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THE REDUCTION OF NOISE FROM HEAVY DIESEL ENGINED GOODS VEHICLES (QHV 90 PROJECT)

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1. INTRODUCTION

Research at Transport and Road Research Laboratory (TRRL)[1, 2] has shown that at least 23% of the residential population of Great Britain were bothered by traffic noise and 8% were seriously bothered. More recent research[3] on nuisance from heavy lorries suggested that of people in their homes, 12% were bothered very much or quite a lot by lorries, although factors other than noise were taken into account in this survey.

As long ago as 1963 the Wilson Committee[4] reported that traffic noise was the most important source of noise nuisance and the results of tests showed that the noise from individual vehicles would have to be reduced to 80 dB(A) for the noise to be judged by the average listener to be on the boundary of 'acceptable' and 'noisy'. This figure of 80 dB(A) has tended to be the target of vehicle noise reduction programmes ever since.

In 1970 a Ministry of Transport working group on road traffic noise recommended[5] that research and development was needed to build a heavy articulated lorry aiming at a sound level at least 10 dB(A) below the then current levels, to demonstrate the feasibility and commercial viability of such a lorry. This led to a target level of 80 dB(A) being adopted. This recommendation was taken up by TRRL which in 1971 launched its quiet heavy vehicle (QHV) project[6] and produced a commercially viable demonstration diesel engined heavy articulated lorry having a maximum external noise level of 81 dB(A).

The Armitage Inquiry reported[7] that, after safety and intrusion, noise was the next most important aspect of nuisance from lorries and recommended that the Government should accept as a policy aim the agreement of an EEC directive requiring lorries to be manufactured to a maximum noise level of 80 dB(A) and that the new limit should be introduced no later than 1990.

Following Armitage, in December 1981, the Government published a White Paper "Lorries, People and the Environment"[8] in which it stated its target "progressively to reduce the perceived noise from new heavy lorries coming on to the road to less than half of the 1981 level, so that by 1990 they would be no noisier than most 1981 new model cars......The Government will therefore set in hand a collaborative programme of research and development involving vehicle and engine manufacturers......The new programme is intended to lead to the development of a 'production' quiet heavy vehicle for the 1990s - the QHV 90. The programme will concentrate on noise reduction at source, which in itself will help reduce airborne vibration."

THR REDUCTION OF NOISE FROM HEAVY DIESEL ENGINED GOODS VEHICLES (QHV 90 PROJECT)

2. NOISE LEGISLATION

A useful history of noise legislation for road vehicles is given by Woolford(9). Prior to 1973 when the UK entered the European Community, noise levels produced by road vehicles in the UK were governed by the "Construction and Use Regulations". While this is still the case the C&U regulations now embody the current EEC rulings.

Thus, before 1977 the directive 70/157/EEC applied which allowed the heaviest vehicles to produce 91 dB(A). An amending directive, 77/212/EEC, completed in 1977 largely as a result of an initiative by the UK, called for a range of noise limits which included one of 88 dB(A) for the heaviest goods vehicles. This applied in the UK to new vehicles manufactured from April 1983 and first used from October 1983.

The latest directive III/31/83-EN, which was confirmed and published as recently as September 1984 calls for reductions in noise level to 84 dB(A) for maximum weight HGVs and is the main reason for the QHV 90 project. Details of the current and future noise levels for goods vehicles are given in Table 1.

The EEC limits outlined above apply throughout the European Community and refer to the vehicle noise produced under a standard test procedure. In the current test procedure (70/157/EEC) the vehicle is driven towards the test site from the lower of either 50 km/hr or the speed corresponding to ¾ maximum power engine speed, in a specified gear. Maximum acceleration is then applied over a distance of 20 metres past a microphone which is set at 7.5 metres from the vehicle centre line, 10 metres from the start of acceleration.

A more stringent test procedure comes into effect in 1985 (Directive 81/334/EEC) in which the vehicle is tested in more than one gear and the highest noise level is the one used for type approval purposes. For a typical heavy goods vehicle the test approach speed will be well below 50 km/hr and the vehicle noise will be dominated by mechanical sources such as engine and exhaust with the tyre rolling noise contributing little to the total noise.

Table 1. Current and future noise levels for goods vehicles.

