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Measuring the Noise Emission of Industrial Machinery

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1. Introduction

The weakest link in the design of noise control in industrial installations is the provision of satisfactory noise data for the machines and equipment. One reason for this is that the demand for information on noise is relatively new and many manufacturers are unfamiliar with the subject, but the main problem is the lack of noise-test procedures which are suitable for use in industrial situations. There is, admittedly, a number of international standards for measuring equipment noise - some published and some still in preparation - but these tend to be too inflexible for use in the variable environments found in industry, even when described as "engineering methods". They may be useful as reference methods where the highest precision is required, but there is still a need for standard test procedures which can be used in industrial conditions.

To satisfy this need, the Oil Companies Materials Association (OCMA) has developed a number of noise-test procedures for use in the oil and petrochemical industries and these are contained in a publication entitled "Noise Procedure Specification, NWG-1" (1). They are intended to derive sound-power level, which is now recognised to be the most useful parameter for characterising the noise emission of equipment. The aim of these procedures is that they should be carried out by an engineer with a basic knowledge of acoustics who is equipped with a sound-level meter and a tape measure. As far as possible they have followed the principles of ISO Standards (2), (3) and the departures have only been made when these standards were considered unsuitable in industry. For example, they give a general scope of the test method but allow a flexibility so that the engineer can make variations to suit the test environment; he must however give full details in his test report of what he has done. This is based on the principle that, for many purposes, results with reduced precision are better than none at all, so long as their limitations are adequately documented.

A particular feature of the OCMA procedures is that they distinguish between "small" and "large" sources and propose different techniques for measuring around them. It is a distinction which still does not seem to be generally recognised in other standards. In practical terms the distinction depends on acoustic considerations rather than the actual physical dimensions of the source. If the dimensions of the source are small in relation to the measuring distance from its surface so that measurements can be made in the far field, the source can be regarded as "small". But if the environment is such that the measurements cannot be made sufficiently far away, so that they are in the near field, the source becomes "large" in relation to the measuring distance.

2. The Small-Source Method

In general, the OCMA test procedures are based on the assumption that the equipment under test will be standing on a reflecting plane and the preferred measuring surface is a hemisphere whose radius is large compared with the source dimensions. Following the definition of ISO 3744 (2) this means that the radius must be at least double the internal diagonal of the reference surface. To minimise acoustic near-field errors, the measuring distance from the source must be at least 1m. It may be noted that ISO 3744 allows a minimum distance of 0.25m and this can lead to a consistent error in the sound-power level of 3dB up to 200Hz due to the acoustic near-field effect (4).

Before making detailed measurements, the engineer should make a preliminary survey around the source, using his ears and his sound-level meter set to dB(A). This is an important feature of the OCMA procedures and will indicate the presence of directivity in the noise emission or of background noise from other equipment; it will also draw attention to tonal components. The choice of microphone positions will depend on the results of this survey.

The preferred microphone positions on the hemisphere include an overhead position and four positions equally spaced around the sides of the source. If the source has any directivity in its emission (where the sound-pressure level is 6dB higher than in neighbouring positions) a measurement must be made in the direction of the maximum and three other measurements must be made at the same height, equally spaced around the hemisphere. The purpose of these extra positions is to weight out the effect of the maximum on the average sound-pressure level (and therefore the sound-power level). Information on directivity may be important to the noise levels in work areas near the source.

When it is not possible to locate a microphone above the source, four other positions must be used to replace the overhead position; they should be at a significantly different height from the four side positions and as near overhead as practical.

A correction for a semi-reverberant test environment can be obtained by making a further set of measurements on a second hemisphere whose area is about four times that of the first. The second sound-power level is compared with the first and if it differs significantly (by more than 2dB) an environmental correction is obtained from a set of curves relating the difference to the ratio of areas. This method is based on a proposal by Diehl (5) and has the advantage that the correction can be made without the use of special equipment such as standard sources or reverberation-time recorders. They may be more precise but they are not usually available in most industrial tests.

