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SURFACE VEHICLE STANDARD

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Superseding J1985 OCT2013

(R) Fuel Filter - Initial Single-Pass Efficiency Test Method

RATIONALE

The previous method required gravimetric measurements of the injection system's contamination level to be used as one criteria for acceptance of a performed test. A replacement acceptance criteria has been added that is based on the upstream particle counts that correspond to the expected counts at the original required contamination gravimetric level. The distribution of upstream particle counts provides more detail of the contaminant challenging the test filter than a gravimetric value and can be used to assess the stability of the filter's upstream challenge. Further, gravimetric results can have a large variation at low contaminant concentrations. The revised standard provides a range and standard deviation of acceptable upstream particle counts for the sizes analyzed which are used to assess the acceptance of a completed test.

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1. SCOPE

This SAE Standard is intended for all sizes of fuel filters, so a variety of test stands may be required depending upon flow rate. The low contamination level, downstream clean-up filter, and short duration of the test ensure that the particle retention ability of the filter is measured in a single pass, as no appreciable loading or regression will occur.

1.1 Purpose

The purpose of this test is to provide a method to determine the ability of a fuel filter to retain a given size of particle in a single pass.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1696 Standard Fuel Filter Test Fluid

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org

ASTM D2624 Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels

ASTM D4308 Test method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter

2.1.3 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 2942 Hydraulic Fluid Power - Filter Elements Verification of Fabrication Integrity and Determination of the First Bubble Point

ISO 3968 Hydraulic Fluid Power - Filters Evaluation of Differential Pressure Versus Flow Characteristics

ISO 4021 Hydraulic Fluid Power - Particulate Contaminant Analysis - Extraction of Fluid Samples from Lines of an Operating System

ISO 4405 Hydraulic Fluid Power - Fluid Contamination - Determination of Particulate Contamination by the Gravimetric Method

ISO 11171 Hydraulic Fluid Power - Calibration of Automatic Particle Counters for Liquids

ISO 11943 Hydraulic Fluid Power - On-Line Automatic Particle Counting Systems for Liquids - Methods of Calibration and Validation

ISO 12103-1 Road Vehicles - Test Dust for Filter Evaluation - Part 1: Arizona Test Dust

3. TEST MATERIAL AND EQUIPMENT

3.1 Test Fluid

Use test fluid conforming to SAE J1696 at 40 °C ± 5 °C.

3.2 Test Contaminant

3.2.1 Use ISO 12103-1, A2 Fine test dust.

3.2.2 The test contaminant should be dried using an open container with a contaminant depth of less than 25 mm in a convection oven at a temperature of 110 to 150 °C for 2 hours. Dried dust should be stored in a desiccator prior to filter testing.

3.2.3 The test contaminant should be poured into the injection system reservoir in a slurry form. The slurry can be prepared using a clean, 200 to 300 mL sample of the test fluid and a mixing jar. After combining the fluid and contaminant in the jar, mix vigorously. Placing the jar in an ultrasonic bath for 2.5 minutes ± 0.5 minutes after initial mixing is recommended. Add slurry to injection reservoir immediately after removal from ultrasonic bath. Rinse remaining contaminant from jar with a spray bottle of clean test fluid or an adequate volume from the injection reservoir to transfer any remaining contaminant.

3.3 Filter Performance Test Circuit

Use a filter performance test circuit comprised of a “filter test system” and a contaminant “injection system” as shown in Figure 1.

