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Fuel/Water Coarse Droplet Separation Test Procedure for Suction Side Applications

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The Engineering Society For Advancing Mobility Land Sea Air and Space
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HIGHWAY VEHICLE REPORT

SAE J1839

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FUEL/WATER COARSE DROPLET SEPARATION TEST PROCEDURE FOR SUCTION SIDE APPLICATIONS

1. INTRODUCTION: The purpose of this fuel/water separator test procedure is to provide a means for evaluating the water droplet removal characteristics of fuel/water separators, using laboratory test equipment. These evaluations, combined with data collected from field observations, may be used to establish standards of performance for fuel/water separators tested and used in applications where water droplets may be present.

Modern-day fuel systems are directly susceptible to degradation from water in fuel and are vulnerable to degradation from side effects resulting from the presence of water; micro-organisms, acids, etc. Both catastrophic failures and gradual degradation of system functions are known to occur when excess water is present in fuels.

The probable presence of water in fuels, well above the saturation point, is apparent from the inclusion of maximum acceptable water concentrations in fuel specifications. (ASTM #2 diesel fuel is allowed up to 500 ppm total water, roughly 400 ppm free water, or 4 liters of water per 8000 liters of fuel.) Water is known to enter and accumulate in fuels during handling and storage. Even if fuel contains no undissolved water when it leaves the refinery, it may possibly contain excess water when it reaches the point of use.

Coarse water droplets (40-300 m and larger) are generated in fuel systems containing bulk water. These droplets generally predominate in pump suction lines and persist on the pressure side of low shear pumps (for example, diaphragm and lobed pumps). This test procedure is primarily designed for evaluating coarse droplet or transfer pump suction side fuel/water separators. Emulsions are generated when fuel water mixtures pass through high shear pumps (for example, 3600 rpm/centrifugal) and predominate in fuel lines on the pressure side of such pumps where undissolved water is present. An emulsified (finely dispersed) water separator testing procedure is covered in a companion document (SAE J1488).

2. SCOPE: To determine the undissolved water removal performance of a fuel/water separator under realistic and controlled conditions, using water droplets.

3. TEST APPARATUS: A test system, as illustrated in Fig. 1, to include:

3.1 Operating sump with a flat bottom. Material to be compatible with diesel fuel (polyethylene, etc.). Sump size to be adequate to hold test fluid volume under test conditions. Outlet to be 2.5 cm from bottom of tank or higher.

3.2 A pump, capable of providing test flow rate, under test conditions.

3.3 A water-dispersing device, as described in Appendix 1.

3.4 Thermometer or temperature readout accurate ±2°C under test conditions.

3.5 The fuel/water separator under test.

3.6 Differential pressure gauge or manometer with 1.0 mm Hg or 0.1 kPa subdivisions, or as required.

3.7 Inline static mixer with at least three internal mixing units, or similar, to provide a representative sample at the sample port.

3.8 Sample port. Provision must be made to allow adequate flushing, immediately prior to sampling.

3.9 Test fuel flow meter, flow range appropriate for the unit under test, accuracy ±5%, repeatability ±2%.

3.10 A final fuel/water separator assembly, such that not more than 50 ppm undissolved water is recycled on an average basis under test conditions.

3.11 Suitable heat exchange and controls for maintaining constant test temperatures as specified.

3.12 Suitable valve or other control for adjusting and controlling test flow.

3.13 Diffuser, to promote uniform mixing in test reservoir.

3.14 Water flow meter with range to suit application capable of measuring flows of 0.25% of fuel flow rate, ±5% accuracy.

3.15 Suitable valve for adjusting and controlling water injection flow.

3.16 Supply of clean deionized or distilled water, adequate pressure must be available to inject water on the high pressure side of the pump. (Use of a deionizing filter, for example, housed Barnstead D8901, will permit use of local water supply and pressure.)

3.17 Automatic Karl Fischer Titration Apparatus for water content analysis.

3.18 All interconnecting piping should be selected, sized, and oriented to prevent the separation of water and solid contaminants from the fuel or provide traps for these contaminants (13 mm PVC is recommended for 0-23 lpm flow rates).

