TRACING AN INDUSTRIAL LOW FREQUENCY NOISE (<20Hz)

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INTRODUCTION

This paper describes the methods used to trace the source of a low frequency noise which turned out to be infrasonic. The work stemmed from a complaint of a type not infrequently encountered in Environmental Health work; that of a seemingly inexplicable hum, commonly only heard by one isolated individual.

Initially, the investigation relied on trying to witness the noise, described as an evidently very unpleasant, throbbing hum, producing not just the sensation of a noise, but also that of a vibration. Additionally, the complainant suffered a reaction in terms of physical symptoms such as headaches, digestive problems, nervous ailments etc., typically found in studies of the effects of low frequency/low level noise [1][2].

Despite many visits, often at night, nothing was ever audible, even when the complainant reported that the noise was intense. Similarly, A-weighted measurements and octave frequency analysis failed to reveal anything that might tally with the complaint, leaving an unsatisfactory conclusion that either there was no real noise and a case of low frequency tinnitus, or a real probably infrasonic noise.

It was in order to attempt to resolve the question that measurements in the range 1 - 20Hz were undertaken.

STAGE 1 - INFRASOUND MEASUREMENTS

The method adopted was to use a 20Hz low-pass filter, coupled to a suitable microphone configuration and a sound level meter capable of statistical analysis. This deposited results at hourly intervals to a portable computer. Since the noise was said to be much more prominent at night, the system was installed in the complainant's home and set to record between the hours of 10 p.m. and 3 a.m.

For comparison, similar measurements were done at another house in the same street and the author's home some nine miles away.

Results

LOCATION	L10 (dB)		L90 (dB)		LEQ (dB)	
	Average	Spread	Average	Spread	Average	Spread
Complainant 7 Mosley St	73.7	8.4	58.2	9.9	70.4	7.4
19 Mosley St	71.9	5.5	56.5	8.0	68.4	5.8
HOME*	56.5		47.0		53.2	

* 15 minute measurement period

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The results showed that at the complainant's premises and nearby, levels were relatively high.

Whilst this offered an explanation of the noise complained of, the source remained a mystery. Locating it was the next step.

STAGE 2 - INFRASOUND SURVEY

Locating the source of the infrasound that had been detected faced some difficulties. Any search would obviously be reliant upon instrumentation and designed around its limitations.

Given the diffraction characteristics of very long wavelength radiation, attempting to direction-find using a standard microphone would be a useless exercise, unless, of course, one of very large dimensions was available. Alternatively two microphones separated by a large distance, operating simultaneously could succeed, but was impracticable.

Hence, taking measurements at different locations on a survey system, was the method adopted. Sites approximately ½ km apart were selected; the results being then used to construct an infrasound contour map. The area to be covered was a small industrial town, Barnoldswick, in north-east Lancashire, fortunately not part of a conurbation, but surrounded by open countryside.

A practical problem encountered in these outdoor measurements was the affect of wind noise. Even quite moderate gusts, which would not trouble ordinary environmental noise measurements, were found to increase sound pressure levels by as much as 40 dB, even though the microphone was protected by a standard windscreen. It was therefore essential to choose as calm weather as possible. Even so, rapid variability of sound pressure levels led to a decision to regard only the L99 parameter as a reliable indicator of ambient infrasound. LEQ, for instance was too susceptible to disturbance.

If then, this parameter was to act as a tracer, a measurement period of sufficient duration would be required to ensure that the levels derived would be adequate. Balanced against these considerations was the need to make progress, so a period of 15 minutes was allocated for measurements at each of the survey points.

In drawing the map, the results were divided into 5 dB class intervals, in order to both simplify the process and take into account measurement error. Repeat measurements were required at several locations where levels were radically different from those of adjacent sites.

The map showed two potential sources, fairly close together. The complainant's home was, however, some 600m away. A model was therefore needed to check if a source at that distance could account for the levels measured.

