COMMITTEE ON THE PROBLEM OF NOISE

Noise from Motor Vehicles

INTERIM REPORT

Presented to Parliament by the Lord President of the Council and Minister for Science by Command of Her Majesty
July 1962

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* Mr. Perring was appointed on the 19th December, 1961, in place of Mr. Lovell, whom he succeeded at the Ministry of Transport.
† Mr. Taylor was appointed on the 16th June, 1961.

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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."

The Committee were informed that the Minister of Transport proposes to make new Regulations to control the noise from motor vehicles and would like to have our views before doing so. We have now completed our examination of this aspect of the problem and have set out our recommendations in this interim report.

On behalf of the Committee,

A. H. WILSON,

(*Chairman*).

INTRODUCTION

1. There is abundant evidence that the noise from motor vehicles is a source of distress to the public, and is indeed often the major source of annoyance due to excessive noise. In our survey of the problem, we have reviewed evidence from witnesses, from published data, and from specially designed experiments, and we have considered :

(*a*) the state of existing legislation against the noise from motor vehicles, in this and other countries,

(*b*) the physical causes of vehicle noise, and the technical possibilities of quietening motor vehicles, and

(*c*) the methods of measurement of such noise, including the relation between objective measurements and subjective assessments.

A list of the organisations and individuals who submitted evidence, either written or oral, is given in Appendix I.

2. From this evidence we conclude that a considerable amount of motor vehicle noise could be reduced, without excessive technical difficulty or disproportionate expense to the community. To bring about this reduction, we believe that new legislation must be introduced, in which noise limits defined by instrumental measurement are specified. Our recommendations outline such legislation.

3. We recommend that numerical noise limits be introduced for new vehicles, and that the police should measure noise emitted from vehicles on the road. The fixing of numerical noise limits has been one of the most difficult parts of our task. We have had to consider (*a*) the limitations of any practical noise-measuring instrument at present available, (*b*) the technical and administrative difficulties of enforcement and (*c*) the sometimes conflicting interests of user, manufacturer and the general public. We believe that the limits we have suggested are the best immediate compromise, and that, if they were accepted forthwith, there would be a notable reduction in the annoyance caused by noisy motor vehicles. We believe also that after further experience and scientific development some progressive lowering of the limits might prove to be possible.

4. Throughout this interim Report, we have considered only the noise from individual vehicles ; we have not separately discussed the general background of noise, e.g. in the streets of large cities, due to the sum of many vehicles.

5. The main body of the Report is in the following sections :—

I. Existing legislation (paras. 6-10).

II. The causes of vehicle noise (11-18).

III. Methods of measurement of vehicle noise (19-25).

IV. The choice of noise levels (26-40).

V. Conclusions and recommendations (41-63).

SECTION I

EXISTING LEGISLATION

6. 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 II.

7. 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.

8. The annual number of offences against these regulations and the numbers of vehicles registered in England and Wales in the years 1936–1938, and 1946–1960 were supplied to us by the Home Office and the Ministry of Transport and are set out in Appendix III. Separate figures of the offences against each regulation were not available. No statistics of offences in Scotland were obtainable.

9. 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 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 International Organisation for Standardisation (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 21–24.

10. 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.

SECTION II

THE CAUSES OF VEHICLE NOISE

Propulsion noise

11. 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.

12. 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.

13. 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 ; a bibliography is given in Appendix IV. We consider, however, that more work is needed, and that in addition manufacturers should be encouraged to take better advantage of existing knowledge.

14. 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 motorcyles 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

15. 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, 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

16. 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.

* 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.

Door slam

17. 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

18. 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 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.

SECTION III

METHODS OF MEASUREMENT OF VEHICLE NOISE

19. Our interest in the methods of measurement of vehicle noise, with which much of this Report is concerned, was stimulated by the difficulties in enforcement, already mentioned in paragraph 7, which may be expected whenever prosecution depends essentially on subjective opinion. Unfortunately, the measurement of any subjective conception, such as " loudness " or " annoyance ", in numerical terms, sets many problems. Appendix V explains something of the scientific background to such measurements, and describes the scales used.

20. 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.

21. 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. Early 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).

22. 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.

23. 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 (BS 3425: 1961) provides a reasonable basis for measuring the noise of vehicles. However, this method 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 decibels (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 noise of vehicles on the road. It does, however, provide a method which is suitable for measuring the maximum noise potential of new vehicles.

24. Most vehicles are, of course, 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 relatively high powered vehicle probably uses its full power far less frequently and is usually using a lower proportion of its available power, than a vehicle of markedly lower power. It could, therefore, be argued that a maximum noise limit measured under conditions of full throttle acceleration is unfair to the higher powered vehicle. We agree that there is force in these arguments. Nevertheless, we consider that it is

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* A glossary of technical terms is contained in Appendix V.

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.

25. The British Standard to which we refer above (paragraph 23) is reproduced in Appendix VI.*

SECTION IV

THE CHOICE OF NOISE LEVELS

26. 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

27. 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".

28. 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 V) in its recommendations ; but the limitations of the instrument are well known to those expert in acoustical measurement.

29. 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

* 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.

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 ".

30. 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.

