LOW FREQUENCY NOISE

By **J W SARGENT**

1 INTRODUCTION

In the early 1970's many reports appeared in the press referring to "hums", "mystery noises", "low frequency sound" etc.

There was the well known Bristol hum which was ultimately attributed to a large factory fan. There were other reports of complaints about domestic oil fired heating boilers and super market refrigeration plants.

At one period in the 70's some credence was given to the idea that there might be a very widespread hum problem affecting people in various parts of the country. This was given national coverage in 1977 when the Sunday Mirror asked its readers "Have You Heard The Hum?" And received 768 replies. However none of the subsequent investigations, to date, have revealed that there is, or ever has been a "National Hum", although speculation that the national gas grid produces widespread low frequency noise is still popular among complainants. Evidence shows that complaints about low frequency noise come from all over the country and the sources that have been found are many.

The Department of the Environment has received a small but steady flow of complaints about low frequency noise (LFN) for many years and in 1988 they funded a review of the disturbance caused by LFN which included a survey of the complaints received by Local Authorities. From this survey it was estimated that complaints were received nationally at the rate of about 500 per year and positive identification of the source causing the complaint was made in slightly less than 90% of cases. Conversely only about 10% of cases proved too difficult to solve.

In 1992 a research contract was placed with Sound Research Laboratories (SRL) to investigate some of the unsolved cases and as a result of the experience gained provide practical guidance for those professionals who have to deal with similar problems.

Sound Research Laboratories subcontracted audiological studies on a sample of the complaints to the Audiological Unit, Addenbrookes Hospital.

2 OBJECTIVES

A) to investigate a small sample of complaints of disturbance caused by low frequency noise with the aim of improving understanding of the problem and provide guidance for those who have to investigate complaints in the future.

B) to develop and test methods of detecting and locating low frequency noise.

As will be seen later in this report the incidence of cases in which a noise relating to the complaint could be detected was extremely low. In all but one of the cases where the offending noise was detected the source of this noise was easily found. As there seems to be an urgent need for an investigation protocol for EHO's and consultants to use when dealing with complaints it was agreed with the contractors to produce this rather than attempt to develop a source location technique which from the cases studied would have little application.

3 PROGRAMME OF WORK

The proposed programme of work was to obtain a list of low frequency noise complainants with brief details of the history of their complaint. From this list to pick 25 cases for detailed investigation. By carrying out site investigations on these cases to develop techniques to detect

the low frequency noise causing the problem and then locate the source. The programme also included audiological investigation on a sample of the complainants from these cases to ascertain any audiological effects that may be contributing to the noise problem experienced by the complainants.

SRL actually investigated 26 cases within this study and provided details of two other cases they had investigated for other clients. Towards the end of the work by SRL a further five cases were investigated by BRE to further test the methods of investigation developed by SRL. Audiological tests were carried out on ten complainants and two non-complaining other family members.

4 SOURCES OF COMPLAINTS.

This research has received publicity by the Low Frequency Noise Sufferers Association (LFNSA), in the press and radio at local, national and international level. Environmental Health Officers were canvassed to ask them for details of cases they received. Contact was established with over 380 complainants. Some of these were people that contacted Sound Research Laboratories, the Building Research Establishment or the Department of the Environment directly as a result of the publicity. However the majority were referred by Environmental Health Officers who had first investigated the complaint. A simple questionnaire was produced to gather the relevant information on each case in a consistent format which could be easily accessed. The questions covered personal details about the complainant, details about the noise causing the complaint and details about the sufferer's residence and surrounding area.

