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AN IMPROVED METHOD FOR CALCULATING NEIGHBOURHOOD NOISE FROM OPEN-AIR INDUSTRIAL INSTALLATIONS

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INTRODUCTION

For a number of years the European oil industry has been co-operating in the development of better procedures for predicting neighbourhood noise, through the agency of CONCAWE, which is the oil companies international study group for environmental affairs. Recently it commissioned a detailed investigation of outdoor sound propagation to be carried out by Acoustic Technology Ltd. of Southampton, England. The present paper gives a brief review of the CONCAWE report on this study (1).

LITERATURE SURVEY

In the first phase of this study a literature survey was made of published information on sound propagation up to distances of 1 to 2 km from ground sources. From the broad spread of published data the consultant was asked to prepare an "engineering" model which could be used for calculating the propagation of noise from industrial installations. Graphs of the various attenuation effects were prepared by drawing best-fit lines through the scattered data.

EXPERIMENTAL WORK

The initial propagation model required testing and refining in a field study. This involved measuring the noise emission from individual sources in some typical oil-industry plants, calculating the neighbourhood noise, and comparing calculated values with measurements in various weather conditions.

Three installations were selected for this experimental work: the first was a small inland gas-producing station in flat agricultural land (Site A); the second, a medium-sized refinery in undulating agricultural land near the coast (Site B); and the third, a major oil refinery and petrochemical complex in a mixed residential and industrial area (Site C). At each of these the total noise emission was derived from the sum of the sound-power levels of individual sources. In all, 16 sources were measured at Site A, 81 at Site B, and 203 at Site C and their sound-power levels were derived in octave bands from 63Hz to 4kHz.

The number of receiving points at each site varied according to the nature of the terrain; there were 21 at Site A, 15 at Site B and 23 at Site B. The distances ranged from 68m to 3300m, most of them being in the range of 100m to 2000m. Sound-pressure levels at each receiving point were measured in dB(A) and in octave bands from 63Hz to 4kHz; 685 spectra were recorded at Site A, 460 at Site B, and 474 at Site C. Measurements were also made of wind speed, wind direction, relative humidity, cloud cover, and air temperatures at 1 m and 11 m.

THE FINAL MODEL

A practical system for defining atmospheric stability has been proposed by Pasquill in terms of wind speed, insolation (cloud cover), and time of day. He defines 7 stability categories ranging from A (unstable) to G (very stable, inversion condition). Using these stability categories in combination with vector-wind speed, v (m/s), 6 meteorological categories were defined for the model to represent different propagation conditions and these are given in the table below:

Meteorological Category	Pasquill Stability Category		
	A, B	C, D, E	F, G
1	$v < -3.0$	-	-
2	$-3.0 < v < -0.5$	$v < -3.0$	-
3	$-0.5 < v < +0.5$	$-3.0 < v < -0.5$	$v < -3.0$
4*	$+0.5 < v < +3.0$	$-0.5 < v < +0.5$	$-3.0 < v < -0.5$
5	$v > +3.0$	$+0.5 < v < +3.0$	$-0.5 < v < +0.5$
6	-	$v + 3.0$	$+0.5 < v < +3.0$

The prediction of the sound-pressure level in the neighbourhood is based on the following general equation:

$$Lp = Lw + D - (K1 + K2 + K3 + K4 + K5 + K6 + K7)$$

where,

Lp	=	Sound-pressure level
Lw	=	Sound-power level of source
D	=	Directivity index of source (usually zero)
K1	=	Loss due to spherical spreading, given by $10 \log 4\pi d^2$ where d is the distance from source to receiver.
K2	=	Loss due to atmospheric absorption, derived from published tables as a function of air temperature, relative humidity and distance.
K3	=	Loss due to ground effects (absorption and reflection). For hard ground K3=-3dB for all frequencies and distances. For other surfaces, graphs are given for K3 as a function of frequency and distance.
K4	=	Loss due to meteorological effects (wind and lapse rate). Graphs for K4 are given as a function of frequency, distance, and meteorological category.
K5	=	Loss due to source and receiver heights and topography. A procedure is recommended for deriving K5 from a graph which is a function of source and receiver height. It is also a function of K3 and K4. This has not been tested for receiver heights other than 1.2 m and is therefore provisional.
K6	=	Loss due to barriers. Provisional recommendations are given for deriving values of K6 but these have not been tested in the experimental work.
K7	=	Loss due to in-plant screening. It was not possible to derive values from the experimental work nor from investigations made by other CONCAWE members and it is recommended that K7=0 until more evidence is available.

Complete details of the graphs and equivalent polynomial equations in the final CONCAWE model are given in reference (1).

STATISTICAL ASSESSMENT OF THE CONCAWE MODEL

The differences between the measured and predicted values from the final model were combined for Sites A and B to derive the 95% confidence limits for the meteorological categories 2 to 6 and these are given below in dB:

95% Confidence Limits for Final Model

Meteorological Category	dB(A)	Octave-Band Centre Frequency, Hz						
		63	125	250	500	1k	2k	4k
2	6.8	5.4	5.4	9.1	9.4	7.8	9.8	12.4
3	6.9	5.0	6.2	9.4	10.1	8.5	8.5	9.4
4	5.7	4.8	6.5	8.7	9.8	6.6	5.6	6.7
5	4.7	3.9	5.4	8.4	8.1	5.2	5.6	6.7
6	4.5	5.2	6.1	6.7	9.3	4.9	5.5	8.2

These confidence limits (CL) imply that there is a 95% chance that an average measured sound-pressure level in a category will be within the range:

(predicted level − CL) to (predicted level + CL)

As a further check on the absence of consistent bias in the model the mean differences between measured and predicted values were calculated and these are given as dB in the following table:

Mean Differences (Observed Minus Predicted) for Final Model								
Meteorological Category	dB (A)	Octave-Band Centre Frequency, Hz						
		63	125	250	500	1k	2k	4k
2	0.5	0.1	0.1	2.0	2.2	2.2	-0.2	0.4
3	0.6	0.0	0.5	1.6	0.4	0.8	0.8	0.4
4	0.5	0.3	0.8	-1.2	-0.2	0.1	1.4	0.2
5	0.0	-0.1	0.0	-2.3	0.4	-0.6	0.9	-0.9
6	0.5	-0.8	-0.3	-1.7	1.2	-0.2	0.1	-0.9

DISCUSSION

The model which has been proposed offers a practical solution to the calculation of noise propagation from open-air installations and it can easily be programmed for computer use. Where required, it can be used to predict a long-term average noise level for a period of, say, a year by taking into account the frequency of occurrence of the various meteorological categories at the place in question. Alternatively it can be used to predict the expected noise levels for, say, light downwind conditions for the site.
A comparison with the OCMA and VDI propagation models shows that the CONCAWE model predicts to within limits that are significantly narrower so that it represents an advance on available techniques for predicting noise levels up to distances of 2000 m. Taken in combination with the CONCAWE and OCMA procedures for deriving sound-power levels of equipment, this model represents part of a systematic and practical approach to the prediction of neighbourhood noise from open-air installations. It can be used for the design of new plants or for the planning of noise reduction for existing plants.

REFERENCES

(1) CONCAWE Report 4/81. The propagation of noise from petroleum and petrochemical complexes to neighbouring communities. May 1981.