

**Code of Practice
for reducing the
exposure of
employed persons
to Noise**

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B60



CODE OF PRACTICE

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B61

Foreword

By the Right Hon. Robert Carr, MP
Secretary of State for Employment

It has been common knowledge for many years that high levels of noise at work can cause impairment of hearing. In a few firms where there is this danger, good work has been done in suppressing noise, but in many others the problem has not been recognised, or has been under-estimated. In those firms, the tragedy is that all too often the workers are accustomed to the noise and do not notice the gradual deterioration of their hearing until it is too late. For hearing lost in this way cannot be recovered.

The general solution to this problem, which is a complex one, has been hampered more by ignorance than by neglect. Until the pioneer work of Professor Burns and Dr. Robinson was published in March 1970*, we lacked the necessary scientific knowledge of the precise levels of noise, and the duration of exposure to them, which can cause damage. It is largely due to their work that this Code of Practice has been made possible. The provisions in the code, and its publication, have been recommended by my Industrial Health Advisory Committee on which both sides of industry are represented. It is the outcome of 12 months' work by a sub-committee. I regard the publication of the Code as the first important step in the prevention of loss of hearing due to noise at work. It should be considered as a blueprint for action. On the shop floor this will require constructive co-operation between management, trades unions and employees, all of whom must play their part if it is to succeed. HM Factory Inspectorate are ready to help by advising industry how best to tackle the problems which will arise. In every Division of the Inspectorate, there is at least one Inspector who has received special instruments and training to equip him for this task. I therefore commend this Code of Practice to industry.

**Hearing and Noise in Industry* HMSO.

B62

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Contents

	<i>Para</i>	<i>Page</i>
INTRODUCTION		
SECTION 1: SCOPE OF THE CODE	1.1 General application	5
	1.2 Application to machinery	5
	1.3 Relation to nuisance noise and vibration	5
SECTION 2: OBJECTIVES OF THE CODE	2.1 Specification of limits	5
	2.2 Reduction of sound levels	5
SECTION 3: SUMMARY OF MEASURES TO BE TAKEN	3.1 Measures to be taken by management	5
	3.2 Measures to be taken by employed persons	5
SECTION 4: LIMITS	4.1 Desirable sound levels	5
	4.2 Limiting sound level	6
	4.3 Continuous exposure	6
	4.4 Non-continuous exposure	6
	4.5 Non-continuous exposure which cannot be adequately measured	6
	4.6 Sampling period for measurement of sound level	6
	4.7 Overriding limits	6
SECTION 5: SURVEYS AND IDENTIFICATION OF PLACES WHERE THE SOUND LEVEL IS EXCESSIVE	5.1 Surveys	6
	5.2 Identification of areas	6
	5.3 Identification of machines	6
SECTION 6: METHODS OF CONTROLLING NOISE EXPOSURE	6.1 General	7
	6.2 Separation of noisy areas	7
	6.3 Exhaust silencing	7
	6.4 Machine enclosure	7
	6.5 Enclosure of the operator's workplace	7
	6.6 Use of quiet machines and processes	7
	6.7 Inspection and maintenance	7
	6.8 Community noise nuisance	8
SECTION 7: EAR PROTECTORS	7.1 General	8
	7.2 Selection of ear protectors	8
	7.3 Inspection and maintenance	8
	7.4 Education and joint consultation	8
SECTION 8: REDUCTION OF EXPOSURE RATION	8.1 General	8
	8.2 Rest rooms	8
SECTION 9: NEW MACHINERY	9.1 Specifications	8
SECTION 10: TRAINING	10.1 Training of engineers	9
	10.2 Training of others	9
SECTION 11: RECORDS	11.1 General	9
	11.2 Personal records	9
	11.3 Proforma	9
APPENDICES	1 Methods of making measurements	10
	2 Equipment and its use	11
	3 Methods of calculating equivalent continuous sound level	14
	4 Ear protectors	20
	5 Methods of converting octave band sound pressure levels to A-weighted sound level	24
	6 Warning notices	28
	7 Specifications for new machinery	29
	8 Specimen record forms	31
	9 Definitions	33
		3

B 64

Introduction

Noise has been described as unwanted sound. In addition to causing annoyance, noise may interfere with working efficiency by inducing stress and disturbing concentration, especially where the work is difficult or highly skilled. By hindering communications and by masking warning signals noise may be the cause of accidents. Particularly, it may damage the hearing of employed persons. A temporary hearing loss, lasting from a few seconds to a few days, may result from exposure to high sound levels for a short time. Regular exposure to lower sound levels over a long period of time may result in destruction of certain inner ear structures and a loss of hearing which is permanent and incurable.

There are various hearing conservation measures which may be taken to reduce the exposure of employed persons to noise. The environmental control of noise may be achieved through proper planning of and the use of appropriate noise absorbing materials. The control of noise at source may be accomplished through efficient design and maintenance of machinery and mountings, and by means of a general reduction of noise transmission in air and through buildings. Where such measures are not effective, other measures may be necessary such as the limitation of exposure to noise and the use of ear protection.

This Code of Practice deals with the engineering aspect of the reduction of noise exposure of employed persons. It does not include advice to machinery manufacturers, which will be covered separately or on the medical management of noise exposed personnel, or on the place of audiometry.

Section 1:

Scope of Code

1.1 General application

1.1.1 This Code of Practice applies to all persons employed in industry who are exposed to noise.

1.1.2 The Code sets out recommended limits to noise exposure. It should be noted that, on account of the large inherent variations of susceptibility between individuals, these limitations are not in themselves guaranteed to remove all risk of noise-induced hearing loss.

1.2 Application to machinery

1.2.1 This Code does not specify the measures which should be included at the design stage to control noise emitted by machines for which a separate code of practice is envisaged. A Technical Data Note (TDN 12) giving simple advice on measures which machine makers can incorporate in their product is available, free of charge, from any office of HM Factory Inspectorate.

1.3 Relation to nuisance noise and vibration

1.3.1 This Code does not seek to indicate measures for the reduction of community nuisance noise although it will clearly have an effect on this problem in some cases, nor does it include the effects of, or measures to be taken against, vibration.

Section 2:

Objectives of Code

2.1 Specification of limits

2.1.1 This Code specifies a limit for exposure to noise, and describes methods of measurement (Appendices 1 and 2) which can be used to determine whether the limit is exceeded.

2.1.2 Methods of measuring continuous steady noise, and for assessing a notional equivalent continuous sound level for fluctuating, intermittent, and impulsive noise are described (Appendix 3).

2.2 Reduction of sound levels

2.2.1 As a primary aim, the Code seeks the reduction of noise exposure to below the specified limit. As a secondary aim it seeks the reduction of sound levels generally.

2.2.2 The Code indicates appropriate measures for the reduction of noise exposure which should be taken by both management and employed persons.

Section 3:

Summary of measures to be taken

3.1 Measures to be taken by management

3.1.1 Management should accept a general responsibility for ensuring that the best practical means for noise reduction are applied.

3.1.2 The aim should be the general reduction of noise exposure. Where noise exposure less than the limits set in Section 4 are not achieved, ear protectors should be provided and their use ensured.

3.1.3 Appropriate staff should have adequate training in noise measurement and control.

3.1.4 Suitable records should be maintained.

3.1.5 Where it is not practical to ensure that the noise exposure is less than the limits set out in Section 4, and people must wear ear protectors, management should:

- (a) identify and mark places where ear protectors are required,
- (b) control entry into ear protection areas,
- (c) ensure that suitable ear protectors are provided and are used,
- (d) ensure that people provided with ear protectors are instructed in their care and use,
- (e) where ear protectors are worn and the limit in Section 4 may still be exceeded at the wearer's ear, ensure that exposure periods are suitably reduced.

3.2 Measures to be taken by employed persons

3.2.1 Employed persons should:

- (a) use and maintain measures adopted for noise control,
- (b) report defective noise control equipment to the person responsible for its maintenance,
- (c) use ear protectors when provided,
- (d) not enter areas where ear protectors are required unless authorised by management,
- (e) not wilfully damage or misuse ear protectors provided and immediately report any damage or loss of such items to a responsible member of management.

Section 4:

Limits

4.1 Desirable sound levels

4.1.1 The limits set out in this section should be regarded as maximum acceptable levels and not as desirable levels. Where it is reasonably practicable

B 66

to do so it is desirable for the sound to be reduced to lower levels.

4.2 Limiting sound level

4.2.1 People should not be exposed to sound levels exceeding the limit set out in 4.3 to 4.5 below, unless they are using ear protectors which effectively reduce the sound level at the user's ear to or below the limits for unprotected ears. **Note:** The allowance for ear protectors, when worn, should be calculated as described in Appendices 4 and 5.

4.3 Continuous exposure

4.3.1 If exposure is continued for 8 hours in any one day, and is to a reasonably steady sound, the sound level should not exceed 90 dB(A).

4.4 Non-continuous exposure

4.4.1 If exposure is for a period other than 8 hours, or if the sound level is fluctuating, an equivalent continuous sound level (L_{eq}) may be calculated and this value should not exceed 90 dB(A). Practical rules for calculating the value of equivalent continuous sound level from the readings of conventional instruments, and a mathematical definition, are given in Appendix 3.

4.4.2 Conventional sound level meters will indicate the value of L_{eq} directly only when the sound level is continuous and reasonably steady. In other cases (fluctuating, intermittent or impulsive) various instruments as described in Appendix 2 should be employed. For the purpose of this Code L_{eq} should be considered to be adequately measured when these instruments have been used in the manner described. Alternatively any other instruments may be used provided that L_{eq} is evaluated with adequate accuracy.

4.5 Non-continuous exposure which cannot be adequately measured

4.5.1 In certain circumstances, for example where employed persons move from one area to another, it may be difficult to measure and control exposure to non-continuous sound. If the non-continuous exposure cannot be adequately measured and controlled, any exposure at a sound level of 90 dB(A) or more should be regarded as exceeding the accepted limit and requiring the use of ear protectors. Places where this level is likely to be exceeded should be clearly identified (see Section 5).

4.6 Sampling period for measurement of sound level

4.6.1 When making measurements to determine whether the acceptable limit is exceeded it will not normally be necessary to measure the sound level during the entire working period. Assessment may be based upon sample periods which are typical of the working day.

4.7 Overriding limits

4.7.1 The A-weighted sound levels set out above are subject to an overriding condition that the unprotected ear should not be exposed to a sound pressure level, measured with an instrument set to the 'fast' response, exceeding 135 dB, or in the case of impulse noise an instantaneous sound pressure exceeding 150 dB.

