Proceedings of the Institute of Acoustics

THE SPECIFICATION OF A TOXIC ALARM SYSTEM FOR A LARGE CHEMICAL PLANT COMPLEX

G Taylor(1), A Giles(2) and B D Claybrook(3)

(1) ICI Engineering Dept. Billingham (2) ICI C & P Environment Dept., Billingham (3) ICI C & P Engineering, Wilton

INTRODUCTION

Installations which might, in the event of accident or failure, release materials harmful to health should incorporate audible warning systems. Such systems are usually only local to the plant and often utilise the plant communication system. On a site comprising many plants this can lead to a multitude of different systems with a resulting inefficiency in communicating the alarm condition beyond the affected plant. Furthermore, areas likely to be affected by a toxic release are not always within range of local alarms and the plant to plant alarm variations gives rise to confusion amongst itinerant workers, contractors and visitors.

ICI has large chemical complexes at Wilton and Billingham each site covering an area of several square kilometres. Wilton is a larger and more open site than Billingham with potentially greater areas not covered by local alarms. On the other hand the congestion at Billingham is likely to give rise to more significant screening. This paper describes the steps taken at both sites to provide integrated site-wide toxic alarm systems.

GENERAL CONSIDERATIONS

The basic criterion for audibility is the difference between the alarm and the ambient sound pressure levels although audibility is also governed by the tonal characteristics of the alarms. With due employee awareness of the nature of the alarm signal, it was considered that a 5 dB increase in sound pressure level would provide a sufficient alarm level.

The most economical alarm system would be provided by the installation of a small number of high power alarms although wide spacing can lead to a tendency for the alarms to be ignored should they sound remote. Also the most effective coverage can be achieved by locating the alarms in areas with the highest ambient noise levels so that the fall off in alarm level with distance is matched by a corresponding reduction in ambient level. However, for this concept to be practicable, the geographical location of plants on a large site needs to be considered since high noise areas may not necessarily be conveniently distributed. Additionally plant areas tend to be adequately covered by local alarms.

The determination of the number and location of the alarms depends on the sound propagation characteristics. Screening has a significant effect on propagation but the level of screening arising from plant structures and buildings on a chemical complex was unknown.

THE SPECIFICATION OF A TOXIC ALARM SYSTEM FOR A LARGE CHEMICAL PLANT COMPLEX

MANUFACTURER'S SPECIFICATIONS

Alarm specifications supplied by manufacturers often quote the sound pressure level at 30 m and also the effective range for a 70 dB sound pressure level. For the alarms tested, a variety of methods had been used by the manufacturer to determine the alarm data. The methods for determination of the sound pressure level at 30 m included measurement in an anechoic chamber, direct measurement outdoors and calculation from the 70 dB range assuming 10 dB attenuation per doubling of distance. The latter method is likely to give widely differing values depending on the validity of the assumed 10 dB attenuation per doubling of distance. The method used for each unit was not identified.

The propagation formulae given here assume a correct value of sound pressure level at 30 m. It is therefore essential to establish that the manufacturer's data is valid at 30 m range.

WILTON ALARM TESTS

Omni-directional alarm

Initial tests were carried out on a high power omni-directional alarm. The manufacturer's specification for the alarm claimed 115 dB sound pressure level at 30 m and a 10 dB reduction for each doubling of distance i.e.:-

$$L_r = 164 - 33.2 \log(r)$$

This dual tone alarm operated at 500 and 700 Hz. It was located on a thoroughfare in a typical works situation and suspended by crane at the recommended height of 15 m.

Some 42 measurement locations were identified - Figure 1. Most were within 500 m of the alarm but some were chosen at greater distances of up to 1300 m, including off site locations, in order to provide some assessment of the environmental impact. All locations were 'off plant' and covered situations with both high and low levels of screening.

The alarm was sounded for periods of two minutes every ten minutes during which time the sound pressure levels with and without the alarm sounding were measured at each location. In order to increase the accuracy of the measurements 500 Hz octave band 'A' weighted readings were taken.

After correction for the background level the alarm sound pressure levels were plotted against distance as shown in Figure 2.

Careful examination of the measurement locations enabled a number of points to be identified as being lightly screened. These points are identified in Figure 2 where it can be seen that it is possible to draw two separate lines through the results approximating to low and high screening levels. Also shown in Figure 2 is the alarm specification line which is 3 dB higher than the low screening curve. Two dB of this difference corresponds to high current cable losses in the experimental set up.

