CASE STUDY OF A LOW FREQUENCY ENVIRONMENTAL NOISE PROBLEM FROM A LARGE AND COMPLEX INDUSTRIAL PLANT

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INTRODUCTION

Over the last ten years, SRL Engineers have handled an increasing number of environmental noise cases involving low frequency noise (20 - 80Hz) causing a nuisance within houses.

SRL were recently retained to investigate a low frequency complaint from residents in a terrace of houses close to a cement works (See Figure 1). The residents were complaining of a rumble which was intermittent in nature, mainly heard at night, but would sometimes last for several days only to disappear for weeks. At its most severe, the noise was said to have "shaken pictures from walls, rattled plates off draining boards and set up ripples in a fish tank".

Prior to SRL's involvement, a number of organisations had looked at the problem without drawing any firm conclusions as to the source of the noise. Several ideas were put forward which included: wind noise through a nearby railway bridge, large pumps a kilometre away, generators on the cement works site and over-imagination on the part of the mainly elderly residents.

The local authority representatives were convinced that a valid nuisance existed, they were however, unable to identify the character or source of the noise with their limited equipment resources. It was for this reason that they engaged SRL to:-

a) measure and record the noise
b) assess its 'nuisance value'
c) determine the precise source of noise
d) recommend means of treatment

The following case study illustrates how this was achieved.

CASE STUDY OF A LOW FREQUENCY ENVIRONMENTAL NOISE PROBLEM FROM A LARGE AND COMPLEX INDUSTRIAL PLANT

Although this is a specific case study, the procedure used has been found to be successful for a range of projects of this type.

CASE STUDY

1. Subjective Assessment of Complaint

The first step in any such project is to 'interview' as many people involved as possible, in an objective fashion, to determine:-

Where and when the noise occurs
The character of the noise
Other directly relevant facts which affect the noise level

In this instance it emerged that:-

a) The problem was always experienced indoors (worse with window closed). The noise varied in level in different positions in the room. The majority of rooms in the house were affected.

b) The problem was intermittent but seemed to occur for periods of up to 3 - 4 hours, mainly at night, and more frequently in winter. Sometimes, the problem was evident continuously for several days only to disappear for several weeks.

c) When the noise was heard it was a steady rumble (similar to the engine noise in a large ship).

2. Measure and Record Offending Noise

The second step was to measure and record the noise in such a way as to obtain a direct link between the subjective response to the noise and the objective measurement of the noise. To achieve this requires:-

CASE STUDY OF A LOW FREQUENCY ENVIRONMENTAL NOISE PROBLEM FROM A LARGE AND COMPLEX INDUSTRIAL PLANT

a) A measurement system capable of obtaining the detailed signature of the noise in real time.

b) A method of recording the noise.

c) Measurement at the place and time of the noise complaint.

In my experience, when dealing with low frequency noise problems, it is not adequate to record the noise for subsequent analysis; nor is it suitable to measure dBA, octave band or 1/3 octave band levels. By far the most informative and accurate method is to use a real-time, narrow band analyser at least in the first instance. This equipment has the advantage of sampling and visually displaying the changes in the sound at the same time as they are being experienced by the complainant.

Taking a paper trace of each measurement, corresponding to the complainants comments enables the absolute link between subjective response and objective measurement to be recorded for future reference.

It may well be that the noise is of a type and character as to then enable other methods of measurement to be used for the future. If, however, the signature shows significant discrete frequencies then the narrow band analyser allows the precise identification of these frequencies. This was the situation in this instance, with Figure 2 showing the steady amplitude, tones as sharp peaks. The advantages of such precise data are discussed later.

It is important to measure the sound at the precise place that the noise is experienced. Before SRL's involvement in this project, attempts had been made to monitor the sound outdoors - to enable a BS.4142 assessment. For such low frequency problems, this method usually gives misleading results since the outdoor sound is usually of a different character to the sound indoors.

It is also important that the noise is measured at the time of the complaint even if this is the middle of the night. It is not appropriate to measure the noise during a more convenient period and expect that any measured noise levels will increase or decrease equally at all frequencies.

In this particular project it was very helpful that the noise was measured in narrow band and real time, and critical that the noise was measured indoors and at the time of the noise complaint. The noise could not be identified unless all these criteria were satisfied.