4.7.2 Other parts of the body should not be exposed to a sound pressure level, measured with an instrument set to the 'fast' response, exceeding 150 dB.

Section 5:

Surveys and identification of places where the sound level is excessive

5.1 Surveys

5.1.1 All places where it is considered the limit in Section 4 may be exceeded should be surveyed.

5.1.2 Surveys are advisable when it is necessary to shout in order to be audible to a person about one metre distant.

5.1.3 Places which are marginally below the limits set out in Section 4 should be re-surveyed whenever any changes are made which may alter the sound level.

5.1.4 Surveys should be carried out by a person who has received adequate training in noise measurement techniques.

5.2 Identification of areas

5.2.1 Areas where persons may be exposed sound levels exceeding the limits set out in Section 4 should be identified as ear protection areas, and the boundaries clearly defined.

5.2.2 Entry to ear protection areas should be restricted to those authorised to do so. All such persons should use effective ear protection.

5.2.3 A prominent warning notice banning unauthorised entry, and entry without the use of ear protection should be posted near every entrance to an ear protection area. A suitable notice is illustrated in Appendix 6.

5.3 Identification of machines

5.3.1 Machines which, in normal operation, are likely to produce a sound level, at the operator's ear exceeding the limit in Section 4 should carry a prominent warning notice. The notice should be situated in a position clearly visible to the operator. A suitable notice is illustrated in Appendix 6.

Section 6:

Methods of controlling noise exposure

6.1 General

6.1.1 The best practical means for noise reduction should be applied in all premises to which this Code applies.

6.1.2 The need for noise control should be taken into account when deciding which of different production methods or processes is to be used.

6.1.3 Reduction of noise is always desirable, whether or not it is practical to reduce the sound level to the limit set out in Section 4, and whether or not it is also necessary for people to use ear protectors. Reduction below the limit in Section 4 is desirable in order to reduce noise nuisance.

6.1.4 Some of the measures which can be taken to control the sound level are indicated in 6.2 to 6.6 below. This Code does not provide detailed technical information needed for carrying these measures into effect, or for deciding which measures are appropriate in particular circumstances. For this information reference should be made to text books and scientific literature.

6.1.5 It should be noted that when designing efficient and economic measures for noise control of existing machines the measurement of the sound produced in terms of A-weighted sound level [dB(A)] may need to be supplemented by some form of frequency analysis (e.g., octave band analysis). Advice on instruments for this purpose is given in Appendix 2.

6.1.6 It is recommended that design and construction of noise control measures should be supervised by a person skilled in noise control techniques.

6.1.7 When introducing noise control measures care should be taken to ensure that safety, and a satisfactory standard of other environmental factors (e.g., temperature and ventilation), are maintained.

6.2 Separation of noisy areas

6.2.1 Where practicable machines and processes producing sound levels in excess of the limit in Section 4 should be set apart.

6.2.2 Suitable partitions may be needed to prevent spread of noise. It is important that these be of correct size and location in relation to the size of the noise source, and the frequency of the sound to be intercepted.

6.2.3 Where a room, or building, is being divided into noisy and quiet areas it is preferable for the separation to be made as complete as possible. This may be achieved by extending partitions to the walls, and the ceiling (except where false ceilings are installed) or roof, and by ensuring that there are a minimum of openings in the partition.

6.2.4 It may be advisable to provide sound-absorbing material in the noisy areas in order to prevent increase of sound level due to reflection from the walls and ceiling. The absorbing material should be such that a fire or health hazard is not introduced.

6.3 Exhaust silencing

6.3.1 Exhaust systems (including internal combustion engine and air exhausts) should be provided with effective silencers, or should be discharged in an area remote from employed persons, but not so as to create a hazard or nuisance to the public.

6.3.2 Silencers should be regularly inspected and maintained.

6.4 Machine enclosure

6.4.1 Where practicable noisy machines should be provided with sound-insulating enclosures. The operator should normally remain outside the enclosure.

6.5 Enclosure of the operator's workplace

6.5.1 In certain circumstances it may be possible and advisable to protect the machine operator by providing a sound-reducing enclosure or cabin.

6.5.2 When providing an enclosure for the operator due regard should be paid to the comfort of the occupant. In particular efficient ventilation and temperature control should be ensured. The enclosure should be as large as is reasonably practicable.

6.5.3 When enclosure of the operator's normal workplace is not considered appropriate it may be practical to provide a noise refuge which he can occupy when not actually working at the machine. A noise refuge is particularly suitable where an operator has no fixed working position.

6.6 Use of quiet machines and processes

6.6.1 When deciding which of different production methods or processes is to be used the need for noise control should be taken into account as well as other factors. It may be possible to control noise by using a quiet process in place of a noisy one.

6.6.2 When appropriate, machines should be supported on anti-vibration mountings.

6.6.3 Metal to metal impact should be eliminated where possible.

6.7 Inspection and maintenance

6.7.1 All machines and areas where the sound level is above, or marginally below, the limit set out in Section 4 should be regularly inspected by a competent person for efficiency of the means for noise control. It is desirable that all new machines should be inspected after installation.

6.7.2 Persons employed on installation and main-

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tenance should receive adequate training in methods of noise control. This should include instruction in the importance of correct installation, lubrication and adjustment of machines, and in the maintenance of any exhaust silencers which may be used as means of preventing excessive noise.

6.8 Community noise nuisance

6.8.1 Due regard should be paid to the need for avoiding the creation of noise nuisance in neighbouring property.

Section 7:

Ear protectors

7.1 General

7.1.1 When the application of means for controlling sound at source, or restriction of exposure duration, does not reduce the noise exposure to below the limit set out in Section 4, employed persons should be supplied with effective ear protection on an individual basis.

7.1.2 Ear protectors should not be used as a substitute for effective noise control. They should normally be regarded as an interim measure while control of noise exposure by other means is being perfected.

7.2 Selection of ear protectors

7.2.1 It is important to ensure that protectors will provide the majority of wearers with reliable and adequate protection. Suppliers should be instructed to provide full information on the sound reduction likely to be provided, the methods used for testing the protectors and details of the laboratory carrying out the test. Appendix 4 describes current test methods, and a procedure for using the test data for predicting the reduction of sound level.

7.2.2 Provided that adequate protection is given, it is preferable for the user to be allowed a personal choice among different patterns of protector.

7.3 Inspection and maintenance

7.3.1 Ear protectors should be regularly inspected to make sure that they are undamaged and have not deteriorated.

7.3.2 Adequate provision should be made for clean storage of protectors when not in use.

7.4 Education and joint consultation

7.4.1 Before protectors are issued the need for their use should be fully explained, and education should continue thereafter. Managers and supervisors should encourage the use of protectors by explanation and personal example.

7.4.2 Education of employed persons issued with ear protectors should include instruction in their use, care and maintenance.

7.4.3 Joint consultation before the issue of ear protectors is recommended.

Section 8:

Reduction of exposure duration

8.1 General

8.1.1 If it is necessary for people to work in places in which the sound level exceeds 90 dB(A) it may be possible to avoid excessive noise exposure of the people by reducing exposure duration.

8.1.2 Possible measures for restricting exposure duration include:

- (a) job rotation,
- (b) re-arranging of work to allow part to be carried out in a quiet place,
- (c) where practical, arranging for jobs involving short-duration exposure to high sound levels to be performed by people who spend the rest of the day in quiet places, and not by people already exposed to noise near the limit in Section 4,
- (d) provision of a noise refuge at the place of work.

8.2 Rest rooms

8.2.1 Where appropriate rest rooms should be separated from noisy areas by effective sound-insulating barriers.

Section 9:

New machinery

9.1 Specifications

9.1.1 When purchasing new machinery the specification should require that the maker incorporates the best practical means for noise control (Appendix 7).

9.1.2 The seller should be required to furnish full information on the sound level likely to be produced. Current British Standard tests should be used where they are applicable and will indicate the sound level produced at the worker's ear, otherwise the test procedure should be agreed between the seller and the purchaser. The seller should be required to give details of the conditions of load during the test, and asked to indicate whether the test levels are likely to be typical of those produced with the machine in normal use in the user's factory.

9.1.3 It should be noted that the sound level produced in test conditions may be less than the sound level near to the same machine when installed in a factory. Possible reasons for an increase

Issue of ear

Include reflection from the walls, floor and ceiling of the workroom, differences in mounting and loading conditions, and the additive effect of noise from nearby machines. It is, therefore, necessary to check the sound level after installation when there is any doubt as to whether or not the limit in Section 4 is exceeded.

- (b) job, department and place at which the person works,
- (c) type of ear protection issued,
- (d) date of issue of ear protection where appropriate.

11.3 Proforma

11.3.1 Proforma of the specimen record forms are to be found at Appendix 8.

Section 10:

Training

10.1 Training of engineers

10.1.1 Persons engaged in the specification, layout and installation of machine tools and factories should be adequately trained in techniques of noise measurement and control, or should be advised by suitably trained technical personnel.

10.2 Training of others

10.2.1 Other employed persons should receive such training as is necessary in the correct installation, operation and use of machines to avoid production of unnecessary noise. As appropriate this training should include instruction in the correct lubrication, adjustment, replacement of worn and loose or unbalanced parts of machines, and in the need for effective and correct maintenance of exhaust silencers and enclosures.

10.2.2 All persons exposed to noise should be acquainted with the hazards involved.

Section 11:

Records

11.1 General

11.1.1 Records of sound levels throughout the factory should be maintained to enable ear protection areas to be determined.

11.1.2 The records should include:

- (a) the department and place in which readings were taken,
- (b) the number of persons normally employed in the place concerned,
- (c) the range of sound levels recorded,
- (d) L_{eq} if calculated,
- (e) instruments used in the survey,
- (f) date of calibration of such instruments,
- (g) date on which measurements were taken,
- (h) any other relevant factor.

11.2 Personal records

11.2.1 Records of personal ear protection used should be maintained.

11.2.2 The records should include:

- (a) the name of the person,

B 70

Methods of making measurements

General

1 This appendix gives advice on the methods which should be used for measuring the sound level. Circumstances may arise in which it is desirable to vary the procedures, and this may be done provided that the measurement obtained is a fair representation of the noise to which people are subject.

