COMMITTEE ON THE PROBLEM OF NOISE

Noise

FINAL REPORT

Presented to Parliament by the Lord President
of the Council and Minister for Science
by Command of Her Majesty
July 1963

LONDON
HER MAJESTY'S STATIONERY OFFICE
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(Ministry of Health)

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* Mr. Perring was appointed on the 19th December, 1961, in place of R. A. Lovell, Esq., C.B.E., A.M.I.Mech.E., whom he succeeded at the Ministry of Transport.

† Mr. Robertson was appointed on the 4th July, 1962, in place of Douglas Taylor, Esq., C.M.G., who resigned from the Ministry of Labour.

Noise

Report of the Committee on the Problem of Noise

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To The Rt. Hon. Viscount Hailsham, Q.C.,
Lord President of the Council and Minister for Science.

You appointed us in April, 1960, "to examine the nature, sources and effects of the problem of noise and to advise what further measures can be taken to mitigate it." We have completed our examination and now submit our Report, which includes the substance of an interim Report on noise from motor vehicles.*

People's reactions to noise vary greatly, and in the past this has prevented the framing of rules for its control except in qualitative terms, with consequent difficulties of administration. We therefore felt that an important feature of our task was to try to define, wherever possible, quantitative levels of noise which should become statutory limits, or, where statutory limits were not desirable or could not be laid down at present, to suggest levels which would serve as guides to what is reasonable. We found that to do this we had to ask for a number of investigations and to break much fresh ground in measuring the annoyance caused to representative samples of the population by noises of various kinds.

There has recently been a great increase in the study of noise problems in their social setting, and we do not doubt that in the coming years important advances will be made. We hope that our own work will contribute something to this movement and will help to put the problem of noise into perspective with other problems of modern life.

(Signed) A. H. WILSON (*Chairman*).
T. FERGUSON RODGER (*Deputy Chairman*).
ALBERT FOGG.
F. B. GREATREX.
A. A. HALL.
NORMAN LONGLEY.
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E. IRIS WEBLEY.

R. S. MATTHEWS (*Secretary*).

March, 1963.

* Cmnd. 1780: 1962.

Chapter I

Introduction

1. We faced our task of examining the problem of noise with, for the most part, no special knowledge of the subject. This lack was in a sense an advantage, for it enabled us to see the problem from the point of view of the layman, and noise affects us all, laymen and specialists alike. We hope, therefore, that our conclusions and recommendations represent fairly the reaction of the ordinary citizen to noise, and the degree of trouble and expense he would approve to mitigate it.

2. We have had the continuous help of assessors, and other expert advice was fully available to us. We hope that in making our recommendations we have sufficiently recognised the difficulties that face the specialists who would be called upon to implement many of the measures that we propose.

3. We have received evidence from many sources; private individuals, local authorities, associations of citizens of various kinds, representatives of industry, specialist and technical bodies. The evidence has ranged from personal complaints to closely reasoned arguments based on measurable facts affecting many thousands of people. In attempting to draw useful conclusions from this mass of material, we have selected particular problems for closer study, e.g. noise from aircraft, from motor vehicles, in buildings, etc. The subject is so wide, and the sources of noise so varied, that we have often found it necessary to divide into sub-committees. The three main sub-committees were those appointed to examine noise from aircraft, from industry and from surface transport. Their respective chairmen were Mr. F. B. Greatrex, Mr. L. H. A. Pilkington and Dr. A. Fogg.

4. Both as a Committee, and as sub-committees, we have attempted to gain first-hand experience of certain matters by visits, experiments and demonstrations; and we have to acknowledge our debt to the companies and other organisations, both government and private, who helped us. We also owe thanks to the Motor Industry Research Association and to the Government Departments and laboratories who carried out specialized investigations at our request; to the local authorities who completed the questionnaires that we sent to them; and to several individual experts who have advised and assisted us. We also wish to thank all those who gave evidence (see Appendix I).

5. Our Assessors undertook many special investigations for us, and helped us in the critical appraisal both of the papers submitted and of our proposals at the formative stages in our discussions. The evidence presented to us was so large and varied in content that a very heavy load fell upon the Secretariat, who maintained an admirable service throughout the three years' existence of the Committee. We wish to express our great appreciation of the work both of the Assessors and of the Secretariat.

WHAT IS NOISE?

6. For the purposes of this Report we accept the definition of noise as "sound which is undesired by the recipient". This simple description emphasizes the cardinal fact that noise is subjective; a noise problem must involve people and their feelings, and its assessment is a matter rather of human values and environments than of precise physical measurement. These values and environments are complex indeed. Not only do people vary in their susceptibility and adaptability to noise, but each of us may be annoyed by one noise but not by another of similar physical characteristics. A sound which most people would ignore in, say, the industrial part of a city, would be a disturbing noise in a quieter environment, for example at night in a residential area or in the country. The annoyance produced by a noise is often related to the information it conveys or the association or emotion it excites rather than to its actual intensity; and a sound of small intensity, such as that from a dripping tap, may become unbearable simply from repetition. Thus, whether a sound is a noise, or whether a noise is annoying, may depend upon many factors which are independent of its physical qualities.

7. The physicist can measure the energies and the frequencies of simple or complex sounds. The psycho-acoustician can set up subjective scales of loudness with reasonable confidence. But it is impossible to foretell with any precision what a particular individual's reaction to a particular noise will be. However, the statistical analysis of the results of social surveys makes it possible to discover how much noise of a particular kind the inhabitants of a given area are prepared to stand without serious complaint. It is clearly impossible to institute an elaborate social survey in every area where a noise problem arises; and one of the major steps forward in recent years has been the establishing of certain correlations between the characteristics of a noise that a physicist can measure and the degree of annoyance caused. Different correlations are required for different circumstances, and we found it necessary to institute a special survey near London (Heathrow) Airport, and to have various trials carried out involving judgments of the degree of annoyance by juries specially collected for the purpose. Much more work is required in this field.

THE MEASUREMENT OF NOISE

8. In dealing systematically with noise problems, sound-measuring instruments are essential. In problems involving the effect of similar noises, the readings on the instruments can often be used directly. In more complex problems it is necessary, as stated above, to use in addition the correlations between the physical characteristics of the noise and the degree of annoyance caused, which can be established through social surveys and other subjective measurements.

9. A description is given in Appendix II of various instruments, methods and units used in the measurement of noise. Very little of the subject matter of this Appendix is used in the main text of the Report, but, since we set out to make quantitative, and not merely qualitative, suggestions concerning the reduction of noise, we have been unable to avoid the use of the technical word "decibel", and a brief reference to this term is necessary.

10. When "decibels" are quoted in this Report, they are usually the readings on a particular kind of noise measuring instrument, the "sound level meter with A weighting" (see Appendix II) and are written dBA. To give some idea of what the readings mean in practice, the second column of Table I quotes the readings obtained in a number of familiar noise situations.

TABLE I

Noise levels of some typical sounds

Noise source or environment (*i*)	Sound level (dBA) (*ii*)	Relative loudness (sones) (*iii*)
Room in a quiet London dwelling at midnight ...	32	—
Soft whisper at 5 ft.	34	1·6
Men's clothing department of large store	53	7
Self service grocery store	60	10·6
Household department of large store	62	11·3
Busy restaurant or canteen	65	13
Typing pool (9 typewriters in use)	65	15
Vacuum cleaner in private residence (at 10 ft.) ...	69	17
Inside small saloon car at 30 m.p.h.	70	24
Inside small sports car at 30 m.p.h.	72	—
Inside small sports car at 50 m.p.h.	75	—
Inside compartment of suburban electric train ...	76	26
Ringing alarm clock at 2 ft.	80	34
Loudly reproduced orchestral music in large room ...	82	—
Printing press plant (medium size automatic)	86	56
Heavy diesel propelled vehicle about 25 ft. away ...	92	111

NOTE:—These figures are given merely as a rough guide; they are for the most part single measurements, and might be expected to differ by several decibels if repeated in similar situations.

11. It will be noticed that the decibel readings are by no means proportionate to one's impression of the "loudness" of these noises; the reading for the heavy diesel engined vehicle, for example, is only about three times that for a soft whisper. This may confuse the layman, so in the third column of the Table we show, wherever possible, the rating of each noise on a loudness scale in which the figures correspond approximately with a normal judgment of relative loudness. The heavy diesel propelled vehicle now appears as seventy times as loud as a whisper. The reasons why both these kinds of scales are necessary in acoustics are explained in Appendix II. It will be helpful to remember that a change of three decibels in the meter reading given by a noise is about the smallest which most people would think significant, and that an increase of 10 decibels in noise of the same kind corresponds approximately to a doubling of loudness.

SOURCES OF NOISE

12. Nearly all activity results in the production of noise of one kind or another, but the noises with which this Report is concerned are those which give rise to substantial complaints. Chief amongst these are the

noises from aircraft and motor vehicles. Other important sources of noise nuisance are manufacturing processes and entertainments and advertising.

13. A general point should be made here. Noise from machines is usually a by-product which represents the escape of only very little of their total energy output (for a jet engine, for example, only one thousandth). It is indeed fortunate for us that this is so; but it means that the most obvious method of noise control, i.e., the re-design of noise sources to emit less noise, may quite often be too difficult or too expensive to be practicable. To halve the energy escaping as noise from a machine may be very difficult and costly, but, if it is done, the sound level is reduced by 3 decibels, which is, as pointed out in paragraph 11 above, only just perceptible.

EFFECTS OF NOISE

14. Most of us will agree that the effects of noise are usually bad, though they are difficult to describe with any precision. We have given in Chapter II a general summary which refers to effects on health in its widest sense, and to effects on efficiency and on communication. We have also devoted a chapter (Chapter XIII) to a special case—the effects of long-continued intense noise, e.g. in causing industrial deafness.

THE MITIGATION OF NOISE

15. In considering the reduction of noise, which was our main concern, we had to examine the chain extending from generation of the noise, through its transmission, to its reception by the hearer, so that control of noise could be applied where that control is most effective and least hampering to the community as a whole.

16. Control at source is the best answer if it is possible; but often it is not possible, for technical or for financial reasons. Nevertheless the opinion we have formed from the evidence given us is that much more could be done to quieten machines and processes in general.

17. Failing a quieter source, noise may be controlled by absorbing it during transmission, e.g. by enclosure. This brings us to the wide questions of building construction, screening and the like; present technical knowledge of these subjects is usually satisfactory, but is not always efficiently applied.

18. If the noise cannot be quietened at source, nor enclosed, then perhaps it can be kept at a distance. This brings us to considerations such as town planning and the control of aircraft flight paths, so that as few people as possible may be disturbed.

19. Finally we have the drastic remedy of prohibition. Beyond a certain point the community may have to decide that a certain noise is intolerable and must be prohibited at any cost.

THE DISSEMINATION OF INFORMATION

20. There is a considerable amount of evidence that, as living standards rise, people are less inclined to tolerate noise. On the other hand, a noise nuisance has to be very great before most people will take it upon themselves to make a formal complaint to a local authority, the police or a magistrate. Very often, the noise nuisance could readily have been avoided if only the people concerned had been aware that a particular noise could cause a nuisance. For example, we were told in evidence that some manufacturers had never considered noise in designing their products; their customers had assumed that the noise was inevitable and had never asked for quieter machines. If quietness were more often sought after by the public in domestic and industrial machinery, we have little doubt that the demand would in time be met.

21. As another example of ignorance, we noted that noise from neighbours is an important source of complaints, yet there are very few people who, when buying a new house or moving into a new flat, would think of asking about the standard of sound insulation.

22. As we point out at various parts of our Report, it is often much easier to take steps to avoid annoyance when planning some new project than to cure a noise nuisance once it has occurred. We therefore consider that an essential step in mitigating the problem of noise is to keep the public informed as to which noise nuisances are readily avoidable, and to disseminate existing knowledge more widely to technicians and professional men who have to deal with noise problems.

RESEARCH AND TRAINING

23. Our detailed examination of a large number of noise problems has convinced us that, while many of them could be dealt with by using existing knowledge, others could not, either because no means are known to reduce the noise or because an adequate reduction would, at present, be too expensive to be practicable. In our Report we recommend research to try to fill a number of the gaps in existing knowledge, but we realize that the facilities and numbers of trained persons which exist to do this work are relatively small. Basic and applied research work in noise problems is being conducted in a number of Government and industrial establishments and in a few Universities, but the number of skilled scientists engaged in the work is meagre.

24. Training in acoustics has traditionally been the prerogative of Physics Departments of our Universities, but interest in the subject has declined, because most of the fundamental physics of acoustics was established many years ago. The important acoustical problems which remain are of an essentially applied nature, which have less interest for the physicists than fundamental work in other fields. One would have expected that the technological aspects of acoustics would have found their way into courses of applied physics, engineering and architecture in Universities and Technical Colleges. But this has not happened, and at the present time there is not a single chair of acoustics in the country.

Any large increase in research into problems of acoustics must, therefore, imply a change in the teaching of applied acoustics in Universities and Technical Colleges, and the establishment of significant and well supported research schools in suitable institutions.

25. Some instruction is essential, too, for the members of the several professions which touch, at one point or another, on noise problems. Such problems can generally more easily be avoided than cured. Architects, civil engineers, mechanical engineers and many other professional men and technicians should, therefore, be sufficiently trained in acoustics to be able to foresee where noise would be a problem and to find ways of avoiding it. The officers of local authorities too, require some training if they are to be able to play a fully effective part in the enforcement of noise abatement.

THE COST OF NOISE AND OF ITS CONTROL

26. It has sometimes been suggested that some measurable figure of noise intensity might be accepted as a universal limit towards which all noise control might be directed. If this were so, our task would have been to find technical solutions to well defined problems. But neither experience nor experimental evidence supports this suggestion. Average judgment of the noise intensity which corresponds with the boundary between " tolerable " and " annoying " or " unacceptable " is found to vary with circumstances over very wide limits (see Chapter II, paragraphs 40 and 41). We have, therefore, had to base our recommendations on what we consider to be the best compromise between the reduction in annoyance and the cost of obtaining it.

27. We have in only a few instances been able to attempt to assess the precise cost of noise or of its control. It is, however, clear that the price of sweeping measures to bring about large reductions of noise quickly would not be acceptable to the community, since the main sources of noise are the machines for the production and distribution of goods which are the source of our material prosperity. In making our detailed recommendations we have, therefore, had to satisfy ourselves that the cost would be small in relation to the benefit gained.

28. In many cases the cost of noise reduction is not entirely financial. Measures to reduce noise often involve a restriction of the liberty of the noise maker. However, we must recognise that, almost always, those who make noise intrude upon others, and not vice versa. In our judgment the present level of noise in our community is such that some additional cost in money and in restriction of liberty to make noise is justified to prevent further increase and, in time, to achieve some reduction.

Chapter II

The General Effects of Noise

INTRODUCTION

29. An important part of our work has been to consider the effects of noise on people, in particular on their health and efficiency. We have found it convenient to discuss the general effects in the present chapter, and to deal later (Chapter XIII) with the effects of occupational exposure to noise of particularly high levels. A selected bibliography is given in Appendix III.

30. What are these general effects? Noise may have an influence on health in many ways, for example, by preventing sleep or inducing stress; it may interfere with specific activities such as communication, education and recreation; it may disturb concentration, and perhaps affect the efficiency of someone working at a difficult or skilful task; it may affect personal safety. At different times it may produce anything from exhilaration to acute irritation in the same individual. We will briefly discuss these possibilities in turn.

EFFECTS ON HEALTH

31. There are many definitions of health, but here perhaps the most appropriate is that used by the World Health Organisation:—

> "Health is a state of complete physical, mental and social well-being, and not merely an absence of disease and infirmity."

For the most part, people's well-being is diminished by noise, so in this sense of the term there is no doubt that noise affects health.

32. Of all effects, repeated interference with sleep is least to be tolerated because prolonged loss of sleep is known to be injurious to health. In the evidence offered to us we heard of many distressing cases where external noise prevented sleep. In the social survey of people living near London Airport (see Chapter VIII) 22 per cent. said that they were sometimes kept from going to sleep by the noise of aircraft, and the proportion rose to more than 50 per cent. with very high levels of noise. A still higher proportion, also increasing with noise intensity, complained that they were sometimes awakened by the noise. It is especially important to diminish noise during the earlier part of the night, because experiments have confirmed the generally accepted fact that during the later phase of deep sleep even loud noises have less effect in wakening the sleeper.

33. In a more restricted sense, however, we have not been able to find any evidence that moderate noise (by which we mean the noise normally met with domestically and socially, specifically excluding the intense noise discussed in Chapter XIII) produces any direct and measurable physiological effect on the average person. The general effect of noise on health must therefore be more psychological than physical; and we are led to consider

those reactions to irritating or disturbing noise which are called, for brevity, " annoyance ".

ANNOYANCE AND ITS ASSESSMENT

34. The annoyance due to noise may perhaps be thought of essentially as the resentment we feel at an intrusion into the physical privacy which we have for the moment marked out as our own, or into our thoughts or emotions. From another point of view, the annoyance may be ascribed to the " information " which sounds may carry from the source to the recipient. The physical energy in the noise of a creaking door, a crying baby, or a distant party may be very small, and if distributed in the form of random noise probably would be quite unnoticed. But it may convey manifold suggestions of alarm, neglect, sadness, loneliness; and so in some people it has an emotional effect out of all proportion to its physical intensity. It is obvious that there are no means of freeing a community completely from noise annoyance arising from such causes.

35. When we consider problems of public health such as smoke abatement it is very desirable to find a physical quantity—e.g. a measure of the opaqueness—which may be used in defining a point beyond which a nuisance may be said to exist, and may, therefore, perhaps be used as the basis of control. It is particularly difficult to do this for noise. It is true that for many noises annoyance increases with loudness; but the annoying effects of a number of noises, all equally loud, will depend much more on the personality of the recipient than on the character of the noise. It seems inconceivable that an " annoyance meter " should ever be designed which would be of practical use to the legislator, or that any universal scale of measurement could be introduced, other than that of normal common sense and consideration for others, by which the pleasure of a minority in some noisy pursuit could be balanced against the pain of a quieter majority.

36. The most readily available indication of annoyance in a community is complaint, and we obtained valuable information from Government Departments, local authorities and other sources about the numbers and types of complaints received. For example, a questionnaire that we sent to a number of local authorities showed that in 1960 seventy-two authorities (and the police in their areas) received 2,350 complaints. The types of noise complained of are shown in the following table:

TABLE II

Complaints received by local authorities

Source of noise (*i*)	Number of complaints (*ii*)
Motor vehicles	498
Railways	4
Boats	2
Aircraft	141
Factories, etc.	454
Construction and demolition ...	112
Agriculture	13
Domestic	680
Entertainment and advertising ...	446

Some of these complaints were not considered justified by the local authorities who received them.

37. Although this information enabled us to form a picture of the types of noise that caused complaint, we do not think that it always gives a reliable guide to the number of people who are annoyed, nor to the degree of their annoyance. For instance, many people who are annoyed do not complain, for one reason or another, although they may be disturbed as much as those who do complain. Nor is there any means of assessing the seriousness of a complaint or the weight which should be attached to complaints from representative bodies compared with those from individuals. Neither do returns of numbers of complaints necessarily give the correct impression of the relative importance of different noise sources as causes of noise nuisance. For instance, 118 of the complaints about aircraft noise shown in the table above were received by one local authority which owns the local airport. Generally, complaints about aircraft are probably not made to local authorities.

38. Social surveys, on the other hand, can give a better guide. By a careful sequence of questions degrees of annoyance can be assessed and irrelevancies disentangled. One such survey was already planned when we began work; this was carried out as part of a noise survey of London by the Building Research Station and the London County Council. Another social survey, in the vicinity of London (Heathrow) Airport, was undertaken at our request. We refer to the results of both these surveys in the appropriate chapters of our Report.

39. These surveys have given us a general picture of the extent of noise annoyance in the areas in which they were carried out, and a more detailed picture of the annoyance caused by aircraft noise near London (Heathrow) Airport. From the results of this survey it was found that the reaction of people who had complained about the noise was not greatly different from that of people who were seriously annoyed but had not complained. Elsewhere in our Report we have often had to rely on complaints as our measure of annoyance, in the absence of any better yardstick.

40. It is interesting to note that the evidence we have received on the effect of noise has at several points involved assessment on some psychoacoustical scale of "annoyance" or "intrusiveness;" and that properly conducted statistical experiments can lead to fairly definite conclusions about the response of the "average" listener in particular circumstances. The experiments to which we refer were carried out in the course of investigations of particular kinds of noise—they are mentioned here, but are described in greater detail in the appropriate chapters of this Report. They are as follows:

(*a*) in the investigations of motor vehicle noise (see Chapter VI), juries were asked to assess a large number of vehicles as "quiet," "acceptable," "noisy," "excessively noisy;"

(*b*) in the experiments carried out at the Farnborough Air Show (see Chapter VIII) several investigations were made. In two of these, judgments were on a scale including the words "noticeable," "intrusive" and "annoying;" in another, the words "quiet," "moderate," and "noisy" were used. The conditions were indoors and out of doors, with and without distracting tasks;

(*c*) as part of the general survey of noise at a network of points over London (see Chapter IV) a selected sample of occupants of houses were asked to assess the noise at their front doors on the scale ... " extremely loud, very loud, fairly loud, not loud at all; " and

(*d*) during the survey of noise conditions round London Airport (see Chapter VIII), the people interviewed were asked to assess in various contexts the noise they usually heard from aircraft and other sources.

41. The results of the survey mentioned at paragraph 40(*d*) above have been used to formulate an index (Noise and Number Index) of noise exposure in the discussion of aircraft noise in Chapter VIII. Some features of the other assessments have been reproduced in a graph in Appendix IV. It is clear from this graph that, while any group of results is reasonably consistent within itself, there are very considerable differences between these results when different circumstances are compared. Thus it appears that a group of observers, asked to say whether a motor vehicle is " acceptable " or " noisy " at the roadside in the open, will make the distinction somewhere about 80 dBA on a sound level meter. For aircraft overhead in the open, they will distinguish between " intrusive " and " annoying " at about 100 dBA; but indoors, engaged on watching a film programme, they will make this distinction at some 84 dBA. At the door of their homes, however, they will call a general background of 60 dBA " not loud," and 70 dBA " very loud."

42. These results emphasise that criteria of judgment in this difficult field of enquiry are very much a matter of circumstance, and that no simple single-figure measurement can be laid down to specify the nuisance of a noise. It certainly appears that the normal person, when asked to assess the noise of a motor-car or an aircraft, makes his judgment on what his previous experience leads him to regard as " average," or what some unknown factors lead him to regard as " reasonable; " he does not carry round with him some absolute standard of annoyance or acceptability applicable to all classes of noise and to all circumstances. This is perhaps not a surprising result; the same would presumably apply to his standards of polite behaviour, his estimate of what constitutes a hard day's work, and many other things.

43. We should comment also on the remarkable extent to which a noise, originally annoying or disturbing, becomes tolerated and even unnoticed by most people when it has become sufficiently familiar. Without this convenient process of adaptation, resentment against noise in modern society would be much greater than it is at present. Nevertheless, there are some people who are more sensitive than most to noise and who, we fear, can only be advised to live and work away from it if possible.

MENTAL HEALTH

44. Granted that noise causes much annoyance, it might be expected that in many cases mental or nervous illness would result; and this was often suggested to us in our enquiries. Nevertheless, we found very little specific evidence to support this view. In talking, for example, to medical practitioners with practices in the vicinity of a major airport, we heard of only one patient whose mental illness was attributed by his doctor to the noise to which he was exposed, and these practitioners had no evidence that

the consumption of sedatives and hypnotics was greater in their areas than in other areas where they had practised.

45. We are unaware of any reliable studies of the effects of noise on the mental health of an ordinary population. We were informed that a study by the United States Navy on the effect of noise on the crews of aircraft carriers included careful examination of psychological effects, but that no discernible effects were found. Jansen, who studied the effects of noise on steelworkers in Germany, reported only one significant result in studies involving personality, which was a higher degree of complaint of domestic difficulty among people who work in intense noise. Even this result might be attributable to a number of causes not directly concerned with noise: it could, however, indicate increased irritability among the people studied.

46. It might be expected that annoyance from noise might, in some people, precipitate a mental disturbance or disorder to which they are predisposed. As far as we are aware, the only relevant investigation that has attempted to explore this possibility is that conducted by the United States Navy. Although the results of this investigation were negative, showing no psychological upsets, it should be borne in mind that the crews of aircraft carriers do not provide a typical cross section of the population.

EFFECTS ON COMMUNICATION

47. One of the commonest and, therefore, most undesirable effects of noise is its interference with communication based on sound—such as conversation, the use of the telephone, and the enjoyment of radio and television programmes—with all that this implies in the disturbance of business efficiency and domestic life.

48. It is possible to make a fairly accurate measure of the background noise permissible, in a variety of conditions, before intelligibility of speech is seriously affected. A criterion called "Speech Interference Level" has been proposed, and widely used, which specifies the permissible levels of interfering noise levels (e.g. in offices) in terms of measured sound pressures in octave bands. (See, for example, ref. 1. Similar criteria are now being proposed for international adoption.) We have adopted criteria based upon speech interference in discussing noise from building operations (Chapter X).

49. One of the most important forms of communication is teaching; and it is appropriate to mention here the disturbing evidence which we received about the effects of aircraft noise on the schools in the neighbourhood of London (Heathrow) Airport. This is discussed in Chapter VIII, in the larger context of the problem of aircraft noise. It is clear from the evidence given that in those schools which are close to aircraft flight paths the normal process of education is being seriously handicapped by noise.

EFFECTS ON WORKING EFFICIENCY

50. The problem of whether or not noise has any effect on the performance of tasks has been the subject of investigation, both in the laboratory and in field experiments, for many years. However, the evidence that we have received shows that no general conclusions have yet been reached.

51. Some experiments in industrial situations have shown that a marked improvement in speed of work has occurred when the noise level of the working environment was reduced. However, in some of these experiments the higher rate of work has been maintained when the noise level has been restored to its original value or the workers in the quietened rooms have been moved into rooms in which the noise level has not been reduced. The conclusion to be drawn from these experiments is, therefore, that the improvement in output arose from increased morale resulting from the workers' realisation that an interest was being taken in their working conditions, and not, directly, from the reduction in noise.

52. Both field experiments and laboratory experiments have, however, shown that noise above about 90 dB causes a significant increase in the number of errors made, particularly after the subject had been working for some time in noise. This effect seems to be produced even in people who are accustomed to the noise.

53. It has also been shown that the effect of noise upon the number of errors committed varies with the conditions of work and the state of the subject. Noise heightens arousal; hence, if people are short of sleep and are doing undemanding work of a routine nature, noise may, by arousing and stimulating them, actually diminish the number of errors made. On the other hand, if people are doing work which, by its nature, already maintains a state of alertness, a loud noise may cause them to become jittery and make more errors. This result supports the general experience that routine work is less affected by a loud noise environment than is work of an exacting kind.

54. None of these effects has so far been found in noise of less than 90 dB. but above this level they are thought to be about the same for continuous and for intermittent noise.

55. The general conclusion from the experiments quoted in the preceding paragraphs, that there is no clear evidence of loss of efficiency at work from moderate noises, will strike some people as surprising. Many, perhaps most, ordinary people would say that their depth of concentration, business efficiency, output, etc., is affected by noises well below the 90 dB level mentioned above. This commonsense opinion must be respected even if it is not supported by such carefully controlled experiments as have so far been made.

56. This field of research presents many difficulties; the experimental situation often fails to reflect the real-life situation, in which the average person works, normally, well below his maximum efficiency and is responding to many stimuli besides that of noise. It is hard to plan experiments, or to find facilities for carrying them out, such that the results will be really convincing and applicable to everyday working conditions. Nevertheless, we feel that more research is needed on these interesting and important problems, and we recommend that industry and the appropriate research bodies should be encouraged to carry out further experiments, both in the factory and in the laboratory, on the effect of noise on efficiency.

EFFECTS ON THE INCIDENCE OF INDUSTRIAL ACCIDENTS

57. We have been able to obtain little evidence on the effects of noise upon the incidence of industrial accidents. It is clear that loud noise may mask audible warning signals, or shouts, and the approach, for example, of trolleys and other moving objects. The use of warning devices which do not rely upon audibility should, therefore, be encouraged where hazards exist in noisy situations. We should also expect sudden noises to have a potential danger in particular places, e.g. where a man might fall if startled, though, of course, actual danger should be rare if factory safety regulations are fully applied.

58. The effect of noise upon the rate of occurrence of accidents caused by errors, distraction or inattention resulting from the psychological effects of noise, has not been studied in industry because the number of accidents in any one work-place is usually too small for statistically significant results to be obtained. It seems reasonable to suppose, however, that if high noise levels increase the number of errors in work, they will also cause errors in safety measures and, consequently, that high noise levels may cause a higher rate of accidents than would occur in quieter conditions.

Reference

[1] BERANEK, L. L. Criteria for office quieting based on questionnaire rating studies. *J. Acoust. Soc. Amer.* 28, 833. 1956.

Chapter III

The Law Relating to Noise

59. There is a considerable body of law relating to noise. Some of it applies generally and some to particular noises. We propose to outline the general law here. More detailed discussion of some aspects of the general law, of local Act powers and of regulations and byelaws which relate to particular noises will be found in the appropriate chapters.

COMMON LAW

60. Noise can be the subject of a civil action for nuisance at Common Law. Nuisance has been defined as the wrong done to a man by unlawfully disturbing him in the enjoyment of his property. The disturbance may take the form of injury to property or interference with personal comfort. The wrong does not involve a direct physical interference like trespass; in relation to personal comfort it must not merely cause transitory disturbance but also substantially interfere with health, comfort or convenience. The following quotation from the judgment of Mr. Justice Luxmoore in the case of Vanderpant v. the Mayfair Hotel Company Limited (1930) expands this definition with particular reference to noise nuisance:

> "Apart from any right which may have been acquired against him by contract, grant or prescription, every person is entitled as against his neighbour to the comfortable and healthful enjoyment of the premises occupied by him and in deciding whether, in any particular case, his right has been interfered with and a nuisance thereby caused, it is necessary to determine whether the act complained of is an inconvenience materially interfering with the ordinary physical comfort of human existence not merely according to elegant or dainty modes and habits of living but according to plain and sober and simple notions obtaining among English people."

61. In England and Wales the remedy sought in an action for nuisance at Common Law is an injunction restraining the defendant from continuing the nuisance. Sometimes damages are sought in addition. If proceedings are brought in a County Court it is necessary for the plaintiff to claim damages as well as an injunction, since otherwise the court has no jurisdiction. In Scotland the corresponding remedy is an action for interdict or for interdict and damages: such actions may be brought in the Sheriff Court or in the Court of Session and it is not necessary in either case to claim damages as well as interdict. There have been many decisions by the courts granting injunctions or interdicts restraining various types of noise including the ringing of church bells, singing, holding noisy entertainments and bringing together disorderly crowds, using a steam organ in connection with a merry-go-round, and making an excessive noise in carrying on a trade.

serve notice on the author of the nuisance or, if he cannot be found, on the occupier or owner of the premises on which the nuisance arises. The notice requires the cessation of the nuisance and the execution of such works or other things as may be necessary for that purpose. If the notice is not complied with, the local authority may apply to the sheriff for its enforcement provided that they can produce in support of their action either written representation from at least three aggrieved occupiers of land or premises, or a medical certificate. Under the Public Health (Scotland) Act, 1897, as read with the Noise Abatement Act, 1960, proceedings may be taken only by a local authority.

THE DEFENCE OF THE BEST PRACTICABLE MEANS

68. Sub-section (3) of Section 1 of the Noise Abatement Act provides that in any proceedings under the Act for statutory nuisance from noise caused in the course of a trade or business, it is a defence for the defendant to prove that the best practicable means have been used for preventing or counteracting the effect of the noise. This provision of the Noise Abatement Act must be read together with Section 110 of the Public Health Act, 1936, which provides that, in deciding whether the best practicable means have been taken for preventing or for counteracting the effect of a nuisance, a Court shall have regard to cost and to local conditions and circumstances. There is no Scottish provision strictly comparable to Section 110 of the 1936 Act, but it is implied in Scottish legislation that considerations of cost, etc., are relevant and there is no evidence that any different approach is adopted on the two sides of the Border. This defence of the best practicable means is not available in a civil action for nuisance at Common Law. In the case of Walter v. Selfe (1851) the judge said " the making or causing of such a noise as materially interferes with the comfort of a neighbour, when judged by the standard to which I have just referred, constitutes an actionable nuisance, and it is no answer to say that the best known means have been taken to reduce or prevent the noise complained of or that the cause of the nuisance is the exercise of a business or trade in a proper manner ".

STATUTORY UNDERTAKERS

69. Sub-section (4) of Section 1 exempts statutory undertakers from the provisions of Section 1. We were informed that the local Acts which provided the precedent for Section 1 of the Noise Abatement Act contained an exemption for railway undertakers and that it was felt to be logical to extend this to all statutory undertakers in the Noise Abatement Act. The argument for exempting statutory undertakers is that they have a statutory obligation to serve the public, and that in some instances what they do may necessarily be noisy. This exemption does not exist in Common Law, under which statutory undertakers must exercise their statutory powers in such a way as to avoid noise nuisance, unless they can show that what Parliament has authorised them to do must inevitably give rise to noise.

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AIRCRAFT

70. Section 1(7) of the Noise Abatement Act exempts aircraft noise from the provisions of the section. The law relating to aircraft noise is discussed in Chapter VIII (Aircraft Noise). The major difference from the law relating to other noise is that, in general, there is no right of legal action for nuisance from aircraft noise.

LOUDSPEAKERS

71. Section 2 of the Act limits the operation of loudspeakers in the streets. Sub-section (1)(*a*) prohibits their use for any purpose between 9 p.m. and 8 a.m.; sub-section (1)(*b*) prohibits their use at any time for advertising any entertainment, trade or business. The penalty for contravening any of these provisions is a fine on summary conviction not exceeding £10. Sub-section (2) and (3) contain a number of exemptions from sub-section (1). The only controversial aspect of this section concerns the use of loudspeakers for advertising, and our views on this are contained in Chapter XI (Entertainment and Advertising Noise).

THE PRESENT WORKING OF THE ACT

72. The Noise Abatement Act came into force on the 27th November, 1960. To ensure that we received the most up-to-date information of the working of the Act we sent a questionnaire to all local authorities in Great Britain. The replies showed that local authorities had dealt with several thousand cases of alleged noise nuisance since November, 1960. In the overwhelming majority of these cases abatement has been secured by informal action without need to issue abatement notices or to take proceedings. Indeed, in most instances it seems that people making noise co-operate readily when they know that it is causing complaints. There is no doubt, however, that in dealing informally with alleged noise nuisances local authorities have been helped by the Noise Abatement Act, although many of them already had similar powers in local Acts.

73. The local authorities' replies showed that, while they welcomed the Act, they felt that there were a number of ways in which it could be improved. Among the specific matters which cause most concern or difficulty to local authorities are the defence of the "best practicable means" and other problems of dealing with industrial noise; the exemption of statutory undertakers from the provisions of Section 1 of the Act; the absence of prescribed standards of what constitutes noise nuisance; the exemption of noise from aircraft from the provisions of Section 1 of the Act; the problems of vehicle and traffic noise; and the use of ice cream chimes. These matters are discussed in other chapters of our Report.

PROPOSED CHANGES IN THE LAW

74. We consider that the main aim of legislation against noise should be prevention, and we have approached our task with this in view. There must, however, be remedy in law where prevention fails or is inapplicable for one reason or another. The law relating to nuisance is this remedy, and in general we can see no alternative to it. The factors which govern

whether or not a noise is a nuisance are so many and so subtle that it is possible in only a few instances to attempt to fix a quantitative limit to noise. Where it is practicable with present knowledge we have recommended such limits.

NOISE ABATEMENT ACT, 1960

75. Our views on a number of matters relating to the Noise Abatement Act, are contained in the following paragraphs.

Complaint to a Justice of the Peace in England and Wales

76. The requirement that in the case of noise nuisance a complaint to a Justice of the Peace must be made by at least three occupiers of land or premises before proceedings can commence (except when the proceedings are initiated by a local authority—see paragraph 64) is intended to prevent vexatious proceedings, which is especially important in view of the subjective nature of noise nuisance. In theory, it appears that the safeguards for an aggrieved individual who cannot find two neighbours to join with him in a complaint to a Justice of the Peace are civil action and the local authority's power to take proceedings whether or not they have received a complaint. However, some local authorities are reluctant, other than in flagrant cases, to use their powers where a nuisance is alleged by an individual against his neighbour. These local authorities consider that, generally, they should use their powers in cases of public nuisance and not where the alleged nuisance involves a dispute between neighbours. While we understand the point of view of these authorities, the fact that these domestic noise nuisances often affect only one or two households makes it impossible for an aggrieved individual to obtain redress under the Act unless the local authority take action for him. Other local authorities feel that the requirement that at least three aggrieved persons must complain to a magistrate is undesirable and an unnecessary safeguard because, in practice, people are reluctant to take, or even be witnesses in, legal proceedings against their neighbours. We have considered whether the balance of advantage lies in the present provisions of the Act or in empowering single individuals to initiate proceedings by complaint to the magistrate. We have concluded that there is, as yet, insufficient experience of the working of the present provisions of the Act to justify disturbing them.

Service of Noise Abatement Notice

77. Under Section 93 of the Public Health Act, 1936, a local authority must be satisfied of the existence of a statutory nuisance before serving an abatement notice. They cannot, therefore, serve a notice where a nuisance has ceased, even if they are satisfied that it has ceased only temporarily and is likely to recur. In Scotland a local authority may serve a notice " notwithstanding that the nuisance may for the time have been removed, if the local authority consider that it is likely to recur on the same premises " [Section 20(2) of the Public Health (Scotland) Act, 1897.] The Scottish powers greatly strengthen the local authorities' hands in dealing with intermittent noise nuisance, and we recommend that local authorities in England and Wales should also have power to serve an abatement notice where they are satisfied that a noise nuisance which has been abated is likely to recur on the same premises.

Speed of Proceedings

78. In England and Wales, from the time that information for a summons has been laid it may take six weeks or even longer before a case under the Noise Abatement Act is heard by the Magistrates. In our view there are instances where this delay may cause serious hardship to the persons who are aggrieved by the nuisance, e.g. loud noise at night from machinery in a factory which had previously been quiet at night may prevent nearby residents from getting reasonable rest. Moreover, where a summons is taken out by a local authority, the subsequent delay before the case is heard is additional to the time which must elapse while the authority's officers investigate the complaint and, perhaps, the authority or a committee authorise action. A local authority have power to take civil action for nuisance from which the authority have suffered no damage, but a similar time may elapse before a decision to seek an injunction is made. We can, therefore, see no way in which, in practice, an aggrieved person may obtain quick amelioration of a noise nuisance, however inconsiderate its perpetrator may be and whatever its effect on the sufferer, unless he has the financial means himself to seek an injunction at Common Law. We recommend, therefore, that local authorities, and the Courts, should be encouraged to deal with noise nuisance cases as quickly as possible, and that a further review of the time taken for such cases to be settled should take place within five years.

Penalties under the Noise Abatement Act

79. In England and Wales the present maximum penalties in statutory nuisance proceedings under the Noise Abatement Act are a fine of up to £5 on conviction for failing to comply with an abatement notice, and a fine of up to £5 followed by continuing daily fines of 40s. for failure to comply with a nuisance order made by the Court. In Scotland the penalties can be greater: as in England and Wales, the maximum penalty for failing to comply with an abatement notice is £5, but the penalty for non-compliance with, or infringement of a decree by the Sheriff for removal of a noise nuisance may be a fine not exceeding £5 for the first offence, not exceeding £10 for the second offence, and for each subsequent conviction a sum not exceeding double the amount of the penalty in the last preceding conviction, but no penalty shall exceed £200: there is also provision for a continuing fine of 20s. per day during the infringement of interdict against recurrence of noise nuisance, although we were advised that there is some doubt whether this penalty would be additional to the fines on conviction.

80. We are convinced that the penalties in England and Wales are quite inadequate, particularly in the case of a substantial industrial firm which may stand to gain more from ignoring notices by the local authority and orders by the Court, than the amount of the fines. Although the local authority can, where the Court's Order is not complied with, themselves abate the nuisance, for example, by carrying out appropriate works, we do not think that this power is of much practical value in the case of most noise nuisances. We recommend, therefore, that in England and Wales there should be substantial increases in both maximum initial penalties and the maximum daily fines for failing to comply with Court orders.

CHANGES REQUIRED BY OTHER RECOMMENDATIONS

81. It seems to us that a number of the recommendations in other chapters might require changes in the present law. These recommendations are:

(*a*) the specification of maximum noise limits for motor vehicles—Chapter VI;

(*b*) the further restriction on the use of motor horns in built-up areas—Chapter VI;

(*c*) that grants should be paid for improving sound insulation in dwellings close to London (Heathrow) Airport—Chapter VIII;

(*d*) that dwellings built close to Heathrow should be required to have a high degree of sound insulation—Chapter VIII;

(*e*) that local authorities should be empowered to require adequate structural precautions in some types of new buildings to minimize the possibility of nuisance from noise transmitted from them—Chapters IX and XI;

(*f*) the registration of specially noisy industrial processes—Chapter IX;

(*g*) the removal of the exemption of statutory undertakers from proceedings under the Noise Abatement Act—Chapter IX;

(*h*) that efficient silencers should be used on the internal combustion engines in construction and demolition plant and agricultural machinery —Chapters X and XII;

(*i*) that the approval of the local authority should be required for the use of particularly noisy processes on construction and demolition sites—Chapter X;

(*j*) that the approval of the local authority should be required to hold noisy events such as motor-cycle scrambles and pleasure fairs—Chapter XI;

(*k*) that there should be more detailed control of the use of loudspeakers on vehicles used for the conveyance of perishable commodities for human consumption—Chapter XI;

(*l*) the restriction on the use of power saws without efficient silencers—Chapter XII; and

(*m*) the specification of maximum noise limits for motor lawn-mowers—Chapter XII.

82. Comment is needed on (*a*) and (*h*) above. The present Regulations concerning noise from motor vehicles are given in Appendix VI. They rely upon qualitative terms to define standards of engine exhaust silencing and it has proved difficult to enforce them. We have, therefore, thought it necessary to recommend that numerical limits should be imposed (see Chapter VI). In other parts of our Report we have recommended that certain internal combustion engines should be fitted with "efficient" silencers, without attempting to define "efficient." These recommendations may seem inconsistent, but the present Regulations concerning motor vehicles have undoubtedly been helpful in restraining their noise, and, though we think these now need strengthening, we feel that somewhat similar provisions relating to other engines, e.g. for powered plant used on construction and demolition

sites, would be helpful until numerical noise limits can be defined, or would be sufficient in view of the small amount of noise annoyance caused, e.g. by agricultural machinery.

83. At a number of points in our Report we recommend voluntary action to control noise, or suggest criteria for noise from certain sources for the guidance of the authorities and industries concerned. When there is experience of these measures it may be possible and desirable to give some of them legislative force.

84. A substantial amount of annoyance results from noise which is caused by thoughtlessness and by irresponsible behaviour. There are many examples of which, perhaps, two will suffice as illustrations: there are frequent complaints about noisy behaviour by people leaving clubs and other places of entertainment late at night; building workers sometimes handle such things as metal scaffolding without regard to the noise they are making. It is very difficult to frame legislation to deal with this, but if experience shows that the increasing awareness of noise and the further measures that we recommend for its mitigation do not reduce this type of noise, we recommend that consideration be given to general legislation making it an offence for anyone to make in any public place unnecessary noise which might give reasonable cause for annoyance to other persons.

Chapter IV

Noise in Towns

THE LEVELS OF NOISE IN TOWNS

85. Although it is obvious that the noise problem is most acute in large towns, it was by no means clear to us at the beginning of our deliberations how many people are seriously disturbed by noise, and by what types of noise. A social survey of noise in homes was carried out in 1948 by the Central Office of Information for the Building Research Station (ref. 1). A survey of noise in semi-detached houses was made in 1951 (ref. 2) and of noise in flats in 1953 (ref. 3). The reports of these surveys contain much valuable information, but we felt that, by themselves, they were insufficient for our purposes. We were, therefore, fortunate that when we began work the Building Research Station, the London County Council and the Central Office of Information were planning a special investigation of the noise levels at 540 points equally spaced over 36 square miles of Central London, and of the reactions of the inhabitants to the noise. This was carried out in 1961–62.

86. The results at about 400 points of the survey have been analysed, and the most important conclusion is that at 84 per cent. of these points noise from road traffic predominated. Industrial noise was dominant at 7 per cent. of the locations, railway noise at 4 per cent., and building operations at 4 per cent., with 1 per cent. unclassified.

87. At the 84 per cent. of the points where road traffic noise predominated, the noise level varied considerably with the district and with the time of day. This is shown by the figures in Table III.

88. In particular places, the predominant noise was due to other causes than road traffic. The causes and levels were as follows:

89. Railway noise was naturally the predominant noise very close to a railway line, where the noise level may reach 80 or 90 dBA. Railway noise was also audible at points in the groups C to F which were not close to a line.

90. Industrial noise was predominant at 7 per cent. of the measuring points, though half of these were in dock areas where there were no houses within audible distance. The louder noises seldom exceeded 60 to 70 dBA, so that industrial noise would have been masked by traffic noise at points in groups A and B.

91. The noise due to building operations and roadworks was significant at 4 per cent. of the measuring points. The louder noises had an average level of 65 to 75 dBA during the day, and the operations ceased at night. (The relative positions of the measuring points and of the sites from which these noises came are not accurately known. The measurements should

TABLE III

Range of noise levels at locations in which traffic noise predominates

Group	Location	Noise climate (in dBA)*		Percentage of the total numbers of points measured falling in each group
		Day (8 a.m.–6 p.m.)	Night (1 a.m.–6 a.m.)	
(*i*)	(*ii*)	(*iii*)	(*iv*)	(*v*)
A	Arterial roads with many heavy vehicles and buses (kerbside)	80—68	70—50	4
B	(i) Major roads with heavy traffic and buses (ii) Side roads within 15–20 yds. of roads in groups A or B(i) above	75—63	61—49	12
C†	(i) Main residential roads (ii) Side roads within 20–50 yds. of heavy traffic routes (iii) Courtyards of blocks of flats, screened from direct view of heavy traffic	70—60	55—44	17
D	Residential roads with local traffic only	65—56	53—45	18
E	(i) Minor roads (ii) Gardens of houses with traffic routes more than 100 yds. distant	60—51	49—43	23
F	Parks, courtyards, gardens in residential areas well away from traffic routes	55—50	46—41	9
G	Places of few local noises and only very distant traffic noise	50—47	43—40	1
			Total	84%

* By noise climate is meant the range of noise level recorded for 80 per cent. of the time. For 10 per cent. of the time the noise was louder than the upper figure of the range and in the case of Group A attained peak levels of about 90 dBA: for 10 per cent. of the time the noise was less than the lower figure in the range.

† In Groups C to F, noise from other sources, such as trains or children's voices, predominated over road traffic noise at particular times, but traffic was the most frequent noise source.

not, therefore, be compared with the limits for noise from construction and demolition sites which are proposed in Chapter X.)

92. Aircraft noise was only noticed at points in the south west quadrant of the area surveyed and then only at points where the noise from other sources was less than 60 dBA.

DATA ON NOISES WHICH ANNOY PEOPLE

93. In the 1961–62 London Survey a sample of approximately 1,400 people were questioned about noise and its importance relative to various other factors. Table IV overleaf summarises the answers given by these people to the question " If you could change just one of the things you don't like

about living round here, which would you choose?" and thus shows the relative importance, for Central London, of the various factors mentioned. The answers to this question which were given in a survey in the vicinity of London (Heathrow) Airport (see Chapter VIII) are similar apart from the greater prominence of aircraft noise.

TABLE IV

Relation of noise to other factors

The one thing that people most wanted to change (*i*)	The percentage of people who wanted to change it (*ii*)
Noise	11
Slums/dirt/smoke	10
Type of people	11
Public facilities/transport/council	14
Amount of traffic	11
Other facilities/shopping/entertainment ...	7
Other answers	1
No answer, or vague reply	5
Would change nothing	30

94. The survey showed, as might be expected, that people are more disturbed by intrusive noise when they are at home than when they are outdoors or at work. Table V shows, for each one hundred people questioned, the number of times that noises were mentioned as being disturbing. Noises found disturbing in the home were mentioned 99 times, noises outdoors 35 times, and noises at work 26 times.

TABLE V

Noises which disturb people at home, outdoors and at work

Description of noise (*i*)	Number of people disturbed, per 100 questioned		
	when at home (*ii*)	when outdoors (*iii*)	when at work (*iv*)
Road traffic	36	20	7
Aircraft	9	4	1
Trains	5	1	—
Industry/Construction works	7	3	10
Domestic/Light appliances	4	—	4
Neighbours' impact noise (knocking, walking, etc.)	6	—	—
Children	9	3	—
Adult voices	10	2	2
Wireless/T.V.	7	1	1
Bells/Alarms...	3	1	1
Pets	3	—	—
Other noise	—	—	—

95. Some people were disturbed by more than one type of noise and, as Table VI shows, of the people interviewed, 56 per cent. had been disturbed from time to time at home, compared with 27 per cent. when they were outdoors, and 20 per cent. of those who went out to work while they were at work.

TABLE VI

Percentage of people who were ever disturbed by noise at home, outdoors and at work

Individuals' reaction to noise	Noise source		
(*i*)	at home (*ii*)	outdoors (*iii*)	at work (*iv*)
Those who are disturbed by noise... ...	56	27	20
Those who notice but are not disturbed ...	41	64	70
Total of people who notice noise	97	91	90
Those who do not notice noise	3	9	10
	100	100	100

96. It was found in the survey that in their own homes people are much more worried by noise caused by passing traffic or by industrial noises (which we will call external noise) than they are by noises made by neighbours in adjacent rooms (which, for convenience, we will call internal noise), or noise which originated in their own homes. The origins of the noises which disturbed people at home (Col. *ii* of Table V above) are shown in Table VII. The figures indicate the number of times that the noises were mentioned by each 100 people questioned.

TABLE VII

Origins of noises which disturb people when they are at home

Description of noise	Origin of noise (per 100 people questioned)		
(*i*)	External noise (*ii*)	Internal noise (*iii*)	Noise from own home (*iv*)
Road Traffic	36	—	—
Aircraft	9	—	—
Trains	5	—	—
Industry/Construction Works	7	—	—
Domestic/Light appliances	1	2	1
Neighbours' impact noise (knocking, walking, etc.)	1	5	—
Children	8	1	—
Adult voices	7	3	—
Wireless/T.V.	2	5	—
Bells/Alarms	3	—	—
Pets	3	—	—
Other noise	—	—	—

97. The proportions of the people interviewed who had ever been disturbed by noises from these three origins are shown in Table VIII.

TABLE VIII

Percentage of people who were ever disturbed by noise at home

Individuals' reaction to noise (*i*)	Origin of noise		
	External noise (*ii*)	Internal noise (*iii*)	Noise from own home (*iv*)
Those who are disturbed by noise... ...	50	14	2
Those who notice but are not disturbed ...	41	14	4
Total of people who notice noise	91	28	6
Those who do not notice noise	9	72	94
	100	100	100

98. The figures given in Table VIII are substantially different from those found in the 1948 survey and, as will be seen from Table IX, the change in respect of external noise is very striking.

TABLE IX

Comparison of people's reaction to noise at home in the 1948 and 1961 surveys

Individuals' reaction to noise (*i*)	External noise (per cent. of people)		Internal noise (per cent. of people)	
	1948 (*ii*)	1961 (*iii*)	1948 (*iv*)	1961 (*v*)
Those who are disturbed by noise	23	50	19	14
Those who notice but are not disturbed ...	19	41	21	14
Total of people who notice noise	42	91	40	28
Those who do not notice noise	58	9	60	72
	100	100	100	100

99. The figures given for the 1961–62 survey in Tables VI, VIII and IX are the percentages of people disturbed from time to time by noise. Further analysis shows that a high proportion of these, approximately 30 per cent. of the total sample, claim to be seriously disturbed by the one noise found most bothersome, generally traffic. Some measurements have been made of the noise climate in the immediate locality of the homes of about half the people questioned, and it appears that whether people live in noisy or in quiet places does not affect the proportion of them who are seriously disturbed. The effective range of the external noise climate is, however, smaller than given in Table III since the number of people living in very

noisy or in quiet places was too small to be significant. The effective range inside the dwellings may be smaller still, since in noisy areas people may keep windows closed more often and in quiet areas open more often. People also become accustomed in some degree to the noise that they usually hear.

100. An analysis of the data from which the figures given in Table III were compiled shows that the highest noise levels are usually produced by buses and heavy lorries. Except for occasional motor cycles and sports cars, other traffic, however dense it may be, does not produce the high levels recorded. The peak noises recorded at the measuring points in groups A and B were as much as 10 dBA higher than the upper figure of the noise climate. Figure 1 overleaf shows four typical records* of the noise in Central London, illustrating that the peaks of noise were usually produced by what sounded to be heavy vehicles. A complete study of the tape records has not yet been made, so it is not known how frequently very noisy vehicles occur. Nor has it yet been possible to examine the social survey results to find whether they give any guide to the proportion of the total annoyance with traffic noise which is caused by these vehicles.

101. We conclude that in London (and no doubt this applies to other large towns as well) road traffic is, at the present time, the predominant source of annoyance, and no other single noise is of comparable importance. There are, however, certain locations where noise from trains and from industry are the major causes of annoyance. In addition, any locality is likely to be disturbed by building operations if construction or reconstruction is taking place in the neighbourhood. We therefore discuss these sources of annoyance in Chapters VII, IX and X, and devote most of the rest of the present chapter to the noise from road traffic. Aircraft noise, which produces intense but localised annoyance, is discussed in Chapter VIII.

102. In the evidence presented by the women's organisations, reference was made to noise made during the delivery of household stores and the removal of garbage. Some of the noise could be avoided by the use of plastic materials instead of metal (for example, plastic covered crates, particularly for milk bottles, and rubber dustbin lids). But a substantial amount of annoyance is caused by thoughtlessness and carelessness. The most effective remedy for this would be a general improvement in good manners, but we have recommended in Chapter III that, if this type of noise is not reduced, legislation should be considered.

METHODS OF REDUCING TRAFFIC NOISE

103. In order to reduce traffic noise, there are three lines of attack. The first is to reduce the maximum noise which a vehicle is capable of making, the second is to reduce the time during which a vehicle is producing its maximum noise, and the third is to reduce the number of vehicles passing a given spot. The first method involves a great many technical considerations, and we therefore devote a separate chapter to it (Chapter VI). Unfortunately, while something can be done in the short term to reduce the

* These records were chosen because the sources of the peak noises were identifiable. At some other measuring points the noise was louder but individual sources were not clearly distinguishable in the general roar.

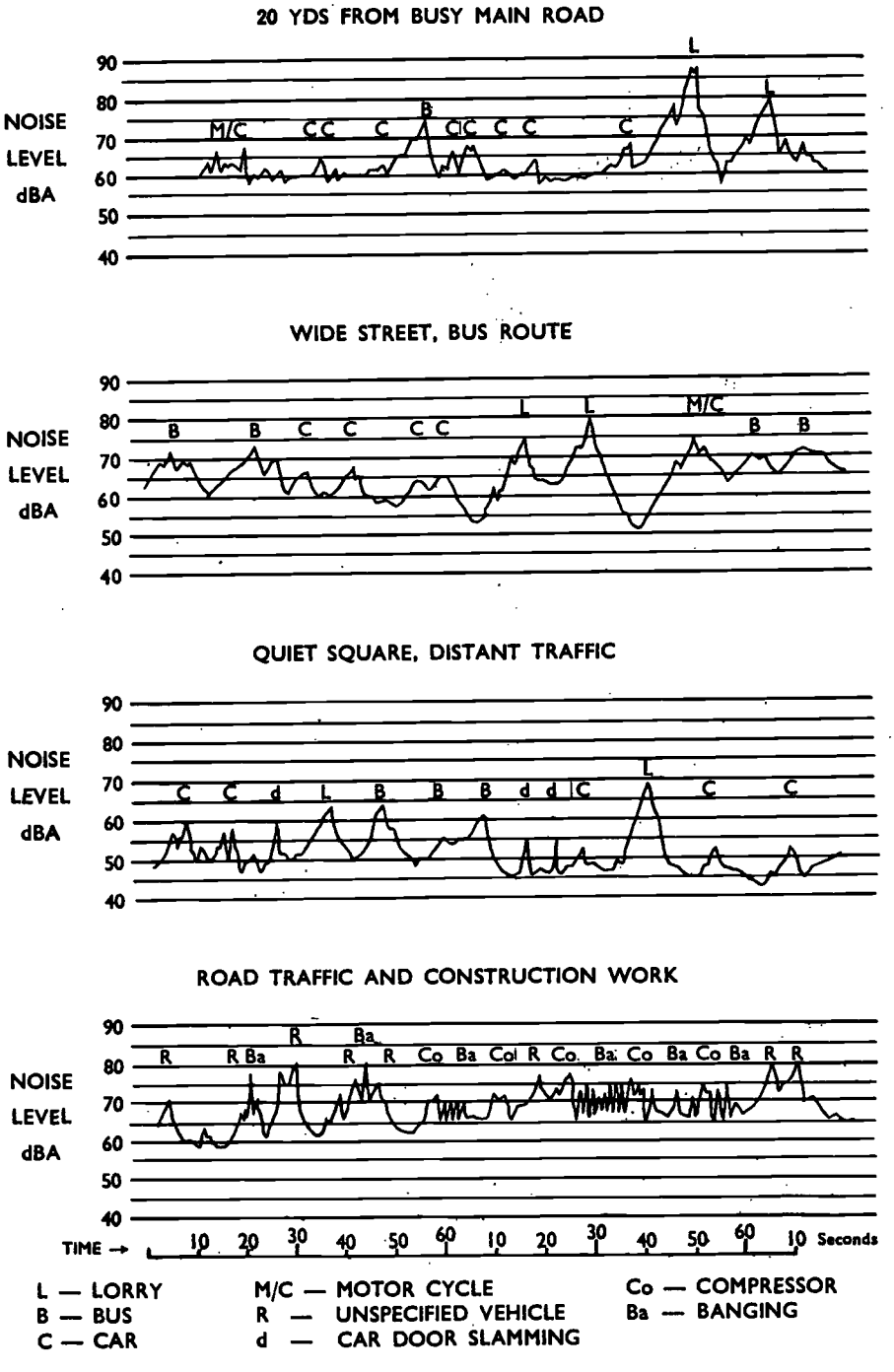

FIG. 1

Relative noise levels of different kinds of vehicles and of constructional work

noise of individual vehicles, the most frequent offenders, diesel-engined buses and commercial vehicles, are the most difficult to quieten. It will therefore be necessary to pay particular attention to the remaining lines of attack.

SMOOTHING THE TRAFFIC FLOW

104. The second method is a matter of smoothing the traffic flow. Vehicles produce their maximum noise when they are accelerating in a low gear. Traffic noise can therefore be substantially reduced by minimising the number of occasions on which vehicles start and stop.

105. Those of us who have been to the United States found the traffic noise there generally less obtrusive than it is in this country. The traffic in most American cities is more homogeneous than it is in this country; there are considerably fewer buses and, because of restrictions on the times at which deliveries are permitted, there are fewer lorries in the streets at peak traffic times. American cars, too, are generally higher powered than British cars and are seldom driven at high engine revolutions in towns. The use of linked traffic lights is widespread, and, because the flow of traffic is interrupted less frequently, drivers do not need to accelerate through the low gears as often as they do in most British cities.

106. In general, because of the layout of the streets, British towns do not lend themselves at present to as smooth a traffic flow as do American towns. But substantial improvements have been made in recent years, and much more can be done in the future, though often at considerable cost. These improvements have been made in order to reduce congestion, but, as we have said above, less congestion automatically means less noise. In many cases, however, the smoother traffic flow has been obtained by the introduction of one-way traffic which has diverted much of the traffic into neighbouring streets which were previously peaceful.

107. As we shall see in the next chapter, properly constructed buildings can be an effective protection against traffic noise, and fortunately buildings along major thoroughfares have in the past been solidly built. This has not always been so on the less important streets, and the spreading of heavy traffic, as distinct from private motor cars, into side roads and minor thoroughfares may therefore create a noise nuisance in these buildings even though the number of vehicles is not so great as to produce congestion in the street. In considering the re-routeing of traffic, local authorities should take into account not only the capacity of the roads to take more vehicles but also the quality and uses of the buildings along them.

BY-PASSES AND RING-ROADS

108. The measures outlined in the preceding paragraphs are essentially methods of dealing with localised congestions and the noise nuisances they create. A more radical approach is to limit the numbers of vehicles which pass through a particular district, which is our third method. This can be done by constructing by-passes and outer ring-roads, so as to reduce through traffic in the centres of towns, which, as we have already said, rarely have a street pattern conducive to a steady flow of a large number of vehicles. From the point of view of noise the proper siting of

by-passes should present no difficulties, but the routeing of outer ring-roads requires very careful consideration to avoid bringing heavy traffic close to existing schools, hospitals and houses, which are more vulnerable to noise than are the shops and commercial buildings which often front main roads. Similarly the traffic noise should be considered when constructing new buildings, particularly near hilly main roads.

109. In the past, the construction of by-passes and outer ring-roads has not kept up with the increase in the amount of traffic, but an adequate road building programme in the future would bring relief from both congestion and noise to most of our smaller towns and to those of our villages which are situated on main highways. Such measures, however, would still leave untouched the problems caused by internal traffic, which, in London and the other large conurbations, forms a very high proportion of all traffic. The local re-routeing of traffic to which we have referred in paragraphs 106 and 107, is at most a palliative which will be effective for a few years only, and much more drastic measures will be necessary in the long run.

CONTROLLING INTERNAL TRAFFIC IN TOWNS

110. Traffic of all kinds is at present allowed to penetrate to all parts of towns and cities, creating danger, fumes and noise. It should instead be canalised as far as possible into a number of main roads which between them would form a network through the town. This network would sub-divide the town into areas from which all but very local traffic would be excluded, so that in these areas the pedestrian would take precedence over the motor vehicle.

111. Measures of this kind are already being considered by the Ministry of Transport. Indeed, the Ministry's Adviser on Urban Road Planning is investigating fundamental planning principles for towns fifty years or so ahead, and in a period of time of this order it is possible to visualise fundamental changes in the structure of our cities. There may then be main roads of adequate traffic capacity passing under buildings with, on the surface, only side roads which do not provide through routes. Conceivably, too, pavements may be raised to first floor level, and the whole of the ground level used for vehicles, being bounded by windowless walls and the underside of the pedestrians' pavement, all of which would be faced with sound absorbent material.

112. In the long term, and in the shorter term where there are major development or re-development schemes, such conceptions as the neighbourhood unit or residential precinct offer a means of separating residential areas from the noise of through traffic. Traffic routes are planned to skirt these areas, in which the housing development can be designed to face away from the peripheral roads, and each unit or precinct to have its own shopping centre and other social amenities. Pedestrian precincts, from which all traffic is excluded, are of course, quiet as well as safe.*

* An example of a road pattern designed to separate pedestrians from vehicles, and residential areas from through traffic is contained in "The Planning of a New Town," London County Council, 1961.

INSULATING BUILDINGS AGAINST NOISE

113. Plans involving their fundamental reconstruction can do little to affect the internal traffic in large cities during the next decade, and during this period the existing roads will be modified and improved, old buildings will be demolished and new buildings will be erected.

114. As we have said above, the walls and windows of buildings give a substantial protection against noise to the people inside them, but the most efficacious methods of sound insulation are expensive. Where a noise nuisance exists, or is likely to appear in the future because of a forecast increase in traffic, it is necessary to consider the relative costs of reducing the noise in the street by the methods discussed above or of spending money on the buildings to increase their resistance to noise. We therefore next turn our attention to the problems associated with the sound insulation of buildings.

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Chapter V

Noise within Buildings

INTRODUCTION

115. We have seen from the previous chapter that people are more concerned about noise when they are at home indoors, than when they are outside; that more people are disturbed by noise from external sources, particularly road traffic, than by internal noise, e.g. from neighbours; and that the range of noise levels to be expected from present traffic can be listed for various categories of streets and sites. In this Chapter we discuss the protection that buildings can provide against noise, whether they are being effectively designed to this end, and whether an improvement is needed and can economically be attained.

ACCEPTABLE LEVELS OF NOISE IN BUILDINGS

116. In order to do this, it is reasonable to enquire into the criteria for intrusive noise acceptable to the occupier, for, ideally, these would give a direct guide to the insulation required to give protection against known noise levels. As the evidence available to us on this is oblique and by no means conclusive, the following levels are only tentative suggestions.

FOR DWELLINGS

117. The data on existing levels of external noise given in Table III (Chapter IV) provide some evidence of the kind of noise levels to which people are at present subject in their homes. Since the proportion of people seriously disturbed by intruding external noise is greater now than in 1948, some reduction in the present noise levels to give more acceptable conditions is desirable. A very tentative estimate is that the following levels inside living rooms and bedrooms should not be exceeded for more than ten per cent. of the time:

Situation	*Day*	*Night*
Country areas	40 dBA	30 dBA
Suburban areas, away from main traffic routes ...	45 dBA	35 dBA
Busy urban areas	50 dBA	35 dBA

Taking into account the insulation provided by walls with ordinary windows, this represents about a 5 dB reduction in the noise in suburban areas away from main traffic routes, and a somewhat greater reduction for dwellings facing very busy main roads in cities. The basis on which these very tentative levels have been arrived at is set out in Appendix V.

118. Social surveys show that noise from neighbours is the chief source of complaint when the insulation between dwellings is less than B.R.S.

Grade II (see paragraph 133 below). It is doubtful whether noise originating in dwellings will often be more than, say, 80 dBA. As B.R.S. Grade II should give a reduction of about 45 dB* it seems that neighbours' noise is the major cause of disturbance at levels of about 35 dBA. On the other hand, at about 30 dBA, i.e. where the insulation between dwellings is about 50 dB (B.R.S. Grade I), neighbours' noise seems no longer to be a major cause of disturbance and at this level seems, therefore, to be acceptable to most people.

FOR OTHER TYPES OF BUILDINGS

119. For other types of building a very wide range of maximum levels can be quoted depending on the use of the building. At one extreme, for concert halls and similar auditoria, a very low level is required, but, as such buildings are always designed with expert acoustical advice we need not discuss them here. At the other extreme are factories having processes so noisy that the first practical target might be a level that will just avoid hearing loss, or loss of efficiency. The levels for these are discussed in Chapters XIII and II. There are, however, several types of building in which communication by speech is of great importance. These include many offices and committee rooms, lecture-rooms, educational institutions in general, and hospitals. The Speech Interference Level (see ref. 1) is a reasonably well accepted criterion, and, although the point beyond which there will be interference will vary according to voice levels, distance between those communicating and so on, it can be taken in general as 55 dBA. This should be the upper limit to be tolerated for these occupancies.

120. The levels suggested in paragraphs 117 and 118 above have been deduced from the data obtained in various surveys. Estimates of a similar character have been given in other countries and agree fairly well. It is understood that a Committee of the International Organisation for Standardisation (ISO) have for some time been engaged in formulating recommended maximum levels, so that in time it can be confidently assumed that a more authoritative guide will be available. Meanwhile, however, we feel that if levels indoors of the order of those given above can be obtained by suitable design and planning, they should command wide acceptance. Measurements relating to one particular site and to the specified requirements of a client will be even more useful to architects, and may well be essential, e.g. on sites subject to very high noise levels or to noises of unusual characteristics ; but the figures suggested above may serve as a general guide.

121. In choosing an appropriate level at which to aim it is important to remember that buildings last for very many years, usually half a century at least. In planning them it is, therefore, desirable to try to forecast the needs of the future. This is difficult indeed, but, unless it is done, buildings that are being erected now may soon become obsolescent because noise hampers their full use. There are already many offices in which it is difficult to hold meetings, or to converse, because of noise.

* The airborne sound insulation of most structures increases with frequency and the single figure values quoted in this and other chapters of the Report are average values for the frequency range 100–3,200 c/s.

