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AEROSPACE RECOMMENDED PRACTICE

ARP 492B

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AIRCRAFT ENGINE FUEL PUMP CAVITATION ENDURANCE TEST

1. PURPOSE

- 1.1 This recommended practice defines procedures for testing aircraft engine fuel pumps for the purpose of determining their resistance to deterioration, during endurance test, while handling a specified mixture of gas and liquid expressed as a ratio of vapor volume to liquid volume.
- 1.2 The procedure recommended herein is based on experience gathered by a number of laboratories conducting component qualification tests to MIL-E-5009, currently MIL-E-5007. It is intended to produce a uniform reproducible steady state test condition for fuel pump cavitation testing as required by various military engine specifications.
- 1.3 This test is not intended to establish altitude or climb rate performance of the article tested.
- 1.4 Reference: SAE AIR 1326, "AIRCRAFT FUEL SYSTEM VAPOR-LIQUID RATIO PARAMETER"

2. SCOPE

- 2.1 This procedure is intended to apply to all pumps downstream of engine inlet.
- 2.2 The procedure will be defined in terms of recommended test setups and recommended testing methods.
- 2.3 Two methods of determining V/L are provided.
 - 2.3.1 Method I - V/L Meter: When using this method, the vapor-to-liquid ratio is sensed in a measuring section installed in inlet line upstream of the pump as shown in Fig. 1. The vapor-to-liquid ratio is assumed to be the indicated volume flow rate vapor-to-liquid ratio and is read out as V/L on a meter dial.
 - 2.3.2 Method II - V/L Calculation: This method assumes that an equilibrium mass flow rate of dissolved air evolves from the flowing air saturated liquid fuel in accordance with Henry's Law for solution of gases in liquids. The volume flow rate vapor-to-liquid ratio is then calculated from the mass flows in accordance with Dalton's Law of Partial Pressures, the Perfect Gas Law and the liquid fuel thermal expansion behavior. The necessary calculations are described in Appendix A.

CAUTION: At low pump inlet pressures and/or high fuel temperatures, special care must be taken to obtain accurate readings of the test data that enter the V/L calculation. As can be seen from the V/L equation in Appendix A, a primary factor in the V/L calculation is the ratio of two pressure differentials measured during the test. If these pressure differentials are small, as is the case when the tank pressure P_1 (and, therefore, the pump inlet pressure P_2) is close to the absolute true vapor pressure of the fuel, P_{TVP} , even small errors in the measurements will cause large errors in the calculated value of V/L. A good practice in this connection would be the inclusion of note(s) on the test sheet calling attention to data points taken at low values of $(P_1 - P_{TVP})$ together with the attendant estimated possible error in the calculated V/L resulting from measurement errors.

Ø 2.3.3 Recommended V/L Meters: Recommended V/L meters are listed in Appendix B.

2.4 Within this document the term "pump inlet" shall define the fuel inlet port of the complete system to be tested. If lines or other components are placed upstream of the inlet of the actual pumping component by specific test requirement, such as to provide an engine inlet, they shall be part of the complete system to be tested.

3. GENERAL REQUIREMENTS

3.1 Fuel: MIL-T-5624, Grade JP-4

3.1.1 Fuel Temperature:

T_1 in supply tank: $\pm 1^\circ\text{F}$ (0.5°C) of T_2 at the pump inlet.

T_2 at pump inlet: In accordance with the specific test requirement.

3.1.2 Fuel Pressure:

P_1 at fuel surface in supply tank: In accordance with the specific test requirement.

P_2 at pump inlet: Depressed below P_1 as required to produce the required V/L.

P_3 at pump discharge: In accordance with the specific test requirement, which typically will be the engine fuel system pressure required for the specified metered flow.

3.1.3 Fuel Flow: System discharge and pump bypass flows shall be in accordance with the specified test requirements.

Ø 3.2 Inlet V/L Condition: In accordance with the specific test requirement.

Ø 3.3 Duration of Endurance Test: In accordance with the specific test requirement.