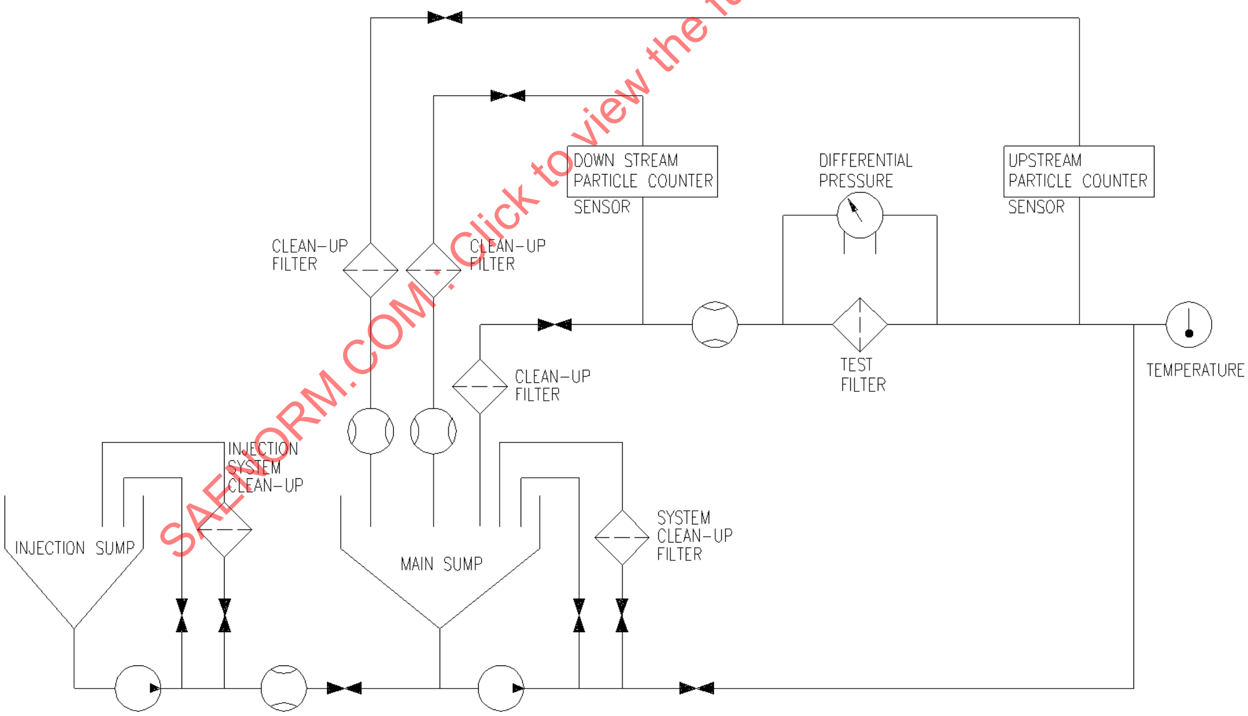

Figure 1 - Informative filter performance test circuit diagram

3.4 Filter Test System

3.4.1 Reservoir

A reservoir constructed with a conical bottom having an included angle of not more than 90 degrees and where the fluid is diffused below the surface.

NOTE: This reservoir design avoids a horizontal bottom and minimizes contaminant settling while the subsurface diffusion reduces the entering of air and gives good mixing capabilities.

3.4.2 Pump

The pump(s) should be insensitive to the contaminant.

WARNING: Pumps exhibiting excessive flow pulses cause erroneous results.

3.4.3 System Clean-Up Filters

The system clean-up filters necessary to obtain initial system cleanliness level of less than 1% of the minimum level specified in Table 2 for the smallest particle size to be counted.

3.4.4 Instrumentation

Pressure gauges, temperature indicator, and flow meters in locations as shown in Figure 1.

3.4.5 Pressure Taps

Pressure taps in accordance with ISO 3968.

3.4.6 Sampling

Upstream and downstream sampling means in accordance with ISO 4021.

3.4.7 Interconnecting Lines

Interconnecting lines which ensure turbulent mixing conditions exist throughout the filter test system and avoids silting areas and contaminant traps.

3.4.8 Particle Counter

Use automatic particle counters calibrated per ISO 11171.

3.4.9 On-Line Counting System

The on-line counting system shall be in accordance with ISO 11943.

3.5 Contaminant Injection System

3.5.1 Reservoir

A reservoir constructed with a conical bottom having an included angle of not more than 90 degrees and where the fluid is diffused below the surface.

NOTE: This reservoir design avoids a horizontal bottom and minimizes contaminant settling while the subsurface diffusion reduces the entering of air and gives good mixing capabilities.

3.5.2 Pump

Use a hydraulic pump (centrifugal or other type) which does not alter the contaminant particle size distribution.

3.5.3 System Clean-Up Filters

A system clean-up filter capable of providing an initial system contamination level less than 1% of the minimum level specified in Table 2 for the smallest particle size to be counted.

3.5.4 Instrumentation

Flow meter in location as shown in Figure 1.

3.5.5 Pressure Taps

Pressure taps shall be in accordance with ISO 3968.

3.5.6 Sampling

A sampling means for the extraction of a small flow (injection flow) from a point in the contaminant injection system where active circulation of fluid exists. Sample per ISO 4021.