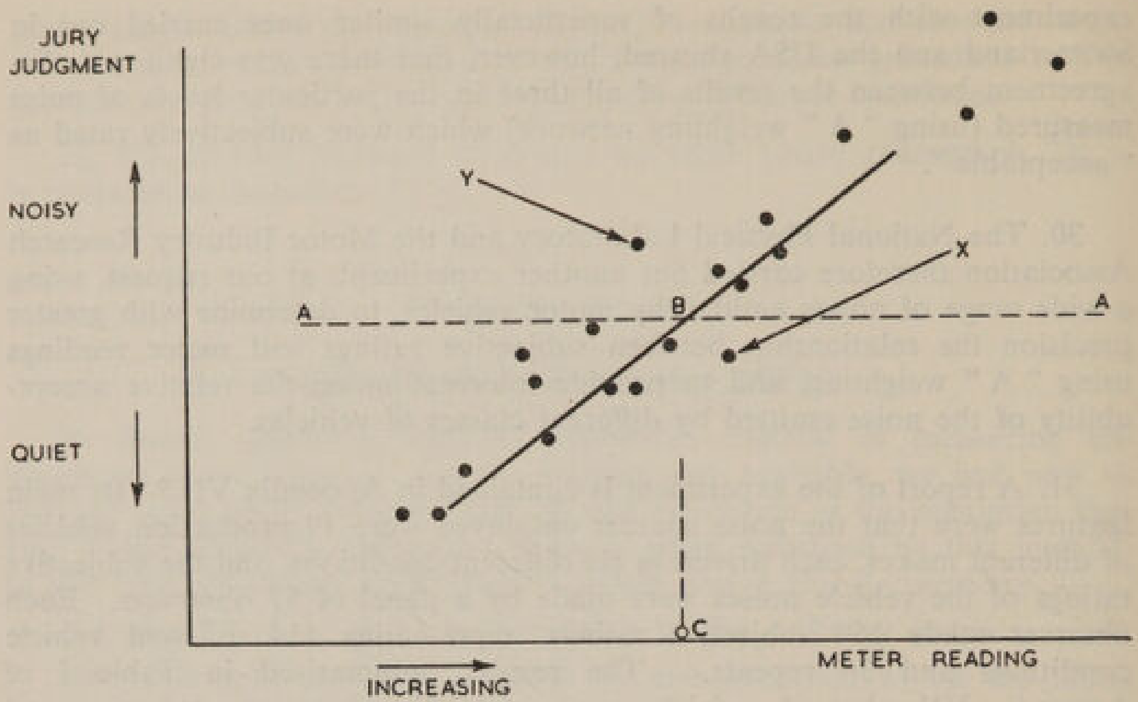
31. A report of the experiment is contained in Appendix VII.* Its main features were that the noise sources employed were 19 production vehicles of different makes, each driven in six different conditions, and the subjective ratings of the vehicle noises were made by a panel of 57 observers. Each observer made 150 subjective ratings, representing 114 different vehicle conditions and 36 repeats. The results, summarised in Table I of Appendix VII, 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 shortcomings 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 VII) with those of the investigation referred to in paragraph 29, which used normal main road traffic, and they showed a close similarity.

32. 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 ; 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.

33. We must, however, emphasise one fact which cannot be avoided. It will be seen from the results given in Appendix VII 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) and must permit more noise from others than is intended (from vehicles which read lower on the meter than others which are equally noisy).

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

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



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, quiet enough, will fail the test ; and vehicle Y, though noisier than X, will pass the test.

35. 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 VII). 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 44) on other considerations.

Levels attainable in practice

36. Passing now to consider (*b*) of paragraph 26, 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.

37. 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.

38. 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

39. On the question of the true cost of achieving a noise limit at any given level (*c*) of paragraph 26, we found it beyond our competence to obtain really positive evidence. The view of manufacturers of motor vehicles is already implied in paragraphs 37 and 38; 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

40. We have examined the information available on the quantitative noise limits introduced in other countries [(*d*) of paragraph 26]. 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.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

41. 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.

42. 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.

43. 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 30 *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

44. Bearing in mind the considerations of paragraphs 26–40, 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.

45. 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 35). 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 33 and 34); (*b*) to fit in with what is immediately technically possible for new vehicles (paragraphs 37 and 38). 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.

46. 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 44 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 „

47. 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.

48. 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

49. 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 silencing 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.

50. 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.

51. 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.

52. 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.

53. 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.

54. 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.

55. 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 53 should, therefore, be regarded as experimental and we recommend that they should be reviewed not more than three years after their introduction.

56. 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

57. 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 44 plus the maximum allowance that we suggest in paragraph 53. 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.

58. 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.

59. The maximum noise levels recommended in paragraph 44 are those that we regard as reasonable in the light of conditions and knowledge that exist at this time. We wish to emphasize that we believe that the enforcement of these levels would considerably reduce the number of noisy vehicles on the road, even though (as paragraphs 57 and 58 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

60. 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.

61. 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

62. As final comment, 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.

Acknowledgments

63. We wish to place on record our appreciation of the help given to us by the National Physical Laboratory, the Motor Industry Research Association and the Ministry of Transport in carrying out, at our request, the experimental investigations to which we have referred. These investigations have been vital to us in formulating our recommendations. We also wish to thank all the organisations and individuals who gave evidence (see Appendix I).

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

64. Noise from motor vehicles is a source of distress to the public. A considerable amount of this noise could be reduced (paras. 1 and 2).

65. We recommend that the use of motor horns, except when necessary to avoid danger, should be forbidden at all times in built-up areas (para. 15).

66. 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" (para. 7).

67. A satisfactory method of measuring the maximum noise which a vehicle can emit is available (paras. 19-25).

68. 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 (para. 26). The levels of noise which are acceptable to the public were investigated (paras. 27-35). Evidence was obtained from the manufacturers on the lowest noise levels that were practicable (paras. 36-38); cost was considered (para. 39); and the practice in other countries was examined (para. 40).