The scatter in the results arises from both differences in screening levels and also inaccuracies involved in determining the alarm sound pressure levels when the difference between the ambient and overall sound pressure levels was small.

After correction for cable losses the propagation lines can be represented by the relations:-

High screening $L_p = 152 - 33.2 \log(r)$

Low screening $L_p = 163 - 33.2 \log(r)$

Directional Alarm

The possibility of using fewer higher power alarms was economically attractive.

An alternative alarm to the omni-directional alarm was available. This unit utilised the same components and had the same power as the omni-directional alarm but the eight sounders were all mounted in line instead of circumferentially. To achieve coverage over 360 degrees the whole unit rotated at 3 rpm. Thus potentially the alarm sound pressure level would be increased by up to 6 dB.

The tests carried out on the omni-directional alarm were repeated for the directional alarm.

The results, which are not presented here, displayed an increase in sound pressure level. The duration of the peak sound pressure level was however very much shorter than expected and seemed of the order of perhaps only 1 or 2 seconds. When operating with the warble alarm signal the peak duration was so short that sensible measurements could not be taken.

Free field tests to check the directivity of the alarm were carried out with the alarm stationary. These test showed that there was little variation in sound pressure levels at angles up to 45 degrees from the alarm axis. Directivity alone could not therefore account for the excessively short duration of the peak signal.

All observers agreed that the rotational alarm would not be suitable for the proposed site-wide system.

WILTON SYSTEM

Surveys showed that the general 'off plant' ambient noise level was less than 70 dBA and so it was aimed to provide an alarm system which generated a minimum sound pressure level of 73 dBA across the whole site thereby increasing the ambient level by 5 dBA.

A decision was made to install omni-directional alarms at key points on the main thoroughfares running through the site. In order to ensure full coverage the high screening propagation relationship was used in determining the siting of the alarms. Initial siting was carried out simply by covering a site plan with circles having a radius corresponding to the 73 dB contour which for the omni-directional alarms was 240 m. It was found that 11 alarms would provide coverage for the whole site. The arrangement was checked by computer and the final arrangement and contours are shown in Figure 3

After installation spot checks substantially confirmed the predicted alarm levels. Subjective assessment was carried out by issuing large numbers of questionaires across the site. Staff were asked to judge the audibility of the alarm system during a series of tests. The responses indicated that the alarms are audible in all areas 'off plant' and most areas 'on plant'. They are inaudible 'on plant' where the background noise levels are very high or within some substantial building structures. Separate arrangements exist for these latter situations.

BILLINGHAM ALARM TESTS

It was considered that the high building density at Billingham could give rise to abnormally high screening levels when compared with Wilton. It was however expected that improved propagation could be achieved by locating the alarms at higher level. Further tests were therefore carried out at Billingham with a single alarm mounted at high levels.

The results are presented in Figure 4 together with the propagation lines previously established. It is clear that increasing the height of the alarm to 68 m improved the propagation to that previously determined for low screening levels. Only a marginal improvement was achieved by increasing the height to 24 m and the results displayed a greatly increased scatter.

BILLINGHAM SYSTEM

By locating the alarms on tall structures at Billingham it was possible to use the low screening propagation line. This effectively doubled the range of the alarms from 240 to 514 m and it was found that the whole site could be covered with a total of six alarms.

Because the alarms were mounted on plant structures two modifications were necessary:-

1) The four pairs of alarms comprising the complete assembly were separated and carefully positioned around the circumference of the structure on which they were located. The lower horn was angled downwards at 30 degs to minimise directivity effects in the areas immediately beneath the alarm.

2) For the first 15 seconds of operation the alarms operate at a low power level (24 dB down) thus giving personnel nearby sufficient warning to fit ear protection and leave the area.

After installation of the complete system, measurements were made at a large number of locations. The results showed that the ambient levels in outdoor areas around the site were generally increased by 16 dB +/- 7 dB compared with the target increase of 5 dB.

Practice tests at Billingham have demonstrated that the objective of clearing the site within 3 minutes of the alarm sounding is satisfied.

COMPARISON WITH PUBLISHED WORK

Figure 5 shows the propagation lines plotted over the results published by Delany[1] for the propagation of sound from a siren source in urban and suburban areas. The close agreement between low screening and suburban areas and between high screening and urban areas is evident.

CONCLUSIONS

In the propagation of 500 Hz octave band sound across a large chemical complex the attenuation per doubling of distance is 10 dB.

