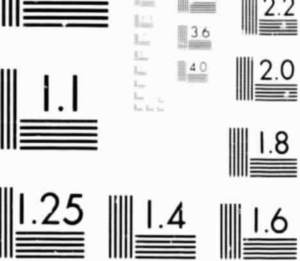

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PROP-FAN

RESULTS OF INITIAL PROP-FAN MODEL ACOUSTIC TESTING

VOLUME I
DISCUSSION

by
F.B.METZGER and T.G.GANGER

DECEMBER 4, 1970

Hamilton Standard
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PROP-FAN MODEL
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Prepared by: F. B. Metzger — Senior Analytical Engineer

T. G. Ganger — Senior Experimental Engineer

Approved by: C. Rohrbach — Head Aerodynamics and Acoustics

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ABSTRACT

This report summarizes the results of a test program conducted to explore the low noise potential of the Prop-Fan, a high bypass ratio, low pressure ratio, variable pitch propulsor. Far field noise data and directional character of a 21-inch diameter Prop-Fan model were determined for two shroud configurations, a bellmouth test shroud and a takeoff/cruise shroud. In addition, near field data were obtained for the bellmouth test shroud. Extensive review of the data from this program reinforce earlier conclusions that a large STOL aircraft powered by Prop-Fans has the potential to meet the objective of 95 PNdB at 500 feet with modest acoustic treatment.

TABLE OF CONTENTS

	Page No.
INTRODUCTION	1
CONCLUSIONS	2
DESCRIPTION OF TEST	
Test Item	3
Test Facility	3
Instrumentation	3
Test Procedure	4
DISCUSSION	
Introduction	5
Performance Test Data	5
Bellmouth Shroud Far Field Data	5
Bellmouth Shroud Near Field Data	7
Compromise Shroud Far Field Data	7
Comparison of Test Data and Estimates	7
Projection of Model Results to Full Scale	8
APPENDIX A. REFERENCES	49

LIST OF FIGURES

Figure No.	Title	Page No.
1	Prop-Fan Rotor	11
2	Prop-Fan Bellmouth Test Shroud	12
3	Prop-Fan Takeoff/Cruise Shroud	13
4	Prop-Fan Model	14
5	Prop-Fan Noise Test Microphone Locations	15
6	Prop-Fan Noise Test Near Field Microphone Locations	16
7	Prop-Fan Noise Tests Far Field Microphone Locations	17
8	Bellmouth Shroud	18
9	Bellmouth Shroud	19
10	Takeoff/Cruise	20
11	Takeoff/Cruise	21
12	Prop-Fan Perceived Noise (Bellmouth Shroud) . . .	22
13	Prop-Fan Overall Noise (Bellmouth Shroud)	23
14	Prop-Fan Sound Power Level (Bellmouth Shroud). . .	24
15	Prop-Fan Tone Noise (Bellmouth Shroud)	25
16	Prop-Fan Tone Noise (Bellmouth Shroud)	26
17	Prop-Fan Model Noise(Bellmouth Shroud)	27
18	Prop-Fan Model Noise (Bellmouth Shroud)	28
19	Prop-Fan Model Noise (Bellmouth Shroud)	29
20	Prop-Fan Model Noise (Bellmouth Shroud)	30
21	Prop-Fan Model Noise (Bellmouth Shroud)	31
22	Prop-Fan Model Noise (Bellmouth Shroud)	32
23	Prop-Fan Model Noise Directivity Analysis	33

LIST OF FIGURES (Cont.)

Figure No.	Title	Page No.
24	Prop-Fan Model Noise (Bellmouth Shroud)	34
25	Prop-Fan Model Noise (Bellmouth Shroud)	35
26	Prop-Fan Near Field Noise (Bellmouth Shroud) . . .	36
27	Prop-Fan Near Field Noise (Bellmouth Shroud) . . .	37
28	Prop-Fan Model Noise (Bellmouth and Takeoff/Cruise Shroud)	38
29	Prop-Fan Perceived Noise Bellmouth Shroud vs Takeoff/Cruise Shroud	39
30	Prop-Fan Overall Noise Bellmouth Shroud vs Takeoff/Cruise Shroud	40
31	Prop-Fan Sound Power Level Bellmouth Shroud vs Takeoff/Cruise Shroud	41
32	Prop-Fan Model Noise Comparison Curve (Bellmouth Shroud)	42
33	Prop-Fan - Acoustic Duct Treatment Estimates . . .	43
34	Projected Noise Level of a Full Scale Prop-Fan STOL Aircraft Based on Preliminary Prop-Fan Estimating Method	44
35	Geometric Extrapolation of Model Test Data to Full Scale	45
36	Projected Noise Level of a Full Scale Prop-Fan STOL Aircraft Based on Geometric Scaling of Model Test Data	46

LIST OF TABLES

Table No.	Title	Page No.
1	Prop-Fan Test Conditions	47
2	Prop-Fan Test Ambient Conditions	48

INTRODUCTION

In order to explore the low noise potential of a Prop-Fan as an aircraft propulsion system, a noise survey was conducted on the Prop-Fan model at NASA Langley, Hampton, Virginia. The model tested consisted of an existing 21-inch diameter, 12-bladed fan (originally designed for wind tunnel performance testing) with 22 swirl recovery vanes mounted downstream of the fan. Noise reduction features were not incorporated in this model except for the use of 22 stator vanes to suppress the level of the tone at the blade passing frequency.

Two shroud configurations were tested: (1) a bellmouth test shroud (static shroud), which was designed for unseparated inflow during static tests and (2) a takeoff/cruise shroud (compromise shroud), which was designed for good in-flight cruise performance with minimum sacrifice in takeoff performance.

The noise tests, which were conducted under carefully controlled free field conditions, included measurement of near field, far field, and directional characteristics of the Prop-Fan model at various combinations of power from 40 to 250 hp and tip speeds from 500 to 900 ft/sec. The far field data from these tests provide accurate reference data for comparison with estimated levels. The near field data provides insight into the Prop-Fan contribution to aircraft cabin noise.

CONCLUSIONS

Based on the results of the Prop-Fan model acoustic test the following conclusions have been drawn:

1. Comparison between preliminary estimates of Prop-Fan model noise made prior to the test and measured results show good correlation on a perceived noise basis but show that the preliminary estimates of overall noise exceed measured levels by 12 dB at the design point of 700 ft/sec and 215 hp.

2. Simple extrapolations from model test data to full scale as well as estimates based on the Preliminary Prop-Fan Noise Estimating Method of reference 3 show that a large STOL aircraft can be designed to meet the objective of 95 PNdB at 500 feet with modest acoustic treatment.

3. The 10 foot sideline noise (PNL and overall SPL) varies approximately 6 dB per doubling of shaft power.

4. The directivity patterns showed maximum noise propagating 110°-140° from directly ahead of the Prop-Fan.

5. The noise spectrum contains significant broad band noise plus several harmonics of blade passing frequency with the strongest being the first or second overtone.

DESCRIPTION OF TEST

TEST ITEM

The test item consisted of a 21-inch diameter, 12-bladed, manually adjustable pitch, shrouded Prop-Fan model with 22 fixed pitch recovery vanes. The Prop-Fan rotor was an existing wind tunnel model which had been designed for 900 ft/sec tip speed, 400 hp, 0.20 free stream Mach Number and a rotor pressure ratio of 1.110. The recovery vanes were designed to be tested at static conditions at 700 ft/sec tip speed, 222 hp condition. The only acoustic design incorporated into the system was the use of 22 stators to ... the decay of rotor/stator interaction tone noise. These were located such that the distance between the trailing edge of the rotor blades and the leading edge of the stators at operating conditions was equal to two rotor chords at the mean radius.

The shroud was designed to accept two inlet lip configurations; a bellmouth/static test inlet (referred to as static shroud in the appendices) and takeoff/cruise inlet (referred to as compromise shroud in the appendices). Figure 1 shows the Prop-Fan rotor while Figures 2 and 3 show the bellmouth shroud and the takeoff/cruise shroud respectively. Figure 4 shows a cross-sectional view of the Prop-Fan assembly including definition of the two inlet lips.

TEST FACILITY

The tests were conducted on a level grass covered field adjacent to Building 1212 at Langley Research Center, Hampton, Virginia. During the test program the Prop-Fan was driven by an electrically powered Propeller Test Rig normally used for aerodynamic testing in the United Aircraft Wind Tunnel. The axis of rotation was approximately 11.5 feet above the ground and the test area was free from obstructions within 100 feet of the test item. Microphones were located in both the near field and far field as shown in Figure 5. The four near field microphones were located on a line two feet from the axis of rotation, both fore and aft of the Prop-Fan plane of rotation as shown in Figure 6. Seven far field microphones were located 10 feet from the Prop-Fan, 11.5 feet off the ground, at 22.5 degree intervals. One microphone was located approximately 6 inches off the ground at the 90° position, 13.5 feet from the Prop-Fan to evaluate ground reflection effects. In addition, one microphone was located on a boom capable of traversing continuously from 0-150° on a 10 foot arc as shown in Figure 7. The traversing speed was held in most cases to approximately 0.5° per second.

INSTRUMENTATION

The following equipment was used for the program:

A. Data Acquisition

1. Eight Bruel and Kjaer type 4133 microphones with flat response to 40 KHz at normal incidence.

2. Eight Bruel and Kjaer type 2614 cathode followers.

3. Two Bruel and Kjaer model 140 four channel signal conditioners.

4. Hewlett Packard model 15117A microphone calibrator providing a 1 KHz signal at 94, 104, 114, or 124 dB ±0.3 dB.

5. CEC model VR3300, one inch, 14 channel, direct record tape recorder with a flat response to 40 KHz at 15 inches per second.

B. Data Reduction

1. General Radio type 1921 one-third octave band real time analyzer.

2. Spectral Dynamics type 101 frequency analyzer with stationary and tracking filter capabilities.

TEST PROCEDURE

Prior to testing, the microphone and power supplies were allowed to warm up to ensure stability. The microphones were then calibrated using the Hewlett Packard calibrator. This calibration procedure was repeated prior to, and following, each set of tests to determine any calibration shifts that may occur during testing.

To ensure minimum interference from background noise and excessive wind velocities, testing was restricted to the hours between midnight and 9 AM. Furthermore, total background noise measurements (ambient and electrical noise) were made prior to each set of tests at the gain settings used during the test.

Data was recorded for approximately 30 seconds for each of the appropriate microphone locations for the test conditions of Table 1. In addition, the Prop-Fan rotor torque and thrust, and RPM and shroud-vane torque and thrust were measured. The net thrust was determined from the sum of the two thrust measurements, and shaft horsepower was determined from the measured rotor torque and RPM.

DISCUSSION

INTRODUCTION

The data from this program were analyzed using both constant bandwidth (50 Hz) and constant percentage (1/3 octave) filters. In addition, the data from the sweep microphone was analyzed with a 50 Hz tracking filter, tracking on the fundamental of blade passing frequency and the first four overtones. Appendix B contains a discussion of the data acquisition/reduction system frequency response, data reduction averaging time, effect of ground reflection on test results, and the influence of total background noise on test results. The data, which will be discussed in this report, are shown in Appendices C, D, E and F. The operating conditions for the test item during the program are summarized below.

PERFORMANCE TEST DATA

The measured static net thrust, shaft horsepower, tip speed and rotor blade angle data are summarized in Figures 8 and 9 for the bellmouth shroud and in Figures 10 and 11 for the compromise shroud. Table 1 summarizes the operating conditions while Table 2 summarizes the ambient condition for the various runs in the test program. It should be noted that the electrical power limitations at the test site limited power to 250 horsepower for the test program. The lower level of performance for the takeoff/cruise shroud is attributed to shroud lip flow instability which was observed in flow visualization checks made during the test program.

Also shown on Figures 8 and 9 are the predicted values of net thrust, shaft horsepower and blade angle at 700 ft./second tip speed. The predicted net thrusts are consistently lower but within 6% of the test values. It is interesting to note that the correlation of the predicted net thrusts with test is better with the takeoff/cruise shroud. Inasmuch as the prediction method does not assume any flow separation, this correlation was unexpected.

BELLMOUTH SHROUD FAR FIELD DATA

Based on the 1/3 octave band data of Appendix C, the maximum perceived noise level (PNL) on a 10 foot sideline was calculated for each test condition. The results, as shown on Figure 12, follow a trend curve

$$PNL_{(MAX)} = 78 + 20 \log SHP \pm 1.5 \text{ dB}$$

over the horsepower range shown. This corresponds to a 6 dB increase in $PNL_{(MAX)}$ per doubling of horsepower. Similarly, Figure 13 shows the maximum overall sound pressure level (OASPL) on a 10 foot sideline generally following a trend curve:

$$OASPL_{(MAX)} = 63 + 20 \log SHP \pm 1 \text{ dB}$$

Again, this corresponds to a 6 dB increase in $OASPL_{(MAX)}$ per doubling of horsepower.

The overall acoustic power level (PWL) was calculated for all test conditions and is shown as a function of horsepower on Figure 14. As expected, the curves follow a similar trend of approximately 6 dB increase in acoustic power per doubling of horsepower.

The maximum tone levels at blade passing frequency and its harmonics on a 10 foot sideline showed a general increase with increasing horsepower for rotor tip speeds of 500, 600, and 800 ft./sec. as shown in Figures 15 and 16. In contrast, the 700 ft./sec. tip speed data showed fluctuating tone levels with increasing horsepower. This can be accounted for in part, by the reduction in levels of the first, second, fourth, and fifth overtones at the stator design point, i.e. 215 HP, 700 ft./sec. tip speed, which is shown in Figure 16.

Figures 17 through 22 show the directivity analysis of the fundamental of blade passing frequency and its first four overtones for typical test cases. In general, the analysis indicates minimum noise near 90° (rotor plane of rotation) while the maximum lobe occurs at approximately 110°-140° (20°-50° behind the rotor plane of rotation). Also evident are many minor lobes (clearly shown in Figure 22, second overtone) which is characteristic of scattering from an acoustic dipole source.

The broad band (full octave) directivity analysis of Figure 23 for the design test condition (45° blade angle, 700 ft./sec. tip speed, 215 HP) shows the low to mid-frequencies to be rather nondirectional, while the upper frequencies greater than 4K Hz are highly directional.

Narrow band analyses of the maximum noise test cases are shown in Appendix D. Figure 24, a curve typical of those in Appendix D, clearly shows the tone content of the noise spectrum due to a rotating steady load (rotor field) and to fluctuating lift on stator due to wakes from the rotor (rotor/stator interaction). The dominance of the higher frequency harmonics is due to selection of a stator count that suppresses propagation of the blade passing frequency. It can be seen in Appendix D that the predominant tone occurs at the second or third overtone of blade passing frequency in all cases. While the higher order harmonics decrease in level they can be seen, in some cases, past the tenth overtone. It should be noted, however, that there are anomalous spikes in the narrow band plots of Appendix D at frequencies not related to blade passing frequency and its harmonics. The source of these tones is not known. Moreover they cannot be explained by any known propeller or turbofan noise theory and are therefore not considered a normal Prop-Fan noise.

Comparison of the narrow band curves to the 1/3 octave band curves, as shown in Figure 25 for the 45° blade angle, 215 HP, 700 ft./sec. tip speed design condition shows the fundamental of blade passing frequency and the second overtone to dominate the noise levels in their respective 1/3 octave bands, while the broad band noise floor dominates elsewhere. Therefore, suppression of these tones by configuration optimization, particularly the dominant second overtone, is expected to reduce perceived noise level of a full scale Prop-Fan significantly.

BELLMOUTH SHROUD NEAR FIELD DATA

Near field noise measurements were made on a two foot sideline for various rotor blade angles and tip speeds. The data, in 1/3 octave band form, is given in Appendix E. The summary of this data presented in Figure 26 shows the overall noise levels for the blade angles and tip speeds tested. The data show similar directivity trends to those found in the far field directivity analysis of Figure 23. The noise level decreases at the plane of rotation due to the directional character of the noise as well as shielding from the shroud. From this point forward the levels increase as the shroud becomes less of a shield at the "two foot forward" location and then decreases due to spherical spreading to the "six foot forward" location, which is no longer in the near field.

Figure 27 shows the change in maximum noise level on a two foot sideline as a function of horsepower at constant rotor tip speed. The data show trends almost identical to those in the far-field data of Figure 13. It is interesting to note however that for a given horsepower the lowest level is achieved at 700 ft./sec. the stator design speed.

COMPROMISE SHROUD FAR-FIELD DATA

The takeoff/cruise shroud far-field data is given in Appendix F. Comparison of a sample 1/3 octave band plot for the takeoff/cruise shroud with a plot for the Prop-Fan with bellmouth shroud operating at the same tip speed and blade angle in Figure 28 shows the takeoff/cruise shroud data to be generally higher than the bellmouth shroud data. Also, from the data in Appendix F, the maximum PNL, as measured on a 10 foot sideline, was calculated and compared to values from the bellmouth shroud tests in Figure 29. It can be seen that the takeoff/cruise shroud configuration produces from 2 to 7 dB more noise than the bellmouth shroud configuration which, in part, is due to the better inflow characteristics of the bellmouth shroud during static testing. The trends and differences of Figure 29 are also evident in Figures 30 and 31 which show the maximum overall noise levels on a 10 foot sideline and overall sound power levels respectively. These differences are not considered a significant problem in noise certification of a full scale Prop-Fan aircraft as inflow characteristics for the takeoff/cruise shroud will be essentially identical to those of the bellmouth shroud as the aircraft passes the measurement locations specified in the Federal Noise Certification Regulations.

COMPARISON OF TEST DATA AND ESTIMATES

Both the maximum overall sound pressure level and the maximum perceived noise level as measured on a 10 foot sideline were estimated prior to testing by use of the method described in Reference 3. This method was based on an empirical propeller noise estimating method modified on the basis of limited shrouded propeller data of low power loading. Although no spectrum shape was included in this method it was assumed that the blade passing frequency tone noise would be suppressed by selection of the proper number of stators and that the rotor-stator interaction tone noise at higher harmonics would not be significant because of the rotor-stator gap. Figure 32 shows how the estimates made by this method compare with model test results at the design tip speed of 700 ft./sec. While the measured overall level is overestimated by the method by as much as 13 dB, surprisingly good agreement between estimated and measured perceived noise level is shown. While no spectrum shape is included in the estimating method, the discrepancy in overall noise and good correlation in perceived noise level indicate that the estimating method assumed more of a low frequency noise contribution than exists in the test results.

PROJECTION OF MODEL RESULTS TO FULL SCALE

The good correlation between estimated and measured perceived noise levels indicates that the estimating method of reference 3 might be satisfactory for estimating the perceived noise level of a full size Prop-Fan. Using this method as published shows that a 7000 shaft horsepower turbine engine driving a Prop-Fan, without acoustic duct treatment, of 7.8 ft. diameter at 700 ft./sec. tip speed would produce 95 PNdB at 500 ft. distance. The spectrum character of the model test data indicates that this level should be reduced by 1.5 dB for atmospheric attenuation of the important higher frequencies producing a level of 93.5 PNdB. A recent review of the results from the NASA acoustic duct lining program presented in reference 4, using current Prop-Fan duct length concepts and assuming that only the centerbody and inner shroud surface would be treated, showed that the attenuation of Figure 33 could be achieved in a full scale Prop-Fan propulsor. Note that the treatment concept for both the turbofan treatment from the reference and the Prop-Fan treatment concept are both shown in the sketches of Figure 33. Application of this attenuation spectrum to the noise spectrum shape geometrically scaled from model data reduces perceived noise level by 3 dB. Therefore, reducing the level estimated by the method of reference 3 for atmospheric attenuation, and installation of acoustic duct lining, produces an estimated level of 90.5 PNdB. A four engine STOL aircraft at 7000 shaft horsepower on takeoff would be 5 dB higher in sideline noise level assuming that some of the higher frequency noise from engines on the opposite side is blocked by the fuselage. This would be reduced 2 dB for engine operation at 80% power based on the test or estimate trends of Figure 32. Therefore, a full scale Prop-Fan aircraft should produce a sideline perceived noise level of 96.5 PNdB without acoustic duct treatment or 93.5 PNdB with acoustic duct treatment. For reference purposes, Figure 34 summarizes all of the levels and adjustments of this paragraph.

