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ESTIMATES OF THE REDUCTION OF TRAFFIC NOISE FOLLOWING THE INTRODUCTION OF QUIETER VEHICLES

by

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ESTIMATES OF THE REDUCTION OF TRAFFIC NOISE FOLLOWING THE INTRODUCTION OF QUIETER VEHICLES

ABSTRACT

This report predicts the effect on traffic noise of reducing vehicle noise. The prediction was made using a computer model which assumed two categories of vehicle in the traffic stream, light vehicles less than or equal to 1.5t and heavy vehicles exceeding 1.5t. Predictions are given for three conditions, firstly when heavy vehicles only are quietened by 10 dBA, secondly when light vehicles only are quietened by 5 dBA and thirdly when both categories are simultaneously quietened by these amounts.

It is shown that quietening heavy vehicles brings an appreciable reduction of traffic noise for streams containing 20 per cent or more heavy vehicles and is most effective for high flows. Conversly reducing light vehicle noise brings most benefit in low flow situations where there is less than 20 per cent heavy lorries. For all traffic containing up to 40 per cent heavy vehicles reducing the noise from both categories gives an appreciable reduction over and above that obtained by reducing the noise of either category alone. Thus there is a strong case for pursuing the development of quieter light vehicles with the same urgency that is at present being given to the development of quiet heavy vehicles.

The rate at which quiet vehicles are introduced will significantly affect the rate at which traffic noise levels are reduced. For the heavy vehicle class it is estimated there will be but little benefit until at least 50 per cent of the heavy vehicles on the road are quiet vehicles.

1. INTRODUCTION

Noise from road transport has increased in both extent and intensity over the past three decades.[1] In order to stop and perhaps reverse the upward trend, research is presently being carried out to determine methods of noise control and reduction. The most obvious method of noise reduction is at source. However, the benefit to be gained from reducing the noise of the different vehicle categories by what seem feasible amounts is largely uncertain.

At the Transport and Road Research Laboratory a computer model has been developed that synthesizes noise from road traffic.[2] The model calculates noise level-frequency distributions emitted from an idealised traffic stream comprising of two acoustically different vehicle categories each travelling with a specified mean speed in each lane of the roadway. The model allows the variation of such factors as the distribution of vehicles in multi-lane roadways, the speeds of the various vehicle categories and the average noise levels emitted by each vehicle category for a specified mean speed. The ability to be able to vary the latter makes it possible to calculate the effects on traffic stream noise produced by changing the average source levels emitted by individual vehicle categories in the traffic stream. The results of such a calculation provide both a means of gauging the future impact of research and development programs into quieter vehicles and a means of estimating whether an expansion of the programme is sociologically worthwhile and economically acceptable. This report describes calculations carried out to determine for a range of traffic conditions the reductions in traffic noise when three possible vehicle source reductions are in operation.

2. SOUND OUTPUT TARGET LEVELS FOR INDIVIDUAL VEHICLE CATEGORIES

In order to make realistic determinations of possible future reductions in traffic noise it is necessary to establish the magnitudes of individual vehicle noise reductions that are either presently technologically achievable or form part of current research objectives.

Various methods of dealing with airborne engine noise are possible, namely by vehicle design employing sound insulation techniques, control of the combustion processes and the design of the engine structure. It is likely that for diesel engines, reductions of the order of 10 dB are possible by a re-design of the engine structure.[3] If it is assumed that tyre and road surface noises can be quietened sufficiently at high speeds to levels lower than that emitted by the re-designed engine, then the indications are that an overall sound reduction of some 10 dB(A) could be achieved under all operating conditions.

It is unlikely that similar reductions can be obtained for saloon cars because they are already quieter. However the results of research suggest that given an appropriate lead-in period it should be possible for manufacturers to meet the I.S.O. drive past test limits for vehicles defined as those of less than 3.5 t gross vehicle weight at a level of 80 DB(A), 5 dB(A) below the current test limits.[1] For the purposes of this study it has been assumed that for the car category* an overall reduction of 5 dB(A) can be achieved under all operating conditions.

