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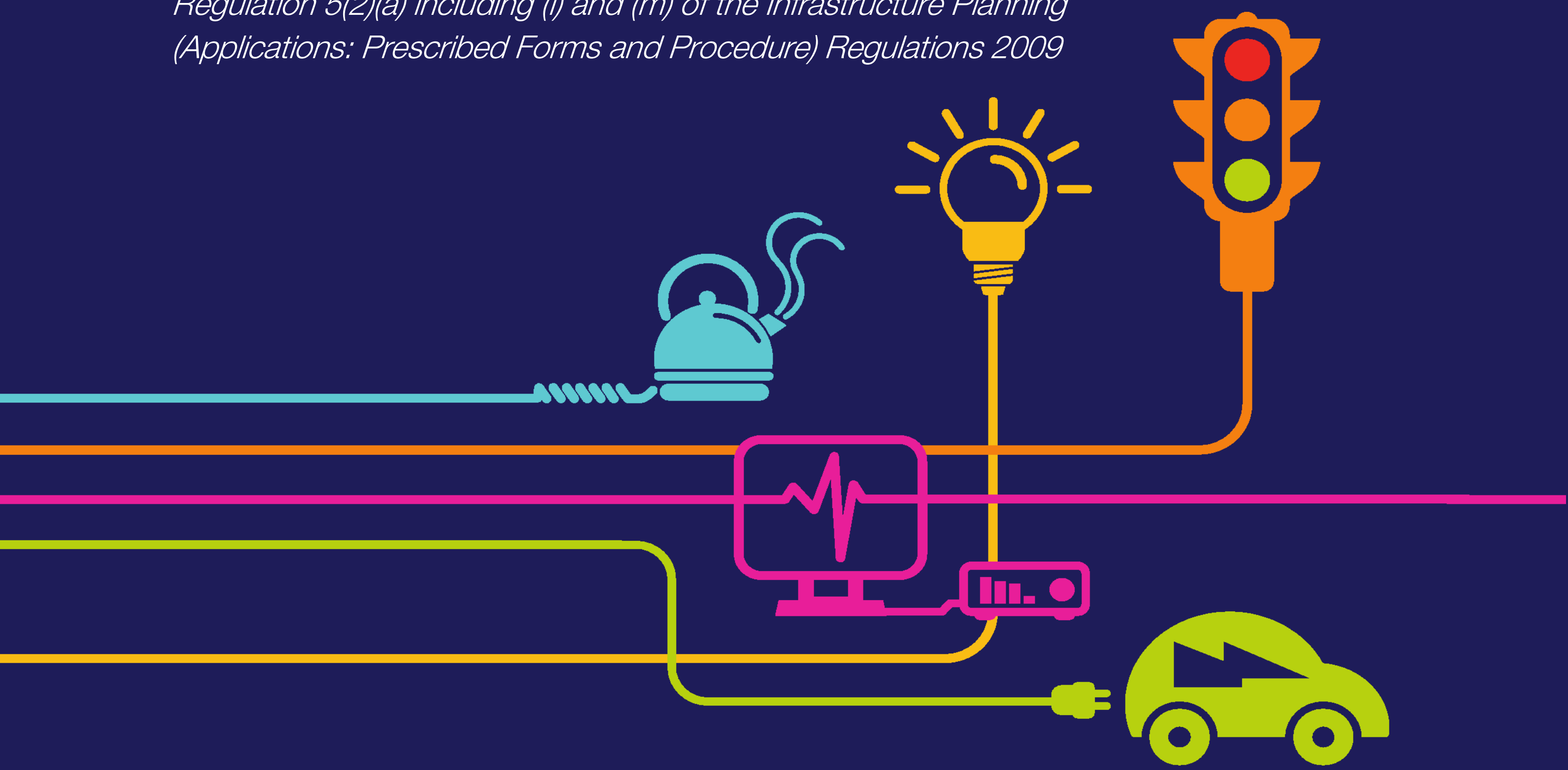
DOCUMENT 5.16.2.6

TR(T)94 - A Method for Assessing the Community Response to Overhead Line Noise

Chapter 16 – Appendix 6

National Grid (North Wales Connection Project)

Regulation 5(2)(a) including (l) and (m) of the Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009



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North Wales Connection Project

Volume 5

Document 5.16.2.6, Appendix 16.6 - TR(T)94 A Method for Assessing the Community Response to Overhead Line Noise

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Final September 2018

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Alan Harrin
12 March 1991

Technical Report TR(T)94
Issue 1
October 1993

A Method for Assessing the Community Response to Overhead Line Noise

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Registered in
England and Wales
No. 2366977

Published by:

The National Grid Company plc
Burymead House
Portsmouth Road
Guildford, Surrey GU2 5BN

NATIONAL GRID COMPANY PLC

TECHNOLOGY AND SCIENCE DIVISION

TECHNICAL REPORT TR(T)94

Title: A Method for Assessing the Community Response to Overhead Line Noise

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Summary:

Overhead line noise is generated when the conductor surface electric stress exceeds the inception level for corona discharge activity. Overhead line conductors are designed to operate below this threshold. Surface contamination (eg. dry debris or water droplets) on a conductor will, however, cause a local enhancement of electric stress and possibly initiate discharge activity. At each discharge site, a limited electrical breakdown of the air occurs. A portion of the energy associated with the corona process is released as acoustic energy and radiates into the air as sound pressure waves.

