Tom Leijen
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15 September 2006

Hon Harry Duynhoven
PO Box 3175
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New Zealand

Dear Mr Duynoven,
Please find enclosed the report ... The report investigates the need to have a correctly working oxygen sensor to reduce poisonous emissions of petrol-fuelled cars in New Zealand.

The key findings include:

- It is predicted that oxygen sensors will remain in use for at least another ten years. It is therefore important for us to keep up to date with this technology
- The ‘check engine light’ is a helpful but not 100% effective way to check the emission control systems.
- The frequency of the rich-lean oscillations of the air-fuel ratio is the most important factor influencing the operation of the catalytic converter.
- Any oxygen sensor can fail at any time.
- An oxygen sensor with a slow response time can increase emission of deadly gases such as CO and HC without producing visible smoke or illuminating the ‘check engine’ light.

If you require any further information, please feel free to contact me at the above address.
Yours sincerely,
Tom Leijen

Investigating the need to have a correctly working oxygen sensor to reduce poisonous emissions of petrol-fuelled cars in New Zealand.

Report produced on behalf of AECS Ltd

(15.9 06)

By: Tom Leijen

To: Hon Harry Duynhoven

Abstract:

In New Zealand there is a great need to reduce emissions produced by our vehicle fleet. One method to further reduce poisonous emissions of petrol-fuelled cars in New Zealand is to improve our knowledge of oxygen sensors. Our current WOF system does not pick up all exhaust gas emission failures. One of the main failures of the oxygen sensor is a delayed response time, caused by factors, such as sensor contamination with water, lead, oil, ash or silicon. Practical research confirms the theory that delaying the response time of the oxygen sensor will cause an increase in CO, HC and NO_x pollution.

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Introduction:

1.1: Main issue

Auckland cars emit twice as much carbon monoxide (CO), twice as much nitrogen oxides (NO_x) and three times the amount of hydrocarbons (HC) as US vehicles (Auckland Regional Council, August 2003). There is therefore a need to investigate further ways to reduce the pollution that is being caused by our vehicle fleet.

1.2: Objective of investigation

The objective of this report is to explain a way that New Zealand can significantly reduce the pollution and fuel consumption caused by our vehicle fleet, by checking the oxygen sensor on our motor vehicles.

1.3: Topic explanation

This report investigates the need to have a correctly working oxygen sensor to reduce poisonous emissions of petrol-fuelled cars in New Zealand. The oxygen sensor is a part that is vital in controlling emissions produced by the petrol engine. The feedback of the oxygen sensor allows very accurate control of fuel injection, making close control of emissions possible (Denton, 2004, p.44).

1.4: Extent of investigation

This report is a summary of research presented in scientific journals and books that have been produced since 1996. It also includes some practical research carried out in conjunction with AECS, a leading private education provider to the New Zealand and Australian automotive industry.

1.5: Limitations

Limitations of this report are the eight weeks to do the research and produce the findings, the resources available online and through the Massey University library, and the word limit of 1500 words.

Background:

2.1: History

In the 1960s emissions laws were first introduced in California, USA. These laws were put in place to limit the amount of poisonous gases, such as carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NO_x), which were polluting the atmosphere, causing smog and acid rain. Many other states and countries, soon after that, introduced similar laws. Since then american CO and HC emissions have been reduced by 96% and No_x emissions have been reduced by 76% (Visser, 2001, p.1543-1549).

2.2: The situation in New Zealand

A study done by the Auckland Regional Council (August 2003) showed that Auckland cars emit twice as much CO, twice as much NO_x and three times the amount of hydrocarbons as US vehicles, so the need for emissions regulation is important in New Zealand. Currently our only regulations on light vehicle emission is that the 'check engine' warning light must be off and that the vehicle may not produce visible smoke for more than 10 seconds (LTNZ, 2006).

2.3: Emission conversion systems

Petrol engines will always produce the poisonous gases CO, HC and NO_x; reacting them with chemicals in the catalytic converter reduces them. When the mixture is lean* HC and CO are converted to water and carbon dioxide (CO_2). When it is rich** NO_x and CO are converted to nitrogen (N_2) and CO_2. Water, CO_2 and N_2 are far less poisonous substances. The catalytic converter works most efficiently when the oxygen sensor system is oscillating the air-fuel ratio between rich and lean (McAfee, 2002, p. 50-51).