The vehicle noise level reductions employed in the calculations can be summarised as:

Case 1 All lorries reduced by 10 dB(A)

Case 2 All cars and car based vans reduced by 5 dB(A)

Case 3 All lorries reduced by 10 dB(A) and all cars reduced by 5 dB(A).

It is worth noting that the three cases specified enable other possible options to be examined without a further calculation. For example, if the lorry category were to be reduced by 5 dB(A) with car levels remaining unchanged then the computed traffic noise level reductions will be 5 dB(A) more at all levels in the traffic noise frequency distribution than the reductions calculated for case 3.

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* The acoustic classification of vehicle types was considered in a previous report.[2] The lorry category includes all vehicles of more than 1.5 t gross vehicle weight. The car category includes all vehicles less than or equal to 1.5 t gross vehicle weight.

3. TRAFFIC INPUTS FOR THE NOISE MODEL

The computer model in the form used considered traffic to flow freely and required as input the specification of the road type, the lane width, and the flow, speed and composition of each vehicle category in each lane of the roadway. The type of surface above which the noise is propagated had also to be specified together with the distance of the observation point from the nearside kerb. In order to achieve maximum generality in the calculation the inputs were chosen to represent, as far as possible, the conditions encountered in a range of both rural and urban roadways where traffic can be assumed to flow freely.

The roadway was considered to be a single carriageway 2 lane road with a standard lane width of 3.6 metres. The distance of the observation point from the nearside kerb was maintained constant throughout at 10 metres and ground absorption was taken into account assuming that propagation was over short grass. The mean speeds of both the lorry and car categories for various flows and lorry compositions were determined using standard formulae derived from observed speed-flow data in rural 2 lane roadways.[4,5]

The generalised reference noise levels for both the car and lorry categories were determined from the calculated mean speeds using the relationships illustrated in figure (1). These curves were described and validated in a previous report.[2]

4. CHANGE IN TRAFFIC NOISE DUE TO AN OVERALL REDUCTION IN VEHICLE NOISE OUTPUT

For practical design purposes a single figure measure of noise annoyance is desirable. L_{10}, the noise level in dB(A) exceeded for 10 per cent of the time has been recommended[6,7] to rate the disturbance caused by road traffic and officially adopted for design and planning purposes by the Department of the Environment. There were two reasons for this; firstly it provided a reasonable correlation with disturbance in residential areas and secondly it was possible to predict its value in various circumstances with some confidence. However sociological studies have indicated that noise units incorporating a measure of the variability of noise level correlate better with expressed annoyance than L_{10} alone. Units incorporating variability factors have been postulated[8,9] but are not being used at present for planning purposes because the precise form of the variability unit has not been agreed and the effects of control measures on the variability of the noise cannot yet be estimated accurately. Nevertheless in order to assess the effects of various vehicle noise level reduction policies in terms of both present and possible future noise annoyance criteria it was useful to examine the changes affected in L_{10} and a unit incorporating noise level variability. The unit chosen for comparison with L_{10} was the Traffic Noise Index (T. N.I.) where

$$TNI = 4(L_{10} - L_{90}) + L_{90} - 30$$

L_{90} is the noise level in dB(A) exceeded for 90 per cent of the time.

4.1 Change in L_{10}

Values of L_{10} were determined assuming that the mean sound ouput levels for both the car and lorry category remain unchanged as specified in figure (1) and for the following values of vehicle flow and percentage lorry composition.

total flow Q = 200, 400, 600, 800, 1000, 2000 vehicles/h.

composition, p = 5, 10, 20, 40, 80 per cent lorries.

Table 1 lists the values of L_{10} obtained. Values of L_{10} were also computed for each of the source reductions specified in chapter 2 and reductions in L_{10}, ΔL_{10} were determined. Table 2 summarises and compares the values of ΔL_{10} obtained.

