In-service noise testing - Motorcycles fitted with non-standard and defective exhaust silencers

by G J Harris and P M Nelson

Unpublished Project Report
PR/SE/188/96
SO30L/VB

TRANSPORT RESEARCH LABORATORY

PROJECT REPORT PR / SE / 188 / 96

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Prepared for:Project Record:SO30L/VB In-Service Noise Testing
Customer:Vehicle Standards and Engineering Division, DoT
(Dr G Sleightholme-Albanis)

	Approvals
Project Manager	
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This report was prepared in the Safety and Environment Resource Centre
(Manager: Mr W Newton), Transport Research Laboratory, Crowthorne, Berkshire.
September 1996

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EXECUTIVE SUMMARY

This Project Report was produced as part of a programme of work specified in Project SO30L/VB, In-Service Noise Testing, for Dr G Sleightholme-Albanis of Vehicle Standards and Engineering Division (VSE2) of the Department of Transport.

The Department of Transport have commissioned TRL to carry out a programme of research and testing to evaluate procedures appropriate for the assessment of in-service vehicle noise. The work has been divided into three phases dealing in turn with motorcycles, diesel powered vehicles and petrol vehicles. To date the first two phases have been completed to the original specification. The work on developing an in-service test procedure for motorcycles was reported in a TRL Project Report 037/94 (Harris and Nelson, 1994) and the corresponding study on diesel powered vehicles was reported in TRL Project Report PR/SE/120/95 (Harris and Nelson, 1995).

The study described in this report was commissioned as an extension to the original study of motorcycle noise to enable a greater range of motorcycle/silencer combinations to be examined using the recommended in-service test procedure. Essentially the study was intended to focus on the establishment of in-service noise levels from motorcycles fitted with replacement, modified, defective or off-road performance (race) silencers. The overall aim was to establish appropriate in-service noise limits to be used in association with the test which would clearly identify motorcycles which were producing excessive noise in-service.

A total of 26 exhaust silencer systems were tested on 9 motorcycles. The silencers chosen for the study included the manufacturers original equipment silencers in both new and used condition, a selection of legal replacement silencer systems, examples of race silencers which were not legal for use on public roads, and silencers which had been modified to simulate defects caused by either tampering (eg baffles removed) or corrosion.

The study confirmed that the in-service motorcycle noise test procedure described in the European Union Directive 78/1015/EEC was a relatively simple test to perform, could be carried out without the need for complex instrumentation and gave a satisfactory degree of reproducibility of the test results.

It was found that the noise levels for the motorcycles fitted with standard original equipment silencers or standard (new) silencers gave the lowest test levels.

For two of the most powerful motorcycles tested fitted with 'race' silencers the noise levels were significantly higher than the levels produced with the original equipment fitted. The differences in noise registered were 9 dB(A) for a 600cc machine and 9 dB(A) for a 900cc machine.

By combining the results of this study with those obtained in the previous study, possible limit values for close proximity noise levels have been suggested. It was found that with the close proximity limits for motorcycles set at 19 dB(A) above the corresponding type approval limit values there would be a very low probability that a motorcycle would fail the close proximity test and would then subsequently pass the drive-by type approval acceleration test. With these limits it was found that of the nine motorcycle/silencer combinations tested, where the silencer was either defective or illegal, three would fail the in-service test. In addition, with these limits none of the motorcycles fitted with legal silencers would have exceeded the proposed in-service close proximity noise limits.

Lower limit values could be set with the advantage of improving the chances of failing illegal machines, however there would be a higher risk of failing some motorcycles which were legal.

It was also suggested that a further 1 dB(A) be added to the noise limit values to take account of slight increases in close proximity test noise levels that might occur at non-standard test locations.

By applying this rationale to the current type approval noise limits for motorcycles it is suggested that in-service noise limits should lie in the following ranges:

Category 1 motorcycles, i.e. ≤ 80cc93 - 97 dB(A)

Category 2 motorcycles, i.e. > 80 - ≤ 175cc95 - 99 dB(A)

Category 3 motorcycles, i.e. > 175cc98 - 102 dB(A)

The exact choice of limit values will depend on the level of confidence required that legal motorcycles will not fail the close proximity test. The results contained in this report will be of use in the decision making process by providing an assessment of the likely consequences of setting limit values in these ranges.

IN-SERVICE NOISE TESTING - MOTORCYCLES FITTED WITH NON-STANDARD AND DEFECTIVE EXHAUST SILENCERS

INTRODUCTION

At present, in-service checks of vehicle noise are mainly limited to visual or aural inspections of exhaust systems for mechanical defects, or in controlling the manner of use of vehicles to reduce the nuisance caused.

Various regulatory standards have been imposed by different countries as a means of controlling the noise emitted by road vehicles in-service. These have been summarised previously by TRL in Working Paper WP/NVU/05 'The control of noise from vehicles in-service (A review of test methods and enforcement practice') (Nelson and Tobutt, 1992). The main conclusions reached in this review were that regulations governing the in-service noise generated by motorcycles and mopeds could be introduced in the UK fairly quickly and the exhaust noise test specified in ISO 5130 (International Organisation for Standardisation, 1982) or EEC Directive 78/1015/EEC[1] (European Communities, 1978) could form the basis of a suitable test.

Following on from this earlier work, the Department of Transport have commissioned TRL to carry out a programme of research and testing to evaluate procedures appropriate for the assessment of in-service vehicle noise. The work has been divided into three phases dealing in turn with motorcycles, diesel powered vehicles and petrol vehicles.

To date, the first two phases have been completed to the original specification. The work on developing an in-service test procedure for motorcycles was reported in a TRL Project Report 037/94 (Harris and Nelson, 1994) and the corresponding study on diesel powered vehicles was reported in TRL Project Report PR/SE/120/95 (Harris and Nelson, 1995).

The work on motorcycles considered the implications of testing noise emissions from motorcycles in both outdoor (standard) and at a range of non-standard test sites including indoors, such as inside a MOT test workshop. The report gave the results for 16 motorcycles selected to be representative of the then current motorcycle population in the UK. The report also considered the specification of limit values to be used in association with an appropriate in-service test.

[1]As amended by Directives 87/56/EEC (European Communities, 1987) and 89/235/EEC (European Communities, 1989).

In the previous study all the motorcycles tested were 'secondhand' but judged to be in either fair or good condition. Most of the bikes tested were less than two years old and none had excessive mileage. Of the 16 motorcycles tested 14 were fitted with standard original equipment silencers. One of the motorcycles was fitted with a non-standard single silencer box and a further motorcycle was tested with the standard silencer fitted and then re-tested with the silencer baffles removed. These particular tests were included to simulate motorcycles either fitted with a non-standard replacement silencer or with an inadequate or faulty silencer.

The study described in this report was commissioned as an extension to the original motorcycle study to enable a greater range of motorcycle / silencer combinations to be examined using the recommended in-service test procedure. Essentially the study was intended to focus on the establishment of in-service noise levels from motorcycles fitted with replacement, modified, defective or off road performance silencers. The overall aim was to establish appropriate in-service noise limits to be used in association with the test which would clearly identify motorcycles which were producing excessive noise in-service.

