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"NEIGHBOURHOOD NOISE"

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CONTROL OF NEIGHBOURHOOD NOISE BY MONITORING OF ENVIRONMENTAL NOISE LEVELS.

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1. Introduction

In recent years it has become more widely accepted that man does not necessarily have the right to inflict his noise on other people; he no longer has the automatic right to tip his acoustic rubbish over the fence. It has been said that the general background noise level throughout the country is increasing at the rate of 1 or 2 decibels per year. This in itself is bad enough, but in addition to this, with the increasing standard of living, the average British householder is becoming much less tolerant towards the minor discomforts of life which would previously have been drowned under the multitude of other large discomforts. Once his attention has been focussed on a particular noise from a factory or an industrial estate due say to the addition of new noisy machinery or plant, he will not be content again until the noise has been reduced to way below the original level.

The establishment of noise abatement or noise control zones is a positive step to control the noise nuisance in certain areas. However, as with most legislations, there are a number of problems associated with the establishment and enforcement of these zones.

The task of controlling the noise within a given zone can be divided into a number of stages. Firstly, a problem area must be defined and an investigation initiated. Secondly, it is necessary to confirm that the noise levels are unacceptably high - or will be too high in the case of a proposed industry or building site. Thirdly, the noisy elements must be identified and suitably treated; and lastly some form of monitoring is required to ensure that the noise levels meet the requirements and continue to meet the requirements.

The problem of trying to decrease the noise in an area in which there is a multiplicity of noise sources can be solved in two different ways:-

1.1. Monitor the acoustic power output around each individual source and if it is above an acceptable level, ensure that it is reduced to that level. This method can be applied to individual factories, or even individual machines within those factories.

1.2. Monitor the noise at the receiver, identify the offending noises with individual sources and reduce the noise output of those offending sources.

Both methods have several advantages and disadvantages, but we are concerned in this paper only with the latter.

2. The Identification of one Source Among Many

Each particular noise source in a noise abatement zone has its own sound signature and the local residents have usually recognised that signature and know the source of the noise only too well. Sometimes it is only obvious to the engineer or inspector who has a good knowledge of the local industry and its noisy machines. There are, however, times when the problem is not so easy and it is necessary to determine the contribution to the total noise of a multiplicity of sources. In this case a number of methods of identifying the various sources are available.

2.1. Sequential Shut-Down

One of the most effective methods of detecting individual noise sources in the industrial complex and of assessing the relative contribution of various factories and machines to the total noise is simply to take noise measurements while individual noise sources are started up or shut down. The major problem associated with this method is that or organisation. Advantage must be taken of natural start ups and shut downs, and in some cases factories must be asked to co-operate in starting and finishing a few minutes early or a few minutes late in accordance with a specific time-table.

In some instances it will be possible to detect changes in noise level at the monitoring position using a dBA scale, but in most instances it would be sensible to record the noise without any weighting networks, in order that, if necessary, detailed spectral analysis can later be carried out on the noise to determine which parts of the frequency spectrum or time spectrum are eliminated when individual factories or machines are stopped. The recordings can always be played back through weighting networks at a later stage, if required.

2.2. Frequency Spectrum Analysis

This can be used in conjunction with the sequential shut-down in which case course filtering of the before and after signals will probably be sufficient to detect the changes in spectral shape. Alternatively, if the sequential shut-down is not practicable, then the problem may be clarified if the frequency spectrum at the environmental monitoring point is compared to that at the individual sound sources. This is only applicable in certain limited instances when for instance the environmental noise is of a tone quality. In general the sound level meter with octave filters is of little practical use here for it is necessary to use a much narrower bandwidth to adequately define the variation in amplitude with frequency. It may, therefore, be necessary to resort to 1/12th octave bandwidth or even narrower to separate the tones of different machines. One of the problems associated with this type of approach is that the acoustic signature of the source is modified due to reflection and standing wave effects and also the preferential attenuation of high frequency sound with distance.

Also, unless simultaneous recordings are made at each noise source and at the environmental monitoring position, any conclusions about the similarity or lack of similarity between source and receiver is based on the assumption that the source state has not changed in between the two recordings.

2.3 Time Spectrum Analysis

This again is only applicable in certain instances when one or more of the noises being monitored has a recognisable fluctuation in level (or frequency) with time. Some of these fluctuations may be of a random nature such as is found on a building site, whereas others may be more regular such as the drop forge. It is important especially in the first instance that simultaneous recordings are made at both source and receiver in order that the variation in amplitude with time at the receiver may be adequately compared to that for the individual sources.

2.4 Signal Correlation

Correlation techniques in the author's experience have very limited use in this particular application but are included for completeness. Correlation is a way of assessing the degree of similarity of two things and in this case we are concerned with comparing acoustic wave forms as a function of time. The correlation coefficient is defined as the long term average of the product of the two waveforms, thus at every moment in time the instantaneous value of one of the waveforms is multiplied by the instantaneous value of the other. If the two signals are similar, the resulting product will be high. At the other extreme, if one signal is an inverted version of the other, then the product will be large and negative. If the two signals are completely dissimilar then the product will be near to zero.

In the situation where two microphones a few feet apart say, are used to monitor the noise of some distant source, then a maximum cross correlation coefficient will occur when the microphones are at equal distances from the source. In correlation, instead of the microphones positions being changed, one signal is delayed progressively with respect to the other while the product is found. We can therefore, see the variation in cross correlation function with time delay and with a knowledge of the geographical locations of the local noise sources with respect to the two measuring microphones,it should be possible to identify each cross correlation peak with a noise source. There are several drawbacks to this method, the major ones (apart from the complexity) being the confusing effect of the reflections which can broaden some correlation peaks and even introduce completely new ones.