BS 4142 : 1990 "A Method for Rating industrial noise affecting mixed residential and industrial areas" is used to assess overhead line noise during dry weather. However, this Standard is necessarily general in nature, and therefore is not directly applicable to all situations. In particular, the Standard excludes measurements taken during rain - the condition under which the majority of overhead line noise is generated. Consequently, an in-house assessment method has been developed.

This Report supersedes NG RDC/HVT/0102/TAN91 "A Method for Assessing the Community Response to Overhead Line Noise".

Conclusions:

The mechanisms of overhead line audible noise generation have been described, and techniques for predicting the noise levels due to a new line have been reported. The community response to corona noise during dry weather has been estimated according to the method described in BS 4142 : 1990, while rain-induced audible noise has been assessed according to a procedure developed by NGC.

NGC will apply these assessment techniques to every overhead line proposal which requires an Environmental Statement. The results of each noise assessment will be used as part of the routing procedure - an iterative process aiming to achieve an environmentally acceptable route which has the minimum visual and physical intrusion on the environment, whilst remaining technically and economically feasible.

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CONTENTS

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A METHOD FOR ASSESSING THE COMMUNITY RESPONSE TO OVERHEAD LINE NOISE

1 INTRODUCTION

Under the Electricity Act 1989, NGC has a statutory duty concerning preservation of amenity and care for the environment. NGC therefore undertakes assessments of the environmental effects of proposed new developments and seeks reasonable practical measures to mitigate adverse effects upon amenity. In the case of proposals to install major high voltage overhead transmission lines along new routes, the results of the assessment are published in an Environmental Statement submitted with each application for consent.

This report describes the methods which have been developed for predicting the increase in noise level caused by the introduction of a new transmission line, and hence estimating the response of residents in the area. The results of these processes are included in each Environmental Statement, and they form part of the information used in line routing.

Only noise from discharge activity on the conductors is considered in this report. Noise may also arise from discharges on insulators and fittings, but this noise is minimised by the use of preferred designs. In addition, point noise sources (such as insulators and fittings) are less often intrusive and if complaints arise these can usually be remedied.

Noise is produced by corona discharges which occur when the electric stress at the surface of a conductor exceeds the breakdown strength of air. Transmission lines are designed to operate below this "corona threshold". However, surface irregularities such as raindrops or solid debris produce voltage gradient enhancements. These may then exceed the threshold or "inception" level and become point sources for corona discharge. At each discharge site, a portion of the energy associated with the corona process is released as acoustic energy which radiates into the air as sound pressure waves. It can be seen from the mechanism of corona discharge generation that transmission line noise will be intermittent in nature.

The magnitude of the audible noise depends on the nature of these surface irregularities. Well-made conductors are normally free from surface defects, but they cannot be kept free from raindrops. Hence rain-induced audible noise is generally the major consideration for the noise section of an Environmental Statement. The relationship between rainfall and corona noise has been studied, and measurements have also been made of corona noise resulting from the presence of solid debris; this information can be used for assessment purposes.

2 METHOD FOR ASSESSMENT OF DRY NOISE

2.1 Generation

This is essentially a random effect, depending on the amount of debris adhering to each conductor. It also depends on conductor quality and cleanliness, as well as line configuration and the type of debris collected. Any estimate of this quantity must therefore be treated with caution. Increased quality control at the manufacture and erection phases of construction should ensure that conductor is initially of high quality, but wind-borne debris cannot be prevented from sticking to an overhead line (particularly when the conductor is new and hence liable to be slightly oily). The level of noise will increase during long spells of dry weather as solid debris builds up, and decrease again after heavy rain when this debris is washed away. Therefore the levels quoted will be average values.

2.2 BS 4142 : 1990

British Standard BS 4142 : 1990 " Method for Rating industrial noise affecting mixed residential and industrial areas" describes methods for determining at the outside of a building:

(a) noise levels from factories, industrial premises or fixed installations and sources of an industrial nature in commercial premises; and

(b) background noise level.

The standard also describes a method for assessing whether the noise referred to in (a) is likely to give rise to complaints from people residing in the building. It therefore provides an acceptable method for assessing dry transmission line noise, with the proviso that it does not indicate how to interpret results in situations where the background noise level is very low, ie. below an A-weighted sound pressure level of 30 dB(A).

The background noise is taken to be the night-time A-weighted 5-minute L_{90} level, where night-time is defined as midnight to 6 am. This parameter was chosen because night-time represents the most sensitive period for disturbance by noise - the background noise will be at a minimum and most people will be asleep.