NOISE FROM OUTDOORS

122. The insulation of the building façade against external noise has not hitherto been regarded as of first importance, except for special buildings such as concert halls. The reason is that insulation against external noise is determined largely by the windows [figures to illustrate this are given in the British Standard Code of Practice for Buildings (ref. 2)], and for practical purposes it may be assumed that a façade with a traditional area of windows in it will not give an insulation of more than about 20 dB and may give less if openable windows are ill-fitting. With the windows open even a little, the insulation will not be more than 10 dB.

123. From the table of ambient noise levels given in the previous chapter and from the desirable maximum interior levels suggested in paragraphs 117 and 118 of this chapter, it can be seen that this degree of insulation is insufficient to prevent disturbance in rooms facing on to streets with busy traffic and bus routes, or near airports and other noisy places. On the other hand the levels in buildings exposed to noise intensities such as those of Group B* could be made acceptable if the insulation of walls with closed single windows could be increased to 25 dB, although, to be acceptable against the peak noise levels, an increase to, say, 30 dB would be better. Insulation of this order would be expected to give a very considerable improvement even in Group A*. We have been told that improvements in the design of windows to give better protection against wind and rain in the upper floors of high buildings are being sought. Success in this may be expected also to give some increase in sound insulation, though possibly it will not attain 30 dB. We feel that if, by additional effort in development, 30 dB could be reached in a façade with single glazed windows it would be of great benefit. (Wherever closed windows are used for sound insulation it is necessary to consider other forms of ventilation. There is, of course, no reason why the window should necessarily remain the source of ventilation : other means might well serve better.)

124. The maximum practicable window insulation is about 40 dB. To achieve this it is necessary to have sealed or very close fitting openable double windows with a space of 8 inches or more between the leaves, and with the reveals lined with a sound absorbent. Such windows, combined with reasonably heavy walling, are probably adequate for the noisiest traffic or industrial conditions likely to be encountered, but this method of insulation requires a system of mechanical ventilation or of complete air-conditioning. It has recently been estimated (ref. 3) that these methods may add 20s. to 30s. per square foot of floor area to the cost of the building, and they have been generally regarded as impracticable in, say, local authority flats. They have, however, been used in some offices, hotels and hospitals in particularly noisy situations. In Chapter VIII (Aircraft Noise) we refer to trials made for us on a system of openable double windows combined with a fan ventilating the room through a noise-attenuating appliance. The system is expensive at present, but we hope that future development may increase the possibilities of its wider use, for it could help to solve many difficulties.

* See Chapter IV, Table III.

125. Much can be done to reduce the ill-effects of noise by putting the most vulnerable parts of a building as far as possible from the main source of noise, and by turning them away from it. Such measures can, of course, be vitiated by changes in the direction of the main noise source, and may be nullified by aircraft noise.

126. It is sometimes argued as an advantage of the high building, that the upper floors are free of noise nuisance because of their distance above the traffic. A survey of conditions in modern office blocks in London by the Building Research Station and the Central Office of Information has established that noise from traffic disturbed occupants of the 1st and 2nd floors more than those of floors above, but disturbance in higher floors still remained and did not further diminish with height above street level. This finding agrees with some measurements made by the London County Council's technical staff of noise levels at different heights on the outside of some multi-storey buildings. From these measurements it appears that the general level falls only slightly with increasing height after the first one or two storeys, which are specially affected by the peak intensities of individual passing vehicles. Height can therefore be over-rated as a defence against traffic noise and may well increase vulnerability to noise from aircraft and helicopters.

127. There has recently been a considerable increase in new forms of construction, for example, multi-storey framed buildings with lightweight exterior claddings, which are now a feature of office and commercial development in cities, and " industrialised building " which extends to schools and dwellings. A tendency to a lowering of standards of interior sound insulation is detectable in some of the newer forms of construction, while the use of lightweight claddings is likely to reduce insulation against external sound compared with more massive construction even though the insulation provided by the latter is not particularly good.

128. Buildings need to achieve certain functional standards in such characteristics as stability, weather resistance, durability, ability to conserve heat, and ability to exclude noise, but these standards are not all absolute: some depend on the needs of users, the amenities they expect, and the practicability of providing them economically ; they may be influenced by aesthetic considerations. Hence there can well arise the possibility that a new form of construction may have an overall balance of advantages which differs from the balance of advantages in an older form in such a way that one or other of the more flexible standards suffers. Standards of quietness are of this more flexible type and, as we have seen above, are tending to be lower in some of the new forms of construction ; it will doubtless entail some difficulty or perhaps extra expense to raise them to the level reasonably easily attained by the traditional method. There needs to be a strong reason to support this extra effort or expense.

129. The reason is to be found in the results of the social surveys, which show quite clearly that, in their homes, people attach as much importance to freedom from noise as they do to other amenities. We conclude that it is essential that standards of noise reduction, at least in dwellings, should not be

relaxed and that strenuous efforts should be made to maintain these standards in industrialised forms of construction.

130. It is technically possible to provide adequate insulation against the highest likely levels of noise from outside by fitting double glazing and mechanical ventilation in buildings constructed of heavy materials by orthodox methods. The widespread application of these palliatives to existing buildings is, however, quite impracticable both on grounds of cost and because it would divert the building industry from its present pressing tasks. Even in a new building the cost will be substantial. A recent estimate for one office building costing about £240,000 without land charges, showed a cost increase of £45,000, or about 19 per cent., to add double glazing (of the sound insulation type) together with suitable mechanical ventilation. The provision of this kind of facility or, in the case of houses, of the individual room treatment (see paragraph 124) to one or two rooms, in no more than one-tenth of the existing stock of buildings in this country has been estimated by the Building Research Station to involve costs of the order of £1,000–£1,500 millions. Even this limited application, which may be only about half of the buildings in which the facilities might be desirable in such a city as London, would require the equivalent of the building industry's entire and exclusive effort for six to nine months.

131. It is not known, moreover, whether (these considerations apart) it would be possible to insulate adequately all types of existing buildings, especially buildings of lightweight type, e.g. those faced with light claddings. On the other hand, the technological advantages of high buildings, prefabrication and light structures are such that their disadvantages from the point of view of sound insulation are unlikely to reverse the trend towards their use. As we have already noted (paragraph 129) strenuous efforts need to be made to bring them up to the level attained by heavier buildings.

132. It follows that it is unwise to look to better sound insulation of buildings for any great contribution towards the mitigation of the problem of external noise, if the advantages of modern methods of building such as light cladding are to be fully exploited. Double glazing and artificial ventilation in buildings of heavy construction provide a means by which people in the noisiest situations can protect themselves against noise, though the high cost restricts its use. The discovery of cheaper means of improving sound insulation against external noise would be extremely valuable, particularly if the means were applicable to light structures. More research on this problem is urgently needed.

INTERNAL NOISE IN DWELLINGS

133. Following surveys in 1948 and 1953 of the disturbance which noise caused to people in their homes (refs. 4 and 5), the Building Research Station defined grades of sound insulation for walls and floors between dwellings (ref. 6). Insulation complying with the Building Research Station's Grade I should reduce the transmission of airborne noise by 50 dB. Grade II should give a reduction of 45 dB. A 9 in. brick party wall between houses should give insulation slightly better than Grade I. Insulation against airborne noise is related to the weight of the wall or

partition between the source of the noise and the hearer. When the weight of the wall or partition is doubled the insulation is increased by 5 dB. It will be seen therefore that to improve by as little as 5 dB on the present Grade I, which gives quite a substantial degree of insulation, the thickness of a brick party wall would have to be 18 in., and the mass of a concrete wall would have to be doubled. Since sound is transmitted through the flanking walls as well as through the party wall, the full effect could not be achieved without increasing the mass of flanking walls and ceilings also. This would clearly be uneconomic for normal housing.

134. Similar considerations apply to the insulation properties of floors. A 5 in. concrete floor with a resilient quilt and a floating floor on top of it will give an insulation of 50 dB against airborne noise. A single solid floor of about 9 in. would probably give the same degree of insulation. In the case of a floating floor it would be possible to increase the insulation a little by increasing the thickness of the structural concrete slab, but again the point would rapidly be reached where transmission through flanking walls would become too great a problem to be solved economically. These considerations do not apply with the same force to insulation against impact noise on a floor, since it is possible to reduce impact noises by adding carpets, cork or resilient rubber finishes on the top of the floating floor.

135. One large building firm said in their evidence that there was a need for better insulation than the higher grade (Grade I) recommended by the Building Research Station for dwellings, but standards of insulation in excess of 50 dB are not likely to be achieved except by methods which would be quite uneconomic. In any event insulation of 50 dB appears to provide sufficient protection against internal noise in dwellings for most people, although a proportion will still not be completely satisfied.

136. The importance of good sound insulation between dwellings is increased by the present tendency towards higher densities in housing and the consequent building of more flats and terraces. We asked local authorities and the larger contractors building multi-storey flats for private sale how far the higher standards of sound insulation mentioned above are being applied. Their evidence showed that there is still room for complete application of these standards, but it was gratifying to learn that the standards have become well known and are being widely adopted. Building Byelaws in Scotland have, since 1954, required a specific standard of insulation for walls and floors in dwellings, and the draft Building Regulations for Scotland specify a defined standard for dwellings equivalent to that of the best standard advocated by the Building Research Station. The Building Byelaws in England and Wales have not hitherto required any specific standard ; the new draft Building Regulations for England and Wales, in " deemed to satisfy " clauses, specify types of floors and walls which attain the highest standard and also require an " adequate standard " for types not specially listed. Both these developments are to be welcomed.

137. Just as proper siting and site planning can reduce the ill effects of noise from outside, so good internal planning can reduce disturbance from internal noise. For example, bathrooms and kitchens should not abut on to living rooms of adjoining dwellings.

138. The services and equipment which people now expect to have in houses and flats are potential sources of extra noise. Such things as lifts and refuse chutes, electrical and plumbing services, labour-saving domestic equipment, radio, television, gramophones and tape recorders all make their contribution. The amount of noise created within buildings, or transmitted through their structures, can be much reduced if quiet domestic services are installed. Information about this has been published by the Building Research Station (ref. 7).

139. The need for quieter domestic tools, such as vacuum cleaners, washing machines, etc., was particularly emphasised by the women's organisations who gave evidence. Their concern for quieter machines is having effect, because some manufacturers now make a point of advertising the quietness of their products. Objective measurements of the noise produced, using a standard procedure, would enable customers to compare the noisiness of different models of machines.

FACTORIES

140. The reduction of noise in factories is discussed in Chapter IX, and the effects of industrial noise on people who work in it in Chapter XIII.

OFFICES

141. Architect witnesses have noted with some misgivings that the light construction which is a feature of many modern multi-storey office blocks, will transmit more noise both from outside and inside such buildings. They also drew attention to the noise made by office machines which are more widely used to-day than ever before. We feel that their doubts are largely justified, in view of the increasing numbers of these light buildings, often with a large area of glass on their façades, being built in city centres and on busy traffic routes.

142. An Institute of Directors publication "Better Offices" (The Institute, London 1961) contains a section on the internal environment of offices, in which noise and its control is discussed. The introductory notes in that part dealing with noise include the following: "Experience tends to show that offices in which there is a good deal of distracting noise are less efficient in terms of mistakes in working, sickness and labour turnover, than offices in which there is little or no distracting noise." The further comment is made that "The growing use of office machinery, the tendency towards open offices and the difficulty in hearing on the telephone because of noise originating both within and outside the building, are making the control of noise one of the more important aspects of office design."

143. Nevertheless, the general impression formed by the Building Research Station from the recent survey of conditions in modern offices in London, to which we referred in paragraph 126, is that not much thought seemed to have been given in the internal design of these buildings to the desirability of keeping down the transmission of noise from one office to another, or from corridors to offices. The separating walls were of light construction, insufficient to give effective sound insulation, in 64 per cent. of the rooms. Insulation between floors was probably better as an accidental consequence

of structural requirements, and noise would be further deadened by carpets and rubber flooring which were found in 64 per cent. of the rooms visited. Further acoustical absorbent treatments, which might minimise noise from machines etc. to the occupants of particular rooms, had been carried out in 25 per cent. of the rooms visited.

144. In a survey of mechanised offices the Building Research Station found in 1960 that people in the machine rooms regarded the office as " noisy " when the level in the room was about 80 dBA ; punch operators placed the " noisy " limit at 75 dBA. For comparison clerical workers rated their office as " noisy " when the level was 70 dBA. Clearly there is scope for reducing machine noise at source to reduce these high levels and we recommend that manufacturers should give urgent attention to this. Purchasers should include quietness as a requirement in selecting suitable appliances.

145. The recommendations of the Institute of Directors' publication mentioned above appear to be directed broadly to bringing noise below the level at which interference with speech or telephone communication occurs, and the commonly used criterion for the acceptable noise level in offices is of course the Speech Interference Level referred to in paragraph 119. Expressed in dBA this gives about 55 dBA as the maximum acceptable level, compared with the rating of 70 dBA classified as " noisy " mentioned in paragraph 144. On the other hand, from the results of the survey of modern offices it seems that such things as " interesting work ", " responsibility ", and " good pay " matter more to the employees than comfortable office conditions. In questions which concentrated on office conditions, external noise was shown to be far more disturbing than internal noise, which was not important to the people questioned. The survey provides no data on how far noise levels which interfere with communication affect the efficiency of operations.

146. The complete findings of the Building Research Station's survey need to be studied as soon as they are published. There are many unanswered questions and possible future changes to consider. Older office blocks were not included in the survey and are probably often quite badly affected by increases in external noise. Longer experience of working in the new blocks, with occupants becoming accustomed to possibly better amenities in some directions, may well also accentuate the obvious deficiencies from the noise point of view ; and an increasing spread of heavy traffic in towns will expose more office blocks to higher noise levels.

SCHOOLS AND OTHER EDUCATIONAL BUILDINGS

147. The Ministry of Education told us that the school building regulations provided for acoustic conditions and insulation against noise appropriate to the use of each part of a school building. At one time, dispersal and grouping of class rooms was possible to ensure that noisier activities did not interfere with quieter ones, but with developments in teaching methods, segregation is not so general a solution to the problem of noise interference as it once was. Adequate insulation against internal noise could generally be obtained in the many schools which were still built by traditional methods, but where, owing to shortages of building craftsmen,

traditional construction had given place to light, dry-jointed methods of construction, it was not so easy to secure a comparable degree of insulation. The Ministry's evidence acknowledged the need for research and development on the reduction of sound transmission through light partitions. Other evidence relating to educational buildings generally also underlined the need for such research. We agree that research of this kind is very necessary and may well benefit not only schools, but flats and office buildings also.

148. The Ministry's evidence suggested that schools built since the war were not in general troubled by noise from outside the school site because they were usually built on open sites. Where schools, technical colleges and other educational institutions had to be in city centres the Ministry has on occasion allowed additional cost for structural insulation against the outside noise. Schools sited near busy airfields have special problems (see Chapter VIII).

HOSPITALS

149. Noise can be very trying to both patients and staff in hospitals. We therefore welcome the campaign against noise in hospitals which has recently been started. The principles of sound insulation and noise reduction in the design and building of hospitals are set out in the Code of Practice (ref. 2), and information about the noises which most disturb patients, and suggested means of reducing internal noise, have been given in reports by the Ministry of Health's Standing Nursing Advisory Committee and the King Edward's Hospital Fund for London. The Ministry of Health and the Scottish Home and Health Department have drawn the Code and these reports to the attention of hospital authorities, who are being encouraged both to minimise internal noise and to pay due attention to noise reduction in hospital building, especially in the new hospital building programme. We feel that further useful research could be done to correlate the reactions of patients and staff to noise with objective measurements. This would make it possible to determine, more accurately than at present, how far disturbing noises should be reduced, and what structural measures need to be taken to minimise their effect.

OTHER BUILDINGS

150. Many other types of buildings, e.g. concert halls, churches, restaurants, have their own special problems. The principles of noise reduction are the same for them as for the types of buildings that we have discussed. The application of these principles in any type of building requires special consideration. Where acoustics is of outstanding importance, as in churches, concert halls, lecture halls, cinemas and theatres, the associated problems of noise will be carefully considered by the architect, perhaps with specialist advice. In other types of building, noise control must be accepted by the developer as being as important as the various other requirements for the building. We would like to emphasize, however, that this problem must be considered from the outset. It may well be very much more difficult to solve it later.

PROFESSIONAL KNOWLEDGE

151. We have referred in previous paragraphs to the Code of Practice for sound insulation and noise reduction in buildings. Except for certain new facts, mainly about noise levels and people's reactions to them, which were not available at the time the Code was drafted, there is little in this chapter which is not already covered by the Code, and the latter contains a good deal of specialised information for the building designer and contractor which would be inappropriate in our Report. It is relevant to enquire into the reason for the obvious gap between the present knowledge as assembled in the Code, and the efficiency of its application as shown in many existing buildings. It seems to be generally accepted by expert witnesses, including the Royal Institute of British Architects, that one of the basic reasons is the inadequate training of architects and builders in the principles of sound insulation and noise exclusion. We think that it is very important that their training in these subjects should be improved, and we hope that the professional bodies will quickly be successful in the efforts they have announced to do this.

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* See also PARKIN, P. H., PURKIS, H. J. and SCHOLES, W. E. Field measurement of sound insulation between dwellings. National Building Studies, Research Paper No. 33. London. H.M.S.O. 1960.

Chapter VI

Noise from Motor Vehicles

152. In Chapter IV we said that there were three lines of attack upon traffic noise and we discussed two of them, i.e. smoothing the traffic flow and the construction of suitable road systems. The remaining method is to reduce the maximum noise which a vehicle is capable of making. This method was examined in an interim Report published in July, 1962*, the substance of which we reproduce below. Although our views and our recommendations remain unchanged we have made some minor textual changes.

EXISTING LEGISLATION

153. All the types of noise produced by single vehicles, except noise from slamming doors, are subject to control in Great Britain under the Motor Vehicles (Construction and Use) Regulations, 1955, made under sections 3 and 30 of the Road Traffic Act, 1930 (consolidated in the Road Traffic Act, 1960). There are no regulations to control the total noise emitted by a group of vehicles, none of which by itself is "unreasonably" noisy, i.e. traffic noise. The regulations are set out in Appendix VI.

154. The enforcement of these regulations is the responsibility of the police, whose evidence to us was that their chief difficulty was the absence of defined, measurable, standards of what constitutes excessive noise under Regulations 81 and 82. In the absence of such standards, prosecutions were rarely attempted in some areas unless the machine, which in a police officer's opinion was causing excessive noise, was found on examination not to have a silencer or to have a silencer which was corroded or damaged so as to render it ineffective. One police force had experimented with the use of sound level meters as an aid to the enforcement of the regulations. Although they felt that the publicity that they received had a salutary effect in the area, the convictions that they obtained were largely on the evidence that, in the opinion of the police officers concerned in each case, the noise was excessive.

155. The annual number of offences against these regulations and the numbers of vehicles registered in England and Wales in the years 1936–1938, and 1946–1961 were supplied to us by the Home Office and the Ministry of Transport and are set out in Appendix VII. Separate figures of the offences against each regulation were not available. No statistics of offences in Scotland were obtainable.

156. Many countries abroad have legislated against the noise from motor vehicles, and have regulations controlling their construction, maintenance and use in this regard. Some of these regulations rely on the subjective

* Cmnd. 1780: 1962.

opinion of a police officer on what is "excessive"; others adopt instrumental measurement in specified conditions. There is, however, a very considerable variety in the regulations and methods specified; and it is largely for this reason that the ISO has been active in the past few years in promoting an international standard for methods of noise testing, in the hope that all countries will incorporate these methods in their own legislation. We discuss these testing methods at greater length in paragraphs 166–170.

157. In spite of some enquiries abroad, we have been unable to find any convincing evidence of the degree to which noise legislation in other countries may be judged to be successful, nor how much it costs to enforce.

THE CAUSES OF VEHICLE NOISE

PROPULSION NOISE

158. The noises from engines, exhausts and transmissions result essentially from the mechanical propulsion of the vehicle and cannot readily be differentiated by an ordinary observer, or measured separately. For most of this Report they are considered together as a single type of noise.

159. Many vehicle manufacturers have done a great deal, not necessarily in a fully scientific manner, to reduce the emission of noise; in fact, they are among the few large-scale manufacturers of machinery who have, over many years, regarded the reduction of noise as an important part of their business. Nevertheless, there is clear evidence that, amongst certain classes of vehicles, noise levels are higher than they need be with the knowledge at present available to manufacturers and, indeed, in a few cases, the emission of exhaust noise of special character appears to be a deliberate part of the design for sales purposes.

160. The reduction of exhaust noise is usually a fairly clear-cut acoustic problem, whose theoretical solution is known; but the practical solution may involve the manufacturer, or the purchaser, in a penalty serious in cost, weight, bulk, or loss of performance. A considerable amount of work has been done on this subject.* We consider, however, that more work is needed, and that in addition manufacturers should be encouraged to take better advantage of existing knowledge.

161. When, however, the noise from the engine mechanism itself is as great as that from the normally-silenced exhaust (as happens at present with some high-performance motor cycles and many diesel engined vehicles), the problem is more difficult. Existing knowledge of the basic causes of this kind of noise is by no means complete; and its effective control might involve radical redesign of the engine or thorough enclosure, with very serious penalties in cost and weight. We feel that more engineering research is needed here.

HORNS

162. Noise from motor horns does not seem to cause widespread annoyance and, in general, drivers appear to use them with restraint. However, at times they are sounded in circumstances in which their use is not justified,

* A bibliography is appended to our interim Report.

although not prohibited by the present law, which provides only that they shall not be sounded in built-up areas between 11.30 p.m. and 7.0 a.m. or when vehicles are stationary. We recommend therefore that the use of horns, except when necessary to avoid danger, should be forbidden at all times in built-up areas, as it is already in some continental cities.*

BRAKE SQUEAL

163. It is not known how much annoyance is caused by brake squeal, but it can be disturbing especially to people living near bus stops, traffic lights and other places where vehicles use their brakes frequently. Recent work by the Motor Industry Research Association has shown that, during brake squeal, the brake components are in a state of high frequency vibration. There is no known method of preventing the excitation of these vibrations, but they, and, in consequence, brake squeal, can be substantially reduced by the introduction of damping into the brake mechanism.

DOOR SLAM

164. There is evidence of a good deal of annoyance from the noise of car doors being slammed. We were impressed by the effort that the principal British manufacturers of door locks are putting into their attempt to minimize noise from vehicle door slam. It seems doubtful whether much more progress can be made without fundamental changes in the design of car bodies and door seals except, possibly, in the reduction of body resonance. Perhaps the most effective immediate mitigation could come from educating the public to use less force in shutting vehicle doors. Many of them at present use unnecessary force and, in doing so, cause permanent distortion of the vehicle body and make subsequent closing a still more noisy operation.

LOADS

165. There has been some evidence of annoyance from noise from vehicle loads, or, in the case of tankers, from the absence of loads. The maximum noise levels which we recommend for roadside tests (see para. 198) would apply to the total noise produced by a vehicle, including noise caused by the load. It would, however, be advisable to retain the existing regulation making it an offence to cause excessive noise as a result of the faulty packing or adjustment of the load.

METHODS OF MEASUREMENT OF VEHICLE NOISE

166. The definition of quantitative limits of noise for motor vehicles has been under consideration, by the Ministry of Transport and by the motor vehicle industry in this country, and in other countries, for many years. There are considerable difficulties in finding a procedure for test and a method of measurement which give reliable and repeatable results. Work on these problems, both in this country and abroad, is well advanced; and, indeed, some countries have already introduced noise limits. There is, however, considerable variation in the test procedures, the maximum levels and the units in which the levels are expressed.

* We do not, of course, intend this recommendation to apply to fire brigade, salvage corps, ambulance, or police vehicles, in circumstances in which they are now exempt from the provisions of Regulation 84 of the Construction and Use Regulations, 1955.

167. In dealing with standards for motor vehicles, which are exported and imported widely and are used extensively in countries other than those in which they are owned, international agreement is important, and a working group was set up by the Acoustics Committee of the ISO to consider the possibility of establishing a standard test procedure in noise measurement. In 1960 the ISO submitted to member bodies a draft recommendation for measuring the noise emitted by motor vehicles (Draft ISO Recommendation 419—October, 1960).

168. The draft recommendation contained proposals for a test made with the vehicle accelerating at full throttle, which was designed to reproduce the maximum noise potential of the vehicle, and for a stationary test which was included in recognition of the existing use of stationary tests in some countries. Work which had been done in this country by the Motor Industry Research Association, in conjunction with the Ministry of Transport and the National Physical Laboratory, has shown that a test on the vehicle while it is accelerating is suitable and practicable, and is superior to either stationary tests or tests of vehicles at constant speed. It is found capable of producing repeatable results, to be simple to carry out and, with the great majority of vehicles, to give a reasonable indication of their maximum noise potential. Stationary tests appear to be of little value unless the engine can be operated under load, and the provision of power absorbing equipment for all types of vehicle is impracticable. Stationary tests without load do not represent a realistic condition and no simple relationship appears to exist between the unloaded stationary test results and the results obtained with similar vehicles in moving tests. Tests of vehicles at specified constant speed, using the appropriate gear and throttle setting to obtain the specified speed, give repeatable results, but the noise emitted is not related to the maximum noise potential of the vehicle in a simple manner. Similar tests using full throttle and controlling the speed with the brakes give repeatable readings and realistic noise levels but impose excessive strain on the vehicle; and, in some high powered vehicles, overheating of the brakes, and even brake fade, occurs after a number of test runs.

169. After an examination of the various procedures for tests of vehicle noise we concluded that the accelerating vehicle test which was suggested by the working party of the ISO and subsequently adopted by the British Standards Institution (B.S. 3425: 1961) provides a reasonable basis for measuring the noise of vehicles. However, this standard, which is reproduced at Appendix VIII,* specifies particular environmental conditions, and an ideal site for its use should be an open space of some 50 yards radius with an ambient noise level at least 10 dB below that produced by the vehicle under test. It also requires the vehicle to be driven in a closely specified manner. It is clear, therefore, that it could be used to the full only on carefully selected sites and could not be used in its entirety for measuring the noise of vehicles on the road. It does, however, provide a method which is suitable for measuring the maximum noise potential of new vehicles.

* B.S. 3425: 1961 " Method for the Measurement of Noise Emitted by Motor Vehicles " is reproduced by permission of the British Standards Institution, 2, Park Street, London, W.1, from whom copies of the standard may be purchased.

170. Except, perhaps, for certain types of heavy commercial vehicle, most vehicles are rarely accelerating at full throttle, and, therefore, producing their maximum noise potential. Traffic noise is made up of noise from vehicles under many driving conditions and, away from the centres of towns, most of them will be maintaining a relatively constant speed. In general, too, a vehicle which has a high power to weight ratio probably uses its full power far less frequently, and is usually using a lower proportion of its power, than a vehicle of markedly less power in relation to its weight. It could, therefore, be argued that a maximum noise limit measured under conditions of full throttle acceleration is unfair to the vehicle with a high power to weight ratio, such as a powerful car. We agree that there is force in these arguments. Nevertheless, we consider that it is important to control the potential noise from a vehicle, and that the conditions of acceleration prescribed in the British Standard procedure will be the best compromise, in practice, among many possible conditions.

THE CHOICE OF NOISE LEVELS

171. Having concluded that a satisfactory method of measuring the maximum noise potential of most vehicles was available, we had next to consider what noise level, or levels, should be chosen as the maximum that any vehicle should be permitted to make when measured by this method. In our view the factors which should ideally govern this decision are:—

(*a*) what level of noise is acceptable to the ordinary public;

(*b*) what levels could be attained by manufacturers within the limits of existing knowledge;

(*c*) the cost of achieving a noise limit at a given level;

(*d*) the practice in other countries (in view of the importance of the export trade in vehicles, and of the importance of international standardisation);

(*e*) the practical aspects—the availability of suitable measuring instruments, and the simplicity of the procedures involved.

LEVEL OF NOISE ACCEPTABLE TO THE PUBLIC

172. Of these factors, perhaps the most debatable is (*a*)—what level of noise is "acceptable"? It would be very unlikely that an "acceptable" motor-car would be as quiet as an "acceptable" sewing-machine, for example; and though much work has been done in recent years on the psychological aspects of noise, we were unaware of any method of fixing, *a priori*, any levels of vehicle noise which could be called "acceptable" (see Chapters I and II).

173. A further complication was the uncertainty of correlation between subjective judgments of loudness or annoyance and the readings given by any available type of noise-measuring instrument. Failing any better instrument, the BSI had specified the use of the sound level meter employing "A" weighting (see Appendix II) in its recommendations; but the limitations of the instrument are well known to those expert in acoustical measurement.

174. An investigation was carried out recently in this country (ref. 1) by the National Physical Laboratory and the Ministry of Transport to determine more precisely the probable uncertainties of this instrument when used to compare the measured noise from motor vehicles with subjective assessments by a jury of listeners. Comparison of the results of this experiment with the results of superficially similar ones carried out in Switzerland and the USA showed, however, that there was significant disagreement between the results of all three in the particular levels of noise measured (using " A " weighting network) which were subjectively rated as " acceptable ".

175. The National Physical Laboratory and the Motor Industry Research Association therefore carried out another experiment, at our request, using a wide range of noises emitted by motor vehicles, to determine with greater precision the relationship between subjective ratings and meter readings using " A " weighting, and to provide information on the relative acceptability of the noise emitted by different classes of vehicles.

176. A report of the experiment is contained in Appendix IX.* Its main features were that the noise sources employed were 19 production vehicles of different makes, each driven in six different conditions, and the subjective ratings of the vehicle noises were made by a panel of 57 observers. Each observer made 150 subjective ratings, representing 114 different vehicle conditions and 36 repeats. The results, summarised in Table I of Appendix IX, showed a fairly good correlation between subjective and objective measurements for private cars and commercial vehicles. The results for motor cycles showed greater dispersion, largely due to short-comings in the sound level meter, which was not significantly improved by sub-classification into 2-stroke and 4-stroke or into single and twin cylinder machines. These results were compared (Table II of Appendix IX) with those of the investigation referred to in paragraph 174, which used normal main road traffic, and they showed a close similarity.

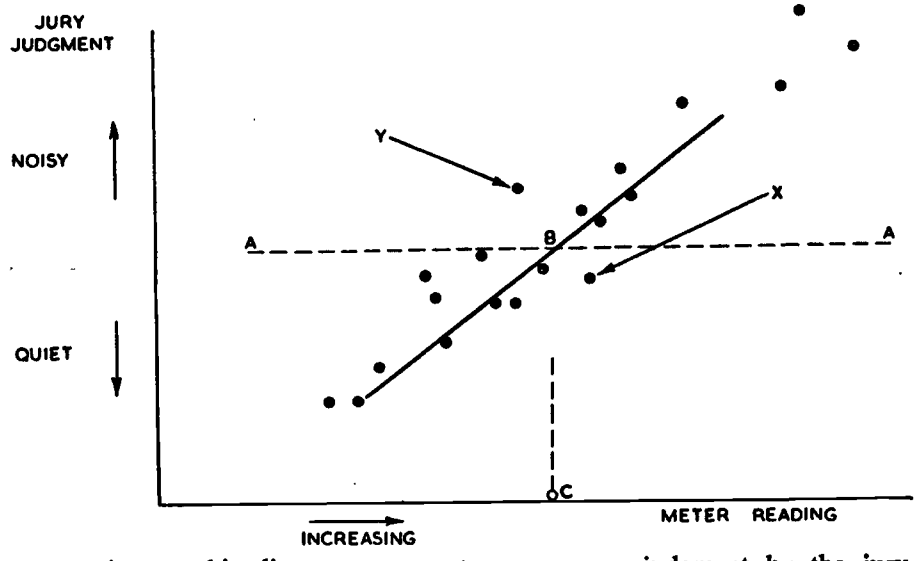
177. This good agreement encourages us to believe that an average jury will agree reasonably well in their estimate of such words as " quiet ", " acceptable ", and " noisy ", when they are asked to make judgments, as detached observers of the noise of motor vehicles ; and also reinforces our belief that the discrepancies with work in other countries arise from the differing background and general attitude of the listening panels who took part in this work. We feel also that in these experiments the nearest practicable approach has been made to a measurement of the opinion of the man in the street.

178. We must, however, emphasise one fact which cannot be avoided. It will be seen from the results given in Appendix IX that the meter used for measurement does not agree exactly (in the order of noisiness in which it places vehicles) with the judgment of the jury. In view of this, the fixing of *any* level on the meter as a legal maximum must impose some degree of injustice on the owners of some vehicles (which read higher on the meter than do others which, judged subjectively, are equally noisy)

* A similar report on this experiment was published in " The Engineer " on the 30th June, 1961.

and must permit more noise from others than is intended (from vehicles which read lower on the meter than others which are equally noisy).

179. This point is perhaps made clearer by a diagram, which represents schematically the type of results which are given fully in Appendix IX.



Each point on this diagram represents an average judgment by the jury of a particular vehicle, plotted against the corresponding meter reading. Let some line A-A represent the maximum noisiness which we think should be allowed. This intersects the *average* meter reading line at B, say. The point C, vertically below B, therefore defines the maximum meter reading which is to be permitted. But now vehicle X, though, in fact, judged quiet enough, will fail the test; and vehicle Y, though judged noisier than X, will pass the test.

180. The choice of any particular point on the jury judgment scale for guidance on permissible levels of noise from vehicles is, of course, a matter of opinion. We might, for example, choose the boundary between "acceptable" and "noisy" for the average listener (i.e. the point "5" on the particular jury judgment scale used in the experiment described in Appendix IX). Then purely on the evidence of this experiment the following would be the average readings on the sound level meter:—

Diesel engined vehicles	80·5 dBA
Petrol engined vehicles	79·5 dBA
Motor cycles	82·5 dBA

Alternatively, we might decide that a vehicle should not pass a test if judged "noisy" or worse (point "6" on the scale). The corresponding figures would then be:—

Diesel engined vehicles	84 dBA
Petrol engined vehicles	84 dBA
Motor cycles	87·5 dBA

These figures do not differ widely from those which we recommend for present adoption (see paragraph 189) on other considerations.

LEVELS ATTAINABLE IN PRACTICE

181. Passing now to consider (*b*) of paragraph 171, we heard evidence from the Society of Motor Manufacturers and Traders and from the British Cycle and Motor Cycle Industries Association Ltd., which satisfied us that there are no technical objections to the introduction of noise limits at reasonable levels and that the accelerating vehicle test proposed by the ISO would be generally acceptable.

182. The Society's evidence was that a maximum limit of 85 dBA under the conditions of this test was the lowest that would be practicable for diesel engined commercial vehicles at the present time. The reason for this is that the level of mechanical noise caused by the engines of these vehicles, as distinct from exhaust noise, was little below this figure, so that further reduction of exhaust noise would have no appreciable effect on the total noise level, and the predominant noise would then become that of the engine. Comparatively little is known about the reduction of engine noise; indeed, the sources of predominant noise in diesel engines have not been fully established, and to effect any substantial reduction might involve a revolution in engine design, which might take some years to achieve. At present most private cars emit noise of less than 85 dBA under the conditions of the test. In the Society's view, manufacturers of sports cars would suffer the greatest penalties if noise limits of this order were introduced, because their policy was to give greater importance than saloon car manufacturers to achieving the maximum possible power.

183. The Association's evidence was that for motor cycles a limit of 90 dBA was the lowest that could be achieved at present, and even this figure would be particularly difficult to achieve in the case of the four-stroke twin cylinder machine. Any limit substantially lower would be impossible for these machines and could only be achieved for other four-stroke machines at considerable cost and with substantial loss of performance. A lower limit might be practicable for two-stroke machines. The Association emphasized the importance of the large capacity machine in the industry's exports. They said that to achieve a substantially lower level than 90 dBA for these machines would involve modifying the engines as well as the silencers.

COST

184. On the question of the true cost of achieving a noise limit at any given level [(*c*) of paragraph 171] we found it beyond our competence to obtain really positive evidence. The view of manufacturers of motor vehicles is already implied in paragraphs 182 and 183; we were not able to obtain specific figures, for example for high-performance sports cars, on the relation between, say, 5 dBA reduction in exhaust noise, and the increase in cost and diminution in performance. The value of sports cars exported in 1960 was over £30,000,000; and of motor cycles of over 250 c.c. engine capacity, £3,700,000. It is indeed difficult to estimate what fraction of this might be lost by the need for alternative designs or special fittings. The cost (e.g. in purchase price) to the vehicle owner in this country, if our recommendations are adopted, is not in our view likely to be serious for the large majority of vehicles; but, of course, if the limits we are suggesting were to be considerably reduced, this cost might

rise very steeply and indeed prohibitively, to the point when most diesel engined vehicles, sports cars and motor cycles were, in effect, banned from the roads. A further item of cost to bear in mind is that of administration and enforcement of noise limits; we have sought no evidence on this point.

PRACTICE IN OTHER COUNTRIES

185. We have examined the information available on the quantitative noise limits introduced in other countries [(*d*) of paragraph 171]. Unfortunately, the methods of test used, most of which were introduced before the ISO proposals were drafted, vary considerably and no comparison with them is fruitful. As far as we are aware, France is the only country which has adopted limits for noise from motor vehicles using a test procedure which is similar to that set out in British Standard 3425 : 1961. However, the French method differs from the British Standard method in the way in which the gear ratio and initial speed of the vehicle are chosen, and the noise limits are different from those that we recommend. Tests have been made by the Motor Industry Research Association on a selection of British vehicles using the BS method and our proposed noise levels and the French procedures and noise levels. These tests have shown that, generally, the two sets of requirements would pass or fail the same vehicles, but that the French requirements are likely to be a little more onerous than our proposals for commercial vehicles and a little less onerous for high performance cars and motor cycles.

CONCLUSIONS AND RECOMMENDATIONS

186. We have considered it of the greatest importance that any recommendations made should be simple to administer and should be related to existing measuring instruments and to procedures in which some experience already existed. No worse service to the cause of noise control could be done than to attempt to impose regulations which could not in fact be administered and which did not carry the support of public opinion.

187. We were informed by the Ministry of Transport that they had considered, and had discussed with representatives of the motor cycle manufacturing industry, the possibility of introducing quantitative noise limits for motor cycles by voluntary agreement within the industry. While the manufacturers expressed willingness to co-operate in this way, there was some fear that those who achieved reductions of noise at the expense, perhaps, of some reduction in power output, coupled with higher costs, might be placed at a disadvantage if other firms ignored the agreement. They felt that an obligatory upper limit binding on all manufacturers would be preferable.

188. We have considered whether different maximum noise limits should be fixed for different types of vehicles. We have concluded that, in principle, different limits would be justified only if they reflected the differing performance of the sound level meter for different types of noise. The experiment conducted by the National Physical Laboratory and the Motor Industry Research Association which is referred to in paragraph 175 *et seq.* did, in fact, show that, for equal noise judged subjectively, the meter reading was higher for motor cycles than it was for cars and commercial vehicles.

NEW VEHICLES

189. Bearing in mind the considerations of paragraphs 171–185, we therefore recommend that legislation should be introduced to provide that, after one year from the date of enactment, all new vehicles should be so designed and constructed that, when using the test procedure set out in BS 3425 : 1961, the following noise levels shall not be exceeded :—

All vehicles excepting motor cycles and other mechanically propelled two wheeled vehicles	85 dBA
Motor cycles and other mechanically propelled two wheeled vehicles	90 dBA

These levels should apply to all vehicles which are licensed to travel on the road, except for those special types, such as fighting vehicles, for which the Minister of Transport may grant exemption, as he does from the existing regulations.

190. These values are significantly higher than those which would be fixed purely on the basis of "acceptability" for the average listener and the average vehicle (paragraph 180). The choice of limits at any level is, however, necessarily a compromise between what is desired by the public and what is technically possible, at a reasonable cost, at any point of time. We consider that the levels which we propose are the lowest that can be recommended at the present time, (*a*) without penalising certain types of vehicle through the deficiencies of the available measuring instruments (paragraphs 178 and 179) ; and (*b*) to fit in with what is immediately technically possible for new vehicles (paragraphs 182 and 183). We emphasize that the levels refer to the maximum noise which a vehicle can normally make ; and in ordinary road conditions, the vehicle, properly driven, should seldom make this noise.

191. Most people have a fairly clear idea in their mind of what is a "quiet" and what is a "noisy" vehicle ; and the limits suggested in paragraph 189 can be considered in their right perspective by comparison with the following figures obtained for particular vehicles in the MIRA tests : —

Luxury limousine	77 dBA
Small passenger car	79 „
Miniature passenger car	84 „
Sports car	91 „
Motor cycle 2 cylinder 4 stroke	94 „
Motor scooter 1 cylinder 2 stroke	80 „

192. Special comment is needed on the apparently more favourable treatment suggested for motor-cycles—regarded by some as the prime cause of noise nuisance ; no favour has, in fact, been shown. We choose the higher figure because of (*a*) the consistently higher reading on the sound level meter (about 3 dBA) given by motor-cycles as compared with four-wheeled vehicles which were judged equally noisy and (*b*) the bigger scatter of results in the motor-cycle measurements [in the 1959 experiments, for example, (ref. 1) a total variation of 15 dB was needed to cover *all* motor cycles of the same loudness, compared with 9 dB for private cars and commercial vehicles]. In other words, the 5 dBA difference we suggest is due to the defects of the only kind of meter which is available at present.

If a " perfect " meter existed, i.e. one agreeing exactly with subjective judgments, we should recommend an identical figure for both classes of vehicle.

193. We consider that these maximum permissible limits for new vehicles should be reviewed from time to time in the light of technical progress. We recommend that the first review should take place in time for any practicable reduction to be introduced not more than five years from the date at which the limits that we recommend come into force.

VEHICLES ON THE ROAD

194. We turn now to the control of noise from vehicles on the road. We have received evidence that certain types of silencers deteriorate in use, before they finally fail, with the result that a vehicle may emit more noise than when it was new. Similarly, bad maintenance, accidental damage or deliberate interference to siiencing systems can have the same result. In our view it is, therefore, also necessary to lay down quantitative noise limits for vehicles when in use on the road.

195. The appropriate noise limits would, however, be affected by the method used for enforcing them. We have considered three ways in which this could be done: —

(*a*) by requiring a vehicle which appeared to be making excessive noise to be taken to a designated place at which the vehicle could be tested using the procedure for new vehicles;

(*b*) by requiring a vehicle which appeared to be making excessive noise to be taken immediately to a road which provided a suitable environment and to be tested there using a procedure as similar as possible to that for new vehicles; and

(*c*) by measuring the noise made by a vehicle on the road, having provided that it should be an offence for the noise emitted by the vehicle to exceed a given level in any circumstances.

196. Our own preference is for method (*c*). Both the other methods would present greater practical difficulties and would also have the disadvantage that the noise level measured in a formal test would not necessarily be that which the vehicle was emitting when a police officer's attention was drawn to it. Whatever method is chosen, we consider that it should be an offence for a vehicle to emit more noise than that which we recommend as a maximum for the same type of vehicle when new.

197. We should point out, however, that if the noise from a vehicle is to be measured on the road, it may, in certain circumstances (e.g. near reflecting walls and buildings) give a higher reading on a meter than it would do on an open site such as is specified for the BS test. Tests have been made by the Ministry of Transport to determine this effect, and have shown that wide variations can occur; but the differences between the readings on an open site from a vehicle with a silencer in good condition and those from a similar vehicle on a roadside site which is reasonably free from enclosing reflecting surfaces is small and would be covered by an allowance of 3 dB in most cases.

198. We recommend, therefore, that the police should measure the noise made by motor vehicles on sections of road which provide a suitable

environment for measuring noise, using that part of the BS procedure which relates to measuring instruments and their position. Under these conditions it should be an offence for the noise measured to exceed by more than 3 dB the levels in force at the time for new vehicles. Time must be allowed for existing vehicles to be modified and we consider that the measurement of noise from vehicles on the road should start two years after the enactment of the empowering legislation.

199. Some experience and training will be necessary to enable the police to choose suitable sites, and we recommend that the roadside sites used for measurement should be approved by the Minister of Transport.

200. We recognise that the enforcement of numerical noise limits upon vehicles on the road is bound to raise many problems. It is also difficult to forecast what effect this would have in practice in reducing the noise of traffic. Both the procedure and the allowance for measurement on roadside sites suggested in paragraph 198 should, therefore, be regarded as experimental and we recommend that they should be reviewed not more than three years after their introduction.

201. It has been suggested to us in evidence that the introduction of maximum noise limits for vehicles on the road may weaken the control of noise, because the police would be able to prosecute only on the evidence of a meter reading, and the number of measurements that they could make would be limited. Also, they would be unable to proceed against a driver who was making noise which was unnecessary but did not exceed the defined limits. Our purpose in recommending quantitative limits is to add to the effectiveness of the law, but this purpose will not be served if the limits are permitted to create a public impression that any noise that cannot be proved to exceed them is acceptable. All unnecessary noise is unacceptable. If a vehicle user is so operating his vehicle that it creates unnecessary noise, for example, by "revving" the engine while stationary, we recommend that he should be liable to prosecution.

EFFECT ON NOISE FROM MOTOR VEHICLES

202. We have attempted to forecast the probable effect on present-day traffic of adopting our recommendations forthwith. Unfortunately, no measurements exist from which this effect can be at all closely estimated. The 1959 measurements (ref. 1) were made on a sample of mid-week traffic on a fairly fast main road. Vehicles were selected for measurement so as to give as wide a range as possible of subjective judgment, from "quiet" to "excessively noisy"; there was no intention of making a statistically random selection. Eight of the 197 cars and commercial vehicles and 3 of the 28 motor-cycles measured exceeded the limits recommended in paragraph 189 plus the maximum allowance that we suggest in paragraph 198. In the conditions of this experiment a particularly noisy vehicle would almost certainly have been selected for measurement; on the other hand, it is not likely that many of the vehicles observed were running at full throttle, and worse conditions for noise nuisance occur, for example, when accelerating away from traffic lights.

203. Better evidence is perhaps obtained from a summary of the measurements which have been made at MIRA on vehicles under BS test

conditions (ref. 2). Here the vehicles were chosen to cover a wide range of performance, size, cost, etc.; though again the choice bears no relation to the frequency with which any particular type of vehicle runs on the road. It was found that 7 private cars out of 30 types tested, 8 out of 18 types of commercial vehicles, and 11 out of 27 types of motor-cycles, would have failed to pass the BS test for new vehicles, at the limits we have recommended.

204. The maximum noise levels recommended in paragraph 189 are those that we regard as reasonable in the light of conditions and knowledge that exist at this time. We wish to emphasise that we believe that the enforcement of these levels would considerably reduce the number of noisy vehicles on the road, even though (as paragraphs 202 and 203 show) we cannot estimate this reduction closely. Nevertheless, we intend that these levels should be regarded as first steps and we recommend that they should be progressively reduced so that vehicle noise becomes inoffensive to an increasingly large proportion of the population. Lower levels could be chosen if the instruments available for measuring noise reflected people's subjective reactions more precisely, and if technical knowledge on means of noise reduction was at some points more extensive.

RESEARCH

205. The inadequacies of present types of meters have been stressed. We recommend that further research should be directed towards the development of a meter which is better suited to the measurement of vehicle noise than those that are available at present.

206. The evidence that we have received indicates that there is at present inadequate understanding of some of the basic principles involved in reducing noise from motor vehicles. Further reductions in noise levels are dependent upon the development of understanding of these principles. We therefore recommend that further research should be directed towards increasing knowledge of the principles of reducing noise from motor vehicles.

CONTRIBUTION BY DRIVERS

207. Finally, we consider that the greatest contribution towards reducing the annoyance caused to the public by noise from motor vehicles must eventually be made by drivers themselves. The noise made by a vehicle is largely controllable by its user. We recommend that every possible means should be employed to educate all drivers in careful, considerate use of their vehicles.

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Chapter VII

Noise from Other Surface Transport

PART I. RAILWAY NOISE

INTRODUCTION

208. The British Transport Commission informed us that the number of complaints about railway noise which they receive is relatively small. For example, in the period of two years preceding our enquiry, the headquarters of the Western Region of British Railways received 18 complaints, and in the first 50 weeks of 1960 the London Transport Executive received 98 complaints spread over 33 different causes. Neither these complaints nor any other evidence that we received indicate that railway noise causes widespread annoyance, although we heard evidence from members of the public that some people living near railway tracks are greatly disturbed by the noise.

209. The noise from railways which affects the public living near them is caused by passing trains, by shunting, by engineering works in depots and on tracks, by steam blowing off from locomotives, and by safety precautions, such as whistles, hooters and detonators.

210. We also considered the noise which affects railway passengers, although we had no evidence that they were particularly disturbed by it. However, in the opinion of those of us who have travelled on railways abroad, the noise levels inside most of the coaches on British Railways are higher than in the coaches used in some other countries. We also felt that the noise in some railway stations is higher than it need be.

PASSING TRAINS

211. The noise from a passing train is mainly from the locomotive and the movement of the wheels over the rails. In recent years the character of the noise from locomotives has been altering as electric and diesel engines have replaced steam, and the British Transport Commission attribute the complaints that they have received about noise from diesel engines to the unfamiliarity of the public with this noise rather than to increased noise levels. No objective data were available comparing the noise levels of steam, electric and diesel engines, but we were informed that an international committee was trying to formulate a procedure for measuring railway noise levels to enable such comparisons to be made and standard noise levels to be laid down.

212. Neither were data available on the comparative noise levels, alongside the railway, of trains running on jointed and on welded tracks. It seems reasonable to suppose, however, that the Commission's policy of replacing jointed rails by long welded rails should reduce noise from passing trains.

213. The noise from brakes and brake gear on goods trains is a source of complaint. We think that this noise would be virtually eliminated by the use of automatic brakes on wagons.

SHUNTING

214. We were informed by the British Transport Commission that most complaints about noise from shunting referred to shunting at night, but that night shunting is an essential feature of rail freight working.

215. Shunting takes place at some six hundred marshalling yards and also in goods yards and smaller groups of sidings. The sources of noise are numerous; they include engines, the binding of the wheels of engines and wagons on curved rails, wagon buffering, mechanical retarders, loose brake gear and audible signals.

216. We were informed of a number of developments which should reduce the noise of shunting. It is the British Transport Commission's policy to concentrate shunting on new, modern yards, each of which will take the place of as many as five or more old ones; they have in hand further research into the control of wagons to eliminate rough shunting; hydraulic wagon buffers are being introduced rapidly; and there are increasing numbers of through freight trains and thus less shunting.

ENGINEERING WORKS

217. Some complaint is caused by noise from railway track maintenance work, much of which is necessarily carried out at night or at other times when rail traffic is at a minimum. This work appears to us to be similar as a source of noise to building and civil engineering work, although the duration of the work on any one site is often shorter. However, we consider that the similarities are sufficient for it to be subject to the same controls as we recommend in Chapter X for building and civil engineering work.

218. Other sources of noise are track pre-assembly and other engineering depots. We recommend that these should be subject to the same controls as we recommend in Chapter IX for industrial premises.

AUDIBLE WARNING SIGNALS

219. The British Transport Commission informed us that there had been a number of complaints about the horns used on diesel powered trains, and again suggested that the reason for the complaints was that the public were not yet familiar with the noise. The rules laid down for the sounding of horns or whistles require train drivers to sound them, for example, when entering and leaving tunnels, when people are seen near the line, and also where there are "whistle" notices. The rules are the same for all types of locomotive, although the Ministry of Transport stated that whistling, or hooting, by drivers of electric and diesel trains is probably more frequent than by drivers of steam trains. This is possibly because drivers may feel that electric and diesel engines are less conspicuous, and that the trains which they pull have more rapid acceleration than steam trains. The British Transport Commission expect drivers to restrict as far as possible the use of horns and whistles in built-up areas, stations and shunting yards.

220. Horns or whistles are also sounded when a train halts at a signal which is not equipped with an automatic device to inform the signalman of the presence of the train. As more signalling installations are modernised the need for hooting and whistling at signals ought to diminish.

221. Similarly the noise caused by steam engines blowing off steam when standing at signals will be heard less frequently with the progressive introduction of electric and diesel engines.

222. It is, of course, essential that an audible warning device should produce a noticeable and distinctive sound, and it does not seem possible to devise a method of giving audible warning of the presence of a train to people who might be endangered by it, or to signalmen, without broadcasting the noise to people who are not concerned.

223. We have no evidence that the noise from detonators is a problem.

NOISE IN STATIONS

224. Noise in stations affects people living nearby, as well as railway passengers. Some noise is inevitable, but we think that it could be reduced below its present levels, and, indeed, some of the developments such as the wider use of automatic brakes on wagons, which are mentioned in other paragraphs, will reduce it. It will also be reduced by the replacement of steam engines by diesel and electric engines (the drivers of diesels being instructed to shut down the main motors when trains are at rest), and by the increasing use of electric visual indicators for signalling to drivers when trains are ready to depart. A major source of noise is the slamming of carriage doors. The Commission are studying this problem but can see no easy solution because of the need to provide locks of adequate security, and the cost and effects upon the internal layout of coaches of using guard-controlled sliding doors. Minor but worthwhile reductions could be achieved by such measures as the use of rubber instead of steel tyres on platform trolleys, and of better designed station announcement systems which would permit intelligible messages to be broadcast at lower volume.

NOISE INSIDE TRAINS

225. The noise inside most British Railways coaches is, in our view, uncomfortably high, and compares unfavourably with that inside the coaches on some foreign railways on which some of us have travelled. The diesel Pullman and some other trains which have been introduced by the British Transport Commission are much quieter than ordinary carriages and the Commission informed us that this is a feature which is popular with passengers. They also said, however, that the cost of achieving this degree of quietness, which involves double glazed windows and air conditioning, was too high for it to be used in all passenger coaches.

226. The primary source of noise in coaches is the rolling of the wheels on the rails. This noise is increased by rail joints, and the level of noise in coaches is being reduced on main lines by the replacement of jointed rails by long welded rails.

Noise in Underground Trains

227. The problem of noise in Underground trains has been studied since 1909, and after many unsuccessful experiments various measures have been adopted to reduce it. These include increasing the standard length of rail; the use of wedges faced with acoustic tiles on the walls of tunnels at about train floor level; rubber carriage suspensions and rubber bushing for shoe gear; non-metallic brake blocks; and the quietening of compressors and other ancillary equipment. The British Transport Commission informed us that the noise level in some new prototype carriages was much lower than in present types, the prototype carriages having double glazing, indirect ventilation, sound absorbent panelling and various mechanical improvements.

THE LEGAL POSITION OF RAILWAY AUTHORITIES

228. The British Transport Commission, like other statutory undertakers, are exempt from action for nuisance under the Noise Abatement Act, 1960, by virtue of Section 1(4) of that Act. This exemption follows similar exemptions in the clauses in local Acts which preceded and set the pattern for Section 1 of the Noise Abatement Act. Similarly, Section 2(2)(*e*) of the Act grants exemption from the prohibition of the use of loudspeakers between 9 p.m. and 8 a.m. contained in Section 2(1), to railway staff making announcements to passengers, prospective passengers or other railway staff. The Commission are not, however, exempt from action for nuisance brought under Common Law.

CONCLUSIONS

229. There is no evidence of widespread public annoyance from railway noise, although we appreciate the inadequacy of complaints as a measure of annoyance. Nevertheless, we are of the opinion that, if serious attempts were made to reduce noise as a primary objective, rather than as a by-product of measures taken with other aims, the comfort of passengers and the public living in the vicinity of railways could be considerably improved. We are reinforced in this view by the encouraging results which have been obtained from the limited efforts which have so far been made.

230. Except in the case of special Pullman trains, and of some London Transport Executive Underground lines, no real effort appears to have been made to reduce noise inside passenger compartments. The Commission have plans for research into this question but we feel that much could be learned from some railways abroad.

231. In the absence of evidence of widespread public annoyance we do not feel that any special legislative action is required. We have, however, recommended in Chapter IX changes in the law relating to all statutory undertakers which would remove altogether the present exemption of railway authorities from proceedings for noise nuisance. We have also recommended (in paragraphs 217 and 218 above) that construction and maintenance work on railway tracks and premises should be subject to the controls that we recommend in Chapter X for construction and demolition sites, and that the controls that we recommend in Chapter IX for industrial premises should apply to railway depots.

232. In view of the obvious scope for systematic study of the various aspects of railway noise, and the resulting probability of significant reductions in the noise from some sources, we also recommend that the railway authorities be urged to attach more importance to noise reduction and to engage in much more extensive research into the subject.

PART II NOISE FROM BOATS

233. In the last few years noise from motor-boats on rivers, lakes and the sea has begun to cause complaint and in some areas to become a nuisance. With the growing popularity of motor-boating and water-ski-ing the nuisance is likely to become worse and more widespread unless preventive measures are taken.

234. Some local authorities have made bye-laws under Section 249 of the Local Government Act, 1933, or Section 76 of the Public Health Act, 1961, requiring motor-boats to be fitted with " silencers suitable and sufficient for reducing, as far as may be reasonable, the noise caused by the escape of exhaust gases from the engine," or simply with " effectual silencers." Some local and navigation authorities look to the enforcement of speed limits as a means of controlling noise.

235. We were also informed that the Ship and Boat Builders' National Federation are considering the formulation of standards of noise for marine engines and that motor-boat racing organisations in this country subscribe to international rules which require all boats to be silenced to the satisfaction of the race organisers.

236. There is insufficient experience of these measures and proposals to judge whether they will be effective. If, in spite of them, noise from boats threatens to become a serious and widespread nuisance, we think that the most effective control would be the introduction of statutory numerical noise limits on the lines of those that we recommend for motor vehicles. The need for the introduction of such limits should be reviewed in, say, two years time and thereafter each two years to guard against a decision being delayed until a serious nuisance has already developed.

PART III NOISE FROM HOVERCRAFT

237. At least in its present experimental form the hovercraft is noisy. Although it is not yet clear in what role hovercraft will be used, the need to consider the control of their noise should be emphasised now while they are still at an early stage of development.

238. The Road Traffic Act, 1962, brings them within the definition of motor vehicles if they are operating on the roads, which means that they would then have to meet the statutory requirements for vehicles, including those for noise.

239. However, at least in this country in the immediate future, it seems that their most likely use is over water, and the first fare paying passenger service, introduced in 1962, was over the sea. When operating in this way the greatest risk of serious noise nuisance seems to be when the craft come on to or leave the shore at terminal points. The establishment of terminal points would almost certainly require planning permission and, no doubt,

planning authorities would be as conscious of the risk of noise nuisance from such termini as they are of the risk from industrial premises (see Chapter IX, paragraph 377).

240. Nevertheless, we consider that criteria for the control of noise from hovercraft should be introduced as soon as possible, not only to help to protect people living near hovercraft termini and routes, but so that hovercraft designers can have standards to which to work. We consider that the criteria might be determined on the following principles:—

(*a*) for commercially operated hovercraft:

(i) in areas where the ambient noise is already high, e.g. near noisy industry, rules based on speech interference level would be appropriate. The limit should be fixed at a level at which noise from the hovercraft would not make conversation unduly difficult inside the nearest inhabited building;

(ii) in other areas the limits should be based upon levels at which noise from hovercraft is acceptable to average people, as measured by procedures similar to those referred to in Chapter IX, paragraphs 379 to 386: and

(*b*) the control of noise from privately operated hovercraft should be similar to the control that we suggest for boats.

Chapter VIII

Aircraft Noise

INTRODUCTION

241. Until the beginning of the Second World War there were few aircraft and these were comparatively low-powered and quiet, but during the war the numbers of military aircraft increased until few parts of Great Britain were unaffected by their noise. To most people the noise was welcome as a sign of allied air strength. After the war, air forces were rapidly disbanded and civil aviation, concentrated on a small number of airfields, began to grow. The airlines using airports in this country were equipped with piston-engined aircraft, but with an increasing number of turbo-propeller aircraft, mainly on short and medium hauls. For some years complaints about noise had been received from people living near these airports. The number of complaints increased sharply with the introduction of the larger turbo-jet engined airliners in 1958 until noise became a major problem. The number of turbo-jet aircraft has continued to increase, and they are forming an ever-growing proportion of civil aircraft. Up to the present the noise has been confined principally to the people living near airports, but the introduction of supersonic civil aircraft threatens to spread the problem over wide areas of the country; helicopters, too, have been developed to the stage where they are being considered as a means of transport between city centres.

242. Aircraft noise is caused principally by the engines and propellers and it increases with the power output. Generally, therefore, it is most intense when aircraft are taking off because they are then using maximum power; certain special features of the noise of jet engines make it also intrusive when the engines are throttled back for landing. Military aircraft may also cause disturbance to the public when flying low for operational or training purposes and when flying supersonically.

243. There is ample evidence that aircraft noise causes much annoyance. Government departments, Members of Parliament, local authorities and airfield authorities receive numerous complaints. We received evidence, ourselves, from Members of Parliament, local authorities, residents' associations, and individuals, which showed their deep concern with this problem. We also held meetings at London (Heathrow) Airport so that we could experience the noise and see the efforts being made there to reduce it. In view of the complexity and obvious seriousness of the problem we requested an experiment on the acceptability of aircraft noise, similar to that on motor vehicle noise, (see Chapter VI) and a social survey in the vicinity of London (Heathrow) Airport to try to provide as accurate a measure as possible of the extent, depth and distribution of public feeling in the area most affected by this noise. The answers given by people interviewed in the survey were correlated with measurements of the noise in the area in an

attempt to get information about the precise features of the noise that were principally responsible for annoyance. Results of the experiment and the survey are described later in this chapter.

MILITARY AND EXPERIMENTAL FLYING

244. For the year ended 30th November, 1962, the Admiralty received 88 complaints about aircraft noise and the Air Ministry 317. The majority of these complaints related to low flying, one third of the complaints received by the Air Ministry relating to flying in the immediate vicinity of airfields. Most of the complaints received by the Air Ministry came in the summer months.

245. The main problem appears, therefore, to be caused by low flying. This is an essential part of military training and is carried out on routes which are chosen as far as possible to minimise disturbance; for example, by avoiding populated areas, hospitals and schools. Military pilots are forbidden to fly below 2,000 feet in fixed wing aircraft or 1,000 feet in helicopters except when specially authorised, or in an aerodrome traffic zone, or when forced to do so by bad weather, or over the open sea clear of shipping.

246. In order to minimise aircraft noise near aerodromes aircraft are deployed as far as possible on airfields in sparsely inhabited areas. The Air Ministry and Admiralty accept, however, that there are few, if any, airfields in this country at which operations will not disturb some local residents, and they do what they can to use traffic patterns and to restrict night and week-end flying to reduce disturbance as far as possible.

247. From time to time complaints are made about noise from Government experimental establishments and manufacturers' airfields. Noise is sometimes inevitable, but arrangements are made to reduce the disturbance to the public, for example, by using silencing devices for ground running engines, by the careful choice of sites for exceptionally noisy work and by restricting it, as far as possible, to the daytime. In some cases noisy work is stopped altogether when, for instance, examinations are in progress at local schools. As at London (Heathrow) Airport, a lot of trouble is taken to explain the noise problems to the communities near these air fields, usually in this case through the medium of visits from the local councils and their officers. They are shown the work causing the noise and given an indication of its importance, and they are able to see the efforts that have been made in the way of silencing arrangements to keep down the annoyance to the public. There is no doubt that toleration of the noises heard round these airfields is greatly helped by an understanding of the problems involved in reducing the noise.

248. Some sonic booms have been produced by supersonic military and experimental aircraft. Military aircraft normally fly supersonically only over the sea, and over land experimental supersonic flying is strictly controlled and is confined to high altitudes over sparsely populated areas. The boom from future supersonic civil aircraft is discussed in paragraphs 342 to 352 below.

THE PRESENT PROBLEM AT CIVIL AIRPORTS

249. As far as civil aircraft are concerned we decided that we should examine the present problem at London (Heathrow) Airport in detail as this is the busiest international airport in Great Britain and provides one of the most difficult aircraft noise problems in the world. The great difficulties at Heathrow arise largely because it is almost surrounded by thickly populated areas, unlike many other airports which have either the sea or sparsely populated land areas on at least one side.

250. The noise problems at Heathrow caused by aircraft taking off and landing are acute, and were exacerbated by the introduction in 1958 of the heavy long-range jets. Their advent brought about a marked rise in the number of complaints about noise, as is shown in the following table of the numbers of these complaints received at the Airport.

TABLE X

Complaints received at London (Heathrow) Airport*

Year (*i*)	Number of complaints† (*ii*)	Number of air transport movements (*iii*)	Estimated number of jet movements included in previous column (*iv*)
1956 ...	87	109,046	Nil
1957 ...	161	116,101	Nil
1958 ...	350	117,295	Negligible
1959 ...	840	118,809	4,750
1960 ...	1,205	135,468	21,500
1961 ...	984	146,700	38,000
1962 ...	.541	145,830	52,200

* Complaints are also made to e.g. Ministry of Aviation Headquarters. It has not been possible to enumerate these.

† Nearly all complainants complain only once but some complain several times and a few many times. The number of complainants is much smaller, between ½ and ⅔ of the number of complaints.

251. There are two main reasons why the heavy long range jets caused the steep rise in complaints. First, these aircraft are much bigger and more powerful than those that they are superseding. Secondly, turbo-jet engines generate noise of a character which was unfamiliar to people living near the airport and which is also intrinsically more disturbing than that of propeller driven aircraft.

252. The characteristic of jet noise which is most apparent at take-off, when the engine is operating at high thrust, is a great roar which quickly rises and then falls as the aircraft passes overhead. This roar is generated by the violent mixing of the jet of gases from the engine with the surrounding air and increases with power output and with the velocity at which the gases are expelled. This noise is heard over wide areas during the subsequent climb.

253. During the landing approach the engine is throttled back and the jet roar becomes subordinate to the whine generated by the air compressor and

turbine blades. This noise is not very sensitive to power change. The rise and fall of the noise as a landing aircraft passes overhead is more rapid than the rise and fall of the jet roar on take-off: this is because during the landing approach aircraft are close to the ground for a greater distance than during take-off. For this reason, and because landing aircraft fly straight for some miles on their landing approach, landing noise tends to become concentrated on a longer, narrower band on the ground.

THE EFFECT OF THE NOISE ON THE LOCAL COMMUNITY

254. Careful studies of the complaints received at Heathrow have been made by the Ministry of Aviation. These studies show, among other things:

(*a*) that the number of complaints reached a peak in the summer of 1960 and has since fallen off, although the annual number of aircraft movements, particularly of jet aircraft, has increased;

(*b*) that, as might be expected, the number of complaints per 10,000 of the population was greatest close to the airport and to busy take-off and landing routes;

(*c*) that most of the complaints concerned take-off and landing noise, with the number and proportion of complaints against landing noise rising;

(*d*) that the number of complaints per 100 movements was greatest for the heavy jets. Second place was taken in late 1959 and in 1960 by a piston-engined aircraft which mainly took off at night. Later, the lighter jets took second place.

255. Although most of the complaints came from individual members of the public, strong representations against the noise were made by Members of Parliament, local authorities and residents' associations, and we had the benefit of discussing the problem with some of them. We were impressed by their constructive approach to the problem, and by the depth of feeling that was caused by the noise.

256. In spite of this evidence of deep local feeling there is evidence that the demand for houses in the areas affected by noise from the Airport is buoyant, and, indeed, that many have been built since the existence of a noise problem became apparent. The demand for housing near any airport which employs nearly thirty thousand people will inevitably be large. Evidence that we received from, among others, Inland Revenue valuation officers, indicated, however, that the demand, as reflected in rents and prices, was at least as great for houses close to the Airport as for those a few miles away. It appeared that, for many people, the advantage of living near the Airport balanced the inconvenience of the noise.

257. In addition to annoying and disturbing people in their homes in the vicinity of the Airport, the noise interferes with work by disrupting conversation, disturbs the patients and staff of local hospitals and disrupts teaching in schools.

258. Some of the hospital authorities concerned have given evidence to us and made representations to the Ministry of Health about the effects of noise. The Ministry of Health have agreed that new buildings at hospitals most affected by the noise should be designed so as to reduce the nuisance, and accept that this will almost certainly involve a large measure of double glazing and mechanical ventilation.

