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Is There an Effective and Environmentally Friendly Way to Control Microbiological Contamination in Distillate

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Is There an Effective and Environmentally Friendly Way to Control Microbiological Contamination in Distillate

by R. D. Haggett

Defence Research Establishment Atlantic, Dockyard Laboratory (Atlantic)
P.O. Box 1012, Dartmouth, Nova Scotia, Canada B2Y 3Z7

ABSTRACT

Defence Research Establishment Atlantic (DREA) has been involved, since 1984, with research into the control and/or elimination of microbiological contamination (MBC) in distillate fuels and fuel systems. The purpose of this research is to determine the most effective and environmentally friendly way to combat MBC. The research included long term laboratory trials to determine the most effective biocide available, the investigation of alternative chemical, mechanical and physical methods of control and the design and development of an innovative flow-through ultrasonic system for the control of microbiological contamination in distillate fuels. All the above control methods will be discussed with particular emphasis on the use of biocides and ultrasonic energy in terms of efficacy and environmental impact.

Is There an Effective and Environmentally Friendly Way to Control Microbiological Contamination in Distillate Fuels?

By

Randall D. Haggett

Defence Research Establishment Atlantic

Introduction

Microbiological contamination in hydrocarbon fuels presents a variety of problems to the operators of land based and marine equipment as well as aircraft. The causative organisms are fungi, yeast and bacteria. Free water must be present in a fuel tank for these organisms to grow and proliferate. When water is present, conditions are favourable for fungal spores (dormant phase) to become viable. The fungi and yeast grow at the fuel/water interface by extracting oxygen from the water and nutrients from the fuel and water layers. The organisms reproduce by cell division creating branching chains (hyphae) which form an interlocking mat at the fuel/water interface. It is this mat which coats fuel tank walls, plugs filters, fouls injectors in diesel engines and causes coking of fuel control nozzles and hot spotting in gas turbine engines. Hot spotting in a gas turbine usually results in catastrophic failure requiring engine replacement. As the organisms grow and reproduce, biosurfactants are produced which reduce the interfacial tension in the fuel and allow water and debris to be suspended in a stable suspension in the fuel layer. This biosurfactant also wets coalescer elements and Teflon coated water separators allowing suspended water and debris to pass through and into the engine.

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TECHNIQUES FOR THE CONTROL AND/OR ELIMINATE MBC

Limited Effect but Environmentally Friendly

Ultraviolet Treatment

Ultraviolet (UV) treatment can be effective in destroying microorganisms. Wavelengths below 290 nanometers (nm) are usefully antimicrobial with an optimum wavelength being approximately 260 nm. Unfortunately the kill effectiveness is inversely proportional to the distance from the UV source and requires a relatively long exposure time. In addition, the effectiveness of ultraviolet disinfection is greatly reduced (due to absorption and screening effects) in media containing suspended matter. The safety of this method is also a concern. For UV to be effective in a fuel system, the light source must be in the fuel system (inside the fuel tank), or the fuel must pass in close proximity to the UV light. This creates the danger of fire or explosion of fuel or fuel vapours, should the media separating the fuel from the light source be breached. Personnel must be protected from direct exposure to the UV radiation. It has also been noted that UV radiation will excite atoms and may cause chemical reactions, which could affect fuel quality.

Thermal Treatment

Thermal treatment is a technique, which has been proposed for the control of MBC in fuels, lubricating oils and metalworking fluids. The application of heat above the optimum growth temperature can destroy microorganisms. Unfortunately the destruction is not instantaneous, due to difference in heat stability of different microbial populations and the amount of growth present. Although this process may be applicable to lubricating oils and metalworking fluids, the temperatures required for pasteurization and effective kill of microbial growth are too high for most fuels (65°C for 100 seconds).

Again, the primary concern is the increased risk of fire or explosion of fuels or fuel vapours.