3.4 Pump Speed: In accordance with the specific test requirement and, in general, will be an intermediate rated speed for the pump application.

4. DETAIL REQUIREMENTS

4.1 Test Setup: The equipment should be in accordance with Figure 1 subject to the limitations provided therein.

4.1.1 Fuel Tank:

4.1.1.1 Shape of the tank is optional.

4.1.1.2 Insulation of the tank is optional. During cavitation test, the temperature difference between T_1 and T_2 should not exceed 1°F (0.5°C).

4.1.1.3 The minimum quantity of fuel shall be a volume equivalent to the system discharge flow for 2 min. plus 15 gal (57 L). The maximum quantity of fuel shall be a volume equivalent to the system discharge flow for 5 min. plus 15 gal (57 L). The system discharge flow shall be as defined by 3.1.3. The tank volume shall be at least 1.1 times the fuel volume.

4.1.2 Inherent Pressure Loss: The pressure loss from P_1 to P_2 should not exceed 2 in. (50 mm) Hg at the test flow rate with the inlet line throttle valve(s) fully open.

4.1.3 Downstream Test Equipment:

4.1.3.1 A pump bypass line and valving may be provided as necessary to control system discharge flow in a manner consistent with the pump/control installation for the applicable engine.

4.1.3.2 Any other elements of the engine fuel system downstream of the pump which have an effect on the pump inlet conditions should be simulated.

4.1.3.3 Care should be taken to assure that the tank return flow is returned below the fuel surface and does not interfere with the tank to inlet line flow. The tank return point should be as isolated as possible from the tank to inlet connection and under no condition closer than 6.0 in. (150 mm) to the tank to inlet connection.

4.1.4 Additional Test Equipment: All necessary devices for testing, other than already described, may be placed in the test system as required other than in the inlet line.

4.2 General Procedure for Testing:

4.2.1 Test setup should conform to 4.1.

4.2.2 Preparation for Test:

4.2.2.1 Prior to cavitation endurance testing, check the leakage of the fuel system from the supply tank to the test system as follows: Without operating the test pump, depress tank pressure to estimated pump inlet pressure required for the cavitation test or lower, then close the vacuum supply line and observe tank pressure. A recommended rate of pressure increase is 0.4 in. (10 mm) Hg/h to 0.6 in. (15 mm) Hg/h maximum. Repair leaks as required. This check may be made with a slave pump in place of the test pump providing the pump inlet connection that must be disconnected for installing the test unit provides a positive seal and that steps are taken to assure that the test pump or components do not introduce new fuel system leaks.

4.2.2.2 The pump or component to be tested shall have fluid passed through it at flows and contamination level and time period as required by the specific test requirements prior to setting of any cavitation test conditions. This precontamination may be performed on a test setup separate from the V/L test setup.

4.2.2.3 In the heating cycle, the test pump may be used for circulating fuel. The rate of heat addition to the fuel mass in the tank should not exceed 4 deg F (2 deg C) per minute. A record of fuel temperature during the heating cycle should be maintained and included with the test data. At no time during the heating cycle should the tank fuel temperature exceed 5° F (2.5° C) above test temperature. Gradually, over a 10-minute period, reduce the tank pressure above the fuel surface to the specified value.

4.2.2.4 With the inlet line throttle valve(s) open wide, with the fuel temperature maintained, establish the speed, flow and discharge pressure conditions for the test.

4.2.2.5 Adjust the inlet throttle valve(s) to obtain the desired V/L ratio. When using the two valve inlet throttling configuration, adjust valves A and B uniformly to maintain approximately the same valve opening. Any further adjustments to maintain the desired inlet pressure should be made with the upstream valve, A. Obtain an initial fuel sample for RVP determination.