69. 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 (para. 43).

70. 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 (para. 44).

71. 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 (para. 48).

72. 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 (paras. 49-56).

73. We consider that the procedure and the allowance for roadside measurement of vehicle noise should be regarded as experimental and be reviewed not more than three years after their introduction (para. 55).

74. We recommend that, quite apart from the adoption of measured limits, drivers making unnecessary noise should be liable to prosecution (para. 56).

75. We consider that our recommendations would considerably reduce the number of noisy vehicles on the road (para. 59).

76. 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 (paras. 60-61).

77. An essential contribution towards reducing noise from vehicles must come from drivers (para. 62).

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APPENDIX I

LIST OF ORGANISATIONS AND INDIVIDUALS WHO SUBMITTED EVIDENCE RELATING TO NOISE FROM MOTOR VEHICLES

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.

Association of British Chambers of Commerce.

*Association of Chief Police Officers (England and Wales).

*Hope Bagenal, Esq., O.B.E., D.C.M., F.R.I.B.A.

*Ronald M. Bell, Esq., M.P.

*British Cycle and Motor Cycle Industries Association Ltd.

British Standards Institution.

*Chief Constables' (Scotland) Association.

Electrical Association for Women.

Home Office.

Institution of Mechanical Engineers.

*Ministry of Transport.

*Motor Industry Research Association.

Mrs. K. Murray.

*Gerald Nabarro, Esq., M.P.

National Association of Parish Councils.

National Federation of Business and Professional Women's Clubs.

*National Federation of Women's Institutes.

National Joint Committee of Working Women's Organisations.

*National Physical Laboratory, Department of Scientific and Industrial Research.

National Union of Townswomen's Guilds.

*Noise Abatement Society.

Royal Society for the Prevention of Accidents.

*Society of Motor Manufacturers and Traders.

*Rupert Speir, Esq., M.P.

Standing Conference of Women's Organisations.

Vicarage Farm Area Residents Association.

†J. L. Waldron, Esq., C.V.O., Assistant Commissioner, Metropolitan Police.

*Wilmot Breeden Ltd.

Women's Group on Public Welfare.

APPENDIX II

EXISTING BRITISH REGULATIONS

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 III

OFFENCES RELATING TO MOTOR VEHICLE NOISE IN ENGLAND AND WALES

Year (1)	Total vehicles registered (2)	Motor bicycles and tricycles (included in total in Col. (2)) (3)	Total offences and alleged offences (4)	Alleged offences in respect of which police gave written warning (5)	Offences dealt with by prosecution (6)	Cases in which the charge was proved (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	8,699,297	1,767,996	7,954	1,765	6,189	6,084

APPENDIX IV

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APPENDIX V

THE MEASUREMENT OF NOISE

Though most people will agree that one noise is louder than another, it is not easy to express this agreement in a consistent numerical *scale* of loudness which might be used, for example, to investigate complaints of excessive noise ; and it is still more difficult to measure noises, in terms of such a scale, by purely instrumental means, without appealing to individual opinions.

The ear is, generally speaking, much less sensitive to very high or very low frequencies than it is to those in the middle range ; it also reacts differently to impulsive and varying noises as compared with steady ones (a road drill compared with a jet engine, for example). In consequence, a group of listeners may judge that two sounds differ widely in "loudness", (or still more in other subjective qualities such as "disturbance" or "annoyance"), where the physicist might describe them as equally "intense", i.e. as corresponding to the same sound power.

Nevertheless, it is 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 reproducible reference sound which is adjusted until it is judged to be equally loud, and 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 obviously 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 approximately an increase of 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 equals 2 to the power $\frac{P-40}{10}$ 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.

If it were easily possible to measure directly in phons (or sones), probably no other loudness scale would be used. Since, however, the measurement demands the resources of a standardizing laboratory, it is impracticable for the majority of noise investigations, and a much simpler procedure is needed.

A microphone, amplifier and rectifying and integrating instrument can be arranged to indicate the sound power reaching the microphone. If in addition, certain frequency weighting networks are included, compensating roughly for the varying sensitivity of the human ear to which we have already referred, we have a *sound level meter*; the construction and performance of such instruments are the subject of national and international specifications, and it may reasonably be expected that the readings which they give will be in the same sequence as subjective judgments of loudness, as long as the comparisons are between noises of the same general type. However, considerable discrepancies may occur if this caution is not observed.

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 (about 10 million to one in terms or 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.

Meanwhile, 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" measurement. 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 of Stevens and of 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. 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*" 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 procedure proposed by Zwicker is the most sophisticated, being based on the known behaviour of the ear as regards the "masking" of one sound by another. It involves a fair amount of calculation, though this may be done by a computer.

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. Generalization 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 amost always be numerically smaller than the loudness level in phons, the difference often reaching 20. Of the methods of deriving phons by computation, Zwicker's is usually considered to be the most reliable.

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 and non-quantitative 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 inter-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

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 judgements 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 scale is precisely defined by its relation to the phon scale, in the formula S equals 2 to the power $\frac{P-40}{10}$ 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 Pressure Level. 20 log ^{10} (p/p°) decibels where p is the r.m.s. sound pressure, and p° 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 (=O dB).

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 Level. A 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 draft British Standards.

Frequency Weighting Network. An electrical network incorporated in the amplifying circuits of a sound level meter to produce a specified overall electro-acoustic 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. Kryter, J. Acoust. Soc. Amer., *31* 1415 (1959).

