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# NOISE SPECTRA OF THE TURBO-BEAVER

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# NOTICE

# ABSTRACT

Sound pressure levels were measured in various positions inside the Turbo-Beaver under various power conditions. A comparison of these data with comparable available data taken from measurements of sound pressure levels in the U-6A show that the overall level and the lower portion of the spectrum in the U-6A had higher sound pressure levels. The octave bands of the Turbo-Beaver's noise spectrum, above the band centered around 500 cps, had higher sound pressure levels.

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## NOISE SPECTRA OF THE TURBO-BEAVER

### INTRODUCTION

A DeHavilland Turbo-Beaver was made available to the Aeromedical Research Unit for measurement of noise spectra. The Turbo-Beaver is an all metal aircraft with high wing, a single engine and fixed landing gear. It is powered by a Pratt and Whitney PT6A-6 engine which is a single-stage free power turbine. The propeller is a constant speed HC-B3TN-3 which is 102 inches in diameter, reversible pitch and has full feathering capability.

### PROCEDURE

Measurements of the internal noise sound pressure levels were made during taxi, take-off and cruising power configurations at various positions in the aircraft. The sound pressure level of the full audio spectrum (FAS) and ten octave bands were measured at positions near the co-pilot's seat, the right passenger's seat in the first row behind the pilot's seat, the left passenger's seat in the second row, and the rear seat.

### INSTRUMENTATION

The sound pressure level measurements were made with a Brüel and Kjaer precision sound level meter type 2203, a Brüel and Kjaer 4132 condenser microphone and a Brüel and Kjaer type 1613 octave band filter set. An acoustical calibration of the microphone and sound level meter was accomplished with a Brüel and Kjaer type 4220 pistonphone.

In the tables and figures where results of the octave band analysis are given, the center frequencies ($f_c$) are defined as the center of each octave band of which the 3 db attenuation cutoff frequencies below and above ($f_c$) on a logarithmic scale are $f_c / \sqrt{2}$ and $f_c \times \sqrt{2}$ respectively. The Brüel and Kjaer type 1613 octave band filter set yield a 40 db per octave slope from the cutoff frequencies. Table I contains the center frequency ($f_c$) and the cutoff boundry frequencies for each of the ten octave bands measured with the Brüel and Kjaer filters. Table II contains similar data on the General Radio filters that were used to analyze the noise spectrum of U-6A the results of which are given in USAARU Report No. 64-1.

## RESULTS AND DISCUSSION

Table III contains the sound pressure level measured under taxi, slow cruise, normal cruise and take-off conditions. The range of over-all levels of the full audio spectra extended from 94 db to 112 db under the various power settings. The rank order of the power conditions with respect to sound pressure level (from the lowest to highest) was taxi, slow cruise, normal cruise and take-off for the full audio spectra and all octave bands except two. The octave bands with 125 cps and 500 cps as center frequencies had higher sound pressure levels in the normal cruise condition than was measured in the take-off condition. Figure 1 depicts the spectra contours of the taxi and take-off conditions. The area between these contours may be considered to be the sound pressure level limits of the various portions of the spectra under all operating conditions of the aircraft.

Table IV shows the sound pressure level values determined from an octave band analysis of the noise at various positions in the aircraft. The range of variation of sound pressure levels of the full audio spectrum was 4 db. The peak sound pressure level at all positions was in the band with 125 cps center frequency.

Figure 2 shows spectra contours of the U-6A and the Turbo-Beaver. The values of sound pressure levels for the U-6A were taken from USAARU Report No. 64-1. These measurements were made with General

TABLE I

Center and Boundry Frequencies of the Brüel and Kjaer Type 1613 Octave-Band Filter Set

| Center Frequencies ($f_c$) | Boundry Frequencies Lower | Boundry Frequencies Upper |
|---|---|---|
| 31.5 cps | 22.3 cps | 44.5 cps |
| 63 cps | 44.5 cps | 89.1 cps |
| 125 cps | 88.4 cps | 176.8 cps |
| 250 cps | 176.8 cps | 353.6 cps |
| 500 cps | 353.6 cps | 707.1 cps |
| 1000 cps | 707.1 cps | 1414.2 cps |
| 2000 cps | 1414.2 cps | 2828.4 cps |
| 4000 cps | 2828.4 cps | 5656.9 cps |
| 8000 cps | 5656.9 cps | 11313.7 cps |
| 16000 cps | 11313.7 cps | 22627.4 cps |

