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MANHATTAN BEACH, CALIF. · MESA, ARIZONA

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ENGINEERING REPORT

SECURITY INFORMATION

REPORT NO. RR-23 **DATE.** March 16, 1954

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REVISIONS:

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APPROVED BY: R. W. McJones, Chief Power Plant Engineer

American helicopter co. inc.
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1.0 S U M M A R Y

A Partial Enclosure has been constructed for noise control, the purpose of which is to permit the testing of Pulse-Jet engines without undue offense to the neighboring community and with reasonable comfort for the engineers and mechanics who take part in the tests. Complete description of the construction and tests of the performance of the partial enclosure is presented.

2.0 INTRODUCTION

This report describes work accomplished on item 1.5 of Exhibit A, Supplementary Agreement No. 5 of Contract AF33 (600)-5860 during the month of January, 1954.

This is the fourth report to be submitted describing the development of Noise Control Measures for Pulse-Jet engines. The report is submitted by the American Helicopter Co., Inc., describing the study program being conducted by Paul S. Veneklasen, Consultant in Acoustics.

The work was carried out and is reported by Paul S. Veneklasen, and staff members G. F. Brockett, M. O. Herwick.

3.0 D I S C U S S I O N:

A noise control enclosure has been constructed, the purpose of which is to permit the testing of Pulse-Jet engines without undue offense to the neighboring community.

3.1 OBJECTIVES:

Certain unusual requirements limit the possible extensiveness and effectiveness of the noise control baffles.

A. The Pulse-Jet engine is highly dependent for its operation upon acoustical resonance phenomena; therefore it is of extreme importance that the Pulse-Jet engine should not be surrounded with a structure which can in any way influence the performance of the engine by altering its acoustical environment. It would be altogether too easy to set up a walled structure in which standing waves, i.e., acoustical resonant modes acting between the walls, could so alter the acoustical condition at either the exhaust or intake that engine operation would be profoundly influenced. Serious attention was given to this factor in the design.

B. For most of the test work it is essential that one or more technicians be in the immediate vicinity of the engine to make adjustment or facilitate starting. To enclose the engine in a structure considerably increases the hazard to such personnel. Therefore, it was essential that easy escape be provided in the event of malfunction or fire. It seemed possible that proper design of the enclosure could actually improve the safety condition for operators.

C. In the event of starting failure, flash fires of controlled proportions are quite frequent. The structure must be designed so as not to enclose such a fire.

D. It was desired to spend just as little money as possible on the structure.

These conditions conspire to very greatly limit the amount of attenuation which can be provided by the enclosure. Nevertheless, it was believed that even the small amount of attenuation which could be expected would greatly alleviate the neighborhood nuisance problem and would also decrease the discomfort which has been experienced by operating personnel.

3.2 DESIGN OF THE STRUCTURE:

A plan drawing of the noise control installation is shown in Fig. 3.1 and an overall photograph of the area is shown in Fig. 3.2. It is clear that the facility is little more than a baffle arrangement. The acoustically treated panels are positioned around the engine stand in such a way that (1) there are many readily available passages for the escape of the operating personnel; (2) these same passages permit easy inflow of air from all sides to the engine; (3) since there is no roof, flash fires are not entrapped; (4) the panels are so oriented with respect to the test stand that the major regions of high noise level cannot be directly viewed through the escape openings. In other words, the intent is to provide maximum exposure of absorbing surfaces to intense sound energy before such energy escapes to the outside of the structure; (5) in addition to the open top, the other major opening, which is required for the exhaust of hot gases, was made as narrow as was considered practical.

The sound-absorbing baffles are constructed as shown in Fig. 3.3. The baffles are made from standard sheets of 4'x 8' plywood, 3/4" thick. Frames are of standard 2"x 4" stock. The acoustical material is Owens-Corning PF-0C9 Fiberglas board material, 1" thick. This material is fastened to the 2"x 4" framework in such a manner that the 3 5/8" space provides a cavity between the Fiberglas board and the plywood. This type of structure provides a large amount of sound absorption for frequencies above about 250 cps. The Fiberglas board is covered only with a light bronze screen for protection against scuffing. (6) The baffles are inclined toward one another to carefully avoid any surfaces which approach parallelism. This factor is shown in the plan view, but it was also accentuated by tilting the tops of the panels somewhat inward.

3.3 PERFORMANCE - Mechanical

These noise control panels which are the essential part of the noise control enclosure are subjected to large oscillatory pressures represented by the high sound levels which are produced by Pulse-Jet engines. Under such exposure the panels undergo considerable vibration, which is readily tolerated and absorbed by a wooden structure. No mechanical failure has been suffered by the woodwork as a result of this vibration. The Fiberglas board is similarly exposed with variable experience: 1. In regions where flash fires have occurred the Fiberglas board has been scorched to varying degrees. When this scorching occurs, the phenolic binder is gasified, leaving the Fiberglas blanket without adequate binder whereupon the glass wool gradually erodes away. In the course of about twenty hours of operation, which has included several flash fires, one region of about 6' square has been completely eroded away. Hence, it is apparent that, in the region opposite and above the tailpipes, frequent replacement of the Fiberglas surface may be required, depending upon the starting experience which occurs during a given group of experiments.

As far as personnel safety is concerned, it has become apparent that, if anything, the noise control facility improves the assurance of operators in the immediate area, because the escape openings are very near by and, once through the opening, a considerable measure of protection is furnished by the panels.

3.4 PERFORMANCE - Acoustical

The effectiveness of the baffles was evaluated in respect to different objectives:

3.4.1 Neighborhood Noise Reduction:

The performance of the baffles was evaluated near the location of the nearest neighbors to the American Helicopter plant. Location No. 1 was outside the service entrance to a neighboring ceramic plant at a distance of 105 yards. In evaluating the importance of any noise source, consideration should be given to the noise levels which otherwise prevail in the neighborhood. Fig. 3.4 shows the various noise spectra which were measured at Location No. 1. The lowest spectrum on the chart represents the minimum background noise produced by more or less steady distant sources. One of the most typical of generally tolerated disturbances in the area results from the take-off of the jet airplanes from an airport which is approximately 1 1/2 mile distant. The resulting spectrum is shown in Fig. 3.4. This figure also shows the noise spectrum resulting from operation of a 6.75" Pulse-Jet engine operating outside the noise baffles. The reduction in noise is shown when the same engine is operated inside the baffles. The residual noise level can be compared with that of the jet airplane.

Residual noise should also be compared with two other criteria which are shown in Fig. 3.5. The noise criteria shown in Fig. 3.5 have been compiled from considerable available material and represent a summary of many authoritative sources. It should be noted that such noise criteria have not in any sense reached the stage of official recognition and there is considerable variation among authorities. It is believed that those shown in Fig. 3.5, which are used by this laboratory, represent a reasonable compromise. If a noise spectrum falls below the noise nuisance criteria, it should not be expected that reasonable complaint would be justified in an industrial area during daytime operation. It will be noted that the residual spectrum in Location No. 1 is still somewhat above the nuisance contour <u>outside the ceramic plant</u>. It is not known what the levels are inside the plant, or how they compare with the plant's own internal noises.