2 If the sound level varies from one day to another, e.g., on account of variations in the number of machines in use, assessment should generally be based on the noisiest condition. In a few instances where there are large and regular variations which result in the sound level being on some days above, and on some days below the limit in Section 4 it may be desirable to produce separate sets of measurements, but this situation should normally be avoided.

3 If it is known that the sound level is dependent on other factors, e.g., ambient temperature, these should be measured and recorded at the same time as the sound level.

4 When making the measurements due account should be taken of any precautions recommended by the instrument maker to ensure accurate measurement.

Single sites

5 When the exposure to sound of a person who works at an approximately fixed location relative to the noise source has to be determined, measurements should be made in one of the following ways:

- (a) with the person absent, the microphone being located at approximately head height at the person's normal working position,
- (b) with the microphone at the side of, or above, the person's head, and within 1 metre of the person's head. If the sound level varies on the two sides of the person's head measurement should be made on the side having the higher sound level.

Areas

6 When a number of people work in an area of approximately equal sound level the following procedure may be used to determine the average sound level to which the people are exposed.

7 Measurements should be made at not less than four locations which are representative of the positions occupied by employed persons, and well distributed over the area to be tested. If possible the microphone should be placed about 1.5

metres above the floor. The sound levels should be averaged to obtain the sound level for the area.

8 The sound level for each measuring location in the area may be either the average reading of a sound level meter in accordance with Appendix 2, or the equivalent continuous sound level.

9 The highest sound level to which people are exposed within an area should differ from the lowest by less than 10 dB(A). Any place occupied by an employed person where the sound level differs by more than this should be treated as a separate area or site.

10 In exceptional cases it may be desirable to make separate sets of measurements for 'noisy' and 'quiet' conditions. If this is done, and the results indicate that ear protectors are required on some days, but not others, then suitable arrangements should be made for informing employed persons whenever the ear protectors are required.

People who move about

11 If employed persons move from one area to another it may be possible to measure the equivalent continuous sound level to which the employed person is exposed during the course of his normal work.

12 Measurements for this purpose may be made by monitoring the sound level to which the employed person is exposed as he performs his normal work. A portable magnetic tape recorder, a noise dose-meter, or any other apparatus capable of measuring the personal sound exposure of the employed person may be used for this purpose, provided that the equivalent continuous sound level can be determined from the instrument readings.

13 As an alternative to monitoring the sound level during normal work, it may be possible to determine the fractional exposure (see Appendix 3) resulting from each of the jobs carried out by the employed person. The equivalent continuous sound level can then be determined by combining the various exposures resulting from each of the jobs carried out during a normal day, using the rules set out in Appendix 3.

14 It is particularly important to ensure that the noise exposure of mobile employed persons can be controlled, and that variations in jobs performed on different days will not cause the sound level to exceed the limit in Section 4. If the exposure cannot be adequately measured and controlled any entry to a place where the sound level is 90 dB(A) or more should be treated as requiring ear protection.

B 71

Appendix 2:

Equipment and its use

Equipment

1 This appendix describes equipment which can be used for measuring noise. Adequate evaluation of most noisy environments can be made using only a simple sound level meter, provided that due account is taken of its limitations when the sound level is strongly fluctuating. Some of the more sophisticated equipment commercially available is, however, also described because this may be needed if it is desired to make the most accurate possible assessment of fluctuating noise before introducing noise-control measures.

Sound level meter

2 This is the basic instrument for noise measurement which can be used for measuring noise exposure in most situations with the exception of widely spaced noise impulses (e.g., a cartridge operated tool).

3 It is preferable to use a sound level meter complying with BS 4197 (Precision sound level meters), although when using certain accessories, for example a windscreen, compliance with every requirement of that standard may not be possible or necessary. The instrument makers should be required to provide full information on the magnitude of any errors likely to be introduced by such accessories, and a suitable allowance should be made for them when interpreting the instrument readings.

4 Meters complying with BS 3489 [Sound level meters (industrial grade)] may also be used provided that allowance is made for the reduced accuracy of these instruments when measuring noise which is marginally above, or below, the limit in Section 4. A simplified list of the tolerances for both industrial and precision grade meters is given in Table 1; for fuller information on this matter, reference should be made to the British Standards, and to the instrument maker's specification.

5 Except where otherwise indicated all measurements for the purposes of this Code should be made with the sound level meter set to the 'slow' response.

6 Provided that the indicated sound level fluctuates through a total range of 8 dB(A) or less during the period of measurement, the average position of the meter indicator may be estimated by eye and taken as the sound level to be reported. When the indicated sound level fluctuates through more than 8 dB(A) it may be possible to estimate the duration of exposure at each sound level with sufficient

TABLE 1

Simplified table of the A-weighting relative response, and tolerance limits of sound level meters complying with BS 4197: 1967 and BS 3489: 1962.

Frequency (Hz)	A-weighting relative response (dB)	Tolerance BS 4197 (precision grade) (dB)	Tolerance BS 3489 (industrial grade) (dB)
31.5	-39.4	+3 -3	+5 -5
63	-26.2	+3 -3	+4 -4
125	-16.1	+1 -1	+3 -3
250	-8.6	+1 -1	+3 -3
500	-3.2	+1 -1	+3 -3
1000	0	+1 -1	+2 -2
2000	+1.2	+1 -1	+3 -3
4000	+1.0	+1 -1	+5.5 -4
8000	-1.1	+1.5 -3	+6 -6
16000	-6.6	+3 -∞	+6 -∞

accuracy for later calculation of an equivalent continuous sound level by the procedures given in Appendix 3. When the fluctuations are both large and irregular it may be impossible, using only a conventional sound level meter, to make a reliable estimate of the duration of exposure at each sound level. If this unreliability leads to doubt as to whether or not the limit in Section 4 has been exceeded, then either more sophisticated equipment of the type described below should be used, or any exposure at a sound level of more than 90 dB(A) should be regarded as exceeding the acceptable limit.

7 When measuring noise produced by a series of rapidly-repeated impacts (e.g., riveting) there is a possibility that short-duration peaks, much greater than the indicated r.m.s. value, may overload the instrument amplifiers leading to an incorrect reading of the sound level. In such circumstances it is an advantage to use a sound level meter equipped with overload indicators which will give warning of this condition. It should be noted that the effect of any error due to overloading will be to reduce the sound level indicated by the instrument, so that indicated levels greater than the limit in Section

B72

will remain excessive, while indicated levels which are slightly below the limit may prove, in fact, to be excessive when measured with an instrument capable of accepting the high peaks.

8 Conventional sound level meters are not suitable for measuring widely-spaced noise impulses (e.g., a cartridge operated tool), which can only be adequately measured by using specialised equipment such as an oscilloscope. Some guidance can, however, be obtained by setting a conventional sound level meter to the 'fast' response and regarding any noise which produces an indicated level of 90 dB(A) or more as worthy of investigation by more advanced means.

9 For the purpose of deciding whether the limit in Section 4 has been exceeded a sound level meter capable only of measurement in terms of A-weighted sound level, and the overall sound pressure level, will be adequate. If it is also required that the measurements be suitable for economic design of noise-reduction measures (e.g., machine enclosures), or for specification of ear protectors, then an instrument capable of some form of frequency analysis will be needed; usually an octave band analysis will provide sufficient information. Sound level meters for this purpose are available either with a built-in filter set (normally octave band) or with provision for attachment of an external filter set which can be either octave band, or narrow band, as needed.

10 It is often found to be an advantage for the sound level meter to be provided with a socket for connection to a tape recorder or other ancillary equipment.

11 The meter should be provided with means for its acoustical checking, and a check should be made on each day during which the meter is used. Various simple calibrators capable of producing an accurately known sound pressure level are available; the most convenient for site use being those which can be attached directly to the microphone of the meter. It should be noted that these devices normally operate only at a single sound pressure level and frequency spectrum, and so their use does not constitute the thorough test referred to in paragraph 27 below.

Noise dose meter

12 Assessment of fluctuating noise is simplified by the use of an instrument which automatically integrates the sound energy received, allowing easy calculation of equivalent continuous sound level. Instruments of this type may be a great advantage when making measurements to determine whether the noise exposure is excessive. A conventional sound level meter and frequency analysing equipment will, however, generally be found more suitable for making the measurements (e.g., frequency analysis) needed for the introduction of noise-control measures.

13 As these instruments are a recent development there is no British Standard to which they conform, and considerable variations are likely in the physical size, accuracy, power requirements and convenience in use of different instruments. The instrument maker should be required to confirm that the instrument will integrate according to either equation 2 or 3 in Appendix 3, or enable L_{eq} to be calculated in some other way, and to provide full technical details of the measuring accuracy likely to be obtained when the instrument is in use.

Graphic level recorder

14 When measuring fluctuating noise this instrument will provide a permanent graphic record of the sound level which can be analysed statistically to determine the duration of exposure at various sound levels. It is possible to carry out a statistical analysis of the record manually, but the process is time-consuming and it will usually be found more convenient to use a statistical analyser attached to the level recorder (see paragraphs 18 and 19).

15 When measuring fluctuating noise to determine whether the limit in Section 4 is exceeded the recorder controls should be set to give a response time approximately equivalent to, or shorter than, the 'fast' response of a sound level meter. The instrument makers should be able to provide details of the necessary control settings.

16 When measuring noise produced by a series of impacts (e.g., hammering) it may be found that the level recorder indicates a slightly lower sound level than a conventional sound level meter. This situation is caused by differences in the response characteristics of the two instruments, and under these conditions the conventional sound level meter may give the more reliable reading.

17 Graphic level recorders are not normally used for measuring widely spaced noise impulses (e.g., cartridge operated tools) because complicated special techniques and ancillary equipment are required.

Statistical analyser

18 When measuring fluctuating noise this instrument enables the duration of exposure at various sound levels to be measured by automatically sampling the sound level at fixed intervals during the measuring period and counting the number of samples on a series of channel counters, each of which corresponds to a small range of sound levels. The analysers normally used for noise assessment are connected directly to a graphic level recorder.

19 The sampling rate of the analyser should be adjusted to give a total of at least 1,000 counts.

Magnetic tape recorder

20 A magnetic tape recorder will be useful to record fluctuating sounds for later analysis in a

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laboratory. If the recorder is battery powered it will be found more convenient for site use.

21 The input to the tape recorder may be provided directly from a suitable microphone although in practice it is usually more convenient to record from the output of a sound level meter because this allows the switched attenuator on the meter to be used for adjustment of the input level after a calibration signal has been recorded.

