MIXTURES OF WATER AND LIQUID HYDROCARBON FUELS

Preamble

This briefing note sets out the type of questions that a cautious user, financier or plant manufacturer might wish to see answered satisfactorily prior to endorsing the use of an additive mixture intended to blend water in a liquid hydrocarbon fuel either to deal with a contamination problem or to influence performance.

Whilst it may be claimed that improved power output can be achieved with a ‘cheaper’ fuel, there is little merit in this if the longer term consequence is premature failure of components, plant outage, expensive repairs and loss of warranty protection.

In addition to highlighting many of the key questions, pointers are given to the kind of Research and Development (R&D) programme required to help provide answers.

Introduction

For the purposes of this discussion the term ‘liquid hydrocarbon fuels’ embraces diesel fuels, gas and heating oils, kerosene and petrol. These fuels are used in both stationary power plant and vehicles, using reciprocating engines, gas turbines and boiler plant.

One important feature of the production process for these fuels is to reduce the water content to an extremely low value, i.e. a very small fraction of *1%.* This is because the accepted view is that ‘oil and water do not mix’, since there is ample evidence that where fuel is contaminated with water, bacteria develop and cause a wide variety of problems.

However, downstream of the production process water may, for a number of reasons, become present in these fuels and the fuel systems associated with the various applications. The reasons for this may be summarised as follows:

1. by accident through some unintentional event,
2. natural ventilation and breathing of the fuel storage tanks leading to condensation forming on the tank walls and then accumulating at the base of the tank, and
3. the intentional addition of water to the fuel to influence the performance of the engine or power plant and/or to improve exhaust gas emissions.

Case (1) may be viewed as a one-off event, normally only requiring draining off the water followed by a thorough cleaning of the affected part of the system. Should a cleaning agent, i.e. an additive, be used and require approval it would only be necessary to demonstrate that it mixed with both the fuel and the water and could be flushed out of the system. Its residence time in the system would be very short and would normally be limited to the fuel tank alone and any pipes closely connected to it. For the purposes of the present discussion, this case is of minor significance and will not be pursued further.

Both case (2) and (3) are much more important. They involve a much longer residence time in the system, possibly the whole life of the power plant and its fuel system.

Case (2) is really a contamination problem involving quite minor amounts of water. The usual remedy is to provide a drainage point at the base of storage tanks and fit water filters or separators in the fuel lines feeding the engines or boilers.

Alternatively, one might consider using one or two additives currently on the market which claim to be able to treat water contaminated diesel and petrol fuel systems, but the extent to which they are all successful, or have been ‘approved’, is moot.
In aeroplane fuel tanks, since they are typically operating at temperatures well below zero, the water will normally freeze at the base of the tanks. It will not, therefore be drawn into the engines and will be drained out later.

Case (3) involves a greater volume of water per unit volume of fuel and, of course, the positive intention of adding water to the fuel. The two main reasons claimed for this, for which there are some data in support, are to improve engine performance and to produce slightly cleaner exhaust emissions. There have also been some instances where entrepreneurs have sought to claim that water, being cheaper than fuel oils, can be added to hydrocarbon fuels as an extender to achieve a modified fuel that, overall, is cheaper than conventional fuels but without compromising performance.

In addition, there is some potential, once one has achieved the ability to ‘control’ how water behaves in the presence of traditional fuels, to develop the technology into areas such as the blending of vegetable oils, which often contain water, with alcohols and with traditional fuels to create relative cheaper fuels. This could be particularly useful to countries not possessing natural oil reserves of their own.

In order to incorporate water successfully in liquid fuels it is, however, necessary to use some mixing agent, i.e. ‘additive’, to overcome the problem that water and oil do not mix naturally. If such an additive is to be developed and gain approval it must meet a number of stringent conditions. This issue is addressed in the following sections.

Criteria for Acceptance of Fuel Additives for Creating Oil-Water Mixtures

In order to convince the owner of expensive plant and equipment, which it is essential should operate reliably and, perhaps, continuously, or a cautious financial institution from which development and operating funds were being sought, answers to some searching questions should be obtained. Such questions would include:

- Would the use of such an additive invalidate the manufacturer's warranty for the engine or power plant in which it was to be used?
- How might one demonstrate to a potential customer that it was safe to use?
- How might I, the developer or user, convince an insurance company to indemnify me against claims for damages?
- Will the whole process be financially viable?

Failure to address such questions could lead to expensive plant breakdown, long outages and large legal claims for damages.

This paper is intended to address only the technical issues. Hence it will focus on identifying a Research and Development Strategy to provide answers to the questions posed above. To achieve this, the R&D strategy would help us to know something about:

- The stability of the additive + fuel + water mixture.
- Tolerance: how accurately should the proportions of additive, fuel and water be measured?
- Climatic factors — especially temperature effects - freezing and tropical conditions.
- Compatibility with all the components with which the additive could be in contact.
- Toxicity — is it safe to use?
- Detailed information on the effects on engine or burner performance.
- Would standard settings (e.g. injection, ignition or valve timing) need changing?
- Would components (e.g. valves or burner nozzles) need changing?

These various points, and their significance, will now be discussed separately. Stability

The long-term stability of oil-water mixtures is crucial to their successful use. The creation of oil-water emulsions is quite simple, merely requiring a surfactant-based additive, even domestic washing-up liquid would suffice. However, mixtures such as these separate out into two or more stratified layers fairly quickly, sometimes in minutes. The separate layers may include the original water as a distinct layer, as well as a viscous layer that may develop into a gel. The water phase would be conducive to fungal growth that, like the gel, would block fuel systems even if not affecting burner or engine performance earlier.

