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AEROSPACE RECOMMENDED PRACTICE

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MEASURING AIRCRAFT GAS TURBINE ENGINE FINE FUEL FILTER ELEMENT PERFORMANCE

1. PURPOSE: Variation in filter element testing methods and requirements make comparison of results difficult. In order to minimize these problems, this ARP describes standard filtration ratings and test procedures. Both manufacturer and customer will have a common means to specify, control, and evaluate filter elements.

2. SCOPE:

2.1 This ARP delineates two complementary filter element performance ratings and corresponding test procedures. It is intended for the noncleanable (disposable), fine fuel filter elements used in aviation gas turbine engine systems.

2.2 Filter Element Performance Ratings:

2.2.1 Filter Element Dirt Capacity: The weight of test contaminant added to the filter element test circuit under specified conditions required to produce a prescribed differential pressure. This value should be used only for comparing elements having similar filtration efficiencies.

2.2.2 Filter Element Efficiency:

2.2.2.1 Filter element efficiency is the capability of a filter element to retain contaminant particles. Efficiency is expressed in terms of a filtration ratio. The filtration ratio compares the number of particles larger than a given size entering a filter element to the number of particles larger than the same size leaving the filter element.

2.2.2.2 The techniques specified in this recommended practice allow measurement of filtration ratios up to 5,000 between 2 and 25 micrometers.

2.3 Filter element performance ratings can be adversely effected by harsh operating environments. Filter elements should, therefore, be subjected to procedures simulating these harsh operating conditions prior to performance testing. Conditioning is the term covering these simulated operating procedures. This ARP does not cover conditioning requirements. They should be determined by the user and reported by the testing agency.

3. APPLICABLE DOCUMENTS: The following documents, of the issue in effect on the date specified form a part of this recommended practice.

3.1 Military Specifications:

MIL-E-5007 Engines, Aircraft, Turbojet and Turbofan, General Specification for

MIL-H-5606 Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance

MIL-T-5624 Turbine Fuel, Aviation, Grades JP-4 and JP-5

MIL-F-81836 Filter and Disposable Element, Fluid Pressure, Hydraulic, 3 Micron Absolute

3.2 Society Of Automotive Engineers Publications:

SAE ARP 24 Aerospace Recommended Practice - Determination Of Hydraulic Pressure Drop

SAE MAP 749 Aerospace Recommended Practice - Aircraft Turbine Engine Fuel System Component Endurance Test (Contaminated Fuel)

SAE ARP 785 Aerospace Recommended Practice - Procedure for the Determination of Particulate Contamination in Hydraulic Fluids by the Control Filter Gravimetric Procedure

3.3 International Organization For Standardization Publications:

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

ISO 4402 Hydraulic Fluid Power - Calibration of Liquid Automatic Particle-count Instruments - Method Using Air Cleaner Fine Test Dust Contaminant

3.4 American National Standards Institute Publications:

ANSI/B93.31 Multi-pass Method for Evaluating the Filtration Performance of a Fine Hydraulic Fluid Power Filter Element

3.5 American Society For Testing & Materials Publications:

ASTM D-971 Test Method for Interfacial Tension of Oil Against Water by The Ring Method

ASTM D-1744 Water in Liquid Petroleum Products by Karl Fischer Reagent - Test Method For

4. GLOSSARY:

4.1 Terms:

β = the filtration ratio obtained using AC Fine Test Dust under multipass test conditions.

C = the percent of accountable contaminant obtained in the dirt capacity test validation.

F_1 = the flow rate (liters/minute) through the filter element during filter element efficiency testing.

F_2 = the rate (liters/minute) of injection flow from the contaminant circuit to the filter element test circuit during filter element efficiency testing.

G_1 = the upstream gravimetric level (milligrams/liter) of contaminant in the filter element test circuit during filter element efficiency testing.

G_2 = the gravimetric level (milligrams/liter) of contaminant in the contaminant injection circuit fluid for filter element efficiency testing.

U_x = the total number of particles per unit volume greater than a given size (x) upstream of the filter element during filter element efficiency testing.

D_x = the total number of particles per unit volume greater than a given size (x) downstream of the filter element during filter element efficiency testing.

τ = the predicted test time (minutes) of the filter element efficiency test.

V_1 = the filter element efficiency test contaminant injection circuit fluid volume (liters).

