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(R) Aircraft Turbine Engine Fuel System Component Endurance Test Procedure (Room Temperature Contaminated Fuel)

RATIONALE

This document has been revised to: (1) Update and clarify the references. (2) Clarify that the test system schematics depict pumps as the test components, although other components may be tested by locating them downstream of a test system pump. (3) Replace NAS 1638 by the more contemporary AS4059 for fluid cleanliness levels (Table I of AS4059 is the same as the NAS 1638 cleanliness levels). (4) Update Figures 1 and 2 to conform to modern hydraulic circuit symbols and to be consistent. (5) Replace the facility filter specification MIL-F-27656 by MIL-PRF-81836 specification. (6) Delete 3.7.2, referencing gravimetric analysis of samples from the pump by-pass loop, since it is out of context in this location. (7) Clarify sampling for gravimetric analysis in 10.3. (8) Editorial changes for clarity.

MAP749C has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

1.1 This SAE Aerospace Recommended Practice describes a method for conducting room temperature, contaminated fuel, endurance testing when the applicable specification requires nonrecirculation of the contaminants. The objective of the test is to determine the resistance of engine fuel system components to wear or damage caused by contaminated fuel operation. It is not intended as a test for verification of the component's filter performance and service life. ARP1827 is recommended for filter performance evaluation.

1.2 The method described herein calls for nonrecirculation of the contaminants and is intended to provide a uniform distribution of the contaminant at the fuel system inlet. Two systems for contamination addition are included, the conveyer and the slurry injection system.

2. REFERENCES

2.1 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Aerospace Technical Report.

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.

ARP492 Aircraft Engine Fuel Pump Cavitation Endurance Test

ARP785 Aerospace - Procedure for the Determination of Particulate Contamination in Hydraulic Fluids by the Control Filter Gravimetric Procedure

ARP1827 Measuring Aircraft Gas Turbine Engine Fine Fuel Filter Element Performance

AIR4023 Aircraft Turbine Fuel Contamination History and Endurance Test Requirements

AS4059 Aerospace Fluid Power - Contamination Classification for Hydraulic Fluids

AIR4246 Contaminants for Aircraft Turbine Engine Fuel System Component Testing

2.1.2 Military Publications

Available from DLA Document Services, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6396, http://quicksearch.dla.mil/.

MIL-E-5007[1] Engines, Aircraft, Turbojet and Turbofan, General Specification for

MIL-E-8593[2] Engines Aircraft, Turboshaft and Turboprop General Specification for

MIL-PRF-7024 Turbine Fuel, Aviation, Grades JP-4 and JP-5

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

MIL-DTL-83133E Turbine Fuels, Aviation, Kerosene Types, Nato F-34 (JP-8), Nato F-35, And JP-8 + 100

MIL-PRF-81836 Filter and Disposable Element, Fluid Pressure, Hydraulic 3 Micron Absolute, General Specification For

JSSG - 2009 Air Vehicle Subsystems

2.1.3 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 D971 Interfacial Tension of Oil Against Water by the Ring Method

ASTM D1094 Test for water reaction of Aviation Fuels

ASTM D1655 Standard Specification for Aviation Turbine Fuels

ASTM D3240 Standard Test Method for Undissolved Water in Aviation Turbine Fuels

[1] MIL-E-5007 is inactive for new design as of January, 1997.
[2] MIL-E-8593Ais inactive for new design and is no longer used, except for replacement purposes, effective October 15, 1975.

2.1.4 U. K. Military Specifications

Available from Defence Equipment and Support, U. K. Defence Standardization, Kentigern House, 65 Brown Street, Glasgow G2 8EX, United Kingdom, Tel: +0141 224 2531/2, Fax: +0141 224 2503, http://www.dstan.mod.uk

Defence Standard 91-91, Issue 6 Turbine Fuel, Aviation Kerosine Type, Jet A-1, NATO Code: F-35, Joint Service Designation: AVTUR.

3. TEST SETUP

Typical arrangements for the conveyor system and the slurry injection system are shown in Figures 1 and 2, respectively. These arrangements depict a fuel pump being tested. However, for testing other fuel system components, those components should be placed immediately downstream of a test system pump.

3.1 General Requirements

3.1.1 Test Fluid

Fluid conforming to the applicable component specification. (The system primary fuel is recommended.)

3.1.2 Test Fuel Temperature

Control is not necessary unless required by the applicable component specification. The construction of the test facility and instrumentation should be reviewed to assure that it is compatible with the fluid, pressures, and temperatures required in the test. For example, standard system cleanup filters may not be designed for operation above 49 °C (120 °F).

3.1.3 Ambient Temperature

Control is not required.

3.1.4 Component Inlet Pressure

0 to 170 kPa (0 to 25 psig) or as otherwise specified by the test specification. Facility pumps may be utilized to achieve this pressure providing they do not interfere with the flow and distribution of the contaminants.

3.1.5 Mounting

Each component shall be mounted in its normal, level flight attitude by its mounting pad. Actual system installation plumbing should be used when possible for connection of test components if two or more components are tested together; where actual installation plumbing is not available, system installation line sizes, lengths, and bends shall be duplicated as closely as possible.