3. The Large-Source Method

Although the small-source method is preferred for technical reasons there are many occasions when it cannot be used because of high background noise or physical impediments at the required measuring positions. A correction for background noise must always be made, but this is not valid if the background noise is within 3dB of the source noise. The measurements must then be made closer to the source so that its own noise predominates.

This means measuring in the near field of the source and it introduces errors into the calculation of sound-power level. The first of these is due to the acoustic near field and can be minimised by ensuring that the measuring distance is at least 1m, as in the small-source method. The second is due to the geometric near-field error (4) and results from sound energy arriving at the microphone over a wide angle, due to the size of the source. For a large source and a small measuring distance the error can amount to 3dB. However, a correction can be calculated from geometrical considerations and this must be applied to all sound-power level calculations for large sources.

The best approximation to the hemispherical measuring surface which can be used for large sources is the conformal surface recommended in ISO 3744. This is a rectangular parallelepiped (or cuboid) with rounded corners and edges so that all points on it are equidistant from the source. It is suitable for sources which radiate evenly in all directions (defined as a variation of less than 6dB over the measuring surface). Five measuring points are recommended in the OCMA specification, one overhead and one at each side. If the overhead position cannot be made, four additional positions must be made at different heights around the sides.

Where the variation over the conformal surface is greater than 6dB, OCMA proposes that the surface should be divided into measuring-surface zones, over which the sound-pressure level is acceptably constant. The sound-power levels of these zones are calculated separately and then summed to give the total sound-power level of the source.

Diehl's two-surface method cannot validly be used to derive an environmental correction for large sources because it assumes an inverse-square-law variation near the source and this does not apply in the geometric near field of a large source. Nevertheless OCMA recommends deriving a sound-power level from a second measuring surface. If it agrees with the first (within 2dB) this is a good indication that the environment is not affecting the measurements. If it does not agree, an environmental correction must be derived from the Room Constant, by making the best estimate of the sound-absorption coefficients of the various surfaces of the room.

There is a third type of large source in which discrete radiating parts can be identified and it is no longer practical to consider a single enveloping measuring surface terminated by the ground. Equipment of this type must be treated as a number of separate sources whose sound-power levels must be measured separately, using small-source or large-source methods as appropriate.

A special type of source dealt with in the OCMA specification is the line source, which could be a noisy pipe or a row of closely-spaced burners in the wall of a furnace. For such sources a cylindrical or semi-cylindrical measuring surface is more appropriate, but as the sound energy arrives at the microphone over a wide planar angle there will be a geometrical near-field error in the derivation of sound-power level. It can amount to 2dB, but a correction can be made according to the subtended angle of the source.

4. Vibration Measurements

Finally, there is the situation often encountered in machinery rooms where several sources are contributing to the general reverberant noise level and they cannot be distinguished acoustically. For this case the OCMA specification recommends the use of vibratory-velocity measurements for deriving sound-power levels. There is a problem in knowing the radiation efficiency of the radiating surface, so the calculated sound-power level may often be too high if it is assumed to be unity. But there is a number of circumstances where it approximates to unity so that the derived sound-power level is reasonably correct. This occurs for example when a pipe or a ducting wall is excited by an internal sound field, so the technique can be of considerable value in assessing noise from pipework in compressor rooms.

5. Applications of the OCMA Specification

The general principles proposed in the OCMA specification have been used for a number of years in the oil industry and individual noise-test procedures have been derived from them for particular items of equipment. These include furnaces for heating hydrocarbon liquids, large fans for air-cooled heat exchangers, and refinery flares; other applications are now being considered.

As these procedures become more widely known it is hoped that more equipment manufacturers will use them so that the noise data they provide for their equipment will have been obtained by a recognised test method and can be used with confidence in the design of oil and petrochemical installations. In some cases in the oil industry there is already a contractual requirement that the manufacturer should test his equipment by a procedure based on the OCMA specification. Much of the equipment involved is not specific to the oil industry so the data obtained may be of value to other industries.

These noise-test procedures are part of a complete system of noise control proposed in the OCMA specification and this covers administration, noise tests, calculations, and noise propagation from installations into neighbourhood areas. They will need improving with experience but they represent an important step in practical noise testing and in the design of noise control in industrial installations.

6. Acknowledgement

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7. References

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