ALTERNATIVE FUEL ENGINES IN HEAVY DUTY VEHICLES

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The goals of Detroit Diesel Corporation's alternative fuel activities are to develop a heavy duty engine capable of complying with the 1991 vehicle emissions standards, and possibly, the 1994 standards.

Emission Standards

Looking at the Environmental Protection Agency (EPA) vehicle standards promulgated in 1989 and going through 1994, the hydrocarbons and carbon monoxides remain constant. The $BSNO_x$ (or NO_x) standard in 1989 was 10.7 grams per brake horse per hour. For 1990, it is 6 grams, and in 1991 it will be 5 grams and will remain constant through 1994. There are proposals being considered now that would reduce this standard to 4 grams in 1997. The emissions standards on particulate has caused all engine manufactures to expend considerable effort. In 1989, the standard was 0.6 gram where it remained through 1990. However, in 1991, it will drop to 0.25 gram and in 1994 to 0.1 gram. The urban bus market is already at the 0.1 gram level. In 1994, 0.1 gram will become the standard level for all certified on highway engines.

Complying with Emission Standards

There are a couple of different ways the engine manufacturers can improve engine emissions. One is through technology evolution to improve the basic engine components. The other is to improve exhaust treatment using particulate traps or, in case of methanol, catalytic converters.

The alternate fuels being studied are methanol and compressed natural gas (CNG). These studies are looking at strategies to comply with emission standards for the 1991-1994 period. The basic approach incorporates an electronic control system on all certified engines and improved injection technology. One of the ways to get a cleaner and more efficient combustion is to use higher injection pressure. The new injectors will function in the 20,000 to 23,000 pounds per square inch (psi) range. The increased pressure improves atomization, thus producing a cleaner, more efficient combustion. Improvements in turbo charger geometry can also improve efficiency. Through electronics, smoke control for diesel engines can be improved. Electronics can be used to keep smoke emissions at a reasonable level, for buses, below the visible range, and still maintain performance characteristics.

Oil consumption is another key element in reducing particulate emission levels. The average diesel powered vehicle in use today would not pass the particulate emissions test due to the rate of oil consumption. Some of the other variables for diesel fuels are low sulphur fuels and low aromatic. Regardless of the fuel, diesel, methanol or CNG, particulate traps and catalytic converters constitute major components of interest.

Multi-Fuel Engines

Multi-fuel engines represent an interesting area for development. The goal is to convert from one fuel to another based on availability or cost. There are some basic engine characteristics that would not change for a multi-fuel engine. For a 2-cycle engine, the block is the same. The head configuration and blower system would be the same. There are some aspects of an engine that should be different to utilize a specific fuel efficiently. For example, the air flow characteristics of the methanol engine are different from those for the diesel engine, so they require different turbo chargers. The cam profile, bypass blower, and electronic unit injector are also different for good combustion in a methanol engine. Methanol is also incompatible with some of the materials commonly used in diesel engines. The size of the holes in the tips must be increased since methanol has half the energy that diesel has by volume. Higher compression ratio pistons, additional glow plugs, and harnesses are also required for methanol engines. A controller for the by-pass blower, controlling the air flow in the engine, and a controller for the glow plug are also required. Based on these differences, additional training will be required for general maintenance and for trouble shooting the different components.

Methanol Demonstration Projects

The current methanol engine can meet the 1991 emission standards. The addition of a catalytic converter will reduce the hydrocarbon and carbon monoxide emissions by 90%, particulate by 70%, and formaldehyde by 50%. The methanol engine with the catalytic converter can achieve emissions values lower than any other heavy duty engine. The catalytic converter is a ceramic monolith device, 9 inches by 6 inches, housed in a canister. The small size allows it to be installed in line with the turbocharger before the exhausts go into the muffler system.

Some methanol demonstrations are on-going. There are 54 methanol buses that have accumulated more than 1.6 million miles. They will have accumulated more than 3 million miles by January 1991. These methanol buses have accumulated more miles than all the other heavy duty low emission engine technologies combined. Three methanol buses are scheduled for delivery to Medicine Hat in Alberta, Canada. After they receive these buses, half of their fleet of 16 will be powered by methanol engines. There are 50 additional methanol powered school buses going to California. It is anticipated that 14 ethanol buses will go to Illinois in 1990. The ethanol engine is similar to the methanol engine with some minor changes in fueling and engine timing. The percentage "up-time," or percent availability, is often used to measure the effectiveness of an engine. The methanol engines at the demonstration sites have had "up-times" between 96-98%, which is comparable to that for diesel engines.

There are also 7 truck demonstrations of methanol engines being implemented. These are geographically distributed over the country. These demonstrations will address durability and reliability concerns. The implementation of this program has not gone real smooth and easy. One of the biggest problem areas was glow plugs. Glow plug failures at extremely early mileage and early hours were experienced. To correct this problem, the compression ration was increased from 18-1 to 20-1. The timing characteristics were modified with the electronic system to keep the cylinder pressures down. Sixteen units have been modified with a reduction in the glow plug problems noted.

Problem have also been noted with the unit injectors: plugging of the spray tip holes and injector seizure. The spray tip hole plugging is primarily a result of the reaction of methanol and oil. As injector comes up to the top, a small amount of oil gets down into the plunger. A fuel additive has been developed and introduced, at 0.06% by volume, to correct the problem. Plunger scoring is caused by the lack of lubricant supplied by the diesel fuel within the injector system. The lubrication characteristics in methanol are significantly different from those of diesel fuel. Reductions in the ash content of the oil may also be necessary. Changes in manufacturing process for the injectors will involve lapping the plunger with the injector. The use of ceramics within the injector is also being considered.

