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TITLE

THE ULTRASONIC DESTRUCTION OF MICROBIOLOGICAL CONTAMINATION IN SHIPBOARD FUEL SYSTEMS

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THE ULTRASONIC DESTRUCTION OF MICROBIOLOGICAL CONTAMINATION IN SHIPBOARD FUEL SYSTEMS

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ABSTRACT

Microbiological contamination of marine diesel presents an expensive problem for naval operations due to the blockage of filters and nozzles, and the ultimate destruction of the turbine blades. Despite the current use of biocides and the full time use of personnel to replace filters, the contamination problem has led to millions of dollars of equipment damage. Through the support of DREA, Aastra has assessed the feasibility of ultrasonic destruction of microorganisms in marine diesel fuel. This approach to microbiological control represents an environmentally friendly and efficient alternative to the use of biocides.

Two different ultrasonic devices were used in this study. The microorganisms most commonly found in marine diesel were identified and inoculation tests were performed. Results showed that processing in each apparatus can reduce the microbiological contamination levels of marine diesel for both aerobic and anaerobic bacteria, yeast and mold by up to 3 orders of magnitude. Laboratory grown microbial mats were effectively dispersed, and microorganism viability was destroyed. Aastra has proposed that the concepts demonstrated through this work could be developed into a full scale treatment system.

INTRODUCTION

The marine industry is increasingly concerned with the problem of microbial contamination in shipboard fuel. Recent increases in microbial populations and the associated damage to tanks and turbines have led to a heightened awareness of the problem, resulting in several studies on chemical and physical control measures.[1] Alternatives to the use of biocides are being considered to improve the effectiveness of these control measures and to reduce their environmental impact.

Fuel tanks and large scale fuel storage systems have become popular only in the last 60 years. Microbial populations are continually changing and adapting to variations in growth conditions. With fuel formulations constantly changing, it is thought that microbial evolution has yet to run its full course.[2] Since biocides are generally only effective for specific species of microorganisms, they must also be continually adapted to combat the new strains of microbes that may develop.

Physical destruction of microorganisms, such as ultrasonic treatment, may be a feasible alternative to the use of biocides. These physical control measures do not share the above concerns about biocide use. Studies have shown that ultrasonic treatment is an effective means of destroying microorganisms. In order to investigate the applicability of this technology to shipboard fuel systems, this study assessed the ability to destroy microorganisms in marine fuel using ultrasound.

METHODS

Ultrasound destroys microorganisms in liquids via cavitation. An alternating voltage is converted to mechanical vibrations in the ultrasonic transducer. These vibrations give rise to alternating compressions and rarefactions in the liquid surrounding the transducer. Upon rarefaction, vapour-filled cavities are created in the liquid and during compression they are collapsed, or imploded. This cavitation produces the fundamental cleaning action of an ultrasonic cleaner. The shock waves, resulting from cavity implosion, dislodge dirt particles from the item being cleaned. The localized mechanical stresses resulting from cavitation have been shown to be destructive to microorganisms.[3, 4]

The factors affecting cavitation are: frequency, power density, time of exposure and the physical and chemical characteristics of the liquid that is being processed. Ultrasonic frequencies extend from about 20 kHz up to the megahertz range. Power density is a function of the power of the transducer and the size of both the transducer and the container over which the sound waves are distributed. It is generally expressed as watts/cm^2, referring to the surface area of the transducer.

The frequency of the ultrasonic wave influences the size and number of cavities created. The larger the cavities, the greater the force of implosion, and thus the greater the effectiveness of cell disruption. Low frequencies cause a few large cavities which generate stronger shock waves. Higher ultrasonic frequencies require much greater power input to produce cavitation. The cavities that are produced are generally smaller than at low frequencies. High frequencies produce a more directed beam of ultrasonic waves, which does not disperse well throughout the medium. Figure 1 shows the difference between high and low frequency effects schematically.

