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LABORATORY STUDY OF THE ANNOYANCE OF AIRCRAFT-INDUCED SECONDARY EMISSIONS

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ABSTRACT
An adaptive paired comparison study was conducted to determine the relative annoyance of runway sideline and aircraft overflight noise, and of the annoyance of rattle associated with low-frequency runway sideline noise. All annoyance judgments were collected in a specialized test facility in which it was possible to produce high sound levels at very low frequencies. It was found that runway sideline noise is more annoying than that of aircraft overflights of similar A-weighted sound levels, and that addition of even minor amounts of rattling noise notably increases the annoyance of runway sideline noise.

1 - INTRODUCTION

The annoyance of aircraft overflight noise is customarily assessed in simple A-weighted units, since they predict annoyance judgments nearly as well as more complex noise metrics. Because the low-frequency content of noise produced by aircraft along runway sidelines (including that produced during takeoff run and during thrust reverser application) is proportionally greater than that of overflight noise, and because such low-frequency noise can cause secondary emissions of household paraphernalia, it is reasonable to inquire whether noise metrics adequate to assess the annoyance of overflight noise are also appropriate for assessing the annoyance of runway sideline noise. The present study was conducted to quantify (1) the relative annoyance of runway sideline and aircraft overflight noise and (2) the annoyance of rattle associated with low-frequency runway sideline noise.

2 - METHOD

2.1 - Test environment and procedures

All annoyance judgments were made in a large concrete chamber built for controlled generation of sounds at low frequencies and high sound levels. Twenty-eight test subjects were seated individually, facing a curtain hung in front of a full-scale plaster wall, behind which low-frequency drive modules were mounted. Two high-quality loudspeakers installed just behind the curtain, but in front of the plaster wall, reproduced the high-frequency (above 100 Hz) portion of the signals.

An adaptive paired comparison procedure was administered to solicit direct judgments of the relative annoyance of test signals. Subjects were instructed to judge whether the first or second signal presentation of each trial was the more annoying. The level of the variable level signal was then incremented or decremented depending on the subject's annoyance response.

Ten such trials were presented for each signal pair. At the end of the tenth trial, the signals were considered equal in annoyance. Signal generation and presentation, as well as all other aspects of data collection, were under real-time computer control. Figure 1 diagrams the signal generation and presentation hardware. The order of presentation of signal pairs was independently randomized and fully interleaved, so that subjects were unable to predict which element of which signal pair would be heard next. Four test sessions lasting approximately 25 minutes each were conducted per day. The A-level of the background noise at the subject's head position was approximately 41 dB.

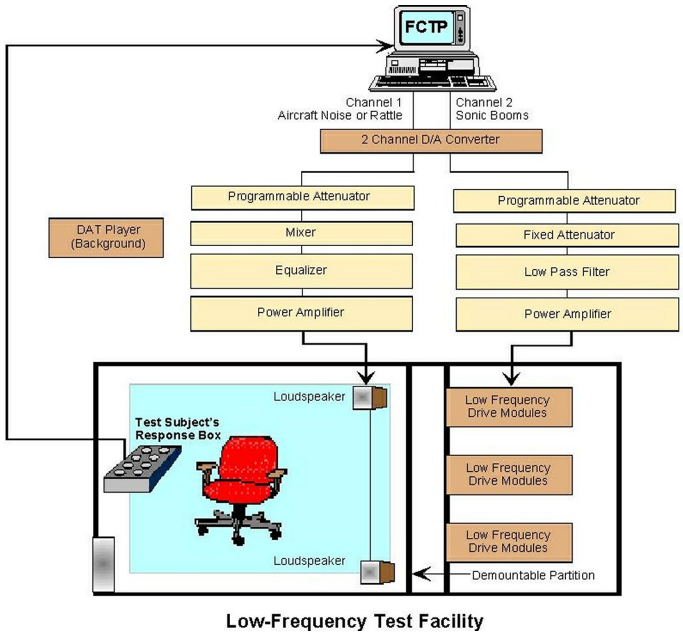

Figure 1: Illustration of instrumentation controlling administration of test conditions.

