SAE The Engineering Society For Advancing Mobility Land Sea Air and Space® INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

SAE ARP868 REV. B

Issued 1966-06-25
Revised 1990-12-18

Superseding ARP868A

METHOD - PRESSURE DROP TESTS FOR FUEL SYSTEM COMPONENTS

FOREWORD

Although written specifically for fuel system components, the methods and suggestions presented herein may be equally applicable to pressure drop tests of other liquid-handling devices.

A pressure drop test is performed on a specimen to establish the static energy (pressure) loss resulting from passing liquid into one port and out of another under stated conditions such as flow rate, attitude, degree of valve opening, flow direction, fluid density, viscosity, and temperature. Resulting pressure drop data may be used to compare relative energy dissipation between similar devices or to make various system analyses, in conjunction with pressure loss data from piping and other components. The procedure should yield pressure drop of the component alone, not including variable external test losses such as piezometer tube loss, attaching fitting loss, and expansion or contraction loss of attaching fittings. In low energy loss situations as typified by many fuel systems, the piezometer tube losses are relatively large and require data correction.

Probably the most common method of making such corrections is to run two successive tests. This may be termed a "single piezometer tube" method. The first test yields "gross" data and the test setup includes single piezometer tubes, attaching fittings, and the specimen under investigation. In the second "tare" test, the specimen is removed, the single piezometer tubes being joined together (possibly using one of the fittings). "Tare" results are suitably deducted from "gross" to yield component "net static" pressure drop. Note that this deduction requires plotting or regression analysis (and possibly curve averaging) of both "gross" and "net" data, then reading pressure drops at identical flow rates before subtraction. This method will yield valid results with less test apparatus length and complexity.

FOREWORD (Continued)

A second test method, the "double piezometer tube" method presented in Section 3, differs in that two differential pressure gages are used, and only one test is conducted. By simple algebraic manipulation of the test data, this method will also yield valid results.

Advantages of the "double piezometer tube" method include:

a. Reduction in test time and use of one test setup instead of two
b. Simplification of data acquisition and data reduction tasks. No curve plotting or regression analysis is needed.
c. Assurance that special conditions under test are identical for specimen and "tare" tests because they are simultaneous.

Disadvantages include:

a. More complex piezometer tube assemblies
b. More complex and longer test setup, including two differential pressure gages
c. More costly to manufacture

Many of the suggestions herein apply equally to use of "double" or "single" piezometer tube methods.

A single piezometer tube is usually prepared similar to the double piezometer tube of Figure 2 except the length is 1/3 less, and one of the two gage port assemblies is omitted.

The methods described herein imply the use of identical size double or single piezometer tubes upstream and downstream of the test specimen. Sometimes, inlet and outlet ports are of different sizes. The methods are equally valid if different size, double or single piezometer tubes are used in the upstream and downstream ports. This can be verified by an analysis similar to that of Figure 6. Use of single piezometer tubes introduces an additional error of expansion or contraction loss, since in the tare test the joining fitting must have different bores ("d") at the inlet and outlet. In either case, calculated test results must be properly interpreted, since the velocity component of Bernoulli's equation is different at each test port. Velocity energy differential is automatically algebraically included in the pressure drop when inlet and outlet tubes are of identical size.

Any use of test results must properly consider this differential, which can exceed the component pressure drop. One valid result which could result from this is a negative static pressure drop (when the outlet tube is the larger and component pressure drop is relatively small). In cases where a large amount of negative static pressure drop is experienced, a point may be reached at which the flow cavitates. This can cause errors in observed pressure readings.

FOREWORD (Continued)

Another useful application is for testing shower-head-type fuel level control valves, or other components which spray rather than collect fuel return in a port. Here, one double or single piezometer tube is used at the inlet port. The component exit simply exhausts into air or liquid. In this case, the downstream lines to the differential pressure gages are omitted, and the downstream gage ports are kept open and dry except when exhausting into liquid[1]. Otherwise, the methods of Section 3 apply. As with the different size tube test described, velocity energy differences involved must be considered. The exit loss is included in the specimen pressure drop. A valid result could occur wherein the static pressure drop is negative although the total pressure drop is positive. This can happen when expansion takes place within the valve, reducing the exit velocity to a point that the velocity energy differential is greater than the total static pressure loss in the specimen. Again, cavitation errors may result. Also note that the pressure drop is different when the shower head is exhausting into air or liquid. This is primarily due to the effects of submersion on exit velocity.

1. SCOPE:

1.1 Purpose:

To describe useful methods for conducting pressure drop tests of fuel system components for MIL-F-8615 or similar requirements and to present general suggestions for improving accuracy of test results.

2. REFERENCES:

MIL-C-7024 Calibrating Fluid, Aircraft Fuel System Components
MIL-F-8615 Fuel System Components: General Specification for

3. DESCRIPTION OF METHOD:

a. Prepare test setup per Figure 1.

b. Establish specified test conditions such as specimen attitude, liquid flow rate, liquid type, liquid temperature, and ambient temperature. Requirements may be per MIL-F-8615, the detail specifications, or as otherwise required. Follow suggestions of Section 4, as applicable.

c. Record simultaneous readings of flow rate and both differential pressures, ΔP1 and ΔP2.

[1]Pressure head effects must be considered. If feasible, keep the setup level with the gage at the same level elevation. Otherwise, note the relative gage elevation and correct data accordingly. When exhausting into or flowing from a quiescent volume of liquid (such as a tank), the applicable differential pressure gage ports should be plumbed to the tank at the same elevation as the specimen, and all of the plumbing shall contain liquid only (no air).