The hearing damage risk criterion is presently the subject of much investigation by the American Standards Association. The tentative criterion which has been in use by this laboratory lies in the lower range of the various criteria which are being considered for standardization. It is clear that the noise levels produced by Pulse-Jet testing in Location No. 1 are well below the levels which are likely to cause any hearing damage and therefore any compensation risk.

Location No. 2 was in a parking lot just outside a neighboring plant to the northwest of the test stand. The minimum general noise in this location does not differ greatly from that for Location No. 1. However, the most prominent noise nuisance in Location No. 2 results from large gravel trucks passing along the nearby highway, for which Fig. 3.6 shows the resulting noise spectra. The noise resulting from testing a 6.75" Pulse-Jet engine inside the baffles is shown for comparison. In this location the residual noise is well below both criteria. The effectiveness of the facility in this location is also shown by Fig. 3.6. It should be noted that this location is the nearest inhabited one in the general direction of the Pulse-Jet exhaust, which is toward the southwest. Since the structure is open, it would be expected that the effectiveness is minimum in this direction.

Location No. 3 is in a residential area about 1 1/2 miles to the southwest of the test stand. In Fig. 3.7 the lowest curve gives a minimum general background level. At a distance about two blocks from the microphone, bulldozers were at work in an earth-moving project. The noise level resulting from their activity is shown. A commercial airliner flying at about 1500' overhead also presents a typical noise spectrum. Pulse-Jet engines operating in the noise control baffles could not even be heard at this location and the spectrum shown for a 6.75" engine outside the baffles is hardly significantly evident above the general background level.

<u>3.4.2 Noise Reduction in the Immediate Vicinity of the Test Stand:</u>

Before the installation of the noise control baffles the testing of Pulse-Jet engines was a rather trying auditory experience. Even when using ear plugs or headphone cushions, the protection is not adequate at low frequencies and a day of steady testing leaves one quite exhausted. Furthermore, the proximity of the test stand to the plant at Manhattan Beach is such that conversation was impossible in part of the plant during testing periods. Therefore, the need for noise control was strongly evident within the "family." The new installation is so arranged that considerable relief is furnished for all operating personnel, except the (usually) one man who handles the air-starting hose, who is able to seek refuge behind a panel for much

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of the operation.

For the measurement of local performance, points were laid out, as shown in Fig.3.8, both in and outside the facility, in such a manner that the results could be compared with earlier tests (Report No. 163-K-1) on an exposed engine. Figs. 3.9 through 3.16 show the degree of improvement which has been achieved at various locations in the immediate vicinity of the installation. Fig. 3.10 shows clearly that considerable reduction is furnished, even in the direction of the opening in the baffles through which the exhaust gases pass. This is not altogether surprising when one realizes that a rather significant portion of the sound energy radiated in an approximately spherical direction from the tailpipe is intersected by the baffles.

It is typical of open-topped enclosures that greater protection is furnished near the enclosure than at a considerable distance. Comparison of Figs. 3.9 through 3.16 with the data for more distant locations thoroughly indicates this fact. Fig. 3.15 is of special interest, since it shows the effect of the shadow produced by a sound-absorbent baffle. Position No. 8 is just inside the structure, i.e., it views the engine, while Position No. 7 is only a foot away, but is in the shadow of a baffle. The reduction of high frequency noise is quite apparent. Of course, Position No. 9, which is at the same distance from the engine but completely shaded therefrom shows very much higher degree of attenuation.

It is of particular interest to point out in connection with all these spectra which show a very useful amount of high frequency noise reduction, that the overall level is relatively little affected. Indeed, that the overall level is reduced to some extent bears witness that the absorption of the panels is effective at a lower frequency than had been expected, plus the fact that for the particular engine under test, the fundamental frequency of approximately 150 cps is fairly high. It will be found that considerably

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less change in overall level will be furnished for larger engines. Nevertheless, the effectiveness of this very simple and inexpensive noise control facility is admirably evident without the use of instrumentation and is due to the considerable reduction in high frequency noise level. Particular attention is called to Fig. 3.16, which shows the residual noise spectra inside and just outside the control room, together with a spectrum for the yard area just outside the plant about 75 feet from the installation. These spectra should be compared with the hearing damage risk criterion. It is evident that the levels in the immediate vicinity of the installation, including the control room, have not been reduced quite to the safe level for continuous exposure to high level noise. Therefore, it is recommended that when operators are expecting to be involved in Pulse-Jet testing for several days continuously they should be instructed to use aural protection devices, such as the MSA Ear Defender, or simply a pair of headphones. For short operations of a few hours, or with several days intervening between tests, it is probable that the residual levels will cause only temporary impairment for average ears. All operators should be conscious of their aural condition after testing and let their feelings be their guide. It is also clear that in the plant areas the noise levels have been reduced sufficiently to remove concern for aural damage.

4.0 C O N C L U S I O N S

A. Low-cost noise control enclosure has been constructed which surrounds the Pulse-Jet static test stand.

B. The enclosure consists of an arrangement of spaced and staggered panels constructed of 3/4" plywood, 2" x 4" stock and Owens-Corning PF-OC-9 Fiberglas.

C. The sound-absorbing panels have proved to be capable of withstanding the vibration resulting from high sound pressure levels. Occasional replacement of Fiberglas in one section will be required, depending upon the frequency of flash shires with engine starting.

D. The enclosure has produced no perceptible alteration in engine performance.

E. The noise levels in the adjoining shop area and in the neighboring community have been sufficiently reduced to avoid all possibility of hazard due to hearing impairment. With one possible exception, the residual noise is below the level which should permit reasonable nuisance complaint.

F. In the immediate vicinity of the test stand, noises have been reduced sufficiently to provide great relief for operators. Except during periods of continuous testing, aural protection devices will not be mandatory except for the mechanic who must work immediately behind the engine to assist with starting.