PNdB ("perceived noise decibels"). The unit of perceived noise level.

APPENDIX VI

B.S. 3425:1961

BRITISH STANDARD METHOD FOR THE MEASUREMENT OF NOISE EMITTED BY MOTOR VEHICLES

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 emphasize 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.* A high quality sound level meter* shall be used. The weighting network and meter time constant employed shall be those which conform to curve A and "fast response" respectively as specified in the IEC Publication 123, "Recommendations for sound level meters". A sufficient technical description of the instrument used shall be stated.

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 measurements 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 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.

b. Wind shield. 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.

* A British Standard covering the meter requirements will shortly be issued and this clause will accordingly be amended.

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.

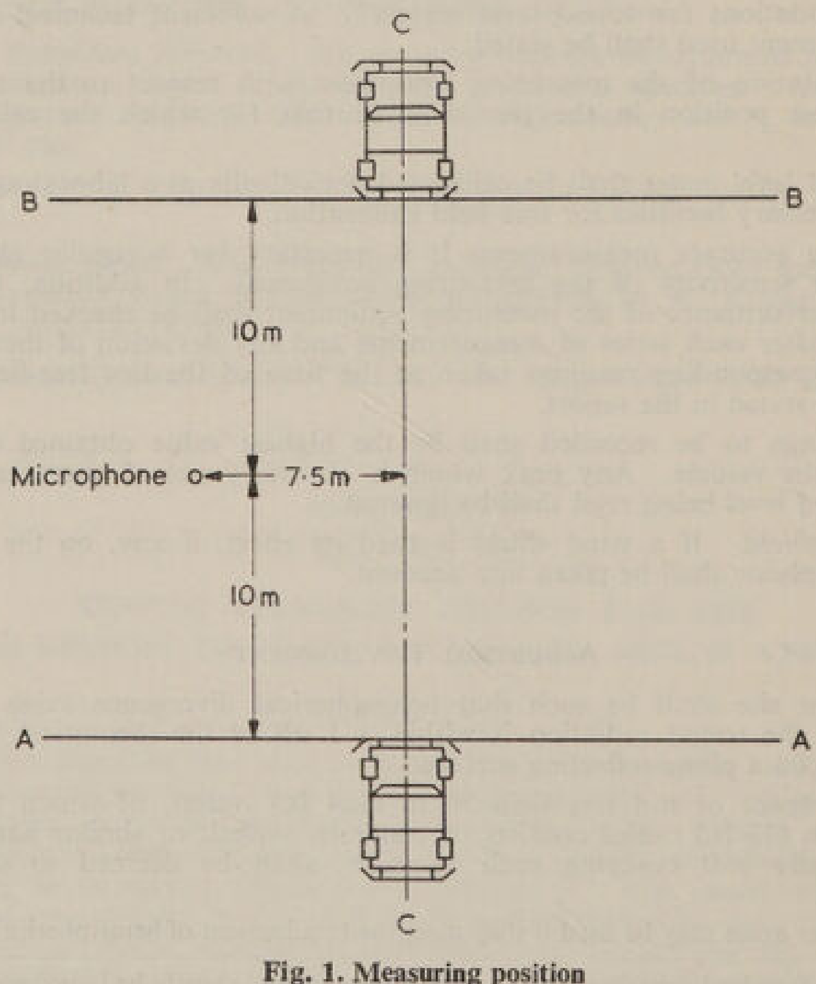

Fig. 1. Measuring position
(7·5 m = 24 ft 7 in; 10·0 m = 32 ft 10 in)

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.

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 is available the " normal drive " or " town " position shall be used.

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 VII

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

* Motor Industry Research Association.
† National Physical Laboratory.

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

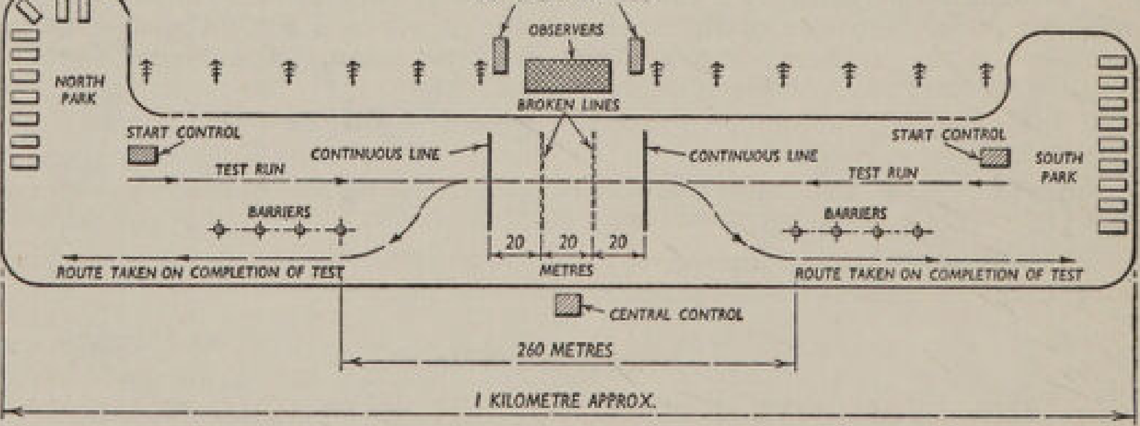

Fig. 1—Test site

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 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 $\frac{1}{4}$ mile. All other traffic on the Proving Ground was stopped throughout the test.