TABLE 1

Values of L_{10} dB(A) obtained assuming no change in vehicle noise output

Flow, Q, vehicles/h	L_{10} dB(A)				
	5% lorries	10% lorries	20% lorries	40% lorries	80% lorries
200	69.3	69.8	70.8	72.5	75.8
400	72.7	73.2	74.3	76.4	79.1
600	74.1	74.7	75.9	78.4	80.6
800	74.9	75.6	77.0	79.4	81.5
1000	75.5	76.3	78.0	80.1	82.1
2000	77.3	78.5	80.2	81.9	83.7

TABLE 2

Reductions in L_{10} dB(A) for various flows and percentage lorries when (1) lorries are reduced by 10 dB(A), (2) cars are reduced by 5 dB(A) and (3) lorries are reduced by 10 dB(A) and cars are reduced by 5 dB(A)

Flow, Q, vehicles/h	Reduction in L_{10} dB(A)														
	5% lorries			10% lorries			20% lorries			40% lorries			80% lorries		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
200	0.7	4.5	5.4	1.4	4.0	5.6	2.5	3.5	6.3	4.5	2.1	7.3	8.4	0.1	9.3
400	0.7	4.5	5.4	1.4	4.0	5.6	2.5	3.1	6.4	5.1	0.6	7.9	8.8	0.1	9.6
600	0.7	4.5	5.4	1.5	4.0	5.8	2.9	2.1	6.7	5.8	0.3	8.6	8.8	0.1	9.8
800	0.7	4.4	5.4	1.5	3.7	5.9	3.1	1.1	7.0	5.9	0.3	8.8	9.0	0.1	9.8
1000	0.7	4.3	5.5	1.6	3.2	6.1	3.5	0.7	7.4	6.0	0.1	8.9	9.0	0.1	9.8
2000	1.1	3.5	5.8	2.4	1.2	6.8	4.2	0.5	7.8	6.3	0.1	9.1	9.0	0.1	9.8

It can be seen that the magnitudes of ΔL_{10} differ appreciably depending upon the vehicle source reduction option employed, the proportion of lorries in the traffic stream and the total vehicle flow. Neglecting for the moment the case 3 outputs, to some extent the table shows expected results. At high percentage lorry compositions larger values of ΔL_{10} accrue by reducing lorry noise levels whereas for flows of traffic containing few lorries it is more beneficial to reduce car noise. These alternatives become less clearly defined at intermediate lorry compositions and the dependence of ΔL_{10} on vehicle flow further complicates the choice between alternative policies. The change in ΔL_{10} with vehicle flow and percentage lorry composition is illustrated in figure (2).

The figure shows that when the flow is 200 vehicles per hour it is more beneficial to quieten cars by 5 dB(A) than lorries by 10 dB(A) even when there are 20 per cent lorries in the traffic stream. When the flow is 2000 vehicles per hour, however, it is only more beneficial to adopt this policy if there are less than 8 per cent lorries in the traffic stream. These marked differences with flow occur because of the increasing dependence of L_{10} on the magnitude of the lorry noise peaks as the flow increases.

When case 3 was investigated, ie when both car and lorry noise levels were reduced, as expected larger values of ΔL_{10} were obtained for all flow and lorry composition combinations. However, although this option produced expected results at high and low lorry compositions, in the intermediate percentage lorry ranges there were some marked differences exhibited between the outcomes of this option and the single category options 1 and 2. For example when p is 20 per cent and $Q = 2000$ vehicles/h a reduction of 10 dB(A) for the lorry category produced a significant ΔL_{10} of 4.2 dB(A) and a separate reduction of 5 dB(A) for cars produced a negligible ΔL_{10} of 0.5 dB(A). However when both these source reductions were affected simultaneously ΔL_{10} was 7.8 dB(A) and was significantly larger than the values of ΔL_{10} obtained by implementing either of the single vehicle category options.

In order to gauge the impact of these predicted changes it is worth noting that a reduction in L_{10} of 8.0 dB(A) could have been obtained by reducing the traffic flow from 2000 vehicles per hour to 200 vehicles per hour or by increasing the distance of the observation point from the nearside kerb from 10 metres to 40 metres.