259. Enquiries by Her Majesty's Inspectors of Schools confirmed the serious effects of the noise on some schools in the area. One Inspector, while doubting whether it was possible to prove what effect the frequent interruptions have on children's attainments over their seven years primary schooling, pointed out that the standards of work in one school were in many ways below average, although the staff were certainly not below average in teaching ability. On a previous visit by the Inspector to this school, the half hour assembly had been interrupted ten times and on the following day it had to be abandoned. We understand that at two existing schools experiments with double glazing and sound attenuating ventilation units are being conducted to try to improve the insulation against aircraft noise. We hope that the sound insulation at other schools which are similarly affected will also be raised to give satisfactory conditions for teaching. It is essential that in future new schools built near Heathrow, or any other airport where noise may seriously affect school activities, should be sited in reasonably quiet places and be laid out and constructed to provide adequate defences against aircraft noise.

LEGAL POSITION

260. Sections 40 and 41 of the Civil Aviation Act, 1949, broadly prohibit actions for nuisance arising from civil aircraft in flight or on aerodromes.* The protection for aircraft in flight dates from the Air Navigation Act, 1920, and was extended to cover aircraft on the ground by the Air Navigation Act, 1947. The main reason for this protection was that unless the individual's right to take action for nuisance was restricted, it was feared that civil aviation in this country would be unable to continue. Noise caused by aircraft is also excluded from the provisions of the Noise Abatement Act, 1960.

261. Since legal action against aircraft noise nuisance is severely restricted, the Minister of Aviation considers himself under an obligation to take steps to minimise the nuisance.

MEASURES ADOPTED TO REDUCE NOISE

Reduction at Source

262. Research and development work on aircraft noise problems is proceeding in Government establishments, universities and industry. The amount of this work, which is estimated to cost about £350,000 per annum, is increasing, and it is estimated that £450,000 per annum will be spent on it in the near future. The bulk of this cost is met by the Ministry of Aviation but engine manufacturers are spending some £100,000 per annum.

263. Some success has already been achieved. Noise suppressors have been developed for the jet engines now in service which are developments of military engines with high jet velocities. These suppressors reduce the noise appreciably and most of the jet aircraft which use Heathrow are equipped with them. Without them the heavy jet airliners would have to climb much higher over the community in order to reduce noise to the level

* A statutory right of action for damages (but not an injunction) is, however, given against the owner of the aircraft whenever material loss or damage is caused by an aircraft while in flight, taking-off or landing. This includes material loss or damage caused by noise.

achieved by aircraft with suppressors. This could only be done by a large reduction in pay load, or in the quantity of fuel carried, which would involve shorter stage lengths. On the other hand, the noise suppressors are themselves costly and add appreciably to the airline's running costs, since they reduce take-off thrust, and increase fuel consumption, drag and weight. These penalties can be additive, but in practice their effect varies with the type of aircraft used and the routes flown. B.O.A.C. have estimated that the additional operating costs per aircraft per annum arising from the use of suppressors are about £16,500 for Boeing 707s and £8,500 for Comets. B.E.A. estimate the additional costs for their Comets at about £7,000 per aircraft per annum. An American airline have calculated their additional operating costs due to the use of suppressors on Boeing 707s as about £43,000 per aircraft per annum.

264. Jet noise is critically dependent on the velocity of the jet. Most of the engines which are now coming into use for civil transport aircraft are of the bypass, or ducted fan, type in which the jet velocity is lower than that of current engines, resulting in an overall improvement in the economy of operation as well as a reduction in noise level which may be as much as 10 or 12 decibels for the same power. Only small further reductions of noise can be obtained by the use of noise suppressors with bypass engines, and the performance penalties will then be high since the suppressors are less effective at low jet velocities.

265. In addition to work aimed at reducing jet noise, attempts have been made to reduce the high pitched whine caused principally by the compressors in jet engines. It is this noise which is the main source of annoyance from aircraft approaching to land. Some progress has been made towards alleviating it and work on the problem is continuing in Government establishments and industry.

Take-off Procedures

266. It was clear to the Ministry of Aviation from the evidence of the early flights by jets at Heathrow that the noise levels were likely to cause serious nuisance to people living in the vicinity. In consultation with other international airport authorities it was concluded that, for take-off, the maximum permissible noise levels in the main built-up areas near the airport should, at worst, be of the same order as those of the larger piston-engined aircraft. The noise made by the large piston-engined aircraft naturally varied and it was felt that it would be unreasonable to choose as the limit which should be placed on jets the highest noise level measured from any piston-engined aircraft in the past. It was also necessary to take into account the character of the noise of jets which, for the same actual measured noise level, is much more annoying than the noise from piston-engined aircraft. Examination of this problem by the Port of New York Authority led to the formulation of a new scale of noise, the Perceived Noise Level in PNdB*, which gave

* The perceived noise level, which was based upon human judgments of the noisiness of a number of piston-engined and jet-engined aircraft, is now generally used to indicate the noise of aircraft. To avoid confusion we will, however, quote aircraft noise levels in dBA, as this is the unit used in the rest of our Report, as well as in PNdB. We have also, in a number of places, used "loudness" in referring to noise measurements quoted in PNdB and dBA. Strictly, neither PNdB nor dBA should be used to measure "loudness." A description of both these units is given in Appendix II.

a reasonable measure of the annoyance value of the noise from both jet and piston-engined aircraft. A limit of 112 PNdB (approximately equivalent to 98 dBA) was adopted at New York as being the figure which was exceeded there by 25 per cent. of the larger piston-engined aircraft there in service. The figure adopted at London (Heathrow) Airport was 110 PNdB (about 96 dBA).

267. Airline operators were not permitted to introduce scheduled services with jets at Heathrow until they had undertaken so to operate their aircraft that the noise level at the first main built-up area reached after take-off would not exceed this figure. The first built-up areas after take-off from each runway were defined. Their distances from the point at which the aircraft started their take-off runs varied between 1·9 miles and 4·2 miles according to the runway in use.

268. It was appreciated that aircraft noise was more troublesome at night than during the day. Initially, therefore, no scheduled operations by jet aircraft at Heathrow were permitted between 11 p.m. and 7 a.m., although delayed aircraft were allowed to land and, in some cases, to take-off. Take-off was allowed up to midnight only if the aircraft was of a type which had been able to show a high degree of compliance with the noise limit of 110 PNdB. For delayed departure after midnight the operator had also to show by practical tests that for the flight in question the noise level would be substantially lower than 110 PNdB [in practice about 102 PNdB (88 dBA)].

269. Since the 1st April, 1960, a number of scheduled services have been allowed at night by airlines which have demonstrated that they can operate them at noise levels not exceding 102 PNdB and have undertaken to do so.

270. The airlines are free to achieve the noise limits in any way that they can, subject to the overriding importance of safety and the approval of their proposals by the authorities in the country in which the aircraft is registered. Most adopt a technique in which full power is used and the aircraft is made to climb as rapidly as possible until it approaches the first main built-up area. Just before it reaches this point, power is reduced to the minimum which enables the aircraft to continue to climb safely. In this way the greatest possible height is gained before the aircraft reaches the first main built-up area and the noise in these areas is minimised. It may be necessary for the operator to reduce the load of the aircraft to enable it to climb to a height from which the noise will be within the limit after power cut-back. This is usually done by reducing the fuel carried and making an additional stop to re-fuel, at considerable cost.

Noise Monitoring Arrangements

271. In order to verify whether the airlines are conforming to the noise limits, airport staff are stationed at a point immediately before the main built-up area as defined, to measure the noise of aircraft taking-off. With the mobile equipment used at present it is practicable to make measurements of nearly 90 per cent. of the take-offs by jets, but the Ministry of Aviation intend shortly to introduce automatic equipment which will measure the noise of all take-offs.

272. The results of these measurements are examined by the airport authorities and explanations are sought from operators in cases of serious or persistent non-compliance with the limits. Although the Minister of Aviation could bar operators, or particular pilots, from using the Airport if they offend against limits, he has not found it necessary to do this. Instead, he has adopted a policy of seeking the co-operation of airlines, and we were assured that all the airlines have appreciated the need to minimise noise. Some have established quite elaborate procedures to help their pilots to conform with the limits.

273. The extent of compliance with the noise limits has constantly improved. During the first eight months of 1962 they were exceeded by only 2 per cent. of all jet aircraft whose noise was measured. In considering this figure it should be borne in mind that the procedures necessary to conform with the limits require a high standard of skill, training and experience on the part of the pilots, and that variations in noise level are found between take-offs which appear to be similar in all other respects. The present level of compliance is, therefore, commendable.

274. Since August, 1961, aircraft taking off to the west from Heathrow have been required to adhere after take-off to new routes which keep them further from the main built-up areas.

275. Although all these measures help to reduce noise for people living in the designated main built-up areas it is recognised that they do not reduce noise for people living alongside the runways nor the communities which are closer to the Airport than the main built-up areas, and whose presence so near to the Airport makes the noise there so serious a problem. Nor do the noise limits apply to propeller driven aircraft, some of which may make more noise than is permitted from jets, particularly at night.

Landing Procedures

276. A substantial and increasing proportion of the complaints received concern noise from jets approaching to land. It is not practicable to vary the approach procedure appreciably, as turns, or steeper descents, would prejudice aircraft safety. Pilots are not permitted to approach at shallower angles than 3° to the horizontal, and radar checks have verified that aircraft rarely depart substantially from this angle of approach.

Ground Running Procedures

277. Like most international airports, Heathrow is a major maintenance base, and an appreciable amount of ground running of engines is essential there. Steps taken to minimise the noise nuisance which may be caused to local residents are:—

(*a*) the use of techniques to keep engine running and, in particular, engine running at full power, to a minimum ;

(*b*) the development of noise screens in the form of earth banks or buildings ;

(*c*) the use of mufflers with jet engines ; and

(*d*) reduction of ground running at night to what is operationally necessary.

278. Considerable progress has been made by operators in reducing the need for ground running, especially at full power. In addition, major maintenance areas at Heathrow are required to have noise screens in the form of buildings or earth banks to shield the main nearby residential areas from noise, and noise mufflers must be used whenever jet engines are run for maintenance purposes at full power during the day and at any power during the night. Night running of engines is permitted only for essential maintenance of an aircraft needed for service the next day. Operators are required to keep a log of all ground running at night. The cost of all these measures falls upon the operators, and B.O.A.C. alone estimate the capital cost of their mufflers and earth banks at £407,000.

279. It appears that the means of bringing under control the problem of noise from maintenance ground running are available and have largely been provided, at considerable cost. The effectiveness of the measures that have been introduced is indicated by the small number of complaints about noise from ground running which are now received at the Airport. It is possible, too, that some of these may relate to noise from aircraft taxiing.

280. Aircraft are normally moved between runways, loading points and maintenance areas under their own power. It has been suggested to us that aircraft should be towed by tractors when moving on the ground, but we consider that the contribution that this would make to the diminution of noise would not counterbalance the great difficulties that it would cause to the Airport and airline operators.

281. It is necessary for piston engines to be run up in order to reach operating temperatures, and to be tested, before take-off. One advantage of jets is that this lengthy preparation is not needed.

INTERNATIONAL COMPARISONS

282. Aircraft noise is an international problem and is receiving attention in many other countries, although the experience of the problem in one country, and any measures taken to mitigate it there, are not necessarily applicable elsewhere. The public attitude to aircraft noise may vary, as may the weight and type of traffic at different airports. The environs of some international airports are less closely built up than the environs of others ; e.g. some airports are on the shores of the sea. Nevertheless we felt that it would be helpful to know what was the experience abroad, and what noise control measures had been adopted. At our request the Ministry of Aviation asked many of the authorities responsible for international airports abroad for information on these questions. The replies showed that most of these authorities regard noise as a grave problem and that the majority of the complaints that they received were caused by jet aircraft, particularly taking-off. Night flights appeared to cause a proportionately greater amount of disturbance than day flights. In these respects the main causes of complaints are similar to those at Heathrow. Many of the overseas airport authorities make arrangements to reduce noise, as shown in the following table. All these arrangements are in force at Heathrow. However, it proved impossible to make detailed comparisons between the problems at Heathrow and at other airports because the circumstances differ so widely.

TABLE XI

Numbers of airport authorities which make specific arrangements for reducing aircraft noise

Authorities that: (*i*)	Nature of specific arrangements					
	Regular noise measurements (*ii*)	Preferential runways (*iii*)	Airline operating techniques (*iv*)	Specific noise limits (*v*)	Ground running rules (*vi*)	Special night restrictions (*vii*)
DO	4	10	12	3	5	7
DO NOT make arrangements shown	6	3	2	9	6	6
Total replies ...	10	13	14	12	11	13

283. The international nature of air travel has an important bearing upon the freedom of airport authorities to impose controls, which would apply to foreign as well as to home-based airline operators. For example, if, in the interests of noise reduction, restrictions are placed upon airline operators at Heathrow which have such serious economic penalties that the use of the Airport becomes unprofitable for them, they may transfer their operations to other airports abroad. A substantial reduction in the air services to Heathrow, which serves London and, indeed, the whole country, would have grave deleterious effects on the country's economy.

THE FUTURE PROBLEM AT CIVIL AIRPORTS

INCREASED NUMBERS OF JET AIRCRAFT

284. The jet aircraft at present in service are long and medium range aircraft, and account for a minority of the movements from Heathrow. In the near future a new generation of short-range jet engined aircraft will be coming into service and, with a general increase in air travel, it is forecast that the number of jet movements at Heathrow will increase from an average of 60 per day in 1960 to an estimated 260 per day in 1965 and 440 per day in 1970. Unless there are marked changes in the attitude of the public to jet noise, or in the noise itself, it seems certain that this increase in the number of jet movements will very seriously increase the present disturbance and annoyance.

285. It seems likely, too, that jet movements will increase at Ringway and Prestwick, and, as jet engined short-range aircraft replace the present propeller driven types, at other airports too. There is little information available to indicate what the reaction of people living near these airports will be, but it would be prudent to assume that it would be similar to that at Heathrow.

NIGHT OPERATIONS

286. There is growing pressure from the airline operators to be allowed to operate more jets at night. Airline profitability depends upon achieving maximum aircraft utilisation with a high passenger load factor. Restrictions on the use of an airport at night have a snowballing effect on the scheduling of aircraft and inevitably reduce aircraft utilisation. In addition, at airports such as Heathrow the traffic capacity during daylight is being reached, and the only way of increasing traffic is to expand the services in the night hours. This increase is illustrated by the inclusion of many more night flights than were authorised in 1961 in the schedules for the summer of 1962 submitted by airlines to the Minister of Aviation. Although the Minister refused to permit the number proposed by the airlines, the schedules he did approve included more night services than had been allowed previously.

LANDING NOISE

287. In the past most attention has been paid to take-off noise, but the increasing number and proportion of complaints about landing noise, and further increases in the number of jet operations, suggest that landing noise is assuming increasing importance. There is little likelihood that operational procedures can contribute to its reduction, as the direction and the angle of the approach path are governed by safety considerations. Any amelioration in the noise level must, therefore, be sought in technical development. Research into this problem is proceeding in industry, universities, and Government research establishments, and some progress has been made, by improvements in engine design.

FUTURE JET AIRCRAFT

288. We have said (para. 264) that the engines now coming into use for civil transport aircraft may be as much as 10 or 12 dB quieter, power for power, than the present jet engines. As a result of this, and of improvements in aircraft performance, the aircraft in which they will be used could be much quieter on take-off than the present jet aircraft, although the exact noise level attained can be determined only by measurement with the aircraft in these operating conditions. It does not follow, however, that the operators of these aircraft will wish to use their improved noise characteristics to reduce noise on take-off below the present limits at Heathrow. In practice the operators may wish to use the improved power to noise ratio of the new engines to get as much extra power as possible within the existing noise limits.

289. It must be recognised, too, that the new, potentially quieter aircraft will replace existing types only gradually, so that the existing types will remain in use for many years to come.

290. The next decade is likely to see the development of supersonic civil aircraft. Since the engines to be used for the proposed Anglo-French project closely resemble existing types of jet engines, it is possible to predict engine noise fairly accurately, but the precise method of operation of the aircraft at take-off has yet to be established. If expectations are realized, the noise in the area at the sides of the runway at take-off will be the same

or a little higher, the noise at the first main built-up area rather lower and that on approach and landing similar to that for present-day jet long range aircraft. In view of the much greater engine power in supersonic aircraft, careful planning of the take-off and initial climb techniques will be needed if the noise is not to be spread over a considerably greater area.

EXPERIMENTAL INVESTIGATIONS UNDERTAKEN

291. It seemed to us from the evidence that the present situation was one of precarious balance between the interests of the local residents and of the airlines and their passengers. We therefore considered it was imperative to obtain more accurate information on the levels of aircraft noise which are acceptable to the public and on the extent, depth and distribution of public feeling in the vicinity of Heathrow. We decided to ask for

(*a*) an experiment on the assessment by a "jury" of the acceptability of aircraft noise, on similar lines to the experiment with motor vehicle noise which is described in Chapter VI; and

(*b*) a social survey in the vicinity of Heathrow.

We also carefully considered whether it would be practicable to investigate any effects that the noise might have on the health of people living near Heathrow. We concluded, after taking the advice of the Medical Research Council, that it was extremely unlikely that such an investigation would produce meaningful results, since the investigators would not know what effects to look for and it would be impossible for them to establish whether any particular condition arose from, or was exacerbated by, the noise. This conclusion was supported by a discussion with a group of doctors working in the vicinity of the airport, who considered that the noise had no significant effects on the health of their patients.

EXPERIMENT ON THE LEVEL OF NOISE WHICH IS ACCEPTABLE

292. In view of the successful outcome of the experiments on the acceptability of noise from motor vehicles which have been carried out by the National Physical Laboratory and the Motor Industry Research Association (see Chapter VI) we thought that a similar experiment with aircraft noise would be valuable. This experiment was done by the National Physical Laboratory at Farnborough in 1961. A report of the experiment is contained in Appendix X. Its main features were that 60 people were asked, under different conditions on each of three days, to make subjective judgments of the noises of a number of different types of aircraft, including jet and propeller-driven machines and helicopters. Two different subjective rating scales were used, as one scale would not have been appropriate for all the conditions under which judgments were made. The average subjective ratings of the noises were compared with their levels measured in dBA.

293. In our opinion the most important conclusions from this experiment are:

(*a*) that it is possible to obtain judgments of the noisiness of aircraft on scales similar to those successfully used in the motor vehicle experiments;

(*b*) that people's judgment of the noisiness of a noise from a recognisable source seems to be related to their previous experience of it. Thus, although, when asked to judge the noisiness, the juries in the two experiments judged both motor vehicles and aircraft to be "quiet" at about 66 dBA at the ear, the mid point of the subjective scale corresponded to about 80 dBA for motor vehicles and 93 dBA for aircraft, reflecting the fact that aircraft noises attain much higher physical levels than those from motor vehicles;

(*c*) that it is possible to construct a scale of "intrusiveness."* When the results of judgments of intrusiveness made out-of-doors were compared with those of annoyance out-of-doors it was found that at very high noise levels intrusiveness and noisiness became equated but at more moderate levels the scales diverged. For example "Very Annoying" corresponded to "Very Noisy" but "Intrusive" came between "Moderate" and "Noisy." Intrusiveness appears to be the more significant feature of noise for judging effects upon people in their day-to-day lives. A way in which these judgments could be used is to say that aircraft might be considered too objectionable at the point "annoying" on the scale or worse. This point corresponded to about 105 dBA when the judgments were made out of doors. It should be noted that in this experiment the jury were asked to make separate judgments of the noise of individual aircraft; and

(*d*) that when the tests for intrusiveness were carried out indoors, the same degree of intrusiveness occurred at about 87 dBA. The reason why people react to lower levels of noise indoors than outdoors is not clear.

SOCIAL SURVEY IN THE VICINITY OF LONDON (HEATHROW) AIRPORT

294. In this country judgment of the disturbance and annoyance caused by aircraft noise has been based in the past upon complaints. This has obvious limitations (see Chapter II) and, at our request, the Central Office of Information carried out a social survey on the effects of aircraft noise in the vicinity of London (Heathrow) Airport. The objects of the survey were to ascertain the effects of the noise on the activities of people living within a 10 mile radius of the airport; the amount of disturbance and annoyance caused to these people; whether they considered that any advantage accrued to them from the presence of the airport; and to provide information from which an assessment could be made of the tolerability of the noise to the people living in the area. (For details see Appendix XI.)

295. To enable comparisons to be made between the disturbance caused and the physical features of the noise it was necessary to measure the noise in the area of the survey and to assess the numbers of aircraft heard. These measurements and assessments were made by the Ministry of Aviation and are also described in Appendix XI.

* The scale of intrusiveness was designed to measure how much the noise disturbed people's activities. The jury were asked, when engaged upon 'tasks' to judge the intrusiveness of the noise immediately after it had occurred. The steps in the scale of intrusiveness were 'not noticeable,' 'noticeable,' 'intrusive,' 'annoying,' 'very annoying,' 'unbearable.'

296. A full report of the survey, which was carried out in September 1961, is being published and a commentary on the results is contained in Appendix XI. We have drawn four major conclusions from this work, two relating to the present situation and two relating to the future. They are as follows :

297. First, there is a considerable correlation between the complaints which have been made in the past and the degree of annoyance revealed by the survey. The survey shows that the complainants are fairly well representative of the people who are highly annoyed with aircraft noises, who, like the complainants, are found in all the levels of aircraft noise exposure. The main difference between the complainants and those who are equally annoyed but have not complained is that the complainants tend to come from those sections of the community who are likely to be more articulate than the average.

298. Secondly, the survey has given us a scale by which we can assess the degree of annoyance caused by aircraft noise. The area round Heathrow can be divided into inner zones containing comparatively few people, the large majority of whom are intensely annoyed, and outer zones containing a large number of people of whom progressively smaller proportions are intensely annoyed. There are, in fact, many people intensely annoyed at all levels of exposure to noise covered in the survey (10 per cent. of the adult population in the outermost zone), and by contrast there are also many (about 30 per cent. of the adult population of all zones) who are unconcerned by the noise whatever its level. Where such large variations in the reaction to aircraft noise exist, only very great changes in its characteristics can have a substantial overall effect, and we have therefore concluded that we should concentrate our attention on the inner zones.

299. The results of the survey show that, as was to be expected, annoyance increases with the number of aircraft heard and with their average peak noise level, and there was a fairly definite correlation between the effect on annoyance due to an increase in noise level and the effect due to an increase in number. This led us to our third conclusion, namely that the survey provides a tentative basis for establishing a combined " noise and number index," defining the total noise exposure which causes annoyance. This is, in a way, a measure of the total noise energy reaching the area in a given time, or a measure of the number of seconds of speech interference in a given time. Since, however, this index is based on a survey of subjective reactions of people living near the Airport, we feel that it is to be preferred for our purposes to other expressions of noise exposure.

300. The concept of a noise and number index implies that, if the average noise level of the aircraft heard increases, the annoyance can be kept constant by reducing the number of aircraft, and vice versa. The evidence for this conclusion must, however, be treated with caution because of (*a*) the inevitable approximations in the basic data of noise levels ; (*b*) the coincidence of high noise levels and large numbers of aircraft, so that there was no-one in the sample of people questioned who heard only a few very noisy aircraft or a large number of aircraft only faintly ; and (*c*) the scatter of the results, i.e. by no means all the people who were very annoyed lived in the noisiest areas. Subject to these limitations we consider that the data showed that a fourfold increase in the number of aircraft heard is very approximately equivalent to

a rise in average peak noise level of 9 PNdB* (see Appendix XI). We have accepted this figure as the basis for deriving the numerical values of the noise and number index in NNI units (see Appendix XI).

301. Finally, if the concept of a noise and number rating is well founded, we believe that the results of the survey provide sufficient evidence for arriving at a NNI value at which the annoyance and disturbance could be regarded as unacceptable.

302. There is, of course, no means of deciding this value by reference to some absolute standard. The decision must be made by comparing reactions to aircraft noise with reactions to other causes of dissatisfaction or by examining people's opinions about the effects of the noise. Among the questions which help to indicate this critical level are those concerning the things people disliked about their neighbourhood, and reasons for wanting to move away from it. From our examination of these factors (see Appendix XI) we think that the most accurate estimate that can be made from the evidence is that the maximum acceptable level lies in the region between 50 and 60 NNI. (80 aircraft heard in a day at a mean noise level of 110 PNdB corresponds to 60 NNI). As shown in Appendix XI, in which the results of the experiment and the survey have been related, these levels correspond with average judgments around " very annoying " on the scale of intrusiveness used in the Farnborough experiment.

303. The " contour lines " of NNI in the vicinity of Heathrow in 1961 are shown in Appendix XII, Figure 1. It must be emphasised that the contours are essentially approximations, but an indication can be obtained from them of the area affected. Estimated noise and number contours at Heathrow in 1970 have also been plotted (see Appendix XII, Figure 2). In drawing these contours account has been taken of the expected increase in the total number of aircraft movements and the probability that a much higher proportion of them will be jets of the current types, and it has been assumed that the present operating procedures and noise limits will continue in force, and that public reaction to " noise and numbers " will be unchanged. The 1970 contours are, therefore, inevitably even more approximate than those for 1961. Nevertheless, they indicate the probable order of magnitude of the growth of the problem in the next 7 to 10 years if no further action is taken.

304. The range 50 to 60 NNI, which we suggest in paragraph 302 as the critical range above which annoyance becomes intolerable, refers to aircraft flying during the day. People are much more sensitive to noise at night than to noise during the day, and the survey provides some evidence, but not a great deal, regarding annoyance at night. Our tentative conclusion is that the concept of noise and number index is probably also valid for aircraft flying at night, but that the same degree of annoyance is produced at night at a NNI which is about 15–20 units less than the corresponding NNI during the day. (In other words, the critical range, which is 50–60 NNI by day, is 30–45 NNI by night.) It must be emphasised that this conclusion, which, if valid, is an important one, is very tentative, and that much more evidence will need to be accumulated before it can be considered to be established.

* This value has been obtained in the vicinity of London Airport and is not necessarily valid at any other airport.

EXPERIMENT ON IMPROVING SOUND INSULATION OF HOUSES

305. It was clear to us that there are many dwellings so near to London Airport that it is impossible to reduce the noise at particular inhabited locations to levels which most people would find reasonable. We therefore decided to see whether ordinary houses could be provided with a better means of insulation against external noise than is given by single windows. To assist us the Building Research Station installed openable double windows, together with a mechanical ventilator incorporating a noise attenuator, in each of two rooms in a building at Garston, and later in a house near Heathrow. This installation is described in Appendix XIII. Measurements made by the Building Research Station showed that the installation reduced aircraft noise by about 40 dB compared with the 20 dB attenuation to be expected with a normal single window. One of our sub-committees visited the house and are satisfied that the installation there is extremely effective against aircraft noise.

ACTIONS WHICH COULD BE TAKEN AT LONDON (HEATHROW) AIRPORT

306. We are agreed that the noise to which many people* near London (Heathrow) Airport are subjected is more than they can reasonably be expected to tolerate. This situation has arisen because no-one, either in Britain or elsewhere in the world, was fully apprised of the great increase in annoyance which would be a consequence of the introduction of large jet aircraft. As a result, Heathrow has proved to have been established in a much too densely populated area, and no good solution to the noise problem is possible. The Ministry of Aviation have had the difficult task of looking after conflicting interests: on the one hand those of the air-lines with their natural desire for unrestricted operation and the development of Heathrow as an international airport; and on the other hand those of the local population with their need for less noise. We are satisfied that, in an unexpectedly troublesome situation, the Ministry have, in general, succeeded in maintaining the balance between these interests, though not without imposing many restrictions on the airlines, increasing or relaxing them as experience showed was necessary.

307. We are convinced that the degree of exposure to noise in areas close to the Airport will not be materially reduced and, indeed, will get a good deal worse, unless appropriate measures are taken now.

308. Unless Heathrow is to cease to be a major airport, and we cannot believe that this is in any way possible, there are only two practicable ways of improving the present situation or possibly even merely of maintaining it. They are as follows:—

(*a*) to reduce the noise of individual aircraft as new types come into service; and

(*b*) to provide houses very near the boundary of the airport with better insulation against noise.

* There are perhaps 20,000 to 40,000 people living inside the 50 NNI contour, of whom about two thirds are highly disturbed by the noise (see Appendix XI).

We discuss below the contribution each of these actions might make to ameliorating the problems, but before turning to them we consider it of value to note that the social survey shows that people's understanding of the problems of aircraft noise will considerably influence their annoyance; for example, it seems that those who think that too little has been done to prevent aircraft noise, those who have a general fear of aircraft and those who think that the noise affects their health, tend to be more annoyed than other people subject to the same noise exposure. The Ministry of Aviation already attempt, through the Airport Consultative Committee which represents local authorities and other local bodies, and through correspondence with the Press, Members of Parliament and the public, to explain the problems involved in trying to minimise the noise from the Airport, and the measures that have been taken. We consider it important to continue and to reinforce these efforts to try to explain the facts about aircraft and their noise.

REDUCTION IN THE NOISE LEVELS OF AIRCRAFT

309. It will be seen from Appendix XII that the NNI contours in 1970 could be contracted to be similar to those in 1961 if the average peak noise level of the aircraft were reduced by 7 PNdB, i.e. a reduction of 7 PNdB in noise level is required to offset the effect of the increased number of jet aircraft movements. A reduction of this magnitude could not practicably be obtained by any modification of existing aircraft or by changes in operational procedures.

310. The only possible way in which the required reduction could be achieved is by exploiting improvements in engines and aircraft. We have seen (paragraph 288) that the next generation of civil transport aircraft are potentially much quieter than the present types, but whether or not they will be quieter in service depends upon how they are operated. In our view it is essential that they and their successors should be operated so as to reduce noise on take-off below the present limits.

311. There are also good prospects of progress in reducing landing noise. If this is achieved, it is equally important that the improvement should be fully and rapidly applied.

312. It must be recognised, however, that the rigid imposition on airlines of limits set at the lowest levels of which their new aircraft are capable, is not practicable. First, unless the airlines gain some economic advantage from the new types they will not buy them; second, the new types will replace the old only gradually; and, third, the international aspects of noise control mentioned in paragraph 283 are important. We are, therefore, unable to lay down any hard and fast rules concerning the future noise limits at London Airport, but we recommend that the present daytime noise limits for take-off should be progressively lowered as the number of aircraft movements rises so as to prevent any increase in total exposure to noise (in terms of NNI) in any area, i.e. by 7 PNdB by 1970 if our estimates in paragraph 309 above remain correct. Similar limits should be introduced for landings.

313. Corresponding reductions in the noise limits for night take-offs, and appropriate limits for night landings, would be required. Their values,

which would depend upon the increase in the number of such flights, should be fixed in the light of our findings in paragraph 304 above. We have noted in Chapter II that it is especially important to diminish noise during the earlier part of the night when people's sleep is more easily disturbed. Night flights at airports in densely populated areas should, therefore, be concentrated as far as possible later in the night.

314. There is one further possible method of reducing noise exposure, and this is the imposition of differential noise limits. At present there is only one limit in the day and another at night which apply to all jet aircraft. The results of the social survey show that a reduction of noise from all flights, even from those which are relatively quiet, would help to reduce annoyance. We consider, therefore, that those aircraft which can be operated well within the present limits should be required to be operated as quietly as is practicable.

315. The reduction of noise limits discussed in paragraphs 312 and 313 is needed to offset the growing number of aircraft movements at Heathrow. By about 1970, however, the number of movements is expected to reach the capacity of the airport, and also by that time most of the present generation of aircraft should have gone out of service and been replaced by quieter ones. It should then be practicable, therefore, to impose still lower noise limits in order to reduce the noise exposure below its present level.

316. We have emphasised in paragraph 283 the bearing which the international nature of air travel has upon the measures which can be adopted. It follows that the reductions of noise limits that are needed at Heathrow could not be made without the co-operation of other countries. The difficulties at Heathrow are greater than those at any other airport. This country should, therefore, take the initiative in attempting to secure greater international recognition of the urgent need to reduce aircraft noise.

INSULATION AGAINST AIRCRAFT NOISE

317. The measures outlined in paragraphs 309 to 316 will be effective in reducing annoyance at locations some distance away from the Airport boundary, but, as we have already said in paragraph 305, the noise level outside some houses very close to the Airport is so high that the normal difference of 20 dB between the noise inside and outside a house with closed windows is insufficient to make living conditions tolerable. On the other hand, the improvement of the insulating properties of the windows of rooms to 40 dB, by fitting the double windows and ventilator mentioned in paragraph 305, would provide a solution to the noise problem in these houses. We feel that the improvement of the insulation of houses, or portions of houses, by this, or some other similar method, is the only practicable means of ameliorating the lot of those who are subjected to excessive noise. But in spite of the fact that a technical solution to the problem is available, we feel that it is most unlikely that it will be adopted unless exceptional measures are taken.

318. The installation by the Building Research Station cost about £200 per room, but this would naturally vary with the type and number of windows. However, the costliest item is the ventilation unit at something over £100

and, although the units installed were intended for larger rooms than those in the average house and the price might also be lower if the units were produced in large quantities, the total cost per room is likely to be greater than the average householder could easily bear.

319. We therefore considered whether a grant should be paid towards the cost of improving the sound insulation in existing houses. The main arguments against this course were:—

(*a*) that it is unprecedented to pay compensation for the loss of an amenity, and

(*b*) that many people are prepared to live close to the airport, as demonstrated by the buoyant prices of houses.

In our view these arguments are outweighed by those for paying a grant. The situation at Heathrow is, itself, unprecedented. The noise in the residential areas close to the airport is the worst known in this country, and the people who suffer from it have no right of legal action to secure its abatement. Also, a grant for improving sound insulation is more akin to a house improvement grant than to compensation for living in a noisy area. We accordingly recommend that grants should be paid towards the cost of improving the sound insulation of existing houses near Heathrow Airport.

THE PROBLEM RAISED BY THE PROPOSAL TO PAY GRANTS FOR THE SOUND INSULATION OF HOUSES

320. The fundamental reason why we feel that grants should be made to help people who are seriously disturbed by noise near London Airport is that they are subjected to noise which is very substantially greater than that which prevails in any other part of the country. This fact should be used to define those people who should qualify for a grant and to decide the source of the funds required.

QUALIFICATIONS FOR GRANT

321. The noise and number index is the obvious criterion to be applied in deciding which householders should be eligible for a grant. There is, however, abundant evidence that personal factors have great influence on the degree of annoyance which is induced by the noise. Thus, the social survey showed that while there are some people seriously disturbed at all levels of exposure in the area covered by the survey, there are also many—about 30 per cent. of the adult population—who are unconcerned by the noise, whatever its level. We know too, that the demand for houses near the airport is high. The level of exposure to noise, as expressed by the noise and number index, cannot therefore equitably serve as the sole criterion for a grant, though it must be a main qualification. In the areas where the noise exposure is such that a grant should be payable it is still necessary to discriminate between the seriously annoyed and those who are less troubled. The former will wish to do something to reduce the nuisance, whereas the latter will not. We propose, therefore, that the grant should never be the whole of the cost. There should also be a maximum grant payable for the insulation of any one dwelling.

322. We recommend that a grant on this basis should be paid

(*a*) only in respect of existing dwellings in areas where aircraft noise is unreasonably high. It is suggested in paragraph 302 that these areas are those in which the noise exposure is more than 50/60 NNI ;

(*b*) on a scale varying from a high proportion of the total cost where the noise exposure is greatest to a small proportion at the boundary of the area within which the grant is payable.

THE COST OF GRANTS

323. We have estimated the total cost of this proposal on the assumptions that every house within the 60 NNI contour would be insulated, and one in five of those between 50 and 60 NNI, and that the cost per house would average £300. On these bases the total cost at present might be of the order of £500,000. If the present noise trends continue until 1970, i.e. if the present noise limits are not reduced by 7 PNdB at least, as recommended in paragraph 312, the additional cost might be about £2,000,000.

THE SOURCE OF THE FUNDS REQUIRED

324. We have considered how the cost of the grant should be met. A case can be made out for its being met from a number of different sources.

325. The first possible source is the Government. There are two main arguments for placing the responsibility here. The first is that Heathrow is a national asset, encouraging tourists and trade to Britain. It is, then, only fair that the nation should help to mitigate the undoubted nuisance that is caused by the noise.

326. The second argument is that, as Parliament has exempted aircraft operators from civil action, or proceedings, the Minister with overall responsibility for civil aviation must accept the onus of protecting people as far as possible from nuisance which might otherwise be objectionable. The Minister of Aviation already considers himself under an obligation to minimise aircraft noise nuisance. It can be argued that, if he is unable to contain the nuisance within limits which are acceptable to ordinary people, this obligation should not stop short of helping those who are subject to unreasonable noise to protect themselves from it.

327. The second source is the local authorities who benefit from the rates paid in respect of the Airport.

328. The third source is the airlines and their passengers. The strongest argument for their participation is that the airlines have some control over the noise. It can be argued that, if they were liable to contribute financially should the noise increase, they would have a powerful incentive to ensure that it did not.

329. In our view the argument can be divided into the responsibility for the present situation and responsibility for its future growth. The principal cause of the present degree of noise nuisance is the jet engine. This was not foreseen when Heathrow was originally planned, but the subsequent attempts to restrict the nuisance have placed considerable financial penalties on the airlines, who might well be thought to have made their financial contribution to the lessening of the nuisance.

330. There seems to be little to be said for requiring a contribution from the local authorities. Nor can present airline passengers be expected to pay for past mistakes.

331. The grant to help to ameliorate the present situation might, therefore, appropriately come from the Government, whereas the contribution that the airlines might make should be the indirect one of seeing that the present situation does not deteriorate, by operating their aircraft at gradually decreasing noise levels.

New Dwellings

332. While part of the cost of improving sound insulation in existing dwellings should fall upon the Government, we do not consider that there should be any liability on the Exchequer in respect of additional sound insulation in new dwellings. If these are constructed in the areas in which the grant is payable, it is obvious that the occupiers are liable to suffer serious disturbance from the noise. It seems, therefore, to be wise to insist that all new dwellings in these areas should be constructed with similar standards of sound insulation to those specified for the payment of a grant for existing dwellings.

OTHER AIRPORTS

333. It is essential that the lessons of Heathrow should be applied at other airports. The important lesson is that, as the noise extends far beyond the physical perimeter of the airport, the environs must be as carefully planned as the airport itself if serious nuisance is to be avoided. This has, of course, already been recognised, and planning authorities near existing airports are advised by the Ministries of Aviation and of Housing and Local Government which areas will be very noisy. On the evidence at Heathrow this system of consultation and advice does not appear to be adequate, and we think that, from the time that the development of an airport is first considered, planning control should be used to secure a pattern of development which is compatible with the future noise condition. We have considered the likely pattern of the spread of noise exposure round a future international airport. The pattern is greatly dependent upon the number of aircraft using each of the runways of the airport, and we think that the best indication of the area affected by the noise is given by the noise and number index contours at Heathrow, which are shown in Appendix XII.

334. There are no sparsely populated areas in this country which are suitable sites for large civil airports, and any new major airports or expansions of existing ones must, therefore, be in areas which are already well populated. Early and firm decisions are, therefore, needed on the sites for major airports. Once these decisions have been made, development around the site must be controlled if intractable and serious noise problems, such as exist at Heathrow, are to be avoided. The present town and country planning powers may be adequate to achieve this, although they have not, so far as we are aware, been used to impose special control on development around airports, except in connection with the control of the height and location of buildings at the approaches to runways, in the interests of safety. If necessary, further powers should be made available to control development so as to avoid serious nuisance from noise.

CITY CENTRE OPERATION

335. Serious consideration is being given to the more extended use of helicopters for travel into city centres, and the use of more sophisticated vertical take-off and landing (VTOL) aircraft is a more distant but nevertheless discernible prospect. A report of the Committee on the Planning of Helicopter Stations in the London Area, which was set up by the Minister of Aviation in 1959, contains valuable data on the noise levels which might be expected in the vicinity of helicopter stations and near helicopter routes.

336. The general conclusions drawn by that Committee from the data are as follows:—

"(i) In cruising flight at altitudes of about 1,000 ft. the noise level on the ground of the different types of helicopter should not be greater than that of traffic in a busy street at pavement level, but the noise would be heard over a wider area. Therefore, even though helicopters should be able to fly at or above 1,000 ft. over most of London, routes should be chosen which, as far as safety and navigational requirements allow, reduce flights over specially noise sensitive areas on the ground.

"(ii) The greatest noise will be heard in the immediate vicinity of the heliport and beneath the approach and take-off paths within half a mile of the pad. During landing and take-off, multi-engined helicopters with shaft-driving gas turbine engines will make either less or about the same noise as the much smaller piston-engined helicopters used at present. But present prototype tip-jet helicopters are very much noisier while landing and taking off."

The Committee also said that if the heliport was on a bank of the River Thames and beside an industrial area "the quietest types of multi-engined helicopters . . . as well as the current versions of piston-engined helicopters, should be able to use it at moderate frequencies without causing a serious problem. We cannot yet say that the same would apply to services operated with a high frequency or during night hours over residential areas". The Committee went on to say that:

"Nevertheless, however much ingenuity is exercised in siting the heliport so as to mitigate noise, the problem is not by any means fully resolved. We do not yet know enough about the effects on the community and of screening by high buildings in the vicinity of sites, and a further detailed study of these matters is required before the construction of a major heliport is put in hand.

"We also consider that a continued effort will be needed to find means of abating the noise at source and we are glad to hear research into this is being carried out by manufacturers and by Government Establishments, especially into the noise from tip jets.

"Meanwhile, we put forward our proposals on the basis that helicopter noise can be brought within reasonable limits by means of a combination of careful siting, operating techniques and further progress in noise abatement at source."

337. It is clear that much remains to be done before city centre operations by helicopters can be introduced on a regular basis without serious risk of causing a very great deal of noise nuisance, even though the tip-jet helicopters referred to in the Heliport Planning Committee's Report have now been abandoned. The most representative evidence on the noise levels from a typical twin rotor helicopter is given in Appendix XIV.

338. Apart from the noise near the heliport, the Committee say that the noise on the ground below a helicopter cruising at about 1,000 feet should not be greater than that of traffic in a busy street, but will be heard over a wider area. It must be appreciated that unless helicopter routes are very carefully planned and the helicopters fly much higher than seems to be envisaged at present, they will introduce this intense noise into areas which have previously been quiet. Although the occasional flight into a city by a helicopter does not cause serious complaint this provides no evidence that frequent operations will not cause serious disturbance. The social survey at Heathrow shows that the number of aircraft heard per day is a powerful cause of annoyance.

339. In their evidence the Royal Institute of British Architects emphasised that noise from helicopters at present levels will not only spread noise over quiet areas but can subject the upper storeys of high buildings to noise equal to or in excess of that on the ground.

340. There is no comparable evidence about noise from other types of vertical take-off and landing aircraft but we feel that as far as noise is concerned the considerations which apply to helicopter operations into city centres should apply to them too.

341. Although we think that it is important to establish criteria for noise for the operation of all types of VTOL aircraft over and into cities, there is insufficient experience of such operations for us to reach any definite conclusions on these criteria. There are a number of different principles underlying noise limits that we propose in various parts of our Report, but all the limits are empirical. Similarly, limits on noise for aircraft flying into city centres can be devised only in the light of the public's reaction to the noise. We recommend that investigations should be undertaken to establish suitable criteria before any substantial increase in air traffic into city centres is permitted.

SONIC BOOM FROM FUTURE SUPERSONIC TRANSPORT AIRCRAFT

342. Up to the present the only supersonic aircraft have been military and experimental whose supersonic flying has been limited to certain areas. The supersonic transport aircraft will raise the problem of sonic boom in a much more acute form.

343. An aircraft flying at supersonic speed produces a complex system of shock waves. At a large distance from the aircraft, however, this wave system degenerates into a pair of shock waves, the so-called bow and tail waves. These two waves produce the sharp rises in pressure separated by a region of gradual fall in pressure, which the ear receives as the characteristic " sonic boom ".

344. It is often not appreciated that shock waves, and, therefore, sonic boom, are in general produced all the time that an aircraft is flying substantially faster than the speed of sound, and not merely when it accelerates from a subsonic to a supersonic speed or decelerates from supersonic to subsonic speed. The boom will be heard below and on either side of the flight path of the aircraft for a distance which is a function of the speed and altitude of the aircraft and of the atmospheric conditions at the time. The belt across the surface of the earth in which the boom is audible may be as much as 50 miles wide although the intensity falls off appreciably on either side of the flight path. In view of the width of the belt in which the boom is audible a much greater number of people would be affected by supersonic flight over land than are now affected by noise from airfields. Thus, even if the proportion of people who are particularly sensitive to sonic boom were small, this minority could possibly represent a very large number of people. The fact that booms might affect large parts of the country will also make it difficult to escape from their noise.

345. There is only limited evidence available from which to judge the public reaction to sonic boom. In this country the Royal Aircraft Establishment have analysed the complaints received about experimental supersonic flights by a Fairey Delta 2 in 1957–60. Also, during demonstrations of sonic booms at a Ministry of Aviation Experimental Establishment in 1961, audiences of about 40 people were asked to record their reactions to booms, and to noise produced by explosive charges, of measured intensity. Work has also been done in the United States.

346. The experimental flying by a Fairey Delta 2 showed that there was strong public protest to sonic booms when the pressure jump was of the order of 4 lbs. per square foot (on the ears in the open*). There was a continuous trickle of complaints about the other sonic booms, which averaged about 1½ lbs. per square foot, but due to focussing effects during acceleration or turns at supersonic speed pressure jumps of around 3½ lbs. per square foot may have occurred in limited areas during a number of these flights. The ratio of complaints to booms remained fairly constant throughout the trials at one complaint for every eight booms, but during the last year of the work, when there were considerably more booms, more of the complaints came from representative bodies rather than from individuals.

347. The results obtained in the demonstrations referred to in paragraph 345 agreed broadly with this experience and with a prediction of the effects of sonic booms contained in a publication by the United States Federal Aviation Agency in 1961 entitled "Some considerations of Sonic Booms". The broad conclusion in this paper was that occasional booms with a pressure jump not exceeding about 1½ lbs. per square foot would be accepted by a great majority of the population, at any rate by day, but that above this figure there would be some public reaction which would increase as the extent of the pressure jump increased. Perhaps the most important features of the Ministry of Aviation's work were :—

(*a*) that there was no significant difference in the subjective reactions to pressure jumps of a given value caused by aircraft and by explosives;

* The phrase "on the ears in the open" means the pressure jump that would occur in the vicinity of flat, level, open ground, out of doors away from buildings and other obstructions. This pressure is roughly double the "free air pressure jump" (see Glossary).

(*b*) that there was no significant difference in the subjective reactions to pressure jumps of given value, as measured out of doors, whether the observers were out of doors or indoors.

The result (*a*) above indicated that further experiments on people's reaction to sonic boom would be possible using explosives to produce the noise, a much more convenient method than using aeroplanes and one which can be applied locally to a small number of people without affecting a large area. Observation (*b*) suggests that in considering the tolerability to people inside ordinary houses of sonic booms of the magnitude of those produced in these experiments, it would be unwise to rely upon the insulation of the building structure to reduce any subjective effects that there might be. The experiments seem to show that, over the limited range of boom intensity heard, there is no single criterion of acceptability, and indicate the difficulty of establishing the reaction of the people who are sensitive to sonic boom by any means less than full scale experiments.

348. There is little evidence to show how the public reacts to varying frequencies of occurrence of sonic boom. Because the duration of the boom is very short, it does not significantly interfere with speech communication. However, the boom is a sudden unheralded noise and, for this reason, may be particularly disturbing.

349. Damage can be caused to buildings, but little damage has, apparently, been experienced in this country. American experience is similar, and United States authorities have suggested in the paper referred to above that damage is unlikely unless pressure jumps exceed 2 lbs. per square foot.

350. The pressure jumps to be expected from supersonic civil airliners have been estimated on a basis of theoretical calculations, checked by measured values for small supersonic military aircraft. It appears that the maximum pressure jump can normally be prevented from exceeding 2 lb. per square foot so long as the aircraft is not allowed to fly supersonically until it has reached a height of about 40,000 ft. There is some evidence that the effect of the sonic boom is related to the shape of the shock wave, and that the shock waves for supersonic airliners of the types now being considered may be of such a form as to cause less disturbance than the shock wave from present day military supersonic aircraft, for the same pressure jump. More experience is needed of the booms from aircraft of a size comparable with that of projected civil supersonic aircraft before any firm conclusion can be reached.

351. The evidence so far available thus makes it clear that damage to property from the effects of supersonic airline operations is unlikely. But, so far as the effect on people is concerned, we are on much less firm ground. Care will be needed in the operation of supersonic airliners, and possibly some restriction in their use, if serious nuisance to the public is to be avoided. The extent of the restriction is not yet clear, but research into the problems involved is proceeding both in this country and abroad. It must be borne in mind that the main problem in this country is more likely to arise from aircraft flying over, but not landing here, than from British based aircraft which may not reach supersonic speed over the British Isles.

352. There is at present very little evidence as to the reaction of people to the boom that would be produced by supersonic civil aircraft. The evidence from the flying of small fighter type aircraft in this country may not be directly applicable, and although the United States Air Force have large supersonic aircraft, reliable information concerning the boom that they produce is not yet available. There will be formidable difficulties in obtaining the necessary data, but it is apparent that the Government and the aviation industry must use every available means to establish the public reaction to sonic boom, both during the day and at night, so that the appropriate controls can be introduced before supersonic civil flying over this country takes place.

Chapter IX

Noise from Industry

INTRODUCTION

353. This chapter is about the problem of noise from industrial premises, as it affects people living within earshot. The effect of noise upon people who work in industry is discussed in Chapter XIII.

354. We have ample evidence that industrial noise causes widespread annoyance. The replies to questionnaires which we sent to local authorities showed that a substantial proportion of the complaints that they received concerned noise from industry, as do most of the complaints about noise that are received by the Ministry of Housing and Local Government. The complaints are against widely varying sources of noise, from drop hammers, woodworking machinery, panel riveting, riveting hammers, fans, burners, punches and other items of factory plant, to the rattling of milk churns and bottles in dairies situated in residential areas, or the noise of the refrigeration plant in butchers' shops.

355. We have elsewhere expressed our misgivings about placing overmuch reliance upon complaints as a measurement of annoyance, but in this instance we were unable to obtain any better measurement if we were to make our Report within a reasonable time.

356. It is suggested by the evidence that was obtained by the Building Research Station in the course of compiling a simple procedure for assessing likely community reaction to industrial noise (see paragraphs 379 to 386 below) that people living in the old established industrial areas of the country are more tolerant of industrial noise than those who live in areas in which noisy industry is not so well established. The simplest explanation of this difference is, of course, that people get used to noise. We think, however, that this explanation may be an oversimplification and that the answer is a more complex one reflecting different social and economic attitudes towards industry. We consider it likely that, as economic standards of living rise, the public's tolerance of noise, as of other discomfort, will fall.

357. We consider, therefore, that greater attention must be given to the control, or reduction, of noise from industrial premises. At the same time we are pleased to be able to say that many local authorities are well aware of this problem and do a great deal to prevent annoyance from noise by advice and good planning; and that in the majority of cases in which complaints are made about noise from industrial premises, the firms concerned go to considerable lengths to eradicate the cause of complaint.

REDUCTION OF NOISE FROM INDUSTRIAL PREMISES

358. In the control of the levels at which industrial noise reaches people who may be annoyed by it, three main factors have to be considered. These are the noise produced at source, the amount of this noise which

escapes from enclosing buildings and the site, and the position of the site in relation to neighbouring houses, hospitals, schools, and other "noise sensitive" places.

THE REDUCTION OF NOISE AT SOURCE

359. The reduction of noise at source, where this is possible, is the most effective method of achieving a diminution in noise levels. It reduces not only the noise which may be emitted from the site but the noise affecting people working on or near the source.

360. The principal types of noise sources in industry are impact, reciprocation or vibration, friction, and turbulence in air or gas streams, but there are few data available on the levels of the noise produced. Some systematic research work is being done in industry and in the National Engineering Laboratory on the problem of reducing the noise at source. There is, however, a lack of textbooks or other literature on the principles of this subject, and the solutions which have been found in specific instances, usually after complaint, appear to have been attained by ad hoc measures.

361. Vibrations can be damped by mounting machines on flexible supports or by altering the mass of certain portions of the machines. Bearing and gear noise can be diminished by proper attention to the casings and to efficient lubrication, while noise caused by gas streams of all kinds can be reduced by the provision of acoustically well designed ducts and by the correct placing of the exits of the ducts. Inherently noisy machines can be surrounded by suitable absorbent or insulating screens.

362. Once it has been realised that a particular machine is producing excessive noise, it is often sufficient for the machine to be studied by a mechanical engineer who is accustomed to development problems. Obvious lines of attack then become apparent, and modifications can be made empirically to the machine which result in a satisfactory reduction in the noise level. This is not always so, and, if the origin of the noise is not readily apparent, it may be necessary to measure the noise emitted and to make a detailed frequency analysis of it to help to establish the origin. This involves complicated techniques and specialist knowledge of acoustics, which would be beyond the scope of the staffs of many firms. Fortunately, there are a number of consultants who are capable of advising firms on noise problems, provided that the solution depends upon existing knowledge. Exceptionally noisy processes, which prove particularly difficult to quieten, however, can scarcely be dealt with in this way, and we refer to them in paragraphs 390 to 396 below.

363. The noise output is rarely considered seriously when machines or plant are designed and installed. It is important that it should be, as it is often at these stages that most can be done economically. It is, however, not sufficient only for machinery manufacturers to pay more attention to noise, as they must supply what their customers want to buy, so it is ultimately upon the purchasers that much of the responsibility for noise reduction must rest, and it is chiefly they who must emphasise and specify the need for quiet machines.

364. In order that prospective purchasers can compare the relative noisiness of different machines and plant, a standard system of assessment of their noise output will be needed. No standard system exists at present, but the British Standards Institution have appointed a Committee to define the principles of measuring the noise of machines. When these principles have been agreed, we hope that the machinery manufacturing industries will develop methods, based on these principles, for measuring the noise of their own products, so that comparable information on the noise levels of machines will be available.

THE REDUCTION OF NOISE BY SITE AND FACTORY LAYOUT AND BY INSULATION

365. The amount of noise which is transmitted beyond the boundaries of the site, or indeed within the site, can be reduced by the proper layout of the site and by using appropriate and well designed enclosing structures.

366. In the open air noise decreases with distance. The noisiest parts of a factory should, therefore, be placed as far as possible from the boundary of the site and from the parts of the factory where quiet is important. Similarly, all noisy processes or machines should, as far as possible, be grouped together and insulated from the surroundings. Ancillary activities, such as loading and moving materials, are quieter to listeners outside the factory building when carried out under cover, with screens or baffles shielding the openings if doors are not practicable. Noise from traffic to and from the site should also be considered.

367. The principles of sound reduction by the use of insulating structures, the effect of gaps and holes in the structures and the use of screens and baffles are described in Chapter III of the British Standard Code of Basic Data for the Design of Buildings and in textbooks (refs. 1–6). These noise control procedures should be more widely publicised and used in the design and operation of all industrial processes. Owners should understand what measures can be taken for noise control in the design of their factories. They should also ensure that their methods of operation can fully utilise these measures; and they must be careful when making subsequent alterations to the buildings or to the processes used in them that these changes do not vitiate noise control.

368. Screens, such as buildings, high walls, or to a limited extent, trees, between the noise source and the areas to be protected can also be useful. To be effective, screens must be fairly close to the noise source or to the persons whom they are intended to protect from noise.

369. Measures to reduce the emission of noise, particularly enclosures built round noise sources, may, by increasing reflection, raise the noise level near the source. This may create or magnify a hazard to the hearing of people working near the noise source. It is important, therefore, that this possibility should be considered when measures to reduce the noise emitted from a factory are proposed. Reflections of noise can be greatly reduced by the use of sound absorbent materials.

THE CONTROL OF NOISE FROM INDUSTRIAL PREMISES

370. The legal remedies for industrial noise nuisance have been outlined in Chapter III. In practice the procedure generally followed is that, when a complaint about noise is made to a local authority, an officer, usually a public health inspector (sanitary inspector in Scotland), investigates it. If he and, perhaps a chief officer of the authority such as the medical officer of health, are satisfied that the nuisance is real, the public health inspector discusses it with the person causing it, and, very often, steps are agreed which will abate it.

371. If the person causing the nuisance is unwilling to take reasonable measures to abate it, an abatement notice is served. In deciding to serve a notice the local authority are, of course, conscious that in proceedings it will be a valid defence for the defendant to prove that the best practicable means have been employed for preventing, and for counteracting the effect of the noise.

372. The local authority and their officers are thus required first to judge whether the noise constitutes a nuisance, secondly to discuss with the person causing it measures by which it can be abated and, thirdly, to decide whether the nuisance justifies proceedings and whether proceedings are likely to be successful.

THE SITING OF INDUSTRY

373. The legal remedies referred to above are suitable means of controlling noise nuisance when a technical solution to the problem is known. When an industrial process must of necessity produce a considerable amount of noise, proper siting of the factory is an important factor in reducing the disturbance caused, and planning authorities can play a constructive part in this by giving due weight to noise as one of the matters to be considered when dealing with applications for planning permission for industrial development. It is, of course, equally important to take account of nearby noisy factories when considering applications to develop land for housing or other uses for which a noisy environment is undesirable.

374. Under the Town and Country Planning Acts the use of land is controlled by making development subject to permission. Development is defined as " the carrying out of building, engineering, mining or other operations in, on, over or under land, or the making of any material change in the use of any buildings or other land ". Planning authorities may grant permission either unconditionally or subject to such conditions as they think fit, or may refuse permission ; and in dealing with any application they must have regard to the provisions of the development plan, so far as they are relevant, and to any other material considerations. An appeal lies to the Minister of Housing and Local Government or the Secretary of State for Scotland against a refusal of permission or against particular conditions attached to a permission.

375. Despite the apparent wideness of the power to impose conditions, we understand that the Courts have made it clear on a number of occasions that, to be valid, conditions must be directed towards some objects of

proper concern to town and country planning. They must relate to land under the control of the applicant; they must be made necessary by the development to be permitted; they must be precise; and they must be capable of enforcement. The following are examples of the kind of conditions which meet these tests and which, in suitable cases, have been imposed by planning authorities when granting permission for a factory or workshop near to houses:—

"The premises shall not be used for manufacturing purposes between the hours of 9 p.m. and 7 a.m. from Mondays to Saturdays or at any time on Sundays."

"The premises shall be used only for the purpose of manufacturing . . . and for no other purpose including any other purpose within Class III of the First Schedule of the Town and Country Planning (Use Classes) Order, 1963."

376. Special mention should, however, be made of light industry as defined in the Use Classes Order, 1963 (S.I. 1963 No. 708). The definition is an industry "in which the processes carried on or the machinery installed are such as could be carried on or installed in any residential area without detriment to the amenity of that area by reason of noise, vibration, smell, fumes, smoke, soot, ash, dust or grit". The introduction of noisy processes bringing the noise level above what could be tolerated in a residential area might amount to a change of use which would require planning permission and would thus enable the planning authority to protect the amenities of the area.

377. The replies that we received to a questionnaire that we sent to all planning authorities in Great Britain showed that most of them placed noise high on the list of factors which they consider when examining applications for planning permission. Many of them emphasised that they regarded noise as particularly important when dealing with proposed industrial development near residential areas. Their officers not only visit the proposed site but also try to hear the noise from processes or machines similar to those which it is intended to instal. A large number of planning authorities informed us that noise had been a ground for refusing applications for planning permission. Once planning permission has been given, however, with or without conditions, planning authorities find that there is little that they can do to verify that the noise is not more than they expected. Some sites are visited by planning or public health officials but many authorities take no action unless complaints are received.

378. The powers of planning authorities to secure that development fits in with its surroundings and does not cause noise or other nuisance are broadly speaking exercised only in connection with their decision to permit or refuse permission for development. In general they are not apt for controlling what happens in a building once it has been erected. Once a factory is built it becomes subject to the general body of statutory provisions governing such matters as safety or fire precautions, emission of smoke, fumes and grit and noise. If despite all the care exercised by the planning authority a new factory turns out to be a noisy neighbour, action would fall to be taken by the public health authority under the Noise Abatement Act.

RULES FOR ASSESSING COMMUNITY REACTION TO INDUSTRIAL NOISE

379. In dealing with complaints from existing factories, the public health authorities and the Courts must usually rely on their unaided judgment in deciding whether a noise is sufficiently disturbing to constitute a nuisance. Planning authorities have an even more difficult task in deciding whether a new factory will, when erected, give rise to justifiable complaints.

380. Annoyance from industrial noise, as from other types of noise, is a subjective phenomenon affected by many factors, such as the local background noise level; whether the noise is produced continuously for 24 hours or only for part of the day; whether during this period it is continuous or whether there are certain impulsive or irregular noises; the pitch or frequency of the noise and whether there are pure tones contained in the spectrum; and some other factors. Without a full examination of all relevant factors it is frequently difficult to assess whether a noise is likely to cause complaint, or whether a complaint made in good faith is justified to the extent that reduction of the noise should be enforced. Scientists who have studied the problem in this country and abroad have suggested various procedures which, if valid, might be used to assess whether a complaint about noise is justified in the sense that the noise complained of would be a nuisance to an ordinary reasonable person. We feel that rules of this sort would help local authorities and others in this country, and also that their use would tend to produce a greater consistency of decision than is possible from purely personal opinions.

381. We have studied the rules for assessing public reaction to noise which are being considered by the ISO, and those of Stevens, Rosenblith and Bolt (ref. 7) for American conditions. They have been applied to a number of cases of industrial noise in this country and it appears that with slight modifications they are appropriate here.

382. The procedures which have been devised abroad require a frequency analysis of the sound, involving the use of expensive equipment. By empirical methods, each of the characteristics mentioned in paragraph 380 above is given a numerical value, and the total of these values determines the annoyance rating. The value given to a particular characteristic depends not only on the sound but also on the type of people involved, e.g. whether the community is used to industrial noise.

383. The noise measurements required in the well established procedures are likely to be too complicated to be carried out by most local authority officers, who will have neither the training, experience and equipment nor, probably, the time, to perform frequency analyses. At our request, the Building Research Station, in co-operation with a number of local authorities, have carried out tests to see whether a much simpler measurement procedure would be sufficiently accurate to enable a reasonable forecast to be made of the community reaction to the types of noise emanating from factories. The simplified procedure (described in Appendix XV) uses only a sound level meter with an " A " weighting network,* and the tests which were carried out showed that a set of rules could be laid down which enabled a correct

* See Glossary in Appendix II.

forecast to be made in nine cases out of ten of whether or not an industrial noise will give rise to complaints from people who have a normal reaction to noise.

384. We recognise that this procedure is not as accurate as the more complex ones, but we are confident that in the majority of cases it will give a reliable guide to the public reaction which can reasonably be expected to industrial noise. In the small proportion of cases in which it does not give a clear answer the more complex procedure could be applied by a specialist. The simplified rules still require confirmation, as do the more complex ones, for use in this country, but, if valid, they would provide a useful guide for local authorities when dealing with complaints about industrial noise and with applications for planning permission for industrial development, or for other types of development near existing industry. However, there is insufficient experience of the use of these rules, or, in this country, of any other rules, for us unreservedly to recommend their use. Before this could be done the criteria should be applied to many more situations in which industrial noise is audible in residential areas, and the results compared with the public reaction to the noise.

385. We recommend, therefore, that a number of local authorities should be asked to co-operate with the Building Research Station in confirming the rules that they have developed, and that, if these trials are satisfactory, their general use by local authorities should be encouraged. We must emphasise that these particular rules are applicable only to the reaction to be expected from residential areas. They do not apply to the reaction of people in any other situation, such as working in offices, or working or lying ill in hospitals. They could no doubt be extended to cover such situations, but much more work would be required to enable this to be done.

386. We have already stated our belief that the public will gradually become less tolerant of noise as the standard of living of the country rises. It may well follow that acceptable noise levels as measured by empirical rules such as those to which we have referred, will become progressively stricter. They must, therefore, be reviewed from time to time to meet current needs.

CONSULTATION BETWEEN PLANNING AND OTHER AUTHORITIES

387. If planning permission is given for a new factory which subsequently proves to be a noisy neighbour, any action taken by a local authority under the Noise Abatement Act, 1960, would (as noted in paragraph 378) be taken by the public health authority and not by the planning authority. Planning authorities should, therefore, consult the public health authority when considering applications for planning permission for new factories. This should present no difficulty, because most county district councils exercise delegated power on behalf of the planning authorities, and county borough councils are both planning and public health authorities.

TRAINING OF LOCAL AUTHORITY STAFF

388. The preceding paragraphs show that local authorities have a large part to play in the control of noise from industrial premises. The local authority officers concerned must be equipped to understand the problems involved, to advise factory owners on measures which are likely to reduce noise to acceptable levels, and to judge the likely efficacy of any measures that factory owners propose to take. They have also to consider whether the "best practicable means have been employed for preventing, and for counteracting the effect of the noise;" for although the Noise Abatement Act places on the factory owner the onus of proving that he is employing the best practicable means, the local authority must form their own opinion before proceedings are taken. To carry out these duties the officers should receive some training in the problems of noise control and methods of measuring noise. The training should include some instruction in the elementary physics of sound and the techniques of measurement, including the use of sound level meters. We understand that a number of Technical Colleges already hold courses in these subjects, and we recommend that training on these lines should be made available to all local authority officers who have to deal with noise problems in their work.

STANDARDS OF SOUND INSULATION IN INDUSTRIAL BUILDINGS

389. We consider that local authorities should have power to require adequate structural precautions to minimise the possibility of nuisance from noise transmitted from industrial buildings. This is not to say that one specified standard of sound insulation should be required in all circumstances. In considering what standards are adequate in any instance it is necessary to take account not only of the machines and processes to be used but the environment of the factory and, particularly, its distance from buildings and other places in which noise could be specially annoying or disturbing. Rigid standards of sound insulation for industrial buildings would, therefore, be inappropriate, since a standard which would provide sufficient insulation to prevent annoyance or disturbance in a nearby school, hospital or residential area would be absurdly onerous upon the owner of a factory which was to be built a great distance from any other building. Local authorities should, therefore, be empowered to require new industrial buildings to be of such construction that, bearing in mind all these factors, noise from the buildings could reasonably be expected not to constitute a nuisance. There should be a right of appeal against the local authority's decision.

SPECIALLY NOISY PROCESSES

390. Although we think that adequate mitigating measures can be devised in most instances, at reasonable cost, by the combined efforts of the factory occupier, noise control consultants and trained public health inspectors, there are some very noisy industrial machines and processes which at present would prove specially difficult to quieten to levels which are likely to be acceptable. We have particularly in mind processes involving high levels of percussive noise such as drop forging and boiler making.

391. The noise from the types of process mentioned in the preceding paragraph could only be reduced as a result of the successful outcome of an expensive research programme. The problems are, by their very nature, highly intractable, and, unless the attack on the problems is well conceived, a great deal of money might be spent to very little purpose. On the other hand, it is clearly undesirable to leave it entirely to the firms concerned to decide whether a particular line of research is worth following or not.

392. We feel that it is desirable that there should be some public supervision over specially noisy processes, both for the protection of industry when it has done all it can to reduce noise and for the protection of the public against firms which adopt a laissez-faire attitude.

393. Accordingly, we recommend that specially noisy processes should be registered by a Minister and that it should be the duty of inspectors appointed by the Minister to ensure that people using these registered processes employ the best practicable means to prevent and to counteract the effect of the noise: the inspectors should become experts in industrial noise problems so that their views are respected, and their help sought, by factory owners and local authorities. We do not doubt that the inspectors' advice would be welcomed in difficult cases involving unregistered processes. We hope that in time the inspectors' relationship with industry would be of similar excellence to that of the Alkali Inspectorate.