NOTE: CO_2 is the preferred emission, it is the same gas that humans breathe out and trees that turn it back into oxygen can absorb it.

*Lean: When the mixture of air and fuel in the combustion chamber has less than the average amount of fuel.

**Rich: When the mixture of air and fuel in the combustion chamber has more than the average amount of fuel.

Discussion:

3.1: The future for oxygen sensors

It is important for New Zealand to keep up to date with oxygen sensor technology. “Spark ignition engines still show further potential regarding emission reduction and fuel economy and will be the major drive assembly for vehicles during the next 10–20 years. Alternative concepts (e.g. electric, fuel cell, hybrid and hydrogen vehicles), in contrast, exhibit the present disadvantageous overall emissions and unfavourable cost to profit relation, respectively” (Riegel, Neumann & Wiedemann, 2002, p.153). Riegel et al. also predict, that, because it seems to be too difficult to start using alternative sensors, the solid state oxygen sensor will remain in use for at least the next ten years.

3.2: Limitations of the ‘check engine’ light

An investigation done in 2002 indicated that there are problems that are not identifiable by emissions test but are identified by the OBDII* system. However it has also found that there are vehicles that fail strict Californian emissions tests but do not have the ‘check engine’ light illuminated (Durbin and Norbeck, 2002,p.1054-1062). This shows that the ‘check engine’ light does not cover all problems that could occur in the emission control system.

*OBDII: On Board Diagnostics 2 – the system that illuminates the ‘check engine’ light when there is a fault.

3.3: The importance of frequency for gas conversion

Silveston’s research (1996, p. 2419-2426) shows that modulation* can both improve and diminish the conversion rate of gases in the catalytic converter. Overall the most important factor of modulation, in maximising the rate of conversion, was found to be the frequency. The optimum frequency for automotive catalytic converters is reported to be between 0.5 and 2 Hz. Further research done in 2002 also says that modulation is an important factor for correct functioning of the catalytic converter (McAfee 2002, p. 55).

*Modulation: Changing the frequency or the amplitude – in this case, frequency is the frequency of the oscillations between rich and lean and amplitude is difference between the maximum 'richness' and maximum 'leanness'.

3.4: Oxygen sensor failure

A few examples of the factors that cause a delay in the response time* of the oxygen sensor are: sensor contamination with lead, oil, ash or silicon. Another major factor, which could happen to any car in any situation, is moisture getting into the sensor through, for example, a cracked seal ("O_2 Sensor Failure", 1996, p.6).

*Response time: The time it takes for the sensor to let the on board computer know whether the mixture is rich or lean.

3.5: Practical research

I also did some research of my own together with AECS (a leading education provider to the New Zealand and Australian automotive industry). Using a PICAXE micro controller (programmable microchip) we manipulated the frequency of the oscillations between rich and lean of the air-fuel ratio, to see what would happen if the time it took for the oxygen sensor to respond were to increase.

3.6: Practical research outcome

First of all it is important to note that at no point during these trials did the 'check engine' light go on, nor was there any visible smoke, it was noticeable however, that the engine started running badly when the frequency got lower than 0.3Hz. Decreasing the frequency, i.e. slowing down the response time, caused an increase in the average CO and HC pollution and a decrease in CO_2 (the gas created in the reaction of CO and oxygen) emission. Figures 1-3 show how the emission composition changed, as the frequency decreased.