4.2 Change in TNI

Values of TNI were computed for the vehicle flow and percentage lorry composition ranges stated previously and reductions in TNI, ΔTNI, were determined for each of the three vehicle source reductions specified. Table 3 summarises and compares the values of ΔTNI obtained.

The change in ΔTNI into vehicle flows and percentage lorry composition is illustrated in figure 3. If the curves in figure 3 are compared with the corresponding curves obtained for ΔL_{10} given in figure 2, dissimilarities between the two indices become apparent although the overall trends with flow and composition are the same. Figure 3 shows that when the flow is 200 vehicles per hour it is more beneficial to quieten cars by 5 dB(A) than lorries by 10 dB(A) provided there are less than 35 per cent lorries in the traffic stream. The corresponding lorry composition on the ΔL_{10} index was 23 per cent. At 2000 vehicles per hour it is only more beneficial to quieten cars when there are less than 4 per cent lorries in the traffic stream. This compares with an 8 per cent lorry composition obtained on the ΔL_{10} index.

TABLE 3

Reductions in TNI for various flows and percentage lorries when (1) lorries are reduced by 10 dBB(A), (2) cars are reduced by 5 dB(A) and (3) lorries are reduced by 10 dB(A) and cars are reduced by 5 dB(A)

Flow, Q, vehicles/h	Reduction in TNI														
	5% lorries			10% lorries			20% lorries			40% lorries			80% lorries		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
200	1	5	5	1	5	5	2	5	5	3	3	6	8	- 1	9
400	1	5	5	1	5	5	2	4	6	5	- 3	8	10	- 1	10
600	1	5	5	1	5	5	3	0	7	8	- 4	11	10	- 1	11
800	1	4	5	2	4	6	4	- 4	8	9	- 4	12	10	- 1	11
1000	1	4	6	2	1	7	7	- 6	10	9	- 5	12	10	- 1	11
2000	2	1	7	5	- 7	10	9	- 7	12	13	- 5	14	10	- 1	11

A further difference between the two indices was shown when the car category alone was quietened by 5 dB(A). The ΔL_{10} index was always positive indicating a reduction in noise annoyance irrespective of the traffic conditions imposed whereas ΔTNI was often markedly negative indicating an increase in noise annoyance. For example in a vehicle flow of 2000 vehicles per hour and ten per cent heavies the tables show that reducing cars by 5 dB(A) reduces L_{10} by 1.2 dB(A) but increases TNI by 7 units. Clearly the increase in TNI reflects the increase in noise variability caused by a reduction in the car levels. However, as with L_{10}, quietening both categories brought reductions of TNI greater than the reductions obtained by quietening either single category.

5. CHANGE IN L_{10} WHEN ONLY A PROPORTION OF THE LORRY CATEGORY IS QUIETENED

In the previous chapter road traffic was considered to comprise of two vehicle classes. This order of subdivision is adequate for the purposes of noise prediction. A further subdivision of vehicle classes only increases the amount of input required without affecting the precision of the output obtained. However with only two vehicle categories it has only been possible to examine the reductions in traffic noise obtained when all the vehicles in a class were quietened by the same amount. The reductions in traffic noise predicted have therefore been the optimum reductions obtainable. The introduction of quiet vehicles will be a lengthy process, their proportions increasing slowly as the existing noisy vehicles wear out and are replaced by quiet vehicles. Perhaps a decade will be required before all the noisy vehicles can be replaced by quiet ones and the optimum benefits achieved. Consequently it is useful to be able to predict the reduction in traffic noise when only a proportion of vehicles in a particular category are quietened.

