Fuel News

Diesel Engine Emission Reduction

The purpose of this document is to briefly outline current strategies for reducing diesel engine exhaust emissions. Emission reduction and costs are summarised in a table at the end of this fuel news.

Key words- Greenhouse, biodiesel, ethanol, Gaseous Fuels, GTL, NOX, PuriNOX, emulsion, CO,HC, Particulates, soot, Cleanburn Additives, Black smoke , White Smoke, sulphur

1. GREENHOUSE GAS – Carbon Dioxide Reduction

A litre of diesel fuel will produce 2.67 kg of carbon dioxide. Because the diesel fuel has been produced from a fossil source of carbon this adds to the carbon dioxide in the biosphere and contributes to the greenhouse effect unless it is removed by some carbon dioxide abatement process (for example -timber plantations). The amount of carbon dioxide produced can be mitigated by adding components that have been produced from a non-fossil source of carbon such as biodiesel or ethanol.

Biodiesel is produced by chemical purification of natural hydrocarbon products, for example vegetable oil, tallow, or cooking oil. The process is called esterification and produces a product containing about 10% oxygen. This product has similar properties to diesel and can be used in normal diesel engines. It can be used as a diesel (B100) or as a blend with normal diesel, normally at 20% (B20). Because the biodiesel is made from carbon taken out of the biosphere it adds no new carbon and so does not add to greenhouse gas emissions. Biodiesel is more expensive to produce than normal diesel at current crude prices unless the base stock is a waste material. Cold temperature properties may be an issue.

Diesel – ethanol blends. Ethanol can be blended with diesel using stabilising additives to produce a diesel fuel. Like biodiesel, ethanol is produced from plants and so is made from carbon taken out of the biosphere and adds no new carbon. The normal ethanol component in a blend is 10%. Ethanol cost more to produce than normal diesel at current crude prices.

Both ethanol and biodiesel can reduce diesel carbon dioxide emissions by the approximate proportion in which they are used as substitutes. There can be an increase in fuel consumption proportional to the amount of oxygen present.

Gaseous Fuels. Diesel engines can be modified to use gaseous fuels. Gaseous fuels such as Butane, Propane, Natural gas have less carbon and more hydrogen than diesel fuels and so produce less carbon dioxide. However there is an increase in fuel consumption and special tanks are needed to store the gases. The gaseous fuels are cheaper than normal diesel but require expensive modifications to engines and storage. Examples are LPG, CNG (compressed natural gas) and LNG (liquefied natural gas).

Gas to Liquid (GTL) – Gaseous fuels can be converted to a diesel and petrol equivalent by a gas conversion process. These products have more hydrogen than refined diesel and less carbon so there is a reduction in carbon dioxide emissions.
All gaseous fuels and GTL fuels contain very low levels of sulphur and heavy carbon compounds and so reduce other exhaust pollutants.

Ultra Low Sulphur Diesel (ULSD) – ULSD is the diesel fuel that meets the Euro 4 fuel specifications. The major benefits of the move to ULSD are provided by the ability to use advanced technology in the engine and the catalyst. These components are often sensitive to sulphur. Vehicle emissions are reduced when ULSD is used with the appropriate Euro 4 fuelled engines – the emissions from a Euro 4 vehicle with advanced on-board diagnostics and a particulate trap will dramatically reduce emissions. BP has an ultra low sulphur diesel fuel called BP Eco Ultra.

Engine Modifications – Engine modifications to improve fuel economy lower exhaust emissions per kilometre, examples are high injection pressure fuel systems.

2. POLLUTANT REDUCTION

The following pollutants are produced in a diesel engine exhaust, there are different strategies for reducing each one and they are summarised in the followed sections.
NOx – oxides of nitrogen
HC – unburnt hydrocarbons
C0 – carbon monoxide
Particulates
Black smoke
White Smoke
Sulphur oxides.

Note that diesel fuel substitutes that reduce carbon dioxide emissions also reduce other exhaust pollutants with the exception of oxides of nitrogen. These are reduced by lower combustion temperature.

2.1 NOX – Oxides of nitrogen

The high temperatures present in the diesel engine combustion chamber can convert nitrogen from the air into oxides of nitrogen (NOx). NOx production is reduced when combustion temperatures are lowered. This is achieved by:-
a) adding water to the fuel (PuriNOX)
b) circulating inert exhaust gas into the combustion chamber (EGR).
c) using exhaust "de-NOx" catalysts.

PuriNOX

PuriNOX is a process for stabilising water in diesel fuel by using additives to produce an emulsion. The process involves the diesel fuel being put through a special blender with an additive and water to produce a10% water in diesel emulsion that can be used in a diesel engine. Because it is blended on site and requires special blending equipment and an additive it is more expensive than normal diesel, there is a power loss due to the presence of water, however the water component is not taxed at the diesel rate. This technology can be applied to older engines.

EGR – Exhaust Gas Recirculation

This is the process of passing part of the exhaust gas into the combustion chamber to reduce temperature and NOX levels. It has the disadvantage that it increases particulate soot levels and so is best used with clean low sulphur diesel fuels. It is a new technology found on later model engines.

Exhaust Catalysts

Exhaust catalysts have been produced that can remove NOx, they are poisoned by diesel fuel sulphur and require fuels with very low sulphur around 10 –50 ppm. They can be fitted to most vehicles but require a very low sulphur fuel. These "de-NOx" catalysts will enable emissions of smog precursors to diminish, improving urban air quality.