4. TEST MATERIALS:

4.1 Test Fluid: Since fuel oil contains various constituents, the test oil type should be categorized and recorded as one of the following:

A. A sample of the fluid used in the application.
B. #2 diesel fuel, locally available.
C. Specially treated fluid, per Appendix 2.
D. A standard reference fluid to be specified.

In all these cases, it should be understood that the results are relevant to this fuel and that some amount of variance in performance can be expected with different fuels, depending on the particular design of the test fuel water separator.

4.2 Clean, distilled or deionized water, to be supplied as in paragraph 3.16.

5. TEST CONDITIONS:

5.1 Volume of fuel in the test system (including filters, piping, etc.) shall be a minimum of 8 times the flow rate per minute.

5.2 Temperature: 30 ± 2°C.

5.3 Flow rate of fuel: rated flow of unit to be tested or as specified.

5.4 Water flow rate: 0.25% of fuel flow rate.

6. TEST PROCEDURES:

6.1 If clay-treated fuel (Appendix 2) is not the selected fluid, use a fresh quantity of fluid. Retreat clay-treated fuel, if used.

6.2 Determine the water saturation level for each batch of test fluid:

A. According to Appendix 3.
B. By using tables or charts where available, see Appendix 4.

6.3 Install clean-up filter (95% efficiency at 5 μm or better suggested) in place of test filter; fill fuel tank; start circulation of fuel at clean-up filter flow rating. Continue system clean-up until a particulate contamination level of 5mg/l or less and 25 ppm undissolved water or less is obtained. Low clean-up flow rates and/or lower efficiencies will require long clean-up times. The final fuel/water separator may be used as a clean-up filter if suitable.

6.4 Install fuel/water separator to be tested (Fig. 1).

6.5 With flow set near zero, start pump, adjust to specified flow rate.

6.6 Bleed air from system if necessary, take initial (fuel only) pressure drop reading at the test flow.

6.7 Open the water valve and adjust water to 0.25% of fuel flow. Start the clock at the same time water begins to flow. Establish proper flow rate within one min.

6.8 Without interrupting test flows, periodically drain the water from the water collection sump of the unit under test. Do not let water build up beyond the maximum recommended level in water sump. DO NOT TAKE ANY SAMPLES WHEN ASSEMBLY IS BEING DRAINED.

6.9 Record test time for each drain.

6.10 Every 20 min carefully withdraw a sample, being sure to flush the sample port thoroughly. Be sure that the sample syringe or container is thoroughly dry. Analyze the sample immediately using the Karl Fischer method (ISO-R-760), or similar. Record each reading. Additional sampling is permitted.

6.11 Record differential pressure across and test temperature at the test water separator at each sample interval.

6.12 Terminate the test if one or more of the following conditions is met:

A. Water concentration in effluent fuel is above an acceptable level, to be specified by manufacturer or user.

B. Two h and 20 min or more of test time has elapsed and an equilibrium pressure drop is attained. Equilibrium pressure drop has been reached when an increase of no more than 2.5 mm Hg (0.34 kPa) occurs during a 20 min interval.

C. Differential pressure exceeds an upper limit specified by the manufacturer or user.

7. PRESENTATION OF DATA:

7.1 Plot concentration of undissolved water in effluent (ppm by volume)* versus time (minutes) on linear graph paper. Undissolved water = total water minus dissolved water (see paragraph 6.2). Indicate drain times on graph.

*Many Karl Fischer titrators will determine micrograms. Convert this to ppm by volume.

$$\text{ppm by vol} = \frac{\text{Karl Fischer reading ugms}}{\text{Sample Volume (ml)}} = \frac{\text{Karl Fischer ugms X Fuel sp. gr.}}{\text{Sample Weight (grams)}}$$

7.2 Plot pressure drop (mm Hg or kPa) versus time (minutes).

7.3 Note the following:

7.3.1 Test fluids

7.3.2 Fuel flow rate

7.3.3 Actual test temperature

7.3.4 Total test time

7.3.5 Equilibrium pressure drop

7.3.6 Dissolved water saturation level, method used to determine level

7.4 Calculate and report the average free water content of effluent:

$$E_{av} = \sum E_i \times [(t_i - t_{i-1})/t_{total}]$$

Where:

E_{av} = Average undissolved water content of effluent, ppm by volume.