There is also evidence that, whilst one can mix a fuel, an additive and water together and achieve an instant result, the blending or bonding process is not limited to just a quick interaction — it continues over several hours. Furthermore, part of the chemical reaction that occurs is believed to involve interaction with the air above the free surface.

Tests for stability would therefore need to be conducted over an extended period of time, and also embrace some of the other features, e.g. climatic effects, discussed below.

Tolerance

Given that, in real life, the use of any additive developed would not be under the control of backroom boffins working in controlled laboratory conditions, it is desirable that the accuracy with which the amounts to be added to a fuel should not need to be very precise. Also, there may be some uncertainty about how much water may be present, initially, in a fuel system and, if the additive is to treat the contamination problem, the fuel-additive mix should be capable of satisfactorily absorbing further water due to ongoing condensation.

Climatic Factors

Power plants, and therefore their fuel systems, operate around the globe, on land, at sea and in the air. The main climatic factor of interest, other than humidity, is temperature, and the range over which it may vary daily, with the seasons, or due to the movement of the plant (e.g. a long distance vehicle, ship or aeroplane) in the normal course of its operation.

To investigate this, as well as developing additive formulae~ at ambient temperatures in a laboratory, it is necessary to explore its consistency, both in the neat form and when mixed in with specimen fuels over the full temperature range of its intended use.

Effects to investigate include: as the temperature changes, do the various components separate out, might the additive evaporate at high temperatures or induce the formation of waxy deposits at low temperature?. Would these effects be temporary or permanent?

Compatibility

Typically, when it comes within the control of a customer or user, a fuel will be deposited in a storage tank. From there, its route to the point of combustion, will take it through valves, meters, filters, pumps, and injectors or burner nozzles, as well as the pipes and their couplings which link them all together. These various components are manufactured from a wide variety of different materials and in any one fuel system one could encounter all or most of the following:

- Standard mild steel for fuel tanks
- Hardened steel or copper for fuel pipes and couplings
- Stainless steel for burner nozzles and injectors
- Brass olives in various couplings
- Aluminium and its alloys used in meters, pump and filter bodies
- Various rubbers, nylon and plastics in flexible hoses, gaskets and diaphragms

Tests, which will have to take place over a period of time, should demonstrate that the neat additive as well as when mixed in with the fuel, will not attack or otherwise interact, with any of these materials, at least not to an extent that is worse than the fuel itself.

Toxicity

Will exposure to the proposed fuel additive have deleterious affects on the user's health? What precautions should be taken when manufacturing it, transporting, selling and using it? For present purposes, it can be stated that it is known that ingredients commonly used in such additives have carcinogenic tendencies and that precautions in their use are essential. These need to be identified and specified, with recommendations being made to protect people coming into contact with the additive and its various ingredients.

Effects on the Performance of Power Plant and Engine Performance

The engineering dimensions to this facet of the R&D programme are:

- Will the manner in which fuel gets into the combustion chamber be affected, e.g. will the spray angle or droplet size change?
- How might the combustion process be affected?
- Does engine size or design of combustion chamber matter?
- Will the specific fuel consumption (fuel/unit power) be higher/lower?
- Will more/different deposits form in the combustion chamber and/or exhaust system?
- Are the exhaust/flue gases hotter or colder?
- Will the exhaust gases meet emission regulations and standards?
- At a given engine speed will the power output be less or greater?
- Are there limits to the speed range over which apparent gains can be maintained?
- Is there an adverse effect on the service life of engine or furnace components?

The superficial question, of course, is: can I run my engine or power plant more cheaply than by using the normal (expensive) fuel? Even if the answer is 'Yes', with a silent 'In the short-term', to stand any chance of seeing the complete picture and the true long-term operating costs — including maintenance and breakdown costs — the prudent customer or financier would seek answers to the other questions. Again, these can all be provided by performing adequate tests on plant and components of various types and styles.

Changes to Standard Settings or of Components

Normally, the addition of water into a combustion process causes that process to take longer. In an engine, this begs the question — will the process of releasing all the energy be complete before the exhaust valves open to release the products of combustion — or will some combustion occur in the exhaust manifold and outlet pipe? Should this be the case, and it will also depend on the amount of water involved, could the situation be changed by changing the injection/ignition timing or of the opening/closing times of the inlet and exhaust valves?

Again, if the fuel spray from the injectors, e.g. droplet size and spray angle, is affected by the presence of the water, does this affect performance and require new nozzles?

Similarly, with a boiler furnace, will combustion still be occurring as the flue gases pass into the exhaust ducting? Could this be rectified by changing the burner nozzles? Or might other changes be required to parts of the system to prevent premature failure?

Concluding Remarks

It should be apparent, from the forgoing, that any proposed additive for use in modern liquid fuels ought to be subjected to a significant range of tests if it is to endorsed as safe, and legal, to use for its intended purpose. The matter of financial viability is clearly important and will often be the first aspect that is considered, often to establish whether, or not, there is merit in considering further investment and research.

These initial demonstration 'tests' to present a prima facie case of financial viability are usually undertaken with an engine test. However, the discussion above indicates that, not only is extensive engine (or power plant) testing required, using several different makes, sizes and designs, but, in addition, extensive bench testing extending over several months is necessary to answer the full range of questions that should be posed prior to fully endorsing a proposed additive.

Occasions have occurred where the 'research' has moved little beyond the demonstration phase — but the prudent user should be very wary of the long term effects of introducing new substances into fuel and power systems for which they were not originally designed.

Professor David Thorley
Professor of Fluid Engineering
City University, London.
Aqua-Frd-nts.doc
29/11/01