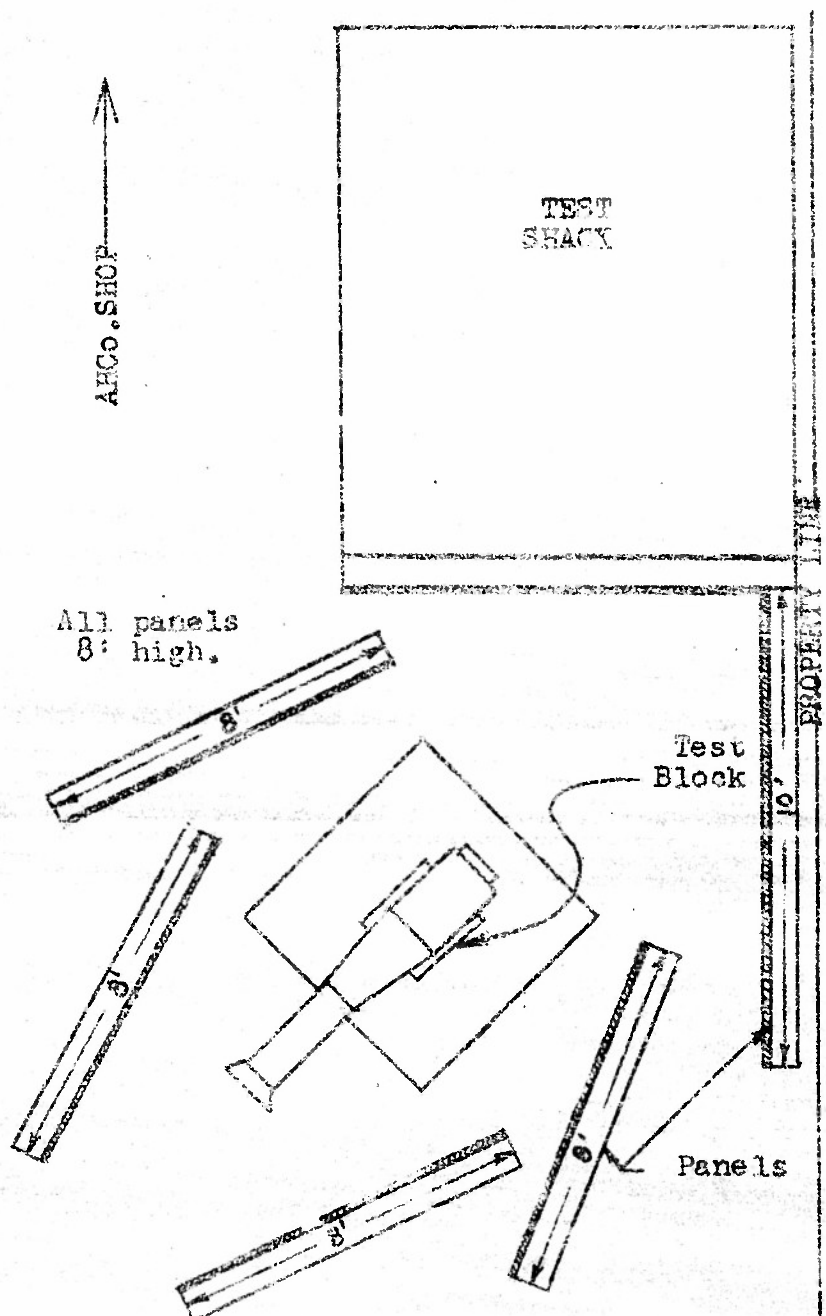


Figure 3.1

Plan Drawing of Noise Control Semi-Enclosure

Scale 1/4" = 1'

Photographs of Noise Control Encl[illegible]

