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The original document contains color images.

14. ABSTRACT
The objective of this effort was to evaluate feasibility for measuring relative permittivity (dielectric constant) to evaluate the free water content in petroleum fuels.

15. SUBJECT TERMS
Relative Permittivity, Dielectric Constant, Fuel, JP-8, Diesel, Free Water

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21386

-Technical Report-

Relative Permittivity to Measure Free Water in Fuel

Joel Schmitigal

October 2010

U.S. Army Tank Automotive Research, Development, and Engineering Center
Detroit Arsenal
Warren, Michigan 48397-5000

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U.S. Army Tank Automotive Research Development and Engineering Center

Warren, Michigan 48397-5000

Relative Permittivity to Measure Free Water in Fuel

Joel Schmitigal
Force Projection Technology

Standard Form 298 (Rev. 8/98)

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1. **Introduction**

The objective of this effort was to evaluate feasibility for measuring relative permittivity (dielectric constant) to evaluate the free water content in petroleum fuels. The relative permittivity is the ratio of the permittivity, resistance to forming an electrical field, of a substance of interest to the permittivity of a vacuum. Simply put the relative permittivity is a measure of a fluids ability to resist an electrical charge from conducting through it. Relative permittivity is defined as:

$$\varepsilon_r(\omega) = \frac{\varepsilon(\omega)}{\varepsilon_0}$$

Where $\varepsilon(\omega)$ is the frequency-dependent absolute permittivity of the fluid being measured, and ε_0 is the constant of permittivity in a vacuum.

US Army TARDEC had previously investigated the use of sensors measuring relative permittivity to determine the condition of diesel engine oil onboard a vehicle (1). In these evaluations relative permittivity measurements were shown to have the ability to track changes in water content, although not independently of other changes in engine oil properties.

Petroleum products have a relative permittivity in the range of 1.7-2.3 while water has a relative permittivity of ~80. These vast differences makes utilizing this measurement very enticing for measuring the contamination of fuel by water.

2. **Approach**

2.1. Free Water Detection

The evaluation of determining the feasibility for measuring relative permittivity to detect the free water content in petroleum fuels was performed by immersing a sensor in a Jet A fuel sample and purposely adding known concentrations water and measuring the relative permittivity after 1 minute of ultrasonic mixing followed by vigorous stirring. The relative permittivity was measured 5 times for each test point, and averages reported. The CSI Oil View Model 5500 from Emerson Process Management (Knoxville, TN) was utilized to perform this evaluation.

2.2. Fuel Baseline Relative Permittivity

Measurements of a small sample size of fuels were measured to establish a set of baseline measurements of the various fuel types. These fuels included three fuels commonly utilized by the U.S. Army, Diesel Fuel No. 2, JP-8, and Jet A fuels. The relative permittivity was measured 5 times for each test point, and averages reported. The CSI Oil View Model 5500 from Emerson Process Management (Knoxville, TN) was utilized to perform this evaluation.

3. **Analysis**

3.1. Free Water Detection

Each of the fuel samples containing a known amount of free water was measured five (5) times. the average relative permittivity is given in Table 1. A minimal amount of change in the relative permittivity was displayed with the higher levels of free water in the fuel. The addition of the free water was clearly visible to the naked eye as shown in Figure 1.

PPM free water	Relative Permittivity
0	2.08
10	2.08
20	2.08
50	2.08
100	2.09
200	2.09
999	2.09

Table 1. Relative permittivity of fuel in relation to amount of free water in the fuel

Figure 1. Zero (0) PPM free water (left) vs 999 PPM free water (right)

3.2. Fuel Baseline Relative Permittivity

The relative permittivity sensor was used to measure eight (2) fuels, 2 Jet A samples, 3 Diesel No. 2 samples, and 3 JP-8 samples, to determine the variation of relative permittivity among the fuel samples.

Fuel Type	Relative Permittivity
Diesel No. 2	2.20
Diesel No. 2	2.18
Diesel No. 2	2.04
JP-8	2.12
JP-8	2.27
JP-8	2.10
Jet A	2.08
Jet A	2.14

Table 2. Relative permittivity of 8 fuel samples

4. **Conclusion**

The variation in the baseline measurement of relative permittivity among the Jet A fuels, Diesel No. 2 fuels and JP-8 fuels is greater than the change in relative permittivity that occurs when 1000 ppm of free water is added to a fuel. This data indicates that measuring the relative permittivity of a fuel is not able to provide an accurate correlation to the amount of free water present in the sample of interest or a change in the free water content of a known sample.

References

1. *Evaluation of Sensors for On-Board Diesel Oil Condition Monitoring of U.S. Army Ground Equipment.* **Schmitigal, Joel and Moyer, Steve.** Detroit : Society of Automotive Engineers, 2005.