MODEL STUDY OF DOUBLE TRAFFIC NOISE BARRIERS

by

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ABSTRACT

This paper investigates double barriers using a scale modelling technique.

SOMMAIRE

Cet article est une étude sur l'attenuation de bruit du trafic par des écrans doubles realisée à l'aide d'un modèle réduit.

Introduction

Each year, governments spend literally millions of dollars on building highway noise barriers. As a result, much research has concerned attempts to achieve the highest overall barrier performance at the least cost. Barriers of various shapes and materials have been tested. This paper examines the performance of double barriers and compares them to conventional single barriers used commonly on highways.

Method

It was decided to investigate double barriers using a scale modelling technique that uses tone bursts as a source signal and a gating unit to eliminate unwanted reflections (1). Variable frequency tone burst signals were produced using an oscillator, tone burst generator, power amplifier and high frequency loudspeaker. The loudspeaker which had been modified to approximate a point source was used over a range from 2 to 20 KHz. On the receiving side, the signal from a 1/4 inch microphone was amplified, high-pass filtered, and fed to the gating unit. The gating unit was used to eliminate undesirable reflections such as those sounds reflected off the laboratory ceiling and other objects. The signal present when the gate was open was integrated and fed to a level recorder. As the level recorder and oscillator moved in synchronization, continuous frequency response curves were plotted automatically. The technique allows one to evaluate the attenuation due to model barriers as a function of frequency in an ordinary room and to accurately include the effects of the ground surface.

FIG. 1 10' APART DOUBLE BARRIERS

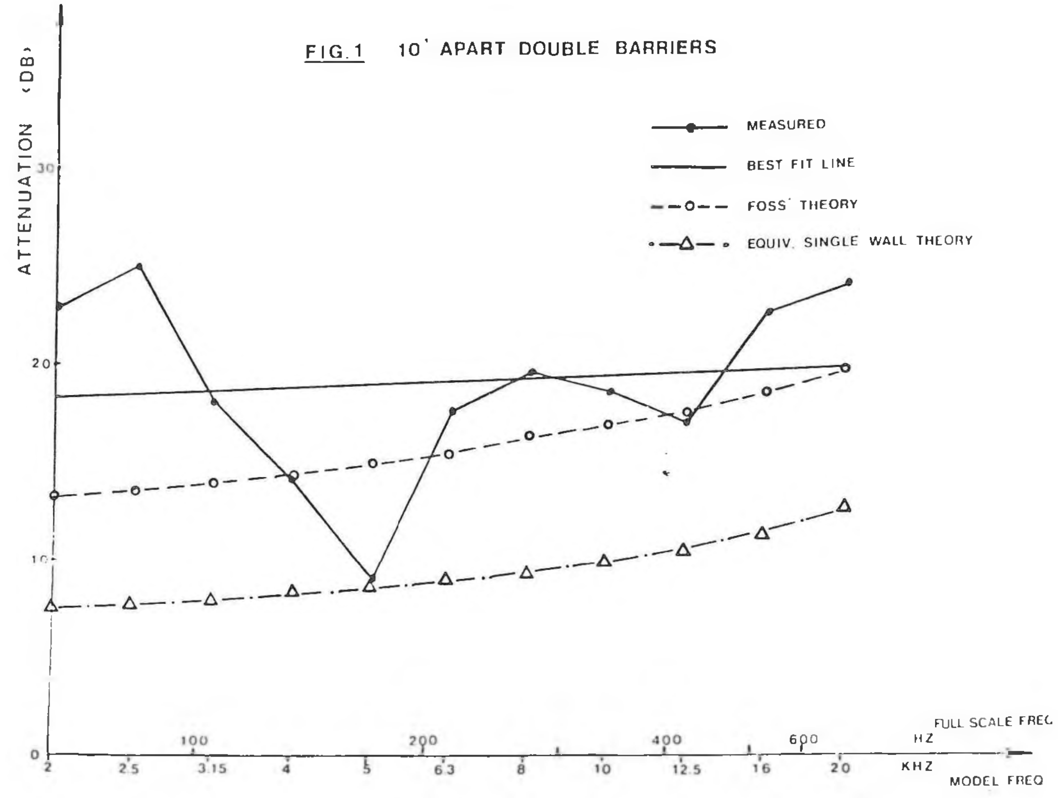
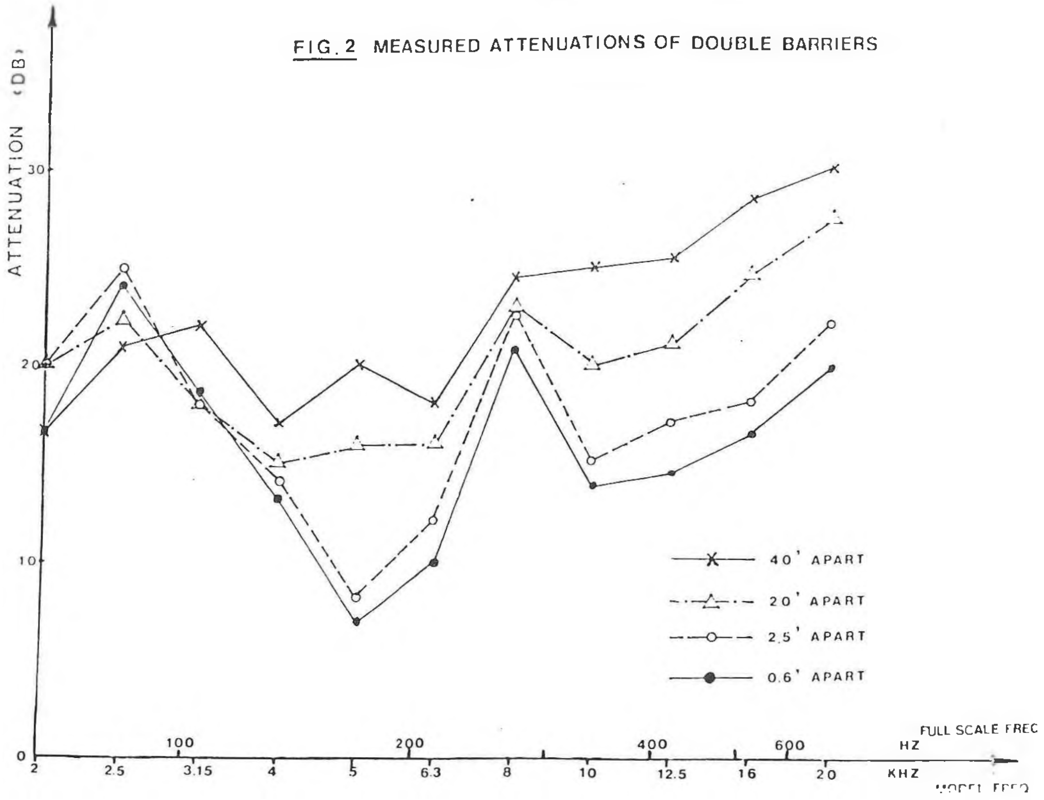


