Proceedings of the Institute of Acoustics

NOISE MEASUREMENT TECHNIQUES AT OPENCAST COAL MINES

P.W. Moore

W.S. Atkins Engineering Sciences, Epsom, Surrey*

INTRODUCTION

In December 1985 the Department of the Environment announced its intention to support a programme of research on the control of noise at surface mineral workings. The purpose of the research was to help determine the most appropriate form of guidance on the subject to be given by the Department to local authorities. Further advice had been promised in DoE Circular 3/84 (1), which described the transfer of responsibility for determining British Coal opencast coal applications from the Secretary of State for Energy to the mineral planning authorities. It was envisaged at the start of the research that any guidelines would principally be concerned with the way in which noise limits might be set and monitored at opencast coal mines, but with the possibility of their application being widened to include other types of surface mineral workings such as rock quarries and sand and gravel pits.

The research was carried out on behalf of the DoE by W.S. Atkins Engineering Sciences over a period of two years, and considered the following objectives:

1. To review the existing literature.
2. To review the current practices of local authorities and site operators.
3. To assess the significance of noise as a factor influencing public attitudes towards mineral extraction.
4. To assess the reliability of noise modelling and prediction techniques in relation to surface mineral workings.
5. To investigate potential means of reducing noise emissions.
6. To consider the most appropriate means of monitoring the noise.

The work relating to the last of these objectives is the subject of this present paper.

FIELDWORK STUDIES

In order to gain an appreciation of the characteristics of the noise produced by surface mineral workings, a programme of measurements was carried out at a selection of sites which included most of the common mineral types.

Various forms of measurement were made at each site. In the context of investigating noise monitoring techniques, the most interesting of these were the measurements taken

*Now at Leslie F. Moore Associates, Dartford, Kent

at an opencast coal site over a continuous period of three weeks during which the parameters L_{10}, L_{50}, L_{90}, L_{max}, and L_{Aeq} were recorded in digital storage at 15 minute intervals for later analysis on a microcomputer. The measurement system used to achieve this degree of detail in the data collection was developed as part of the research program.

Description of site

A plan of the opencast coal site is given in Figure 1, showing the main features of the site and the monitoring positions for the three-week survey. At the time of the survey, the site was approximately half way through its expected ten year lifespan. The excavation of the site had commenced at the northern end, from where earth was transported to form the south and east overburden mounds. With the cut established, work had progressed in a southerly direction with overburden being used as backfill, and it was this stage of the work which was being carried out during the survey. Ultimately the stored overburden will be used to refill the site.

The cut unusually took the shape of an 'L', as a result of the site's geology. 85 tonne dump trucks were used to transport overburden cut by excavators from the southern face of the cut round to the tipping area on the northern side, completing a circuitous route around the 'L' to return for another load. A 27.6 m^3 dragline was used to move the larger areas of overburden. Overburden was loosened by blasting, which took place typically once per day.

The dump trucks, of which there were eight normally operating, were found to be the main source of noise on the site on the basis of sound power level measurements, and this was confirmed subjectively. The only extraneous noise of note was caused by low flying military aircraft, and was readily detectable in the measurement data as a high value of L_{max} without a corresponding rise in the L_{10} or other percentile levels.

Noise measurements

Measurements were made simultaneously over the three weeks at three positions. Position 1 was close to the dump truck haul road where the noise level was susceptible to slight variations in the line taken by the trucks along the haul road, and was dominated by the noise from the trucks as they passed along the short section of haul road adjacent to the microphone position. Positions 2 and 3 were further away from the dump truck route, and therefore recorded noise that was far more representative of the overall noise from the site than at position 1. A fourth position had been placed at the top of the large southern overburden mound, but the measurement equipment became damaged and the data was lost.

Hourly weather records were obtained from the Met. Office for the survey period, which contained the mixture of good and bad weather that might be expected in early February. Information concerning the hours of working and the typical site activities were obtained from the site engineer, which was combined with a knowledge of the site's modes of operation gained during earlier attended noise surveys.