22 Before or after each recording at least one sound signal of known level should be recorded as a reference signal for an adjustment of the level during replay. If only one signal frequency is recorded, it should preferably be in the range 250 Hz to 4,000 Hz. Careful note should be made of any adjustments made to the sound level meter attenuator after recording the reference signal.

23 In order to obtain accurate reproduction of the recorded noise, a good quality recorder is required. The record/replay frequency response should preferably be uniform to within ± 2 dB in the range of 90 Hz to 11,200 Hz, enabling the octave bands from 125 Hz to 8,000 Hz to be measured. The signal to noise ratio should preferably be greater than 50 dB in order to allow satisfactory recording of fluctuating noise levels.

24 When recording noise containing repeated impulses (e.g., pneumatic hammers, riveting, and punch presses) some care is needed to prevent short-duration peaks overmodulating (overloading) the recording tape because this will produce a distorted recording leading to an inaccurate, low, sound level being indicated on replay. Most recorders are provided with a 'VU' meter to indicate the recording level. This instrument indicates the average level (i.e., considerably lower than the peak level), and is normally adjusted to give correct modulation of the tape when recording speech which has only fairly small peaks above the average. When recording noise containing repeated impulses using a recorder fitted with a 'VU' meter it is, therefore, advisable to adjust the indicated recording level to a relatively low level so that the peaks can be accommodated by the recording system. The more expensive recorders may be fitted with a 'peak programme meter' or 'modulometer' type of recording level meter which indicates the peak level so that overmodulation can readily be avoided, and this type of recording level meter is, therefore, to be preferred for accurate work.

Oscilloscopes

25 A cathode ray oscilloscope can be used to indicate the peak pressure and the waveform of isolated noise impulses. The method of using these instruments and of interpreting the results, is not simple and the process is best left to a person experienced in the technique.

Other equipment

26 Any other equipment may be used, provided that the sound level can be measured with sufficient accuracy to determine whether the limits in Section 4 have been exceeded.

Accuracy and calibration

27 It is important that all equipment used should be in good condition and correctly calibrated. All measuring equipment should be provided with means for its acoustical checking, and a check should be made on each day during which it is used. At suitable intervals all instruments should be thoroughly tested by a competent person who should issue a certificate of calibration. The intervals between thorough testing will depend on the conditions of use and the robustness of the equipment, but should not be longer than 2 years.

28 The person in control of the measuring operation should be adequately trained and should be responsible for ensuring that the equipment is in good condition and suitable for the purpose for which it is used.

B 74

Methods of calculating equivalent continuous sound level

General

1 The methods described in this appendix are intended for use where it is possible to exercise effective control over the duration of exposure to the sound. Where effective control is not possible, or where the practical difficulties of measurement are such that it is not possible to ensure that the equivalent continuous sound level (explained below) is less than 90 dB(A), any exposure to a sound level of more than 90 dB(A) should be regarded as requiring ear protection. The methods described in paragraphs 2 to 8 do not apply to widely separated noise impulses (see paragraph 15).

Continuous exposure to a steady sound for 8 hours in one day

2 Equivalent continuous sound level is the same as the measured sound level.

Continuous exposure to steady sound for other than 8 hours in one day

3 Periods of exposure at less than 85 dB(A) may be ignored.

4 The equivalent continuous sound level can be obtained from the nomogram, fig. 1, by drawing a straight line connecting the measured sound level dB(A) on the L scale with the exposure duration on the t scale (a transparent ruler is the most convenient straight edge to use). The equivalent continuous sound level can be read at the point of intersection of the centre L_{eq} scale.

Example:

A man is exposed to a sound level of 102 dB(A) for $2\frac{1}{2}$ hours per day. During the rest of the day the sound level is less than 80 dB(A) which may be ignored.

Connect 102 dB(A) on the L scale with $2\frac{1}{2}$ hours on the t scale and read $L_{eq}=96$ dB(A) (to the nearest decibel) on the central L_{eq} scale.

When the duration of exposure at more than one level is known

5 Exposure at each sound level should be converted to a value of fractional exposure f ; the values of f received during one day should be added together; and the total value of f converted to equivalent continuous sound level. Either the nomogram fig. 1, or Tables 1 and 2, can be used for this purpose. Fractional exposure is explained in paragraph 9.

Figure 1

6 This is used as follows:

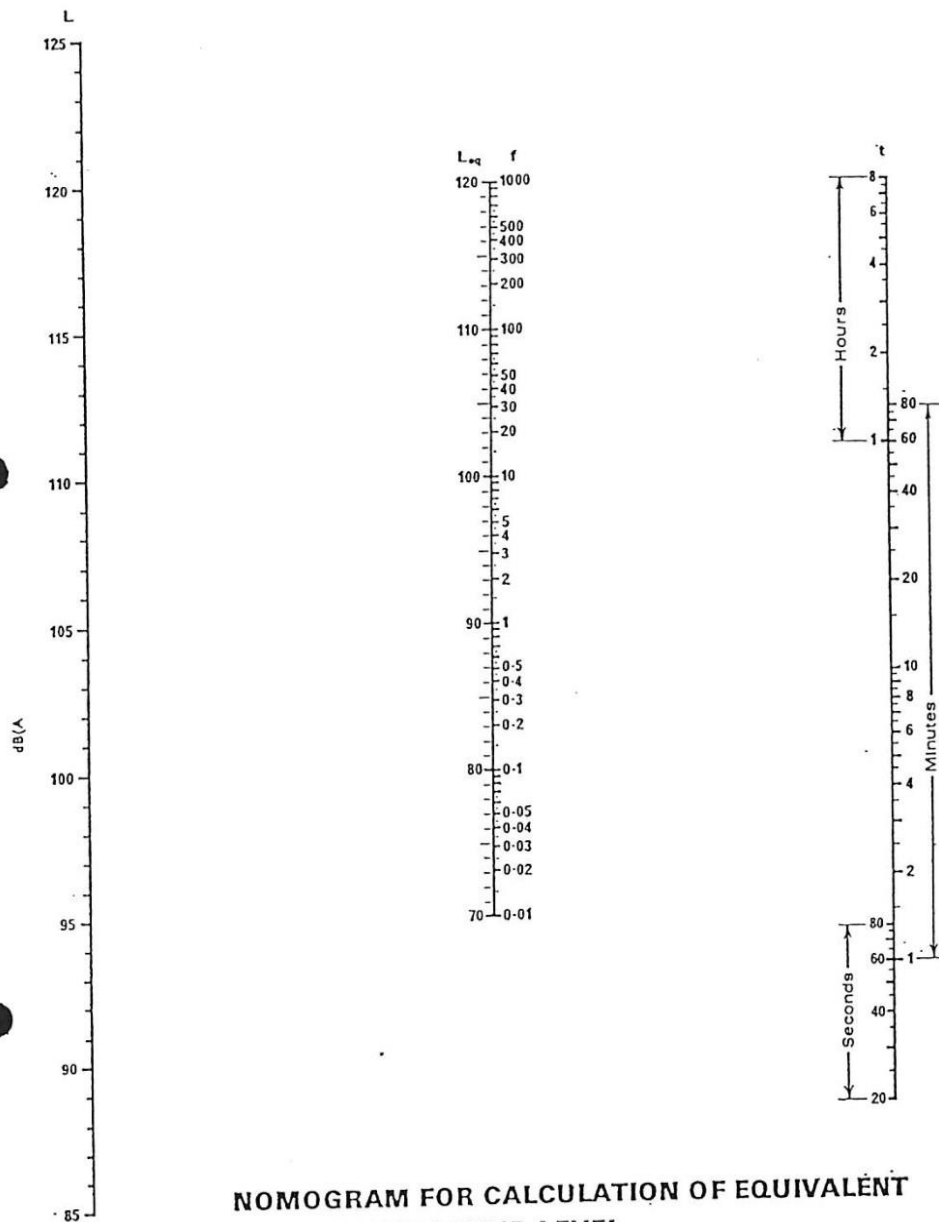
- for each period of exposure draw a straight line connecting the sound level [dB(A)] on the L scale with the exposure duration on the t scale and read the value of f on the centre scale,
- add together all the values of f received during one day,
- read the value of equivalent continuous sound level on the L_{eq} scale opposite the total value of fractional exposure on the f scale.

Example: A man is subjected to the pattern of sounds given in the first two columns of the Table below. The third column shows the corresponding values of f which are added together and converted to equivalent continuous sound level.

Sound level dB(A)	Duration of exposure	f (from fig 1)
114	10 mins	5.2
105	45 mins	3.0
92	5 hours	1.0
total value of f		= 9.2

From fig. 1 $L_{eq}=100$ dB(A) (to nearest decibel)

B 75



NOMOGRAM FOR CALCULATION OF EQUIVALENT CONTINUOUS SOUND LEVEL

From:

$$f = \frac{1}{8} \text{antilog} [4 - 1(L - 90)]$$

where t is in hours.

Also:

$$L_{eq} = \frac{\log f}{0.1} + 90$$

- (1) For each exposure connect sound level dB(A) with exposure duration t and read fractional exposure f on centre scale.
- (2) Add together values of f received during one day to obtain total value of f .
- (3) Read equivalent continuous sound level L_{eq} opposite total value of f .

Fig. 1

B 76

Tables 1 and 2

7 Equivalent continuous sound level can also be calculated from Tables 1 and 2 by first adding or subtracting to each measured sound level the adjustment given in Table 1, and converting the adjusted levels to values of f using Table 2. The daily total value of f is converted to L_{eq} using Table 2.

TABLE 1

Adjustments to measured sound level for non-continuous exposure

Total exposure per day (hours)	Adjustment to measured level	Total exposure per day (hours)	Adjustment to measured level
12.0	+1.8	7.5	- 0.3
11.5	+1.6	7.0	- 0.6
11.0	+1.4	6.5	- 1.0
10.5	+1.2	6.0	- 1.2
10.0	+0.9	5.5	- 1.7
9.5	+0.8	5.0	- 2.0
9.0	+0.5	4.5	- 2.5
8.5	+0.3	4.0	- 3.0
8.0	+0.0	3.5	- 3.6
		3.0	- 4.3
		2.5	- 5.0
		2.0	- 6.0
		1.5	- 7.3
		1.0	- 9.0
		0.5	-12.0

Add or subtract adjustment to the measured level before converting to fractional exposure with Table 2.

