T James Sprott OBE
MSc PhD FNZIC
Consulting Chemist
Forensic Scientist

10 Combes Road
Remuera
Auckland 1050
NEW ZEALAND

Phone & Fax:
+64-9-5231150
sprott@iconz.co.nz

Function of Fuelstar catalytic units;

Catalytic effect on combustion
Valve seat recession (VSR)

Date 11 December 2006

The catalytic and other effects provided by Fuelstar units are caused by particulate stannous (tin) oxide, usually known as tin suboxide, SnO. The vibrating action of the Fuelstar unit in the presence of flowing hydrocarbon fuel forms sub-micron particles of tin suboxide which are not adherent to the base alloy of the catalytic unit and are thus carried in the fuel stream to the combustion chambers of the engine. The tin suboxide is formed by an irreversible galvanic reaction.

The size of the particles is such that they are colloidal in the fuel, and they reach the combustion chambers of the engine in this form.

There are two major effects:

1. Enhanced oxidation (combustion) of the fuel

2. Formation of a refractory layer on the mating seats of poppet valves thus protecting valve surfaces from VSR.

To explain these effects a comparison can be drawn with the now obsolete practice of adding tetra-ethyl lead to petrol. When the “leaded” fuel/air mixture is ignited in the combustion chambers the highly combustible ethyl groups attached to the lead burn extremely quickly, and the lead is oxidised to lead suboxide, PbO, a very finely divided solid. Tin suboxide oxide reacts in a similar manner to that of lead suboxide.

1 Oxidation

The following chemistry of hydrocarbon fuels must be explained at this stage.

Hydrocarbon fuels comprise a complex mixture of aliphatic and aromatic hydro-carbons, the term “hydrocarbon” meaning compounds made up from carbon and hydrogen. The terms “aliphatic” and “aromatic” in this context refer to the structure of the carbon chains of the molecules of hydrocarbon. The carbon chains of aliphatic hydrocarbons are either straight or branched chains, whereas the aromatic fraction contains cyclic “unsaturated” carbon chains.

The basic aromatic hydrocarbon is known as benzene (C_6H_6) with the six carbon atoms generally depicted as a hexagon, and this structure is known as the “benzene ring”. One hydrogen atom is attached to each carbon atom.

The term unsaturated means that the molecule is not fully “saturated” with hydrogen, so that more hydrogen could be accommodated in the molecule. Thus unsaturated hydrocarbons burn more slowly than saturated hydrocarbons.

The hydrogen atoms attached to the carbon atoms forming an aromatic “ring” can be replaced by aliphatic carbon-hydrogen chains, giving rise to compounds such as toluene (methyl benzene) and xylene (di-methyl benzene). There are many such compounds, comprising both single ring and multiple ring molecules and various side-chain combinations.

As stated above, the benzene ring and polycyclic molecules are far more stable than aliphatic carbon chains, and thus while the side-chains on aromatics burn quickly the benzene ring nucleus more slowly than the aliphatic side-chains.

(As an aside, this was the reason why the permitted aromatics content in petrol was increased markedly when the use of tetraethyl lead was discontinued. The slower-burning aromatics acted as “octane enhancers” thus reducing the likelihood of pinking.)

Aromatics, especially polycyclic aromatics, often burn incompletely when compression-ignition (diesel) engines are under heavy load; and when this occurs, unburnt or partially burnt carbon-chain molecules are present in the exhaust gases. This results in waste of fuel, unwanted and wasteful exhaust emissions comprising partially burnt organic species, and particulate carbon in the form of smoke or soot.

Experience has shown that the SnO particles formed by Fuelstar units provide a strong catalytic action for the combustion of the partially burnt species mentioned above. The exact mechanism of catalysis has not been fully explained, but it is undoubtedly due to the huge surface area of the minute particles of tin suboxide. Catalysis of this type is almost always a surface effect, by bringing the reactive molecules into intimate contact with each other on the surface of the catalyst. Just as lead suboxide provided this catalytic effect so does tin suboxide.

The same effect has been achieved with oxides of other polyvalent metals, manganese being one, and compounds of this metal have been suggested for use in petrol; however manganese is regarded as toxic whereas tin is known to be non-toxic.

2 Valve seat recession (VSR)

Valve seat recession in poppet valves comes about because of erosion of metal from the mating surfaces, especially the surfaces of the valves, which operate at a higher temperature than the valve seats. It is much more prevalent with exhaust valves and valve seats than with inlet valves because of the higher operating temperatures of exhaust valves, and from incandescent burning gases passing through the gaps of partially closed valves, thus eroding the metal. Incomplete combustion of fuel during the power cycle of the engine exacerbates VSR.

It has long been known that lead in petrol protected valves against VSR. The reason is as follows:

Hydrocarbon fuels contain trace amounts of various impurities, two of them being silicon in the form of silica or silicate, and vanadium, probably as a vanadyl compound. Both of these elements form glass-like compounds with metals, known as “silicates” and “vanadates” respectively. Of these two, silicates are almost certainly the most important as regards internal combustion engines.

At high temperatures such as those in an internal combustion engine silica acts as an acid and combines with various metals to form silicate compounds. Fusible silicates form “glass”, and one such glass is lead silicate, widely referred to as the trade name “Pyrex glass” (meaning heat resistant). This type of leaded glass is well known for its resistance to cracking by heat, and it also adheres to metallic surfaces.

In the days of lead additives to petrol, a thin, very hard adherent layer formed on the mating surfaces the valves and valve seats, especially on exhaust valves, and it was this glass-like (ceramic) layer of lead silicate which protected the metal surface against erosion by hot or flaming gas.

Tin suboxide reacts with silica at high temperatures, just as lead suboxide does; and therefore the tin suboxide particles formed within the Fuelstar unit combine with silica during the combustion cycle to form tin silicate, also a glass; and this adheres to the valve surfaces as a very thin ceramic layer, thus protecting the valves from VSR.

The problem of VSR in diesel engines has become more apparent now that most of the sulphur has been removed from diesel fuel. While removal of sulphur is undoubtedly beneficial to the environment, there is a downside in that sulphur (closely related chemically to oxygen) assisted in the combustion reaction. Effectively sulphur compounds in fuel acted as “oxygenates”.

But modern diesel fuel does not contain much sulphur, and thus the burning process is slower, and the use of this type of diesel fuel can expose exhaust valves to burning fuel resulting in VSR. To obviate the effect of lower sulphur content some other catalytic system is required, and Fuelstar units meet this need.

3 Conclusion

Two main benefits arise from tin-based catalysts, of which Fuelstar is the prime example:

a) Catalytic enhancement of the combustion of hydrocarbons, especially polyaromatics, resulting in improved power output, lower fuel consumption and greatly reduced unburnt and visible exhaust emissions;

b) Protection of valve mating surfaces by means of the formation on the mating surfaces, especially on valve seats, of a thin, refractory tin silicate (possibly combined with vanadate).

Note that no harmful emissions arise from the use of Fuelstar catalytic units.

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