V_2 = the filter element test circuit fluid volume (liters) used during filter element efficiency testing.

W_1 = the total weight (grams) of contaminant added to the test circuit during dirt capacity validation procedures.

W_2 = the weight (grams) of contaminant collected on the cleanup filter element in the dirt capacity validation procedure.

W_3 = the weight (grams) of contaminant washed from the cleanup filter element during degreasing, plus the weight (grams) of contaminant remaining in the cleanup filter housing, in the dirt capacity validation procedure.

W_4 = the weight (grams) of remaining suspended contaminant in the test fluid found during dirt capacity validation procedures.

W_5 = the estimated weight (grams) of AC Fine Test Dust required for the test filter element to reach the terminal differential pressure during the filter element efficiency test.

W_6 = the required amount of contaminant (grams) to be added to the contaminant injection circuit to achieve the desired upstream gravimetric level in the filter element test circuit during filter element efficiency testing.

W_7 = the required amount of contaminant (grams) to be added to the filter element test circuit to achieve the target upstream gravimetric level required to validate the filter element test circuit during filter element efficiency testing.

x = contaminant particle size (micrometers).

4.2 Conversions: The units milligrams per gallon used in the dirt capacity validation cleanup procedure may be converted to milligrams per liter by multiplying by 0.26417.

5. GENERAL TEST CONDITIONS:

5.1 Test Fluids:

5.1.1 The fluid used for dirt capacity testing shall conform to JP-4 fuel per MIL-T-5624. The JP-4 fuel is to have an interfacial tension (IFT) of 30 + 3 dynes/centimeter per ASTM D-971. The fuel interfacial tension shall be maintained throughout the test. IFT testing should occur at the beginning and end of each test and at other times not to exceed two hours. It is recommended that a Fuller's Earth filter be utilized for maintaining interfacial surface tension, since this has been shown to give reproducible results. The fuel shall be saturated but contain no free water as determined by the Karl Fischer method per ASTM D-1744.

5.1.2 The fluid used for filter element efficiency testing shall conform to MIL-H-5606. This fluid is readily available, internationally acceptable, and has been proven to give repeatable results.

5.2 Test Fluid Temperature:

5.2.1 The temperature of the test fluid for the dirt capacity test shall be maintained at 85°F ± 5° (29°C ± 3°).

5.2.2 The temperature of the test fluid for the filter element efficiency test shall be maintained at 100°F ± 2° (38°C ± 1°).

5.3 Cleanup Filter: The cleanup filter elements used during testing and for initial cleaning of test fluids shall have a minimum efficiency of 99.5 gravimetric using 50 AC Fine Test Dust and 50 APM F-9 beads per MIL-F-81836. Filter elements meeting this efficiency will control silt sized particles which can affect both the particle counts at two (2) microns and the filter element's dirt capacity.

5.4 Pressure Measurements: Pressure measurements are to be performed in accordance with SAE ARP 24.

5.5 Test Housing:

5.5.1 The service filter housing shall be used whenever possible, and it shall be installed in a normal service attitude. If this housing contains a by-pass valve, it should be blocked and tested for zero leakage at twice the normal cracking pressure.

5.5.2 If a service filter housing is not available, the test housing shall duplicate the inside configuration, including size, direction and location of the inlet and outlet flow ports used in the service filter housing. The volume beyond the ends of the filter element can vary ± 10% of the corresponding volumes of the actual housing.

5.6 Test Hardware:

5.6.1 Vessels, conduits, reservoirs and fittings shall be selected with smooth contours, no pockets, and shall be properly oriented to prevent contaminant entrapment.

5.6.2 All lines shall be sized to maximize turbulent flow throughout the system.

5.6.3 Reservoirs shall be constructed with smooth conical bottoms that have an included angle of not more than 90 degrees.

5.6.4 Fluids entering the reservoir shall be diffused, as discussed in ANSI/B93.31. Diffusion should take place below the reservoir fluid surface in order to eliminate the formation of air bubbles. These air bubbles could adversely affect automatic particle counter readings. Reservoir diffusion can also aide contaminant dispersion.

5.6.5 All component parts of the dirt capacity test stand shall be electrically grounded to insure static electricity is discharged to earth. National and local fire and explosion safety standards should be observed when using JP-4 fuel for testing.

