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THE DESIGN OF A SEMI ANECHOIC CHAMBER FOR INDOOR VEHICLE NOISE TESTING AT BL TECHNOLOGY

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The British weather makes it difficult to carry out ISO drive-by tests on demand. It has been suggested that suitable conditions occur on only 25 days per year. The new semi anechoic chamber at Gaydon was designed to allow simulated drive by tests indoors. To reduce costs it was built inside an existing building, adjacent to an anechoic test bed for engines and a garage for vehicle preparation.

Main dimensions of the chamber are 17m x 9.6 m x 3.5m high. The longest dimension allows microphones to be placed 7.5m from the vehicle centre line as required for the ISO test. The chamber is fitted with a vehicle dynamometer capable of power absorption or of driving the vehicle wheels at surface speeds up to 240 km/hr. A variable flow ventilation system able to deliver up to 835 m^3 per minute is provided.

Setting the Specification

The noise from all the systems had to be controlled so that the broad band background noise was 10 dB below the quietest car expected to be tested in the foreseeable future and was free of tonal components. To estimate the likely vehicle noise a series of modern vehicles were "drive-by" tested at a range of speeds. From these results the specifications for individual items of equipment were set. A considerable number of items of equipment contributed to the background noise. The figures in brackets indicate the specifications set.

Dynamometer (PNC 30 at 40 km/h, PNC 40 at 100 km/h, PNC 50 at 240 km/h, all at 0.5m from roll surface)

Main Ventilation Extract Fans (PNC 35 at 1m from air entry)

Roll Chamber Ventilation Fans (PNC 30)

Dynamometer Chamber Ventilation Fans (PNC 30)

Exhaust Extract Fan (PNC 35 at 1m)

Break-in from Engine Test Cell (PNC 30)

Break-in from External Noise Sources (PNC 30)

Dynamometer Noise Control

Flow noise generated by air entrained by the 2 metre diameter rolls was identified as a problem. Absorptive silencers were fitted where the roll surface emerged from the floor. Initially these were made of glass wool contained behind perforated metal sheet, but it was necessary to replace this with unprotected plastic foam because of the flow noise generated by the perforate. A stripper plate was also fitted below floor level with its edge close to the roll surface, to peel off as much entrained air as possible before it reached the narrow slot between the roll surface and the floor. Absorptive silencers were also fitted at the sides of the rolls. All the small tapped holes drilled in the roll surface which allow attachment of bumps and slats had to be filled flush to prevent noise. The roll noise specification was met at the lower speeds, but the noise could only be reduced to about PNC 60 at maximum speed, but this was still well below tyre noise.

A DC motor with thyristor control was used to absorb power and to drive the rolls as required. Casing radiated noise from the motor was expected to be a problem, which was prevented by enclosing the dynamometer in a separate chamber with concrete roof and double leaf brick wall separating it from the roll chamber. A close fitting absorptive silencer was used around the drive shaft. Also located in the dynamometer chamber was the hydraulic power pack for the hydrostatic bearings of the roll shafts. These bearings were chosen to give low noise and low vibration levels. Hydraulic power pack airborne noise was well contained by the chamber walls, but hydraulic noise was, as predicted, transmitted to the anechoic chamber via the roll chamber. This was cured with an in-line silencer on the power pack. Experience with other thyristor driven DC machines made us expect that the motor would generate noise at the chopping frequency. This proved to be the case, the noise being transmitted to the rolls via the drive shaft. An early decision had been made not to use a resilient coupling in the drive shaft to avoid the possibility of torsional resonances affecting the computer controlled road load simulation system. The structure-borne noise had, therefore, to be dealt with by electrical means. Another early decision affecting this noise path was whether to add damping inside the rolls during manufacture. Damping was not fitted because of concern about its ability to last for many years without causing changes in roll balance. Balance is critical in these high speed rolls. They are balance to within 375 gm. cm. after manufacture of the complete roll and shaft assembly, to give a vibration amplitude at the bearings not exceeding 0.0025 mm. at 500 rev./min. roll speed.

Main Ventilation System

Ventilation air is sucked through the chamber by a variable pitch axial fan, fitted with a 4m long splitter type inlet silencer and an exit silencer to prevent radiation of excessive noise externally, to meet boundary noise planning requirements. A very high performance fan inlet silencer was needed with predicted attenuation of:-

Frequency (Hz)	63	125	250	500	1k	2k	4k	8k
Attenuation (dB)	29	45	55	55	55	55	55	55

Self generated noise was of concern at maximum air flow. This concern was justified by start up experience. Detailed modification to the entry area was necessary to meet the targets. Even after apparently identical modifications to all splitters, one splitter continued to give easily detectable local noise for reasons which could not be discovered.

Air enters the chamber by passive inlet ducts, which are also fitted with silencers, in this case to prevent break-in of external noise caused by vehicles in the area or by the exaust or ventilation systems of the engine test bed. The lower parts of the inlet ducts which are exposed to the inside of the semi-anechoic chamber are lined with absorptive material to prevent reflection of sound back into the semi anechoic chamber.

Other Fan Systems

The roll chamber and dynamometer chamber had to be separately ventilated to cool the machinery and the rolls, which could be significantly heated by tyre losses at high speeds. The cooling air also removes any potentially dangerous gasses from the area. Both chambers have inlet and extract fans and the dynamometer chamber is pressurised to a higher pressure than the roll chamber to prevent ingress of combustable fumes from spilt fuel or oil into the electrical hazard areas. These fans operate continuously and have to be quiet enough not to add to the anechoic chamber background noise. All these fans are vibration isolated from their supports.

The exhaust extract fans also run during normal testing. They extract air through flexible trunking from points near the exhaust pipes of the vehicle, rather than being directly coupled, to avoid affecting engine performance.

Portable radiator cooling fans and local spot cooling fans are also provided but these are turned off during noise testing. They were selected to avoid hearing damage risk.

Break-in from External Noise Sources and Structure Borne Noise

The semi-anechoic chamber is surrounded on three sides by potentially serious noise sources, the engine test cell (separated by a corridor and the electrical switch room), the vehicle work shop and vehicles maneouvering outside.

To maximise wall transmission loss a double wall was used. The outer wall was the original brick concrete wall. A new inner wall of concrete blocks was constructed, completely separated from the outer walls. The existing concrete floor slab was retained, but was cut between inner and outer walls. An inner roof of concrete beams screeded above was built. Main access for vehicles is via the work shop, through a double door system. The outer doors are "38 dB" sliding acoustic doors. The inner doors are hinged "48 dB" acoustic doors with an absorptive threshold seal. They are lined on the inside with absorptive wedges. The alcove between the doors provides space for opening the hinged doors. Three personnel access doors lead from the main chamber. These are "44 dB" doors. The outside fire escape has to resist external vehicle noise. The inner ones have to resist personnel noises.

To prevent structure borne noise eminating from the dynamometer machinery the DC motor was mounted on a steel and concrete inertia block weighing 30 tonnes mounted on vibration isolators with a 3 Hz vertical mounted resonance frequency. The mounting selection was checked to ensure that torsional oscillations of the whole would not interfere with the road load control. The rolls are also mounted on a 40 tonne concrete inertia block, mounted on rubber pads with a vertical natural frequency of 20 Hz. This high frequency system was chosen to prevent excessive low frequency torsional oscillations of the assembly when "bumps" were fitted on the rolls for vibration testing of vehicles.

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To prevent structure borne noise from the engine test chamber affecting the vehicle chamber the engine bed plate is mounted on air springs with a vertical frequency of 2 Hz. Many vehicle chambers have inner shells which are completely vibration isolated from the main building structure. At Gaydon it was considered that this expense could not be justified and that individual vibration isolation of identifiable structure borne sources was more cost effective.

Acoustic Treatment of the Semi Anechoic Chamber

A hard floored chamber was chosen because the ISO drive-by test is carried out over a hard surface. Perfectly non reflecting walls and ceiling would then produce similar acoustic conditions to outdoors, but not acoustically non interfering conditions, because of floor reflections. Complete simulation of drive-by conditions is not possible because the vehicle does not pass the microphone, but the road load simulation allows the correct driving conditions to be reproduced. Thus the effect of vehicle changes on side-line noise can be evaluated and the chamber can be "calibrated" by practical comparison of indoor and outdoor results.

The chamber is lined with over 11,000 glass fibre wedges 0.9m long held in a wire grid and protected with a fabric net covering glued in place. The chamber cut off frequency is 100 Hz.

There are various interuptions in the wedge system caused by the need for air entries and exits, chamber heating, and doors. Personnel doors are faced with glass fibre panels. The vehicle access doors are wedge covered but the wedge sizes had to be graduated to allow the doors to open. A wedge filled basket allows the viewing window to be covered.

A series of tests was made to see whether the ventilation openings and other absorption imperfections had any significant effect on the acoustic performance. Using a hemispherical loud speaker array at the vehicle position plots of decay of SPL with distance were made, both at normal microphone height of 1.5m metres above the floor and at 50 mm above the floor level. As expected the 1.5m height tests showed the effect of ground interference. The floor level measurement showed that reasonable acoustic conditions were achieved at frequencies of 125 Hz and above. Further tests were done with a three microphone array and impulsive excitation, so that the presence of any discrete reflecting surfaces and their positions could be deduced. Apart from floor reflections no other reflections within 15 dB of the direct sound signal could be detected.

Conclusions

The semi anechoic chamber is now in use. Its design was an interesting combination of acoustic engineering, mechanical engineering, aerodynamics and heating and ventilation engineering, all aimed at producing the most cost effective facility within the constraints applied. Almost all the potential problems were identified during the design process. In some cases a conscious decision was made to delay the fitting of noise control measures until practical experience had shown them to be necessary. In other cases where there was no chance of a second try, for instance the vibration isolation of the rolls and dynamometer, and the selection of roll bearings, the most suitable solution was built in from the beginning.