SECTION OF PANEL CONSTRUCTION

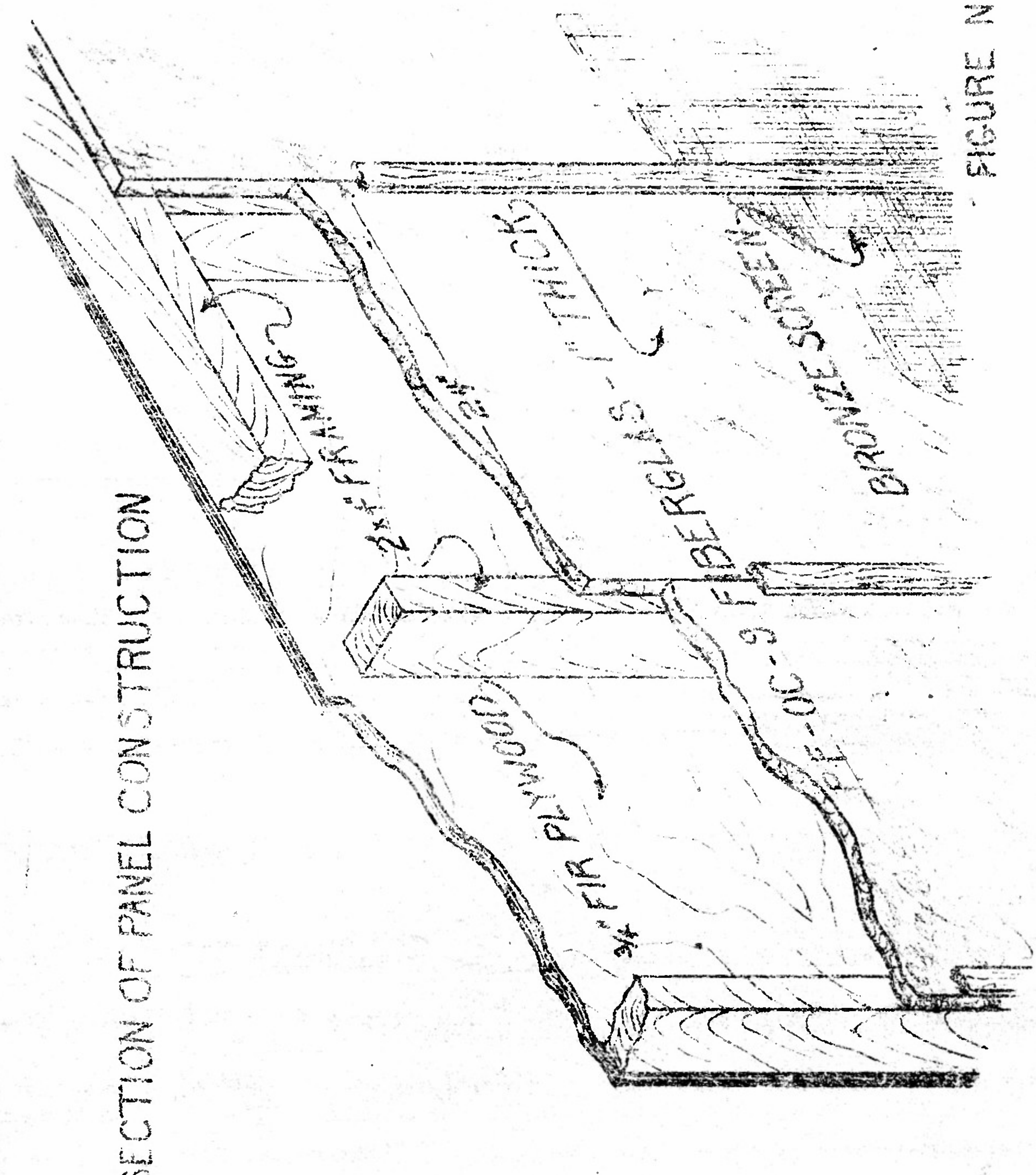


FIGURE NO. 3.3

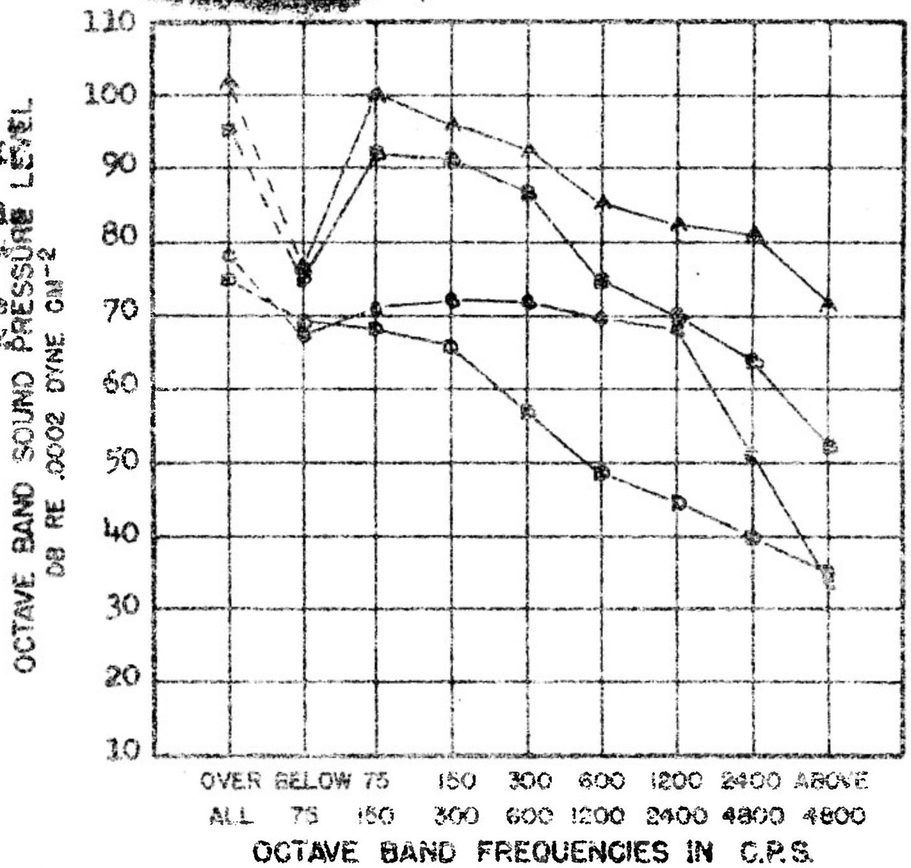


Figure 3.4

NOISE SPECTRA AT NEIGHBORHOOD LOCATION II

A. 6.75" engine outside noise control baffles.

B. 6.75" engine inside noise control baffles.

C. Jet plane during takeoff from airport

D. Minimum background

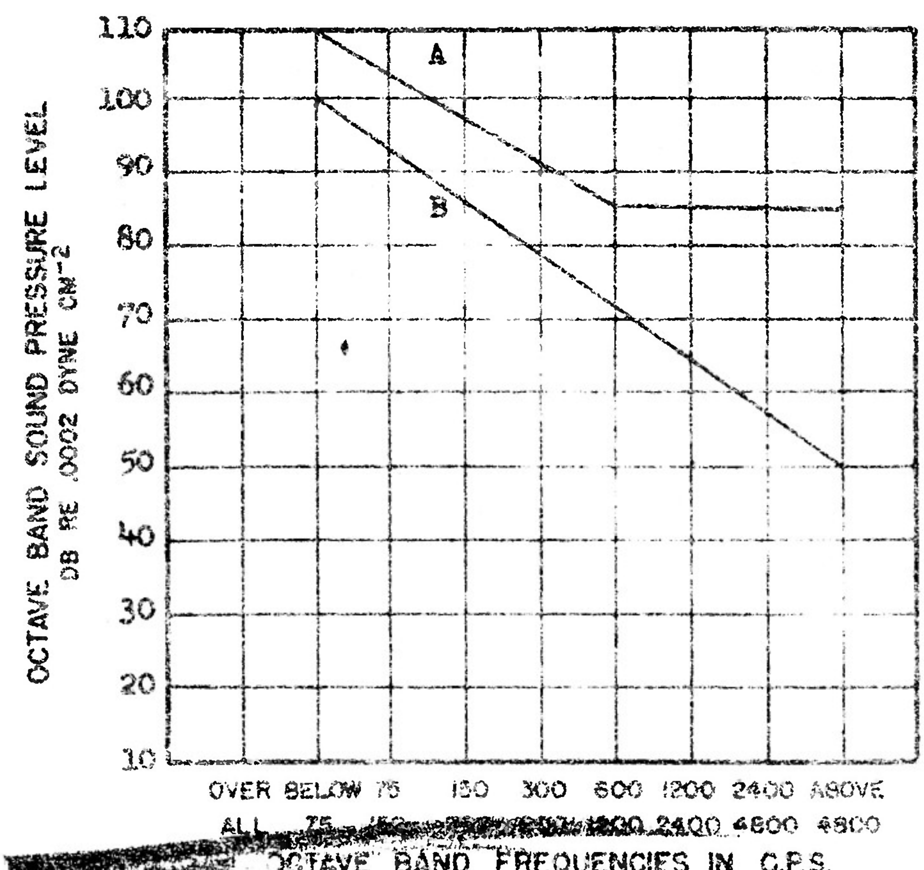


Figure 3.5

TENTATIVE STANDARDS FOR NOISE SPECTRA

A. Hearing Damage Risk Criterion

B. Noise Nuisance Criterion

WESTERN ELECTRO-ACOUSTIC LABORATORY

Figure 3.6

NOISE SPECTRA AT NEIGHBORHOOD LOCATION II

A. 6.75" engine outside noise control baffles.
B. 6.75" engine inside noise control baffles.
C. Truck passing.
D. Minimum background.
E. 12" engine inside noise control baffles.

