NOISE OF CURRENT DIESEL ENGINES

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This paper gives some typical breakdowns of noise sources from situations where the diesel engine is used and shows how the noise of the engine itself varies with operating parameters. The methods that can be used to reduce the noise level from the engine are examined and discussed.

INSTALLATIONS

The table below gives the source contributions to the overall dBA noise level in terms of how far below the total each source lies. Only the major noise sources of engine, fan, exhaust and intake have been included.

dBA DOWN FROM OVERALL LEVEL			
	Aircooled Stationary	Diesel Passenger Car	Diesel Truck
Engine	-5	-3.5	-3.5
Cooling Fan	-4.5	-8	-8
Exhaust	-6	-10	-4
Intake	-10	-7	-8

It is very difficult to generalize on these breakdowns, but it is clear that although the engine may be the greatest culprit it is far from alone. The immediate lesson is that any noise reduction measures taken on the engine must be accompanied by improvements in silencing and fan design. We are only concerned for the moment with the engine unit, but it should be noticed in passing that the design of silencers and better fans can involve a great deal of work optimising the various parameters involved in the complete system.

DIESEL ENGINE NOISE GENERATION

The combustion process is the prime noise source in any engine, since without this the engine does not run; on a higher level of argument it is clear that the combustion process is also in detail the main noise source rather than mechanical noise sources. It is the path which the combustion noise takes that is important in externally radiated noise. A colleague of mine some years ago showed that this path is in fact via the piston and connecting rod and the stressed areas of the engine to the relatively weak regions of the lower part of the engine which can then vibrate and radiate noise. This work utilised a "Banger" technique in which the static engine structure was subjected to gas pressures in the combustion space simulating those in the running condition. The explosions were derived by firing a mixture of propane, air and oxygen. (This work is reported in ref. 1). Various builds of the engine were examined, from a very rigid condition where a blanking plate replaced the piston. In this build, only the explosions with the highest rates of pressure rise gave any readings at all. The builds progressed through fixing the piston in the bore with a circlip, thus stressing the cylinder liner, to a very rigid build where the piston/connecting rod/crankshaft were replaced by a very rigid assembly. The average energy levels under these three conditions were 1% of the normal running conditions for the 'bomb' build, 13% for the piston and circlip arrangement and still only 26% for the final stiff arrangement.

Due to the form of the frequency spectrum of the combustion process, there is a very rapid rise in radiated noise level with speed. This rate of increase is closely connected with the detail of the cylinder pressure development, specifically with the rate of pressure rise, since this changes the cylinder pressure spectrum shape. In this way, in fact, it is possible to estimate approximately how much mechanical noise exists, although this can be more accurately obtained from a comparison of the cylinder pressure and radiated noise spectra over a range of fuel injection timings. It is interesting to note that although combustion noise usually predominates in diesel engines, substantial amounts of noise due to piston slap and timing gear rattle can occur, amounting to some 25% of the total radiated energy. For most diesel engines, the rate of increase in noise level with speed lies between 25 and 35 dBA/decade. As has been shown here at ISVR, the combustion noise generally predominates to such an extent that predictions of engine radiated noise can be based solely on engine speed and cylinder bore, with an adjustment for turbocharged or two-stroke operation. That the predictions made by this method do correlate well with measurements shows also that fine differences in design do not have much bearing on the eventual radiated noise, although some small structural changes can be significant.

DIESEL ENGINE NOISE REDUCTION

a. Combustion

Since the engine radiated noise is so much a function of the combustion process, it is clear that a start should be made towards noise reduction in this area. If the fuel initially injected into the cylinder is limited to that required merely to start the combustion, the remainder can be delivered at a higher rate whilst achieving a smooth pressure development. Such a system is known as pilot injection and there has been a substantial amount of work towards developing a practical system within acceptable limits of performance, economy and cost. Ricardo are now developing a pump injector system, using a two-rate cam profile to provide a pilot injection. This system has been shown to work satisfactorily at all loads and speeds, giving a very smooth