Analysis of the data concentrated on the 15 minute L_{Aeq} values. The full set of approximately 2000 values at each measurement position was considered in a number of ways of which the most illuminating are shown in Figure 2. Two histograms are plotted for each measurement position. One shows the distribution when the data relating to weekends and to bad weather periods (e.g. heavy rain or winds over 10 m/s) is removed, bearing in mind that the site is operational for the whole of the day and night during

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weekdays. The other shows the distribution when the data relating to breaks in the working at meal times and tea breaks is additionally removed.

The mean and standard deviation for each set of data has been calculated, and the corresponding normal distribution curve is superimposed on each histogram. Both of the measured distributions for position 1 are seen to be rather different in shape to the normal distribution, being skewed towards the high end of the range of noise levels. The measured distributions at the other two positions are by contrast fairly well approximated by the normal distribution. This can be explained by the relative proximities of the three positions to the main areas of working on the site. Position 1 is primarily affected by dump trucks moving on the nearby haul road and is therefore measuring a local effect. Positions 2 and 3 are sufficiently far away from the workings that they are representative of noise from the whole site, which results in any local effects being less pronounced and therefore the noise being statistically better behaved.

The effect of removing the data relating to meal and tea breaks is, as may be expected, to reduce the number of samples at low noise levels whilst leaving the histogram virtually unchanged at higher noise levels. This also has the effect of making the distribution more narrow, the standard deviation being reduced from 3.28 dB to 2.50 dB at position 2 and from 2.96 dB to 2.49 dB at position 3. It is also apparent that in both cases the distribution is skewed slightly towards the high noise levels compared to the normal distribution when only the bad weather data is excluded, but when meal and tea breaks are additionally excluded the measured distribution follows the normal distribution very closely.

APPLICATION TO SUPERVISORY MONITORING

The study of the current practice of local authorities that was included in the research programme indicated a degree of confusion over the way in which measurements of surface mineral noise should be made, in their supervisory capacity of ensuring that limits are met. There was concern that their staff should be obliged to measure over long periods such as 8 or 12 hours to correspond with the L_{Aeq} periods specified in planning consents, but uncertainty over whether shorter measurement periods would suffice. Another problem related to measurement techniques, although of somewhat more concern in the specification of planning controls, is the question of whether measurements should be made at the site boundary or at the nearest noise sensitive property.

Measurement duration

The fieldwork studies showed that, provided the normal constraints of weather conditions are observed and periods of low activity such as meal breaks on the site are avoided, a standard deviation of 2.5 dB would appear to be achievable for measurements sufficiently far from the main site activities to be outside the influence of local effects, yet sufficiently close for extraneous and background noise not to be significant. On the basis of this, the curves given in Figure 3 have been derived to indicate the duration of measurement required to achieve a desired confidence in the accuracy of the result, using the Student t-distribution method (see, for example, (2) for an explanation of the method). A commonly used confidence level is 95%, at which the graph indicates for example that if an average L_{Aeq} had been obtained from four 15 minute measurements then the 'true' mean would be no more than 2dB higher than the measured mean. Of course as more measurements are taken to calculate the average, the more reliable that average becomes, but a law of diminishing returns operates on the improvement of accuracy.

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It can be seen from these results that in many cases measurements over periods much shorter than 8 or 12 hours are adequate to determine whether a site is meeting the noise limit. Only in cases where the noise is very close to or indeed over the limit, when an unambiguous comparison with the limit might be required, would a full measurement under the complete terms of the limit be necessary.

Measurement location

The fieldwork did not investigate the question of the best measurement location so explicitly as the question of duration, but nevertheless some conclusions were drawn. Experience suggested that measurements at nearby properties only give a representative evaluation of the site's noise if the prevailing noise from other sources is exceptionally low. Measurements taken within or close to the site, provided they are not taken near to any one noise source, have been found to be more reliable indicators of the site's overall noise. Monitoring at the affected property is popular because the noise heard by the occupant is being measured more directly, but it is inappropriate for testing whether the site is meeting its obligations unless it can be shown that no other noise sources have affected the results. Monitoring at the site boundary is to be preferred for its reliability, and may if required be related to noise at properties by calculation using an analytical model of the site.