The specific noise level from a planned overhead line is, where possible, determined by measurement on a line of identical design to that being proposed. In some cases it is not possible to find the required line design in an area of low background noise, and it is then necessary to calculate a value by interpolation from existing data. The reduction or attenuation of the noise level over the distance to each property in proximity to the planned route is calculated, and a 5 dB character correction factor is added to produce the rating level. Finally, the background noise level is subtracted from the rating level to give a value for the "assessment level".

BS 4142 : 1990 states that assessment levels of 10 dB or higher indicate that complaints are likely. An assessment level of around 5 dB is of marginal significance. At an assessment level below 5 dB, the lower the value the less likelihood there is that complaints will occur. An assessment level of -10 dB is a positive indication that complaints are unlikely.

3 METHOD FOR ASSESSMENT OF WET NOISE

3.1 Generation

Audible noise in wet weather is generated by water droplets on the energised conductors distorting under the electric field and causing a localised enhancement of the electric stress, thus initiating corona discharge activity and hence audible noise.

3.2 BS 4142 : 1990

The British Standard specifically excludes measurements taken during "extreme weather conditions", and lists rain as one of these conditions. Therefore it is not appropriate to use BS 4142 : 1990 to assess rain-induced noise. This is mainly due to the fact that the background noise itself becomes a function of rain-rate and it can no longer be represented by a single sound level measurement. It was consequently necessary for the Technology & Science Laboratories to develop the following in-house assessment method.

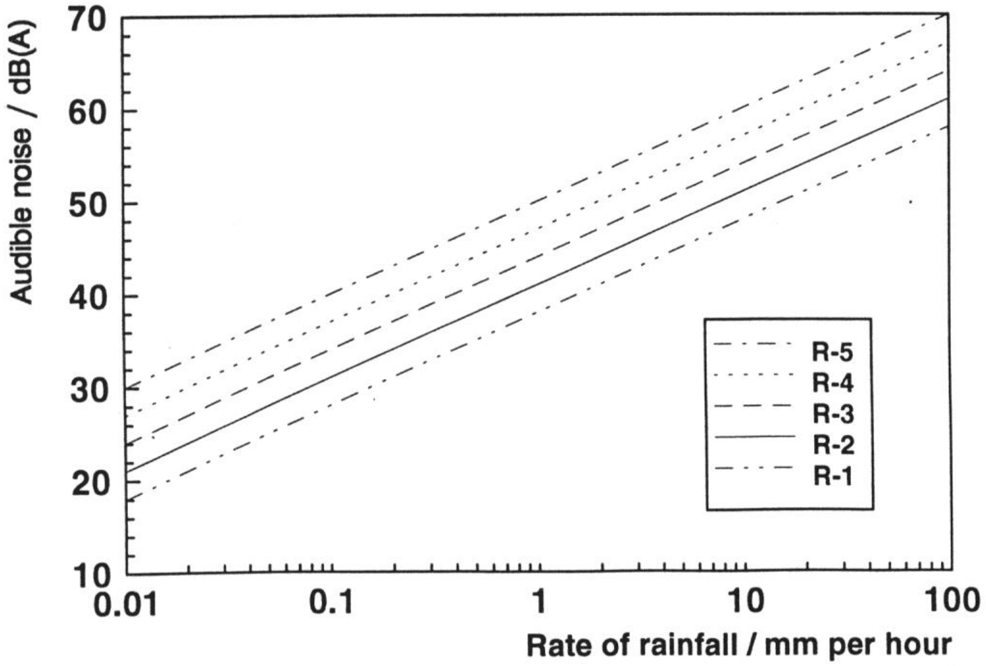
3.3 NGC Assessment Method

Firstly, the background noise during rain must be quantified. Miller (1978) conducted a study of rain-induced noise, from which he produced five empirical curves for sound levels due to rainfall on various types of ground cover, ranging from bare, porous ground to fully-leafed trees. These curves are presented in Figure 1, with ground cover descriptions in Table 1.

Table 1. Curve number to be used for estimating A-weighted sound levels due to rainfall

Curve no.	Condition of ground and vegetation
R-1	Essentially bare, porous ground (that is ploughed field or snow covered ground); no standing puddles of water. Relatively small-leafed ground cover vegetation, such as grass lawn, meadow, hay field shortly after mowing, field of small-leafed plants.
R-2	Non-porous, hard, bare ground or pavement; falling raindrops splash on thin layers or puddles of collected water; or in or beside wooded area of deciduous trees without leaves or with only small leaves; or in or beside wooded area of coniferous trees or evergreens having needles rather than leaves; or thin-leafed ground cover or crop, such as hay, clover or grain.
R-3	A few small, fully-leafed deciduous trees at 15 to 30 m or a few large, fully-leafed trees at 30 to 90 m.
R-4	Large area of fully-leafed trees or large-leafed crops or vegetation, such as corn, starting at 15 to 30 m distance.
R-5	Large area of fully-leafed trees or large-leafed crops or vegetation entirely surrounding the area of interest.