3.1.6 Supply Tank

The size of the supply tank is optional. However, it is recommended that the size of the tank be kept small and have the capability to be checked inside to assure there is no buildup of contaminant and water (see Figure 3).

3.1.7 Receiving Tank

The use of a receiving tank is optional. The receiving tank should also be kept small and have the capability of being checked inside to assure there is no buildup of contaminant and water. (The supply tank and the receiving tank may be combined.)

3.1.8 The entire test system should be electrically grounded.

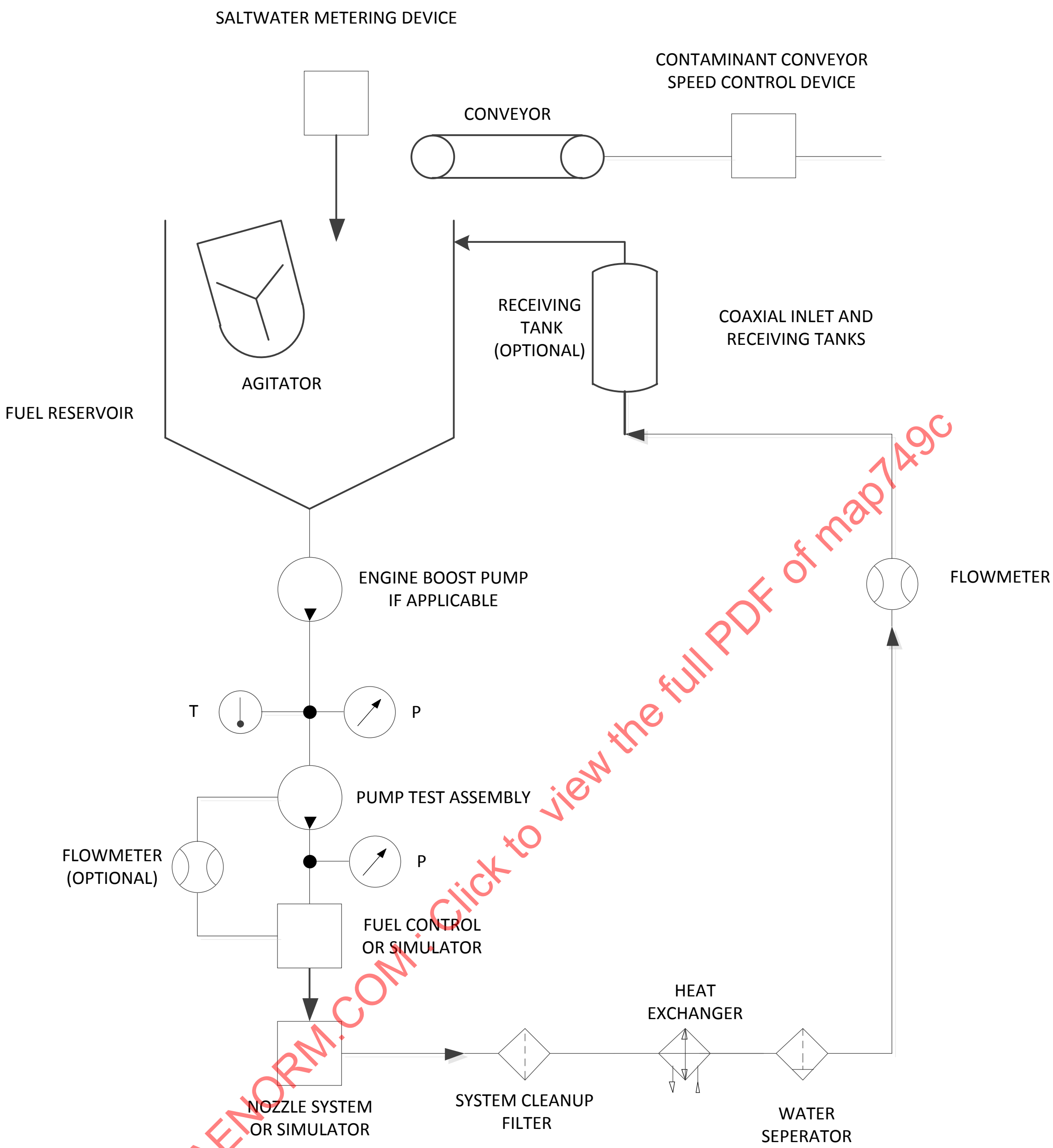

Figure 1 - Conveyer test setup

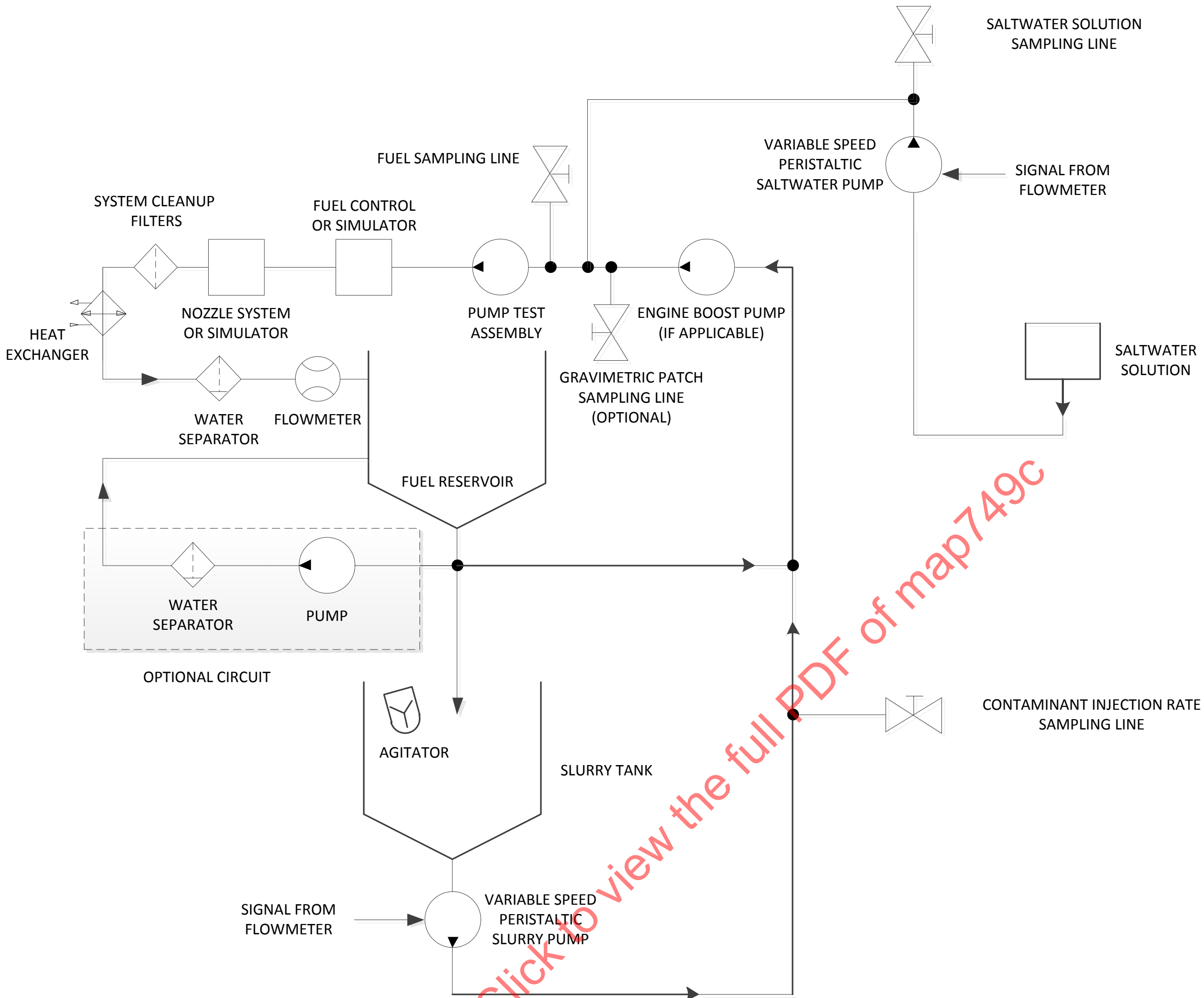

Figure 2 - Slurry injection system - test setup

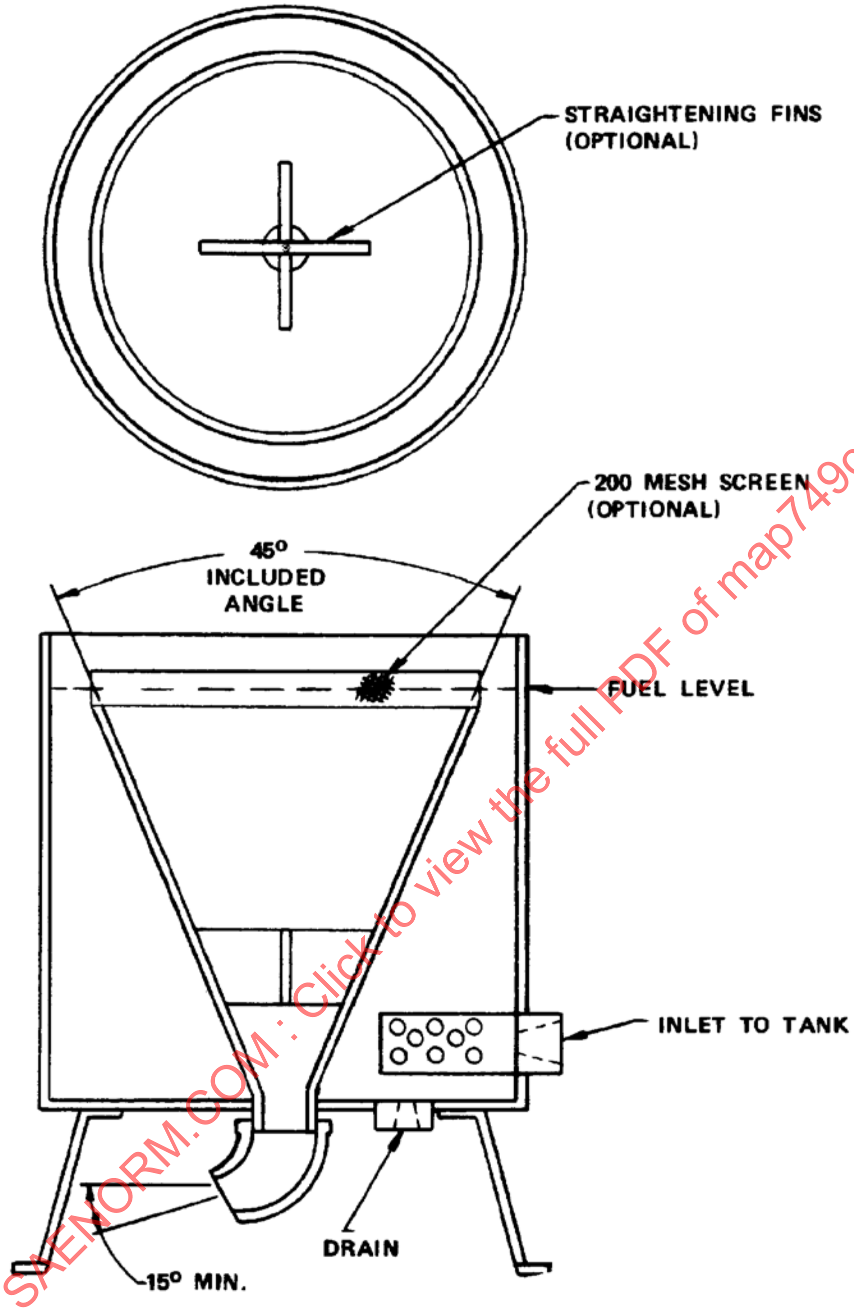

Figure 3 - Aircraft turbine engine fuel system component endurance test (contaminated fuel) supply tank

3.2 Plumbing

3.2.1 The supply line to the fuel system component inlet shall not be smaller than the diameter of the component inlet port. The line shall be smooth and avoid interruptions to trap contaminants. The length of the inlet piping from the supply tank shall not exceed 3.6 m (12 feet) when using the conveyer system. An inlet line downward slope of not less than 15 degrees with no low spots or flat areas is recommended to insure even contaminant distribution and ingestion.

Should a rising slope be required, care should be exercised to give a velocity that will maintain the contamination in suspension, usually 5 to 10 feet/second. With the injection method, the line length is not as critical since the injection is done at the pump inlet.