394. If the recommendation in the preceding paragraph is accepted, firm central control will eventually be exercised over registered processes, but the compilation of a register and the training of an inspectorate can only be done gradually. We consider that, when this control is fully in force, the users of registered processes in England and Wales should be exempt from statutory nuisance proceedings under the Noise Abatement Act in respect of their use, unless the Minister responsible for registering the processes consents to the proceedings. We envisage that consent would be given where the Minister considered that the factory occupier was not employing the best practicable means of preventing or counteracting the effect of the noise. In Scotland the decision whether to take action in the case of a registered process would be taken by the Crown authorities.

395. We have already stated in paragraph 367 that a good deal of information is available on the principles and practice of noise reduction by planning and by building techniques, but that the situation is much less satisfactory as regards the principles underlying the reduction of machinery noise at source and their practical application. While the members of the central inspectorate which we have recommended to be set up would be able in time to give great help on practical applications, they could not be expected to elucidate the basic principles. We therefore recommend that more research work should be undertaken on the origin of noises of high intensity.

396. Specially noisy processes are in general associated with heavy industries which, when once set up, cannot easily be moved. It is therefore extremely desirable that, when a planning authority is considering an application for the siting of a factory in which a specially noisy process might be used, the authority should be required to consult the Minister responsible for the register of such processes before they grant the application.

STATUTORY UNDERTAKERS

397. As mentioned in paragraph 69 (Chapter III), statutory undertakers (and in particular the railways) are exempt from proceedings under the Noise Abatement Act. If our recommendations concerning the registration of specially noisy processes are accepted, we consider that statutory undertakers should no longer be exempt. Any specially noisy activities of statutory undertakers would be registered and would therefore be protected from unjustified attack. The other activities would differ in no way from those of industry in general, for which the defence of the " best practicable means " is at present an adequate safeguard, but which will, as stated in paragraph 399, tend to fall into disuse.

THE DEFENCE OF THE BEST PRACTICABLE MEANS

398. Many local authorities consider that they have serious difficulty in abating noise nuisance from trade and industry if the occupier of the premises from which the noise is coming claims that he is using the best practicable means of preventing it. The local authority cannot readily confirm or deny this, and, therefore, hesitate to take proceedings.

399. We believe that at present this defence must be available to trades and industries but that in the long run it is undesirable. Our recommendations in this chapter and the next will, we feel, help to make it unnecessary. Once all specially noisy processes have been registered, all the others will presumably be capable of emitting so little noise as to fulfil the criteria for good neighbourliness which we have laid down in various parts of our Report. There will, of course, always be some complaints about the noise from unregistered premises, but if these are justified, they ought only to occur because of some defect in the factory equipment or some other transitory cause, which could in time be remedied. Continued justified complaints of an unregistered process would be the strongest possible evidence that the " best practicable means " were not being used.

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Chapter X

Noise from Construction and Demolition Sites

INTRODUCTION

400. This chapter is concerned with noise from building construction, civil engineering and demolition sites and road works, as it affects the public and not as it may affect men working on these sites. The effects of noise on people who work in noisy environments are discussed in Chapter XIII.

401. Construction and demolition works pose special problems of noise control compared with most other types of industrial activity. They are mainly carried on in the open; they are of temporary duration, though in built-up areas they may cause great disturbance while they last; the noise they make arises from many different activities and kinds of plant; its intensity and character may vary greatly at different phases of the work; and, finally, the sites cannot be divorced by planning control, as factories can, from areas which are sensitive to noise.

402. We have had evidence of complaints received from the public by local authorities, Members of Parliament and Government departments, about noise from construction and demolition sites near homes, offices, etc. Nearly a quarter of the complaints about industrial noise which were received in 1960 by a sample of local authorities to whom we issued a questionnaire, related to noise from construction or demolition work. The effects of the noise were not only to cause anoyance but, in some cases, to hinder people from carrying out their work. In some instances legal action to restrict the noisy activity had been threatened or taken, sometimes successfully.

403. We do not like to rely on complaints as a measure of disturbance or annoyance but no better measure is here available to us, and we are convinced, from the evidence that we received and from our own observations, that noise from construction and demolition work is a serious cause of disturbance and annoyance to people nearby.

SOURCES OF NOISE AND METHODS OF REDUCING IT

404. Obviously, most noise from construction and demolition sites arises from machinery. We have received evidence from manufacturers and users of contractors' plant, and one of our sub-committees visited building sites and demonstrations of plant in operation. We were able to make these visits through the courtesy of the trade federations and firms concerned, and we are grateful to them for their help. The sub-committee also held a meeting in a room which was exposed to noise of varying known intensities from typical contractors' plant, as part of our consideration of reasonable criteria for noise from construction and demolition sites.

405. The Building Research Station, manufacturers, and contractors have measured the noise levels of some plant. These noise levels are shown in the following table:—

TABLE XII

Typical noise levels of contractors' plant

Type of plant (*i*)	Sound level dBA at 50 feet (*ii*)	Type of plant (*i*)	Sound level dBA at 50 feet (*ii*)
Unmuffled concrete breaker ...	85	Petrol poker vibrator	64
Muffled and screened breaker...	65	Electric poker vibrator... ...	71
4 tool diesel compressor ...	73	10/7 diesel concrete mixer ...	75
4 tool electric compressor ...	73	10/7 electric concrete mixer ...	61
Petrol concrete breaker ...	76	Earth auger driven from diesel	
Rock drill	87	tractor...	66
Thermite tool	62	Hand held tree saw	82
180 h.p. Angledozer	83	¾ cu. yd. dragline	74
90 h.p. Angledozer	74	1½ cu. yd. dragline	78
1½ cu. yd. tractor shovel ...	76	300 c.f.m. reciprocating diesel	
Rubber tyred tractor-scraper ...	93	compressor	77
30 cwt. dumper	75	600 c.f.m. rotary diesel com-	
4 cu. yd. concrete carrying		pressor	79
vehicle...	75		

NOTES:

(i) The noise levels quoted are with the machines operating normally, and fitted with exhaust silencers where appropriate.

(ii) The levels given in the table each relate to one particular item of equipment at the specified distance, 50 ft. Two machines, each individually producing the same level, when operated at the same time give an increase of 3 dB and with 3 equally noisy machines the corresponding figure is 5 dB. If one machine is markedly noisier (6–10 dBA) than the other, the total noise level is not significantly increased when the quieter machine is added.

(iii) The effect of halving or doubling the distance from the machine is to add or subtract 6 dB from the measured level, e.g. an unmuffled breaker at 25 ft. would be 91 dBA and at 100 ft. 79 dBA. Reflections from adjacent buildings can increase the noise level by a few dB compared with levels measured under open conditions.

406. Much of this machinery has come into use in the last twenty or thirty years, and it is probable that the number and types of machines used will continue to increase. Quietness has not been a factor to which much attention has been given by most manufacturers or users of contractors' plant, so that unless the need for effective noise control is recognised, further increases of mechanisation in the construction and demolition industries will inevitably result in further increases in noise. We think that it is in the interests of the industry, as well as of the public, that the need for noise control should be recognised. There is a growing public demand for less noise, and this is likely to become more insistent as standards of living improve.

407. Some firms in the construction industries are conscious of the annoyance and disturbance caused to nearby people by noise from their sites, and take measures to reduce it. Among these measures are the choice of speedy, efficient techniques; the minimum use of very noisy processes;

good site planning; keeping plant in good repair and fitted with noise suppressors where possible, and the provision of screens and hoardings. If the standards of practice of the best contractors were achieved on all sites, the amount of disturbance caused by noise would be very significantly reduced. We discuss in this chapter measures which can be taken by developers, designers, contractors, statutory undertakers and local authorities to ensure that good practices are employed.

408. However, the manufacturers of contractors' plant told us that there is little demand from their customers for quieter plant; the contractors, on the other hand, said that the noise emitted was largely outside their control and could be reduced effectively only by the manufacturers. We feel that the initiative to break this vicious circle must come from the contractors. If they demand quieter plant the manufacturers will have the incentive to supply it, which at present they lack. It is, therefore, necessary to create conditions which will encourage contractors to work as quietly as possible.

409. We think that, in principle, there should be statutory limits to the noise from powered plant used on construction and demolition sites, and that the definition of limits will be practicable when standard methods of measuring noise from machines have been established. We were glad to hear that the British Standards Institution is examining the possibility of the formulation of such methods.

410. The overall noise level produced on and around a building site can be reduced by treatment of the individual machines or by providing mufflers, screens or barriers to prevent noise made by such machines from reaching vulnerable places. We have examined the possibility of reducing the noise from some of the commonest plant and we are satisfied that there is a good deal that could be done if more attention was given to reducing noise in both the design and operation of the plant. Some examples are given in paragraphs 411 to 426 below.

PNEUMATIC TOOLS

411. Pneumatic concrete breakers, rock drills and similar tools are prominent sources of noise from construction and demolition sites and roadworks. Their noise has several origins, including the exhaust of the compressed air in the pneumatic types, the prime mover in the case of those which incorporate a source of power, the impact noise within the tool and the impact of the bit on the material which is being drilled. A typical noise level produced by a pneumatic drill is about 85 dBA at 50 feet. With several operating at once under practical conditions, with some sound reflection, the level may well exceed 90 dBA at nearby buildings.

412. There are various ways in which the total noise can be reduced. Silencers can be fitted to the compressed air exhaust, padded jackets (mufflers) put on the machines, or screens used to enclose the drills and their operators. These measures are rarely used, although some local authorities and contractors have experimented with them. The Building Research Station has measured the reduction of noise which is obtained when silencers, padded jackets, or screens are used with typical pneumatic

drills. The results of these measurements are shown in the following Tables:—

TABLE XIII

Noise levels of typical pneumatic drills, with and without mufflers or silencers

Type of tool (*i*)	Sound level (dBA) at 50 ft. in direction		
	West (*ii*)	South (*iii*)	East (*iv*)
Type A—weight 83 lbs.	83	82	81
Type A with fabric muffler (weight 10 lbs.) ...	76	70	71
Improvement, dBA	7	12	10
Type B—weight 80 lbs.	81	82	80
Type B with rubber silencer (weight 22 lbs.) ...	75	76	75
Improvement, dBA	6	6	5
Type C—weight 62 lbs.	79·5	81·5	79·5
Type C with rubber silencer (weight 22 lbs.) ...	76	76·5	76
Improvement, dBA	3·5	5	3·5
Type D (integral silencer removed)	81	83·5	79·5
Type D—weight with integral silencer 77 lbs. ...	76	79	74
Improvement, dBA	5	4·5	5·5

NOTE: The figures in the three columns show the measurements recorded 50 ft. from the drill respectively to the West, South and East with the operator standing North of the tool. In the case of measurements with silencers the exhaust normally pointed to one side, East or West.

TABLE XIV

Measured reduction given by a muffler and two types of partial enclosure

Type of enclosure (*i*)	Reduction (dBA)		
	Facing the opening(s) (*ii*)	Sideways (*iii*)	Facing screened side (*iv*)
1. Plain open-sided shed; no screen	−3 (an increase)	6	13
2. Plain open-sided shed; with reflecting screen in front.	4	4	5
3. Open-sided shed lined with absorbent; no screen.	1	9	14
4. Open-sided shed lined with absorbent; with reflecting screen in front.	10	6	8
5. Open-sided shed lined with absorbent; with absorbent screen in front.	10	10	10
6. Plain 'tunnel'	−1 (an increase)	5	—
7. 'Tunnel' lined with absorbent	3	12	—
8. Drill with muffler and no enclosure	10	—	—
9. Muffled drill in absorbent shed and screen as 5	18	15	18

NOTE: The shed had a roof, one open side and a removable screen which could be placed a small distance away from the open side. The tunnel had two sides and a roof but open ends.

413. The measurements showed that the reduction obtained varied greatly, but that with a muffled drill and a suitable enclosure the noise level could be reduced by nearly 20 dBA. The enclosure need be of no more than ¼ in. plywood or other solid materials of equivalent weight (1 lb./sq.ft.) on simple framing, providing the joints and corners are butted well together and leave no gaps. No worth-while advantage is obtained from using heavier enclosures in this case, bearing in mind the need for mobility; on the other hand, open textured materials, fibre-boards or other soft building boards are not likely to be as effective. An absorbent lining on the interior of the enclosure does not increase its effectiveness as an insulator to any substantial extent, although it does reduce the noise on the open side of the enclosure; but, by preventing a build-up of noise inside the enclosure, it improves conditions for the operator.

414. The effectiveness of noise control by this means is very much increased if the site management and operatives take an intelligent and sympathetic interest. For example, since the enclosure must be moved at intervals, it is likely to be fitted with rollers or wheels. The gap between enclosure and ground should be closed with a flap of roofing felt or similar flexible material. The operative himself becomes part of the insulation: he can help to keep the noise down by facing *into* the enclosure when operating the breaker. On the other hand the efficiency of the enclosure can partly be lost if there is a reflecting surface such as a vehicle opposite the open side. Attention to small details of this kind makes a considerable difference to the results achieved.

415. The results obtained in these experiments are promising and we recommend that contractors, local authorities and statutory undertakers should be encouraged to undertake further practical trials and to make use of enclosures.

416. Contractors claim that exhaust silencers on pneumatic tools are easily damaged, and that both they and mufflers make the tools more cumbersome and reduce their efficiency. We accept that anything which adds significantly to the weight or bulk of pneumatic drills will almost certainly make them harder to use. Attempts are being made to determine the relative efficiency of tools with and without silencers etc., but conclusive results are not yet available.

417. There seems little doubt that with appropriate precautions pneumatic drills could meet the daytime noise limits that we propose in paragraph 435 below.

POSSIBLE ALTERNATIVES TO PNEUMATIC DRILLS

418. We have enquired whether there are methods of breaking concrete, road surfaces, etc. which are quieter than pneumatic drills and breakers and are known to be effective and economical. We were pleased to find that several quieter methods are available or are being developed. These include different types of drills, and a process for burning holes in concrete. The latter, and diamond tipped rotating drills, are available now, but at present they are so much more expensive to use that they are practicable only where quietness is of paramount importance. A comparatively recent development is that of a hydraulic drill operated from a hydraulic generator

which can be diesel, electric or gas driven. The noise level produced by one example of this tool has been measured and the results are as follows:

TABLE XV

Noise levels of a hydraulic drill operated from a hydraulic generator

Condition (*i*)	Sound level (dBA) at 50 ft. in directions*		
	West (*ii*)	South (*iii*)	East (*iv*)
Hydraulic drill with generator on 30 ft. hose ...	81·5	83	82·5
Hydraulic drill with generator on 60 ft. hose ...	78	79	79·5
Reduction when extra 30 ft. hose is used ...	3·5	4	3

* See Note to Table XIII.

NOTE: The noise level from the generator was at least 10 dB below that of the drill.

Although the measured values for this particular example do not indicate a major reduction in noise level compared with the levels for some of the pneumatic tools quoted, the kind of noise produced may be more acceptable subjectively. A great advantage, however, appears to be that this tool is much quicker in operation than conventional pneumatic tools, thus markedly reducing the length of time for which the noise is produced.

PRIME MOVERS

419. Many of the prime movers used to provide power for construction plant are diesel engines. Most of these, but not all, have exhaust silencers, but the silencers are not always used and many that are seem ineffective. Some local authorities have local Act powers requiring stationary engines to have silencers. We recommend that, pending the establishment of statutory noise limits, general legislation should be introduced to provide that all internal combustion engines, used as prime movers, should be fitted with efficient exhaust silencers.

420. Apart from the need for adequate silencers, the extent to which diesel engine noise can be reduced is limited by relatively high mechanical noise level and incomplete knowledge of the sources of noise in such engines. Research into noise in diesel engines of the types used as prime movers is being carried out and should be encouraged, as should the application of the knowledge gained.

421. Electric motors are sometimes used instead of diesel engines as prime movers. These are quieter than diesel engines but can, of course, function only where there is a power supply on site. If no mains supply is available, a generator must be used which is itself probably driven by a diesel engine, so that there is no reduction in noise. However, if a diesel powered generator is used to provide power for a number of pieces of plant it may be possible to site or screen it so that less noise reaches the site boundary than if each piece of plant had its own diesel engine.

422. The prime movers of contractors' plant are often left running even when the plant is not in use. This should be discouraged wherever it may result in a noise nuisance.

AIR COMPRESSORS

423. The noise from air compressors and other machines which are powered by internal combustion engines would be reduced by better silencing of the prime movers. There are also other simple ways in which design or operation, or both, could help to reduce noise. Air compressors are frequently operated with the side panels raised. They would be less noisy if the side panels were closed, but the operator tends to open the side panels and to leave them open because the instrument panels and controls of many types are inside the side panels and cannot be used if they are closed. Plant manufacturers have told us that it would not be difficult to re-design machines so that the instrument panel and controls could be used with the side panels closed. A certain amount of noise could also be avoided if the ground under such machines as compressors were covered with sacks, as these reduce sound reflection.

424. A more ambitious method of reducing the noise is to put the compressor inside a box. An open ended, or un-roofed, box can be used if it is necessary to reduce noise in some directions only. Such a three sided plywood box was found in one experiment to reduce noise in the shielded directions by about 6 dBA, and over a running period of about an hour did not cause the compressor to overheat. Obviously a box which wholly enclosed the compressor would more effectively reduce noise if suitably designed, but the problems of providing an adequate air supply to the machine are not easy to solve.

PILING

425. A less common but intensely loud and disturbing impulsive noise is caused by pile driving, particularly the driving of sheet steel piles and their subsequent withdrawal. Conventional methods of measuring dBA and of computing loudness levels are not applicable to such intermittent and impulsive noises, but a measurement of the instantaneous peak sound pressure level of one diesel pile hammer driving a precast concrete pile gave a reading of 104 dB at 50 feet. We were informed of various experiments to reduce the noise, such as introducing pads between the hammer and the pile, the use of damping on sheet piles to reduce their vibration and resonance and the enclosure of the hammer head and the pile in a screen or tent, but none of these methods has been found practicable. A British company has also devoted a considerable effort to developing a machine to drive sheet steel piles by vibration, a method which is said to be used successfully in Germany and Russia. The variation in the types of soil found in this country has proved to be an obstacle, but it may be that the machine will be available commercially in a few years' time. One type of vibratory pile driver driving piles into suitable soils produced a noise level of only about 70 dBA at 50 feet.

POSSIBLE ALTERNATIVES TO DRIVEN PILING

426. Quieter alternatives to driven piles are practicable where conditions suit. These include bored piles, timbering and strutting, and a system of constructing a concrete retaining wall in a deep trench, the sides of which are

retained until the concrete is poured by filling the trench with a suitable liquid clay. We saw this system being used in constructing the underpass at Hyde Park Corner, where, because of the proximity of St. George's Hospital, a great deal of thought was given to noise reduction. The methods adopted in this scheme were successful in reducing the noise but undoubtedly at considerable expense. We understand that the system of constructing retaining walls, which was, as far as we are aware, used for the first time in this country at Hyde Park Corner, has since been successfully used on other jobs, and it may be that costs will fall as more experience of the system is gained.

THE IMPORTANCE OF PROPER PLANNING

427. We now turn to the contribution which can be made by developers, architects and civil engineers, as it is their designs which largely govern the processes that the contractor must use. We feel that designers should consider, in preparing their designs, whether there are alternatives which will involve less noise in construction. They should be specially careful to avoid the use of very noisy processes such as sheet steel piling, if the circumstances of the site and the costs make this feasible.

428. The noise from building sites can be reduced if this factor is considered in planning the layout of the site. Admittedly, the contractor has many problems, and his freedom of action is restricted by the physical characteristics of the site and by the design of the structure on which he is working. Nevertheless, there is much that he can do; and we have ourselves seen sites on which a great deal has been done to reduce the noise heard by people living and working nearby, for example, by putting compressors in a basement, the shell of which had been completed. Other possible measures are to arrange access to the site at points on the perimeter where the noise of vehicles will cause least disturbance to neighbours, and to keep noisy plant as far as may be from neighbouring buildings.

429. Some contractors are well aware of the importance of maintaining good relations with the people living and working nearby. It is quite common nowadays for contractors to provide viewing platforms with descriptions of the building to be erected and statements of the progress of the work. Similarly a contractor can help to make noise more tolerable to nearby people by explaining to them, perhaps by personal letter, why he has had to use noisy processes, the problems that he had to overcome, and the steps he has taken to avoid disturbing the public more than is necessary. We were informed of one contractor who had to make noise at night in a residential area and whose efforts to explain his problem to the people living nearby were amply rewarded in good will.

COSTS

430. Very little information exists on the cost of reducing building and civil engineering noise. Moreover, the costs of using different processes will vary with their suitability for the job on which they are to be used, and whether or not the intention to use them is known from the earliest design stages. It is probable, however, that the extra cost in use of quieter machinery on a typical large building scheme, even if the machinery was substantially dearer initially, would be a very small proportion of the total cost of the work.

431. We considered whether it would be possible to assess the cost of the noise to people working near a major building or civil engineering site in, say a commercial district in London. We felt that the cost in working time lost, inability to hold meetings, or to converse, particularly on the telephone, and efficiency lost through annoyance, would sometimes be high and would rarely be negligible, but we could not discover how to make a reasonable estimate of it in money terms. It exists, however, and must be weighed in the balance against any additional cost falling upon developers, or contractors, from noise reduction.

MAXIMUM DESIRABLE NOISE LEVELS

432. We feel that some numerical criteria should be available by which the industries concerned, local authorities and, perhaps, Courts could judge whether noise from construction and demolition sites is reasonable or not. In considering what criteria would be appropriate in the daytime, we have given most weight to the following factors:

(*a*) the noise should not interfere unduly with the lives and work of people in nearby buildings;

(*b*) the work on most construction and demolition sites does not last very long, usually for some weeks or months at most;

(*c*) a great deal of building is done in urban areas where there is noise from other sources, such as traffic;

(*d*) the efficiency of the building industry depends upon the use of machines; and

(*e*) any criterion must be practicable for contractors.

433. We conclude that the simplest and most objective criterion is that the noise between, say 7 a.m. and 7 p.m., should not exceed the level at which conversation in the nearest building would be too difficult with the windows shut. Most buildings have openable single windows which, if new and well fitting, can reduce outside noise levels by 20 dB or more; the exterior walls of many existing buildings have ill-fitting windows and provide only about 15 dB reduction. Moreover, the reduction at low frequencies is less than at high frequencies, thus emphasising the low frequency components of the intruding noise and tending to make conditions for speech less acceptable. In these circumstances, with a noise level of about 50–55 dBA inside a building, a telephone could be used with some difficulty, and normal conversation carried on at a distance of several feet. This inside level corresponds to a level outside the building, with closed conventional single windows, of 65–75 dBA.

434. In order to confirm that noise at this level does not seriously interfere with conversation one of our sub-committees held a meeting in a room which was exposed to noise, of varying known intensities, from typical contractors' plant. With a level of 70 dBA outside a window which reduced the noise by about 15 dBA they found that they could conduct business, and telephone, without undue difficulty.

435. However, if a level of 70 dBA were introduced immediately, it would require the construction industries to restrict noise to a level which is

below the level already produced at times by traffic in the busy central areas of cities, and below the level existing in some heavy industrial areas. We feel, therefore, that, for the present, higher levels must be accepted in some areas. These levels must be practicable and fair to the construction and demolition industries as well as to their neighbours, but they must also provide the industries with an incentive to reduce noise below the existing levels. We suggest, therefore, that, at present, noise levels outside the nearest building at the window of the occupied room closest to the site boundary, should not exceed :—

70 dBA in rural, suburban and urban areas away from main road traffic and industrial noise

75 dBA in urban areas near main roads and heavy industrial areas*.

436. These noise limits are intended to apply only between the hours of 7 a.m. and 7 p.m. Building work is not usually done outside these hours but, if it is, we consider that it should not be allowed to disturb people sleeping nearby. We know of no measurements which have been carried out specifically for assessing what levels of building noise are likely to disturb people at night. There are empirical procedures and criteria for assessing the likely reaction of the public to noise from industrial premises (see Chapter IX, paragraphs 379–386) and we recommend that corresponding criteria be established for building noises at night. Since building at night is a comparatively rare occurence, it may take a considerable time to establish such criteria.

437. The noise limits that we suggest for the daytime, and those which are developed for night work, should be useful to local authorities in deciding whether to take statutory nuisance proceedings under the Noise Abatement Act, or possibly in actions for nuisance at Common Law. We are aware, of course, that there may be occasions on which it is unreasonable to expect observation of these standards. We have in mind particularly emergency work by public authorities, statutory undertakers, etc., which may be necessary for reasons of safety or public health and may have to be done at night. But apart from these exceptional circumstances and the specially noisy operations mentioned below, we think the limits set out above are not unreasonable. We have considered whether they should be given legal force but think this step would be premature until enough experience has been obtained to establish their validity. They would best be considered as a desirable code of practice for the industry.

438. There are certain particularly noisy operations which cannot be quietened sufficiently when they are taking place on confined sites to meet the criteria set out above; sheet steel pile driving is perhaps the most outstanding example. We think there should be some statutory control over

* These noise levels may seem to be in contradiction with those suggested in paragraphs 379–386 of Chapter IX (and more explicitly in Appendix XV) for permissible noise levels produced by industrial processes. The two situations envisaged are, however, radically different. Chapter IX is concerned with the noise emitted by factories permanently located in or near a residential area, where the criterion of acceptability is lack of complaints. In the present chapter we are concerned with noise temporarily introduced into a district, and the criterion proposed is that the noise should be such as not to interfere unduly with speech in the nearest inhabited building during the construction period.

operations of this kind and that it should be exercised by local authorities, who should be empowered to obtain such information as they need to satisfy themselves that no alternative quieter process to that proposed is practicable and reasonably economical, and to impose conditions, such as restrictions on the times of day and days of the week during which the process might be used. The times of day during which a noisy process is used are obviously important. A great noise in a residential area will be most disturbing during the night, and in commercial areas, such as are found in central London, probably during the day. It would be necessary for this approval to be sought at a very early stage in the planning of the construction scheme, so that architects and designers and the contractors tendering for the work would be aware of any limitations on the methods that they could use, and the times at which they could use them. There should be a right of appeal against the local authority's decision.

439. Much noise from building, civil engineering and demolition sites is unnecessary, but is of short duration and is often impact noise, the peak level of which might not be registered by normal sound level meters. We feel strongly that this noise should be minimised, so we welcome the suggestion made to us by the Federation of Civil Engineering Contractors, that a publicity campaign should be conducted within the industry to remind contractors and their employees of the need to reduce noise and of the large contribution that they could make.

Chapter XI

Entertainment and Advertising Noise

INTRODUCTION

440. In this chapter we discuss the noise of streets and public places, public houses, cafes and so on, which affects people outside or inside their homes, but arises from sources which are not discussed in other chapters. Most of these noises are caused by other people enjoying themselves in their own way, or by advertisers. The sources of the noise are many and varied. They include people singing, shouting, and playing musical instruments in the streets or in cafes, public houses, dance halls, etc.; fairgrounds; children playing; sporting events, particularly motor rallies, motor cycle scrambles and go-kart racing; and advertising by noise from mobile shops, or by hawkers.

441. The evidence of witnesses, and the information that we have had from local authorities about the complaints that they received in 1960, shows that noises of these types are a major source of annoyance and complaint. We have no better way of judging the extent of annoyance caused and we have no reliable means of assessing which among this group of noises are the worst offenders. However, the evidence that we have suggests that the principal sources of annoyance are general disturbance in public places, music and general noise from cafes, public houses and clubs, ice cream chimes and noisy hawking. Others, such as motor sports of one sort or another may well cause a good deal of disturbance in the areas that they affect.

442. We think that the major constituents of this problem may change with time as they have in the past. The use of transistor radios out of doors is assuming increasing importance as a source of annoyance; we noted the strength of the complaints about ice cream chimes and that complaints about noise from cafes frequently referred to juke boxes, both of which were rare in this country not many years ago. The greater number of townspeople who are now able to get out into the countryside is also causing more noise in country places. We know little about the noises that may have caused annoyance in the more distant past, though no doubt noises which are now rarely, or never, heard were sources of annoyance in their day. The problem is, therefore, a constantly changing one, and the means of control must be flexible, too, if they are to be effective. . . .

EXISTING CONTROLS

443. Technical achievements, such as the transistor, may introduce new means of amusing some people and annoying others, but we doubt whether technical advances will contribute much to the solution of the problem. A contribution may come from town and country planning and from the better insulation of buildings from external noise, but fundamentally the problem discussed in this chapter is one of human behaviour. The primary

cause of annoyance from entertainment and advertising noise is that the people making the noise lack consideration for the interests of others. On the other hand some of the complaints may reflect a lack of reasonable tolerance. The problem cannot, therefore, be solved by laws, although they may help to reduce it.

444. The changes in the sources of annoyance are reflected in the legislation about noise. Some statutes and byelaws relate to noises which are unlikely to be heard today. On the other hand the model byelaw to deal with nuisance caused by unreasonable use of wireless loudspeakers has recently been revised by the Home Office in direct response to complaints about nuisances arising in public places from the increased use of portable and transistor wireless sets. In its new form the byelaw is more readily enforceable and it is more clearly seen to apply to nuisances arising in parks, pleasure grounds and on public beaches: all places in which the use of transistor radios is particularly likely to cause annoyance.

BYELAWS

445. The principal legislation relating to noise in streets and public places is contained in byelaws. In England and Wales, county councils and borough councils have power under Section 249 of the Local Government Act, 1933, to make byelaws for the good rule and government of the whole or any part of the county or borough, and for the suppression of nuisances. In London, the London County Council and the Metropolitan Borough Councils have similar powers under Section 146 of the London Government Act, 1939. Scottish local authorities can make byelaws under various statutes, including the Local Government (Scotland) Act, 1947. In England and Wales the byelaws must be confirmed by the Home Secretary, and in Scotland by the Secretary of State or, in a few instances, by the Sheriff.

446. In England and Wales there are model forms of a number of byelaws relating to noise in streets and public places. These model forms are reproduced in Appendix XVI. Some local authorities have adopted other byelaws or variations of the models, either under their powers in the 1933 or 1939 Acts or under other powers to make byelaws for the regulation of behaviour in particular places, e.g. in public parks under the provisions of the Public Health Act, 1875, or on the foreshore under the provisions of the Public Health Acts Amendment Act, 1907.

447. In Scotland there are few model byelaws, but the Burgh Police (Scotland) Act, 1892, makes it an offence for people selling articles in a public place to shout, call, or use any noisy instrument so as to cause annoyance to any inhabitant after being requested by a constable or inhabitant to cease, and for a street singer or musician to continue to perform after being asked to cease by a householder. This Act applies to all burghs in Scotland except five which have similar local Act powers. There are no similar provisions in general Acts applying to the county areas outside the burghs.

448. We sent a questionnaire to the councils of all counties and boroughs in England and Wales and of all counties, counties of cities and burghs in

Scotland, to find the extent to which they had needed to make "good rule and government" byelaws about noise and whether they found them useful. The replies that we received show that most of the authorities in England and Wales, but few in Scotland, have some byelaws about noise. In general, over half the authorities who have byelaws find them useful in controlling nuisance from noise, although few needed to prosecute under them, in the five years 1956 to 1960, which was the period about which we enquired. In a few areas a large number of prosecutions had taken place, particularly for rowdy behaviour in the streets or other public places at night. It was noticeable that the byelaws which were most commonly adopted were the models, and that many authorities had adopted most of these.

449. The replies to the questionnaire also showed that in many areas the enforcement of the byelaws is effected by the police, or the police play a significant part in their enforcement.

THE NOISE ABATEMENT ACT, 1960

450. The general noise nuisance provisions of Section 1 of the Noise Abatement Act, 1960, are likely to be most effective where the source of noise is static and the nuisance continues for a period. They are unlikely to be useful against temporary, transient nuisance such as rowdiness, or playing a portable radio in the street.

451. Section 2 of the Act limits the operation of loudspeakers in streets. It prohibits their use for any purpose between 9 p.m. and 8 a.m. and at any other time for advertising any entertainment, trade or business. A number of exceptions are allowed. These include the operation between noon and 7.0 p.m. of a loudspeaker fixed to a vehicle to inform the public, otherwise than by means of words, that perishable foodstuffs are on sale from the vehicle, provided that the loudspeaker is not so operated as to give reasonable cause for annoyance to persons in the vicinity.

452. The information about the working of the Act that we obtained from local authorities showed that most prosecutions under the Act were for the mis-use of ice cream vendors' chimes, and that proceedings were taken in a much higher proportion of cases of this than of other types of noise nuisance. Similarly, the majority of prosecutions under local Act powers regarding noise relate to the use of chimes by ice cream vendors in areas where a local Act forbids the use of loudspeakers at any time to advertise a trade or business.

CONCLUSIONS AND RECOMMENDATIONS

453. The types of noise which are discussed in this chapter can be divided into three broad classes :

(*a*) those which are occasional and unpredictable, such as noise caused by people shouting as they walk along a street ;

(*b*) those which are occasional but predictable, such as the noise made by noisy sports which occur only occasionally at any place, such as motor scrambles ; and

(*c*) those which recur frequently and are predictable, such as noise from cafes, public houses, dance halls, etc. and the noise of, for example, hawkers, and ice cream chimes.

NOISE WHICH IS OCCASIONAL AND UNPREDICTABLE

454. Generally, the first type of noise cannot be reduced except by improvements in the standards of social behaviour and by making the creation of noise an offence. We have little doubt that there is now less noise from rowdiness, from street musicians and from other activities in streets and public places than there was, say, thirty years ago. We hope that with rising standards of living and of education this improvement will continue. Byelaws seem to be effective instruments against this type of noise where it does occur, and appear to be in force in most areas in England and Wales. In Scotland there appear to be few byelaws in force, apart from byelaws prohibiting the playing of musical instruments in a public park without the local authority's permission. Many local authorities have made byelaws to this effect, following the issue of a model by the Scottish Home Department. Edinburgh's Park Byelaws also forbid the use of loudspeakers and there is nothing to prevent other Scottish local authorities from making a similar byelaw if they need. Perhaps the relative scarcity of byelaws in Scotland is explained by the powers already existing in the Burgh Police (Scotland) Act, 1892.

455. In England and Wales the police play a prominent part in the enforcement of byelaws. In dealing with the type of noise to which byelaws generally relate this seems to us to be proper and, indeed, inevitable. These noises can be stopped only at the time and place at which they occur and this is a function which only the police can effectively perform.

NOISE WHICH IS PREDICTABLE

456. A number of different lines of attack seem to be available in tackling the second and third classes into which we have divided these types of noises (see paragraph 453). They include requiring the organisers to obtain prior approval to holding events which may cause disturbance from noise, minimum standards of sound insulation in buildings to control noise escaping from them, restricting the hours during which noisy events are permitted, town planning, and byelaws concerning noisy behaviour. Different combinations of these lines of attack may be appropriate in different circumstances and some of the necessary measures are better laid down for the country as a whole, or for parts of it, while others can best be applied by a local authority with an intimate knowledge of all the relevant local circumstances. These various approaches are discussed in more detail in the following paragraphs. The types of noise that we mention specifically are not intended to comprise an exhaustive list of all the types that cause disturbance. They are chosen because they serve to illustrate the points that we feel should be emphasised.

NOISE WHICH IS OCCASIONAL BUT PREDICTABLE

457. This group, which is, of course, an arbitrary classification, covers noise produced by events which occur infrequently, but predictably, at particular places. It includes the noise produced by fun fairs, motor cycle scrambles, go-kart races and similar activities. Their common features are that their noise is a part of, or an inevitable accompaniment to, the amusement and pleasure that they provide to the people who attend them, or participate in them; they are relatively infrequent and last for a limited

time, but the number of suitable venues is not extensive. Many, perhaps most, of them take place out of doors.

458. In most cases these activities are not subject to the controls under town and country planning legislation as they involve only the temporary use of land and little or no works. We do not think that further control should be sought in this direction.

459. We do not think that the nuisance provisions of the common law, the Noise Abatement Act or local Acts are likely to be effective. They come into play only after the event, and the necessary procedures take some time to operate. Neither, in our view, is total prohibition the right answer as this would not hold a reasonable balance between the liberty of those people who enjoy the noisy activity and those who are disturbed by the noise.

460. The right course, in our view, is to try to arrange that these events are held in places and at times when they will not cause unreasonable disturbance to people who live nearby. We consider that this can best be done by requiring the organisers of these events to obtain prior approval before they are held and, indeed, in Scotland, Section 397 of the Burgh Police (Scotland) Act, 1892, as amended by Section 313(2) of the Local Government (Scotland) Act, 1947, provides that "no public show of any description whatever" may be opened or set up without the permission of the town council. We understand that this control works without friction. We recommend that the permission of local authorities in England and Wales, and of county councils in Scotland, should similarly be required before events are held which may cause noise nuisance. The local authorities should be empowered to reject an application, to approve unconditionally or to approve subject to appropriate conditions. Conditions that they might be empowered to impose should, we feel, cover exact siting, the hours of the day and days of the week for which the approval is valid, and any other reasonable matters. The applicant should have the right of appeal to the courts against a rejection of his application or against conditions attached to an approval. It should be an offence, punishable by fine, to hold an event which is subject to control, without approval or without complying with the conditions of the approval.

461. The main difficulty that we see in this procedure is that of defining which events should require approval. We feel that the procedure should apply to motor cycle scrambles, go-kart races, pleasure fairs and to any other similar events which are from time to time found by the responsible Minister to cause considerable justified complaint about noise. We do not, of course, intend this procedure to be applied to events which are held on land or in premises which have been provided for the purpose and for which planning permission has been received, or would have been necessary if the present town and country planning legislation had applied at the time of their provision, e.g. motor racing tracks.

462. Neither do we intend this procedure to apply to motor sport events, such as car rallies, which are held on the public roads and which will be subject to regulations to be made under Section 36 of the Road Traffic Act, 1962.

NOISES WHICH RECUR FREQUENTLY AND ARE PREDICTABLE

463. In this group we include noise from cafes, public houses, hotels, clubs, and other places of entertainment, and advertising. We include the latter because the noise from ice-cream vendors occurs, in many areas, so regularly as to constitute a recurring noise in any one place.

464. At present the noise from places of entertainment is subject to proceedings under the noise nuisance provisions in the Common Law, the Noise Abatement Act, local Acts and Byelaws. These provisions seem to us to be an effective means of control. Their existence undoubtedly helps local authorities to deal, often informally, but sometimes by serving a notice, with many cases of noise nuisance from these sources. In the case of licensed premises the laws of nuisance are reinforced by the licensing laws, as we understand that it is open to anyone who, after complaining to the owners, remains aggrieved by noise from licensed premises to object when an application for renewal of the licence is made to the licensing courts.

465. The ability of private citizens and local authorities to take action or proceedings after noise nuisance has occurred seems, however, to be second best. It would be better to be able to prevent or minimise the possibility of nuisance occurring. Indeed, there are at present controls which operate to this end, including town planning, the licensing of premises for public amusements and for the sale of liquor, and section 2 of the Noise Abatement Act.

Places of Entertainment

466. The construction of new buildings, or the change of use of existing buildings for use as clubs, theatres, cinemas, cafes, public houses, swimming baths, etc., requires approval by the planning authorities, and we know that most planning authorities regard noise as an important factor to be taken into account when considering applications for planning permission. Planning authorities are fully aware that some of the noise which may be caused by the use of premises for entertainment occurs when the patrons arrive and especially when they leave, and arises from shouting, talking, and the use of their cars. We can, therefore, be confident that new developments of this type will be permitted only after the possibility of noise nuisance has been considered. It must, however, be recognised that cafes, public houses, cinemas and the like can generally serve their functions only if they are situated in, or close to, residential areas. The contribution that planning can make to the reduction of noise annoyance from these causes is, therefore, limited.

467. In order to minimise noise from such buildings when they are close to dwellings, hospitals and other places where noise might be objectionable we must, therefore, look to sound insulation. We have, elsewhere, recommended that local authorities should have power to regulate the standards of construction of buildings so as to minimise noise annoyance. We recommend that these powers should apply to new buildings which are to be used for entertainment, including the performance of music. Buildings such as concert halls, cinemas and theatres need good standards of sound insulation to prevent external noise interfering with the music or speech which is produced inside them, and we doubt whether

their performances often cause annoyance. But the standards of sound insulation in cafes, public houses, dance-halls and clubs are not so rigorous and we feel that local authorities should be enabled to ensure that they are adequate, taking into account their environment and local conditions.

468. The present laws relating to the licensing of premises for the performance of music or for use as theatres or cinemas provide a means of control of the hours of performance. These controls can be used to reduce noise annoyance, especially late at night, but in the case of public performances of music, they do not, at present, exist in all parts of the country. In England and Wales the provisions of Part IV of the Public Health Acts Amendment Act, 1890, under which public music and dancing is licensed outside London and the Home Counties, are adoptive, and in those places where these provisions are not in force and there are no similar provisions in the local Acts, no licence is required for the public performance of music. In Scotland, places of public resort for public music or dancing are subject to licensing control in burghs under the Burgh Police (Scotland) Acts or local Acts, but generally no similar powers are available in county areas.

469. We feel that town planning, the control of standards of sound insulation in buildings, which we recommend in paragraph 467 above, the licensing of premises for public amusements and for the sale of liquor, the nuisance provisions of the Common Law, the Noise Abatement Act, and byelaws provide effective means for the control of noise nuisance from places of entertainment.

Advertising

470. Section 2 of the Noise Abatement Act restricts the use of loud-speakers for advertising in the street. In most parts of England and Wales there is also a bye-law which makes it an offence to shout or use any noisy instrument to advertise any article for sale so as to cause annoyance to the inhabitants of the neighbourhood. In Scotland similar powers are given in burghs by the Burgh Police (Scotland) Act 1892 or by local Acts (see paragraph 447). Advertising from aircraft, except by public authorities in emergencies, is prohibited by the Civil Aviation Act, 1960, and the Civil Aviation (Aerial Advertising) Regulations, 1961.

471. With some exceptions, therefore, using noise to advertise is, over most of Great Britain, prohibited altogether, or is an offence if it causes annoyance. In principle we think that this is right and we propose to discuss only the major criticism of the present law which has been brought to our attention. This is the use of chimes to advertise the presence of vehicles from which perishable foodstuffs, usually ice cream, are for sale.

Ice Cream Chimes

472. The use of chimes by mobile ice cream vendors was keenly debated in Parliament during the passage of the Noise Abatement Act, and the provisions of Section 2 of the Act are a compromise between complete prohibition and unfettered freedom. In addition to the provisions of the Act a representative body of ice cream manufacturers have issued a code of practice which enjoins vendors to restrict their use of chimes during the permitted hours, for example by sounding them for periods of not

more than four seconds at intervals of at least three minutes, and not at all near hospitals, where shiftworkers are known to be asleep, or anyone is known to be seriously ill at home, on Sundays near churches during the hours of service, near schools during school hours or after school hours unless the van is on the same side of the road as the school, on main roads or near busy crossings. The evidence that we have received shows that in spite of the Act and the efforts of these manufacturers the annoyance caused by chimes continues, and indeed that in some areas vendors conform neither to the Act nor to the code of practice. The evidence from local authorities shows that only in the case of ice cream vendors do they find it necessary to institute proceedings in any substantial proportion of instances of noise nuisance; with most other types of noise nuisance informal action is almost invariably successful.

473. We note that, in general, it is only ice cream vendors among the mobile vendors of perishable foodstuffs who find it necessary to use loudspeakers to advertise their presence, although the Act permits their use to advertise any perishable commodity for human consumption.

474. The evidence that we received from representatives of the ice cream industry was that the use of chimes was essential to ice cream traders who sell from vans. Sales from vans using other methods of attracting attention were as much as one-third below those of vans using chimes. Where companies had experimented with selling methods which did not involve any noisy instruments, e.g. by building up "rounds" of customers, they had not been able to obtain sufficient trade to justify continuing the service.

475. Nevertheless, the industry accepts that the use of chimes does cause annoyance. They claim, however, that, although the Noise Abatement Act has seriously affected sales of ice cream from vans, particularly by prohibiting the use of chimes after seven in the evening, it has also greatly reduced the number of complaints they receive about chimes. Even so, they agree that some drivers use their chimes irresponsibly, but point to the difficulty of enforcing rules, such as the code of practice mentioned above, upon their many van drivers, the more irresponsible of whom can be deterred from unrestrained use of their chimes only by someone who is on the spot. They consider that the standard of discipline is improving and will improve further, but some companies would welcome measures, particularly in relation to the duration of frequency of broadcasts, which would help them to curb excessive use of chimes. They have been discussing with the manufacturers of the chimes equipment the possibility or restricting, automatically, the duration and frequency of the chimes. The control of loudness presents different problems as, to attract attention, the chimes must be louder in, say, a busy street than in a quiet area, and their range of audibility is also dependent upon the wind and upon local physical conditions.

476. Thus, although ice cream chimes annoy some people, they help to provide a service to others. As is to be expected, the chimes appear to cause fewer complaints in rural areas than in towns. However, both in town and country there is likely to be objection to the chimes or to any other noisy advertising from people who regard advertising by noise as an intrusion upon their privacy which they cannot exclude from their

consciousness as they can, for example, advertisements in newspapers or on hoardings, and we have received strong representations from such people. There is, therefore, a considerable clash of interest among the public quite apart from the case that is put forward by the ice cream industry. We feel that it would not be right, at the present time, to insist upon the abolition of ice cream chimes, but we feel that further and more detailed restrictions on their use should be introduced.

477. The problem seems to resolve into two parts. The first part concerns the control of the operation of the individual van and the second the annoyance caused by a succession of vans, the chimes of any one of which may be operated perfectly reasonably. We will consider these two parts separately.

478. The detailed control of the individual salesman is primarily a matter for his employer. It is clear that, for one reason or another, this control is not satisfactory and requires reinforcement. We recommend that this should be done by giving statutory force to detailed rules of conduct for mobile ice cream vendors. There seems to be some doubt as to whether this could be achieved through local byelaws. Whatever else is done we would regard it as essential that the use of chimes should continue to be allowed only during the hours, and subject to the conditions, already provided in the Noise Abatement Act, 1960.

479. The detailed rules should include:—

(*a*) the restriction of the duration, frequency and loudness of broadcasts of the chimes, the controlling mechanism being sealed so that it could not be tampered with by drivers;

(*b*) provision for forbidding the sounding of chimes in places where the sale of ice cream from parked vans would be exceptionally dangerous or disturbing.

Some of these matters are already the subject of the code of practice referred to above.

480. It is possible that all the detailed rules required to control mobile ice cream vans could not easily be laid down by general legislation. General legislation, if this is found to be necessary, should define the broad principles within which local authorities could make detailed rules applicable in their areas.

481. This system of control should, in time, enable a more exact judgment to be formed than is possible from the evidence available now of the general public feeling about the advantages of ice cream chimes and of the need for restrictions on their use. After, say, three years' experience of this system the position should be reviewed. If it were then found that the measures taken had been insufficient to reduce to a reasonable level annoyance caused by the chimes, we feel that the best course would be to make sure that individual local authorities, with the approval of a Minister, had power to prohibit ice cream chimes altogether in their areas.

482. We are doubtful whether the existing law is likely to be effective in dealing with the annoyance caused by a succession of vendors, which is the second part of the problem. Provided that the chimes are being used within

the permitted hours the only sanction against the salesmen is the provision in the Noise Abatement Act that the chimes "must be so operated as not to give reasonable cause for annoyance to persons in the vicinity." But each of the succession of salesmen may be operating his chimes reasonably and it does not seem possible to say that any of them, in these circumstances, is blameworthy or guilty of an offence.

483. Restriction of the duration, frequency and loudness of chimes would undoubtedly do something to help, but if this proved insufficient, short of prohibiting the use of chimes, the only solution to this source of annoyance appears to be to restrict the number of traders permitted to sell from vans in any area. This is a somewhat drastic remedy involving the granting of monopolies or partial monopolies which should be considered only if the nuisance proves very serious in spite of the measures that we recommend for improving control of individual salesmen.

RADIO AND TELEVISION SETS, ETC.

484. A special reference must be made to the disturbance from neighbours' radio and television sets, record players and tape recorders, which are sources of frequent complaint. Ultimately, the best remedy for this disturbance is sympathy and consideration between the people concerned. In periods of fine weather when people have windows open the broadcasting authorities play their part by transmitting appeals to their listeners to make sure that their loudspeakers are not causing disturbance. Where the noise amounts to a nuisance, there are legal remedies under the Noise Abatement Act, the Common Law and, where it applies, the Model Byelaw on radios, gramophones, etc.

485. It has been pointed out to us that even considerate listeners can scarcely avoid giving offence at times since when sets are adjusted to give comfortable reception of speech, the background music associated with the speech often sounds too loud. The relative loudness at which speech and music are broadcast is based upon the results of research into listeners' preferences. These results show that, on average, people prefer music louder than speech but that the variety of preference is wide. The broadcasting authorities must pay due regard to the majority's preferences but it follows that if someone who likes speech to be loud adjusts his receiver accordingly, any accompanying music will be very loud indeed.

PUBLIC EDUCATION

486. Whatever can be achieved in controlling the types of noises discussed in this chapter by legislation and administrative method, their reduction depends most upon standards of public social behaviour. We recommend, therefore, that local authorities should be encouraged to direct some of their publicity activities, both in schools and generally, towards teaching that the creation of unnecessary noise is inconsiderate and ill-mannered.

Chapter XII

Noise in the Country

INTRODUCTION

487. There is no doubt that the countryside is getting noisier. We have noted in Chapter XI that the greater number of townspeople who are now able to visit and find their recreation in the countryside tends to increase the noise there. We hope that in such places as National Parks and National Trust properties endeavours will be made to preserve, or create, havens of quiet where those who wish to can escape from noise for a time. Major factors affecting the countryside are the general increase of road traffic, the construction of high speed motorways and the spreading use of machinery on farms. In fact most of the noises that occur in towns also occur in the country, but to different degrees. It must be remembered, however, that the same noise may give rise to greater annoyance in the country on account of the lower background noise, and for the same reason a lesser noise may still cause significant annoyance. If a noise constitutes a nuisance the methods of mitigating it are substantially the same wherever it occurs.

488. In addition to disturbance caused by the normal urban noises which we have considered in previous chapters, annoyance is caused in the country by motor vehicles taking part in rallies of various kinds, in scrambles and in hill climbs. We have already made recommendations in paragraphs 460 and 461 (Chapter XI) for reducing annoyance caused by these sporting events, and in paragraphs 233–236 (Chapter VII) we have referred to the possible need in the future for imposing noise limits on motor-boats.

489. In certain areas, noise is caused by low-flying military aircraft. The measures which are taken to mitigate the noise nuisance have been outlined in paragraphs 245 and 246 (Chapter VIII).

490. Other types of noise which occur predominantly in rural areas are those arising from mineral workings, agriculture and forestry, which are dealt with in the following paragraphs. We also include here a short section on gardening and horticultural equipment, although lawn-mowers are likely to be more of a nuisance in towns than in the country.

MINERAL WORKINGS

491. The noise from mineral workings, i.e., from quarries, gravel pits and the like, involves some special problems. Some of the work, such as removing and replacing top soil and overburden, is akin to civil engineering, while the processing of the mineral in permanent or semi-permanent plant is similar, from the point of view of noise control, to an industrial activity. In addition, blasting is used in some quarries.

492. There appear to be very few complaints about noise from mineral workings, many of which are remote from residential areas. New workings are subject to planning permission, and where working may disturb the

surroundings because of noise or other factors, permission, if given, may be subject to conditions which restrict the method of winning or working the mineral. Conditions which have been imposed include limiting hours of work, requiring processing plant to be suitably sited and to be enclosed with sound insulating material, and requiring excavators and bulldozers to be fitted with efficient, well maintained silencers. Some operators voluntarily take these and other measures to reduce noise and to protect local residents from annoyance.

493. Blasting sometimes causes complaints, but there are known techniques by which the noise can be greatly reduced, and these should be employed as widely as possible. Some explosives manufacturers are willing to advise quarry owners and managements who receive complaints, as are Her Majesty's Inspectors of Mines and Quarries, although they have no statutory function in relation to noise nuisance.

494. Although noise from mineral workings does not appear to be a major problem, we consider that it should be controlled in the same way as noise from other similar operations. We accordingly propose that our recommendations for the control of noise from construction and demolition sites (see Chapter X) should apply to those operations which are akin to civil engineering works and that our recommendations about noise from industrial premises (see Chapter IX) should apply to those mineral working operations which are comparable with industrial processes.

NOISE FROM AGRICULTURE, FORESTRY AND GARDENING

495. We do not think that noise from agriculture and forestry is a serious problem, but there are sources of noise in these industries which do cause annoyance to some people. These sources are agricultural machinery powered by internal combustion engines, devices for scaring birds by noise, and power saws.

AGRICULTURAL MACHINERY

496. All agricultural machines which are licensed to use the roads, such as tractors, come within the range of our recommendations regarding noise from motor vehicles (see Chapter VI). We do not consider that it is necessary at present to devise similar procedures and fix maximum noise levels for other mechanically powered types of agricultural machinery. However, we recommend that all agricultural machines which are powered by internal combustion engines should be fitted with efficient exhaust silencers.

BIRD SCARERS

497. Devices for scaring birds by noise present an unusual problem in that they are one of the rare examples in industry or agriculture of noise which is deliberately produced. Unfortunately noise is an unavoidable ingredient in bird scaring during daylight. We were informed by the Ministry of Agriculture, Fisheries and Food that means of scaring birds visually, such as scare-crows and models of owls, hawks and other birds of prey, had not proved very effective in this country. Nor is it possible to scare birds by using sound at frequencies or of a type which will not

cause annoyance to human beings. The range of frequencies to which birds react is similar to that which is audible by human beings, and a type of noise which alarms birds is also likely to disturb human beings. Limited experiments suggest that a noise level of about 85 dB at a bird's ear is needed to scare the bird.

498. The types of audible bird scarers most commonly used now produce a loud bang at regular intervals. Some local authorities have adopted a byelaw which prohibits the operation of these devices during the hours of darkness. A method of bird scaring which has recently been introduced into this country is the broadcasting of birds' distress calls. This method is used effectively in some countries on the continent of Europe and is arousing interest here. The broadcast is highly directional and can be heard for a considerable distance.

499. One of the important limitations of all types of bird scarers is that birds get used quite quickly to any stimulus designed to produce fear if it is present constantly or for long periods. For this reason the Ministry recommend that the duration of broadcasts of birds' distress calls should not exceed two minutes in every twenty or thirty minutes, and can be less under favourable conditions.

500. We considered whether the seasons, or periods in crop cycles, in which audible bird scarers might be used could be limited, but we are satisfied, on the information that we could obtain, that this is impracticable. The mixture of crops grown, and of different types of a similar crop, and the varying periods at which crops are ripening, would make any limitation of this sort extremely complex if it was possible at all.

501. We were informed that the only known damage caused to crops at night is to water-cress beds by wild fowl in hard weather, but it is possible that this could be prevented by the use of scarers which do not involve noise, such as flashing lights or flares. We therefore recommend that the existing model byelaw prohibiting the use of explosive bird scarers during the hours of darkness should be varied to apply to all types of audible bird scarers. In addition, we recommend that farmers should be made aware of the disadvantages of the continuous use of bird scarers and that they and local authorities should be reminded that if the noise from bird scarers constitutes a nuisance it is subject to proceedings under the Noise Abatement Act.

POWER SAWS

502. Portable chain saws powered by internal combustion engines are very noisy, but, when used for forestry work they are mostly distant from houses and thus do not cause nuisance. Sometimes, however, they are used near houses and give rise to complaints. We were informed that there is little prospect of their noise being substantially reduced, as better exhaust silencers reduce the handiness of the saw too much. They are rarely used in one place for very long, so the nuisance provisions of the Common Law and the Noise Abatement Act are unlikely to be effective in preventing nuisance when the saws are used near inhabited buildings. In the circumstances we consider that their use should be restricted where the noise is likely to cause undue disturbance. In view of the short time for which they are normally used in any

one place, we consider that the most appropriate criterion to apply in deciding the extent of the restriction needed is that the noise should not unduly interfere with speech in the nearest building. The available information on the levels of noise from these saws suggests that they would need to be about 200 feet from a building to meet this criterion. We therefore recommend that the use of saws powered by internal combustion engines without effective silencers should be prohibited within 200 feet of inhabited buildings, other than buildings occupied by the owner of the timber.

GARDEN AND HORTICULTURAL EQUIPMENT

503. There are many mechanical tools in use in market and private gardens some of which are noisy and cause annoyance. Perhaps the machines which cause most complaint are rotary grass cutters and motor lawn-mowers, and we have examined the possibility of quietening them.

504. The main source of noise in motor lawn-mowers is the engine—electric machines are much quieter—although the rotary type of mower which is becoming increasingly popular is much noisier than the cylinder type. Although some manufacturers emphasise quietness in their advertisements, we were told that it is unlikely that, apart from the rotary type, motor lawn-mowers will become quieter. We were also told that the main obstacle to this trend was that the machines could now be made quieter only at greater cost. Individual manufacturers were not willing to incur these higher costs, and thus raise the selling price of their machines, unless they were satisfied that their competitors would follow suit. They would, however, welcome statutory limits to noise from mowers.

505. We recommend that the British Standards Institution should be invited to devise a method for testing the noise output from motor lawn-mowers and other types of motor driven garden machinery, and that, when a satisfactory method has been found, legislation should be introduced fixing maximum noise limits for new machines.

506. Many of the hundreds of thousands of lawn-mowers which have already been sold in this country are likely to be in use for many years to come. We recommend that the manufacturers should be encouraged to provide facilities for modifying these machines to reduce their noise, if they exceed the limits for new mowers, although there may be some models which it will be difficult to improve at reasonable cost.

Chapter XIII

Occupational Exposure to High Levels of Noise

INTRODUCTION

507. In Chapter II we discussed the general effects of noise upon human beings, including disturbance of sleep and concentration, annoyance and other psychological effects. In this chapter we discuss the physical effects of exposure to noise of relatively high intensities such as exists in some industries. These effects are largely upon the mechanism of the ear and can result in damage to hearing. There are also other bodily effects which we mention briefly. A selected bibliography is given in Appendix III.

EFFECTS ON THE EAR

508. Damage to hearing can arise in three different ways. Temporary reductions in sensitivity of hearing, for periods ranging from seconds to days, can occur after exposure to noise. Permanent reductions in sensitivity of hearing can be caused by damage to the inner ear, resulting from exposure over a considerable period to certain types of noise. The existence of this damage, which is irreversible, has been demonstrated in people who work in noisy industrial environments. Sudden gross damage to the middle or inner ear can be caused by noise of very high intensity and short duration, such as that produced by an explosion. We have not examined this effect, which is known as acoustic trauma, and will make no further reference to it.

509. Though the existence of these temporary and permanent reductions is well established, as this chapter shows, our knowledge is very inadequate. This is not surprising when the practical difficulties of acquiring it are considered. It is not usually possible to find groups of people who have been exposed to a constant high noise level for a long time, and the state of whose hearing was known before the exposure commenced. Nor would it be acceptable deliberately to expose groups of people to noise where permanent damage to hearing might be expected. Because of this limitation investigations must be undertaken in existing rather than experimentally controlled conditions.

510. The temporary and permanent effects on hearing of exposure to noise are discussed in the following paragraphs. In this chapter temporary reductions in hearing sensitivity are referred to as " temporary threshold shift " and permanent reductions as " permanent threshold shift ".

PRESBYCUSIS

511. Hearing sensitivity normally deteriorates with age. This effect, which is known as presbycusis, varies between individuals, but the average course of the deterioration appears to be established with reasonable certainty. In assessing degrees of hearing loss from noise exposure it is generally assumed that this loss and the loss due to presbycusis are additive.

Temporary Threshold Shift

512. Following exposure to an intense enough noise for even a short period, minutes or hours, there is a reduction in hearing sensitivity which is recovered after an interval varying from seconds to days. This reduction is commonly called " temporary threshold shift ". Its extent seems to depend upon the characteristics of the noise exposure and the susceptibility of the individual, and to be inversely related to the degree of permanent threshold shift initially present as a result of previous noise exposure. Temporary threshold shift is most marked at the frequency about half an octave above the predominant frequency of the noise causing the shift.

Permanent Threshold Shift

513. It has been established that a permanent reduction of hearing sensitivity can occur in people who are exposed for long periods to noisy environments, such as are found in some industries. The loss has a gradual onset which is usually unsuspected by the individual although it can be detected by audiometry. In most cases it occurs first as a small loss of hearing acuity, often at a frequency near 4,000 cycles per second, although other frequencies may be affected. As the condition progresses the loss increases around the frequency first affected and a loss in other adjacent frequencies occurs. When appreciable loss occurs at frequencies below 3,000 cycles per second speech will become less easy to understand, and the individual may then become conscious of an increasing deafness. No appreciable recovery is possible from this condition as the loss of sensitivity of the hearing arises from irreversible damage to delicate parts of the inner ear.

The Relation between Noise Exposure and Threshold Shift

514. The assessment of the relation between noise exposure and threshold shift is complex because of the many possible variables. These include the sound pressure levels, the distribution of sound energy over the frequency spectrum, the duration of exposure and its distribution in time, individual susceptibility and changes in the hearing threshold due to increasing age. The present knowledge of the significance of each of the variables is briefly outlined in the following paragraphs.

Sound Pressure Level and Frequency

515. Other things being equal, the higher the sound pressure level the greater the temporary and permanent threshold shift. However, it is not sufficient in considering the degree of shift that may be caused by a given noise to have regard only to its level. Dissimilar noises may produce the same reading on a sound level meter but represent quite different hazards to hearing. It has been thought that a noise containing peaks of energy at discrete frequencies is more dangerous to hearing than is a noise of similar overall sound pressure level in which the energy is evenly spread over the frequency spectrum, but recently this view has been disputed. It is also widely believed that impulsive noises, e.g. gunfire, hammering, are more damaging to hearing than continuous noise.

516. It is thought that, provided the sound pressure levels are not very high, somewhat less damage to hearing would occur from low frequency sound than from higher frequencies at comparable sound pressure levels. It is known that temporary threshold shift occurs maximally at about half an octave above the frequency of a pure tone or the frequencies of maximum energy, and a similar relation may exist in permanent threshold shift, but no precise data are yet available. It is unlikely that sound energy in frequencies above 8,000 cycles per second could cause damage which would have any serious effect on the hearing of speech, and there is no evidence that airborne energy at ultrasonic frequencies at the levels met in industry produces any damage to hearing.

The Duration and Intermittency of Exposure

517. If a noise is capable of producing hearing loss, the extent of the loss will increase with time, over and above the normal effects of age. Account must, therefore, be taken of the total time for which a person is exposed to noise. The relationship between the effect produced by continuous exposure for a given time to a given noise and by exposure to the noise for several shorter periods which in total are equal to the same time, is still in doubt, as is also the still more complex case of intermittent exposure to different noises.

Individual Susceptibility

518. Different individuals vary considerably in the amount of hearing loss produced in them by a given noise exposure. The distribution of susceptibility in the population is not known. In an investigation of hearing loss incurred by flight deck personnel in Royal Navy aircraft carriers, the median loss, in a period of nineteen months, was shown to be 3 to 4 dB in the lower range of speech frequencies, but in ten per cent. of the men the loss at these frequencies was of the order of 10 to 15 dB.

CRITERIA FOR SAFEGUARDING HEARING

519. We were informed of a number of investigations which have been conducted into the relationship between noise and hearing loss. These investigations have mostly taken place in other countries, particularly the United States. They indicate the average hearing loss to be expected from a given noise exposure, but the results refer to groups, and do not indicate the loss that might be expected in any individual in a particular noise environment.

520. On the basis of these investigations, noise levels have been suggested at which measures to protect the individual against hearing loss should be undertaken. To arrive at these levels it is necessary to make assumptions about the type of noise, the duration of exposure and the extent of the hearing loss which can be accepted as tolerable.

521. Somewhat similar levels have been suggested by experts in this country and the U.S.A. for long exposure to broad band noise. Thus,

(*a*) Professor W. Burns of Charing Cross Hospital Medical School and Dr. T. S. Littler of the Wernher Research Unit on Deafness, have proposed that for exposure to broad band noise for 8 hours per day, 5 days per

week, for a working life-time, hearing conservation measures should be instituted if the noise in any of the frequency bands reaches the level shown in the following table:—

TABLE XVI

Frequency band (cycles per second) (*i*)	Sound pressure level value (decibels) (*ii*)
37·5–150*	100
150–300	90
300–600	85
600–1,200	85
1,200–2,400	80
2,400–4,800	80

* NOTE: This is a two-octave band

They do not consider that it is possible to stipulate sound pressure levels for frequencies outside the bands specified in the table above, as there is insufficient knowledge of the effects of noise at these frequencies. Nor are the criteria applicable to impulsive noise or noise containing intense pure tones which may be damaging at somewhat lower levels. They also think that, using the above criteria, certain slight losses of hearing might be suffered after long periods of daily exposure, and that in view of the differences between individuals, a few susceptible people might suffer significant losses at noise levels below those quoted:

(*b*) the British Medical Association stated in their evidence that they believed "that there is general acceptance of the view that working conditions involving continuous exposure throughout working hours for a prolonged period to noise whose intensity exceeds 85 dB in any octave band in the speech frequency range (250–4,000 cycles per second) may cause permanent damage to hearing:"

(*c*) Dr. Aram Glorig of the United States Academy of Ophthalmology and Otolaryngology, has suggested that "for habitual exposure to continuous (non-intermittent) steady noise that is on more than five hours a day, hearing conservation measures should be initiated where the sound pressure level in any octave band exceeds International Standards Organisation Noise Rating number 85." Noise rating number 85 allows the following octave band levels.

Octave mid frequency	63	125	250	500	1,000	2,000	4,000	8,000
Sound pressure level (dB) approx.	103	96	91	87	85	83	81	79

THE EFFECT OF VARIATION OF THE DURATION OF EXPOSURE

522. It has been suggested that the total energy incident on the ear over a given time determines the possible occurrence of hearing loss. On this basis, each doubling of the energy (that is, the addition of 3 dB) could be compensated by halving the duration of exposure. This principle, which is known

as the equal energy assumption, was derived from experiments done in the United States on temporary threshold shift and is now not thought to be applicable to durations of exposure of less than about one hour. It is also subject to the limitation that no unprotected ear should be exposed, however short the period of exposure, to a sound pressure level exceding 135 dB. The British Medical Association's opinion was that "since pain is considered a sign of physiological damage, the noise level in the ear canal should never exceed [the threshold of pain] no matter how short the exposure period."

THE ASCERTAINMENT OF INDIVIDUAL SUSCEPTIBILITY

523. Criteria for noise levels and data on the extent of hearing loss in given circumstances are generalisations which do not allow the prediction with any degree of certainty of the effect on an individual of exposure to noise. This is because of the variation in susceptibility between individuals. Clearly some means of obtaining an early indication of the susceptibility of individuals to hearing loss in any given noise environment would be useful.

524. This is particularly important because work done in the United States and recently confirmed in this country suggests that, in a noise environment that causes hearing loss, the rate at which hearing loss occurs is most rapid in the early years of exposure. In industrial noise the loss usually occurs first and proceeds quickest at about 4,000 cycles per second. The rate of loss slackens after a time until, at this frequency, after about ten years the total rate of deterioration approximates to that due to presbycusis alone. At other frequencies the decay appears to be more gradual and to go on for much longer.

525. There would be important advantages if the liability of an individual to permanent threshold shift could be measured in terms of temporary threshold shift. As a result of work in the United States, an empirical relationship has been reported between the temporary threshold shift at 4,000 cycles per second after eight hours exposure, and the permanent threshold shift at the same frequency after ten years for the same noise. It should be emphasised that this relationship refers only to average values for groups of people and to one frequency, and its validity is still the subject of discussion. It is obviously important that this relationship should be further investigated.

526. The evidence that we received was that, at least until the exact relationship between permanent and temporary threshold shift has been more closely determined, individual susceptibility to permanent threshold shift can only be found by periodical audiometric examination.