FIG. 2 MEASURED ATTENUATIONS OF DOUBLE BARRIERS



The model used a scale of 1:30. The position of the microphone and the source were fixed on each side of the barriers with 40 inches in between, which is equivalent to 100 feet in full scale. (Unless otherwise specified, all measurements refer to the full scale case.) The source and receiver heights were each 10 feet. The distance between the source and the first barrier was kept constant at 50 feet. Only the second barrier was moved so that barrier separations of 0.6, 2.5, 10, 20 and 40 feet were measured. The barrier was assumed to be infinitely long and the ground was assumed to be perfectly reflective. Any sound that travelled around the two ends of the barriers was eliminated by the gating unit. The height of the barrier was 15 feet. The frequency of the sound source varied from 67 Hz to 667 Hz (corresponding to 2 KHz to 20 KHz at model frequencies), thereby covering a critical but limited portion of the real-life frequency spectrum.

Double Barrier Prediction Techniques

In the past, as a very simple approach, an equivalent single wall theory has been used to predict double barrier performance based on work by Maekawa (2). This theory predicts that the combined attenuative effect of the two walls is equivalent to the effect of a hypothetical single wall located between the barriers, to the point of intersection of lines from the source and receiver to the top of each barrier. This method has been widely used but not thoroughly validated. Recently, Foss (2) found that the equivalent single wall method consistently underpredicts the amount of attenuation and came up with another approach. Foss calculated the diffractive attenuation caused by the first wall as if the other wall were not present. Similarly, he calculated the attenuation caused by the second wall as if it is by itself. The larger attenuation between the two was chosen and denoted as F. Then, he imagined a source located at the top of the first wall, and used this source to calculate an attenuation J. The sum F + J represents the actual attenuation due to the two walls. Both of these methods have been developed for free space and ignore the effects of ground reflections. Work at NRC by Isei et al (3) has clearly demonstrated that outdoor sound propagation over barriers depends on the complex interference of direct and ground reflected waves. The present work examines the attenuation of the double barriers including the ground reflections and compares the results with the previous two prediction methods.