This report describes the work carried out and the results obtained. It also includes a description of the test procedures, motorcycles and silencer combinations studied and provides a rationale which could be used for establishing appropriate limit values for motorcycle noise to be used in association with the recommended in-service test.

2. EXPERIMENTAL DESIGN CONSIDERATIONS

The main objectives of the study described in this report are:-

(i) To extend the previous study of in-service noise from motorcycles to include motorcycles fitted with replacement, defective and off-road performance silencers.

(ii) To compare this data with data collected as part of the previous study.

(iii) To determine, on the basis of the combined data set, an appropriate rationale for the setting of in-service noise limits for motorcycles and mopeds.

In the previous study of in-service noise from motorcycles consideration was given to the various test procedures that could be used and the locations where in-service noise testing might be carried out. In particular, it was considered important to identify the basic test site requirements that would be required so that in-service measurements of motorcycle noise could be carried out simply at low relative cost. It was also important to establish a test which gave results proportionate to the noise generated when the motorcycle under test was driven normally in traffic.

Since the previous study was able to provide information on the most appropriate test procedures to use and to describe the basic requirements for the test site this aspect will not be considered further in this study. However, in determining an appropriate experimental design to achieve the objectives of this study listed above, consideration has to be given to the range of motorcycles that will be tested and, in particular, to the different types of replacement and off-road silencer systems that will be included so that adequate coverage of the range is given.

This section of the report is concerned, therefore, with establishing the most relevant test protocol to adopt for this study.

2.1 TEST SITE SELECTION RATIONALE

It was established in the previous study that the main difficulty in determining a suitable in-service test procedure for motorcycles was to establish a method which is independent, as far as can be made possible, of the test environment. If a suitable test procedure is to be introduced, then, in practice, in-service noise checking will be done under a range of different test conditions. Some vehicles may be tested in an open space where the ambient noise is low whilst others will be tested where the acoustic and ambient noise conditions may vary greatly from site to site.

In order to examine the broad range of possible test sites that could be used, the previous study design included tests carried out inside an enclosed space such as might occur in a motorcycle MOT test bay, as well locations chosen to represent 'non-standard' conditions outdoors, such as on a garage forecourt or at the roadside.

The results of measurements taken in workshop locations indicated, that the in-service test procedure did not give measured noise levels which were consistent with the test levels obtained at the standard outdoor test site. The differences in noise were found to be due to the complex influence of reverberation and to the production of standing waves in the enclosed spaces.

Although there were considerable reservations associated with using the close proximity test procedure with the motorcycle located inside an enclosed space, the errors associated with this test location were reduced when the motorcycle was positioned in an open doorway and were virtually eliminated when the motorcycles were tested outdoors but under non-standard site conditions. This indicated that provided motorcycles can be tested outdoors, virtually any location will be suitable provided the ambient noise levels produced by other sources are not excessively high. It was concluded that tests carried out on garage forecourts, outside workshops and at the roadside, would, with few exceptions, all be suitable for in-service testing of motorcycles.

Bearing in mind this result, it was considered sufficient in this study to carry out the noise tests at two sites representing:-

(i)A standard test site in an open area which is consistent with the requirements of the in-service noise measurement standard as specified, for example, in Directive 78/1015/EEC or in ISO 5130.

(ii)A non-standard test site located outdoors as specified in the previous report.

2.2 VEHICLE SELECTION

The project specification stipulated a vehicle sample size of 8 motorcycles. As for the previous study it was considered important to select a sample representative of the types of machine in use in the UK. In order to assess the relative popularity of different motorcycles, recent sales statistics were obtained from the Motorcycle Industry Association (MCI(A)).

In selecting a range of motorcycles types it was considered appropriate to take account of the relative numbers of machines registered in different engine size categories. Table 2.1 shows the percentages of machines registered in each of seven engine size categories over a five year period (Motorcycle Industry Association, 1996). From the same reference source, Table 2.2 gives the specific models that were most popular in each of three engine size categories for the year ending February 1996.

A further consideration governing the choice of the sample of motorcycles was to ensure that the selection included motorcycles which were representative of the different categories identified as part of type approval noise legislation. This would help to ensure that the objective of being able to specify appropriate limit values for each vehicle category would be achieved. The categories defined in the type approval Directive 87/56/EEC are:-

Category 1≤80cc

Category 2>80cc - ≤175cc

Category 3>175cc

As well as engine size it was considered important to select different styles of machine such as trail machines which typically have different gear ratio characteristics relative to sports/touring machines. It was also felt that the selection process would need to consider including both 2 stroke and 4 stroke engine types.

2.3 EXHAUST SILENCER SELECTION

It was intended that this study would compare noise levels from motorcycles fitted with non-standard or defective exhaust silencers with motorcycles fitted with standard equipment. In order to achieve this objective it was planned to test each of the selected motorcycles with 3 types of exhaust silencer where possible. In each case the motorcycle would initially be tested with a standard silencer as fitted by the manufacturer. The results of these measurements would then be compared with the noise levels generated during repeat tests with non-standard or defective exhaust silencers fitted to the machine. This would show whether the results of the proposed in-service stationary noise test procedure clearly differentiated between motorcycles with legal and illegal exhaust silencers.

It was decided that a number of after-market replacement silencers should be included in the selection. Replacement exhaust silencers fitted to motorcycles in the UK are required to have a silencing performance comparable to the standard silencer fitted by the manufacturer when tested under type approval acceleration test conditions (HMSO, 1986). However, using the proposed in-service noise testing procedure, it cannot be assumed that the noise levels from replacement silencers would be comparable with the levels from equivalent standard silencers. If in-service test noise levels were found to be disproportionately higher for legal, replacement silencers, the choice of in-service test noise limits would have to make allowance for this. Clearly it would not be acceptable for the noise emission from a motorcycle fitted with a legal replacement silencer to fail the in-service noise test limit and then subsequently be found to pass the type approval acceleration noise limit.

It was also considered important to include in the sample a selection of non-road legal silencers, that is, race silencers and silencers that had either been modified or were defective.

Race silencers are available for a number of motorcycles and are fitted to increase the power output of the engine. These silencers are not intended for use on road-going machines and are usually labelled to that effect. A motorcycle presented for MOT inspection with this type of silencer fitted would be failed as the appropriate stamp markings approving its use on the road would be absent (HMSO, 1992). Despite this, there is a temptation for some motorcycle owners to fit race silencers to motorcycles used on the road. This may be done to improve the performance of the machine or because the distinctive exhaust noise and perhaps the visual style is preferred by the rider. To obtain a MOT test certificate the standard, legal exhaust system can be replaced temporarily when the machine is presented for MOT inspection and the off-road silencer refitted afterwards.