The computer model was therefore extended to include three vehicle categories and values of L_{10} were calculated for the range of flows and lorry compositions specified in the previous chapter but with a range of percentage quiet lorries, Q_L, in the total vehicle population. The quiet lorries were classified by stipulating at the input stage that the average source level emitted from these vehicles was 10 dB(A) lower than the unmodified lorries. An investigation of the output data was carried out and simple curve fitting techniques were tried in order to obtain a relationship describing the reduction in L_{10} in terms of the percentage lorries, p, the total flow, Q, and the percentage quiet lorries, Q_L. The relation obtained chosen for its degree of simplicity and correlation with the observed data is

$$\Delta L_{10} = 0.01\ Q_L\ p(0.038 + 0.0006p + 0.045(1 - 0.01p) \log_{10} Q) \quad \cdots\cdots\cdots\cdots \quad (1)$$

The standard error of the difference between the computer derived output and the values of ΔL_{10} given by equation 1 was 0.3 dB(A) and the flow and vehicle composition ranges over which validation was achieved were

$Q = 200 - 2000$ vehicles/h

$p = 0 - 40$ per cent lorries

$Q_L = 0 - 100$ per cent quiet lorries

The equation implies that ΔL_{10} is directly proportional to Q_L, the percentage quiet lorries on the road. However, although this is a good approximation to the observed behaviour over the ranges stated, it ceases to be a good approximation when the percentage of lorries is very large. The true calculated dependence of ΔL_{10} with Q_L is shown in figure 4 for a range of total percentage lorries and for both high and low vehicle flows. Clearly the increase in ΔL_{10} with Q_L is approximately linear over all vehicle flows provided the total lorry composition is less than or equal to 20 per cent. This approximation is still valid at higher lorry compositions but only when the flow is low. When both the percentage of lorries and the total vehicle flow are high and consequently the number of lorries is high, the characteristic is not linear. This shows that when the total number of lorries in the traffic stream is large the reductions in L_{10} afforded by quietening a proportion of these lorries is likely to be very small even when the percentage lorries quietened is fairly large. Clearly under these conditions there is still a sufficient number of unquietened lorries to keep the L_{10} levels high.

The most important conclusion to be drawn from equation (1) and figure 4 is that L_{10} levels will not be reduced by more than 2 dB(A) until at least 50 per cent of the lorries have been quietened. Consequently if quiet lorries were to replace noisy lorries at a rate of, say, 10 per cent per year it would be 5 years before noticeable reductions in noise levels were experienced.

Similar estimates could be made without serious error for the case when only a proportion of the car category was quietened by 5 dB(A). It is unlikely, however, that this simple analysis can be extended to the case when both the car and lorry categories were quietened since cars are replaced at a different rate than lorries.

6. SUMMARY AND CONCLUSIONS

The calculations described in this report demonstrated that quietening lorries by 10 dB(A) should bring considerable reductions of noise on roads carrying high traffic flows and many heavy lorries. Such conditions prevail on the many trunk roads and motorways which are the primary sources of complaints against traffic noise. However quietening lorries is not very effective for reducing noise in lightly trafficked streets where the percentage of lorries is low. Although at present such traffic conditions may not attract complaints against noise, L_{10} levels at 10 m from the kerb can exceed 68 dB(A) (the current 18 hour limit for new roads). The levels in these roads can most readily be reduced by reducing car noise. (In this report it was assumed that a reduction of 5 dB(A) was feasible for this category.) There were suggestions in the calculation of the change of TNI that reducing car noise alone could, at certain flows and compositions, increase the variability of the traffic noise sufficiently to increase annoyance. Further both the L_{10} and the TNI calculations indicated marked reductions of noise when both vehicle categories are quietened. It seems therefore that, while reducing lorry noise should bring worthwhile reductions of noise on the busiest roads, reductions of noise from both cars and lorries are needed if any general benefit is to be experienced. A further calculation indicated that whatever vehicle quietening may be undertaken traffic noise will hardly be reduced until the quiet vehicles have replaced at least 50 per cent of the existing vehicles. This report therefore has shown the need for including in the present programmes of research into quieter vehicle development an urgent programme to reduce the noise emitted by the car category.

