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Study of the Application of British Standard BS 4142:1990 "Method for Rating Industrial Noise Affecting Mixed Residential and Industrial Areas" (The Data Sheet Study)

Nicole D Porter

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ABSTRACT

This report describes a study of the application of British Standard BS 4142:1990 "Method for rating industrial noise affecting mixed residential and industrial areas". This standard was revised in 1990 and the study is a systematic evaluation of the revised version. The investigation was conducted using data sheets to collect together information on investigations of complaints in accordance with the standard. One hundred and thirteen data sheets were returned to NPL for analysis. Data were collated on the types of noise sources, the nature of the complaints, the measurement data, rating assessments and the performance of the rating procedure. In addition, information was obtained identifying areas of weakness in the standard and details of its various applications.

In over 80% of cases where the relevant information was reported, the prediction of complaint likelihood by the BS 4142:1990 rating method, in the opinion of the investigating officer, agreed with the actual reported complaint occurrence. However, although this shows that the rating method is working relatively well at predicting complaint likelihood, there are problem areas that need attention and clarification. In the light of new data on the application of the standard, recommendations are made for improvements to the methods of rating industrial and environmental noise.

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Approved on behalf of Director, NPL, by Dr P Christmas, Acting Head of Division of Radiation Science and Acoustics.

CONTENTS

1 INTRODUCTION

A three year programme of research at the National Physical Laboratory (NPL), sponsored by the Building Research Establishment (BRE) on behalf of the Department of the Environment, has examined the objective and subjective assessment of industrial noise. Work began in December 1990 with the overall aim of refining current methods for rating industrial noise. The research was divided into three parts:

(1) A systematic evaluation of BS 4142:1990 "Method for rating industrial noise affecting mixed residential and industrial areas" by means of a data sheet study on its application.

(2) A review of various national practices for rating industrial noise.

(3) Subjective listening tests on the judged annoyance of specific types of industrial noise to explore the effect of impulsiveness and tonality on subjective annoyance and assess the performance of objective assessment methods.

This report is concerned only with item 1 of this programme of work. Items 2 and 3 are covered in separate reports (2)(3).

British Standard BS 4142 was revised in 1990. Development, implementation, review and revision is a continuous cycle for all standards, and for BS 4142 there is a large body of literature relating to past phases of this cycle (4). This report sets out to examine the current phase - the implementation of the revised BS 4142:1990.

The report firstly outlines the background to BS 4142, and describes the development of the current standard and its rating procedure. The aims of the study are then set out, followed by a brief account of how the data were gathered. The results are summarised in chapter 7, and this is followed by a discussion of key aspects of the standard and of the findings of the study. Finally, conclusions and recommendations are presented and BS 4142 is examined in the wider context of the basic requirements of a noise assessment method.

2 INDUSTRIAL NOISE

The Wilson Report (5) refers to the London Noise Survey of 1961/2, which revealed that of the noises which disturbed people at home, 7% were from industrial sources. In a recent study of environmental noise levels in the UK (6), industrial noise was reported as being heard either from the front or rear of dwellings in only 3.8 % of cases. However, despite the relatively low reported prevalence of industrial noise, the environmental health report from the Institution of Environmental Health Officers (7) details the upward trend in the number of complaints received by environmental health officers. In 1991/92 over 35,000 noise complaints were received by local authorities (1,036 complaints per million population) relating to over 24,000 industrial and commercial premises, of which over 15,000 were confirmed as statutory nuisances. 1,933 abatement notices were served leading to 90 convictions in the magistrates courts. Thus, whilst the prevalence of industrial noise may be relatively low, where it does occur the annoyance caused is high and growing.

Monitoring and controlling environmental noise is a costly process. One can examine the costs of industrial noise in many ways including the time and financial resources expended by environmental health officers in dealing with the problem, the cost to industry of planning or implementing noise control solutions, or the social costs to the community. Although the World Health Organisation commented in their recent draft report WHO Criteria Document on Community Noise (8) that economic calculations of the total costs to society of community noise exposure are difficult to perform, certain calculations have been carried out based on cost/benefit analysis or as case studies such as those given in references (9) and (10). One study in Germany was performed (11) to investigate the full economic costs currently incurred for noise reduction measures and the general economic costs of noise pollution. This study assigned values to "willingness to pay for peace and quiet" and a value of DM 5.2 billion (£2.1 billion approx.) was estimated for industrial noise. The annual noise abatement expenditure in France in 1987 was reported in (12) to be FF 2668 million (£325 million approx.) with FF 700 million (£85 million approx.) spent in industry.

Noise pollution can be controlled through good planning processes, good engineering design, regular monitoring and good regulatory and legal processes, supported by agreed methods for measuring and assessing noise. Ideally a noise measurement and assessment procedure should accurately describe the noise and lead to consistent decision making. It should also indicate cost-effective approaches to noise control, which offer an equitable trade-off between lowest cost and maximum benefit to the community (3). In this report a description is given of current practice for measuring and assessing industrial noise in the UK, which is based on BS 4142:1990 "Method for rating industrial noise in mixed residential and industrial areas" (1). A companion report (2) reviews practices in other countries.

3 BRITISH STANDARD BS 4142

3.1 HISTORICAL INFORMATION

Community noise rating procedures have been developed over many years. In 1955, work was done by Stevens, Rosenblith and Bolt (13) on developing fundamental community noise rating procedures which still form the core of the methods used today. This work played a large part in the evolution of forecasting methods for predicting the community response to noise and many of the factors and assessment procedures used today can easily be traced back to this work. The method used composite noise rating curves and involved noise levels, spectra, background noise and time schedules.

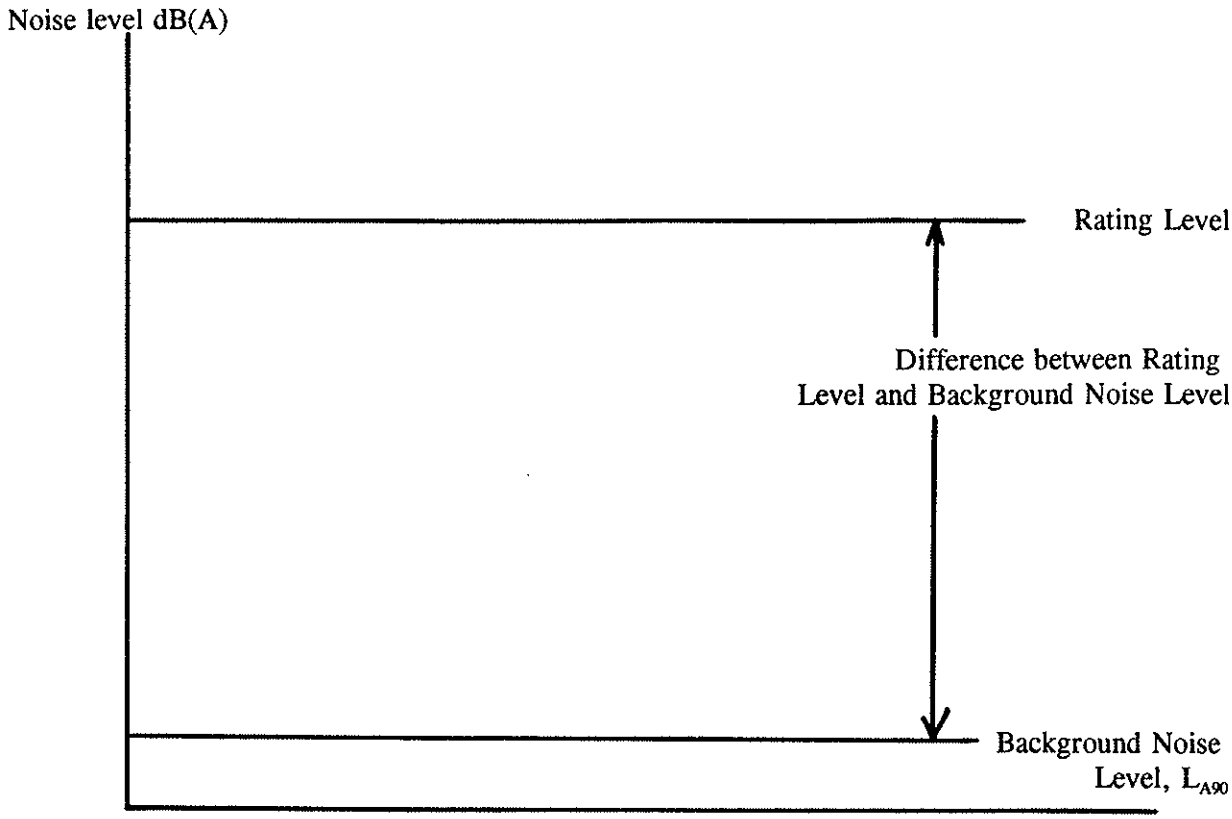
In 1958 work at the Building Research Station (BRS) led to the development of a simplified method which was included as an appendix to the Wilson report of 1963 (5). It was recommended that the method should be tested before adopting it as a recommended procedure for community noise assessment. The BRS in collaboration with local authorities, as well as NPL, had between them accumulated some 80 case histories which validated the simpler method using just the A-weighted sound pressure level, and these data were taken up by the British Standards Institution. In 1967 the first edition of BS 4142 was published. In 1975 the first amendment to BS 4142 was published, the effect of which was to get away from too much reliance on absolute levels and to emphasise the preference for judging complaints on the excess-over-background principle. Notional background levels could, however, be used when direct measurement was impracticable. Further amendments were made in 1980 and 1982. In 1990 the second edition of BS 4142 was produced as a revision to bring it in line with ISO 1996 (14) with the adoption of L_{Aeq} as the descriptor for the specific noise level. Various changes were made to the standard as detailed in the next section. An excellent account of the historical background was given by Robinson in his presentation to a BSI Seminar on rating industrial noise (15).

3.2 BS 4142:1990

3.2.1 The rating method

The standard applies only to noise of an industrial origin affecting mixed residential and industrial areas and gives a method for predicting the likelihood of complaint by examining the "intrusion" of a specific noise (assessed by a rating level) above the background noise level. The standard is intended primarily for investigating complaints and can be used for planning purposes. The foreword explains that a noise is liable to provoke complaints whenever its level exceeds the background noise by a certain margin; or when it attains a certain absolute level. It points out that the method of rating in the standard examines the first of these, i.e. it bases its rating procedure on comparing the specific noise level, corrected to take account of its character, with the background noise level. The standard gives methods for measuring the background noise level and specific noise level. It also points out that if the noise has certain audible characteristics (judged subjectively), a 5 dB correction should be included.

The rating procedure is shown in Figure 1. Table 1 describes the differences between noise levels in terms of the rating of complaint likelihood.



Rating Level is the sound pressure level (L_{Aeq}) at the measurement position produced by the specific noise over a given reference interval plus any adjustment for the character of the noise.

Figure 1: The BS 4142:1990 Rating Method

Table 1: Complaint Potential as inferred by BS 4142:1990

Rating level minus background noise level	Complaint likelihood
10 dB or higher	Complaints are likely
Around 5 dB	Marginal significance
Below 5 dB	The lower the value, the less likelihood there is that complaints will occur
-10 dB	Positive indication that complaints are unlikely

3.2.2 Changes made to the standard in the 1990 edition

Many changes were made to BS 4142 during this revision. The main objectives of the revision were the conversion to the use of L_{Aeq} and the tightening up of requirements on equipment, traceable calibration, and measurement procedures. In the absence of new data on noise complaints, it was difficult to justify major changes to the assessment procedure, and the overall aim was that the revised standard should give the same assessment as the existing standard for a given situation. Details of the changes can be found in reference (16) by Berry and reference (17) by Horrocks. Various details are given below.

Scope
The scope emphasises that the standard should only be used outside buildings. It is extended by including within it sources of an industrial nature in commercial premises. The scope further confirms that the standard is not to be used for assessing noise in situations where the background noise is very low, i.e below 30 dB(A).

Definitions and symbols
The definitions and symbols are set out at the beginning of the standard explaining the terminology adopted within the standard.

Calibration
Advice is given concerning the calibration of measuring instruments before and after each series of measurements and asks that such tests be recorded. Furthermore to ensure the traceability of the results, the performance of the sound calibrator itself shall be tested and compliance of the complete measuring equipment with BS 6698 or BS 5969 shall be performed every two years by a NAMAS accredited laboratory.

Determination of the specific noise level
The largest change to the standard is the adoption of L_{Aeq} as the descriptor for the specific noise level. A distinction is drawn between measurements made during the day with the reference time as 1 hour and measurements made during the night with a reference time of 5 minutes. The revised standard asks for necessary corrections to be made to the measured source noise level to minimise the influence on the measurements of noise from sources other than the specific source(s) under scrutiny. The specific noise level is determined through measuring the specific noise source over a time interval T_m not greater than the reference time interval T_r such that all significant variations of noise emissions and transmissions are covered and corrected for intermittency. In order to ensure that the specific noise source is being measured under truly representative conditions, it may be necessary to first observe the premises over relatively long periods, so as to be fully acquainted with the operation of all the plant and noise sources on the premises.