E_i = Undissolved water content of the "i th" sample = Total water content of the sample - water saturation level (Paragraph 6.2), ppm by volume.

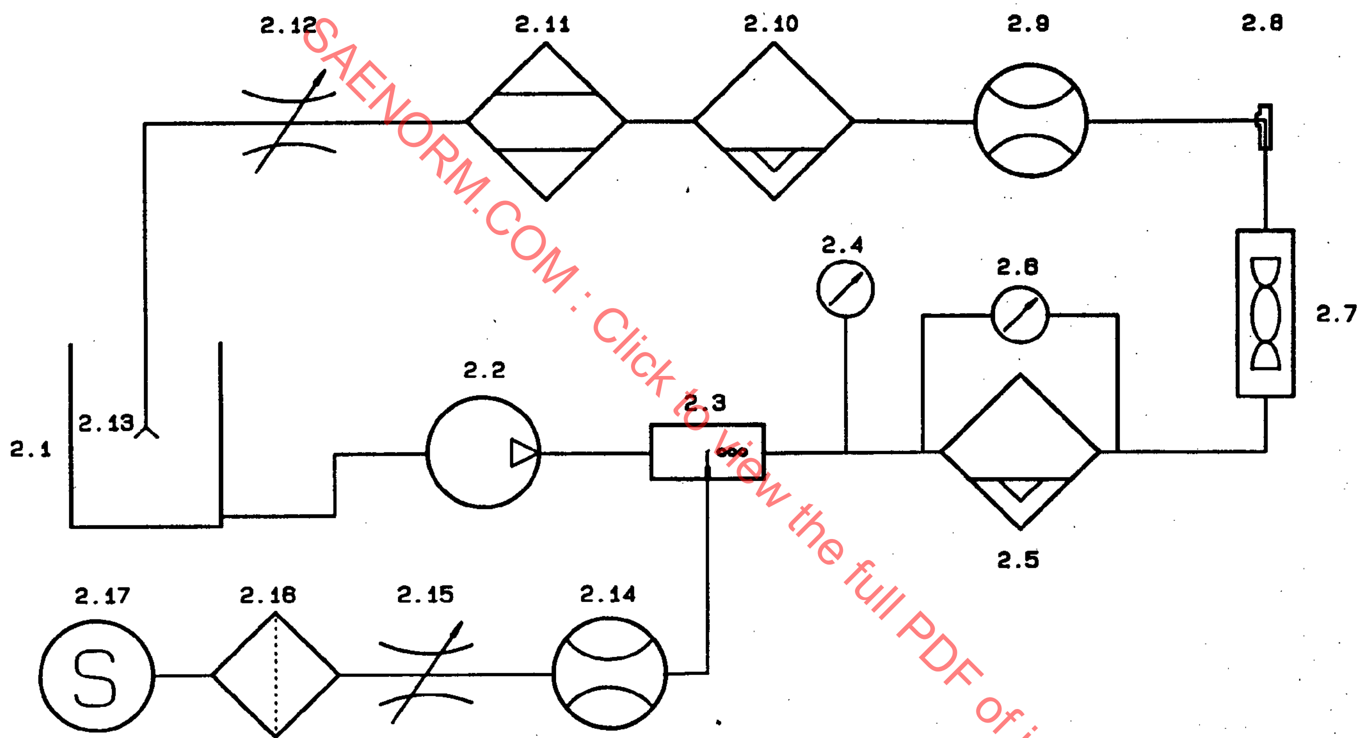
$t_i - t_{i-1}$ = time since previous sample, minutes.

t_{total} = total test time to final sample, minutes.