The modified silencer category to be investigated in the study represents standard or legal replacement silencers which have been altered such that the noise emission is clearly in excess of that produced in its unmodified state. A typical modification to a silencer would be to remove the baffles from the silencer chamber. This might be carried out by the owner of a motorcycle in the hope that the engine performance would be increased. Assuming the silencer is of a type where this tampering is relatively easy, the silencer could be returned to its normal state when the machine is presented for MOT inspection.

Exhaust silencer systems may also become defective not by deliberate tampering but through incorrect fitting, corrosion or damage (as might occur in a collision). Where possible, it was intended that a number of the exhaust silencers to be tested would be altered to simulate some of these defects. Example noise test results would then be obtained for motorcycles with this type of fault.

Table 2.1 Motorcycle registrations in the UK, 1992 - 1996 (source: MCI(A))

	Percentage of market share at year ending February					
	1992	1993	1994	1995	1996	Average
Mopeds						
≤50cc	21.3	13.9	13.0	11.7	13.3	14.6
Motorcycles						
>50 - 100cc	12.5	12.0	8.1	7.3	6.5	9.3
101 - 125cc	14.8	13.3	13.2	10.2	11.4	12.6
126 - 500cc	16.0	14.0	15.0	14.9	11.8	14.3
501 - 700cc	14.4	14.5	17.1	19.6	20.3	17.2
701 - 900cc	10.8	17.2	21.3	21.3	22.8	18.7
Over 900cc	10.3	14.9	12.3	14.9	14.0	13.3
Total	100%	100%	100%	100%	100%	100%

Table 2.2 Top five selling models of motorcycle in UK
for year ending February 1996 (source - MCI(A))

Engine size category	Ranking	Make	Model
Mopeds	1.	Honda	SH 50 K
	2.	Suzuki	AE 50
	3.	Easy rider	CJ 50 K
	4.	Yamaha	CW 50
	5.	Piaggio	Typhoon 50
Motorcycles 0-125cc	1.	Honda	C 90 G
	2.	Honda	CG 125
	3.	Yamaha	SR 125
	4.	Piaggio	Typhoon 125
	5.	Piaggio	Hexagon
Motorcycles 125cc and over	1.	Honda	CBR 900 RR
	2.	Honda	CBR 600 F
	3.	Suzuki	GSF 600
	4.	Suzuki	GSXR 750 T
	5.	Suzuki	GSF 600S

3. METHOD

3.1 TEST SITE LOCATIONS

(i) ISO vehicle noise testing site

Measurements of motorcycle drive-by acceleration noise were taken on the TRL type approval standard test surface according to EC type approval requirements described in Directive 78/1015/EEC. This test site is located on the central area of the TRL test track facility. The design of the surface and the layout of the test site and its surroundings conform to the specifications given in BS ISO 10844 (British Standards Institution, 1995). The test site is located in an area with no significant acoustically reflecting objects within a 50m radius of the centre of the site as required by the Standard. A further description of the test site is given in section 3.3.1.

(ii) Non-standard noise testing location

To compare noise test results taken on the standard ISO test site with results obtained at a non-ideal test site environment, a second test site was selected. The location was chosen to be representative of conditions that might be found at a vehicle workshop forecourt or at the roadside where it may be necessary to carry out noise tests in relatively close proximity to acoustically reflecting surfaces. A site was chosen which was located directly in front of a wide, single storey workshop building. The building had a concrete facade with steel 'concertina' type doors. The ground in front of the workshop was surfaced with concrete. Further details of the site and the measurement set up are given in section 3.3.2.

3.2 MOTORCYCLES AND SILENCERS SELECTED FOR THE STUDY

(i) Motorcycles

A total of 9 motorcycles were eventually tested rather than 8 which was the planned sample size. In view of the need to select motorcycles to represent the different noise type approval categories listed above, it was decided that from the 9 motorcycles, 2 motorcycles would be selected to represent category 1 (i.e. $\leq$ 80cc), 3 motorcycles would be chosen as representative of category 2 (i.e. > 80 - $\leq$ 175ccs) and 4 motorcycles from the most powerful group, category 3 (i.e. > 175cc). This division of the sample reflected the range of motorcycle types in each category, and their popularity in the vehicle fleet. For example there is a far greater diversity of machine types available in category 3 (large motorcycles) than there are in category 1 (mopeds). Also, it can be seen from Table 2.1 that the number of motorcycles registered in each category increases with category number.

Table 3.1 lists the motorcycles eventually selected for the study. All motorcycles were obtained from a local dealer. Most of the motorcycles were less than 2 years old and none was greater than 5 years old. The particular models chosen were taken from those available which could be fitted with current designs of after-market silencers. Where possible, machines were chosen which were included in the top 5 selling models in the UK as shown in Table 2.2 . Where this was not possible, the most popular of the available models was chosen based on the advice of local motorcycle dealers.

The motorcycles chosen in category 1 (i.e. ≤80cc) were a sports moped and a 'step-through' scooter style moped. These machines were representative of the common types of machine available in this category. During the period of the study it was not possible to obtain a motorcycle with a four-stroke engine in this category. The 3 machines in category 2 all had 125cc engines which is a popular engine size for this category of vehicle. This engine size is the maximum allowable engine capacity for learner riders in the UK. Most motorcycles available in the UK with engines larger than 125cc have engine capacities greater than 175cc and are therefore grouped in category 3. The types of motorcycle selected in category 2 were a road / sport machine, a trail bike (both with 2-stroke engines) and a 'commuter' machine with a 4-stroke engine.

The motorcycles chosen for category 3 represented a range of sport, sport / touring and high powered sport machines all with 4-stroke engines.

(ii) Silencers

Table 3.2 lists the various exhaust silencers fitted to each motorcycle during the study. The silencers listed in the Table are referred to as one of 5 'generic' types. A brief definition and description of each type is described below:

Standard-

A 'standard' silencer was considered to be the original equipment fitted by the manufacturer when the machine was first registered. It was found that for each of the motorcycles tested in this study, the silencer was the original equipment supplied by the manufacturer. In each case, before finally selecting each motorcycle from the supplier, the silencer was given a close examination to ensure that it was in good condition with no defects or damage which could have affected its noise performance.

Standard (new)-

Standard (new) silencers used in this study were those produced by the manufacturer to the same design as the original equipment. Previously unused standard silencers were tested on several of the machines to compare the results with those obtained with the original equipment (standard) silencers.

Replacement-

In this study, 'replacement' silencers were after-market silencers supplied as an alternative to the manufacturers original equipment silencer. These silencers are often less expensive than the manufacturers design and/or claim to enhance engine performance. Replacement exhaust silencers fitted to motorcycles in the UK are required to have a silencing performance comparable to the standard silencer fitted by the manufacturer when tested under type approval acceleration test conditions (HMSO, 1986). Such a silencer should also bear appropriate markings to identify it as an approved type for road use.

All replacement silencers used in this study were properly certified and legal silencers for road use.

Race-

Race silencers are intended to improve the power output of the engine for competition use. Such silencers are not legal for road use and are usually labelled to this effect.

Modified/defective-

For the purpose of this study, modified or defective silencers were those which were not effectively controlling exhaust noise emission because of either deliberate alteration to the silencer, incorrect fitting, damage or corrosion.