Background noise levels
The notional background noise calculation was deleted from the standard. The Background Noise Level is defined as the A-weighted sound pressure level of the residual noise exceeded for 90% of a given time interval, L_{A90}, which should be at least 5 minutes. The standard distinguishes three situations against which background noise levels are to be measured: a new and modified specific noise source, an existing specific noise source not operating continuously, and an existing specific noise source which operates continuously. Again, guidance is given on the measurement time interval and it is pointed out that consideration should be given to ensuring that measurements are made during periods when the background noise is typical of that present when the specific noise is or will be operating.

Determination of rating level
Appendix C of the previous version of the standard (which covered further measurements to identify noise components likely to cause annoyance) has been removed. This included a recommended procedure for objectively identifying distinctively tonal components of the noise. The revised standard does not include an objective means of identifying a distinctive tonal component. The standard stipulates that only a single 5 dB correction shall be applied if one or more of the mentioned characteristics are present.

Assessing the noise for complaint purposes
Although the method of assessment remains unchanged, the comparison of noise levels now involves comparing the rating level (an L_{Aeq} value) with the background noise level (an L_{A90} value).

Information to be reported
This section of the standard has been extended and provides a more extensive and comprehensive format for reporting all the relevant information.

4 AIMS OF THE STUDY

The aims of this study were:

(1) To determine how well assessments using the BS 4142:1990 rating method compare with the outcome of the actual investigated noise complaints.
(2) To identify weaknesses in the revised 1990 version of the standard and to identify the areas where investigating officers are having problems applying the measurement and rating procedure.
(3) To provide data on measurement values.
(4) To gather information on the various applications of the standard.

Information was gathered by means of data sheets distributed to environmental health officers and other users of BS 4142 who volunteered to participate in the study.

5 PREPARATION OF THE DATA SHEETS

5.1 THE DATA SHEET

In order to collate data on the application of the standard, data sheets were designed that could be completed when investigating a noise complaint in accordance with the standard. These were made up such that carbon copies were produced to be returned to NPL for analysis. It was intended that the data sheets would assist the investigating officer in applying the new standard by providing a guide through the assessment procedure. For this reason, the data sheets were designed to closely follow section 9 of the standard "Information to be Reported" so that little extra time or resources would be required to complete the data sheets.

Each data sheet was divided into five sections:
general information
description of the noise source
description of complaints
measurements
assessment

Extra questions were included in addition to the requirements of section 9 in order to gain further valuable information. These included questions relating to the opinion of the investigating officer on how the rating of the complaint likelihood by the BS 4142:1990 rating procedure compared with the actual complaint occurrence and an opinion on whether the complaint was considered justified. A space was provided at the end of most sections for additional comments. Appendix I gives an example of a blank data sheet.

5.2 PILOT STUDY

Before the data sheet was printed in full, a small pilot study was conducted. Firstly, at the end of 1990, the data sheet was sent to various members of the BSI Committee EPC 1/3 "Industrial and Residential Noise" for comment, and various amendments were made.

Ten local authorities were chosen from information given in a previous NPL study (18). The explanation of the study and the data sheets were sent for comments on layout, ease of use, etc. in January 1991. Two months later the data sheet was approved by the Central Survey Unit of the Department of Environment. The main distribution commenced in April 1991.

6. RESPONSE TO THE STUDY

6.1 RECRUITING VOLUNTEERS

The project was publicised in order to attract interest from those people who could assist in the collection of data. The sources of the 167 volunteers who offered to participate in the collection of data on the application of the standard are shown in Table 2 below. A copy of the letter requesting assistance is given in Appendix II.

Table 2: Source of Volunteers

	Number of volunteers	
Source	EHOs	Other
Letter in IOA Bulletin, Jan 1991	25	18
Letter in Environmental Health News, April 1991	48	5
BSI Seminar April 1991	10	14
IOA/Noise Council Seminar May 1991	7	4
Follow up letter in IOA Bulletin	1	2
IOA Autumn Conference	5	8
Other	10	10
Total	106	61

6.2 RESPONSE

113 completed data sheets were returned for analysis. These came from 44 different sources, representing a 26% return rate, with 41% returning more than one data sheet. These including six planning cases. 87% of the returned data sheets were received from local authority departments. In response to our request for co-operation, in addition to returned data sheets, several letters and telephone calls were also received with comments on the standard. All the information was entered into a computer database for analysis.

7 RESULTS

7.1 DESCRIPTION OF NOISE SOURCES

7.1.1 Types of noise sources

Although on first examination there appeared to be a large variety of noise sources, several categories could be identified to account for a large proportion of the cases. Table 3 below gives a summary of the description of the sources and their characteristics.

Table 3: Description of noise sources

Noise Source	% of Total
Fans	35
Compressor units, generators and air conditioning units	19
Metal handling plant	11
Refrigeration plant	10
Car wash	6
Activities relating to paint spray booths	5

Continuous	47
Intermittent	34
Cyclic	18
Fluctuates at random	11

Specific characteristics	81
Tonal	50
Irregular enough to attract attention	28
Impulsive	21

Groups are not necessarily mutually exclusive

In some cases the type of source fell outside the scope of the standard. This is discussed in section 8.10.

An obvious yet important observation which can be made from this data is that over a third of all the noise sources were described as types of fan unit. Fan noise usually gives rise to tonal character and in fact over half of all the noise sources were described as tonal in nature. Extending the scope to include sources of an industrial nature in commercial premises may have served to increase the proportion of fan noise sources. The rating of noise with tonal characteristics therefore seems to be highly important in the assessment of industrial noise. A discussion of tonality is given in section 8.4.

81% of the noises were described as having specific characteristics i.e they were subjectively identified as tonal or impulsive in nature or irregular enough to attract attention. This again points towards the necessity of effective rating of noise with particular characteristics. The noise sources were described as new in around 60% of the cases (for which data was available). Nearly half of the noise sources were located adjacent to the complainant's property and about a third were located opposite the complainant's property.

An examination of the types of noise source which contributed to the residual noise showed that of those cases giving sufficient data, 90% referred to noise from transportation, 30% referred to noise from plant or local industry.

7.1.2 Hours of operation

Details were obtained relating to the hours of operation of the noise sources as summarised below.

Table 4: Hours of operation

Hours		Number of cases			
		Weekends only	Weekdays only	Both	Not operating during these hours
Early am	(0600-0900)		21	41	50
Daytime	(0900-1800)	1	44	55	12
Evening	(1800-2200)		20	44	48
Night	(2200-0600)		13	36	63

(Missing data values = 1)

Note that although BS 4142:1990 does not stipulate times for day and night, it was decided that for this study, in order to get detailed data, the times of operation would be specified. The note in section 5.2 of the standard points out that the choice of day and night periods will depend on normal local circumstances. It is intended that the night period should cover the times when the general adult population are preparing for sleep or actually sleeping.

Over half of the noise sources were reported to operate in the early morning, with two thirds of these both at weekends as well as weekdays. Almost 9 out of 10 of the noise sources operated during the daytime hours with half of these operating both at weekends as well as weekdays. Over half of all the noise sources were not operating at night-time.

7.2 DESCRIPTION OF COMPLAINTS

Table 5 gives a summary of the description of complaints.

Table 5: Description of complaints

	Number of cases with number of complaints received as:			
	one	less than 10	more than 10	Row total
Intensity of complaints:				
not severe				
1	1	3	0	4
2	13	15	1	29
3	12	17	6	35
4	4	14	9	27
severe				
Total	30	49	16	95
Frequency of complaints:				
rarely	5	4	0	9
occasionally	16	25	4	45
fairly often	7	20	10	37
most of the time	1	2	2	5
Total	29	51	16	95

In 80% of cases, the number of complaints necessary to prompt the assessment to BS 4142 was less than 10. About a third of the cases related to action arising from a single complaint. Complaints were described as "occasional" for around half of the cases and "fairly often" in 40% of cases. In 65% of cases, the intensity of complaints was indicated as approaching severe (i.e 3 or 4 on a four point scale).

The correlation was examined between the above actual complaint data and

(a) the justifiability of the complaint
(b) the BS 4142 rating of the likelihood of complaint.

However, with this sample of data no relationships could be found.

Adverse subjective reaction to the noise was reported to be experienced "indoors only" in 33% of the cases, "outdoors only" in 15% of the cases and in both locations in 53% of the cases (out of 99 cases).

Over 80% of the cases where "nuisance" was experienced "indoors only" referred to cases where there was no garden or during night-time situations where the occupier would be indoors. 65% of the cases where problems were experienced "indoors only" related to night-time complaints. A discussion of noise inside dwellings is given in 8.11.

7.3 MEASUREMENT DATA

7.3.1 Measurement positions

About half of all the reported measurements were taken at a distance of between 10 and 50 m away from the specific noise source, with many of these in the gardens of the nearest residential building or complainant's house. 14 sets of measurements were taken outside the first floor facade and 2 sets were taken inside the complainant's bedroom (see section 8.10).

7.3.2 Measuring equipment

Table 6 below describes the instrumentation used for the measurements. A discussion of the instrumentation requirements is given in section 8.14.

Table 6: Details of Instrumentation

Equipment type	Number of cases	Number of different respondents
Brüel and Kjær 2231	40	19
Brüel and Kjær 2230	3	1
Brüel and Kjær 4427	9	2
Brüel and Kjær 2209	1	1
Brüel and Kjær undefined	1	1
Lucas CEL 162(E)	4	3
Lucas CEL 262	9	4
Lucas CEL 393(A&B)	35	16
Lucas CEL 160	5	1
Lucas CEL 193	1	1
Lucas CEL undefined	2	1
Cirrus 236	1	1
Nagra IV SJ	8	1
Metrosonics Noise Analyzer	3	1
DAT recorder	5	2

7.3.3 Measurement times

Table 7 summarises the measurement time intervals selected for measurements of both the specific noise levels and the background noise levels.

Table 7: Measurement time durations

	% of cases in each measurement time duration category								
	< 300 s	300 s	300-600 s	600 s	600-900 s	900 s	900-3600 s	3600 s	>3600 s
Specific noise measurement									
Day total=66	18	27	1.5	10	1.5	10	6	21	5
Night total=48	8	72	4	2	0	8	4	2	0
Background noise measurement									
Day total=61	1	30	7	13	0	13	8	18	0
Night total=43	9	42	0	21	0	14	5	9	0

7.3.4 Measurement values

Figure 2 shows the distribution of rating levels for all of the data.

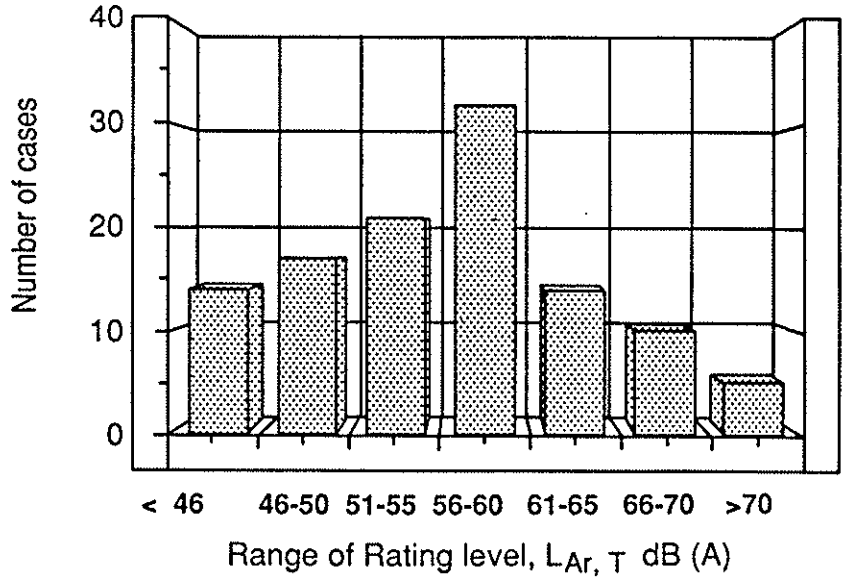


Figure 2: Distribution of rating levels

This distribution is slightly skewed with the greatest number of cases having a rating level of 56-60 dB(A). The lowest value for the rating level was reported as 33 dB(A) which was a night-time level measured indoors of low frequency noise from a music roller disco. The highest level was measured as 94.6 dB(A) which was due to works at the edge of the road (on this occasion no complaints had been received since the residents were directly benefitting from the work). It should be noted that both of these cases were strictly speaking outside the scope of BS 4142:1990.

Closer examination of these levels revealed that for the cases where complaints were predicted by the BS 4142 method as "likely" and where the investigating officer agreed with this prediction, the levels (dB(A)) above which the following number of cases lay were:

	DAY	NIGHT
All cases above	47.5	33
90% of cases above	54	44
Action Level A from draft PPG (19)	55 (mixed sources)	42 (all sources)

It is interesting to compare these with the draft PPG proposed action levels. The rating level values however contain character correction and duration corrections. It should also be pointed out that since little data was obtained on complaints that were rated as "unlikely", a minimum value for a noise action level for planning would be difficult to determine from these results. It is interesting to note that the values given above do correspond fairly well with the proposed action levels.