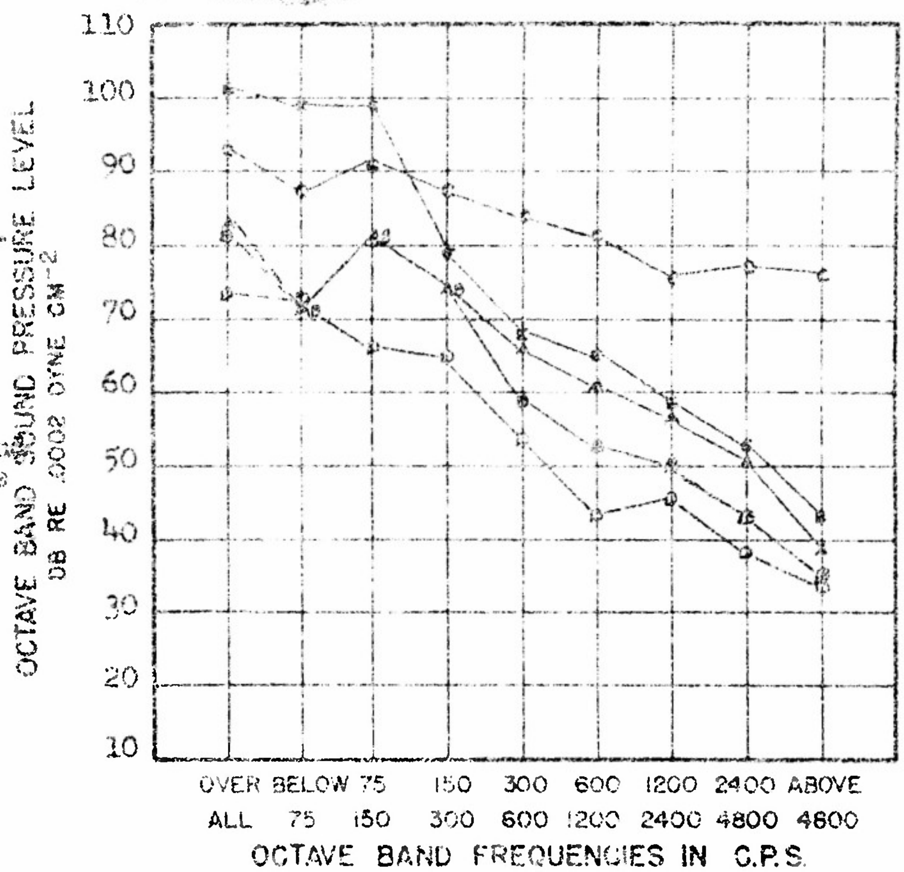
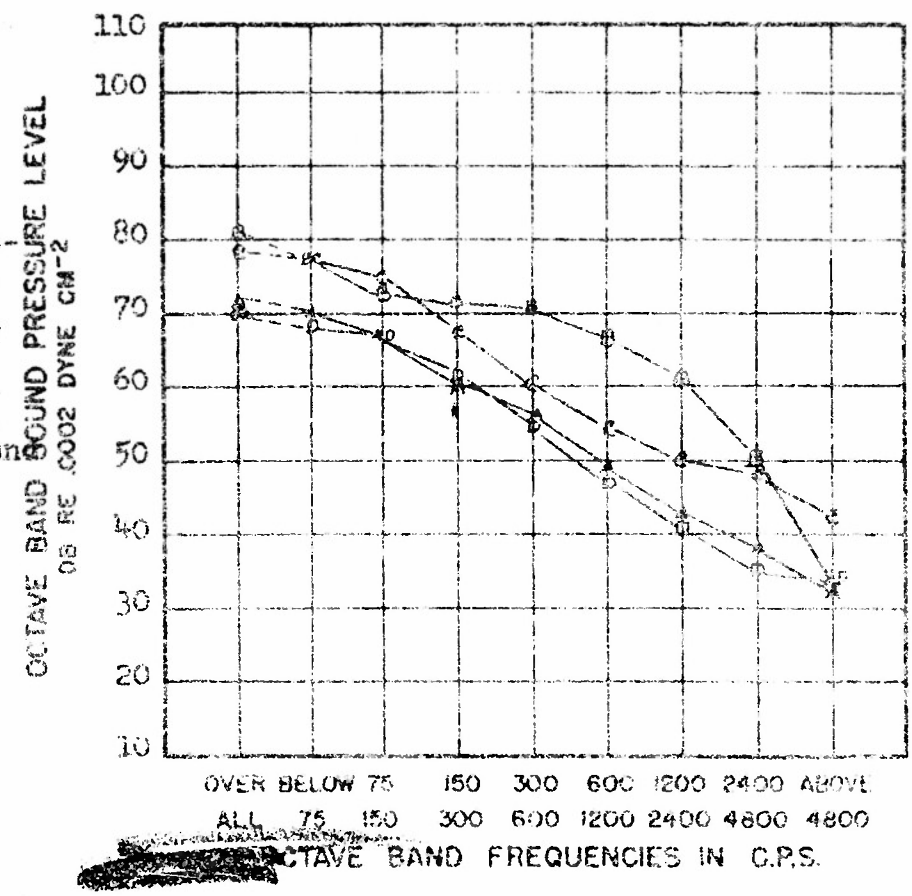
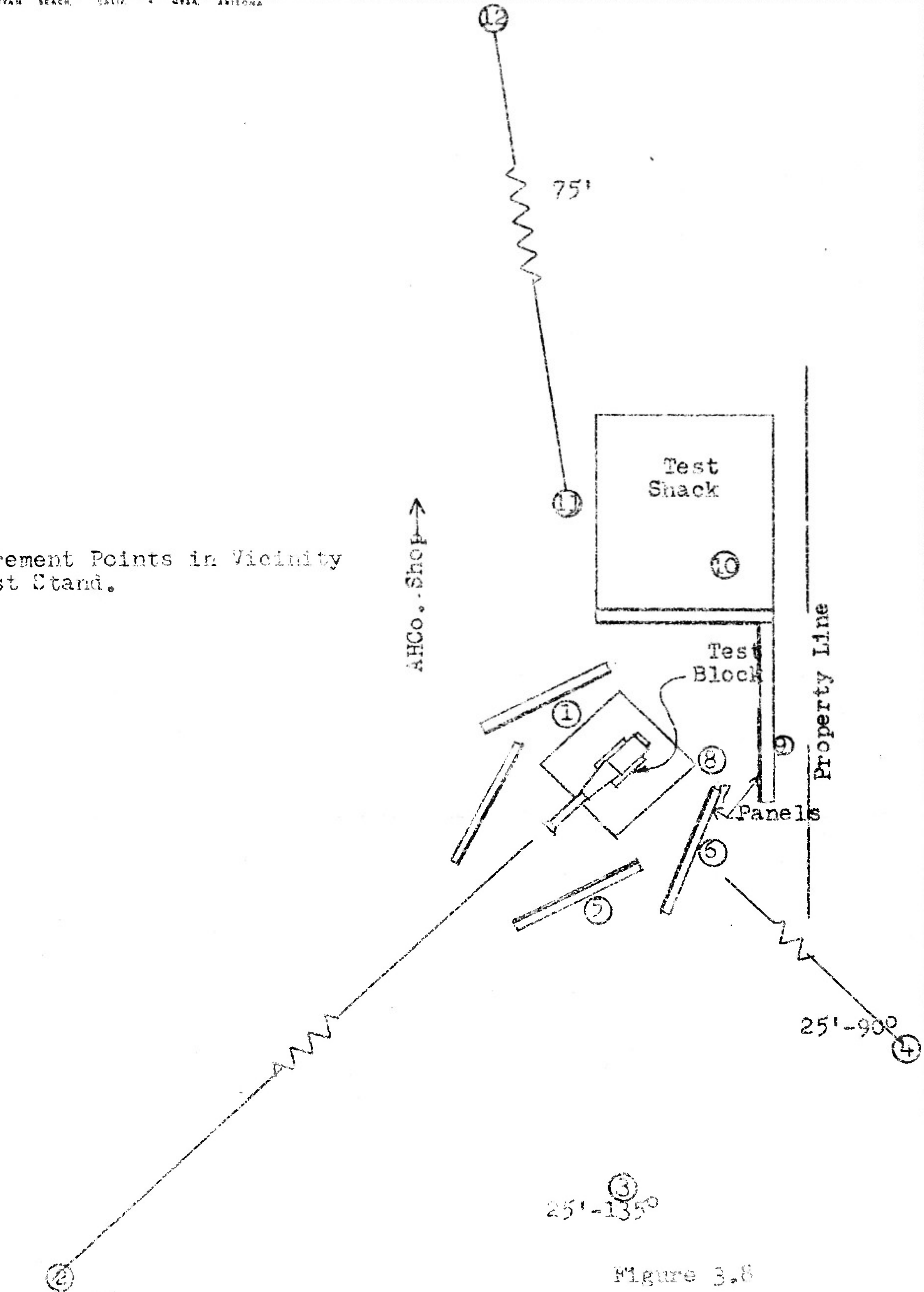


Figure 3.7

NOISE SPECTRA AT NEIGHBORHOOD LOCATION III

A. 6.75" engine outside noise control baffles.
B. Airliner passing overhead.
C. Bulldozers working 1/4 mile away.
D. Minimum background.





