RSA(EXT) 0057A
May 1995

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
Acoustics Branch
Division of Radiation Science and Acoustics
National Physical Laboratory
Teddington
Middlesex
United Kingdom
TW11 0LW

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.

ISSN 0955 9655

National Physical Laboratory
Teddington, Middlesex, United Kingdom, TW11 0LW.

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.

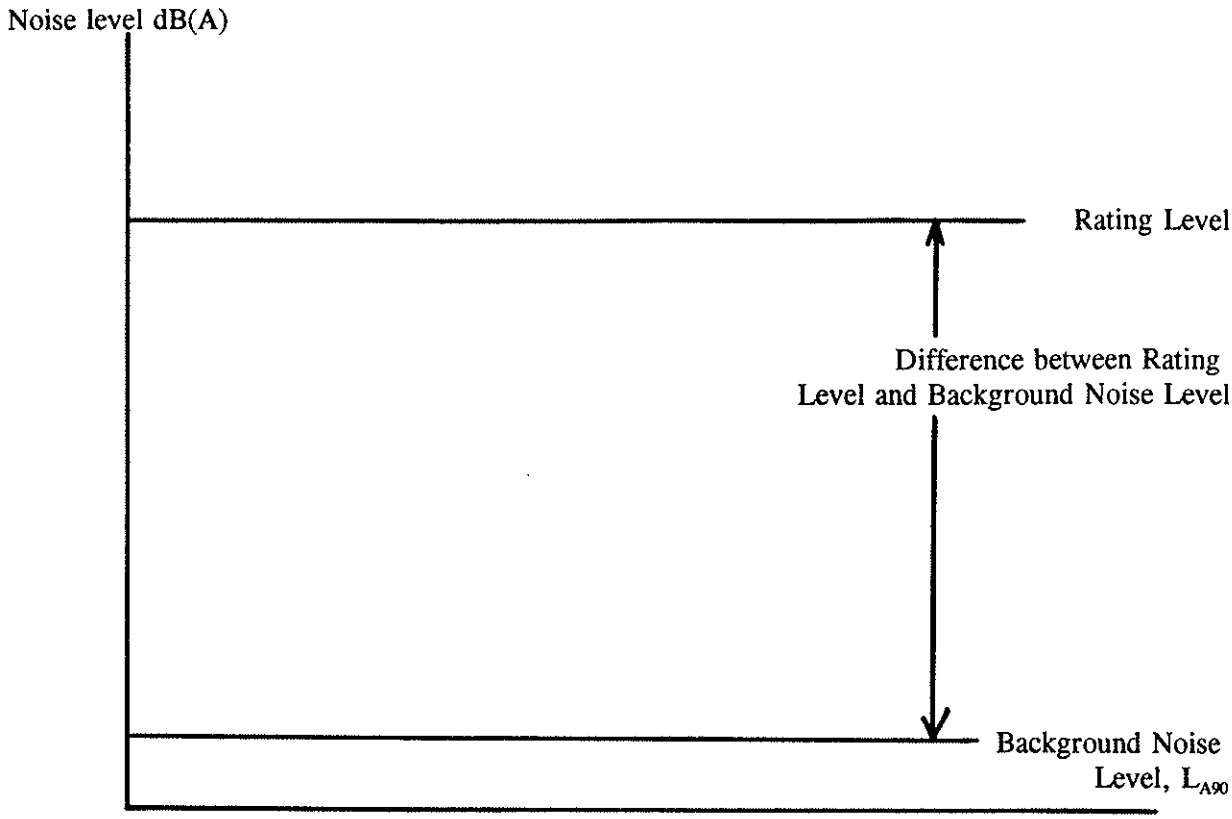
In 1958 work at the Building Research Station (BRS) led to the development of a simplified method which was included as an appendix to the Wilson report of 1963 (5). It was recommended that the method should be tested before adopting it as a recommended procedure for community noise assessment. The BRS 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.