Figure 3 gives a comparison of the rating level with the L_{Aeq} and L_{A90} of the residual noise, where data were available for daytime. It should be pointed out that this offers no information on the variability of these levels over time.

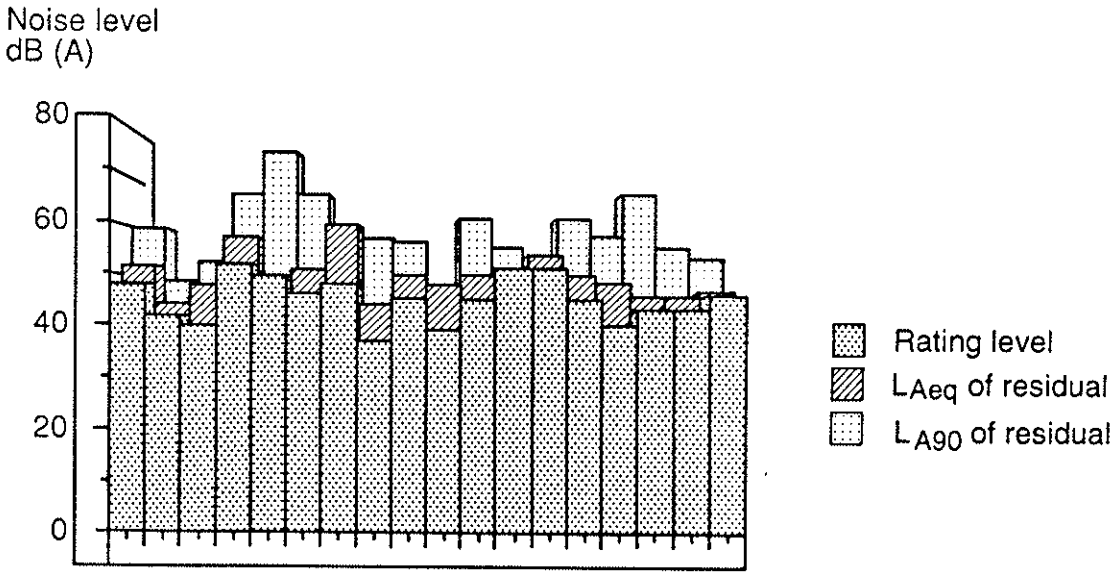


Figure 3: Comparison of rating level with L_{Aeq} and L_{A90} of the residual noise: Daytime

This information could be useful in various respects. Firstly some users of the standard appear to be having problems dealing with fluctuating residual noise where there is a difference between the L_{Aeq} and L_{A90} before the noise source is introduced, as shown in two daytime cases and one night-time case. This area is dealt with in detail in section 8.15.

Secondly, the data could prove useful in examining the use of L_{Aeq} as a suitable descriptor for measuring the residual noise. However, as already pointed out, there are no data given for the variability over time.

Thirdly, the information would be useful should new rules or assessment procedures be devised in future versions of BS 4142 for rating the likelihood of complaint. For instance, let us consider for all the daytime cases that the residual noise will be described by the L_{Aeq} descriptor but using the same assessment rules. Out of 18 cases, 9 would have no change to the prediction of complaint likelihood, 7 would change from complaints predicted as "likely" to be somewhere between "marginal and significant" etc.

Background noise corrections were made to the specific noise level in 20 of the 73 daytime cases (27%), and 13 out of the 51 night-time cases (25%).

7.4 RATING ASSESSMENTS

The chart in Figure 4 shows how the investigating officer rated the justifiability of complaints. A discussion is given in section 8.16. Figure 5 shows the number of complainants who contacted the source operator directly.

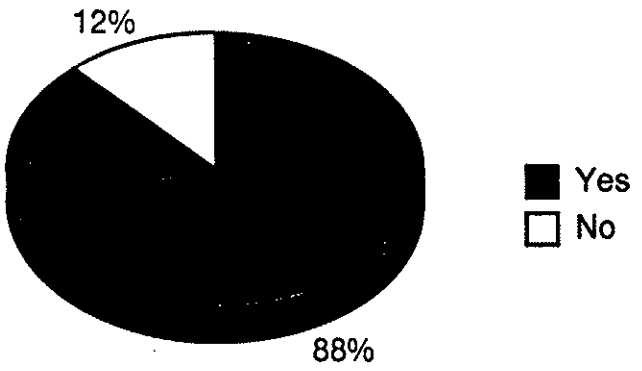


Figure 4: Does EHO consider complaint justifiable ?

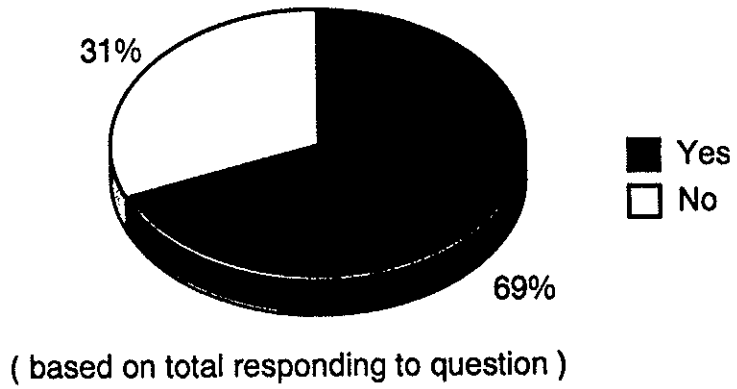


Figure 5: Has complainant contacted source operator directly ?

The predictions of complaint likelihood by the rating method of BS 4142:1990 for the cases where data was available are shown in Figure 6a for day (out of 77 cases) and 6b for night-time (out of 54 cases).

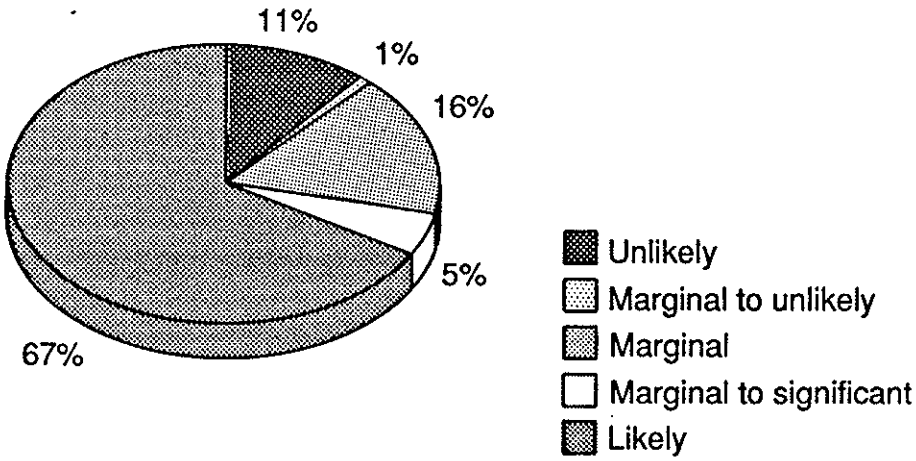


Figure 6a: Assessment of likelihood of complaint for daytime

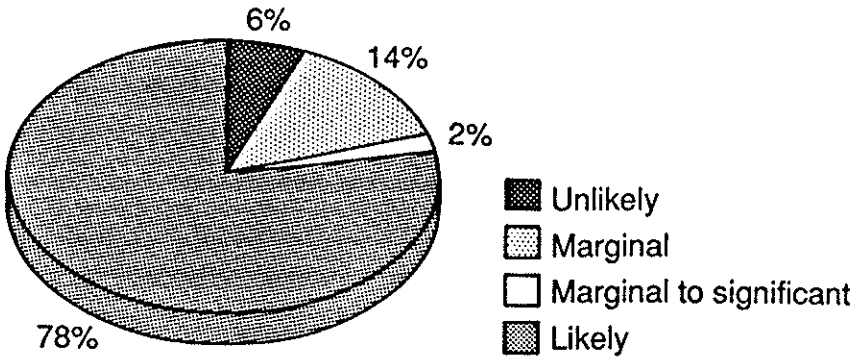


Figure 6b: Assessment of likelihood of complaints for night-time

BS 4142 is primarily intended for use with complaint investigations although it should be noted that a complaint does not have to occur to undertake a BS 4142 investigation - it may be as part of a planning study, regular monitoring, statutory undertaking, etc. These statistics give a limited amount of information about the actual reaction to complaints about industrial noise. However, it is interesting to note that as part of the new duties on Environmental Health Departments which came into force on 1st January 1991 (20) there is a requirement for local authorities "to take such steps as are reasonably practicable to investigate complaints". Clearly the level of response to complaints will vary between authorities and will depend on different perceptions of the problem of noise and the priority given to noise control in resource allocation. Although the data contained in this study are not limited to local authorities, the data show that local authorities do react to even a single complaint.

Since BS 4142:1990 is intended to be used as a tool in noise complaint investigations, it is not surprising that most of the predictions based on the BS 4142 method rate the complaints as likely, since the standard is often used "reactively". At night-time more cases (as a percentage of the total with data available) were assessed as likely to give rise to complaints as compared to daytime. This accords with the common sense conclusion that noise occurring at night carries with it a greater likelihood of complaint.

For a closer investigation of the BS 4142:1990 rating method, it may be more informative to examine the data relating to the marginal cases. As discussed in section 8.9, the rating method is rather coarse, and it is interesting to look at this problem in terms of these marginal cases in addition to examining the cases which, in the opinion of the investigating officer, are "not working".

Table 8 cross-tabulates the BS 4142:1990 assessment of the complaints with the specific characteristics of the noise. The data contained in this table do not represent all the 113 cases since information was not available in all the returned data sheets. This data will be discussed further in sections 8.4 and 8.13.

Table 8: Relationship between the BS 4142 rating of complaint likelihood and the specific characteristics of the noise.

	Number of cases with the BS 4142 assessment of complaints as:							
	Day				Night			
	likely	marginal	marginal to unlikely	unlikely	likely	likely to marginal	marginal	unlikely
Noise has specific characteristics ?								
No	10	2	0	1	5	0	0	0
Yes	39	10	1	4	33	1	6	3
Noise is tonal ?								
No	10	3	1	1	12	1	1	1
Yes	29	7	0	3	21	0	5	2
Noise is impulsive ?								
No	28	8	1	4	24	1	6	3
Yes	11	2	0	0	9	0	0	0
Noise is irregular ?								
No	28	4	0	3	24	0	5	3
Yes	11	6	1	1	9	1	1	0

7.5 PERFORMANCE OF RATING PROCEDURE

Figure 7 below shows how the investigating officer responded to the question:

How does the BS 4142:1990 assessment of the likelihood of complaint compare with the actual reported occurrence of complaint ?

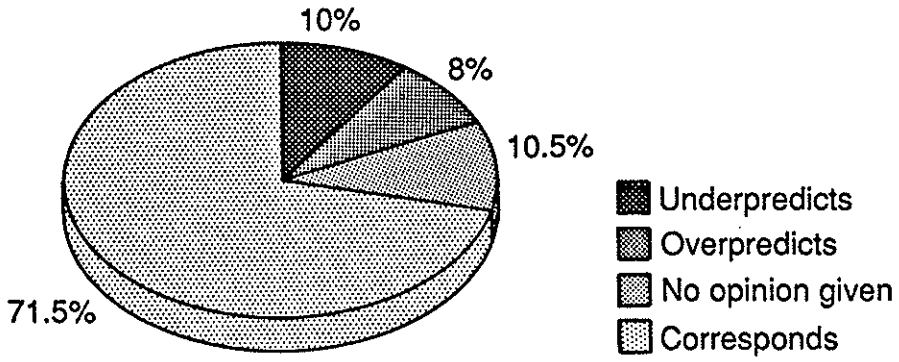


Figure 7: Comparison of the BS 4142:1990 assessment of the likelihood of complaints with the actual reported occurrence

Cross-tabulation information was obtained on the relationship between correspondence, overprediction and underprediction, and the specific characteristics of the noise. The details are given in Table 9. Cross-tabulation information was also obtained on the relationship between the performance of the BS 4142 rating method and the assessment of complaint likelihood. The details are given in Table 10. Again, these tables do not represent all 113 cases since relevant data was not available in all data returns. The information is discussed further in sections 8.2, 8.3, 8.4 and 8.13.

Table 9: Relationship between the performance of the BS 4142 rating method and the characteristics of the noise.

	Number of cases with the BS 4142:1990 prediction compared to complaint occurrence described as:			Row total
	corresponding	overpredicting	underpredicting	
Noise has specific characteristics ?				
No	18	1	0	19
Yes	62	8	11	81
Noise is tonal ?				
No	23	2	5	30
Yes	39	6	6	51
Noise is impulsive ?				
No	46	7	6	59
Yes	16	1	5	22
Noise is irregular ?				
No	41	6	7	54
Yes	21	2	4	27

Table 10: Relationship between the performance of the BS 4142 rating method and the assessment of complaint likelihood.