7. ACKNOWLEDGEMENTS

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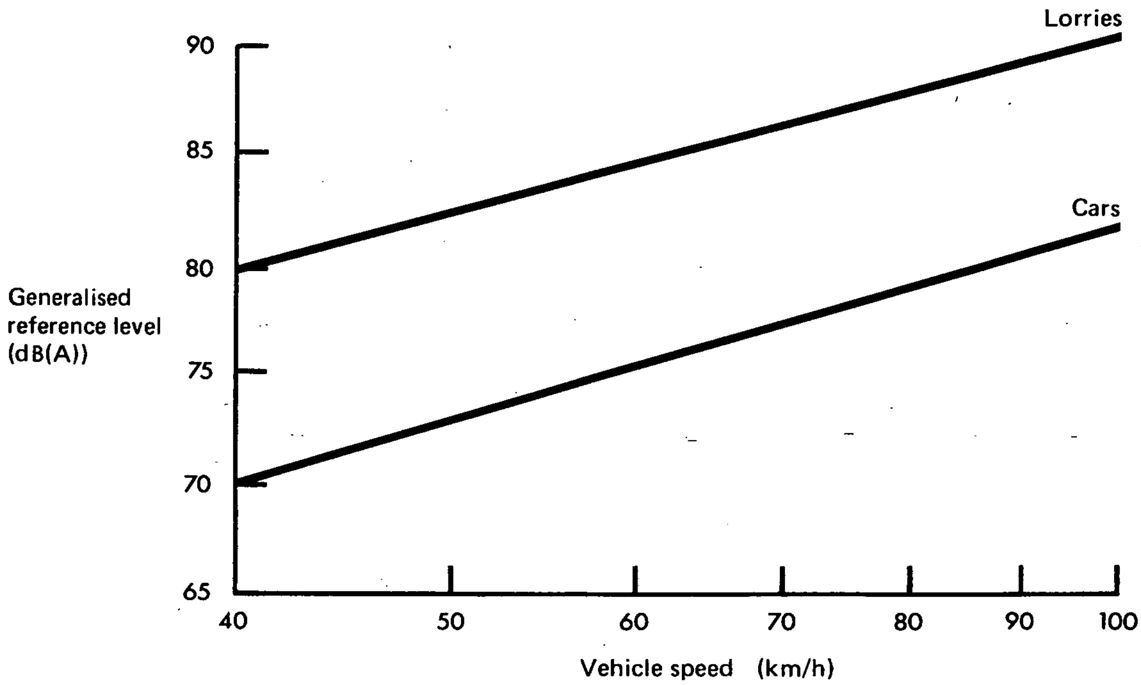

