

Diesel Fuel/Water Separation Test Methods—Where We Are and Where We Are Going

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ABSTRACT

With the automotive industry using high-pressure common rail fuel systems to meet current and future emissions requirements, water removal is even more critical to extend the life of these fuel systems. To meet this challenge, the automotive industry is attempting to improve the current water removal test methods. International Organization of Standardization (ISO) and Technical Specification (TS) 16332 [1] and Society of Automotive Engineers (SAE) J1488 [2] are the two major standardized test methods used by the automotive industry at this time. ISO/TS 16332 is replacing ISO 4020 [3] and SAE J1488 is still the U.S. National test method. ISO/TS 16322 is still being developed at the time of the writing. The SAE Filter Test Methods Committee (FTMC) is incorporating improved methodologies to SAE J1488 to improve our National test method and meet the automotive industry's needs. This paper will discuss only the SAE FTMC action items and results.

INTRODUCTION

Water removal for diesel fuel is a very critical process for automotive and heavy-duty diesel applications. High-pressure common rail fuel systems are currently on many vehicles and will be the norm for the future. The free water limits for diesel fuel are still being determined for high-pressure common rail fuel systems, but one current recommendation is 200-ppm total water. This

would even apply to B5 biodiesel fuel blends. Depending upon the saturation limit of the base fuel, the allowable free-water content could range from 0–100 ppm.

Currently, both ISO and SAE are working on test methods to improve the current methods used by the automotive industry, SAE J1488 and ISO 16332. This paper will only discuss a proposed method to improve the water emulsion generating process being discussed in the SAE Filter Test Methods Committee – SAE J1488 – Emulsified Water Removal Test Method.

BACKGROUND

The current SAE J1488 diesel emulsion removal test procedure does not properly define the centrifugal pump parameters used to generate fine water emulsion for fuel water separation testing. The current test method also allows a rather wide range of pump flow capacities (5 to 20 times the test flow rate). This means that for a fuel filter rated for a flow rate of 2 gpm, pumps rated from 10 to 40 gpm could be used to generate the emulsion.

In addition to the pump impeller dimensions, it has been determined that one of the other parameters not addressed in the current test method is the residence time of the water in the pump impeller. At 3,500 rpm, a pump designed for high flow rates with a large impeller volume will take longer to exchange the emulsion inside the propeller than a much smaller volume and lower flow

rate. As a result, a large pump size relative to the test flow rate will generate a finer emulsion than a smaller pump at the same test flow rate. These issues create a problem in the filtration industry, as the emulsion is not standardized, creating a major variable that allows for variations in reproducibility between the laboratories.

This proposed “slip-stream” emulsion-generating method would greatly reduce, if not eliminate, this variable. The current proposal is for the SAE Filter Test Methods Committee (FTMC) to specify a 3,500-rpm main pump with a defined impeller size and a given flow rating above which the majority of the diesel fuel water separators are normally rated (6gpm is the current recommendation).

This new test system would consist of two circuits: (1) a circuit to generate a constant emulsion at a constant fuel flow rate for any test filter, and (2) a second circuit to test the fuel water separators at the recommended flow rate.

EMULSION GENERATING CIRCUIT

The proposed emulsion generating circuit will consist of a loop containing a defined 3,500-rpm main pump rated at the maximum flow rate for most diesel fuel water separators (currently 6gpm). All of the important variables defining the pump, including impeller dimensions, will be defined. This will minimize variations from pump to pump and also better define the shear parameters for the emulsion. This will most likely require recommending one manufacturer, but hopefully the parameters will allow other pumps to be included.

The emulsion generating loop will also include the following:

- A sump
- A flow meter
- A water reservoir with a flow meter and control valve for metering the water at the appropriate rate
- A flow loop control valve
- A clean up filtration system capable of removing 2500 ppm emulsified water at 6 gpm for the duration of the test at a high efficiency rating. See Figure 1.

EMULSION RESEARCH

Previous attempts to quantify droplet size distribution in the droplet generating loop of the proposed modification were suspect due to the high concentrations of water called for in the procedure. Without dilution of the sample fluid, particle counter saturation resulted in a uniform response in droplet numbers, regardless of concentrations used between 1500 ppm and 2500 ppm (data from October 5, 2006). Data provided in the June 20, 2007 meeting was limited by the upper channel size limit of the particle counter used for those measurements (greater than 30 microns).