All lines, fittings, etc., that are in contact with the test fluid should be stainless steel (300 Series).

3.2.2 An optional fuel sampling valve may be installed immediately upstream of the system or component being tested (as shown in Figure 2).

3.2.3 The routing of return plumbing to the supply tank from the discharge of the fuel system test components is not critical other than to assure the recirculated fuel is properly cleaned and excess water removed. The heat exchanger should always be downstream of the cleanup filters to protect it from any contamination buildup.

3.2.4 The plumbing from the injection point to the component on test should be inspected to minimize traps or discontinuities where contamination or lint could accumulate at low flow rates and be sucked out and slug the component at higher rates.

3.3 Facility Filters

Very fine facility filters are required to remove the contaminant (solid and lint), such as iron oxide fines, from the fuel prior to the return of the fuel to the supply tank. These filters will also prolong the life of the water separator elements. It is recommended the filters conform to MIL-PRF-81836 specification, or equivalent.

3.3.1 The facility filter capacity shall be sufficient to allow a reasonable test period before cleaning is required, preferably in excess of 10 hours. The filter(s) shall be arranged in parallel banks so that one bank can be serviced while using the other(s). The filter differential pressure should be monitored and should be serviced at 85 to 95% of its rated change-out differential pressure.

3.4 Facility Water Separator

A facility water separator device shall be used to remove free, entrained salt water from the fuel prior to the return of the fuel to the supply tank. The water separator should always be located at the lowest point in the system.

In the set-up in Figure 2, an optional water separator may be located in a separate flow loop connected to the tank to better control the water content level if the duty cycle flow variation exceeds the capability of the separator in the normal flow sequence with the slurry system. With the addition of water directly into the tank, as in the set-up in Figure 1, the water separator cannot be relocated.

3.5 Facility Heat Exchanger

If a facility heat exchanger is used to lower the fuel temperature, it must be located downstream of the cleanup filter(s) and must be located upstream of the water separator. The design of the heat exchanger should be such that lint/contamination will not collect and plug the heat exchanger passages. Contamination testing with elevated fuel temperatures is normally not required.

3.6 Functional Cycling Simulation

The cyclic variations in system fuel flow shall be accomplished through the use of the fuel control or a fuel control simulator.

Where this is impractical, a duty cycle should be defined and automated cycling equipment provided to repetitively reproduce the desired duty cycle using facility valves as necessary.