Results

For a single barrier, in addition to the direct path over the barrier, there are three other possible ground reflected paths. Obviously, the combination of these different paths will create interference effects. By considering only the principal interference frequencies of the three paths, it can be calculated that there will be destructive interference at 167 Hz and 333 Hz if the source and receiver are 100 feet apart and the barrier is 91 feet away from the source. The calculated frequencies were confirmed by the measured results shown by the single barrier curve in Figure 4. It can be seen from this figure that the peak attenuation at the destructive interference peak is almost 20 dB above the constructive interference point. This is a considerable difference. It is clear that a simple smooth curve prediction of these measured results would not be a good representation.

Now, let us look at the double barriers case. There are then 8 different paths between source and receiver, and the situation is more complicated. It is not at all easy to predict theoretically the total amount of attenuation when ground reflected sound paths are included.

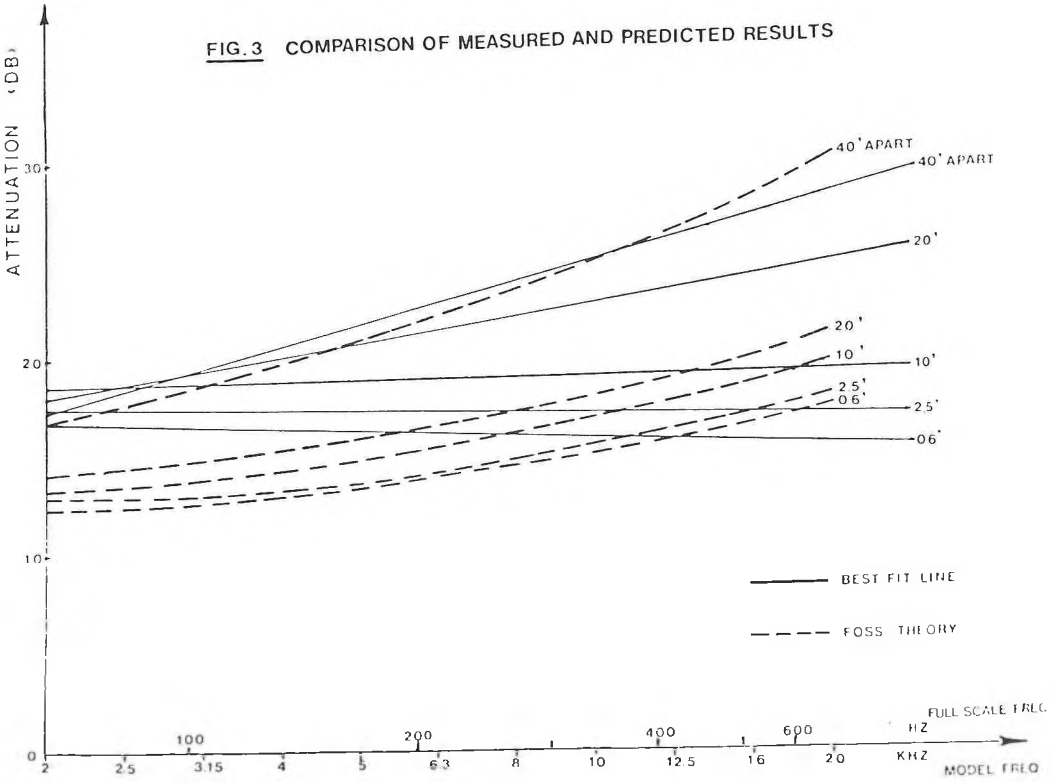


FIG. 3 COMPARISON OF MEASURED AND PREDICTED RESULTS

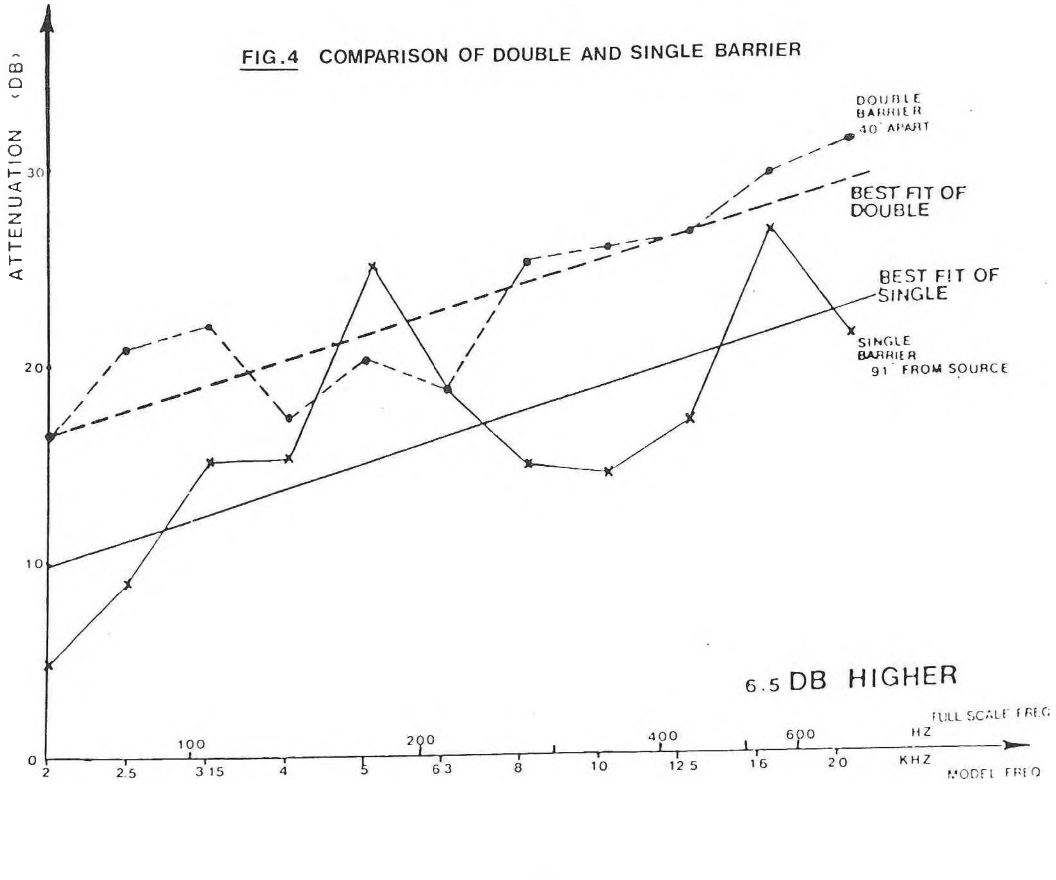


FIG. 4 COMPARISON OF DOUBLE AND SINGLE BARRIER

The first double barrier results are given in Figure 1, which is a plot of attenuation versus frequency for a 10 foot separation between barriers. The peaks and dips occurring at various frequencies are due to the interference among the different sound paths. Also shown are the predictions of Foss and of equivalent single wall theory which both ignore the ground effects completely. In order to consider the overall