5 SUMMARY OF QUESTIONNAIRE INFORMATION.

A total of 385 questionnaires were sent out during the project and of these 273 were returned completed, a return rate of 71%. These numbers cannot in anyway be used to indicate the number of sufferers in the country. A total of 295 sufferers were listed in the 273 questionnaires. Of the sufferers 111 were male and 184 female, that is, 38% male and 62% female. The distribution of the age range of sufferers is shown in fig. 1. It can be seen that in this sample of sufferers the distribution of female sufferers with age rises steadily to a peak of 36% in the range 60 to 70 and then falls rapidly. Whereas in the distribution of males there is very little difference between the age ranges 40 to 50 (29%), 50 to 60 (28%) and 60 to 70 (25%). The most common description of the noise use the words "droning, distant plane, lorry diesel engine, generator and motor hum". Other words used are "turbine, whine, high pitched sissing, whistle and hissing" Some descriptions use a number of these words. In a few cases the sufferers have said it is too difficult to describe. Complainants that have returned details live in all regions of England, in Wales and in Scotland. There also have been details received from complainants living in the Channel Islands and the Isle of Wight.

6 SELECTION OF SAMPLE FOR INVESTIGATION

The sample for site investigation was chosen using information in questionnaire data. The sample includes male and female complainants; cases in rural and urban areas. Cases were chosen in various geographical areas from the south coast of England to Ayrshire in Scotland and from Bristol in the west of England to Ipswich in the East. Cases where, from details given, the complainant was suspected of suffering from tinnitus were not included in the sample. As the work progressed investigations were concentrated on cases where more than one person in the same household were reported to hear the noise.

7 SITE INVESTIGATION METHOD

As one of the aims of the project was to develop a method for the investigation of low frequency noise complaints, this method evolved through experience gained during the investigation. It was soon apparent that to detect a low level "hum" in the presence of normal broadband background noise would require real time narrow band analysis. Generally investigations were conducted within the sufferer's property as this was the place where the noise was heard. The investigations would normally be made in the evening and sometimes into the early hours of the morning, as the noise was usually either not heard or said to be less noticeable during the daytime. As far as

possible measurements were carried out on relatively calm days. The outline of the investigation procedure was as follows:-

(i) Initial interview with suffer

(ii) Investigator listens for noise

(iii) Tests, such as tone matching, to try to establish more about the nature of the noise heard

(iv) Measurements of the ambient noise levels to try to identify the specific noise causing the noise nuisance. Narrow band (1/24th octave) real time analysis was normally used however in some cases a Fast Fourier Transform Analyser was used. The initial interview was used to confirm details given on the questionnaire and for the sufferer to add further details, to describe the noise including its current audibility and to give the investigator an idea of what to look for. The investigator listened for the noise with the complainant at the places in the residence where the complainant said they could hear the noise.

Tone matching was developed so that the investigator could try to get an approximate idea of the frequency of the perceived noise and the sufferer's subjective impression of the level of the noise. This was considered to be especially necessary in cases where the investigator could not hear any specific noise.

Tones derived from a signal generator were played to the suffer through a loudspeaker. Various tones of higher and lower frequency were played and the suffer was asked to indicate whether each tone was higher or lower than their perceived noise. Gradually the tone was brought to the same frequency as the perceived noise. To start with, the amplitude of the sound was kept clearly audible to both the suffer and the investigator. If the frequency of the perceived noise could be established an attempt was made to adjust the sound level until it matched the level of the perceived noise. In some cases the minimum level at which the suffer could hear the tone frequency was also established.

During the tone matching the frequency and level were monitored with a real time frequency analyser using microphone near the ear of the suffer. Details of the frequency and tone levels were noted from readings on the analyser. If two suffers were in the same residence, the tone matching was done independently in order that one suffer did not influence the other.

It should be pointed out that tone matching can be misleading due to the likelihood of octave confusion and other factors associated with these tests. In many cases the pure tone was said to sound completely different from the perceived noise. Other noises generated such as beating tones and bands of broadband noise were also tried but failed to produce matching sounds.

To carry out a measurement of the ambient noise in order to detect the perceived noise the microphone was normally placed at the position where the suffer considered the noise to be most noticeable. The frequency spectrum was closely observed to see whether or not any specific noise could be detected which related in any way to the description of the sufferer's perceived noise.