Measurement Points in Vicinity of Test Stand.

Figure 3.8

Scale 1/8 - 1'

[redacted]

Figure 3.9

6.75" Engine at Position 1 (3 ft. - 90° - 130 pphr.)

A. Without baffles. (Report No.163-K-1)

1 - 1. Inside baffles.

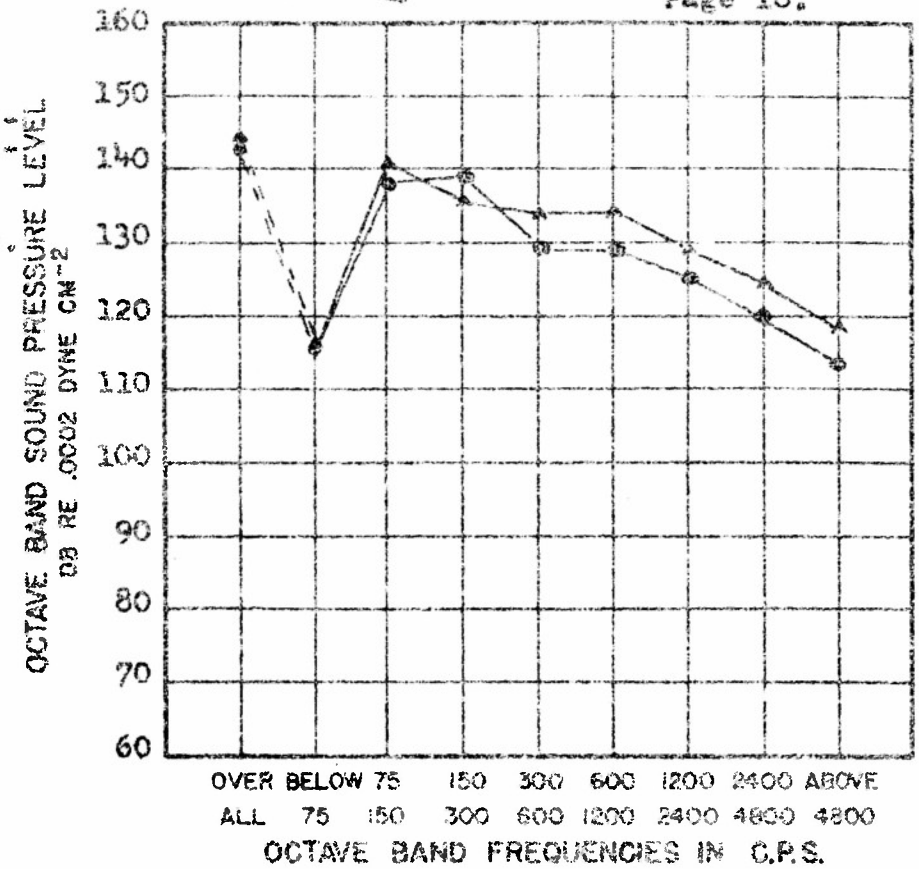


Figure 3.10

6.75" Engine at Position 2 (50 ft. - 180° - astern)

A. Without baffles. (Report No.163-K-1)

2 - 2. Engine in baffles.

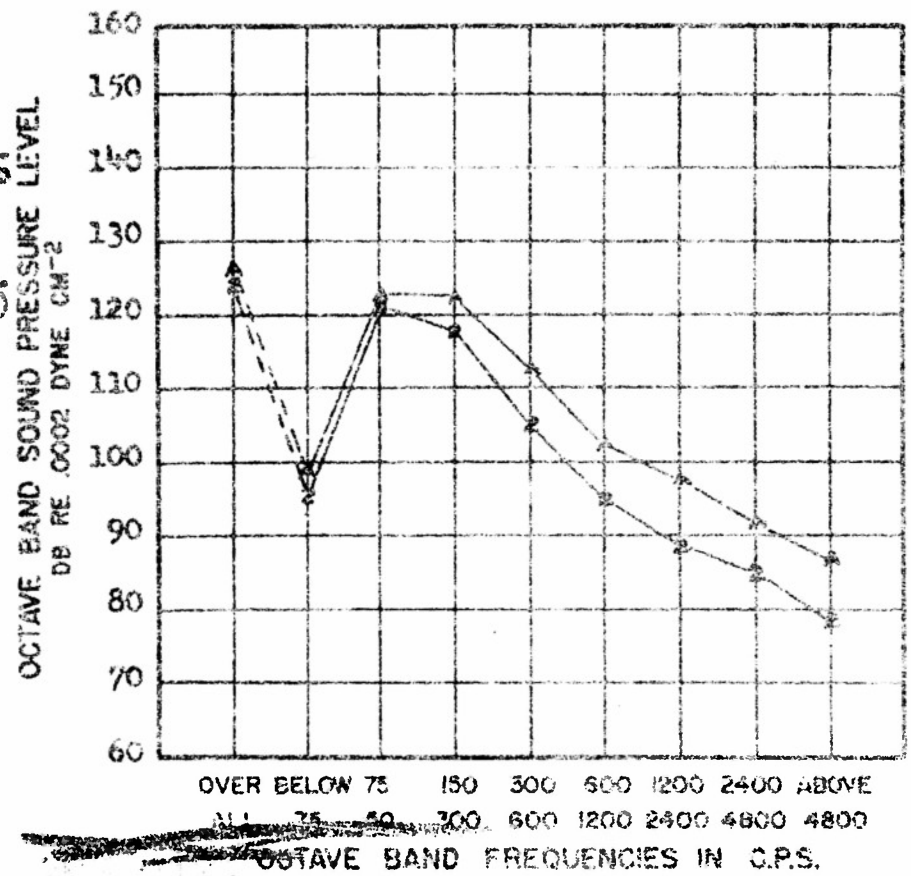


Figure 3.11

6.75" Engine at Position 3 (25 ft - 135°)

A. Without baffles. (Report 163-K-1)

3 - 3. Engine in baffles.