The positioning of the microphone at the boundary can have a marked effect on the levels measured, and should ideally be fully specified in any noise limits. Difficulties arise particularly where a baffle mound has been erected close to a boundary, when a measurement at 1.5 m above ground level on the boundary line might be very well shielded by the mound, with the measured level then being highly dependent on the distance between the mound and the microphone, which is not desirable. A much better position for reliability would be on top of the baffle mound (with the microphone raised 1.5 m) but this would then fail to take into account the attenuating effect of the mound.

An appropriate compromise might be that, in situations where a measurement of site boundary noise is required within the influence of a baffle mound, the noise measurement should be made at the top of the mound and an appropriate correction applied to account for the attenuating effect of the mound, to be agreed by the parties concerned.

Normal good measurement practice should of course be exercised, and this would include ensuring that locations are not unduly affected by unrelated noise sources such as traffic on public roads. Noise should be measured at a selection of locations around the site, unless experience or complaints point to specific locations.

RELEVANCE TO OTHER TYPES OF WORKINGS

Although the measurements were made at an opencast coal site, it is possible that other types of surface mineral workings might have similar degrees of variation in their noise levels. At sand and gravel sites, the washing and grading machinery will often be the dominant source and produces a fairly steady noise level. At rock quarries the crushing and grading machinery may be dominant, although there may be significant intermittent sources such as rock drills and regular blasting, so that greater noise level variation is likely. Long term measurements would have to be made at such sites to determine the variations in noise levels that can be expected at each type of site.

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CONCLUSIONS

The standard deviation of 15 minute L_{Aeq} noise levels measured at an opencast coal mine has been found to be 2.5 dB, provided measurements are made away from undue local influences or relatively high background noise levels. In practice this means that measurements over periods much shorter than the 8 or 12 hours commonly specified in noise limits are often sufficient to confirm that a site is meeting the noise limit, although measurements under the full terms of the limit would of course be necessary in marginal cases or if an exceedance were required to be proved.

The location for measurement is preferably at the site boundary, as this is likely to give results that are more representative of the noise being produced by the site than a measurement at the nearest noise sensitive property. Care has to be taken however if baffle mounds are close to the measurement position.

REFERENCES

1. DoE Circular 3/84, "Opencast Coal Mining", HMSO, 1984
2. Kreysig, E., "Advanced Engineering Mathematics", J. Wiley, 1979