5.7 Particle Counting: On-line automatic particle counters shall be used to determine the number and size distribution of the contaminant particles in the fluid of the filter element efficiency test.

5.8 Cleanup Filter Element Weighing: Dry the cleanup filter element in an oven at 160° ± 10°F (71° ± 6°C) for one (1) hour and desiccate to room temperature. Weigh cleanup filter element to an accuracy of ± 0.1 gram. Place element in oven at 160°F for an additional 15 minutes, desiccate to room temperature, and weigh again. Repeat this procedure until two successive weights are within ± 0.1 gram or ± 1% the weight of the total contaminant added, whichever is greater.

6. DIRT CAPACITY TEST:

6.1 The dirt capacity test is to be performed according to SAE MAP 749 with several modifications. A diagram of the major components of the dirt capacity test apparatus is given as Figure 1.

6.1.1 The contaminant used shall be in accordance with Table X of MIL-E-5007, or as otherwise specified.

6.1.2 In order to insure repeatable results, the ratio of the test element flow rate to the contaminant reservoir (and optional bypass loop) volume must be greater than 0.2 for a 20 minute, or longer, test. This will insure the maximum error for Dirt Capacity measurement is limited to 2 percent.

6.2 Dirt Capacity Validation Procedure:

6.2.1 Validation Method:

6.2.1.1 Preclean the test fluid, using the system cleanup filter, to a maximum contaminant level of 3 mg/gal. The contamination level shall be determined by SAE ARP 785 procedures.

6.2.1.2 Install a free flow dummy element into the test housing per 5.5. The dummy element shall be the same as the test element without the filter media. If the test filter element is not constructed with a rigid support core, the dummy element shall be provided with a core having a minimum open area equal to twice the filter element outlet area and a diameter approximating the inside diameter of the media pack.

6.2.1.3 A new cleanup filter element per 5.3 shall be weighed per 5.8.

6.2.1.4 Install cleanup filter element in system.

6.2.1.5 Attain required system flow rate.

6.2.1.6 Add required amount of contaminant (W_1) to the reservoir using a belt feed system per SAE MAP 749 at the rate of one (1) gram per minute of contaminant per GPM of test system flow.

6.2.1.7 Allow flow to continue for an additional ten minutes after contaminant feed has been completed.

6.2.1.8 Obtain a one (1) liter (approximate) sample of fluid from sampling valve A.

6.2.1.9 Stop flow through the cleanup filter element. Remove cleanup filter element, thoroughly rinse with prefiltered degreasing solvent, and dry to a constant weight per 5.8. The difference between this weight and the original dry weight of the cleanup filter element per 6.2.1.3 is denoted W_2 (grams).

6.2.1.10 Weigh all contaminant washed off the cleanup filter element during degreasing as well as any contaminant remaining in the cleanup filter housing per SAE ARP 785. This contaminant weight is identified as W_3 (grams).

6.2.1.11 Obtain a gravimetric analysis of the sample taken in step 6.2.1.8 per SAE ARP 785. Convert this result into grams/liter. Multiply by the volume of the test system fluid (liters) to obtain W_4 (grams).

6.2.1.12 Calculate percent accountable contaminant using the following formula:

$$C = \frac{W_2 + W_3 + W_4}{W_1} \times 100$$

6.2.2 Validation Requirement: The test setup is considered validated if the percent of accountable contaminant (C) is between 95 and 100.

6.3 Dirt Capacity Test Procedures:

6.3.1 Test Method:

6.3.1.1 Preclean the fluid as described in 6.2.1.1.

6.3.1.2 Install the test filter element into the test housing.

6.3.1.3 Install a new cleanup filter per 5.3.

6.3.1.4 Open valves upstream and downstream of the filter and set rated flow through the test filter. Measure and record the test filter element differential pressure.

6.3.1.5 Add contaminant at the appropriate rate per SAE MAP 749 and start timer. For example, the required contaminant addition rate (grams per minute) equals the specified contaminant concentration level (grams per gallon) times the required flow rate through the filter (gallons per minute).

6.3.1.6 Record testing time (minutes) at 20, 40, 60, 80 and 100 percent of the test filter terminal differential pressure. Additionally, test filter differential pressure and time (minutes) shall be recorded at 30-minute intervals.

6.3.2. Test Data Reporting:

6.3.2.1 The results of dirt capacity testing should be presented as a curve showing differential pressure across the filter element (psid) versus contaminant weight added (grams).

6.3.2.2 Report the "Dirt Capacity" as the amount of contaminant, in grams, added into the test stand to reach the terminal differential pressure across the test filter element.

7. FILTER ELEMENT EFFICIENCY TEST:

7.1 General:

7.1.1 This procedure determines a filtration ratio designated the Beta value (β_X). The formula for determining the filtration ratios is:

$$\text{Filtration Ratio} = \beta_X = \frac{U_X}{D_X}$$

7.1.2 The filter element efficiency test is to be performed per the following procedures. A schematic diagram of the filter element test circuit is shown in Figure 2. The contaminant used shall be Air Cleaner Fine Test Dust per ISO 4402.

7.1.3 The target upstream gravimetric level (G_1) in milligrams per liter is defined as the desired contaminant weight per unit volume of fluid in the filter element test circuit challenging the upstream side of the test filter element. The target upstream gravimetric level shall not normally be less than 3 mg/l nor more than 10 mg/l in order to achieve a sufficient number of particles challenging the filter while minimizing saturation and dilution errors for the automatic particle counters.

7.1.4 The target gravimetric level shall be selected from 3, 5, or 10 mg/l to obtain (if possible) a test time of 30-120 minutes. The predicted test time (τ) can be calculated by dividing the estimated weight of AC Fine Test Dust (W_5) required to achieve terminal differential pressure by the base upstream gravimetric level (G_1) selected times the test element flow rate (F_1) per the following equation:

$$\tau = \frac{W_5 \times 1000}{G_1 \times F_1}$$

7.2 Contaminant Injection Circuit:

7.2.1 A turbulent means should be provided for transferring fluid from the contaminant injection circuit to the filter element test circuit to yield a flow rate (F_2) of at least 0.25 liters per minute.

7.2.2 The total fluid volume (V_1) of the contaminant injection circuit may be adjusted by varying the level of the fluid in the reservoir and shall be sufficient to contain the fluid volume required by the following equation:

$$V_1 = \frac{W_5 \times F_2 \times 1200}{F_1 \times G_1}$$

NOTE: Injection fluid volume may be increased as needed by increasing the amount of test dust proportionately.

7.2.3 Before adding contaminant, the cleanup filter element (Item 4 on Figure 2) per 5.3 shall clean the contaminant injection system to the extent that particles greater than two (2) micrometers in size do not exceed 200 per milliliter. Gravimetric analysis of fluid samples, taken from valve C, shall be less than two (2) percent of the required gravimetric level (G_2) of the contaminant injection circuit fluid, as shown by the following equation:

$$G_2 = \frac{G_1 \times F_1}{F_2}$$

7.3 Filter Element Test Circuit:

7.3.1 The total fluid volume (V_2) of the filter element test circuit shall be numerically equal (± 2 percent) to one-fourth the required filter element flow rate value (F_1). This volume may be attained by adjusting the reservoir fluid level. The filter element test circuit volume should be maintained within ten (10) percent of the initial volume during the test.

7.3.2 Valve D as shown in Figure 2, is for adjusting the amount of fluid to be discarded. Total fluid discarded must equal the contaminant injection flow rate.

7.3.3 Before adding contaminant, the filter element test circuit shall be sufficiently cleaned so that particles in each size range do not exceed five percent of the actual downstream test values using a cleanup filter (Item 1 on Figure 2) per 5.3.

7.3.4 Turbulent sampling means, in accordance with ISO 4021, shall be located upstream and downstream of the test element in order to provide fluid sample flow to the automatic particle counters (Items 2 and 3 on Figure 2). Flow to the automatic particle counters shall be high enough to minimize lag time. The portion of the sampling flow not passing through the counters may be returned to the filter element test circuit reservoir via a bypass line. Flow through the automatic particle counters may also be returned to the reservoir, or it may be discarded. Do not interrupt sample flow during the test.

7.4 Filter Element Efficiency Validation Procedures:

7.4.1 The contaminant used in the validation procedures is AC Fine Test Dust per 7.1.2.

7.4.2 The particle counters are calibrated in accordance with ISO 4402 for sizes given in Table A using contaminant per 7.1.2.