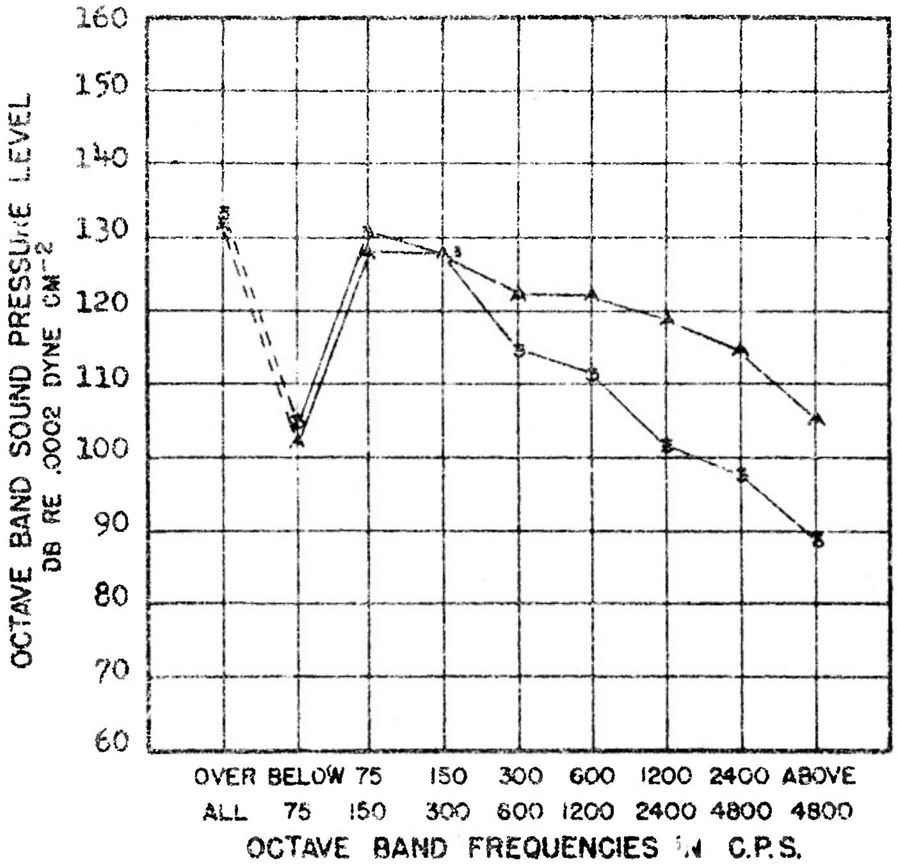


Figure 3.12

6.75" Engine at Position 4 (25 ft. - 90°)

A. Without baffles. (Report 163-K-1)

4 - 4. Engine in baffles.

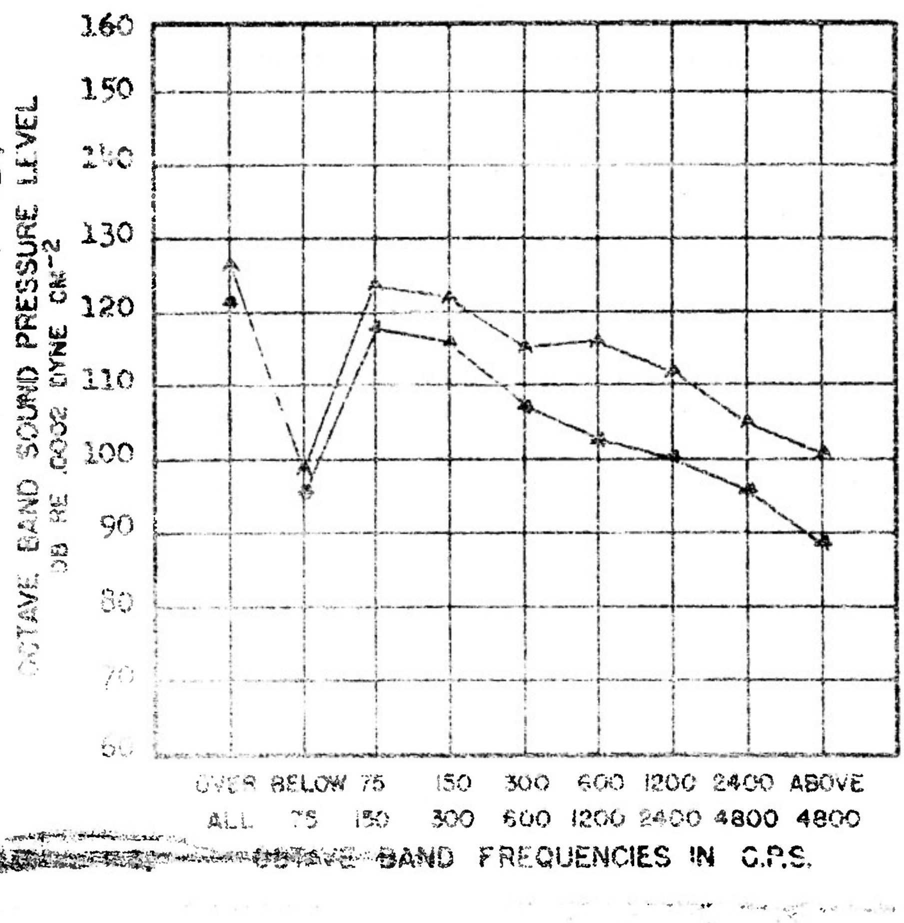


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Figure 3.13

6.75" Engine at Position 5 (6 ft. - 135°)

A, Without baffles. (Report 163-K-1)

5 - 5. Engine in baffles.