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FIGURE 1 : SITE PLAN

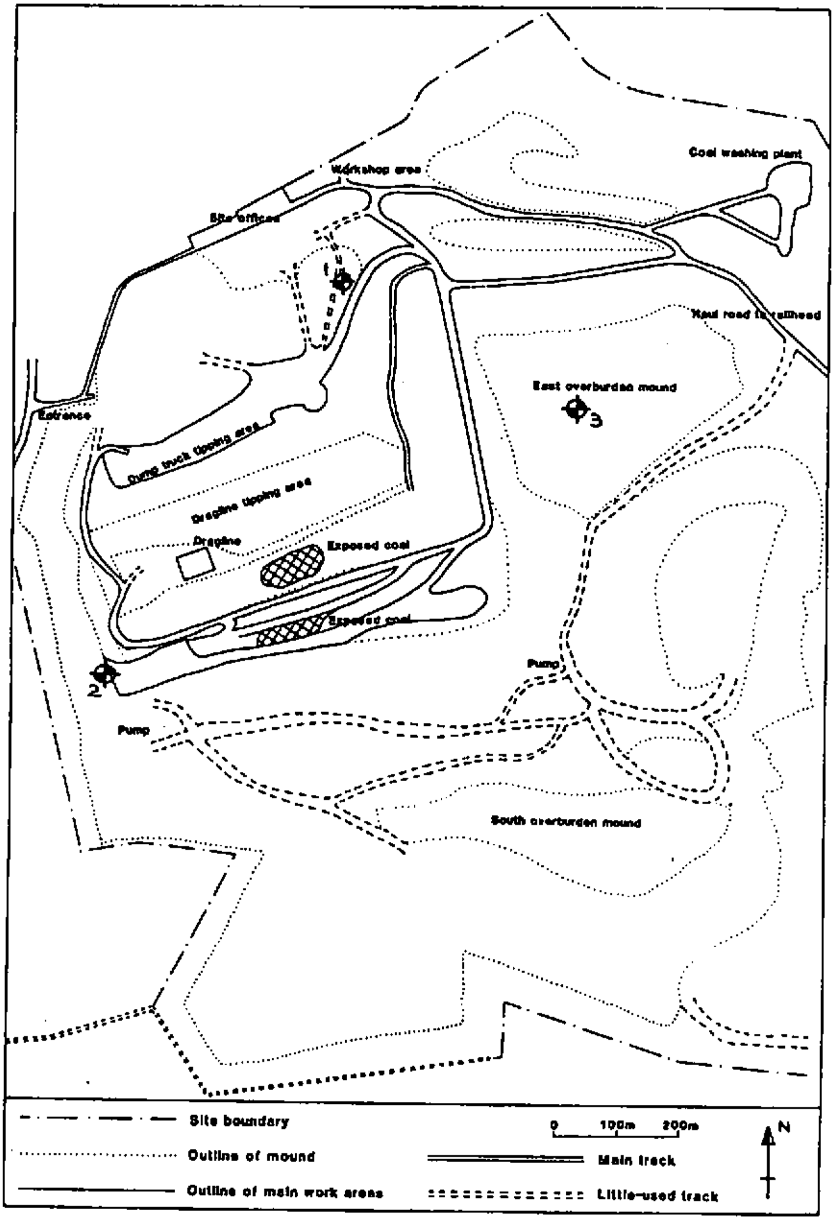

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FIGURE 2 : SOUND LEVEL DISTRIBUTIONS