TABLE 2

Values of fractional exposure f for adjusted sound levels and equivalent continuous sound level

Level [dB(A)]	Fractional exposure f	Level [dB(A)]	Fractional exposure f
85	0.3	103	19.9
86	0.4	104	25.1
87	0.5	105	31.6
88	0.6	106	39.8
89	0.8	107	50.1
90	1.0	108	63.1
91	1.3	109	79.4
92	1.6	110	100
93	2.0	111	126
94	2.5	112	158
95	3.2	113	200
96	4.0	114	251
97	5.0	115	316
98	6.3	116	398
99	7.9	117	501
100	10.0	118	630
101	12.5	119	794
102	15.9	120	1000

1 To combine two or more adjusted levels the fractional exposure is found for each one. The fractional exposures are added together arithmetically and the resulting level corresponding to this total is then read from the Table. This is now the equivalent continuous sound level L_{eq} .

2 Total values of fractional exposure lying between two values in the Table are dealt with by taking the next higher figure in the Table.

Calculating the equivalent continuous sound level from the results of a statistical analysis

8 A statistical analyser divides the measuring range into a series of classes, usually with a class width of 5 dB(A) or 2.5 dB(A), and indicates the relative frequency of each class on a series of counters. The equivalent continuous sound level L_{eq} can be obtained from the readings of the channel counters using equation 1. There are other equally satisfactory methods of calculating L_{eq} , and these can be used if preferred.

$$f = \frac{t}{8N} \sum n g \quad \text{Equation 1}$$

where:

f =fractional exposure.

t =daily duration of exposure, in hours.

n =number of channel counts for each class.

g =a weighting factor for each class, obtained from Table 3 or Table 4.

$N = \sum n$. This should not be less than 1000.

The value of f can be converted to L_{eq} by using fig. 1 or Table 2.

TABLE 3

Weighting factors for 5 dB(A) class width.

Under 80 dB(A) g may be regarded as 0 for the purposes of this Code.

L dB(A)	g
80	0.18
85	0.56
90	1.8
95	5.6
100	18
105	56
110	180
115	560
120	1800
125	5600
130	18000
135	

TABLE 4

Weighting factors for 2.5 dB(A) class width.

Under 80 dB(A) g may be regarded as 0 for the purposes of this Code.

L dB(A)	g
80	0.13
82.5	0.24
85	0.42
87.5	0.75
90	1.3
92.5	2.4
95	4.2
97.5	7.5
100	13
102.5	24
105	42
107.5	75
110	130
112.5	240
115	420
117.5	750
120	1300
122.5	2400
125	4200
127.5	7500
130	13000
132.5	24000
135	

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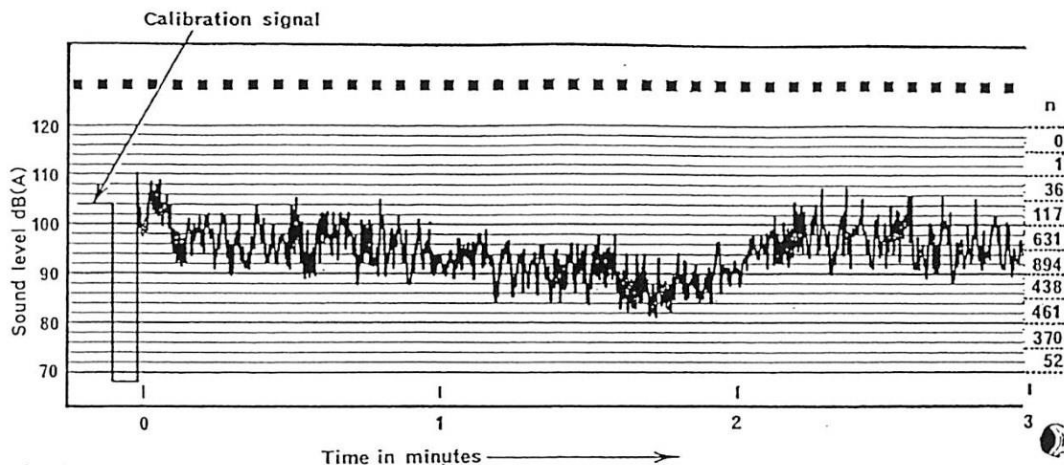


Fig. 2

Example:

Fig. 2 shows the beginning of the graphic level record of noise in a small wood-working shop in which the workers were exposed for 6 hours per day to a sound level varying between 74 dB(A) and 111 dB(A). A 15 minute sample of the noise was analysed using a counting rate of 200 counts/minute to give a total of 3,000 counts. 5 dB(A) class intervals were used and the resulting statistical analysis for the whole sample period is shown in the right hand column of fig. 2. L_{eq} can be found as shown in the Table and calculation aside.

(The graphic level recorder controls were set to give a writing speed of 100 mm/sec, a lower limiting frequency of 20 Hz and a paper speed of 1 mm/sec)

TABLE 5
Calculation of Σng for statistical analysis in fig. 2.

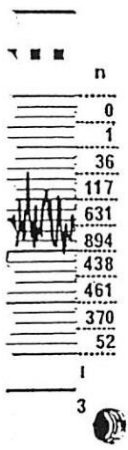
Class limits dB(A)	n	g (from Table 3)	ng
70			
75	52	0	0
80	370	0	0
85	461	0.18	83
90	438	0.56	245
95	894	1.8	1609
100	631	5.6	3534
105	117	18	2106
110	36	56	2016
115	1	180	180
120	0	560	0
			$\Sigma ng = 9773$

Then:

$$\begin{aligned}
 t &= 6 \text{ hours} \\
 \Sigma ng &= 9773 \text{ (from Table 5)} \\
 N &= 3000 \\
 f &= \frac{6 \times 9773}{8 \times 3000} = 2.44
 \end{aligned}$$

From fig. 1, $L_{eq} = 94$ dB(A) (to the nearest decibel)

Conclusion: Exposure is excessive, and remedial action is needed.



in fig. 2.

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Fractional exposure

9 Fractional exposure can be regarded as the dose of A-weighted sound energy received, expressed as a fraction of the dose received from exposure to 90 dB(A) for 8 hours. Values of f less than 1 represent an acceptable daily dose, while values more than 1 represent the number of times that the acceptable dose has been exceeded.

The mathematical basis of equivalent continuous sound level

10 Methods of calculating the value of equivalent continuous sound level from the readings of conventional instruments are explained above. The following explanation and definition is provided for the benefit of people who wish to devise other methods for determining its value.

11 In Section 4 unprotected exposure to a steady sound which is continued for 8 hours in any day is limited to a maximum sound level of 90 dB(A). Frequently the period of exposure may be more, or less, than 8 hours, or the sound level may fluctuate. In such circumstances an equivalent sound level L_{eq} , normalised to an 8 hour exposure period can be calculated and used for deciding whether the acceptable limit has been exceeded.

12 Equivalent continuous sound level can be regarded as a notional sound level which, in the course of an 8 hour period, would cause the same A-weighted sound energy to be received as that due to the actual sound over the actual working day. L_{eq} is expressed in terms of A-weighted sound level [dB(A)].

13 L_{eq} is defined mathematically by:

$$L_{eq} = 10 \log \frac{1}{T} \int_0^T \frac{[p_A(t)]^2 dt}{p_o^2} \quad \text{Equation 2}$$

where:

L_{eq} = equivalent continuous sound level, normalised to an 8 hour exposure

T = total working period in hours

p_A = instantaneous A-weighted sound pressure in N/m²

p_o = reference r.m.s. sound pressure as specified in BS 661:1968 clause 2006, viz 2×10^{-5} N/m²

t = time

14 In practice measurement over the whole working period will not usually be needed. The calculation of L_{eq} can then be based on measurements made during sample periods judged to be typical of the working day. If the working day is less than 8 hours the sound level during the rest of the 8 hour period may be assumed negligible. L_{eq} (not normalised to an 8 hour exposure) is then defined by:

$$L_{eq} = 10 \log \frac{1}{Ts} \int_0^{Ts} \frac{[p_A(t)]^2 dt}{p_o^2} \quad \text{Equation 3}$$

where:

Ts = total sampling period.

If the working period is not 8 hours, L_{eq} calculated according to equation 3 will need to be normalised to an 8 hour period. This can be done using fig. 1 by treating L_{eq} (not normalised to an 8 hour exposure) in the same manner as a single exposure to steady sound (see paragraph 4).

15 When the sound level is continuous and reasonably steady L_{eq} is equal to the reading of a sound level meter. This is the only condition under which a conventional sound level meter will directly indicate L_{eq} . In other circumstances the duration of exposure at each sound level can be determined and L_{eq} calculated as explained above. Alternatively any other instruments capable of evaluating equation 2 or 3 above may be used. The methods described in paragraphs 2 to 9 are unsuitable for noise consisting of widely separated impulses (e.g., cartridge operated tools) because they involve the use of instruments which do not give a useful measurement of such noise (see Appendix 2). Present techniques for dealing with widely separated noise impulses (e.g., by the use of an oscilloscope) are complicated and assessment is best left to a person capable of interpreting the latest technical literature on the subject, until such time as simple instruments capable of evaluating equation 2 or 3, and of indicating the peak pressure in accordance with Section 4.7 become available.

B 80

Appendix 4:

Ear protectors

Permanent re-usable ear plugs

1 These are soft rubber or plastic bungs which are fitted into the ear canal.

2 This type of protector is cheap, but in order to obtain a good seal in the ear canal it is essential that the correct size is used, resulting in a slightly tight fit. Some people require a different size plug in each ear.

3 The most effective types of these plugs are available in a range of 3 to 5 sizes to suit different sizes of ear canal. 'Universal fitting' ear plugs are also available, and these have administrative advantages because only one size is needed, but they are not so satisfactory acoustically as properly fitted individual-sized ear plugs and tend not to be used properly (they can be retained by the ear with minimal insertion, but then give little protection). All permanent ear plugs, including the 'universal fitting' types, should be initially fitted to the individual by a trained person who should instruct the user on the correct method of inserting the plugs.

4 It is most important that this type of plug is kept clean by regular washing.

8 Ordinary dry cotton wool is an extremely poor protector and is not recommended.

Semi-insert protectors (canal caps)

9 These have soft rubber caps attached to a headband which presses them into the openings of the ear canal.

10 This type of protector has the advantages that, unlike the permanent, reusable ear plugs, one size will fit most people, and the fact that the caps are captive may make them more suitable for use in industries where loss of an ear plug must be avoided (e.g., the food industry). As the ear is not covered, these protectors may be more acceptable in a hot environment than ear muffs. However, to be effective the headband must press the caps firmly into the openings of the ear canals, and some people will find the pressure intolerable, especially if they must be used for long periods. They have the advantage of lightness and can be slipped round the neck when not in active use, and may therefore, be suitable for people who must frequently enter a noisy place for short periods.