3.6.1 An example of a functional cycling requirement is shown in Figure 4. The applicable component specification will detail specific cycling operating conditions of speed, flow, pressure and time, rates of change of these parameters, and the shutdown periods.

3.6.2 The contaminants shall be introduced to the fuel system for all phases of the cycle except for shutdowns.

3.6.3 The scheduling of events can be programmed through the use of timers, solenoid valves, etc.

3.6.4 The contamination type, size, and concentration shall be as described in the applicable specification. AIR4246 provides a guide for the contamination normally specified for fuel system components.

3.7 System Changes

3.7.1 Periodically, the test system may be stopped to recharge the contaminant and to clean the rig filters. Fuel may be changed as frequently as necessary to maintain supply tank fluid background cleanliness of Class 5 or better per AS4059, Table 1, for residual contamination level.

3.7.2 The interfacial tension (IFT) measurement between the fuel and air, at the start of the test, shall be measured per ASTM D971, and have a value in excess of 35 mN/m (dynes/cm). The test fuel shall be changed when the interfacial tension measurement decreases 8 to 10 mN/m (dynes/cm) from the initial measurement.

A second method of ensuring minimal surfactancy is to use the water interface reaction test per ASTM D1094 as an easy alternative. The minimum interface classification should be per paragraph (1)b as defined in Table 1 of ASTM D1094. A clean fuel start separation of (one) per ASTM D1094 should have a tolerance rejection when the value exceeds two.

3.7.3 When conducted, the interfacial tension measurement tests shall be made at least once every 24 hours using fuel samples from the supply tank.

3.8 Test Facilities Maintenance

3.8.1 It is desirable to establish what action would be taken as a result of test facility shutdowns. However, in lieu of a negotiated position, the following actions are suggested.

If testing is interrupted because of a test facility failure for more than one normal shutdown period or 4 hours, whichever is longer, advisory action is suggested, as follows:

a. The test components shall be flushed with the applicable clean test fluid without disassembly.

b. The test components shall then be stored immersed in clean test fluid or suitably inhibited from additional contamination effects until the test is resumed.

c. If test components have been preserved because of facility failures, the testing shall be resumed at the point where facility failure was experienced without penalty.

A facility shutdown that is not scheduled may be counted as a normal shutdown if the required procedure in the equipment specification is followed.

3.8.2 The test system between the fuel tank and the system cleanup filters shall not be disassembled for maintenance before a shutdown period is completed (if shutdowns are a requirement).