As an alternative to the method of reference 3, full scale Prop-Fan noise can be estimated using the model test data scaled geometrically on the assumption that spectrum shape remains constant for a fixed power loading (shaft horsepower per diameter squared) and that the model data was obtained in the far-field so a simple spherical spreading correction of 6 dB per doubling of distance applies. Figure 35 summarizes how these corrections can be applied to a 1/3 octave band spectrum from the model test data.

The first curve in Figure 35 shows the spectrum shape selected from Appendix C which produces the maximum sideline perceived noise level in full scale. Since an estimate of a 7.8 ft. diameter Prop-Fan is required, the scale factor of 7.8 divided by 1.75, or 4.5, is applied to shift the spectrum downward in frequency to produce the second curve. Note that by applying this scale factor the distance from the Prop-Fan to the measuring point increases by the same factor and assuming the same power loading the full scale Prop-Fan now absorbs 4260 horsepower. It is now a simple matter to apply the spherical spreading adjustment to produce the third curve in Figure 34 for a 7.8 ft. diameter Prop-Fan at a 500 ft. distance. This results in an estimated level of 98.6 PNdB for a single Prop-Fan.

A Prop-Fan to be used for a specific application, i.e. a high speed STOL transport designed to abosrb 7000 shaft horsepower in a 7.8 ft. diameter rotor would be designed both for low noise and high performance. Therefore it would differ acoustically, aerodynamically, and geometrically from the scaled version of the model as shown below.

First, as previously noted, the rotor was designed for performance testing and had a design point of 950 ft./sec. tip speed at 400 horsepower while the stator system was installed for the acoustic test program and designed for 700 ft./sec. tip speed at 222 horsepower. The rotor was therefore operating further off design than one designed for a specific application. In fact the static blade angle for the test was higher than the original design blade angle increasing rotor drag coefficients and consequently the noise as predicted by the method of reference 5. Considering the results of initial calculations using the theoretical method of reference 5, it is conservatively estimated that reductions of 2 dB can be achieved.

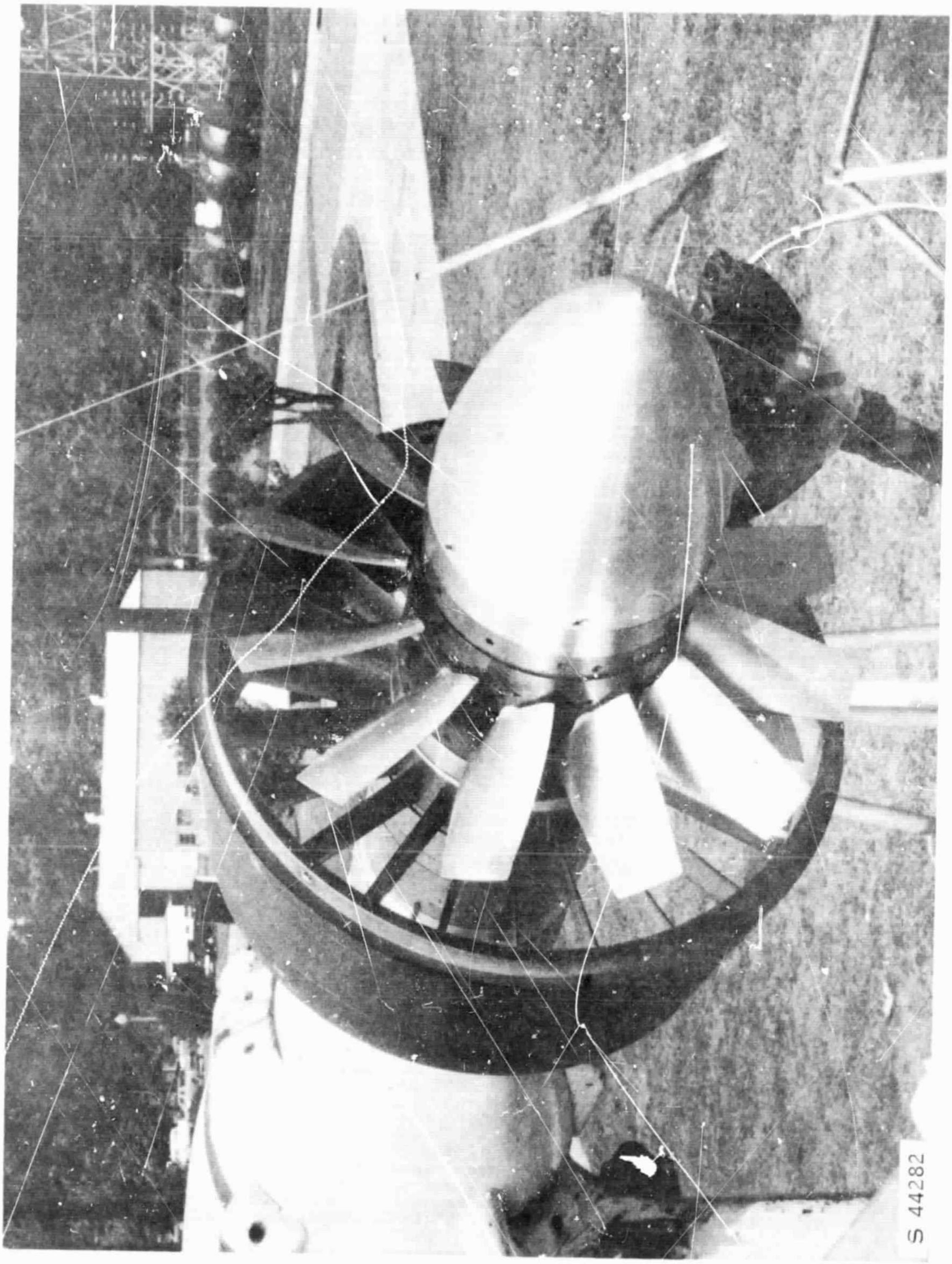
Second, for the model test the modifications of the stator to minimize noise were somewhat limited in that only one set of stators could be tested at one vane angle and fixed axial location. The selection of 22 stators to suppress propagation of the blade passing frequency was based on turbofan noise control technology. However, it appears from references 5 and 6 that as few as three long chord stators would provide a reduction in levels of tone and broad band noise. Also, optimization of stator angle of attack and axial location may produce significant reductions. These reductions which will be called "stator configuration noise reductions" are conservatively estimated to be 2.5 dB.

Third, on the basis of the Lift Fan noise suppression work of reference 7 and test results for quiet Lift Fans, a reduction of 4 dB is expected when the stators are leaned in the direction of rotation. This produces a scissors-like interception of the wakes from the rotor with the stators rather than the chopping action of radial stators. Limited theoretical work shows that this scissors like shearing action can be optimized to reduce the level of selected rotor stator interaction tones by generation of higher radial modes of low efficiency.

Finally, an adjustment is required to account for increasing the power loading from that of the model to that of the 7.8 ft. diameter, 7000 shaft horsepower Prop-Fan. Again, using the trends established by use of the theory in reference 5, an increase of 4.0 dB has been estimated. This increase is also verified by the trend of the model test data in Figure 12.

Totaling all of the above adjustments, and including 1.5 dB reduction for atmospheric attenuation which does not exist in the model data, a reduction of 6 dB is estimated for a full scale optimized Prop-Fan. Therefore, one 7.8 ft. diameter Prop-Fan operating at 7000 SHP and 700 ft./sec. would produce 92.6 PNdB at 500 ft. distance. Using the adjustments for four engines operating at 80% power and that for acoustic treatment, a level of 95.6 PNdB for a STOL aircraft without treatment or 92.6 PNdB for a STOL aircraft with acoustic treatment is estimated for a takeoff condition. For reference purposes, Figure 36 summarizes all the levels and adjustments used in these estimates.

From these two methods of estimating noise produced by a large Prop-Fan powered STOL aircraft, it can be seen that levels meeting a 95 PNdB objective at 500 ft. are possible without performance compromises being introduced as would be the case for multiple ring acoustic duct treatment currently recommended to minimize noise of conventional turbofans.



PROP FAN ROTOR
Figure 1

PROP-FAN
BELLMOUTH TEST SHROUD
Figure 2

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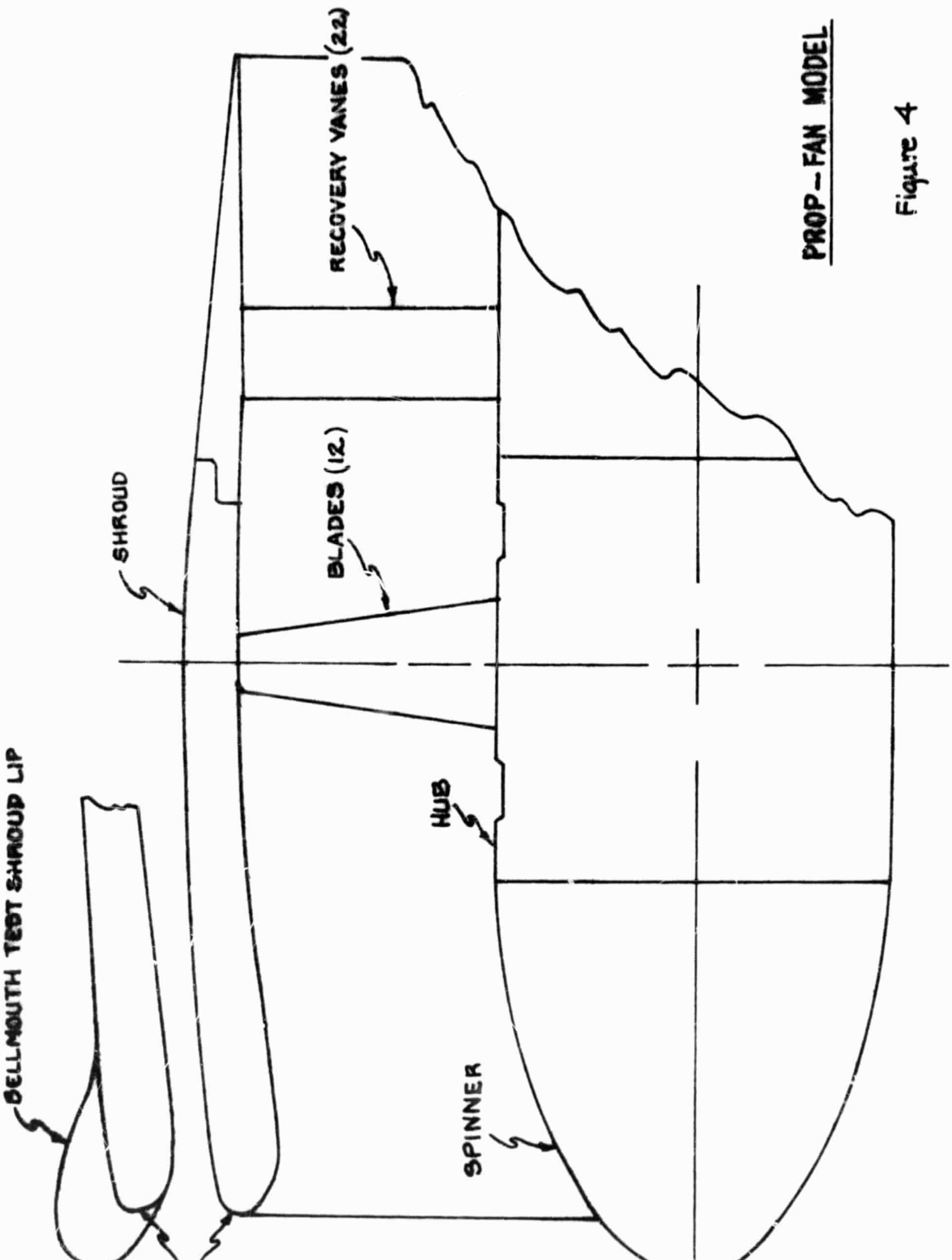
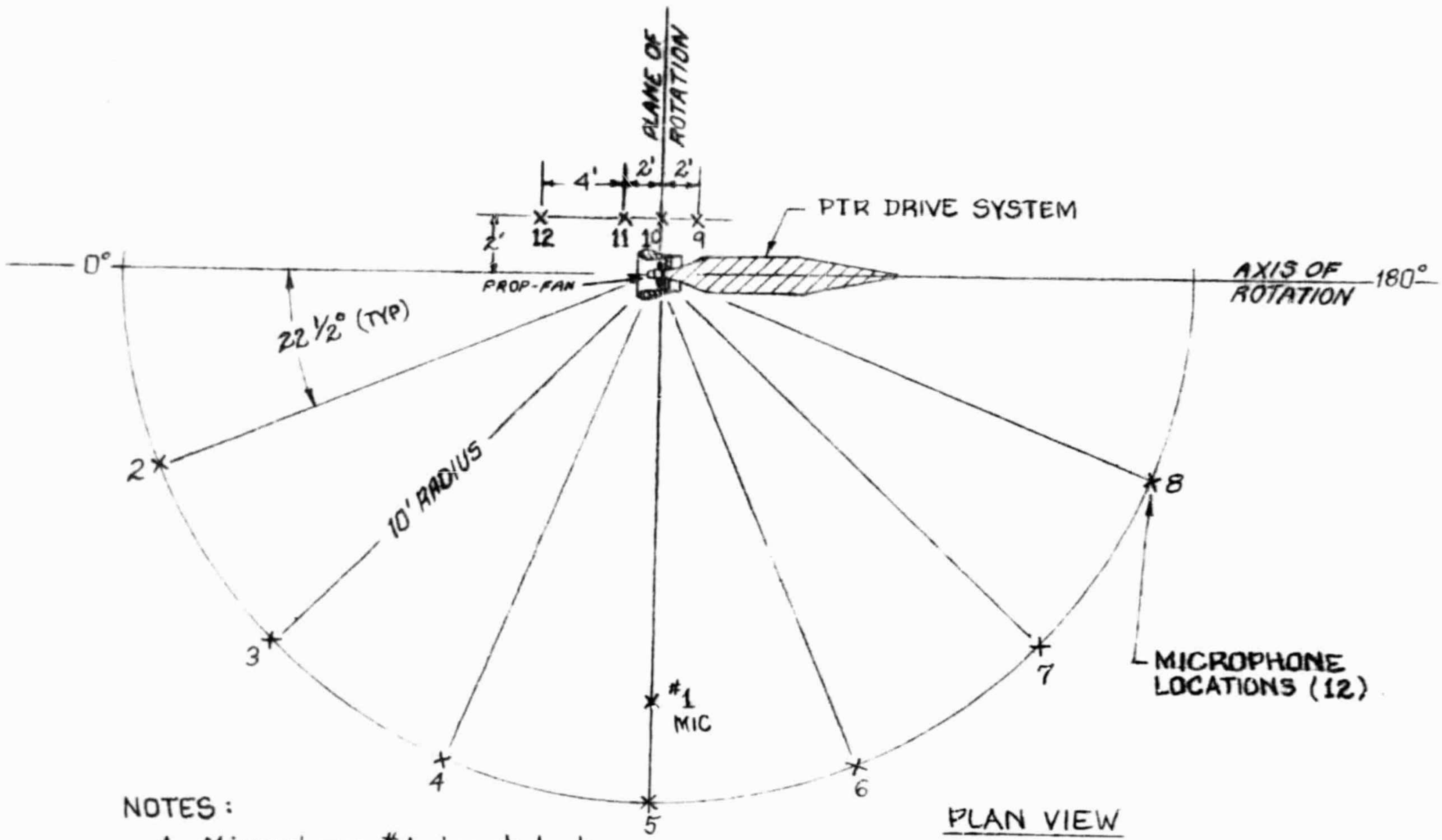
PROP-FAN TAKE OFF/CRUISE SHROUD
Figure 3



PROP-FAN MODEL

Figure 4

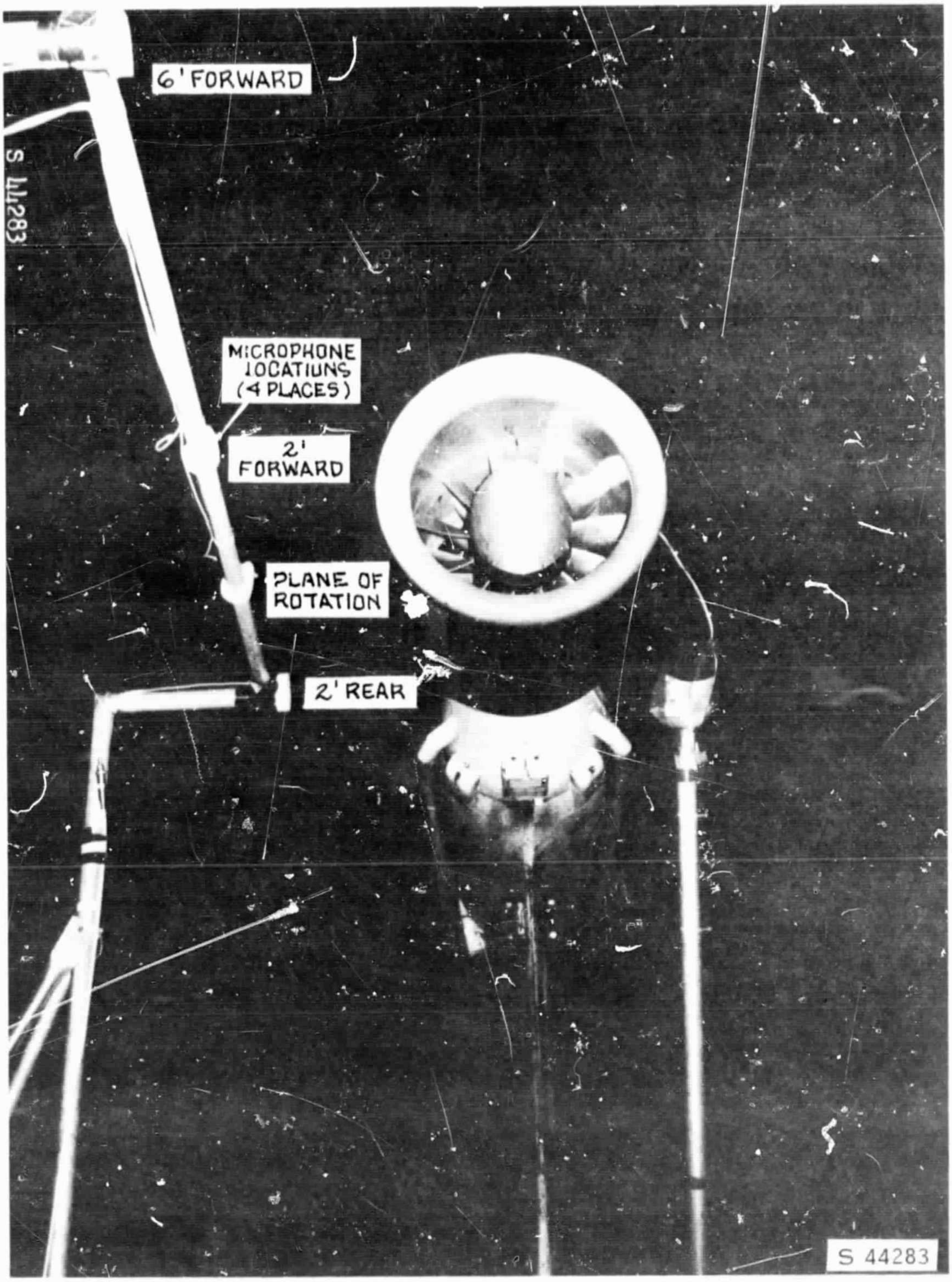


NOTES:

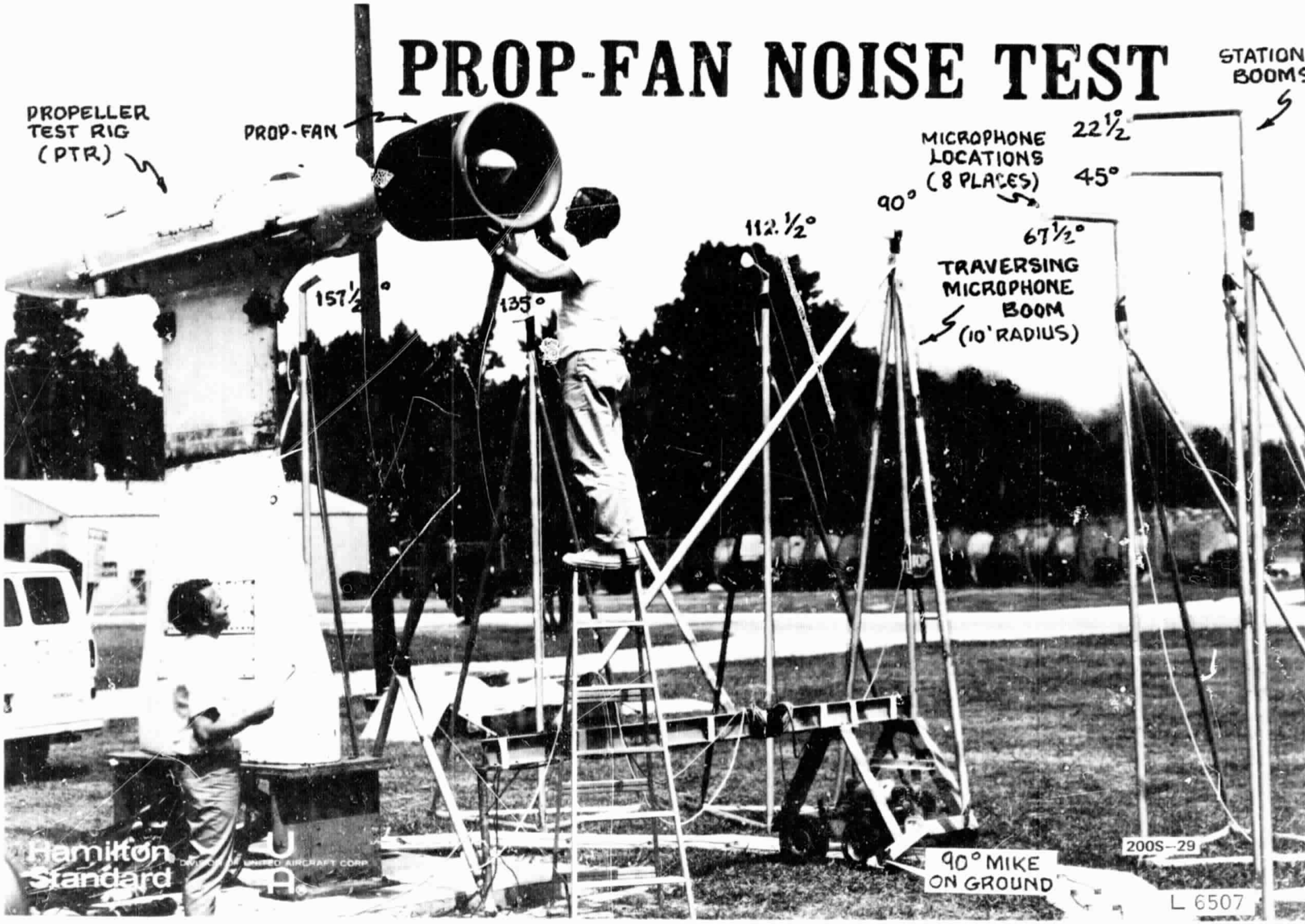
1. Microphone #1 located at ground plane, 13½' from axis of rotation.
2. Microphones #2 thru #12 located at height of axis of rotation

PROP-FAN NOISE TEST MICROPHONE LOCATIONS

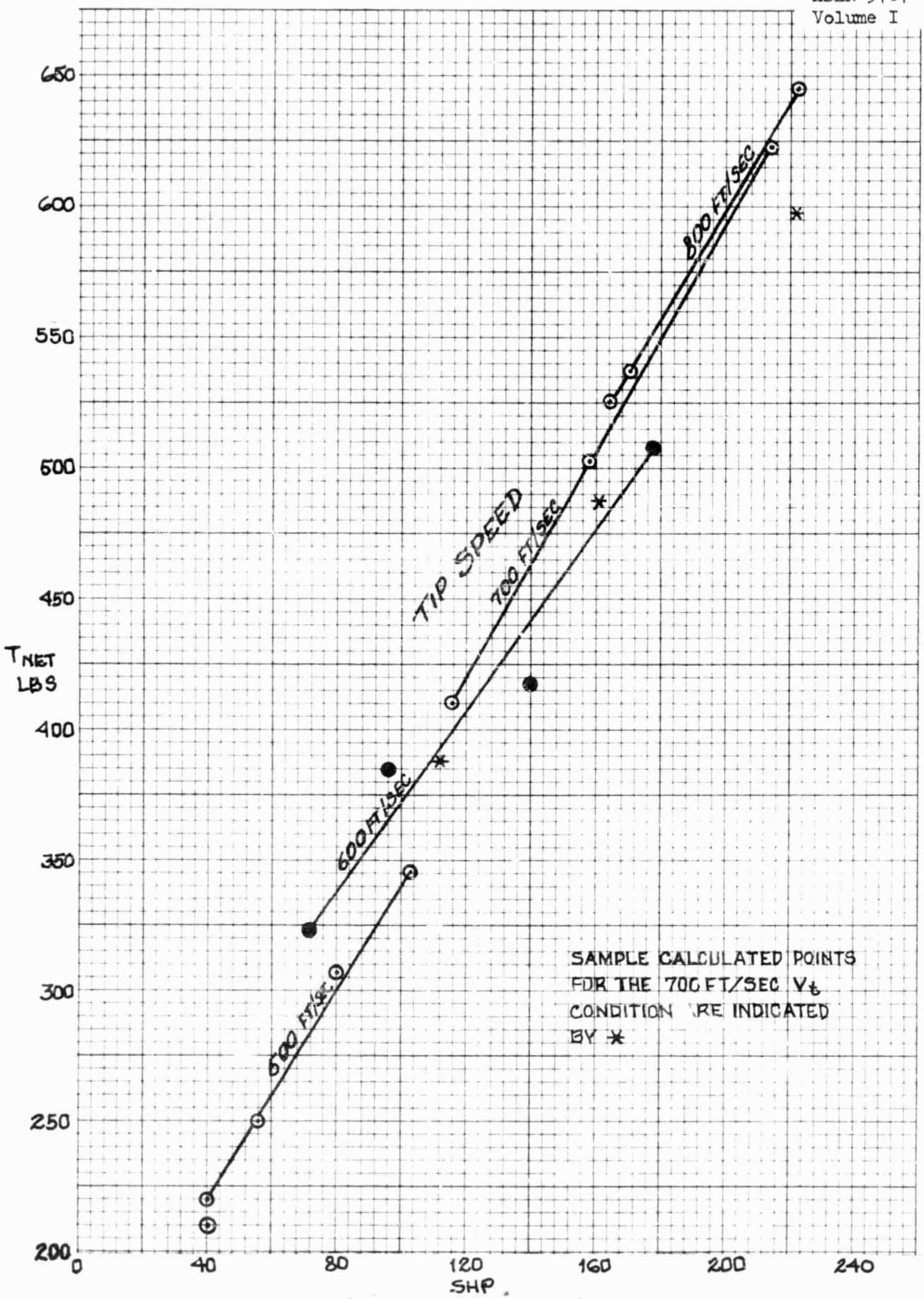
Figure 5



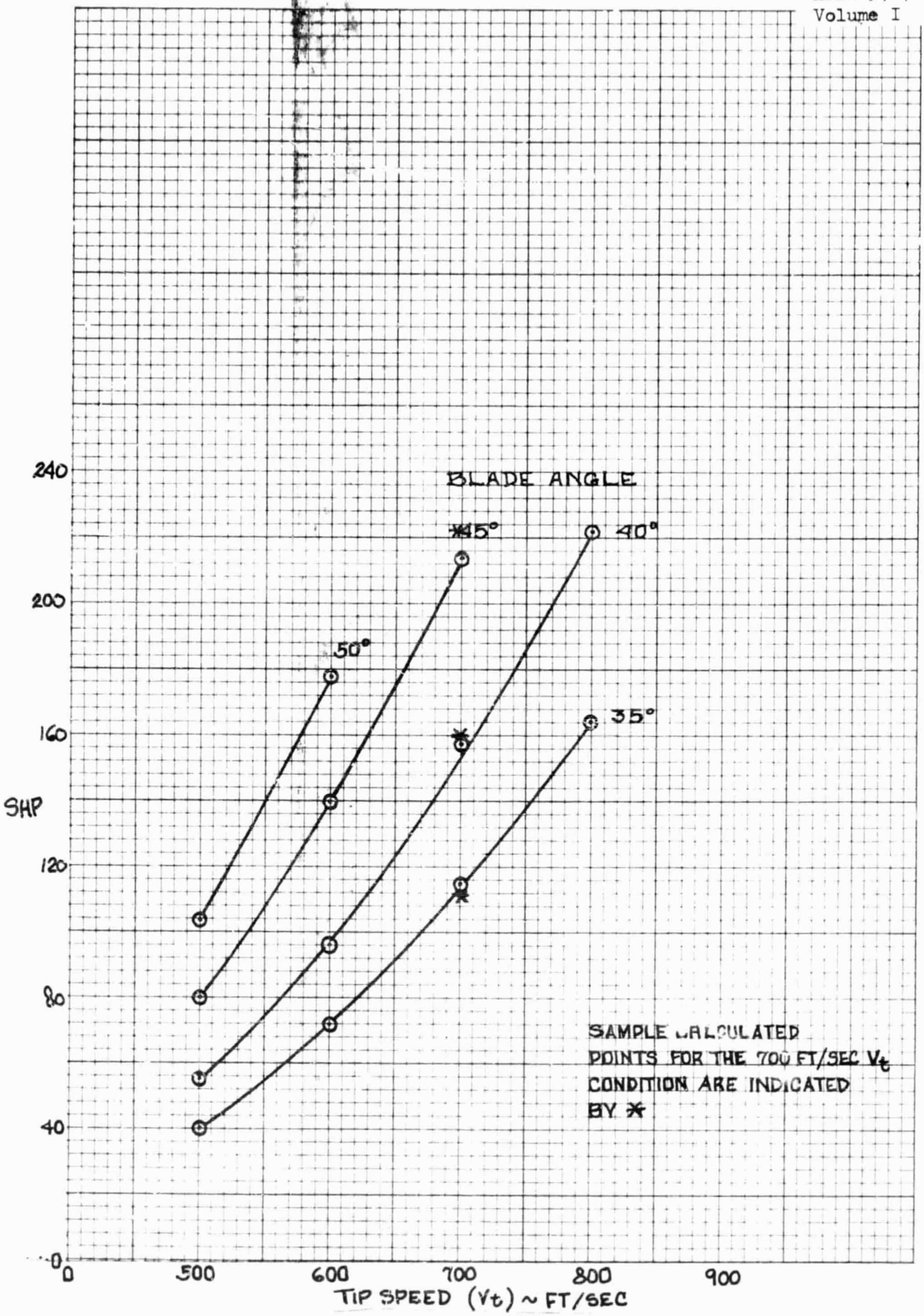
PROP-FAN NOISE TEST
NEAR FIELD MICROPHONE LOCATIONS
Figure 6



