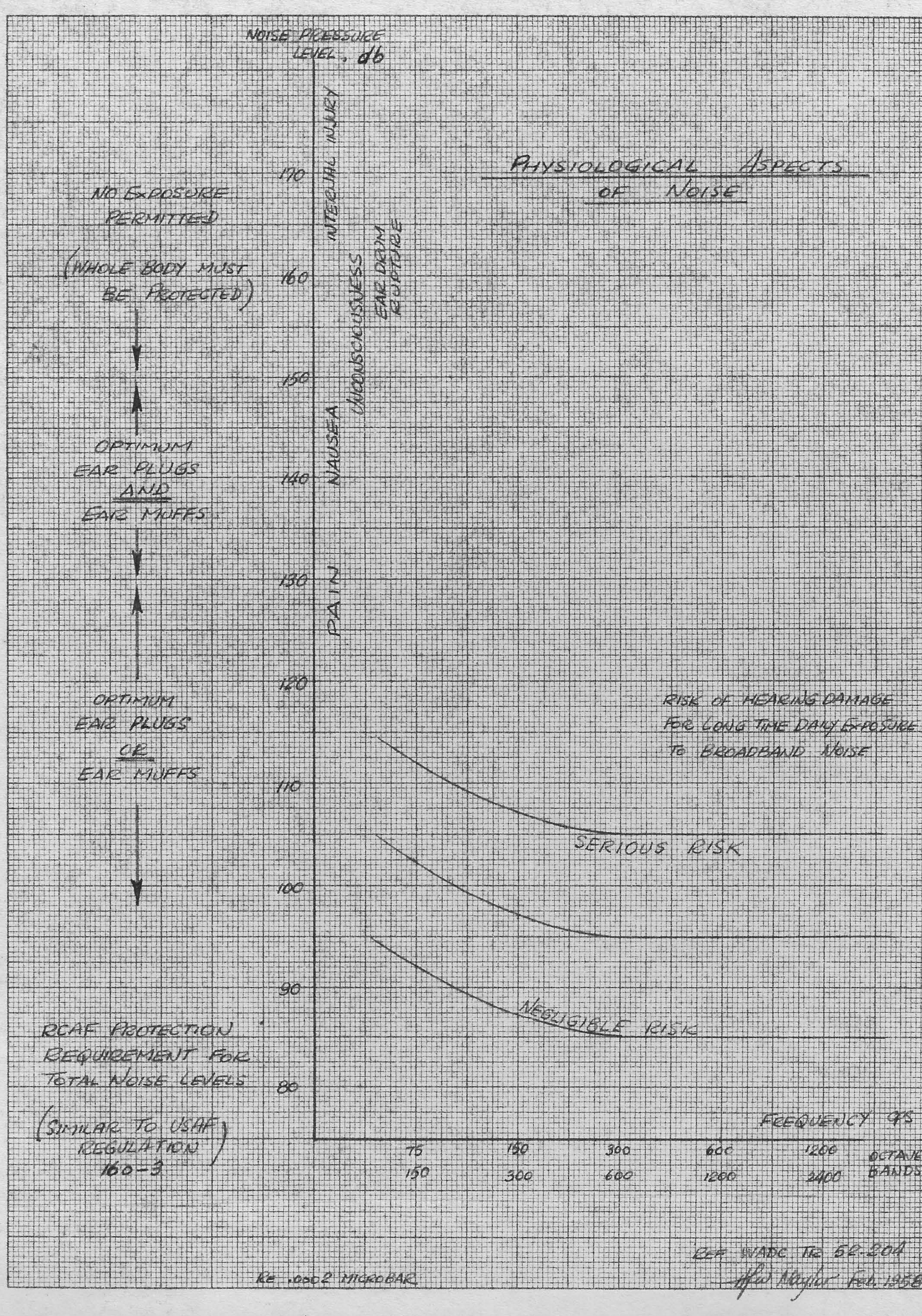

G9-71
SEMI LOGARITHMIC
3 CYCLES X 70 DIVISIONS
CANADIAN CHARTS AND SUPPLIES, LTD.
OAKVILLE, ONT.
AIR CONDITIONING RIG
TURBO - BLOWER NOISE AT 1 FOOT
(ESTIMATED)
REF. 16.
124 db TOTAL NOISE.
SOUND PRESSURE LEVEL
db
120
110
100
100
1000
FREQUENCY CPS.
ZERO db = .0002 μbar