Assessment of complaint likelihood	Number of cases with BS 4142:1990 prediction compared to complaint occurrence given as: DAY			Number of cases with BS 4142:1990 prediction compared to complaint occurrence given as: NIGHT		
	corresponds	overpredicts	underpredicts	corresponds	overpredicts	underpredicts
likely	40	5	2	33	5	0
marginal to likely	0	0	0	1	0	0
marginal	5	2	3	4	1	0
marginal to unlikely	1	0	0	0	0	0
unlikely	2	0	3	1	0	2

8 DISCUSSION

8.1 GENERAL

The results in Figure 7 of section 7.5 are important. The question asked was intended to see how the users of the standard actually viewed whether the standard was working with its main task, the prediction of complaint potential. In over 70% of all the cases, the opinion was given that in the view of the investigating officer, the rating method of BS 4142:1990 was corresponding very well with the actual reported complaint occurrence, in fact this was 80% of all of those who replied to the question i.e four in five cases.

This important result shows that the rating method of BS 4142:1990 is actually working very well at achieving its primary aim, the prediction of complaint likelihood. Comments in the discussion that follows may highlight the difficulties that users of the standard are having, but these actually refer to only a small number of cases where the prediction method is not working as intended. However, the comments in the discussion section may also refer to cases where the prediction of likelihood of complaint corresponds but there are other difficulties with the application of the standard. Finally, it should be taken into account that these data may be slightly biased towards those who are confident in using the standard and have taken part in the study by completing data sheets. Comments from those who felt that they could not use the standard are not taken into account.

8.2 OVERPREDICTION BY THE BS 4142 RATING PROCEDURE

There were 9 reported cases of overprediction by the BS 4142:1990 rating method as defined by the answer to the last question of the data sheet:

> *In your opinion, how does the above assessment of the likelihood of complaint as predicted by BS 4142:1990 compare with the actual occurrence ?*
>
> *The assessment corresponds fairly well*
> *The assessment method has overpredicted the likelihood of complaints*
> *The assessment method has underpredicted the likelihood of complaints*

The cases of overprediction could be described as where the rating method was predicting complaints as likely whereas from experience or from the opinion expressed by the investigating officer, complaints were actually very rare or never actually received.

Two of these assessments referred to statutory undertakings and not the investigation of complaints. The BS 4142:1990 rating method predicted that complaints were likely but no complaints had been received. In the opinion of the investigating officer, the BS 4142 rating method was clearly overpredicting the complaint likelihood.

Interestingly two cases referred to sources of noise producing low frequency pulsations. In contrast to the often reported underprediction of such complaints by the BS 4142 rating method, the investigating officer considered that the tonal penalty was actually too severe, and was the cause of the overprediction of complaints.

One case referred to work outside residences where the local population were directly benefitting from this work (supply of gas) and therefore non-acoustic factors were playing an important role. Indeed the noise

levels were excessive, and the BS 4142 rating method was predicting that complaints were very likely, although none were received. This example is one case that emphasised a need for noise assessment to describe the total situation, taking all factors into account - acoustic and non-acoustic.

Another case referred to noise from a source which had a silencer fitted to decrease the noise emission. In the opinion of the officer, the character of the specific noise was not distinguishable or noticeable in the total noise environment although the actual specific noise level was greater than the background noise. Therefore although the BS 4142 rating method was predicting complaints as likely, the specific noise did not seem to be apparent. This may have been due to a masking effect by another source in the residual noise environment or another dominant source of noise with other characteristics more dominant than the characteristic of the specific noise.

Finally, one officer commented that for an intermittent noise at night-time of duration 2.5 mins, a 3 dB "correction" arising from the reference interval of 5 minutes was not enough, effectively resulting in an "inflated" rating level, resulting in the BS 4142 method overpredicting the likelihood of complaint. The day time intermittency correction of 11 dB appeared to be more reasonable.

8.3 UNDERPREDICTION BY THE BS 4142 RATING PROCEDURE

There were 11 cases of reported underprediction by the BS 4142:1990 rating method as defined by the final question on the data sheet. Many of these cases referred to situations where BS 4142:1990 predicted that complaints were not likely or marginal, when from experience and the opinion of the investigating officer numerous, severe complaints had been received. Examples of the noise sources in these cases are given in Table 11 and reference is made in subsequent sections to these cases and the implications.

Table 11: Examples of Noise Sources which led to Underprediction by the BS 4142:1990 Rating Method

EXAMPLES OF UNDERPREDICTION
Impulsive shooting noise
Noise from impacts resulting from waste transfer process
Tonal, intermittent new noise
Car wash (on-time correction)
Structure borne noise inside dwelling
Low frequency noise
Impulsive, intermittent and unpredictable noise
Tonal noise inside dwelling
Tonal noise from refrigeration plant
Internal noise from machine against party wall

The sources included in the scope of the standard are actually fairly limited and one can see that some of the sources in the Table 11 are strictly speaking, outside the scope. It may be that the method is more likely to fail when it is not applied sensibly to sources outside its scope.

8.4 TONAL CHARACTER

Many returned data sheets made reference to tonal character. As detailed in section 7.1, around 50% of the cases involved sources subjectively described as tonal in nature. A summary of some of the points highlighted in written comments is given below:

Table 12: Some reported problems relating to tonal character

TONAL CHARACTER
Definition of tonality, no guidance on objective procedure for measurement/detection
Reliance on subjective identification
Addition of penalty can have a significant effect on BS 4142 rating
Underrating of subjective impression
Overrating of subjective impression
Indoor noise and its effects
Low frequency hum

One change that was made during the 1990 revision of BS 4142 was the exclusion of an objective identification for tonality. It is understood that guidance relating to the objective identification of tonal character and the magnitude of the associated penalty was omitted due to the lack of completed research at the time of writing the standard. Since the method contained in the 1967 version of the standard was somewhat arbitrary, a decision was made to leave out any guidance at all until more accurate data and methods could be incorporated. Work has been ongoing at the Institute of Sound and Vibration Research (ISVR), Southampton (21) (22) which examines identification of tonal character in terms of sensation levels and relates this to relevant correction factors. This work is limited to single discrete tones in broadband background noise and would need to extend to detection of multiple tones if it was to be included in future standards for real environmental noises. There are other standards which give objective methods for identifying tonal features in noise. These are referred to in the companion report (2) reviewing national practices in assessing industrial noise. Many of these standard procedures e.g. Joint Nordic Method (23) use third octave band analysis. However, work at ISVR has shown that at least 1/9 octave band analysis is required to determine whether a noise has distinctly tonal components (24).

Identification of tonal character and therefore the application of the 5 dB character correction relies on the subjective impression of the noise as described by BS 4142:1990:

> *"If the noise contains a distinguishable, discrete, continuous note (whine, hiss, screech, hum, etc.,)..."*

Omitting an objective procedure has however given rise to problems with the application of the standard. Five data returns indicated a need for a definition of tonality and the need for guidance on the objective measure of tonality. The rating procedure in BS 4142 is rather coarse and the addition of 5 dB can make a significant difference to the rating of complaint potential, particularly in the marginal cases. The absence of an objective measurement procedure has led to an increased reliance on the subjective identification of tonal character by the investigating officer which, in turn, can lead to inconsistent decision making when one uses the standard. This is contrary to the requirement that the rating procedure should lead to consistent decision making.

Research has shown that the correction required for the presence of tonal character is not a constant, for example, it may be dependent on the level of the specific noise or the background noise spectrum (22). It is not surprising that using the 5 dB correction in the standard has resulted in both the underrating and overrating of the effect of the presence of tonal character as reported in sections 8.2 and 8.3. However, the 5 dB character correction led to more cases of underprediction than overprediction of the complaint potential, suggesting that the 5 dB was too small in more cases than it was too large.

Williams and Robinson (25) in their survey of local authority practice and opinion in 1988 summarise some reported short-comings of the existing tone correction procedure and focus on the dependency of the required correction on tone frequency and relative level of the tone. They discuss single and multiple tonal components, the need for more guidance on the objective determination of tonal components, and the magnitude of the tonal penalty. They also comment on the implication of the 'go - no go' definition of tonal character for those noises with 'marginal' tonality, which can have a critical effect on the outcome of the rating procedure.

As tonal noise sources form a significant proportion industrial noise sources, this study has re-emphasised the need for an objective procedure for identifying tonal character and a method for assessing the impact of the tonal character on the listener.

The measurement of tonal nature has been discussed but this section will now focus more on some specific cases which have given rise to problems with the application of the standard. Several cases referred to indoor noise and the effects of tonal noise inside closed spaces. Indoor noise measurement is actually beyond the scope of the standard as detailed further in section 8.11. Tonal noise inside dwellings can produce nodes and antinodes inside a room which may increase the overall annoyance, particularly where maximum pressure is set up near to the head position at night.

Seven cases referred to a certain type of tonal noise, low frequency noise or hums. Often the low frequency noise was structure-borne and exhibited itself indoors as a low frequency hum, which, according to the scope of the standard should not be assessed at a position indoors. It was reported that noise of this nature could not be adequately accounted for with the use of an A-weighted measurement and the difference between the background noise measurement and specific noise measurement was often insignificant or very hard to determine. The added annoyance due to the presence of the low frequency component was often underrated using 5 dB suggesting that a different measure was needed for noise of this type.

In summary, what is actually needed to assess the effect of tonal noise, is a reliable method to identify the tonal nature, and a method to assess whether the tonal nature is the dominant feature of the noise giving rise to annoyance. Furthermore users of the standard need to recognise the limitations of the BS 4142 method where assessments by the method are not relevant or suitable i.e. indoors and for low frequency noise measurement. Finally, if an assessment method such as BS 4142 were aimed at targeting cost-effective noise control, then provision of an accurate identification of tonal nature, and the rating of it as the most important feature giving rise to an adverse response, would provide valuable data when recommending noise control solutions. This is discussed further in reference (26).

8.5 IMPULSIVE CHARACTER

21% of all reported cases involved noise that was subjectively judged to be impulsive in nature. The 1990 version of BS 4142 made no change to the subjective identification of impulsive character. At present the standard relies on subjective impression and defines an impulsive noise as ...

"If there are distinct impulses in the noise (bangs, clicks, clatters, or thumps).."

Comments on the data returns indicated a need for guidance on the objective measurement of the impulsive nature of a noise.

One case referred to the need for the correction for the added annoyance of an impulsive noise to be dependent on the level of the noise i.e that in their opinion what was actually needed was a level dependent penalty. Research has confirmed that the added annoyance due to impulsive character is greater at lower levels of background noise and smaller at higher levels (27). Subjective impressions of noise, particularly at low levels, are dependent on the acoustic features actually present in the noise and their sensation levels above their detectability thresholds.

In three cases, the impulsive nature of the noise was felt to be underrrated by the BS 4142:1990 rating method. The results from this study indicate that a 5 dB penalty is insufficient. One case referred to shooting noise (strictly speaking outside the scope of BS 4142). This noise had a very high onset rate (rate of rise of the noise level) and using L_{Aeq} as a descriptor with a 5 dB character correction severely underrated the impact of the noise on the listeners. The user commented that adopting Impulse time weighting (I) and subtracting the background noise measurement gave a difference which was some 18 dB greater than the BS 4142:1990 method. In this case complaints were rated as likely with a difference of 12 dB between the rating level and background noise level. The investigating officer considered that the subjective impression of this noise was "very annoying" and that a difference of this amount was not sufficient to fully describe the extent of the problem.

Research has led to various descriptors being developed for impulsive noise including the use of short term L_{Aeq} and the increment descriptor (28). At present these methods have not been sufficiently "field tested" for them to be incorporated into standards such as BS 4142. However, this study has shown the importance of this feature in determining an adverse response to noise and that there is a need for an objective procedure to identify impulsive character. Further work is continuing at ISVR (29) to establish detection thresholds for impulsive noise and the dependence of annoyance response on sensation levels.

8.6 INTERMITTENT NOISE

The current version of BS 4142 takes into account intermittent noise in two ways.

Firstly in clauses 5.5.6 and 5.5.7 of the standard, reference is made to the on-time of the intermittent noise. Relevant adjustments are made depending on the reference time interval. This is calculated as per equation 4 of the standard where an adjustment is made to the measured level in cases where the on-time is less than the reference time interval, in accordance with:

$$10\log(T_{on}/T_{ref})$$

Thus for an intermittent noise of duration one minute, an effective penalty would be subtracted of 17 dB for day and 7 dB at night, implying a night-time correction of around 10 dB. These "effective corrections" always subtract a value from the measured level to obtain a rating level. This results in a noise having a lower rating level than it would if continuous, with the consequence that the noise may be rated as less likely to give rise to complaints than it would if continuous. For on-times greater than the reference time interval, no correction is made.

A second method of taking into account intermittent noise applies in cases where the noise is subjectively described as irregular enough in character to attract attention. In this instance a character correction of 5 dB may be added to the measured level. A few data returns were received which made specific reference to the intermittent noise and the effective on-time corrections. In particular these referred to the following cases.

One case involved three air conditioning units which operated both together and separately depending on the demand. The noise source was tonal and a 5 dB character correction was added to obtain the rating level. However, it was the opinion of the investigating officer that the intermittent nature of the noise actually attracted attention giving rise to added annoyance. Since only a single 5 dB correction can be added at one time for one or more of the specific characteristics described in section 7.2 of the standard, the intermittent nature of the noise source was not, in the opinion of the investigating officer, adequately accounted for by the BS 4142 rating method.