The whole frequency range was studied even if the perceived noise had been matched to a specific tone frequency by the sufferer. The analyser was normally set to have a lower limiting frequency of 0.7 Hz The real time analyser was initially used in "free run" mode (exponential averaging) with an averaging time of ¼ sec. This technique allowed any modulation, "beating" at a particular frequency to be observed. This was considered important because a number of suffers had described a noise like a twin engined propeller aircraft, which did not have the propellers synchronised - a classical "beating" phenomenon.

8 SUMMARY OF INVESTIGATIONS

Of the 26 cases investigated by SRL under the contract there were only three cases where the noise could be positively detected by measurement and/or audible to the investigator. In two cases the noise complained of was consistent with 100 Hz noise emitted by electrical sub stations nearby. In the other cases there was a narrow band of measured noise centred on 104 Hz which

although at a low level was audible to the investigator. This noise was not audible or detectable outside the house.

There are another seven cases, where for a variety of reasons, there is evidence to suggest that with much longer term noise measurement, it may be possible to detect the noise causing the problem. In most of these cases it is suspected that the sufferer has been sensitised to the noise at some time in the past when it was louder and more continuous than now. In one of these cases the noise was identified by the sufferer outside in a nearby street, it was detected by measurement and the source located to a distant factory, however, this noise could not be detected when measurements were made within the complainant's residence. It is known that the noise from this factory has been reduced and although previously disturbing a number of surrounding house occupants now only affects the complainant who still hears the noise almost continuously.

SRL have investigated two additional cases for other clients and with the permission of those clients included details of these investigations in this study. In both cases there was little doubt that the source of the noise was from industrial machinery or plant, measurements being used to confirm the cause and to provide information on which to base recommendations.

Table 1 gives a summary of the results of the investigations.

Towards the end of the project BRE carried out another five investigations testing the methods established by SRL . In none of these cases was a noise level measured in the complainant's residence that related to the noise they described. In one case it seemed possible that the complainant had experienced low level industrial type noise within his home from a water pumping station and this may have sensitised him to low frequency noise. In the other cases although low level low frequency noise was present in the residences it could not be related to what the complainant experienced, either in terms of its temporal or spatial characteristics.

9 SUMMARY OF AUDIOLOGICAL FINDINGS

The Audiological Department of Addenbrookes Hospital were asked to perform audiological investigations on a small number of participants in the study. As it became apparent that the majority of cases were those in which no noise corresponding to the complaint could be identified the significance of the audiological findings increased. Comprehensive audiological was undertaken of ten complainants and in two cases of non-complaining spouse or family member. True hyperacusis, being hypersensitivity and annoyance from all sounds, was indicated in one case, but an additional three showed specific hypersensitivity to the noise of their complaint.

Three complainants were considered to be suffering from tinnitus. In one of these cases the wife was the principle complainant, and on hearing the noise of complaint clearly in the sound proof room. The conclusion was made that his wife's complaint had drawn the husband's attention to low frequency sound in the environment, and so he had become convinced of the complaint and shared the distress. A second case was similar to this but since in this case the wife only had a mild tinnitus the possibility of a noise relating to the complaint being present could not be ruled out. In one case there was strong evidence that a noise was indeed present as the noise was heard by the whole family, and only in one bedroom, and indeed measurements within the home identified the presence of a noise relating to the complaint.

It should be noted that the conclusions drawn from the results of the audiological investigations can only be hypotheses, as definite diagnosis is not possible, other than in the cases where the noise source complained of was measured in the complainant's bedroom.

A significant failing in this study was the unavailability of the noise measurements at the time of audiological investigation, through this was done as a crude control method.

Whilst the comprehensive audiological battery failed to identify any complainants with significant ear disease this possibility remains and creates a strong case for this being undertaken in any clinical work with such cases in future.