The vehicles proceeded up and down the marked centreline of the road and the observers sat at a mean distance of 7·5m 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

Fig. 2—The test site showing disposition of the listeners and a test vehicle

raised 30cm above the forward facing row, to avoid the forward facing heads casting a sound shadow on the other row. Each row of chairs was 12m 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 7·5m, "sighted" subjects being 15cm less than the mean distance and "unsighted" subjects 15cm 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 5m 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 emission, 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 I.S.O.* test conditions, each vehicle was tested under two other driving conditions, in order to extend the range of 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 I.S.O. 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 10m 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 10m past the measuring position. The throttle was then fully closed and drivers made every attempt to coast until they were at least 100m 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 30m before the measuring position to 30m 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.

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* International Organisation for Standardisation Technical Committee 43, Draft Recommendation No. 419, October, 1960.

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 7·5m 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. 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

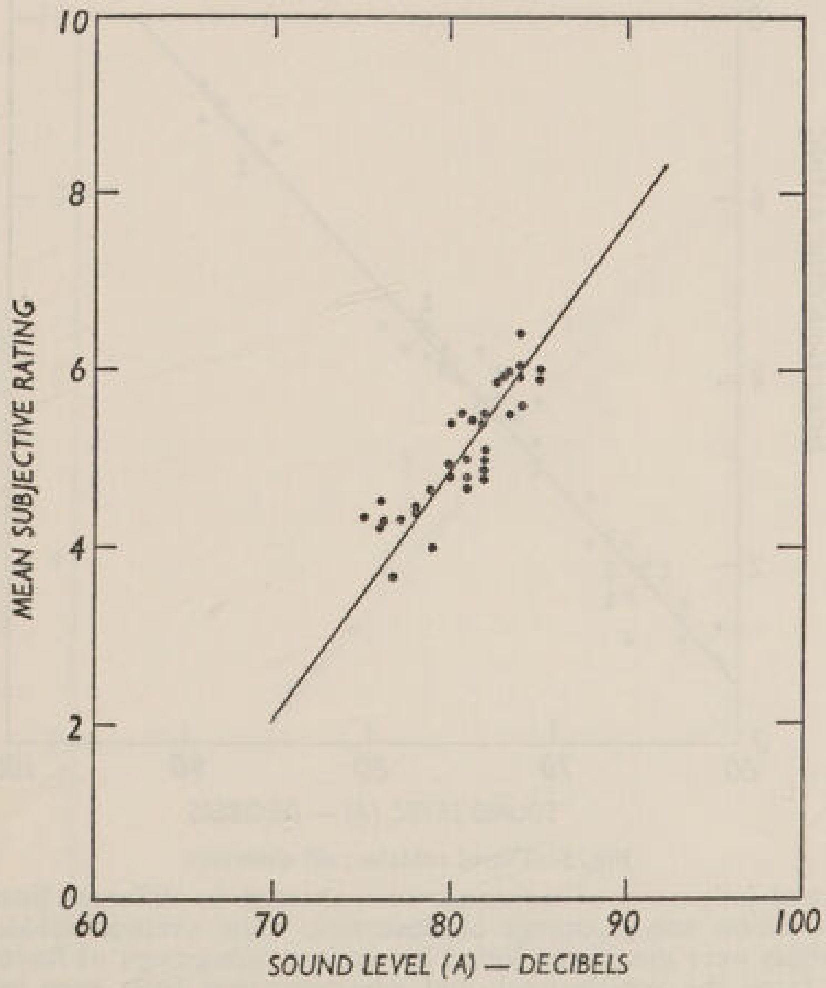

Fig. 4—Diesel vehicles: all observers

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 (5·5dB and 7dB 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, 11dB; four-strokes, 7dB), and, as shown in Fig. 8, the scatter is scarcely increased if both classes are combined (11·5dB). 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, 11dB; twin-cylinder machines, 10dB). 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 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,

