OVERVIEW OF RECENT LIGHT DUTY ALTERNATIVE FUEL ENGINES

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ABSTRACT

Some light duty vehicles are now available for purchase that use M85, E10, propane, CNG, and reformulated gasoline. The engines for these vehicles have some special design features to accommodate the physical characteristics of these fuels. The available vehicles include sedans, pickup trucks, and vans. Several thousand such vehicles have been sold in the U.S. last year, and the outlook is good for both continued demand and continued supply of these vehicles. The costs for these vehicles are not settled, and they have some limitations on weight and range.

INTRODUCTION

The alternative fuels that are now being widely considered for use in light duty engines are M85 (a blend of 85% methanol and 15% gasoline by volume), E15 (a blend of 15% ethanol and 85% gasoline by volume), propane, compressed natural gas (CNG), electricity, and reformulated gasoline. While other fuels can be used in light duty engines, these six are the fuels for which engines are currently available by major manufacturers. Most notable by their absence from this list are M100 (pure methanol); E100 and E85 (pure ethanol and 85% ethanol in gasoline, respectively); and liquified natural gas (LNG). While these other alternative fuels are being used successfully in heavy duty applications today, none are being endorsed by the major domestic manufacturers of light duty cars and trucks at this time.

Light duty engines in the U.S. today are predominantly spark ignited, fuel injected, four cycle machines with electronic fuel and ignition control. The alternative fuels have some physical properties that must be considered and accommodated for successful use in light duty engines.

FUEL PROPERTIES

M85 has its fuel properties dominated by the alcohol fraction. It has low lubricity. Its heat content is roughly half that of gasoline for an equal volume. Its volatility, as expressed by Ried vapor pressure, is lower than gasoline. Its heat of vaporization is significantly higher than gasoline. It has a high octane rating and is somewhat corrosive.

Propane and CNG share a set of physical properties as gaseous fuels. While propane is stored in liquid form, it is introduced into the engine as a gas. Since these substances are gases at standard atmospheric conditions, they avoid all issues of atomization and vaporization. Their gaseous form also demands that the fuel charge occupy many times the volume of an equal energy charge of gasoline. This volume is significant compared to the volume of the air charge for a combustion cycle. Both of the gaseous fuels have a high octane rating compared to gasoline. Both also share a very low lubricity compared to gasoline.

Both E10 and reformulated gasoline can be considered gasoline substitutes. Almost any engine sold in the U.S. today that uses gasoline can use E10 or reformulated gasoline without any ill effect. For engine design, most of their important physical characteristics are like gasoline. E10 does have a higher volatility than gasoline as expressed by Ried vapor pressure. The 15% ethanol makes the fuel more corrosive to metals and elastomers than gasoline alone, though all major manufacturers now account for this in their selection of materials. E10 is now sold widely as gasoline, with the ethanol included as an inexpensive octane enhancer. Reformulated gasoline has a lower volatility than current unleaded gasolines. The fuel has a lower fraction of aromatics and other chemistry changes, including the substantial use of ethers to increase its oxygen content.

ENGINE REQUIREMENTS

When the properties of alternative fuels are considered for engine design, a few requirements emerge. The lower lubricity of the gaseous fuels and M85 demand that the piston rings and valves be hardened against wear. The higher volumes required for a charge of these three fuels require an increased capacity for the fuel delivery system. The electronic programming for the fuel and ignition schedules must be changed. M85 also requires corrosion resistant materials and an enhanced cold start system.

ENGINE DESIGN APPROACHES

The design approach being used for M85 engines is a "fuel flexible" design. The engine can accept any concentration of methanol in the gasoline from 0 to 85%. The valve faces and seats are hardened. The top piston ring is plated for hardness. Internal parts of the fuel pump are plated against corrosion.

None of the engines offered now take advantage of M85's high octane rating. They operate at common gasoline compression ratios. M85 engines are universally supplied from original equipment manufacturers, with no aftermarket conversion kits widely available.

The design approaches used now for the gaseous fuels include both single fuel and bi-fuel vehicles. The bi-fuel vehicles retain their gasoline fuel tanks and can switch between the two fuels while running. The valve faces and seats are hardened, and the exhaust valves have no rotators. The cylinder heads are stress relieved to increase heat resistance. Many designs have abandoned port injection for a gas mixer in the throttle body. The gaseous fuels are available both from the original equipment manufacturer and as aftermarket conversions. Engines are available from the manufacturer with a "gaseous fuel prep kit" that includes the upgraded parts for wear and heat resistance, although the fuel system is entirely gasoline. These are intended for use with aftermarket conversions to the alternative fuel.