In total, 26 silencer types were tested with the sample of 9 motorcycles. The distribution across the range of silencer types was as follows:-

- 9 standard silencers
- 5 replacement silencers
- 6 modified or defective silencers
- 2 race silencers
- 4 new standard silencers.

All of the silencer fitting and modification work was carried out at the workshops of the local motorcycle dealer supplying the machines. The general condition of each machine was checked before delivery to TRL. In particular, before the first tests were carried out with each motorcycle, the condition of the standard exhaust silencer system was checked to ensure that it was fitted properly and that it operated correctly.

A number of the silencers were modified to represent exhaust silencers which had become excessively noisy as a result of deliberate alteration. In the case of one exhaust silencer fitted to a 125cc machine, the baffles were removed from the silencer chamber. This type of modification might be carried out by the owner of such a machine in the hope that the engine power would be increased beyond the 12 bhp restriction for learner motorcycles in the UK. On another 125cc machine the silencer chamber at the rear of the exhaust system was removed leaving the front expansion chamber and exhaust pipe intact. In this case, the front expansion chamber might possibly afford a certain degree of silencing to the exhaust noise emission although the noise level would be expected to increases significantly in the absence of the silencer. Again, such a modification might be carried in the belief that engine power would be increased.

The influence of using defective silencers was simulated by drilling or sawing holes in the silencer system at positions where corrosion would normally be expected to occur in practice. If corrosion takes place it is usually found on the underside of the silencer and can ultimately cause holes in the silencer chamber giving rise to increased levels of exhaust noise. The workshop technicians were asked to make a sufficient number of holes in the silencer such that the silencer would leak to an extent that an MOT inspector would judge the noise to be excessive. This assessment was carried out by a member of the workshop staff qualified as a motorcycle MOT inspector. As guidance the technician referred to the definition of an excessively noisy exhaust system given in the MOT inspection manual (HMSO, 1992). This states:-

'A silencer which is in such a condition or is of such a type that the noise emitted is clearly in excess of that which would be produced by a similar machine fitted with a standard silencer in average condition.'

The judgements, made by the workshop technicians, in creating a 'typical' defective silencer were also based on their previous experience in dealing with corroded motorcycle silencers.

3.3 NOISE MEASUREMENTS

Noise tests were carried out with each motorcycle at both measurement locations using the close proximity noise test procedure described in European Union Directive 78/1015/EEC. It is this procedure (which is carried out with the motorcycle stationary) that is proposed as the basis of an in-service noise testing method for motorcycles (Harris and Nelson, 1994). Type approval acceleration noise tests were also carried out with each motorcycle at the ISO vehicle noise testing site according to the procedure described in Directive 78/1015/EEC. The same rider was used to operate the motorcycles for all of the tests described in this study. The details of the measurement and analysis procedures are given below.

3.3.1 Type approval acceleration tests

As specified by the type approval method given in Directive 78/1015/EEC the maximum A-weighted noise level was captured as the test motorcycle was accelerated through the ISO noise test site. A plan of the test site showing its layout and the position of the measuring microphone is given in Figure 3.1. The method requires that the motorcycle approaches the start of the 20m site at a steady speed in a low gear. The gear setting was either 2nd or 3rd depending on the engine capacity of the machine and the number of gear ratios. According to the Directive, the engine speed should either be ¾ of the speed at which maximum power is developed or the engine speed that corresponds to 50 km/h. The condition which gives the lower engine speed is the condition assumed for the test.

When the motorcycle reaches the start line of the test area the rider fully opens the throttle and accelerates the machine through the site. When the rear of the vehicle crosses the end of the 20m test strip the throttle is quickly closed. A minimum of 2 measurements are required on each side of the motorcycle.

The test results were interpreted from the sound level meter readings according to the procedure described in the Directive. The result is based on the highest level recorded during the measurements. In this way a single noise level value was obtained for each motorcycle. In all cases the engine of the test motorcycle was brought to its normal operating temperature prior to testing.

Measurements of noise were taken using a precision sound level meter with its microphone pointing towards the centre of the site and with the diaphragm in the vertical position. As required by the method the microphone was located 7.5m from the centre of the test site at a height of 1.2m above the surface of the test track. The operator was able to verify that the approach speed of the vehicle was correct using a radar speed meter. Engine speed was checked by means of an electronic tachometer device which calculated and displayed engine speed by detecting the voltage pulses on the high tension leads of the test vehicle.

In order to ensure that the accuracy of the sound level meter, radar speed meter and engine speed tachometer were within acceptable tolerances the calibration of each instrument was checked before the study began. The sound level meter was checked by the manufacturers to confirm that its operational tolerances were within specified levels for a precision grade meter. The readings from the radar speed meter were checked against those from another radar speed measurement system which had itself been calibrated by the manufacturer. This was carried out by staff at TRL. The measurement accuracy of the tachometer was confirmed by using the device to record the engine speed of a test vehicle and simultaneously monitoring engine speed acoustically by detecting the firing frequency from the engine noise spectrum. This was performed by placing a measurement microphone close to the exhaust outlet and connecting the microphone output to a narrow band signal frequency analyser. The frequency range of the analyser was set to give a high level of frequency resolution to the measured signal for maximum precision. From the resultant noise spectrum it was possible to identify the dominant firing frequency and calculate the rotational speed of the engine. This gave good agreement with the engine speed reading of the tachometer for a wide range of engine speeds. Allowing for the maximum specified tolerance errors of the frequency analyser, the accuracy of the tachometer was found to be well within 3 percent which is the requirement stipulated in Directive 78/1015/EEC. The accuracy of the signal frequency analyser had been recently checked by the manufacturers and was confirmed as being within specified tolerances.

3.3.2 Close proximity stationary tests

The close proximity stationary noise test described in Directive 78/1015/EEC requires the maximum A-weighted noise level to be captured as the engine decelerates from an initial steady engine speed. The test site requirements demand a flat, hard surface with no acoustically reflecting objects within 3m of the edges of the motorcycle. A typical layout showing the position of the microphone relative to the motorcycle exhaust outlet is shown in Figure 3.2(a). The photograph was taken during tests on the ISO noise test site. As shown in the Figure the motorcycle was parked on its stand during the tests to ensure the position of the machine did not change relative to the microphone. Where possible the main stand was used. If a main stand was not fitted the side stand was used[2].

The microphone is placed with its most sensitive axis, parallel to the ground and pointing at the exhaust outlet making an angle of 45 degrees with the vertical plane containing the direction of gas flow. The microphone is positioned at the same height as the exhaust outlet but not less than 0.2m above the ground. The initial engine speed is 1/2 the maximum power speed (*n*) if *n* is greater than 5000 rpm and ¾ *n* if *n* is less than 5000 rpm. Once this initial engine speed has been achieved, the maximum A-weighted noise level is then recorded over a period encompassing a short duration of the steady engine speed and the deceleration of the engine to idle. The method requires that at least 3 measurements are performed and the result is based on the highest level recorded. Full details of the procedure can be obtained by consulting the Directive.