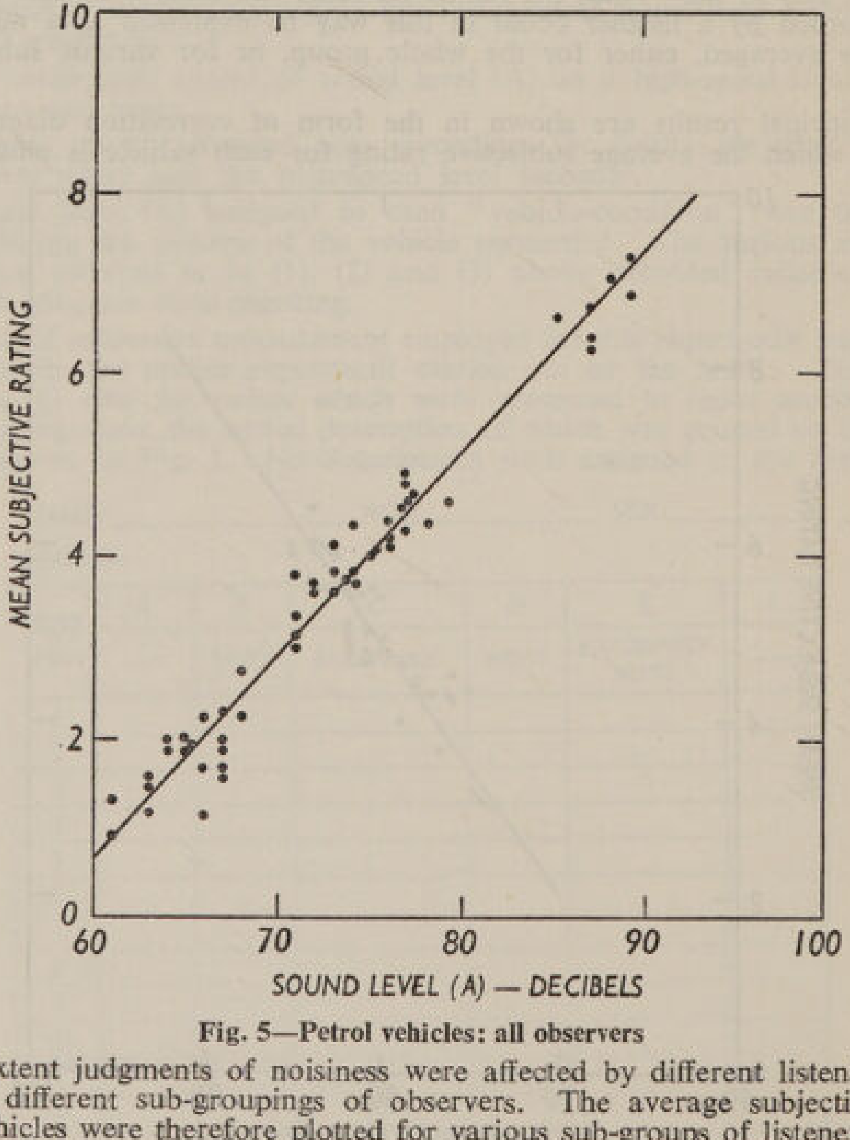

Fig. 5—Petrol vehicles: all observers

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.

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

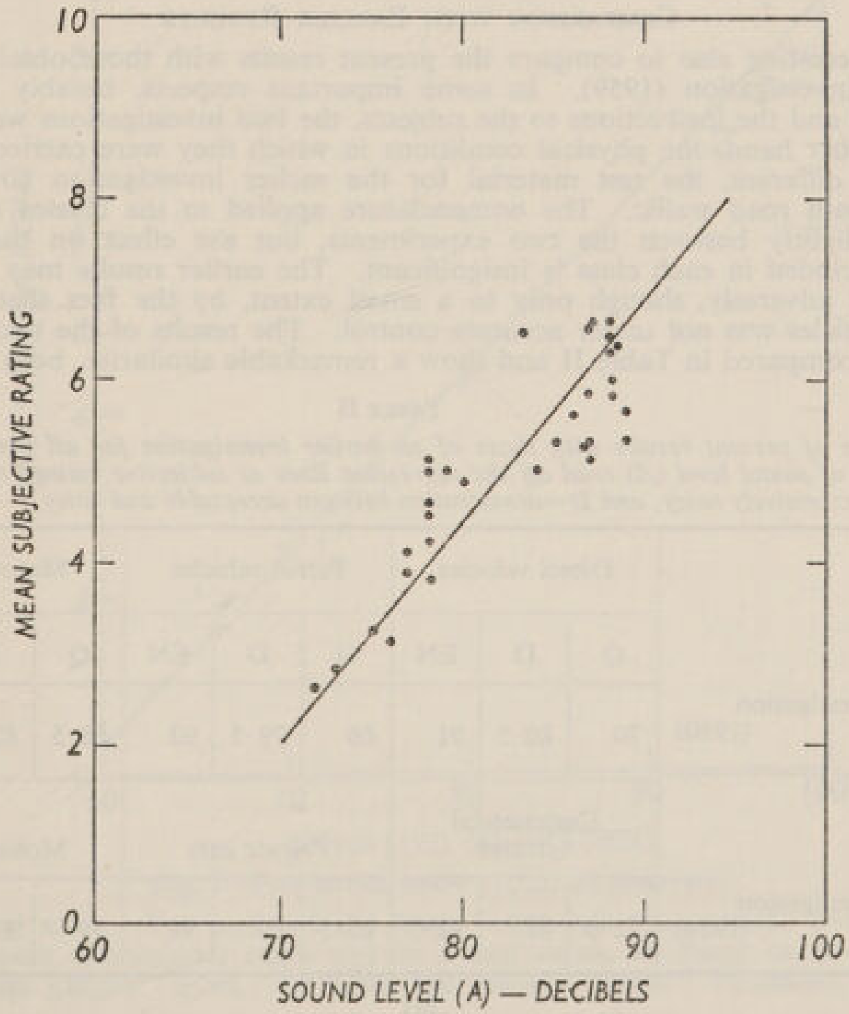

Fig. 6—Two-stroke motor-cycles: all observers

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 dB (A). 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 dB 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[2] that this demarcation line should be set around 73 dB on the sound level (A) scale, 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