TABLE II

Center and Boundry Frequencies of the General Radio Octave-Band Filters

| Center Frequencies ($f_c$) | Boundry Frequencies Lower | Boundry Frequencies Upper |
|---|---|---|
| 53.0 cps | 37.5 cps | 75 cps |
| 106.1 cps | 75 cps | 150 cps |
| 212.1 cps | 150 cps | 300 cps |
| 424.3 cps | 300 cps | 600 cps |
| 848.5 cps | 600 cps | 1200 cps |
| 1697.1 cps | 1200 cps | 2400 cps |
| 3394.1 cps | 2400 cps | 4800 cps |
| 6788.2 cps | 4800 cps | 9600 cps |

TABLE III

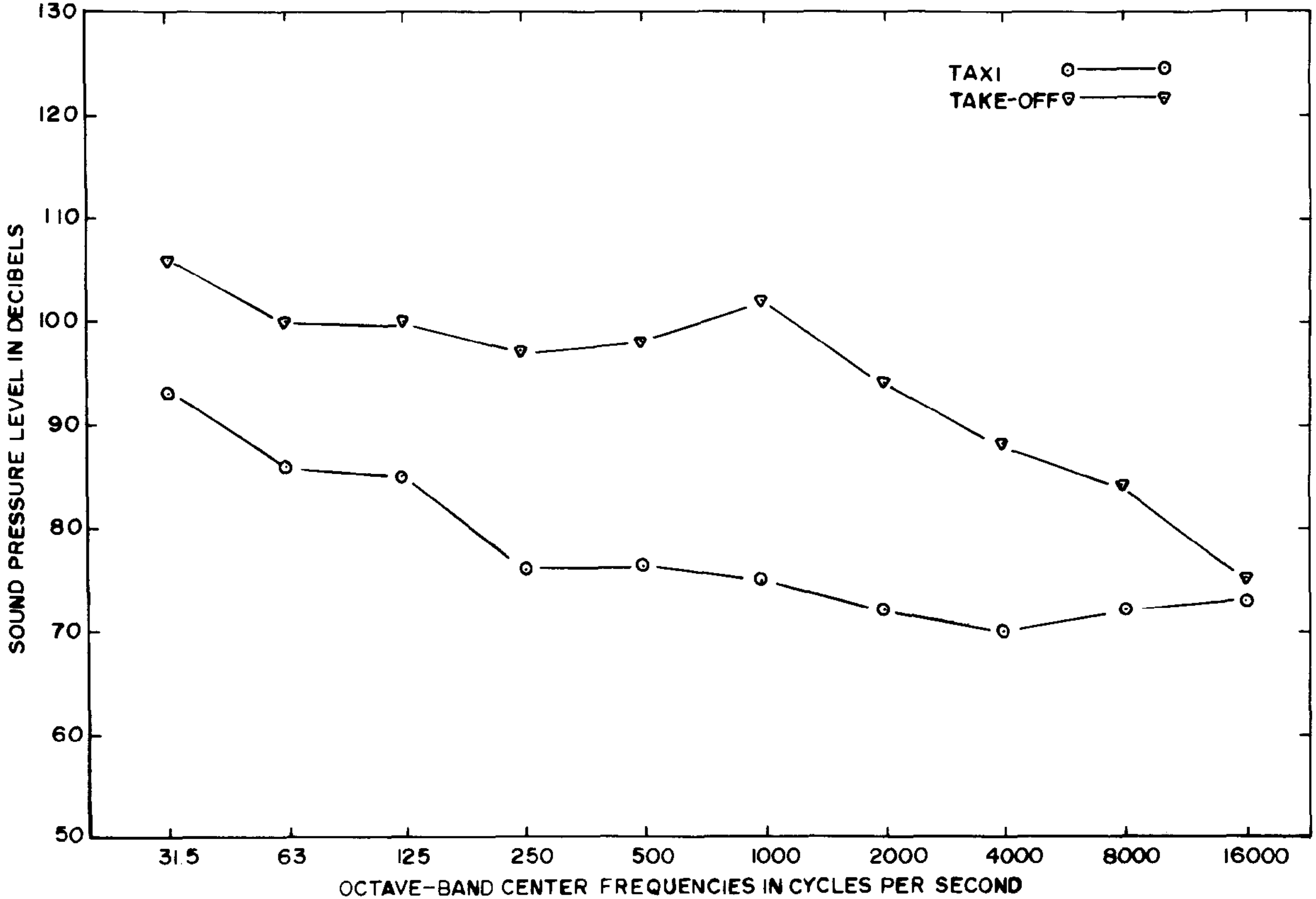
Sound Pressure Levels of Octave-Bands and Full Audio Spectra Measured in Front of the Right Pilot's Seat in the DeHavilland Turbo-Beaver Under Various Power Conditions