AVAILABLE VEHICLES

Battelle Memorial Institute has recently obtained a fleet of light duty panel vans using M85, propane, reformulated gasoline, CNG, and electricity. These vehicles are in the South Coast Alternative Fuels Demonstration project, also known as the Clean Fleet Project. The demonstration attempted to obtain full size panel vans from Chrysler, Ford, and Chevrolet that operate on these fuels. Table 1 shows that vehicles were actually available in the summer of 1992.

Table I Alternative fuel vans provided for the Clean Fleet project

Fuel	Chev. G30	Chrysler B350	Ford E250	Other	Total
Compressed Natural Gas	7	7	7	0	21
Liquefied Petroleum Gas	7	0	13	0	20
Methanol (M-85)	0	0	20	0	20
Reformulated Gasoline	7	7	7	0	21
Electric	--	--	--	4	4
Control	9	6	12	0	27
Total Vehicles	30	20	59	4	113

The vehicles began normal daily service as Federal Express package delivery trucks in southern California in the fall of 1992, and will be carefully monitored by the project for two years.

The California Energy Commission provided a list of alternative fuel light duty vehicles that are currently available in California. This is shown in Table 2.

Table II Light duty alternative fuel vehicles available for sale in California

Vehicle	Approx. Price	Fuel
Ford Taurus	$14,000	M85 FFV
Chevy Lumina	$14,000	M85 FFV
Chrysler Spirit/Acclaim	$12,000	M85 FFV
GMC Sierra Pickup	$20,000	CNG
Mercedes 300S	$70,000	M85 FFV
Chrysler RAM Van	$25,000	CNG
Volkswagen Jetta	$13,000	M85 FFV

Light duty vehicles that run on alternative fuels are now offered for sale by all three major domestic auto manufacturers as well as some imports. In general, one can obtain some sort of vehicle in any fuel, and can obtain either a sedan, pickup truck, or van. The selection is not yet broad enough, though, to choose both the vehicle type and the fuel. If a prospective purchaser is willing to consider aftermarket conversions, then propane and CNG can be used in almost any light duty vehicle.

The outlook for availability is promising. Chevrolet sold 1,200 M85 Lumina sedans in California recently. The CNG Sierra pickup was originally scheduled for a 1,000 unit production run, which quickly sold out. The run was extended to 2,000 trucks, and demand has remained strong. General Motors has recently announced that the 2,000 unit figure is an estimate rather than a limit, and all orders received will be filled.

The manufacturers are concentrating on supplying the types of sedans and trucks that are favored by fleet operators. This is in reaction to the recent legislation at Federal and State levels which target these fleets for incentives and mandates to use alternative fuels. Much has been written of the free market stalemate between supply and demand for alternative fuel vehicles and their fueling infrastructure. It appears that this impasse has been overcome by legislation, at least in part. The regulations have created a market for which the manufacturers are now supplying vehicles.

COST, WEIGHT AND RANGE

The cost of alternative fuel vehicles has not yet stabilized. The 1992 M85 Chevrolet Lumina sedan carried a price premium of $2,000. It is not clear that the prices charged for the earliest alternative fuel vehicles are accurate reflections of the costs for developing and producing them. It may not be reasonable to expect that the manufacturers can price them accurately at this time, given the great uncertainty about the number of vehicles that might be sold in these newly emerging markets.

The weights and ranges of the vehicles are different from gasoline vehicles. M85 vehicles trade weight for range. At an equal weight as a gasoline vehicle, a M85 vehicle will have about half the range. This can be overcome by adding the weight penalty of a double size fuel tank. M85 is a liquid stored at atmospheric pressure. The tank is much like a gasoline tank, in that it can use lightweight materials and be made into odd shapes. This allows the extra M85 volume to be fit into the available space in the vehicle geometry with an odd shaped stamped steel tank.

The gaseous fuels cannot trade weight for range, but must accept some penalty in both areas. The sturdy pressurized fuel tanks are heavy compared to gasoline tanks, and must be restricted to cylindrical shapes. The packaging efficiency of round end cylinders is low compared to a stamped steel gasoline tanks made in an odd shape to fit the available space in a vehicle. The problem is less severe for propane than for CNG, because the storage pressure is lower for propane. The CNG vans provided for the Clean Fleet project have a weight penalty of between 200 and 500 kg. while simultaneously having about half the range of otherwise identical gasoline trucks. The alternative fuel vehicles have shown a slight energy consumption penalty compared to gasoline vehicles. Some portion of this is undoubtedly due to the extra weight of fuel being carried. Also, the engines provided to date don't fully exploit the high octane of the alternative fuels, and are not fully optimized for the fuels in many small design features.