Type of vehicle	Max SPL 70/157/EEC 1981	Max SPL 77/212/EEC 1983	Max SPL III/31/83-EN 1990
Goods vehicles more than 3½ tons	dB(A)	dB(A)	dB(A)
-with engine power of 150kw or more (200hp)	91	88	84
-with engine power of 75 to 150kw (100 to 200hp)	89	86	82
-with engine power of less than 75kw (100hp)	89	86	80
Goods vehicles less than 3½ tons	85	81	78

THE REDUCTION OF NOISE FROM HEAVY DIESEL ENGINED GOODS VEHICLES (QHV 90 PROJECT)

3. REDUCTION OF NOISE FROM HEAVY GOODS VEHICLES

3.1 Noise sources and their relative importance.

The sources of vehicle noise have been identified as engine, air inlet, exhaust, cooling fan, transmission, aerodynamic, road surface/tyres (rolling noise), brakes, body rattles and load[10].

The relative importance of these sources depends on the type of vehicle and the operating conditions. With light vehicles the engine is dominant only at low road speeds and acceleration in low gears; at higher road speeds in top gear with reduced engine speed and power, tyre noise is likely to be the dominant source.

However, with heavy diesel engined lorries the engine, exhaust and cooling system noise (fan) are the dominant sources under most operating conditions although the noise of the tyres rolling on the road surface can be noticeable at high speeds.

Internal cab noise is also a problem with commercial vehicles and much effort has been directed by the manufacturers to reduce this as of course for the driver the cab is his 'place of work'.

Because the separate noise sources combine logarithmically to produce overall vehicle noise, it is imperative that all main noise sources are reduced together; little or no noticeable improvement is made if, say, exhaust noise is reduced while engine noise is left untreated. Thus any viable programme of vehicle noise reduction has to take into account every important noise source.

3.2 Research into noise reduction: The TRRL Quiet Heavy Vehicle.

The Quiet Heavy Vehicle (QHV) Project was initiated by TRRL in 1971 and was aimed at demonstrating that practical heavy diesel engined articulated vehicles could be produced with external noise levels some 10 dB(A) lower than the 1971 values (down to about 80 dB(A), about the level of a private car).

The overall aim of the project at the time was to assist the British vehicle industry to meet future legislation on maximum noise levels, and to demonstrate which levels were reasonable, having regard for the likely extra costs involved. In the event, the project provided important technical input to the EEC negotiations on vehicle noise legislation.

The principal objective was to produce demonstration quiet articulated vehicle tractors. The first was based on a Leyland vehicle with a gross weight limit of 32.2 tonnes and an engine of 158kw. The second was a Foden vehicle designed for a maximum weight of 44.7 tonnes and fitted with a Rolls-Royce engine of 262kw. A target level of emitted sound of 80 dB(A) was set to be achieved not only under the conditions of the standard acceleration test, but also under any normal operating conditions. In addition to the external noise target the noise level in the driver's cab was not to exceed 75 dB(A); the then current in-cab levels were around 92-94 dB(A).

In order to achieve the overall target of 80 dB(A) it was considered that the target levels for the major vehicle components should be as given in Table 2.

Table 2. Upper limits of noise levels of vehicle components.

Noise source		Maximum level dB(A) at 1m	at 7.5m
Engine including gearbox	(ISVR)	92	77
Air intake, exhaust system	(MIRA/ISVR)	84	69 (also 90 dB(C)
Cooling system	(MIRA/NEL)	84	69
Cab noise	(MIRA)	--- 75 ---	
The vehicle cab was to be designed to provide 3 dB(A) attenuation of the sound level emitted to the roadside by the power unit.			

The research on the basic noise sources of the vehicles, including the design, construction and testing of quieter components was carried out at the Institute of Sound and Vibration Research (ISVR) of Southampton University, the Motor Industry Research Association (MIRA), and the National Engineering Laboratory (NEL). The TRRL undertook the work on tyre-road surface noise and the overall management and coordination of the project. The allocation of the tasks is shown in Table 2. Important objectives were that the experimental components should be commercially practicable, and that the differences in production and operating costs should be evaluated for various degrees of quietening. To this end the close cooperation of the manufacturers was essential.

The QHV project was divided into two phases: (i) the research phase which led to experimental versions of the two vehicles and (ii) a development phase leading to commercially viable vehicles for demonstration. Both the experimental vehicles were produced, but only the Foden/Rolls-Royce vehicle was developed to demonstration form. The results from the Leyland vehicle were to be used in future product designs. The following is a summary of the work on the Foden/Rolls-Royce vehicle.

3.2.1 The complete vehicle. The original Foden vehicle used at the start of the project was a 6x2 tractor unit with a 13 litre Rolls-Royce diesel engine. MIRA and ISVR carried out work on the exhaust, cooling system and cab noise of the vehicle until it was superceded by a later design based on a 4x2 chassis with a maximum gross vehicle weight of 38 tonnes.

When Fodens were preparing this vehicle they built into it the revised designs of cooling and exhaust systems then reached by ISVR and MIRA, provided a new design of cab with improved sound insulation, and fitted the engine with an improved turbocharger and camshaft, both of which gave useful reductions in open pipe exhaust noise emission. The final experimental version of the Foden vehicle included the quietened exhaust and cooling systems produced by MIRA and ISVR and the quietened ISVR/Rolls-Royce engine in a tunnel enclosure. In this condition the vehicle was evaluated and returned to Fodens for the development phase of the project.

3.2.2 Engine. To establish the baseline noise levels of the original Rolls-Royce engine, the engine and gearbox were installed in a semi-anechoic test cell at ISVR and coupled to a dynamometer to absorb the power.

To assess the relative importance of different parts of the engine surface as noise radiators, the entire engine was covered with lead sheet lined with glass fibre matting. The noise level of the engine was measured with the individual components exposed in turn. Although this is not an accurate method of measuring the absolute noise output of any individual component (the noise of the completely enclosed engine was only 10 dB(A) below that of the uncovered engine) the method is of value in establishing a rank order of the strength of the various sources. The rank order of components for this engine was (1) structure (cylinder block and crankcase), (2) sump, (3) front end, (4) gearbox and (5) air inlet. The frequency spectrum of the engine is shown in Figure 1. This work together with a vibration survey of the engine surface and static bending tests led to the design of the research engine at ISVR.

The basic philosophy of the research engine was to use the running gear (pistons, connecting rods, crankshaft etc.) from the standard engine in a strengthened cylinder block/crankcase structure. This reduced the flexing of the cylinder block walls caused by the distortion of the crankcase. Another requirement of the crankcase design was to provide flat sides to enable close fitting damped panels to be attached for the attenuation of transmitted vibration. The fuel pump was replaced by a quieter version and the sump was isolated from the engine by a thick U-section rubber moulding. The sides and front surfaces of the engine were fitted with laminated damped panels consisting of a central sheet of steel perforate and outer sheets of mild steel sandwiched together with layers of Neoprene.

Although the target noise level was not quite reached at maximum load and speed, the final noise level was nearly half that of the standard engine (9-10 dB(A) less).

3.2.3 Exhaust. The open pipe exhaust noise level from the Rolls-Royce engine was 109 dB(A) at 2100 rev/min with the microphone 7.5m from the end of the pipe and 60 degrees of the axis. Before the work on the silencers started this noise level was reduced by the fitting of an improved turbocharger (-3 dB(A) at higher speeds), and a modified camshaft with different valve clearances (-6 dB(A) to -8 dB(A)).

ISVR produced computer-based designs from exhaust data supplied by MIRA from their engine tests. MIRA then used the ISVR basic designs to produce practical versions and tested these in a special noise test facility.

The final design was completely reactive, i.e. it contained no absorptive material which would become clogged with exhaust products and be blown out of the system with consequent loss of performance. It consisted of two cylindrical boxes with a total volume of 186 litres, and it met the target of 69 dB(A) at 7.5m but exceeded the dB(C) target by 2 dB(C) at high engine speeds; at low engine speeds the dB(C) level was short of the target by a larger margin due to difficulty in silencing the engine firing frequency components.

3.2.4 Cooling system. Measurements of noise made with the original cooling system, which used an axial fan running at up to 2400 rev/min, showed that a reduction of noise of the order of 25 dB(A) would be needed to meet the project target of 84 dB(A) at 1m in front of the fan. Using the existing fan would have meant a reduction in fan speed of about one half with an unacceptable loss in cooling performance. Also the fan duty in the research vehicle was considerably increased due to the engine enclosure. A new design of cooling system was therefore required and this was eventually based on a mixed flow fan designed by the NEL.

3.2.5 Tyre noise. The research on tyre noise at TRRL[11] led to the recommendation that the research and demonstration vehicles be fitted with radial tyres having five or more circumferential ribs and no pronounced edge patterns which would give rise to tonal noise.

3.2.6 Noise level of research vehicle. The maximum external noise level of the final research vehicle was reduced to 83.5 dB(A) and the cab noise to 78 dB(A).