3. Evaluate Noise Nuisance

The third step in the process, having measured and obtained a frequency trace of the offending noise, is to determine the specific offending tone/tones, or band of frequencies. It is recommended that this be accomplished by a mix of two methods:-

1. Comparing the measured noise with British Standard curves - 'NORMAL EQUAL-LOUDNESS CONTOURS for Pure Tones and Normal Threshold of Hearing under Free-Field Listening Conditions'. The curve, extracted from these contours, showing 'Normal Binaural Minimum Audible Field (MAF)', is superimposed on the measured trace in Figure 3.

2. Comparing the subjective response to the objective measurement. In many cases the switching on and off of individual items of equipment is helpful in this respect. If this is not possible then with intermittent noise problems the most reliable means is to continually monitor the noise, subjectively and by measurement, until the noise problem increases/decreases. At this point, the traces with/without the offending noise may be compared.

CASE STUDY OF A LOW FREQUENCY ENVIRONMENTAL NOISE PROBLEM FROM A LARGE AND COMPLEX INDUSTRIAL PLANT

In this particular project, the noise nuisance was thought to be due to the tone at 27.6Hz. Monitoring over a period of time confirmed that this tone was always evident at an amplitude of 50 to 60dB. At this level, it was just audible. At certain times, however, it increased to a higher steady level of up to 82dB. It was at times when the tone was above 65dB to 70dB that complaints occurred.

This subjective reaction from the residents, closely reflected reactions at other SRL projects involving noise problems, in the frequency range 20 to 80Hz. It appears that - if there is a relative lack of masking noise as is usually the case - indoors/at night/ in rural locations, then people complain if there is a low frequency, tonal noise at levels of around 5dB above the contour for normal binaural minimum audible field. In rare cases complaints have been made of tonal noise levels up to 10dB below this curve. This is particularly so if the noise in question has been in evidence over a long period of time - several years - in which case the 'apparent' noise level seems to increase with the increased sensitivity and annoyance of the listener.

At the frequency in question for this project, the writer was able to hear this tone clearly at 50dB and would have found it annoying for long periods, at 65dB (the sound level of the MAF contour at 27.6Hz is 61dB).

4. Identifying the Noise Source

Having measured and recorded the offending noise, the fourth step is to determine the noise source and any source-receiver path, influences. In this instance the process was made easier since an offending tone at a steady level could only have been produced by an item of rotating or reciprocating equipment. (Having said this, such items of equipment tend to be numerous on large industrial sites in comparison to say combustion noise sources.) Moreover, the offending tone, will usually be produced by an item of equipment with a corresponding rotational frequency/blade passage frequency/firing frequency.

Rotating/reciprocating equipment of different types tend to produce similar sound power levels which are dependent on the power consumed, or alternatively in the case of say fans, the pressure developed and volume of air supplied. Standard equations are readily available which enable the calculation of such power levels.

Several other factors may attenuate or amplify the calculated sound power levels, as explained later. However, it is useful to draw up a very rough guide as to the size of machine necessary at various distances to produce the sound levels measured within the complainants house or property. It is important to realise that an attempt to identify the source of such low frequency noises by conventional sound measurements is usually extremely difficult.

Reference to such a guide will greatly assist in pinpointing the industrial premises requiring detailed investigation.

Having highlighted the general area of the source - a factory, pumping station etc., then an inspection of the company's equipment list is very often useful. The data required is:-

a) size of machine, power consumed or pressure/volume delivered
b) rotational/reciprocating speed
c) number of blades/cylinders

an example of such a list is shown in Figure 4.

In this particular case study, one of the three largest and most powerful fans in the cement works, the principal supply fan, providing air/coal dust to the kiln, had a rotational speed corresponding exactly to the tone identified within the complainants property. See Figure 5 for the general layout of the system.

In subsequent detailed sound and vibration measurements, made on and around the fan, it was found that the noise producing mechanism was not radiation of noise from the fan casing but radiation of noise from the concrete mezzanine floor on which the fan stood. The floor was found to have a natural frequency within 10% of the fans rotational frequency. The vibration velocity within the floor, the area of the floor and the radiation efficiency of the floor were such as to radiate a sound power level adequate to produce the sound levels measured in the nearby properties.