3.5.7 Interconnecting Lines

Interconnecting lines which ensure turbulent mixing conditions exist throughout the filter test system and avoids silting areas and contaminant traps.

NOTE: Alternate contaminant injection system may be used provided that injection system meets validation requirements.

4. TEST CONDITION ACCURACY

Set up and maintain equipment accuracy within limits given in Table 1.

Table 1 - Equipment accuracy limits

Test Conditions	Unit	Maintain Within ± of True Value
Flow	L/min	2%
Pressure	kPa	2%
Temperature	°C	5 °C
Volume	L	2%

5. VALIDATION OF CONTAMINANT INJECTION SYSTEM

5.1 Validate at the maximum gravimetric level, the maximum injection circuit volume, minimum injection flow rate and for the length of time required to deplete the usable volume.

5.2 Add the required quantity of contaminant in slurry form to the injection fluid and circulate for a minimum of 15 minutes. Initiate injection flow from the contaminant injection system, collecting this flow external to the system.

5.3 Obtain an initial injection fluid sample at this point and measure the injection flow rate.

5.4 Maintain the injection flow rate within ±5% of the desired injection flow rate.

5.5 Obtain samples of the injection flow and measure the injection flow rate at 30 minutes, 60 minutes, 90 minutes, and 120 minutes, or at a minimum of four equivalent intervals depending on the system's depletion rate.

5.6 Analyze the gravimetric level of each sample obtained in 5.5 in accordance with ISO 4405.

5.7 Measure the volume of fluid remaining in the injection system at the end of the validation test. This is the minimum validation volume, Vv.

5.8 Accept the validation only if:

5.8.1 The gravimetric level of each sample obtained in 5.6 is within ±10% of the gravimetric level determined in 5.1 and the variation between the samples does not exceed ±5% of the mean.

5.8.2 The injection flow rate at each sample point is within ±5% of the selected validation flow rate (see 5.1) and the variation between sample flow rates does not exceed ±5% of the average.

5.8.3 The volume of fluid remaining in the injection system, Vv (see 5.7), plus the quantity (total injection time multiplied by the average injection flow rate [see 5.8.2]) is within ±10% of the initial volume (see 5.1).

6. VALIDATION OF TEST CIRCUIT

These validation procedures reveal the effectiveness of the filter performance test circuit in providing the appropriate particulate challenge to the test filter, maintaining contamination entrainment, and/or preventing contaminant size modification. The particulate size and quantity targets for the dust challenge are given in Table 2. A description of the test data and process that produced Table 2 is given in Appendix A. The particulate count limits established by Table 2 used the SAE J1985 OCT2013 5.0 mg/L target concentration of A2 Fine, so the same approximate concentration should be used for this validation procedure. Small variation in the actual concentration is acceptable with the overriding objective of the test stand challenging the test filter with particulates as defined by Table 2. An estimate of the range of concentrations that could satisfy the limits of Table 2 is 4.6 to 5.4 mg/L (see Appendix A). The ideal concentration is likely test stand dependent and should be used consistently on a given test stand to promote test repeatability.

6.1 Validate at the minimum flow that the filter test system will be operated.

NOTE: Use straight pipe in place of filter during the validation.

6.2 Conduct a simulated filter test per Sections 8, 9, and 10 without a filter test element installed.

6.3 Accept the validation only if:

6.3.1 Particle counts obtained in 10.9 for a given size meet the test acceptance criteria in 12.6.

6.3.2 The average for all particle counts per mL at all the particle sizes to be validated for both upstream and downstream particle counters are within the limits shown in Table 2.

Table 2 - Validation counts

Particle Size µm(c)	Acceptance Range of Particle Counts/mL Greater than Indicated Particle Size for Target 5.0 mg/L ISO A2 Fine Test Dust	
	Minimum	Maximum
4	15028	17996
5	7726	9804
7	2468	3451
10	597	1039
15	130	277
20	41	119

NOTE: The range of particle sizes used for validation should cover the range of particle sizes to be used for subsequent filter element testing

7. PRELIMINARY PREPARATION

7.1 Test Filter Assembly

7.1.1 Ensure that the test fluid cannot bypass the filter element being evaluated.

7.1.2 Subject the test filter to a fabrication integrity test in accordance with ISO 2942 using SAE J1696 fluid prior to the single-pass test or following the test if the element is not readily accessible as in a spin-on configuration.