Many of the complainants arrived at the Audiology Department suspicious and concerned about the testing and discussion. Careful reference to the independent role of the audiological scientists and to the genuineness of the distress caused by the perception of the noise removed this suspicion in each case recommended. In many cases these subjects had been treated without respect or care by those previously investigating their complaints. In addition some found discussion by the SRL and BRE investigators of their complaint to be unhelpful. The utmost care must be taken in discussion in such cases, and raising possible diagnoses or sources can be very unhelpful.

Categorising LFN complainants would be spurious if it did not lead one to options for therapy. A detailed consideration of this area is far beyond the scope of the original brief to the Audiologists involved, but a thumbnail sketch may be helpful. A patient with tinnitus may be helped with a hearing aid or white noise generator (previously known as a tinnitus masker). The use the white noise generators in hyperacusis is becoming popular and has seen some success. In cases of specific hypersensitivity then therapy may be utilised.

10 DISCUSSION

This project was started with the goal of developing simple measurement techniques that acoustic professionals could use to establish the cause of low frequency noise complaints and to locate the source. Complaints about low frequency noise have occurred over a number of years and have been referred to both Local Authorities and Central Government the latter usually being referred to if the former could not, or did not do anything.

Low frequency noise can arise from many sources, such as distant traffic, trains, aircraft and industrial/commercial premises, even wind around buildings can cause low frequency noise. The normal background noise within most dwellings will contain noise from across the whole frequency spectrum including noise at low frequencies. In dwellings well insulated against external noise the background noise is likely to be biased towards the low frequency part of the audible spectrum as the higher frequency components of the external noise will be attenuated to greater extent by noise insulation measures.

The questionnaire was formulated to enable sufferers to provide information about the details of their noise problem and information about themselves. This questionnaire enabled some statistical data to be collected. It must be remembered that this data is from a self-selected sample of low frequency noise sufferers who contacted the researchers, or were put in touch with the researchers by a third party, and who then completed the questionnaire.

Distribution of age of complainant and distribution of complaint have been studied for the total sample and also for male and female complainants independently. The majority of recorded sufferers in the sample are in excess of 50 years old and for every 10 males suffering there are 16 females also suffering.

It was also interesting to note that approximately 50% of sufferers had experienced their problem between one and five years, but nearly another 40% had experienced the problem for greater than five years. The results of this study cannot be used to indicate the total number of people in the UK with an unsolved low frequency noise problem. Descriptions of the noise heard by sufferers appeared to be very similar and typically referred to engines, distant lorries, generators, motors and twin engined propeller aircraft. All these produce low frequency noise, rumbling sounds and in the case of twin engined propeller aircraft can produce "beating"

Some descriptions referred to much higher frequency noise, such as turbines whining, "sissing" sound and whistling which all suggest that there has been confusion in these cases between low level noise and low frequency noise. These high frequency sounds are also indicative of tinnitus. The lack of measurable specific low frequency noise relating to the complaints was of concern at the beginning of the project, especially when dealing with sufferers who were very obviously experiencing what they thought to be a real specific noise. However, it was clear from the early stages of the project that a lot of cases being referred to SRL by EHO's were because the EHO had been unable to find any specific noise relating to the complaint and SRL were effectively being asked to "clear up" the outstanding problems.

SRL's approach to surveys was to keep these "simple" as the original goal was to provide simple measurement techniques. Having to use narrow band analysis meant deviating from the original goal, but it was realised that conventional sound level meters would not allow the investigator to look at a "picture" of the frequency spectrum in order to pick out any specific noise components. By using narrow band techniques it meant that the vast majority of EHO's would not be able to carry out low frequency noise investigations, unless they can borrow or hire equipment, as most have no more than simple sound level meters.

Of the investigations carried out as part of the project, the only specific noise measured clearly which did not have an immediately obvious source such as a local factory or transformer sub station, was in Bristol. A spectrum of the noise measured in the room where the problem was of most concern is shown in fig 2. The noise causing the complaint in this room appeared to set up a standing wave with the maximum level at the antinodes of approximately 38 db and at the nodes approximately 20 db. The presence of a standing wave suggested that there may have been amplification of up to 20 db at the resonant frequency.