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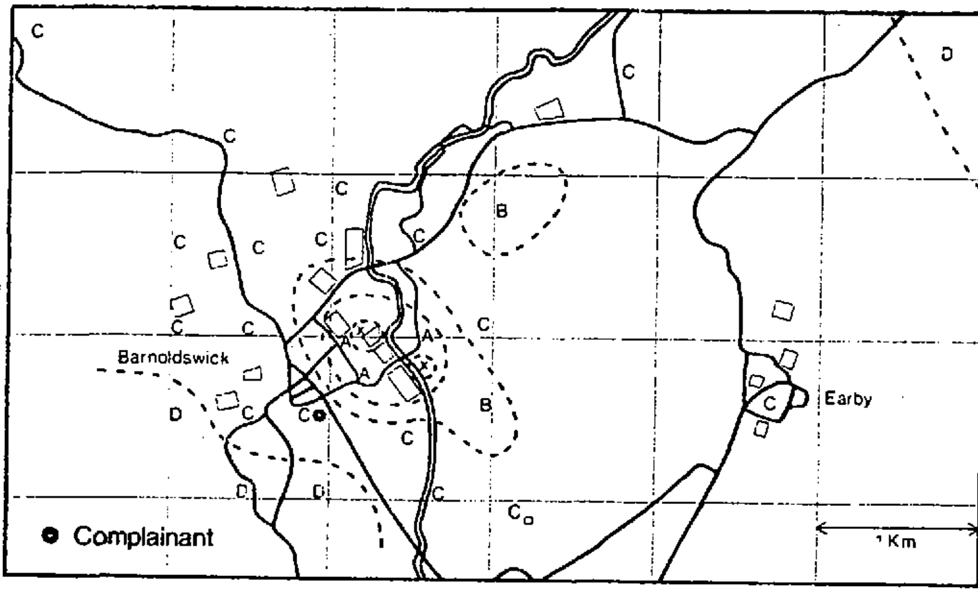

INFRASOUND L99 CONTOUR MAP

Class	Interval (L99,dB)
X	65-69.9
A	60-64.9
B	55-59.9
C	50-54.9
D	45-49.9

The model chosen was that of a source radiating uniformly in all directions through a hemisphere over a reflective plane. Given that the absorption of sound by air is proportional to the square of the frequency (hence minimal in the case of infrasound) [3], and the property of long wavelength radiation of diffracting easily around most common objects, it was thought to be able to provide a good elementary description. Factors such as humidity, temperature and wind were excluded.

The difference in sound pressure level between any two points A and B, radial distances r_A and r_B from the source (A being the closer), would then be:

$$\Delta L = L_A - L_B = 20 \log_{10} \left(\frac{r_B}{r_A} \right) \quad [4]$$

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From the values for locations 30 and 16 (the complainant's home):

Location 30	L90 = 64	L99 = 61	r_{30} = 250m
Location 16	L90 = 56	L99 = 53.5	r_{16} = 600m
	ΔL90 = 8	ΔL99 = 7.5	
Predicted ΔL = 7.6			

Similarly, for locations 12 and 13:

Location 12	L90 = 65.5	L99 = 62	r_{12} = 150m
Location 13	L90 = 54.5	L99 = 52	r_{13} = 600m
	ΔL90 = 11.0	ΔL99 = 10	
Predicted ΔL = 10.5			

The outcome of the survey was that two potential sources had been found, one being an iron foundry, the other a bed manufacturer. A simple model suggested that these sources could be responsible for the levels of infrasound detected at the complainant's home. This conclusion was further supported when it was found during the annual shutdown of both plants, levels fell by around 15 dB (L90), at the complainant's home.