The sound pressure at a distance from an alarm may be calculated from the relation:-

$$L_p = L_{po} - 33.22 \log(r/r_o) - K$$

The screening factor K has a value of 11 at alarm heights of 15 metres and decreases with height to a minimum value of 0 at 70 metres.

Alarm levels which increased the background sound pressure by 5 dB proved satisfactory.

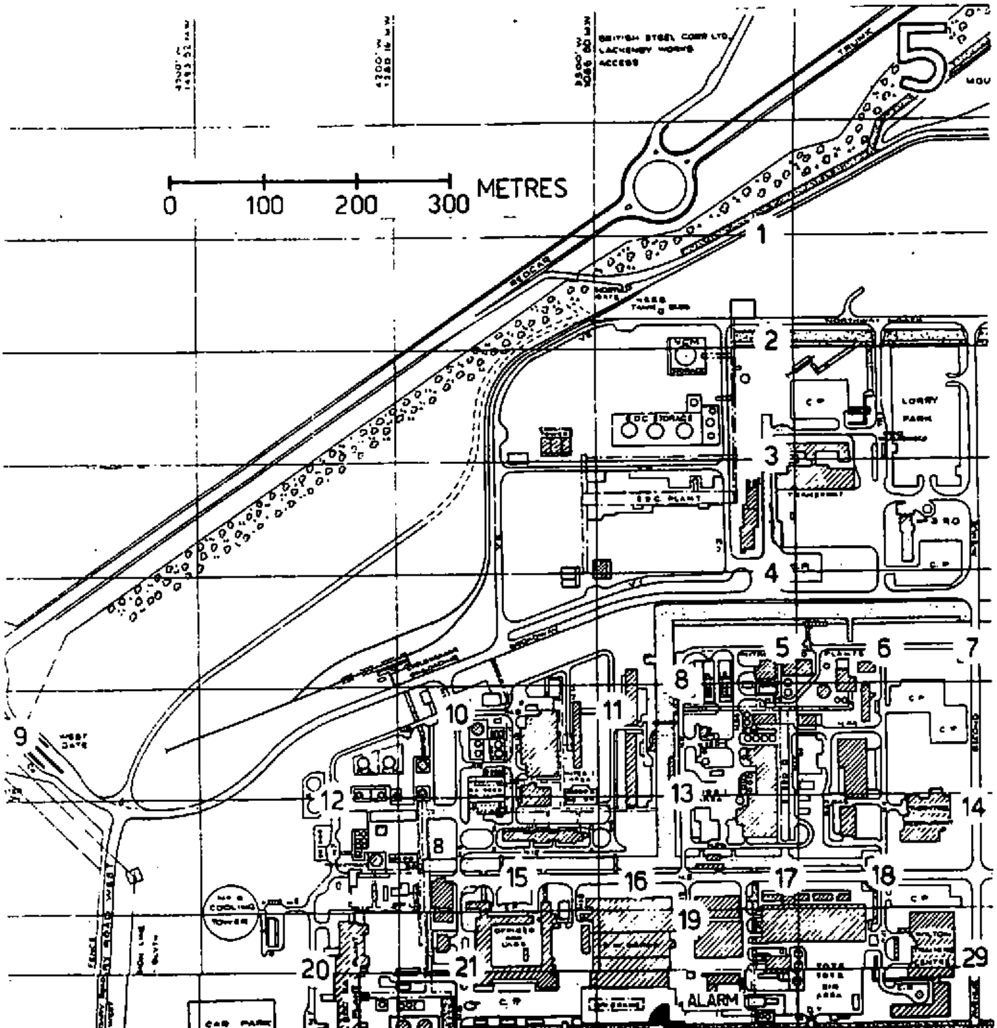
Rotational alarms with high directivity proved entirely unsatisfactory particularly when on warble signal.

NOMENCLATURE

L_p = alarm sound pressure - dB re 2×10^{-5} N/m^2
L_{po} = alarm sound pressure at 30 m - dB re 2×10^{-5} N/m^2
r = distance from alarm - metres
r_o = 30 metres
K = constant dependant on the level of screening.