7.1.3 Disqualify the element from further testing if it fails to meet the designated fabrication integrity requirement.

8. CONTAMINANT INJECTION SYSTEM

8.1 To calculate the minimum volume required for operation of the contaminant injection system (V, liters) which is compatible with the desired injection flow, use Equation 1:

$$V = 1.2 * 60\ (min) * injection\ flow (L/min) \qquad \text{(Eq. 1)}$$

NOTE 1: The volume calculated in Equation 1 will ensure a sufficient quantity of contaminated fluid for the test.

NOTE 2: Injection flow rates below 0.25 L/min are not recommended due to silting characteristics and accuracy limitations.

8.2 Calculate the gravimetric level (Y', mg/L) of the injection system fluid using Equation 2:

$$Y' = \frac{target\ upstream\ concentration\ (mg/L) * test\ flow\ (L/min)}{injection\ flow\ (L/min)} \qquad \text{(Eq. 2)}$$

NOTE: The target upstream concentration is nominally 5.0 mg/L but can be slightly different to match the concentration used to successfully validate the test circuit in Section 6.

Report on Figure 2A the target upstream concentration used.

8.3 Calculate the quantity of contaminant (W, grams) needed for the contaminant injection system using Equation 3:

$$W = \frac{Y'(mg/L) * injection\ system\ vol\ (L)}{1000} \qquad \text{(Eq. 3)}$$

8.4 Adjust the injection flow rate at stabilized temperature (40 °C) to within ±5% of the value selected in 8.1 and maintain throughout the test.

8.5 Adjust the total volume of the contaminant injection system to the value determined in 8.1.

8.6 Circulate the fluid in the contaminant injection system through its system clean-up filter until a level of less than 1% of the minimum level specified in Table 2 for the smallest particle size to be counted is achieved.

8.7 Bypass the system clean-up filter after the required initial cleanliness has been achieved.

8.8 Measure the fluid conductivity at 40 °C per ASTM D2624 or ASTM D4308. If the conductivity is below 1000 pS/m, add Octel Stadis 450 anti-static additive to produce a conductivity level of 1500 pS/m ± 500 pS/m. Circulate the fluid at a minimum of 15 minutes to thoroughly disperse the contaminant and anti-static additive.

8.9 Add in slurry form the quantity of contaminant (grams) as determined in 8.3 to the injection system reservoir.

9. FILTER TEST SYSTEM

9.1 Install the filter housing (without the test element) in the filter test system.

9.2 Adjust the total fluid volume of the test system (exclusive of the system clean-up filter) to a level where no air entrapment can occur and can accommodate the injection fluid during the test.

9.3 Circulate the fluid in the filter test system at the rated flow and a stabilized temperature of 40 °C ± 5 °C and record the pressure drop of the empty filter housing.

9.4 Circulate the fluid in the filter test system through the clean-up filter until a contaminant level of less than 1% of the minimum level specified in Table 2 for the smallest particle size to be counted is achieved.

9.5 Ensure on-line counting accuracies; make sure upstream and downstream sampling lines have continuous flow throughout the test. Silting in the sampling lines is to be avoided by sizing the tubing bore to maintain the right line velocity.

NOTE: All fluid flow not being sampled should be returned to the main sump and dispersed below the test fluid level.

10. SINGLE-PASS FILTER EFFICIENCY TEST

10.1 Install the filter element per the manufacturer specifications and subject the assembly to the specified test conditions (test flow with test temperature of 40 °C ± 5 °C). Measure the fluid conductivity at 40 °C per ASTM D2624 or ASTM D4308. If the conductivity is below 1000 pS/m, add Octel Stadis 450 anti-static additive to produce a conductivity level of 1500 pS/m ± 500 pS/m. If antistatic additive is added, do not initiate test until the conductivity has stabilized.

10.2 Measure and record the clean assembly pressure drop. Calculate and record the clean element pressure drop (clean assembly pressure drop minus the housing or the spin-on without the element pressure drop).