STAGE 3 - THE INFRASOUND SPECTRUM

The survey had turned up two potential sources, fairly close to each other. At the iron foundry, there were cold blast cupolas and grit arresters. At the bed manufacturer, there was a wood-waste fired boiler and ancillary pneumatic wood-waste collection plant, including cyclone arresters. Either or both of these might be the true source. Examination of the infrasound spectrum by real-time narrow band analysis in the vicinity of both factories and also at the complainant's home was therefore required. The object was to find a component common to the latter and one of the other two.

The spectra are reproduced in Appendices I, II and III. Note that they are averaged over 32 spectra and thus do not properly reflect time variance.

Near the bed manufacturer, (Appendix I), the spectrum featured a spike at 9.8 - 9.9 Hz that fluctuated over a period of a few seconds by over 20 dB above background. Other prominent though stationary components were present and were also found, more marked still, near the iron foundry (Appendix II)

It was considered that these latter were originating in the iron foundry, whilst the variable 9.8 - 9.9 Hz spike was associated with the wood-waste boiler etc., at the other factory.

The spectrum at the complainant's home (Appendix III) again showed the 9.8 - 9.9. Hz spike to be present, there fluctuating up to about 10 dB above background. Clearly, this component could fit the complainant's description of the noise.

CONCLUSION

An investigation of an isolated complaint of low frequency noise had revealed that infrasound might be the cause. A survey method was then used to map potential sources. The spectra of these were then examined by real-time narrow band analysis.

A pulsating component of 9.8 - 9.9 Hz, emitting from a wood-waste fired boiler and /or its ancillary plant, was identified. If the complainant was an exceptional individual able to perceive noise at the frequency concerned, then this could be the source.

Aknowledgement
The author wishesto thank Mr. J. Houldsworth of Bruel & Kjaer (UK) Ltd. for his assistance with the spectral analysis of the source.

References

[1] Leventhall, H. G. Annoyance Caused by Low Frequency/Low Level Noise. Proceedings of the Institute of Acoustics.

[2] Low Frequency Noise. National Society for Clean Air Reference Book.

[3] Kinsler, L. E. & Frey, A. R. Fundamentals of Acoustics. J. Wiley & Sons, U.S.A.

[4] Acoustic Noise Measurements. Bruel & Kjaer Ltd.

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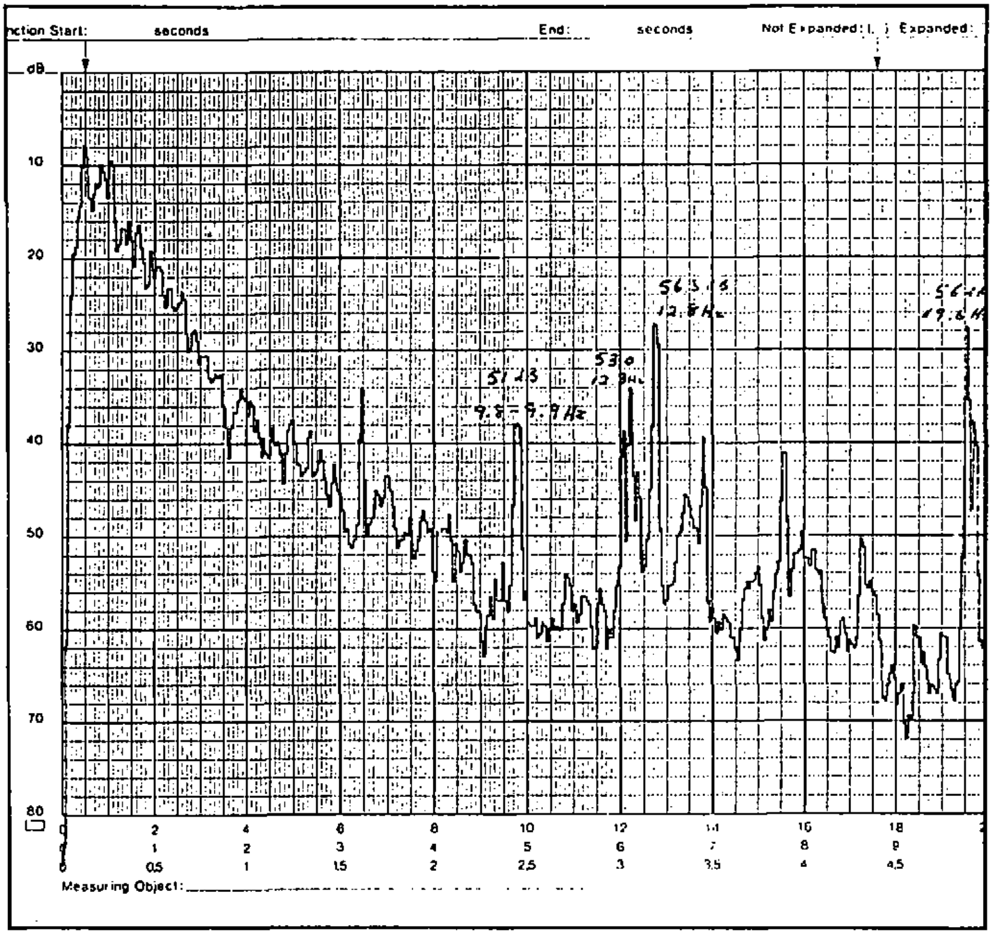
APPENDIX I



