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NEW MEANS OF REDUCING PROPELLER INDUCED CABIN NOISE

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Introduction

Noise levels in current propeller driven aeroplanes are substantially above those in jet engine powered aeroplanes. To achieve an acceptable level of passenger comfort in the Fokker F27 "Friendship", a noise reduction of at least 6 dB(A) was required.

The main noise sources of the aeroplane are the pressure pulses caused by the blades passing the fuselage. The resulting noise level in the forward part of the cabin is determined almost completely by the three first propeller harmonics, the so-called 4P (88 Hz), 8P (176 Hz) and 12P (264 Hz) frequencies. Unfortunately, the fuselage frames have fundamental resonance frequencies between 70 and 90 Hz, so initially the 4P-noise was transmitted effectively into the cabin. Vibration neutralizers reducing the 4P-noise with 10 dB have therefore been applied to the frames for the past 20 years. However, the only feasible noise reduction method for the 8P and 12P noise appeared to be the application of a flexibly mounted inner wall (ref. 1). Laboratory tests with double walls indicated a potential transmission loss improvement of at least 4 dB(A) for a weight increase of 3 kg/m². After in flight tests, however, the double wall by itself proved inadequate in reducing the noise with the required 6 dB(A). Two reasons brought about this disappointing result, viz. (i) flanking noise paths and (ii) the narrow airgap between the resiliently mounted inner walls and the skin. It was especially the flanking noise which caused the discrepancy with laboratory experiments. To tackle the flanking noise, some reverberating enclosures outside the cabin were filled with fibre glass blankets. These were installed under the floor (13 kg) and above the ceiling (18 kg), in addition to the already present blankets between the interior trim and the outer skin. The adverse effect of the airgap is due to its resonance frequency of about 120 Hz (ref. 2). Consequently, the airgap will act as a stiff coupling between inner and outer wall especially for the 4P. A solution for this was the use of vibration neutralizers on the inner wall. The finally selected design consists of three main parts :

1. Resiliently mounted interior.
2. The application of vibration neutralizers.
3. The addition of fibreglass in reverberant encloures.

In the following chapters the most important results and their associated weight penalties are presented. It should be noted that mentioned parameters such as weights are typical for the F27 Mark 500, the stretched version of the Friendship.

Measurement method and data analysis.

Most measurements were performed in the forward part of the cabin with seats removed, on 45 locations at the ear-level of a seated passenger (1.065 m above the floor). To determine the precise tuning of the vibration neutralizers it was necessary to perform measurements over a range of engine rpm's, between 13800 and 14600 rpm, or a frequency range for the 4P of 85.5-90.5 Hz. The two engines were adjusted asynchronous, resulting in a 1 Hz beat for the 4P-frequency. Under this condition short recordings of 5 seconds were adequate.

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The average of the 45 measuring locations was calculated on an energy basis and corrected for differences in flight conditions. The resulting average spectra were used to compare the many different configurations tested.

Double wall.
The resiliently mounted inner wall consists of 4 panels at each side of the forward part of the cabin, the luggage bins, the passenger service panels and the ceiling. The 15 mm thick honeycomb sandwich sidewall panels are relatively small, each containing 1 window of 5 mm thick acrylic. The weight of one panel is about 10 kg. They are connected to the frames with 4 rubber mounts, which are not located at the corners, but 15 cm inwards.
The noise levels reached after an extensive optimization programme were compared with the levels before the acoustical treatment (fig.1). The resulting noise reduction at cruise rpm is 5 dB(A) and 4 dB-SIL. It is emphasized that this result could only be achieved after blocking all flanking noise paths, but still includes the negative effect of the airgap. Because the 8P frequency is dominating the A-weighted spectrum, the noise reduction of 5 dB(A) results mainly from the reduced 8P level.

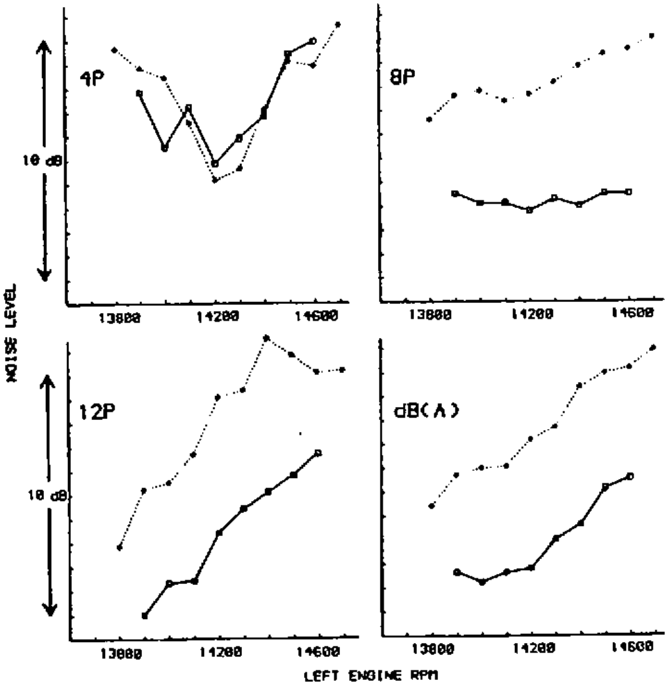

Fig. 1. Comparison of the noise levels before (dotted line) and after (drawn line) the acoustical treatment.