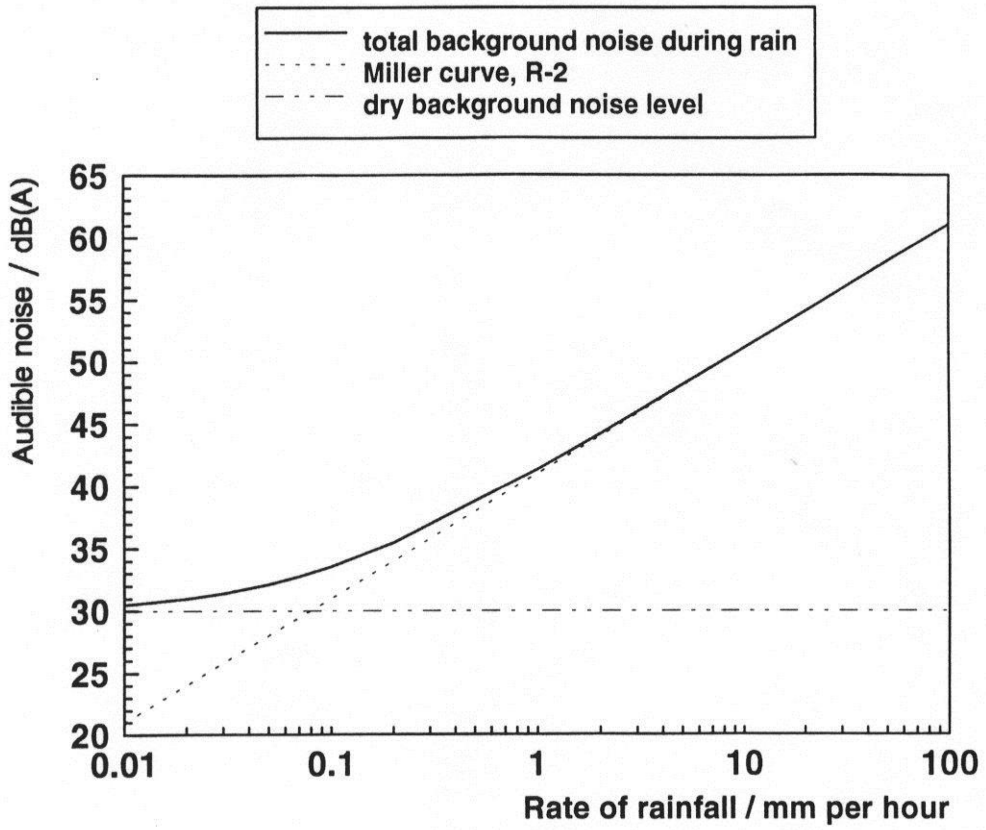
Figure 1. Miller curves for estimating sound levels due to rainfall



3.4 Total Background Noise During Rain

The total background noise during rain will be given by the logarithmic sum of the ambient dry background noise and the noise due to rainfall. The night-time A-weighted 5-minute L_{90} is used to quantify the dry background noise level, in line with BS 4142 : 1990. For example, when a background noise level of 30 dB(A) is combined with the R-2 Miller curve, the total background noise curve shown in Figure 2 is produced. This case, representing a house in a relatively quiet location, will be used throughout the report as a graphical worked example.

Figure 2. Total Background Noise During Rain



3.5 Rain-induced Audible Noise

Assuming steady rain, the droplet distribution on a conductor surface will be relatively stable for a given conductor geometry and surface condition. Therefore, the audible noise produced in steady rain tends to follow well behaved curves when plotted against the rate of rainfall. Each construction of transmission tower and conductor bundle geometry has its own rain noise curve.

Long-term monitoring has been carried out by the CEGB, and subsequently by NGC, under an L2 twin Zebra line at Bramley. The results obtained for aged conductor (Ellett *et al*, 1990) provide the base data for the method. For other constructions and conductor types, new curves can be obtained by similar monitoring programmes. A faster alternative is to use the appropriate correction factors which can be derived from the experimental work of Comber and Cortina (1976) checked against the empirical results of Lundquist (1985).