7.5 Calculate and report average undissolved water separation efficiency.

$$\text{Average Efficiency} = (1 - \frac{E_{av}}{2500}) \times 100$$

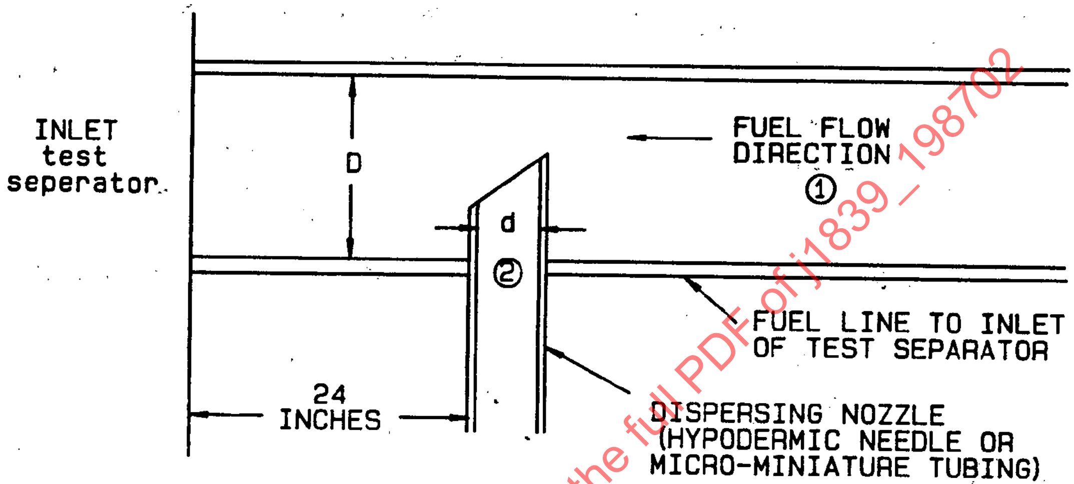
FIGURE 1



2.1 OPERATING SUMP
2.2 PUMP
2.3 WATER DISPENSING DEVISE, APPENDIX 1
2.4 THERMOMETER
2.5 TEST FUEL FILTER/ WATER SEPARATOR
2.6 DIFFERENTIAL PRESSURE GAUGE
2.7 INLINE MIXER
2.8 SAMPLE PORT
2.9 FUEL FLOW METER
2.10 FINAL FUEL FILTER/ WATER SEPARATOR
2.11 HEAT EXCHANGER
2.12 FLOW CONTROL VALVE
2.13 DIFFUSER
2.14 WATER FLOW METER
2.15 WATER FLOW CONTROL VALVE
2.16 WATER FILTER/ DEIONIZER
2.17 HIGH PRESSURE WATER SUPPLY

APPENDIX 1

WATER DISPERSING DEVICE



① FUEL VELOCITY PAST NOZZLE TIP SHOULD BE BETWEEN .75 AND 1.50 M/SEC.

② WATER VELOCITY THROUGH NOZZLE SHOULD BE BETWEEN 4.7 AND 7.0 M/SEC.