All stationary noise test measurements were taken using a precision grade sound level meter mounted on a low tripod at the reference distance. Initial engine speed was monitored using the electronic tachometer described in the section above.

For each motorcycle/silencer combination, measurements of stationary noise were taken at the ISO noise test site and at the non-standard test location. At the non-standard location the test motorcycle was placed directly in front of the workshop doors perpendicular to the line of the facade. Figure 3.2(b) shows the general layout of the tests carried out at the non-standard test site. During the tests, the workshop doors were closed to simulate 'worst case' conditions where a motorcycle might be tested in front of a continuous, acoustically reflecting facade. In each case the machine was positioned such that the exhaust outlet was 2m from the line of the facade which for most motorcycles was the closest position achievable bearing in mind the need to leave sufficient room to manoeuvre he motorcycle on to its main stand.

[2]For motorcycles with exhaust silencer outlets >0.3m apart on either side of the machine, Directive 78/1015/EEC specifies that separate noise measurements should be made at each outlet and the result taken from the highest value recorded. In the case of such a motorcycle fitted only with a side stand, the two exhaust outlets would be at different heights above the ground because of the angle of the motorcycle when parked. No mention of this eventuality is made in the Directive and it must therefore be assumed that the test result is taken from the highest noise level measured regardless of the different outlet heights.

Table 3.1 Details of the motorcycles selected for the study

Make and model	Mileage	Type of machine	Engine capacity (cc) and stroke	Cooling system/ No. of cylinders	Age (years)
Category 1 ≤80cc					
Kawasaki AR50	6920	sports moped	49 2-stroke	air cooled / single	2
Suzuki AH50	2180	step-through moped	49 2-stroke	air cooled / single	1
Category 2 >80-≤175cc					
Yamaha DT125R	4404	trail bike	124 2-stroke	liquid cooled / single	1
Honda NSR125R	6813	sports	125 2-stroke	liquid cooled / single	4
Yamaha SR125	6984	commuter (custom)	124 4-stroke	air cooled / single	3
Category 3 >175cc					
Kawasaki GPZ500S	6638	sport	498 4-stroke	air cooled / single	2
Suzuki GS500E	6589	sport	498 4-stroke	air cooled / twin	1
Suzuki GSX600F	9861	sport / tourin g	599 4-stroke	liquid cooled / 4 cylinder	1
Honda CBR900R	10386	high power sport	918 4-stroke	liquid cooled / 4 cylinder	5

Table 3.2 Silencers used for the study

Motorcycle make and model	Description of exhaust silencers		
	Silencer 1	Silencer 2	Silencer 3
Category 1 ≤ 80cc			
Kawasaki AR50	STANDARD *(Kawasaki part)*	REPLACEMENT *('Micron' performance road exhaust)*	———
Suzuki AH50	STANDARD *(Suzuki part)*	MODIFIED / DEFECTIVE *(Suzuki standard - simulated corrosion)*	STANDARD (NEW) *(Suzuki part)*
Category 2 >80-≤175cc			
Yamaha DT125R	STANDARD *(Yamaha part)*	REPLACEMENT *('Fresco' replacement)*	MODIFIED / DEFECTIVE *('Fresco' replacement - baffle removed)*
Honda NSR125R	STANDARD *(Honda part)*	MODIFIED / DEFECTIVE *(Honda standard - final silencer chamber removed)*	STANDARD (NEW) *(Honda part)*
Yamaha SR125	STANDARD *(Yamaha part)*	MODIFIED / DEFECTIVE *(Yamaha standard - simulated corrosion)*	STANDARD (NEW) *(Yamaha part)*
Category 3 > 175cc			
Kawasaki GPZ500S	STANDARD *(Kawasaki part)*	MODIFIED / DEFECTIVE *(Kawasaki standard - simulated corrosion)*	STANDARD (NEW) *(Kawasaki part)*
Suzuki GS500E	STANDARD *(Suzuki part)*	REPLACEMENT *('Motad Nexus' type XS53)*	MODIFIED / DEFECTIVE *('Motad Nexus' replacement - simulated corrosion)*
Suzuki GSX600F	STANDARD *(Suzuki part)*	REPLACEMENT *('Motad Nexus' type X56F)*	RACE *('Yoshimura' race exhaust)*
Honda CBR900R	STANDARD *(Honda part)*	REPLACEMENT *('Motad' type FH9R)*	RACE *('Micron' type PCH42)*

4. RESULTS

The results of the noise measurements taken on the test track under drive-by acceleration type approval conditions are given in Table 4.1. and the results of the measurements taken in close proximity on the test track and at the non-standard test site are given in Table 4.2. In each case the results presented are the test results derived from the actual measured values using the stated selection and rounding processes described in EU Directive 78/1015/EEC.

The following sections examine these results in more detail.

4.1 EFFECT OF DIFFERENT SILENCERS

(i) Type approval acceleration test conditions

The type approval noise levels given in Table 4.1 for each motorcycle/silencer combination studied are shown graphically in Figure 4.1.

It can be seen that in nearly every case the noise levels for the motorcycles fitted with standard original equipment silencers or standard (new) silencers gave the lowest type approval levels.

For the two most powerful machines fitted with 'race' silencers the noise levels were significantly higher than the levels produced with the original equipment fitted. The differences in noise registered were 9 dB(A) for the 600 cc machine and also 9 dB(A) for the 900 cc machine. Finally, the results obtained with the modified or defective silencers generally showed substantial increases when compared with the original equipment results. The most notable change in noise occurred for the AH50 moped where the noise increased by approximately 16 dB(A) under the type approval test when the defective (illegal) silencer was fitted. It can also be seen that a similar large increase in noise also occurred when the modified silencer was fitted to the category 2 motorcycle, NSR125R. In this example the difference in noise between the motorcycle fitted with the standard silencer and the modified silencer was approximately 14 dB(A). Interestingly, when the SR125 was fitted with a defective silencer, the noise levels were not found to increase to the same extent. In this case the noise level was only 3 dB(A) greater then for the standard silencer although the holes in the silencer would have caused the machine to fail a MOT test inspection.

(ii) Close proximity stationary test conditions (test track)

Table 4.2 lists the results obtained from the close proximity test at the test track location for the different motorcycle/silencer combinations studied. Figure 4.2 illustrates the trend and, as might be expected, the results appear to show a similar pattern to those obtained from the acceleration drive by test. For example, in all cases the lowest noise levels were obtained with the motorcycles fitted with the standard and standard (new) silencers. Large, significant increases in noise were generally noted when these silencers were changed to the modified / defective silencers. The exception to this was again the SR125 which showed only a slight increase in stationary test noise level when the defective silencer was fitted. The large increases in noise noted in Figure 4.1 for the two most powerful motorcycles fitted with 'race' silencers were not as apparent when comparing the results obtained as part of the close proximity test.