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In the aft section of the aeroplane a light-weight version of the new interior was installed for reasons of uniform appearance. The panels are not resiliently mounted, nor are vibration neutralizers used. Nevertheless, the noise reduction amounts to 2 dB(A).

Vibration neutralizers.

The noise-level was substantially reduced by the application of a "double wall", but to attain the target of 6 dB(A) an additional treatment was needed. Although the inner wall is isolated from the vibrating structure, it is still excited by the airspace behind. As the prevailing vibration levels were relatively low it was expected that fairly light vibration neutralizers mounted on the inner wall could provide an extra noise reduction. To suppress the dominant propeller harmonics, three differently tuned sets of vibration neutralizers were tested. To determine the optimum positions and the maximum spacing of the neutralizers, two different types of tests were performed : (i) determining the vibration modes of a single panel on a shaker, with and without neutralizers, and (ii) measuring the noise levels in-flight with different location patterns of the neutralizers. The final configuration consists of several hundreds of simply constructed but carefully tuned (± 0.2 Hz) and carefully positioned neutralizers. They are attached to the sidewall panels (4P, 8P and 12P neutralizers), the ceiling (4P and 8P only) and the cabin frontwall (4P only).

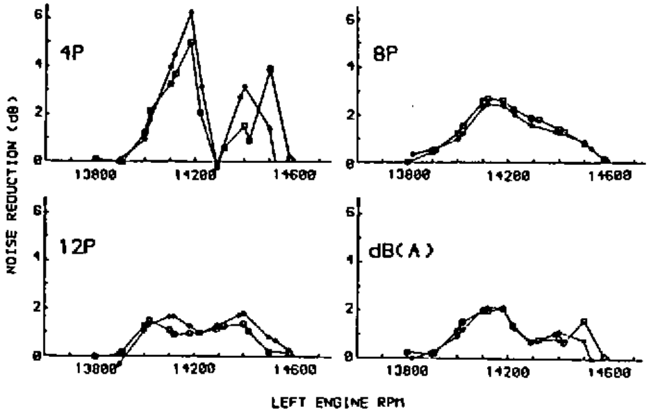

Fig. 2. Noise reduction of the 4P, 8P and 12P vibration neutralizers.

The noise reduction of the neutralizers with respect to the "new interior" without neutralizers is illustrated in fig. 2. The 4P neutralizers show peculiar noise reduction maxima on both sides of the cruise rpm. This typical behaviour is due to the interaction between the neutralizers on the frames and those on the panels. Nevertheless the noise reduction of the 4P neutralizers at the cruise rpm is about 1.5 dB. This is sufficient to cancel the negative effect of the airspace at this frequency. In addition, the effective rpm range of the 4P neutralizers has become wider than that of the frame neutralizers on their own. The 8P and 12P vibration neutralizers reduce the noise with 2.5 and 1 dB respectively over a fairly broad engine rpm region. The total effect of the neutralizers is 2 dB(A). This is a large noise reduction for a weight penalty of only 25 kg, especially if compared with the total weight/noise-reduction ratio of the new interior of 24 kg/dB(A).

Concluding remarks.
With the double wall, the vibration neutralizers and some fibre glass, the target noise reduction of 6 dB(A) was amply reached in the F27. The total weight increase of the aeroplane amounts to 170 kg.
The average A-weighted noise spectra on the seats in the forward part of the cabin before and after the treatment are plotted in fig. 3. It is noted that the presented spectra suggest a large improvement at the 4P-frequency, because they are given for left hand engine rpm 14200 , right hand 14100 , the last value being not exactly the cruise rpm. The noise reduction in the 4P band at actual cruise condition (both engines 14200 rpm) is somewhat less. The noise level in the F27 "Friendship" equipped with the new interior, although not as low as in jet-powered aeroplanes, is quite acceptable now.

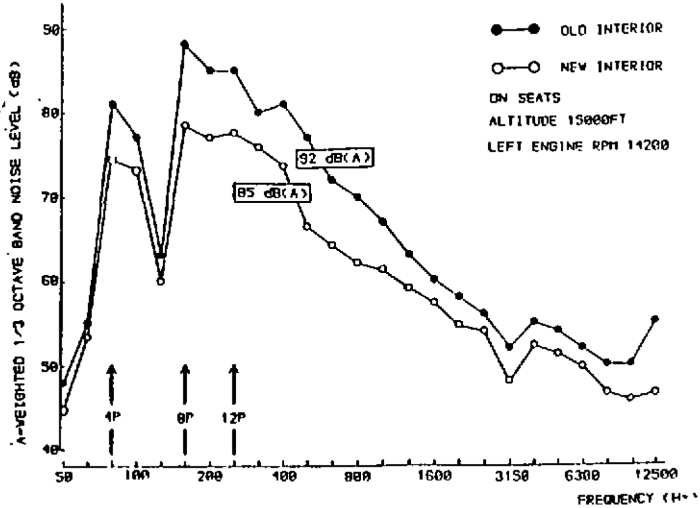

Fig. 3. Average noise spectra in the forward cabin, before and after acoustical treatment.

Further suppression of the noise, which is still dominated by the propeller harmonics 8P, 12P and even higher, is desirable, but it is expected that this cannot be obtained by improving the interior design without unreasonable high weight penalties. The next step will probably have to be an improvement of the acoustical characteristics of the main source, the propeller, by lowering its rotational speed or by replacing it with a propeller with an advanced blade shape.

References

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