PROP-FAN NOISE TESTS
FAR FIELD MICROPHONE LOCATIONS
Figure 7

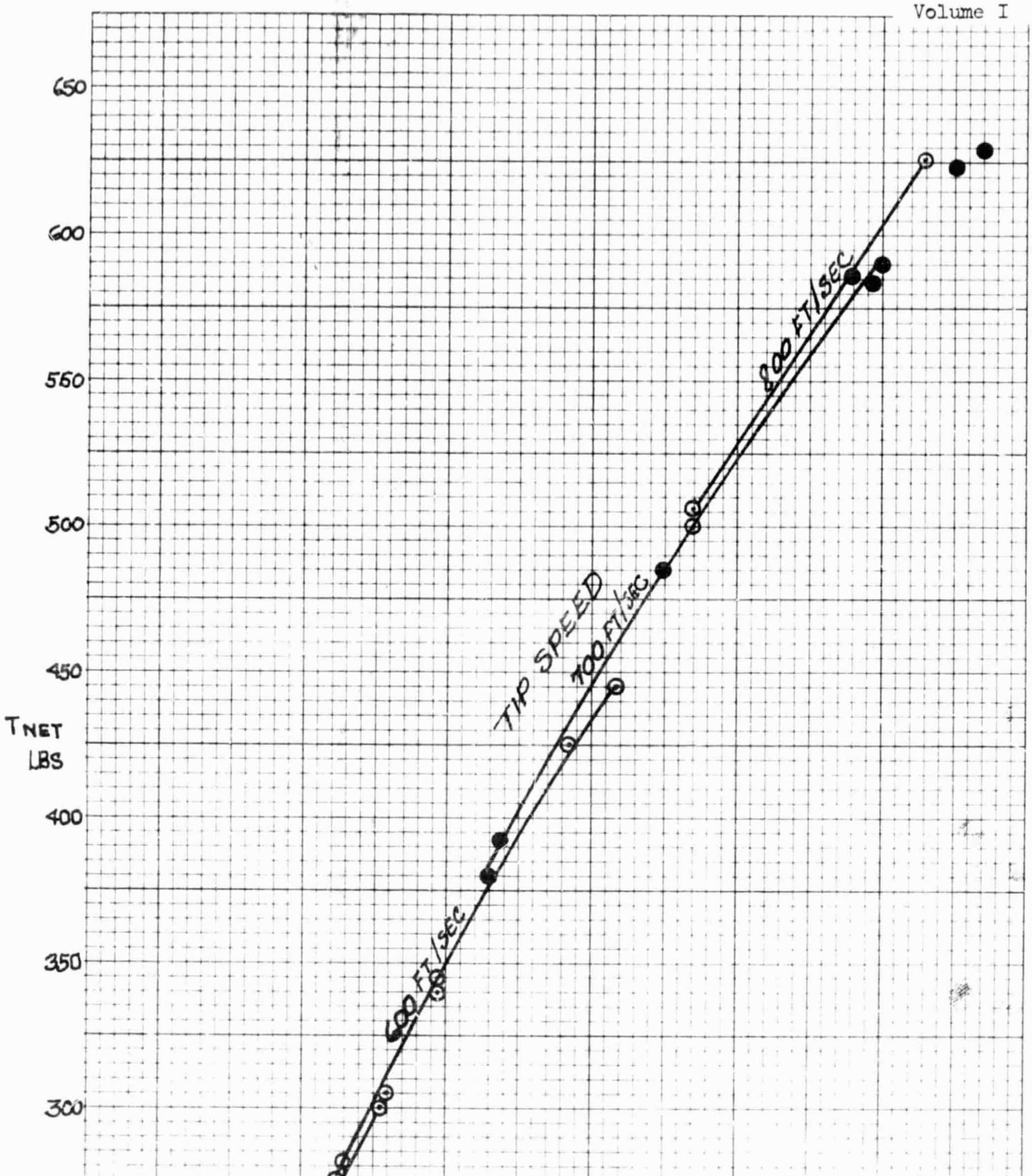


BELLMOUTH SHROUD
Figure 8



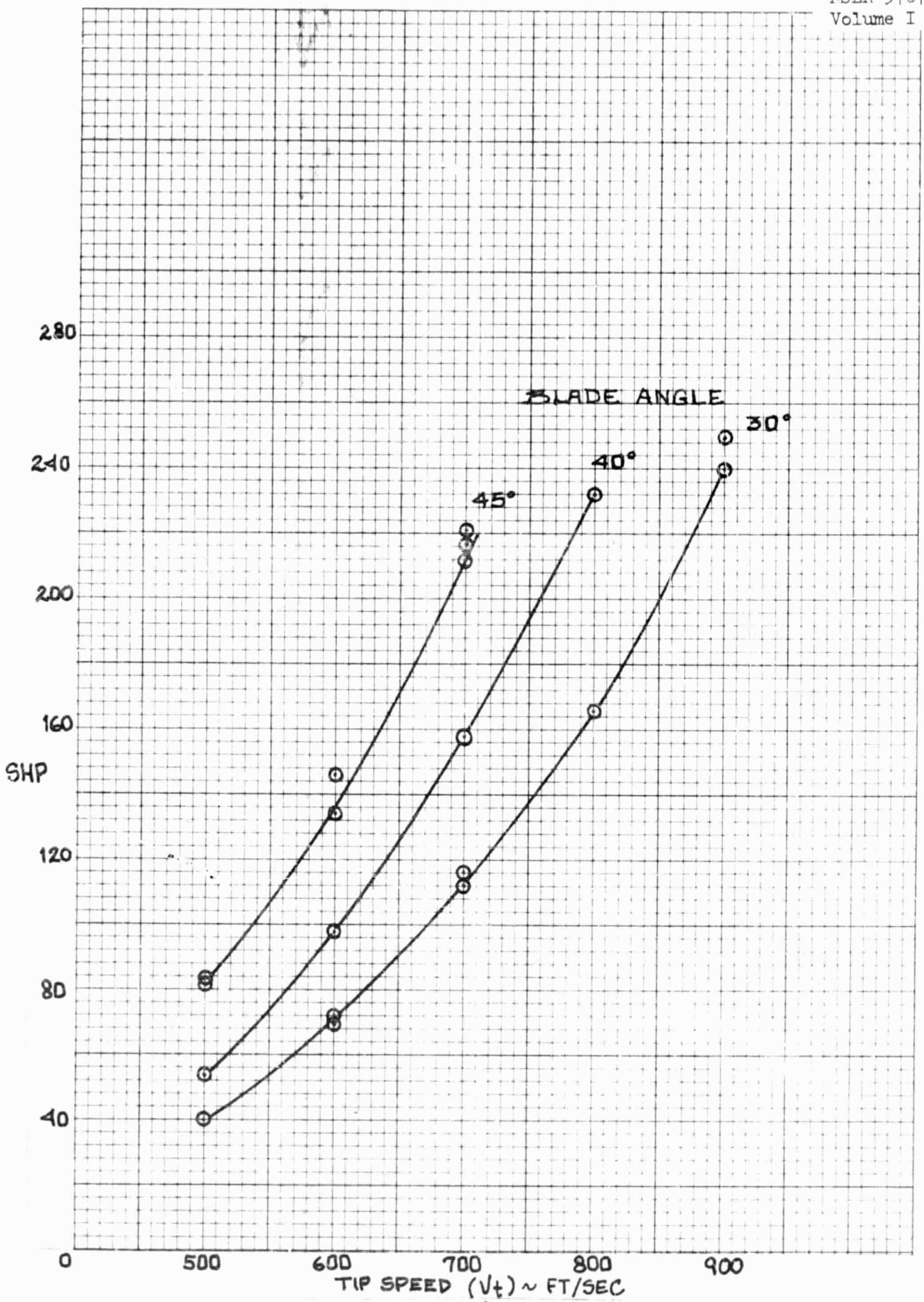
BELLMOUTH SHROUD

Figure 9 19

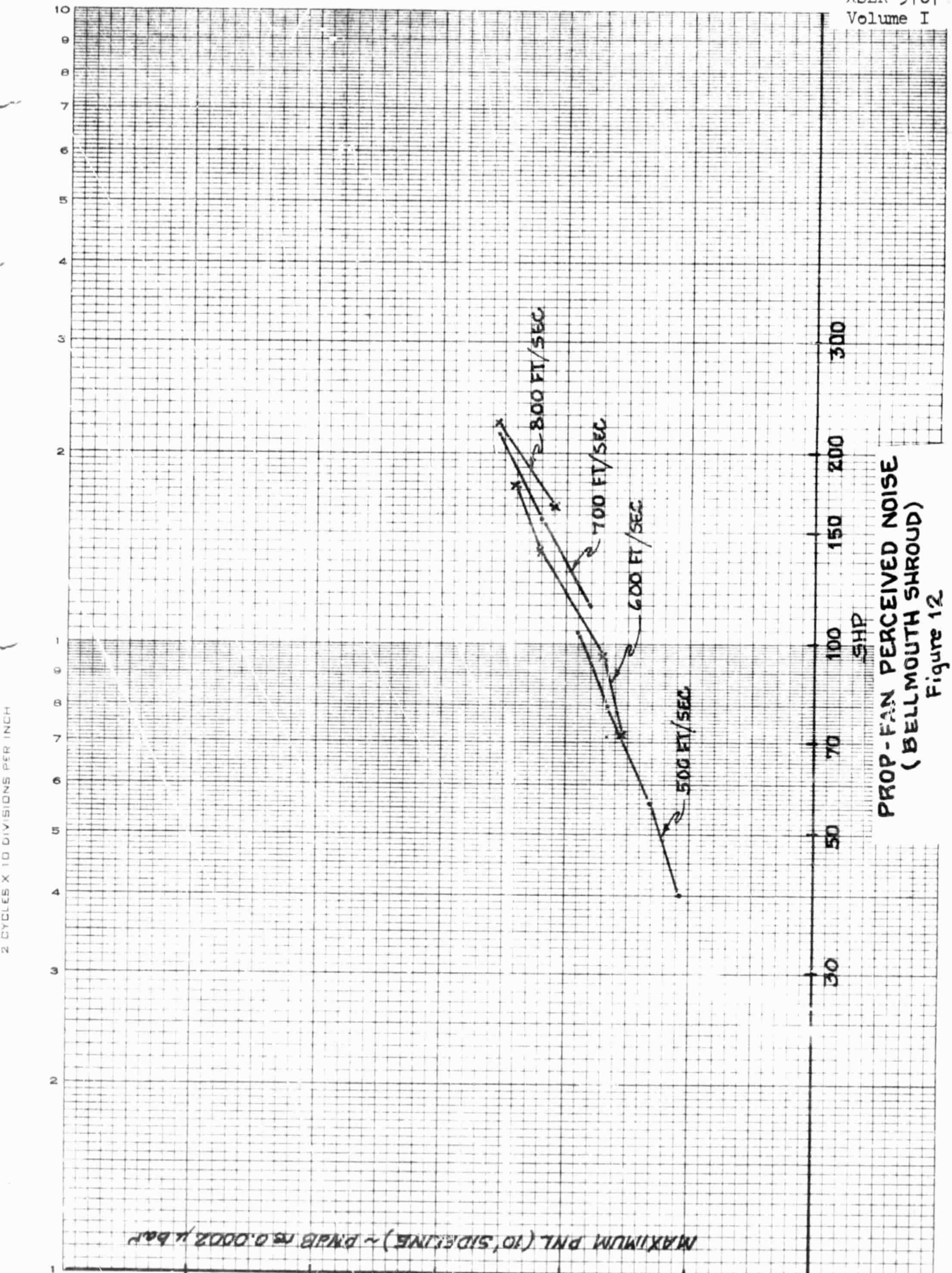


TAKEOFF/CRUISE

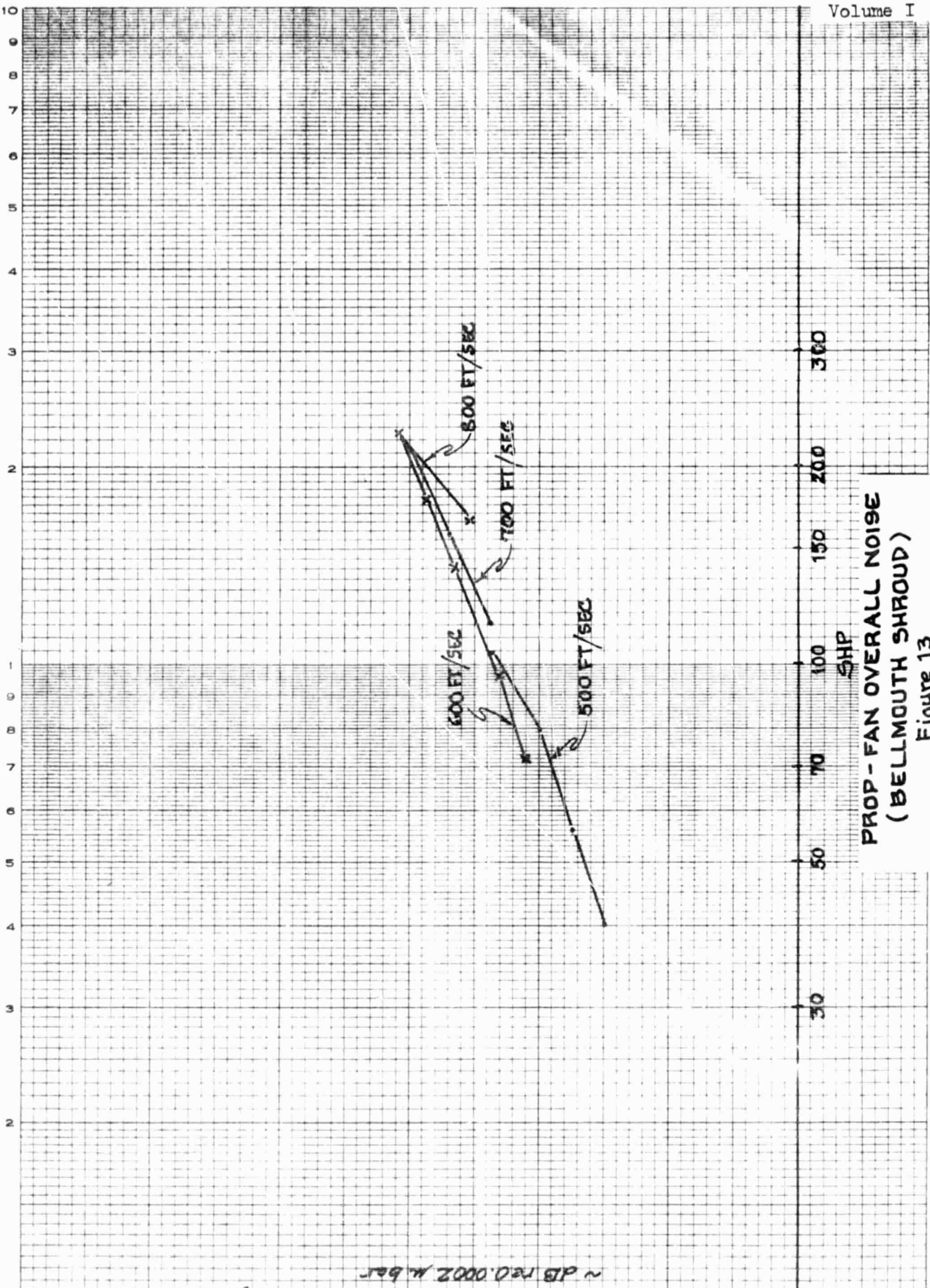
Figure 10



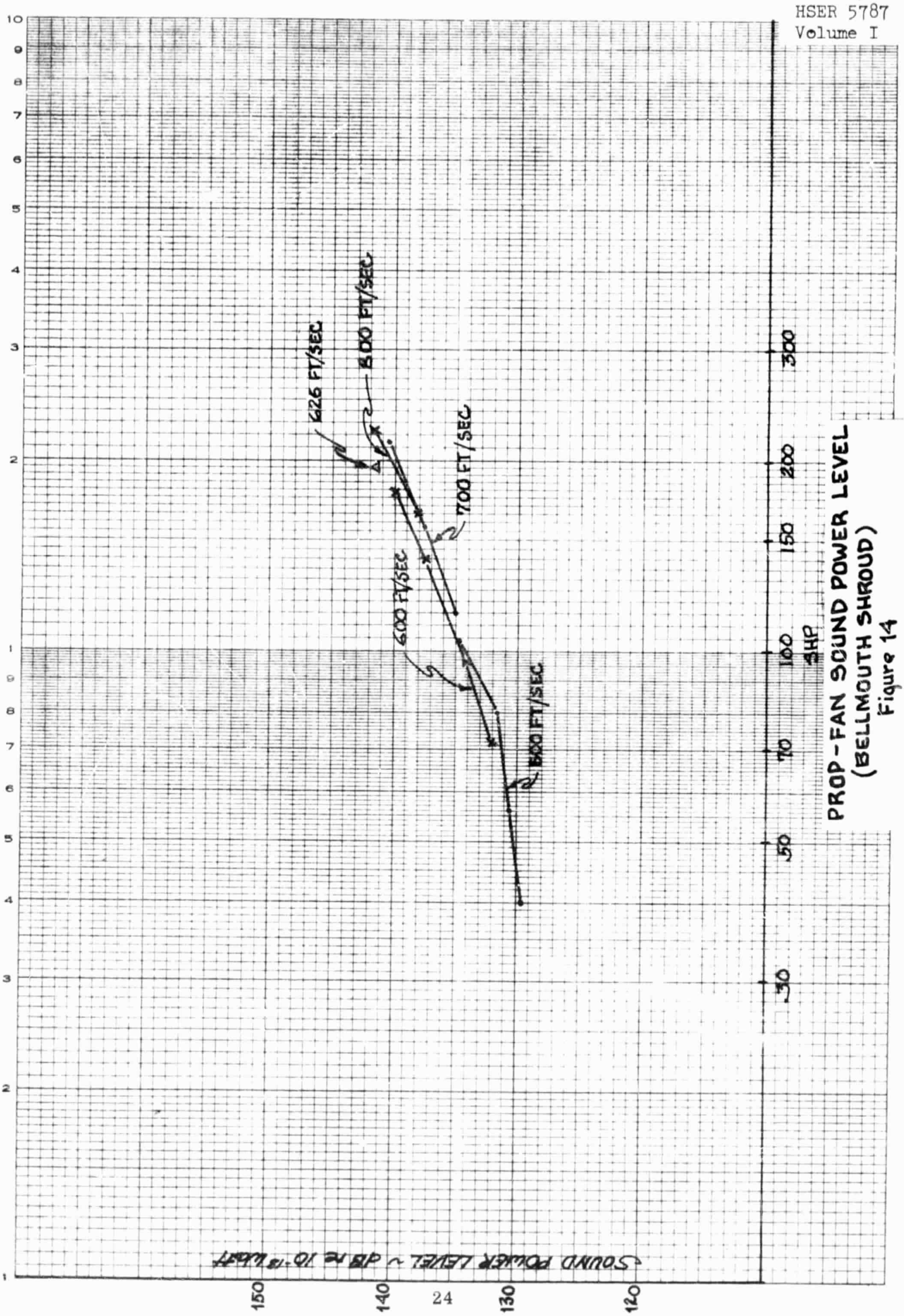
TAKEOFF/CRUISE
Figure 11



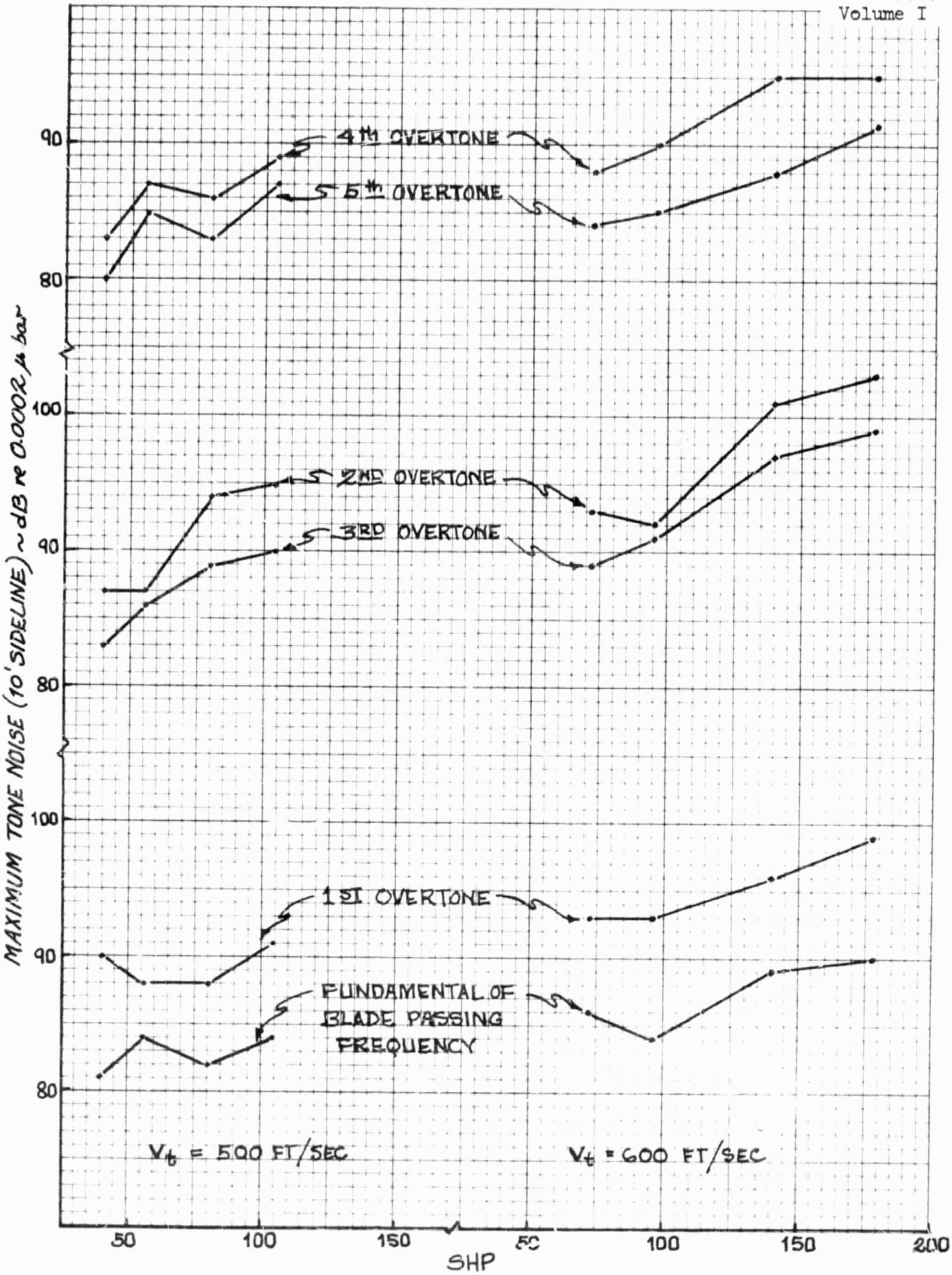
PROP-FAN PERCEIVED NOISE
(BELLMOUTH SHROUD)
Figure 12



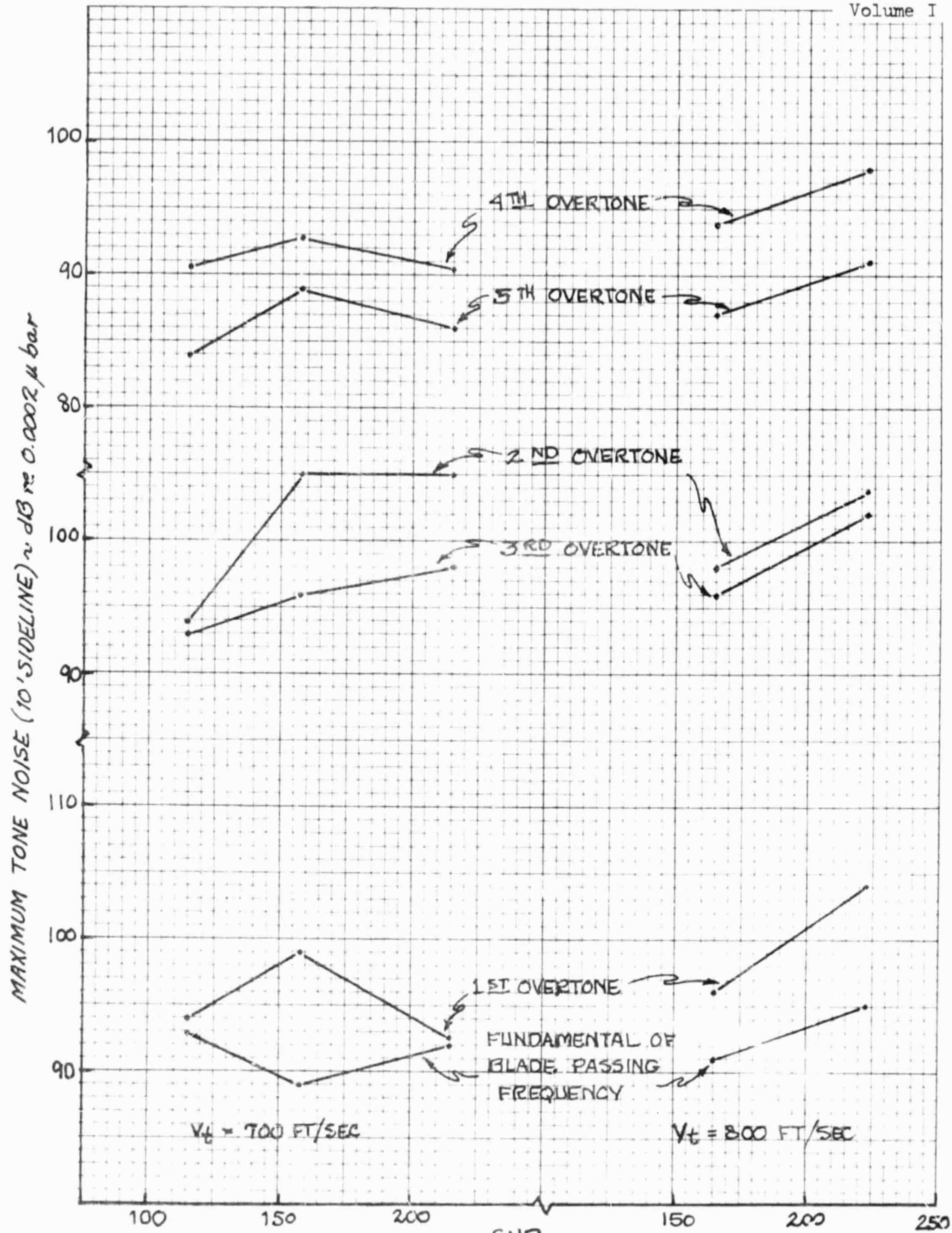
PROP-FAN OVERALL NOISE
(BELLMOUTH SHROUD)
Figure 13