FIGURE 14



NOISE PRESSURE LEVEL, db
PHYSIOLOGICAL ASPECTS OF NOISE
NO EXPOSURE PERMITTED
(WHOLE BODY MUST BE PROTECTED)
OPTIMUM EAR PLUGS AND EAR MUFFS
OPTIMUM EAR PLUGS OR EAR MUFFS
RCAF PROTECTION REQUIREMENT FOR TOTAL NOISE LEVELS
(SIMILAR TO USAF REGULATION 160-3)
170
160
150
140
130
120
110
100
90
80
INTERNAL INJURY
PAIN
NAUSEA
UNCONSCIOUSNESS
EAR DROM RUPTURE
RISK OF HEARING DAMAGE FOR LONG TIME DAILY EXPOSURE TO BROADBAND NOISE
SERIOUS RISK
NEGLIGIBLE RISK
FREQUENCY
75 150
150 300
300 600
600 1200
1200 2400
OCTAVE BANDS
Re .0002 MICROBAR
REF WADC TR 52-204
Feb. 1958

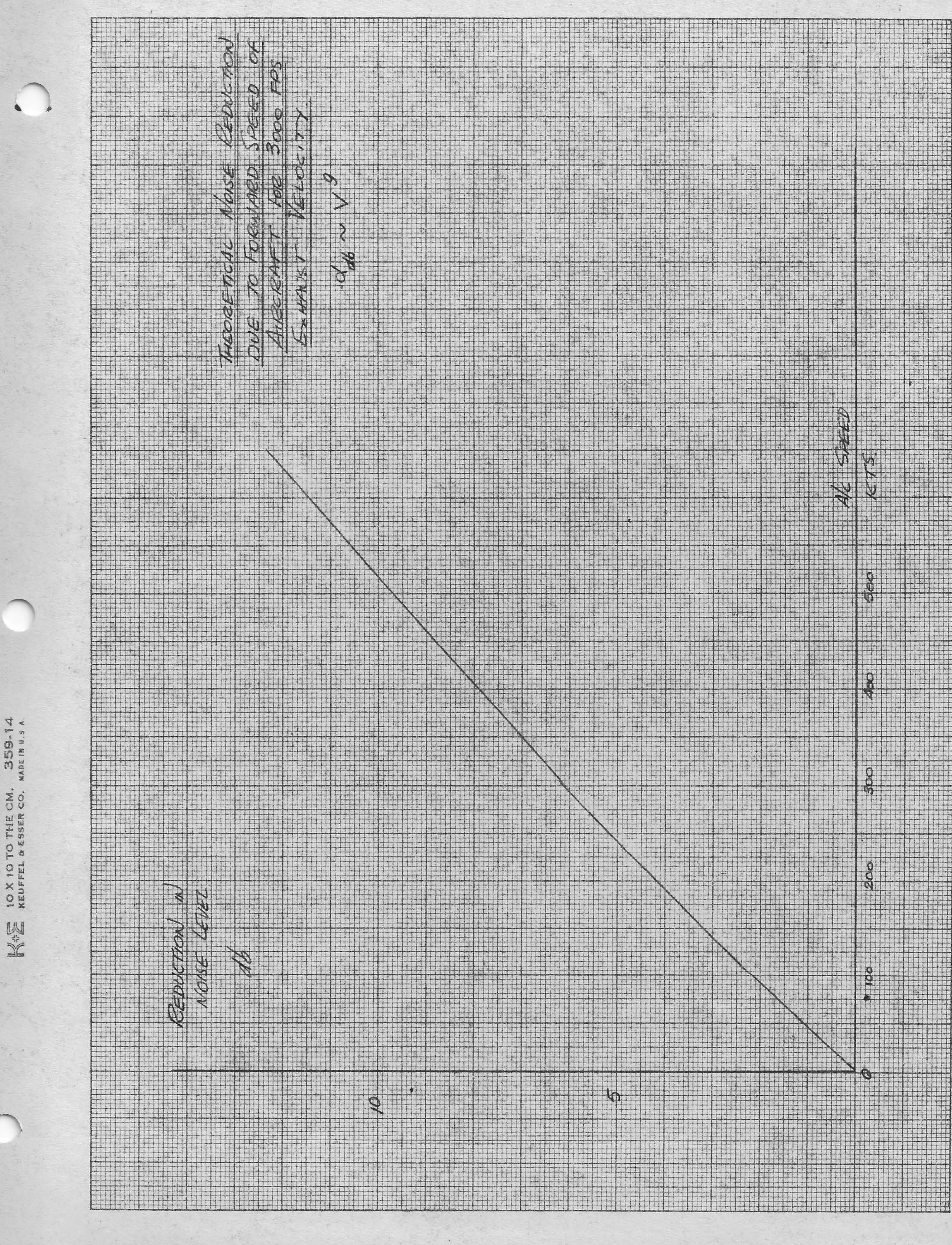