WHERE LPM = TEST FLOW RATE

D = MAXIMUM DIAMETER (MM) FOR .75 M/SEC VELOCITY $= 20\sqrt{LPM \times .07074}$

D = MINIMUM DIAMETER (MM) FOR 1.50 M/SEC VELOCITY $= 20\sqrt{LPM \times .03536}$

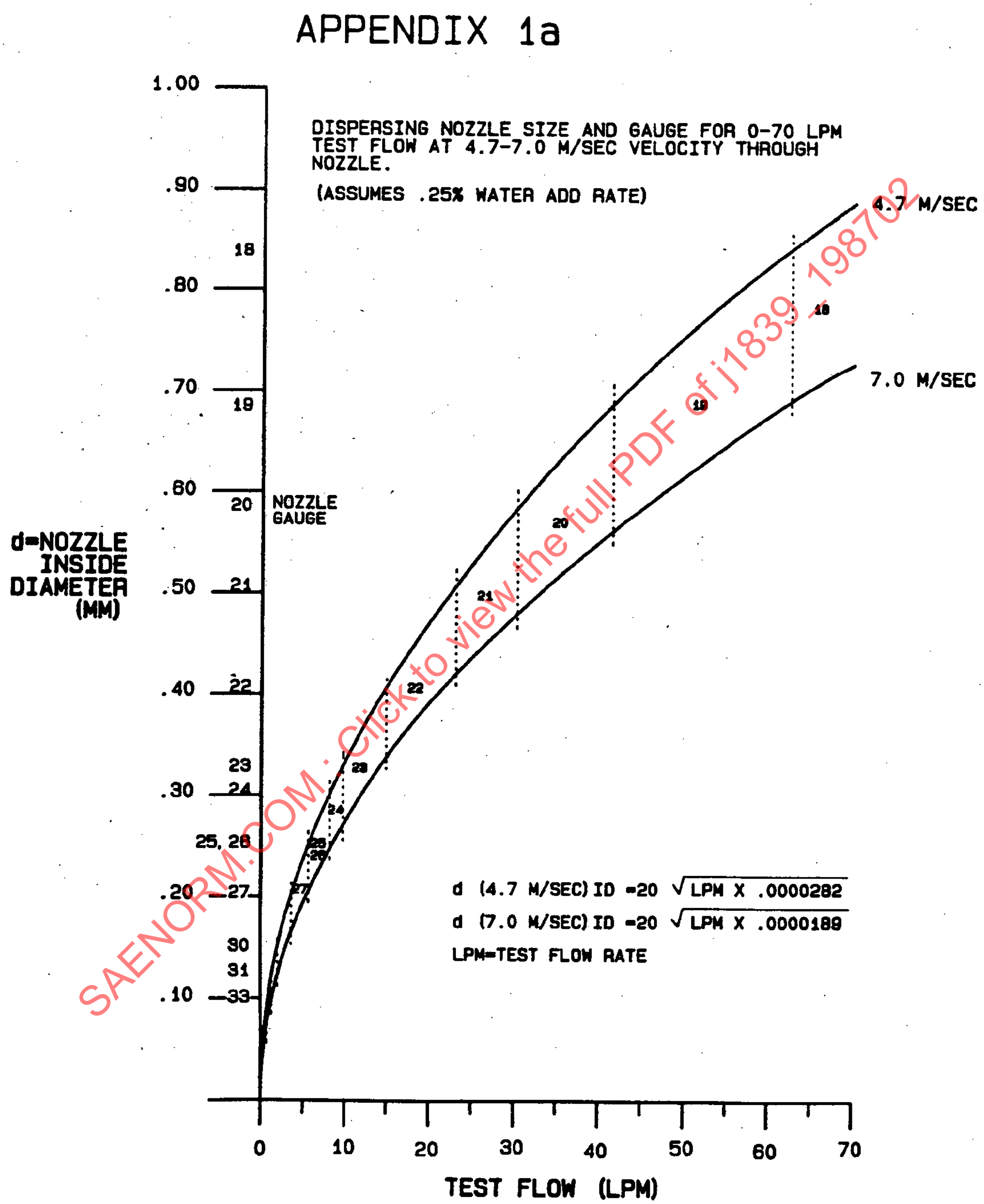
d = MAXIMUM DIAMETER (MM) FOR 4.7 M/SEC VELOCITY $= 20\sqrt{LPM \times .0000282}$

d = MINIMUM DIAMETER (MM) FOR 7.0 M/SEC VELOCITY $= 20\sqrt{LPM \times .0000189}$

(SEE APPENDIX 1a AND 1b FOR NOZZLE I.D. AND GAUGE AT VARIOUS TEST FLOW RATES)