Another case involved a granulator for plastics. Since this was used on demand, the on-time was often difficult to determine. For this case, the investigating officer worked backwards and defined acceptable levels and the operator then calculated the acceptable on-time of the machine.

This study has also highlighted the importance of investigating a noise source over a relatively long time period so as to establish truly representative conditions based on full acquaintance with the operation of the plant. Since the reference time interval is only 5 minutes during the night-time, there is a danger of noise measurements being taken for only five minutes, which is not in accordance with what the standard requires or intends.

In different cases, the "effective on-time correction" was reported variously as being too large and too small. The first was in the case of a "cyclone" machine requiring an on-time correction of -11 dB if operational during the day for only five minutes every hour. The investigating officer considered that this would "over-reduce" the rating level, thus decreasing the rating of the likelihood of complaint from a source which he considered would still be a "nuisance".

The effective correction was reported as being insufficient for a similar case at night-time. This involved a compressor which was only operational for 2.5 minutes every 30 minutes. This specific noise was given a 5 dB penalty for being irregular enough to attract attention. The night-time "on-time correction" of -3 dB was considered to be excessive.

In fact the opinion from the latter example concurs with various comments received by telephone referring to the intermittent noise at night being equally or even more annoying than a continuous noise during the night time period since it may wake up a sleeping person with the actual change in noise conditions.

Keeping this in perspective, the number of users that are unhappy with the standard in relation to the intermittency correction represents less than 4% of those completing the data sheets. However, this section illustrates some of the problems which may result when using the standard and points towards the need to investigate the noise source over a sufficiently long time period. Problems have been reported for intermittent noise that has other annoying features. These will be referred to within the combined effects cases and are detailed in the next section 8.7.

8.7 COMBINED EFFECTS

The 1990 version of BS 4142 states that only a single 5 dB correction should be applied if one or more of the described characteristics are present. This contrasts with ISO 1996 which allows for more than one adjustment for the presence of more than one feature. This leads to the question of what is the appropriate method to deal with the situation when there is more than one acoustic feature present. The method contained in BS 4142 implies that two features present are no more annoying than a single feature, whereas the method of ISO 1996 implies the opposite. Research has shown that both could be true under various circumstances e.g. where one feature is dominant, an annoyance judgment could be based on the subjective reaction to that one feature, but where two are present the response is based on a judgment of both features, as described in recent work at NPL (30) on subjective response to combined tonal and impulsive noise.

Assessment of noise with more than one feature according to the method of BS 4142 may lead to underrating the impact of the noise and underprediction of the likelihood of complaint by the standard as described in sections 8.2 and 8.3. Table 13 gives a summary of some examples from the data returns on combined effects where more than one feature is present.

The table includes non-acoustic features such as odours. This shows the importance of assessing the situation as a whole since noise is but one of the possible reasons for complaining about an industrial site. These factors are not included in the BS 4142 assessment procedure but can have a considerable effect on the prediction of complaint likelihood and highlight the important (yet often overlooked) fact that BS 4142 is **only a tool** to be used in noise complaint investigations. Response to noise is subjective and affected by many factors (acoustic and non-acoustic). The likelihood that an individual will complain depends on individual attitudes and perceptions in addition to the noise levels and acoustic features present. Assessing response to a noise source is complex and care should be taken since without full examination of all relevant factors (acoustic and non-acoustic) it may be difficult to assess whether the noise is likely to cause complaint. Assessment of all relevant factors is in line with an environmental impact assessment approach (31) described by Horrocks (17) (32) which adopts an integrated approach to the appraisal of development proposals and adopts scoping techniques. Consideration should perhaps be given to re-wording the foreword of the standard to re-emphasise these aspects.

Table 13: Examples of combined effects or features

COMBINED EFFECTS OR FEATURES
Intermittent and new
Tonal, unpredictable, intermittent
Short duration, irregular, impulsive
Continuous and bland
Impulsive and tonal
Intermittent and cyclic
Vibration and noise
Odours and noise

8.8 MULTIPLE NOISE SOURCES/BACKGROUND NOISE LEVEL MEASUREMENT

Difficulties were identified with the assessment of noise from multiple sources. Problems arose when trying to measure the background noise level and having to make a decision as to whether the noises should be considered separately with each noise contributing to the residual noise of the other. In such cases, a decision has to be made as to whether the industrial plant as a whole or a particular noise source alone should be rated. Generally, each individual noise source was examined separately thereby including other sources in the residual noise. Adopting this approach may be sensible when trying to identify the individual noise sources that need controlling. In some cases, the shutdown of one piece of equipment revealed an additional offending source. Users of the standard seemed to want some guidance on this matter.

There was one case where the specific noise was not distinguishable from the residual noise but the rating methods suggested that there was a problem. This situation was commented on in section 8.2. The noise was from a source which had a silencer fitted to decrease the noise emission. In the opinion of the officer, the character of the specific noise was not distinguishable or noticeable in the total noise environment although the actual specific noise level was greater than the background noise. Therefore although the BS 4142 rating method was predicting complaints as likely, the specific noise did not seem to be apparent. This may have been due to a masking effect by another source in the residual noise environment or another dominant source of noise with characteristics more dominant than the characteristic of the specific noise.

Creeping background and diminishing background were also identified as factors which were not properly addressed within the standard although this was only highlighted in telephone calls and not on the data returns. In the event of a modification to a relatively new site, does the noise from the relatively new site become part of the residual noise to be used in the assessment of noise from modified plant? Again, some

of the users of the standard would like to see some guidance on this matter or at least for attention to be drawn to this area. Some users of the standard however actually recognise this to be a plus point! The importance of the experience of the investigating officer when applying the standard is again highlighted.

8.9 ASSESSMENT PROCEDURE

No changes were made to the assessment procedure in the 1990 revision of the standard primarily because of the lack of any new research data on complaints. BS 4142's prime objective is to rate the complaint likelihood from those living in the vicinity of an industrial noise source. As the results in section 7.5 have shown, the users of the standard have reported that in excess of 80% of the time, the standard is indeed meeting this objective.

However some users of the standard made comments specifically about the assessment procedure. It was the opinion of a few that the procedure was too coarse. In fact a 5 dB character correction (judged subjectively) could often make a significant difference to the outcome of a rating. The application or non-application of the character correction to a noise level in a given situation could therefore lead to inconsistent decision making based on the outcome of such an assessment by two parties. This particularly would be highlighted in marginal cases as described in section 8.13.

Consideration could be given to alternative assessment procedures. Difficulties may arise in developing and testing the procedures to the same extent that the current procedure has been tested. Ideas leading to an alternative assessment procedure are described in reference (26) which focuses on the general requirements of a noise assessment procedure which will be described at the end of this report. It is the opinion of some that the L_{A90} measurement determining the background noise level should be replaced by an L_{Aeq} measurement of the residual noise.

One user of the standard commented that he would like night-time noise to be assessed on the basis of sleep disturbance and related to maximum levels not energy equivalent levels. Another user pointed out that he would like to see guidance on setting boundary noise levels. These two points refer to methods which are not used by the BS 4142 rating procedure. In fact these refer to some "absolute level" being used to rate the noise rather than the "intrusion" above a background noise level. As the foreword of the standard details, noise is liable to provoke complaints either when the noise level exceeds the background by a certain margin or when it attains a certain absolute level. The BS 4142 method is involved in the former but not the latter method of rating. What may be needed in some cases is guidance on the role of absolute level methods of assessment. In fact at what stage does the absolute level becomes more important than the intrusion above background? This may be answered in part by the new PPG document at present only in draft form with its defined action levels. However, it will always be difficult to define absolute noise level limits for all circumstances.

8.10 USES OUTSIDE SCOPE

It is well known that BS 4142 is often used outside its scope. This was confirmed in this study in about 10% of the cases. The reason for applying the standard outside its scope seems to be primarily the lack of alternative standards or guidelines to use in given situations. The data sheet study was never intended to police the use of the standard and letters sent to the users asked for information on all of its applications whether or not they were within the scope. Table 14 below summarises some of the uses outside the actual scope of BS 4142.

Table 14: Examples of uses outside existing scope

USES OUTSIDE SCOPE
Shooting noise
Structure-borne noise inside dwelling
Music from DJ/night club
Shunting operation in private sidings ?
Moving sources ?
Squash club
Roller disco
Nuisance assessment
Low background noise levels

It was interesting to note that many of the applications outside the scope gave rise to procedural problems or under/overprediction. There were 5 cases of use outside the scope which led, in the opinion of the investigating officer, to underprediction of the complaint likelihood by the rating method. In fact this covers nearly 50% of the "underpredicted" cases. These mainly included assessments of noise at positions inside dwellings (as covered in the following section).

One may conclude from this that using BS 4142 as intended within its scope would increase its effectiveness at predicting complaint likelihood. Options to overcome the use of the standard outside its scope include the development of alternative methods of measurement and assessment as discussed in section 10.

It is often commented that the rating method of BS 4142 is used in assessing the existence of nuisance. In several cases reported in this study, BS 4142 was used in nuisance assessment cases. The user of the standard commented that they were using the method of BS 4142 to back up their subjective judgment of the situation. Furthermore, comments raised at various seminars have identified the need for a "nuisance assessment standard", explaining that if BS 4142 is not a "nuisance standard" then what place does it have in noise or nuisance assessment, since in many cases nuisance assessment is exactly what it is used for? Nuisance assessment, strictly speaking, is outside the scope of the standard since nuisance, in this sense, is a legal term and should take into account both acoustic and non-acoustic factors. However, although BS

4142 was never intended as a determinant (let alone the sole determinant) of the existence of nuisance, it is often the only objective measure available for determining the likelihood of complaint due to noise and has therefore resulted in the method carrying significant weight in nuisance assessment cases. The view is held by some that the method is relied upon too heavily and carries too much weight in such instances. It is most important to recognise that the method of BS 4142 should only be considered as part of the process of assessing cases with respect to nuisance.

BS 4142 is often used in situations outside its scope by virtue of it being one of the only tools available for use in rating noise. Those who attend a magistrates court to make noise control recommendations, need to show that they have complied with a recognised procedure for measuring the noise. Standards should provide for an objective comparison between different situations to encourage fair treatment across similar cases. This allows future decisions to be based on precedents and leads to consistency and fairness in decision making. BS 4142 is often used in inappropriate circumstances due the absence of any other standard and therefore it is not surprising that it sometimes yields inconsistent results.

What is really needed is some other guidance to define for those involved what should be used and what aspects should be taken into account. The investigating officer usually has in his mind what the main cause for complaint is and whether the complaint is justified. What he requires is an objective measure to confirm his subjective opinion. BS 4142 can be used in this way but does have some pitfalls (26). However, the more it is put to use outside its scope, the more likely that it will not predict complaint likelihood effectively. It should not be followed as a rule book and the investigating officer should use his initiative in certain cases. Some people have suggested that the scope should include a list of acceptable applications of the standard. This could be rather limiting and put outside the scope other perfectly reasonable uses.

8.11 NOISE INSIDE DWELLINGS

A repeated example of use outside the existing scope of BS 4142:1990 was the measurement and/or assessment of noise at positions inside dwellings. This was carried out in 8 cases. The user of the standard was basically applying the principle that if noise exceeds the background noise level by a certain margin then it is likely to provoke complaints. Comments were received relating to the indoor assessment of noise as being more representative of the real situation.

The method of BS 4142 is intended for the measurement of noise outside the building. However, it seems that people living in the vicinity may experience additional annoyance from a source inside a dwelling where it may not be appropriate or possible to measure the noise outside at the building facade. An example of this phenomenon was demonstrated in a case involving structure borne noise which exhibited itself as noise inside the dwelling but was not evident outside the building. Measurement and assessment at positions outside the building using the "correct application" of BS 4142 would not be appropriate. This phenomenon is particularly evident with low frequency hums which can propagate over relatively large distances. Furthermore, noise inside closed spaces can create standing wave patterns with nodes and antinodes spaced throughout a room. Measurement of the noise outside the dwelling would not take account of the effects of listening to noise inside a closed space.

Another case referred to noise from a machine attached to a shared party wall from commercial premises adjacent to the residential property. The method of BS 4142 was applied and measurements were taken inside the dwelling. Had the standard been followed as intended, the noise may not have been predicted

as likely to give rise to complaints because measurement of the noise at the facade would not have been in the sound propagation or transmission path and therefore would not have been appropriate.

Noise problems are often assessed and solved by a combination of lateral thinking, discussion and experience. BS 4142 can be refined in the light of new experience gained from this type of study but one should not expect the standard to answer all noise problems or lay down definitive rules. BS 4142 is primarily an objective measurement procedure assessing a subjective effect and is therefore only a tool. The experience of the investigating officer is undoubtedly important. Examination of the application of the standard has confirmed that some aspects of the standard are open to individual interpretation by the investigating officer and personal judgment is often required, indeed it is necessary when examining the suitability of applying the standard outside its scope.

For noise inside dwellings, the investigating officer is aware that measurement out of doors may not be appropriate but that he needs to follow the general principle of the "intrusion" of the noise above a background noise level. However, what is really needed is an agreed objective method that confirms the existence of noise which is liable to lead to an adverse response.