FIXED LEVEL SIGNAL	A-WEIGHTED PRESENTATION LEVEL (dB)	VARIABLE LEVEL SIGNAL	PAIRED COMPARISON NUMBER
Sideline noise recorded at 1,500 feet	70	B-727	1
		B-757	2
		Departure (”backblast”)	3
Sideline noise recorded at 1,500 feet with added rattle	70	B-727	4
		B-757	5
		Departure (”backblast”)	6
Sideline noise with 5 dB of C-weighted noise reduction	65	B-727	7
		B-757	8
		Departure (”backblast”)	9
Sideline noise with 5 dB of C-weighted noise reduction with added rattle	65	B-727	10
		B-757	11
Sideline noise with 10 dB of C-weighted noise reduction	60	B-727	12

Table 1.

2.2 - Test signals and presentation levels

Table 1 shows the five test signals presented at fixed levels and the three test signals presented at variable (subject-influenced) levels. Figure 2 shows the one-third octave band spectra of the signals at the listening position. All signals were presented for judgment as they would be heard indoors, at a fixed duration of 15 seconds each. In two test conditions, intermittent rattle was digitally added to the indoor sideline noise test signal near its peak. The rattle was added at a level that did not alter the A-weighted level of the test signal. The variable level signals were a flyover by a Stage II aircraft (a

Boeing 727), a flyover by a Stage III aircraft (a Bœing 757), and a recording of the rear of an aircraft departure ("backblast") noise.

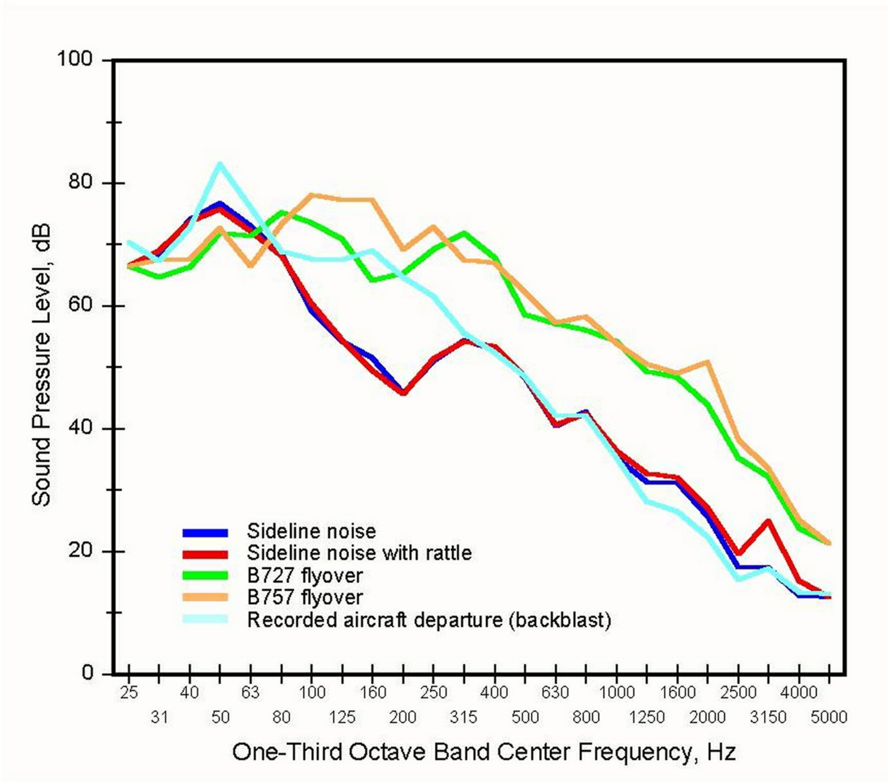

Figure 2: Spectra of test signals as measured at subject's head position.