4.2 COMPARISON OF CLOSE PROXIMITY STATIONARY TEST NOISE LEVELS AT STANDARD AND NON-STANDARD SITES

Figure 4.3 shows a comparison of the close proximity noise levels obtained at the standard test site and at the non-standard test site. The values shown on the Figure are differences in maximum A-weighted noise level between the results recorded at the two test sites. For each test condition an averaged result was calculated from the 3 measurement results recorded. The noise levels used to calculate the averages were *not* rounded. In this way the typical differences in noise between the two test sites for each motorcycle / silencer combination can be seen to the nearest 0.1 dB(A). The Figure shows that the results were typically higher at the non-standard site. Most of the increases in noise were within 1 dB(A) with none in excess of 1.5 dB(A). In a few cases the noise levels recorded at the non-standard test site were found to be slightly lower than the result obtained at the standard ISO site. This phenomenon cannot be explained in terms of the acoustical influence of the test environment and could therefore be attributed to slight variations in the noise emission from the motorcycles during different test sessions. This could perhaps have been caused by vehicle dependent factors such as differences in engine or silencer temperature during the two test sessions. These variations are, however, relatively small given that differences of up to 1 dB(A) between the results of consecutive tests were not uncommon during measurements at any single location. As an indication of the expected repeatability of the procedure, Directive 78 / 1015 / EEC states that the test result can be determined from three consecutive tests provided that the variation in the recorded values does not exceed 2 dB(A).

It should also be noted that when the data is compared in terms of actual test levels (i.e. rounded according to the standard procedures) the differences in the test noise levels were found to be either zero or 1 dB(A) for all cases studied.

Generally, these results comparing standard and non-standard test sites confirm the findings of the previous study (Harris and Nelson, 1994). For both studies it was found that the noise levels obtained at a non-standard test site of the type described do not differ significantly from results obtained at a standard ISO test site.

4.3 COMPARISON OF ACCELERATION AND CLOSE PROXIMITY STATIONARY TEST NOISE LEVELS OBTAINED ON THE TEST TRACK

The type approval acceleration test noise levels and stationary test noise levels measured from the different motorcycle/silencer combinations studied as part of this report have been combined with the corresponding data set obtained from the previous study of motorcycle noise. This was reviewed in previous sections (Harris and Nelson, 1994). This combined data set is plotted in Figure 4.4.

The data plotted in the Figure differentiate between the different motorcycle categories studied and whether the exhaust silencers fitted to these vehicles were either legal (i.e. were either standard, standard (new) or road legal replacement silencers) from silencers which would not be legal for road use (i.e. silencers which had been modified, were defective or designed only for off-road use). Included on the Figure is the regression line drawn through the whole data set and the associated 95% confidence and prediction boundaries. The current UK drive-by acceleration noise limits associated with the three motorcycles categories are also indicated on the Figure[3]. It can be seen that a number of motorcycles in engine size categories 2 and 3 gave noise levels higher than the current UK acceleration test noise limits. All of these motorcycles were registered after the current noise limits were brought into force and therefore did not comply with road vehicle regulations on control of noise emissions (HMSO, 1986).

It can be seen that the degree of correlation between the in-service stationary test results and the acceleration test results is reasonably high when considering the data as a whole. The correlation coefficient obtained was 0.85.

The Figure also shows the relatively high noise levels obtained generally for the motorcycles fitted with the road illegal exhaust silencers when compared with the bulk of the data which was obtained for road legal silencer systems. However, by examining the three motorcycle categories separately it is clear that the effects of using illegal or ineffective silencers is also dependent upon the category of motorcycle. For example, for the smallest motorcycles and mopeds and the medium capacity motorcycles tested (ie. categories 1 and 2) the results obtained for the illegal silencer systems were generally significantly higher than the corresponding levels obtained for motorcycles fitted with legal silencers. This was the case for both drive-by acceleration noise levels and stationary test noise levels. However, for the most powerful motorcycles studied (i.e. category 3) the differences in noise between legal and non-legal exhaust systems was smaller in all cases examined.

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[3] The acceleration test noise limits are those given in the road vehicles (construction and use) regulations (HMSO, 1986).

Table 4.1 Type approval acceleration test noise levels of motorcycles fitted with standard and non-standard exhaust silencers

Motorcycle	Maximum SPL (dB(A))				
	Standard silencer	Standard (new) silencer	Replacement silencer	Race silencer	Modified/Defective silencer
Category 1 ≤ 80cc					
Kawasaki AR50	68	-	73	-	-
Suzuki AH50	75	74	-	-	91
Category 2 >80-≤175cc					
Yamaha DT125R	80	-	82	-	88
Honda NSR125R	80	78	-	-	94
Yamaha SR125	78	78	-	-	81
Category 3 > 175cc					
Kawasaki GPZ500S	82	82	-	-	88
Suzuki GS500E	82	-	82	-	93
Suzuki GSX600F	82	-	82	91	-
Honda CBR900R	83	-	83	92	-

Table 4.2 Close proximity stationary test noise levels of motorcycles fitted with standard and non-standard exhaust silencers

Motorcycle	Maximum SPL (dB(A))									
	Standard silencer		Standard (new) silencer		Replacement silencer		Race silencer		Modified/Defective silencer	
	ISO site	Non-std site	ISO site	Non-std site	ISO site	Non-std site	ISO site	Non-std site	ISO site	Non-std site
Category 1 ≤ 80cc										
Kawasaki AR50	78	79	-	-	82	82	-	-	-	-
Suzuki AH50	78	78	78	78	-	-	-	-	101	102
Category 2 >80-≤175cc										
Yamaha DT125R	80	81	-	-	81	82	-	-	95	96
Honda NSR125R	87	88	84	85	-	-	-	-	101	102
Yamaha SR125	83	84	83	84	-	-	-	-	85	86
Category 3 > 175cc										
Kawasaki GPZ500S	87	87	87	87	-	-	-	-	94	94
Suzuki GS500E	89	90	-	-	89	89	-	-	93	94
Suzuki GSX600F	95	95	-	-	94	94	97	96	-	-
Honda CBR900R	95	94	-	-	95	95	99	100	-	-

5. DISCUSSION

5.1 GENERAL

The primary objective of the work described in this report was to extend the previous study of in-service noise from motorcycles to include motorcycles fitted with replacement, modified, defective or off-road performance silencers. It was anticipated that, with this additional data, it would be possible to determine an appropriate rationale for the setting of limit values for in-service noise from motorcycles which would clearly enable the tester to identify motorcycles fitted with ineffective, modified or illegal silencers. The earlier study had already established the basic test requirements for an in-service test and had examined, for example, the suitability of the test area, the influence of ambient noise, the type of instrumentation and, perhaps most importantly, the relationship between in-service stationary test results and type approval acceleration test results.

In addition to the main objective, therefore, this study has also provided an opportunity to examine further the relationship between in-service and type approval noise levels and to reaffirm the basic requirements of the test site. It has been shown, for example, that when considering the data set as a whole there is a reasonably high degree of correlation between the results obtained for the drive by test and the results obtained in close proximity from the stationary vehicle. The correlation coefficient obtained was 0.85 which suggests that about 75% of the variance in the type approval levels can be explained by close proximity noise levels and vice versa.