Figure 1:

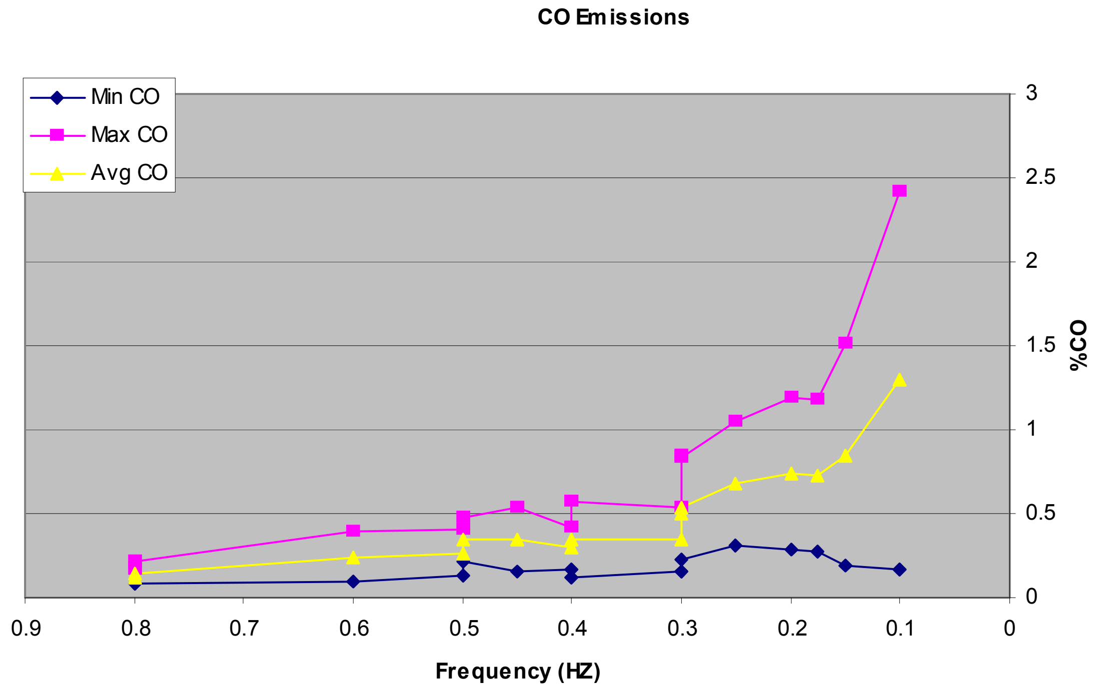


Figure 1 shows a clear rise at 0.3Hz it is clear that at that point the catalytic converter stops converting CO.

Figure 2:

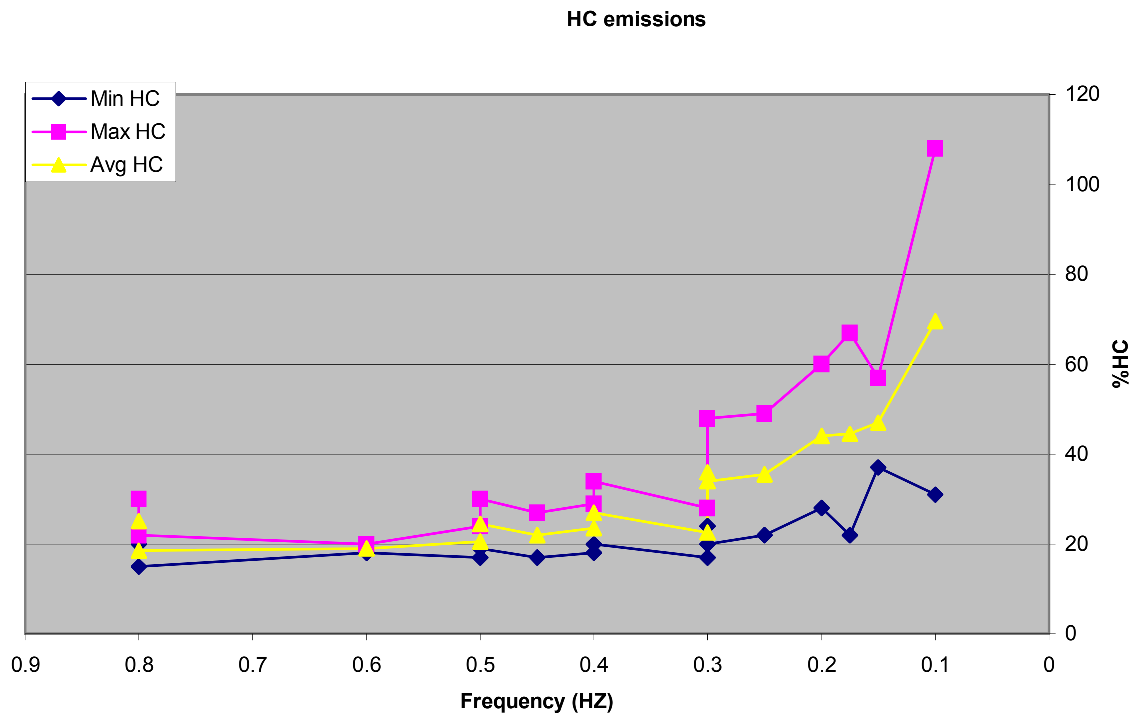
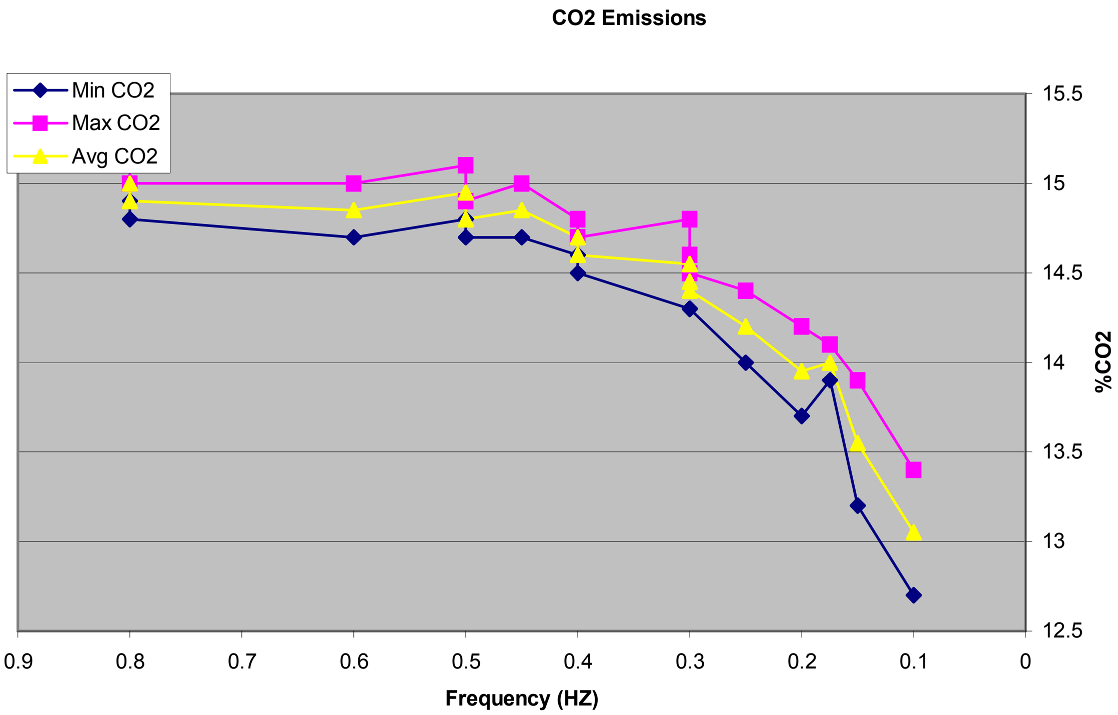


Figure 2 shows a clear increase at 0.3Hz also showing that at that point the catalytic converter has stopped converting HC.

Figure 3:



In figure 3 it can be seen that the CO_2 clearly starts decreasing at 0.5Hz, showing that the operation of the catalytic converter starts deteriorating at this point.

Conclusions:

3.1: It is very important for New Zealand to increase its knowledge of oxygen sensors

3.2: Our current WOF system does not pick up all emissions failures, because the OBDII system (‘check engine’ light system) is not failsafe.

3.3: Most, oxygen sensor related, emissions failures are caused by a delayed response time of the oxygen sensor

3.4: Oxygen sensor response time delays are caused by sensor contamination with water, lead, oil, ash or silicon.

3.5: Practical research proved that delaying the response time caused an increase in CO, HC and NO_x pollution.

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Appendix: