Auckland UniServices Limited

VEHICLE EMISSIONS PILOT PROJECT

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Prepared for

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Preface

Some conclusions drawn from the Pilot work have been based on relatively small vehicle samples. Due to the small sample sizes, care is required in extrapolating these findings to the New Zealand fleet, as the results are indicative only unless supported by appropriate statistical analysis.

1. Executive Summary

1.1. Introduction

Emissions from motor vehicles have been attracting increasing attention in New Zealand. An option put forward by the Government for the control of vehicle emissions was to test the exhaust emissions of vehicles using simple test methods similar to those in use in some overseas countries. There are, however, peculiarities in the make-up of the New Zealand vehicle fleet making it necessary to check the application of these simple test methods to New Zealand vehicles. This was the basis of the Vehicle Emissions Pilot Project (the Pilot).

The Pilot comprised identifying the indicative current emissions performance of the vehicle fleet by testing a sample of vehicles using the simple emissions test methods, piloting simple emissions testing in order to gain the experience needed to aid the development of a simple emissions test régime for New Zealand, and understand the improvements in vehicle performance that may arise from the introduction of such a régime.

There are inherent differences between petrol and diesel engines and different simple emissions tests are involved. For this reason, reporting was divided into that concerning petrol vehicles and that concerning diesel vehicles. This report concerns petrol vehicles and the associated simple emissions test, the idle simple test.

1.2. Idle Emissions Performance of the Petrol Fleet

Idle simple testing was piloted at nine safety inspection and repair workshop sites around New Zealand over a four-month period beginning in September 2004. Around 1400 petrol vehicles were idle simple tested and visually inspected, 2100 petrol vehicles were visually inspected only, and a further 1400 were idle simple tested only as part of the Pilot. Quality assurance and analysis methods reduced the amount of data used in the main analysis to that from around 1100 vehicles for idle simple test analysis work and that from a further 1300 vehicles for visual inspection analysis work.

Much of the data was analysed using multiple variable statistical regression analysis in log-space, a particularly appropriate method of analysis given the high number of emissions-related variables involved, the high variability of the data and the severe skewedness in its distribution. This technique enabled the effects of individual variables to be isolated, their specific statistical significance to be gauged and the results to be modelled. This analysis found that:

- The technological make-up of the engine ('engine' including the exhaust system and hence any after-treatment system such as an exhaust catalyst if one is fitted) best described the high variability in idle simple test emissions results and found, at above a 90% confidence level (p-value <0.1), that vehicles fitted with exhaust catalysts exhibited on average 75% lower CO and HC idle simple test emissions than vehicles not fitted with catalysts.[1] Hence fewer catalyst-equipped vehicles failed to meet given pass-fail idle simple test 'cut-points'. Next most significant was a variable derived from a combination of the year of manufacture and the odometer reading, with a two- to three-fold increase in emissions expected in moving from vehicles of recent year of manufacture and low distance travelled to vehicles of less recent year of manufacture and most distance travelled, within an engine technology group;
- There are expected regional variations in the idle emissions performance of the petrol fleet, predominantly due to regional variation in fleet make-up with regard to engine technology;
- Whether a catalyst-equipped vehicle was registered before or after October 1996, when retail sale of leaded petrol was banned in New Zealand, was a statistically significant parameter but of small effect for (natural) idle[2] and fast idle[3] HC. The difference was to the order of 0.5% for fast idle CO for catalyst-equipped vehicles registered before October 1996. Around 5% of the Pilot's petrol sample were NZ-New vehicles that fitted into this category and around 5% were used imported vehicles that fitted into this category;
- Whether a petrol vehicle was NZ-New[4] or a used Japanese import was not consistently a statistically significant variable for describing idle simple test emissions results, where engine technology, year of manufacture and odometer were already considered. Engine power, engine size or whether a petrol engine was turbocharged were also not statistically significant indicators of expected idle simple test emissions performance;
- Around 60% of the visually inspected Pilot sample (around 2400 vehicles) were fitted with catalysts. It is expected the proportion of petrol vehicles fitted with catalysts in the New Zealand petrol fleet would currently be of similar order but it is expected that business-as-usual fleet turnover will increase this proportion substantially and average idle simple test emissions would be expected to decrease substantially as a result. Further, analysis of the Pilot results found around 60% of the catalyst-equipped vehicles to exhibit near-zero idle simple test emissions results, a proportion that is also expected to increase over time. It is believed this limits the usefulness of idle simple testing in the future;
- ▪ For a 3.5% (natural) idle CO, 1200 ppm (natural) idle HC cut-point, an idle simple test cut-point applied in the inspection of non-catalyst petrol vehicles in the UK, 35% of pre-1990 year of manufacture non-catalyst equipped vehicles did not meet this cut-point compared with 8% for pre-1990 catalyst-

[1] Note care is required in the interpretation of this as vehicles fitted with exhaust catalysts tend also to be fitted with more sophisticated engine control systems and the average improvement in emissions is therefore not necessarily a function of the presence or absence of the exhaust catalyst alone.
[2] '(natural) idle' refers to the normal engine speed of a non-loaded engine without any depression of the accelerator.
[3] 'fast idle' refers to no-load operation at an engine speed of around 2500rpm.
[4] 'NZ-New' refers to vehicles that are not used Japanese imports.

equipped vehicles. The proportion of vehicles not meeting this cut-point decreased as their year of manufacture became more recent with all catalyst and non-catalyst post-2000 year of manufacture vehicles meeting this cut-point. Emission profile curves were developed that allowed the proportion of vehicles not meeting other cut-points to be easily determined.

1.3. Value of Idle Simple Testing

Sixty-one variants[5] of petrol vehicles were tested to various drive cycle tests on a chassis dynamometer and the emissions results compared to the idle simple test results on an individual-vehicle basis. The vehicles were chosen to provide a broad range of variants. The drive cycles used were chosen so as to provide a representation of different on-road driving conditions. The idle simple test results were not found to provide a reliable indication of expected on-road emissions performance for this vehicle set. Some vehicles exhibited high idle simple test emissions and yet were expected to exhibit low on-road emissions, and vice versa. The coefficient of determination, R^2, for the comparison of various drive cycle emissions results to those from idle simple testing typically ranged from 0.1 to 0.6. An R^2 above 0.8 describes a reasonable correlation.

Analysis of test data from other studies also found there to be a poor relationship between idle simple test results and results from drive cycle testing.

1.4. Emissions-Related Repair

Seventy-two vehicles were idle simple tested before and after emissions-related repairs. Ten of these vehicles were subjected to detailed dynamometer testing to understand the effect of the repairs on on-road emissions and fuel consumption performance. Analysis found that:

- There was a high degree of variability in the response to repair for CO, HC, NOx and fuel consumption. Variations found in the repair of highest emitters ranged from a reduction in CO of 90% to an increase in CO of 60% and a reduction in fuel consumption of 18% to an increase in fuel consumption of 10%, based on the results from drive cycle testing (carried out to represent on-road performance);
- An average reduction in (natural) idle emission by 2.5% CO was achieved through repair for the repair-sample vehicles;
- A high proportion of repair costs were found in the range of $250-$500 and the average was around $350. For a fleet-wide programme a wide range of repair costs are expected and repair of older vehicles may be considered uneconomic at the upper end. A post-repair test (say, to test compliance to an idle simple test requirement) may add a further $60 to the cost of repair;
- In general the reduction in annual fuel costs achieved through repair is expected to be small compared to the cost of repair;

[5] That is, different vehicle models or different emissions-related configurations of the same vehicle, examples of the latter being a vehicle with and without an exhaust catalyst or before and after repair.

- Some vehicles in reasonable mechanical condition could not achieve low or even average idle simple test emissions even after repair;
- The majority of faults on modern engines were found to be the result of faulty sensors. A faulty oxygen sensor is a particularly common fault for the early vehicles fitted with such;
- Engine technology is becoming more sophisticated and requires more specialist equipment and skills to diagnose and repair faults. It is believed the industry will require a degree of re-tooling and up-skilling in order to provide an appropriate level of service. It is recommended high priority be given to encouraging this.

Applying the Pilot's repair results to various fleet scenarios suggests a régime that repairs the 10% worst emitters as identified by idle simple testing would be expected to reduce on-road[6] petrol fleet CO and HC emissions somewhere in the order of 10% and reduce NOx emissions much less than this. A reduction in fuel consumption of less than 0.5% would be expected.

1.5. Implementation of Idle Simple Testing

There are issues peculiar to New Zealand that would make it difficult to implement a fleet-wide régime based on idle simple testing:

- Around 50% of the fleet were not built to an emissions standard and it would therefore be difficult to require these vehicles retrospectively to meet a given emissions performance standard, unless it were a very lenient pass-fail cut-point;
- It is believed difficult retrospectively to require vehicles which were legitimately modified under the rules (or lack of them) prevailing at the time to then undergo re-engineering to meet a given emissions performance standard. A similar argument could be applied to those catalyst-equipped vehicles that have been 'modified' through poisoning of the catalyst on account of being fuelled with leaded petrol, the fuel that was made available at the time;
- The ability of the industry to provide sufficient capacity and capability to support such a régime is questioned;
- The poor relationship between idle simple test emissions and on-road emissions means that there is a risk the results of idle simple testing would be challenged;
- Implementation of idle simple testing would be a relatively expensive undertaking and would risk the industry over-investing in its formative years.