527. Audiometry consists of the measurement of hearing acuity against a base line of average normal hearing. Audiometric examination before an individual is exposed to a noisy environment, and again after a suitable interval, will indicate whether any change in hearing has occurred in that time. The appropriate interval must be decided by experience and should be short enough to detect any change in auditory threshold before it has assumed significant proportions. Care has to be taken to ensure that there is sufficient time between the audiometric examination and the last noise exposure to allow for the disappearance of a large proportion of temporary threshold

shift. The disappearance of temporary threshold shift is initially rapid and then progressively slower, although the degree, speed and other features of the recovery vary greatly between individuals. Ideally, the gap between the examination and the last noise exposure should be long enough to allow for the disappearance of all temporary effects, but this might be of the order of weeks. As gaps of more than, say, a weekend between noise exposure and audiometric examination are normally impracticable in industry, it is necessary to compromise between the ideal and the attainable. Periods of between sixteen and twenty-four hours have been suggested as a minimum gap, although longer periods are desirable.

THE REDUCTION OF NOISE HAZARD

528. Where noise represents a hazard to hearing there are two courses open ; to reduce the noise to which the individual is exposed to levels which are safe, or reasonably so, or to protect the ears. The reduction of noise from machinery and methods of insulating against noise by screening are discussed in Chapter IX.

Ear Protection

529. There are two types of ear protectors : ear plugs and ear muffs. If ear plugs are to be effective they must form a good seal at the entrance to the ear canal. Cotton wool plugs are found to be of little value for this purpose. A number of ear plugs are manufactured commercially, which, if carefully fitted, will reduce the sound received at the ear drum. They may, however, be uncomfortable if worn for long periods, and there is some danger of skin infection unless proper precautions are taken. Ear muffs are heavier, bulkier, and more conspicuous, but may be more comfortable and, if properly designed and fitted, provide a greater degree of protection than ear plugs.

530. If efficient types of ear plugs or muffs are worn continuously, Professor Burns and Dr. Littler suggest the following levels of noise exposure as compared with those shown in paragraph 521(*a*) above. These figures are, however, based upon laboratory results. In practice the attenuation provided by the ear protector may be lower than is indicated by comparison of this table with that in paragraph 521(*a*). The attenuation provided in practice by ear muffs is likely to vary less from the laboratory figure than that provided by ear plugs, as the efficiency of ear muffs is less dependent upon accuracy of fit.

TABLE XVII

Minimum sound pressure level values, in specific frequency bands, at which hearing conservation should be instituted if ear protection is used

Frequency band (cycles per second) (*i*)	With ear plugs (dB) (*ii*)	With ear muffs (fluid seal type) (dB) (*iii*)
37·5–150	110	120
150–300	110	115
300–600	110	118
600–1,200	110	125
1,200–2,400	110	122
2,400–4,800	110	125

CONCLUSIONS AND RECOMMENDATIONS

531. Although it is not possible to state with certainty the characteristics of noise exposure which may cause permanent threshold shift and there are few data on the levels of industrial noise in this country, it is likely that a hazardous noise environment exists in many industries. The existence of this hazard has been widely recognised in some other countries, and here in some industries, and in the Services. We received evidence that some industrial firms, the Royal Navy and the Royal Air Force, have hearing conservation programmes based upon regular audiometric examination of people who are exposed to noise which may be hazardous, and upon the minimising of exposure, as far as possible, by reducing noise at source and by protecting the ear. However, there is little doubt that the noise environment in many other industries is hazardous but that little is being done at present in these industries to investigate the degree of hazard and to minimise it.

532. We have considered three lines of attack on the problem of hearing loss from noise exposure:

(*a*) more widespread voluntary action within industry on the basis of existing knowledge;

(*b*) legislation on the basis of existing knowledge; and

(*c*) research to try to obtain a more definite understanding of the relationship between noise and hearing loss, with legislation to follow, if necessary, when the results of the research are available.

533. Much could be done voluntarily within industry, and, indeed, we know that some firms already have well established hearing conservation programmes. There is, however, a need for a wider and more urgent interest in the problem. We recommend, as immediate steps, that the Ministry of Labour should:

(*a*) disseminate as widely as possible existing knowledge of the hazard of noise to hearing;

(*b*) impress on industry the need to take action to reduce the hazard as it is at present recognised; and

(*c*) advise industry on practical measures to this end.

534. Although voluntary action is now possible and, indeed, essential, we do not consider that the present knowledge of this complex problem provides a sufficient basis for legislation. Although the levels of continuous, broad-band noise which represent a hazard to the hearing of people who are exposed to them for long, unbroken periods have been established within certain margins of error, many uncertainties remain. There is no satisfactory means of predicting the susceptibility of individuals to hearing loss, nor is the distribution of susceptibility known; the comparative danger of noises in which energy is concentrated in narrow frequency bands is not determined; nor is the influence on hearing loss of impulsive noises, which are common in industry. Neither is there much information on the physical properties of industrial noise, the distribution of noise of any given type in industry and the practicability of minimising those properties which are found to be dangerous to hearing. If early legislation were introduced it could do no more than lay down general standards, the effect and cost of which cannot

at present be estimated. If the standards adopted proved to be too severe in some respects the industries affected might be exposed to heavy unnecessary expenditure; on the other hand if minimum standards were adopted, these would tend to suggest that compliance with these standards was all that was needed even in parts of industry where there were important hazards at lower sound pressure levels or with shorter exposure. Legislative insistence on the wearing of ear protectors would be particularly difficult to introduce until there is a wider recognition of the need for them in noisy industries. Early legislation would, therefore, have to be very general in its terms and it would be impossible to enforce effectively. We think that, at present, it would not achieve as much as vigorous voluntary action. In our view, before practical legislation could be considered, it would be necessary to establish the extent of the risk to average people of exposure to industrial noise, and the cost and possibility of measures which would effectively reduce this risk to the point which, on balance, was regarded as acceptable.

535. We concluded that research should be undertaken to provide the basic knowledge of these problems which would enable detailed studies to be carried out, industry by industry, to show where noise hazards exist and how they could be reduced by noise suppression and hearing conservation measures. We were, therefore, pleased to learn that the Government had decided to carry out a research programme designed:

(*a*) to compare the state of hearing of persons with varying known histories of noise exposure;

(*b*) to secure pre-exposure audiograms and to monitor the state of hearing of persons throughout their early years of working in noisy locations by means of serial audiograms;

(*c*) to determine, if possible, whether any significant relation exists between temporary and permanent threshold shift;

(*d*) to evaluate the physical properties of industrial noises and to determine the physical features of the noises which constitute an effective criterion for measuring exposure; and

(*e*) to obtain data indicating the need for hearing conservation and to make recommendations on measures to be employed.

This programme is likely, in the next few years, to result in important additions to the knowledge of these problems. The research will require the ready co-operation of industries and individual firms with the research workers, who will be studying a variety of working environments and testing the hearing of many workers.

536. As the results of this research become available, it should be possible to conduct more detailed surveys of individual industries and processes, and we recommend that at that stage the Ministry of Labour should bring to the attention of all interested bodies the need for such surveys and should stimulate any industries which seem reluctant to take the necessary action. We further recommend that, when the results of a number of such surveys are available, the Ministry of Labour and other interested Government Departments should consider whether the time has not then come to lay down by legislation minimum standards to protect workers against damaging noise exposure in industry.

537. In some countries there is provision for compensation to be paid to people who suffer loss of hearing from exposure to noise in their occupations. There is no such provision in this country. We have not examined this complicated question as we do not consider that it falls within our terms of reference. We understand, however, that one of the main objects of the research referred to in paragraph 535 is to furnish knowledge which is needed to help in the consideration of this question by the Minister of Pensions and National Insurance.

OTHER BODILY EFFECTS

538. We were informed that certain physical effects, such as disturbance of peripheral blood flow, abnormal heart rhythms and unusual pallor have been reported by G. Jansen from field work on the effects of noise on steeiworkers in Germany. From the laboratory work of others, more general effects were known to appear in noise conditions which were novel to the subjects, but the disturbance of peripheral blood flow was the only one to persist when the subjects were accustomed to the noise condition. This effect is not known to be harmful.

539. Jansen's work did not show that any significant effects on the general health of the men he studied were reliably related to noise, and investigations by the United States Navy into the effect of noise on the health of the crews of aircraft carriers similarly showed no deleterious effects.

540. Very intense noise, in the region of 130 dB or more, can produce effects such as giddiness and body swaying and there have been reports of excessive fatigue. At levels of about 150 dB noise can produce resonances in the bronchial cavities, the nasal cavities and the sinuses, facial pain, nausea and pronounced giddiness. It is not thought that protection of the ears, for example, by ear muffs, would modify these effects significantly. It has therefore, been suggested that any exposure of the body to sound of 150 dB and above should be avoided, because of these effects alone irrespective of any hazard to hearing.

541. In view of the possibilities of the occurrence of these effects the Central Medical Establishment of the Royal Air Force asked medical officers at all the flying stations in the Royal Air Force to report any incidents involving these effects so that they might be investigated. No incidents have been reported although the noise near a jet engine being run-up on the ground may exceed 130 dB. The Royal Air Force stated, however, that it is likely that, with increasing intensity of noise from jet engines with increasing power, mobile acoustically treated chambers from which ground engineers can conduct test runs may become necessary.

542. It seems unlikely that these very intense noise levels will be widely encountered in industry. However, they are to be found near jet engines being run at high speeds, and we therefore recommend that research should be undertaken into the special effects of very intense noise, the thresholds at which these effects appear, the variation of individual susceptibility to them and the means of protecting people who are necessarily exposed to such noise levels.

Chapter XIV

Summary of Conclusions and Recommendations

INTRODUCTION

543. For the purposes of this Report we accept the definition of noise as "sound which is undesired by the recipient". A noise problem must involve people and their feelings, and its assessment is a matter rather of human values and environments than of precise physical measurement. (Paragraph 6.)

544. Certain correlations between the physical characteristics of a noise and the degree of annoyance caused have been established. Much more work is required in this field. (Paragraph 7.)

545. An essential step in mitigating the problem of noise is to keep the public informed as to which noise nuisances are readily avoidable, and to disseminate existing knowledge more widely to technicians and professional men who have to deal with noise problems. (Paragraph 22.)

546. In our Report we recommend research to try to fill a number of gaps in existing knowledge. Any large increase in research into problems of acoustics must imply a change in the teaching of applied acoustics in Universities and Technical Colleges, and the establishment of significant and well supported research schools in suitable institutions. (Paragraphs 23 and 24.)

547. Some instruction is essential, too, for the members of the several professions which touch on noise problems. (Paragraph 25.)

548. Neither experience nor experimental evidence support the suggestion that some measurable figure of noise intensity might be accepted as a universal limit towards which all noise control might be directed. (Paragraph 26.)

549. The price of sweeping measures to bring about large reductions of noise quickly would not be acceptable to the community, but, in our judgment, the present level of noise is such that some additional cost in money and in restriction of liberty to make noise is justified to prevent further increase and in time to achieve some reduction. (Paragraphs 27 and 28.)

THE GENERAL EFFECTS OF NOISE

550. Since health is defined as "a state of complete physical, mental and social well-being and not merely an absence of disease and infirmity", there is no doubt that noise affects health. (Paragraph 31.)

551. Of all effects, repeated interference with sleep is least to be tolerated; it is especially important to diminish noise during the earlier part of the night, because during the later phase of deep sleep even loud noises have less effect in wakening the sleeper. (Paragraph 32.)

552. We have not been able to find any evidence that moderate noise produces any direct and measurable physiological effect on the average person. The general effect on health must therefore be more psychological than physical. (Paragraph 33.)

553. There are no means of freeing a community completely from noise annoyance, since noise may have an emotional effect out of all proportion to its physical intensity. (Paragraph 34.)

554. It is particularly difficult to find a physical quantity which may be used in defining a point beyond which a noise nuisance may be said to exist. Complaints alone are not a reliable indication; social surveys can give a better guide. Properly conducted statistical experiments can lead to fairly definite conclusions on the response of the "average" listener in particular circumstances, but there are considerable differences between those results when different circumstances are compared. (Paragraphs 35 to 42.)

555. A noise, originally annoying or disturbing, becomes tolerated and even unnoticed by most people when it has become sufficiently familiar. There are some people who are more sensitive than most to noise and who can only be advised to live and work away from it if possible. (Paragraph 43.)

556. We found very little specific evidence to support the view that noise causes mental or nervous illness. We are unaware of any reliable studies of the effects of noise on the mental health of an ordinary population. (Paragraphs 44 to 46.)

557. One of the commonest and most undesirable effects of noise is its interference with communication based on sound. (Paragraphs 47 to 49.)

558. The problem of whether or not noise has any effect on the performance of tasks has been the subject of investigation for many years. The evidence that we have received shows that no general conclusions have yet been reached. The common sense opinion of ordinary people that noise does have an effect must be respected. We recommend that industry and the appropriate research bodies should be encouraged to carry out further experiments on the effect of noise on efficiency. (Paragraphs 50 to 56.)

559. We have been able to obtain little evidence on the effects of noise upon the incidence of industrial accidents. It seems reasonable to suppose that, if high noise levels increase the number of errors in work, they will also cause errors in safety measures and, consequently, that high noise levels may cause a higher rate of accidents than would occur in quieter conditions. (Paragraphs 57 and 58.)

THE LAW RELATING TO NOISE

560. The general law relating to noise is discussed (paragraphs 59 to 73). We consider that the main aim of legislation against noise should be prevention. Where prevention fails or is inapplicable we can see no alternative to the law relating to nuisance. (Paragraph 74.)

561. There is, as yet, insufficient experience of the working of the provisions of the Noise Abatement Act to justify disturbing the requirement that, except when the proceedings are initiated by a local authority, a complaint to a Justice of the Peace in a case of noise nuisance must be made by at least three occupiers of land or premises. (Paragraph 76.)

562. We recommend that local authorities in England and Wales should have power to serve an abatement notice where they are satisfied that a noise nuisance which has been abated is likely to recur on the same premises. (Paragraph 77.)

563. We recommend that local authorities, and the Courts, should be encouraged to deal with noise nuisance cases as quickly as possible. (Paragraph 78.)

564. We recommend that in England and Wales there should be substantial increases in both maximum initial penalties and the maximum daily fines under the Noise Abatement Act for failing to comply with Court orders. (Paragraph 80.)

565. If experience shows that the increasing awareness of noise and the further measures that we recommend for its mitigation do not reduce noise caused by thoughtlessness and irresponsible behaviour, we recommend that consideration be given to general legislation making it an offence for anyone in any public place to make unnecessary noise which might give reasonable cause for annoyance to other persons. (Paragraph 84.)

NOISE IN TOWNS

566. In London (and, no doubt, in other large towns) road traffic is, at the present time, the predominant source of annoyance from noise, and no other single noise is of comparable importance. (Paragraphs 85 to 101.)

567. Some of the noise made during the delivery of household stores and the removal of garbage could be avoided by the use of plastic materials instead of metal. (Paragraph 102.)

568. A substantial amount of annoyance is caused by thoughtlessness and carelessness. The most effective remedy for this would be a general improvement in good manners. (Paragraph 102.)

569. Traffic noise can be reduced by reducing the maximum noise which a vehicle is capable of making, by smoothing traffic flow and by building by-passes, etc. (Paragraphs 103 to 109.)

570. The spreading of heavy traffic into side roads and minor thoroughfares may create a noise nuisance in the buildings there. In considering the re-routeing of traffic, local authorities should take into account not only the capacity of the roads to take more vehicles but also the quality and uses of the buildings along them. (Paragraph 107.)

571. The local re-routeing of traffic is at most a palliative which will be effective for a few years only, and much more drastic measures will be necessary in the long run. (Paragraph 109.)

572. Traffic should be canalised as far as possible into a number of main roads which between them would form a network through the town. (Paragraph 110.)

573. Such conceptions as the neighbourhood unit or residential precinct offer a means of separating residential areas from the noise of through traffic. (Paragraph 112.)

574. Where a noise nuisance exists, or is likely to appear in the future because of a forecast increase in traffic, it is necessary to consider the relative costs of reducing the noise in the street or of spending money on the buildings to increase their resistance to noise. (Paragraph 114.)

NOISE WITHIN BUILDINGS

575. People are more concerned about noise when they are at home indoors than when they are outside, and more people are disturbed by noise from external sources than by internal noise. (Paragraph 115.)

576. A very tentative estimate of the noise levels inside living rooms and bedrooms, which should not be exceeded for more than ten per cent. of the time is:—

Situation	*Day*	*Night*
Country areas	40 dBA	30 dBA
Suburban areas, away from main traffic routes	45 dBA	35 dBA
Busy urban areas	50 dBA	35 dBA

(Paragraph 117.)

577. 55 dBA should be the upper limit to be tolerated in buildings in which communication by speech is of great importance. (Paragraph 119.)

578. We feel that, if levels indoors of the order of those given above can be obtained by suitable design and planning, they should command wide acceptance. (Paragraph 120.)

579. In planning buildings it is desirable to try to forecast the needs of the future, otherwise they may become obsolescent because noise hampers their full use. (Paragraph 121.)

580. We feel that if an insulation of 30 dB could be reached in a façade with single glazed windows it would be of great benefit. (Paragraph 123.)

581. We hope that future development may increase the possibilities of the wider use of a system of double windows giving, perhaps, 40 dB insulation, combined with a fan ventilating the room through a noise-attenuating appliance, for it could help to solve many difficulties. (Paragraph 124.)

582. Much can be done to reduce the ill effects of noise by putting the most vulnerable parts of a building as far as possible from the main source of noise, and by turning them away from it. Such measures can, of course, be vitiated by changes in the direction of the main noise source, and may be nullified by aircraft noise. (Paragraph 125.)

583. Height can be over-rated as a defence against traffic noise and may well increase vulnerability to noise from aircraft and helicopters. (Paragraph 126.)

584. It is essential that standards of noise reduction, at least in dwellings, should not be relaxed and that strenuous efforts should be made to maintain these standards in industrialised forms of construction. (Paragraphs 127 to 129.)

585. The discovery of cheaper means of improving sound insulation against external noise would be extremely valuable, particularly if the means were applicable to light structures. More research in this problem is urgently needed. (Paragraph 132.)

586. Insulation of 50 dB appears to provide sufficient protection against internal noise in dwellings for most people, although a proportion will still not be completely satisfied. The importance of good sound insulation between dwellings is increased by the present tendency towards higher densities in housing and the consequent building of more flats and terraces. (Paragraphs 135 to 136.)

587. Good internal planning can reduce disturbance from internal noise. (Paragraph 137.)

588. The amount of noise created within buildings, or transmitted through their structures, can be much reduced if quiet domestic services are installed. (Paragraph 138.)

589. Objective measurements of the noise produced by domestic tools, using a standard procedure would enable customers to compare the noisiness of different models of machines. (Paragraph 139.)

590. We feel that architects' misgivings about the degree of insulation against external and internal noise of many modern office blocks of light construction are largely justified. (Paragraph 141.)

591. There is scope for reduction of office machine noise at source and we recommend that manufacturers should give urgent attention to this. (Paragraph 144.)

592. Research and development on the reduction of sound transmission through light partitions is very necessary. (Paragraph 147.)

593. We welcome the campaign against noise in hospitals which has recently been started. We feel that further useful research could be done to correlate the reactions of patients and staff to noise with objective measurements. (Paragraph 149.)

594. Noise control must be accepted by the developer as being as important as the various other requirements for the building. We emphasise that this problem must be considered from the outset. (Paragraph 150.)

595. We think that it is very important that the training of architects and builders in the principles of sound insulation and noise exclusion should be improved and we hope that the professional bodies will quickly be successful in the efforts they have announced to do this. (Paragraph 151.)

NOISE FROM MOTOR VEHICLES

596. We recommend that the use of motor horns, except when necessary to avoid danger, should be forbidden at all times in built-up areas. (Paragraph 162.)

597. The chief difficulty in the enforcement of the present law controlling propulsion noise from motor vehicles is the lack of numerical definition of "excessive noise". (Paragraph 154.)

598. A satisfactory method of measuring the maximum noise which a vehicle can emit is available. (Paragraph 166 to 170.)

599. The choice of the noise level which should be the maximum permitted involves striking a balance between the levels which would be acceptable to the public, present knowledge of reducing vehicle noise, cost, the practice in other countries and the availability of suitable instruments. (Paragraph 171.) The levels of noise which are acceptable to the public were investigated. (Paragraphs 172 to 180.) Evidence was obtained from the manufacturers on the lowest noise levels that were practicable (paragraphs 181 to 183); cost was considered (paragraph 184), and the practice in other countries was examined. (Paragraph 185.)

600. We consider that different limits for different types of vehicles would be justified only by the differing performance of the sound level meter for different types of noise. (Paragraph 188.)

601. We recommend that legislation should be introduced to provide that, after one year from the date of enactment, new vehicles should be so designed and constructed that, when tested in accordance with British Standard 3425 : 1961, their noise levels do not exceed the following :—

Motor cycles	90 dBA
Other vehicles	85 dBA (Paragraph 189.)

602. We consider that these maximum permissible limits for new vehicles should be reviewed from time to time in the light of technical progress. We recommend that the first review should take place in time for any practicable reduction to be introduced not more than five years from the date at which the limits that we recommend come into force. (Paragraph 193.)

603. We recommend that the noise levels of vehicles on the road should also be measured and that it should be an offence to emit more noise than is permitted from new vehicles. We consider that the measurement of noise from vehicles on the road should start two years after the enactment of the empowering legislation. (Paragraphs 194 to 201.)

604. We consider that the procedure and allowance for roadside measurement of vehicle noise should be regarded as experimental and be reviewed not more than three years after their introduction. (Paragraph 200.)

605. We recommend that, quite apart from the adoption of measured limits, drivers making unnecessary noise should be liable to prosecution. (Paragraph 201.)

606. We consider that our recommendations would considerably reduce the number of noisy vehicles on the road. (Paragraph 204.)

607. We recommend further research into the development of a meter which is better suited to the measurement of vehicle noise than those that are available at present, and into the principles of reducing noise from motor vehicles. (Paragraphs 205 and 206.)

608. An essential contribution towards reducing noise from vehicles must come from drivers. (Paragraph 207.)

NOISE FROM OTHER SURFACE TRANSPORT

RAILWAY NOISE

609. There is no indication that railway noise causes widespread annoyance. (Paragraph 208.)

610. Railway track maintenance work is sufficiently similar to building and civil engineering for it to be subject to the same controls as we recommend in Chapter X for building and civil engineering work. (Paragraph 217.)

611. Railway engineering depots should be subject to the same controls as we recommend in Chapter IX for industrial premises. (Paragraph 218.)

612. Noise in stations could be reduced below its present levels. (Paragraph 224.)

613. The noise inside most British Railways' coaches is uncomfortably high and compares unfavourably with that inside the coaches on some foreign railways. (Paragraph 225.)

614. If serious attempts were made to reduce noise the comfort of passengers and of the public living in the vicinity of railways could be considerably improved. (Paragraph 229.) Railway authorities should be urged to attach more importance to noise reduction and to engage in much more extensive research into the subject. (Paragraph 232.)

615. We do not feel that any special legislative action is required. We have, however, recommended changes in the law relating to all statutory undertakers which would remove altogether the present exemption of railway authorities from proceedings for noise nuisance. (Paragraph 231.)

NOISE FROM BOATS

616. In the last few years noise from motor-boats has begun to become a nuisance in some areas and this is likely to spread. (Paragraph 233.)

617. If noise from boats threatens to become a serious and widespread nuisance, statutory numerical noise limits on the lines of those recommended for motor vehicles should be introduced. (Paragraph 236.)

NOISE FROM HOVERCRAFT

618. Hovercraft, in their present experimental form, are noisy and there is a need to consider the control of their noise now. (Paragraph 237.)

619. We consider that criteria for the control of noise from hovercraft should be introduced as soon as possible, to help to protect people living near to termini and routes and so that designers can have standards to which to work. The criteria might be determined on the following principles:

(*a*) for commercially operated hovercraft:

(i) in areas where the ambient noise is already high the limit should be fixed at a level at which noise from hovercraft would not make conversation unduly difficult inside the nearest inhabited building;

(ii) in other areas the limits should be based upon levels at which noise from hovercraft is acceptable to average people; and

(*b*) the control on noise from privately operated hovercraft should be similar to the control that we suggest for boats. (Paragraph 240.)

AIRCRAFT NOISE

INTRODUCTION

620. The main problem from military aircraft appears to be caused by low flying. This is strictly controlled. (Paragraph 245.)

621. As far as civil aircraft are concerned we decided that we should examine the present problem at London (Heathrow) Airport in detail as this provides one of the most difficult aircraft noise problems in the world. (Paragraph 249.)

622. The noise problems at Heathrow caused by aircraft taking off and landing are acute. (Paragraph 250.)

623. In spite of the evidence of deep local feeling caused by the noise, it appeared that, for many people, the advantage of living near London (Heathrow) Airport balanced the inconvenience of the noise. (Paragraph 256.)

624. In addition to annoying and disturbing people in their homes in the vicinity of the Airport, the noise interferes with work by disrupting conversation, disturbs the patients and staff of local hospitals and disrupts teaching in schools. (Paragraph 257.)

625. The Ministry of Health have agreed that new buildings at hospitals most affected by the noise should be designed so as to reduce the nuisance. (Paragraph 258.)

626. At two existing schools experiments are being conducted to try to improve the insulation against aircraft noise. We hope that the sound insulation at other schools which are similarly affected will also be raised to give satisfactory conditions for teaching. It is essential that in future new schools built near Heathrow or any other airport where noise may seriously affect school activities, should be sited in reasonably quiet places and be laid out and constructed to provide adequate defences against aircraft noise. (Paragraph 259.)

MEASURES ADOPTED TO REDUCE NOISE

627. Measures are discussed which have been adopted to reduce aircraft noise—reduction at source, take-off procedures, noise monitoring arrangements, landing and ground running procedures. (Paragraphs 262 to 281.)

628. It appears that the means of bringing under control the problem of noise from maintenance ground running are available and have largely been provided. (Paragraph 279.)

629. If aircraft were towed by tractors when moving on the ground, the contribution that would be made to the diminution of noise would not counterbalance the great difficulties caused to the Airport and airline operators. (Paragraph 280.)

INTERNATIONAL COMPARISONS

630. It proved impossible to make detailed comparisons between the problems at Heathrow and at other airports because the circumstances differ so widely. (Paragraph 282.)

631. The international nature of air travel has an important bearing upon the freedom of airport authorities to impose controls. If, in the interest of noise reduction, restrictions are placed upon airline operators at Heathrow which have such serious economic penalties that the use of the Airport becomes unprofitable for them, they may transfer their operations to other airports abroad: this could have grave deleterious effects on this country's economy. (Paragraph 283.)

THE FUTURE PROBLEM

632. The future problem at civil airports is discussed, including increased numbers of jet aircraft, night operations, landing noise and future jet aircraft. (Paragraphs 284 to 290.)

EXPERIMENTAL INVESTIGATIONS UNDERTAKEN

633. It seemed to us that the present situation was one of precarious balance between the interests of the local residents and of the airlines and their passengers. We therefore considered it was imperative to obtain more information about people's reaction to aircraft noise. (Paragraph 291.)

634. We concluded that it was extremely unlikely that an investigation into the effects that the noise might have on the health of people living near Heathrow would produce meaningful results. (Paragraph 291.)

635. The most important conclusions from an experiment on the subjective judgment of aircraft noises are:

(*a*) that it is possible to obtain judgments of the noisiness of aircraft on scales similar to those successfully used in the motor vehicle experiments (see Chapter VI);

(*b*) that people's judgment of the noisiness of a noise from a recognisable source seems to be related to their previous experience of it;

(*c*) that it is possible to construct a scale of " intrusiveness "; and

(*d*) that when the tests for intrusiveness were carried out indoors the same degree of intrusiveness occurred at about 87 dBA. as occurred outdoors at about 105 dBA. (Paragraph 293.)

636. Our major conclusions from the results of a social survey on the effects of aircraft noise in the vicinity of London (Heathrow) Airport are:

(*a*) there is a considerable correlation between the complaints which have been made in the past and the degree of annoyance revealed by the survey;

(*b*) the survey has given us a scale by which we can assess the degree of annoyance caused by aircraft noise;

(*c*) the survey provides a tentative basis for establishing a combined " noise and number index," defining the total noise exposure which causes annoyance. We consider that the data showed that in causing annoyance a four-fold increase in the number of aircraft heard is very approximately equivalent to a rise in average peak noise level of 9 PNdB; and

(*d*) if the concept of a noise and number index is well founded, we believe that the results of the survey provide sufficient evidence for arriving at a NNI value at which the annoyance and disturbance could be regarded as unacceptable. We think that the most accurate estimate that can be made from the evidence is that the maximum acceptable level lies in the region between 50 and 60 NNI. (Paragraphs 294 to 302.)

637. People are much more sensitive to noise at night than to noise during the day. Our tentative conclusion from the survey is that the concept of noise and number index is probably also valid for aircraft flying at night, but that the same degree of annoyance is produced at a NNI which is about 15–20 units less than the corresponding NNI during the day. (Paragraph 304.)

638. To assist us in investigating whether ordinary houses could be given better sound insulation against external noise, openable double windows, together with a mechanical ventilator, were installed in rooms at the Building Research Station and at a house near Heathrow. The installation was extremely effective. (Paragraph 305.)

ACTIONS WHICH COULD BE TAKEN AT HEATHROW

639. We are agreed that the noise to which many people near London (Heathrow) Airport are subjected is more than they can be reasonably expected to tolerate. (Paragraph 306.)

640. We are convinced that the degree of exposure to noise in areas close to the Airport will not be materially reduced and, indeed, will get a good deal worse, unless appropriate measures are taken now. (Paragraph 307.)

641. There are only two practicable ways of improving the present situation or possibly even merely of maintaining it :—

(*a*) to reduce the noise of individual aircraft as new types come into service ; and

(*b*) to provide houses very near the boundary of the airport with better insulation against noise. (Paragraph 308.)

642. We also consider it important to continue and to reinforce the efforts to explain the facts about aircraft and their noise which influence people's annoyance. (Paragraph 308.)

643. A reduction of 7 PNdB in the average peak noise level of aircraft is required to offset the increased number of jet aircraft movements expected between 1961 and 1970. The only possible way in which the required reduction would be achieved is by exploiting improvements in engines and aircraft. (Paragraphs 309 to 310.)

644. It must be recognised that the rigid imposition on airlines of limits set at the lowest levels of which their new aircraft are capable is not practicable. (Paragraph 312.)

645. We are unable to lay down any hard and fast rules concerning the future noise limits at London Airport, but we recommend that the present day time noise limits for take off should be progressively lowered as the number of aircraft movements rises so as to prevent any increase in total exposure to noise (in terms of NNI) in any area. Similar limits should be introduced for landings. (Paragraph 312.)

646. Corresponding reductions in the noise limits for night take-offs, and appropriate limits for night landings, would be required. Night flights at airports in densely populated areas should be concentrated as far as possible later in the night. (Paragraph 313.)

647. One further possible method of reducing noise exposure is the imposition of differential noise limits: those aircraft which can be operated well within the present limits should be required to be operated as quietly as is practicable. (Paragraph 314.)

648. By about 1970, when the number of movements is expected to reach the capacity of the airport and most of the present generation of aircraft should have gone out of service and been replaced by quieter ones, it should be practicable to impose still lower noise limits in order to reduce the noise exposure below its present level. (Paragraph 315.)

649. This country should take the initiative in atempting to secure greater international recognition of the urgent need to reduce aircraft noise. (Paragraph 316.)

INSULATION AGAINST AIRCRAFT NOISE

650. We feel that the improvement of the insulation of houses, or portions of houses, is the only practicable means of ameliorating the lot of those who are subjected to excessive noise. A technical solution to the problem is available, but we feel that it is most unlikely that it will be adopted unless exceptional measures are taken. (Paragraph 317.)

651. The total cost per room is likely to be greater than the average householder could easily bear. (Paragraph 318.)

652. We recommend that grants on a varying scale should be paid towards the cost of improving the sound insulation of existing dwellings in areas near Heathrow Airport where aircraft noise is unreasonably high. (Paragraphs 319 to 322.)

653. The grant to help to ameliorate the present situation might appropriately come from the Government, whereas the contribution that the airlines might make should be the indirect one of seeing that the present situation does not deteriorate, by operating their aircraft at gradually decreasing noise levels. (Paragraph 331.)

654. All new dwellings in areas in which grant is payable should be constructed with similar standards of sound insulation to those specified for the provision of a grant in existing dwellings. (Paragraph 332.)

OTHER AIRPORTS

655. It is essential that the lessons of Heathrow should be applied at other airports. Planning control should be used to secure a pattern of development which is compatible with the future noise conditions. The present town and country planning powers may be adequate to achieve this. If necessary, further powers should be made available to control development so as to avoid serious nuisance from noise. (Paragraphs 333 and 334.)

CITY CENTRE OPERATION

656. The use of helicopters and more sophisticated vertical take-off and landing aircraft for travel into the city centres is discussed. (Paragraphs 335 to 341.)

657. It is clear that much remains to be done before city centre operations by helicopters can be introduced on a regular basis without serious risk of causing a very great deal of noise nuisance. (Paragraph 337.)

658. It must be appreciated that unless helicopter routes are very carefully planned and the helicopters fly much higher than seems to be envisaged at present they will introduce intense noise into areas which have previously been quiet. (Paragraph 338.)

659. Although we think that it is important to establish criteria for noise for the operation of all types of vertical take-off and landing aircraft over and into cities, there is insufficient experience of such operations for us to reach any definite conclusions on these criteria. We recommend that investigations should be undertaken to establish suitable criteria before any substantial increase in air traffic into city centres is permitted. (Paragraph 341.)

SONIC BOOM FROM FUTURE SUPERSONIC TRANSPORT AIRCRAFT

660. Sonic boom from future supersonic transport aircraft is discussed. (Paragraphs 342 to 352.) Even if the proportion of people who are particularly sensitive to sonic boom were small, this minority could possibly represent a very large number of people. (Paragraph 344.)

661. There is only limited evidence from which to judge the public reaction to sonic boom. (Paragraph 345.)

662. More experience is needed of the booms from aircraft of a size comparable with that of projected civil supersonic aircraft before any firm conclusions can be reached on the disturbance they will cause. (Paragraph 350.) Care will be needed in the operation of supersonic airliners, and possibly some restriction in their use, if serious nuisance to the public is to be avoided. The extent of the restriction is not yet clear. (Paragraph 351.)

663. The evidence so far available makes it clear that damage to property from the effects of supersonic airline operations is unlikely. (Paragraph 351.)

664. It is apparent that the Government and the aviation industry must use every available means to establish the public reaction to sonic boom, both during the day and at night, so that appropriate controls can be introduced before supersonic civil flying over this country takes place. (Paragraph 352.)

NOISE FROM INDUSTRY

665. Industrial noise causes widespread annoyance. (Paragraph 354.)

666. Many local authorities are well aware of this problem and do a great deal to prevent annoyance from noise by advice and good planning. In the majority of cases in which complaints are made the firms concerned go to considerable lengths to eradicate the cause of complaint. (Paragraph 357.)

667. The reduction of noise at source is the most effective method of achieving a diminution of noise levels. There is a lack of textbooks or other literature on the principles of this subject. (Paragraphs 359 and 360.)

668. The noise output is rarely considered seriously when machines or plant are designed and installed: it is important that it should be. It is ultimately upon the purchasers of machinery that much of the responsibility for noise reduction must rest and it is chiefly they who must emphasise and specify the need for quiet machines. (Paragraph 363.)

669. A standard system of assessment of the noise output of machines and plant will be needed. (Paragraph 364.)

670. The amount of noise which is transmitted beyond the boundaries of the factory site, or indeed within the site, can be reduced by the proper layout of the site and by using appropriate and well designed enclosing structures. (Paragraph 365.)

671. Siting is an important factor in keeping down disturbance from industrial noise, but the powers of planning authorities are not apt for controlling what happens in a building once it has been erected. (Paragraphs 373 to 378.)

672. The Building Research Station have developed a simple measurement procedure for use in assessing public reaction to industrial noise The rules require confirmation, but, if valid, they would provide a useful guide for local authorities when dealing with complaints or applications for planning permission. We recommend that a number of local authorities should be encouraged to co-operate with the Building Research Station in confirming the rules, and that if these trials prove satisfactory, their general use by local authorities should be encouraged. (Paragraphs 379 to 386.)

673. Planning authorities should consult the public health authority when considering applications for planning permission for new factories. (Paragraph 387.)

674. We recommend that training should be made available to all local authority officers who have to deal with noise problems in their work. (Paragraph 388.)

675. Local authorities should have power to require adequate structural precautions to minimise the possibility of nuisance from noise transmitted from industrial buildings. (Paragraph 389.)

676. There are some very noisy industrial machines and processes which at present would prove specially difficult to quieten to levels which are likely to be acceptable. Both for the protection of industry and of the public there should be some public supervision over these processes. We recommend that such processes should be registered by a Minister and that it should be the duty of inspectors appointed by the Minister to ensure that people using these registered processes employ the best practicable means to prevent and to counteract the effect of the noise. When this control is fully in force the users of registered processes in England and Wales should be exempt from statutory nuisance proceedings under the Noise Abatement Act in respect of their use unless the Minister responsible

for registering the processes consents to the proceedings, or, in Scotland, unless the Crown authorities so decide. (Paragraphs 390 to 394.)

677. We recommend that more research work should be undertaken on the origin of noises of high intensity. (Paragraph 395.)

678. When a planning authority is considering an application for the siting of a factory in which a specially noisy process might be used, the authority should be required to consult the Minister responsible for the register of such processes before they grant the application. (Paragraph 396.)

679. If our recommendations concerning the registration of specially noisy processes are accepted, we consider that statutory undertakers should no longer be exempt from proceedings under the Noise Abatement Act. (Paragraph 397.)

680. The defence by the occupier of premises from which a noise is coming that he is using the best practicable means of preventing it is, in the long run, undesirable: our recommendations will, we feel, help to make it unnecessary. (Paragraphs 398 and 399.)

NOISE FROM CONSTRUCTION AND DEMOLITION SITES

681. Noise from construction and demolition work is a serious cause of disturbance and annoyance to people nearby. (Paragraph 403.)

682. Typical noise levels of contractors' plant are quoted. (Paragraph 405.) Unless the need for effective noise control is recognised, further increases of mechanisation will inevitably result in further increases in noise. (Paragraph 406.)

683. If the standards of practice of the best contractors were achieved on all sites the amount of disturbance caused by noise would be very significantly reduced. (Paragraph 407.)

684. It is necessary to create conditions which will encourage contractors to work as quietly as possible. (Paragraph 408.)

685. In principle there should be statutory limits to the noise from powered plant used in construction and demolition sites. (Paragraph 409.)

686. There is a good deal that could be done to reduce noise if more attention was given to it in both the design and operation of the plant. (Paragraph 410.)

687. Noise levels of typical pneumatic drills, with and without mufflers or silencers, and the reduction given by a muffler and two types of enclosure are quoted. (Paragraph 412.) We recommend that contractors, local authorities and statutory undertakers should be encouraged to undertake practical trials with, and to make use of, enclosures for pneumatic drills. (Paragraph 415.)

688. We recommend that, pending the establishment of statutory noise limits, general legislation should be introduced to provide that all internal combustion engines, used as prime movers, should be fitted with efficient exhaust silencers. (Paragraph 419.)

689. Research into noise in diesel engines of the types used as prime movers is being carried out and should be encouraged, as should the application of the knowledge gained. (Paragraph 420.)

690. The prime movers of contractors' plant are often left running even when the plant is not in use. This should be discouraged wherever it may result in a noise nuisance. (Paragraph 422.)

691. Developers, architects and civil engineers should consider, in preparing their designs, whether there are alternatives which will involve less noise in construction. (Paragraph 427.)

692. The noise from building sites can be reduced if this factor is considered in planning the layout of the site. (Paragraph 428.)

693. It is probable that the extra cost in use of quieter machinery on a typical large building scheme would be a very small proportion of the total cost of the work. The cost of noise from building and civil engineering sites to people working nearby must be weighed in the balance against any additional cost from noise reduction. (Paragraphs 430 and 431.)

694. The noise from construction and demolition sites between, say, 7 a.m. and 7 p.m. should not exceed the level at which conversation in the nearest building would be too difficult with the windows shut. (Paragraph 433.)

695. We suggest that, at present, noise levels in daytime outside the nearest building at the window of the occupied room closest to the site boundary, should not exceed :—

70 dBA in rural, suburban and urban areas away from main road traffic and industrial noise.

75 dBA in urban areas near main roads and in heavy industrial areas. (Paragraph 435.)

696. We recommend that criteria be established for building noises at night corresponding to the empirical procedures and criteria for assessing the likely reaction of the public to noise from industrial premises. (Chapter IX.) (Paragraph 436.)

697. The noise limits that we suggest should be useful to local authorities in deciding whether to take proceedings under the Noise Abatement Act or action at Common Law. We think it would be premature to give legal force to the limits until enough experience has been obtained to establish their validity. (Paragraph 437.)

698. There should be statutory control by local authorities over particularly noisy operations which cannot be quietened sufficiently to meet the criteria. There should be a right of appeal against the local authority's decision. (Paragraph 438.)

699. We welcome the suggestion made to us that a publicity campaign should be conducted within the industry to remind contractors and their employees of the need to reduce noise and of the large contribution that they could make. (Paragraph 439.)

ENTERTAINMENT AND ADVERTISING NOISE

700. Entertainment and advertising noises are a major source of annoyance and complaint. (Paragraph 441.) The problem is a constantly changing one, and the means of control must be flexible, too, if they are to be effective. (Paragraph 442.)

701. We doubt whether technical advances will contribute much to the solution of the problem, which is fundamentally one of human behaviour. (Paragraph 443.)

702. Noises which are occasional and unpredictable, such as the noise caused by people shouting as they walk along the street, cannot be reduced except by improvements in the standards of social behaviour and by making the creation of noise an offence. Byelaws seem to be an effective instrument against this type of noise. (Paragraphs 454 and 455.)

703. We recommend that the permission of local authorities in England and Wales, and of County Councils in Scotland should be required before events, such as motor-cycle scrambles, go-kart races, and pleasure fairs, are held which may cause noise nuisance. (Paragraphs 457 to 462.)

704. We recommend that the local authorities should have power to regulate the standards of construction of buildings which are to be used for entertainment. (Paragraph 467.) We feel that with this addition, present legislation provides effective means for the control of noise nuisance from places of entertainment. (Paragraph 469.)

705. With some exceptions, using noise to advertise is prohibited altogether or is an offence if it causes annoyance. In principle we think that this is right. (Paragraph 471.)

706. Although the chimes used by mobile ice-cream vendors annoy some people, they help to provide a service to others. We feel that it would not be right at the present time to insist upon the abolition of ice cream chimes, but more detailed restrictions on their use should be introduced. (Paragraph 476.)

707. We recommend that statutory force should be given to detailed rules of conduct for mobile ice cream vendors. (Paragraph 478.)

708. After, say, three years' experience of this system the position should be reviewed. If it were then found that the measures taken had been insufficient to reduce to a reasonable level annoyance caused by the chimes, we feel that the best course would be to make sure that individual local authorities, with the approval of a Minister, had power to prohibit ice cream chimes altogether in their areas. (Paragraph 481.)

709. Restriction of the duration, frequency and loudness of chimes would undoubtedly do something to help when annoyance is caused by successions of vendors, but if this proved insufficient, short of prohibiting the use of chimes, the only solution appears to be to restrict the number of traders permitted to sell from vans in any area. This somewhat drastic remedy should be considered only if the nuisance proves very serious in spite of the measures that we recommend for improving control of individual salesmen. (Paragraphs 482 and 483.)

710. Ultimately, the best remedy for the disturbance from neighbours' radio and television sets, record players and tape recorders is sympathy and consideration between the people concerned. (Paragraph 484.)

711. We recommend that local authorities should be encouraged to direct some of their publicity activities, both in schools and generally, towards teaching that the creation of unnecessary noise is inconsiderate and ill-mannered. (Paragraph 486.)

NOISE IN THE COUNTRY

712. We hope that in such places as National Parks and National Trust properties endeavours will be made to preserve, or create, havens of quiet where those who wish to can escape from noise for a time. (Paragraph 487.)

MINERAL WORKINGS

713. Our recommendations for the control of noise from construction and demolition sites (Chapter X) should apply to those mineral working operations which are akin to civil engineering works, and our recommendations about noise from industrial premises (Chapter IX) to those which are comparable with industrial processes. (Paragraph 494.)

AGRICULTURAL MACHINERY

714. All agricultural machines which are licensed to use the roads come within the range of our recommendations regarding noise from motor vehicles (Chapter VI). All other agricultural machines which are powered by internal combustion engines should be fitted with efficient exhaust silencers. (Paragraph 496.)

BIRD SCARERS

715. We recommend that the existing model byelaws prohibiting the use of explosive bird scarers during the hours of darkness should be varied to apply to all types of audible bird scarers. Farmers should be made aware of the disadvantages of the continuous use of bird scarers, and they and local authorities should be reminded that if noise from bird scarers constitutes a nuisance it is subject to proceedings under the Noise Abatement Act. (Paragraph 501.)

POWER SAWS

716. We recommend that the use of saws powered by internal combustion engines without effective silencers should be prohibited within 200 feet of inhabited buildings. (Paragraph 502.)

GARDEN AND HORTICULTURAL EQUIPMENT

717. The British Standards Institution should be invited to devise a method for testing the noise output from motor lawn-mowers and other types of motor driven garden machinery, and, when a satisfactory method has been found, legislation should be introduced fixing maximum noise limits for new machines. (Paragraph 505.)

718. Manufacturers should be encouraged to provide facilities for modifying existing lawn-mowers to reduce their noise if they exceed the limits for new mowers. (Paragraph 506.)

OCCUPATIONAL EXPOSURE TO HIGH LEVELS OF NOISE

719. The temporary and permanent effects on hearing of exposure to high levels of noise are discussed. (Paragraphs 508 to 518.)

720. Noise levels have been suggested at which measures to protect the individual against hearing loss should be undertaken. (Paragraphs 520 and 521.)

721. Criteria for noise and data on the extent of hearing loss in given circumstances are generalisations which do not allow the prediction with any degree of certainty of the effect on an individual of exposure to noise. (Paragraph 523.)

722. It is important that the relationship between temporary and permanent threshold shift should be further investigated. At least until the exact relationship has been more closely determined individual susceptibility to permanent threshold shift can only be found by periodical audiometric examination. (Paragraphs 525 and 526.)

723. Where noise represents a hazard to hearing there are two courses open: to reduce the noise to levels which are safe or to protect the ears. (Paragraphs 528 to 530.)

724. It is likely that a hazardous noise environment exists in many industries. Some industrial firms and Services recognise this and have hearing conservation programmes. (Paragraph 531.)

725. We recommend, as immediate steps, that the Ministry of Labour should :—

(*a*) disseminate as widely as possible existing knowledge of the hazard of noise to hearing;

(*b*) impress on industry the need to take action to reduce the hazard as it is at present recognised; and

(*c*) advise industry on practical measures to this end. (Paragraph 533.)

726. We do not consider that the present knowledge of this complex problem provides a sufficient basis for legislation. (Paragraph 534.)

727. We concluded that research should be undertaken to provide the basic knowledge which would enable detailed studies to be carried out, industry by industry, to show where noise hazards exist and how they could be reduced. We were pleased to learn that the Government had decided to carry out a research programme which is likely, in the next few years, to result in important additions to the knowledge of these problems. (Paragraph 535.)

728. As the results of the research become available it should be possible to conduct more detailed studies of individual industries and processes, and we recommend that at that stage the Ministry of Labour should bring to the attention of all interested bodies the need for such surveys and should stimulate any industries which seem reluctant to take the necessary action. (Paragraph 536.)

729. We recommend that, when the results of a number of such surveys are available, the interested Government Departments should consider whether the time has not then come to lay down by legislation minimum standards to protect workers against damaging noise exposure in industry. (Paragraph 536.)

730. We recommend that research should be undertaken into other bodily effects of very intense noise, the thresholds at which these appear, the variation of individual susceptibility to them and the means of protecting people who are necessarily exposed to such noise levels. (Paragraph 542.)

APPENDIX I

LIST OF ORGANISATIONS AND INDIVIDUALS WHO GAVE EVIDENCE

In some cases oral evidence was given in support of written evidence (*), or oral evidence only was given (†). In addition, a considerable volume of evidence was received from local authorities and members of the public.

The Admiralty.
*Ministry of Agriculture, Fisheries and Food.
Air Ministry.
Miss G. H. Allen.
Amplivox Limited.
N. W. Angell Esq.
The Association of British Chambers of Commerce.
*The Association of Chief Police Officers (England & Wales).
The Association of Counties of Cities in Scotland.
The Association of Municipal Corporations.
Ministry of Aviation.
*Hope Bagenal Esq., O.B.E., D.C.M., F.R.I.B.A.
Mrs. M. Baker.
*Barnes Borough Council.
*Ronald M. Bell, Esq., M.P.
*Berkshire County Council.
Birkbeck Residents Association.
Birmingham City Council.
*Board of Inland Revenue.
Board of Trade.
F. C. Booker Esq.
F. V. A. Bosc Esq., M.B., B.S.
British Association of the Hard of Hearing.
†British Association of Otolaryngologists.
British Broadcasting Corporation.
*British Cycle and Motor Cycle Industries Association Ltd.
British Employers' Confederation.
*British European Airways.
British Internal Combustion Engine Research Association.
*British Lawn Mower Makers' Federation.
*British Medical Association.
British Non-Ferrous Metals Federation.
British Occupational Hygiene Society.
*British Overseas Airways Corporation.
British Standards Institution.
*British Steel Piling Company.
*British Transport Commission.
British Waterworks Association.
*D. E. Broadbent, Esq., M.A., Director, Applied Psychology Research Unit, Medical Research Council.
*H. R. Broadbent Esq.
Broom and Wade Ltd.
Building Research Station, Department of Scientific and Industrial Research.
*Burgess Products Company Ltd.
*Professor W. Burns, Charing Cross Hospital, University of London.
Cement Makers Federation.
*Central Office of Information.
Chelsea Borough Council.
Chief Constables' (Scotland) Association.

The Churches Main Committee.
*Colnbrook Residents Association.
Consumers Association Ltd.
Craelius Company Limited.
*Cranford and District Residents Association.
N. M. Cosslett Esq., M.B., Ch.B.
The Council for the Preservation of Rural England.
Lt. Col. W. E. Cross, F.R.I.B.A., F.R.S.H., F.R.S.A.
*Datchet Parish Council.
†Air Vice-Marshal E. D. D. Dickson, C.B., C.B.E., M.D., F.R.C.S.
Bruce Delve Esq.
R. S. Duff Esq., M.D., M.R.C.P.
East Ham Road Safety Council.
Ministry of Education.
*Egham Urban District Council.
The Electrical Association for Women.
The Electricity Council.
*Esher Urban District Council.
Esso Petroleum Company Ltd.
*Eton Rural District Council.
Euclid (Great Britain) Ltd.
Lt. Cdr. R. B. Fairthorne, M.I.Mech.E., M.I.E.E.
Federated Quarry Owners of Great Britain.
*Federation of British Industries.
*Federation of Civil Engineering Contractors.
†Federation of Manufacturers of Construction Equipment.
J. C. Floyd, Esq., Chief Engineer, Advanced Projects Group, Hawker Siddeley Aviation Limited.
*Forestry Commission.
D. Foyle Esq.
W. and C. French Ltd.
*Fulham Borough Council.
The Gas Council.
R. K. Gee Esq.
General Post Office.
Glamorgan County Council.
Rev. H. S. Goodwin.
R. Green Esq.
*Harmondsworth Residents Association.
*Heston and Isleworth Borough Council.
Holland and Hannen and Cubitts Ltd.
Home Office.
Hovercraft Development Limited.
Ministry of Housing and Local Government.
*H. R. Humphreys Esq., A.R.I.B.A.
Ice Cream Alliance.
Ice Cream Federation Limited.
Industrial Welfare Society.
Institution of Civil Engineers.
Institution of Electrical Engineers.
Institution of Mechanical Engineers.
*Institution of Municipal Engineers.
*International Air Transport Association.
Iron and Steel Board.
K. R. H. Johnston Esq.
Mrs. D. E. Kemp.
Alfred King Esq.
King Edward's Hospital Fund for London.
*Kingston-upon-Thames Borough Council.
Ministry of Labour.
J. Laing Research and Development Limited.

P. G. Laurie Esq.
J. Leslie and Co. Ltd.
R. A. Lister and Co. Ltd.
*T. S. Littler Esq., Ph.D., F.Inst.P., Director, Wernher Research Unit on Deafness, Medical Research Council.
The Local Authorities (Airport) Committee (Consisting of representatives of eight local authorities in the neighbourhood of London (Heathrow) Airport).
London County Council.
The London Motor Boat Racing Club.
London Transport Executive.
*Longford Residents Association.
Los Angeles Sound Abatement Co-ordinating Committee.
Y. J. Lovell (London) Ltd.
The Master Builder.
T. McQuade Esq.
The Metropolitan Boroughs' Standing Joint Committee.
Middlesex County Council.
Middlesex Local Medical Committee.
Military Engineering Experimental Establishment.
J. Miller and Partners Ltd.
Edward Millward Esq.
*Motor Industry Research Association.
Mrs. K. Murray.
C. H. Muggeridge Esq., A.I.A.
Myton Ltd.
*Sir Gerald Nabarro, M.P.
National Association of Parish Councils.
*National Association of British Manufacturers.
National Coal Board.
National Council of Associated Iron Ore Producers.
*National Farmers Union.
*National Federation of Building Trades Employers.
National Federation of Business and Professional Women's Clubs of Great Britain and Northern Ireland.
*National Federation of Women's Institutes.
National House-Builders Registration Council.
*National Industrial Fuel Efficiency Service.
National Joint Committee of Working Women's Organizations.
*National Physical Laboratory, Department of Scientific and Industrial Research.
National Union of Townswomen's Guilds.
Nature Conservancy.
*New Bedfont Residents Association.
*New Windsor Borough Council.
F. Douglas Nicholson Esq.
*Noise Abatement Society.
Noise Research Committee of the Aeronautical Research Council.
H. Nuttall Esq.
B. R. Ostler Esq.
Sir Lindsay Parkinson and Co. Ltd.
Mrs. W. F. Parsons.
Ministry of Pensions and National Insurance.
K. M. Petter Esq.
Petters Ltd.
R. S. W. Pollard Esq.
Port of London Authority.
Ministry of Power.
R. E. Prentice Esq., M.P.
†Charles H. Pugh Ltd.
Reema Construction Ltd.

Richmond Borough Council.
The River Boards' Association.
Royal Aircraft Establishment, Farnborough.
†Royal Forestry Society of England and Wales.
Royal Institute of British Architects.
Royal Society for the Prevention of Accidents.
Royal Society for the Prevention of Cruelty to Animals.
Rural District Councils Association.
Ruston and Hornsby, Ltd.
H. Rutter Esq.
Sand and Gravel Association of Great Britain.
C. Vaughan Saunders Esq.
The Scottish Council (Development and Industry).
Scottish Home and Health Department.
Scottish Trades Union Congress General Council.
H. H. Sherrard Esq.
The Ship and Boat Builders' National Federation.
Showmen's Guild of Great Britain.
H. Sinclair Esq.
*F. S. Snow Esq., C.B.E., M.I.C.E., M.I.Mech.E., P.P.I.Struct.E., M.Cons.E.
Society of Licensed Aircraft Engineers.
*Society of Motor Manufacturers and Traders.
*Southall Borough Council.
*South Harlington Residents Association.
Rupert Speir, Esq., M.P.
Staines Group Hospital Management Committee.
Standing Conference of Women's Organisations.
*Stanwell Residents Association.
Miss Cecily Statham, B.A., M.B., B.S.(Melbourne), D.Obst., R.C.O.G., D.A.(Eng.).
Mrs. Pauline Stebbing.
Suffolk Iron Foundry Ltd.
*Surbiton Borough Council.
*Surrey County Council.
The Thames Conservancy.
†The Timber Growers' Organisation Ltd.
Town Amenities.
The Town Planning Institute.
William Townson and Sons Ltd.
Trades Union Congress.
*Ministry of Transport.
Vicarage Farm Area Residents Association.
†Villiers Engineering Co. Ltd.
A. J. Wait and Co. Ltd.
*Walton and Weybridge Urban District Council.
Wates Ltd.
H. C. Webb and Company Ltd.
Westmorland County Council.
Miss M. Wheldon, S.R.N., R.M.N., R.M.P.A.
*Willesden Borough Council.
*W. S. Williams Esq.
*Wilmot Breeden Ltd.
G. Wimpey and Co. Ltd.
*Winchester Borough Council.
*Windsor Rural District Council.
Women's Group on Public Welfare and Standing Conferences of Women's Organisations.
*Wraysbury Parish Council.

APPENDIX II

THE MEASUREMENT OF NOISE

SOUND LEVEL AND DECIBELS

Throughout this Report, measures of noise have been expressed for the most part in "decibels on the A scale" (dBA) i.e., in readings on a "sound level meter" having a particular characteristic (c.f. Ch. I para. 10). This choice has been made because this kind of instrument is the only one easily available to the non-specialist for noise measurement, and is therefore the one most frequently used. It consists essentially of a microphone, an amplifier, and a rectifying and indicating instrument, with the addition of frequency-weighting networks which compensate to some extent for the varying sensitivity of the human ear to sounds of different frequency.

The readings of the sound level meter are expressed as *sound levels* in *decibels*, and it is perhaps for this reason that the word "decibel" has become in recent years almost a synonym for "noise". As the definition in the glossary shows, decibels are measures of multiplicative increments (like percentages), not of additive ones (like inches). An increase of 3 decibels in a sound level meter reading corresponds (roughly) with a doubling of the corresponding sound energy, wherever it may occur in the scale; this is confusing to those who are familiar only with the scales of the additive or linear type (such as centimetres or degrees on a thermometer), but it agrees much better than any linear scale could do with the increase in sensation produced, and has the further advantage that the enormous range from the weakest sounds we can hear to the loudest we can endure (more than a million million to one in terms of energy) can be expressed by figures of convenient size.

A considerable amount of work has been carried out in recent years (*a*) to define the limits within which the sound level meter may be relied on for the comparison of noises and (*b*) to design improved instruments. Nevertheless, in noise measurement, we are interested essentially in people's subjective reactions, rather than in some objective concept of energy or intensity. Asked to compare two noises, the average man makes his judgment in such terms as "loudness," "annoyance," or "intrusiveness," which do not in general correspond exactly with the readings of any objective measuring instruments so far designed. The establishment of a scale of loudness, and of methods of measuring loudness, is therefore important.

LOUDNESS, PHONS AND SONES

Two sounds with the same sound pressure level may have different loudnesses if their frequency distributions are not the same. It is found to be possible for a group of listeners to make consistent judgments of the relative loudness of sounds (though individuals in the group may vary considerably in their judgments); and this is the basis of the accepted scale of *loudness level* (c.f. glossary). The sound is compared with a standard pure tone. The intensity of the latter is adjusted until it is judged equally as loud as the sound being investigated and the intensity of the pure tone is then measured instrumentally, in terms of *sound pressure level* in decibels (a definite physical concept), above an arbitrary *reference level*, the answer being in "phons".

The numbers of the phon scale do not in any obvious way correspond with one's normal assessment of noise. In an ordinary living room, for example, 50 phons might be unnoticed, 80 unpleasantly loud, and 100 intolerable; but the ratio 100/50 does not correspond at all well with the relative sensation. It is possible, however, to construct a loudness scale purely on the basis of such subjective judgments as "twice" or "half" as loud; this judgment is surprisingly

consistent, and it is found that an increase of approximately 10 phons corresponds with an apparent doubling of loudness, over a good part of the practical range of loudnesses. By international agreement, therefore, an alternative scale of loudness in *sones* has been fixed, according to the formula $S = 2^{(P-40)/10}$ where "S" and "P" are the measures in sones and phons respectively. The room loudnesses quoted above would then become 2, 16 and 64 sones respectively—figures agreeing much better with subjective impressions.

CALCULATED MEASURES OF LOUDNESS

If it were easily possible to measure directly in phons (or sones), probably no other noise measurement scale would be used. Since, however, the measurement demands the resources of a standardising laboratory, it is impracticable for the majority of noise investigations.

As an alternative, methods have been developed for computing the loudness of a noise from instrumental readings more elaborate than the single observation of the sound level meter, but nevertheless much simpler than the strict "phon" assessment. The results of such calculations are expressed in the same units as loudnesses directly measured by subjective experiments (phons or sones) but should always be qualified by the term "calculated". (See glossary.)

The methods put forward by Stevens and by Zwicker, which are now widely used, are based on measurements of the sound pressure level within a number of restricted frequency bands (covering the whole audible range): these values are modified and summed in various ways, to give a single loudness figure. Of the methods of deriving phons by computation, Zwicker's is usually considered to be the most reliable. A method similar in principle to that of Stevens, but modified in detail, has also been evolved by Kryter to measure the so-called "*perceived noise level*" (PNdB) of noises with special reference to aircraft. The results are intended to place noises in order of "disturbance" (or "noisiness") rather than of "loudness."

The diversity of scales for noise measurement undoubtedly tends to confuse the layman. However, it reflects the complexity of the subject. At least two scales are necessary in any case, one (e.g. in decibels) to express physical magnitudes and one (e.g. in phons) to express some appropriate subjective measure. Generalisation is dangerous: but it is fair to say that straightforward sound level meter measurements are adequate for many purposes, particularly comparative ones. The meter readings (sound levels in dB) will almost always be numerically smaller than the loudness level in phons, the difference often reaching 20.

ANNOYANCE

In the preceding paragraphs we have assumed that the chief need in noise measurement is the evaluation of loudness; though, in fact, for general purposes of control, it is really "disturbance" or "annoyance" which we would wish to assess, were there any practical means of doing so, short of the cumbrous mechanism of a social survey. For specialist investigation, however, it is often desirable to measure other attributes of noise, in particular the energy associated with particular frequencies (e.g. in the investigation of noise from rotating machinery); and to use more sophisticated techniques, such as the correlation between measurements taken at known intervals of time or space. Analyses of this kind are often made in the laboratory from tape recordings made in the field.

GLOSSARY

Level. This term is used to indicate quantities which are measured in a logarithmic scale, i.e. in decibels.

Decibel (abbreviation dB). A dimensionless unit used in the comparison of the magnitudes of powers. The number of decibels, expressing the relative magnitudes of two powers, is 10 times the logarithm to base 10 of the ratio

of the powers. In the case of sound pressure, whose square corresponds to power, the corresponding expression becomes 20 times the logarithm to base 10 of the ratio of the pressures.

Sound Pressure Level. 20 $\log_{10}(p/p_0)$ decibels where p is the r.m.s. sound pressure, and p_0 is a reference sound pressure, usually 0·0002 dyn/cm^2.

Reference Level. The sound pressure level corresponding to a r.m.s. sound pressure of 0·0002 dyn/cm^2 (=0 dB).

Loudness. An observer's auditory impression of the strength of a sound.

Loudness Level. The loudness level of a sound of any nature is measured by the sound pressure level of a standard pure tone of specified frequency which is assessed, as the modal value of the judgments of normal observers, as being equally loud.

Phon. The unit of loudness level when

(*a*) the standard pure tone is produced by a sensibly plane sinusoidal progressive sound wave coming from directly in front of the observer and having a frequency of 1000 c/s, and

(*b*) the sound pressure level in the free progressive wave is expressed in decibels above 0·0002 dyn/cm^2.

Calculated Phon. It is recommended in a current draft ISO proposal that values in phons resulting from calculations based on sound pressure levels in frequency bands should be designated phons (OD), phons (GF) etc. depending on the particular basis of calculation. The first symbol describes the width of the frequency bands and the second the character of the sound field. OD for example signifies calculation by Stevens' method using octave frequency bands, and GF Zwicker's method.

Sone. The unit of loudness on a scale designed to give scale numbers approximately proportional to the loudness. The relationship of the scale to the phon scale is precisely defined by the formula $S=2^{(P-40)/10}$ where "S" and "P" are the measures in sones and phons respectively.

Calculated Sone. Similar remarks apply as to calculated phons, i.e. the nomenclature sones (OD) etc., should be used.

Sound Level. A frequency-weighted value of the sound pressure level as determined by a "sound level meter".

Sound Level Meter. An objective noise meter designed to measure a frequency weighted value of the sound pressure level, in accordance with International Electrotechnical Commission and British Standards.

Frequency Weighting Network. An electrical network incorporated in the amplifying circuits of a sound level meter to produce a specified overall electroacoustic frequency response. Three such networks, designated A, B and C, are in common use.

dBA. The unit of measurement of sound level, using frequency weighting network A.

Perceived Noise Level. A measure of "noisiness" derived from sound pressure levels in frequency bands, by a procedure described by K. D. Kryter, *J. Acoust. Soc. Amer.*, 31, 1415 (1959).

PNdB. The unit of perceived noise level.

Free Air Pressure Jump. The discontinuous rise in pressure due to a shock wave travelling in a medium remote from any reflecting boundary; usually expressed in lb/ft^2.

Speech Interference Level (SIL). This has been defined (e.g., L.L. Beranek, Acoustics, 1954, p. 419) as the arithmetic average of the sound pressure levels in the three octave bands 600–1200, 1200–2400 and 2400–4800 c/s. However, if the level in the 300–600 band exceeds that in the 600–1200 band by more than 10 dB, the average of the four levels is taken.

Noise Rating Numbers. The use of Speech Interference Levels however may be superseded by internationally proposed "Noise Rating Numbers" of wider

application. These are determined by setting the measured sound pressure levels in specified octave bands against a set of agreed numbered contours. For speech communication, for example, the number of the highest contour reached for the three octave bands centred on 500, 1000 and 2000 c/s has been proposed as the Noise Rating (NR); as a typical figure, for NR = 55, conversation is considered to be intelligible at about 4 feet without raising the voice. Noise Rating numbers are also proposed for hearing conservation criteria, and for the estimation of probable community annoyance.

Average Peak Noise Level. For the purposes of Ch. VIII and Appendix XI of this Report it has been found convenient to define the *average peak noise level* of a number of aircraft as the logarithmic average of the individual noise levels, thus:

$$\text{average peak noise level} = 10 \log_{10} (1/N) \sum_{1}^{N} 10^{L/10} ,$$

where L is the peak noise level (in PNdB) occurring during the passage of each aircraft and N is the number of aircraft concerned.

Noise and Number Index (NNI). A composite measure, defined for the purposes of this Report, taking into account the average peak noise level as well as the number of aircraft heard in a specified period. The numerical value is given by:

$$\text{NNI} = (\text{average peak noise level}) + 15 \log_{10} N - 80 ,$$

where N is the number of aircraft heard in the specified period, e.g. 1 day or 1 night.

APPENDIX III

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APPENDIX IV

COMPARATIVE JUDGMENTS OF DIFFERENT NOISES

The diagram overleaf is an attempt to show the wide variations in people's judgments of different noises.