Disposable ear plugs

5 These are made from mineral down (or 'acoustic wool') which is a special extremely fine glass down with fibres about 1 micron in thickness, or from waxed cotton wool, and are intended to be used once only and then thrown away. They can fit any size or shape of ear canal, and provide protection equivalent to good quality permanent ear plugs. Because fresh material is used every time the ear is plugged they may be more hygienic than the permanent ear plugs.

6 Waxed cotton wool may be found messy because it must be formed with the fingers before insertion into the ear. The ear canal changes shape slightly with jaw movements and this may cause the plugs to be compressed and lie loose in the ear canal; they should then be extracted, reshaped and reinserted periodically. Neither this operation nor the original insertion should be performed with dirty hands.

7 Mineral down plugs are more resilient than waxed cotton wool and usually retain a good fit provided sufficient material is used to form the plug, and it is folded and inserted in accordance with the makers instructions. Mineral down is available in packets containing sufficient material for about a week, from dispensers which automatically supply the correct quantity of material, or in packets of pre-formed plugs.

Ear muffs

11 These are hard cups which fit over the ear and are sealed to the head with soft cushion seals. They have several advantages compared with ear plugs. One size will fit most people, more protection is usually provided, and they are easy to remove and replace – an advantage for people who frequently move from a noisy to a quiet place. It is possible to include ports or valves which can be manually opened during quiet periods, or an electronic device which permits passage of low-intensity signals without attenuation (see paragraphs 16 to 19). However, they tend to make the ears hot, and are bulky so that they are less convenient if slipped around the neck when not in active use.

12 Two types of seal are in general use. A 'liquid seal' type comprises a soft annular tube filled with liquid. This type of cushion forms an excellent seal with only slight pressure against the head, but if the tube is damaged due to rough handling the fluid will leak. More robust cushions are filled with soft plastics foam, but some of these need more pressure than the liquid seal type in order to obtain a satisfactory seal. When ear muffs are first issued the user should be asked to check that the cushion is in contact with his head around the entire periphery of the muff.

13 Maintenance of correct pressure on the head is important and the user should be instructed not to

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14 Some ear muffs are asymmetrical; i.e., they have one cup intended only for the left ear and another for the right ear. The correct way of wearing these muffs should be prominently marked on them and the user's attention drawn to this matter.

15 All types of ear muffs are liable to be damaged, and it is an advantage if individual parts, especially the seals, can be replaced separately and easily (e.g., on site or in the factory).

Special types of ear protector

(a) Amplitude-sensitive protectors

16 There are obvious advantages in protectors which attenuate loud sounds more than quiet ones, and several attempts have been made to develop protectors of this type.

17 Protectors made with small apertures in them usually have rather more attenuation at high sound levels than at low levels due to increased turbulence in the air flow through the apertures at high levels. This effect is used in the 'Gundefender' ear plug developed by the Institute of Naval Medicine for use against gunfire noise (which involves very high levels for short durations). These plugs may be useful for other explosive noises (e.g., cartridge operated tools), but the evidence available at the time of publishing this Code suggests that they are not suitable for most industrial noises (e.g., drop forging or fettling) in which the noise is usually more sustained or repetitive than gunfire and in which a high level of continuous noise may also be present, for which insufficient attenuation is given and all communication advantages are lost.

18 Ear muffs are available incorporating an electronic system which will transmit low level sound, but in which a peak limiting circuit stops the electronic transmission of high level sounds so that the basic ear muff then provides the attenuation. These protectors can be extremely valuable in situations in which people are exposed to impulse noise, but must be able to communicate easily during quiet periods between impulses. They are, however, somewhat more expensive than normal types of ear muff, and must be handled with more care.

19 Amplitude-sensitive protectors are difficult to test because the threshold method described in paragraphs 23 to 27 will not measure the attenuation at high sound levels. Ear plugs are particularly difficult to test effectively. It is recommended that these protectors should only be used when the supplier can furnish test data showing the attenuation at the sound levels in which they are to

be used. As these data will be in a non-standard form, expert assistance is desirable.

(b) Frequency-selective ear protectors

20 All protectors attenuate some frequencies more than others, but certain types are especially designed to emphasise this effect. Usually they are designed to attenuate frequencies over about 1,500 Hz, but to give only slight attenuation at lower frequencies. If the noise is all at high frequency these protectors can give improved speech communication, but they are unsuitable for most industrial situations which usually involve noise at frequencies less than 1,500 Hz.

Testing the performance of ear protectors

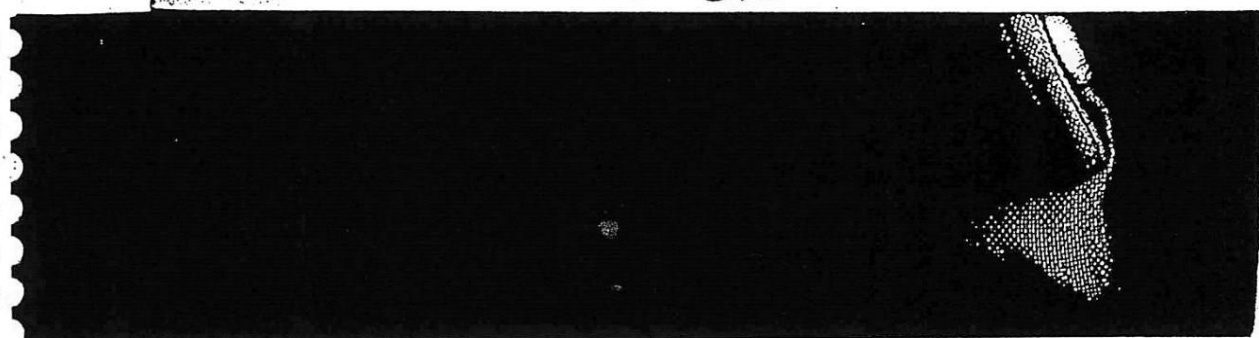
21 When purchasing ear protectors the supplier should always be instructed to furnish test data showing the attenuation of sound which will be provided. Because the size and shape of people's heads and ears varies considerably it is important that the test data should show not only the average attenuation, but also the consistency with which the attenuation is maintained when the protectors are worn by different people. The test data should normally give information on the average attenuation in dB at each of a range of test frequencies and on the scatter likely to occur in practice (see paragraph 26). It is not possible to give an overall figure for the attenuation in terms of sound level dB(A) since the value depends on the frequency distribution in the noise. Guidance on interpreting the data is given in paragraphs 29 to 31.

22 At the time of writing this Code there is no British Standard test for ear protectors. If such a test becomes available it should be used, but in the absence of a British Standard test other procedures may be accepted if they are properly conducted and provide adequate information. Most protectors are tested by the threshold method described below. When using such test data it is good practice to obtain the name of the laboratory in which the tests were carried out, and details of any standard to which they were tested.

Threshold tests

23 Most commercially available ear protectors are tested by this method in which the sound attenuation at each of a range of frequencies is measured. Several countries (e.g., the USA and Canada) have produced national standards specifying the way in which the test is to be conducted.

B 82



24 To carry out the test a person is seated in a quiet room and the minimum sound pressure level which he can hear is found. The person then puts on the ear protection and the increase in sound pressure level needed before the person again hears the sound is taken as a measure of the attenuation provided by the protector.

25 For each frequency to be tested this procedure is repeated several times on the same person, and also on different people in order to test the reliability with which the measured attenuation is maintained. The American procedure is to select 10 people at random, and test each of them three times giving a total of 30 test results at each frequency.

26 The results of the tests are usually supplied as a table or graph showing the mean value of the test results and the standard deviation¹ at each frequency. Sometimes the results may be given as a table showing the median, and the upper and lower quartile² values of the test results.

27 This test has been accepted by the standards organisations in several countries as being the best at present available. However it suffers from several serious problems, including:

- (a) it is difficult to ensure that the test room is adequately quiet,
- (b) part of the standard deviation is in fact not due to variations in fit of the protector, but to variations in a person's ability to detect consistently the minimum audible sound,
- (c) the quality of fit obtained on the people under test may be better than on people in an industrial situation,
- (d) the sound attenuation of the protectors may not be the same at the very low sound levels

of the test as at the high levels in which it is intended to be used. A few protectors are designed to give increased attenuation at high sound levels,

- (e) the method is unsuitable for routine testing during production, or by purchasers and users,
- (f) tests at low frequencies tend to over estimate the performance due to the fact that the threshold may be masked by physiological noise³ when the protectors are worn.

Other tests

28 In attempts to overcome the difficulties associated with threshold tests several other test methods have been devised. However, these methods usually suffer from difficulties of their own, and at the time of publishing this Code none are in general use. Until standard test procedures have been laid down for any of these methods it is recommended that such test results should only be used on the advice of a person or laboratory capable of interpreting the latest scientific literature on the subject.

Calculating the reduction of sound level

29 Suppliers of ear protectors will usually furnish data obtained from threshold tests described in paragraphs 23 to 27. It should be assumed that the degree of protection (in decibels) given to most people is equivalent to either:

- (a) the mean value of the test results minus the standard deviation,
- (b) the lower quartile of the test results.

Typical values for a good quality fluid seal ear muff are given in Table 1.

TABLE 1

Typical performance of fluid seal ear muffs. The assumed protection is the sound reduction given to the majority of users.

Frequency	Hz	125	250	500	1000	2000	4000	8000
Mean attenuation standard deviation	dB	13	20	33	35	38	47	41
	dB	6	6	6	6	7	8	8
Assumed protection	dB	7	14	27	29	31	39	33

¹ The standard deviation is a measure of the way in which individual test results vary from the mean value. A small value of standard deviation compared with the mean value indicates consistent results. It can be assumed that 50% of test results will be worse than the mean value, 16% will be worse than the mean value minus the standard deviation, and 3% will be worse than the mean value minus twice the standard deviation.

² Median — 50% of test results are worse than this value
upper quartile — 25% of test results are better than this value
lower quartile — 25% of test results are worse than this value

³ Physiological noise is audible sound generated in the outer ear. It can readily be heard by covering the ears with the hands.