Another way of applying correlation techniques to this problem of detecting one sourse among many is in the use of the normalised cross correlation co-efficient. This would simply be a measure of the degree of correlation between the signal as recorded at the measuring site, and the signals as measured near to each particular source. Thus it is possible to construct a table giving the degree of similarity (in any frequency band) on a percentage basis say, between each particular source and the receiver. This method again suffers badly from reflection effects etc. but the one factor that eliminates it as a realistic possibility is the necessity of using not only simultaneous recordings of source and receiver, but also phase coherent recordings, which adds considerably to the complexity of the equipment.

2.5. Directional Microphones

These do have limited use in identifying one noise source among many. In fact they are not quite as directional as is commonly thought being at best some 20 dB down at 90^{o} to the direction in which they are pointed. Both line microphones and microphones with parabolic reflectors fitted are used, the length of the line microphone being about the same as the diameter of the parabolic reflector for the same directivity. The microphone used with a parabolic reflector has the advantage of a high signal to noise ratio, due to the focusing of sound onto the microphone, but its directivity is proportional to frequency, being poor at low frequency and good at high frequency. This is also true of those line microphones in which directivity is maximised although there are several available in which the directivity has been held constant with frequency in which case the directivity is usually less than 9dB at 90^{o}.

3. Practical Approach to Source Identification

There are several advantages and disadvantages associated with both the monitoring of environmental levels and also the monitoring of sound power levels. The chief drawback of environmental monitoring apart from the complexity of source location is that measurements made throughout the day may be greatly affected by other noises such as from road traffic or aircraft. Obviously measurements made near to the noise source are relatively unaffected by these other extraneous noises. On the other hand, one of the main disadvantages of monitoring the sound power level at source is the inherent difficulty of measuring total power radiated. This becomes more serious as the size of the machine or factory increases in that it is usually only practical to take measurements up to a certain height above the ground and the upwards radiation from the source is often not measured. There is also some difficulty in translating these sound power levels at the source to meaningful sound pressure levels at the receiver, bearing in mind such factors at the polar radiation patterns of the sources, reflection, wind effects. etc.

Obviously the resources that a country can use for a project such as the establishment and control of noise abatement zones are not unlimited and so levels must be decreased in the most effective way. In many instances, although there may be a multiplicity of noise sources, it is a relatively simple matter to identify the main offenders and would be a complete waste of time and effort to monitor the sound power levels of all noise sources in the area. On the other hand, once measurements of all major noise sources in an industrial complex have been made, the subsequent control of noise in that area should be somewhat easier. Having once established acceptable noise levels, the simplest way of control is in ensuring that any future buildings or machines introduced into the area conform to suitable noise regulations. Periodic checks can then be made to ensure that noise levels in the area have not increased. If it is found that they have, then it is a simple matter to see what changes have been made in the industrial complex since the previous measurements.

In most cases though a quick answer is required to "Neighbourhood Noise" problems and it is quite obvious that there is no single solution. A procedure might therefore be followed which would provide sensible guidelines for approaching all types of problems. A suggested procedure is as follows:

1. If it has been decided that a certain residential area may be suffering too much noise, measurements should be taken at either the address from which the complaint came or the house nearest to the suspected noise sources. If the noise level is found to be too high then:-

2. From a knowledge of the local industry and the likely noise sources it must be decided whether the main offenders can be detected simply by listening. Directional microphones can be invaluable at this stage. It is extremely useful to be able to diagnose a problem on the spot rather than taking numerous recordings back to the laboratory to analyse. In many situations there is no direct line of sight between the sources and the parts of a residential estate where the sounds are annoying, in which case it may be necessary to probe further and move to the end of the street or take measurements from an upstairs window etc., and in this type of situation the additional information provided by a directional microphone - probably coupled through an amplifier to headphones - is well worthwhile. If the sources cannot be determined in this way then:-

3. Determine the times at which factories or machines are started and stopped and arrange a timetable with the factory owners such that by process of elimination the offending factory or machine can be identified. If this is either not possible or the results of analysis are inconclusive then:-

4. If the offending noises are either discrete frequency or have a recognisable time variation, it will be necessary to make recordings outside each noisy factory, adjacent to each major noise outlet, and then compare the frequency and time spectra of each position with those for the residential site.

5. If these methods fail, then it will probably be necessary to resort to measuring the acoustic power radiated from each individual factory or even machine in the industrial complex.

The use of correlation techniques has not been included in this procedure because of the relative complexity of this way of tackling the problem. It may, however, be an attractive alternative in some situations where the problem is very complex and access is available to suitable equipment.

The concept of noise abatement zones can be applied both to those areas which are at present too noisy and those areas which are not too noisy (by today's standards). The short term solution to controlling noise is to concentrate all our attention on those areas which are at the moment too noisy i.e. zones in which noise must be reduced to a more tolerable level. In this way we would ultimately ensure ideally that no residential area in the country had to tolerate above a certain level of noise. However, the areas which are often in most danger of having their background noise level increased are the areas which are at present very quiet. These are the areas which would be particularly sensitive to increases in noise levels from industry or construction plants. And it is not sufficient to say that because nobody lives there, because it is so remote, it doesn't matter if noise is introduced, for with the increasing chaos of city life, the peace of the country-side is becoming a very valuable commodity. In addition, to investigating those areas which are at the moment too noisy, it is equally important therefore, in the long term, to control the noise in quiet areas.