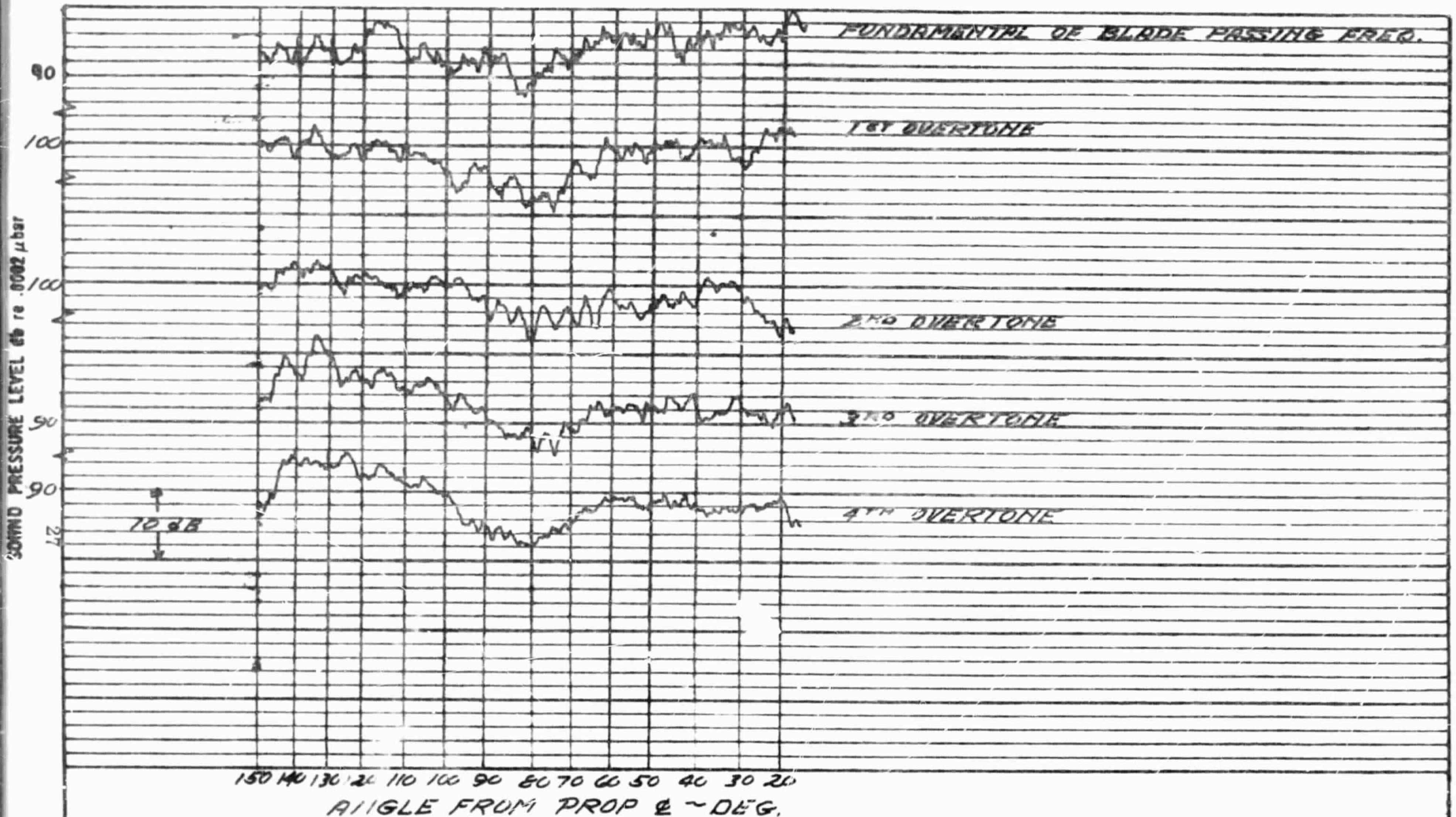
PROP-FAN SOUND POWER LEVEL (BELLMOUTH SHROUD)
Figure 14