Note -Fuels that contain oxygen such as biodiesel and ethanol blends tend to increase NOX production.

2.2 HC – Unburnt Hydrocarbons

Unburnt Hydrocarbons are produced when the diesel combustion chamber exhaust valves open before all the fuel has been burnt., Levels are very low for a diesel engine representing less than 0.1% of fuel used. Unburnt Hydrocarbons can be removed or reduced by using a catalytic converter in the exhaust system. Catalytic converters work best with low sulphur (<500ppm) or ultra low sulphur diesel fuel (<50ppm). HC is also be reduced by lowering the density and distillation characteristics of the fuel through refining.

2.3 CO – Carbon Monoxide

Carbon Monoxide is produced when carbon molecules are not completely burnt to carbon dioxide when the combustion chamber exhaust valves are opened. Carbon monoxide levels are naturally very low, the low levels produced can be removed using an exhaust catalytic converter as for HC. Exhaust catalytic converters work best with low sulphur (<500ppm) or ultra low sulphur diesel fuel (<50ppm). Using diesel fuel with lower density and distillation properties also reduces carbon monoxide.

2.4 Particulate Matter - Soot

Particulate matter represents compounds with a high carbon content (e.g. aromatics) that have not completely burnt when the combustion chamber is exhausted. These combine with sulphur and water to form particulate matter (soot). There are a number of ways to reduce particulate matter:-

a) **Better Refining** – reducing sulphur and aromatic content and lowering the distillation final boiling point removes compounds high in carbon and so reduces exhaust particulate. BP Eco Ultra is a good example of this.
b) **Substitution with alternative fuels** – biodiesel and ethanol have no sulphur and contain no aromatic compounds. Replacing normal diesel with an alternative fuel reduces sulphur and heavy carbon compounds.
c) **Alternative processes** – the gas to liquid process **(GTL)** converts gas to diesel. GTL diesel has no sulphur and aromatics hence particulates will be reduced.
d) **Particulate traps** – these are canisters that sit in the exhaust from the engine and collect particulate matter, at specified intervals they use excess fuel to burn away the particulates.
e) **Engineering**- engine modifications to improve injection spray patterns, remove cool spots in the combustion and preventing the burning of crankcase oil. These changes have been made for modern engines to meet current emission standards.
f) **Cleanburn additives** – Adding a metal additive to the diesel fuel reduces the particulate size, examples are manganese, magnesium, iron. Some additives also help to burn off the particulates collected on the exhaust trap, e,g. cerium additives.

2.5 Black Smoke

Black smoke is visible particulate and is a transient exhaust emission when the engine is not running as lean. It also indicates poor engine maintenance or filter blockage. Reduction of black smoke uses the same strategy as that used for particulate matter but can also be reduced by engine overhaul or driver training so that the engine is at optimum. Black smoke indicates wasted fuel.

2.6 White Smoke

White smoke is fuel that has failed to ignite; normally it occurs on cold start. White smoke can be reduced by raising the fuel cetane or by the addition of cetane improving additives.

2.7 Sulphur oxides

Sulphur in the fuel is converted to sulphur oxides when the fuel is burnt. These are corrosive and contribute to particulate emissions. Sulphur emissions can be reduced by removing sulphur during the refining process or substituting with fuels with no sulphur such as biodiesel, ethanol, gaseous fuels, water.

3. SUMMARY

Note –costs quoted in the summary are indicative only, the actual costs depend on tax treatment, type of operation and other circumstances.

Emission	**Reduction**	**Comments**
Carbon dioxide	Substitute with biodiesel	Increases NOx Costs up to 5cpl extra depending on tax Supply of raw material. Reduces other exhaust pollutants
	Substitute with ethanol at 10%	Increases NOx Requires blending plant Additive cost up to 5 cpl, Power loss up to10%
	Substitute with gas	Power loss and increased fuel consumption up to 30% Capital investment of engine modifications. Gas is cheaper with lower tax rate.
	Substitute with GTL	Cost of GTL component. Other pollutants are reduced.
	Engine modifications to reduce fuel consumption	Require clean fuels with low particulate content
NOx	PuriNOX	Requires blender. additive cost up to 5cpl, neutralised because water component is not taxed. Power loss (10%) leads to increased fuel consumption
	Exhaust Gas Recirculation	Cannot be retrofitted Increases engine oil soot levels – reduced drain periods
	DeNOX Catalyst	Requires very low sulphur diesel <50ppm.
HC and CO Particulate matter	Refining to reduce Density, distillation and sulphur and to increase cetane	Requires refinery investment Cleaner fuels result in cleaner engines and extended oil drain periods
	Fuel substitution	Depends on availability of alternative fuel.
	Engine maintenance	Can be done locally

	Exhaust catalyst	Can be retrofitted, requires low sulphur diesel
	Metal additives	HSE concerns, cost additional 0.1-0.3 cpl, fuel application issues, engine wear and maintenance issues
White Smoke	Increase Cetane number.	Additional refining costs Additional additive costs
Sulphur Oxides	Lower sulphur content	Additional refining costs. Requires additional refinery equipment.

For further information, please call the BP Lubricants and Fuel Technical Helpline 1300 139 700 local call or visit www.bp.com.au/fuelnews