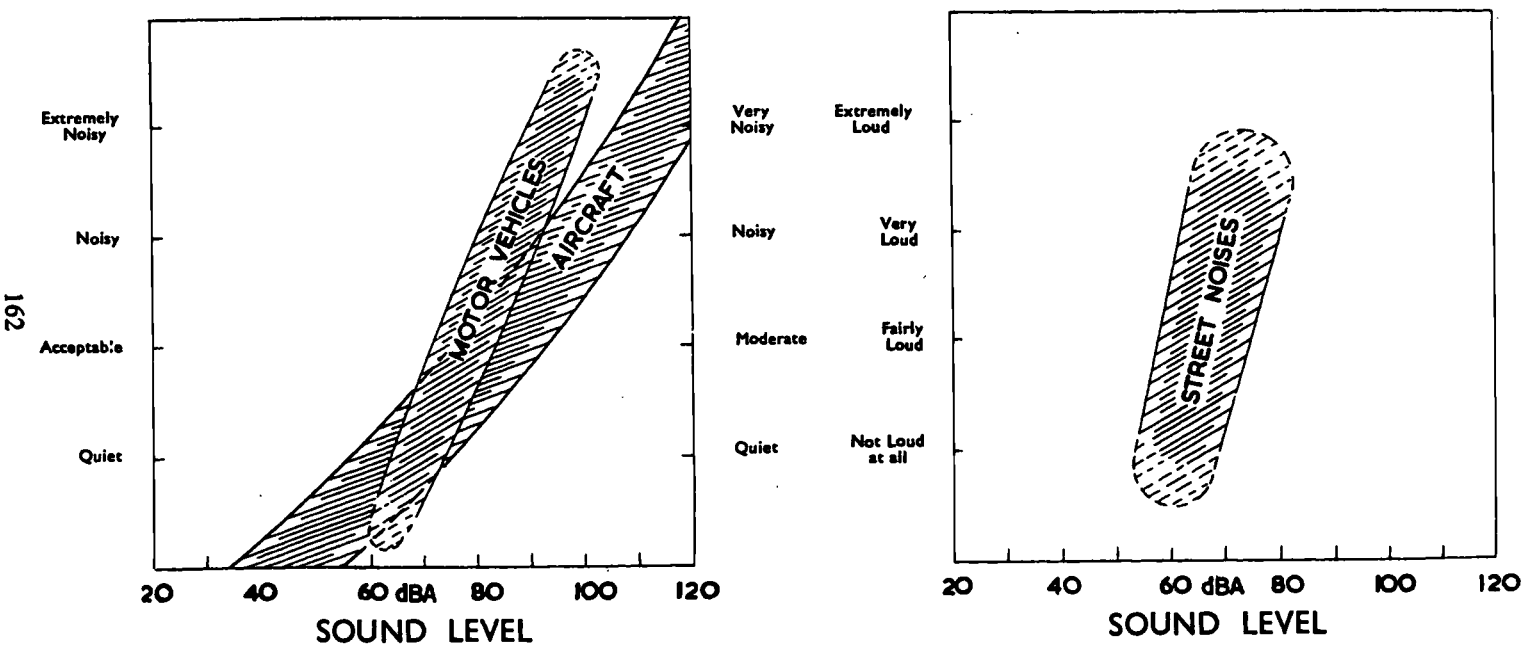
"Motor vehicles" represents the assessments of motor vehicle noise in the experiments described in Chaper VI.

"Aircraft" gives the assessments made at the Farnborough Air Show (Chapter VIII).

"Street noises" gives results obtained in the survey of noise in London, carried out by the Building Research Station, when a sample of householders were asked to assess the noise just outside their front doors (Chapter IV).

In each case, the shaded area on the graph has been drawn to include about 70 per cent. of the results obtained, and its vertical width is a measure of the degree to which individuals differ. If, for a given kind of noise, all individuals agreed, these bands would become narrow lines (not necessarily straight). If, in addition, judgments were the same for different noises and different conditions, these lines could be superimposed one on the other. It is obvious from the figure that, though most people will agree that a noise of sound level 60 dBA is "quiet," at 80 dBA their estimate of its "noisiness" may vary very considerably.

COMPARATIVE JUDGMENTS OF DIFFERENT NOISES



APPENDIX V

ACCEPTABLE INTRUSIVE NOISE LEVELS IN DWELLINGS

1. It is evident that there cannot be a single value to represent the maximum permissible intrusive noise level in dwellings. Apart from variation of sensitivity from one individual to another, there are likely to be different values depending on the kind of noises involved, on the kind of activity in which the occupants are engaged (for example quiet activities or activities themselves producing some noise), and on the general environment to which the occupants have become accustomed. The classification given in paragraph 117 of Chapter V takes some account of these variables in a simplified form. The aim is towards values acceptable to the majority. A proportion of people may not be satisfied at the levels suggested in that the intruding noises may still be too loud or disturbing for them. On the other hand, many people like the intrusion of a little noise (e.g. from neighbours) and a very high level of insulation against intrusive noise, even if practicable, could produce dissatisfaction at the "too quiet" end of the scale. It is impossible to give accurate figures of what is meant by "the majority" of people being satisfied by the present suggested levels, but the aim is to include about 70–75 per cent. of people.

2. The possibility of varying the level in accordance with occupants' activities is, in practice, limited because there is little that an occupant can do to change the insulation around him other than by opening or closing windows: the conditions to be specified must therefore preferably be such as will deal with the most difficult situation, that of quiet activities during the day and very quiet, or sleeping conditions, at night.

3. As to kinds of noise, the simplest separation is that between noise from neighbours (or "internal" noise) and that from outside.

4. Apart from the above difficulties there are also considerable technical difficulties in defining permissible intrusive noise levels, the most important of these being the lack of comprehensive experimental evidence. For example, while a very large number of measurements have been made of the sound insulation between dwellings, there has been no systematic research on the noise climate people produce for themselves within their own homes. Thus to obtain a maximum permissible noise level for noise from neighbours, it is necessary to assume that radio is probably as loud a noise source as any and to make the reasonable assumption that the level is about 80 dBA for 10 per cent. of time. When the sound insulation of the party wall or floor is subtracted we arrive at a figure for the intrusive noise level. Similarly, there have been no measurements of the noise levels from road traffic in rooms in dwellings, and thus it is necessary to take the comprehensive figures for road traffic noise and subtract the not-so-comprehensive figures for sound insulation between the outside and inside of dwellings to arrive at the figures for the interior noise levels due to traffic. The estimates for permissible noise levels which follow should therefore be regarded with some caution; they are thought to be the best possible estimates that can be made at the present time in the light of present knowledge, but as work on this subject develops they may have to be modified.

INTERNAL NOISE

5. The known facts are that from surveys of flats, a Grade II insulation between neighbours (i.e. 45 dB) results in some 42 per cent. of the occupants being dissatisfied, whereas with Grade I insulation, although some 26 per cent. remain dissatisfied, this proportion is about the same as the degree of dissatisfaction with a number of other factors of flat life.

6. Noise from neighbours' radios can rise to about 80 dBA and this is taken to represent about the loudest of normal domestic activities. With Grade I separating walls, the noise transmitted will be at a level of about 30 dBA and this is therefore taken as the acceptable limit.

EXTERNAL NOISE

7. There are various pieces of evidence which can be used as a basis for discussing the levels of external noise which are acceptable in dwellings. The most recent and most direct evidence is that obtained in the survey of reactions to noise in London carried out for the Building Research Station in 1961–62, the results of which are given in detail in Chapter IV. We use this as the primary evidence, and use the results of other investigations to reinforce our conclusions.

Evidence from the 1961–62 London Survey

8. The "external noise climates" for locations of various types are given in Table III (Chapter IV). Each "climate" is expressed as a range of noise levels, which have been obtained as averages of measurements from a large number of similar locations at all hours of the day or the night. Since windows can be either open, shut or sealed, the intrusive noise inside dwellings can have an even wider range than those shown in the Table. The results of the survey show that 30 per cent. of people regard traffic noise as very disturbing, whatever the actual level is of the traffic noise to which they are exposed. This finding can be analysed in the following two ways:

9. First, we may try to relate the reactions of people to the higher figures given in the Table as defining the noise climates. These figures are exceeded for 10 per cent. of the time, and so they clearly have a considerable significance, but the numbers of people in the noisiest and quietest locations (A and B, and F and G) were small and may not be representative. If therefore for the moment we consider only groups C, D and E, we have people exposed to noise of 70 dBA, 65 dBA and 60 dBA. In the locations in group C the windows overlooking the traffic will probably be closed during most of the time, and the noise level inside the dwellings will then be about 50 dBA. In the locations in Group E the windows will probably be open at times, and this will result in the noise inside the buildings reaching about the same levels as those inside the dwellings in group C. This is a possible reason why the same percentage of people are disturbed in all the various groups of locations.

10. This argument leads to a figure of 50 dBA as a not unacceptable level of noise inside dwellings, in groups C, D and E.

11. An alternative line of argument is to base the discussion upon people's probable reactions to an average noise climate, i.e. to a level which is exceeded for 50 per cent. of the time. In this case, it can safely be said that the average noise climate round the dwellings in group E is acceptable to people who live in suburban areas. Allowing for 10 dBA attenuation due to walls with open windows, this results in an acceptable level of 45 dBA inside dwellings in suburban areas away from main traffic routes. For other areas we may argue as follows:

12. The average noise climate in group C, namely 65 dBA, is attained in busy urban areas. With an attenuation of 10 dBA for walls with open windows and 20 dBA for those with closed windows, the corresponding level inside dwellings lies in the range 45 to 55 dBA. People may be able to adapt themselves to this environment and accept the higher of these figures, but at this and the even higher levels which exist for half the time, intruding noise can interfere with speech communication.

13. Similarly, those who live in the country will probably not accept an average noise climate worse than that of group G locations, i.e. a figure of 48 dBA outside their dwellings, leading to a figure of about 40 dBA indoors.

14. All the above figures refer to day-time noises. Corresponding arguments using the night-time data give the following results. Consideration of the higher figures for the noise climates gives 35 to 40 dBA as an acceptable level for locations in groups C, D and E, while the arguments based on the average noise climates lead to 40 dBA for busy urban areas, 35 dBA for suburban areas and 30 dBA for country areas.

15. However, while it is possible that many people in the various categories mentioned either find the present situation acceptable or have become accustomed to it, the findings of the social survey are that 30 per cent. of people are very disturbed by noise and that the percentage disturbed by external noise has increased substantially since 1948. We therefore feel that some reduction in the present noise levels is desirable, and, taking all the various arguments into account, we feel that it would be reasonable to try to ensure that the following noise levels inside dwellings should not be exceeded for more than 10 per cent. of the time.

Situation	*Day*	*Night*
Country areas	40 dBA	30 dBA
Suburban areas, away from main traffic routes	45 dBA	35 dBA
Busy urban areas	50 dBA	35 dBA

These are the figures given in paragraph 117 (Chapter V).

Evidence from the Reaction to Industrial Noise

16. In Appendix XV below data are given concerning the levels of different types of industrial noise which are likely to cause complaints in residential districts situated near factories. If we consider cities and their suburbs containing only light industry producing continuous noise without any specially distinctive characteristics it has been found by experience that complaints will be made if the noise level outside the nearest inhabited house exceeds 50 to 80 dBA, the value depending upon the type of locality in which the house is situated. If we assume that windows will be closed in noisy locations and open in quieter ones, the corresponding noise levels inside dwellings lie between 40 and 60 dBA. Some correction is required in the noisier locations to make the noise level acceptable rather than just tolerable, and once again we arrive at inside noise levels of 40 to 50 dBA. The corresponding figures for night-time are 30 to 40 dBA, and are substantially the same as those given in the Table above.

Other Evidence

17. In paragraph 41 (Chapter II) it is noted that occupants of houses rated noises heard at the doors of their houses as "not loud" at 60 dBA and "very loud" at 70 dBA. The corresponding indoor levels are 40–50 dBA and 50–60 dBA, the alternative figures depending upon whether windows are closed or open.

18. Kosten & Van Os. (ref. 1), describing the method of rating industrial noise at present being considered by the ISO, suggest acceptable levels in rooms in various locations which are approximately equivalent to the following levels in dBA:—

	Day	*Night*
Country	35 dBA	25 dBA
Suburban/urban	40–45 dBA	30–35 dBA
Busy urban	50 dBA	40 dBA

19. Blachere, in discussing the desirable levels of noise in dwellings (ref. 2), suggests the following levels:

For night rest 25–30 dBA
For day rest 30–35 dBA
Reading, mental activities 35–40 dBA
Housework, family activities 35–45 dBA

20. The British Standard Code of Practice on Sound Insulation and Noise Reduction does not contain any recommendations for desirable noise levels, but in general, is limited to recommendations on grades of insulation for various purposes, so far as the structure of buildings is concerned.

References

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APPENDIX VI

EXISTING BRITISH REGULATIONS ON NOISE FROM MOTOR VEHICLES

Regulations relating to noise from motor vehicles, in the Motor Vehicles (Construction and Use) Regulations, 1955, made under Sections 3 and 30 of the Road Traffic Act, 1930 (consolidated in the Road Traffic Act, 1960), are as follows:—

Silencers

Regulation 20:

Every vehicle propelled by an internal combustion engine shall be fitted with a silencer, expansion chamber or other contrivance suitable and sufficient for reducing as far as may be reasonable the noise caused by the escape of the exhaust gases from the engine.

Use and maintenance of silencer

Regulation 77:

(1) No person shall use or cause or permit to be used on a road any vehicle propelled by an internal combustion engine so that the exhaust gases from the engine escape into the atmosphere without first passing through the silencer, expansion chamber or other contrivance required by these Regulations to be fitted.

(2) Every such silencer, expansion chamber or other contrivance shall at all times while the vehicle is used on a road be maintained in good and efficient working order, and shall not have been altered in such a way that the noise caused by the escape of the exhaust gases is made greater by the alteration.

Excessive noise

Regulation 81:

No person shall use or cause or permit to be used on a road any motor vehicle or trailer which causes any excessive noise either directly or indirectly as a result of:—

(1) Any defect (including a defect in design or construction), lack of repair or faulty adjustment in the motor vehicle or trailer or any part or accessory of such motor vehicle or trailer, or

(2) the faulty packing or adjustment of the load of such motor vehicle or trailer:

Provided that it shall be a good defence in proceedings taken under this Regulation:—

(*a*) to prove that the noise or continuance of the noise in respect of which the proceedings are taken was due to some temporary or accidental cause and could not have been prevented by the exercise of due diligence and care on the part of the owner or driver of the motor vehicle; or

(*b*) in the case of proceedings against the driver or person in charge of the motor vehicle who is not the owner thereof, to prove that the noise arose through a defect in design or construction of the motor vehicle or trailer or through the negligence or fault of some other person, whose duty it was to keep the motor vehicle or trailer in proper condition or in a proper state of repair or adjustment or properly to pack or adjust the load of such motor vehicle or trailer as the case may be, and could not have been prevented by the exercise of reasonable diligence and care on the part of such driver or other person in charge of the motor vehicle.

Regulation 82:

No motor vehicle shall be used on a road in such a manner as to cause any excessive noise which could have been avoided by the exercise of reasonable care on the part of the driver.

Stopping of engine when stationary

Regulation 83:

The driver of every motor vehicle shall, when the vehicle is stationary otherwise than through enforced stoppage owing to the necessities of traffic, stop the action of any machinery attached to, or forming part of, such vehicle, so far as may be necessary for the prevention of noise:

Provided that this Regulation shall not apply—

(*a*) so as to prevent the examination or working of the machinery attached to, or forming part of, a motor vehicle where any such examination or working is rendered necessary by any failure or derangement of the said machinery or where the machinery attached to or forming part of the vehicle is required to be worked for some ancillary purpose ; or

(*b*) in the case of a motor vehicle which is propelled by gas produced in plant carried on the vehicle or on a trailer drawn by the vehicle.

Warning instruments

Regulation 19 *as amended by the Motor Vehicles (Construction and Use) (Amendment) Regulations,* 1959:

Every vehicle other than a works truck, a pedestrian controlled vehicle, or a locomotive, shall be fitted with an instrument capable of giving audible and sufficient warning of its approach or position:

Provided that no such instrument shall consist of:—

(*a*) a gong or bell, except in the case of a motor vehicle used solely for fire brigade, ambulance, salvage corps or police purposes or being used for the purpose of the Land Incident Company of the Royal Army Service Corps ; or

(*b*) a siren, except in the case of a vehicle used solely for fire brigade, salvage corps or police purposes.

Use of warning instruments

Regulation 84:

No person shall sound any instrument fitted to any motor vehicle for signalling its approach between the hours of 11.30 p.m. and 7 a.m. on any road on which there is provided a system of street lighting furnished by means of lamps placed not more than 200 yards apart or where a direction that the road shall be deemed to be a road in a built-up area is in force under the Road Traffic Act, 1934.

Provided that this Regulation shall not apply to any vehicle on an occasion when it is being used for fire brigade, salvage corps, ambulance or police purposes if the observance thereof would be likely to hinder the use of the vehicle for the purpose for which it is being used on that occasion.

Regulation 85:

When a motor vehicle is stationary on a road no person shall use or permit to be used any audible warning instrument with which it is fitted.

APPENDIX VII

OFFENCES RELATING TO MOTOR VEHICLE NOISE IN ENGLAND AND WALES

Year	Total vehicles registered	Motor bicycles and tricycles (included in total in Col. (2))	Total offences and alleged offences	Alleged offences in respect of which police gave written warning	Offences dealt with by prosecution	Cases in which the charge was proved
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1936	2,554,618	470,842	12,480	5,221	7,259	7,028
1937	2,712,978	454,191	11,016	4,787	6,229	6,018
1938	2,857,033	431,299	9,129	3,585	5,544	5,386
1946	2,874,917	436,094	1,976	998	978	958
1947	3,251,715	498,816	2,697	1,107	1,590	1,541
1948	3,441,859	523,123	2,318	1,015	1,303	1,268
1949	3,788,762	611,741	2,763	842	1,921	1,856
1950	4,066,361	705,022	4,436	1,754	2,682	2,602
1951	4,265,092	797,808	5,314	2,200	3,114	3,029
1952	4,524,023	893,738	5,384	2,319	3,065	2,988
1953	4,878,234	978,614	5,017	2,105	2,912	2,818
1954	5,337,490	1,076,471	5,157	2,013	3,144	3,057
1955	5,936,235	1,188,670	5,018	2,055	2,963	2,876
1956	6,407,863	1,255,455	5,772	2,228	3,544	3,455
1957	6,881,497	1,393,646	6,759	2,405	4,354	4,242
1958	7,317,334	1,439,821	7,513	2,450	5,063	4,947
1959	7,973,095	1,643,123	7,896	2,307	5,589	5,405
1960	8,699,300	1,768,000	7,954	1,765	6,189	6,084
1961	9,178,100	1,774,500	7,960	1,669	6,291	6,077
1962	9,730,600	1,773,600	9,673	2,010	7,663	Not available

APPENDIX VIII

B.S. 3425:1961

BRITISH STANDARD METHOD FOR THE MEASUREMENT OF NOISE EMITTED BY MOTOR VEHICLES

(As amended 2nd April, 1963)

FOREWORD

This British Standard has been prepared under the authority of the Acoustics Standards Committee with a view to providing a uniform and repeatable method of determining objectively the noise of a moving motor vehicle, so that this can be compared with a predetermined and arbitrarily set sound level value representing an acceptable standard of performance. The specification is based on and follows closely Draft ISO Recommendation No. 419, "Methods of measurement of noise emitted by vehicles." It should not be regarded as generally applicable to all aspects of vehicle noise investigation and is in no way intended to restrict future developments.

The method specified is based on an acceleration test at full throttle from a stated vehicle running condition in an acoustical environment which can only be obtained in an extensive open space. This test, whilst not necessarily measuring the highest noise of which the vehicle is capable, is nevertheless considered to give results adequately representative of the noise producing potential under full throttle conditions.

In view of the fact that this standard relies on the use of sound level values as the criterion of acceptability, the use of a high quality sound level meter is included in the specification.

It is necessary to emphasise that the method specified gives only an objective measure of the noise emitted under the prescribed conditions of test and that subjective appraisals of noise, e.g. loudness, annoyance or noisiness, are not simply or uniquely related to sound level meter readings.

METHOD

Scope

1. This British Standard specifies a method of determining the noise emitted by motor vehicles which is intended as far as possible to meet the requirements of simplicity consistent with reproducibility of results and realism in the operating conditions of the vehicle.

Measuring Equipment and Technique

2. A sound level meter complying with B.S. 3539* shall be used.

If the measurements are to be made on a test site, the meter shall comply with Part 1 of B.S. 3539.

The orientation of the measuring equipment with respect to the test vehicle at its nearest position in the run shall be that for which the calibration is appropriate.

The sound level meter shall be calibrated periodically at a laboratory equipped with the necessary facilities for free-field calibration.

To ensure accurate measurement it is necessary for a regular check to be kept on the sensitivity of the measuring equipment. In addition, the overall acoustical performance of the measuring equipment shall be checked immediately before and after each series of measurements and any deviation of these readings

* B.S. 3539, Sound level meters for the measurement of noise emitted by motor vehicles.

from the corresponding readings taken at the time of the last free-field calibration shall be stated in the report.

The readings to be recorded shall be the highest value obtained during the passage of the vehicle. Any peak which is obviously out of character with the general sound level being read shall be ignored.

If a wind shield is used its effect, if any, on the sensitivity of the microphone shall be taken into account.

Acoustical Environment

3. The test site shall be such that hemispherical divergence exists to within ± 1 dB, i.e., the sound radiation is within ± 1 dB of the theoretical value of a point source on a plane reflecting surface.

An open space of not less than 50 m (164 ft.) radius, of which the central area of 10 m (33 ft.) radius consists of concrete, asphalt or similar hard material free from any soft covering such as snow, shall be deemed to satisfy this requirement.

Note. Smaller areas may be used if they meet the requirement of hemispherical divergence.

In practice, departures from the "ideal" conditions arise from four main causes:

(*a*) sound absorption by the surface of the ground,

(*b*) reflection from objects such as buildings and trees, or from persons,

(*c*) ground which is not level or of uniform slope over a sufficient area,

(*d*) wind.

It is impracticable to specify in detail the effect produced by each of these influences. It is considered important, however, that the surface of the ground in the vicinity of the measurement area (see Fig. 1) should be free from powdery snow, long grass, loose soil or ashes.

To minimize the effect of reflections it is further recommended that the sum of the angles subtended at the measuring position by each of the surrounding buildings within 50 m (164 ft.) radius should not exceed 90° and that there should be no substantial obstructions within a radius of 25 m (82 ft.).

Acoustical focusing effects and sites between parallel walls should be avoided.

The level of background noise shall be such that the reading produced on the meter is at least 10 dB below that produced by the test vehicle.

Testing Ground and Measuring Positions

4. The testing ground shall be substantially level and its surface condition shall be such that it does not cause abnormal tyre noise.

The distance from the measuring position to the reference line CC (Fig. 1) on the road shall be 7·5 m (24 ft. 7 in.). The path of the centre line of the vehicle shall follow as closely as possible the line CC.

The microphone shall be located 1·2 m (3 ft. 11 in.) above the ground level.

Note. Care should be taken to avoid taking measurements during gusts of wind.

The presence of bystanders may have appreciable influence on the meter reading if such persons are in the vicinity of the vehicle or the microphone. No person other than the driver and the observer reading the meter should therefore remain in the neighbourhood of the vehicle or the microphone.

Suitable conditions exist if bystanders are at a distance from the vehicle which is at least twice the distance from vehicle to microphone.

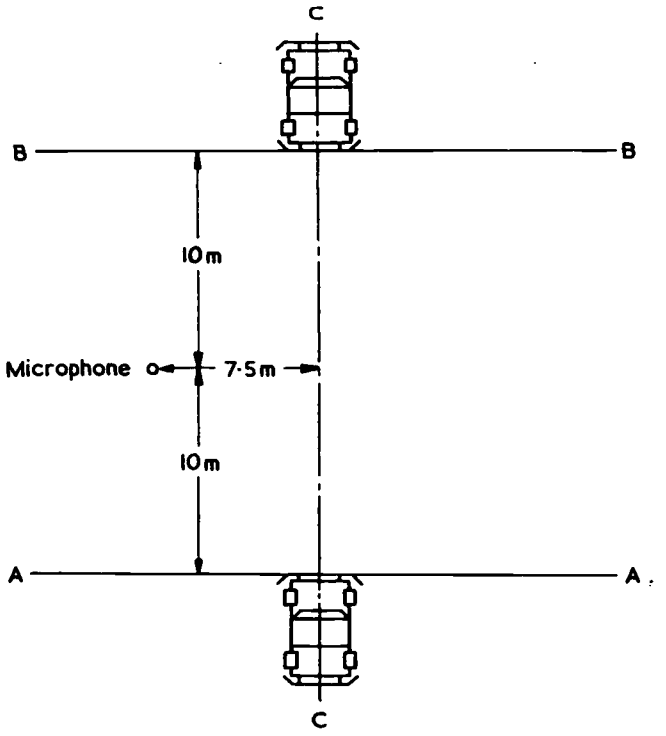

Fig. 1—Measuring position
(7·5 m.=24 ft. 7 in.; 10·0 m. | 32 ft. 10 in.)

Vehicle Conditions

5. Vehicles shall be driven unladen in such a manner as to comply with one or other of the following conditions:

(*a*) When the vehicle is fitted with a manually operated gearbox, with or without automatic clutch, the vehicle shall approach the line AA (Fig. 1) at a steady road speed which corresponds to an engine speed of ¾ of the revolutions per minute at which, according to the manufacturer, the engine develops its maximum power (as installed in the vehicle) and in such a gear ratio (excluding first gear in the case of vehicles fitted with more than three forward gears) that the road speed approaches 50 km/h (31 mile/h) as closely as possible.

(*b*) When the vehicle is fitted with a fully automatic gearbox it shall approach the line AA at a steady speed of 50 km/h (31 mile/h), or at ¾ of its maximum speed, whichever is the lower. Where a choice of forward drive positions is available, that position which results in the highest sound level of the vehicle shall be selected. If a drive position is provided on the vehicle which is primarily intended for engine braking this shall be excluded.

When the front of the vehicle reaches the position, in relation to the microphone, shown as AA in Fig. 1, the throttle shall be fully opened as rapidly as practicable and held there until the rear of the vehicle reaches position BB in Fig. 1, when the throttle shall be closed as rapidly as possible. The test shall then be repeated with the vehicle travelling in the opposite direction.

Trailers, including the trailer portion of articulated vehicles, shall be ignored when considering the crossing of line BB.

If the vehicle is fitted with more than two-wheel drive, it shall be used in the drive which is intended for normal road use.

Statement of Results

6. Measurements shall be made on at least three runs in each direction. The readings on a given side of the vehicle shall be within 3 dB. The average in decibels of the corresponding readings shall be taken. The higher average shall be taken as the sound level of the vehicle.

If the range of readings on either side exceeds 3 dB the whole test shall be repeated.

Note. It is recommended that trial runs be made for the purpose of selecting an appropriate range for the measuring instruments.

All readings taken on the sound level meter shall be stated in the report, except that the results of trial runs need not be included.

APPENDIX IX

THE SUBJECTIVE RATING OF MOTOR VEHICLE NOISE

By C. H. G. MILLS* and D. W. ROBINSON†

A subjective experiment is described, which was designed to establish a relationship between the subjective rating of noise emitted by motor vehicles, and objective measurements made with a sound level meter employing "A" weighting. The noise sources employed were nineteen production vehicles driven in a number of different conditions, and the subjective ratings were made by a panel of fifty-seven observers. The results show that in the case of private cars and commercial vehicles satisfactory correlation is obtained between the subjective and objective measurements. The results of motor-cycles as a group show a greater dispersion which is largely caused by shortcomings of the sound level meter when measuring motor-cycle noise; the dispersion is not significantly improved by sub-classification into two-stroke and four-stroke or into single-cylinder or twin-cylinder machines. Guidance is given on interpretation of results by means of numerical examples.

The broad object of the experiment was to make objective measurements (sound level A) and subjective measurements on a wide range of noises emitted by motor vehicles, and to determine the relationship between the subjective ratings and the objective meter indications. It was also required that the experiment should be so designed that it yielded information on the relative acceptability of the noises emitted by different classes of vehicles.

THE DESIGN OF THE EXPERIMENT

It was necessary to carry out the subjective experiment employing the widest range of noises and the largest number of subjects that could be accommodated, taking into account the practical difficulties of organisation. Unfortunately, the tests had to be made during late autumn in 1960, and the attendant difficulties caused by the weather at that time of year imposed some limitations. The tests were carried out using "live" motor vehicle noise, in the open air, on one of the test tracks at the Proving Ground of the Motor Industry Research Association. The number of vehicles employed, and the total number of noises which were rated, were limited to some extent by the time for which the subjects could be exposed to the weather conditions which were likely to prevail.

When the tests were actually carried out fifty-seven subjects were available who rated the noises emitted by nineteen vehicles, each vehicle operating under six different conditions. The number of subjective ratings which each observer made was 150, representing 114 different vehicle conditions and thirty-six repeats. The test was carried out between the hours of 12 noon and 3 p.m. in two parts, separated by a lunch interval. The observers were seated back to back in two lines parallel to the track of the test vehicles, and the vehicles were driven past them in alternately opposite directions. Half the observers made "sighted judgments", facing the test vehicles, and half made "unsighted judgments" sitting with their backs to the test vehicles.

One of the test surfaces at the Proving Ground of the Motor Industry Research Association was employed for the experiment and a plan of the test site is shown in Fig. 1. The track, which was surfaced with a smooth, porous, asphalt carpet, was a little over 1 km in length, with ample space at each end for parking and turning vehicles. One side of the track was bounded by young, widely spaced conifers, and the observers sat in line with the trees in a wide gap

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approximately half-way along the track. The test site was approximately in the centre of the Proving Ground, with no buildings or other objects capable of causing an acoustic disturbance within a radius of ¼ mile. All other traffic on the Proving Ground was stopped throughout the test.

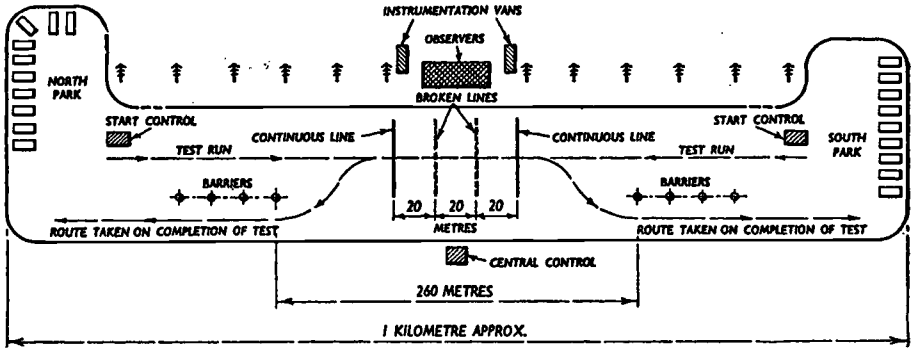

Fig. 1—Test site

The vehicles proceeded up and down the marked centreline of the road and the observers sat at a mean distance of 7·5 m from the centreline. Two rows of chairs, thirty chairs in each row, were placed alongside the track at the listening position, arranged back to back. The row facing away from the test track, was raised 30 cm above the forward facing row, to avoid the forward facing heads casting a sound shadow on the other row. Each row of chairs was 12 m long with a gap of one chair width in the centre of the row to accommodate the measuring microphones. The mean distance of the observers' heads from the centreline of the track was 7·5 m, "sighted" subjects being 15 cm less than the mean distance and "unsighted" subjects 15 cm more than the mean distance from the centreline of the track.

Two instrumentation vans were parked, one at each end of the rows of observers, about 5 m from the nearest observer. The "unsighted" observers had only a very restricted view of the test vehicles even if they turned their heads, the instrumentation vans and the small conifers acting as efficient sight screens. Fig. 2 shows the test in operation and the disposition of observers, instrumentation vans and a test vehicle. It should be noted that the theoretical difference in loudness of a sound caused by rotation of the head is insignificant in the case of sound spectra such as motor vehicles emit. For this reason it was preferable to orientate half the listeners facing away rather than to employ blindfolds, which would have been inconvenient in view of the duration of the trials.

The choice of test vehicles was based upon obtaining a representative range of noise emission from each class of vehicle. Vehicles were selected from four classes, private cars, commercial vehicles, and four-stroke and two-stroke motor-cycles. Within each class, vehicles were chosen, on the basis of previous measurements, to represent extremes of noise emissions, plus a few vehicles reasonably distributed between the extremes. The nineteen vehicles finally selected included three private cars, three high-performance cars, one moped, one motor-scooter, two two-stroke motor-cycles, four four-stroke motor-cycles and five commercial vehicles. All vehicles employed were new or in virtually new condition. No attempt was made to modify vehicles to produce either higher or lower noise levels than standard production types.

Although the actual vehicles were chosen to give a representative range of sound levels when tested under the proposed ISO* test conditions, each vehicle was tested under two other driving conditions, in order to extend the range of

* International Organisation for Standardisation Technical Committee 43, Draft Recommendation No. 419, October, 1960.

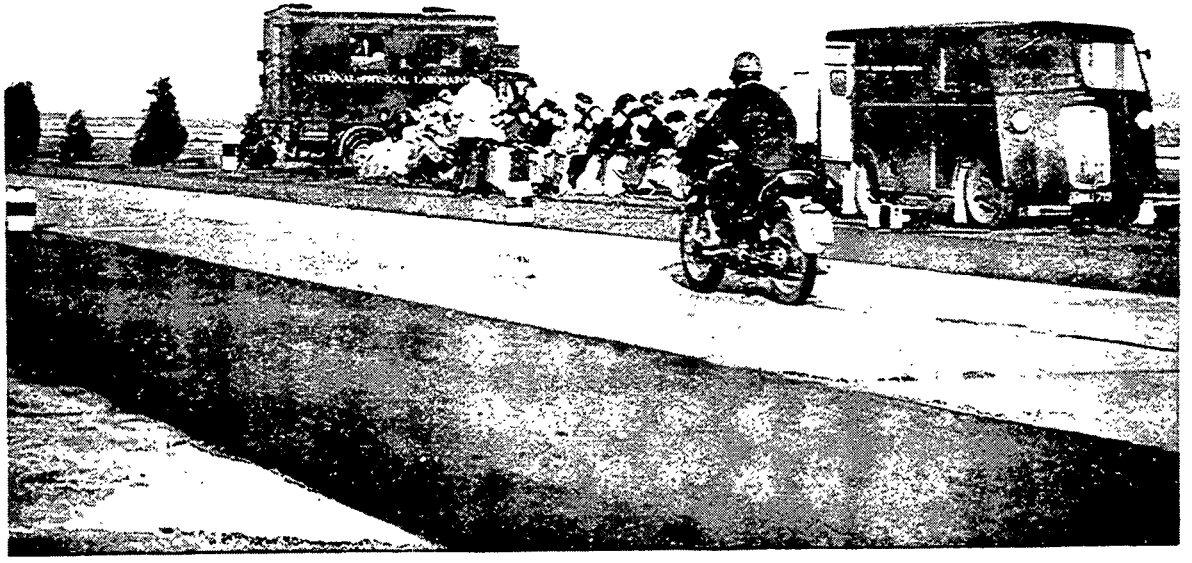

Fig. 2—The test site showing disposition of the listeners and a test vehicle

sounds to be judged by the subjects. Each vehicle passed the observers in two directions, employing each of three distinct driving procedures, thus providing, in general, six different noises at the listening positions.

The three vehicle operating conditions were as follows:

(1) PROPOSED ISO PROCEDURE.—The vehicle approached the test area at an engine speed of three-quarters of the r.p.m. at which, according to the manufacturer, the engine developed maximum b.h.p. A gear was chosen such that the road speed approached 50 km.p.h. as closely as possible, but first gear was excluded with vehicles having more than three forward gears.

As the front of the vehicle crossed a line 10 m from the measuring position (the centre of the line of observers in this case) the throttle was fully opened and held open until the rear of the vehicle crossed a line 10 m past the measuring position. The throttle was then fully closed and drivers made every attempt to coast until they were at least 100 m from the measuring position.

(2) BRAKED FULL THROTTLE TESTS.—The engine and road speed of each vehicle was the same as for the approach conditions in test (1), but the vehicle was driven past the observers at full throttle and constant speed, the speed being controlled by steady application of the vehicle brakes. The operating conditions for the test were stabilised from at least 30 m before the measuring position to 30 m after it.

(3) CONSTANT SPEED CRUISING TESTS.—Each vehicle was driven past the observers at a constant indicated speed of 50 km.p.h. in top gear. Test conditions were stabilised over the same distance as in (2) above.

Each vehicle carried out all the above tests at least once in each direction past the observers.

The provision of about sixty subjects presented some difficulties, and only a minimum of selection could be applied. Apart from ensuring that males and females were represented, no further control could be exercised. Fifty-seven subjects actually took part in the tests, twenty-three females and thirty-four males. The male subjects were selected mainly from M.I.R.A. staff, excluding those who worked habitually in a noisy environment, plus seven males from the N.P.L. and two from the Ministry of Transport. The majority of the female subjects were kindly loaned by the National Coal Board West Midlands No. 4 Area Office, and were all office workers. A further three females were selected from the M.I.R.A. staff and one from the N.P.L.

TEST PROCEDURE

Each separate test run, under one of three conditions and in one or other direction past the observers, was treated as a separate " vehicle-condition ". The order in which the " vehicle-conditions " were presented to the observers was randomised, within the limitation that no one vehicle could undertake consecutive runs in opposite directions. Each vehicle operated under each of the six " vehicle-conditions " and many vehicles carried out the same test procedure twice during the experiment for control purposes, resulting in a total of 150 " vehicle-conditions " being presented to the observers. Only one vehicle was permitted to be in the central test area at any one time, but the vehicles followed each other with as little delay as possible. A central controller was in contact with controllers at each vehicle park by means of V.H.F. radio, and by this means it was possible to present a different vehicle to the observers each thirty seconds.

Measuring microphones were set up 7·5 m from the centreline of the test surface, in the open space in the centre of the lines of observers. The following objective measurements were made during the test:

(1) Sound level A measured on two independent sound-level meters employing I.E.C. weighting.

(2) A continuous record of sound level A on a high-speed level recorder, adapted to read r.m.s.

(3) Single track calibrated tape recordings for future play-back on to a sound-level meter and the high-speed level recorder.

The sound level A assigned to each "vehicle-condition" was the highest recorded during the passage of the vehicle concerned. The various methods of measurement referred to in (1), (2) and (3) above provided reliable objective results with adequate cross checking.

The form of subjective measurement employed for this experiment was identical to that used in the earlier experiment carried out by the N.P.L. (ref. 1). The subjects were asked to rate the noises which were presented to them according to a six-point rating scale, the verbal description of which was printed on the answer sheets as shown in Fig. 3. No descriptions were assigned to the first and last

NAME:_____ AGE:_____ SEX:_____

SEAT No:

TEST No.	A	B	C	D	E	F
	—	QUIET	ACCEPTABLE	NOISY	EXCESSIVELY NOISY	—
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						

Fig. 3—Form of answer sheet used for the subjective measurements

categories, which the subjects were instructed to regard as extremes to provide a reference for the intermediate categories. The subjects were permitted to interpolate between adjacent categories by marking both of them. Instructions were given verbally to the subjects as a group and were kept as brief as possible without reference to any hypothetical environmental conditions.

The subjects were allocated numbered seats, and did not change position during the first seventy-five test runs. For the second group of seventy-five tests the five subjects at each end of the forward facing line changed places with the subjects immediately behind them in the "unsighted" line of observers. The purpose of the interchange was to check the relationship between results obtained with "sighted" and "unsighted" observers in case a marked difference were apparent, but this proved to be unnecessary. All "unsighted" observers were asked to make no attempt to look at the vehicles.

For most of the test the weather was cold, clear, and bright, with a light N.E. wind. Towards the end of the test the wind increased slightly, increasing the discomfort of the subjects but not causing any difficulty with the relevant objective measurements reported herein. All subjects were protected by warm clothing, and blankets and rugs were provided. No clothes were worn which could affect hearing.

RESULTS

For convenience in expressing the results, the verbal categories of the rating scale were first expressed numerically, so that "quiet" became 2, "acceptable" became 4, and so on. Thus, the numerical scale ran from 0 to 10. Each judgment recorded by a listener could in this way be expressed as a number, and the values averaged, either for the whole group, or for various sub-groups of listeners.

The principal results are shown in the form of correlation diagrams (Figs. 4–10), in which the average subjective rating for each vehicle is plotted against

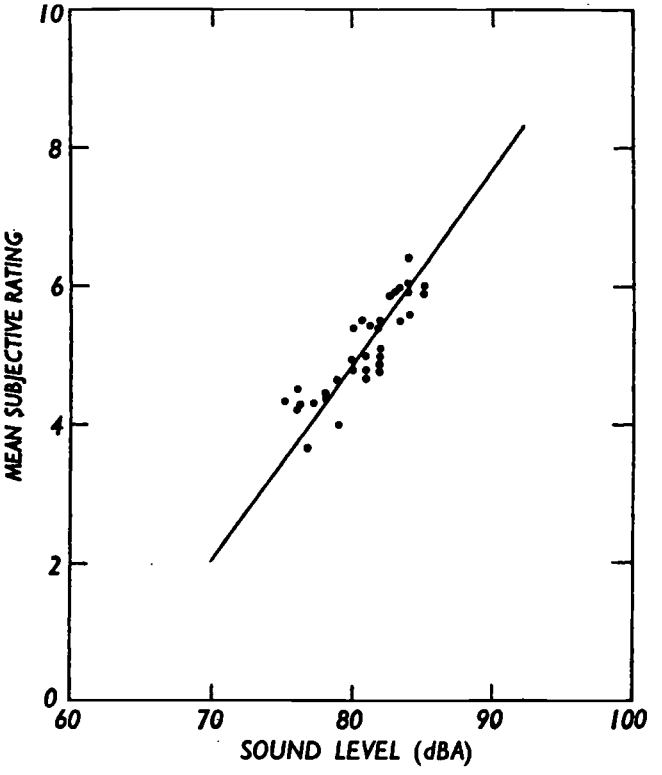

Fig. 4—Diesel vehicles: all observers

the recorded sound level A in decibels. Each point in the diagrams represents the passage of one vehicle. Previous experience has shown that the scatter of the points in such diagrams is excessive if all vehicles are included in one group. The vehicles have therefore been sub-classified in various ways in order to determine how many such sub-classes are needed to reduce the scatter to reasonable proportions. Referring to the figures, it is apparent that the scatter of results in the case of petrol-driven and diesel-driven vehicles respectively is quite small (5·5 dB and 7 dB respectively), and that there seems to be no need of sub-classification within these groups.

Initially, the motor-cycles were divided into two classes, two-stroke and four-stroke respectively, with the results shown in Figs. 6 and 7. The scatter in each of these cases is seen to be larger (two-strokes, 11 dB ; four-strokes, 7 dB), and, as shown in Fig. 8, the scatter is scarcely increased if both classes are combined (11·5 dB). An alternative classification into single and twin-cylinder machines was therefore made. The results in this case are shown in Fig. 9 and 10, and indicate no marked advantage of this manner of sub-classification (single-cylinder machines, 11 dB ; twin-cylinder machines, 10 dB). In particular, the most discordant points in Fig. 6 (two-strokes) and Fig. 9 (single-cylinder) respectively, represent the same machines. Clearly, there would be no advantage in further sub-classification.

In view of some conflicting evidence (refs 2 and 3) on the relation between sound level and subjective rating, which has been discussed in the previous paper, it was of interest to ascertain, so far as possible within the limitations of the present tests, to what extent judgments of noisiness were affected by different listening conditions and different sub-groupings of observers. The average subjective ratings for the vehicles were therefore plotted for various sub-groups of

listeners, namely those who faced the vehicle track and who may thus have been influenced by seeing the vehicles, those who were unsighted and faced away from the vehicles, males only, females only, and various age groups.

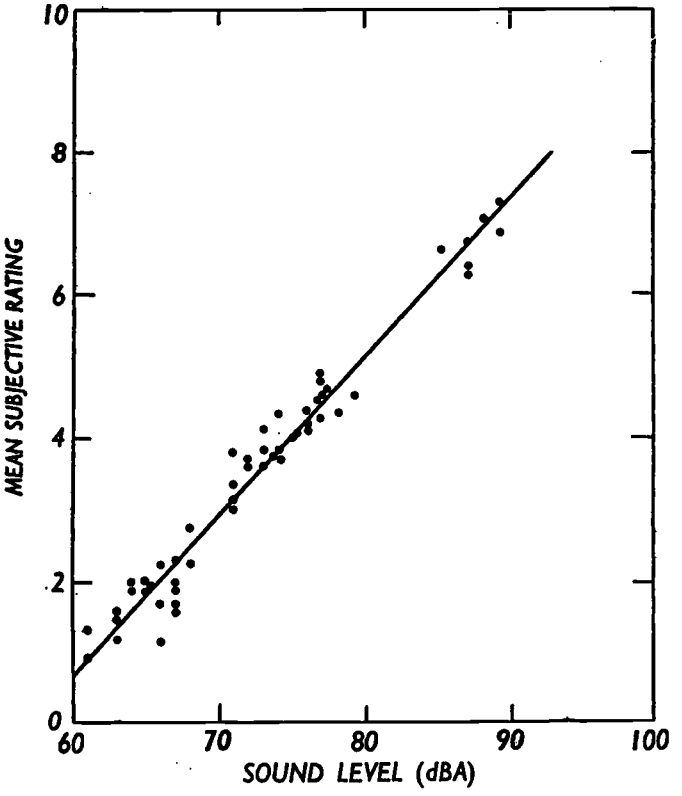

Fig. 5—Petrol vehicles: all observers

Since the results for the whole group were substantially unaffected by any of these sub-groupings of the listeners, the detailed results are not reproduced, but the summarised results are shown in Table I.

TABLE I

The values of sound level A read off the regression lines at subjective ratings of Q=quiet, EN=excessively noisy and D=demarcation between acceptable and noisy

Group	Diesel vehicles			Petrol vehicles			Two-stroke motor-cycles			Four-stroke motor-cycles		
	Q	D	EN	Q	D	EN	Q	D	EN	Q	D	EN
10 to 29 years of age	69·5	80	90·5	65·5	79	92	70	82	94	67·5	82	96·5
30 to 59 years of age	70·5	81	92	66·5	80·5	94	70	82·5	95	69	83	97·5
Males	69	80·5	92	66	79·5	93	69	82	94·5	67·5	82·5	97
Females	71·5	80·5	89·5	66·5	79·5	92·5	71	83	94·5	69	83	97
Facing	69	79·5	90·5	65·5	79	92·5	71·5	82·5	94	68·5	82·5	96·5
Non-facing ...	70·5	81	91·5	66·5	79·5	92	67·5	81·5	96	67	82	97
All	70	80·5	91	66	79·5	93	70	82·5	94·5	68	82·5	97

In order to make detailed comparison possible, a straight line is shown on each of the correlation diagrams. This is the calculated regression line, obtained by regarding the mean subjective rating as an independent variable and the indicated sound level as the dependent variable. There is, of course, no logical

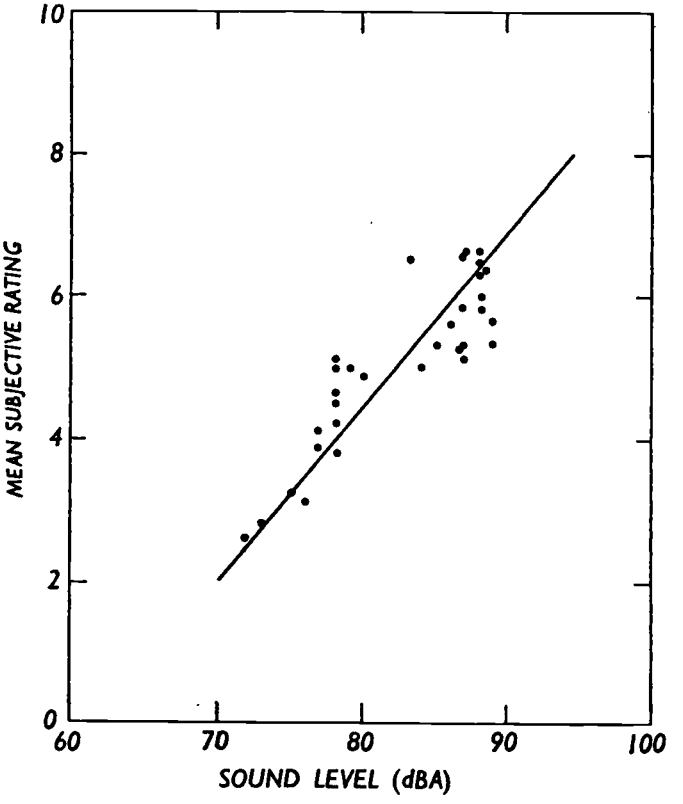

Fig. 6—Two-stroke motor cycles: all observers

reason to assume a linear relation, but it is evident that the scatter of the experimental points does not justify the fitting of higher order curves. By means of these straight lines, it is possible to read off the sound level corresponding to steps of the subjective rating scale as judged by the average listener.

Possibly the most significant point on the rating scale is the numerical value 5, which corresponds to the demarcation line between " acceptable " and " noisy ". However, some interest also attached to the rate at which the noisiness grows with the objectively-measured sound level, i.e. to the slope of the regression lines. A convenient way of comparing these features for the different vehicle classes and sub-groups of listeners is by a tabulation of the sound levels corresponding to the numerical steps, 2, 5 and 8 of the rating scale. Table 1 shows these levels, and demonstrates clearly that the demarcation line referred to is, for all cases, close to 80 dBA. From the table small but definite trends can be detected as between sub-groups of listeners. Thus, the age groups thirty plus consistently rate vehicles less noisy than the younger listeners, or otherwise expressed, they are more tolerant of a given objective noise level. For the four vehicle classes the effect amounts to 1·2 dB, 1·6 dB, 0·6 dB and 1·1 dB (average 1·1 dB), and could perhaps be dismissed as insignificantly small in relation to the dispersion if it were not persistently observed.

Comparing the results for males and females, a different, but equally persistent, effect is observed, namely, that the former compass a wider range in decibels for a given subjective interval than the latter. In terms of the interval " quiet " to

" noisy " the respective decibel ranges for the four vehicle classes are: Males 15·1, 18·1, 17·0 and 19·4 (average 17·4); Females 12·3, 15·4, 15·4 and 18·5 (average 15·4). Once again, the effect, though probably real, is inconsiderable in absolute magnitude.

No systematic trend is apparent on comparing the results of sighted and unsighted observers. Moreover, the magnitude of the differences is unimportant.

COMPARISON WITH EARLIER RESULTS

It is interesting also to compare the present results with those obtained in the previous investigation (1959). In some important respects, notably the rating scale used and the instructions to the subjects, the two investigations were similar. On the other hand, the physical conditions in which they were carried out were markedly different, the test material for the earlier investigation consisting of normal main road traffic. The nomenclature applied to the classes of vehicles differed slightly between the two experiments, but the effect on the types of vehicle included in each class is insignificant. The earlier results may have been influenced adversely, though only to a small extent, by the fact that the track of the vehicles was not under accurate control. The results of the two investigations are compared in Table II and show a remarkable similarity, both as regards

TABLE II

Comparison of present results with those of an earlier investigation for all listeners. The values of sound level A read off the regression lines at subjective ratings of Q = quiet, EN = excessively noisy, and D = demarcation between acceptable and noisy

	Diesel vehicles			Petrol vehicles			Motor-cycles		
	Q	D	EN	Q	D	EN	Q	D	EN
Present investigation (1960)	70	80·5	91	66	79·5	93	68·5	82·5	96·5
	Commercial vehicles			Private cars			Motor-cycles		
Earlier investigation (1959)	72·5	82	91·5	65·5	80	94	71	83·5	96·5

the levels in decibels corresponding to the demarcation line between " acceptable " and " noisy " and to the rate of growth of the subjective rating on the noisiness scale with sound level. One feature, for example, observed in 1959 was that the range from " quiet " to " noisy " was compassed in a smaller objective range for commercial vehicles than for other classes. This is clearly exemplified again in the present work.

Bearing in mind that the two investigations have been carried out quite independently, with different people as observers, and noting that no marked differences are apparent with age, sex, aid of visual observation, &c., it seems reasonable to conclude that a level close to 80 dBA fairly represents the demarcation line in the opinion of typical British listeners, under the conditions of this type of experiment.

No support can be found for the results of a Swiss investigation (ref. 2) that this demarcation line should be set around 73 dBA, but differences of national habit in regard to the attitude to motor-vehicle noise cannot, of course, be discounted. It may be significant, however, that the Swiss observers were instructed to assume a hypothetical listening situation related to their normal daily activities.

STATISTICAL DISCUSSION

That there are appreciable divergences of opinion by individuals may be seen from the fact that the standard deviations of the judgments (of the whole group) were about 0·97 units of the numerical rating scale (values for individual vehicle tests ranged from 0·5 to 1·3). This represents some 4 dB when interpreted on the

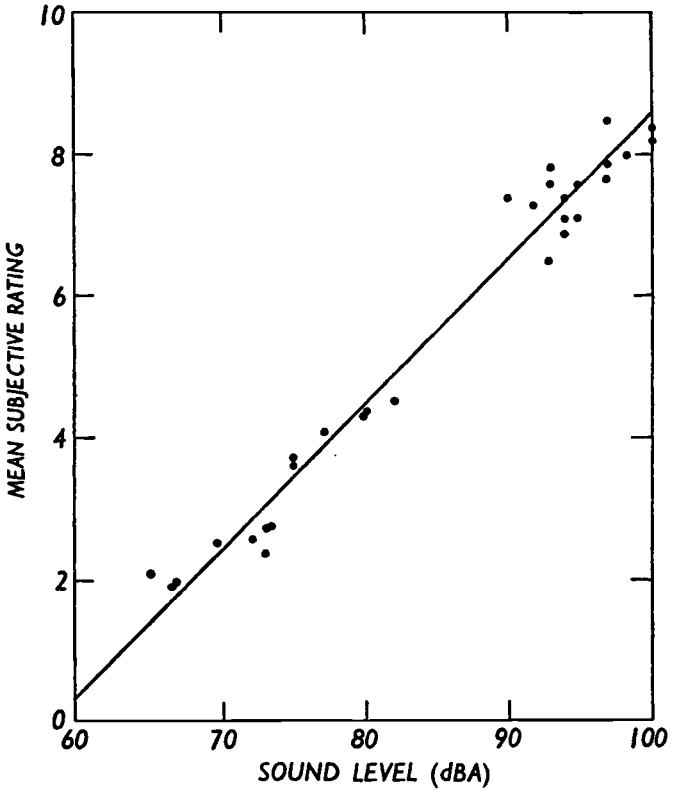

Fig. 7—Four-stroke motor-cycles: all observers

sound level scale. For most of the tests, judgments were spread over three or four adjacent (numerical) steps and in a few cases, as many as five, meaning that a noise judged " quiet " by some was judged " noisy " by others.

One listener recorded an average (numerical) judgment of 5·87 (nearly " noisy ") over the whole 150 tests, whilst at the other extreme a value of 3·76 occurred (quieter than " acceptable "), the grand average being 4·63. Significance should not be attached to these considered as absolute values, of course, since they depend on the particular vehicles used and the manner in which they were driven. The relative attitude of these extreme listeners, however, is significant, corresponding to a difference of the order of 9 dB. Even the existence of these extreme listeners, however, does little to bridge the gap between the Swiss observations and the present results.

The scatter of the points on the diagrams (e.g. Fig. 4) is compounded of a number of factors, namely:

(*a*) the uncertainty of individual judgments;

(*b*) the fact that such judgments were quantised in units on a scale running from 0 to 10;

(*c*) the inherent lack of correspondence between the action of the meter and that of human listening; and

(*d*) errors of objective measurement.

Of the above factors, (*b*) and (*d*) are unlikely to be of any consequence, but it is difficult to resolve the importance of (*a*) and (*c*). To do this, it is necessary to estimate the magnitude of (*a*) independently by repeat judgments under identical physical conditions. A number of such repeats were included in the tests

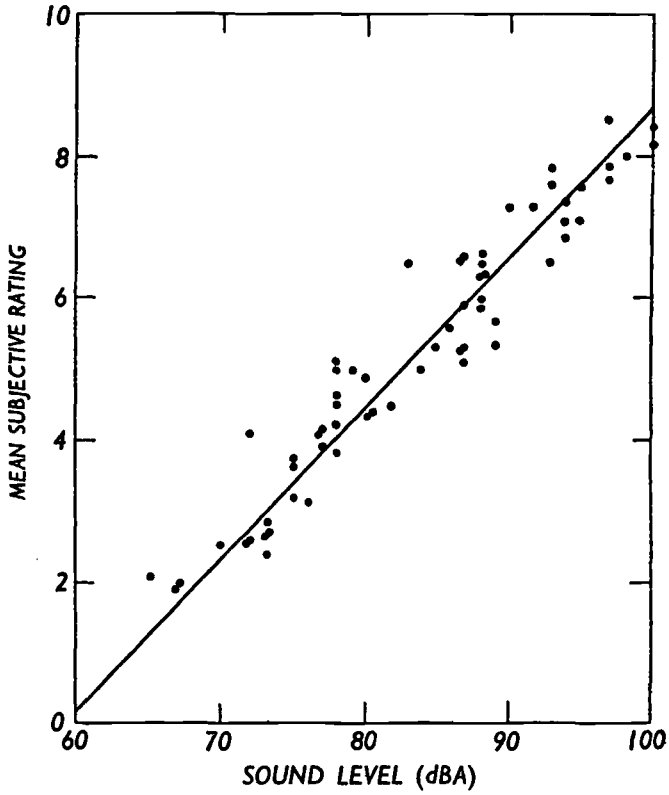

Fig. 8—All motor-cycles: all observers

(thirty-six out of 114), and by analysing the corresponding results the standard deviation associated with the repeatability of listeners' judgments was evaluated to be 0·82 (numerical) units on the rating scale. This component of variance can, in principle, be extracted to estimate the residual scatter due to (*c*). This net residual scatter corresponds to a standard deviation in decibels of 1·0, 1·3 and 2·4 for diesel-engined vehicles, petrol-engined vehicles and motor-cycles respectively.

The fact that a large part of the scatter is attributable to the shortcomings of the sound-level meter is qualitatively obvious from some of the diagrams. For example, two four-stroke motor-cycles which gave sound level meter readings of 65 and 90 respectively were invariably (i.e. by whatever group of listeners) judged noisier than the meter reading would suggest, and two which gave meter readings of 82 and 100 were invariably judged less noisy. Similar discrepancies are evident with two two-stroke motor-cycles which read 83 and 84 respectively, and a close study of the scatter diagrams reveals a large number of similar examples. Since there can be no correlation whatever between the judgments of individual male

and female listeners, it follows that similarities of the male and female average scatter diagrams must result from factors (*c*) and (*d*) above, and of these (*d*) may be ruled out, in view of the many cross-checks in the sound-level meter readings.

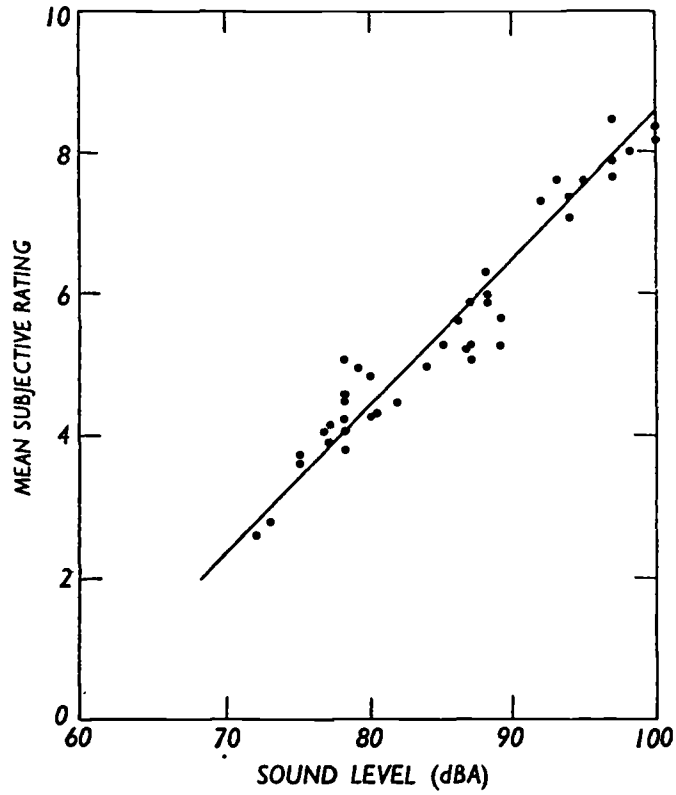

Fig. 9—Single-cylinder motor cycles: all observers

INTERPRETATION OF RESULTS

Subject to the limitations of any experiment of a statistical character, the straight lines in Figs. 4–10 represent the conclusions of this work in so far as the average listener is concerned. To interpret the results fully it must be appreciated that two main variances are associated with the subjective data, one arising from the dispersion of the subjects' individual judgments, and the other from the shortcomings of the meter. A further small uncertainty is associated with the fact that the results refer to a limited sample of listeners (fifty-seven), and there is the possibility of a sampling error, estimated to be not more than 0·8 dB, in the interpretation of absolute values. This, however, may be discounted in view of the magnitude of other uncertainties.

Each point on the graphs represents the average judgment of fifty-seven observers and if, for example, it was required that all observers were " protected " at some predetermined point on the subjective rating scale, rather than only the less susceptible half, then the basic level associated with this point (as read off the diagrams, or obtained from Table III) would have to be adjusted downwards. If three standard deviations are taken as the criterion (the probability of any results lying between ± 1 std. deviation (σ) is 68 per cent., within $\pm 2\sigma$ is 95 per cent., and $\pm 3\sigma$ is 99·7 per cent.) a downward adjustment of some 12 dB would be necessary to ensure that it would be very improbable that any subject

would rate any noise above the predetermined point on the scale. Similarly if 12 dB were added to the basic level, it would be very improbable that any subject would rate any noise below the predetermined point.

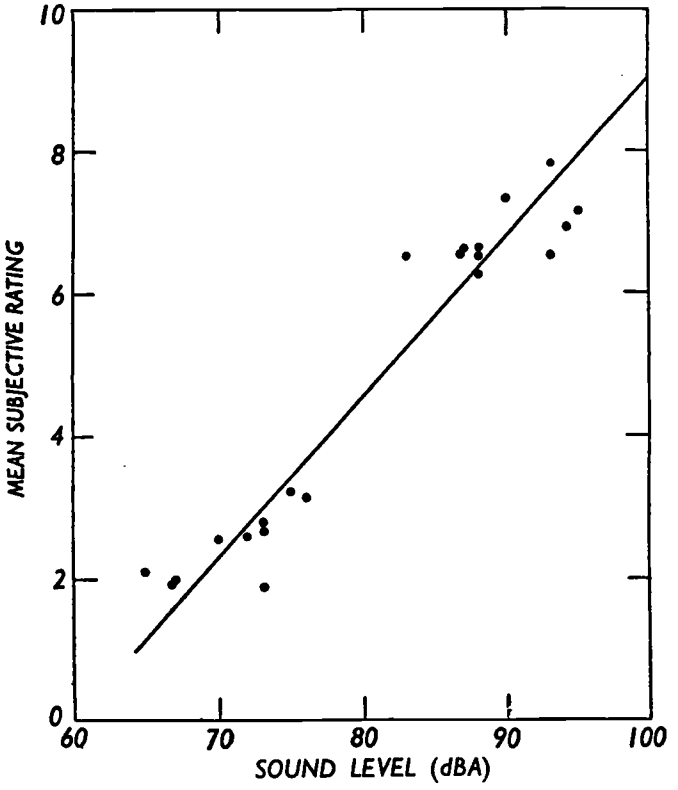

Fig. 10—Twin-cylinder motor cycles: all observers

On the other hand it has been shown that the sound-level meter has shortcomings in representing the subjective noisiness of motor vehicles, especially motor-cycles, in the sense that it does not place all vehicles in the same rank order for noisiness as does the average listener, i.e., two vehicles judged equally noisy might yield different meter readings. It might be argued that shortcomings of the meter should not be permitted to " penalise " the vehicle giving the higher reading but which is still subjectively acceptable. To offset this, upward adjustments of the basic level would be required of, say, three standard deviations of the residual scatter due to the shortcomings of the meter. The upward adjustments would amount to about 4 dB, 3 dB and 7 dB for petrol-engined vehicles, diesel-engined vehicles and motor-cycles respectively.

It should be appreciated that any upward adjustment that is made in order to avoid the " penalisation " of vehicles by the shortcomings of the meter, must result in a reduction of the proportion of listeners who are " protected ". Thus various levels may be set corresponding to " noisy ", " acceptable ", " quiet ", &c., and according to the degree of " protection " required by the listeners, or the vehicles, or both.

By way of illustration the case is considered in which the basic point on the subjective rating scale at which " protection " is required is the demarcation between " acceptable " and " noisy ". Referring to Table III, this point is represented by sound levels of 79·5 dBA, 80·5 dBA and 82·5 dBA for petrol-engined vehicles, diesel-engined vehicles and motor-cycles respectively, and if no vehicle exceeded these sound levels approximately half the listeners would judge them to

be "just acceptable". It is of interest to note that the average listener permits a slightly higher sound level A for motor-cycles than for the other two classes of vehicles.

If it is required to "protect" all listeners then 12 dB (3σ criterion) should be subtracted from the basic levels quoted above resulting in sound levels of 67·5 dBA, 68·5 dBA and 70·5 dBA respectively for the three classes of vehicles. On the other hand, if it is required that no vehicle is "penalised" by the shortcomings of the meter, then upward adjustments should be made to the basic levels amounting to 4 dBA, 3 dBA and 7 dBA (3σ criterion) resulting in sound-levels of 83·5 dBA, 83·5 dBA and 89·5 dBA for petrol-engined vehicles, diesel-engined vehicles and motor-cycles respectively.

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APPENDIX X

ON JUDGING THE NOISE FROM AIRCRAFT IN FLIGHT

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Sixty subjects made judgments of the sounds of aircraft flying overhead, on three occasions. Two rating scales were used for outdoor judgments using criteria of "noisiness" and "intrusiveness". The second criterion was also used for indoor tests. Noise levels were expressed in dBA and PNdB. The level just regarded as noisy outdoors was 93 dBA. Comparison of the indoor and outdoor tests showed that subjects made roughly the same judgment on a given aircraft although the sound level indoors was reduced by the building structure.

INTRODUCTION

In this experiment subjects made judgments of the sounds of aircraft flying over them. Earlier work had been carried out on similar lines with motor vehicle noise (refs. 1 and 2), and one object of the present tests was to discover whether the previous results were specific to the very familiar class of noises made by motor vehicles or whether they had a more general significance. The internal consistency and repeatability of the previous tests lends confidence to the method of direct rating scale judgments for the estimation of trends or relative effects, and one has the advantage of hearing the test sounds in realistic conditions.

For obvious reasons it is more difficult to make use of aircraft for such tests than road vehicles since the former cannot usually be flown in a manner specified by the experimenter. We therefore looked for an occasion when many aircraft would be flying under a range of operating conditions.

The experiment took place on three afternoons (6th-8th September, 1961) of the 1961 S.B.A.C. Show at Farnborough and on each day a different experimental configuration was used. On Day 1 the subjects were in the open air in a field about 300 metres from the landing end of and in line with the runway in use during the show. The aircraft were not visible from the test ground, which was surrounded by trees, until they were nearly overhead. The subjects were asked to imagine that they were outside in their gardens, etc., and during the test, which occupied about two hours, to perform some "task". Ideally we should have arranged a specific distracting task but this was considered impracticable and the choice was left to the individual subject. It ranged from simply walking about in groups and talking, to playing cards, knitting or reading.

The method of "posterior judgment" was used throughout Day 1, the subjects being asked *after* an aircraft had passed to record their impressions on the following scale:

Not Noticeable, Noticeable, Intrusive, Annoying, Very Annoying, Unbearable.

Less than half of the total flyovers were used for judgments so that the subjects could not know when they were expected to judge, and we found that they quickly stopped looking up at every aircraft and concentrated upon their various activities.

On Day 2 the test site was about 150 metres from the take-off end of the runway and slightly to one side. Most of the flying display was clearly visible from the site and the method of "anterior judgment" was used. The rating scale above was not suitable for this purpose and one was chosen to accord with that used for the subjective tests on motor vehicle noise (refs. 1 and 2) save that the label of one point on the scale was changed from "Acceptable" to

" Moderate " which was felt to be more appropriate. The following six-point scale was therefore used:

(Unnamed), Quiet, Moderate, Noisy, Very Noisy, (Unnamed).

No descriptions were assigned to the first and last categories which the subjects were asked to regard as extremes for use when necessary.

On Day 2 the subjects were asked to record a judgment corresponding to the greatest sound during each fly-past. The words " loudness " or " noisiness " were deliberately not used in the preliminary verbal instructions. The procedure was to choose a suitable aircraft and to direct the attention of the subjects to it. We found it necessary to announce a conclusion to each test because some aircraft flew around for a considerable time.

On Day 3 the experimental procedure was similar to that of Day 1 except that the subjects were indoors in a conference room at the Royal Aircraft Establishment equipped as a cinema and viewed a programme of films as their distracting task. The cinema was some 250 metres to the side of the runway at the landing end. The aircraft to be judged were selected by one of the experimental team situated on the top of a nearby high building, and the subjects were informed of each test by another member of the team inside the cinema who was in headphone communication with the first. The instruction to judge was given a few seconds after each of the selected aircraft had passed.

