1. Using Lead Free Fuel in Older Vehicles - Mechanical Implications

While lead is added to gasoline for the purpose of raising octane number and therefore allowing higher compression and more efficient engines, it also has other effects on engine operation. Lead salts are formed by the combustion of lead additives and are deposited on the walls of the combustion chamber. These deposits serve as lubricants between valves and valve seats; at the same time, these deposits can corrode exhaust valves, foul spark plugs, increase emissions of unburned hydrocarbons and degrade lubricating oil in the crankcase.

a. Potential Concerns With Valve Seat Recession

i. The Nature of the Problem

In modern high speed gasoline engines, exhaust valves and the surfaces they rest on (the valve seats) operate at high temperatures and with severe mechanical stresses. Under conditions of high speed, and to a lesser extent high load, and in the absence of special protection of the valve seat, it has been found that the material of the valve seat can be eroded away, i.e. “recede” into the cylinder head. In the extreme, this can cause lower compression, poor fuel economy, high emissions and mechanical problems.

Lead compounds formed by the combustion of lead anti knock additives prevent valve seat recession by forming a thin non metallic layer of lead oxides and sulfates on the surface of the seat. This acts as a lubricant, preventing metal - metal contact and welding which causes valve seat recession.[1]

ii. International Experience

While concern over valve seat recession in older vehicles has been raised as an argument against the complete conversion to unleaded fuel, the actual incidence of valve seat recession in countries around the world is small even in vehicles with “soft” valve seats.[2] Only vehicles which travel consistently a very high loads and speeds appear to be at all vulnerable in actual use. And even for these vehicles, additives other than lead have been shown to protect valve seats.

Typically, when unleaded gasoline is introduced, government authorities with the assistance of vehicle manufacturers prepare a list of existing vehicles in the country which will be able to operate with unleaded gasoline without fear of valve seat recession.

Other vehicles with soft valve seats may face some theoretical risk if operated exclusively with lead free fuel but even for these vehicles the risk has tended to be minimal in typical operation. As noted by the World Bank, “As a result of extensive tests and studies, the conclusion was

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1/”Prevention of Valve-Seat Recession in European Markets”, McArragher, Clark & Paesler, CEC/93/EF19, May 1993.

2/Weaver, C.S. 1986. The Effects of Low-Lead and Unleaded Fuels on Gasoline Engines. SAE Paper No. 860090. SAE International, Warrendale, Pennsylvania.

drawn that much of the concern about valve seat recession in normal use had been misdirected and exaggerated".[3]

iii. Alternative Additives To Address Any Problems

Where concerns remain, various gasoline additives are available to substitute the lubricating function of lead. Compounds based on sodium and potassium, for example, have been shown to provide sufficient protection against valve seat recession. Special sodium naphthenate lubricating additives have been used in Austria, Denmark and Sweden where leaded gasoline has been completely phased out but where some old cars with soft valves are still running. In the Slovak Republic, where approximately 70 percent of the car park was estimated to still have soft valves at the time leaded gasoline was phased out, a special additive was introduced that enabled all motorists to use unleaded gasoline; the cost has been estimated at US$0.003 per liter.

Use of anti valve seat recession additives has generally fallen into one of two categories:

- bulk treatment of unleaded gasoline
- sale of aftermarket additives for application to unleaded gasoline by individual consumers.

The relative advantages and disadvantages of each approach have been summarized in a recent study:[4]

Approach	Advantages	Disadvantages
Bulk Treatment	< all cars requiring lead replacement gasoline receive additive treated fuel < controlled level of additive in treated fuel	< cost: additive cost borne by retailer < requires segregated pumps and tanks for lead replacement gasoline < additive selected to be compatible with catalysts < generally lower level of additive use < less effective additives used < wasteful: some older cars not requiring anti valve seat recession additives use treated fuel

3/"Phasing Out Lead from Gasoline: World-Wide Experience and Policy Implications", Environment Department Papers, Paper No. 40, Magda Lovei, August 1996.

4/"A Review of Worldwide Approaches to the Use of Additives to prevent Exhaust Valve Seat Recession", Vincent & Russel, 4th Annual Fuels & Lubes Asia Conference, January 14-16, 1998.

Approach	Advantages	Disadvantages
Aftermarket	< low cost: additive purchased by customer < only those requiring additive use it < greater operating flexibility: no need to segregate tanks and pumps to sell lead replacement gasoline < wider choice of additive products: more effective additives can be sold < additional margin for retailer	< less well controlled. Use is at owner's discretion < cars requiring additive may not be adequately protected.

iv. The Potential For Valve Seat Inserts

Valve seat recession can be greatly reduced by hardening the seat, thus increasing its resistence to abrasive wear. Techniques to do this include valve seat hardening by heat treating the seat area or the use of special hard alloy seat inserts.

v. Alternate Fueling

Vehicles equipped with catalytic converters *require* unleaded gasoline to prevent the catalyst being poisoned by lead deposits. Vehicles without catalytic converters can use unleaded gasoline but do not *require* it. Reducing or eliminating gasoline lead is desirable for public health reasons, however. Therefore, one transition strategy to be used while catalyst technology is being phased in is to continue to market leaded fuel with minimal lead content.