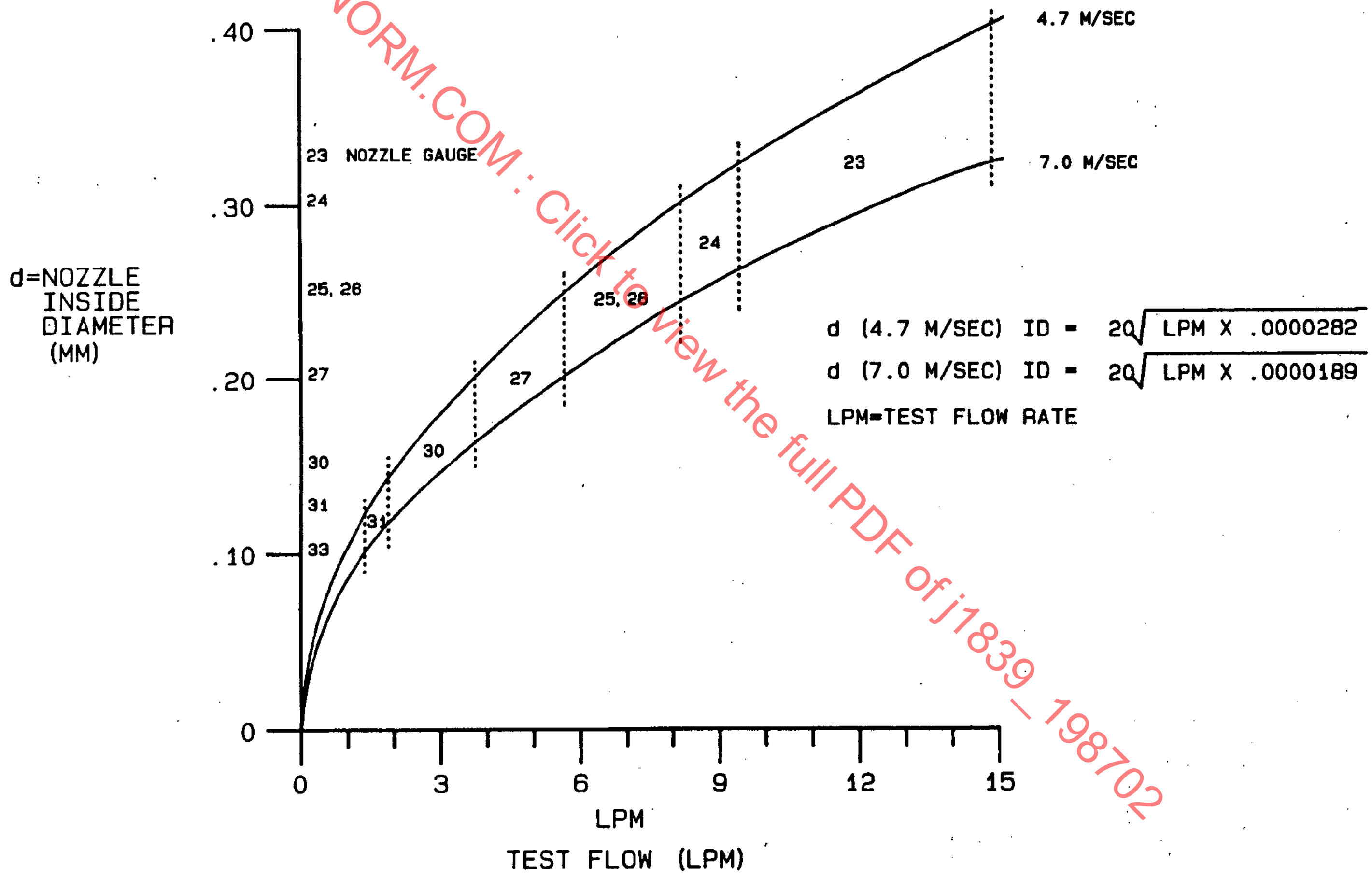
THIS WATER DISPERSING METHOD HAS BEEN FOUND TO PRODUCE DISPERSED PHASE DROPLET POPULATIONS WITH MEAN DIAMETERS OF APPROXIMATELY 180 TO 260 MICROMETERS.