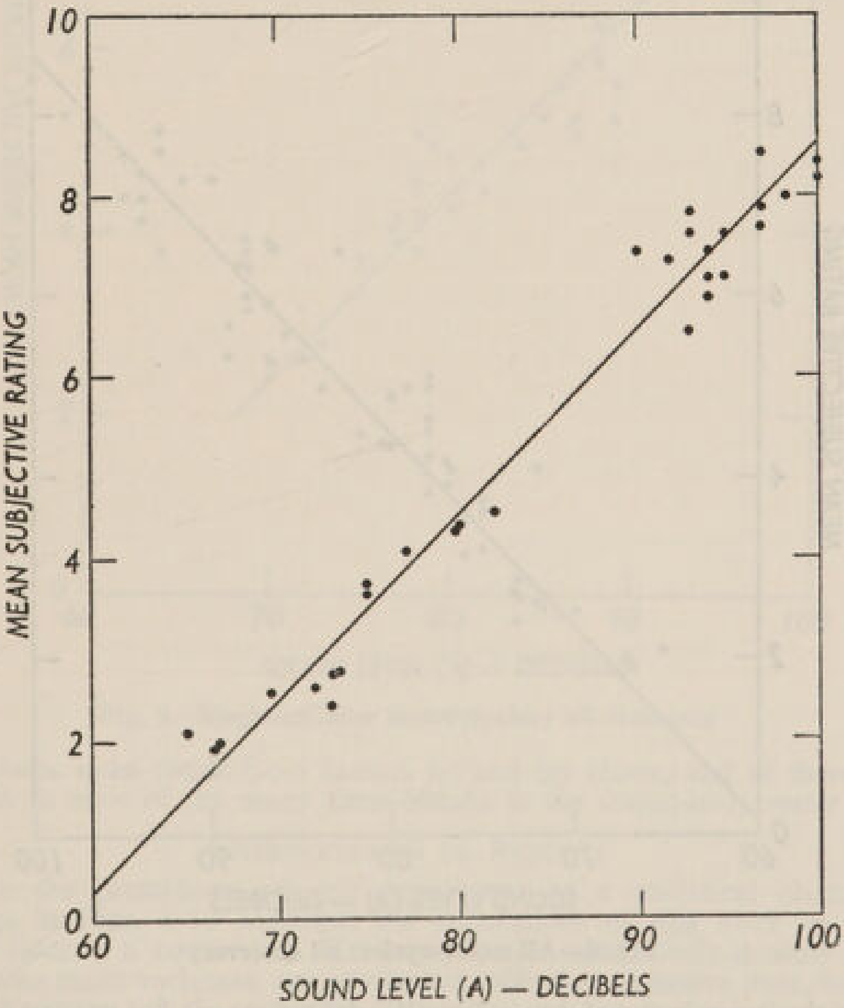

Fig. 7—Four-stroke motor-cycles: all observers

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

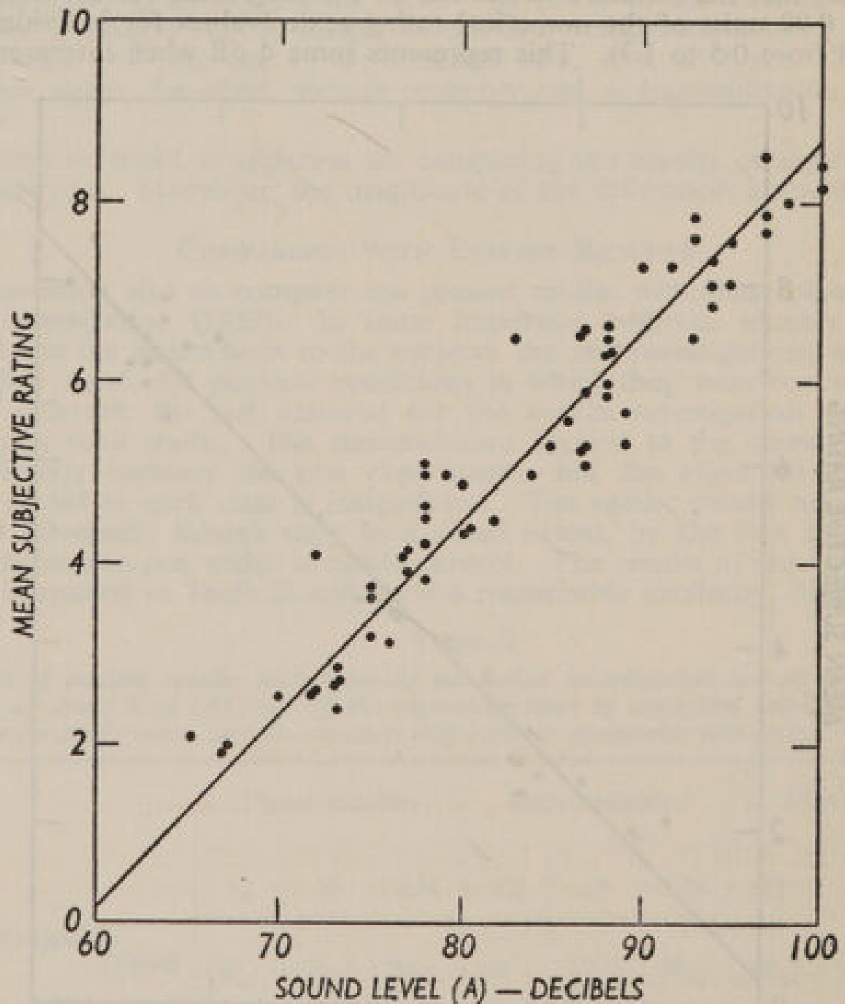

Fig. 8—All motor-cycles: all observers

to estimate the magnitude of (*a*) independently by repeat judgments under identical physical conditions. A number of such repeats were included in the tests (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