The precise reason why the floor was set into vibration at higher levels at certain times could not be determined within the available brief. However, it is thought that a possible cause was the fan being called upon to produce more pressure at certain times than others. These times corresponded to periods when the coal dust/air mixture, being transported by the fan, contained a higher level of moisture. This moisture enabled the mixture to 'clog' equipment elsewhere in the system, thus putting more pressure on the fan and moving the fan to a less efficient point on its pressure-volume operating curve. It is thought that during the operation, this clogged coal would periodically clear thus letting the fan return to its normal duty. This hypothesis would account for both

a) the seasonal nature of the noise nuisance - more prevalent in winter (coal stored outside)

<u>and</u>

b) the intermittent nature of the nuisance.

The efficiency in which the sound passed into the terrace of houses was assisted not only by the low frequency nature of the noise but by the coincidence between the frequency of the noise and the natural frequency of certain secondary building elements, particularly windows. This resulted in the resonance of windows with the consequent reduction in attenuation that this brings. It was interesting to note that the fairly slight pressure of a hand placed in the middle of the large window panes was enough to change the response of the window to reduce the sound level of this particular tone by 3dB.

The picture at the terrace of houses was further complicated by a severe standing wave set up in the open ended passageways between houses in the terrace. This was felt to have a secondary though marked effect on the noise problem since residents in the only two houses not to have a passageway did not experience the problem to the same degree as the other occupants.

5. Remedial treatment recommended

The fifth and final step was to make recommendations for reducing the noise level to stop the noise nuisance. The following recommendations were made:-

a) as a first step, install pressure sensors within the fan duct system to prove or disprove the hypothesis of varying fan duty,

b) modify the floors' stiffness to change its natural frequency, by adding support beams thereby reducing floor spans,

c) move the fan to the ground floor.

In the end event, the decision was made to move the fan to the ground floor.

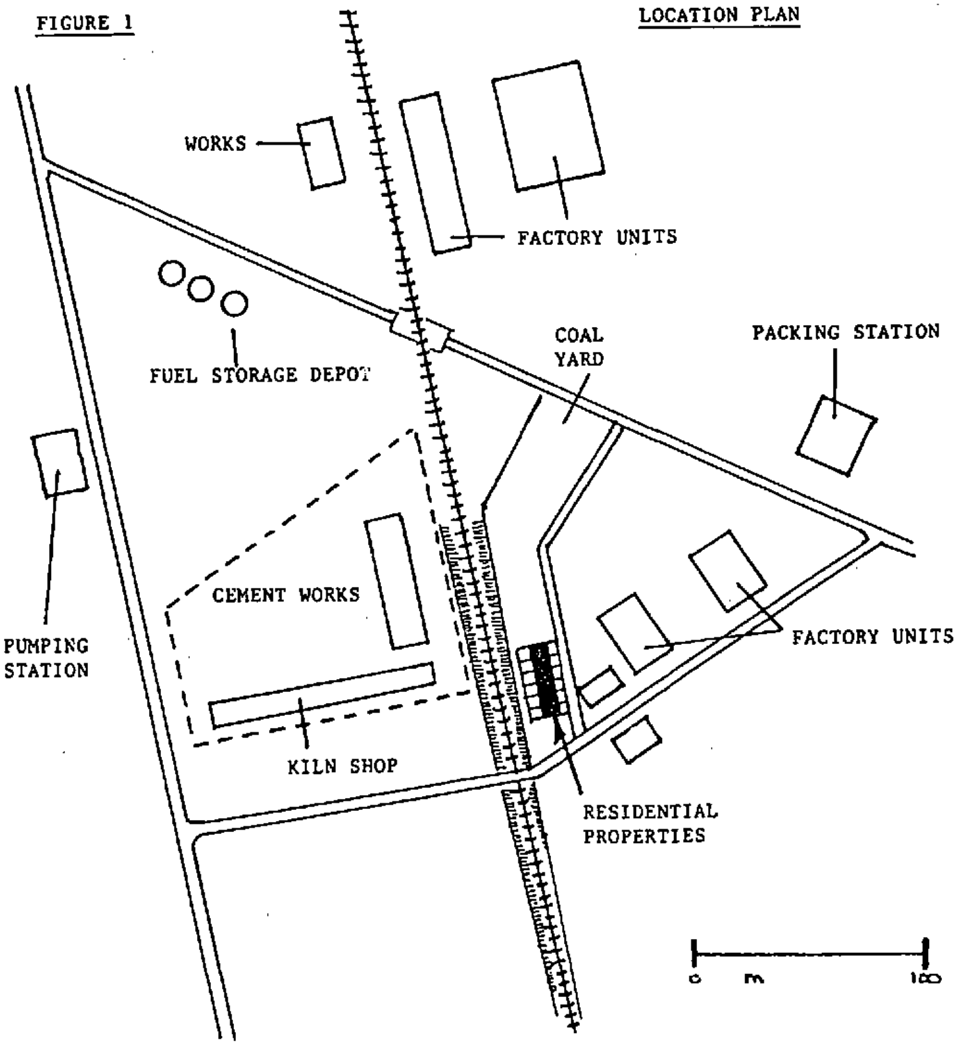
It is understood that since this modification, complaints have ceased.