trends as the barrier spacing was varied, a best fit straight line of the measured results was obtained for each case. For this case, it shows an average of around 3 dB more attenuation than Foss's theoretical prediction. The equivalent single wall method predicted attenuations of about 6 dB less than Foss's method at all frequencies. This shows that the use of the equivalent single wall theory to predict double wall attenuations considerably underestimates their effectiveness.

Similar results were also obtained for double barriers spaced 0.6, 2.5, 20 and 40 feet apart. Figure 2 gives the measured attenuations versus frequency for those four barrier spacings. Figure 3 compares the best fit straight lines to the measured values of Figure 2 and the predictions of Foss's method. The best agreement between measured attenuations and predictions using Foss's technique occurred for the largest barrier spacing. The effectiveness of the double barriers is seen to increase as the separation between the two barriers increased. This increased effectiveness can be seen by comparing measured attenuations for a double barrier with those for a single barrier. Figure 4 compares measured attenuations for the double barriers with a 40 foot spacing with attenuations for a single barrier of the same height at the location of the most effective member of the double barrier pair. The double barriers attenuated more than the single barrier at all frequencies except at 167 Hz. By comparing the two best fit lines, the double barriers are about 6.5 dB higher than the single barrier. The single barrier would have to approximately double its height to give 6.5 dB more attenuation, which would presumably be much more expensive than a second barrier of the same height.