APPENDIX 1a


APPENDIX 1a
DISPERSING NOZZLE SIZE AND GAUGE FOR 0-70 LPM TEST FLOW AT 4.7-7.0 M/SEC VELOCITY THROUGH NOZZLE.
(ASSUMES .25% WATER ADD RATE)
4.7 M/SEC
7.0 M/SEC
d=NOZZLE INSIDE DIAMETER (MM)
NOZZLE GAUGE
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
18
19
20
21
22
23
24
25, 26
27
30
31
33
d (4.7 M/SEC) ID =20 √LPM X .0000282
d (7.0 M/SEC) ID =20 √LPM X .0000189
LPM=TEST FLOW RATE
0
10
20
30
40
50
60
70
TEST FLOW (LPM)

APPENDIX 1b

DISPERSING NOZZLE SIZE AND GAUGE FOR 0-15 LPM
TEST FLOW AT 4.7 -7.0 M/SEC VELOCITY THROUGH NOZZLE.
(ASSUMES .25% WATER ADD RATE)



APPENDIX 2

A2 Fuel Treatment to Obtain Fluid as Specified in Paragraph 4.1 (C):

A2.1 Take the required volume of #2 fuel oil and continuously contact the fuel with Fuller's Earth. This may be done by filtering the fuel through commercially available Fuller's Earth or clay cartridge filters. The test fluid sump may be used.

A2.2 Periodically (about every 2 h) take a sample of the fuel in a beaker. Filter the sample through a 0.2 μm membrane and measure the interfacial tension (IFT) with distilled water at 16°C + 2°C. The platinum ring detachment method (ASTM D971) is recommended, although other correlatable methods may be used.

A2.3 If the IFT is greater than or equal to 30 mN/m, stop further contacting with Fuller's Earth or clay. Generally 2-4 h of contacting will more than adequately ensure that this condition is met. Report the IFT of the treated fuel.

A2.4 Remove the Fuller's Earth cartridges from the test loop or adjust valving to isolate them from the test loop.

A2.5 Add to the Fuller's Earth treated fuel (in the test sump) 0.1% (1000 ppm) of cetane number improver Ethyl D112 (Ethyl Corporation).

A2.6 Circulate the fuel with additive through the test system for 15 min or two complete turnovers of the fuel volume in the sump. The fuel treatment is now complete.

APPENDIX 3

A3 Method of Determining Saturation Level of Dissolved Water in Fuel: Use this method for maximum accuracy or when tables or charts are unavailable.

A3.1 Wash a clean sample bottle (with a rubber diaphragm cap; minimum 100ml capacity) with distilled water so as to remove traces of detergent; dry bottle thoroughly.

A3.2 Take 150 ml of test fuel and filter fuel through a 0.2 micrometer membrane compatible with fuel oil.

A3.3 Determine total water concentration in the fuel by the Karl Fischer method in ppm by volume.

A3.4 If the water concentration is below or equal to 100 ppm, proceed to A3.5; if not, repeat A3.2 and A3.3. If necessary, cool fluid to -4°C before filtering (step A3.2).

A3.5 Place 75 ml of the filtered fuel into the dried clean 100ml sample bottle. Insert a PTFE coated magnetic stirrer.

A3.6 Fill a 50 ml hypodermic syringe fitted with a long, large diameter needle with clean distilled water and remove any air. Carefully insert 25 ml of the water into the bottom of the sample bottle taking care to create and maintain the water-fuel interface with minimal agitation. Completely fill the bottle with filtered fuel. Place the bottle on a magnetic stirrer and stir at the lowest possible speed. Make sure that the fuel water interface is not strongly agitated and that no appreciable vortex develops as a result of mixing.

A3.7 After mixing for approximately 18 h (overnight), place the bottle gently in a water bath at the test temperature for two h; insert a clean, dried, hypodermic syringe through the rubber diaphragm in the cap; gently withdraw 2 ml of fuel from the top and analyze for water content using the Karl Fischer method. Take three readings. The average is the water saturation.

A3.8 Convert water saturation to ppm by volume; if the concentration is not between 100-150 ppm by volume, then repeat steps A3.6 through A3.8 to confirm; otherwise report this as the dissolved water saturation level in fuel.