The following data were generated using the same test stand as described in the October 2006 and June 2007 meeting minutes, with modifications made to allow quantified dilution of the particle counter sample stream with clean dry fuel (June 2007 meeting). Another particle counter was used in these measurements that allowed measurements up to those droplets greater than 100 microns.

The test stand used for these measurements was modified in three ways from the October 2006 measurements:

1. A sample dilution system was added that included a 12-volt fuel pump submersed in the main fuel sump. This pump passed fuel from the sump to an additional high-efficiency fuel filter and then to a flowmeter that could measure the add rate to the sample stream (100 ml/min). A similar flowmeter was also used on the sample stream (15 ml/min.), so that the ratio of dilution fluid to sample stream could be quantified and controlled to a total flow of 115 ml/min.
2. Additional fine polishing cleanup filters were added in series after the coalescers to ensure that clean up particle levels were about 22 to 30 particles per milliliter at 2 microns (ISO 4402 calibration).
3. Additionally, a Parker CM20 portable six channel on-line particle counter with channel settings up to greater than 100 microns was implemented, replacing the previous particle counter.

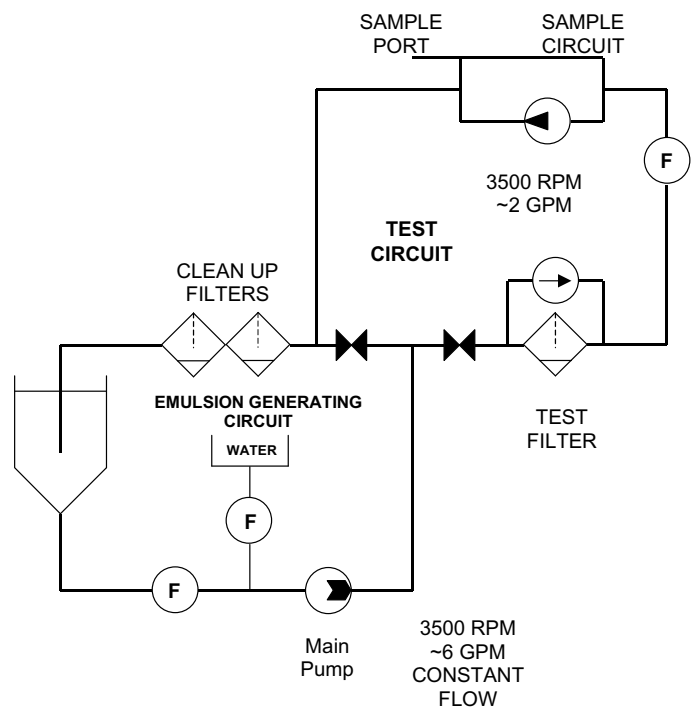


Figure 1. Proposed “Slip-Stream” Droplet Generation Flow Loop

In this investigation, two pumps were tested for emulsion droplet size generation using ULSD-CARB, kerosene, and the higher capacity of the two was tested using B20 biodiesel. The first tested was a 0.5 HP, 3450 rpm centrifugal pump and the second was 1.0 HP version of the same. The 0.5 HP pump represents the lower end of the J1488 specification for pump size (55 gpm @ 10 ft. head, generation loop = 6 gpm x 5 = 30 gpm, allowable minimum pump size). The 1.0 HP pump represents the upper end of the J1488 specification for pump size (108 gpm @ 10 ft. head, generation loop = 6 gpm x 20 = 120 gpm, maximum allowable pump size). The J1488 specification states that the pump should be within a range of 5 and 20 times the test filter flow rate.