2. THE SUBJECTS

About 60 people volunteered to be subjects. It was arranged that men and women and as wide an age range as possible would be represented ; audiometric screening was impracticable but people with hearing defects had been asked not to volunteer. The NPL provided 11 subjects from the staff of the Acoustics Section, the RAE provided about 30 of various occupations ; the remainder came from other government departments which had no connection with acoustics, and did not normally work near an airfield. We included as many laymen as possible because we felt that there might be a bias in the results if all the observers were professionally interested in either acoustics or aircraft ; this point is discussd further below.

Before the exercise started each subject filled in a short questionnaire giving his name and age, etc., and some indication of his previous exposure to aircraft sounds. The following questions were asked:

(*a*) Is your home near an airfield? If so, how near approximately?

(*b*) How many aircraft would you expect to hear at home

(i) during a night?

(ii) during a day?

(*c*) How many aircraft would you expect to hear during a day at work?

(*d*) Do you find that one type of aircraft is particularly annoying?

Question (*d*) was included not so much to give us information on annoying types of aircraft as to enable us to distinguish the experienced aircraft observers from the more lay members of the team. On the basis of the answers the subjects were divided, after the experiment, into three groups: A, B and C. Group A comprised those who lived near an airfield and who heard a large number of aircraft daily, group C comprised those who lived far from an airfield and who rarely heard aircraft at home, and group B comprised the remainder.

3. OBJECTIVE MEASUREMENTS

The experimental equipment used during the exercise was basically very simple. On Days 1 and 2, two condenser microphones were used with their diaphragms oriented so that noise from the majority of the aircraft would be approximately in the plane of the diaphragm, thus minimizing the effects of varying direction. The heights were adjusted to be approximately those of the subjects' heads so that any effects of ground reflection would be similar. Cylindrical muslin shields

were used round each microphone to reduce the background noise, due to wind, below the levels of interest. The signal from one of the microphones was led to a level recorder via an amplifier with a frequency response corresponding to the I.E.C. A-weighting (ref. 3). The signal was also fed to both channels of a twin-track tape recorder with gains set 10 dB apart. The output of the second microphone was connected to both channels of another twin-track recorder with gains set 10 dB apart so that the whole system of both recorders had a range of gain settings covering 30 dB. This arrangement ensured at least one satisfactory recording of noises: these varied widely and unpredictably in level since the flight paths were not under our control.

On Day 3, the experimental details were different. One microphone was placed on the roof of the cinema and its diaphragm inclined as explained above. The other was placed inside the cinema approximately in the middle of the clear area between the screen and the audience. This position was chosen after some preliminary experiments as giving typical values of the reverberant sound level. The random incidence calibration of the microphone was appropriate in this situation. The level recorder and amplifier with A-weighting were connected to the indoor microphone, and the recorder ran throughout the experiment, thus measuring the background due to the film commentary and the total noise when an aircraft was present. To facilitate the location in time of the various test noises during subsequent playback the tape recorders were connected with one channel to each microphone. The recording amplifier gains were set 16 dB apart on each machine to allow roughly for the noise reduction due to the cinema building. The gains of the two machines were set 20 dB apart to cover the wide range of noises expected.

At the end of the third day, after the subjects had left, the noise reduction due to the building was measured using the sound of 16 Hunter aircraft that were passing and repassing at the time. Several determinations were made in octave bands and averaged.

4. ANALYSIS OF OBJECTIVE RESULTS

An examination of the combined results from previous work with motor vehicles (refs. 1 and 2) shows that the variance depends on the objective measure chosen. The choice lies between an objectively simple measure, such as sound level A, or one of the more complicated measures based on spectrum analysis: perceived noise level or calculated loudness level. The best of the measures turns out to be loudness level calculated by Zwicker's method (ref. 4) but compared with the use of sound level A it only reduces the total variance by about 25 per cent. Considering the excessive complication of spectrum analysis of the aircraft sounds which were fluctuating from instant to instant and the labour of the calculations involved in Zwicker's method we decided, initially, to restrict the objective measurements to sound level A readings for each noise. Use of perceived noise level shows no advantage over use of sound level A for the motor vehicle noises but since this measure is of current interest for the rating of aircraft noises we have extended the present results to include PNdB by the method outlined in section 10.

For Days 1 and 2, the channel having the best of the four recordings of each noise was selected and the output connected through an amplifier having a response incorporating the A frequency-weighting and the inverse of the microphone response to a level recorder indicating r.m.s. values. A single figure measure for each noise was arrived at by taking the maximum reached on the level recorder with a suitably low writing speed.

On Day 3 the noise experienced by the subjects was composed of a mixture of aircraft noise and film commentary. In the case of the quieter aircraft, therefore, the aircraft noise alone could not be analysed directly from the recordings. For these cases the records from the outside microphone were used in the following way. The noise reduction due to the building was determined by analysis into octave bands of the sound inside and outside the cinema as already mentioned. The level difference varies somewhat; it is a function of

the flight path of the aircraft since sometimes the sound enters more by the (double) windows, and at other times more through the roof. The average value is shown in Table I.

TABLE I

Level differences between a position on the roof of the cinema and a typical listening position inside, in octave bands

Centre frequency of band (c/s) ...	53	106	212	425	850	1,700	3,400	6,800
Difference (dB)	10·0	12·5	18·5	23·5	27·5	28·5	30·5	33·5

An electrical network was constructed to simulate this characteristic. When the recordings from the outside microphone were played back through this network and an A-weighting network in tandem, a record of sound level A inside the cinema as though without the film commentary was obtained. Whenever possible, the direct (indoor) measurements were adopted, i.e. when the aircraft noise exceeded the commentary by 15 dB or more; this also provided a cross-check with the indirect results (outdoors corrected by noise reduction).

The difference between sound level A on the roof and inside is, of course, a frequency-weighted average of the values in Table I and was found to average 23·9 dB for 49 test noises. Individual values varied from 17 to 28, partly due to differences in the noise spectra and partly to the variable level difference between outside and inside mentioned above.

5. ANALYSIS OF SUBJECTIVE DATA

The principal results of the tests are presented in Figs. 1, 2 and 3 in the form of correlation diagrams. The ordinates of Figs. 1 and 3 correspond to the rating scale of "intrusiveness", interpreted in numbers running from 0 to 10; that of Fig. 2 corresponds to the rating scale of "noisiness" used on the second day. The values plotted are the average judgments (r) of the whole group of listeners, each point representing a group judgment on one aircraft. The average was used rather than the median or mode simply because of the relatively coarse steps of the subjective scale. Jet aircraft, propeller-driven aircraft and helicopters are indicated by different symbols but it is apparent that no distinction need be drawn between the results for these classes.

To facilitate interpretation, curves have been fitted to the data points. In view of the arbitrary relation assumed between the steps of the rating scales and the natural numbers no particular mathematical relation can be expected between sound level A and average subjective judgment. The simplest curve which would reasonably fit the points, namely a function quadratic in the sound level, was chosen.* There are, perhaps, grounds for preferring a sigmoidal curve since no rating can be less than zero nor more than ten whereas the sound level scale can be imagined to extend far to the left and the right, but the important central region is rather insensitive to the choice of function.

The most important results emerge directly from Figs. 1, 2 and 3. For simplicity we consider first the intersections of the curves with the value $r=5$ (mid-point of the category scale). On Fig. 2 this corresponds to the value 92·8 dBA, which can be construed as the level that is just regarded as noisy by the average subject. Day 2 provided the nearest basis of comparison

* In the motor vehicle experiments the regression of sound level on subjective judgment was chosen, since this is appropriate to answering the question: what is the expected sound level corresponding to a given average judgment? However, the data points, probably due to their covering a smaller decibel range, were adequately represented by straight lines. In the present work a function of at least the third degree in r would be necessary in view of the sign of the curvature. The quadratic functions adopted represent, formally, the regression of judgment on sound level and should strictly be used to answer the question: what is the expected average judgment for a given sound level?

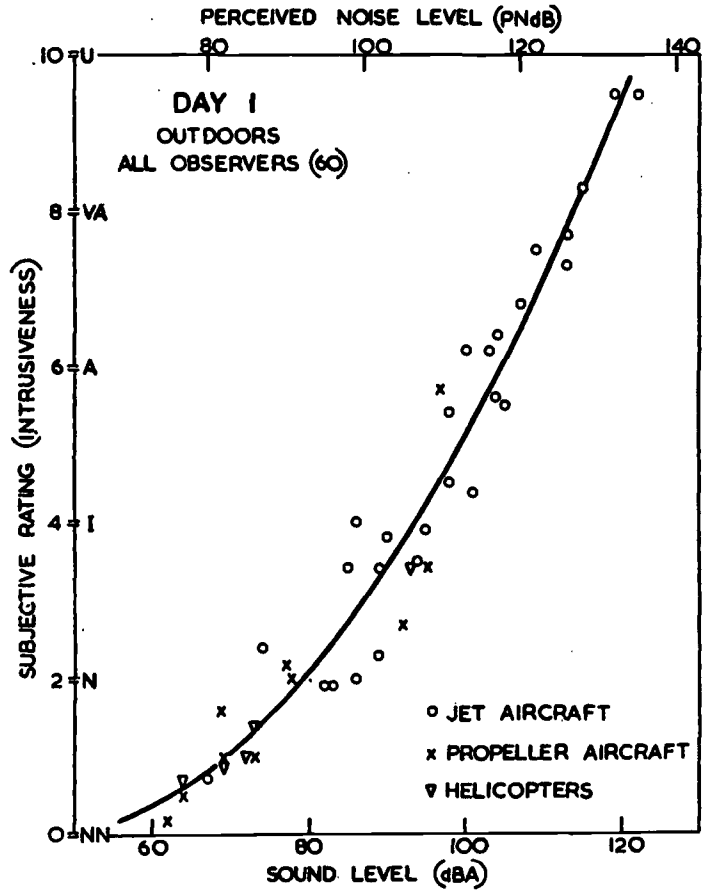

FIG. 1.

Outdoor judgments on the category scale of intrusiveness plotted against sound level A and perceived noise level

with the motor vehicle work, both as regards the scale used and the listening conditions. The present result of 92·8 dBA is, however, markedly different from the corresponding value for vehicles which was about 80 dBA. The probable reason for this is discussed later.

Considering next Figs. 1 and 3, the corresponding values of sound level A at r=5 are 99·5 and 81·7. These should not be compared directly with the result from the second day since a different rating scale was used, but the difference between them is of great significance. It must be remembered that these are the sound levels actually received by the listener. Superficially one might expect that people's judgments would depend primarily on the sound reaching their ears and the fact that the environment was different on the two days would not be expected to lead to the difference observed. Some critics might suggest that the listeners' attention was focussed to a greater extent on the distracting task indoors than outdoors; in these circumstances they would argue that a higher level of the intruding noise would be necessary to evoke the same response, contrary to the actual results. Others might say with equal force that the listeners were more interested in the content of the film commentary than in their outdoor activities and so more resentful of the intruding noise; this would lead to a difference of judgment in the observed direction. At least as regards the general trend we discount both these arguments. The first would require the curve to be flatter towards the high end (the listener is so engrossed as to be impervious to the intruding noise however loud). The other argument would require a steeply rising curve because any sound tending to mask the commentary would qualify for a high intrusiveness rating. In fact the curves on Figs. 1 and 3 are very nearly parallel, and taken together suggest a constant shift in judgment due simply to the change of environment. Possible explanations are discussed later but we note here that the results for Days 1 and 3 would fall much closer together if in the latter case the sound level *outside* the building were plotted.

6. DISPERSION OF DATA

Before discussing further the implications of the results it is appropriate to enquire into their reliability, for Figs. 1–3 show considerable scatter. Apart from objective measurement error, which can be disregarded in relation to other items, the total variance about the curves may be treated as being compounded of two principal sources, namely subjective uncertainty and a lack of correspondence between the objective measure (sound level A) and subjective magnitude.

In the case of motor vehicles, repeat tests enabled independent estimates of these sources of variance to be made, and the second of them was found to be the larger. Although it was impossible to contrive any replication in the aircraft tests, the following argument suggests that the same applies. First, the standard deviation of the judgments between different listeners was evaluated, for each test on each day. The root mean square of these values for Day 2 was 1·1 units on the r-scale. This is rather close to the value of 0·9 obtained with the motor vehicles and suggests a similar distribution of opinions in the groups, in spite of there being no more than 5 of the 60 listeners common to the two experiments. Noting that the total variance in the aircraft tests is much larger than with motor vehicles and that the smaller (between observers) component of both is about the same, we conclude that by far the largest source of scatter in the present data is in the horizontal direction on the diagrams. This is another way of saying that sound level A does not correspond uniquely with subjective impression, a proposition which is certainly true, since the limitations of the sound level meter are well known. On the other hand Fleming (ref. 5), Parkin (ref. 6) and others have shown that sound level A correlates reasonably well with calculated loudness level (provided comparisons are restricted to noises of not too dissimilar a character) and hence by implication with loudness levels determined subjectively. The work on motor vehicle noise, subject to the classification of vehicles into three

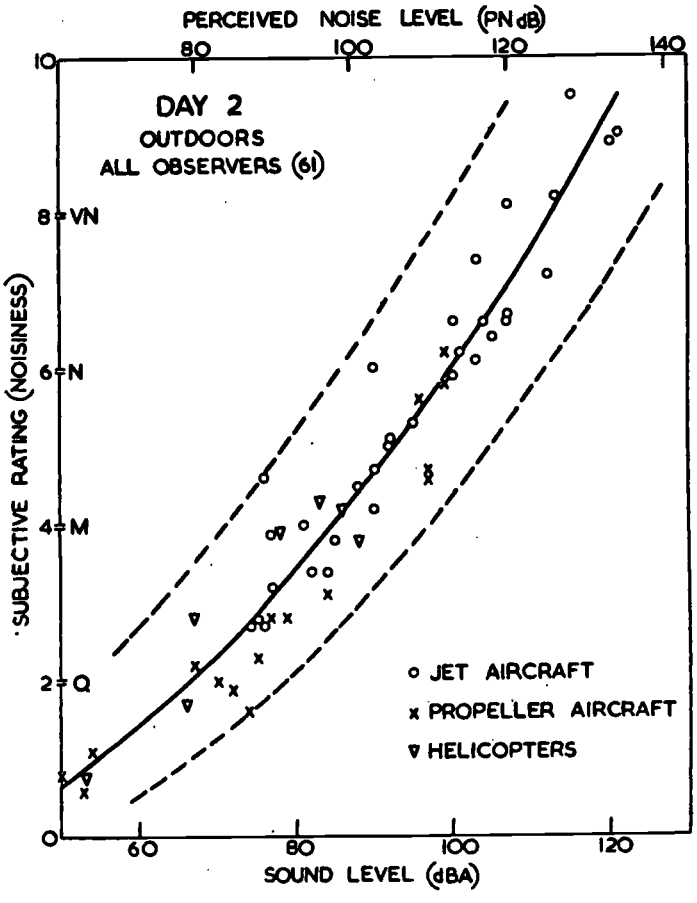

FIG. 2.

Outdoor judgments on the category scale of noisiness plotted against sound level A and perceived noise level

classes, also shows satisfactory correlation between sound level A and subjective rating. Our own work (ref. 7) on jet and helicopter noise showed that when these were equally loud in the average opinion of several hundred observers the values of sound level A varied by some 5 dB. From these observations we should not expect a spread of more than perhaps ± 5 dBA about the curves. Referring to Fig. 2 as an example, a considerably larger scatter is seen. It should be noted that the estimate of ±5 dB relates only to the comparatively simple question of correspondence between sound level and loudness level as though the signals were continuous and ignores the possible influence of duration and onset rate. These factors varied enormously according to the flight paths and the types of machine, and we could reasonably expect a somewhat larger dispersion. Another contributory factor was the difficulty caused (more particularly on the second day) by deviations from straight flight paths and unexpected variations of engine power on the part of some of the aircraft executing manoeuvres. One could not always be sure that the listeners judged the noise at the same epoch and in a few cases it was not easy to decide from the level recordings exactly which value to take as the maximum sound level A, for example when the judgment was interrupted by another fast-moving or noisy aircraft. On Day 3 a source of scatter was the background sound track of the films which inevitably had intermittent passages louder and quieter than the average.

It is unfortunately impossible to isolate the contributions to the total variance of all these factors, but an attempt was made to estimate the influence of one of them, namely the duration of fly-past. There is no well-defined theory for taking into account duration effects of noise nor do our data permit of exact analysis by partial correlation techniques. We therefore adopted the arbitrary principle of adding to the measured sound level a quantity $k \log_{10} t$, where t was the time in seconds between the " 5 dB-down " points read from the level recorder trace. The data points were then replotted with the modified abscissa $L = SLA + k \log_{10} t$. After one or two trials the value $k = 10$ was adopted as it had the simplest interpretation and was as effective as other values. The result of this is illustrated in Fig. 4 showing the data from Day 2; it is to be compared directly with Fig. 2. The dotted lines on the Figures just enclose all the points. The improvement in correlation is only marginal, shown by the dotted lines or, more formally, by the fact that the root mean square deviations about the curves are 4·3 and 3·8 dB respectively. This improvement is not significant by the " F "-test, but this may be due to the rather crude way of estimating duration.

7. EFFECT OF BACKGROUND NOISE

The results from Day 3 have been plotted in Fig. 5 in terms of a " signal to noise ratio ", i.e. the difference between the maximum value of sound level A indoors due to the passing aircraft and the average value of sound level A due to the film commentary prevailing at the time. The variations in the latter were comparatively small while spoken commentary or background music prevailed but in a few cases a test noise occurred during a quiet passage. Seven doubtful cases have not been plotted; for the remainder the background level varied from 52 to 77 dBA, the great majority being within the range 66–70. Comparing Figs. 3 and 5, therefore, many of the points are not shifted much in relative position. Of those that are, the most significant is perhaps the one having the value $r = 1{\cdot}5$. On Fig. 3 this is seen as a quite typical judgment, but on Fig. 5 it has moved to an extreme position on the right owing to the low background level during the judgment. The conclusion suggested by this is that the subjective judgments correlate less well with the " signal to noise ratio " than with the absolute level of the intruding signal.

It is interesting to note that the average judgment " noticeable " in Fig. 5 corresponds to a " signal to noise ratio " of −3·2 dB which is much as would be expected. On the other hand, in the light of the conclusion in the previous paragraph, this value may simply be a fortuitous consequence of the particular background level. We would expect that if the tests were repeated for different

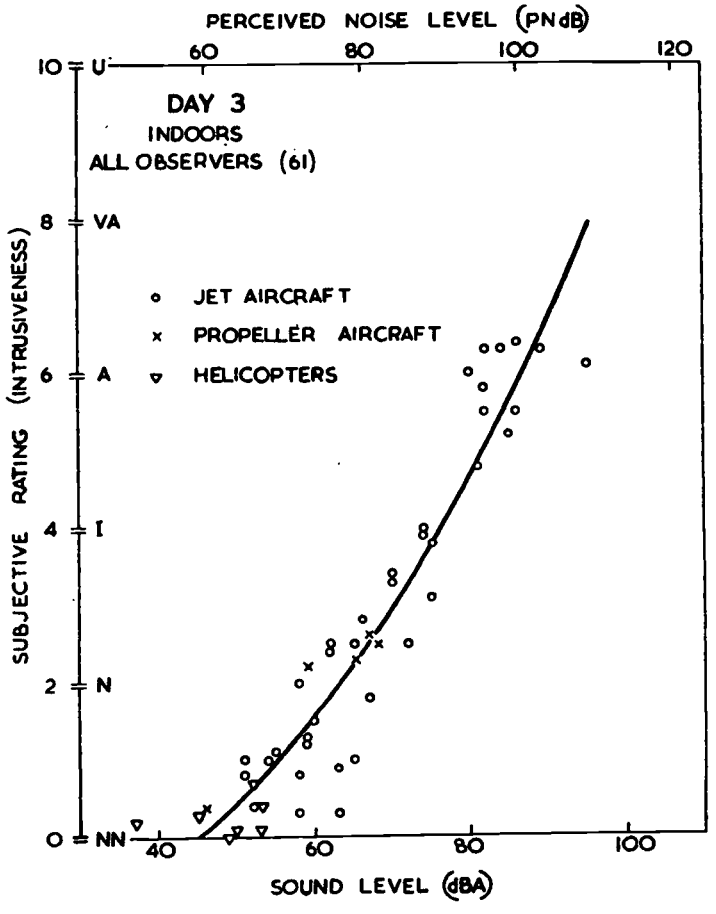

FIG. 3

Indoor judgments on the category scale of intrusiveness plotted against sound level A and perceived noise level

levels of the background the upper part of the curves would remain unchanged, whilst the foot would alter a little, becoming steeper as the background increased. In support of this, one may compare the shape of the curves of Figs. 1 and 3. If the latter is shifted 18 dBA to the right it will be found practically to coincide with the former from r=3 upwards.

8. EFFECTS OF AGE, SEX AND CONDITIONING

The results for each of the three days have been calculated for various sub-groups of listeners: (i) a simple division into two age groups at the median (37 years), (ii) men and women, and (iii) the three groups already defined in Section 2. Correlation curves similar to Figs. 1-3 were plotted but it is more convenient to compare them in tabular form and for this the intersections of the several curves with the rating values r=2, r=5 and r=8 are given in Table II.

TABLE II

Summary of results classified by age, sex and conditioning

Group of listeners	Sound Level (dBA)											
	Day 1				Day 2				Day 3			
	n	r=2 (N)	r=5 (JA)	r=8 (VA)	n	r=2 (Q)	r=5 (JN)	r=8 (VN)	n	r=2 (N)	r=5 (JA)	r=8 (VA)
A*	25	81·1	100·7	114·8	26	67·4	93·4	113·2	26	63·9	83·0	97·5
B	22	76·6	97·5	112·6	22	65·3	91·4	111·5	22	62·4	80·1	93·8
C	13	80·0	99·9	114·6	13	66·5	94·0	114·0	13	65·3	82·1	94·6
Men	42	78·7	99·5	114·3	44	65·3	92·3	112·7	44	62·8	81·6	96·1
Women	18	80·9	99·4	113·2	17	69·5	94·2	113·4	17	64·5	81·9	94·3
Aged 37 or less	31	79·1	99·0	113·4	29	67·1	92·2	111·6	31	63·1	81·5	95·6
Aged over 37	29	79·4	99·9	114·6	32	65·7	93·4	113·9	30	64·1	81·9	95·5
All	60	79·3	99·5	114·0	61	66·4	92·8	112·8	61	63·6	81·7	95·6

Key:

n = number of subjects in group

N = noticeable — Q = quiet

JA = just annoying — JN = just noisy

VA = very annoying — VN = very noisy

* A, B and C refer to groups with different conditioning, see Section 2.

The Table shows that there is no material difference between any of the groups, bearing in mind possible sampling error. Perhaps a little surprisingly, groups A and C are hardly distinguishable, yet, so far as it was possible to classify, these represented markedly different cases of residential conditioning to aircraft noise.

Whilst it would be imprudent to read much significance into distinctions of a decibel, much less of a fraction of a decibel, it is remarkable how the results

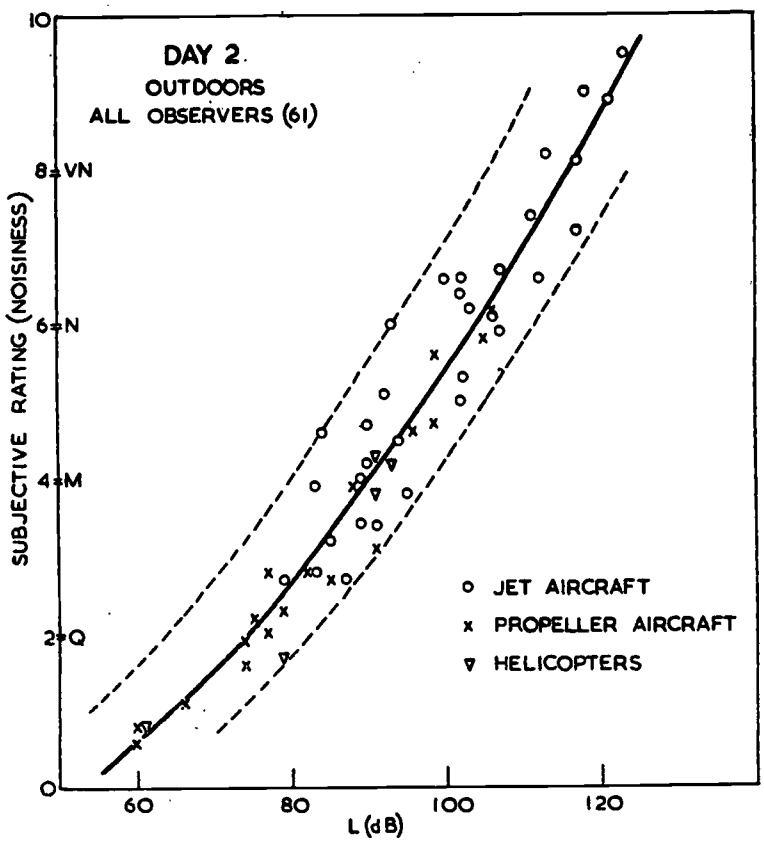

FIG. 4.

Outdoor judgments on the category scale of noisiness plotted against a combined measure of sound level and duration

in Table II mirror the findings of the motor vehicle investigation. This is illustrated by the following small but persistent effects:

Sound level A for r=5 (difference between males and females)

Aircraft tests	−0·7
Motor vehicle tests ...	−0·4

Sound level A for r=5 (young and old)

Aircraft tests	−0·8
Motor vehicle tests ...	−1·1

Range in sound level A between the values r=2 and r=8 (males and females)

Aircraft tests	+3·6
Motor vehicle tests ...	+2·4

Range in sound level A between the values r=2 and r=8 (young and old)

Aircraft tests	−1·2
Motor vehicle tests ...	−0·8

In the above comparisons the values shown for "aircraft tests" are the average over the 3 days; the values for "motor vehicle tests" are the average of those given in References 1 and 2.

The meaning of these results is that women are marginally more tolerant than men and the older group marginally more tolerant than the younger at medium levels, but the absolute differences are small enough to be discounted for all practical purposes. Slightly more significant is the result that the range of levels required to pass from "Quiet" to "Very Noisy" or "Noticeable" to "Very Annoying" is appreciably smaller for women than men (about 3 dB in 30).

As remarked in Section 2, the group contained a number of people whose professional concern with acoustics or aircraft might have unbalanced the judgments. We examined the results for three sub-groups, using as the criterion the average score over all tests on a given day. On this basis the seven "acousticians" tended to award a given noise a higher subjective rating, and the thirteen concerned in one way or another with aircraft a lower rating than the "lay" group. In the case of the seven, the difference from the average of the whole group was just about significant statistically. The results for the "lay" group differed from those of the whole group by about half a decibel on Days 1 and 2 and still less on Day 3. The results in the principal figures, therefore, are little affected by the composition of the group.

9. DISCUSSION

Comparison with the motor vehicle results is made in Fig. 6, showing the data from Day 2 and a composite straight line typifying the vehicle results (ref. 2). It has already been mentioned that there is a difference of some 13 dBA at the ordinate r=5 meaning that at the borderline of noisiness a larger noise level is tolerated from aircraft. However, considering the complete range of sound levels encompassed it is seen that this difference varies markedly, becoming zero at a "pivot-point" close to the levels accepted as "Quiet" for both. It is as though subjects make all judgments relative to a concept of "Quiet" and then judge any particular noise in relation to its position in the range with which they have become familiar. Since this is objectively greater in the case of aircraft (especially at the upper end) they change their scale-factor to fit the new circumstances. The same argument may account for the small but repeatable difference in slope of the straight lines fitted to the petrol and diesel vehicle data (ref. 2).

The results from Day 3 reveal a very interesting phenomenon. It was mentioned in Section 7 that if the results from Day 3 are shifted 18 dBA to the right they accord very closely with those from Day 1. This shift is of the order of magnitude of the transmission loss through normal building structures with

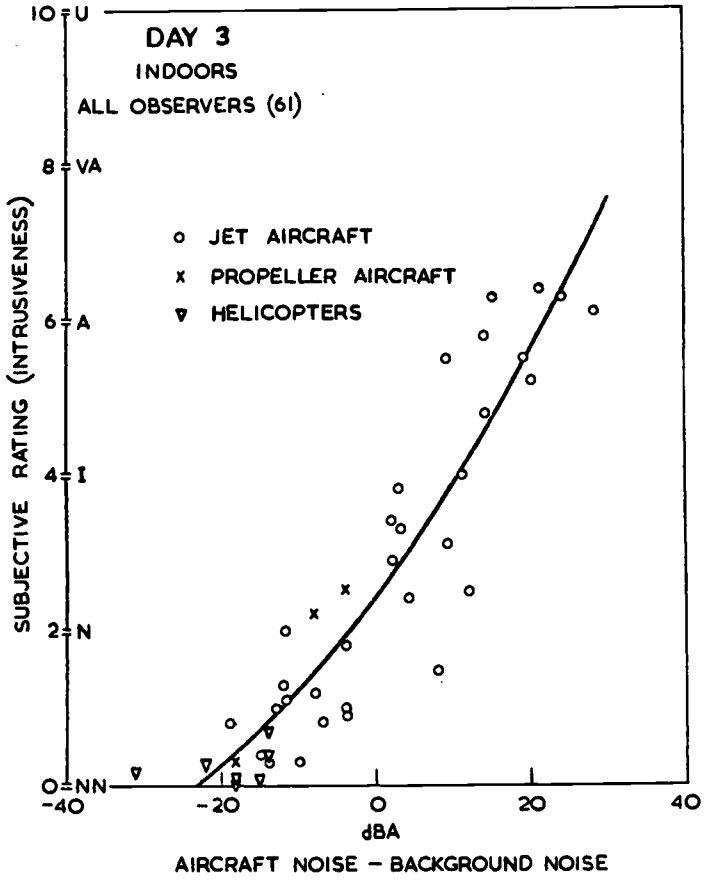

FIG. 5

Indoor judgments on the category scale of intrusiveness plotted against the difference between the level of the aircraft noise and that of the prevailing film sound track

closed windows. Expressed most simply, this might just mean that more stringent noise standards are required indoors than outdoors, i.e. that there exist in the mind distinct criteria separated in level by a value which corresponds to the subject's past experience of the transmission of sound into buildings. The allowance made will depend on the subject's appraisal of the type of building structure: he would allow more for a structure that is obviously solidly built than for a flimsy building. If this is the explanation, the results of tests carried out in rooms of similar appearance should always coincide, irrespective of the particular transmission loss and (within limits) of the locally-produced sound level.

We can look at this matter in another way. We note first that correlation between subjective rating and "signal to noise ratio" for Day 3 is inferior to that between subjective rating and actual level heard, so that the role of the sound track (except at the lowest levels of the intruding signal which are masked) can apparently be discounted. It is possible, then, to see the shift of 18 dBA arising from subjects projecting themselves, perhaps unconsciously, to the situation outside. It should be noted that the physical noise reduction was 23·9 rather than 18 dBA. It would be remarkable and of far-reaching implication if the compensation were complete, but the results suggest that it is nearer the truth to assume this compensation than to expect a building to alter the assessment of an external noise by the full amount implied by the measured reduction. The scatter of the data points in the present tests, though considerable, does not admit of Figs. 1 and 3 being equivalent. The observation that the inside noises were judged as though greater than they really were by 18 rather than 24 dBA would need further investigation to interpret fully; it is possible that partial compensation is the rule. The degree of projection may be assumed to depend primarily on preconditioning but with adjustment (possibly not total) to the apparent nature of the surroundings, e.g. a greater allowance would be made if the room is patently sound proof. On this assumption we should be able to deceive subjects by giving a false appearance of sound-proofing to a flimsy construction or vice versa, provided that due allowance is made for the possibility that change of spectral distribution may provide the clue. Indeed, in this experiment, the discrepancy between the 24 and the 18 may be due to the subjects not realising that the cinema was above average in sound insulation, having double windows. Experiments to test these ideas appear possible in principle. There are obvious practical difficulties but the feasibility of such investigations is being examined. We do not consider that the magnitude of the "transmission penalty" observed on Day 3 would necessarily apply in other circumstances or to general background noises of unidentifiable origin, but conclude that it is quite erroneous to allow for the full amount of noise reduction when estimating indoor effects from outside measurements of recognisable sounds.

We have finally to compare the results from Days 1 and 2, thereby obtaining a subjective relationship between the scales of intrusiveness and noisiness; this is shown diagrammatically in Fig. 7. It will be seen that at very high sound levels annoyance and noisiness become equated but at more moderate levels the scales diverge much in the manner that might intuitively be expected. For example "Intrusive" comes between "Moderate" and "Noisy", and the "Just Noticeable" level (say r = 1) corresponds, rather reasonably, to "Quiet". We conclude that the most intense aircraft sounds are annoying primarily because of their intrinsic noisiness (or loudness).

It may be objected that when presented with a scale of judgment and a succession of stimuli the subjects will automatically fill the space, so that the two scales cannot diverge very far. In spite of this, the mid-points are some 7 dB apart, a significant quantity. We should point out, also, that there chanced to be no extreme noises until nearly half-way through each test, yet the judgments for the first periods do not fill the range. If the tests had ended at half-time many of the points at the top and bottom would be lacking but the curves would be barely changed. Moreover, it is noticeable that the range was never filled on Day 3. We prefer to conclude that subjects judge each noise fairly objectively against a background of their prior experience.

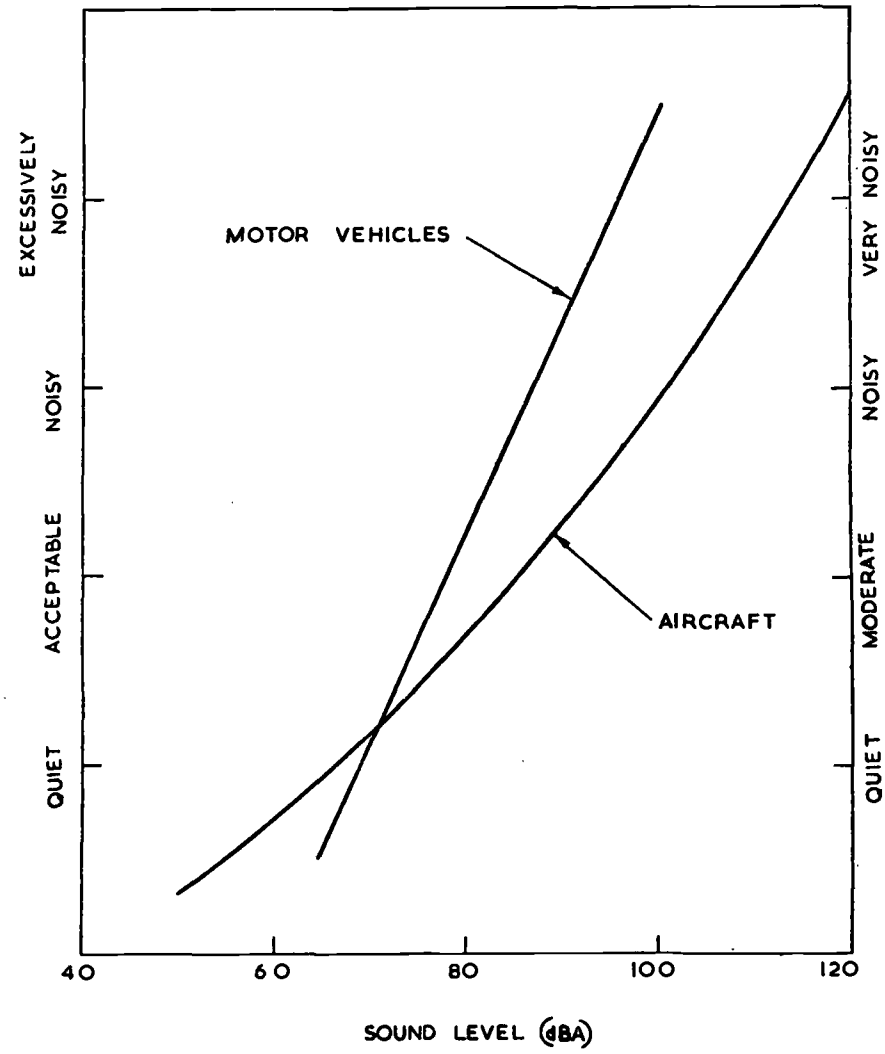

FIG. 6

Comparison on the category scale of noisiness of motor vehicle and aircraft sounds

10. RELATION OF RESULTS TO PERCEIVED NOISE LEVELS

The main results of this paper have been presented in terms of sound level with A-weighting to facilitate comparison with analogous experiments for motor vehicles. Since it is more usual when dealing with aircraft to use the " perceived noise level " scale we consider in this Section the relation between PNdB and dBA values for aircraft noises and summarise the principal results in terms of PNdB.

The relation between perceived noise level in PNdB and sound level in dBA is already known for a wide variety of spectra, and, although the numerical difference between these measures is obviously not a constant, it varies (for aircraft noise) only within limits which are small compared with the dispersion along the abscissa of the results of the present work as exemplified by Figs. 1 and 2. We therefore estimated an average difference between these measures taking into account the relative numbers of aircraft of different types. To determine such an average, 13 examples from Days 1 and 2 for which the recordings were most satisfactory were analysed into octave bands and the perceived noise levels calculated. These data were supplemented by a number of other typical aircraft noise spectra for which dBA and PNdB had been evaluated previously. They are also supplemented by over 230 examples calculated by Fleming (ref. 5).

Table III shows the resulting values, both mean and extreme.

TABLE III

Source of noise	PNdB—dBA			
	This paper		Fleming's data	
	Mean	Range	Mean	Range
Jet aircraft	12·3	10·7 to 14·4	11·9	8·8 to 15·6
Jets (approach)	12·1	10·1 to 14·0	15·3	10·4 to 19·5
Propeller aircraft	14·3	13·0 to 15·9	14·2	11·2 to 16·7
Propellers (approach) ...	16·0	15·4 to 16·7	14·7	13·1 to 17·3
Helicopters (piston) ...	13·6	11·8 to 15·5	—	—

Allowing for the actual numbers of aircraft movements (jets, pistons, fly-pasts, landings, etc.) the weighted mean differences between PNdB and dBA were found to be 13·1 from our data for Day 1 and Day 2 and 13·3 and 12·8 for Days 1 and 2 respectively from Fleming's data. The estimates from Fleming's values, however, omit the helicopters. We conclude that the round number 13 expresses the difference with sufficient accuracy for present purposes.

To determine the corresponding value indoors we took 13 typical examples of outdoor spectra, corrected them by the values of noise reduction in Table I, and evaluated PNdB and dBA for the resulting indoor spectra. For the examples selected the difference between these measures outdoors averaged 13·4; the corrected indoor values ranged from 11·6 to 18·1 with an average of 14·4. It is interesting to note that, although the change of spectral character was considerable, neither the individual PNdB–dBA differences nor their mean were much affected. We have adopted the value 14 to represent the difference on Day 3.

For convenience we have included along the top of Figs. 1, 2 and 3 the appropriate scale of PNdB. It might have been expected that the correlation diagrams would exhibit appreciably smaller dispersion if a complete analysis were carried through in terms of PNdB. However, an examination of a few points for which the exact difference was known showed that there was not a uniform tendency to reduce the dispersion, and for this reason we consider the approximate derivation of the PNdB–dBA conversion and the presentation of the data on a single diagram adequate.

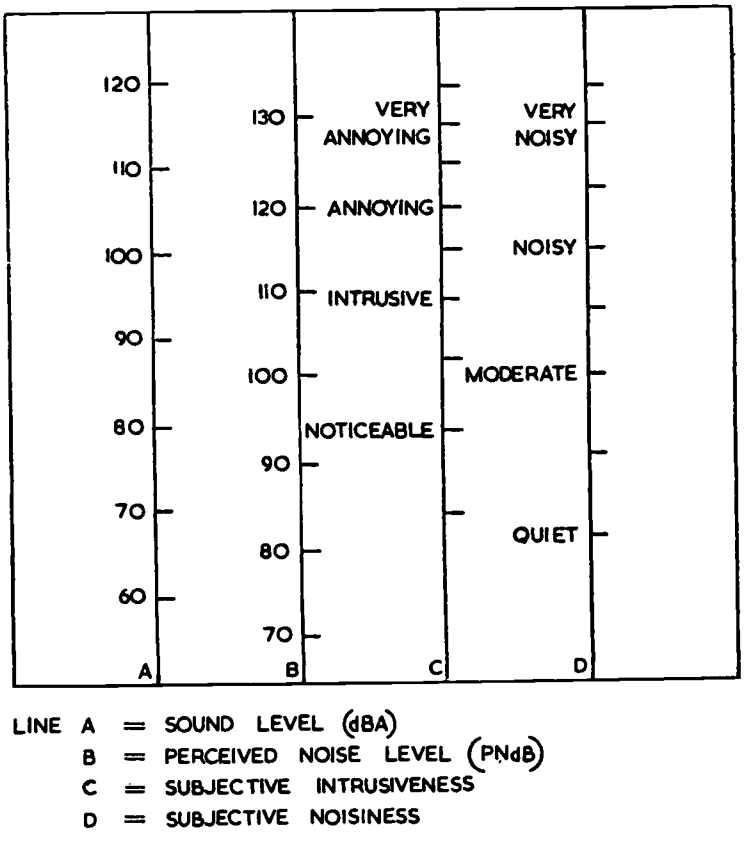

FIG. 7

Relation between the objective scales of sound level A and perceived noise level (PNdB), and the category scales of intrusiveness and noisiness

12. CONCLUSIONS

Tests carried out over three days with a group of 60 subjects using two different 6-point rating scales lead to the conclusions following:

(i) Aircraft and motor vehicles are both judged "quiet", for the same sound level at the ear, about 66 dBA.

(ii) At higher levels, subjects are more tolerant of aircraft than of motor vehicles, the difference amounting to some 20 dBA for the criterion "very noisy",

(iii) Judgments on the second scale devised to rate intrusiveness or annoyance when the subjects had a distracting task showed that the level for "very annoying" was the same as for "very noisy" in (ii). These judgments were called for *after* the event whereas the noisiness judgments were cued *in advance*.

(iv) The correlation between sound level and subjective rating was somewhat improved by making an allowance for transit time, but the evidence is insufficient to formulate a precise expression for taking duration into account.

(v) When the tests in (iii) were repeated indoors the same degree of intrusiveness occurred for a received sound level about 18 dBA less than outdoors.

(vi) No important distinctions can be drawn between judgments of men and women, younger and older age groups or the degree of conditioning to aircraft noise in the residential environment.

(vii) The above results are consistent with the argument, which might be put forward *a priori*, that subjects' judgments are made in relation to their previous experience.

(viii) One tentative explanation for conclusion (v) is that subjects make an allowance, presumably unconsciously, for the reduction of sound by building structures when they are inside.

(ix) A comparison of perceived noise levels (PNdB) and sound levels (dBA) for numerous aircraft noises shows that the two measures may be regarded as having a constant difference (about 13) with a variability which is small compared with the dispersion in the present results. This enables the present results to be read in either scale with comparable precision.

13. ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance of Mr. C. H. E. Warren and the Administration of the Royal Aircraft Establishment, who provided all the facilities at Farnborough under the code name "Exercise Peppermint", and of Miss C. Jenkinson and Miss M. Root (Mathematics Division, NPL) who performed the numerical analyses. The work described forms part of the general research programme of the National Physical Laboratory and the paper is published by permission of the Director of the Laboratory.

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APPENDIX XI

SOCIAL SURVEY IN THE VICINITY OF LONDON (HEATHROW) AIRPORT

PURPOSE OF THE SURVEY

1. The representations made by the various Residents' Associations and local authorities convinced us that London (Heathrow) Airport gives rise to a considerable amount of annoyance, but the evidence they gave was largely of a qualitative nature. Further, although there are detailed records of the complaints received by the Ministry of Aviation concerning the noise caused by aircraft using the airport, we did not feel that the evidence that they provided was sufficiently representative or precise for our purposes. We therefore asked the Central Office of Information to carry out a social survey for us to see what information could be obtained about the following subjects:

(*a*) all the direct effects of aircraft noise upon local residents and the proportion of people who experience each one,

(*b*) the extent of subjective annoyance caused, as distinct from direct (objective) effects,

(*c*) the characteristics of the noise which people find annoying with the proportion of people who are affected by each annoying characteristic if there is more than one,

(*d*) the extent to which people would be affected by a variation in any one of the characteristics of the noise,

(*e*) the socio-pyschological factors that affect the degree to which people are annoyed,

(*f*) the relative importance of each of these socio-psychological factors,

(*g*) the effect of a variation in each of the socio-psychological factors, e.g. whether it would be possible to vary the acceptability of noise of given characteristics,

(*h*) whether people get used to aircraft noise and if so over what period, and whether people who grew up with it will re-act in a similar manner to people who did not,

(*i*) whether there is a relationship between complaints and the period for which people have experienced aircraft noise of a given severity,

(*j*) whether aircraft noise causes people to move away from the area of a major airport and whether there are limits of aircraft noise beyond which people will move away from the area in sufficient numbers to distort the pattern of population remaining in the vicinity of an airport,

(*k*) any other data which would be necessary to a complete understanding of the interaction of aircraft noise and people's reaction to it, in such a form as to enable us to predict the result of a change in any variable.

2. The survey was carried out in September, 1961, and it covered all the residential districts within 10 miles of London (Heathrow) Airport.

METHODS EMPLOYED

3. In principle all that it is necessary to do is to measure the loudness and the duration of the noise and the number of aircraft to which a representative sample of the population is subjected, and to correlate these with the subjective reactions of the same people to the noise.

Objective Measurements

4. The physical measurements involved were carried out by the Ministry of Aviation at 85 typical locations spread over the whole of the built-up area covered by the enquiry. The noise of each of about one hundred successive

aircraft heard at any particular location was recorded on a tape recorder, so that data were readily available afterwards concerning such matters as the peak noise levels attained, the total number of aircraft heard, the noise level exceeded by 10 per cent. and by 50 per cent. of the aircraft, and the number of seconds during which the aircraft noise on average exceeded 85 PNdB and 95 PNdB. This comprehensive set of data could be used to define a large number of measures of "noise exposure." From the 85 sets of measurements it was possible to estimate the noise exposure of each of the nearly 2,000 people interviewed.

Subjective Measurements

5. In investigating the attitudes of people, psychologists have found that, where there is a strong emotional factor, there usually exists a general disposition to like or dislike a situation as a whole. This seemed likely to apply to people's reactions to London Airport, and though well established techniques exist for the measurement of general dispositions of this kind, it was necessary in this particular survey to separate out as far as possible the part played by aircraft in determining people's reactions to their surroundings. A questionnaire was therefore drawn up containing 42 questions which would probe different types of satisfaction and annoyance, and 1,909 people were interviewed. Of these people, 1,731 were chosen at random from the electoral registers, and 178 from a list of people who had complained about aircraft noise.

6. The questionnaire contained questions designed to discover what the persons interviewed liked and disliked about their neighbourhoods; the effects on them of aircraft, and other noise; their attitudes towards the Airport and its importance locally; and their attitudes to noise in general. Background information such as the age, sex and occupation of the persons interviewed was also obtained.

7. The survey was introduced to those interviewed as an investigation into living conditions in their area. It would have defeated the purpose of the survey if people had been told immediately that information about annoyance from aircraft was the purpose of the enquiry. Noise, as such, was not mentioned by the interviewer until question 11 was reached, and aircraft were not mentioned until question 13. The early questions could, therefore, be used to determine the informants' attitudes to their general living conditions, with noise of aircraft as one of many factors determining these conditions, while the later questions revealed in greater detail their specific attitudes to aircraft noise.

8. It would also have defeated the purpose of the survey if the people interviewed had known of it beforehand. The final question was, therefore, whether the person interviewed had heard anything about the enquiry before. Ninety-eight per cent. of them said that they had not.

The Scale of Annoyance

9. In order to answer some of the questions raised in paragraph 1 above, and in particular those concerned with the topics (*c*), (*d*), (*f*) and (*g*), it was necessary to establish a quantitative scale of annoyance and to use the most exact techniques available. It is, of course, possible to ask informants to rate the degree of annoyance that they feel with aircraft, and such ratings were in fact obtained in the answers to question 13B, which was "Does the noise of aircraft bother you very much, moderately, a little, not at all?" There are, however, limits to the degree of discrimination with which people can rate their own feelings, and there is no way of equating exactly the ratings of different individuals. Also, a certain amount of unreliability and bias may follow from the use of one question. This can be avoided by the use of several questions, but it is then essential to see that the proper techniques are employed when the answers to several questions are combined to give a single score.

10. Several alternative procedures were tried out, and the scale finally used was formed from the answers to the question 13B, and the five questions "Does the noise of aircraft ever (*a*) wake you up, (*b*) interfere with listening to T.V. or radio, (*c*) make the house vibrate or shake, (*d*) interfere with conversation, (*e*) interfere with or disturb any other activity, or bother, annoy or disturb you in any other way?" An informant scored one if he rated himself at

least a little annoyed by aircraft in question 13B, and an additional point for each kind of disturbance from aircraft—sleep, television or radio, house vibrating or interference with conversation—which he said annoyed him when it occurred. Only a few of the more extremely annoyed informants mentioned any kind of disturbance not in the prompt list, and these received an additional point.

11. The selection of the items and the degree of annoyance associated with each item was determined by the specialised technique known as the Guttman scale criterion. This ensured that the scale established was not an arbitrary one, but gave a continuous measure of annoyance.

12. The scale gave annoyance ratings from 0 to 6, but the number of people scoring 6 was so small that for most purposes they could be combined with those scoring 5. The answers to question 13B showed that the scale points 0, 2, 3 and 4 correspond approximately to the verbal categories "not at all," "a little," "moderately" and "very much" annoyed.

Methods of Analysis

13. From the physical measurements carried out, 14 different variables could be picked out as characterising the noise climate, and 58 socio-psychological variables could be found from the answers to the questionnaires. The inter-correlation of these variables was determined by means of a computer. It was found that the results could be considerably simplified because all the significant correlations with the physical variables could be reduced to two, namely those with the average peak noise level* of the aircraft and with the number heard per day.

14. The noise levels of the aircraft lay between 84 and 108 PNdB, while the number of aircraft heard per day varied from 1 to 110. The data were divided into eight groups according to the noise level and seven according to the number of flights, but in general this proved to be too fine a sub-division. For most purposes the observations were therefore aggregated so as to refer to four loudness ranges and three number ranges. The four loudness ranges were 84 to 90 PNdB, 91 to 96 PNdB, 97 to 102 PNdB and 103 to 108 PNdB, whose mid-points are 87, 93, 99 and 105 PNdB. The number ranges chosen were 1 to 9, 10 to 39 and 40 to 110 aircraft per day, in order to give roughly equal numbers of people in each range; the average numbers of aircraft in these ranges were 5·75, 22·5 and 81 per day. The distribution of the main body of the informants (that is, excluding the 178 known complainants) over the twelve cells determined by these noise levels and number ranges is given in Table I. It will be seen that the numbers of people in four of these cells are comparatively small (less than 40), and we have effectively only eight cells. This makes it difficult to separate out the variation of the informants' reactions with noise level and with number separately, since those districts with a high noise level tend to have a large number of flights, and, conversely, districts with low noise levels tend to have few aircraft. It was, however, possible to disentangle the two effects sufficiently (see paras. 15 and 16).

TABLE I

The number of informants classified by noise level and number of aircraft per day

Average number of aircraft (*i*)	Noise level in PNdB				Totals (*vi*)
	84–90 (*ii*)	91–96 (*iii*)	97–102 (*iv*)	103–108 (*v*)	
5·75	512	158	7	—	677
22·5	155	321	82	11	569
81	38	110	200	137	485
Totals	705	589	289	148	1,731

* See Glossary (Appendix II).

NOISE AND NUMBER INDEX

15. The annoyance ratings of the 1,731 people in the main sample are shown in Table II for the four noise level ranges and the three number ranges.

TABLE II

The number of people with various annoyance ratings classified by noise level and number of aircraft per day

(*i*) Noise level in PNdB	(*ii*) Average number of aircraft per day	(*iii*) Annoyance score						(*iv*) Average annoyance score	(*v*) Number people in in stratum
		0	1	2	3	4	5		
84–90 ...	5·75	230	128	113	5	5	31	1·1	512
	22·5	45	33	26	17	12	22	1·9	155
	81	5	7	2	7	10	7	2·8	38
91–96 ...	5·75	51	41	28	17	11	10	1·5	158
	22·5	90	64	55	45	35	32	1·9	321
	81	18	15	13	23	18	23	2·7	110
97–102 ...	5·75	2	1	—	3	1	—	2	7
	22·5	13	9	20	16	11	13	2·5	82
	81	20	22	38	26	30	64	3·1	200
103–108 ...	5·75	—	—	—	—	—	—	—	—
	22·5	1	—	1	5	2	2	3·2	11
	81	11	7	17	16	19	67	3·6	137

These figures show how individual are the reactions to noise—in the worst situations some people are untroubled by the noise, while some people are very disturbed by even a few comparatively quiet aircraft.

16. Table II shows the average annoyance of the people in each noise stratum, calculated by taking the arithmetic means of the individual annoyance scores. When these figures are analysed, it turns out that the average annoyance can be considered to be a function of one physical variable only and that this single composite variable can be taken to be the sum of the noise level in PNdB and 15 log N, where N is the number of aircraft per day. We have called the composite variable the "noise and number index," and the presentation of the results is considerably simplified by plotting the results of the survey as functions of this index. The argument leading to the above conclusion, which is one of the most important findings of the survey, is as follows.

Derivation of the Noise and Number Index

17. As stated in paragraph 13, it was found that annoyance varied with the average peak noise level of the aircraft and with the number of flights per day. There was obviously a possibility of a certain equivalence between a change in noise level and of number. One method of estimating this equivalence is to

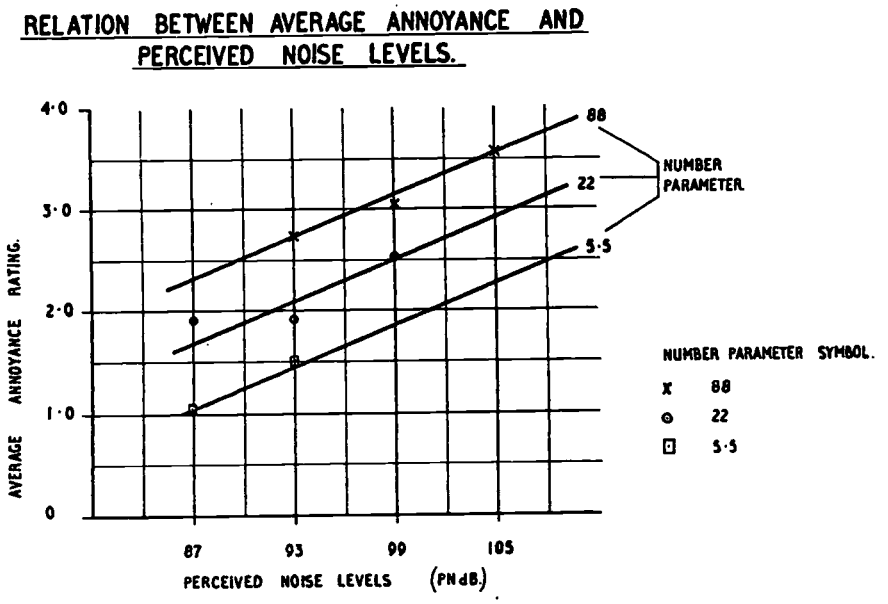

RELATION BETWEEN AVERAGE ANNOYANCE AND PERCEIVED NOISE LEVELS.
AVERAGE ANNOYANCE RATING.
4·0
3·0
2·0
1·0
0
88
22
5·5
NUMBER PARAMETER
NUMBER PARAMETER SYMBOL.
88
22
5·5
87
93
99
105
PERCEIVED NOISE LEVELS (PNdB.)

FIG. 1

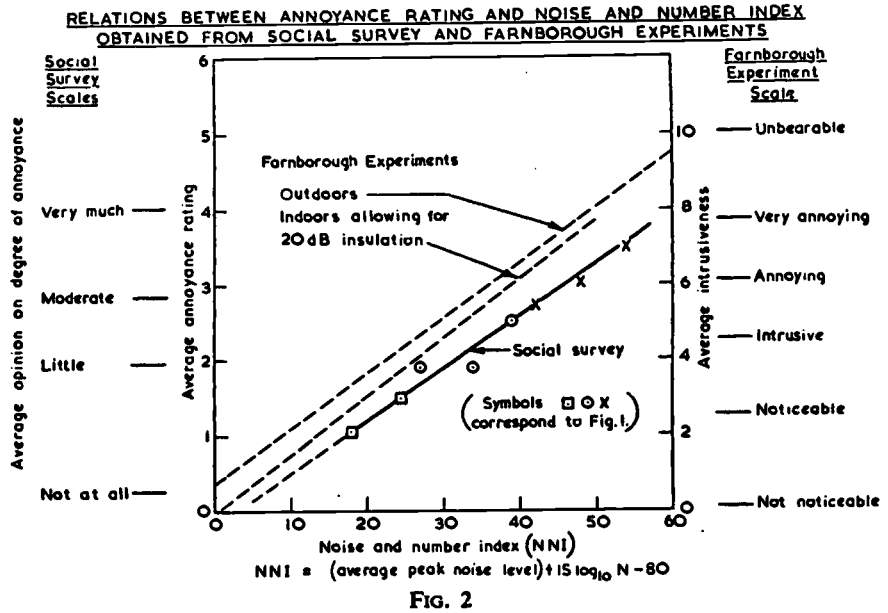

RELATIONS BETWEEN ANNOYANCE RATING AND NOISE AND NUMBER INDEX OBTAINED FROM SOCIAL SURVEY AND FARNBOROUGH EXPERIMENTS
Social Survey Scales
Farnborough Experiment Scale
Average opinion on degree of annoyance
Very much
Moderate
Little
Not at all
Average annoyance rating
Average intrusiveness
Farnborough Experiments
Outdoors
Indoors allowing for 20dB insulation
Social survey
Symbols ⊡ ⊙ X correspond to Fig.1.
Unbearable
Very annoying
Annoying
Intrusive
Noticeable
Not noticeable
Noise and number index (NNI)
NNI = (average peak noise level) + 15 log10 N − 80

FIG. 2

plot the average annoyance against noise level. This has been done in Figure 1.

18. The equivalence may be estimated by drawing through the points three straight lines having the properties that they are parallel, equidistant and fit the points well. This has been done in the Figure, in which, with only slight distortion, the values of the number parameter are taken as 5·5, 22, 88, i.e. they form a geometrical series of ratio 4 (c.f. para. 14). From the slope and separation of the lines it can be found that quadrupling the number of flights is equivalent to increasing the noise level by 9 PNdB. If the lines are drawn using the method of least squares giving a weight to the point in each cell proportional to the number of observations the same result is obtained.

19. The annoyance rating of the people interviewed appears to vary almost linearly with this total noise exposure figure, with zero annoyance at about 80 PNdB. We have, therefore, subtracted 80 from the total noise exposure figures expressed in PNdB, and called the resultant number "Noise and Number index" (NNI). In Figure 2 the average annoyance rating of each of the eight groups of people examined has been plotted against the corresponding NNI of these groups to show the close relation between annoyance and NNI.

Comparison with the "Farnborough Experiment"

20. During the Social Survey people were asked to give their own opinions on how much annoyed they were by aircraft noise. A relationship between these opinions and annoyance rating is described in para. 12. In Figure 2 the vertical scale is drawn in terms of this annoyance rating, and against it also are shown the various terms used to express people's opinions (column headed "Social Survey Scales").

21. During the Farnborough experiment (see Appendix X) terms in an ascending scale of "intrusiveness" were used to describe people's opinions. Since this is also a measure of annoyance the scale has been shown in Figure 2 (column headed "Farnborough experiment scale") in the appropriate position on the same vertical scale, certain assumptions about the spacing on this scale having been applied which are explained in the full account of the Farnborough work which is in course of separate publication. We may now use Figure 2 to compare the Social Survey and the Farnborough results.

22. Two experiments on intrusiveness were carried out at Farnborough, one indoors and one outdoors. The outdoor results can be plotted directly on Fig. 2 (since the noise level figures used in the Survey are those occurring outdoors) by adding 14 to correct from dBA to PNdB, the "number" contribution to the NNI being zero, as the judgments were made separately on each individual aircraft (i.e. $N=1$).

23. The indoor results can be used for comparison also if we assume that 20 dB is an average figure for the attenuation produced by a house with windows closed, corresponding to the conditions of the indoor Farnborough experiment. The three sets of NNI figures are plotted in Figure 2, and it will be seen that the agreement is quite good, considering the nature of the assumptions made, i.e. in these three very different sets of conditions the annoyance rating (an expression of public reaction to annoyance or intrusiveness) is smoothly related to the NNI (a number objectively derived from the measured sound levels and the numerical frequency of the disturbing sound).

THE EFFECTS OF AIRCRAFT NOISE

24. A detailed report on the data collected and some of the inferences which can be drawn from them will be published by the Central Office of Information. In this Appendix it is only possible to discuss a small fraction of the information available. We first discuss the direct effects of aircraft noise, namely interference with activities, and then go on to deal with the indirect effects of noise, the most important of which is the annoyance it produces.

Direct Effects

25. The direct effect of noise is that it disturbs activities of various kinds. The data concerning the percentage of people whose activities are affected by

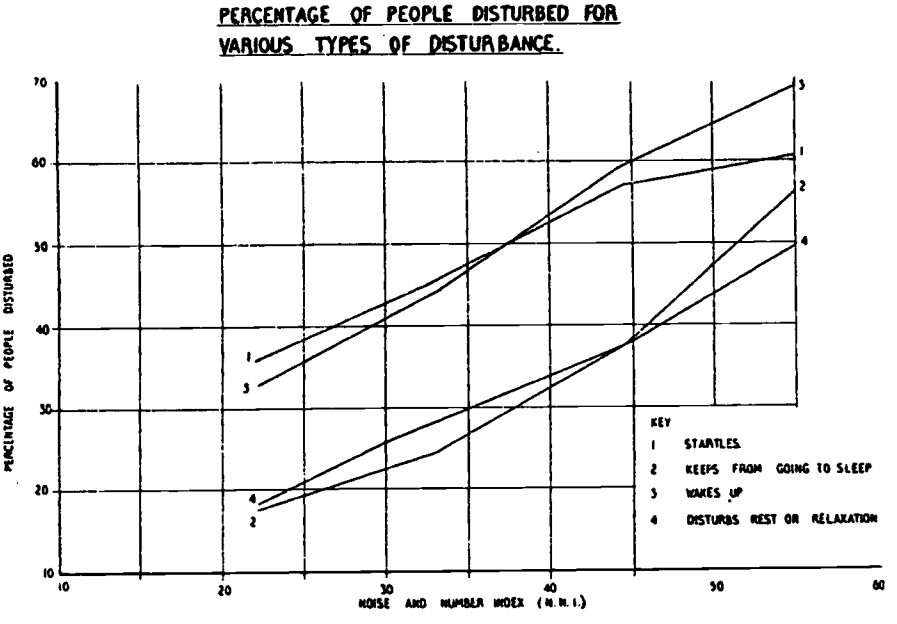

PERCENTAGE OF PEOPLE DISTURBED FOR VARIOUS TYPES OF DISTURBANCE.
PERCENTAGE OF PEOPLE DISTURBED
NOISE AND NUMBER INDEX (N. N. I.)
KEY
1 STARTLES
2 KEEPS FROM GOING TO SLEEP
3 WAKES UP
4 DISTURBS REST OR RELAXATION

FIG. 3A

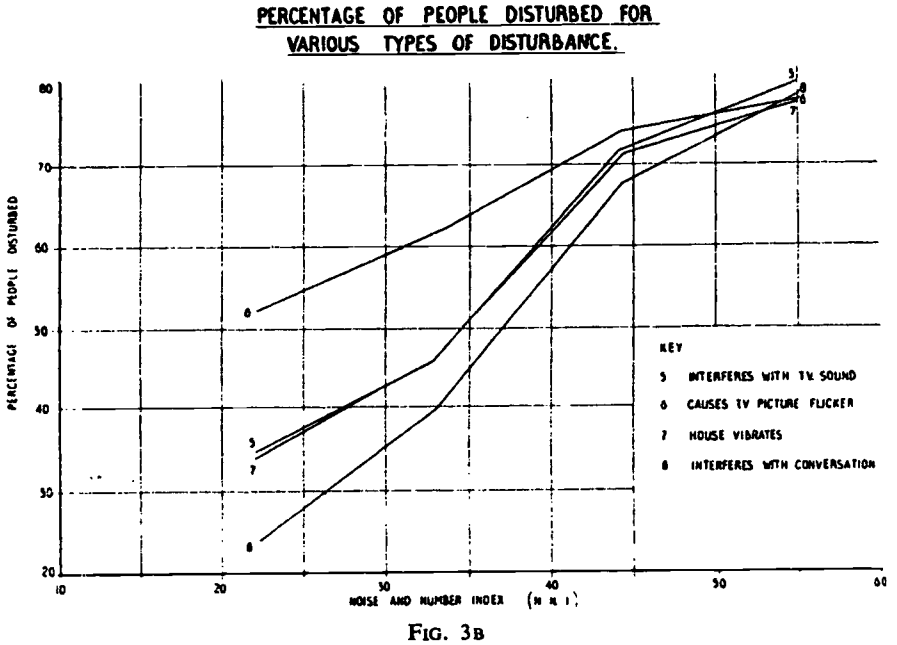

PERCENTAGE OF PEOPLE DISTURBED FOR VARIOUS TYPES OF DISTURBANCE.
PERCENTAGE OF PEOPLE DISTURBED
NOISE AND NUMBER INDEX (N. N. I.)
KEY
5 INTERFERES WITH TV SOUND
6 CAUSES TV PICTURE FLICKER
7 HOUSE VIBRATES
8 INTERFERES WITH CONVERSATION

FIG. 3B

aircraft noise are given in Figure 3. It will be seen that the curves for the various activities disturbed are more or less parallel. (The bending over of the curve relating to interference with television would be expected since in 1962 the national proportion of adults living in households with television sets was 82 per cent.)

Indirect Effects

26. The indirect effects of noise are all manifestations of annoyance in one form or other. Details of how aircraft noise affects people's attitudes near London Airport are given in Figures 4, 5 and 6. The data for these graphs were obtained in answer to the questions (*a*) "What are some of the things you dislike about living round here?" (*b*) "If you could change just one thing about living round here, which would you choose?" (*c*) "I have a list of things here. How would you rate this area for them?"

27. Further data were obtained in the answers to the questions "Do you find that you like living in this area more than you used to or not as much?" and "Have you ever felt like moving away from this area, and if so why?" The answers to these two questions are analysed in Figures 7 and 8. The percentage of people who liked the district less now than formerly was 24 per cent., while a considerably smaller percentage had ever considered moving away from the district.

28. These graphs all give us a measure of people's reactions to aircraft noise in comparison with their reactions to other sources of dissatisfaction, and we have used them in an attempt to estimate the point at which this exposure becomes unreasonable.

(*a*) We find that those who dislike aircraft noise outnumber those who dislike all the other things mentioned (spontaneously) when 53 NNI is reached. (Fig. 4.)

(*b*) Similarly those who would change aircraft noise outnumber those who would change all the other things mentioned (spontaneously) put together when 48 NNI is reached. (Fig. 5.)

(*c*) We also have a comparison of people's ratings of the area in which they live, under various headings, one of which is noise of all kinds. (Fig. 6.) Since these are prompted headings it is fair in this case to compare reaction to aircraft noise with reaction to any of the other individual items queried. These answers referred to noise of all kinds, and it was found in the survey that 15 to 20 per cent. of the population are disturbed by noise other than that of aircraft. If we subtract this percentage we find that rating of aircraft noise becomes worse than that of any other individual item at 50–54 NNI.