7.4.3 Contaminant Injection Circuit Validation:

7.4.3.1 Validate at the maximum injection circuit volume (V_1) to be used per 7.2.2 and the maximum contaminant injection circuit gravimetric level (G_2) specified per 7.2.3.

7.4.3.2 Preclean the injection fluid system per 7.2.3. then bypass the cleanup filter loop (Item 4 in Figure 2).

7.4.3.3 Dry the test contaminant per 7.1.2 at 275°F ± 25° (135°C + 14°) for one (1) hour and desiccate to room temperature prior to weighing.

7.4.3.4 Calculate the required amount of contaminant (W_6) to be added to the contaminant injection circuit per the following formula:

$$W_6 = \frac{G_1 \times F_1 \times V_1}{F_2 \times 1000}$$

7.4.3.5 Add the required quantity of contaminant (W_6) to the contaminant injection circuit reservoir fluid and circulate for two (2) hours.

7.4.3.6 Extract fluid samples at 30, 60, 90 and 120 minutes. Analyze each sample gravimetrically per SAE ARP 785.

7.4.3.7 Validation Requirement: The gravimetric level of each sample taken in 7.4.3.6 shall be within ten percent of the average of the four samples and within five percent of required gravimetric level (G_2) per 7.2.3 for acceptable validation of the test stand contaminant injection circuit.

7.4.4 Filter Element Test Circuit Validation:

7.4.4.1 Install a straight pipe in place of the filter element test housing.

7.4.4.2 Adjust the volume (V_2) of fluid in the filter element test circuit per 7.3.1. Clean fluid to level required in 7.3.3 by using the filter element test circuit cleanup filter (Item 1 on Figure 2).

7.4.4.3 Adjust the filter element test circuit to the required flow rate (F_1) (±2%). Adjust the test circuit fluid temperature per 5.2 as measured at the filter element housing inlet.

7.4.4.4 Contaminant Addition:

7.4.4.4.1 Dry contaminant per 7.4.3.3.

7.4.4.4.2 Calculate the required amount of contaminant (W_7) to be added to the filter element test circuit reservoir per the following formula:

$$W_7 = \frac{G_1 \times V_2}{1000}$$

7.4.4.4.3 Add the required quantity of contaminant (W_7) per 7.4.4.4.2 to the filter element test circuit reservoir to yield the target (3, 5, or 10mg/l) base upstream gravimetric level of the test circuit (G_1) per 7.1.3. Circulate the contaminant through the filter element test circuit for fifteen minutes prior to starting the particle counters.

7.4.4.5 With the automatic particle counters connected in-line, set particle counter to count for 60-second intervals. Synchronize the counting periods of the two automatic particle counters as closely as possible. Size ranges to be counted are per Table A. Record 30 one-minute counts at each size range.

7.4.4.6 Validation Requirements: The filter element test circuit is only valid if all the following apply:

7.4.4.6.1 There is less than a ten percent difference between the cumulative particle counts obtained from the upstream counter at each 60-second counting interval in each size range and the cumulative counts obtained from the downstream counter for the same sized particles during the corresponding count interval.

7.4.4.6.2 The average particle counts obtained for a given size for the first ten minutes do not deviate more than ten percent from the average particle counts of that size from the last ten minutes for each particle counter.

7.4.4.6.3 The average particle counts per milliliter for each size range is within the appropriate interval given in Table B for each particle counter.

7.5 Filter Element Efficiency Test Method:

7.5.1 Test Preparation:

7.5.1.1 Install the filter element test housing with a flow-through dummy filter element per 6.2.1.2 into the element test circuit.

7.5.1.2 Adjust the fluid volume of the filter element test circuit to the required volume (V_2) per 7.3.1.

7.5.1.3 Adjust the fluid volume (V_1) of the contaminant injection circuit per 7.2.2.

7.5.1.4 Start filter element test circuit automatic particle counters.

7.5.1.5 With contaminant injection flow stopped to the filter element test circuit reservoir, circulate the fluid in both circuits through the cleanup filter elements (Items 1 and 4 on Figure 2) until the required cleanliness levels are attained per 7.2.3 and 7.3.3.