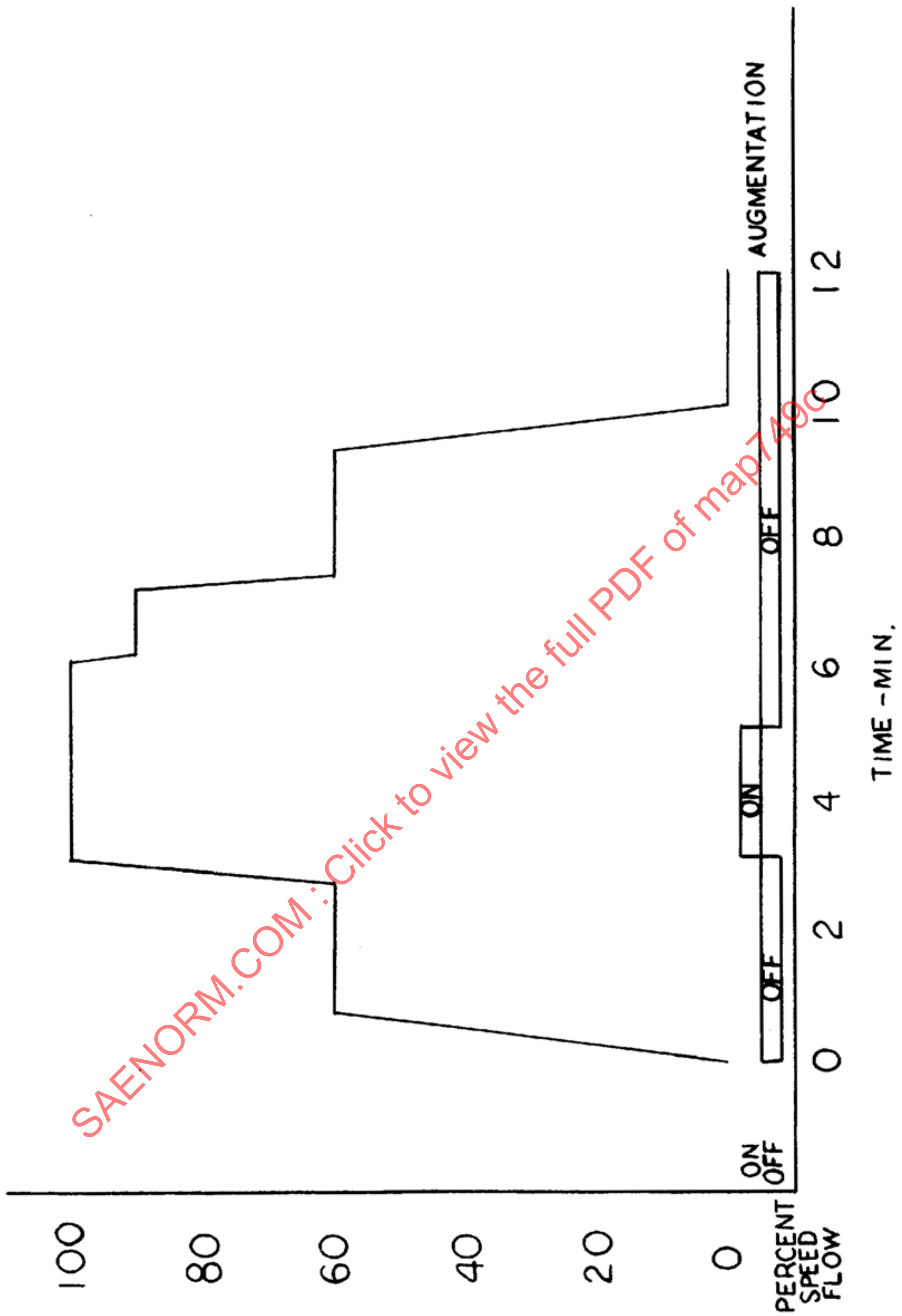

Figure 4 - Functional cycling requirement

3.9 Termination of Test

3.9.1 The test shall be terminated at the point where the fuel system components have been operated as required under the applicable specification.

3.9.2 The fuel system components shall be functionally tested using the specified clean fluid after completion of the contamination test requirements.

3.9.3 It is frequently necessary to terminate the test for adverse reasons prior to successful conclusion. Causes requiring termination should be negotiated in advance and clearly specified before the test is started. These causes may include shutdowns for unscheduled maintenance in excess of 24 hours, malfunction of the contamination injection system, obvious component malfunction, ruptures of test stand filters, etc.

Provisions should be made in advance, when concurrence is required, for termination prior to successful completion of the test.

4. CONTAMINATION TEST CIRCUIT

Two systems are described for injection of the contamination into the inlet fluid for the test component. Either system is acceptable for compliance to this recommended procedure.

4.1 Conveyer System

4.1.1 Circuit Schematic

A typical system arrangement is shown in Figure 1.

4.1.2 Circuit Components

4.1.2.1 Tanks

The supply tank shall be stainless steel or an inert material (plastic, rubber, Teflon®, etc.) and of the recommended configuration of the supply tank as shown in Figure 3. A mixing device should be used within the funnel to prevent slugs of contaminant from entering the fuel system inlet. A pneumatic or electrically (explosion-proof) driven nonferrous propeller is acceptable for the application.

4.1.2.2 Contaminant Conveyer

The design of the conveyer is optional. A suggested design is shown schematically in Figure 5.

The width, length, and speed of the conveyer belt should be sufficient to handle the required amount of dry contaminant for a minimum of 1 hour without exceeding a depth of 13 mm (1/2 inch). This will minimize a tendency to produce dirt slugs.

The contamination is loaded on the belt in terms of grams per inch of belt, and the belt is driven in terms of inches of belt per minute per gallon per minute of engine flow through the flow meter. The result is expressed in terms of grams of contaminant per gallon of fluid through the flow meter.

The speed of the conveyer is controlled so that it is proportional to fuel flow through the test component's inlet. The flow sensing system used should have a linear output from the component minimum flow to the component maximum rated flow.