PROP-FAN TONE NOISE
(BELLMOUTH SHROUD)
Figure 15



PROP-FAN TONE NOISE
(BELLMOUTH SHROUD)
Figure 16



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DIRECTIVITY ANALYSIS

SHROUD STATIC (BELLMOUTH)
BLADE ANGLE 35°
TIP SPEED 800 FT/SEC
MICROPHONE LOCATION 10' SWEEP

Figure 17 PROP-FAN MODEL NOISE

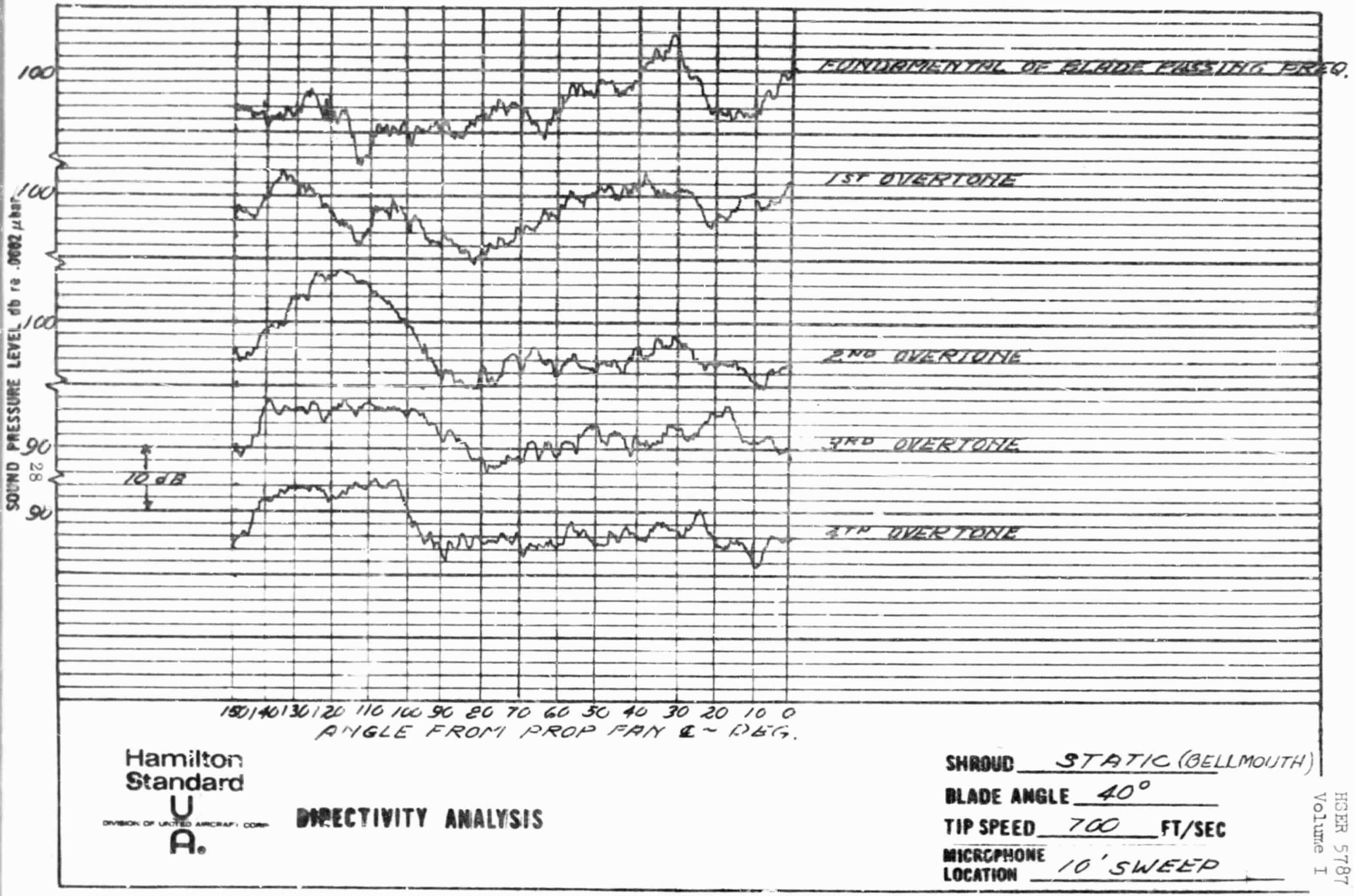


Figure 18 PROP-FAN MODEL NOISE

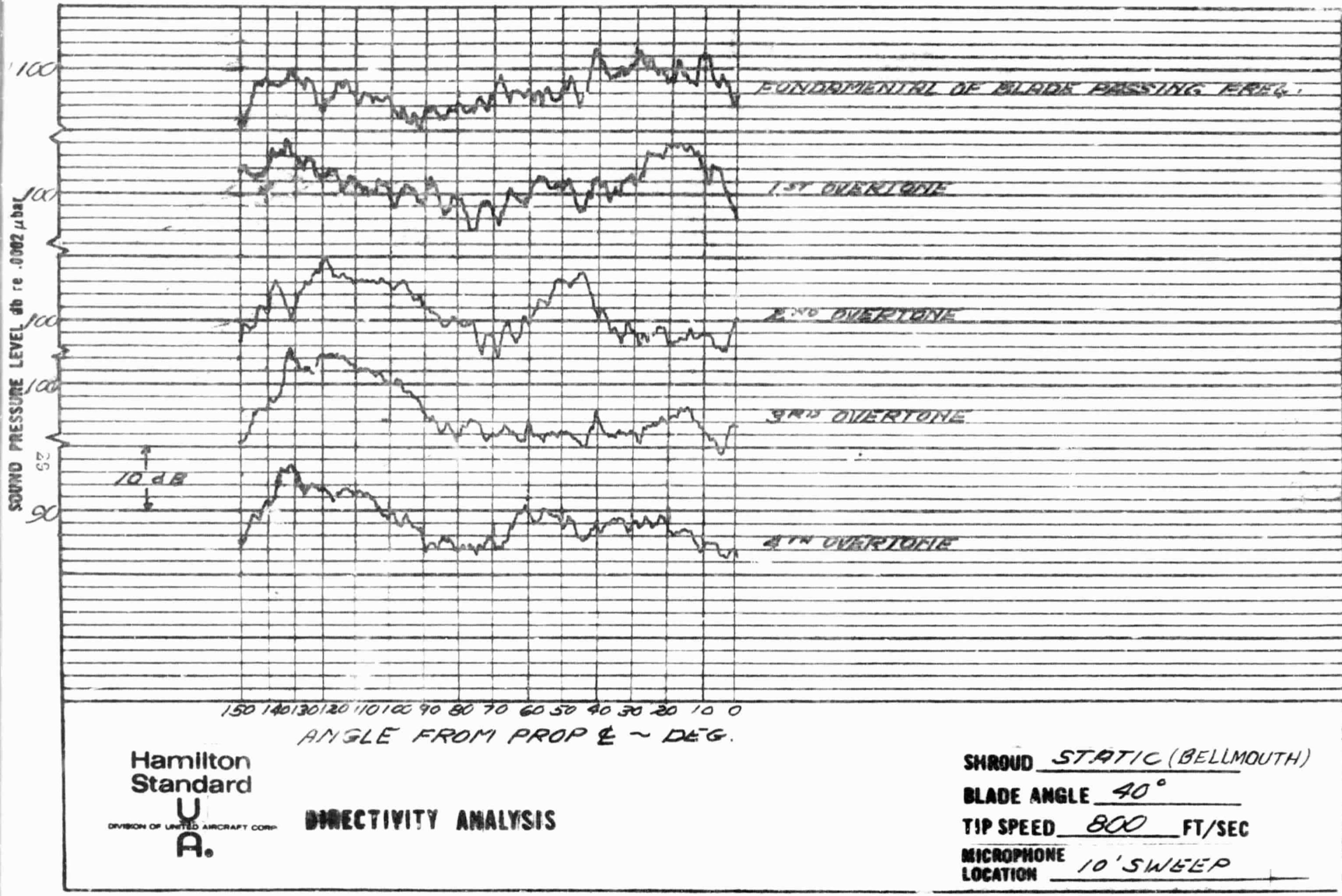


Figure 19 PROP-FAN MODEL NOISE

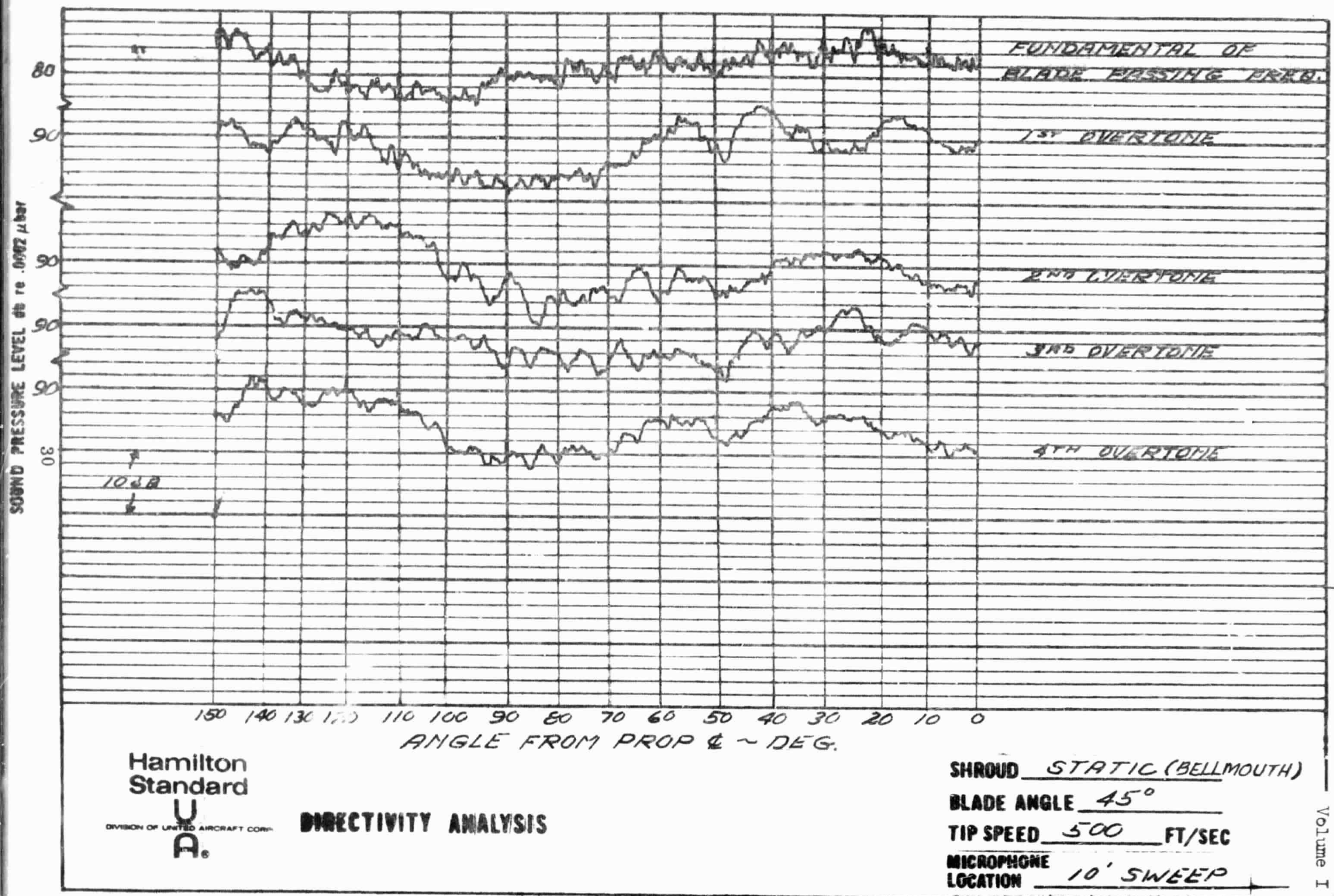


Figure 20 PROP-FAN MODEL NOISE

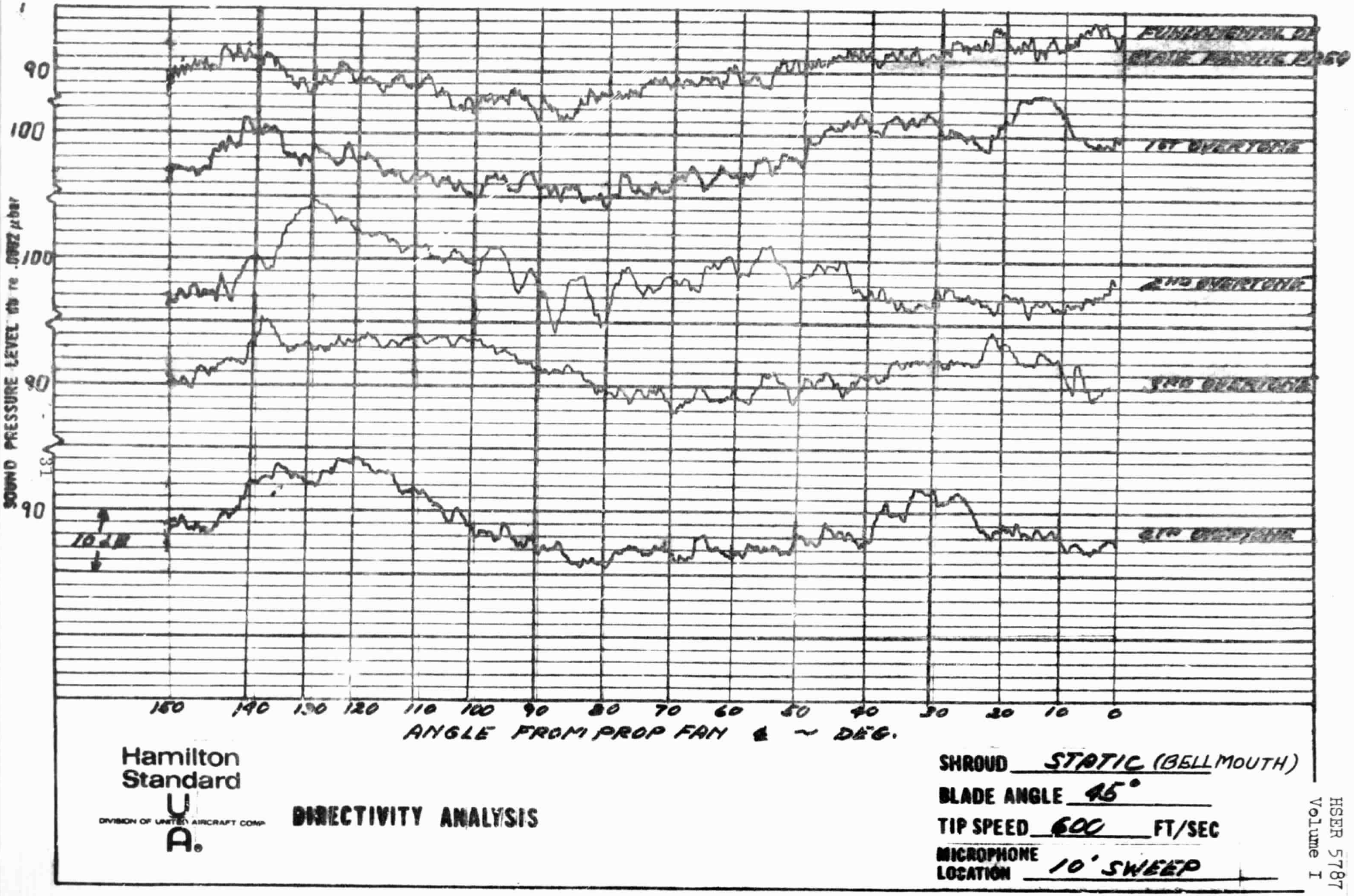


Figure 21 PROP-FAN MODEL NOISE

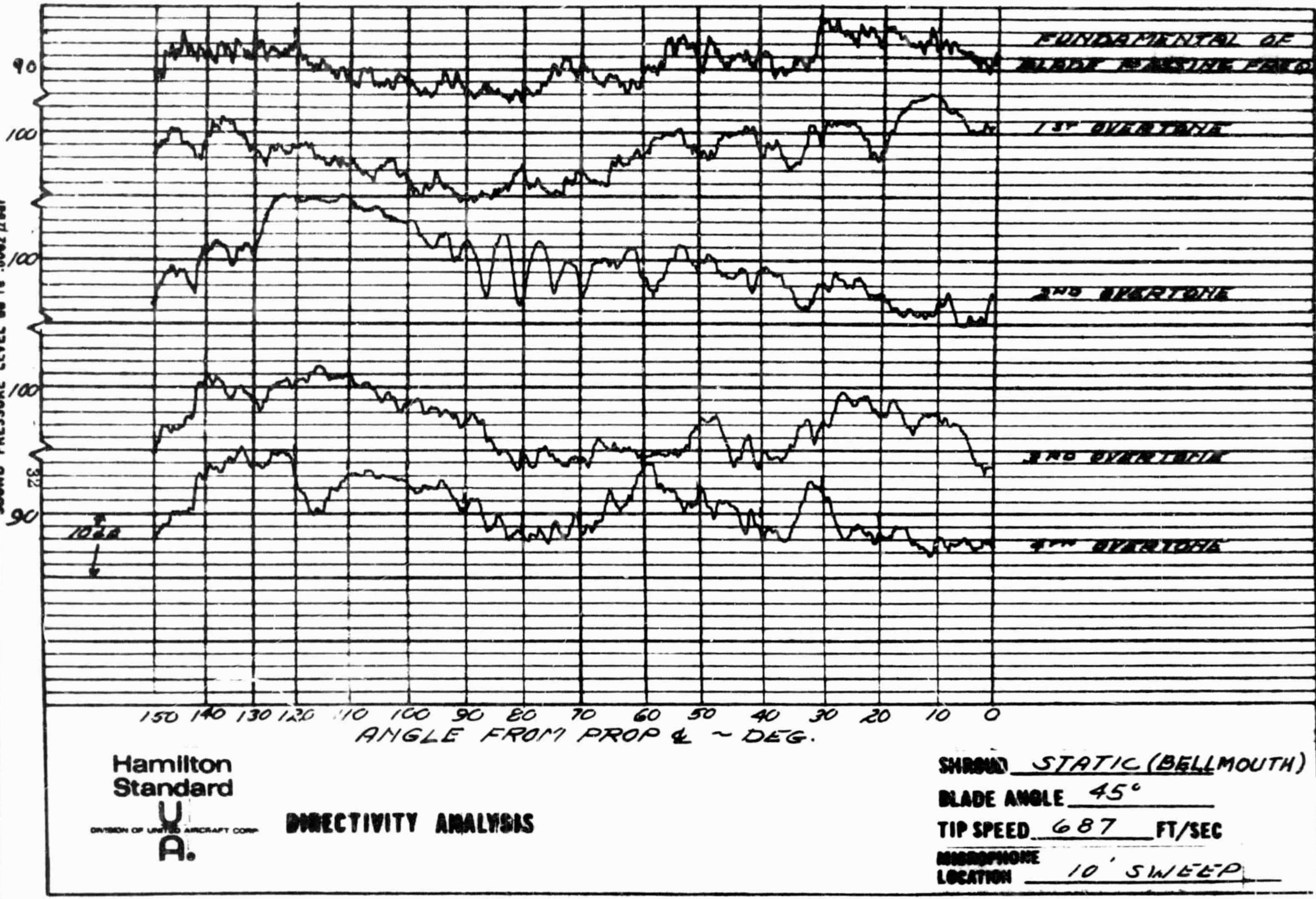


Figure 22 PROP-FAN MODEL NOISE

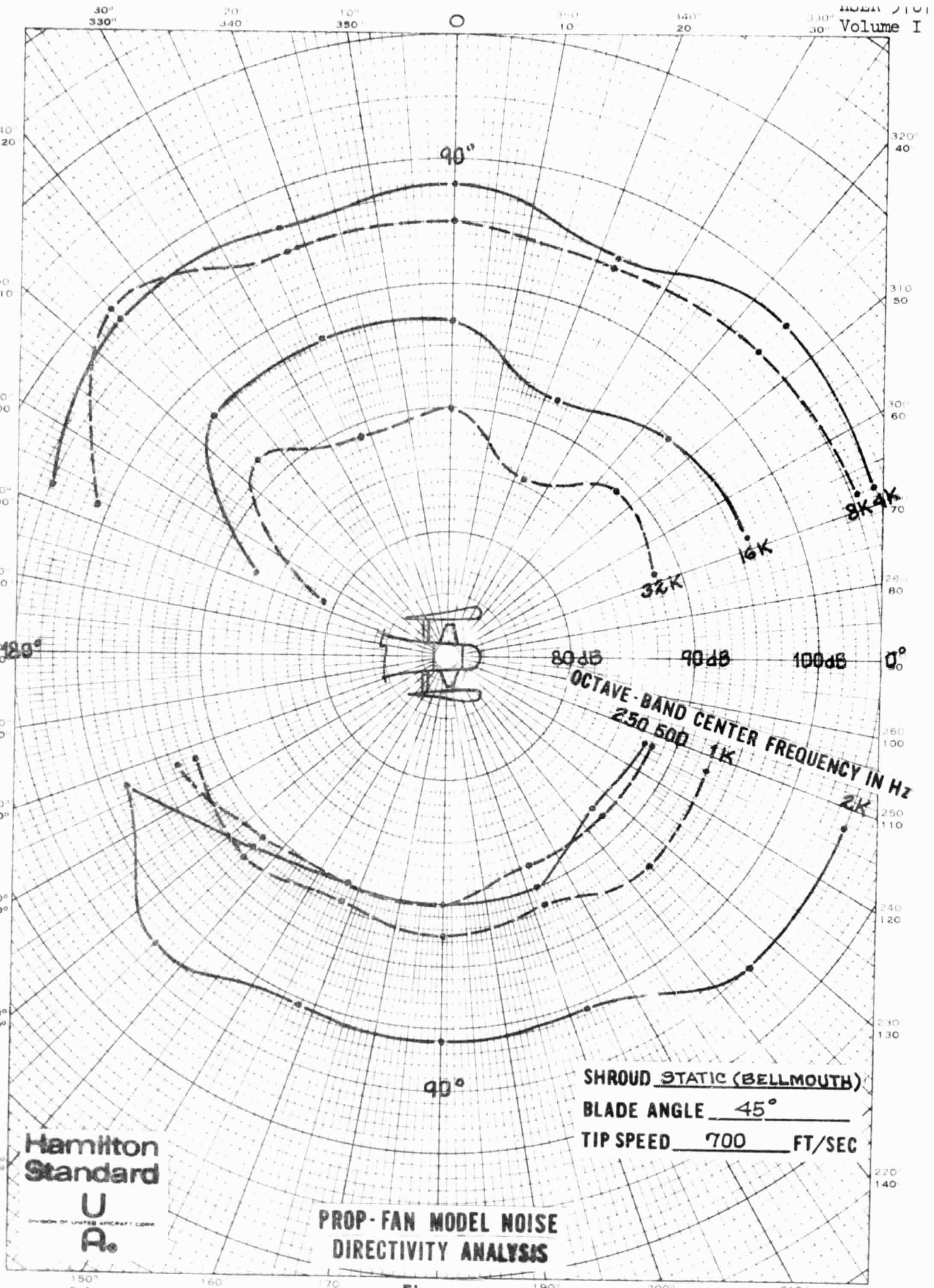
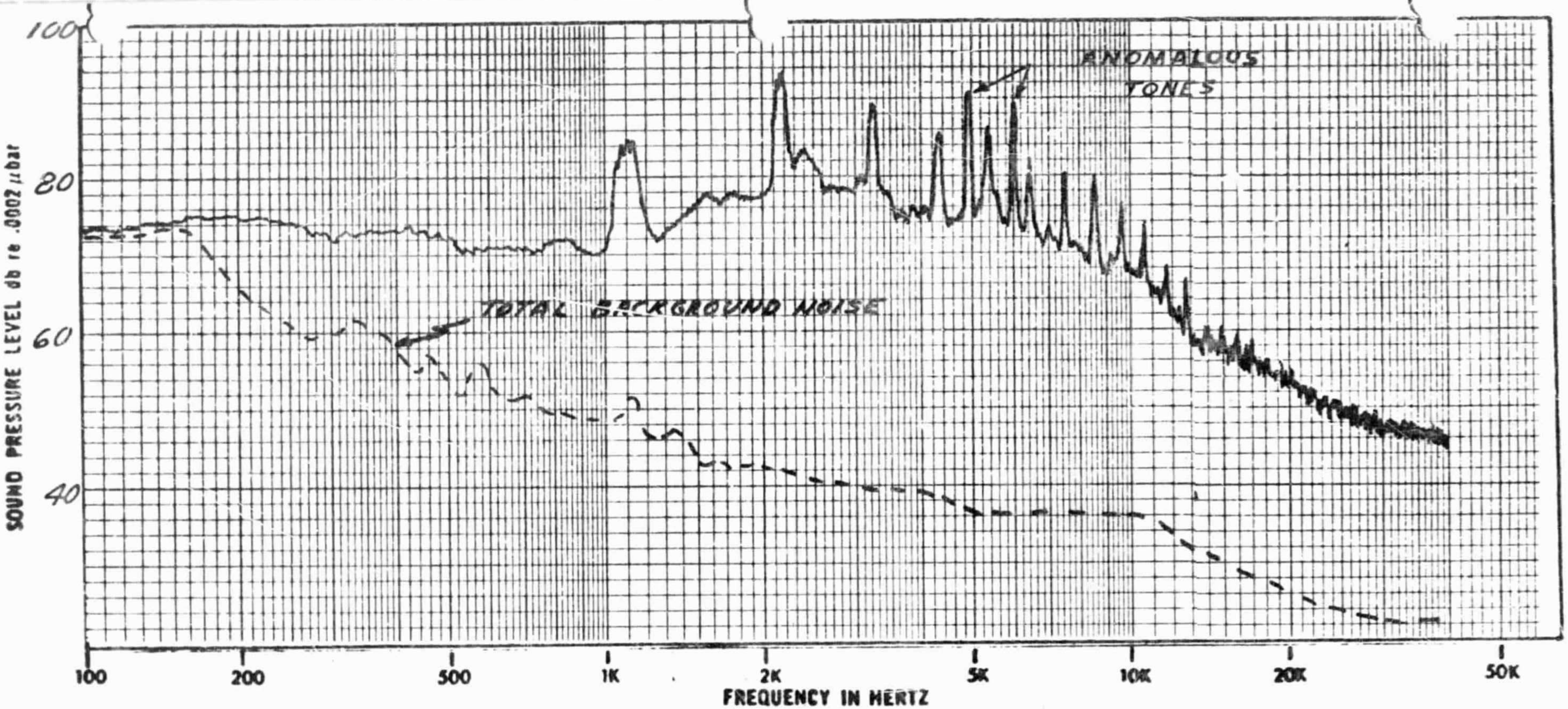

90°
8K
4K
16K
32K
180°
80dB
90dB
100dB
0°
OCTAVE-BAND CENTER FREQUENCY IN Hz
250
500
1K
2K
90°
SHROUD STATIC (BELLMOUTH)
BLADE ANGLE 45°
TIP SPEED 700 FT/SEC
Hamilton Standard
PROP-FAN MODEL NOISE
DIRECTIVITY ANALYSIS

Figure 23



Hamilton Standard — DIVISION OF UNITED AIRCRAFT CORP. — UA • SPECTRUM ANALYSIS

TITLE PROP-FAN MODEL NOISE

ANALYSIS EQUIPMENT AVERAGING TIME 0.5sec
50 Hz FILTER

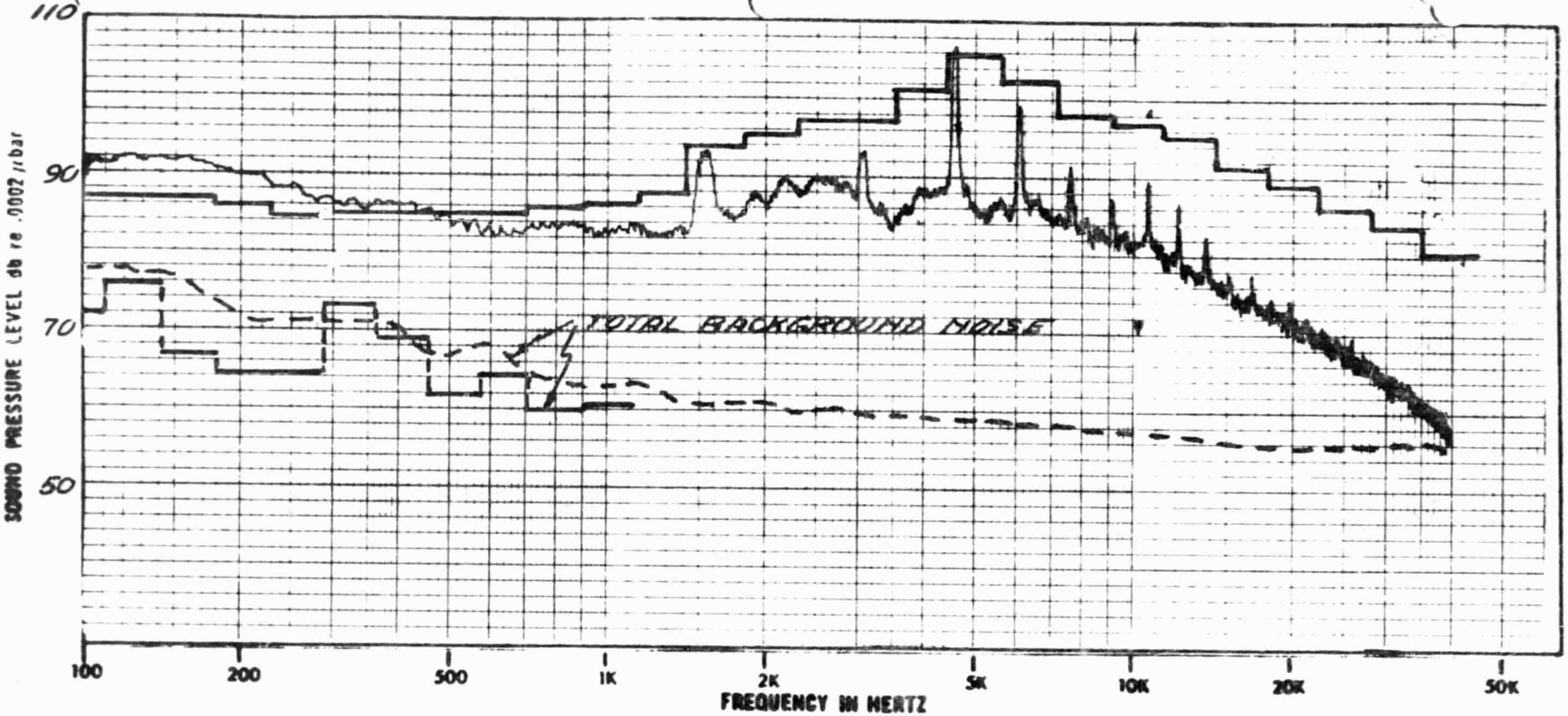
Sheet ___ of ___ Date ______ Analyzed by ______

Comments, Sketches, Etc.

SHROUD STATIC (BELLMOUTH)
BLADE ANGLE 35°
TIP SPEED 500 FT/SEC
MICROPHONE LOCATION 10' 45°

HSF-1678 3/68*

Figure 24



Hamilton Standard — DIVISION OF UNITED AIRCRAFT CORP. — SPECTRUM ANALYSIS

TITLE PROP-FAN MODEL NOISE

NARROW BAND VS. 1/3 OCTAVE BAND

ANALYSIS EQUIPMENT

50 Hz FILTER & 1/3 OCTAVE

Sheet ___ of ___ Date ______ Analyzed by ______

Comments, Sketches, Etc.

SHROUD STATIC (BELLMOUTH)