7.5.1.6 Record the differential pressure drop at rated flow across the test housing with the dummy element installed.

7.5.1.7 Bypass the contaminant injection circuit cleanup filter element (Item 4 on Figure 2).

7.5.1.8 The test contaminant per 7.1.2 shall be dried per 7.4.3.3 and weighed per 7.4.3.4.

7.5.1.9 Add the required amount of contaminant (W_6) to the contaminant injection circuit reservoir and allow mixing for 30 minutes to throughly disperse the contaminant.

7.5.1.10 Stop filter element test circuit flow. Install the filter element to be tested into the test housing. Readjust filter element test circuit volume (V_2) per 7.3.1 as required.

7.5.1.11 Restart, adjust, maintain and record actual filter element test circuit flow rate (F_1) and temperature per 7.4.4.3.

7.5.1.12 Continue to circulate until required cleanliness levels per 7.3.3 are once again achieved then bypass the filter element test circuit cleanup filter (Item 1 on Figure 2).

7.5.1.13 Record the differential pressure drop at rated flow (F_1) across the test housing with the test filter element installed.

7.5.2 Filter Element Efficiency Test Procedure:

7.5.2.1 Start recording particle counts per Table A. Set counting intervals per 7.4.4.5.

7.5.2.2 Once counts have stabilized, record five one-minute counts at each size range. These are the blank (control) counts.

7.5.2.3 While the injection system continues recirculating, collect 500-ml (approximate) sample from Valve C.

7.5.2.4 Start flow from contaminant injection system to the filter test system. Maintain and record the required injection flow rate per 7.2.1.

7.5.2.5 Start test recording timer.

7.5.2.6 Maintain the total volume (V_2) of fluid in the test system, as described in 7.3.1 and 7.3.2, throughout the test.

7.5.2.7 Obtain automatic particle counts continuously, with one-minute counting intervals, throughout test. If the predicted test time per 7.1.4 is less than 20 minutes, the counting interval shall be reduced to one-half minute.

7.5.2.8 Collect another 500-ml (approximate) sample of the contaminant injection fluid at completion of test. Also record the final injection flow rate.

7.5.2.9 When the required differential pressure across the test filter element is reached, stop timer, stop fluid sampling flow, stop injection flow from the contaminant circuit, and stop flow through the test filter element.

7.5.2.10 Analyze gravimetrically (mg/liter) per SAE ARP 785 the two samples extracted from the contaminant injection circuit (per paragraphs 7.5.2.3 and 7.5.2.8).

7.6 Test Data Reporting:

7.6.1 Calculations:

7.6.1.1 Calculate and record the average of the two gravimetric levels (G_2) (mg/liter) analyzed in 7.5.2.10. The gravimetric level of each sample is to be within ten percent of this average for the test to be valid.

7.6.1.2 Calculate and record the average contaminant injection circuit flow rate (F_2) (liters/minute) by using values recorded in 7.5.2.4. and 7.5.2.8. This value must be within ± 5 percent of the required rate.

7.6.1.3 Calculate and record the base upstream gravimetric level (G_1) achieved during the test by multiplying the average injection gravimetric level (G_2) (7.6.1.1.) by the average injection flow rate (F_2) (7.6.1.2) and dividing by the actual filter element test circuit flow rate per (F_1) 7.5.1.11.

7.6.1.4 Average and record the upstream and downstream test results taken in 7.5.2.7 for each size range over the entire length of the test (from a clean filter to termination pressure drop).

7.6.1.5 Average and record the five one-minute upstream and downstream blank (control) counts taken in 7.5.2.2 for each size range. Also record the maximum downstream blank count at each size range.

7.6.1.6 The average upstream blank (control) counts shall be less than one percent of the average upstream results (G_1) per 7.6.1.3. The maximum downstream blank count at each size range shall be less than five percent of the actual average downstream test results recorded in 7.6.1.4.

7.6.1.7 Calculate and record the beta values (β_x) at each particle size level of Table A by dividing the average upstream counts by the average downstream counts recorded in 7.6.1.4.

7.6.1.8 Calculate the initial (clean) element differential pressure drop at rated flow by subtracting the tare value per 7.5.1.6 from the assembly value per 7.5.1.13.

7.6.2 Data Presentation:

7.6.2.1 The results of filter element efficiency testing should be plotted on semi-log graph paper with the filtration ratio (Beta) plotted on the log-scale and the particle size range (x), in micrometers, plotted on the normal scale.