- Pump 1 was a 3450 rpm / 0.5 HP centrifugal Sherwood Model 200J 05363 2 0005. The pump housing was 5.4 inches diameter and the impeller was 3.25 inches diameter.
- Pump 2 was a 3450 rpm / 1.0 HP centrifugal FHP Model A4C34DC67A, McMaster-Carr P/N 8249K83. The pump housing was approximately 6 inches in diameter.
- Five fuels were used for these tests: Two batches of California Air Resources Board (CARB) ULSD fuel with interfacial tension of 16.5 mN/m and 20 mN/m Microseparometer (MSEP) 93 and 87, respectively)
- Kerosene with Interfacial Tension (IFT) of 21.5 mN/m and 20 mN/m (MSEP 55 and 88, respectively)
- 20% mixture of ULSD/CARB diesel from the second of the above batches
- Soy biodiesel (B20) (IFT = 7 mN/m and MSEP = 00)

Water was supplied directly from city tap water supply and de-ionized using a Cole Parmer mono-bed deionizer.

The droplet generation loop was flowing continuously at 6 gpm. The sample loop or test loop, which was sub-sampled for droplet size, was flowing at 2.1 gpm continuously simulating a water separator being tested at that flow rate. All fuel samples were taken continuously on line and diluted on line to 7.67 times their original volume using clean dry fuel.

Emulsion droplet sizes were measured at test concentrations of approximately 2500 ppm and 1200 ppm to detect any influence of water concentration on droplet size distribution.

A Parker Model CM20 Laser particle counter was used for droplet size measurement. Total diluted sample line flow through the counter was 115 ml/min. Droplet sizes were averaged at 3.5, 10, 20, 37.5, and 75-micron sizes. Five sample replicates were measured and averaged for each test condition (4 minutes per sample replicate), except the biodiesel measurements where test time was limited due to drop in efficiency of the clean up filters (one replicate only).

RESULTS AND DISCUSSION

LOW-FLOW CAPACITY PUMP (ULSD/KEROSENE/TWO WATER CONCENTRATIONS) - Figure 2 illustrates the droplet distributions resulting from the 0.5 HP pump in kerosene and CARB fuel at approximately 2500ppm and 1200 ppm water concentrations. There were some problems with dissolved gas in the deionizer column; therefore, at times, continuous water add rates may not have been totally precise due to air bubbles in the water add flowmeter. This would explain why droplet numbers at 1200 ppm were not always half of the numbers at 2500 ppm in these tests.

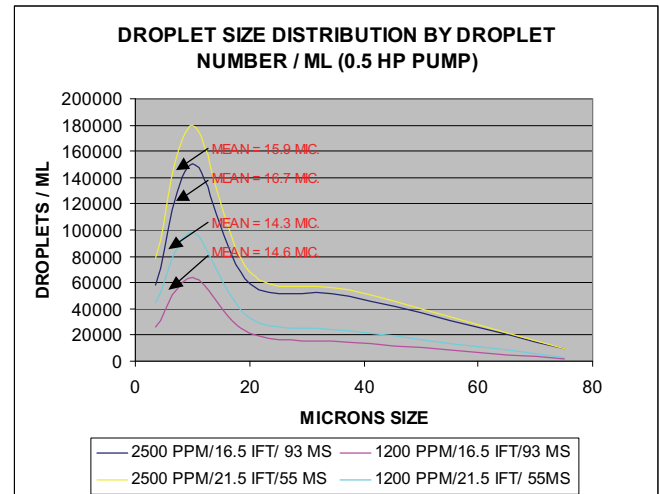


Figure 2. Droplet Size Distribution by Droplet Number/mL (0.5 Hp Pump)

This graph characterizes the droplet distributions in terms of numbers of droplets per ml using the smaller 0.5 HP pump (i.e. low end of the J1488 pump capacity specification). These measurements were made in kerosene at 21.5 mN/m IFT and MSEP = 55, and in untreated CARB fuel (ULSD) at 16.5 mN/m IFT and MSEP = 93.

These curves reveal that the majority of droplet numbers in all cases were at 10 microns. There was little difference in the general shape of the distribution curves due either to fuel types (within the ranges shown above) or water concentration between approximately 1200 ppm and 2500 ppm. Additionally, the mean droplet diameters were all very similar, ranging from 14.3 microns to 16.7 microns.

Figure 3 reveals the same droplet distributions when plotted as percent of total water/ml volume versus droplet size. This representation shows a shift in the distribution maximum values to the larger droplet sizes. Since a single 75-micron droplet is equal in volume to about 425 ten-micron droplets, it does not take very many large droplets in the distribution to shift the droplet volume curves toward larger droplets.