| Octave-Band Center Frequencies ($f_c$) | Taxi | Slow Cruise | Normal Cruise | Take-Off |
|---|---|---|---|---|
| 31.5 cps | 93 db | 93 db | 97 db | 107 db |
| 63 cps | 86 db | 93 db | 100 db | 100 db |
| 125 cps | 85 db | 95 db | 105 db | 100 db |
| 250 cps | 76 db | 91 db | 97 db | 97 db |
| 500 cps | 76 db | 92 db | 99 db | 98 db |
| 1000 cps | 75 db | 87 db | 96 db | 102 db |
| 2000 cps | 72 db | 81 db | 88 db | 94 db |
| 4000 cps | 70 db | 76 db | 84 db | 88 db |
| 8000 cps | 72 db | 72 db | 80 db | 84 db |
| 16000 cps | 73 db | 66 db | 74 db | 75 db |
| Full Audio Spectra | 94 db | 101 db | 108 db | 112 db |

TABLE IV

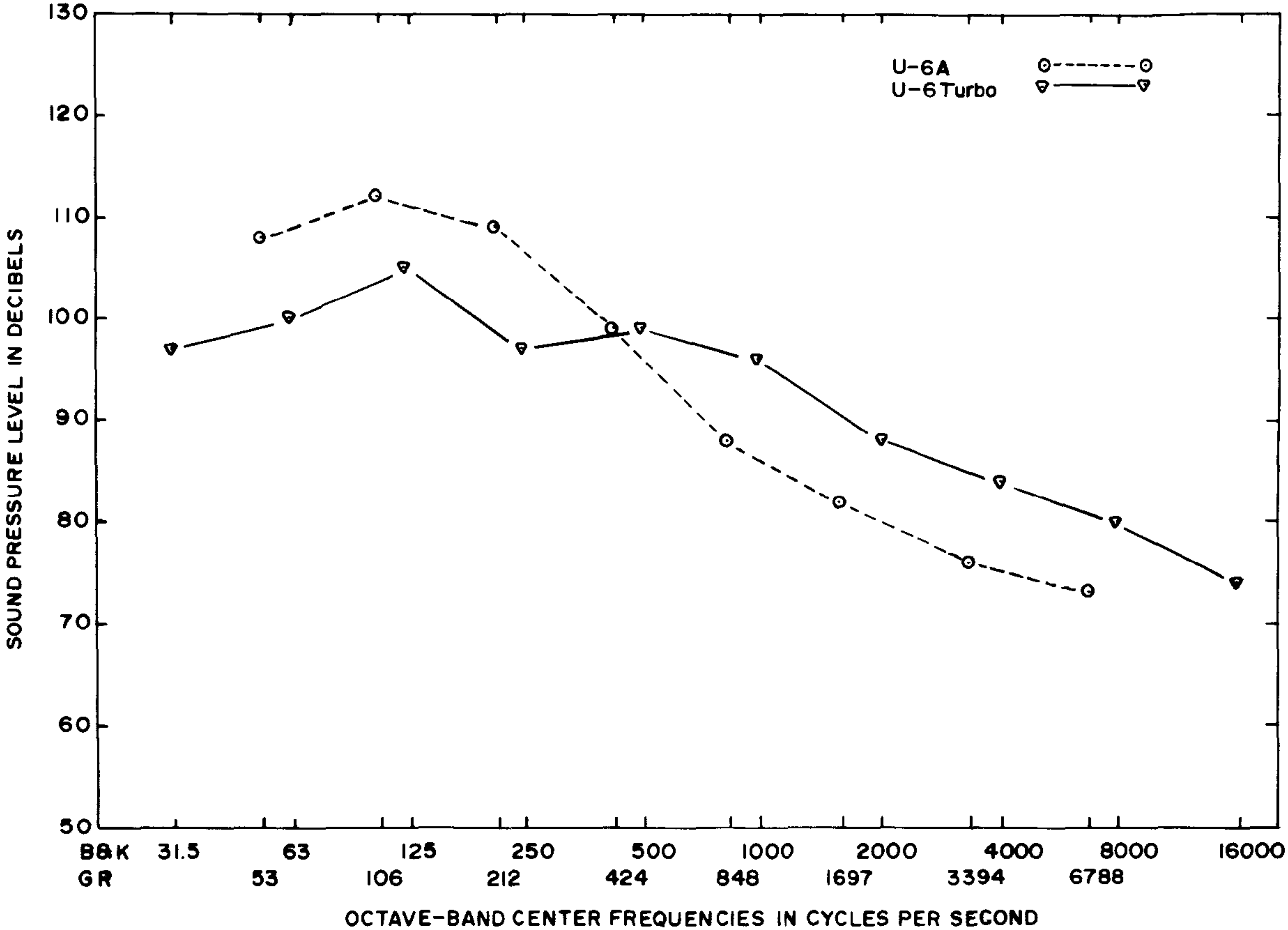
Sound Pressure Levels of Octave-Bands and Full Audio Spectra Measured at Various Positions in the DeHavilland Turbo-Beaver Under Normal Cruise Conditions