Fig.1. LEVEL-SPEED RELATIONSHIPS FOR CARS AND LORRIES

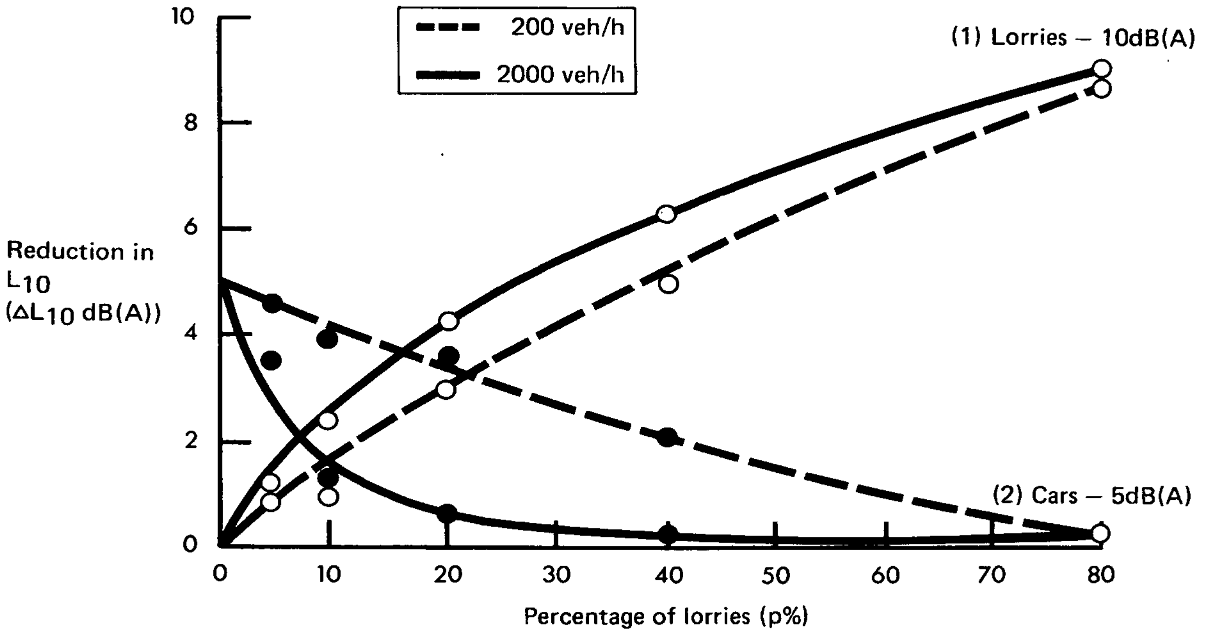

Fig.2. **REDUCTION IN L_{10} FOR VARIOUS FLOWS AND LORRY COMPOSITIONS**

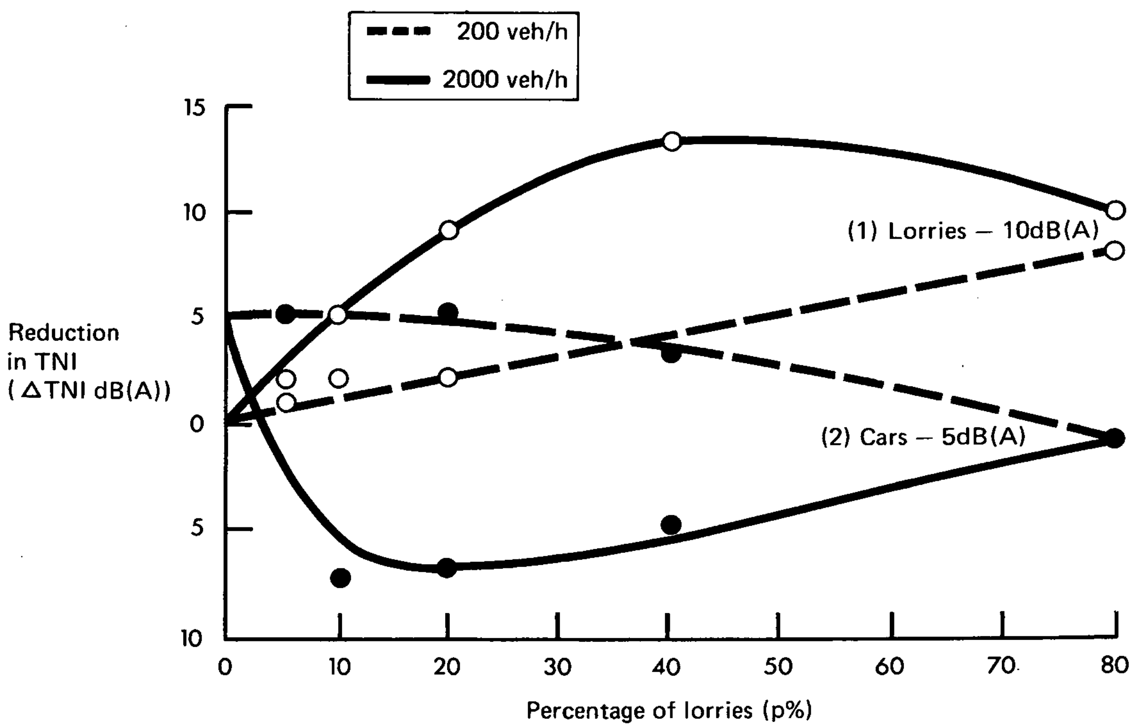

Fig.3. REDUCTION IN TNI FOR VARIOUS FLOWS AND LORRY COMPOSITIONS