3.6 Attenuation over Distance

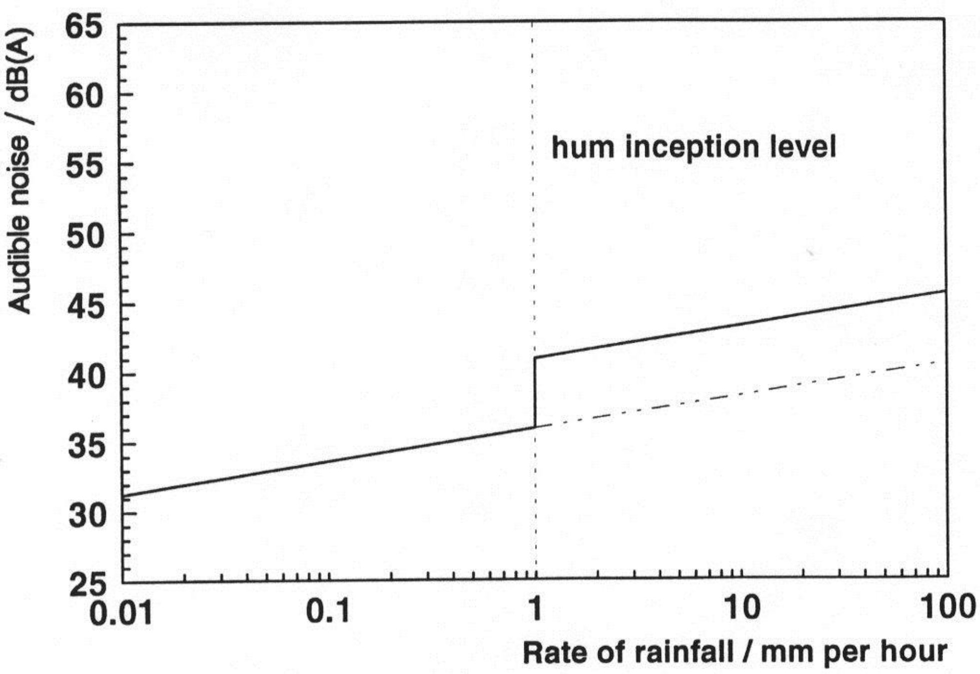
Each property, or group of properties, will be a certain distance from the line axis, and so the attenuation of the line noise due to dispersion and absorption by the atmosphere can be calculated. Each conductor bundle is assumed to be a line source emitting white noise at a specific acoustic power.

The total noise received by an observer is thus the sum of the individual contributions, attenuated in an atmosphere of given temperature and relative humidity (usually 290 K and 70% respectively).

3.7 100 Hz Hum

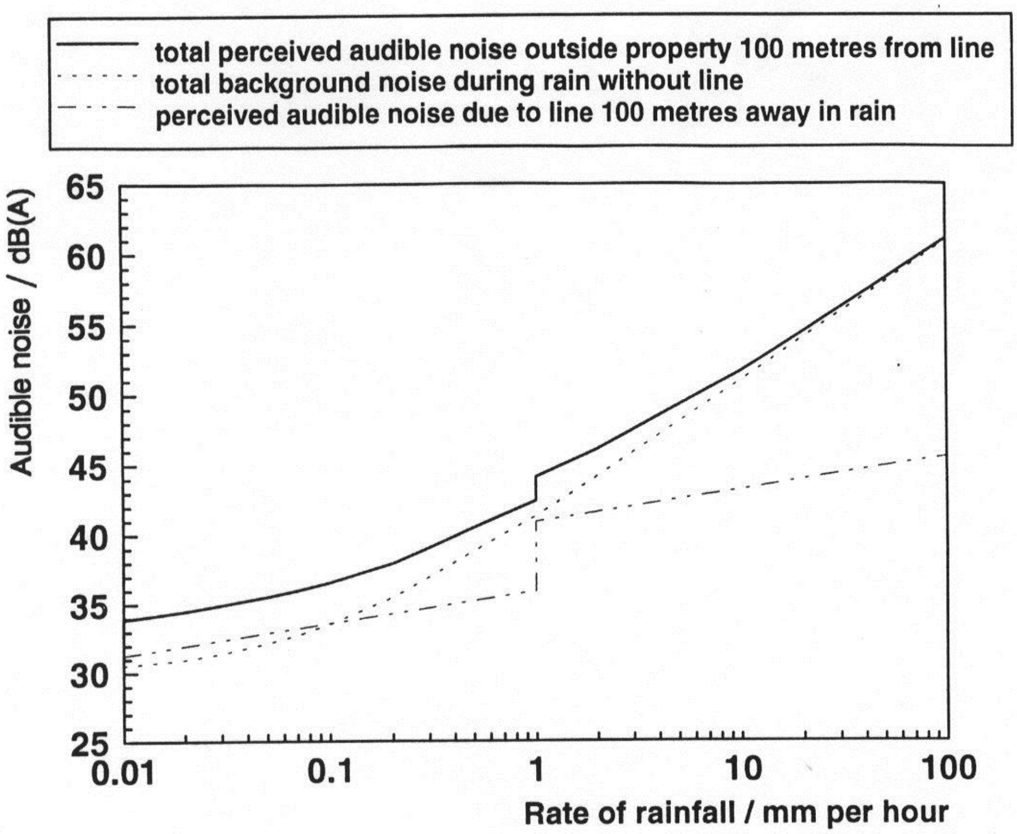
The corona induced audible noise so far described is a characteristic broad-band "crackling" sound of frequency 1 to 10 kHz. An additional feature of rain-induced audible noise is 100 Hz hum, the variation of which with rain-rate is not fully understood. It has been noted, however, that a hum appears to "switch on" above a certain rain-rate, or once the conductors are sufficiently wet. In order to allow for this effect, a 100 Hz hum inception rain-rate of 1.0 mm/hr was selected (in accordance with limited data from the study at Bramley). Following the recommendations of BS 4142 : 1990, a character correction factor of 5 dB is added to the A-weighted audible noise levels above this inception level (Figure 3). This compensates for the added intrusiveness of a continuous pure tone.