4.2.3 Endurance Testing:

- 4.2.3.1 $\emptyset$ Operate the test system at the required conditions for the required time period. Maintain the test conditions within the following limits during the entire endurance period.

$$T_1 \quad \pm 3^\circ \text{F} (1.5^\circ \text{C})$$

$$T_1 - T_2 \quad \pm 1^\circ \text{F} (0.5^\circ \text{C})$$

$$P_1 \quad \pm 0.1 \text{ in. (2.5 mm) Hg}$$

$$P_2 \quad \text{As required to maintain the required V/L}$$

V/L at pump inlet: Maintain at the required level or higher.

Absolute Fuel RVP: 2 psi (13.8 kPa) minimum

System Discharge Flow: +10%, -0, or as specified

Bypass Flow: As required to maintain system discharge flow

Pump discharge Pressure: +4%, -0, or as specified

- 4.2.3.2 Test fuel may be emptied and replaced as necessary to maintain test conditions.

- 4.2.3.3 The following data should be recorded at intervals not exceeding one hour.

1. Inlet fuel temperature and pressure T_2 and P_2 .
2. Tank pressure above fuel (in. (mm) Hg Abs.) P_1 and fuel temperature T_1 .
3. Pump discharge temperature and pressures T_3 and P_3 .
4. System discharge flow.
5. V/L ratio, if Method I is used.
6. Time of day.
7. Pump speed.
8. Barometer.
9. Bypass flow, plus any other flow(s) supplied by the pump which have an effect on the $\emptyset$ pump inlet conditions should be recorded.

- 4.2.3.4 $\emptyset$ The following additional data shall be recorded initially and at least every 12 hours when Method II is used for V/L determination. RVP checks shall also be made when Method I is used to assure that the fuel RVP does not fall below the required minimum.