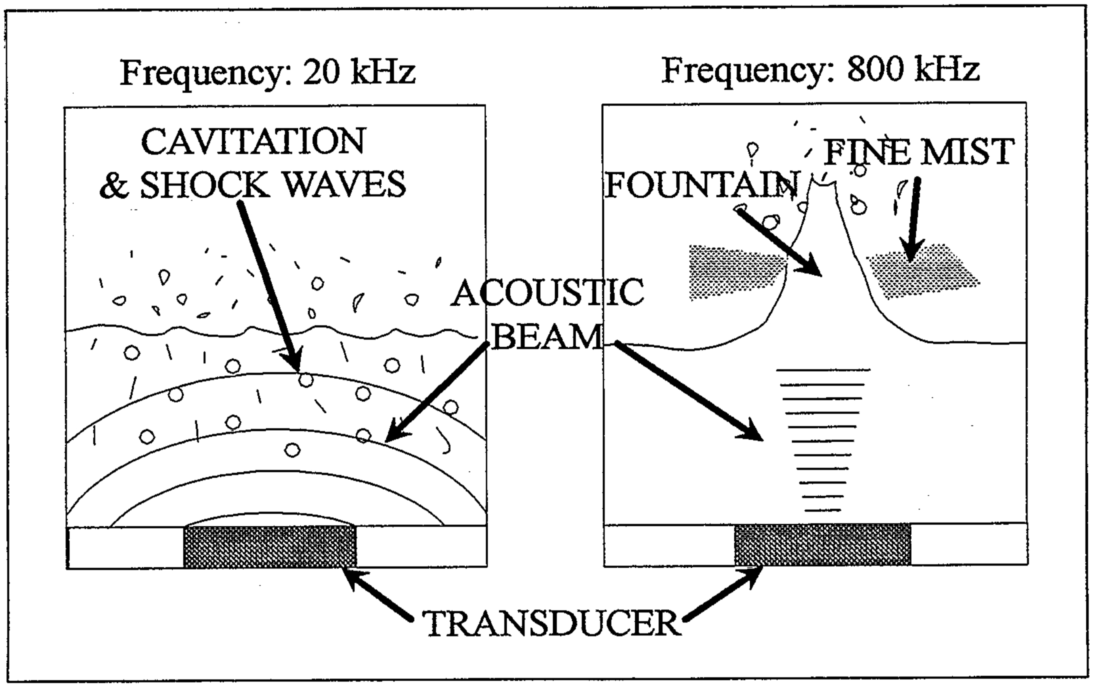

Figure 1: Low vs High Frequency Ultrasound Waves in Liquid [4]

Two different approaches to ultrasonic treatment of fuel were assessed in this study. One apparatus consisted of the ultrasonic horn system, a treatment cell, and a peristaltic pump. This horn operated at a frequency of 20 kHz, and had a power range of 10 to 175 watts. The tip of the horn had a surface area of 1 cm^2. A schematic of the equipment set-up is shown in Figure 2.

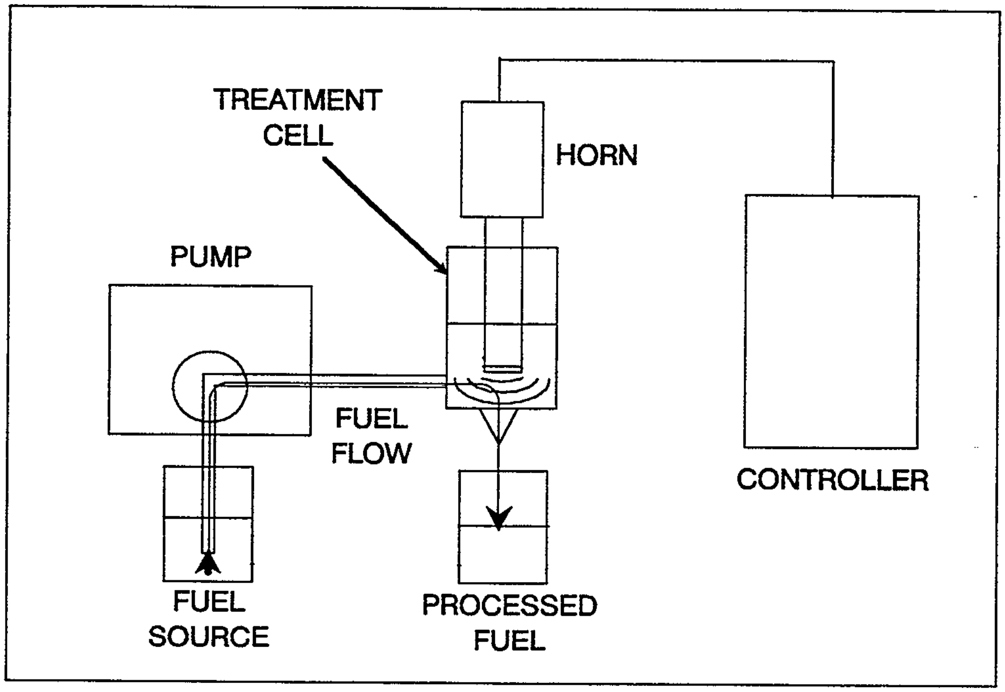

Figure 2: Ultrasonic Horn Equipment Set-up

An industrial cleaner was used as an alternative to the ultrasonic horn flow test. This system operated at 40 kHz. The fuel was pumped through a length of tubing which was immersed in the sonicator bath. The cleaner reservoir had 18 transducers distributed across the bottom. The bottom surface had dimensions 18" x 12". This maximized the length of tubing immersed in the liquid and allowed longer treatment times for a given flow rate. A schematic showing the set-up for this flow test is shown in Figure 3.