INFRASOUND SPECTRUM
(Bed Manufacturer)

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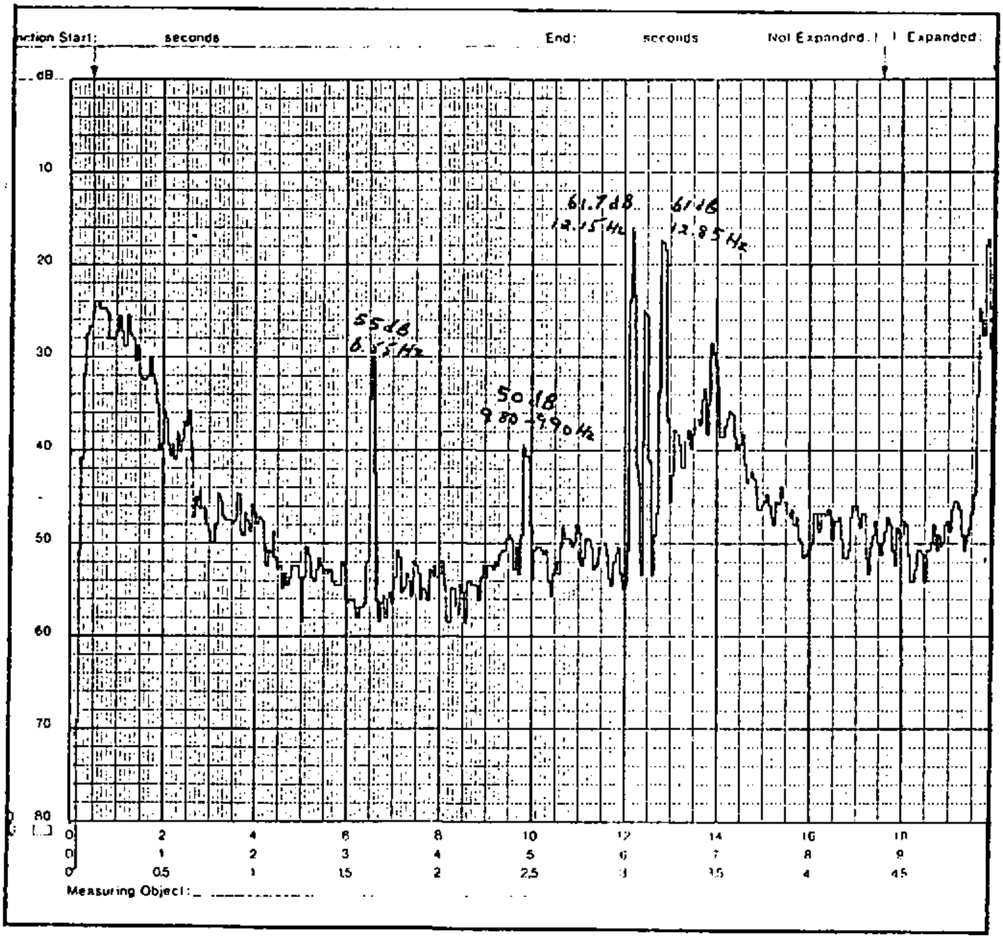
APPENDIX II