3 - RESULTS

3.1 - Reliability of annoyance judgments

One paired comparison was administered for initial screening purposes, and to quantify the reliability of annoyance judgments. In this paired comparison the variable level signal and the fixed level signal were identical. Subjects unable to judge the variable level signal to be equally annoying when it was within 7 dB of the same (fixed level) signal were not permitted to participate in the study. Only two potential test subjects were unable to do so. Figure 3 shows the levels of the variable level signals when judged to be equal in annoyance to the same signal for each test subject. The level of the fixed signal was always 75 dB, whereas the mean level of the variable level signal at the point of subjective equality was 74.5 dB. Most subjects were able to judge the variable level signal to be equally annoying when it was within 4 dB of the same signal in this initial paired comparison.
The standard deviations of the differences between the levels of the sideline noise and the variable level signals at points of equal annoyance for the 12 paired comparisons ranged from 3.2 to 9.2 dB. Widths of the 90% confidence intervals of the mean annoyance judgments were 1 to 2 dB.

3.2 - Analysis of relative annoyance of sideline and overflight noise

Figure 4 displays the differences in A-weighted sound level between the variable level signals and the fixed level signals (sideline noise) when judged equal in annoyance by each subject for all 12 comparisons. (Many overlapping judgments are obscured by the plotting symbols.) Points above the heavy horizontal line at 0 dB indicate that the variable level signal was higher in level than the sideline noise signal at the point of subjective equality of annoyance. Therefore, if the levels of the sideline noise signals and the variable level signals are made equal, the sideline noise signals would be judged more annoying than the variable level signals.

3.3 - Analysis of relative annoyance of rattle

The six leftmost comparisons shown in Figure 4 were subjected to a repeated measures analysis of variance (ANOVA) to investigate the effects of rattle and type of variable level signal on differences between levels

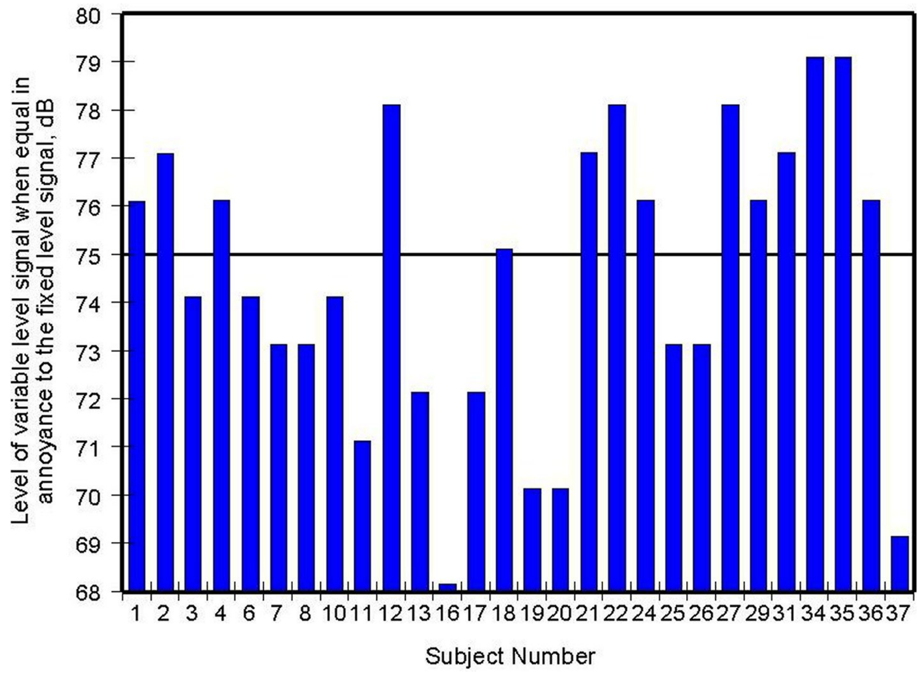

Figure 3: Level of variable signal when equal in annoyance to itself.

of comparison signals and sideline noise signals at points of subjective equality of annoyance. The ANOVA confirmed that the effect of rattle on annoyance judgments was a statistically reliable one. Figure 5 shows that the mean differences in A-weighted levels of the variable level signals and sideline noise signals at points of subjective equality were greater when sideline noise signals were presented with rattle than without. The greatest difference in judgments (4.6 dB) shown in Figure 5 is between the B-757 and sideline noise. The ANOVA also revealed a smaller but reliable effect of type of variable level signal on judged annoyance.

