BRITISH ACOUSTICAL SOCIETY

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ACOUSTIC TESTING FACILITIES.
16th June, 1971.

ACOUSTIC MEASUREMENTS IN DUCTS, STANDING WAVE TUBES AND AIR MOVING SYSTEMS.

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The Lecture will briefly consider three contrasting aspects of acoustic measurement which have been successfully employed in duct situations. These are:-

i) The measurement of the attenuating insertion loss of unit air conditioning silencers for broad band noise.

ii) The assessment of pane transmission loss values using pure sine wave tones.

iii) The use of in-duct microphone techniques to measure duct borne and duct generated noise in the presence of air flow.

Static Insertion Loss of Unit Silencers

During the considerations of setting up a test code for measuring the performance of unit silencers, it became clear that it was necessary to employ diffuse field reverberation room techniques for the accurate measurement of the self generated sound power levels under air flow conditions. However, although the acoustic insertion loss can be measured, employing the reverberation room technique, an alternative in-duct technique is also recommended. This has initial cost and subsequent operational advantages.

Basically, the apparatus measures the reduction of the in-duct sound pressure level achieved by the insertion of the given attenuator between a loudspeaker random noise source and a microphone. The arrangement of the test-rig constructed by N.A.Grundy at Sound Attenuators Ltd., is shown in Fig.1. It is appreciated that the performance of a duct mounted attenuator will depend on the exact duct modes being employed at given frequencies. Although some degree of random field incidence can be intentionally created by the use of wall mounted loudspeakers, the exact mode distribution will depend on duct size and become less predictable. Thus, to standardise on a more repeatable system, the loudspeaker noise source is specified to preferentially excite the (0,0) mode producing plane waves in the duct & constant phase across the plane perpendicular to the duct axis. The loudspeaker arrangement employed in our test rig is a baffle of 3 x 3 8" dual cone loudspeaker units in parallel, backed by an 18" deep box filled with Crown 200 glass fibre. This is connected to the 30"x24"duct through a double flexible connector, to minimise vibrational flanking transmissions to the ductwork. The anechoic termination is about a 4' cube filled with simple "stepped" acoustic wedges made up from 1" thick Crown 200 sheet. A test for the effectiveness of this termination, when the rig is employed with bands of random noise, is to carry out a microphone probe traverse along the axis of the duct at each of the proposed bands of noise. Although the use of random noise does not allow complete comparison with a pure tone standing wave tube, the variation of the measured sound pressure level along this axis may be taken as an indication of the anechoic termination's suitability. A peak to trough variation in this axial traverse of 3 dB may be thought of as 'representing' an absorption efficiency of 97%

Axial microphone traverses were taken, using octave and 1/3 octave bands of random noise and also using pure sine waves. Both the octave and 1/3 octave results indicated that this assembly easily satisfied a 3 dB criterion over the frequency range 125-4000 Hz extending down to 63 Hz for octave bands only. Pure tone sine wave tests indicated ± 5 dB fluctuations.

For the tests an array of 4 microphones was employed midway between the silencing test section and the anechoic termination, the average sound pressure level being taken as representative of the induct sound pressure level. Both 1/3 octave and octave broad bands of random noise were obtained from a specially prepared tape and it is very interesting to note that, over a period of operation of 12 mths, the overall stability of this arrangement - tape, tape-recorder, amplifier, loudspeakers, standard ducting, microphone, sound level meter - has not varied by more than 1 dB. Some results from this test assembly are shown in Figs. 2, 3 & 4 including an encouraging comparison with more conventional insertion loss techniques employing reverberation chambers.

Measurement of Sound Transmission Through Plates.

It has been shown that, by employing an array of finite size sound sources at one end of a duct, a known number of modes may be exclusively excited down this duct. This feature was incorporated into a 24" x 24" concrete measuring duct some 60' long, using 5 x 5 array of loudspeakers at one end, by P.Fryer at Imperial College. The test panel was located in the duct about 30' from these speakers and the remainder of the duct, behind the sample, filled with low density fibreglass to act as an anechoic termination. A traversing microphone, able to probe every location between the test panel and the loudspeaker sound source, was employed to monitor the incident sound field. The sound field transmitted from the far side of the panel in the region of the anechoic termination was monitored by a single microphone location immediately behind the panel. For all even modes, this microphone was located centrally within the duct close to the panel, while for odd modes it was placed near to the edge of the duct. This ensured that the microphone was at a maximum although its location across the panel was not at all critical. The loudspeaker arrangement ensured the production of plane waves (0,0) mode up to about 3 Hz, the sound pressure level across the duct also remaining constant with ± 0.5 dB. Although most of the test work was to proceed with plane waves(pure tones), it is interesting to note the approximate frequency range for other exclusive modes:-

Mode	Range
(0,0)	20 - 2380 Hz
(1,0)	300 - 2550 Hz
(2,0)	600 - 2250 Hz
(3,0)	890 - 2000 Hz
(4,0)	1150 - 1700 Hz

The measuring technique employs pure sine tones allowing detailed assessment of panel resonances. For frequencies between 20 - 200 Hz the sound pressure level at the incident surface of the panel was measured - the readings being taken in steps as small as 2 Hz. At higher frequencies, 40 Hz steps were employed, these being the separation between duct resonances but the microphone was located at a pressure peak in the standing wave formed away from the panel's surface.

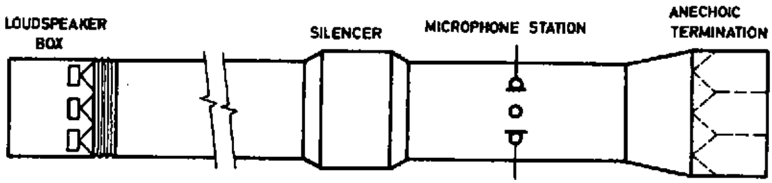
The modal sound pressure level patterns, which were only produced across the width of the duct, remain constant as the frequency is varied (above cut-off) and this feature was employed to study coupling between this driving mode pattern and the driven panel resonance pattern.

Checks were made to ensure that modal impurity was not affecting the significance of the results. Results from this experiment will be presented in the lecture, including a tie-up with more conventional room to room transmission loss evaluations by way of London's correction.

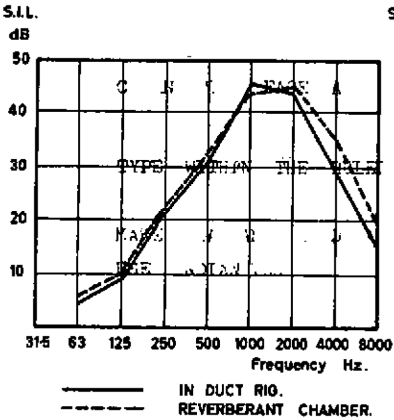
Fig.5 illustrates the influence of mastic shear layer damping on a 3 mm steel plate in the frequency range of 20 Hz to 1500 Hz for normally incidence plane waves.

Induct Measurement with Air Flow.

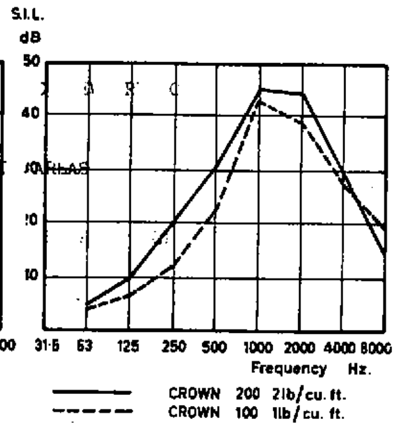
Induct measurements have been taken by Dr. J. Halstead on the noise generated from take off branches from large main ductwork. A 10" spur was studied being fed from a 24" diameter main duct run. Various flow rates were employed in the main duct and down this spur duct. The measuring microphone being located some 24" down this spur duct from the take off point. Satisfactory results were indicated and were considered accurate for no flow conditions in this stub duct, however flow noise generation from the microphone was suspected when flow was allowed down this 10" spur. A second more simple experiment was set up to study this microphone flow noise. In this experiment the 10" duct was fed from a well silenced air flow supply. The noise in this duct was determined by reverberation chamber technique and with suitable end corrections. This duct contained sound pressure levels below N.C.50 at all flow rates. However, the induct microphone indicated increasing sound pressure level with flow rate, this increase being greater without the wind shield than with the wind shield or nose cone. These results did not tally with those published by the microphone manufacturers for the effect of laminar wind flow to the microphone. Thus, for instance, under these turbulent air flow conditions at 2000 ft/min sound pressure levels of 95 dB at 125 Hz may be registered by the induct microphone when only 60 dB would be indicated from the more conventional reverberation chamber assessment of sound pressure levels.



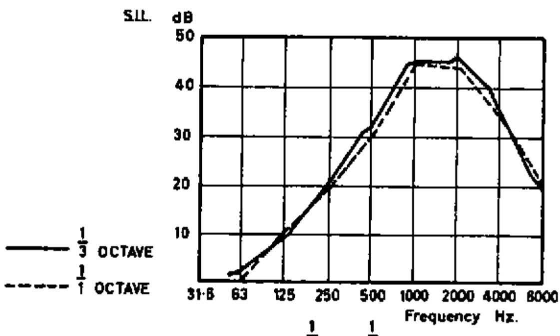
STATIC INSERTION LOSS TEST ASSEMBLY. Fig. 1



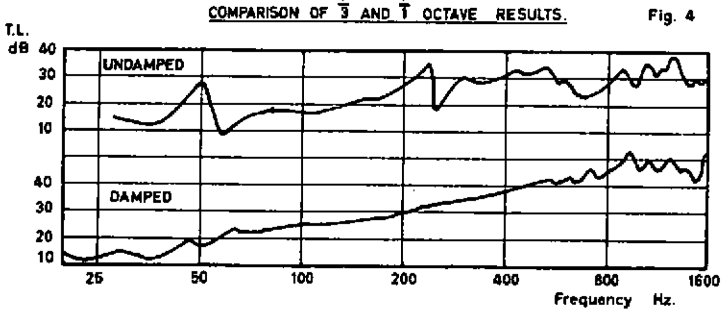
COMPARISON OF TECHNIQUES. Fig. 2



COMPARISON OF MATERIALS. Fig 3



COMPARISON OF 1/3 AND 1/1 OCTAVE RESULTS. Fig. 4



INFLUENCE OF DAMPING ON 3mm. STEEL PLATE. Fig. 5