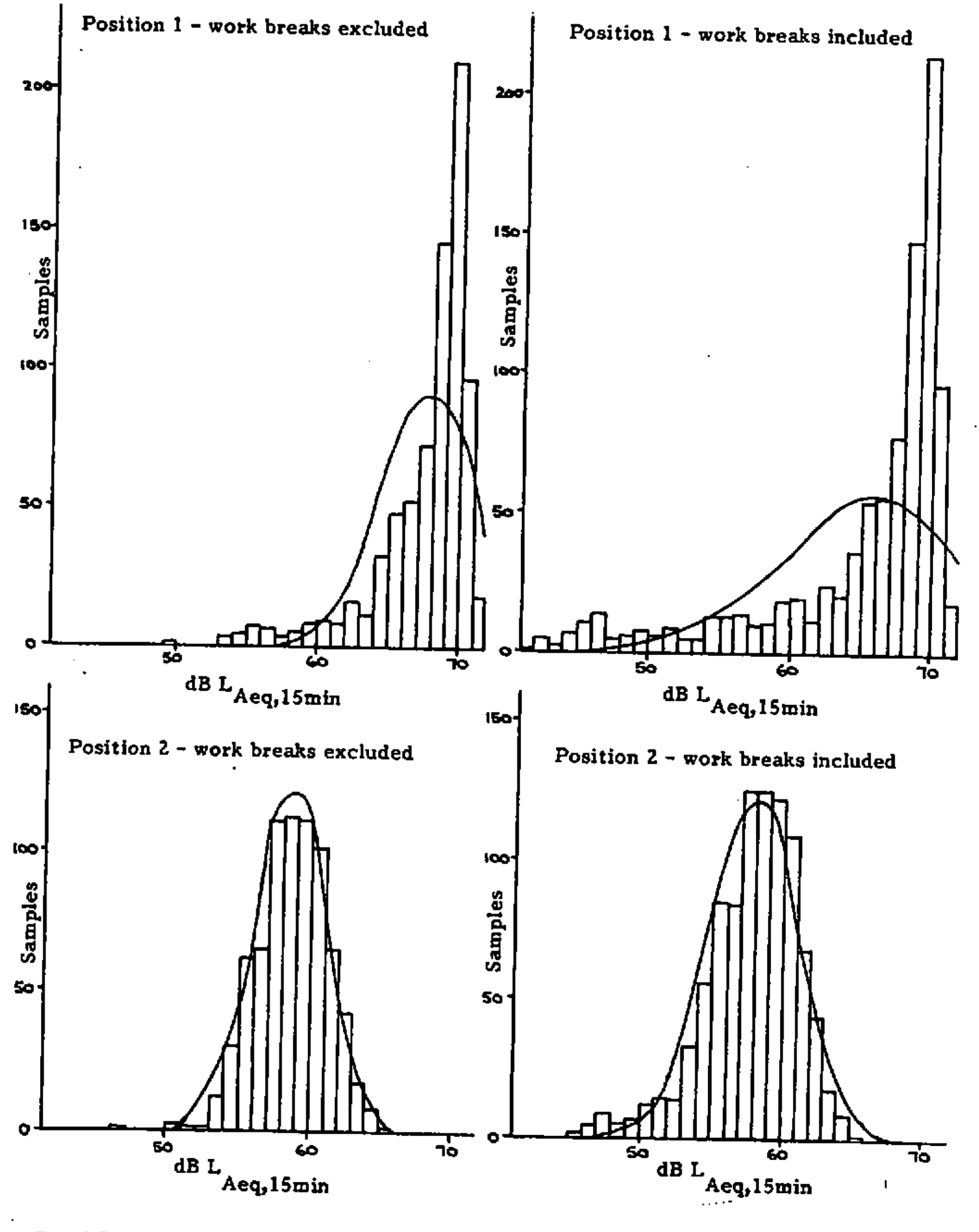

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FIGURE 2 (contd.) : SOUND LEVEL DISTRIBUTIONS

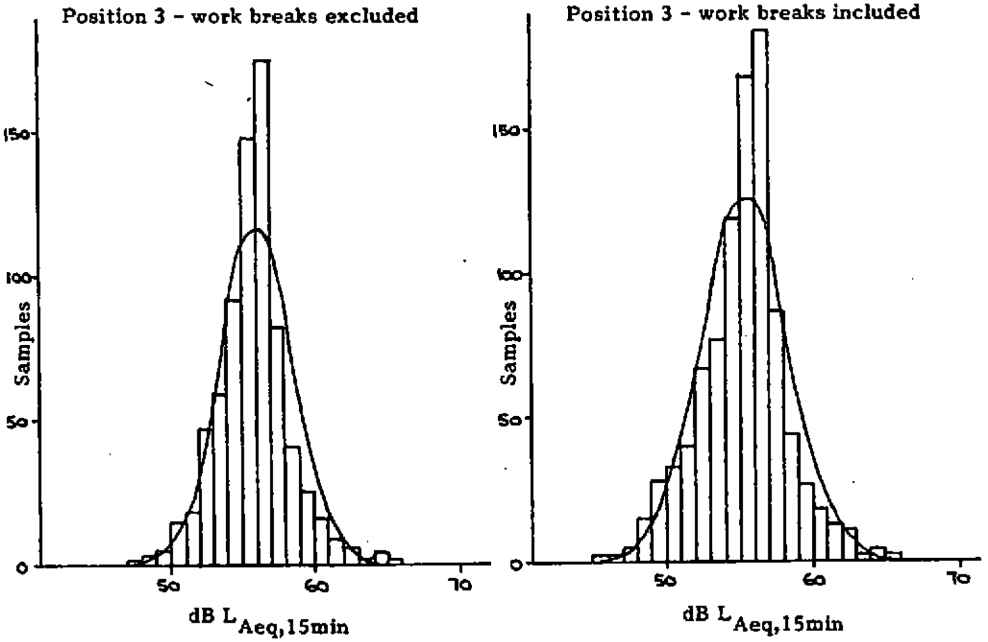

FIGURE 3 : NOISE MEASUREMENT ACCURACY