3.2.7 The demonstration Foden/Rolls-Royce vehicle.[12] The final demonstration vehicle, which included a version of the quiet ISVR/Rolls-Royce engine built by Rolls-Royce to production standards, commercially made examples of the new silencers, the new cooling system and other components, measured 81 dB(A) in the current EEC test and the cab noise was reduced to 72 dB(A) under normal operating conditions. The cooling fan contributed no more than ½ dB(A) to total vehicle noise. The modifications to the vehicle resulted in an increase in first cost of 7.5% and a 0.6% increase in gross weight. The spectra of the modified and unmodified vehicles are given in Figure 2.

3.2.8 Operational trials. In order to evaluate the durability of the vehicle's noise reduction measures, to assess the running costs and to discover any special problems involved in maintaining and operating the vehicle, the QHV was placed with a haulage contractor for a trial period of two years[13]. This work showed that generally the QHV operated very satisfactorily during the period of the trial. The subjective impression given by the vehicle was of quietness and smoothness and wherever the vehicle was driven in the day to day business of the haulier the driver reported frequent and consistently favourable comments about the noise emission characteristics; in particular the exceptionally quiet idling condition was noted.

4. QHV 90 PROJECT

As described in the introduction the QHV 90 project was launched after the publication by Government of the White Paper[8] and during 1982 the TRRL held discussions with the vehicle and engine manufacturers to define the programme for the QHV 90 project. Mitchell[14] gives full details of the setting up of the project but a summary of the main features is given here.

The original QHV project concentrated on maximum weight vehicles and it is clearly necessary to include this class in QHV 90. However since QHV 90 is intended to assist the whole of the British commercial vehicle industry to meet the 1990 noise limits, and to reduce the noise from goods vehicles as perceived by the public, it has been necessary to put together a much broader project than the original QHV. Thus it has been decided to include in the project 16 tonne vehicles, engines to cover almost the complete range of goods vehicles, and components such as exhaust systems and cooling fans, that contribute towards overall vehicle noise.

The QHV 90 project is expected to cost about £10 million over five years, half of which will be contributed by Government and half by industry. The Government funding will come about equally from the Department of Transport and the Department of Trade and Industry. The project will be overseen by a Steering Committee of government officials advised by an Advisory Group of senior representatives from the manufacturing industries.

Prototypes of goods vehicles typical of those that the companies will be producing in the 1990s and conforming to all existing and proposed legislation including, of course, noise will be constructed by ERF, Foden Trucks, Leyland Vehicles, Bedford and Ford. Similarly the project will include prototype quiet engines from Gardner, Perkins, Cummins, Ford and Bedford. Research on components will include work on silencers, air intakes, cooling systems, transmissions, fuel systems, engine auxiliaries and tyres. The project will also include some work on methods of predicting noise from components, engines and complete vehicles which should improve the analytical design techniques available to industry as a whole.

By the 1990s the quality of diesel fuel will be lower than it is today. This may have an effect on engine noise. Quite a number of studies(15, 16) have been made and it appears that degradation of fuel quality could increase engine noise by 1 or 2 dB(A). The main implication of this is to point to the need for noise testing to be done using fuel which is typical of that likely to be available for vehicles in service in the 1990s.

5. CONCLUSIONS

Following the Wilson Committee Report in 1963 and the MOT/TRRL Working Party on Traffic Noise in 1970, the QHV project of the 1970s and the EEC directives of 1977 and 1984 have ensured that the prospect for reduced noise from heavy commercial vehicles is good. The latest programme of vehicle noise reduction, the QHV 90, covering as it does a wide range of goods vehicles and born of the Armitage Report, the Government's White Paper of 1983 and the initiative of DTp and TRRL, should ensure that techniques of noise reduction will be improved and applied and will result in nuisance from traffic noise being markedly reduced in the final two decades of this century.