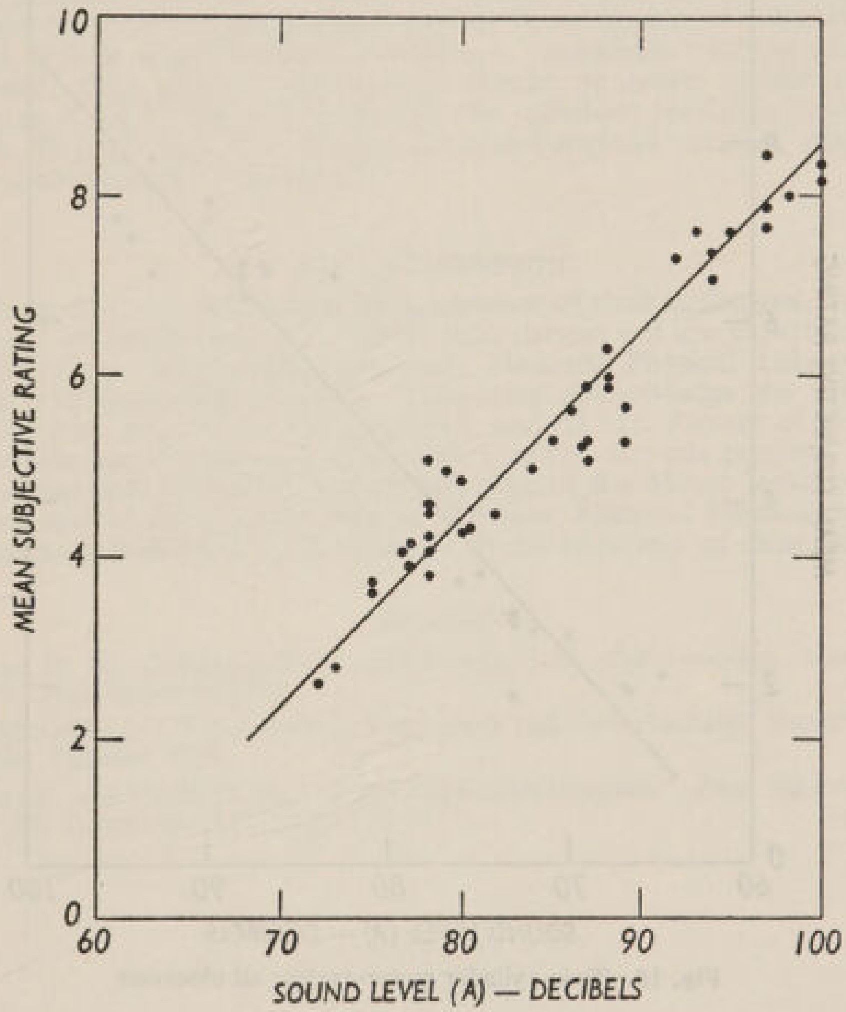

Fig. 9—Single-cylinder motor-cycles: all observers

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.

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.

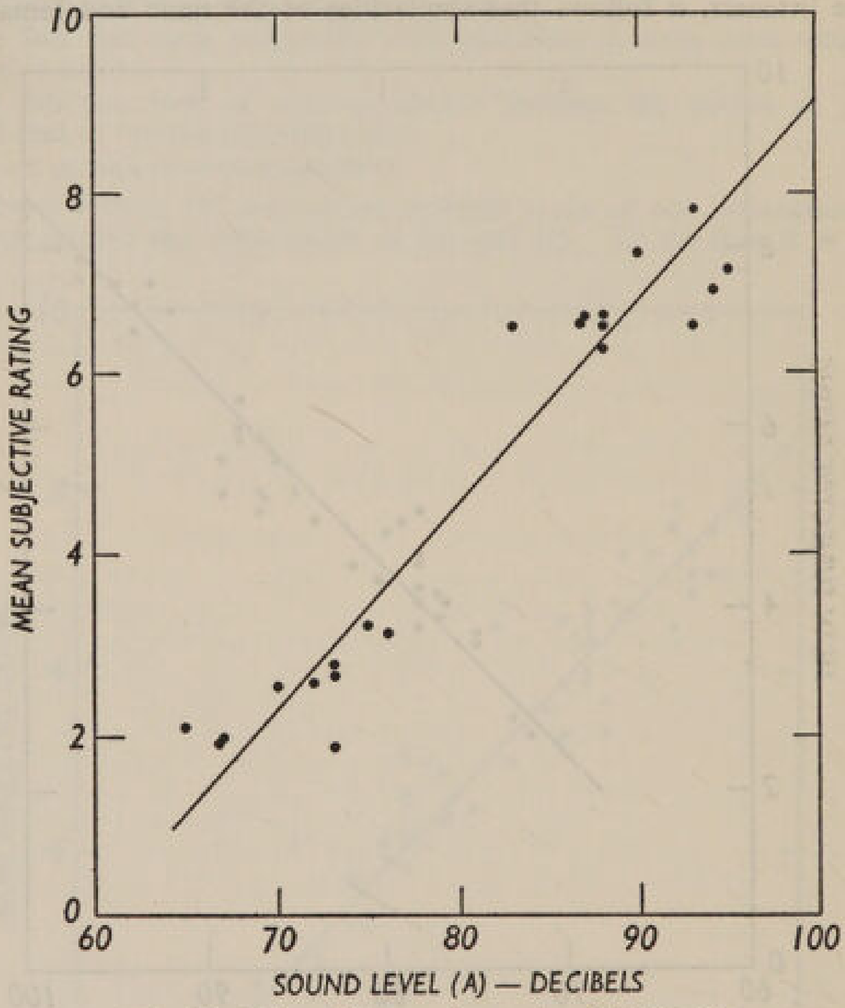

Fig. 10—Twin-cylinder motor-cycles: all observers

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 dB, 80·5 dB and 82·5 dB (A) 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 dB, 68·5 dB and 70·5 dB (A) 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 dB, 3 dB and 7 dB (A) (3σ criterion) resulting in sound-levels of 83·5 dB, 83·5 dB and 89·5 dB (A) for petrol-engined vehicles, diesel-engined vehicles and motor-cycles respectively.

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