| Octave-Band Center Frequencies ($f_c$) | Right Pilot's Seat | Right Passenger's Seat 1st Row | Left Passenger's Seat 2nd Row | Rear Passenger's Seat |
|---|---|---|---|---|
| 31.5 cps | 97 db | 96 db | 96 db | 98 db |
| 63 cps | 100 db | 97 db | 97 db | 99 db |
| 125 cps | 105 db | 100 db | 103 db | 101 db |
| 250 cps | 97 db | 98 db | 101 db | 98 db |
| 500 cps | 99 db | 98 db | 103 db | 92 db |
| 1000 cps | 96 db | 96 db | 90 db | 84 db |
| 2000 cps | 88 db | 86 db | 83 db | 78 db |
| 4000 cps | 84 db | 82 db | 79 db | 74 db |
| 8000 cps | 80 db | 79 db | 75 db | 69 db |
| 16000 cps | 74 db | 74 db | 62 db | 52 db |
| Full Audio Spectra | 108 db | 105 db | 106 db | 105 db |



TAXI
TAKE-OFF
SOUND PRESSURE LEVEL IN DECIBELS
130
120
110
100
90
80
70
60
50
31.5
63
125
250
500
1000
2000
4000
8000
16000
OCTAVE-BAND CENTER FREQUENCIES IN CYCLES PER SECOND


Figure 1



U-6A
U-6 Turbo
SOUND PRESSURE LEVEL IN DECIBELS
130
120
110
100
90
80
70
60
50
B&K 31.5 63 125 250 500 1000 2000 4000 8000 16000
GR 53 106 212 424 848 1697 3394 6788
OCTAVE-BAND CENTER FREQUENCIES IN CYCLES PER SECOND


Figure 2

Radio octave band filters whereas the measurements of the Turbo-Beaver were made with Brüel and Kjaer filters. The values of the center frequencies on abscissa are plotted in their true relationship on a logarithmic scale which makes the comparison of the two spectra valid. The values in the Turbo-Beaver spectrum contour were taken from the right ear position of the co-pilot. These measurements were considered to be the most comparable, of these available, to the set of the measurements taken at the left ear of the U-6A pilot. Both positions were at ear level and near the side of the aircraft.

The differences between the two spectra are as one might expect in a comparison of the noise of a turbine and reciprocating engine. The U-6A has higher sound pressure levels below the octave bands center around 424 and 500 cps and lower sound pressure levels in all octave bands above these frequencies. The overall level of the full audio spectrum was 116 db SPL in the U-6A and 111 db SPL in the Turbo-Beaver.

In an evaluation of the noise spectra of the two types of aircraft one must consider more than the absolute level of the spectrum. The effective levels at the ear with earphones or earmuffs is a more important consideration. While it is true that the Turbo-Beaver has higher sound pressure levels at the high frequencies, it is also true that these frequencies are easily attenuated. Almost any type of earphone or earplug will yield enough attenuation to make the effective sound pressure level of the high frequencies below 85 db. Therefore, in view of the high sound pressure levels of the low frequency components of the U-6A and the difficulty of attenuating these frequencies, the U-6A is considered to have a less desirable type of noise spectrum from a hearing conservation viewpoint.

## CONCLUSIONS

The noise spectra of the Turbo-Beaver was measured in various positions in the aircraft under taxi, take-off and cruising power conditions. These measurements were compared with similar measurements taken in the U-6A as was reported in USAARU Report No. 64-1. A comparison of the data collected on these type of aircraft show that the Turbo-Beaver has an overall level of the full audio spectrum 5 db less than the U-6A. Also, the Turbo-Beaver had three octave bands lower sound pressure levels below the band centered around 424 cps. The U-6A had lower sound pressure levels in the high frequency portion of the spectrum.

In view of the shape of the noise spectra of the two aircraft and the nature of the attenuation characteristics of most earphones, earmuffs and earplugs it is considered that the U-6A has the most undesirable noise spectrum.

The US Army Technical Bulletin, TB MED 251, 25 January 1965, requires that personnel wear ear protection who are subjected to relatively steady broad-band noises of sound pressure levels of 92 db in the 150-300 cps and 85 db at all higher octave bands through 9600 cps. The sound pressure levels in the Turbo-Beaver and the U-6A are above these levels and therefore require measures be taken for conservation of hearing for both maintenance and operating personnel.