Figure 3. A-weighted line noise outside a property 100 metres from an L12 twin Araucaria line showing 5 dB penalty for hum



Finally, the total background noise during rain must be added logarithmically to give the total noise level as would be perceived by an observer standing outside their property in that rain (ie. the attenuated rain-induced corona noise including a 5 dB penalty for hum above 1 mm/hr plus the dry background noise plus the noise due to the falling rain as represented by the appropriate Miller curve for that property). Figure 4 shows an example of one such logarithmic addition. This gives a curve of dB(A) versus rain-rate for each property which can then be compared to the total background noise during rain in the absence of the line.

Figure 4. Total A-weighted audible noise outside a property 100 metres from an L12 twin Araucaria line



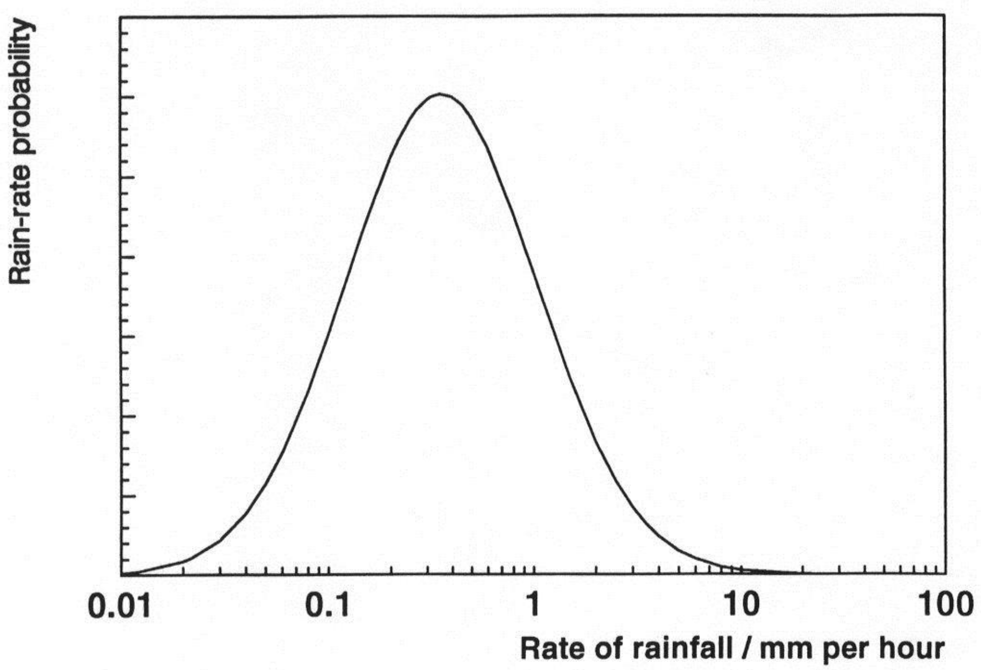
3.8 Rainfall Data

The amount of rainfall varies over England and Wales, being generally greater in the west than in the east. Most of the meteorological data available is for daily totals, but we require more detailed information on the rates of rainfall. The Meteorological Office is beginning to collect data which will help in this respect, but it will be several years before statistically valid results will be available. In the mean time, a general cumulative rain-rate frequency curve can be utilised (Figure 5).

This is generated by assuming that rainfall data follows a logarithmic-normal distribution - a reasonable assumption for a natural phenomenon of this nature (ie. the result of a large number of events which must happen in sequence). In the absence of more detailed rain data, it was assumed that the shape of this curve or, more precisely the standard deviation of rain rate, is approximately constant nationally, while the mean rain-rate varies from place to place. The standard deviation is taken to be that of Bramley, since the CEGB study incorporated accurate measurements of rain-rate and thus constitutes the most detailed database available to us at present. The mean rain-rate can be easily calculated by dividing the mean total rainfall by the mean annual hours of rainfall. This data is available from maps published by the Meteorological Office, and hence the rain-rate probability function can be calculated for any location.

The average annual duration of rainfall in hours also allows us to estimate the percentage of the year for which rain-induced corona noise is generated. Heavy fog and very light drizzle, which may also give rise to corona noise, are not included in these statistics (see Section 4).