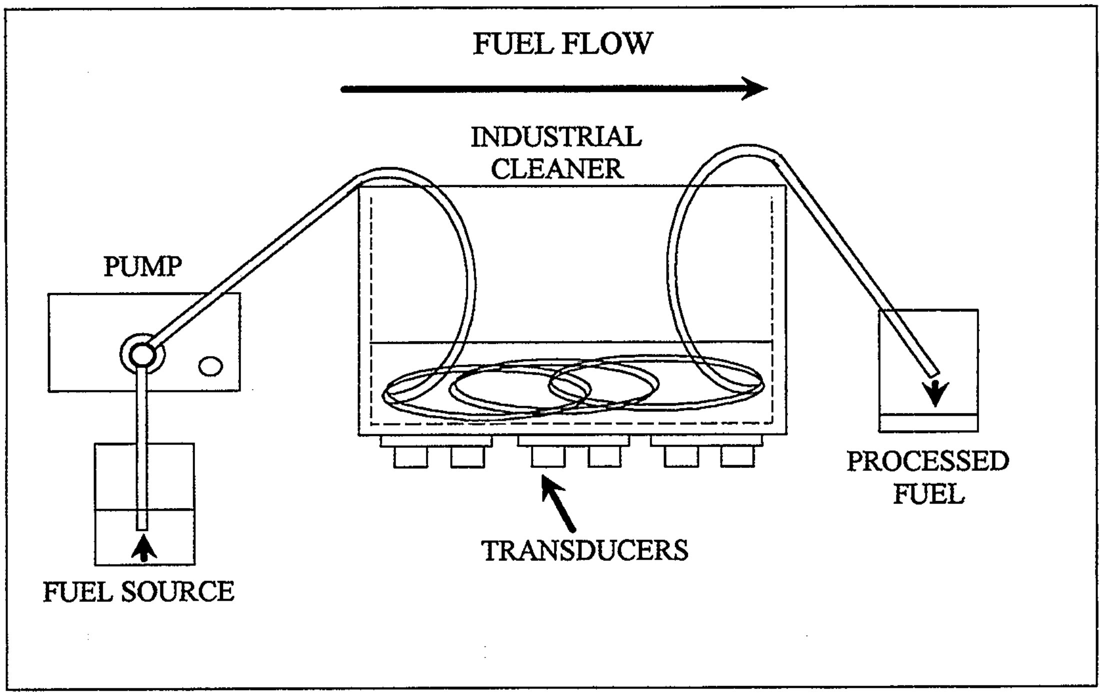

Figure 3: Industrial Cleaner Flow Test Set-up

Field tests were performed with actual contaminated marine diesel. The results of these tests were assessed by counting the number of colonies of microorganisms per millilitre of fuel before and after treatment. The microorganisms were classified as:

- aerobic bacteria,
- anaerobic bacteria,
- aerobic yeast and mold, and
- anaerobic yeast and mold.

Additionally, the most typical microorganisms found in marine diesel were inoculated into sterilized fuel. The following standard microorganism cultures were used:

- Pseudomonas aeruginosa ATCC 15442,
- Candida albicans ATCC 14053, and
- Hormoconis resinae ATCC 18215.

The viability of these microorganisms was also assessed by counting colonies before and after ultrasonic processing for each type.

RESULTS

The results showed that contamination levels were typically reduced by 2-3 orders of magnitude in this preliminary assessment. The microbiological testing was performed by three independent laboratories, all of which were able to show reduced counts after processing.

Figure 4 shows the results of the field tests before and after processing with the ultrasonic cleaner bath. These tests were performed with the fuel immersed in the water bath for the times given in the legend at a power level of 100 watts.