Magnetic Treatment

Exposing contaminated fuel to, or passing fuel through, a strong magnetic field is commercially reported to be an effective method of destroying microbial growth. It is claimed that when microorganisms are subjected to a specific magnetic flux field, the ability of the protein channels to maintain the electrical and chemical potential across the cell's membrane is greatly affected and the organism is torn apart and destroyed. The manufacturer claims a kill efficiency of 97.6 percent in one pass. Several commercial units are being marketed in North America and Europe. However, the reported results have yet to be duplicated by a reputable research institution.

Fuel System Design and Maintenance

One of the greatest contributing factors to fuel and fuel system contamination, with microbial growth, is the lack of thought that goes into fuel tank design and construction. Marine fuel tanks are very seldom designed with bottom drains or a stripping system that reaches the tank bottom. Structural members, piping and conduits usually transit marine fuel tank walls. Fuel tanks in commercial vessels are generally not epoxy coated which leads to corrosion problems when water is present. It seems that the location of marine fuel tanks is dictated more by the space available than need for an efficient fuel system.

Some of the more obvious features that must be incorporated into fuel tank design if the effects of microbiological growth are to be minimized are:

(a) The walls and bottoms of storage tanks should slope to give a positive fall to a single low point sump for easy removal of any residual water by either a drain or a suction system.

(b) Marine fuel tanks should have smooth epoxy coated walls free of longitudinal and frame braces. This would prevent the trapping of water in the fuel layer and allow any accumulated water to be removed from the sump.

(c) Fuel tank air vents should be fitted with filters to prevent the ingress of air born organisms.

(d) Fuel tanks should be fitted with floating suction, which would greatly reduce the chances of contaminating the fuel system with bottom debris.

Marine fuel tanks should undergo regular inspections and cleaning if required. The argument often made against this practice is the expense and downtime required. In response to this argument, the expense and downtime incurred for periodic maintenance is minimal compared to the cost of a destroyed gas turbine or diesel engine.

An important part of any maintenance program is the practice of good fuel husbandry. This involves the regular stripping of water bottoms and fuel interfaces as well as regular cleaning of fuel filters, centrifuges, coalescer vessels and delivery lines. The removal of water bottoms is perhaps the single most important factor in the prevention of microbial contamination of fuels. Unfortunately, because of poor tank design it is virtually impossible to remove all water from a system.

Effective but Not Environmentally Friendly

Biocides

There is no doubt that the most effective way to control and/or eliminate microbiological growth in a fuel system is with the use of a biocide or biocidal agent. DREA has evaluated the efficacy of selected biocides and biocidal agents, which were reported in the literature to be the most effective in controlling MBC. These evaluations have shown that biocides containing chlorinated and non-chlorinated isothiazalon-3-one, as the active ingredient, were the most effective in eliminating the mixed populations of organisms commonly found in contaminated distillate fuel. The least effective biocides overall were those which contain organo-borates. These products not only appear to be ineffective against pure and mixed cultures but were found to actually stimulate growth when used in concentrations greater than the recommended dosage.

The primary concerns with the use of any biocide are the environmental effects of the active ingredients when present in discharged water bottoms and the effect on the health of personnel who may come in contact with treated fuel and fuel tank water bottoms.

Effective and Environmentally Friendly

Ultrasonic Energy

Ultrasonic energy has been used for several decades in the medical field for cleaning and sterilizing instruments and for destroying certain types of cells. The cavitation produced by ultrasonic energy can be applied for the destruction of microbial cells. Cavitation occurs when bubbles, created by ultrasonic energy, collapse. The collapse of these bubbles will produce shock waves and turbulence, which causes fractures in the cell walls of microorganisms.

Since 1993 DREA Dockyard Laboratory has been conducting research to development a flow-through system for the ultrasonic destruction of microorganisms in distillate fuels. The work consisted initially of the proof of concept of the process, then the design, development and testing of a full-scale flow through Ultrasonic Fuel Conditioner (UFC).

The UFC being constructed is a four cavitator unit with each cavitator unit made up of 16 stacked piezoceramic rings. Each cavitator has an optimum flow rate of 60 gallons per hour with a power consumption of approximately 500 Watts. Depending on the flow-through volume required the unit could be run with one to four cavitators in place. The frequency which produces the optimum cavitation, resulting in maximum kill rate is 23.5 kHz.