BLADE ANGLE 45°

TIP SPEED 700 FT/SEC

MICROPHONE LOCATION 10' 112½°

HSF-1678 3/68*

Figure 25

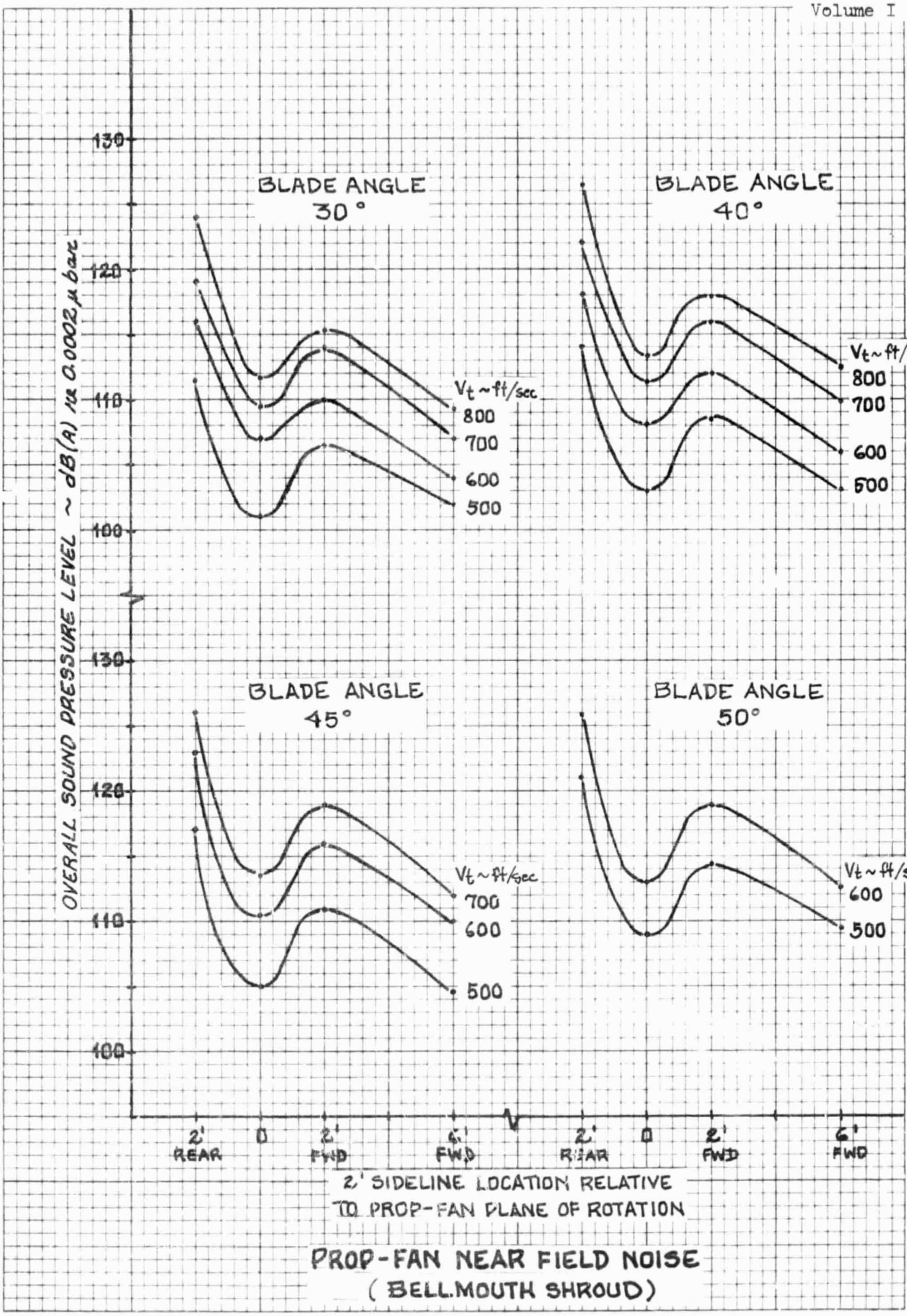
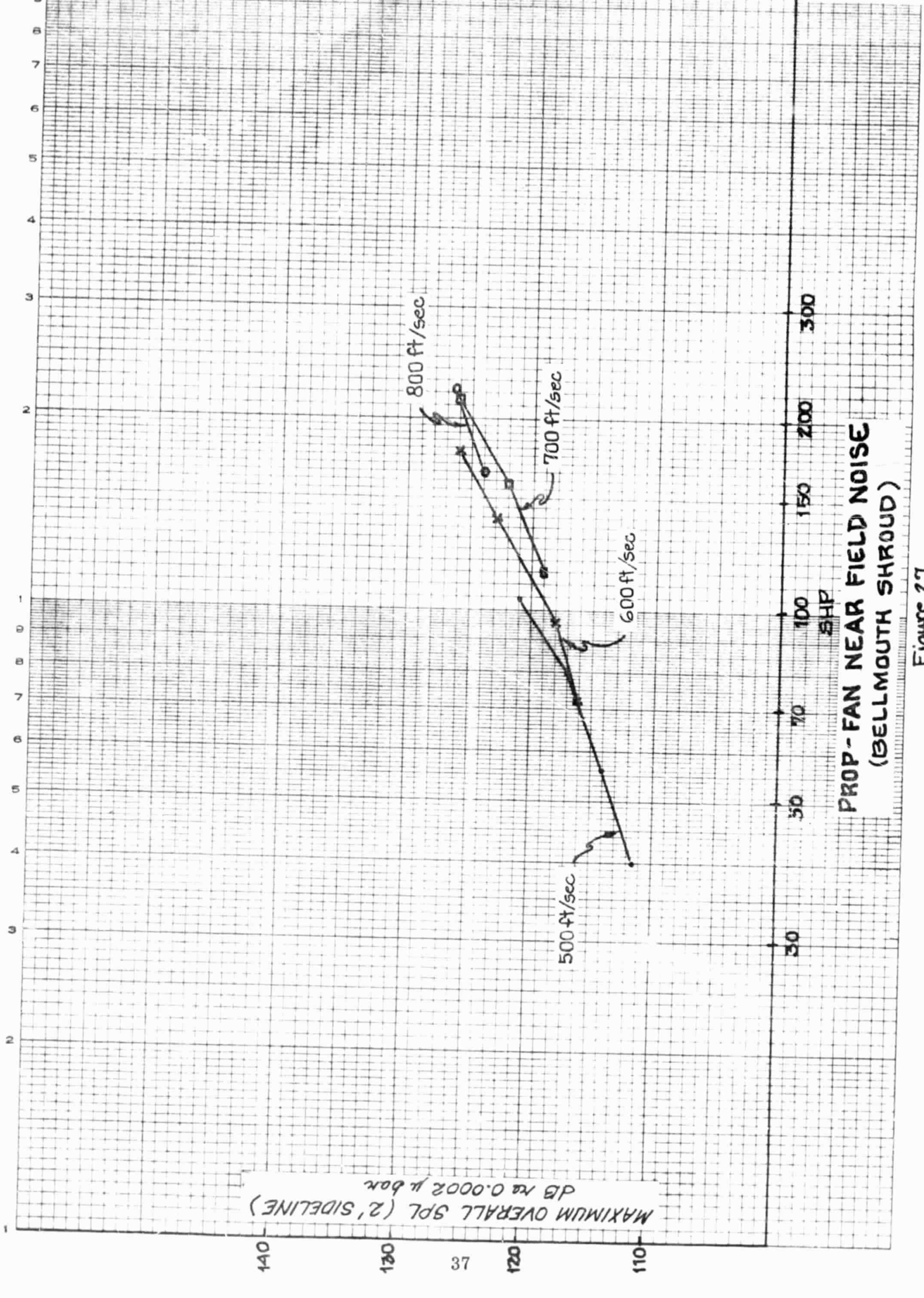
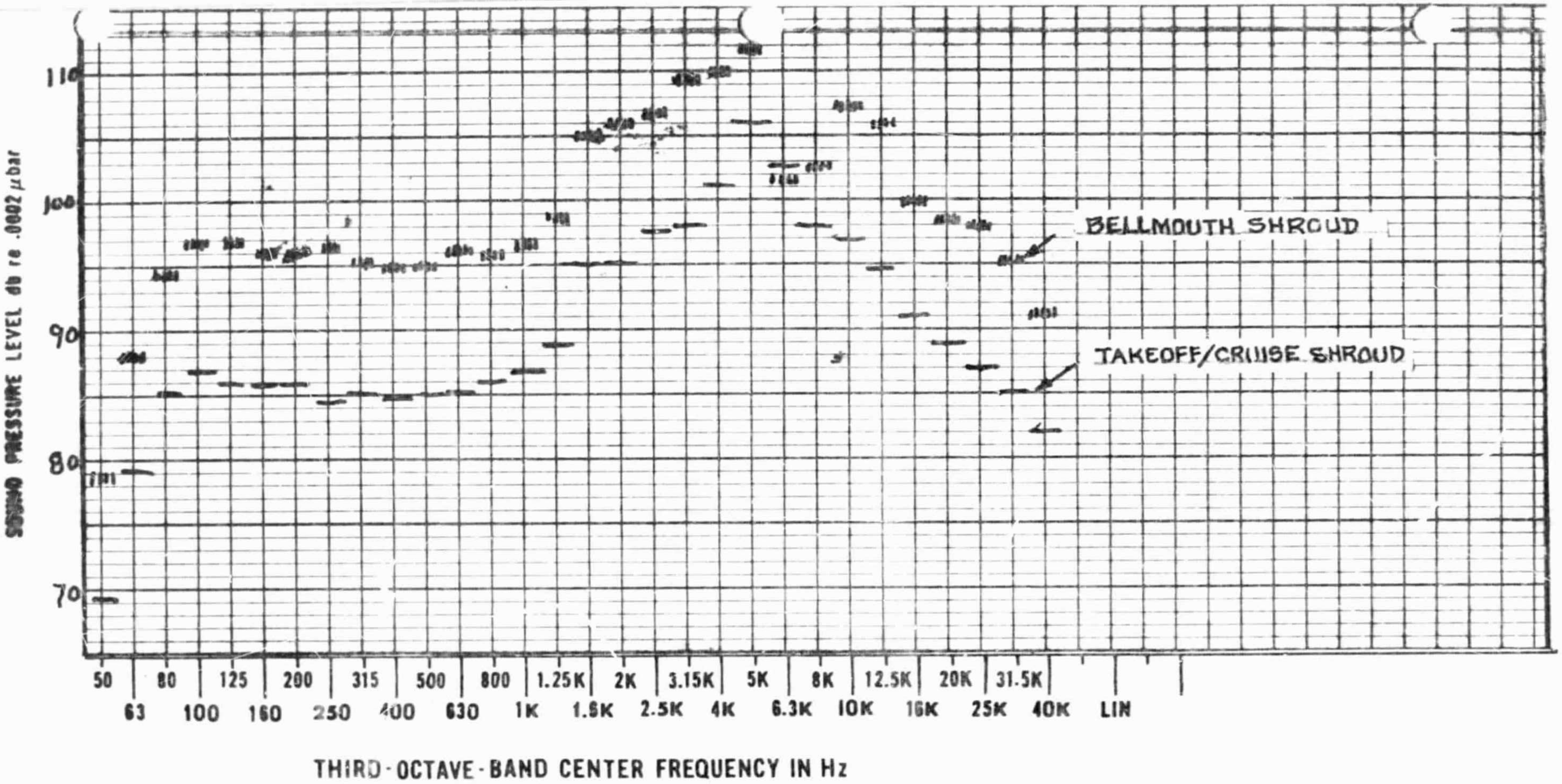

OVERALL SOUND PRESSURE LEVEL ~ dB(A) re 0.0002 μ bar
130
120
110
100
BLADE ANGLE 30°
Vt ~ ft/sec
800
700
600
500
BLADE ANGLE 40°
Vt ~ ft/sec
800
700
600
500
BLADE ANGLE 45°
Vt ~ ft/sec
700
600
500
BLADE ANGLE 50°
Vt ~ ft/sec
600
500
2' REAR
0
2' FWD
6' FWD
2' SIDELINE LOCATION RELATIVE TO PROP-FAN PLANE OF ROTATION
PROP-FAN NEAR FIELD NOISE
(BELL MOUTH SHROUD)

Figure 26



PROP-FAN NEAR FIELD NOISE
(BELLMOUTH SHROUD)