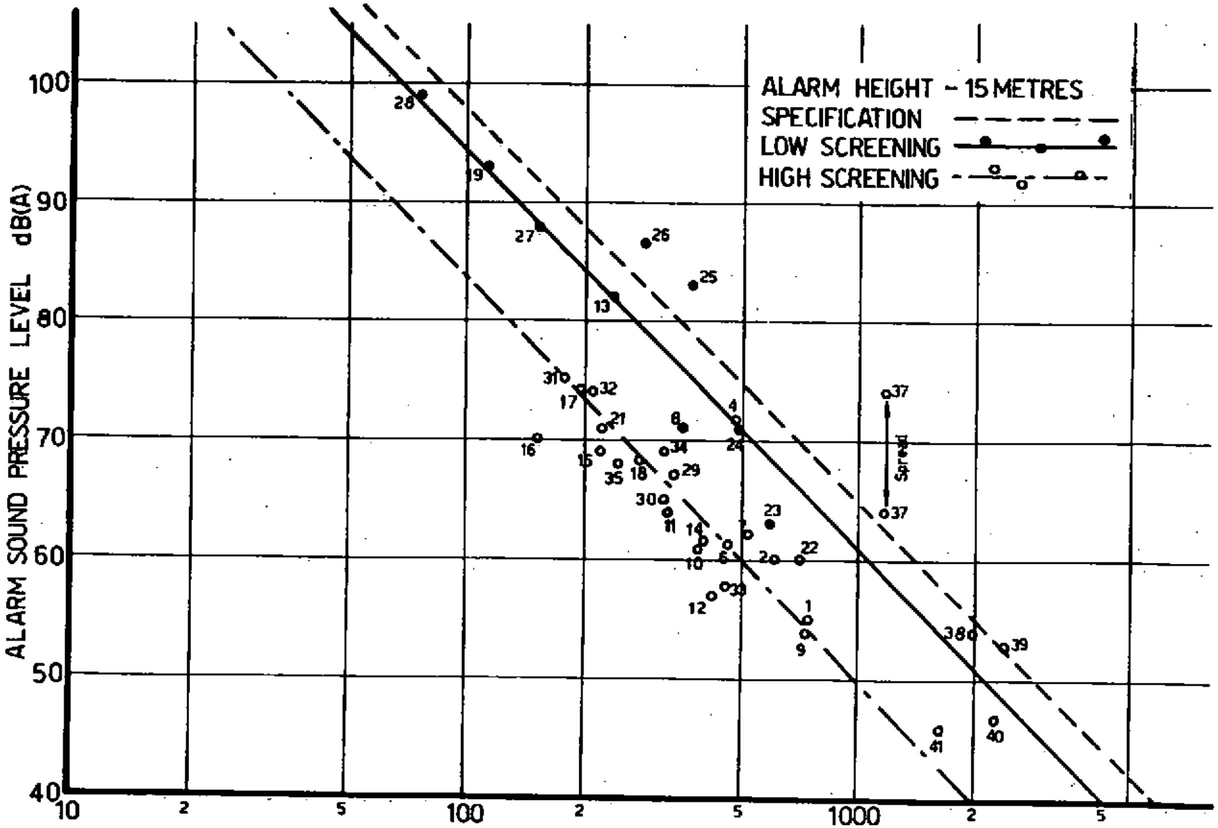
REFERENCES

[1] M E Delany, "Range Prediction for Siren Sources" National Physical Laboratory, Aero Special Report 033. November 1969.