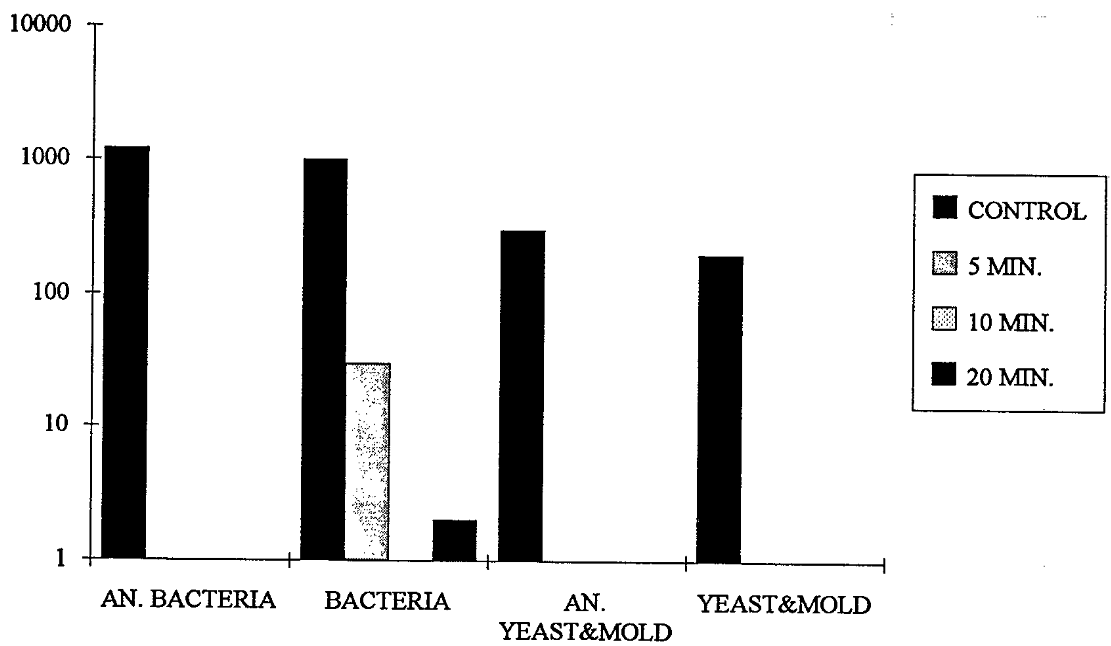

Figure 4: Ultrasonic Cleaner Field Test Results

Figure 5 shows the results from the inoculation tests before and after processing with the ultrasonic horn. These tests were conducted at a medium effective power setting of 55 watts.

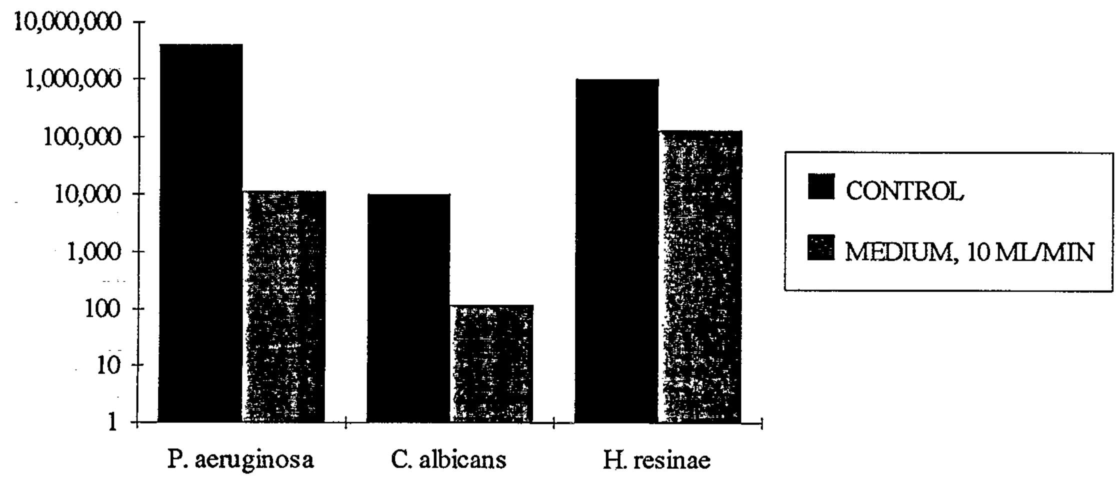

Figure 5: Ultrasonic Horn Inoculation Test Results

DISCUSSION

These preliminary results showed that ultrasonic processing could be a feasible approach to the destruction of microorganisms in marine diesel. Based on the findings from the literature on ultrasonic destruction of microorganisms in other applications, it was found that the frequency, power and geometry of the system can affect the results of this process. For this reason, two alternative configurations were used to evaluate the process with marine diesel. Both field tests and inoculation tests resulted in the reduction of viable colonies of different types of microorganisms that are typically present in fuel.

It was also found that ultrasonic treatment can be useful in disrupting microbial mats that grow at the fuel water interface. Ultrasonic processing can effectively destroy the viability of the microorganisms within the mat, and disrupt the mat to facilitate filtering.

Water reaction tests showed that the quality of the fuel is not degraded by ultrasonic processing. However, it was found that large amounts of water should not be mixed with the fuel during processing. The quality of contaminated fuel as assessed by the water reaction tests was actually improved by ultrasonic processing.

It is recommended that these techniques be adapted for full scale field trials in a marine environment. The proper implementation of large piezoceramic transducers will be critical in the success of scaling up this technology from the laboratory to a marine environment.

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