REFERENCE

British Standard 3383 - NORMAL EQUAL-LOUDNESS CONTOURS for Pure Tones and Normal Threshold of Hearing under Free-Field Listening Conditions.

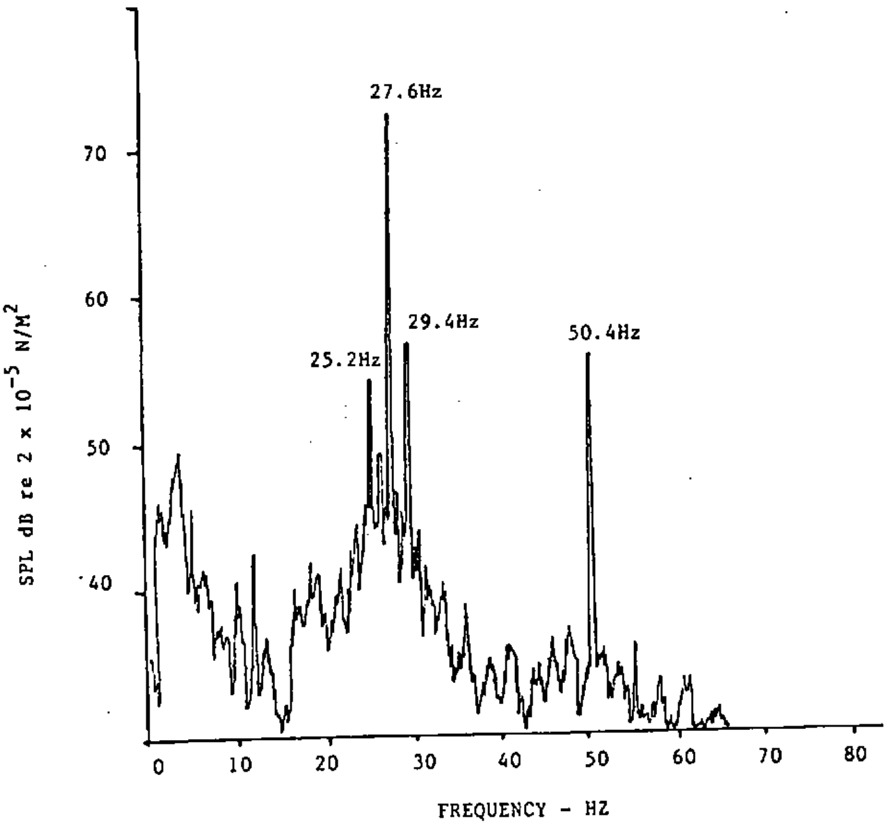
CASE STUDY OF A LOW FREQUENCY ENVIRONMENTAL NOISE PROBLEM FROM A LARGE AND COMPLEX INDUSTRIAL PLANT