10.3 Obtain an on-line sample upstream of the test filter element to determine the system initial contamination level.

10.4 Select the injection flow rate and allow it to stabilize.

10.5 Obtain a fluid sample from the contaminant injection system.

10.6 Measure and record the injection flow rate.

10.7 Record the initial injection system volume.

10.8 Initiate the filter test as follows:

10.8.1 Ensure that the downstream clean-up filter is in the flow circuit.

10.8.2 By-pass the system clean-up filter.

10.8.3 Allow the injection flow to enter the filter test system at the suction side of the pump as shown in Figure 1.

NOTE: Older versions of this document allow contaminant injection into the sump. It has been shown that injection of the contaminant into the pump provides better particle count stability. This stability provides better consistency in the test results.

10.8.4 Start the timer.

10.8.5 Start the on-line upstream and downstream sample flow.

10.8.6 Allow 1 to 2 minutes of injection before taking the first fluid samples.

10.9 Initiate on-line sampling at 1-minute increments until 60 minutes after initiation of the test. The sampling flow should be per recommended sensor flow. A minimum of 20 seconds of sampling should be obtained for each count.

10.10 After 60 minutes from test initiation, measure and record the final injection flow rate.

10.11 Record the final injection system volume.

10.12 Obtain a final fluid sample from the injection system.

10.13 Conclude the test by stopping the injection flow and element flow.

11. DATA ACCURACY

11.1 Select and maintain instrumentation so that data accuracy is within the limits of Table 3, unless otherwise specified.

Table 3 - Data accuracy limits

Quantity	Unit	Accuracy within True Value
Injection Flow Rate	L/min	±5%

12. DATA ANALYSIS

12.1 Analyze the on-line counts by determining the number of particles ≥4, 5, 7, 10, 15, and 20 µm(c), or as specified with a particle counter calibrated per ISO 11171.

12.2 For each particle size setting, calculate the average upstream particle count, $\bar{c}$, over the duration of the test. Report on Figure 2B and Figure 3.

12.3 For each particle size category, indicate on Figure 3 whether the average upstream particle count, $\bar{c}$, is between the limits of Table 2. Accept the test only if the average particle count for each size is within the limits of acceptable particle counts.

12.4 Calculate the standard deviation of the upstream particle counts, σ, for each particle size setting using the standard deviation equation found in ISO 11943. Report on Figure 3.

12.5 Calculate the acceptable standard deviation, $\sigma\ Acceptable$, for each particle size setting using Equation 4. Report on Figure 3.

$$\sigma\ Acceptable = 2\sqrt{\bar{c} + 0.0004\bar{c}^2} \quad \text{(Eq. 4)}$$

12.6 For each particle size setting, indicate on Figure 3 whether the standard deviation of upstream particle counts meets the criteria of acceptable standard deviation. Accept the test only if the standard deviation in 12.4 is less than or equal to the acceptable standard deviation in 12.5 for each particle size setting.

12.7 Calculate the filtration ratio (FR) and filtering efficiency (Eff) for each particle size as shown in Section 15 and report on Figure 2B.

12.8 Record the sample time used for each particle sample during the test and report on Figure 2A.

12.9 Calculate the average downstream particle count for each particle size by averaging the individual downstream particle counts obtained during the test and report on Figure 2B.

12.10 Using Equations 5 and 6, with the average particle counts from 12.2 and 12.9, calculate and report on Figure 2B the average filtering efficiencies and filtration ratios for each particle size.

12.11 Plot on semi-log (log linear) coordinates the average filtration ratio versus particle size, FR values being on the log scale with FR = 100000 as the highest value plotted.

NOTE: When FR values of infinity are recorded (zero downstream particle count), they should be plotted as FR = 100000.

12.12 Plot on linear coordinates the average Eff versus particle size, with Eff values on the ordinate.

12.13 Using Equation 7 in Section 15, calculate and record on the report sheet given in Figure 2A the particle size values corresponding to average filtration ratios of 2, 10, 75, 100, 200, and 1000, using interpolation of straight-line segments connecting points on the semi-log FR versus particle size plot. Do not extrapolate.

NOTE 1: For many filters, particle size values for each of the above FR values cannot be obtained by interpolation. In these cases, the unobtainable values should be noted as either less than the minimum particle size counted or greater than the maximum particle size counted, whichever is appropriate. Values should be reported for at least two or more consecutive filtration ratios from the above values.

NOTE 2: For calculation of the interpolated particle size, x, for a specified filtration ratio, FRx, where the value falls between two of the points from the plot in 12.10 (corresponding to filtration ratios FRx1, FRx2, and particle sizes x1, x2, respectively), use Equation 7.