The test results using both water and distillate fuel show that ultrasonic energy does kill some portion of the population of all exposed microorganisms. Although the kill rate was not dramatic (45-70 percent in a single pass with a four second residence time) it was encouraging. Test results indicate that with, more work and refinement, the application of ultrasonic energy has the

potential of becoming an environmentally friendly and effective way to control microbiological growth in distillate fuels.

Conclusion

Many methods have been proposed for the control and/or elimination of microbiological contamination in distillate fuels. The use of biocides or biocidal agents is an effective means to control or eliminate MBC in distillate fuels. Unfortunately the use of biocides presents some serious health and safety concerns. The use of UV radiation or the application of heat may have limited success and be environmentally friendly but the safety of these techniques with distillate fuel is an issue. The use of magnetic energy and the practice of good fuel husbandry are both safe and environmentally friendly but the effectiveness of these techniques is either questionable (magnetic treatment) or of limited success (fuel husbandry). The application of ultrasonic energy for the control and/or elimination of microbiological contamination in distillate fuel is not only safe and environmentally friendly but has the potential to be a very effective technique.

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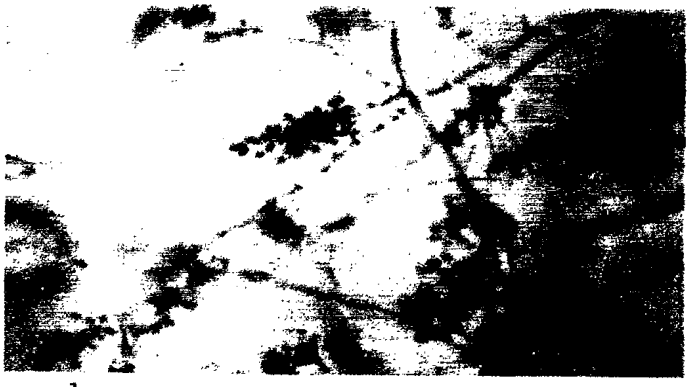
Randall D. Haggett
Defence Research Establishment Atlantic

National Defence / Défense nationale

Canada

Hormoconis resinae



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Filter/Coalescer Element Showing Microbiological Contamination

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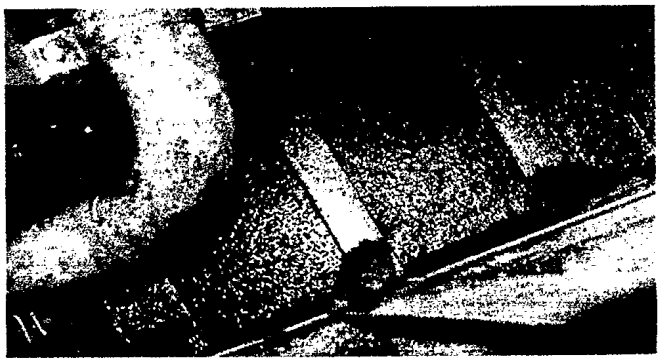
Microbial Mat on Bottom of Distillate Fuel Tank



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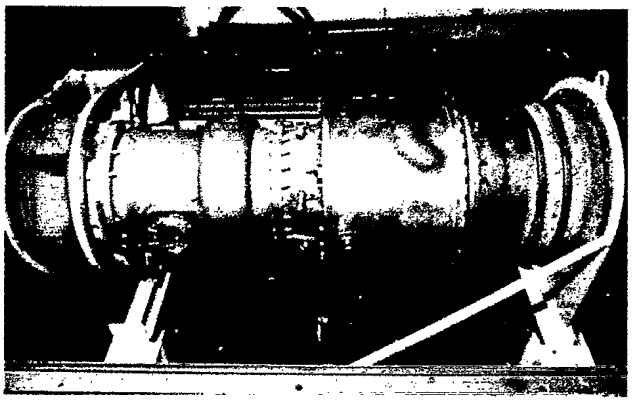
Hot Spotting on Gas Turbine Engine