1. RVP of fuel.
2. Distillation Test at 5% and 15% points.
3. Specific gravity.

4.2.3.5 For Method II testing, calculation of vapor liquid ratio shall be according to Appendix A.

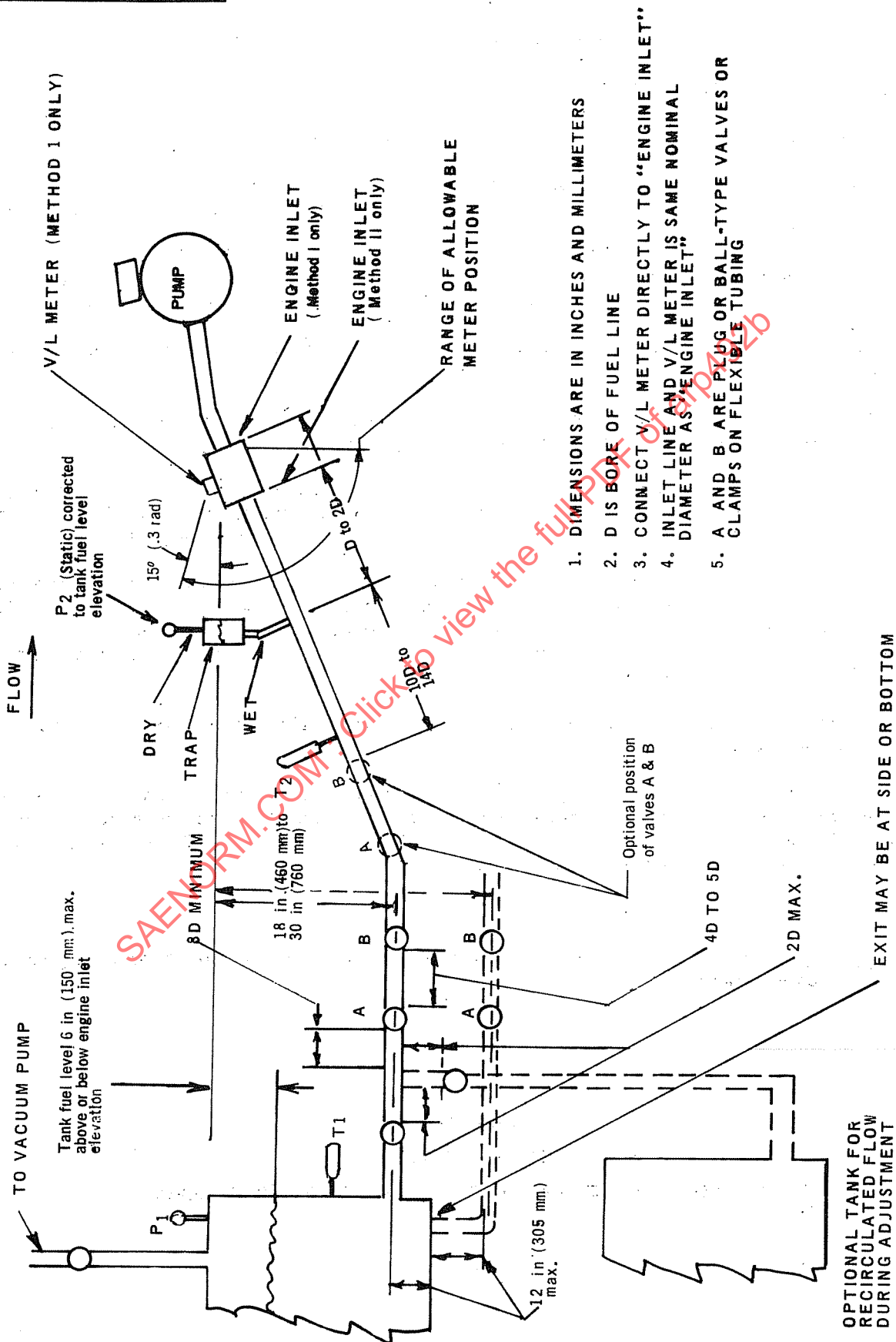
5. SUGGESTED TESTING TECHNIQUES

- 5.1 Insulation of the tank and lines may be necessary to provide temperature stability.
- 5.2 Adjustments to inlet pressure may be made conveniently by very slight adjustments of flow instead of $\emptyset$ by readjustment of the setting on the upstream throttle valve. System discharge flow must be maintained within specified limits.
- 5.3 The inlet side of the test system must be reasonably airtight to minimize fuel weathering as a result of vapor loss entrained in the air through flow to the vacuum system and to assure accurate test results. $\emptyset$
- 5.4 A test tank with adjustable elevation will provide flexibility for meeting the requirements of test fuel volume and fuel level elevation.
- 5.5 A plastic gage line may be used to connect the P_2 pressure gage instead of the gage trap shown in Figure I to observe fuel level allowing for fluid head correction.
- 5.6 The fuel line must be arranged to avoid either separated or slugging type flow. Transparent piping may be used for viewing sections. The inlet line, including the inlet throttle valve(s), should be substantially the same size as the engine inlet. Any transition in line size should be gradual.
- 5.7 V/L determination by the Method II calculation assumes equilibrium conditions both in the tank and at the engine inlet and the change in equilibrium conditions accounts for the evolution of air/vapor. The application of line loss in the throttle valve(s) should be as gradual as possible to minimize local low pressure regions that could cause evolution of air/vapor that would not be either reabsorbed or accounted for at the engine inlet.
- 5.8 A cooling arrangement may be added to the vacuum system line to allow the condensation and return of vapor to the fuel tank. $\emptyset$
- 5.9 It may be necessary to avoid a horizontal V/L meter sensing element installation where inside diameter differences between the sensing element and inlet line can allow vapor to be trapped within the sensing element. Tilting the V/L meter sensing element; e.g., 15 deg, from horizontal may be necessary to prevent erroneous readings due to retained vapor. $\emptyset$

7. NOTES

- 7.1 Marginal Indicia: The phi ($\emptyset$) symbol is used to indicate technical changes from the previous issue of this recommended practice.