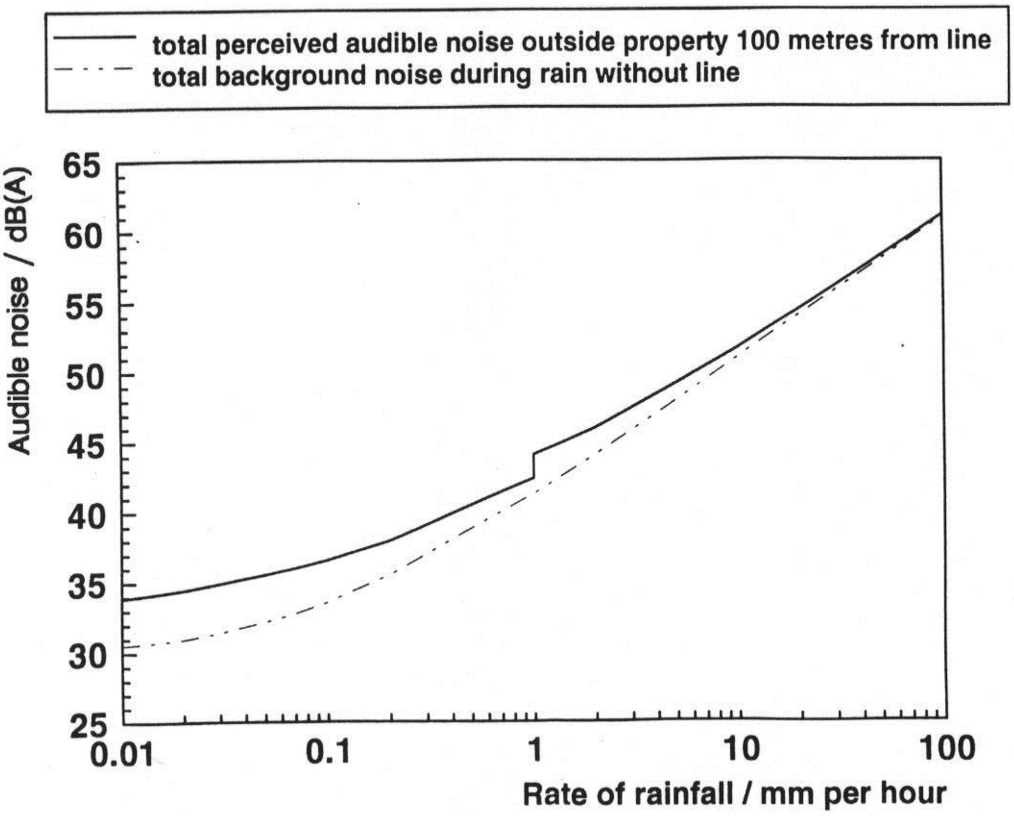
Figure 5. Probability distribution function for mean rain-rate of 1.25 mm/hr



3.9 Calculation of Weighted Mean Increase in Background Noise

Possible annoyance to the general public occurs when the audible noise at a site, including the noise generated by the line, significantly exceeds the background noise without the line. The greater the exceedance, the greater the possible annoyance. For rain-induced corona noise, the increase in background noise level will be a function of rate of rainfall, as demonstrated by Figure 6. The upper curve is that derived in Figure 4, while the lower dotted curve is that shown in solid in Figure 2.

Figure 6. Graph showing example of total rain-induced audible noise exceeding background noise during rain



For each property included in the noise assessment, a single noise assessment figure is obtained by calculating the mean value of the increase in background noise level, weighted according to the local rain-rate probability function. Therefore, the increase in noise experienced during the most probable rate of rainfall will have the most influence on the final assessment figure.

In order to simplify the calculation of a weighted mean increase in background noise, cut-off points of 0.01 mm/hr and 100 mm/hr are chosen. Any contributions outside this range are ignored (Figure 5 demonstrates why these limits are justified).

In general, the NGC method will give higher noise assessment levels than the BS 4142 : 1990 method, and it is therefore more likely to alert NGC to potential areas of difficulty at an early stage of the planning process.

3.10 Assessment of Community Response

So far we have calculated a weighted mean increase in background noise level and estimated a percentage time for which rain-induced corona noise will be present. Interpreting the effect of these noise levels on the individual is probably the most difficult part of the assessment, due to the high variability in the response of different individuals to the same noise source. The weighted mean increase in background noise level will always, by definition, be positive. Therefore the BS 4142 : 1990 interpretation of these results will not be appropriate since it allows for negative assessment levels.

3.10.1 Complaint Assessment

The public response to increased noise levels has been studied in a number of countries for a variety of noise sources, and the results are summarised in Table 2 (Hassall & Zaveri, 1979).

Table 2. Estimated community response to noise levels exceeding the normal background (Hassall & Zaveri, 1979)

Amount in dB(A) by which the new sound level exceeds the background noise	Category	Description
0	None	No observed reaction
5	Little	Sporadic complaints
10	Medium	Widespread complaints
15	Strong	Threats of community action
20	Very strong	Vigorous community reaction

3.10.2 Subjective Response

An alternative way of interpreting these results is to use the results of psycho-acoustic studies which have investigated the subjective response of individuals to increased noise levels (Hassall & Zaveri, 1979). These results are summarised in Table 3.