6. ACKNOWLEDEMENTS

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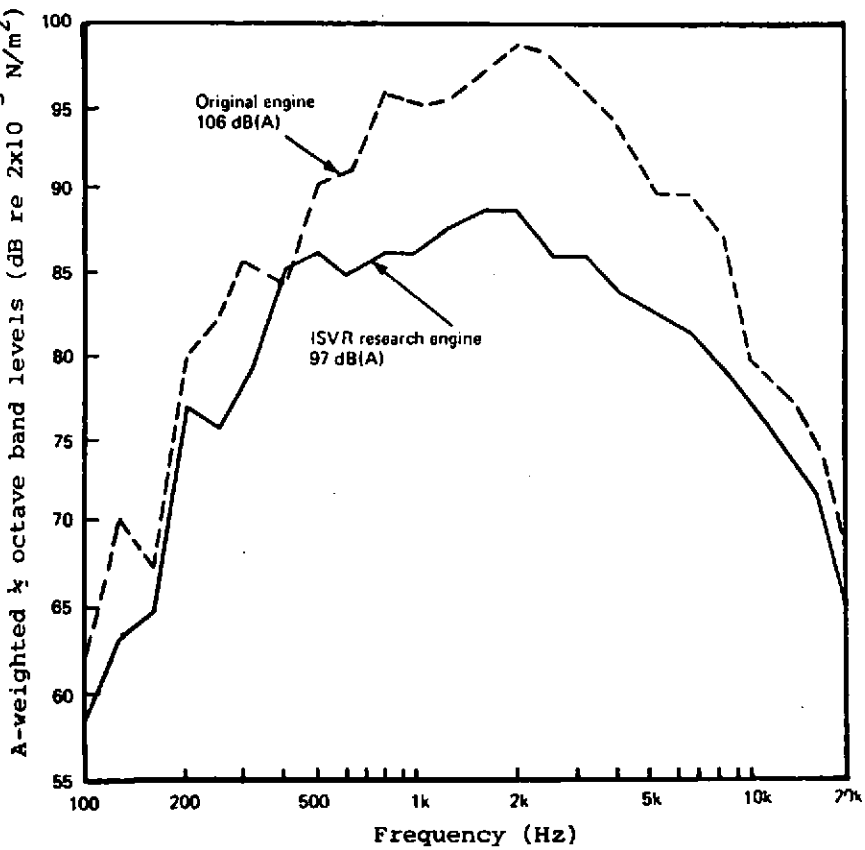

Fig.1. Comparison of spectra of original and research Rolls-Royce Eagle engine at rated conditions (near side)

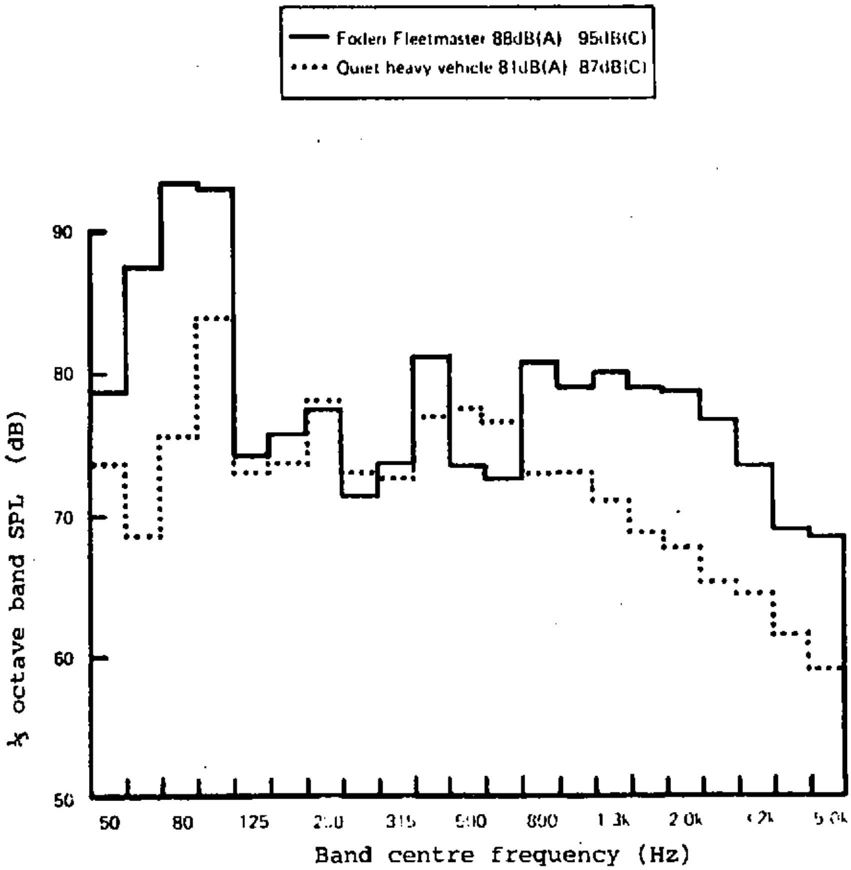

Fig.2 Comparison of ⅓ octave band spectra for QHV and Foden Fleetmaster during standard test condition 81/334/EEC (Composite peak level in each band)