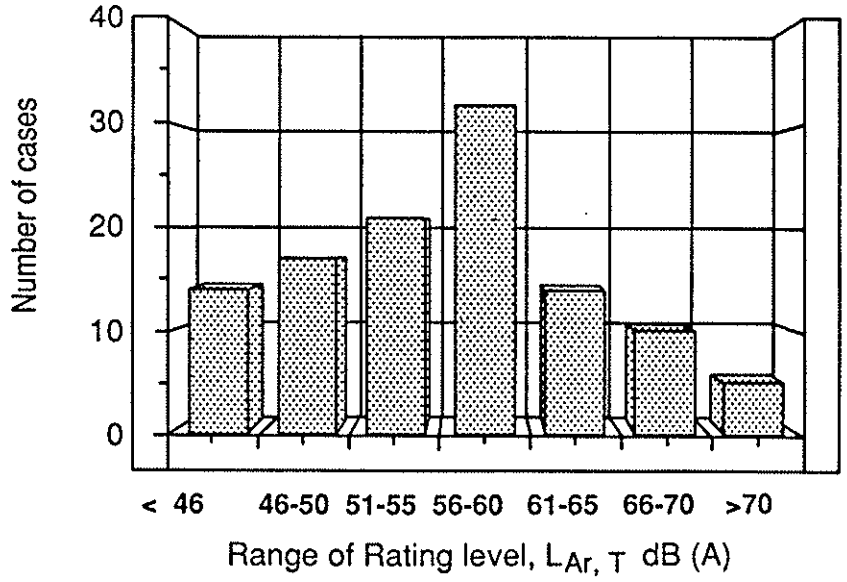


Figure 2: Distribution of rating levels

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.

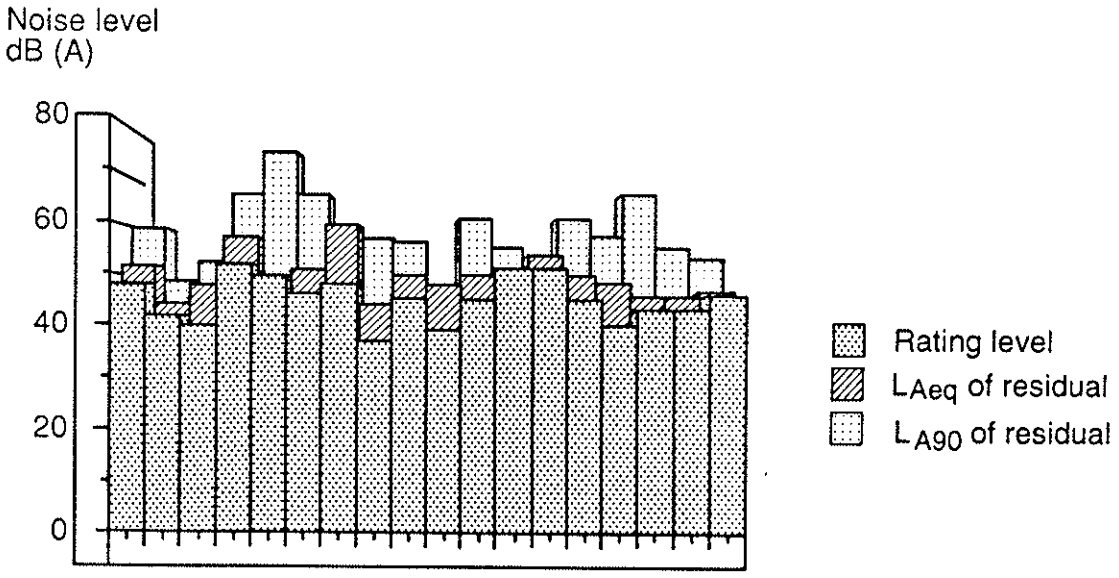


Figure 3: Comparison of rating level with L_{Aeq} and L_{A90} of the residual noise: Daytime

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.

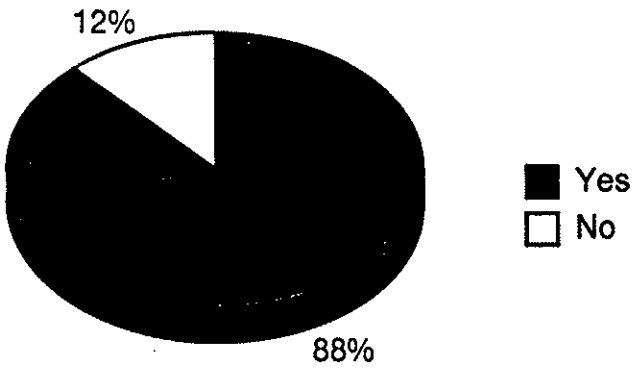


Figure 4: Does EHO consider complaint justifiable ?

