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A METHOD FOR PREDICTING NOISE INTENSITY FROM AN EXPLOSIVE SOUND SOURCE

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INTRODUCTION

A method has been developed at the Royal School of Artillery Larkhill to predict noise intensities at distances up to 35km from an explosive source.

Given the charge weight of the explosive and wind and temperature profiles to a height of about 2km, a small computer predicts noise intensities at 2km intervals for each 10 degrees of azimuth

There has been a marked reduction in the number of complaints of noise and/or damage from the public since using the method some eighteen months ago.

Preliminary results suggest that 80% of the predicted intensities, measured in peak linear dB, will be within 5dB of the measured value, using on site measurements of wind and temperature profiles.

Further work in co-operation with Salford University and ICI Buxton is being done to extend the prediction method to anywhere in the UK using synoptic data that is readily available at any meteorological office.

THE PREDICTION METHOD

This uses a sound ray tracing technique similar to that described by Suggitt (Ref 1).

Profiles of wind and temperature are used in combination to obtain a speed of sound profile for each 10 degrees of azimuth ie 36 profiles for a full 360 degree scan.

The lower atmosphere is divided into layers, 150M in depth, and the speed of sound calculated at the boundaries of each layer. The speed of sound within the layer is assumed to change at a constant rate and hence sound rays passing through the layer would describe arcs of circles whose radii are proportional to the inverse of the rate of change in the speed of sound. If the speed of sound increases with height, the rays are refracted down; for a decrease with height the rays are refracted up and for a constant speed of sound the rays pass through the layer in a straight line (see figure 1).

Given an initial angle to the horizontal of 1 degree, the computer traces the path of the sound ray through the atmosphere until it returns to earth. It then repeats the process for a 2 degree angle and so on until a ray leaves the top of the atmosphere (about 2km above ground level). It has been found that all rays with an initial elevation of 20 degrees or more will leave the atmosphere, the average being about 8 to 10 degrees.

The number of rays returning is governed by the speed of sound profile and this changes with direction scanned, wind and temperature. The wind and temperature profiles change with time and distance presenting a formidable four-dimensional problem in data input to the computer. Fortunately the atmosphere is sufficiently conservative in the times and distances under consideration so that mean profiles of wind and temperature yield useful noise predictions.

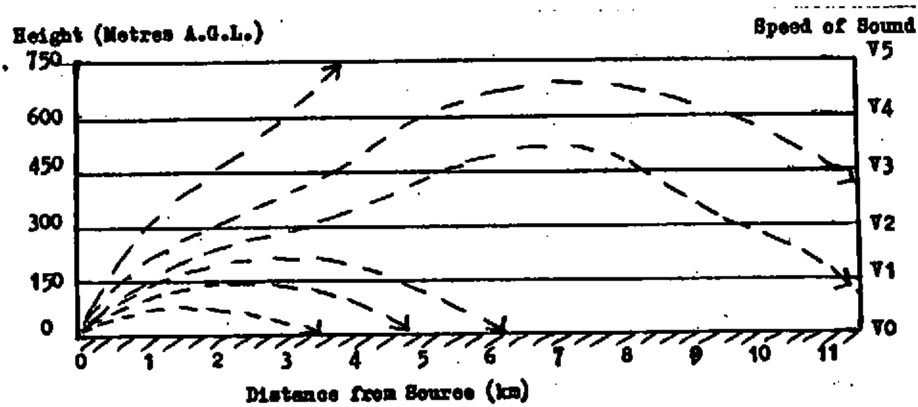

FIGURE 1.

Figure 1.shows a small section of sound ray trajectories through 150M layers of the atmosphere whose speeds of sound at their boundaries are V0,V1,V2 etc. The atmosphere is assumed to be unchanging with time and distance from the source hence rays that return to earth are symmetrical about their apex and the horizontal distance from source to apex is half that of source to the return point on the earth.Thus calculation time can be halved by computing trajectories only to the apex.Once a ray has left the top of the model atmosphere the scan for that azimuth is complete since all rays with larger angles of elevation will also leave the atmosphere.

The intensity of sound at a point has been shown to be a function of:-
(i) The charge weight of the explosive source
(ii)Whether the charge is exploded in free air or contained by burial
(iii) The direction and distance of the point from the source
(iv) The density of rays returning to earth ie the number of rays returning per km of horizontal distance
(v) Topography.

NOTE:THE VARIABLE HAVING THE GREATEST EFFECT ON SOUND INTENSITY IS THE WIND.

Charge Weight and Location

The sound intensity for a given charge should ideally be measured as close to the source as is practical and safe.For a gun a distance of 50-100M is ideal since the meteorological effects on the measurement will be negligible. If direct measurement is impossible then a reasonable estimate can be made using tables contained in Ref 2.

If the charge weight is unknown,the prediction method uses a standard charge of 0.45kg (10lb) of H.E. exploded in free air.This is equivalent to a peak overpressure of 130dB at a distance of 1km,in an isothermal,windless atmosphere.

Complete containment of the charge markedly reduces the sound intensity but it must be emphasised that the containment must be total ie no blow out through charge holes.Walls built around gun emplacements are virtually of little use since the sound escapes by reflection,diffraction and refraction. Quarries over 100M deep or even open ended shafts sunk to nearly 1000M deep can still have a noise problem when blasting.

Direction and Distance from Source

By geometry alone,the attenuation of sound is 6dB per doubling of distance. Measurements have shown that this value is increased probably by diffraction in the air and by absorption near the ground.The value quoted in Ref 2 is 9dB per doubling distance but no information is given on how the figure was determined.Measurements at Larkhill indicate a value of about 7½dB taken in a near isothermal,windless atmosphere at distances up to 800M from the source. This type of atmosphere is rarely experienced and since the greater the distance from the source the greater the depth of atmosphere that must satisfy the above conditions,it is clear that direct measurement tens of km from the source is impossible.

The method therefore assumes a standard attenuation of 7½dB per doubling of distance for an isothermal,windless atmosphere in which sound rays will be straight and diverging.

Absorption of sound by air is frequency dependent and by direct observation the attenuation of explosive sound with frequencies in the range 10-20HZ is very small and almost certainly less than 1dB per km of path length in the atmosphere.

Temperature gradients in the vertical are a scalar quantity and apply equally in all directions.The observed variation in sound intensities with direction from the source can be attributed almost entirely to the wind,as will be shown later.

Density of Rays Returning to Earth (see Figure 2)

The density of rays returning to earth(ie the number of rays returning within each km) depends on the gradients of speed of sound in the lower atmosphere.

If the speed of sound increases with height the rays are bent down and the attenuation with distance decreased (Noise Enhancement).The intensity can be increased by some 10-20dB over the value to be expected in the standard atmosphere.

In the standard atmosphere the speed of sound is constant with height,the rays are straight and diverging and,apart from the grazing ray at zero degrees elevation,no ray returns to earth.(attenuation rate 7½dB per doubling of distance)

If the speed of sound decreases with height so that no rays return to earth at all then the value of the speed of sound gradient in the lowest 150M layer is used to increase the attenuation rate.Values of 25dB per doubling of distance are possible on extreme days.(Noise Suppression)

The conditions of most interest are when sound rays are bent up at first and then bent down to converge on a small area (Noise or Blast Focus).These conditions are by no means rare and in the UK are usually associated with the polar front weather systems that frequently cross the British Isles. The speed of sound decreases with height at first,then increases with height usually because of a marked increase in wind speed at height coupled with a change in wind direction .The upper wind direction can differ from that at the surface by as much as 180 degrees.Thus the surface wind is not a reliable

predictor of sound intensity.
The area of sound focus can experience an increase of 40dB above that normally expected at that distance. It can be located in any direction, even upwind of the surface wind, at distances normally between 4 and 15km but a focus could occur, that could give rise to complaints of noise, at 30-40km.

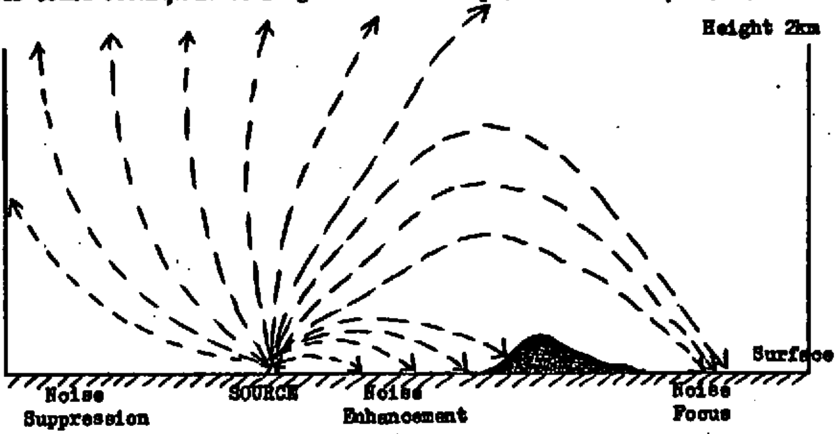

FIGURE 2.

__Topography__
The presence of hills and valleys affects the local sound intensity but a prolonged investigation would be required to determine the magnitude of the effect in isolation from the other variables. There is subjective evidence that steep-sided valleys increase the observed noise intensity but the shadow effect of hills is obscure. What is certain is that areas out of the line of sight to the source can still experience high noise levels because rays can be refracted over intervening high ground.
No corrections for topography are incorporated in the prediction method because the terrain of the Salisbury Plain did not warrant it and because the the main source of the noise (artillery) was mobile and could change its position by tens of km in almost as many minutes.

__Results__
Isopleths of predicted noise intensity are shown in Figure 3.

They show a typical noisy day with a noise enhancement area downwind and to the right of the surface wind,but also a well marked focus almost upwind.The upper winds on this day were veering and increasing with height,from 145 degrees 6m/sec on the surface to 276 degrees 17m/sec at a height of 1800M A.G.L. Note the area to the southeast where the noise decreases with increasing distance before increasing again at the focus.Note also the area where the sound would be inaudible.All of these features have been observed in the real atmosphere.

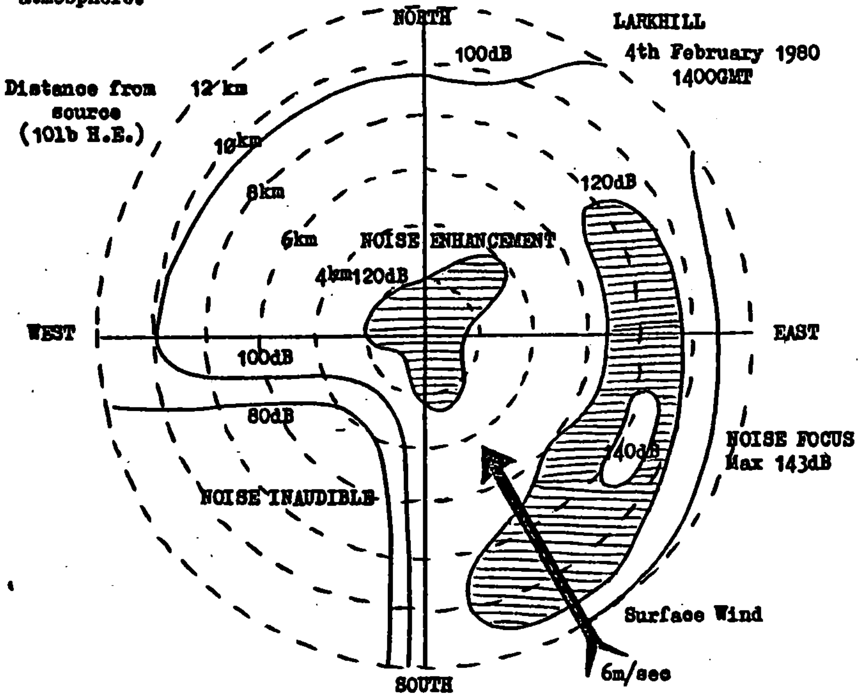

FIGURE 3.

Preliminary measurements,within a radius of 5km,have shown that 80% of the predictions were within 5dB of the measured value with a maximum error of 10dB

REFERENCES

1.R.T.SUGGITT."A Method for the Production of Accustic Forecasts Using a Digital Computer".Meteorological Magazine Vol 107 1978

2.B.PERKINS and W.F.JACKSON."A Handbook for Prediction of Air Blast Focussing" Ballistic Research Laboratories Report No 1240.Feb 1964