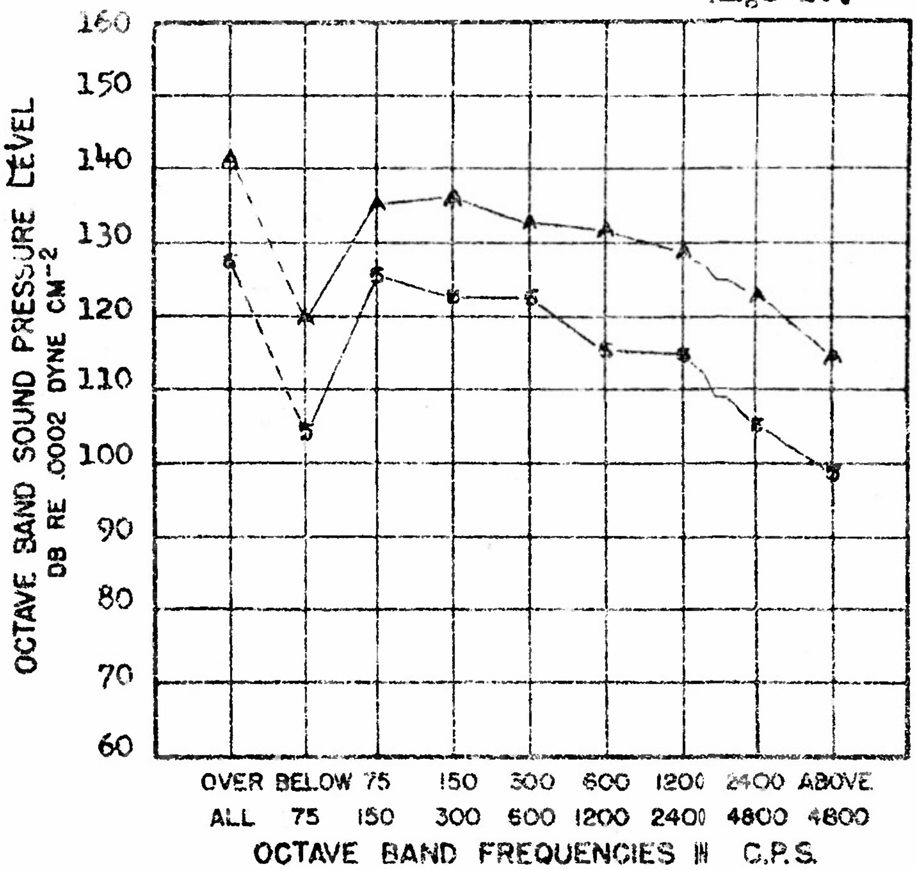

Figure 3.14

6.75" Engine at Position 6 (6 ft. - 90°)

A. Without baffles. (Report 163-K-1)

6 - 6. Engine in baffles.

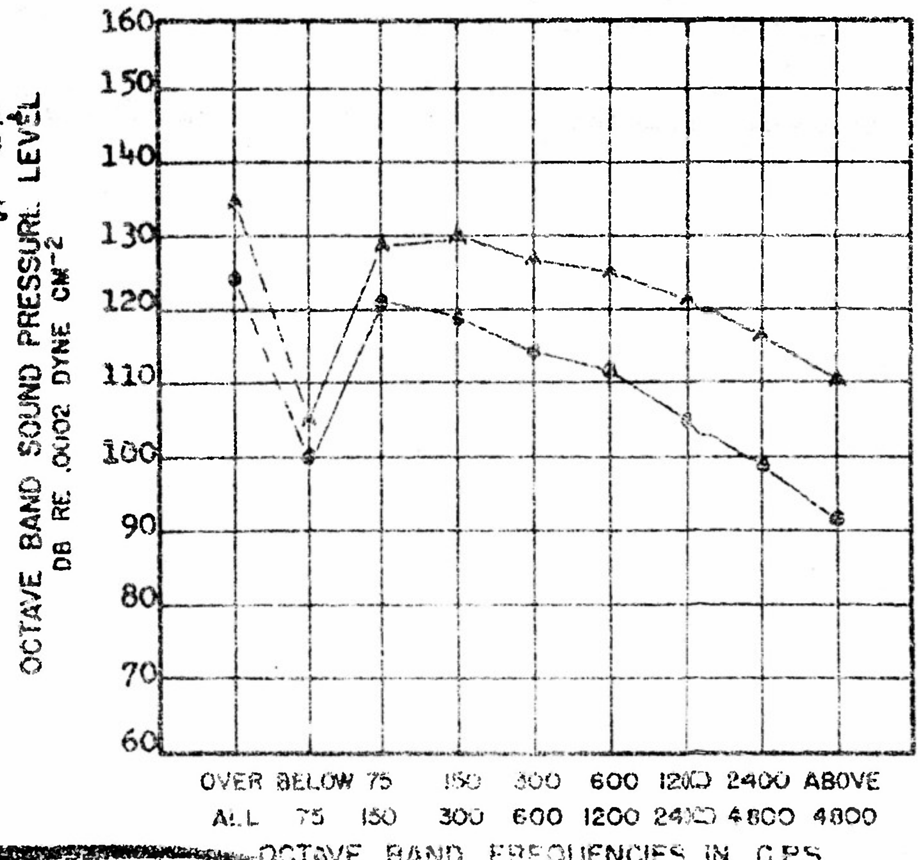

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Figure 3.15

6.75" Engine at Position 7, 8, 9

A. Without bafflex (6 ft. - 45°) (163 - K - 1)

7 - 7 Engine in baffles xxx.
8 - 8 Engine in baffles.
9 - 9 Engine in baffles.

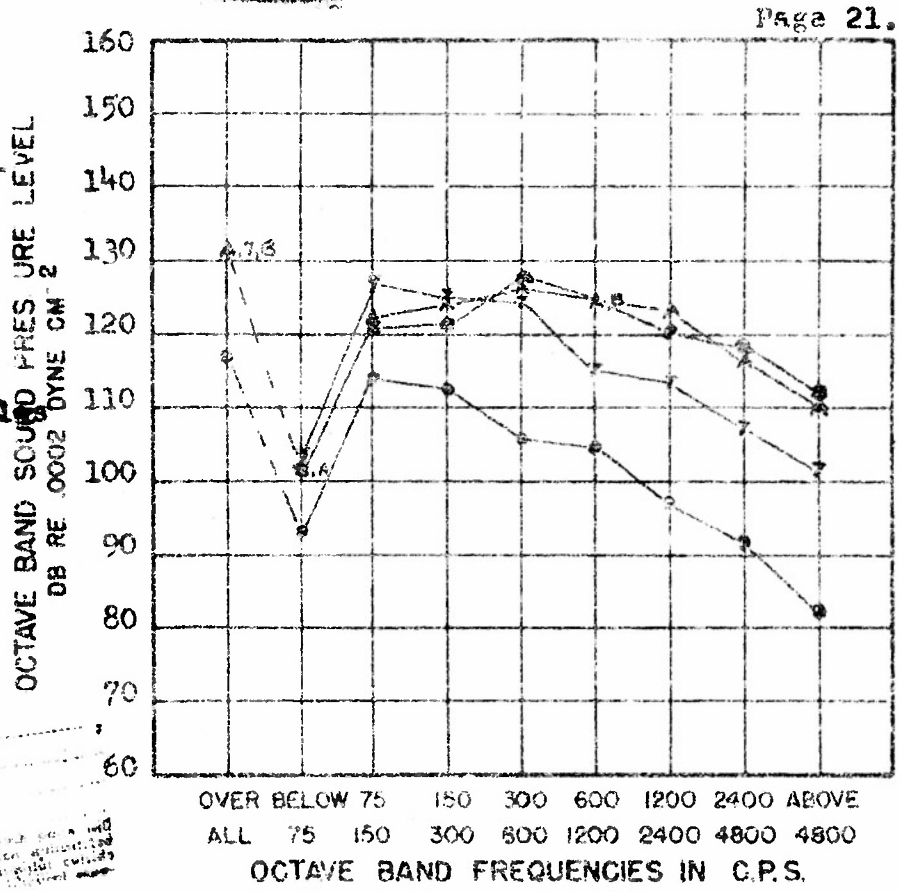

Figure 3.16

6.75" Engine at Positions 10, 11, 12

A. Without Baffles (6 ft. - 0°) (Report 163-K-1)

10-10 Engine in Baffles.
11-11 Engine in baffles.
12-12 Engine in baffles.