8.12 LOW BACKGROUND NOISE LEVELS

The 1990 version of BS 4142 states in the scope that:

> *"The method is not applicable for assessing the noise measured inside buildings or for assessing noise in situations where the background noise level is very low, i.e. below an A-weighted sound pressure level of 30 dB."*

It is the author's understanding that this part of the standard was intended to bring about a cut-off point below which noise generated inside the dwelling may form the most dominant noise source. Attenuation of outdoor noise levels of less than 30 dB(A) by the walls or windows of a dwelling may result in indoor levels less than those generated from sources indoors. The following explanation was given at the BSI Seminar of 1991 as reported in (33).

> Question:
> **Why was the lower limit of 30 dB specified for the background and how does one deal with situations where the background is less than 30 dB ? Does this mean that one cannot predict the likelihood of complaint however high the level of the source noise ?**
>
> Reply:
> **Measurement of background noise giving results below 30 dB may not be reliable because of the limitations of the instrumentation, and is unlikely to be found in the sort of area for which the standard was intended, i.e mixed residential and industrial areas. Also, internal noise would usually tend to mask the perception of external noise levels of this order. If the measured background level is lower than 30 dB the measurement procedures might still be useful for providing information for specific cases.**

In 2 daytime cases and 5 night-time cases the background noise level was measured as below 30 dB(A) and of these, all of the daytime cases and two of the night-time cases referred to measurements inside the building. The other three cases referred to night-time noise in a quarry with distant road traffic noise, and night-time noise in the garden or outside the bedroom window with distant road traffic noise. In two of the

cases with low background noise levels, the assessments lead to underprediction of complaints by the standard rating method, both cases involving measurements inside the dwelling.

It has been commented on several occasions (although not in the data sheets) that some rural areas have background noise levels below 30 dB(A) and therefore BS 4142:1990 cannot be applied. However, as was noted at the BSI seminar, in some of these cases, the measurement procedures could still provide valuable information. In fact if the specific noise level is relatively high in comparison to the background noise level, then the principles of the rating method should still be applicable. However, BS 4142:1990, as currently worded, effectively provides a "get out clause" for non-application of the standard where in essence the rating method should still apply. Consideration should perhaps be given to including within the standard all cases where the specific noise level is significantly greater than the background noise level.

Apart from data returns received concerning low noise level situations, telephone calls have been received about using BS 4142 for a specific application - noise from wind farms. Wind farms are usually placed in remote quiet areas with background noise levels below the minimum value of 30 dB(A). Furthermore, the wind farms are usually sited in locations such that the note of clause 5.4.1:

> *"Noise level measurements should generally not be made under extreme weather conditions such as high winds (greater than 5 m/s average)..."*

may not be adhered to. Commercially available wind turbine generators do not start turning until their cut-in wind speed, typically 5 m/s, has been achieved. However, this is the wind speed at the noise source and not necessarily at the assessment position. Therefore, although the limits set for weather conditions are principally about minimising extraneous effects on the meter readings, the existence of these limits seems to preclude use of the standard for this particular application. Hayes comments in his paper (34) that since BS 4142 is meant to be applied in situations where mixed industrial and residential premises exist, its application in quiet rural areas must questioned.

Guidance is needed on how to treat noise from these types of operations and how to define acceptable noise levels. In fact one would have to consider whether levels above a background noise level would be the best method or whether absolute noise level limits should be adopted.

Therefore it may be concluded that the method of BS 4142:1990 needs to be clarified with respect to its application in situations of low background noise levels. Consideration could be given to including all cases where the specific noise level is significantly greater than the background noise level. Noise assessment for specific applications may require separate "codes of practice" avoiding the need to apply BS 4142 to situations for which it was not intended. It is understood that a document describing the assessment of noise from windfarms is under preparation by a DTI Working Group (35).

8.13 MARGINAL CASES

Table 15 summarises some of the data on cases rated as being of marginal significance by the BS 4142:1990 rating method.

As section 8.9 has described, the assessment procedure is fairly coarse and may result in the application/non-application of a 5 dB correction making a significant difference to the outcome of the

assessment procedure. This problem is most evident in the cases rated by the BS 4142 method as of marginal significance, and the incorrect rating of such cases may lead to inconsistent decision making. The results from the data sheet study suggest that the method is more likely to over or underpredict the likelihood of complaint for the "marginal" rated cases. A large proportion of the marginal cases referred to noise with specific characteristics. An assessment procedure based on the evaluation of the dominant features in the noise giving rise to these specific characteristics may actually be more suitable for these cases.

The results suggest that special attention should be given to these marginal cases. It also follows that any rating procedure that works well for marginal cases should work for the more extreme cases.

Table 15: Data on cases rated as of marginal significance by the BS 4142:1990 rating method.

MARGINAL CASES	
17%	of all cases were rated as marginal
88%	of the marginal cases had specific characteristics
73%	of the above were tonal
43%	of marginal cases were rated as cases of under/over prediction by the BS 4142 rating method
as compared with only	
20%	of all cases being rated as "under or overpredicting"

8.14 INSTRUMENTATION REQUIREMENTS

Section 7.3 gave a summary of instrumentation used to carry out measurements in accordance with the standard. The two most popular models of equipment used were the Bruel and Kjaer sound level meter, type 2231 and the Lucas CEL meter type 393(A&B) which are both capable of measurements of equivalent continuous levels and percentile levels. These can measure with both Fast and Slow time constants. The measurement of the specific noise level in terms of L_{Aeq} seems to have been successfully carried out with the available instrumentation. Some users have even adopted the use of DAT recorders to provide a record of the noise which (given correct and sufficiently accurate calibration) could be used to analyze or reanalyse noise levels back in the office or laboratory.

The main objectives of the 1990 revision of BS 4142 were the conversion to the use of L_{Aeq} and the

tightening up of requirements on equipment, traceable calibration, and measurement procedures. This study suggests that the users have had few problems with making the actual measurements in terms of L_{Aeq}. However, it has become evident that there are pitfalls in making some measurements using this quantity, especially if the instrument is left unattended. Measurements of the specific noise level should not include measurements of "extraneous noise" and therefore should be "paused out" of the measurements. This "pausing out" should be done during the measurements. In fact using relatively new techniques such as short term L_{eq} (now offered by a variety of manufacturers) and coding buttons, the calculation of L_{eq} can be done after the actual measurement.

As technology improves, the availability of good integrating sound level meters, meters that interface directly with computers, and stand-alone PC based systems, is increasing. However, all users have limited resources to buy new equipment. Although the transition to measurements using L_{Aeq} seems to have been relatively successful, any future changes e.g. with respect to objective identification of specific characteristics, will have to take into account the capabilities of existing instrumentation and costs. For example, narrow band or FFT analysis of noises to determine sensation levels of particular features may present a problem to some users lacking the resources to procure the relevant instrumentation.

Many comments and telephone calls have been received relating to the new traceability requirements for the instrumentation as set out in clause 4.2 of the standard. These include concerns such as:

(1) The cost of calibration by a NAMAS accredited laboratory may be of the same order as the cost of the instrument.

(2) How does one compare measuring equipment against a reference set that has been calibrated within the last two years? (See (31) for answer given at BSI Seminar).

(3) Is it really necessary for such levels of accuracy given that the levels measured for the purposes of the standard are to the nearest dB?

It is the author's understanding that the requirements for traceable calibration are to ensure good measurement practice. However, although users wish to comply with the requirements of the standard, they are having problems both with knowing how to proceed and with the associated costs. The standard needs to be clarified in this area and additional guidance given on how to comply. In addition the levels of traceability required should be re-examined. If the difference between the rating level and background noise level is large, then very high levels of accuracy may not be required. However, one cannot rely on the situation always being so clear cut, and in any event it is still necessary to demonstrate that the instrument is working correctly.

An interesting consultant's view on acoustical measurements and NAMAS accreditation with respect to BS 4142 is given in the paper by Fleming (36). In addition a rather poignant comment was made by Hinton during the IOA Autumn conference of 1993 (37) referring to the possibility of user error being greater than instrumentation error and that using competent persons was as important as using well calibrated instrumentation. He also re-affirmed that the level of accuracy required depends on the use of the results and recognised that traceability is about ensuring quality and is not just for the sake of accuracy, but he questioned how far it should be taken and called for additional guidance to be produced.

8.15 RESIDUAL NOISE - MEASUREMENT AND EFFECTS

Residual noise is defined in BS 4142 as

> *"The ambient noise remaining at a given position in a given situation when the specific noise source is suppressed to a degree such that it does not contribute to the ambient noise"*

Background noise level is defined as

> *"The A-weighted sound pressure level of the residual noise in decibels exceeded for 90% of a given time interval, T."*

Therefore, it is difficult to measure the background noise level and specific noise level at the same time and measurement position.

BS 4142 calls for the procedures in clause 5.4.4(a), (b) or (c) of the standard to be followed if the noise level measured with the specific source on does not exceed the background noise by 10 dB or more. The intention of this clause is to minimise the effect of the residual noise on the specific noise level measurements. In the light of various comments, it is the author's view that clause 5.4.4 does not work as intended due to incorrect wording and that the procedures of sub-clauses (a), (b) and (c) are not being adopted correctly. This clause needs clarification, the main concern being 5.4.4(b) which refers to fluctuating residual noise. Sub-clause 5.4.4(b) in the author's opinion, should be called for in all cases irrespective of the measured difference described above. Sub-clause 5.5.4(b) reads

> *"If the residual noise fluctuates, make a series of short term readings of the noise level at times and during intervals when the residual noise level has subsided to typically low or mean minimum values.."*

This effectively requires that noise sources such as an overflying aeroplane, train passes etc be "paused out" of the measurement of the specific noise level. This should be carried out for all measurements at all times.

Data was obtained for 18 daytime and 15 night-time cases on the A-weighted equivalent level of the residual noise in addition to the background noise level (L_{A90}). One daytime case and two night-time cases gave examples where the difference between the L_{Aeq} and L_{A90} of the residual noise was greater than 10 dB.

Some users of the standard expressed concern that if the L_{Aeq} and L_{A90} of the residual noise were measured simultaneously, then the difference between the values for fluctuating noise sources would already in some cases be greater than 10 dB. In this case, applying the principles of the assessment procedure, it would be predicted that complaints were likely even before the specific noise was introduced to the noise environment. However, the situation should not arise because the L_{Aeq} value for the specific noise level is not actually measurable without the specific noise operating.

To help clarify the situation, clause 5.4.4 could be re-worded to bring 5.4.4 (b) into action in all cases, so that all measurements of specific noise are taken only during times when the residual noise has subsided to a typically low level.

Questions raised at the BSI seminar (33) addressed clauses 5.4.4, 6 and 8.2. In particular, note the following question and reply:

Question:
Should extraneous noise be measured ?

Reply:
'Extraneous noise' as a component of residual noise should not be included in the specific noise but may be included in the background noise if it occurs over a substantial proportion of the time and is therefore included in the measured L_{A90} value. It is this 'extraneous noise' that gives rise to the difference between L_{Aeq} and L_{A90} when measuring the background noise.

It has been recognised that using Table 1 of BS 4142 and comparing L_{Aeq} with L_{A90} may introduce an uncertainty into the calculation correcting for the influence of residual noise on the specific noise measurements. It would appear that the intention of the standard is to use the L_{A90} values in Table 1 as an approximation to an L_{Aeq} measure of the residual noise when the residual noise is at a mean minimum value. Therefore, if the background noise level is not measured when the residual noise level is at a mean minimum value as set out in sub-clause 5.4.4 (b), the uncertainty introduced by this approximation will increase.

Another method of correcting for the influence of residual noise on the specific noise level could be to determine the L_{Aeq} of the residual noise more accurately for the purposes of subtracting away the influence of the residual noise on the specific noise level. In most cases it would be preferable to measure the specific noise directly and free of influence from the residual noise. Recent work has been carried out by Rickaby and Vasudevan (38) into the problems of fluctuating residual noise and background noise corrections.

Finally, from various comments at seminars etc some users of BS 4142 have expressed concern at the variability with time of the L_{A90} index. Unfortunately no data were obtained on this aspect but past studies include that of reference (39).

8.16 JUSTIFIABILITY OF COMPLAINT

The rating method of BS 4142 is intended to be used to investigate the likelihood of complaint and can be applied for planning purposes. The method is used to predict the complaint likelihood due to industrial noise affecting those living nearby. Often the results of the predictions by the BS 4142 method are used in a magistrates court as part of the evidence in a case to determine whether the noise in question should be abated or controlled. As part of this, one may have to determine whether the complaints due to the noise are justifiable.

Because noise rating is only one of the factors to be considered, a standard cannot rule on whether or not a specific noise is a nuisance or whether a complaint is justified. Therefore any decision reached must be based on all relevant factors and the BS 4142 assessment should form just a component part of the evidence.

In the opinion of the investigating officer, the complaints were considered as not justified in 12% of the cases reported. Most of these referred to situations where the differences between the rating level and background noise level were less than 5 dB. However, the importance of taking other factors into account and not relying solely on the BS 4142:1990 rating was demonstrated in three cases. One of these cases involved a situation where the complainant had been satisfied about the noise situation before he took possession of his premises and this was agreed by all parties involved. Although the most dominant noise sources remained unchanged, an additional much quieter noise source was added which triggered complaint. This complaint was not considered justified. This example shows the importance of other

factors, which may be non-acoustic.