INFRASOUND SPECTRUM
(Iron Foundry)

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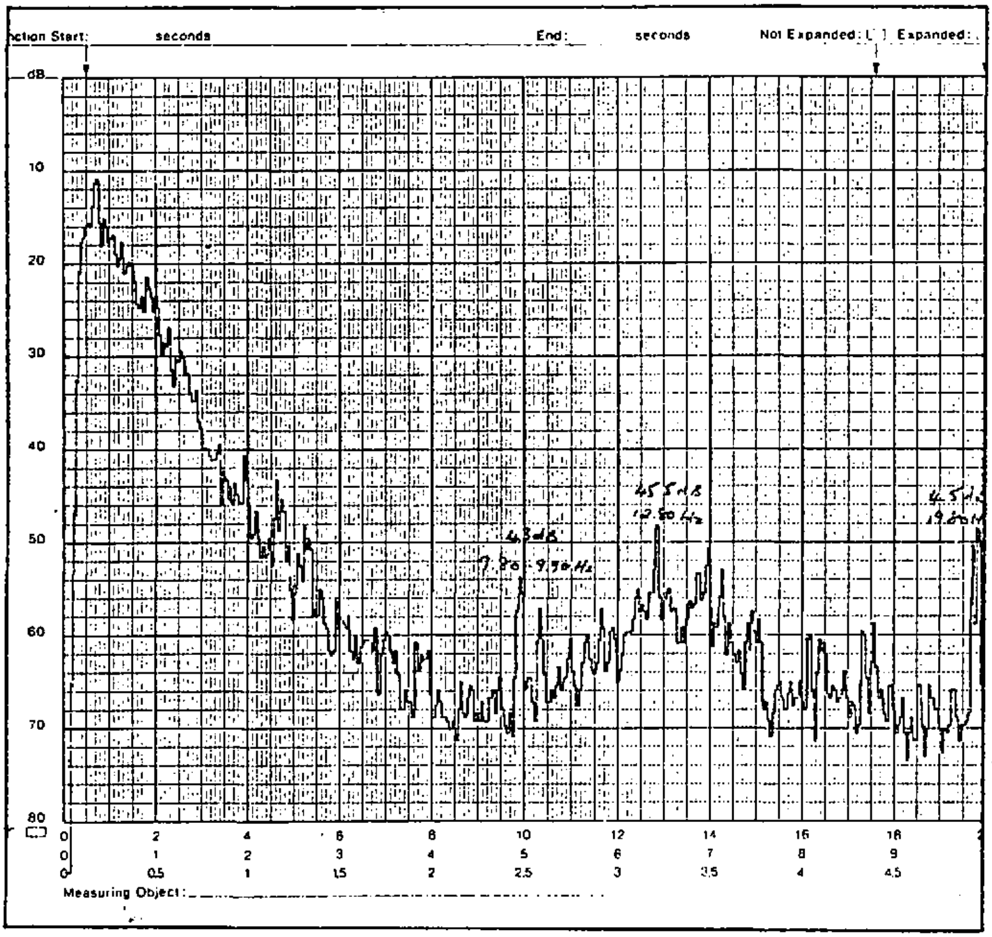
APPENDIX III



INFRASOUND SPECTRUM
Complainant's Home