Therefore, the external noise level at this frequency, about 104 Hz could have been as low as 20 db. Outside the house noise at this frequency was not audible above the general background noise. The noise within the room was not dissimilar to a transformer hum (100 Hz) typically associated with electricity sub stations. The local Authority Environmental Health Department had spent some time trying to ascertain the source of the noise without success. From subjective testsby the sufferer's family, switching everything off in the property and the neighbouring property it was considered that the source must have been external.

South Western Electricity Board also helped in this matter by switching off a sub station in the same road as the sufferer's property, just in case this could have been a source although the frequency measured was slightly higher than 100 Hz but the noise was still audible. The sufferer first noticed the noise during a winters evening in January 1992. Although the sufferer maintains that the noise started that particular evening, there is still a chance that the noise had been present for much longer and it was some particular event which drew the sufferer's attention to it and subsequently the sufferer's family.

The only cases where the complainant described the problem as a sensation rather than an audible noise, was not covered as part of the contract. In this case the sufferer was affected badly by the "pressure sensation" and it forced her to sleep at her mother's house 6 out of 7 nights. The only night she slept at hr own home was when the source, namely a local foundry was shut down. This was from Saturday morning to Sunday evening. The problem had arisen as a result of an audible noise caused by fan machinery bearings squeaking. Whether or not the low frequency sub audible excitation was present at this time was difficult to judge.

However, the foundry repaired the fan bearings and stopped the audible noise, but the sufferer then started complaining about the "pressure sensation". The investigation of this problem revealed a clear peak at 12 Hz up to a level of approximately 68 db. This peak certainly seemed to confirm the sufferer's feelings that this was "pressure sensation". She had also referred to physical problems, such as feeling nauseous, having headaches and feeling giddy. These are known problems associated with this type of low frequency noise.

However, most studies of low frequency noise appear to suggest the noise levels at these sub audible frequencies would need to be in excess of 100 db to cause significant effects. Bryan & Tempest (1979) did report an example of low frequency noise, a 12 Hz tone caused by a shaker table at a foundry. The shaker table produced noise levels in the range of 79 to 91 db at the nearby complainants property. The complainant reported headaches and feelings of unease. Compared to these levels the case investigated by SRL had significantly lower noise levels, at lease 10 db(A) lower.

Unfortunately after the foundry was shut down due to mechanical reasons, the sufferer remained convinced they were still working and causing her a problem. A further investigation by SRL revealed that the 12 Hz tone had disappeared into the background noise, well below 40 db, a reduction of at least 28 db. Although this case appeared to be one where there was a very clear excitation albeit at a relatively low level in terms of annoyance, and which when removed should have completely relieved the sufferer, this sufferer was subsequently diagnosed as having tinnitus,

thereby throwing doubt on whether or not the 12 Hz tone was actually causing the problem in the first place.

One area of concern which SRL could nor resolve was whether or not a noise had existed in the past and the sufferer had been sensitised to it and although the noise had long since gone, they were still convinced it was there. Unless there was positive information from EHO's regarding previous noise nuisances, this would be very difficult to prove. One of the cases investigated by SRL appears to be of this type. In this case a noise nuisance from a factory had occurred in the past but no longer affected people except the sufferer.

Although during three visits nothing was measured in the property, it was considered possible that occasionally a tonal noise, albeit of a low level, could permeate the property and re-heighten the awareness. Noise that the sufferer complained of was identified by the sufferer and measured nearer to the factory site. The noise spectrum is shown in fig 3 and it can be seen that the frequency of the "hum" in this case is rather higher than would be normally judged as low frequency noise. This factory site had been the source of the noise nuisance many years before and measures had been taken to reduce the noise. Given the right weather/ambient conditions it is possible this could radiate to the sufferer's property.