To re-iterate some earlier conclusions, the users of the standard often would like BS 4142 to do more than it was intended to do as defined in the scope. It can be used to provide quantitative data but the qualitative assessment of nuisance and the justifiability of complaint is beyond the scope of the standard. An interesting discussion relating to nuisance assessment is given by Horrocks (17) in which he questions the role of BS 4142, given its limited value in the assessment of nuisance. The role of BS 4142 should perhaps be re-examined in the light of final comments in section 10 of this report.

8.17 KEY ISSUES HIGHLIGHTED IN DISCUSSION

Table 16 on the following pages highlights the key issues raised during the discussion of section 8. The author's observations are made in the final column.

Table 16 : Summary of Key Issues

TOPIC	KEY ISSUES	OBSERVATIONS
Tonal character	1. Definition of tonal No guidance on objective measurement Reliance on subjective identification Addition of penalty can have a significant effect on BS 4142 rating 2. Underrating/overrating of subjective impression 3. Indoor noise and effects Low frequency hums	1. Could lead to inconsistent decision making 2. Heightened response is level dependent 3. Standard does not address indoor noise measurement
Impulsive character	1. Definition of impulse No guidance on objective measurement 2. Underrating of subjective impression	1. Could lead to inconsistent decision making 2. Heightened response is level dependent
Intermittent noise	1. Often attracts added attention which may not be accounted for adequately 2. On-time sometimes difficult to determine accurately 3. On-time "effective penalty" reported both as too large and too small	1. May lead to underrating of subjective impression of noise
Combined features or effects	1. Noise may contain more than one acoustic feature e.g tonal and impulsive etc, 2. Noise may be accompanied by other stimuli, e.g odour, vibration	1. BS 4142 allows for only a single 5 dB penalty, (inconsistent with ISO 1996), may lead to underrating of subjective impression 2. BS 4142 only deals with predicting complaint likelihood due to noise, therefore forms only part of a complete complaint investigation.
Multiple noise sources	1. Sometimes difficult to establish specific source Sometimes difficult to measure background noise level Shutting off one source often reveals another problem 2. Creeping background	1. One must decide whether to examine multiple sources as one complete source or whether to investigate each source separately with other sources contributing to residual of the other. 2. Decisions must be made about choice of background noise level in case of modifications or addition of new installations to existing industrial premises

Table 16 (cont/d): Summary of Key Issues

TOPIC	KEY ISSUES	OBSERVATIONS
Assessment procedure	1. Too coarse Addition of penalty can have significant effect on outcome 2. Use of other procedures for night-time noise or boundary levels based on absolute noise level limits. 3. Comparison of L_{Aeq} with L_{A90} - particularly with reference to fluctuating residual noise - where difference may be greater than 10 dB before specific noise is introduced	1. Could lead to inconsistent decision making 2. BS 4142 only addresses margin by which specific noise exceeds background noise level although foreword points out that complaint likelihood may also depend on attaining a certain level. BS 4142 is therefore only part of the story in a noise complaint investigation. 3. 5.4.4 (b) should be applied in all cases for good measurement practice and to minimise uncertainty in approximation in Table 1 - rewording required.
Uses outside existing scope	1. Standard often applied outside scope since no alternatives available 2. Applicability to assessment of nuisance and justifiability of a complaint.	1. Use outside scope decreases probability that standard will meet its objective of predicting complaint likelihood. 2. The likelihood that an individual will complain depends on individual attitudes and perceptions, in addition to the noise levels and acoustic features present. BS 4142 makes no recommendations in respect of the extent to which such non- acoustic factors should be taken into account. Since noise rating is only one of the factors used for deciding justifiability and nuisance, any decision must be based on all relevant factors and BS 4142 can only form a component part of the evidence.
Noise inside dwellings	1. More representative of real problem ? Structure borne noise Shared party walls Low frequency hums	1. BS 4142 does not address measurements inside dwellings, and if used as such, often leads to underrating of complaint likelihood.

Table 16 (cont/d) : Summary of Key Issues

TOPIC	KEY ISSUES	OBSERVATIONS
Low background noise levels	1. Applicability of rating procedure in low noise environments e.g quiet rural areas 2. Applicability to windy rural areas e.g windfarms	1. BS 4142 at present not intended for use where background noise level is below 30 dB(A), but is the use of rating procedure legitimate if specific noise level is high ? 2. Alternative procedures/guidance may be required for specific applications.
Instrumentation requirements	1. Calibration/verification requirements Cost considerations of above Required accuracy for more extreme cases	1. Although section is about good measurement practice, difficulties are experienced with meeting the requirements in terms of how, cost of calibration, and necessity of such accuracy for a standard measuring to 1 dB.
Complaint likelihood predicted as of marginal significance	1. 88 % of marginal cases had specific characteristics 2. For marginal cases, significant increase in probability that BS 4142 will not work as intended.	1. Application/non-application of 5 dB penalty will have a significant effect on rating of marginal cases - may lead to inconsistent decision making. 2 If rating method can be made to work for marginal cases, it follows that it should work for more extreme cases.

9 CONCLUSIONS OF THE STUDY

This study has given a useful insight into the application of BS 4142:1990 and has provided some valuable information. At the start of this report it was commented that the development, implementation, review and revision of a standard is a continuous cycle and that this systematic evaluation of the application of BS 4142 is intended as a major contribution towards the review of this standard.

The aims of the study were set out in section 4. The study was intended to give an insight into the views (both positive and negative) of users concerning (i) how well BS 4142 is doing its job of predicting complaints from neighbours living in the vicinity of an industrial noise source and (ii) areas of weakness in the standard. It also aimed to provide information on measurement values and the various applications of the standard. This study has gone some way towards meeting these aims as well as examining the needs of the user and the general problem of rating noise. Let us summarise the main results.

The prime objective of the rating method of BS 4142 is to predict the likelihood of complaint. The results have shown that the rating method generally gives a good indication of the likelihood of complaint (in over 80% of the cases reported). The standard therefore appears to be achieving its primary objective relatively successfully. However, there are problem areas and ambiguities that need attention which should be taken into account in any future revision of the standard.

One important finding is that many of the investigated noise sources had specific characteristics. In fact over half of the noise sources were tonal. It is therefore essential that the rating method is capable of assessing the impact of noise with characteristics which give rise to a heightened response. More accurate and reliable objective procedures for identifying these characteristics and methods for assessing the impact of the perceived character on the listener are needed. Furthermore the reliance on the somewhat subjective judgment of the presence of characteristics often leads to a lack of consistency in decision making particularly with cases which may be judged as of marginal significance. Therefore this study has shown that the assessment of noise with specific characteristics needs improvement.

The study has also shown that there are many applications outside the scope of BS 4142, e.g for non-industrial sources, indoor noise measurements and low background noise levels. The study has indicated that using the standard outside its scope reduces its efficacy in predicting the complaint likelihood.

The study has repeatedly re-affirmed the importance of an experienced user. As pointed out in the Foreword of BS 4142, noise assessment is a skilled operation and should be undertaken only by persons who are competent in the procedures. Individual interpretation and personal judgment are required.

Furthermore, response to noise is subjective and is affected by many factors (acoustic and non-acoustic). Assessing the impact of noise is a complex process and assessments according to this standard can only form part of a complete investigation. BS 4142 is an objective procedure assessing a subjective effect and therefore can only be used as a tool in noise complaint investigations. It can be refined in the light of new experiences but one should not expect it to answer all of our noise problems or to lay down definitive rules.

10 FURTHER COMMENT AND RECOMMENDATIONS

The comments in section 8 have been restricted to comments and observations reported in the data returns. This section focuses on the author's views of the underlying reasons for the problems experienced in applying BS 4142.

(1) There are procedural difficulties in applying the standard as it is at present. These include ambiguities, wording, difficulties in interpretation and the application of the actual measurement procedure.

(2) One is attempting to measure objectively a subjective response. Subjective response to noise is variable between both individuals and situations and therefore perhaps such a standard can never succeed in working 100% of the time. However, the standard is a valuable tool and should be improved with the aim of enabling consistent decision making and providing an accurate description of the noise environment.

(3) The standard is often used outside its scope due to the absence of other standards or guidelines to rate the impact of noise. The prime objective of BS 4142 as set out in its scope is to predict complaint likelihood and applications outside the scope may increase the probability that the rating method will not meet this main objective effectively.

(4) BS 4142 is often used as a "rule book" and not as part of a complete study taking into account all other factors (acoustic and non-acoustic).

(5) Too much significance seems to be given to noise level comparisons and insufficient account is taken of "noise quality" in terms of the features of the noise which may be the main cause for complaint in the first instance.

Possible ways forward to address these problems and refine the standard include:

(1) Refinement of the current standard to address the short term problems of ambiguities, wording, requirement for clarifications, re-emphasis in the Foreword etc.

(2) Modifications to procedures for identifying and rating noises with various acoustic features.

(3) Improvement of the assessment procedure.

(4) Development of a more general framework document which would reference BS 4142 and provide guidance on alternative approaches to assessment outside the scope of BS 4142. This might take the form of DoE guidelines.

(5) An approach to assessing the environmental impact of a noise source taking relevant factors (acoustic and non-acoustic) into account, for example a method in line with environmental impact assessment (EIA) (31) which could use the rating method of BS 4142 as part of the process of analysis.

Item 1 is currently in hand and addresses some of the issues raised in this study. However, to refine the standard further in the longer term, items 2 to 5 would require a significantly greater amount of time and research. Work is currently in hand to address item 2, including work at ISVR into tonal and impulsive noise descriptors (21) (22) (29) and at NPL on combined features (30). Work is also progressing at NPL

and ISVR on the development of an assessment procedure based on the acoustic features in the noise (26).

Finally let us go back a step and consider the requirements of a general noise assessment procedure. A noise assessment procedure should provide a means to:

- adequately describe the noise including the magnitude of all the significant acoustic features of the noise which are actually present that might influence a reasonable person's response,

- encourage fair treatment of the producer of the noise and any complainants, and promote consistency in decision making,

- target cost-effective noise control and aim for an equitable trade-off between lowest cost and maximum benefit to the community.

BS 4142 has the prime objective of predicting the complaint likelihood. However, the more general question needs to be asked, how can we develop an assessment procedure capable of meeting these broader requirements?

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12 REFERENCES

1. British Standard BS 4142:1990 *Method for rating industrial noise affecting mixed residential and industrial areas*.

2. Porter, N.D. The assessment of industrial noise - a review of various national practices, *NPL Report RSA(EXT) 0057B*, May 1995.

3. Porter, N.D The assessment of industrial noise - subjective listening tests and objective assessment procedures, *NPL Report RSA(EXT) 0057C*, May 1995.

4. Institute of Acoustics, Noise Nuisance Assessment, BS 4142 Reviewed and Criticised, *Proceedings of Institute of Acoustics*, 8 February, 1982.

5. Committee on the Problem of Noise. *Noise - Final Report*. HMSO, London, 1963.

6. Sargent, J. A noise incidence survey of England and Wales. *Proceedings of Institute of Acoustics Autumn Conference*, Windermere, November 1993, Vol 15, Part 8, 181.

7. The Institution of Environmental Health Officers, *Annual Report* 1991/92.

8. World Health Organisation, *WHO Criteria Document on Community Noise; Environmental Health Criteria*, External Review Draft, 28 June, 1993.

9. Broner, N. Environmental Noise - is it an issue? *Proceedings of Internoise 91*, 907-910.

10. Munro, M, The economic impact of incorrect sound level data. *Proceedings of Internoise 91*, 911-914.

11. Weinberger, M. Social costs of noise in Federal Republic of Germany, *Zeitschrift für Lärmbekämpfung*, 39, 1992, 91-99.

12. Organisation for Economic Co-operation and Development (OECD). *Fighting Noise in the 1990s*, 1991, ISBN 92-64-13457-3.

13. Stevens, K.N., Rosenblith, W.A., and Bolt, R.H. A Community's Reaction to Noise: Can it be forecast? *Noise Control*, 1, 1955, 63-71.

14. International Organization for Standardization, ISO 1996 Part 1: 1982, Parts 2 & 3, 1987. *Acoustics - Description and measurement of environmental noise.*

15. Robinson, D.W. *Presentation to BSI Seminar on the Rating of Industrial Noise*, 18 April 1991.

16. Berry, B.F. The 1990 edition of British Standard 4142. *Proceedings of the Institute of Acoustics*, Vol 13, Part 8, 1991, 21.

17. Horrocks, D. BS 4142: 1990 An Evaluation of the Revised Standard and its Relevance to the Assessment of Community Noise. *Proceedings of the BSI Seminar on the Rating of Industrial Noise*, 18 April 1991.

18. Berry, B.F and Moss, I.K. A Survey of Local Authorities on Noise. *NPL Report Ac 113*, 1987.

19. Department of Environment, *Planning and Noise*, Consultation Draft PPGXX, 1992, Welsh Office, HMSO.

20. UK Environmental Protection Act 1990.

21. Flindell, I.H. The detection of discrete tones in broadband background noise in respect of typical residential exposure to industrial noise. *ISVR Contract Report 92/35*, December 1992.