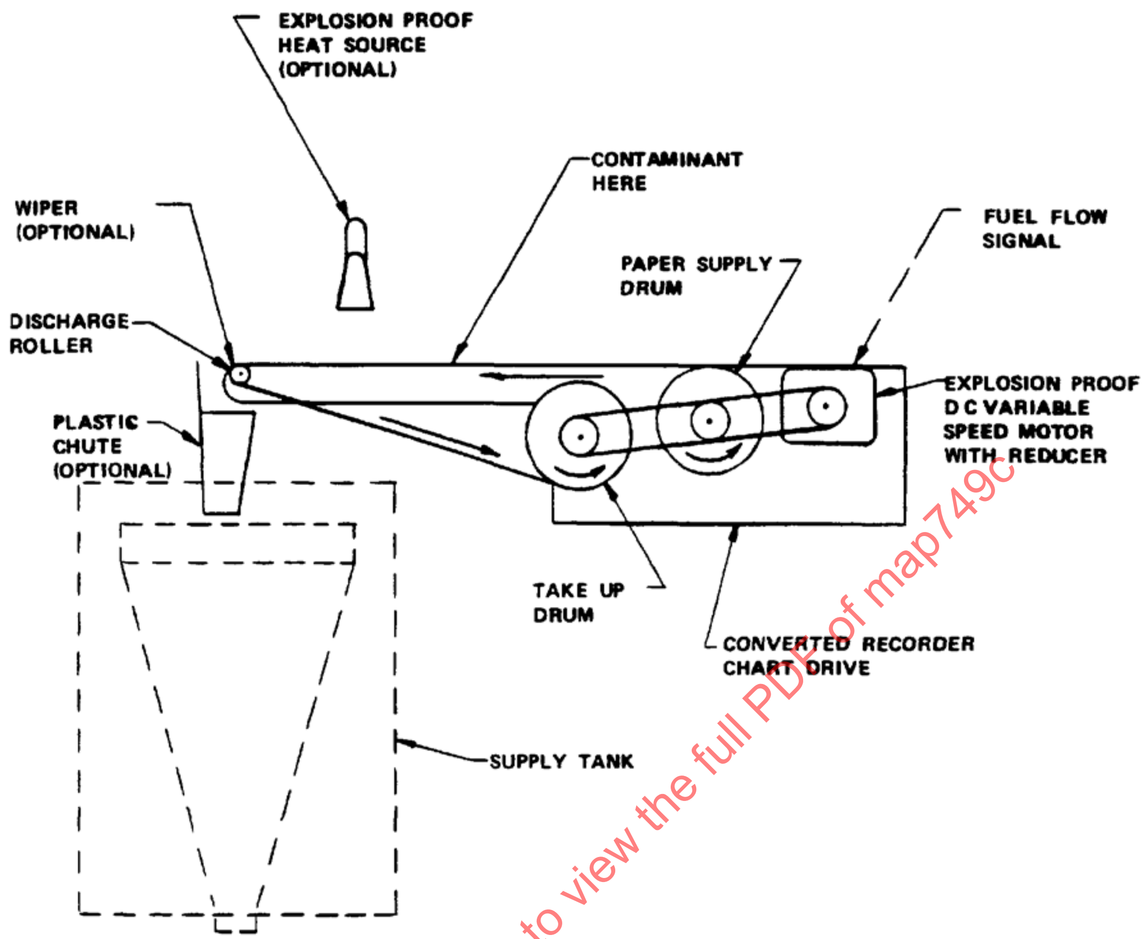

Figure 5 - Suggested conveyor design

4.1.2.3 Saltwater Injection

The saltwater (the quantity determined from the system flow for the 1-hour trial period) may be introduced by a metering device into the funnel outlet neck portion of the supply tank. Introduction of the water at this point will help eliminate contaminant slugs from accumulating in the supply (inlet) line.

When continuous addition is not specified, the required amount of water is normally added to the system based on the total volume of fuel, and the water separator is removed from the test circuit.

4.1.2.4 Test Preparation

All instrumentation shall be calibrated prior to the start of the testing.

The entire test setup shall be prepared for a start.

Instrumentation "zero" readings shall be made, and the empty conveyer belt shall be marked for "start travel" position.

The test setup shall be run for 1 hour to the applicable component duty cycle (sample cycle shown in Figure 4) with clean fuel.

At the completion of the 1-hour trial period, the total flow and conveyer travel shall be recorded. The solid contaminant and quantity of saltwater required shall be computed.

The solid contaminant, with the exception of the lint, shall be thoroughly mixed by tumbling and then evenly distributed along the length of the conveyer, corresponding to the intended length of the run.

The lint shall be evenly distributed along the conveyer as a separate ingredient or evenly distributed under the contamination.

4.2 Slurry Injection System

4.2.1 Circuit Schematic

A typical system arrangement is shown in Figure 2.

4.2.2 Circuit Components

4.2.2.1 Slurry Tank

The tank shall be stainless steel or an inert material (plastic, rubber, Teflon®, etc.), of a suitable volume and with a sloping bottom that supplies the contaminant slurry mix to the injection (peristaltic) pump. A suitable agitator is needed to keep the contaminants suspended in solution prior to injection. The agitator may be either pneumatic or electrically (explosion proof) driven with a nonferrous impeller.

4.2.2.2 Injection (Peristaltic) Pumps

These pumps shall be suitably sized, variable speed, peristaltic pumps used to inject both the contaminant and the saltwater at rates proportional to the fuel flow of the test component's inlet. Fuel-resistant Tygon® or clear plastic tubing of appropriate size, fuel compatible, may be used on the slurry pump injection line. Water-compatible Tygon® or clear plastic tubing of appropriate size may be used on the saltwater injection line.

Contamination is prepared to be injected in terms of grams per gallons per minute per gallon of engine flow using a concentrated contaminated fuel solution. The result is expressed in terms of grams of contamination per gallon of delivered fluid (excluding system bypass flow) through the system flow meter.

The speed or injection rate of the injection pumps is controlled so that it is proportional to the fuel flow through the inlet of the test component. The flow sensing system used should have linear output from the component minimum flow to the component maximum rated flow.

4.2.2.3 Slurry Mixture Preparation

1. Select a desired injection rate to be used for the lowest system flow encountered during the duty cycle. Experience has indicated that this injection rate should be 30 cm^3/min or greater in a 3.175 mm (1/8 inch) O.D. line to ensure a high enough fluid velocity to keep the contaminant in suspension.

2. The remaining injection rates corresponding to the higher engine flows in the duty cycle are then determined by the ratio of the higher system flows to the lowest system flow.