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47	41
8	8
33	

than this value
better than this
worse than this
generated in the
covering the ears

30 In order to calculate the effective reduction in A-weighted sound level, dB(A), a frequency analysis of the noise will be needed; usually this will be an octave band analysis. The assumed protection as in paragraph 29 (a) or (b) should be subtracted arithmetically from each octave band level to obtain the assumed octave band levels at the wearer's ear. An example of this procedure is given aside. The assumed octave band levels at the wearer's ear should be converted into A-weighted sound level using any convenient method of conversion; two methods are given in Appendix 5.

Example:

The first two columns of the table below show the octave band sound pressure level of the noise produced by a riveting machine. Column 3 shows the protection provided by the muff quoted in Table 1 above, which is subtracted from the measured levels to give the assumed sound pressure level at the user's ear in column 4. Examples of how these levels can be converted into A-weighted sound level, dB(A), are given in Appendix 5.

1 Octave band centre frequency Hz	2 Measured octave band sound pressure level dB	3 Assumed protection given by muff, from Table 1 dB	4 Assumed band sound pressure level at user's ear - dB
125	95	7	88
250	99	14	85
500	104	27	77
1000	107	29	78
2000	111	31	80
4000	109	39	70
8000	102	33	69

31 Ear protectors should normally be specified so that the sound level at the user's ear is always effectively reduced to 90 dB(A) or less.

32 Exceptionally, where exposure is for short periods only, protectors may be chosen so that the assumed value of L_{eq} is reduced to 90 dB(A) or less. However, this procedure should be avoided where possible, and if adopted it is particularly important to ensure that the exposure to noise is effectively controlled, and that the ear protectors are correctly used.

Hygiene

33 Before any type of ear plug is issued, the user should be asked whether he has ever had any ear troubles such as irritation of the ear canal, or earache and discharging ears, or is under treatment for any ear disease. People with such troubles should be referred to a doctor for an opinion as to whether they may wear ear plugs with safety.

34 Issue of ear plugs should be on an individual basis. If ear muffs are to be transferred from one person to another they should be cleaned before re-issue.

35 Users should be instructed not to insert ear plugs with dirty hands. This is particularly important with waxed cotton wool disposable plugs.

B 84

Appendix 5:

Methods of converting octave band sound pressure levels to A-weighted sound level

1 The attenuation of partitions or ear protectors varies greatly with frequency. The normal procedure for predicting the reduction of A-weighted sound level is to make a frequency analysis (usually an octave band analysis) of the noise which is to be reduced, subtract from each measured level the predicted attenuation at that frequency and convert the resulting reduced levels into A-weighted sound level. Two methods of performing the conversion for octave band analysis are given below.

Conversion by calculation

2 The procedure is as follows:

- the A-weighting corrections given in Table 1 should be added or subtracted arithmetically to each octave band sound pressure level,
- the A-corrected band levels should be converted into arbitrary intensity units / using Table 2,
- the values of / should be added together arithmetically,
- the total value of / should be converted into A-weighted sound level, dB(A), using Table 2. When the total value of / falls between two of the values in the table, take the next higher value of sound level.

TABLE 1
A-weighting corrections

Octave band centre frequency Hz	63	125	250	500	1000	2000	4000	8000
A-weighting correction dB	-26	-16	-9	-3	0	+1	+1	-1

TABLE 2
Values of arbitrary intensity units / corresponding to sound pressure levels from 60 dB to 119 dB.

dB	0	1	2	3	4	5	6	7	8	9
60	-0010	0-0013	-0016	-0020	-0025	-0032	-0040	-0050	-0063	-0079
70	-010	-013	-016	-020	-025	-032	-040	-050	-063	-079
80	-100	-126	-158	-200	-251	-316	-398	-501	-631	-794
90	1-00	1-26	1-58	2-00	2-51	3-16	3-98	5-01	6-31	7-94
100	10-0	12-6	15-8	20-0	25-1	31-6	39-8	50-1	63-1	79-4
110	100	126	158	200	251	316	398	501	631	794

Example:

The first two columns of the Table below show the assumed octave band sound pressure level from column 4 of the example in Appendix 4, paragraph 30. Column 3 shows the A-weighting corrections taken from Table 1 which are added to the levels in column 2 to obtain the A-corrected octave band levels in column 4. These are converted into values of I using Table 2, added together, then converted into A-weighted sound level using Table 2.

1 Octave band centre frequency Hz	2 Octave band sound pressure level dB	3 A-weighting correction (from Table 1) dB	4 A-corrected octave band level dB	5 I (from Table 2)
125	88	-16	72	-016
250	85	-9	76	-040
500	77	-3	74	-025
1000	78	0	78	-063
2000	80	+1	81	-126
4000	70	+1	71	-013
8000	69	-1	68	-006
Total value of I =				-289

From Table 2 A-weighted sound level 85 dB(A) (to the nearest decibel)

It should be noted that the values of the arbitrary intensity units, I , given in Table 2 have the same numerical value as the values of f given in Table 2 of Appendix 3, but they represent a different quantity.

Graphical method

4 This is a little less precise than the previous method, but is sufficiently accurate for many purposes.

5 To convert the octave band sound pressure levels into A-weighted sound level they should be plotted on fig. 1, * and the point of highest penetration into the A-weighted sound level contours should be noted. The A-weighted sound level, dB(A), is given by the contour corresponding to this point.

6 The octave band levels used in the previous example in paragraph 2 are plotted on fig. 2. The corresponding sound level contour is 86 dB(A).

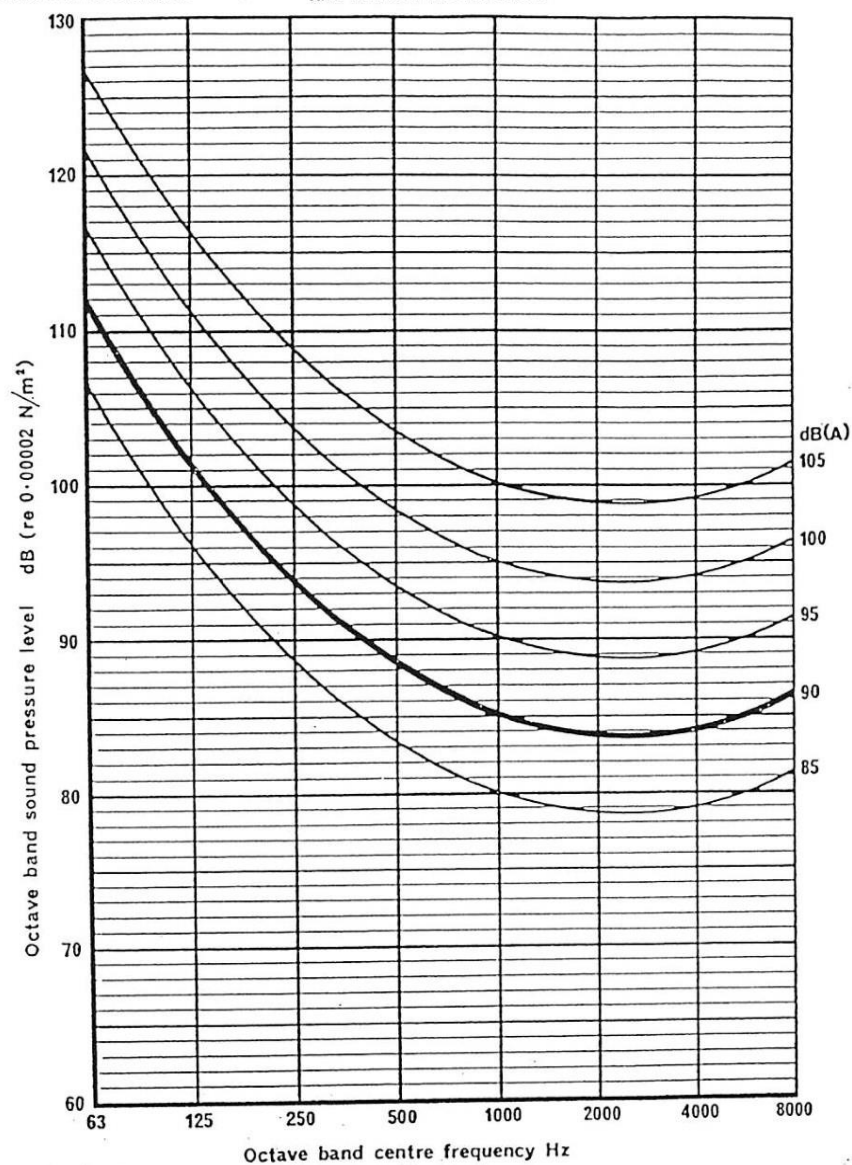
7 In broad-band noise this method is usually accurate enough for specification of ear protectors. It becomes less reliable under the following conditions, neither of which frequently arise in practice:

- when the plotted sound pressure levels follow very closely an A-weighted sound level contour over more than 3 octaves. The true sound level will then be more than that indicated by the figure. It is most unlikely that the error will be more than 3 dB(A),
- when there are prominent pure tones, or when one octave band level penetrates more than 5 dB(A) into the contours than any other octave band. The true sound level will then be a little less than that indicated by the figure. The maximum possible error is 5 dB(A).