FIGURE 1 LOCATION PLAN



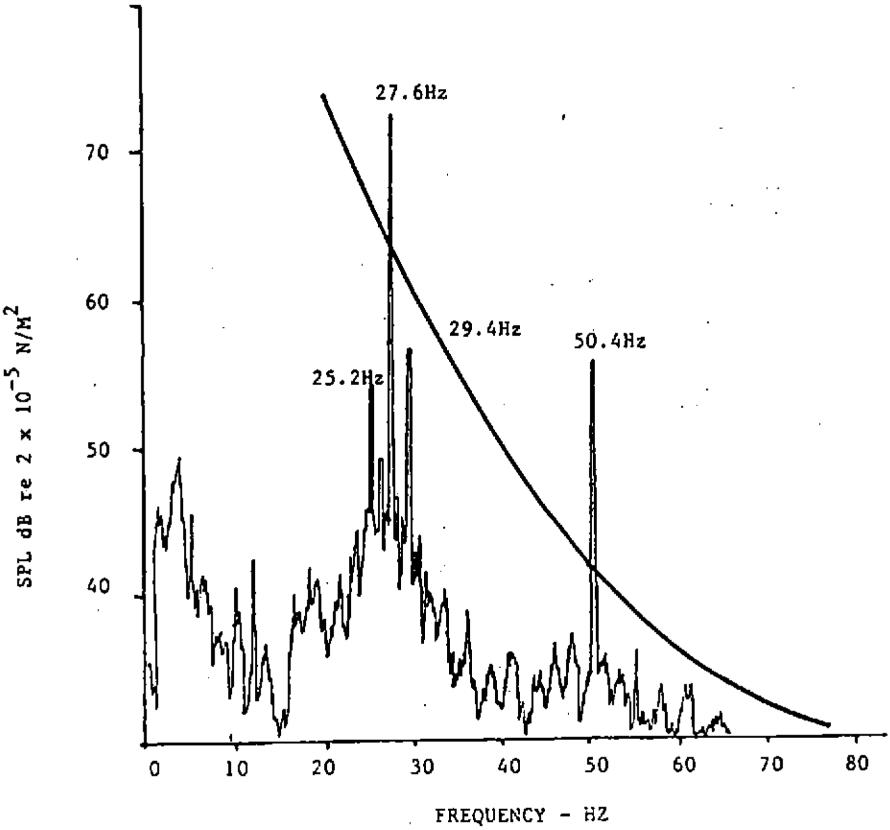
CASE STUDY OF A LOW FREQUENCY ENVIRONMENTAL NOISE PROBLEM FROM A LARGE AND COMPLEX INDUSTRIAL PLANT

FIGURE 2 SOUND LEVEL IN LOUNGE
0 - 100Hz 0.3Hz BANDWIDTH



CASE STUDY OF A LOW FREQUENCY ENVIRONMENTAL NOISE PROBLEM FROM A LARGE AND COMPLEX INDUSTRIAL PLANT

FIGURE 3 SOUND LEVEL IN LOUNGE 0 - 100Hz 0.3Hz BANDWIDTH WITH BS 3383 NORMAL THRESHOLD OF HEARING CONTOUR (M.A.F.)

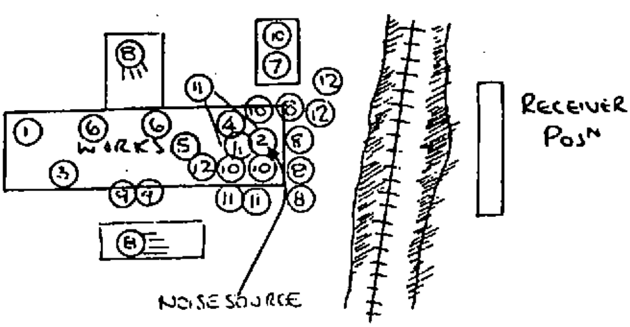


CASE STUDY OF A LOW FREQUENCY ENVIRONMENTAL NOISE PROBLEM FROM A LARGE AND COMPLEX INDUSTRIAL PLANT

FIGURE 4 EQUIPMENT LIST

ANNOYING FREQUENCY

ITEM	EQUIPMENT	POWER(HP)	MOTOR(HZ)	MACHINE(HZ)	NO.OF BLADES/ CYLINDERS
1	Centrif. Fan	390	16.4	7.9	10
2	"	350	24.5	27.6	6
3	"	200	16.4	12.4	8
4	"	100	24.8	40.2	16
5	Mill	150	23.0	0.9	-
6	Drive Motor (Kiln)	200	8.4	1.0 (RPM)	-
7	Conveyor	20	16.0	-	-
8	Misc Fans (30 off)	5 to 30	IGNORE - TOO	SMALL TO CONSIDER	
9	Compressors (2 off)	150	14.9	11.0	4
10	Compressors (4 off)	100	12.0	12.0	6
11	Pumps (10 off)	10	IGNORE - TOO	SMALL TO CONSIDER	
12	Pump	70	15.2	15.2	-



CASE STUDY OF A LOW FREQUENCY ENVIRONMENTAL NOISE PROBLEM FROM A LARGE AND COMPLEX INDSUTRIAL PLANT

FIGURE 5 CEMENT PROCESS PLANT