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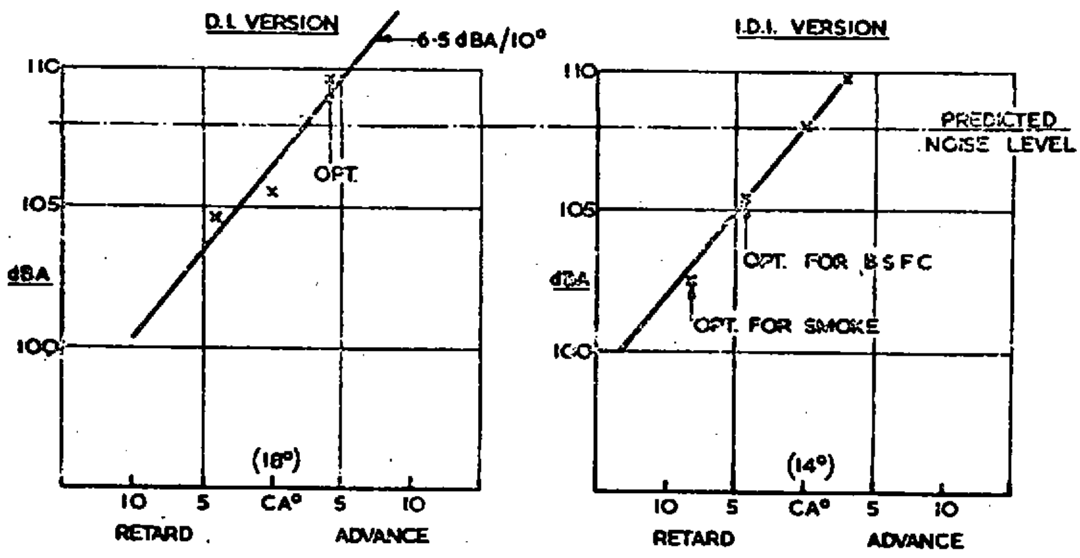
FIGURE 1



EFFECTS OF FUEL INJECTION TIMING ON THE RADIATED NOISE LEVELS OF AN ENGINE USING D.I. AND I.D.I. COMBUSTION SYSTEMS pressure diagram and resulting in low noise levels. Typical results obtained at 3000 rev/min show a reduction of 5.5 dBA (see ref. 2).

The type of combustion chamber also has an effect on the noise of a diesel engine, and it has long been recognised that indirect injection engines are quieter than direct injection engines. Since a reduction in the rate of pressure rise can be achieved in a diesel engine by a retard of the fuel injection timing, this retardation can be used to reduce radiated noise levels. One major difference between D.I. and I.D.I. engines is that the latter normally run at a more retarded fuel injection timing due to better fuel/air mixing. Figure 1 shows the relationship between static injection timing and noise for an engine in both I.D.I. and D.I. form. The approximate rate of change is some 6 dBA per 10° timing change.

b. Structure

However much the combustion process is quietened, there must come a limit, since power has to be developed outside the motoring compression curve. This leaves open two possibilities, firstly that the noise from the engine is accepted and palliative treatments applied to reduce the radiated noise, or secondly that the structural response of the engine is reduced. Ideally the load bearing structure of the engine should be isolated from the external surfaces, and this approach has been adopted in some research work (refs. 3, 4, 5) and has shown that major reductions in noise level can be achieved. Alternatively, some reduction may be achieved by stiffening the lower part of the engine, by increasing casting thicknesses and by the use of a beam interconnecting the main bearing caps. This latter method has also been used successfully by my design colleagues to eliminate "rumble" in a high compression petrol engine. For efficient noise reduction the walls of the crankcase should be made of some material which has high damping so that little vibrational amplification occurs in the unsupported areas.

The noise of current production engines can be reduced, however, by the painstaking application of isolation, damping and shielding techniques. Such items as the valve cover, oil sump, timing cover and manifolds generally contribute substantial percentages of the total radiated energy and are responsive to treatment. As a generalisation it is true that reductions by such treatments are limited by economic factors in their application where reductions of more than 3 or 4 dBA are aimed for. Nevertheless in some applications where the engine is already partially enclosed, the application of enclosures can be simple and very rewarding.

LEGISLATION

The progress of future legislation on vehicle noise and engine noise will hopefully be regulated by some consideration of the economics concerned, since as legislated levels fall, the relative importance of noise sources other than the engine increases greatly.