*F2381 obtainable in pads of 25 sheets from HMSO price 20p

B. 86

Reference _____

DEPARTMENT OF EMPLOYMENT
H.M. FACTORY INSPECTORATE

Department _____ Date _____

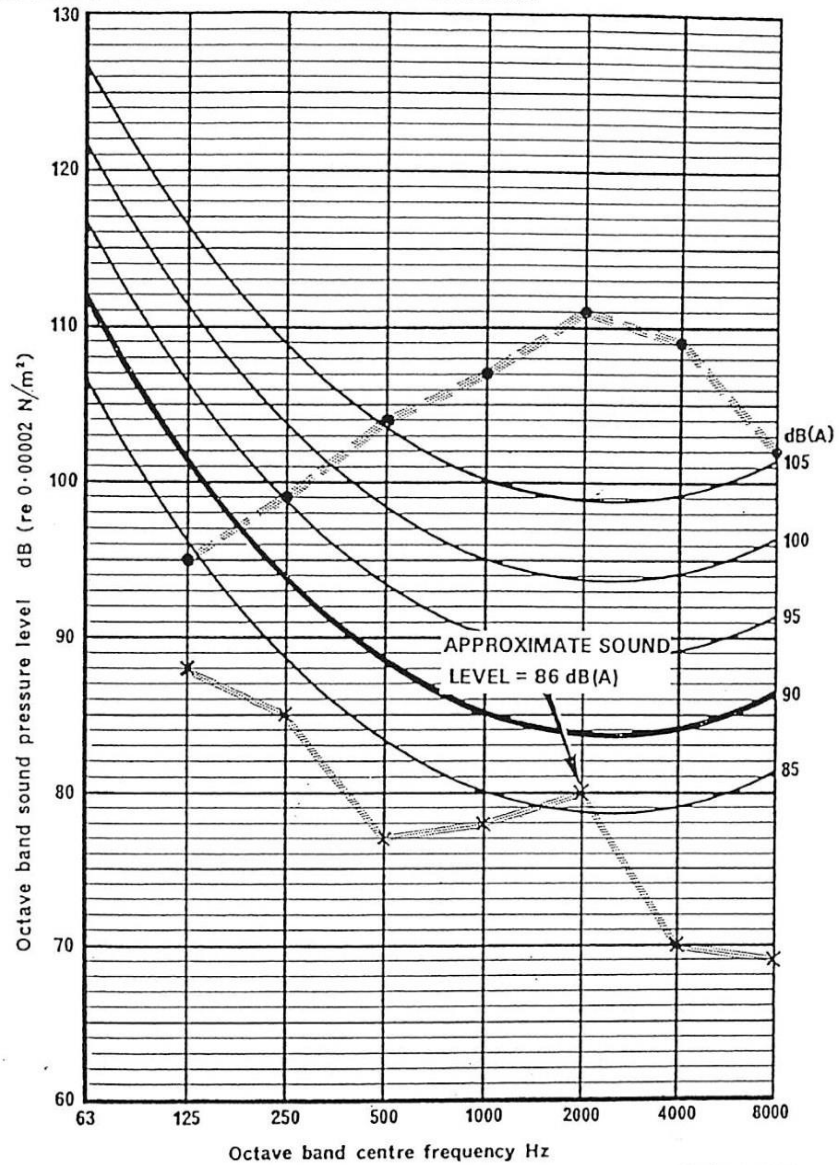
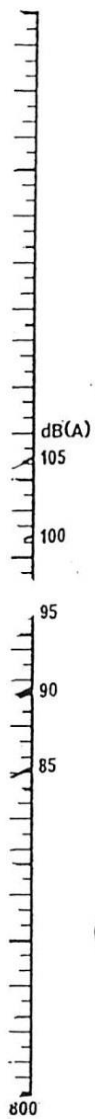
Machine _____

Contours indicate approximate sound level dB(A)

B87

Fig. 1

Reference 1009/71

DEPARTMENT OF EMPLOYMENT
H.M. FACTORY INSPECTORATE

Department Sheet metal shop Date 20 Sept 1971
 Machine Riveting machine; on-time 1½ hours per day
 Ear protectors: XY Co. Ltd., model Z ear muffs.

—●— measured octave band levels of machine (measured sound level = 115 dB(A)).
 —x— assumed octave band levels after subtracting the protection of the ear muffs.

Contours indicate approximate sound level dB(A)

B 88

Fig. 2

Appendix 6:

Warning notices

1 The symbol in fig. 1 is suitable for use on the warning notices required by Sections 5.2 and 5.3 of this Code, with an appropriate caption. When used at the entrance to an ear protection area, as in Section 5.2, employed persons should be instructed that only persons authorised to do so may enter the area, and that they must use ear protection when in the area.

2 The following captions may be used as appropriate:

- (a) for notices at the entrance to ear protection areas
USE EAR PROTECTORS
- (b) for notices attached to noisy machines
USE EAR PROTECTORS WHEN
OPERATING THIS MACHINE

These captions may be amended or supplemented if necessary to suit local conditions.



Fig. 1 Symbol for warning that ear protection is required
Colour: Black symbol on a yellow background

Appendix 7:

Specifications for new machinery

Noise control measures

1 When new machines are being purchased the maker should be required to show that he has incorporated the best practical means for noise control.

2 The maker should be requested to provide full details of any additional components, e.g., exhaust silencers, not supplied with the machine, or of any special mountings which may be needed to control the noise produced.

Noise tests

3 The machine maker should preferably be instructed to provide test data indicating the sound level which will be produced by the machine.

4 Where they exist, and will indicate the sound level in the vicinity of the employed persons' ear, British Standard test procedures should be used. In the absence of British Standard tests a test procedure appropriate to the class of machines concerned should be agreed between the purchaser and the seller. An outline procedure which may be varied according to individual requirements is given at the end of this Appendix. This procedure is not suitable for machines producing widely spaced impulses.

5 The main use of these tests is for comparing the noise produced by machines of similar type and size. Some skill is needed if they are to be used for predicting the sound level likely to be produced when installed in the user's premises. Variations in the machine load, method of mounting, reflections from the walls and ceiling of the room in which the machine is used, and the presence of other nearby noisy machines, will all affect the sound level near the machine when finally installed. It will frequently be found that the sound level in practice is somewhat higher than the test levels.

2 Method of measurement

Sound levels are to be measured in dB(A), using a calibrated sound level meter meeting the requirements of BS 4197:1967, with the response speed set to 'slow'. The supplier may also include 'linear' and octave band levels.

3 Conditions of test

The tests of the equipment shall be carried out by a competent person in a suitable location. The background noise level should be at least 10 dB(A) below the operating noise level of the equipment.

Tests shall be made with the equipment running in the (a) unloaded and (b) loaded conditions. Details shall be given of the nature of the loading. The test report should contain details of the environment in which the test was carried out, and the method of mounting the machine.

4 Position of measurements

(a) Hand-held tools and portable equipment

Measurements shall be made at five locations. Four locations shall be equi-spaced one metre from the outline of the machine on a plane at right angles to the major axis of the machine, and passing through its geometric centre. The fifth location shall be one metre from the major outline of the machine on its major axis away from the workpiece. These locations are shown in fig. 1.

(b) Machine tools and production equipment

Sound levels shall be taken at a minimum of five locations equi-spaced on a prescribed path one metre from the vertically projected plan of the machine, at a height of 1.5 metres. Additional measurements shall be made at the location on the prescribed path giving the highest sound level meter reading, and at every location likely to be occupied by an employed person for a substantial part of the working day. This is illustrated in fig. 2.

Outline test procedure for use when there are no appropriate British standard tests

1 Submission of tenders

The supplier shall submit with his tender, details, in accordance with paragraphs 2 to 4, of the noise levels which will be produced by the machine.

B 90

Measurements shall also be taken at any other positions likely to be occupied by a person for a significant length of time.

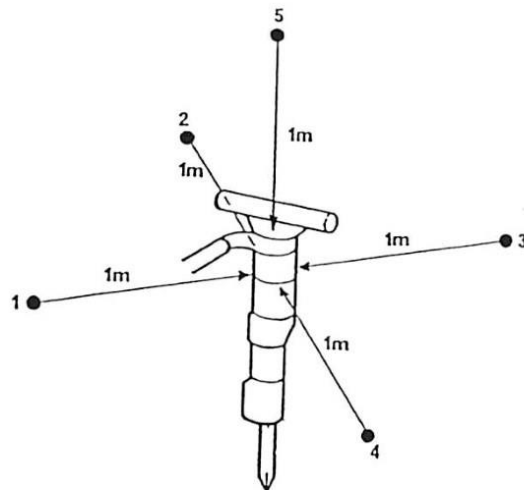


Fig. 1 Positions of measurement for hand-held machines.

Measurements shall also be taken at any other positions likely to be occupied by a person for a significant length of time.

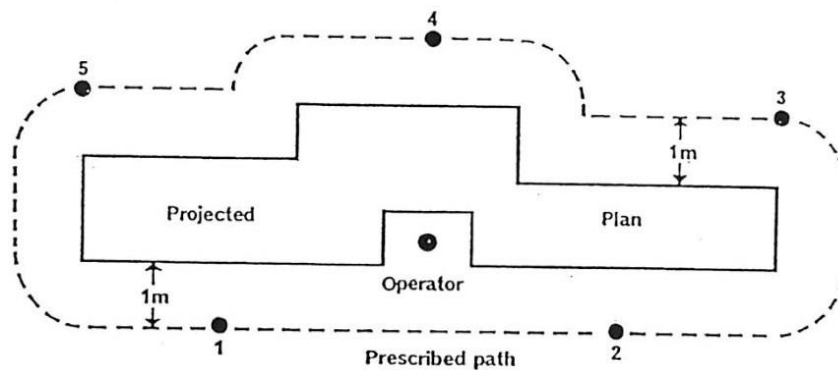


Fig. 2 Positions of measurement for machine tools and other stationary plant.

Specimen record forms

RECORD OF SOUND LEVELS

- (1) Name of occupier:
- (2) Address of factory:
- (3) Date of survey:
- (4) Department(s):
- (5) Particulars of sound levels recorded:

(1) Place	(2) Number employed	(3) Max (dBA)	(4) Min (dBA)	(5) L_{eq}^*	(6) Ear protection area Yes/No

*If L_{eq} calculations are made they should be based on the persons with the longest personal exposure in the area.

- (7) Instruments
- (i) Type(s) used in survey:
 - (ii) Date of last calibration:

Signature: _____
Date: _____

B 92

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Name of occupier:

Address of factory:

*Entries in cols. (4) and (5) are not required where the type of ear protection issued is disposable.

Appendix 9:

Definitions

For technical terms not listed below reference should be made to BS 661:1969 (glossary of acoustical terms).

1 Continuous exposure

Exposure to a sound which is at the same level for substantially the whole working day, discounting breaks for meals and rest periods unless these are taken in a noisy environment.

2 Equivalent continuous sound level L_{eq}

A notional continuous sound level which is calculated from the measured A-weighted sound level by the procedures given in Appendix 3 of this Code. Equivalent continuous sound level can be regarded as a notional level which would, in the course of an eight hour period, cause the same A-weighted sound energy to be received as that due to the actual sound over the actual working day. The value of L_{eq} is expressed in A-weighted sound level [dB(A)].

3 Fractional exposure f

An arbitrary unit, calculated according to the procedures given in Appendix 3 of this Code, which is used for calculating the value of equivalent continuous sound level. The units of fractional exposure may be regarded as representing the dose of A-weighted sound energy received, expressed as a fraction of the dose received from exposure to 90 dB(A) for eight hours.

4 Noise

For the purposes of this Code any audible sound may be regarded as a noise.

5 Reasonably steady sound

Sound where the level fluctuates through a total range of less than 8 dB(A) as measured on the 'slow' response of a sound level meter.

B 94