Clearly, the degree of correlation and the associated confidence intervals associated with the regression line have a bearing on the development of limit values that might be applied for the close proximity test for motorcycles as it is important that noise levels measured in close proximity should provide a reasonable prediction of the noise levels that would be generated if the vehicle were tested using the standard type approval acceleration noise test.

5.2 CLOSE PROXIMITY STATIONARY TEST NOISE LIMITS FOR MOTORCYCLES

A fundamental principle guiding the setting of limits for in-service noise levels must be to ensure that, to a reasonable probability, a motorcycle failing to meet the in-service limit for the appropriate category of motorcycle should not be found to subsequently pass the drive-by acceleration type approval test. A further consideration must be to avoid the situation occurring where a motorcycle fails the close proximity test when the motorcycle is properly fitted with a legal silencer which is in good condition. If such situations occurred in practice this would cast doubt on the validity of the test and the applicability of the limit values leading to a loss of confidence in the test by the enforcement authorities.

Table 5.1 identifies all possible, pass or fail, combinations for the in-service and type approval test. Clearly, a motorcycle either passing both tests or failing both tests would be an acceptable combination. However, as mentioned above a motorcycle failing the in-service test and passing the type approval test would be unacceptable. A final possibility is that a motorcycle would pass the in-service test but would fail the type approval test. This has been labelled undesirable since, although it would not cause a significant problem in practice, it clearly would mean that the motorcycle would not be identified as a noisy vehicle using the in-service test even though it would fail the drive by noise limit.

Table 5.2 uses a similar format to identify the acceptability of various combinations of pass and fail using the in-service test on motorcycles fitted with good condition legal silencers and those fitted with illegal, modified or faulty silencers. In this case it is acceptable to pass a good condition legal silencer and fail an illegal silencer. However, it is suggested in the Table that it would be an unacceptable outcome to fail a motorcycle using the in-service test if it were fitted with an exhaust system which was in good condition, fitted properly, and legal for road use for the motorcycle type tested.

In order to determine how the levels of probability vary for unacceptable outcomes with different limit values, the data given in Figure 4.4 can be used. As was mentioned earlier, the data in the Figure shows a significant correlation between close proximity noise levels and drive-by acceleration type approval noise levels for the sample of motorcycles tested.

From the statistical analysis of all measurements it is possible to estimate the probability of a motorcycle failing the close proximity test and then subsequently passing the drive-by acceleration type approval test. The same rationale can be applied to each category of motorcycle, however, the limits will be different to achieve the same degree of confidence in the result.

(i) Category 1 motorcycles, i.e. ≤ 80ccs

Using the upper 95% prediction boundary (i.e. 2 standard deviations from the mean) as a criterion for determining pass or fail under the close proximity test it would appear that the limit for the small (≤80cc) motorcycles should be set at approximately 15 dB(A) above the type approval limit value. This correction factor can be read from the graph at the point where the drive by type approval limit for this category of motorcycles intersects with the upper prediction boundary. With this in service limit, the statistics suggest that only about 2-3 motorcycles in every 100 tested that just meet the drive by type approval noise limit will fail the close proximity noise test. For example, for a motorcycle which just meets the drive-by acceleration noise limit of 77 dB(A), i.e. just meeting the current limit value, there will be a 2.5% chance of the motorcycle exceeding the close-proximity noise limit of 92 dB(A), (i.e. 77 dB(A) + 15 dB(A)). Clearly, for motorcycles in this category which have lower type-approval noise levels, the probability of the same bikes failing the close proximity test will be less than 2.5%.

It can be seen that, for the data given in Figure 4.4 for this category of motorcycle, all the motorcycles fitted with legal silencers comfortably passed both the type approval noise test and the in-service noise test. However, the motorcycle fitted with an illegal silencer failed both the type approval noise limit and the recommended in-service noise limit by a substantial margin.

The outcomes of the test results for this category of motorcycle are summarised in Tables 5.3 and 5.4. It can be seen that the test outcomes using the proposed limit values satisfy all the requirements specified in Tables 5.1 and 5.2.

(ii) Category 2 motorcycles, i.e. >80 - ≤175ccs

Using the same rationale as in (i) above the in-service noise limit for medium capacity motorcycles should be set 15 dB(A) above the relevant type approval limit. Consequently a motorcycle just meeting the current type approval noise limit of 79 dB(A) would be expected to meet a close proximity limit of 94 dB(A). The probability of this occurring in practice is, as before, 97.5% with higher probabilities associated with machines producing lower type approval levels.

Again using the data set in Figure 4.4 and the summaries provided in Tables 5.3 and 5.4, it can be seen that of the 14 motorcycle/silencer combinations tested in this category, three out of the four illegal silencer systems gave noise levels which would have failed a 94 dB(A) in-service noise limit. Each of these motorcycle/silencer combinations would also have failed any relevant type approval drive by noise limit. However, one of the machines in this engine size category fitted with a defective silencer gave stationary test noise levels well below 94 dB(A). It should be noted though that the corresponding type approval acceleration test level of 81 dB(A) was not substantially greater than that obtained when the machine was fitted with its standard silencer (i.e. 78 dB(A)). As discussed in Section 4.1, the holes in the defective silencer would have caused the machine to fail a MOT test inspection.

The summaries in Tables 5.3 and 5.4 show that all essential requirements are met with the close proximity test and the proposed limit values but the desirable aspects, described previously, are not. It can be seen that five motorcycles in this category passing the close proximity test would have subsequently failed the type approval test, and, as mentioned above, one motorcycle with an illegal silencer passed the close proximity test.

(iii) Category 3 motorcycles, i.e. > 175ccs

For the most powerful category of motorcycles, a correction factor of 15 dB(A) is also required. With this correction, motorcycles in this category that are required to meet the current type approval limit of 82 dB(A) would be required to meet an in-service noise limit of 97 dB(A). By applying this limit to the relevant data given in Figure 4.4 it can be seen from this Figure and Tables 5.3 and 5.4 that only one of the four motorcycles fitted with illegal silencers would have failed the in-service test.

Nevertheless, even though the in-service test and proposed limit was not sufficiently sensitive to identify all illegal silencer systems fitted to these motorcycles, the system that was identified gave a drive-by acceleration noise level which was far in excess of the type approval noise limit.

On the test criteria outlined in Tables 5.1 and 5.2 therefore the limits as proposed would not give any unacceptable outcomes. An undesirable outcome is that 6 motorcycles passing the close proximity test would fail the drive by type approval test.