TEST MEASUREMENT LOCATIONS

FIGURE 1



ALARM SOUND PROPAGATION

FIGURE 2

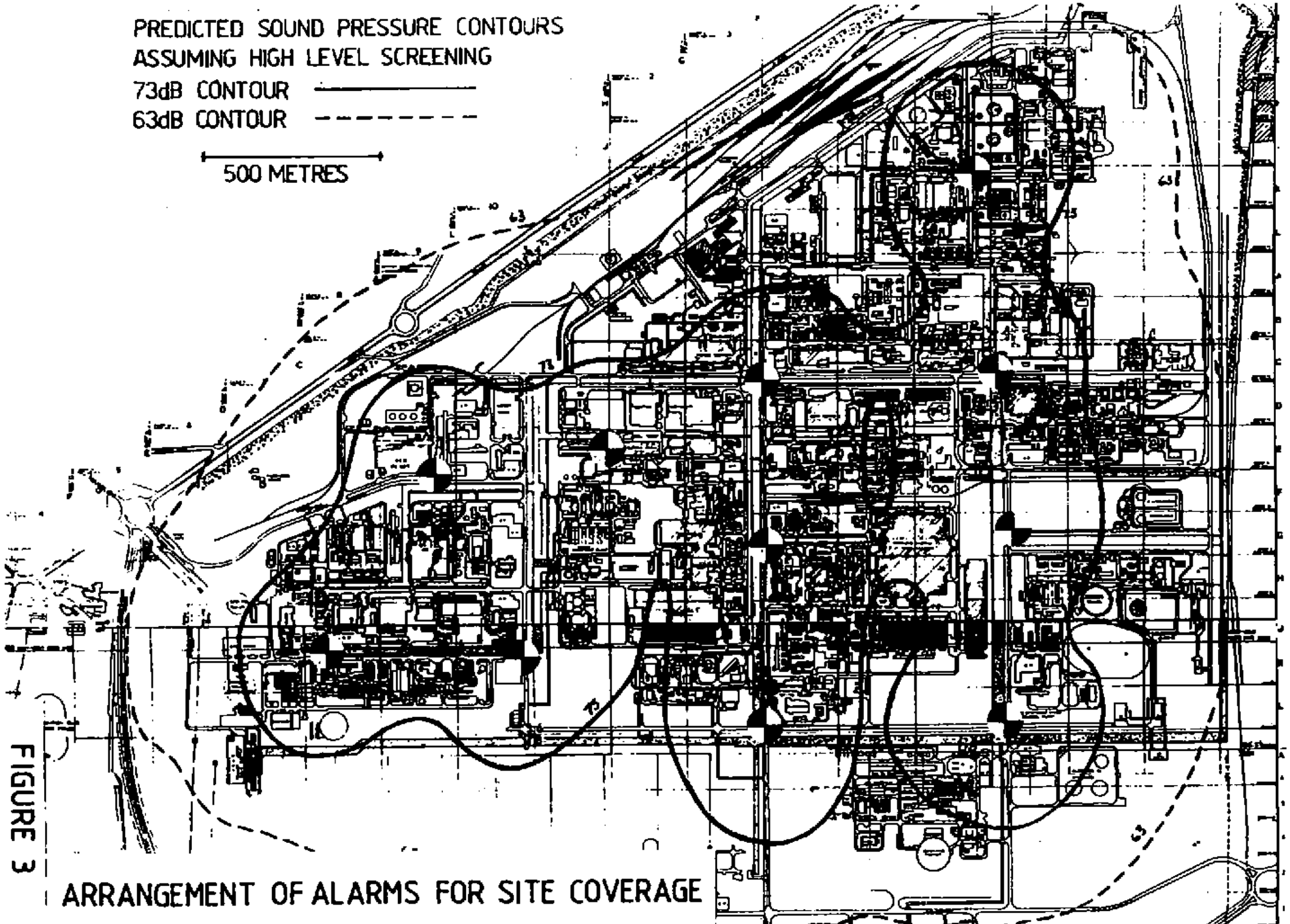
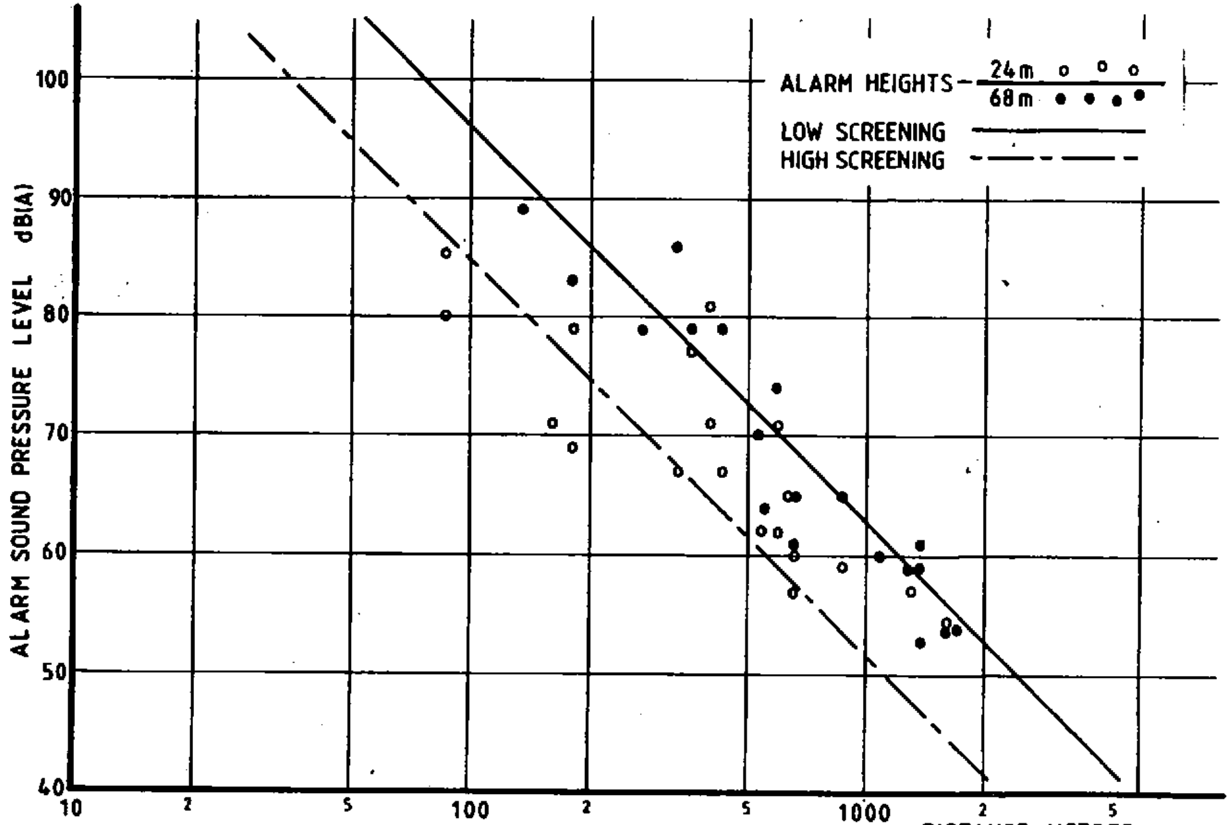


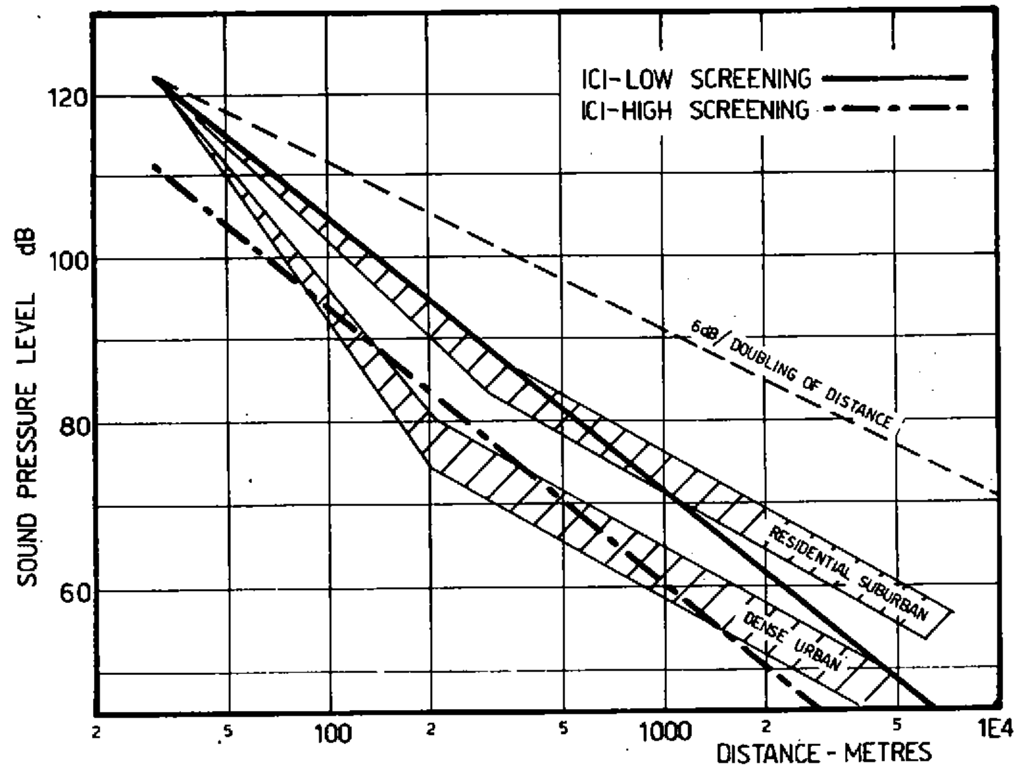
FIGURE 3

ARRANGEMENT OF ALARMS FOR SITE COVERAGE



ALARM SOUND PROPAGATION

FIGURE 4



COMPARISON OF RESULTS WITH URBAN PROPAGATION GRAPH
OF NPL AERO SPECIAL REPORT 033

FIGURE 5