SRL had expected to measure specific low frequency noises at sufferer's property. The lack of measurable real noises and the findings of the audiological research suggests that there may be noise problems with physiologically related causes. One sufferer was very adamant about a noise which could not be found. However, since undergoing a detailed audiological examination they have been diagnosed as suffering from tinnitus.

They have now accepted this and are trying to come to terms with it and are to some extent relieved at knowing what the problem was. The one problem which must be overcome and it is hoped the "Protocol" proposed in this report will achieve it, is the way sufferers are treated by those called upon to investigate their problem. It was quite clear during a number of interviews with sufferers that they had been treated unsatisfactorily, even in some cases made to feel they were mad.

By causing distress and hostility at an early stage, the investigator is likely to create more problems, because the sufferer will persist in trying to get something done about reducing or stopping the noise which is affecting them. If there is no obvious audible noise and narrow band noise measurements do not show any specific noise that can relate to what the sufferer is hearing, they need to be referred to an audiological specialist as quickly as possible. There may be still be some hostility and the situation will need to be handled carefully.

11 RECOMMENDATIONS

As a result of the experience gained from this research the following recommendations are made:

That EOH's acoustic consultants or others investigating LFN complaints have normal hearing.

That LFN complainants are treated with respect and that care is taken not to speculate about sources or diagnoses.

That comprehensive noise surveys be undertaken before an audiological opinion is sought and that these be available to the audiological scientist. A suggested protocol for carrying out low frequency noise investigation is in annex 2.

That the Department of Health consider how specialist tinnitus clinics might be involved in the treatment and therapy of LFN complaints.

That therapy and treatment be available to these patients who are suffering considerable and genuine distress.

That low frequency noise complaints to Local Authorities should be monitored to assess the continuing scale of the problem.

That further investigations are carried out on complaints of low frequency noise to build up a clearer picture of the causes of complaint, particularly in cases where the complainant appears to show hypersensitivity to the noise of their complaint but no noise relating to this can be measured.

ANNEX 1 CENTRAL HYPERACUSIS

"Hyperacusis" is used to describe abnormal discomfort caused by sounds that are usually tolerable to normal hearers. Although there are impairments in the hearing mechanism which can cause discomfort to sound, central hyperacusis refers to problems arising from the way the brain processes auditory information. This is a subjective phenomenon and, like tinnitus or headache, it cannot be verified or quantified by objective tests. This fact should not prevent professional recognition of hyperacusis as a clinical entity.

This symptom occurs with a range of other clinical conditions including depression, migraine, post viral fatigue syndrome or ME. The underlying cause is thought to be due to a reduction in a brain chemical which controls the amount of information arriving at the brain from the sense organs. For this reason it may also occur with oversensitivity or "photophobia".

Hyperacusis will describe the sensation caused by particular sounds as "painful", "startling" or anxiety producing. It is not clear why some sounds cause problems while other (often louder) sounds do not, for individual sufferers. It does not appear to relate to the loudness of the sound, though there may be some other feature common to hyperacusis stimulation which we have yet to identify. It is not usually helpful to measure the intensity of the offensive sound because it is the sensitivity of the sufferer which is abnormally heightened.

Although the primary cause of central hyperacusis appears to relate to the imbalance of brain chemicals, there is a secondary mechanism which can underlie a long term hyper-sensitivity. Where a sound has become associated with pain or discomfort, a fear -potentiated startle reaction may become established. This is the same as the startle reaction to an unexpected sound when in an anxiety situation (eg watching a horror movie). The establishment of the fear potentiated startle can turn an acute hyperacusis into a chronic debilitating condition.

The association between central hyperacusis and people sensitive to low frequency noise or hum is not clear at present. There are apparent similarities in the symptom profiles of subject case histories but further work is necessary to clarify the mechanism underlying the two conditions.

Josephine Marriage Msc
Audiological Scientist

Back to Contents