Furthermore, the usefulness of idle simple testing is expected to lessen as the fleet modernises, for example, due to the increasing proportion of vehicles that exhibit 'near-zero' idle simple test emissions (for although the idle simple test emissions are near-zero, the on-road emissions would not be expected to be near-zero, raising the

[6] It is important to differentiate between 'idle emissions' as given in the second bullet point above, which are those from the idle test, and 'on-road fleet emissions', which are those from operation on the road. On-road fleet emissions are more important for emissions inventory purposes.

question: how relevant is the test?). When all these aspects are considered, idle simple testing is not recommended for New Zealand as a mainstream vehicle emissions control programme. However, idle simple testing may be useful for awareness purposes, for emissions testing of specific, targeted vehicles or in support of other vehicle emissions programmes.

Elements that may make up an alternative vehicle emissions control programme include: visual inspection for visible emissions at the time of safety inspection; a mechanism to forbid or at least discourage tampering with emissions-related equipment; identifying and monitoring the engine technology make-up of the fleet for emissions inventory purposes; emissions screening for potentially high-emitting vehicles using remote sensing supported by a more robust emissions assessment (such as interrogation of the onboard diagnostics system or cautious use of gas analysers); proof the emissions system on used imported vehicles is functioning correctly before they are permitted to enter the fleet, and simple testing exhaust O_2 as an awareness tool at the time of a safety inspection. It is recommended these options be further investigated.

Note that there is currently no mechanism to demand the repair of a high-emitting vehicle unless it emits continuous visible emissions. This less than satisfactory situation will persist if an idle simple test régime or high emitter test and cut-point of some sort is not adopted. This weakens the authority upon which other emissions reduction programmes could be supported.

A recommended idle simple test procedure for New Zealand has been identified, should idle simple testing be introduced, as well as programmes required to support such.

Should idle simple testing be introduced as a fleet-wide requirement for petrol vehicles, it is expected the industry would require a further 1000 to 1200 personnel to support the testing involved and a further 600 full-time equivalents for personnel involved in the repair of vehicles. This is quite apart from personnel who may be involved in testing diesel vehicles, should there be such a programme. This being the case, the introduction of idle simple testing would require careful management, as this step increase in industry capacity would take several years to achieve, at best, and there is also a risk that the industry could over-invest in the earlier years. An over-optimistic introduction would also risk compromising the quality of the programme.

Once introduced, an idle simple test would be expected to take 5 to 20 minutes and cost around $35 on average, ranging from $20 to $60, depending upon the facility type and whether vehicles may be tested easily. The cost of idle simple testing may be higher still during any phase-in period.

1.6. Fleet On-Road Emissions Performance

The results from idle simple testing do not provide a good indication of expected on-road vehicle emissions performance, particularly on an individual-vehicle basis. As determined by multiple variable regression analysis applied to the results from detailed dynamometer testing of vehicles, a better assessment of expected on-road emissions performance could be achieved through modelling where the engine technology make-up, average year of manufacture and average odometer readings of a fleet of vehicles were known. This analysis found engine technology to be a statistically significant variable, at above the 90% significance level (p-value <0.1), with catalyst-equipped vehicles expected to exhibit, on average, 70-90% lower on-road emissions of CO, HC and NOx (emissions specie dependent) than vehicles not equipped with catalysts. The next most significant vehicle-related variable was a factor related to year of manufacture and odometer reading.

The drive cycle used for the basis of emissions determination was also found to be a significant variable, with emissions results from a drive cycle representing driving in congested driving conditions four to five times higher than those for a drive cycle representing more normal urban and inter-urban driving conditions. The combination of congestion and the absence of a catalyst could see, on average, 20 times higher emissions than driving in free-flow traffic in a vehicle fitted with a catalyst. Fuel consumption was two- to three-fold higher when testing vehicles to the drive cycle representing congested traffic conditions.

Through the use of the Pilot's emissions modelling and results from the Pilot's visual inspections on vehicles, it is expected to the order of 40% of the active petrol fleet in New Zealand are not fitted with catalysts and are responsible for around 80% of total on-road fleet emissions. Location-to-location variations are expected, predominantly due to differences in the local engine technology make-up of the fleet. Using the location-to-location variations found in the Pilot's visual inspection sample and applying Pilot-developed emissions prediction model to these produced ranges from 25% of an area's petrol fleet being non-catalyst and predicted to contribute to 65% of the total area's petrol fleet emissions, to 55% of the area's petrol fleet being non-catalyst and predicted to contribute to 90% of the total area's petrol fleet emissions.

Business-as-usual fleet turnover is expected to cause a substantial decrease in the proportion of non-catalyst-equipped vehicles, bringing about a substantial reduction in average vehicle on-road emissions.