PREPARED BY
SUBCOMMITTEE AE-5B OF
SAE COMMITTEE AE-5, AEROSPACE FUEL, OIL & OXIDIZER SYSTEMS



1. DIMENSIONS ARE IN INCHES AND MILLIMETERS
2. D IS BORE OF FUEL LINE
3. CONNECT V/L METER DIRECTLY TO "ENGINE INLET"
4. INLET LINE AND V/L METER IS SAME NOMINAL DIAMETER AS "ENGINE INLET"
5. A AND B ARE PLUG OR BALL-TYPE VALVES OR CLAMPS ON FLEXIBLE TUBING

Ø FIGURE 1 - TEST SYSTEM

APPENDIX A: CALCULATION OF V/L RATIO

A1 Introduction

A1.1 The V/L ratio (vapor volume to liquid volume ratio) at the inlet of the pump may be determined by calculation as outlined below. A uniform method of determining V/L ratio is needed to insure repeatable results for tests performed in various laboratories. Because of the possible differences in the assumptions and approximations that might be used in such calculations, the procedure for determining V/L ratio is completely outlined and each step must be strictly followed.

A1.2 This method is based upon the assumption that the fuel is 100% saturated with air as it leaves the fuel tank and again 100% saturated at the new condition at the inlet of the pump. The calculation determines the amount of air released due to change of pressure on the fuel, in terms of a ratio.

A1.3 The physical properties of the fuel needed for the calculation are:

1. Distillation according to Federal Test Method Standard Number 791 (latest revision), at 5% and 15%.
2. Reid vapor pressure according to Federal Test Method Standard Number 791 (latest revision).
3. Specific gravity according to Federal Test Method Standard Number 791 (latest revision).

A2 Step One.

A2.1 The first step is to determine the slope of the distillation-temperature curve at the 10% point.

$$\text{Slope} = \frac{T_{15} - T_5}{10}$$

Where T_{15} = temperature °F (°C) at the 15% distillation point and T_5 is temperature °F (°C) at the 5% distillation point.

A3 Step Two.

A3.1 The next step is to determine the true vapor pressure at the pump inlet. This is based upon the Reid vapor pressure of the test fuel and the measured fuel temperature at the pump inlet during the test. NACA Technical Note 3276 shall be used to determine true vapor pressure. For convenience, Chart A-1 may be used to determine true vapor pressure when Step One results in a slope of 0° F (0° C)/% to 8° F (4.4° C)/%. For slopes beyond this range, or for more precise calculation, the procedure for determining true vapor pressure is as described in NACA Technical Note 3276.

A4 Step Three.

A4.1 The next step is the calculation of the air solubility coefficient. $k = .2116(\text{S.G.}) [1 - 1.125 (\text{S.G.})]$.
Where S. G. is the specific gravity of the fuel at 60° F/60° F (15° C/15° C).

A5 Step Four.

A5.1 The next step is the calculation of the V/L ratio.

ENGLISH SYSTEM

$$V/L = 1.54k \left(\frac{P_1 - P_2}{P_2 - P_{TVP}} \right) \left(\frac{t + 460}{95.8 + .07t} \right)$$

Where P_1 = absolute pressure at initial condition of fuel (tank), psi

P_2 = absolute pressure at new condition of fuel (pump inlet), psi

P_{TVP} = absolute true vapor pressure of fuel at test temperature, psi, step 2

t = fuel temperature at the pump inlet, °F

k = is the solubility coefficient, step 3

Ø INTERNATIONAL SYSTEM

$$V/L = 2.78k \left(\frac{P_1 - P_2}{P_2 - P_{TVP}} \right) \left(\frac{t + 273}{98 + .13t} \right)$$

Where P_1 = absolute pressure at initial condition of fuel (tank), kPa

P_2 = absolute pressure at new condition of fuel (pump inlet), kPa

P_{TVP} = absolute true vapor pressure of fuel at test temperature, kPa, step 2

t = test temperature at the pump inlet, °C

k = is the solubility coefficient, step 3

A5.1.1 This formula assumes no change in temperature from the initial condition (tank) to the new condition (engine inlet).

A5.1.2 This formula also provides no correction of vapor pressure due to vapor - liquid ratio. This correction may be neglected for values of V/L up to 1.0 (for higher values of V/L a correction may be made by referring to formula I-18 of WADC Technical Report 55-422, Part 2).