4 - DISCUSSION

4.1 - Annoyance of sideline noise

Although individual subjects= annoyance ratings were characteristically variable, mean differences in A-weighted signal levels for the group were orderly and readily interpretable:

- In all but one comparison, subjects would have (on average) been more annoyed by sideline noise than by the B-727, the B-757, and the backblast noise signals at equal A-weighted levels.
- Sideline noise accompanied by rattle would have been judged to be more annoying than sideline noise without rattle had the A-weighted levels of the variable signal and sideline noise signals been equal.

4.2 - Loudness level interpretation of findings

Another perspective on the current findings may be gained by expressing signal levels at points of subjective equality of annoyance in terms of Zwicker loudness level (Zwicker, 1977), a more complex spectral weighting procedure than the A- or C-weighting networks. Two recent studies of the annoyance of subsonic aircraft noise (Pearsons *et al.*, 1996, 1997) have shown that loudness levels calculated by Zwicker's procedures reduce the variability in judgments of the annoyance of aircraft overflight and other transportation noise.

Figure 6 compares the mean differences of comparison signal levels and sideline noise signal levels at points of subjective equality in all 12 comparisons as measured by A-level and Zwicker loudness level, in descending order. The mean A-weighted difference between the variable signals and sideline noise at points of subjective equality was 3.8 dB, whereas the mean difference with Zwicker loudness level was only -1.1 dB. Zwicker Loudness Level was clearly superior to A-level as a predictor of the relative annoyance of the present suite of aircraft noise signals.

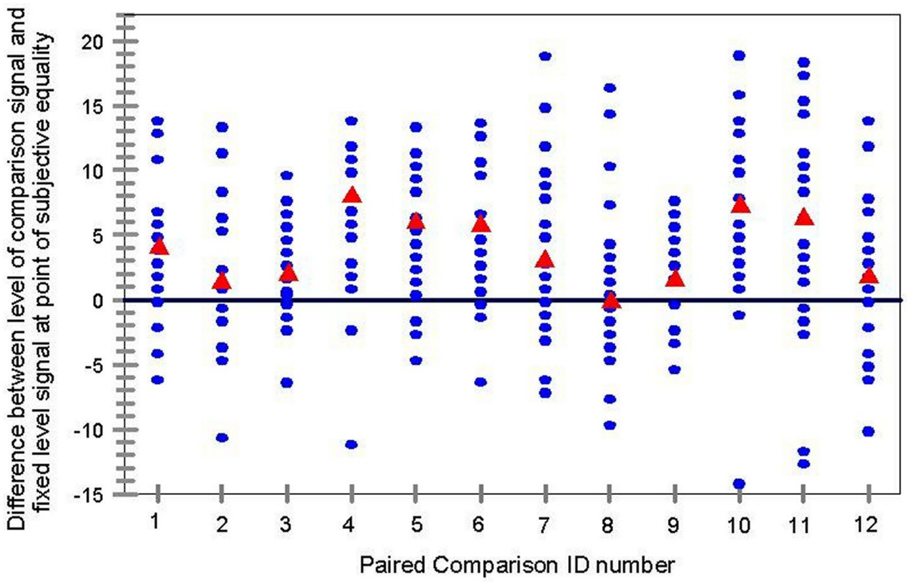

Figure 4: Differences between levels of comparison signals and sideline noise signals at points of subjective equality for all subjects; mean values are plotted as solid triangles.

5 - CONCLUSIONS

- Runway sideline noise is more annoying than that of aircraft overflights of similar A-weighted sound exposure level.
- The addition of even minor amounts of rattling noise notably increases the annoyance of runway sideline noise.
- Zwicker loudness level appears to be a better predictor than A-weighted level of the annoyance of low-frequency noise associated with runway sideline noise.