22. Robinson, D.W. Annoyance due to discrete tones in broadband background noise: Part II - analysis. *ISVR Technical Report 202*, 1992.

23. Lydteknisk Institut, Joint Nordic method for determination of audible tones in noise, *Note to IEC TC 88/WG5*, 1992.

24. Robinson, D.W. The assessment of noise containing tonal components. *ISVR Technical Report 163*, 1988

25. Williams, P.R. and Robinson, D.W. A survey of practice and opinion of local authorities on the assessment of industrial noises containing tonal components. *ISVR Memorandum 686*, 1988.

26. Porter, N.D., Flindell, I.H. and Berry, B.F. An acoustic feature model for the assessment of environmental noise, *Proceedings of Institute of Acoustics Spring Conference*, Southampton, 1993, Vol 15, Part 4, 1993, 1015, and published in *Acoustics Bulletin*, Institute of Acoustics, November/December 1993 edition, 40.

27. Rice C.G. CEC Joint research on annoyance due to impulse noise: laboratory studies. *Proceedings of 4th International Congress on Noise as a Public Health Problem*, Turin, Italy, Vol 2, 1984, 1073-1084.

28. Berry, B.F. Recent advances in the measurement and rating of impulsive noise, *Proceedings 13th ICA*, Belgrade, Vol 3, 1989, 147-150.

29. Ikeda, M., Flindell, I.H. Subjective tests of impulse noise annoyance and the listening environment. *ISVR Contract Report 93/37* December 1993.

30. Porter, N.D, Berry, B.F. Subjective effects and objective assessment of combined tonal and impulsive noise. *Proceedings of the 6th International Congress of Noise as a Public Health Problem (ICBEN), Noise and Man "93*, Nice, France, Vol 2, 1993, 597.

31. EC Directive 85/337 on the Assessment of the effects of certain public and private projects on the environment.

32. Horrocks, D. The relationship between environmental health and planning. *Proceedings of Institute of Acoustics, Planning and Noise*, Vol. 14, Part 1, 1992.

33. Porter, N.D. Industrial and residential noise - questions asked at the BSI seminar on BS 4142. *Acoustics Bulletin*, Institute of Acoustics, January/February 1992, 11-13.

34. Hayes, M.D. Noise Impact Assessment of Wind Farms. *DTI/BWEA Proceedings of a Workshop on Wind Turbine Noise*, 30 June 1992.

35. Legerton M. Wind turbine noise in the DTI Wind Energy Programme. *Proceedings of Institute of Acoustics, Autumn Conference* 1993, Vol 15, Part 8, 35.

36. Fleming, D. An Acoustic Consultants View. *Proceedings of Institute of Acoustics, Acoustical Measurements and NAMAS Accreditation*, Vol. 15, 1992, Part 5.

37. Hinton, J. *Presentation to Institute of Acoustics Autumn Conference 1993*, Investigation of Domestic Noise Complaints in Birmingham, Proceedings of Institute of Acoustics, Autumn Conference, Vol 15, Part 8, 1993, 165.

38. Rickaby, M and Vasudevan, R.N. Background Noise Correction for Measurements of Specific Noise Level $L_{Aeq,Tr}$ of BS 4142: 1990. *Proceedings of Institute of Acoustics, Autumn Conference*, Vol 15, Part 8, 1993, 195.

39. Evans, P.S. and Hood, R.A. Variability of Noise Indices. *Proceedings of Institute of Acoustics, Autumn Conference*, Vol.13, Part 8, 1991, 51.

APPENDIX I: Example of Data Sheet

DATA SHEET- COMPLAINTS ABOUT INDUSTRIAL NOISE
THE APPLICATION OF BS 4142:1990

GENERAL INFORMATION

Local Authority..... Date investigated.....

Investigating Officer..... Complainant:Single/Multiple Complaints?

DESCRIPTION OF NOISE SOURCE

Description of noise source (eg fan, boiler etc).....

.....

Please indicate the nature of the noise:-

Continuous	☐						
Cyclic	☐	with period	<5mins	☐	5-60mins	☐	>60 mins ☐
Fluctuates at random	☐						
Intermittent	☐	with on time	<5mins	☐	5-60mins	☐	>60 mins ☐

Does the noise have any specific characteristics ?

Tonal ☐ Impulsive ☐ Irregular enough to attract attention ☐ Other (please specify).....

Hours of operation:-		Weekdays	Weekend
Early morning	(06.00-09.00)	☐	☐
Daytime	(09.00-18.00)	☐	☐
Evening	(18.00-22.00)	☐	☐
Night	(22.00-06.00)	☐	☐

Mode of operation:-

Continuous over the above time period(s) ☐

Other ☐ please specify (eg: twice a day, only in hot weather etc).....

.....

Description of premises in which source is situated.....

.....

Position of source in relation to complainant:-

Adjacent ☐ Below ☐

Opposite ☐ Other ☐ Please specify.....

Any other relevant comments:-.....

.....

DESCRIPTION OF COMPLAINTS

How many complaints have been reported ?

One ☐ Less than 10 ☐ More than 10 ☐

How frequently are the complaints received ?

Rarely ☐ Occasionally ☐ Fairly Often ☐ Most of the time ☐

Please rate the intensity of the complaints:- (please ring the relevant number rating)

Not severe 1 2 3 4 Very severe

Where is nuisance experienced ? Indoors ☐

Outdoors (in garden) ☐

Any other relevant comments:-.....

.....

MEASUREMENTS

Measurement Location (please enclose a small diagram if appropriate).....

.....

Distance from specific noise source (m).....

Description of intervening ground.....

.....

Instrumentation.....

Weather Conditions.....

Date and Time.....

The next section is divided into day and night time periods. Please answer the questions for each time period. If the noise source is not operational for both of these periods, please complete the relevant time period only.

	Daytime	Night-time	Relevant clause
Measurement Time, T_m (secs)	.....	.....	5.5
Noise level over T_m, $L_{Aeq,Tm}$ (dB(A))	.....	.....	5.5
Background Noise Level, $L_{A90,T}$ (dB(A))	..... T=	..... T=	6
Residual Noise Level, $L_{Aeq,T}$ (dB(A)) (if available)	..... T=	..... T=	2.7
Correction for background level (dB)	.....	.....	5.4.4
Specific Noise Level, $L_{Aeq,Tr}$ (dB(A)) (corrected for reference time etc)	.....	.....	5.5
Character correction (dB)	.....	.....	7
Rating Level, $L_{Ar,T}$ (dB(A))	.....	.....	7

How long has the noise been operating ?.....
Is it a new noise ? Yes/No
What are the main sources contributing to the residual noise ?.....

.....

Any other relevant comments (eg methods of measurement and calculation (para 5.4.4(c) etc)).....

.....

ASSESSMENT

What is the difference between the Rating Level and the Background Noise Level ($L_{Ar,T}$ - $L_{A90,T}$) ?

	Daytime	Night-time		Daytime	Night-time
Greater than 10 dB	☐	☐	Between -5 and 0 dB	☐	☐
Between 5 and 10 dB	☐	☐	Between -5 and -10 dB	☐	☐
Between 0 and 5 dB	☐	☐	Less than -10 dB	☐	☐

What is BS 4142:1990's assessment of the likelihood of complaints ?.....(daytime)
.....(night-time)

Does the EHO consider the noise to be a justifiable complaint ? Yes/No
Has the complainant taken up the matter direct with the source operators ? Yes/No
In your opinion, how does the above assessment of the likelihood of complaints as predicted by BS 4142:1990 compare with the actual occurrence ?

The assessment corresponds fairly well	☐
The assessment method has overpredicted the likelihood of complaints	☐
The assessment method has underpredicted the likelihood of complaints	☐

Additional comments:-.....

.....

.....

Thank you for your help

Please return to Nicole Porter, Acoustics Branch, Division of Radiation Science and Acoustics, The National Physical Laboratory, Teddington, Middlesex, TW11 OLW

APPENDIX II: Example of Letter asking for Volunteers

Bulletin Briefs

Management appointments at HHB Communications

HHB Communications have announced a series of key personnel changes, designed to reinforce the company's management structure.

The most significant of these is the well-deserved promotion of Steve Angel to Sales Manager, a post giving him additional responsibility for the company's UK sales and marketing activities. This allows long serving director Martin Westwood to concentrate on HHB's rapidly growing export sales market and product purchasing. Fellow director Richard Kershaw assumes control of broadcast sales and personnel matters. Completing the company's management changes, Stephen Dunn has joined the company in the new position of Financial Controller.

Kelston Consultants (Noise and Acoustics) have recently moved to new offices in Bristol (Tel: 0272 862956). The practice is completely independent and has been advising on building acoustics and noise control, environmental noise and associated noise and acoustic aspects for several years. Clients include Consultants, Architects, Contractors, Government Authorities and Blue Chip Companies. The workload has increased dramatically, particularly where surveys are involved.

The practice is thus seeking to purchase sound measuring equipment and would like to hear from any party trying to 'off load' used or surplus equipment in good working order. Please ring Kelston Consultants at the above number and contact Stephen Peliza.

Arup Acoustics Preferred London telephone number 071-636 2853. Correction to London address: **Parkin (not** Parking) House Ltd.

Letter to the Editor

Industrial Noise Complaints
The Revision of British Standard BS 4142 : 1990

Members of the Institute of Acoustics may probably be aware that the 1990 revision of BS 4142 : 1990 'Method for Rating Industrial Noise Affecting Mixed Residential and Industrial Areas' was published in December. This standard gives a method for determining noise levels and assessing whether the noise in question is likely to give rise to complaints from people living in the vicinity of the noise source.

The revision has a broadly unchanged scope but uses the equivalent sound pressure level, L_{Aeq}, to describe the noise and tightens up the requirements on equipment, traceable calibration and measurement procedures. In the absence of new data on noise complaints, major changes were not made to the actual assessment procedure.

There is therefore a need to collate information on the application of this new standard in order to investigate how the assessments compare to the actual investigated noise complaints. A need has also been recognised to investigate the treatment of noise judged to be tonal or impulsive in order to further refine this standard. We would be grateful for the assistance of noise consultants or anyone else involved with this type of noise assessment in improving our knowledge and understanding of industrial noise disturbance.

The National Physical Laboratory in consultation with the Building Research Establishment have developed a data sheet for future industrial noise complaints to be investigated in accordance with the revised BS 4142 : 1990. The sheet has been designed in such a way that it should assist an investigating officer in the application of the new standard. It has been prepared so that little or no extra resources will be required for completion and it will, we hope, provide a detailed and useful record of the complaints for the noise consultant's own file. The sheet is in a form that will produce a duplicate to be returned to NPL.

For those who would like to assist us in the collection of data about this important source of noise disturbance and its assessment, copies of the data sheet may be obtained from Miss Nicole Porter, Acoustics Branch, National Physical Laboratory, Teddington, Middlesex TW11 0LW, tel: 081-943 6705 or fax: 081-943 6161.

We will, of course, keep members of the Institute informed about the results of our investigation through the *Bulletin* when the data have been analysed.

N D Porter
National Physical Laboratory

AP250 computerised screening audiometer

Permanent loss of hearing through industrial noise is caused by degeneration of the nerve endings in the inner ear. Audiometry will detect the earliest stages of this degeneration before it becomes an irreversible handicap and workers with an already severe degree of hearing loss can be protected against further deterioration. The AP250 computerised Screening Audiometer has been designed for this task. Furthermore, automatic audiometry takes much of the workload of the audiometrician, especially when large numbers of tests have been carried out daily and on successive days, as is likely to be the case in many large industries. The AP250 and associated software have been designed with those busy medical centres in mind.

The AP250 complies with the IEC 645 specifications for Class 4 instruments and conforms with the electrical safety specification BS 5724 Part 1 (IEC 601-1). Since it is fully computerised, there are no external controls: all functions and options are selected from the computer keyboard. Simplicity was utmost in the minds of the software engineers when the program was written and this is reflected in the way it helps the operator through the procedure and test options with ease. Pull-down windows opening into daughter windows are incorporated with highlighted options. Standard MS-DOS commands are used throughout. 'HELP' is available for options where it is considered an explanation may be necessary, but the program is so simple to use, that for the most part no help is needed.

A test is initiated by entering a patient's details and selecting certain test options. These options provide the choice of a full audiometric screening test at all 8 test frequencies on both left and right ears followed by a re-test at 1 kHz on the left ear or a selection of test frequencies on one or both ears. This last option is extremely useful if a re-test is required to verify the validity of threshold results at certain spot frequencies. The overall test-time can be reduced by selecting certain frequencies only, and some companies may wish to adopt such a procedure as general practice. However, it must be emphasised that HSE categorisation cannot be applied unless all test frequencies are employed. There is also an option to conduct a pre-test in order to allow patients to familiarise themselves with the test procedure. Pulsed tone is also selected at the option stage and is useful if a patient suffers with tinnitus. The program defaults to continuous tone and full audiometric test when a new test is initiated.

The program provides a real time audiogram plot on the

Note: Similar letter was published in Environmental Health News, April 1991.