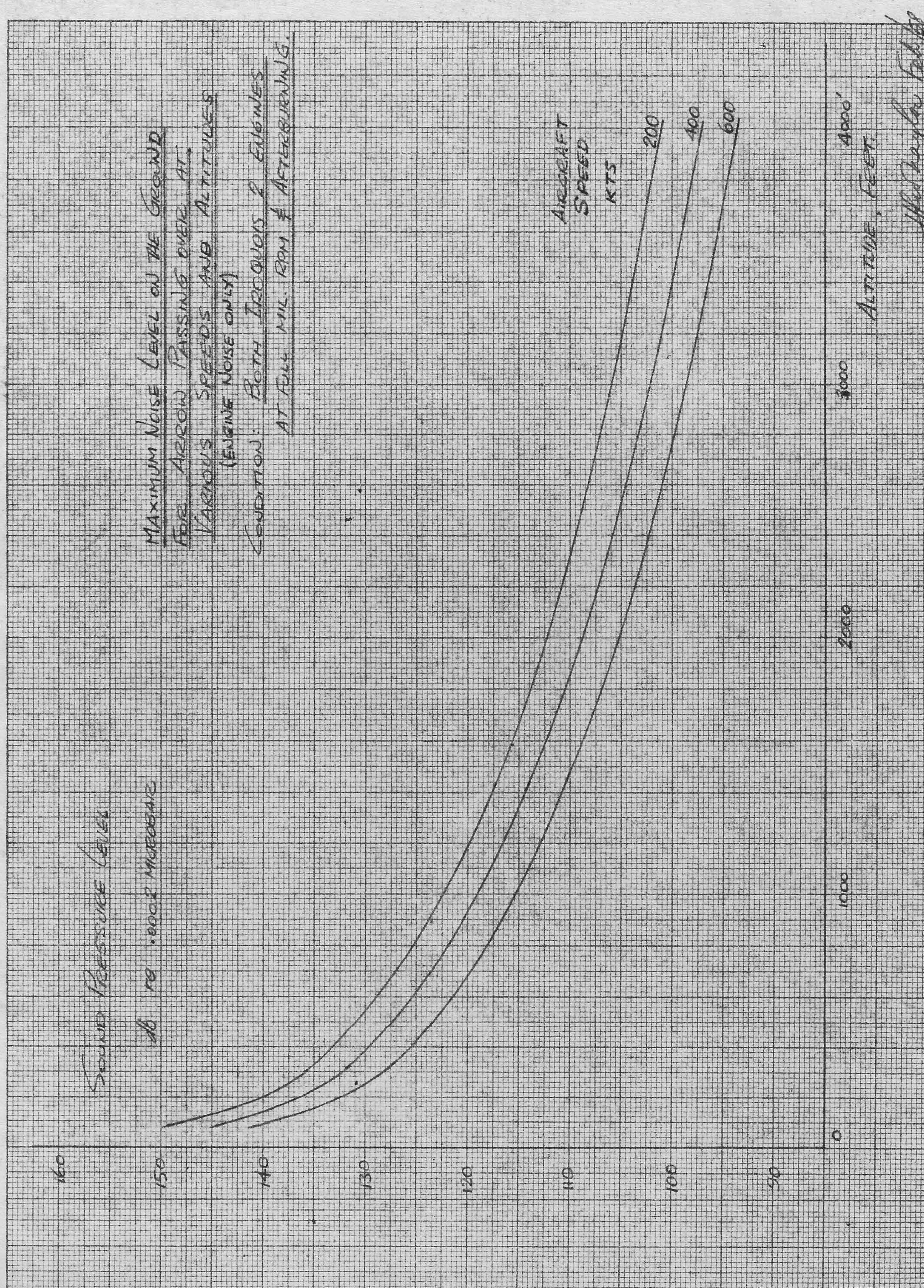

THEORETICAL NOISE REDUCTION
DUE TO FORWARD SPEED OF
AIRCRAFT FOR 3000 FPS
EXHAUST VELOCITY
$d_{db} \sim V^9$
REDUCTION IN
NOISE LEVEL
db
10
5
0
100
200
300
400
500
A/C SPEED
KTS
10 X 10 TO THE CM. 359-14
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIGURE 16


MAXIMUM NOISE LEVEL ON THE GROUND
FOR ARROW PASSING OVER AT
VARIOUS SPEEDS AND ALTITUDES
(ENGINE NOISE ONLY)
CONDITION: BOTH IROQUOIS 2 ENGINES
AT FULL MIL. RPM & AFTERBURNING.
SOUND PRESSURE LEVEL
db re .0002 MICROBAR
160
150
140
130
120
110
100
90
0
1000
2000
3000
4000'
ALTITUDE, FEET.
AIRCRAFT
SPEED
KTS
200
400
600