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Coking on Fuel Control Nozzle

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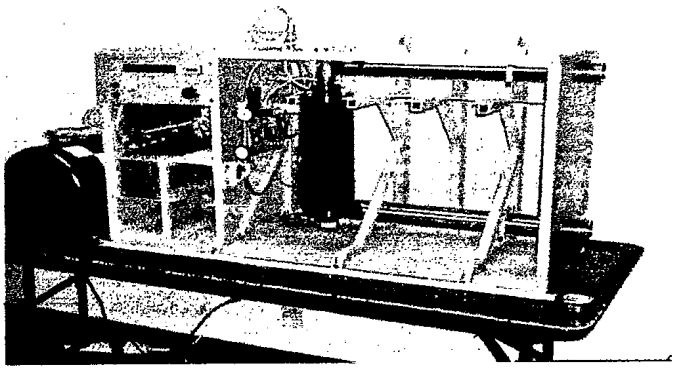
Ultrasonic Fuel Conditioner Evaluation Unit



Treatment Methods to Control and/or Eliminate MBC

- **Ultraviolet Radiation**
- **Thermal Treatment**
- **Magnetic Treatment**
- **Fuel Husbandry and Fuel Tank Design**
- **Biocide Treatment**
- **Ultrasonic Energy**

Ultraviolet Treatment

Effectiveness

- **inversely proportional to distance from source**
- **reduced by suspended matter**
- **requires long residence time**

Safety

- **UV can cause chemical reaction**
- **Personnel must be protected from UV radiation**

Thermal Treatment

Effectiveness

- **requires temperatures higher than fuel flash point**
- **requires long residence time**

Safety

- **risk of fire or explosion**

Magnetic Treatment

Effectiveness

- **reported to use magnetic flux fields to alter chemical and electrical potential across cell membrane and destroy organism**
- **no conclusive proof that it actually works**

Safety

- **no reported safety concerns**

Improved Fuel System Design and Maintenance

Effectiveness

- **will allow an operator to control MBC and/or maintain MBC at a manageable level**

Safety

- **No reported safety concerns**

Biocides

Effectiveness

- most effective way to control/eliminate MBC
- partitions in both the fuel and water layer

Safety

- untreated water bottoms are toxic to marine organisms
- hazard to personnel working with fuel system

Ultrasonic Energy

Effectiveness

- used for decades in medical field to destroy cells
- cavitation fractures cell membrane

Safety

- no reported safety concerns

Magnetic Treatment Unit

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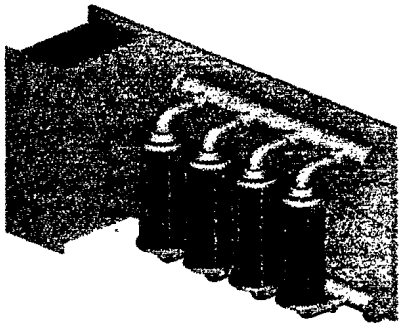
Ultrasonic Fuel Conditioner



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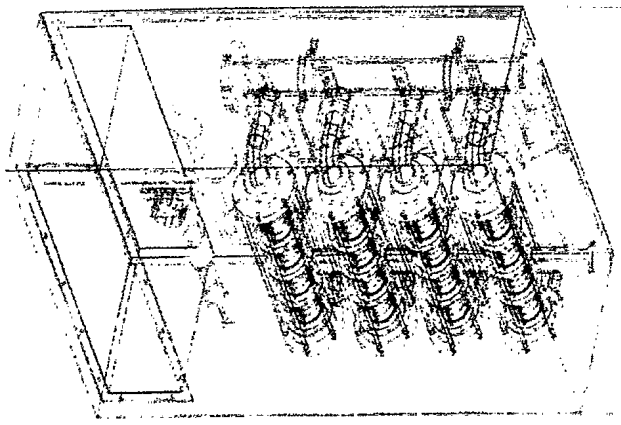
Ultrasonic Fuel Conditioner



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