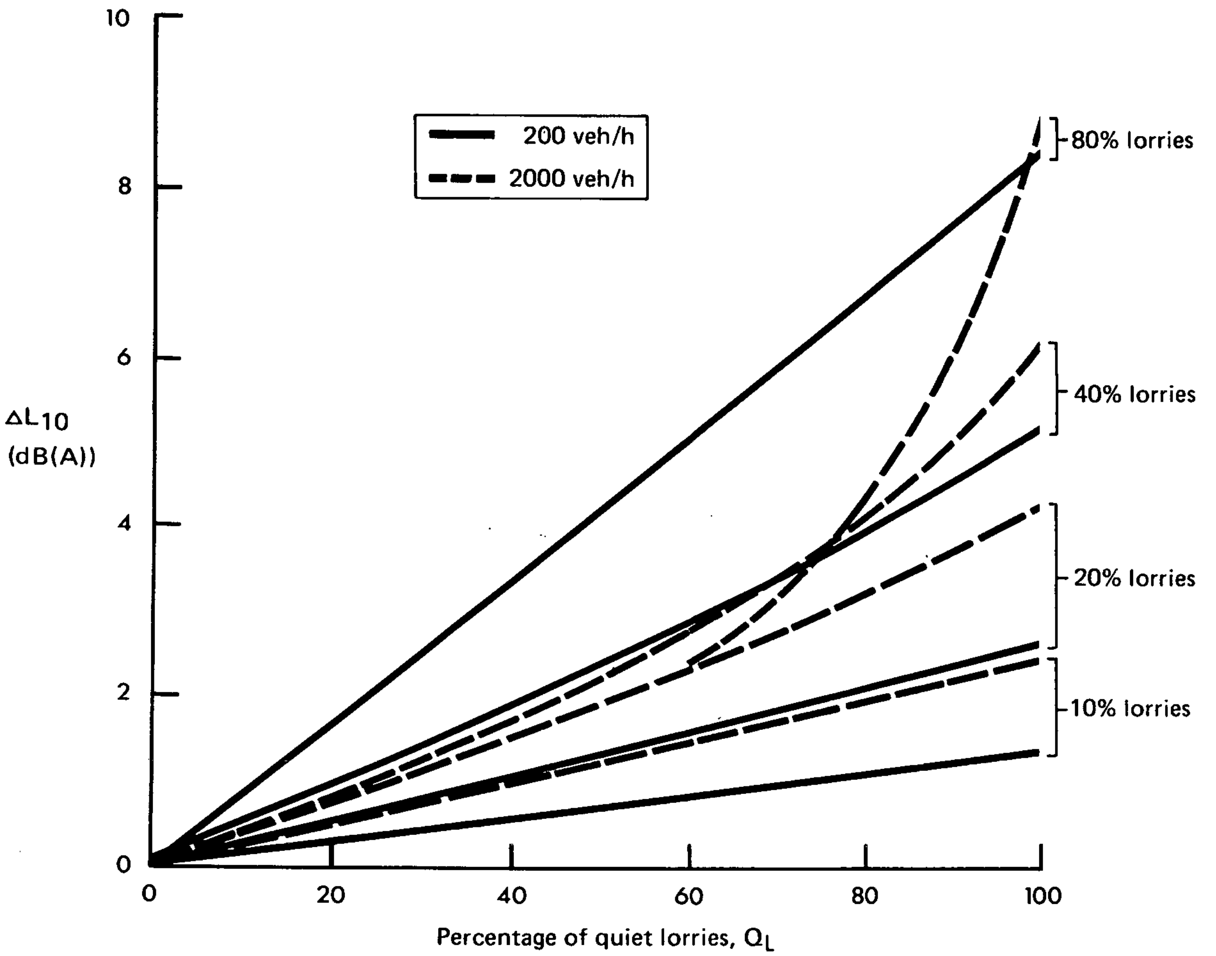

Fig.4. REDUCTION IN L_{10} AS A FUNCTION OF THE PERCENTAGE QUIET LORRIES FOR VARIOUS FLOWS AND TOTAL LORRY COMPOSITIONS

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