ACKNOWLEDGEMENTS

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REFERENCES

1. **Zwicker, E.**, Procedure for calculating loudness of temporally variable sounds, *J. Acoust. Soc. Am.*, Vol. 62, pp. 675-682, 1977
2. **Pearsons, K., Howe, R., Sneddon, M., and Fidell, S.**, Comparison of the performance of noise metrics as predictors of the annoyance of Stage II and Stage III aircraft overflights, *NASA Contractor Report 198348, Langley Research Center*, 1996

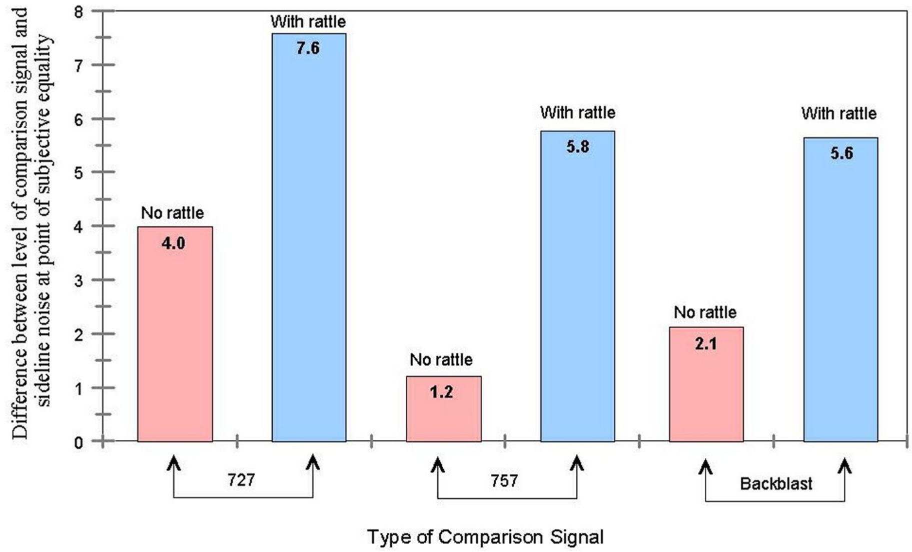

Figure 5: Difference between variable level and sideline noise presented with and without rattle when the two signals are judged equal in annoyance (mean judgments for 28 subjects).

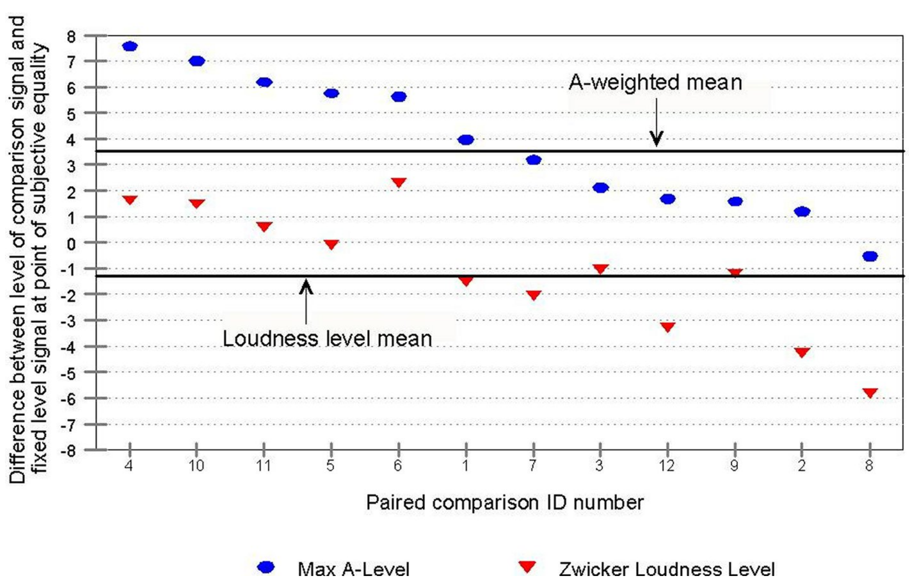

Figure 6: Comparison of A-level and Zwicker Loudness level as measures of relative annoyance of signal pairs.