(*d*) We also have a comparison of the reasons why people like the area in which they live less than they used to (Fig. 7). Since the numbers of people concerned are small, all we can say is that whereas aircraft noise is one among many reasons at low NNI levels, at the highest level of 55 NNI it is dominant. Hence we have a limit somewhere below this figure.

(*e*) We have some similar comparisons of reasons why people felt like moving away from their area (Fig. 8). The numbers are even smaller than in (*d*) above, but the same arguments apply, and again we have a limit somewhere below 55 NNI.

29. Taking into account all the inevitable uncertainties of the above comparisons, we consider that exposure to aircraft noise reaches an unreasonable level in the range 50–60 NNI. Support for this conclusion comes from the fact that it corresponds roughly with the exposures judged to be "very annoying" in the Farnborough experiment, and at which people considered themselves "very much annoyed" in the Social Survey, and from the fact that Cranford, which is known to be a particularly sensitive area, is exposed to just these levels of NNI (see contours in Appendix XII).

NUMBER OF TIMES PER 100 PEOPLE QUESTIONED, THAT AIRCRAFT NOISE, AND OTHER THINGS AFFECTING LOCAL LIVING CONDITIONS, WERE DISLIKED.

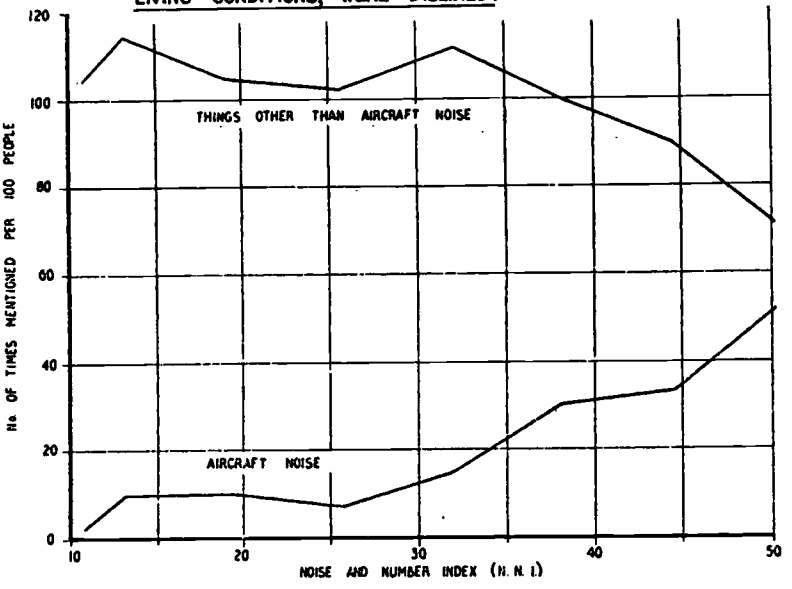


FIG. 4

PERCENTAGE OF PEOPLE WISHING TO CHANGE THEIR LIVING CONDITIONS.

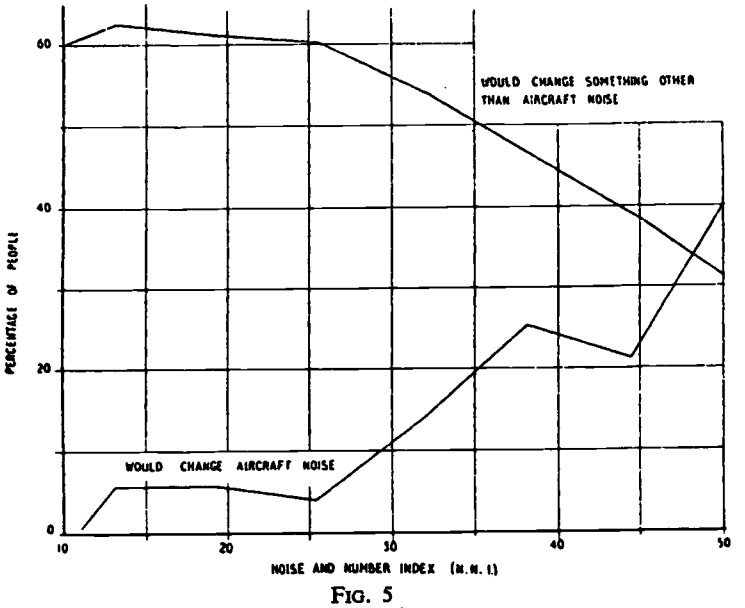


FIG. 5

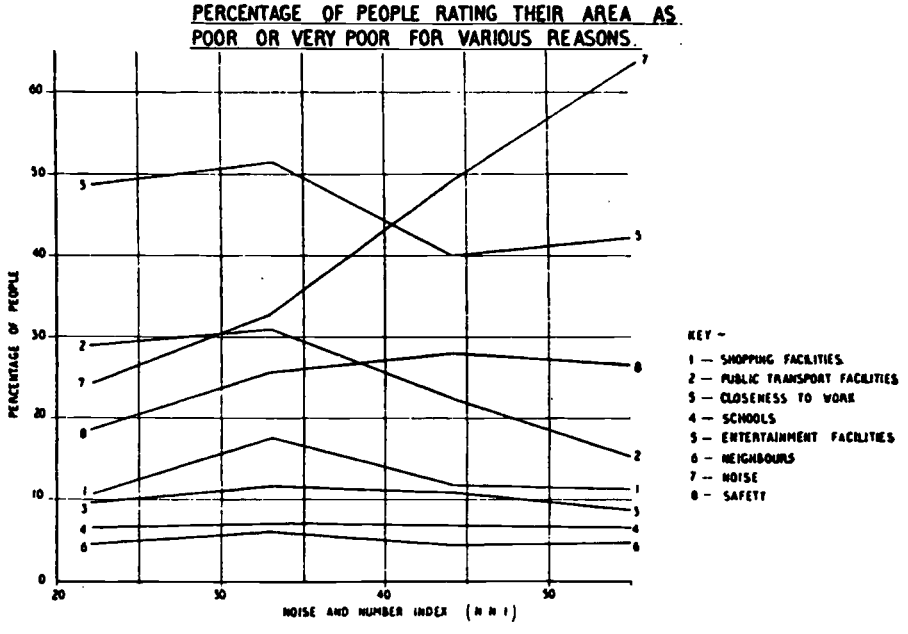

PERCENTAGE OF PEOPLE RATING THEIR AREA AS POOR OR VERY POOR FOR VARIOUS REASONS.
PERCENTAGE OF PEOPLE
NOISE AND NUMBER INDEX (N N I)
KEY -
1 — SHOPPING FACILITIES
2 — PUBLIC TRANSPORT FACILITIES
3 — CLOSENESS TO WORK
4 — SCHOOLS
5 — ENTERTAINMENT FACILITIES
6 — NEIGHBOURS
7 — NOISE
8 — SAFETY

FIG. 6

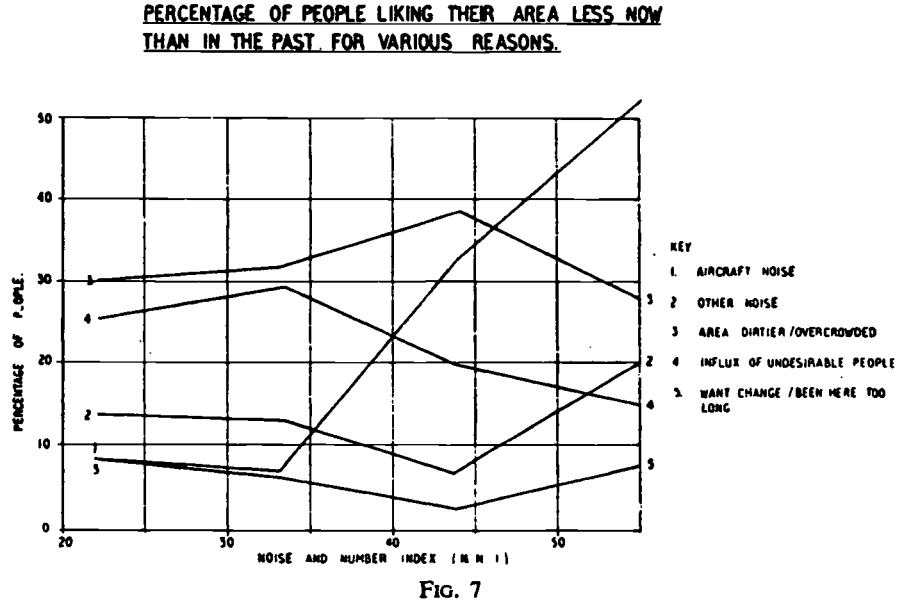

PERCENTAGE OF PEOPLE LIKING THEIR AREA LESS NOW THAN IN THE PAST FOR VARIOUS REASONS.
PERCENTAGE OF PEOPLE
NOISE AND NUMBER INDEX (N N I)
KEY
1. AIRCRAFT NOISE
2 OTHER NOISE
3 AREA DIRTIER/OVERCROWDED
4 INFLUX OF UNDESIRABLE PEOPLE
5 WANT CHANGE/BEEN HERE TOO LONG

FIG. 7

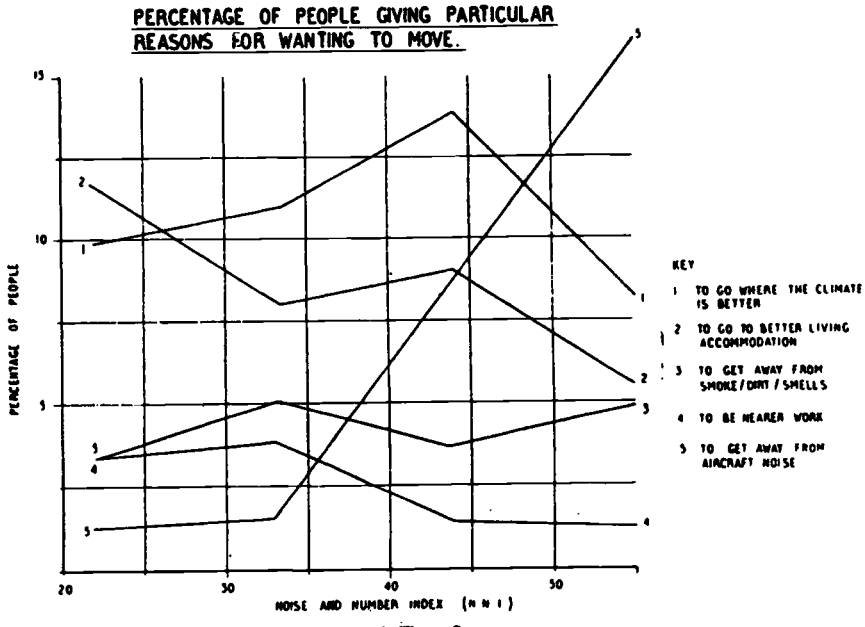

PERCENTAGE OF PEOPLE GIVING PARTICULAR REASONS FOR WANTING TO MOVE.
PERCENTAGE OF PEOPLE
15
10
5
20
30
40
50
NOISE AND NUMBER INDEX (N N I)
KEY
1 TO GO WHERE THE CLIMATE IS BETTER
2 TO GO TO BETTER LIVING ACCOMMODATION
3 TO GET AWAY FROM SMOKE/DIRT/SMELLS
4 TO BE NEARER WORK
5 TO GET AWAY FROM AIRCRAFT NOISE

FIG. 8

COMPARISON OF DAY-TIME AND NIGHT-TIME ANNOYANCE

30. We have so far made no distinction between day-time and night-time conditions in this discussion. Some work has been done on this subject in other countries but the results are inconclusive. We have, therefore, attempted to extract from the Social Survey some information which could apply to the area round Heathrow.

31. If we consider first the values of annoyance rating, we can say that these are some sort of mean of the annoyance experienced by day and by night. We have three pieces of evidence suggesting that the total annoyance caused to the population is roughly the same by day and by night :

(*a*) The answers to question 20 of the Survey show that about as many people are annoyed by day (24 per cent.) as by night (28 per cent.).

(*b*) The Survey also shows that plots of annoyance rating against NNI (as so far defined) for all the different day-time and night-time activities disturbed are all roughly the same.

(*c*) Analyses of complaints show that there are roughly the same number for day and night.

Hence any value of the annoyance rating of Figure 2 can be taken to represent either the day-time or the night-time annoyance value.

32. Considering now the values of NNI, these are in fact for the whole 24 hours, but under the present operating conditions almost identical values would be obtained for the 16 hours of day-time only. The numbers of aircraft and their average noisiness are so much lower at night that they barely contribute to the overall average. As a rough guess they are 8 NNI lower in respect of noise level (since the day-time and night-time limits at Heathrow are 110 and 102 PNdB respectively) and about 9 NNI lower in respect of number, i.e. about 17 NNI lower.

33. The 9 NNI arises from the fact that four times as many aircraft movements occur by day as by night. This figure is based on the records for some 3,500 movements at Heathrow made between 1st July and 8th August, 1961, i.e. just before the Survey. Since the original curve really represents day-time conditions we therefore draw the following conclusion.

If we assume that there is an exactly similar relationship for night-time conditions, it will be a curve some 15–20 NNI lower, which we can use in the same way as the day-time curve. For example for critical day-time levels of 50–60 NNI, the corresponding night-time levels are 30–45 NNI.

34. We must emphasise, however, that this particular conclusion concerning critical night-time noise exposure levels must be regarded as only a very tentative estimate, in view of the scanty evidence on which it is based.

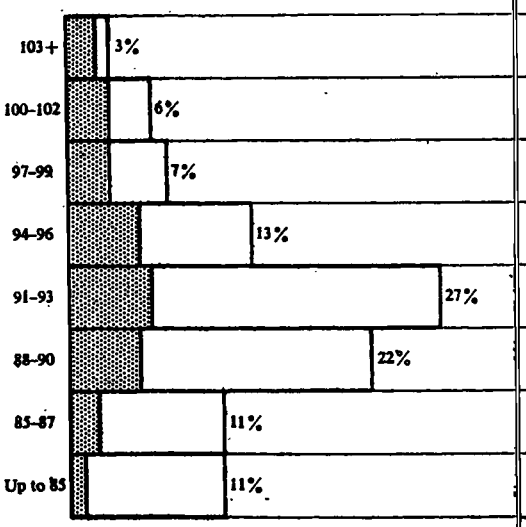
PERSONAL FACTORS AFFECTING AIRCRAFT ANNOYANCE

35. Before the survey was undertaken, it was clear that considerable variations could be expected in the reactions of individuals exposed to the same level of noise. Many of the complaints received by the airport authorities came from residents in regions a long way from the airport. On the other hand, it became obvious during the field work of the survey that, in areas very close to the airport, people who were very seriously annoyed frequently had neighbours who were very little or not at all concerned about aircraft noise.

36. In Table III overleaf the distribution of the adult population round London Airport over the various noise strata is shown, together with the number seriously annoyed in each stratum. (The criterion for being seriously annoyed is an annoyance score of 3·5 or more.) It will be seen that the average number of people seriously annoyed in the whole area is 27 per cent., but that, if individual strata are considered, the percentage of seriously annoyed people varies from 68 per cent. in the noisiest stratum to 10 per cent. in the quietest. This suggests that about 32 per cent. of these people are not seriously annoyed whatever the noise level is, and in confirmation of this 29 per cent. of all the

TABLE III

Data showing the distribution over noise levels of the total population, and the seriously annoyed in the population



PNdB Stratum (*i*)	Percentages			Absolute Numbers	
	% of total population in stratum (*ii*)	% of stratum seriously annoyed (*iii*)	% of total population seriously annoyed (*iv*)	Number of people seriously annoyed (*v*)	Number of people in stratum (*vi*)
103+	3	68	2	28,000	42,000
100–102	6	51	3	42,000	84,000
97–99	7	48	3	42,000	98,000
94–96	13	36	5	70,000	182,000
91–93	27	24	6	84,000	378,000
88–90	22	23	5	70,000	308,000
85–87	11	16	2	28,000	154,000
Up to 85	11	10	1	14,000	154,000
Totals	100	—	27	378,000	1,400,000

NOTES:
1. In the figure, the width of the column represents the total number in that PNdB stratum.
2. The shaded section represents the number seriously annoyed in that stratum.
3. Total in all strata is 1,400,000.
4. Total in shaded section is 27% of this, or 378,000.

NOTES:
1. For these data "seriously annoyed" refers to those having a score on the annoyance scale of 3·5 or above.
2. The population is that within a ten-mile radius of London Airport; 1,400,000 adults.
3. Entries in column (*iv*) are derived from those in columns (*ii*) and (*iii*); e.g. 68% of 3% gives 2% (rounded).
4. The numbers in column (*vi*) correspond to the percentages in column (*ii*), and those in column (*v*) to column (*iv*).

informants said that there was nothing they disliked in their area. These individuals (about 30 per cent. of the population) form a hard core of imperturbables who are present in about the same proportions in all the noise strata.

37. On the other hand, even in the quietest locations there are about 10 per cent. of people who are seriously disturbed by aircraft. In analysing the results of the survey, it was found that, the more things informants disliked about their areas, the higher their scores on the aircraft annoyance scale, and this is probably one reason why the number of people who are seriously annoyed by aircraft never falls below 10 per cent. even in the quietest area.

38. Some other suggestions to account for the apparently anomalous behaviour of the hard core both of " imperturbables " and of sensitive people are given in the detailed account of the survey.

ADAPTABILITY

39. One of the important questions to which we hoped to find an answer was whether people become less annoyed by aircraft noise as time goes on or whether they merely cease to complain about it. The answer to the question " Would you say you were more bothered by aircraft this year than in the past, or have you become used to the aircraft? " was inconclusive, since 34 per cent. of the informants said that they had become more used to aircraft, while 24 per cent. said that they had become more bothered by them. Moreover, for those informants with an annoyance score of 3·5 the two proportions are the same.

THE COMPLAINANTS

40. As mentioned in paragraph 5 a special sample of 178 known complainants were selected for separate study. The distribution of the complainants over the twelve noise strata is given in Table IV. It will be seen that the complainants are not confined to the noisiest strata, but are to be found at all levels of noise, and there is a substantial number of complainants in the cell with the lowest noise level and least number of aircraft. The survey shows that the complainants are not typical of the population at large; for example, the average annoyance score for all the complainants is 4·6, while the average annoyance score for the main sample who have the highest noise exposure is only 3·6. It is, however, found by a detailed analysis of the data that the complainants are reasonably representative of non-complainants who have the same high annoyance score, wherever they happen to live.

TABLE IV

The distribution of complainants classified by noise level and number of aircraft per day

Average number per day	Noise level in PNdB				Totals
	84–90	91–96	97–102	103–108	
(*i*)	(*ii*)	(*iii*)	(*iv*)	(*v*)	(*vi*)
5·75	20	7	1	0	28
22·5	9	37	9	0	55
81	7	35	37	16	95
Totals	36	79	47	16	178

APPENDIX XII

NOISE AND NUMBER INDEX AT LONDON (HEATHROW) AIRPORT

During the Social Survey made in 1961 in the vicinity of London (Heathrow) Airport, measurement of noise levels and studies of the numbers of aircraft likely to be heard were made throughout the area covered by the Survey. The results have been combined, on the lines described in Appendix XI to form a Noise and Number Index (NNI), and contours of NNI's of 50, 55, 60, 65 and 70 have been superimposed on a map of the vicinity of London (Heathrow) Airport in Figure 1.

Similar contours have been estimated for 1970, taking into account the expected increases both in the total number of flights and in the proportion of jet aircraft, and assuming that operating procedures will continue as at present. These contours are given in Figure 2.

It is emphasised that the contour lines give a rough indication only of the NNI at any particular point. Those for 1961 are derived from the evidence of the 1961 Social Survey by approximate methods and by making particular assumptions. Extrapolation of the data to 1970 involves further approximations and assumptions, and the whole should be interpreted as a rough guide only to the order of magnitude of the problem now and during the next seven to ten years.

APPENDIX XIII

THE PROTECTION OF ROOMS FROM OUTDOOR NOISE

(A NOTE BY THE BUILDING RESEARCH STATION)

This appendix describes a method of protecting single rooms from outdoor noise. While it is intended mainly for application in houses (living rooms or bedrooms), it could also be used for other types of occupation, such as small offices.

THE BUILDING PROBLEM

1. The problem of protecting rooms from outdoor noise turns mainly on providing an external façade to the building having sufficient sound insulation. But the noise level inside also depends to a limited extent on the amount of absorption normally provided by the furnishings and internal surface finishes. In large highly absorbent rooms the level may also vary with the distance from the windows. The insulation provided by the external wall is very strongly influenced by the amount of openings in the wall which are required for ventilation; in dwellings this is mainly a question of openable windows. The importance of this can be judged from the following figures. If an external wall has an opening or gap amounting to one per cent. of its area, then the noise reduction will be no more than 20 dB, even if the remainder of the wall is such as to provide very high insulation. If the opening is 10 per cent. of the wall area, the maximum noise reduction which can be expected is about 10 dB. A common proportion of opened windows to total external wall is in fact 10 per cent. although the whole window may frequently be about one-third of the external surface, so that, in a building with windows open for ventilation, not much more than 10 dB sound reduction can be expected.

2. With windows closed tightly, there is an improvement, although single glass windows are not as good for sound insulation as the more massive part of the wall. A wall of 9 in. brickwork with no windows or other openings will produce a reduction of about 50 dB. If windows take up one-third of the wall, the overall insulation falls to 25 dB; the windows if measured separately would give about 20 dB.

3. Experience of present noise levels indicates that the small reduction (10 dB) of façades with open windows is becoming less and less adequate as outdoor noise increases. Walls containing tightly closed single windows (25 dB reduction) are, however, probably enough for the great majority of cases, although in practice windows are not tightly sealed and a normal façade is not likely to give much more than about 20 dB. When required, there is no difficulty in increasing this insulation up to 40 dB by means of double windows. But the crux of the problem is that keeping windows (single or double) closed for long periods means providing some form of mechanical ventilation and perhaps air-conditioning.

DWELLINGS

4. In some buildings mechanical ventilation is now taken for granted. This applies to many auditoria and sometimes to office blocks (though not yet to most offices), but mechanical ventilation in dwellings is normally regarded as unacceptable, both on social and economic grounds. The installation and running costs of mechanical ventilation would add appreciably to housing costs. (Figures for installation costs for offices suggests an increase in cost in the range 20s. to 30s. per square foot of floor area. If corresponding figures apply to dwellings the cost would be £1,000–£1,500 for a 1,000 square foot house.) At the same time some dwellings are exposed to excessive noise at least part of the time (e.g. from aircraft, heavy road traffic or industrial plant), and the occupants may be willing to accept mechanical ventilation in order to obtain

relief from the noise. Even so, in most cases full house ventilation is either not necessary or cannot be afforded, and consideration has therefore been given to the ventilation and protection from noise of single rooms. Special ventilating units are now available commercially which are capable of giving adequate air changes for normal living rooms and bedrooms, are very quiet in operation, and are designed to reduce noise penetration to a degree that will match the noise reduction of ordinary but properly designed double windows. Two of these units were incorporated in trial measurements of sound insulation of windows, etc., recently conducted at the Building Research Station using a jet aircraft in flight as the source, and a further set of windows and units was installed in a house near London (Heathrow) Airport.

THE EXPERIMENT

5. Both the buildings used for the trials were of traditional load-bearing brick house construction, two-storey, with pitched tiled roofs. Measurements of noise reduction from outside to inside were made with single windows, double windows, and double windows with ventilator units. Precautions were taken to ensure that the penetration of sound into the room via indirect paths, such as doorways, would not exceed the transmission via the more direct path through the room windows or ventilator units, or (in the case of upper rooms) the roof structure.

6. At the Building Research Station the existing single windows were standard domestic-type metal windows in a pressed steel sub-frame, set close to the outer face of the 11 inch cavity brick wall. For the double windows an extra wooden window was fixed in the opening close to the inner face of the wall, giving an air space of 7½ in. between the double glazing. The reveals between the double windows were lined with sound absorbent tiles. The opening lights of the new windows were closed against sponge-rubber sealing strips. The metal windows were temporarily sealed by taping the joints of the opening lights.

7. The ground floor room treated in the house near London Airport had two sliding sash windows, one on each of two adjacent walls, and the first floor two wooden opening casement windows in the same positions as the ground floor. The extra wooden windows fitted throughout both rooms were on the inner face of the wall and were essentially the same as those described above for the previous installation. One ventilation unit was installed underneath the front wall window in each room.

8. The ventilating unit used is very compactly designed for the job it has to do, but it is nevertheless somewhat bulky for domestic use, being 3 ft. wide by 2 ft. 6 in. high by 11 in. deep. It consists of a metal cabinet which is fixed in the room against the external wall, simply by screwing into rawlplugs. It can be placed under the window if the window cill is more than 2 ft. 6 in. high. A horizontal slot has to be formed in the external wall about level with the top of the unit; this slot needs to be protected against rain penetration, etc., e.g. by a louvred grille. A makeshift covering of expanded metal was used for the tests. The unit contains a dual-speed electric fan drawing air into the room through a narrow duct designed for high noise attenuation at all frequencies, with variable control of recirculated-to-fresh air proportions, and an electric heating element to warm the air when required. The installation only required wiring up to the electrical supply (10–15 amp.). A diagram of the double windows and the ventilator unit is shown in Fig. 1, and sketches of the general appearance are given in Fig. 2 for the installation at the Building Research Station. The installation in the house near London Airport was essentially the same in all material respects.

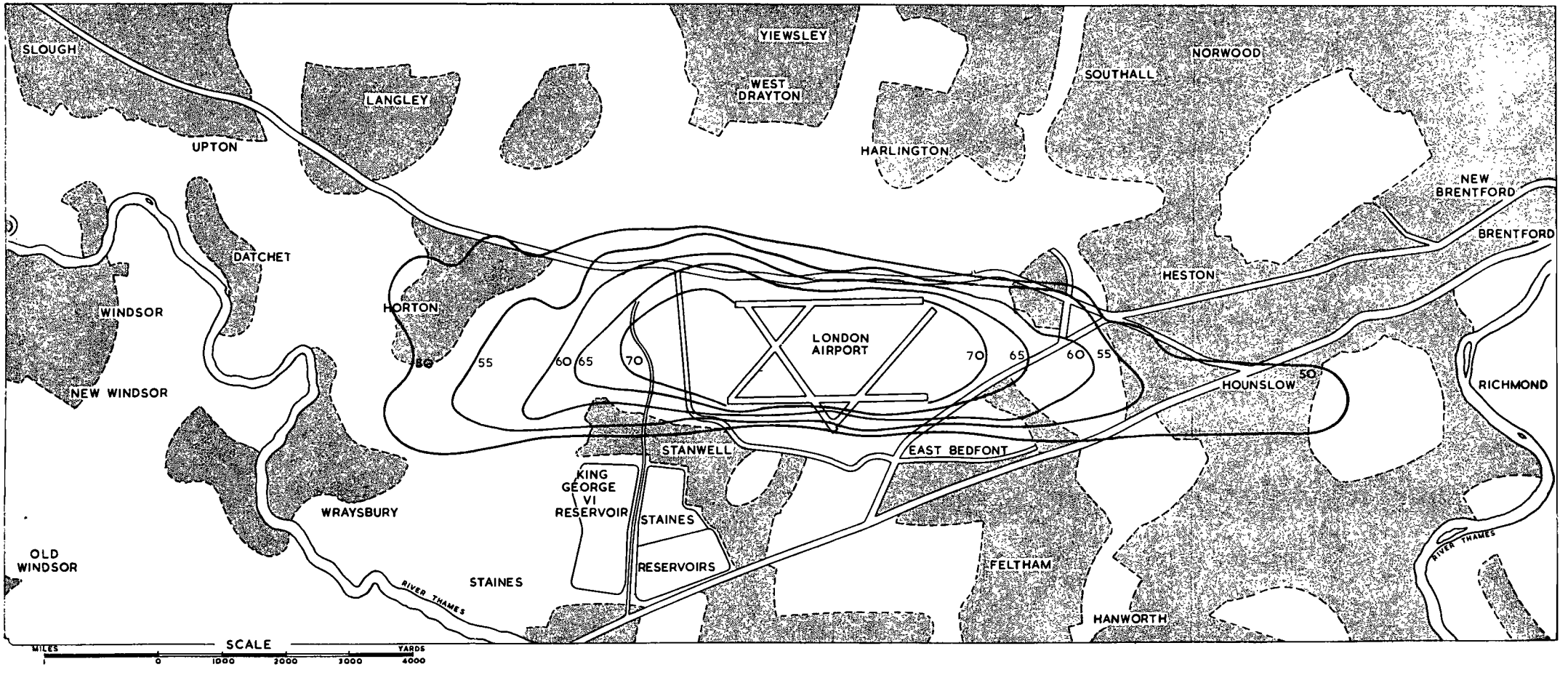
CONCLUSIONS

9. The following conclusions can be drawn from the test results:

(*a*) the special ventilator and a normal double window when built into an ordinary room in a dwelling house give about the same sound reduction, the average net reduction over the frequency range shown being of the order of 40–45 dB (Fig. 3). This applied also in the rooms containing two windows;

APPROXIMATE NOISE AND NUMBER INDEX 1961

FIGURE 1



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ESTIMATED NOISE AND NUMBER INDEX 1970

FIGURE 2

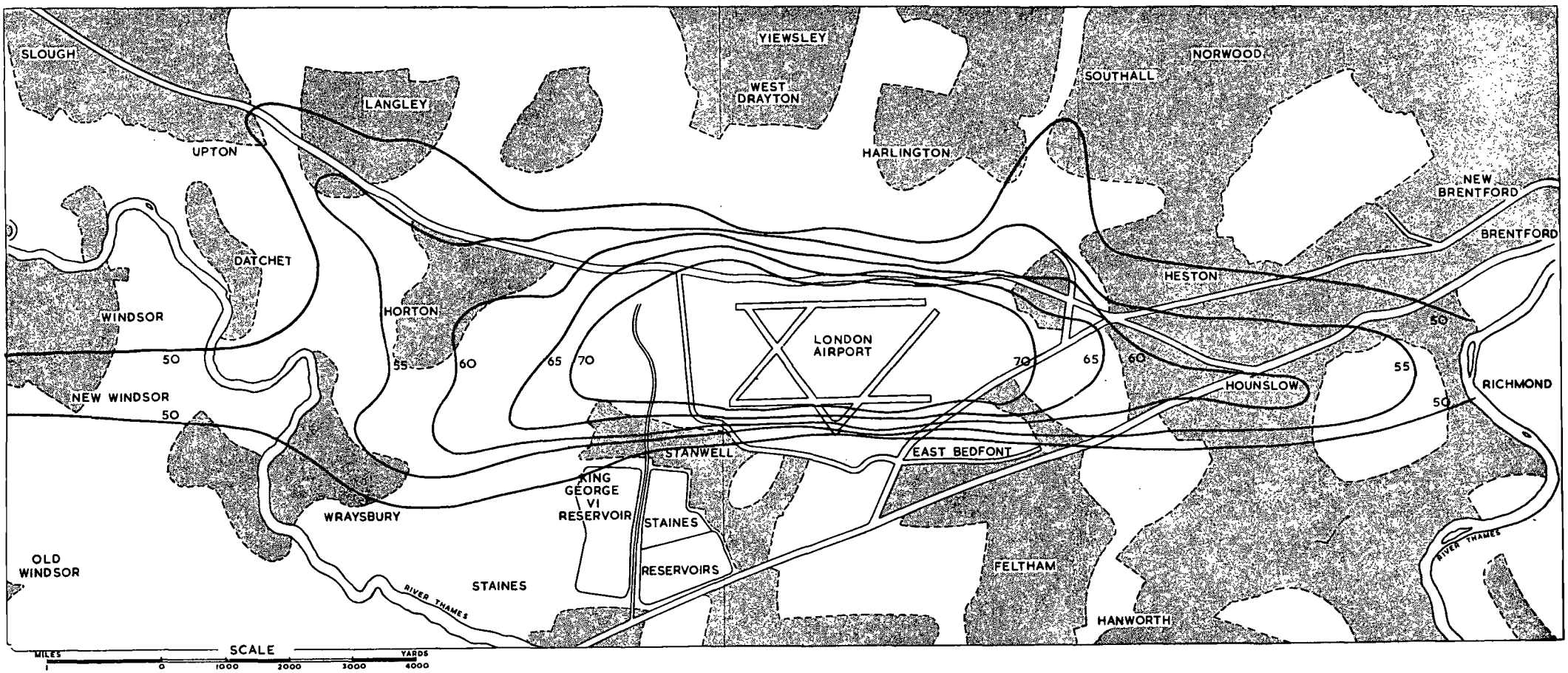


DIAGRAM OF MEASURED INSTALLATION

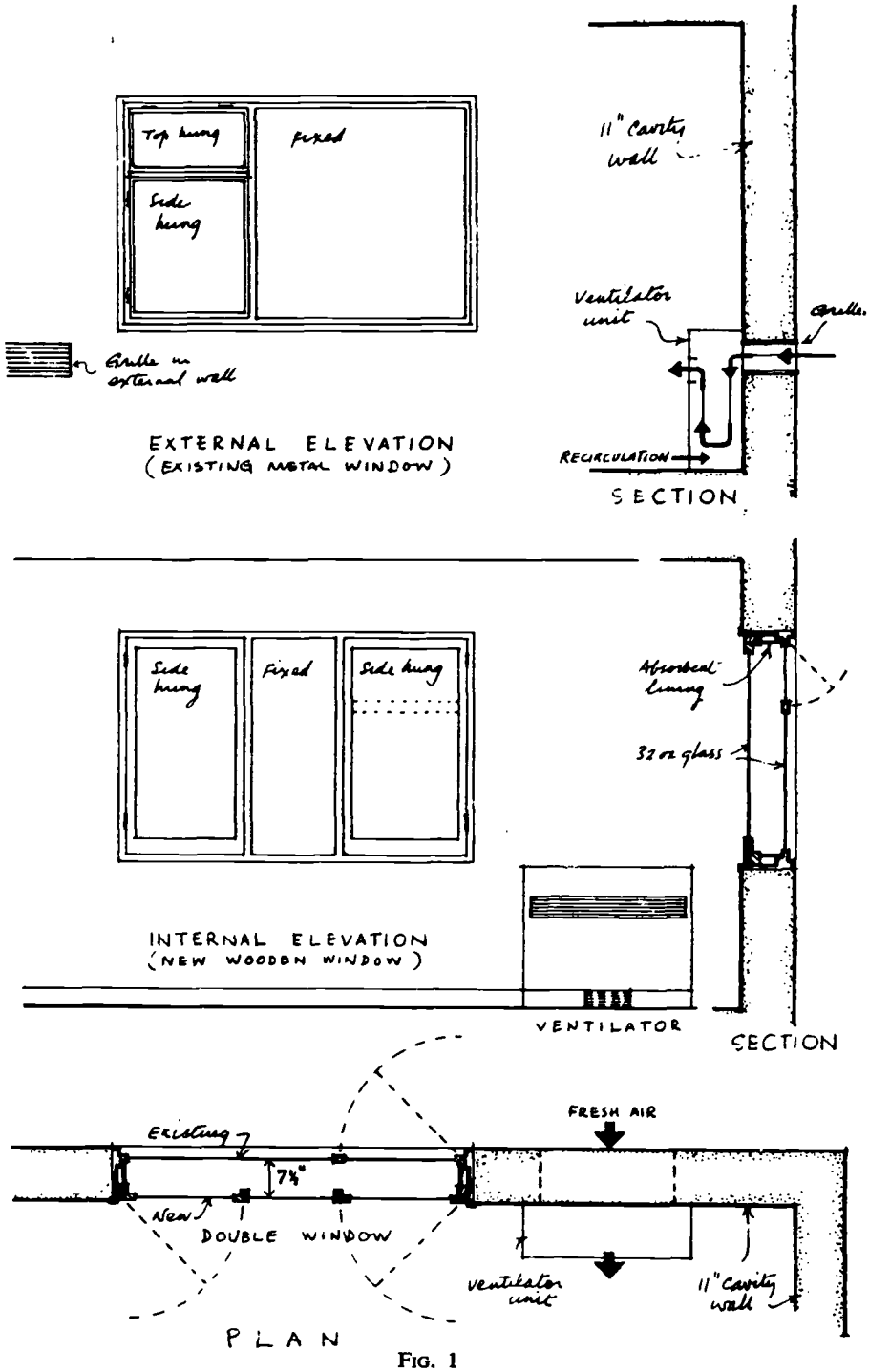


FIG. 1

SKETCHES OF MEASURED INSTALLATION

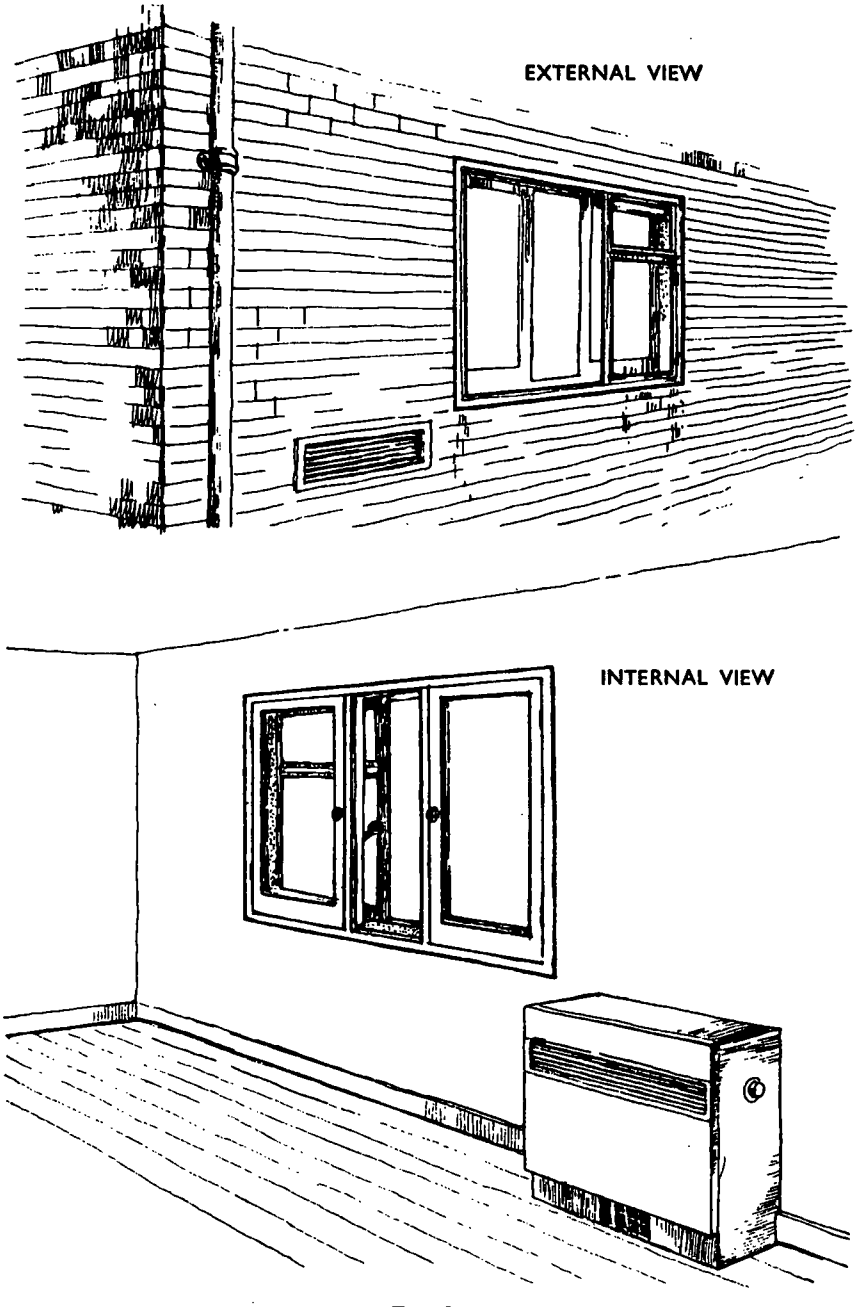


FIG. 2

(*b*) for purposes of comparison the wall with the existing single windows gave about 25 dB reduction with the windows closed and 10 dB reduction with the windows open in both buildings (See Fig. 3);

(*c*) the insulation of an ordinary tiled roof with a plasterboard and plaster skim-coat ceiling below is of the order of 35 dB, which is less than the full potential of either the unit ventilator or a proper double window, but is better than a single closed window. Thus the installation of the ventilator and double window in a top floor room of a house is beneficial, but less so than in a ground floor room;

(*d*) care must be taken to avoid any other outdoor noise paths into the room of greater sound transmission than the ventilator and window, otherwise the latter will not be fully effective in reducing the noise. A possible path is the chimney of an open fire. The effect of one chimney serving an open fire was investigated, that of the ground floor room in the house near London Airport. Here the noise levels in the treated room were 3 dB greater with the chimney free than with the chimney blocked, with aircraft as the sound-source, i.e. just appreciably louder. It would be less with a closed stove but not necessarily negligible. In the upstairs rooms the chimney length would have been shorter, but the insulation is already limited by the roof structure;

(*e*) through-living rooms with more than one window would need to have each window made double. Extra difficulty would arise in the case of french doors, which would also have to be double. The presence of two windows in a room does not necessarily mean that two ventilator units will be required; a single unit of the type used is adequate for winter ventilation needs of rooms up to 2,000 cu. ft. volume or more, and would probably serve for most summer requirements also if the general conditions are satisfactory; and

(*f*) it should be borne in mind that this ventilator unit is not a full air-conditioner, i.e. it has no cooling and only the simplest form of filter. The maximum rate of air change it can give in a normal living room of about 1,500 cu. ft. is about ten changes per hour, but this (or any lesser rate) can only be obtained if adequate outlets from the room are provided. Fig. 4 shows the ventilation performance of this unit in terms of the effective free area for the air outlet. This free area is normally made up of many small cracks at floor level and around doors. In normal traditional housing this escape of air through floor and door may be expected to be adequate, but in more tightly sealed rooms it might be found necessary to provide for extraction by fan and absorbent-lined duct into a well-ventilated part of the house. An expensive alternative would be to have a second ventilator unit working in reverse flow to the outside air.

COMMENTS

10. There should be no difficulty in designing new houses with double windows and ventilator units in one or more rooms. The problem of installing the treatment in existing houses will vary, but should seldom present serious difficulty. Bay windows will obviously make the installation of double windows more costly. Otherwise the chief difficulty of double windows occurs when the existing window is not close to the outer face of the wall; as the airspace between the glazing should not be less than six inches, though eight inches is desirable, the existing window may have to be moved to the outside of the wall. In some cases when standard metal windows are encountered, the new internal windows can be similar standard types but inward instead of outward opening. Occasionally the existing windows may be unsuitable (e.g. pivot hung) and may need to be replaced. In all cases, new and old, the need to avoid alternative transmission paths (e.g. airbricks, chimney flues, open-jointed or lightweight roof construction, over-ventilated wood-joist ground floors, etc.) must not be overlooked.

11. Houses do not normally have mechanical ventilation, and it may be that a little time may be required for occupants to become accustomed to the new conditions which the method described above will produce. The treatment of

SOUND INSULATION OF (a) DOUBLE, (b) SINGLE, AND (c) OPEN WINDOWS

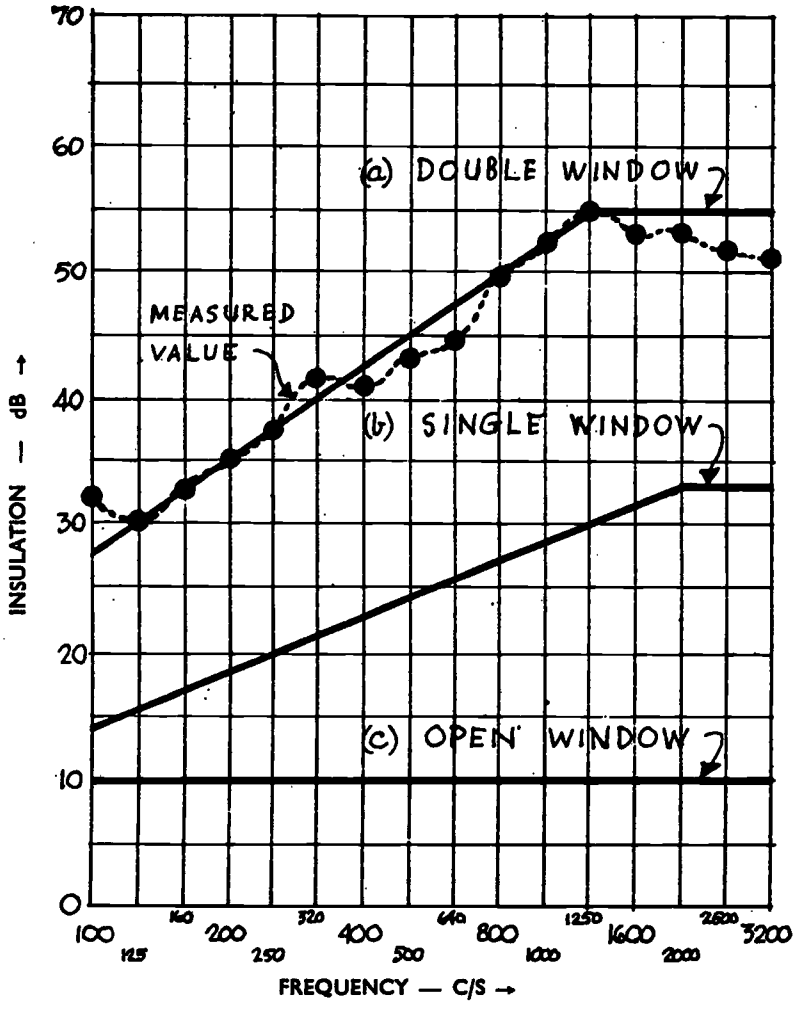


FIG. 3

FLOW CHARACTERISTICS OF VENTILATOR UNIT

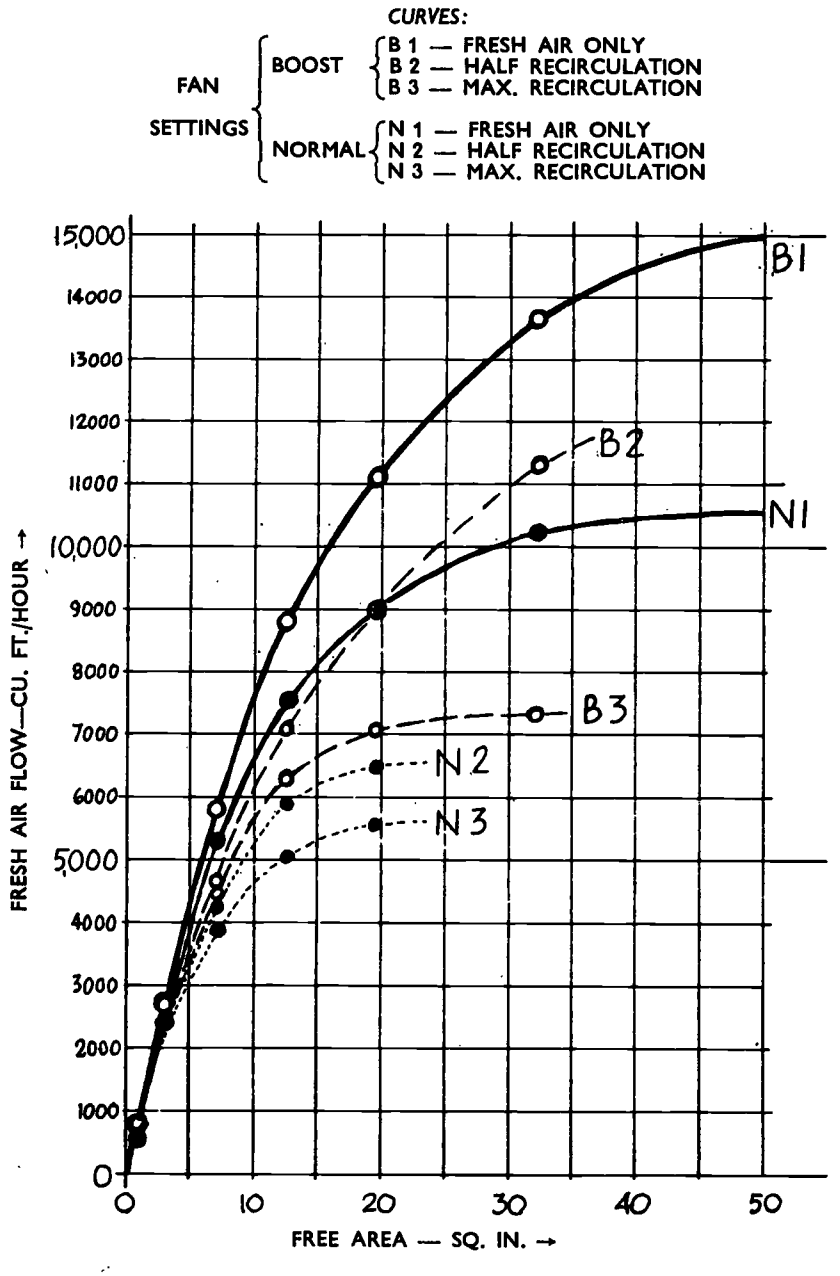


FIG. 4

single rooms will give occupants the opportunity of constantly comparing treated and untreated rooms, and this should lead to the maximum appreciation of the noise protection offered. The windows have been made openable mainly to allow ease of cleaning, and it will be better if the number of occasions on which they are opened are limited to those needed for cleaning because it is important that the windows should retain a tight seal when closed. However, for those who continue to prefer open window ventilation, the windows can always be opened if desired, during temporary periods of quiet. Windows which open *inwards* are a rarity in this country and therefore occupants may need to adjust their disposition of furniture, curtains and small decorative pieces to suit. Such windows are quite common in dwellings abroad.

APPENDIX XIV

SOME DATA ON NOISE FROM HELICOPTERS

(A NOTE BY AVIATION OPERATIONAL RESEARCH BRANCH, MINISTRY OF AVIATION)

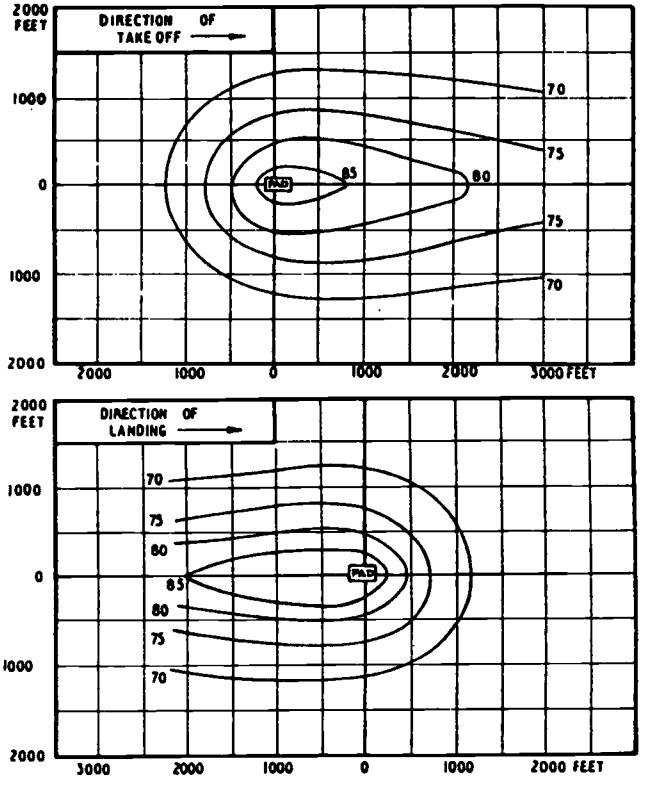
The twin-rotor Belvedere may be taken as typical of the larger helicopter that might be used in city centre operations.

The results of extensive systematic measurements on the distribution of noise around a Belvedere helicopter when it is taking off and landing, and also beneath the flight path when it is cruising, have been published in Ministry of Aviation Operational Research Note No. 133 by J. G. Roberts, P. Mahoney, R. Barfield and B. Atkinson. These results reflect the operating procedures in use when the tests were made (November, 1961).

In the table below are given the maximum noise levels heard by an observer immediately below the flight path when the aircraft is cruising at constant height.

Cruising Altitude (Feet)	Sound Level dBA	
	Mean	Range
500	81	79–82
1,000	74	73–75

The distribution of noise around a Belvedere helicopter taking off or landing is best shown as a set of contours. These have been given in the figure overleaf. The noise level for each point is the maximum heard during the operation.



Contours of maximum sound level (dBA) for a Belvedere helicopter taking off and landing

APPENDIX XV

SIMPLIFIED PROCEDURE FOR ASSESSING REACTION TO INDUSTRIAL NOISE IN MIXED RESIDENTIAL AND INDUSTRIAL AREAS

(A NOTE BY THE BUILDING RESEARCH STATION)

1. The simplified procedure mentioned in paragraphs 379-386 in the Chapter on Industrial Noise is described here. It is intended as a quantitative guide to whether an existing industrial noise is likely to cause complaint from those people, having a normal reaction to noise, who live nearby, and also to give an indication of the probable limiting level of noise from a proposed factory without likelihood of complaint.

2. It is well known that the actual loudness of a noise is not, by itself, a measure of whether it will give rise to annoyance or complaint. The reaction of the hearer is affected, for example, by the kind of noise, by whether it occurs during the daytime or at night, by the general level of noise already existing, by whether the hearer has become accustomed to it, and so on. It seems that it is possible to make quantitative allowances for these effects, at least for the particular kinds of noise produced by industry and affecting occupants of nearby dwellings. In this procedure for assessment, a basic noise level is first identified and then allowances are added to or subtracted from it in accordance with a set of rules. These rules differ only in detail from those described in the more complex procedures (ref. 1, 2). They have been derived from the latter and from examination of a number of examples in this country and may have to be revised from time to time in the light of further experience or to meet current needs.

3. The essential simplification in the present procedure is that the noise measurement is made with a sound level meter giving a single figure expressed in dBA. Comparison of the measured value with the level calculated from the rules is used as an indication of whether complaints may be expected about noise from the industrial premises.

4. The procedure is insufficient to give much aid to decisions on the steps which may be needed to mitigate the noise nuisance; for such purposes a more elaborate analysis is needed. Borderline cases might also need to be investigated by the more exact methods.

MEASURING APPARATUS

5. The measurements are made with a sound level meter which complies with B.S. 3489:1962, British Standard for industrial grade Sound Level Meters, and which is fitted with an "A" weighting network and capable of measurements in the range 30 to 90 dBA at least.

6. If battery operated, the appropriate checking of battery voltage is necessary every time the instrument is used. Since the meter gives an absolute reading of sound level its accuracy must be checked from time to time. Accidental damage, to the microphone for instance, may result in the change in sensitivity, giving erroneous readings although the instrument is apparently functioning satisfactorily. Complete calibration is done at a competent acoustical laboratory, but a satisfactory practical check can be made with an acoustic calibrator which produces a standard noise. The most suitable kind of calibrator available commercially from the manufacturers of sound level meters is probably the mechanical type in which the noise is made by steel balls falling on to a diaphragm. The instructions regarding the orientation and distance of the microphone from the calibrator, and the correct weighting network to use for calibration, should be carefully followed. If the reading obtained in calibration differs from the correct one by more than 2 dB, the sensitivity of the sound level meter should be adjusted by means of the appropriate preset control. If this adjustment is frequently necessary, or if the difference is 4 dB or more, the overall sensitivity of the instrument should be checked at a competent laboratory.

7. All noise readings are made with the network selector switch in the "A" position irrespective of the magnitude of the reading.

MEASURING TECHNIQUE

8. (*a*) The noise levels are to be measured using a Sound Level Meter (B.S. 3489) which has had its acoustic calibration checked within the previous week.

(*b*) All measurements are to be made out of doors approximately 12 ft. from the side of the nearest inhabited building which faces the noise source and with the microphone of the sound level meter at 4 ft. above ground level: it is intended that this measurement should be representative of the noise at the outside of the building from which complaints have occurred or might be expected.

(*c*) Precautions are to be taken to ensure that the values recorded correspond to the noise being investigated and are not due to wind, electrical interference or extraneous background sources.

(*d*) The sound level meter is to be used in accordance with the makers' instructions except that all readings are to be taken with the weighting switch in the "A" position.

(*e*) The general level of noise which is present for most of the time is first to be measured and compared with the values calculated from the rules and allowances 1 to 4 below. Louder or more disturbing noises which occur occasionally are also to be measured and compared with the values calculated from the rules and allowances 1 to 5.

RULES FOR DETERMINING THE BASIC LEVEL AND ALLOWANCES

Basic Level

9. (*a*) A basic level of 50 dBA is to be taken for either

(i) new factories;

or (ii) existing factories in which structural alterations are being made such as are likely to increase the noise transmission to the outside; for example, a change from a solid wall to one of light frame construction or the provision of new ventilation openings;

or (iii) existing factories in which a new process likely to cause noise is being installed.

(*b*) a basic figure of 55 dBA is to be taken for factories which have been established for a few years but which are not typical of the area in which they are situated, or are in districts where such factories would not normally be expected; i.e. they do not obviously fall into either categories (*a*) or (*c*).

(*c*) A basic figure of 60 dBA is to be taken for old established factories which are completely in character with the area in which they are situated. (These would normally be found in well established industrial areas, such as iron works on Tees-side and ship-building on the Clyde.)

Allowances

10. (1) If the noise has a definite distinguishable continuous note (whine, hiss, screech. squeal, noticeable humming noise), subtract 5 dBA.

(2) If there are any bangs, clanks, thumps, hammering, rivetting or other significant impulsive irregularities in the noise; also if the noise is irregular enough continually to attract attention, subtract 5 dBA.

(3) If the noise occurs on:

Weekdays only 8 a.m.–6 p.m.	add 5 dBA	the lowest appropriate one of these to be applied.
Evenings up to 10 p.m.	add 0 dBA	
Week-ends	add 0 dBA	
Night time 10 p.m.–7 a.m.	subtract 5 dBA	

(4) Type of district:

(*a*) Rural (residential)	subtract	5 dBA	Select one only.
(*b*) Suburban or urban, no road traffic	add	0 dBA	
(*c*) Residential urban	add	5 dBA	
(*d*) Urban with light industry or main roads	add	10 dBA	
(*e*) General industrial area	add	15 dBA	
(*f*) Heavy industrial area	add	20 dBA	

(5) In some cases the noise from the process is not constant, but significantly louder noises occur at intervals, say for less than half the time. When these louder noises occur during the day the following allowances may also be made to determine an intermittent limiting level:

Noise occurring approximately 15 minutes per hour	add 5 dBA
,, ,, ,, 5 minutes per hour	add 10 dBA
,, ,, ,, 1 minute per hour	add 15 dBA
,, ,, ,, 1 minute per half day	add 20 dBA

NOTE:—This allowance is not applicable to noises occurring during the evening or at night.

ASSESSMENT

11. If the measured noise level in dBA exceeds the limiting level given by the rules as the sum of a basic level and appropriate allowances, then complaints from an ordinary reasonable person may be expected. For intermittent noise made during the day, the general level measured for most of the time is compared with the normal limiting level, and the occasional higher noise level measured is compared with the higher intermittent limiting level obtained by including the last allowance. Complaints may be expected if either or both limiting levels are exceeded.

12. The criterion levels determined by this procedure relate to noise measured outside dwellings, although the complaints generally arise from people disturbed inside. The predicted levels take account of this factor.

CONCLUSIONS

13. The various allowances proposed in the rules are those which appear to be most appropriate in this country from examination of the case histories available. Experience may show that other factors may also be relevant. For instance, in some of the more complex procedures an allowance of 0 for winter and −5 for summer conditions is thought to be appropriate, since in the summer both the factory and the residents may have more windows open for ventilation thus giving higher noise levels in the dwelling. It is probable that the procedure could be extended to apply to offices, schools, hospitals, etc., using similar rules, provided that these buildings are of the traditional kind of construction which is most common for houses. But buildings of light cladding construction will offer less resistance to the passage of sound to the interior and can be expected to be more badly affected.

14. For an existing noise found to be causing complaint, the procedure gives no indication what steps should be taken to reduce the noise to an acceptable level. It could, however, be used when planning the situation and construction of a new factory to determine what noise levels would not be expected to cause complaint from the surrounding community.

COMMENTS

15. The Local Authorities who co-operated in providing the results used were asked to give details of the measured noise levels, type of noise, times of operation, background noise levels and environment as well as details of any known complaints, in the form of answers to a questionnaire. The measured noise levels at any one site often varied considerably according to the operation

being performed and in most cases the average values of the more continuous noises were taken rather than the absolute peak values of intermittent noises since it was intended that impulsive or irregular noises should be considered as a separate item, by making a suitable correction or allowance. Data were also used from a number of cases investigated by the Building Research Station from time to time where originally a full frequency analysis had been made. The corresponding single figures in dBA have been calculated in these cases.

16. An example of some of the variations of tolerable noise levels for the same factory in differing circumstances, calculated by the procedure given, may help to show how it is intended to work. Suppose that a new factory is established in a general industrial area and that a general noise is emitted from it by day without any noticeable special features (e.g. no characteristic whine, or irregular hammering etc.). The method would lead to an assessment that noise up to 70 dBA would not give rise to complaint. An old established, exactly similar factory would not be the subject of complaint at noise levels up to 80 dBA. On night work, however, in either case, the level at complaint would be 10 dBA less (i.e. 60 and 70 dBA respectively). Exactly the same factory, if newly sited in a quiet suburban area, would lead to complaint at any noise level above 55 dBA by day, or 45 dBA at night.

17. As a guide to the comprehension of these noise levels, 80 dBA is about the average noise heard at kerb-side in very heavy traffic; 60 dBA is the corresponding level inside an office with normally closed single windows facing on to such a busy street, while 45 dBA is that of a quiet office.

18. Table I is a selection from some of the various sources from which information and data were secured when developing the procedure for assessment. It is included as a further illustration to assist those wishing to use the procedure. The measurements in almost all cases were made in the region of the houses affected by the noise and from some of which complaints had been received.

References

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2. KOSTEN, C. W. AND VAN OS, G. J. In *The Control of Noise*, the National Physical Laboratory Symposium No. 12. H.M.S.O., London, 1962.

3. PURKIS, H. J. The practical assessment and control of industrial noise. Assoc. of Pub. Health Insp. 17, 3, pp. 211–217 and 221. December 1962.

Wireless sets, gramophones, etc.

Any person who by operating or causing or suffering to be operated any wireless set, gramophone, amplifier or similar instrument—

(*a*) in or on any street or public place or in or in connection with any shop, business premises or other place which adjoins any street or public place and to which the public are admitted, makes or causes or suffers to be made any noise which is so loud and so continuous or repeated as to give reasonable cause for annoyance to other persons, or

(*b*) in any other premises makes or causes or suffers to be made any noise which is so loud and so continuous or repeated as to cause an annoyance to occupiers or inmates of any premises in the neighbourhood,

shall be guilty of an offence:

Provided that:—

(i) no proceedings shall be taken under this byelaw against any person in respect of anything done in any premises referred to in paragraph (*b*) thereof unless the nuisance does not cease before the expiration of a fortnight from the date of the service on that person of a notice alleging a nuisance, signed by not less than three house-holders residing within hearing of the instrument in question,

(ii) this byelaw shall not apply to any wireless set, gramophone, amplifier or similar instrument used by a police constable in the execution of his duty.

In this byelaw the expression "public place" includes any park, pleasure ground or other like place to which the public are admitted and any part of a beach to which the public are admitted.

Noisy hawking

No person shall, for the purpose of hawking, selling, distributing, or advertising any article, shout or use any bell, gong or other noisy instrument in any street or public place so as to cause annoyance to the inhabitants of the neighbourhood.

Explosive bird-scaring devices

No person shall cause or permit any device for scaring birds by means of periodic explosions to be in operation during the hours of darkness.

Provided that a person shall not be convicted of an offence against this byelaw if he proves to the satisfaction of the court that the operation of the device during the hours of darkness was caused by a mechanical failure which was not due to his negligence.

Noisy animals

No person shall keep within any house, building, or premises any noisy animal which shall be or cause a serious nuisance to residents in the neighbourhood. Provided that no proceedings shall be taken against any person for an offence against this byelaw unless the nuisance be continued after the expiration of a fortnight from the date of the service on such person of a notice alleging a nuisance, signed by not less than three householders residing within hearing of the animal.

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APPENDIX XVI

MODEL BYELAWS RELATING TO NOISE IN STREETS AND PUBLIC PLACES

(ENGLAND AND WALES)

The model forms of byelaws which may be made by county councils and borough councils under section 249 of the Local Government Act, 1933, or in London by the County Council and Metropolitan Borough Councils under section 146 of the London Government Act, 1939, are set out below:

Music near houses

No person shall sound or play upon any musical or noisy instrument or sing in any street or public place within 100 yards of any dwelling-house or office, after being requested to desist by any inmate or occupant thereof, either personally or through a servant, or through a constable, on account of the interruption of the ordinary occupations or pursuits of any such inmate or occupant or for other reasonable and sufficient cause: Provided that this Byelaw shall not apply to properly conducted religious services, except where the request to desist is made on the ground of the serious illness of any inmate of the house.

Music near churches, etc.

No person shall sound or play upon any musical or noisy instrument or sing in any street or public place within 100 yards of any place of public worship or public entertainment or other place of public assembly in which persons are for the time being assembled, to the annoyance or disturbance of any person or persons so assembled, after being requested to desist by any constable, or by any person so annoyed or disturbed, or by any person acting on his behalf.

Music near hospitals

No person shall sound or play upon any musical or noisy instrument or sing in any street or public place within 100 yards of any hospital, infirmary, convalescent home, or other place used for the reception or treatment of the sick, after being requested to desist by any constable, or by any inmate or officer of such hospital or other place, or by any person acting on his behalf.

Organs

No person shall in any street or public place, or on any land adjoining or near to any street or public place, use or play, or cause to be used or played, any steam organ or other musical instrument worked by mechanical means, to the annoyance or disturbance of residents or passengers.

Organs, alternative form

No person shall, in connection with any roundabout, show exhibition or performance, placed or held in any street or on any vacant ground adjoining or near to any street, make or cause to be made any loud and continuous or repeated noise by means of any organ or other similar instrument to the annoyance of residents or passengers.

Noises at night

No person shall in any street or public place between the hours of 11 p.m. and 6 a.m. wantonly and continuously shout or sing or otherwise make any loud noise to the annoyance or disturbance of residents.

TABLE I

Type of noise or process (*i*)	Local authority (*ii*)	Comments (*iii*)	Basic level dBA (*iv*)	Allowances (*v*) 1 Note	2 Impulsive	3 Time of day	4 District	5 Duration	Total allowances (*vi*)	Total + basic dBA (*vii*)	Average measured level (*viii*)	Complaints (*ix*)	Agreement with criterion (*x*)
Drop hammer ...	Newcastle		60	0	− 5	− 5	+15	0	+ 5	65	70	Yes	Yes
Woodwork and circular saw ...	Newcastle		60	− 5	0	+ 5	+15	0	+15	75	69	No	Yes
Metal spray and shot blast ...	Newcastle	No houses adjacent ...	55	0	− 5	0	+15	0	+10	65	82	No	None expected
Engineering works	Newcastle		55	0	− 5	+ 5	+10	0	+10	65	78	Yes	Yes
Compressor and exhaust fan ...	Newcastle		55	− 5	0	0	+ 5	0	0	55	68	Yes	Yes
Refrigeration plant	Salford ...		50	− 5	0	+ 5	+10	0	+10	60	65	Yes	Yes
Bottling plant (dairy) ...	Salford ...	Early morning	55	− 5	− 5	0	+ 5	0	− 5	50	65	Yes	Yes
Metal loading and cutting ...	Watford	B.R.S. analysis	50	0	− 5	0	+ 5	+ 5	+ 5	55	65	Yes	Yes
Fan noise ...	Oxford ...	Firm's analysis	55	− 5	0	− 5	+ 5	0	− 5	50	45	Yes	No
Power station ...	Glasgow	Generator hum	60	− 5	0	− 5	+15	0	+ 5	65	56	No	Yes

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