NOTE 3: For FR values greater than 100000, use the value of 100000 in Equation 7.

13. DATA PRESENTATION

13.1 Report the following information as a minimum for a filter element evaluated using this method.

13.1.1 Present all test data and calculation results in a report. An informative report format shown in Figures 2A and 2B.

14. CRITERIA FOR ACCEPTANCE

14.1 There should be no visual evidence of filter element damage that could have resulted from performing this test.

14.2 The filter restriction should not have exceeded a predetermined maximum value at any time during the 60-minute test.

15. CALCULATIONS

15.1

$$Filtering\ Efficiency = \frac{Upstream\ Count - Downstream\ Count}{Upstream\ Count} * 100 \qquad \text{(Eq. 5)}$$

15.2

$$Filtration\ Ratio = \frac{Upstream\ Count}{Downstream\ Count} \qquad \text{(Eq. 6)}$$

15.3

$$x = \frac{(x_1 - x_2) \times log(FRx/FRx1)}{log(FRx1/FRx2)} + x_1 \qquad \text{(Eq. 7)}$$

Laboratory identification

Test laboratory: ____________________________ Test date: ____________ Operator: _____________

Filter a element identification

Element ID: ___________________________________ Housing ID: ___________________________________

Spin-on: Yes / No

Minimum element bubble point (Pa): ______________

Filter orientation: Vertical _________ Horizontal _________

Operating conditions

Test fluid

Fluid Type:________________________ Ref.: ____________________________ Batch no.: ____________

Viscosity at the test temperature (mm²/s): _______________________ Temperature (°C): __________________

Conductivity-test circuit (pS/m): ________

Antistatic: Yes ______ No ______ Type: ________________

Conductivity-inj. circuit (pS/m): ________

Test contaminant

Type: ISO 12103-1 A2 test dust Batch no.: ____________ Target Concentration (mg/L):_________

Test system

Flow rate (L/min): ________________ Volume (L): ___________________

Injection system

Injection parameters	Initial	Final	Average injection parameters	
System volume (L)			Injection flow (L/min)	
Gravimetric level (mg/L)			Gravimetric level (mg/L)	

Counting system

Location	Counter and sensor ref.	Flow rate (mL/min)	Dilution ratio
Upstream			
Downstream			

Sampling time per particle count: ______________________

Counter calibration: Method: ____________________________________ Date: ________________

Test results

Element integrity

Bubble point to ISO 2942 (Pa): ___________________ Test fluid: ______________________

Differential pressure

Filter housing (kPa): ____________________________ Clean assembly (kPa):___________________________

Clean element (kPa): ___________________________

Filtration ratio and efficiency

Average filtration ratio	2	10	75	100	200	1000
Average efficiency	50%	90%	98.7%	99%	99.5%	99.9%
Particle size, µm(c)						

Figure 2A - Fuel filter element single-pass test report sheet

Test results, continued

Particle counts per mL and filtration ratio													
Time interval		*d* > µm(c)	*FR* *Eff %*	*d* > µm(c)	*FR* *Eff %*	*d* > µm(c)	*FR* *Eff %*	*d* > µm(c)	*FR* *Eff %*	*d* > µm(c)	*FR* *Eff %*	*d* > µm(c)	*FR* *Eff %*
Initial	Up												
3 minutes	Up												
	Down												
5 minutes	Up												
	Down												
10 minutes	Up												
	Down												
20 minutes	Up												
	Down												
30 minutes	Up												
	Down												
40 minutes	Up												
	Down												
50 minutes	Up												
	Down												
60 minutes	Up												
	Down												
Avg.	**Up**												
Avg.	**Down**												

Figure 2B - Fuel filter element single-pass test report sheet (concluded)

Particle Size, µm(c)	**Average Upstream Particle Count, $\bar{c}$**	**Average Upstream Count Meets Table 2 Limits (Yes/No)**	**Upstream Particle Count Standard Deviation, σ**	**Upstream Particle Count Acceptable Standard Deviation, σ $Acceptable$**	**Upstream Particle Count Standard Deviation ≤ Acceptable Standard Deviation (Yes/No)**
4					
5					
7					
10					
15					
20					

Figure 3 - Average upstream particle counts and standard deviation assessment

16. NOTES

16.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE FILTER TEST METHOD STANDARDS COMMITTEE