3. Next, the total number of cubic centimeters injected is calculated (using the above injection rates) for one duty cycle of the unit being tested. This gives the theoretical number of cubic centimeters of slurry injected per duty cycle and effectively sizes the slurry tank depending on how long the operator desires for one slurry load to last. The total amount of fuel flowed through the test unit is also calculated to give the theoretical number of gallons flowed through the test unit per duty cycle.

4. The size of the slurry tank/load should be chosen so that the slurry will last at least one duty cycle minimum, usually more, depending on the duration of a cycle. This is to allow the test operator time to monitor the amount of slurry in the tank during testing, which gives a good indication as to whether the injection rates are correct and to monitor whether the injection system is plugged. A 5-gallon slurry has been successfully used which would typically last 2 hours depending on the injection rates selected.

5. The contaminant amount required (typically stated in number of grams of contaminant per 1,000 gallons of fuel flowed through the test unit) is calculated for one duty cycle by using this ratio times the number of gallons of fuel flowed through the test unit for one cycle. The ratio of the above number of grams of contaminant to the theoretical amount of slurry injected per cycle times the slurry load size (in gallons) equals the amount of contaminant to be mixed with the desired slurry load. This is repeated for each contaminant in the specification to give a mixture that is for the desired slurry load. The normal maximum concentration of contaminant in the slurry solution is 15 g/gal of fluid.

6. Typically, mixtures are made 5% heavier than the theoretical ratios to account for some coating of the inlet line during resting.

7. Using ratios, it is easy to vary the slurry concentrations and/or injection rates in the event problems are encountered with the system plugging due to low injection rates and/or high contaminant slurry concentrations. As long as the number of grams of contaminant injected per cycle is as calculated in step 5, the required amount of contaminant is being introduced to the unit under test.

8. Saltwater injection rates are determined by the ratio of the number of gallons of saltwater per 1,000 gallons of fuel flowed through the test unit times the number of gallons actually flowed through the test unit.

4.2.2.4 Test Preparation

All instrumentation shall be calibrated prior to the start of the testing.

Injection rates are selected and slurry mixes are calculated to ensure that the contaminant injected into the test component's inlet is of the correct concentration.

Slurry injection lines should be made as short as possible to minimize the possibility of the contaminant settling out of solution and plugging up the injection line. It is also desirable that the injection line be installed so that it slopes "downhill" to the injection pump and to the test circuit injection point.

The test circuit injection points for the slurry and the saltwater should be made separate with the slurry point well upstream of the saltwater point. The saltwater injection point should be as close as possible to the test component with the contamination injection point 4 to 10 diameters upstream. This will help minimize the formation of dirt slugs prior to entering the test component's inlet port.

The entire test setup shall be prepared for a start.

Instrumentation "zero" readings shall be made and the calculated slurry loads added.

Prior to starting the test, the test setup including the test component shall be run for 1 hour with clean fuel and one clean slurry load (no contaminants) to the applicable component duty cycle (sample shown in Figure 4) to verify that the injection rates are correct and that the slurry load will last the correct (calculated) amount of time.

5. CONTAMINATED FUEL TEST (CONVEYER OR SLURRY SYSTEM)

5.1 Criteria for replacement and/or cleaning of system filter elements shall be established by test specification prior to the start of the test.

5.2 The test system will be started and advanced to the first test condition as required by the duty cycle at the rate required by the applicable specification.

5.3 Within 10 seconds of reaching the first test condition, the contamination injection system (conveyer or slurry) and saltwater introduction shall be started.

5.4 Establish the test cycle conditions as required by the applicable specification.

5.5 Data recordings shall be made to insure component compliance with the applicable specification.

5.6 The test shall continue for the time, or cycles, specified in the applicable specification requirement.

5.7 The test component and contaminant system shall be shut down within a 30-second period with the contamination system being shut down first. The entire system shall remain undisturbed for the entire shutdown period (if specified).

5.8 Control of ambient conditions during shutdown is not required.

5.9 After completion of the shutdown period, system maintenance may be performed.

5.10 Repeat 5.2 through 5.9 until the completion of the required number of test hours or cycles.

6. DATA

Prior to the start of the endurance test, a detailed test procedure shall be prepared. Some of the information supplied in a typical procedure follows.

6.1 Pretest Data

6.1.1 Pretest Component Inspection or Performance Data

Selected hardware should be measured for a base line when wear rates/erosion rates are desired for determination of the rate of hardware deterioration.

6.1.2 A detailed test system schematic showing all components and connecting plumbing.

6.1.3 Component installation instructions.

6.1.4 Cycling requirements.

6.1.5 Component performance checks during test.

6.1.6 All filters, other than the test facility filters, shall be inspected, including a bubble point check, before being used in the test. Replacement or servicing of system filters should be in accordance with the prescribed maintenance schedules, or following a pending blockage indication (if applicable).

6.2 Test Data

The following list is an example of recorded data that may be required, as applicable:

a. Component speed

b. Component discharge pressure

c. Component inlet pressure

d. Inlet fuel temperature

e. System flow

f. By-pass flow (where applicable)

g. System or pump filter differential pressure

h. Pressure and flow readings as required to monitor component(s) functioning