A block barrier was built by putting one more piece of barrier on top of the double barriers to give an outline shape like a building. The attenuations were measured for the block barrier and as illustrated in Figure 5, it shows similar performance to a double barrier. It seems that the building type barrier performs like a double barrier and is thus more effective than would be expected by the equivalent single wall prediction method.

A "T" cross-section barrier was also built by putting one more piece on top of a single barrier. Such a configuration has been found to produce 6.5 dB more attenuation than a similar single barrier (4). The result obtained in this study, as seen in Figure 6, shows that this barrier was not much better than a single barrier. It is possible that a thinner top piece would have produced improved results, but further studies of their effectiveness should be considered.

Conclusions

As a result of this work, several conclusions can be made:

1. It is essential to include ground reflections when predicting the attenuation of barriers.

2. In some cases, double barriers may be more econimical and provide better performance than a single barrier. They have not been considered seriously in the past because the commonly used single equivalent wall prediction method underestimated their performance.

FIG. 5 COMPARISON OF DOUBLE AND BLOCK BARRIER

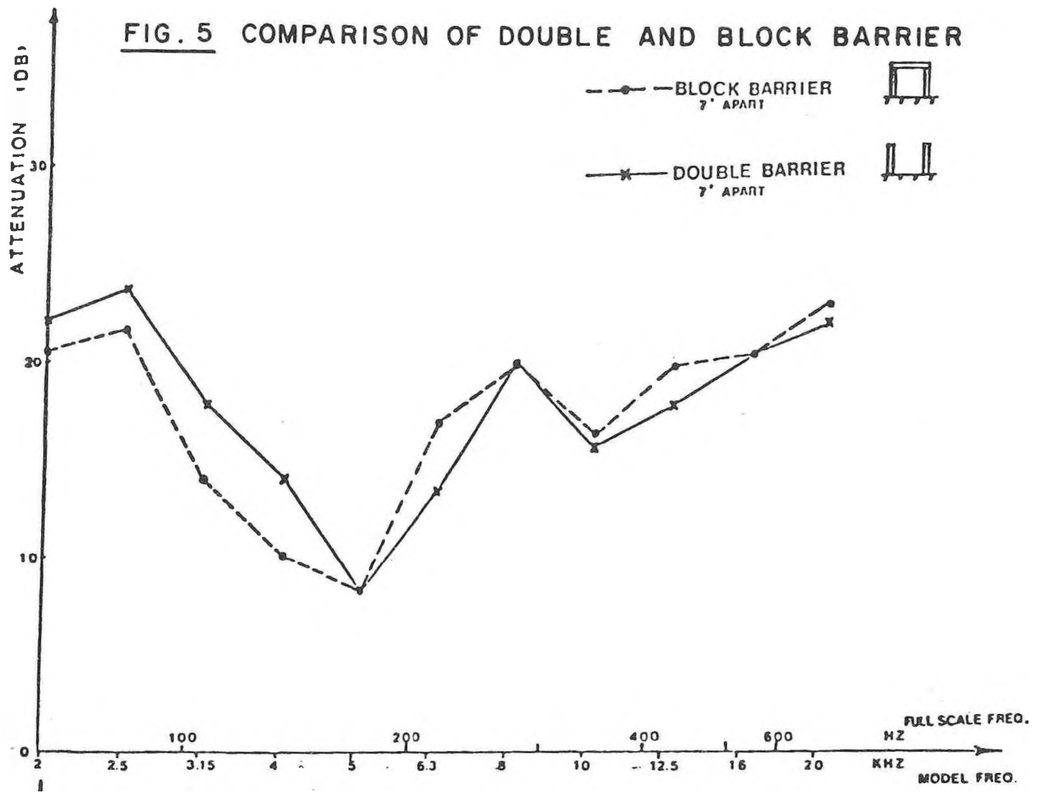
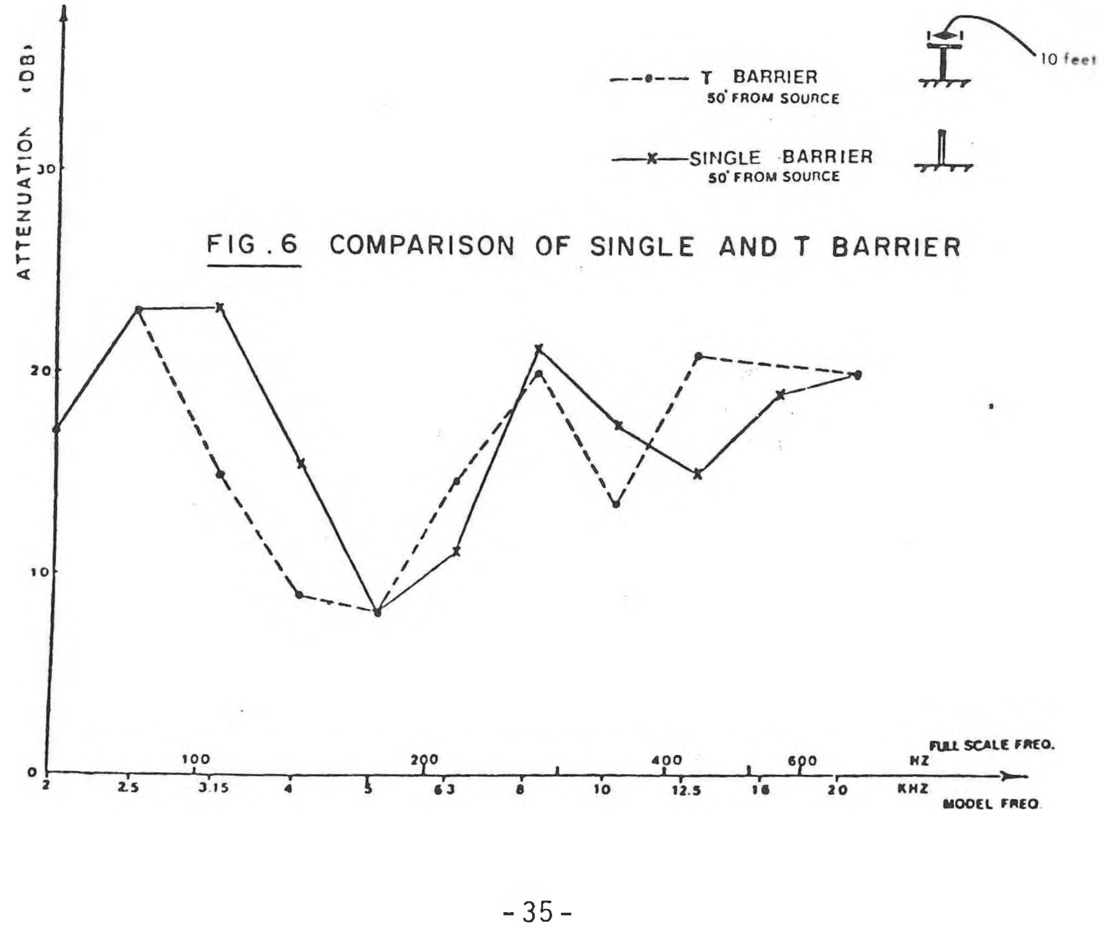


FIG. 6 COMPARISON OF SINGLE AND T BARRIER



3. Foss's theory gave better predictions of the double barrier attenuations than did the equivalent single wall theory.

4. The average performance of double barriers, with the ground effect, increases as the distance between them increases.

Acknowledgement

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References

1. "Modelling Environmental Sound Propagation". J.S. Bradley and C. Hugh. CAA meeting, Windsor (1979).

2. "Double Barrier Noise Attenuation and a Predictive Algorithm". R.N. Foss. Noise Control Engineering, Vol. 13, No. 2, pp. 83-90 (1979).

3. "Noise Reduction by Barriers on Finite Impedance Ground". T. Isei, T.F.W. Embleton and J.E. Piercy. J. Acoust. Soc. Am., Vol. 67, pp. 46 (1980).

4. "Highway Noise Barriers: New Shapes". D.N. May and M.M. Osman. J. Sound and Vib., Vol. 71, No. 1, pp. 73-101 (1980).

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OCTOBER 22 - 24, 1980

SUMMARY OF SESSION ON MEASUREMENT AND PROTECTION OF HEARING IN INDUSTRY

Thursday a.m., November 23rd, 1980

Chairman: A.Behar

Seven papers were presented in this session. Abstracts for the first six of these are as follows: --