The octane boost due to lead does not increase linearly with lead concentration. The first 0.1 g/liter of lead additive gives the largest octane boost, with subsequent increases in lead concentration giving progressively smaller returns. This means that supplying two units of low-lead gasoline will result in lower lead emissions than one unit of high-lead and one unit of unleaded gasoline having the same octane value. If octane capacity is limited, the quickest and most economical way to reduce lead emissions may thus be to reduce the lead content of existing leaded gasoline grades as much as possible, rather than by encouraging non-catalyst cars to use unleaded fuel. This also helps to reserve supplies of unleaded gasoline (which may be feasible to produce and distribute only in limited quantities) for those catalyst-equipped vehicles that truly require it. Reducing the allowable lead content will also reduce the refining cost difference between leaded and unleaded gasoline. If this is reflected in retail prices, it will reduce the temptation for owners of catalyst-equipped vehicles to misfuel with leaded gasoline. In the United States between 1985 and 1995, the leaded content of leaded petrol was limited to 0.1 grams per gallon. In Europe, the maximum lead content of leaded petrol is 0.15 grams per liter.

Levels as low as 0.05 g/l are deemed adequate for valve seat protection.[5]

b. Maintenance Savings with Lead Free Fuel

The elimination of lead from gasoline has several additional benefits. For example, the use of lead free gasoline can save money for motorists by reducing the need for frequent replacements of spark plugs, mufflers and the automobile hardware exposed to gasoline and its combustion products.[6] A major reason is that the lead scavengers are highly corrosive and reactive. Several surveys carried out when leaded gasoline was widely used in the United States and Canada demonstrated that motorists who use lead free gasoline spend much less for exhaust system and ignition servicing than motorists who use leaded gasoline.[7] As a rough rule of thumb, spark plug change intervals are roughly doubled by the use of unleaded gasoline and at least one exhaust system and exhaust silencer (muffler) replacement is eliminated. Lead free gasoline has also been linked to a cost advantage regarding carburetor servicing but this has been more difficult to quantify.

Another significant advantage associated with the use of lead free gasoline is the lengthened oil change interval. The use of unleaded fuel has been demonstrated to significantly reduce engine rusting and ring wear and to a lesser degree sludge and varnish deposits and cam and lifter wear.[8] Because of this, oil change intervals on cars in the United States using unleaded fuel were at least twice as long as had traditionally been the case. Intervals of 10,000 miles are not uncommon with late model cars. Increased oil change intervals cannot be attributed solely to lead removal (as is indicated by some increases in vehicles using leaded gasoline) but the lead removal appears to be a major contributing factor. This is significant not only because of the reduced cost to the motorist but also because of the oil savings over the life of the vehicle and the reduction of the potential pollution problem resulting from the disposal of used oil. Experience had shown that in the United States significant quantities of used oil are disposed of in ecologically unacceptable ways such as dumping it on the ground.

According to an Australian review,[9] the cost savings associated with maintenance reductions from lead free gasoline would be significant. Expressed as 1980 Canadian cents per liter, the results of the principal studies are: Wagner (American Oil Co.); 1971; 1.4c/liter

Gray and Azhari (Am. Oil Co.) 1972	2.1c/liter
Pahnke and Bettoney (DuPont) 1972	0.3c/liter
Adams (Ethyl Corp.) 1972	0.4c/liter

5/Personal Communication from Nancy Homeister, Ford Motor Company.

6/"Saving Maintenance Dollars With Lead Free Fuel", Gray and Azhari, SAE # 720014.

7/ "Gasoline Lead Additive And Cost Effects of Potential 1975-1976 Emission Control Systems", Hinton et. al., SAE # 730014.

8/ "Gasoline Lead Additive And Cost Effects of Potential 1975-1976 Emission Control Systems", Hinton et. al., SAE # 730014.
"A Study of Lengthened Engine Oil-Change Intervals", Pless, SAE # 740139.

9/"The Benefits of Unleaded Petrol", M.G. Mowle, Institution of Engineers Transportation Conference 1981

Environment Canada 1979 1.2c/liter

Using the Environment Protection Agency of Canada study, Australia concluded that the following savings would result if unleaded gasoline were used instead of leaded gasoline:

	leaded	unleaded
spark plug changes	every year	every other year
oil changes and filter	twice per year	one per year
muffler replacements	twice per 5 yrs	one per 5 yrs
exhaust pipe replacements	one per 5 yrs	None

Overall maintenance savings from unleaded fuel were estimate to average about $38 per year; for a car averaging 10 liters per 100 kilometers fuel consumption, this is equivalent to 2.4c per liter of gasoline.[10]

With regard to maintenance savings, it is important to note several points:

< the potential benefits may not always be readily apparent to the motorist, especially if the vehicle manufacturer does not modify his recommended maintenance schedule.

< the studies cited above reflect experiences gained in industrialized countries; extrapolating these estimates to developing countries may not be fully valid.

c. Conclusions Regarding Mechanical Effects

One of the most definitive reviews of the impact of unleaded fuels on gasoline engines reached the following overall conclusion:

> "In summary, the potentially detrimental effects of eliminating leaded gasoline appear to have been greatly exaggerated in the public mind, while the potentially beneficial effects have been understated or ignored. The present widespread public alarm over the effects of this change has little foundation in fact."[11]

Further as noted by US EPA at a Workshop on lead free gasoline in China in March 1997, the maintenance savings are well documented as summarized below.[12]

	Savings per Year (1995$)
Exhaust Systems	$18.36
Spark Plugs	$2.66

10/"The Benefits of Unleaded Petrol", M.G. Mowle, Institution of Engineers Transportation Conference 1981

11/Weaver, C.S. 1986. The Effects of Low-Lead and Unleaded Fuels on Gasoline Engines. SAE Paper No. 860090. SAE International, Warrendale, Pennsylvania.

12/Comments of Chuck Freed, Director Fuels and Energy Division, US EPA.

	Savings per Year (1995$)
Oil Changes	$16.07