Table 3. Subjective response to increased noise levels (Hassall & Zaveri, 1979)

Change in level / dB(A)	Subjective effect
3	Just perceptible
5	Clearly perceptible
10	"Twice as loud"

4 OTHER WEATHER

Throughout it has been assumed that weather can be broadly categorised as "rain" or "dry". Other more specific conditions have not been identified due to limitations on available data. Of most concern is fog, as condensation on a line could give rise to similar effects as rain, but without the increase in background noise associated with the latter. Although a method for predicting noise levels under this condition does not exist, a qualitative discussion of the nature of the problem may be given in areas where fog is a significant feature of the local weather. Meteorological data on the occurrence of fog is only available from some Meteorological Office sites, usually those associated with airfields.

In addition, post-rain noise is neglected. A line will continue to emit increased noise levels after a rain event, during which time dry background noise conditions will apply. This effect is known to be much less significant for aged conductors than new, and is also a function of the prevailing drying conditions. The number of parameters involved in this process and the very limited rain event data make its quantification practically impossible. However, this effect is offset by the fact that at the start of a rain event it takes a finite time for the conductors to become wet enough to generate corona noise. During this time, there are increased background noise levels while the rain-induced corona noise is minimal.

5 OTHER FACTORS

It should be noted that, when a high voltage overhead line is first energised, noise levels in excess of those predicted here are possible. It would also seem to be the case that new lines are more likely to generate 100 Hz hum during rain. After energisation, the conductors will age progressively (inverse exponentially) until the noise level approaches its long-term value. The speed of the ageing-in process depends on many factors, including local weather conditions and ambient air pollution levels, but the process should be well advanced after a period of 6-12 months.

It must also be remembered that the response of individuals to a given stimulus varies widely, and as such any response description can only be treated as "average" or "typical". However, it is believed that the method will yield a reasonable estimate of likely response within the limits of current data and understanding.

The influence of weather conditions and local geography on sound propagation is ignored because the effects are mostly negligible over the distances involved here. In extreme cases, such as a ridge of land shielding a property from line noise, some "common sense" must be applied. In addition, wind noise has been neglected. This will obviously be significant in areas near fully-leafed trees, for example. In general, correction would be required for windspeeds of greater than 5 m/s over any terrain (Miller, 1978). In neglecting this fact, our estimate of total background noise will be too low and hence the assessment level too high.

Our noise assessment levels will also tend to be higher than in reality due to the fact that the ambient background noise is taken to be the L_{90} night-time noise. The mean night-time level is on average 10 to 15 dB(A) quieter than mean day-time levels (Hassall & Zaveri, 1979). By effectively assuming night-time levels occur 24 hours a day, we are again taking a worst-case scenario.

Dwelling attenuations have not been taken into account in these noise assessment methods. Typical attenuations provided by facades with windows range between 10 and 20 dB(A) as shown in Table 4 (Hassall & Zaveri, 1979).

Table 4. Approximate corrections for the insulation of facades with windows (Hassall & Zaveri, 1979)

Window conditions	Correction / dB(A)
Windows open	-10
Single window shut	-15
Double windows shut or non-openable window	-20

6 SUGGESTED WORDING FOR INCLUSION IN ENVIRONMENTAL STATEMENTS

The audible noise assessment should contain a general discussion of overhead line corona noise, followed by one or more statements of the following form:

For the majority of the year, the transmission line will be operating in dry weather. During this period, the assessment level predicted according to BS 4142 : 1990 is less than x dB(A) at the outside of all dwellings in the vicinity of the proposed line. Therefore, this is a positive indication that complaints about noise in dry weather are unlikely.

For a% of the year, rain will induce transmission line audible noise. During this period, the weighted mean increase in background noise level outside most dwellings in the vicinity of the proposed line is estimated to be less than y dB(A). Therefore, from Table 2, the increase in noise level is \description\ (eg. unlikely to cause complaints). However, outside n properties, the weighted mean increase in background noise level is estimated to be between y and z dB(A). Therefore it is likely that the increase in noise level will result in \description\ (eg. sporadic complaints) from these residents.

7 CONCLUSIONS

The mechanisms of overhead line audible noise generation have been described, and techniques for predicting the noise levels due to a new line have been reported. The community response to corona noise during dry weather has been estimated according to the method described in BS 4142 : 1990, while rain-induced audible noise has been assessed according to a procedure developed by NGC.

NGC will apply these assessment techniques to every overhead line proposal which requires an Environmental Statement. The results of each noise assessment will be used as part of the routing procedure - an iterative process aiming to achieve an environmentally acceptable route which has the minimum visual and physical intrusion on the environment, whilst remaining technically and economically feasible.

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