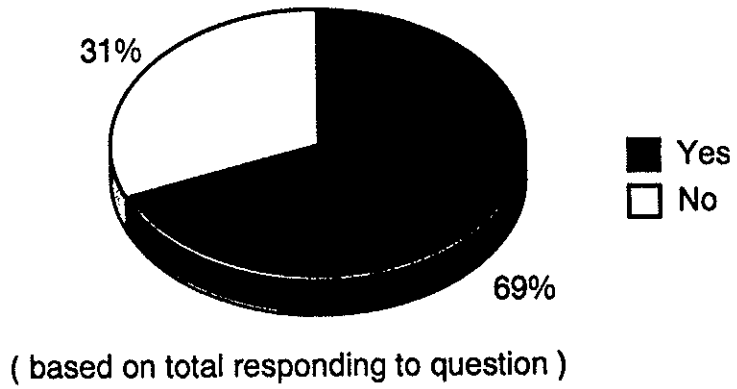


Figure 5: Has complainant contacted source operator directly ?

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).

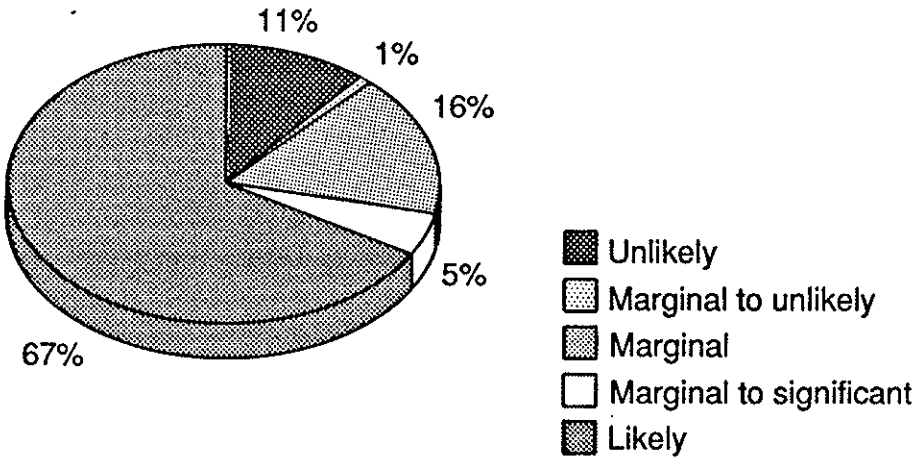


Figure 6a: Assessment of likelihood of complaint for daytime

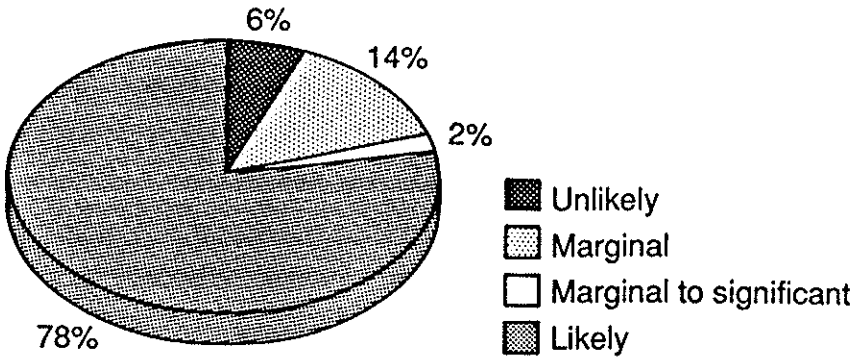


Figure 6b: Assessment of likelihood of complaints for night-time

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 ?

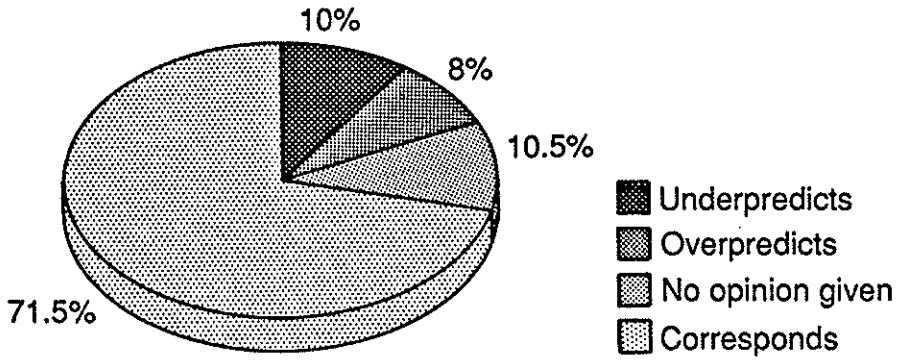


Figure 7: Comparison of the BS 4142:1990 assessment of the likelihood of complaints with the actual reported occurrence

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.