Figure 27



Hamilton Standard

THIRD-OCTAVE-BAND ANALYSIS

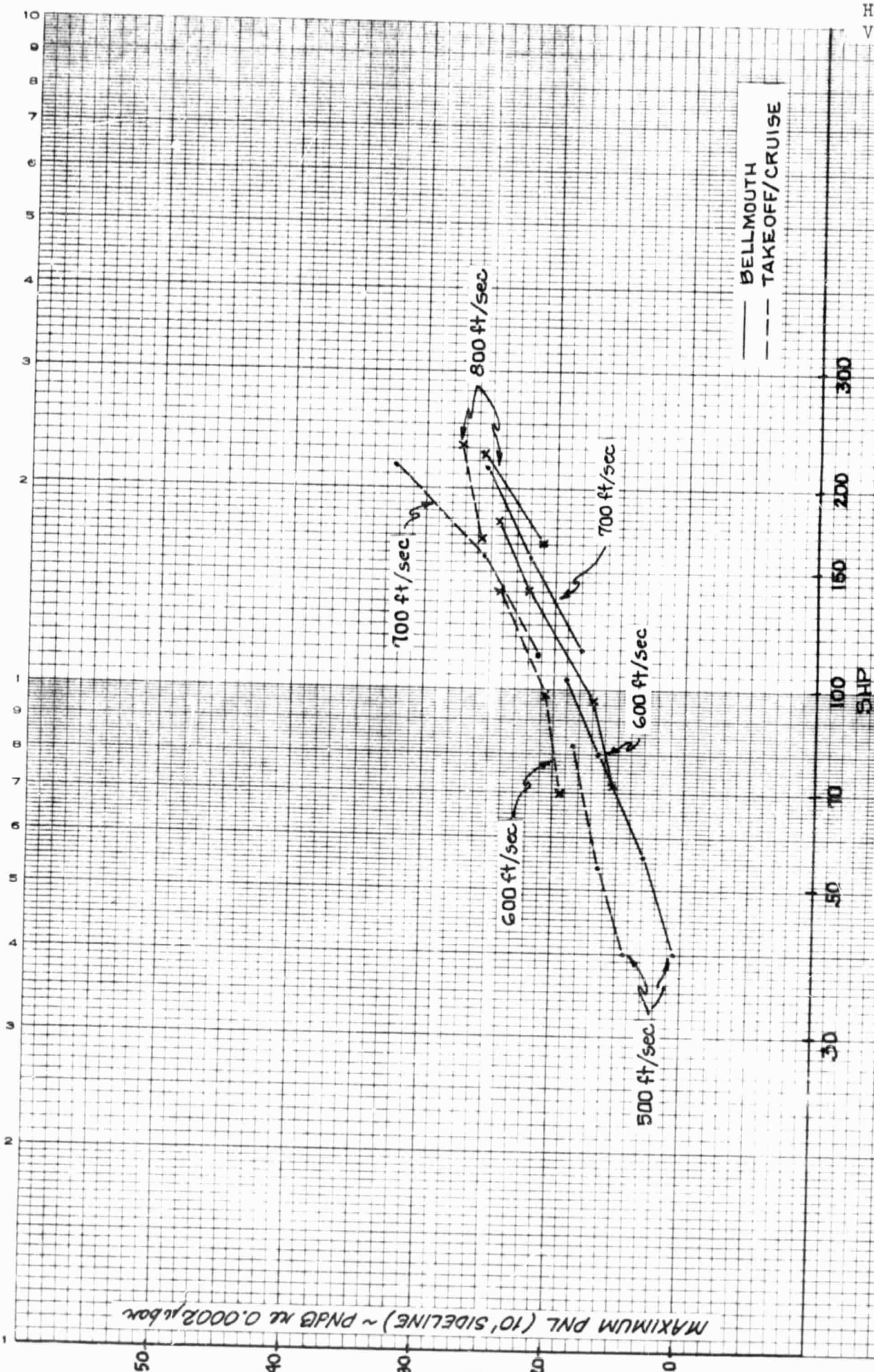
SHROUD BELLMOUTH & TAKEOFF/CRUISE

BLADE ANGLE 45°

TIP SPEED 700 FT/SEC

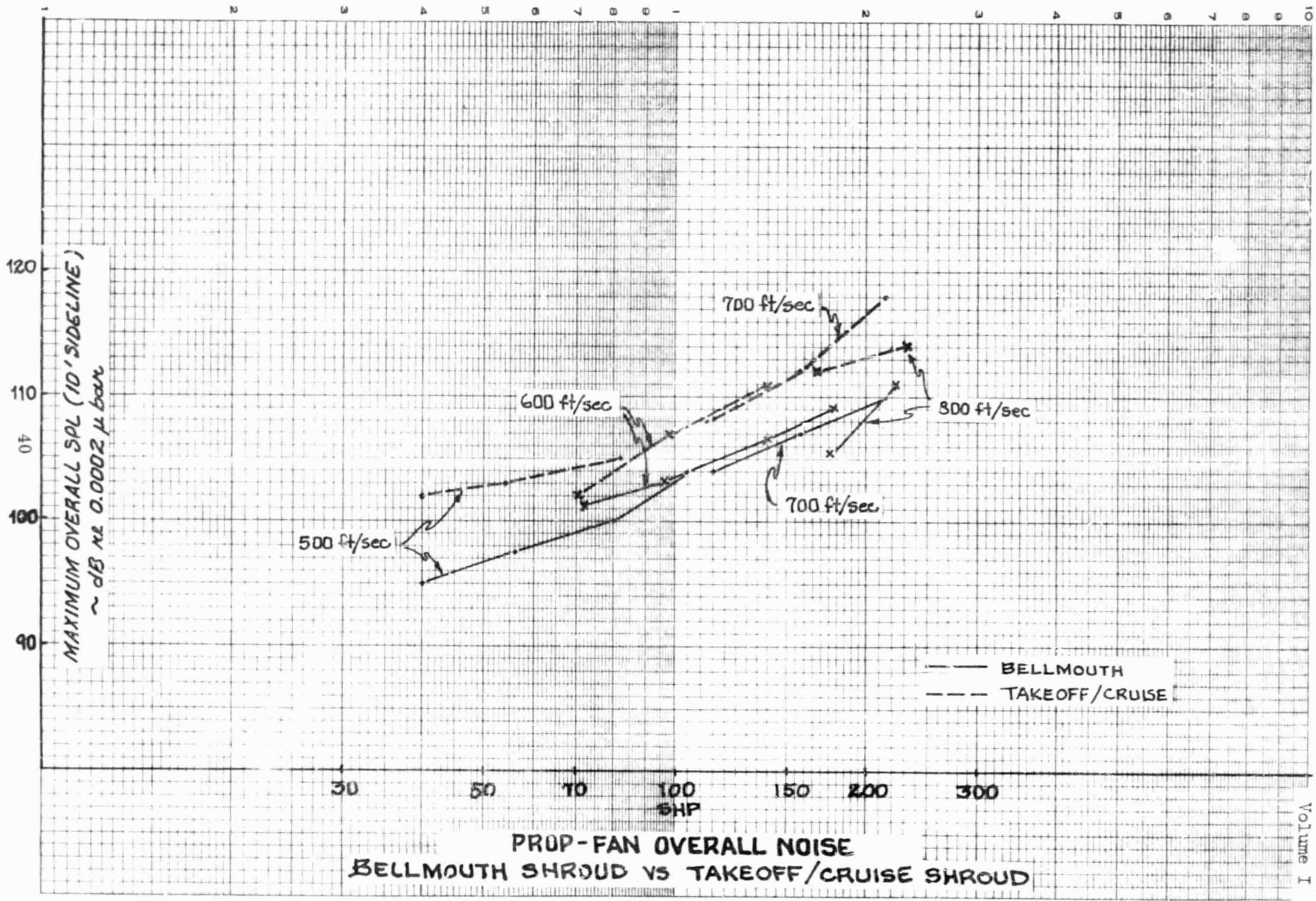
MICROPHONE LOCATION 10' 90°

Figure 28 PROP-FAN MODEL NOISE



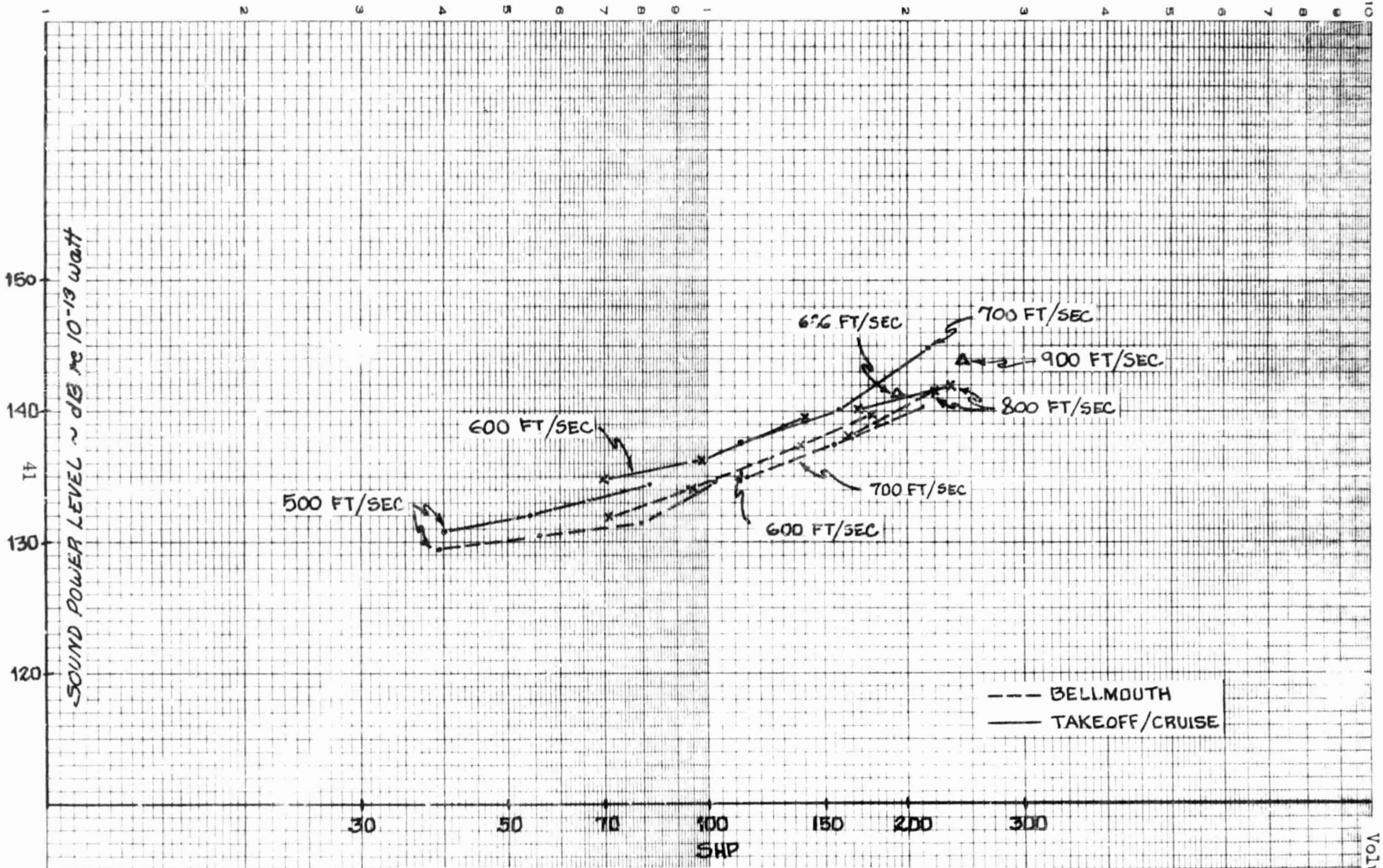
PROP-FAN PERCEIVED NOISE
BELLMOUTH SHROUD VS TAKEOFF/CRUISE SHROUD

Figure 29



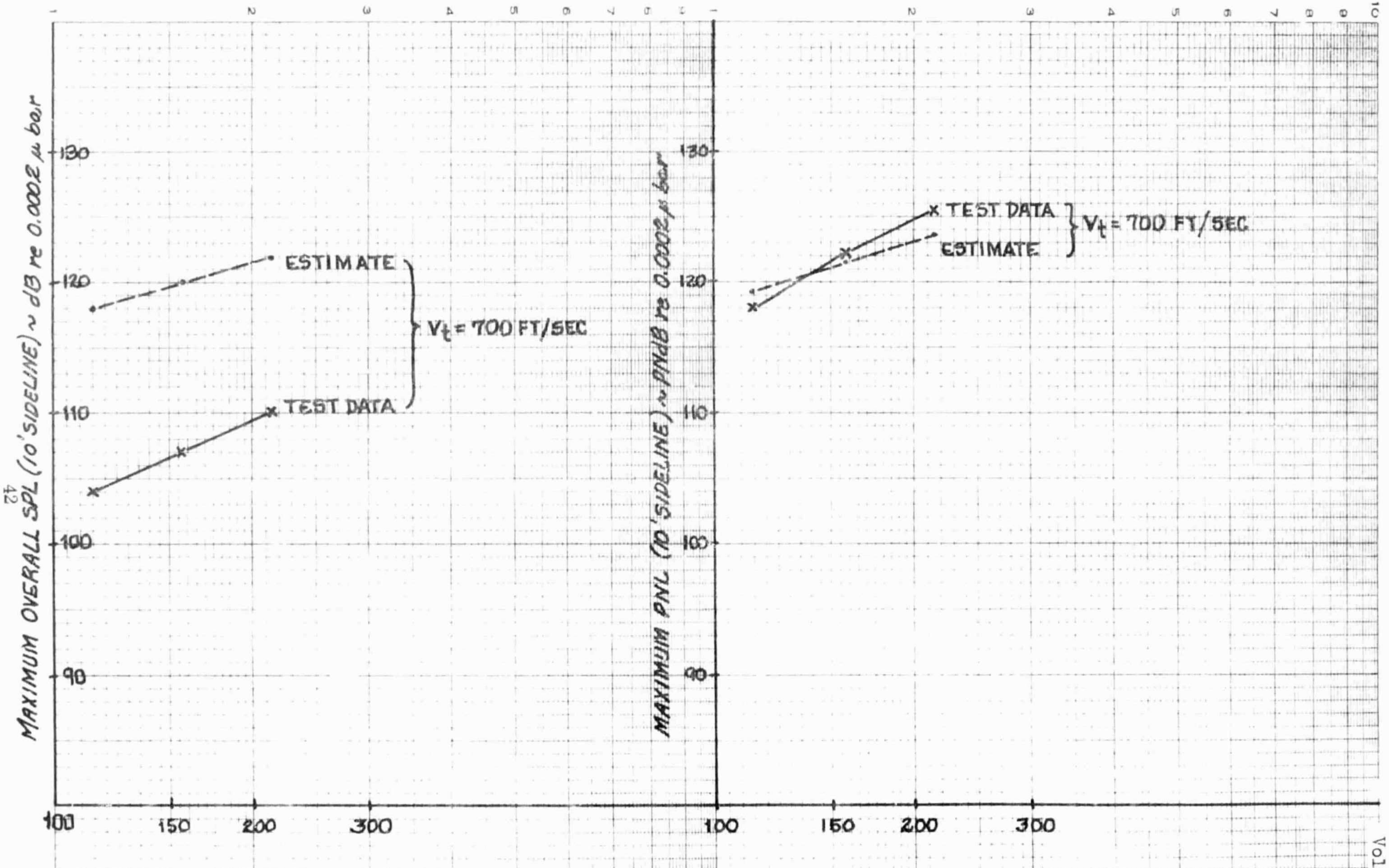
PROP-FAN OVERALL NOISE
BELLMOUTH SHROUD VS TAKEOFF/CRUISE SHROUD

Figure 30



PROP-FAN SOUND POWER LEVEL
BELLMOUTH SHROUD VS TAKEOFF/CRUISE SHROUD

Figure 31



PROP-FAN MODEL NOISE COMPARISON CURVE
(BELLMOUTH SHROUD)

Figure 32

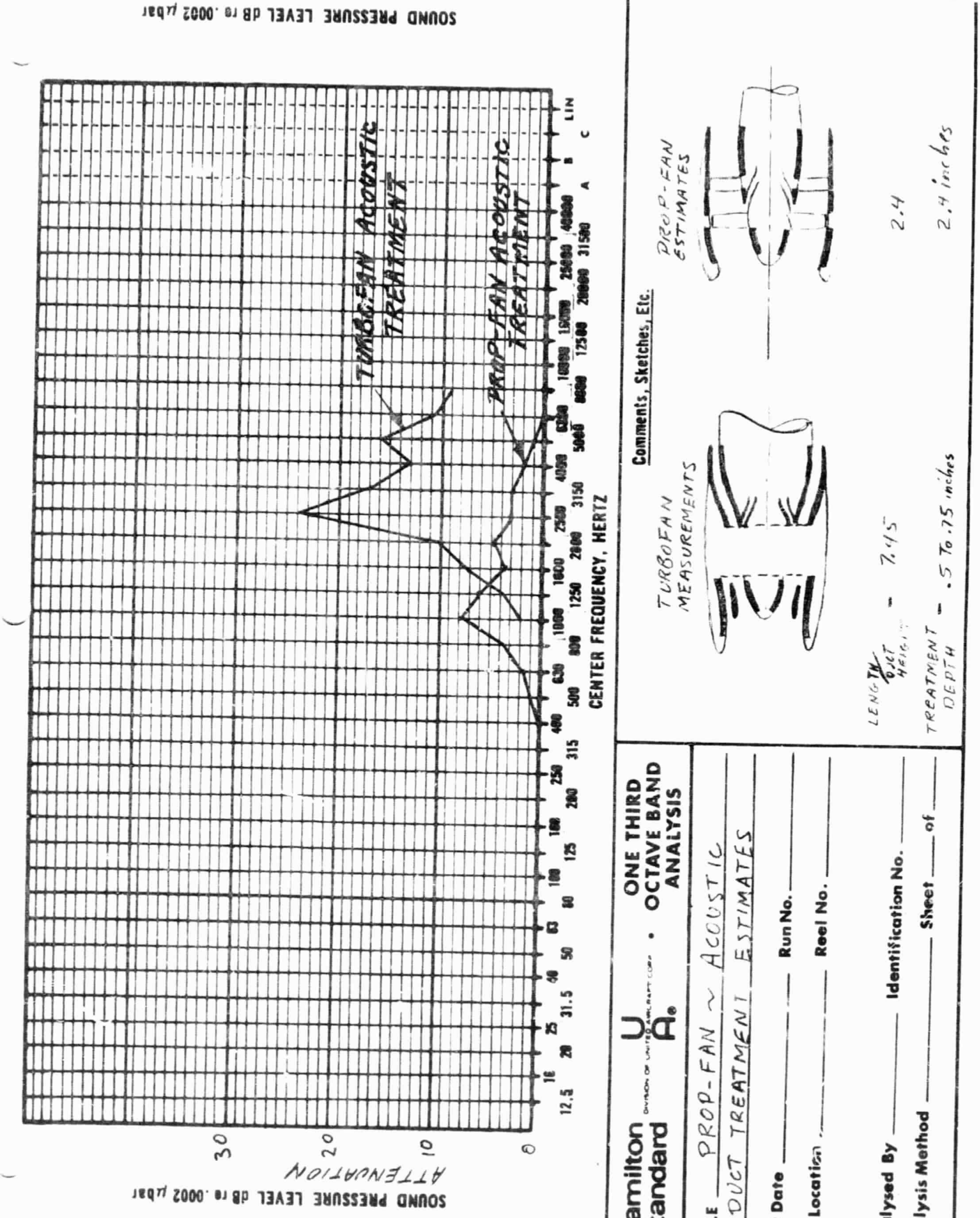

SOUND PRESSURE LEVEL dB re .0002 μbar
ATTENUATION
30
20
10
0
12.5 16 20 25 31.5 40 50 63 80 100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000 6300 8000 10000 12500 16000 20000 25000 31500 40000 A B C LIN
CENTER FREQUENCY, HERTZ
TURBOFAN ACOUSTIC TREATMENT
PROP-FAN ACOUSTIC TREATMENT
Hamilton Standard
ONE THIRD OCTAVE BAND ANALYSIS
TITLE PROP-FAN ~ ACOUSTIC DUCT TREATMENT ESTIMATES
Test Date
Run No.
Mic Location
Reel No.
Analysed By
Identification No.
Analysis Method
Sheet of
Comments, Sketches, Etc.
TURBOFAN MEASUREMENTS
PROP-FAN ESTIMATES
LENGTH / DUCT HEIGHT - 7.45
2.4
TREATMENT DEPTH - .5 To .75 inches
2.4 inches

Figure 33

PROJECTED NOISE LEVEL
OF A
FULL SCALE PROP-FAN STOL AIRCRAFT
BASED ON PRELIMINARY PROP-FAN ESTIMATING METHOD

CONFIGURATION: 7000 SHP, 700 FT/SEC TIP SPEED, 7.8FT DIAMETER, TAKEOFF CONDITION

REFERENCE LEVEL BASED ON PRELIMINARY PROP-FAN ESTIMATING METHOD

95 PNdB AT 500 FT FOR ONE PROP-FAN

→ ADJUSTMENTS

EXCESS ATMOSPHERIC ATTENUATION - 1.5dB

→ ESTIMATED LEVEL FOR 7.8 FT DIAMETER PROP-FAN OPERATING AT 7000 SHP

93.5 PNdB AT 500 FT FOR ONE PROP-FAN WITHOUT ACOUSTIC TREATMENT

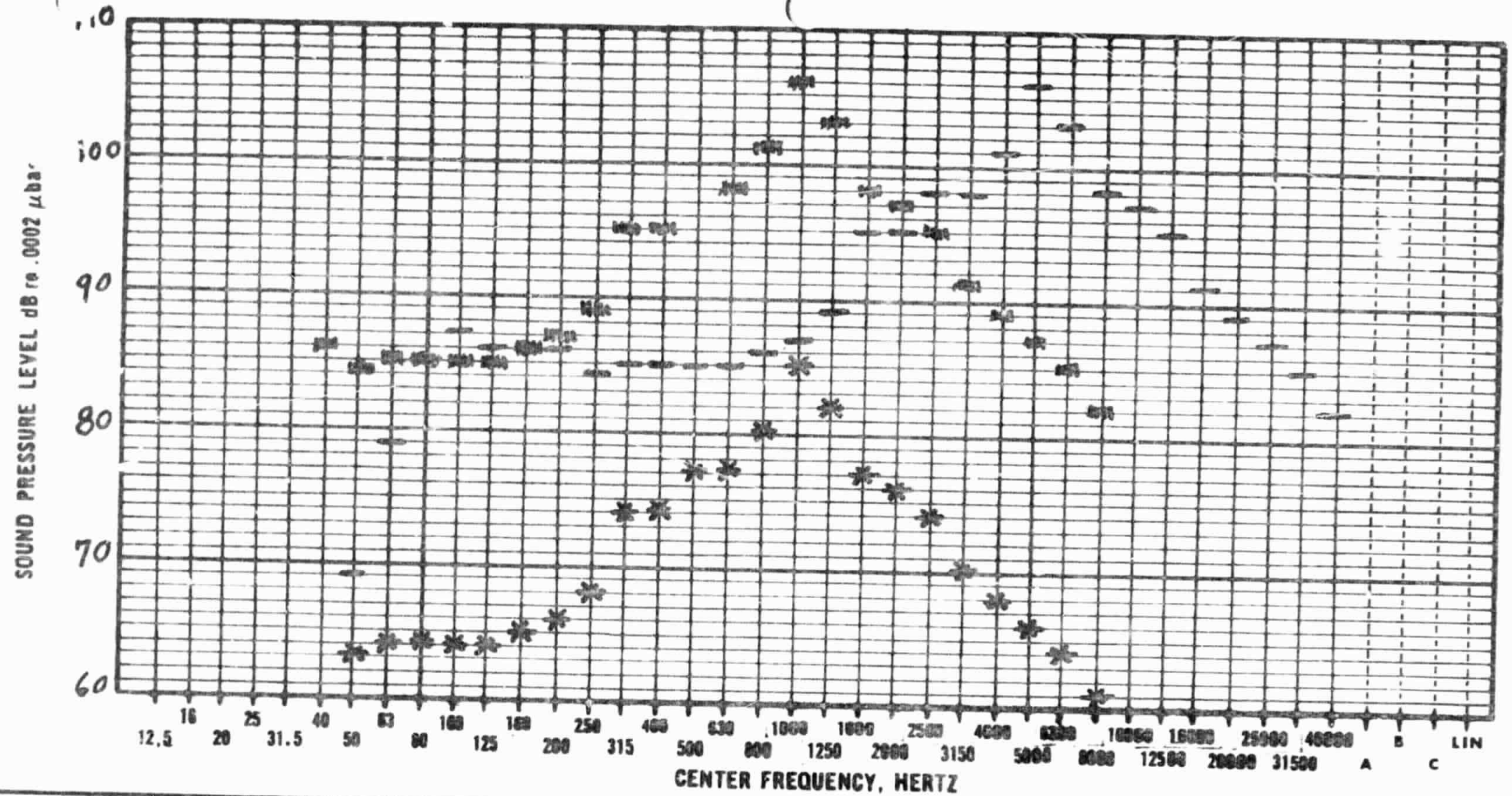
- FOR SIDELINE ESTIMATE OF FOUR ENGINE PROP-FAN STOL ADD 6dB TO ACCOUNT FOR FOUR ENGINES AND SUBTRACT 1dB TO ACCOUNT FOR SHIELDING OF ENGINES ON FAR SIDE & SUBTRACT 2dB FOR ENGINE OPERATION AT 80% POWER

→ **96.5** PNdB FOR A PROP-FAN STOL AIRCRAFT WITHOUT ACOUSTIC TREATMENT

- TO ACCOUNT FOR DUCT LINING SUPPRESSION OF PROP-FANS SUBTRACT 3dB

→ **93.5** PNdB FOR A PROP-FAN STOL AIRCRAFT WITH ACOUSTIC TREATMENT

Figure 34



Hamilton Standard — DIVISION OF UNITED AIRCRAFT CORP. • **ONE THIRD OCTAVE BAND ANALYSIS**

TITLE GEOMETRIC EXTRAPOLATION OF MODEL TEST DATA TO FULL SCALE

Test Date ______ Run No. ______

Mic Location ______ Reel No. ______

Analysed By ______ Identification No. ______

Analysis Method ______ Sheet ___ of ___

Comments, Sketches, Etc.

—— 1.75' DIA. 700 FT/SEC 215 HP @ 10' IN PLANE OF ROTATION

uuuuu 7.8' DIA. 700 FT/SEC 4260 HP @ 45'

* 7.8' DIA. 700 FT/SEC 4260 HP @ 500'

Figure 35

PROJECTED NOISE LEVEL OF A FULL SCALE PROP-FAN STOL AIRCRAFT BASED ON GEOMETRIC SCALING OF MODEL TEST DATA

CONFIGURATION: 7000 SHP, 700 FT/SEC TIP SPEED, 7.8 FT DIAMETER, TAKEOFF CONDITION

REFERENCE LEVEL BASED ON STATIC TEST OF 21 INCH DIAMETER MODEL

98.6 PNdB
AT 500 FT FOR ONE FULL SCALE PROP-FAN

→

ADJUSTMENTS TO ESTIMATE FULL SCALE PROP-FAN NOISE

Optimization of Fan Aerodynamics:	−2 dB
Change in Stator Configuration:	−2.5 dB
Excess Atmospheric Attenuation:	−1.5 dB
Effect of Stator Lean:	−4 dB
Increase in Power Loading:	+4 dB
TOTAL ADJUSTMENT OF PERCEIVED NOISE	− 6 dB

→

ESTIMATED LEVEL FOR 7.8 FT DIAMETER PROP-FAN OPERATING AT 7000 SHP

92.6 PNdB
AT 500 FT FOR ONE PROP-FAN WITHOUT ACOUSTIC TREATMENT

- FOR SIDELINE ESTIMATE OF FOUR ENGINE PROP-FAN STOL ADD 6 dB TO ACCOUNT FOR FOUR ENGINES AND SUBTRACT 1 dB TO ACCOUNT FOR SHIELDING OF ENGINES ON FARSIDE & SUBTRACT 2dB FOR ENGINE OPERATION AT 80 % POWER →

95.6 PNdB
FOR A PROP-FAN STOL AIRCRAFT WITHOUT ACOUSTIC TREATMENT

- TO ACCOUNT FOR DUCT LINING SUPPRESSION OF PROP-FANS SUBTRACT 3 dB →

92.6 PNdB
FOR A PROP-FAN STOL AIRCRAFT WITH ACOUSTIC TREATMENT

Figure 36

TABLE 1

PROP-FAN TEST CONDITIONS

Blade Angle (Deg)	Tip Speed (Ft/Sec)	Static Shroud			Compromise Shroud
		Far Field Stationary	Far Field Sweeps	Near Field	Far Field Stationary
30	500				X
30	600				X
30	700				X
30	800				X
30	900				X
35	500	X		X	
35	600	X		X	
35	700	X		X	
35	800	X	X	X	
40	500	X		X	X
40	600	X		X	X
40	700	X	X	X	X
40	800	X	X	X	X
45	500	X	X	X	X
45	600	X	X	X	X
45	687		X		
45	700	X		X	X
50	500	X		X	
50	600	X		X	
50	626	X			

TABLE 2

PROP-FAN TEST
AMBIENT CONDITIONS

Test	Temp. (°F)	Relative Humidity (%)	Barometric Pressure (" HG)	Wind Velocity (kts)
Static Test Shroud				
Far Field Data	63	80	30.16	< 3
Near Field Data	67	95	30.20	< 3
Compromise Shroud				
Far Field Data	75	93	30.16	< 3

APPENDIX A

REFERENCES

1. "Instructions and Applications of Half-inch Condenser Microphones," Bruel & Kjaer, Naerum Denmark, 1957

2. "Acoustic Effects Produced by a Reflecting Plane," Unpublished Aircraft Information Report, SAE Committee A-21, Aircraft Noise Measurement

3. "Preliminary Prop-Fan Noise Estimating Procedure" Hamilton Standard Memorandum MG #1644, May 11, 1970

4. "Aircraft Noise Symposium: Acoustical Duct Treatments for Aircraft" Journal of the Acoustical Society of America, Volume 48 No. 3 Part 3, September 1970

5. Lowson, M. V., "Theoretical Studies of Compressor Noise," National Aeronautics and Space Administration, Washington, D.C., NASA CR-1287, March 1969

6. Smith, M. J. T. and House, M. E., "Internally Generated Noise from Gas Turbine Engines. Measurement and Prediction," Transactions of the American Society of Mechanical Engineers Journal of Engineering for Power, April 1967, pp. 177-190

7. Benzakan, M. J. and Volk, L. J., "Study Program for Lift Fan Noise Reduction and Suppression" National Aeronautics and Space Administration, Washington, D.C., NASA CR 1493, March 1970