7.6.2.2 The filtration ratios for at least two sizes shall be reported to define the filter element efficiency.

7.6.2.3 Report calibration procedure of automatic particle counters used during the filter element efficiency test.

7.6.2.4 Report the initial (clean) differential pressure drop of the filter element (net) at rated flow per 7.6.1.8.

7.6.2.5 Figure 3 provides a standard form that may be used to present the filter element efficiency test data.

8. LESSONS LEARNED:

8.1 Deviations from the conditions stated in this ARP can alter the results obtained. If deviations are made they should be reported. (e.g. - alternative fluids used).

8.2 A slurry injection system used in lieu of belt feeds per this ARP for Dirt Capacity testing will result in a different dispersion of the contaminant. This, in turn, may result in varying dirt capacity values for the same filter.

8.3 It has been found that a diatomaceous Fuller's Earth filter per 5.1.1 is the easiest method of maintaining the fuel IFT in the dirt capacity test. Local deviations are acceptable but should be reported.

8.4 The contaminants required in 6.1.1 and 7.1.2 must receive proper care and handling to insure repeatable test results. They should be stored in tightly sealed containers to prevent humidity incursion. Prior to use, the contaminants should be dried and mechanically stirred. This will prevent agglomeration and insure a homogeneous mixture.

8.5 The flow versus volume ratio given in 6.1.2. is derived from the formula:

$$\frac{\text{Flow of test element (gpm)}}{\text{Volume upstream of element (gal.)}} \geq -\frac{\text{(natural log of the maximum error allowed)}}{\text{Time of test (min.)}}$$

This formula may be used when the maximum permissible error is different than 2 percent (0.02 in the formula above) or the time to complete the test is less than 20 minutes. Use of this formula insures rapid equilibrium of the upstream contamination level, minimizing dirt capacity variations.

8.6 A bypass loop between the pump and the dirt capacity test housing, which returns to a subsurface diffuser in the reservoir, has been found to increase dispersion of the contaminant in the reservoir. This loop also aids in adjusting the required flow rate to the test housing per 6.2.1.5.

8.7 This ARP allows measurement of filter element efficiencies up to 99.98 percent by particle count. This is equivalent to one particle passing through the filter element for every 5000 particles challenging it. This is reported as a filtration ratio (Beta value) of 5000 or $\beta_X = 5000$.

8.8 The filter element efficiency procedure of this ARP accomplishes high sensitivity by incorporating the following:

8.8.1 Automatic particle counting

8.8.2 In-line sampling

8.8.3 High efficiency cleanup filter elements

8.8.4 Low control (blank) counts required at the start of testing

8.9 The high sensitivity for filter element efficiency obtained by this ARP has the advantages to the user of:

8.9.1 High reliability of the test procedure for any filter element efficiency (filtration ratio) up to Beta = 5000 for particle sizes between 2 and 25 microns is insured.

8.9.2 Significant filter element leakage can now be identified. One percent leakage means the maximum filtration ratio obtainable is 100 for all size ranges.

8.9.3 Filter element efficiencies for several particle sizes can be quantified during one test.

8.10 Current automatic particle counters cannot differentiate between air bubbles, water droplets, and contaminant particles. It is, therefore, essential that the MIL-H-5606 test fluid used for the filter element efficiency tests be free of water and that precautions be taken to prevent air entrapment (such as the diffusers recommended in 5.6.4).

8.11 Data reporting is as required for each application. If applicable, the particle size at which the filtration ratio equals 5000 is designated the Quantitative Dirt Removal Rating. The filtration ratio for particles greater than 2 micrometers is designated the Silt Control Rating. It is recommended that the Silt Control Rating be reported if $\beta_2 \geq 2$.

8.12 An appropriate size sample can be taken from a turbulent upstream sampling valve (Valve A in Figure 2) at the 80 percent level and analyzed. This sample may be used for comparative purposes to insure the targeted upstream gravimetric level has been achieved per 7.6.1.3.

8.13 Free flow dummy elements per 6.2.1.2 and 7.5.1.1 are recommended to prevent differential pressure measurement errors due to hardware variations and pressure sensing port locations. Without these dummy elements, the clean element differential pressure may actually be a negative number when used in certain filter housings.