(iv) Setting in-service noise limits

Clearly, the probability of a motorcycle failing the close proximity test and passing the drive by type approval test, or having a motorcycle fitted with a good condition legal silencer failing the close proximity test, can be reduced by raising the close-proximity limit values further. For example, by setting the limit values at three standard deviations from the mean rather than two as suggested in the previous paragraphs, would mean raising the close proximity limit values by approximately 4 dB(A) for each category of motorcycle. With this higher setting it would be expected that there would be approximately a 0.1% chance that a motorcycle just meeting the relevant drive-by acceleration type approval limit will fail to meet the close proximity noise limit. Using this criterion the noise limit values would be 96, 98 and 101 dB(A) for motorcycle categories 1,2 and 3 respectively. Assuming these limits, the test outcomes have been determined for the same data set and are shown in brackets in Tables 5.3 and 5.4.

As would be expected, the number of undesirable outcomes increase with the higher close proximity limits. For example, six out of nine motorcycles fitted with illegal silencers would *pass* the close proximity test as compared with four out of the nine motorcycles for the lower noise limits.

The increase in undesirable outcomes is a consequence of ensuring a high level of confidence that the unacceptable test results do not occur in practice. Clearly, it is the latter which must take precedence when setting a practical limit.

The level of confidence required is a matter of judgement and ultimately is a political decision. However, the results contained in this report should prove useful in the decision making process by quantifying the likely consequences.

It is recommended that a further 1 dB(A) be added to the noise limit values to take account of the slight increase in the close proximity noise test result that can occur at non-standard test locations. As described earlier, the differences in the close proximity test result for the standard and non-standard test site were found to be no greater than 1 dB(A) when the results were rounded according to standard procedure. It is suggested that the corrected limit values for each motorcycle category should lie at either the 2.5% prediction boundary or the higher 0.1% boundary, or possibly at an intermediate point between these values. The range of limit values would therefore be as follows:

Category 1 motorcycles, i.e. ≤ 80cc93 - 97 dB(A)

Category 2 motorcycles, i.e. > 80 - ≤ 175cc95 - 99 dB(A)

Category 3 motorcycles, i.e. > 175cc98 - 102 dB(A)

A final point to make which was referred to earlier in the discussion is the number of motorcycles of those examined in the two studies which were fitted with legal exhausts in good condition which did not meet the current type approval noise limits. For the category of motorcycle with the smallest engines (all two-strokes in this study), all of the machines with legal silencers were found to pass the type approval test. For the intermediate category 40% of the machines tested failed to meet the appropriate limit. In the case of the larger motorcycles in category 3, 12% of the machines gave type approval test results greater than the limit value. All of the motorcycles were secondhand and, although judged to be in good condition when tested, some deterioration in their, as new, condition is to be expected which could have accounted for some of the observed test results. However, the large number of machines in category 2 failing the test would seem to be worthy of further investigation since it does appear, from this data set at least, that many motorcycles currently in use would fail the type approval test by a substantial margin, even when they were fitted with good condition, legal silencers.

Table 5.1 Acceptable outcomes from close proximity and type approval tests

Close proximity test	Type approval test	
	Pass	Fail
Pass	Yes	Undesirable
Fail	Unacceptable	Yes

Table 5.2 Acceptable outcomes for close proximity and silencer condition

Close proximity test	Silencer condition	
	Legal[1]	Illegal[2]
Pass	Yes	Undesirable
Fail	Unacceptable	Yes

[1] Good condition legal silencers.
[2] Illegal, modified, and poor condition silencers.

Table 5.3 Summary of test outcomes from close proximity and type approval test

Close proximity test	Type approval					
	≤80 cc		>80cc - ≤175cc		> 175cc	
	Pass	Fail	Pass	Fail	Pass	Fail
Pass	6 (6)[1]	0 (0)	6 (6)	5 (6)	14 (14)	6 (7)
Fail	0 (0)	1 (1)	0 (0)	3 (2)	0 (0)	1 (0)

Table 5.4 Summary of test outcomes from close proximity and silencer condition

Close proximity test	Silencer condition					
	≤80 cc		>80cc - ≤175cc		> 175cc	
	Legal[2]	Illegal[3]	Legal	Illegal	Legal	Illegal
Pass	6 (6)[1]	0 (0)	10 (10)	1 (2)	17 (17)	3 (4)
Fail	0 (0)	1 (1)	0 (0)	3 (2)	0 (0)	1 (0)

[1] Values in brackets give results at the higher cut-off test limits.
[2] Legal: a good condition legal silencer.
[3] Illegal: a modified or a poor condition silencer or a silencer which is illegal for road use.

6. CONCLUSIONS

The following main conclusions can be drawn from the results of this study:-

1. It was confirmed that the in-service motorcycle noise test procedure described in the European Union Directive 78/1015/EEC was a relatively simple test to perform, could be carried out without the need for complex instrumentation and gave a satisfactory degree of reproducibility of the test results.

2. Measurements carried out using the close-proximity test at the standard test location agreed well with the corresponding test results obtained at a non-standard test site. The differences between the test result were, in each case, 1 dB(A) or less.

This result again confirms the findings of a previous report by the same authors which found that provided motorcycles can be tested outdoors, virtually any location will be suitable provided the ambient noise levels produced by other sources are not excessively high. Tests carried out on garage forecourts, outside workshops and at the roadside, would, with few exceptions, all be suitable for in-service testing.

3. It was found that the noise levels for the motorcycles fitted with standard original equipment silencers or standard (new) silencers gave the lowest type approval levels.

4. For the two most powerful machines fitted with 'race' silencers the noise levels were significantly higher than the levels produced with the original equipment fitted. The differences in noise registered were 9 dB(A) for both a 600cc machine and a 900cc machine.

5. By combining the results of this study with those obtained in a previous study, possible limit values for close proximity noise levels have been suggested. It was found that with the close proximity limits for motorcycles set at 19 dB(A) above the corresponding type approval limit values there would be a very low probability that a motorcycle would fail the close proximity test and would then subsequently pass the drive-by type approval acceleration test.

6. By applying these limits to the combined data set contained in Figure 4.4 it was found that of the nine motorcycle/silencer combinations tested, where the silencer was either defective or illegal, three would fail the in-service test. In addition, with these limits none of the motorcycles fitted with legal silencers would have exceeded the proposed in-service close proximity noise limits.

7. Lower limit values could be set with the advantage of improving the chances of failing illegal machines, however there would, of course, be a higher risk of failing some motorcycles which were legal.

8. To take account of the slight increase in close proximity noise test results that occur in non-standard test locations, it is suggested that an additional 1 dB(A) is added to the

noise limit values.

9. Using the above rationale, it is suggested that in-service noise limits for motorcycles should lie in the following ranges:

Category 1 motorcycles, i.e. $\leq$ 80cc93 - 97 dB(A)

Category 2 motorcycles, i.e. > 80 - $\geq$ 175cc95 - 99 dB(A)

Category 3 motorcycles, i.e. > 175cc98 - 102 dB(A)

The exact choice of limit values will depend on the level of confidence required that legal motorcycles will not fail the close proximity test. Although the choice of limit values will ultimately be a political decision, the results contained in this report will be of use in the decision making process by providing an assessment of the likely consequences of setting limit values in these ranges.

7. ACKNOWLEDGEMENTS

The Authors would like to acknowledge the contribution made to this work by Mr R Stait who assisted with the measurements and analysis.

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