Some of the initial concerns with methanol were ease of starting and performance with the glow plugs and higher compression ratio, 23-1. The methanol engine actually starts better than a diesel in cold weather. This has been demonstrated at several locations in Canada. The acceleration and performance characteristics of the methanol engine are actually better than diesel. Below 10 mph the methanol engine accelerates quicker than the diesel, because there is no smoke control as is required on the diesel engine. Above 10 mph the acceleration rate is the same, due to the same horsepower characteristics.

Methanol fuel does not have the energy that diesel has, so there is a fuel penalty. Theoretically, diesel fuel has 2.3 times more energy than an equal volume of methanol. In practice, the best ratio has been 2.35 to 1 with the average for all pre-production type engines being 2.66 to 1. The fuel economy is duty cycle dependent and the ratios cited include 1986 and 1987 diesel engines which are in a range of 6 to 10 grams of NO_x.

Methanol engines require a little more maintenance than a diesel engine. Glow plugs should be changed at 50,000 miles, and injectors at 100,000 miles. A few components in the blower by-pass controls will also require some preventive maintenance. Oil and filter changes are no different. The initial change of the fuel filter will be at 1,000 miles, and then at intervals of 6,000 miles. The methanal filter is much finer and, because of the lubrication problems, it's critical that methanal fuel supply be clean. The fuel fittings for refueling are dryback with a vapor recovery tank. Stainless steel fuel tanks are required with approximately double the capacity with compatible lines and fittings. The electric fuel pump is outside the engine compartment because of the need for a "fuel cooler" to keep the fuel below its boiling point.

In conclusion the ethanol engine has demonstrated that it can exceed the 1991 emission standards. Catalytic converters can be added to achieve even lower emissions. It requires a little more maintenance than a diesel engine. Additional training will be required for trouble shooting the fuel system. Methanol engine technology is more costly than diesel, but not as costly as other reduced emission alternatives.

Particulate Traps

Another part of the reduced emissions program is particulate traps. The goal of particulate traps is to trap soot and particles that are exhausted from an engine. The particulate trap does not change the hydrocarbons, the NO_x, or the carbon monoxides. However, the particulate levels will drop from 0.33 to 0.05 grams per hour. The negative impact of the particulate trap is that it requires a little more space than a standard muffler. The particulate trap, installed, costs about $4,000 to $8,000 per vehicle. Positive regeneration is also required.

CNG Programs

There are 2 CNG programs: a dual fuel, pre-chamber type engine, and a direct injection engine. The fuel tank will require four times the volume required for a diesel. The tank will also add from 2,500 to 5,000 pounds to the weight of the vehicle. A gas pressure regulators will be required as well as special fittings for refueling.

ALTERNATIVE FUEL ENGINES IN AUTOMOBILES
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This paper provides a brief overview of Chrysler Corporation's efforts in the development of a flexible fuel vehicle (FFV) and how such a vehicle (cars and light trucks) will affect the equipment mechanic.

An FFV is a car or truck designed to operate equally well on gasoline or M85, 85% methanol and 15% gasoline, or any mixture of gasoline and M85. For example M20 is 20% methanol and 80% gasoline, M50 is 50% methanol, and so on. An FFV can be fueled with either M85 or gasoline, as well as the intermediate blends that will result from topping off a partially full tank with the either fuel. Methanol was selected since it can reduce smog formation; is an alternative energy source; and may be mandated by law, perhaps in fleets first.

Why was M85 selected rather than pure methanol? There are three reasons: the 15% of gasoline provides flame luminosity for safety, since pure methanol has an almost invisible flame; it provides the ability to start at lower temperatures than would be possible with pure methanol; it gives M85 the distinctive order and taste of gasoline, a safety factor.

There will be no readily discernable difference between a gasoline vehicle and an FFV. However, an FFV will have some additional <u>systems</u> that a gasoline only car does not have and it will have some <u>material</u> differences.

Systems. The FFV will have a sensor to detect the percentage of methanol in the fuel and a computer program to adjust the fuel delivery schedule, the spark advance schedule, and other engine operating parameters for the specific fuel mixture. If you pump M85 into an FFV, it adjusts itself to run properly on that fuel. If you pump gasoline into an FFV, it adjusts for gasoline. And if you mix the fuels as you would if you topped off a tank, it sets itself to run on the resulting intermediate mixture.

Materials. One of the undesirable properties of methanol is its tendency to be corrosive to many of the metals used in cars, such as steel, aluminum and terneplate. It also attacks many elastomeric materials, such as seals, gaskets, diaphragms. The solution to this problem is not an insurmountable design task - we simply go through the fuel system and wherever we find materials that are incompatible with methanol, we substitute materials that are compatible. This is repeated for the induction system, because air going into an engine does not flow in a steady stream but is full of instantaneous flow reversals. The average flow is in, but at any instant, the flow can be either way. This means that small amounts of fuel & fuel vapors can be found far upstream of where they are injected. So, the air cleaner, for example, must be able to survive when it is subjected to methanol vapors or liquid droplets.

Blowby in the crankcase contains fuel vapors, so anything that comes in contact with oil such as gaskets, oil filters, and positive crankcase ventilation system components must be made of methanol resistant materials. This also includes bearings, piston rings and other internal components. Finally, there is the evaporative control system. The canister, lines, switches and valves in this system must be modified to accommodate methanol. Since the FFV will more than likely be implemented in fleets first, you may be the first to maintain it.

Servicing Flexible Fuel Vehicles

The key areas for servicing an FFV will involve:

- Sensor system;
- Part substitution;
- Water in the fuel;
- Special oil;
- Travel range; and
- Toxicity of methanol.

Sensor System. The most intimidating difference between an FFV and its predecessors, is the fuel composition sensing system. But I am sure that will not be a problem