Proceedings of The Institute of Acoustics

ENGINE NOISE TEST CELLS - ARE SPECIAL ROOMS STILL NEEDED?

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INTRODUCTION

The need for accurate measurements of engine noise has become more important in recent years as the legislation limiting radiated vehicle noise has increased in severity. Generally, anechoic test cells have been adopted, although some measurements have been carried out under semi-anechoic and under reverberent conditions. There has been considerable debate about the various advantages and disadvantages of the three approaches, the only point of agreement usually being that an undefined acoustic condition is unacceptable. One clear advantage of anechoic testing is that the directivity of the engine noise can be measured. Directivity can be important in many vehicle installations, where a useful correlation is found between test cell and vehicle results. In particular the variation of noise level from side to side of the engine is generally seen in the vehicle noise radiation, given that the engine is the major noise source and is installed longitudinally in the vehicle.

Reverberant engine test cell design is not always simple. If the engine were the sole equipment in the cell the problem would not be too severe, but normally there is a substantial amount of peripheral equipment which can modify the reverberation time. Frequent calibration of the room must be made. In general it is also necessary to employ a spatially sweeping microphone, which tends to increase testing times. The subsequent calculation of radiated total sound power carries no directional information.

The final decision on which technique is to be adopted should therefore reflect the use to which the information is to be put. In research and development work the more detailed information which is available from anechoic testing is generally regarded as essential, whilst allowing subsequent calculation of sound power.

The relatively recent development of sufficiently accurate methods of measurement of acoustic intensity around sources such as internal combustion engines has caused further thought on the subject of test facilities. The development and calibration of anechoic cell and acoustic intensity measurement techniques, togther with the limitations which are present in both are outlined below.

ANECHOIC ENGINE TEST CELLS

Although the authors are concerned with the noise from all types and sizes of engines, the provision of anechoic test cells for the largest classes becomes prohibitively expensive. The first anechoic engine test cell to be constructed at Shoreham was designed around the largest truck engine which was likely to be tested. With a radiating length greater than 1m, the establishment of the far field region of noise radiation is at least this far from the engine surface. Earlier measurements on such engines had suggested that this simple rule might apply and subsequent measurements have confirmed it. An adequate distance behind the microphone position to the absorbing surfaces had to be allowed, together with the depth of absorber on the walls. This led to a cell design some 7m square and 4.5m high. Calculations of the room modes showed some low frequencies which might be important, so that the original specification of 300mm (12") foam wedges was upgraded to 450mm (18"). The normal incidence acoustic absorbtion curve of the selected wedges is shown in figure 1.

The acoustic performance of the cell was tested using fixed sound sources, either mounted at the centre or edge of the cell, and a microphone moved along a straight path either on a diagonal or bisecting the cell as appropriate, in a manner similar to that used in ref.1. Single frequencies in the range 80Hz to 8kHz were used as this was thought to be a more stringent test than band filtered white noise. Two such calibration curves are shown in fig.1 for 100Hz and 1kHz with the acoustic source positioned in one corner and the microphone traversing a diagonal. These calibrations indicated free field conditions within 1dB down to 80Hz.

Subsequent anechoic test cells at Shoreham have been designed to a less demanding specification of free field conditions down to circa 250Hz. This was achieved by lining the cells with 100mm thick acoustic grade open cell polyurethane foam (Dunlop DF123).

ACOUSTIC INTENSITY MEASUREMENT

Following the pioneering work of Fahy (ref.2) and Chung (ref.3) the two-microphone FFT cross-spectrum method of acoustic intensity measurement was implemented at Shoreham to aid the identification and measurement of component source strengths on running engines.

The traditional method of source identification involves covering the entire engine in absorbent-backed lead sheet. This covering attenuates the noise such that uncovering a single source enables the contribution of that source to the overall level to be established. This process is a tedious and expensive operation and requires considerable care to achieve accurate results. It is also subject to errors due to the mass loading of the lead and the changes made to the local acoustic environment of each source.

Following basic acoustic source tests of the two-microphone acoustic intensity measurement system under free field conditions, a series of tests were run on two truck diesel engines, ref.4. For the main series of tests, carried out in one of the later designs of anechoic cells referred to earlier, measurements of sound power were made using the Ricardo standard 4-microphone array, the swept two-microphone acoustic intensity system, and an 18-microphone hemispherical array over an acoustically hard floor. A comparison of the calculated total engine sound power spectra is given in fig. 3, whilst the total engine and three component levels are compared in figure 4.

To check the user repeatability of the swept acoustic intensity measurement method the same engine component was measured by four different operators. The repeatability was found to be within 1dB (at the 68% confidence level) for most 1/3-octave bands.

In a short final series of tests acoustic intensity measurements were made on an engine installed under both anechoic conditions and in a relatively untreated 6.1m x 3.6m x 4.2m high test cell (the dynamometer being in the cell with the engine). These tests showed that useful results can be obtained under reverberent conditions.

DISCUSSION

The choice of engine noise test cell must depend upon the type of results required. If the sole object is overall radiated engine sound power measurement then either reverberent or semi-anechoic cells can prove satisfactory. However most engine development programs involve noise source identification and reduction and here the choice of technique depends upon the preference for sound pressure and directivity or sound power source ranking. Both may involve lead uncovering tests.

Acoustic intensity measurement offers the ability to measure component sound power without lead covering to a good standard of accuracy and if this technique is available overall sound power can also readily be determined without the need for a closely controlled acoustic environment.

The measurement of acoustic intensity does involve the operator being in close proximity to a running engine and this raises obvious safety considerations which robotics will eventually overcome. However, one shortcoming is the lack of directional information and at present acoustic intensity measurement must be regarded as a complementary technique to lead covering, rather than as a direct replacement.

REFERENCES

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FIG.1

NORMAL ABSORBTION COEF. DUNLOP DF123

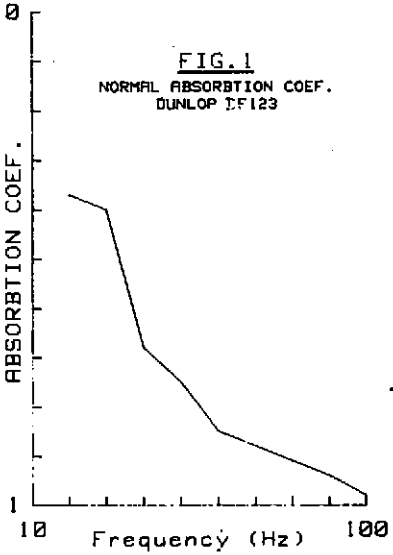

FIG.2

ANECHOIC CELL CALIBRATION

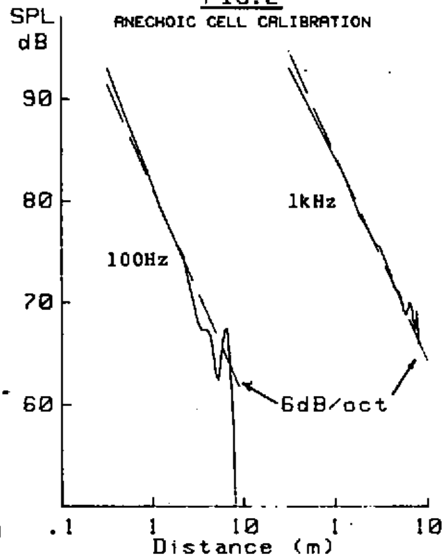

FIG.3

POWER SPECTRA-TOTAL ENGINE

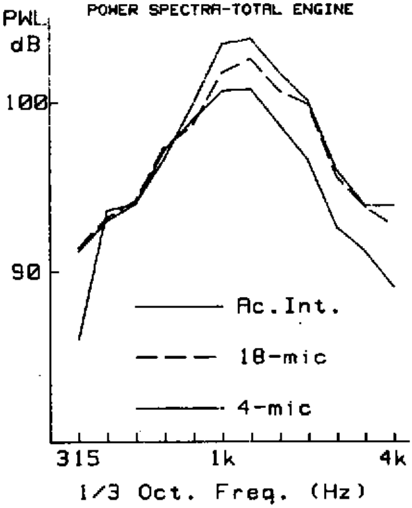

FIG.4

MEASURED PWL