3. (Continued):

   d. Repeat for other flow rates as required.

   e. Calculate specimen pressure drop (see Figure 6):

$$\Delta Ps = 2\Delta P1 - \Delta P2 \qquad \text{(Eq.1)}$$

   f. Reduce data and correct for density or other conditions as required.

4. SUGGESTIONS FOR IMPROVING TEST RESULT ACCURACY:

4.1 Observe all notes on Figures 1 and 2.

4.2 Air bubbles in gage lines and gages are a major source of pressure drop data errors. Where feasible, use of transparent tubing for gage lines is recommended to permit observation. Before performing the test, bleed air and run the system to assure complete purging of all air from the entire system.

The use of a transparent flowmeter or downstream tube section will assist in visually assuring absence of entrained air during test.

4.3 Pumping source pulsations may affect accuracy in several ways: (1) by influencing the specimen or, (2) by upsetting the flowmeter or pressure gages. Use of pulsation dampers or flow forced by air pressure rather than pumps will help.

4.4 System error analyses should be performed when selecting differential pressure gages. In general, properly used manometers may yield better accuracy than mechanical or electronic pressure gages. However, be sure to consider reading error in your error analysis.

4.5 Assure proper calibration and installation of flowmeters, differential pressure gages, and piezometer tubes.

4.6 Calibration of double piezometer tubes may be performed by a test using a typical fuel and the method of Section 3. The test setup should be per Figure 1, except omit any test specimen and join and seal the double piezometer tube together with bore diameter "d" of each accurately aligned with the other. Attachment fittings will add a small pressure drop error and should be avoided. If required, they should be as short as possible and must have a bore equal to "d". The pressure drop should equal zero for all flow rates tested. If not, (1) check accuracy of dimension "A", (2) inspect intersections per note 1, Figure 2, (3) check system for leaks or air bubbles, (4) check fitting bores and, (5) check other notes and suggestions of this document.

4.7 When performing a pressure drop test, always increase flow rate to each test point before taking readings. Do not overshoot flow rate and then reduce flow to any test point. If hysteresis data are of interest, perform a second test run starting at the maximum and reducing flow rate to each test point.

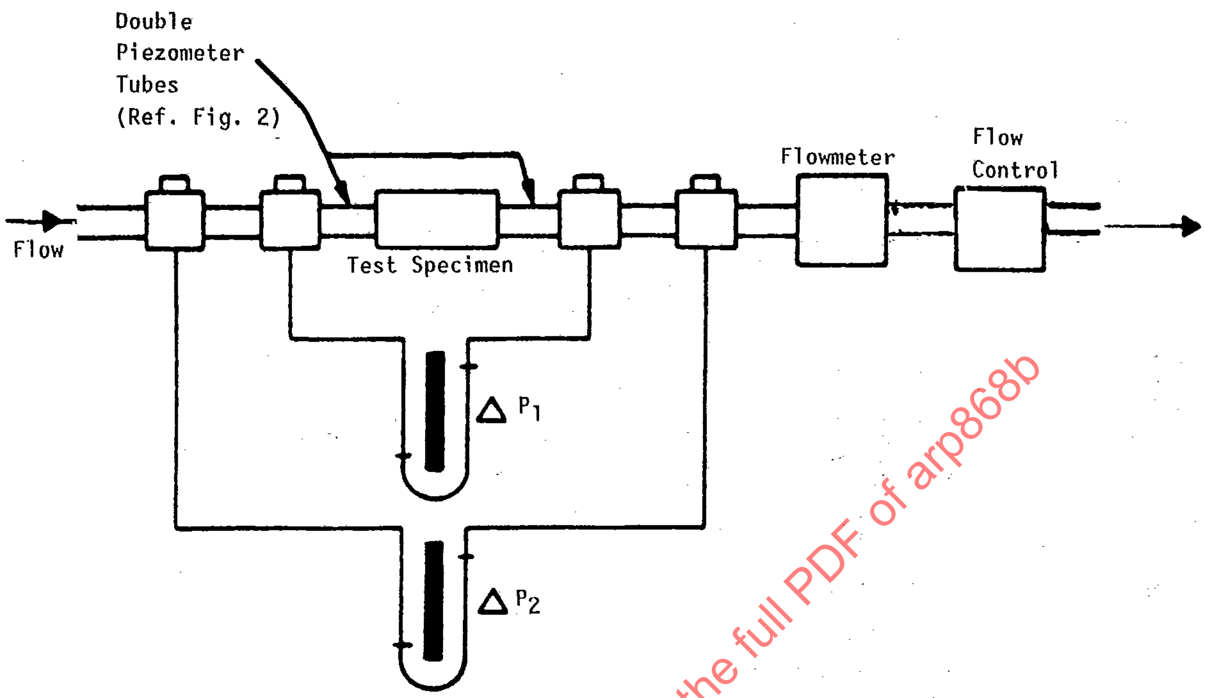

FIGURE 1 - Test Setup - Fuel Pressure Drop

NOTE:

1. Omit fittings whenever feasible. Keep the bores of fittings which join the double piezometer tubes to the specimen equal to "d," concentric and aligned with "d". (Reference Figure 2.)

2. Locations of flow control and flowmeter optional. May be upstream, downstream, adjacent to, or in line remote from piezometer tubes as required.

3. Arrange fuel source and fuel return so that system flows full of fuel and free from entrained air.

4. Bleed all air from gages and gage lines.

5. Eliminate all external leaks. This is especially important for gages and gage lines.

6. Keep the setup level with both double piezometer tubes in the same horizontal plane to avoid head errors. If not level, analyze system and apply suitable head error corrections, considering the true fluid density. Note that the height location of differential pressure gages or manometers (above or below), when bled of air, do not introduce head errors.

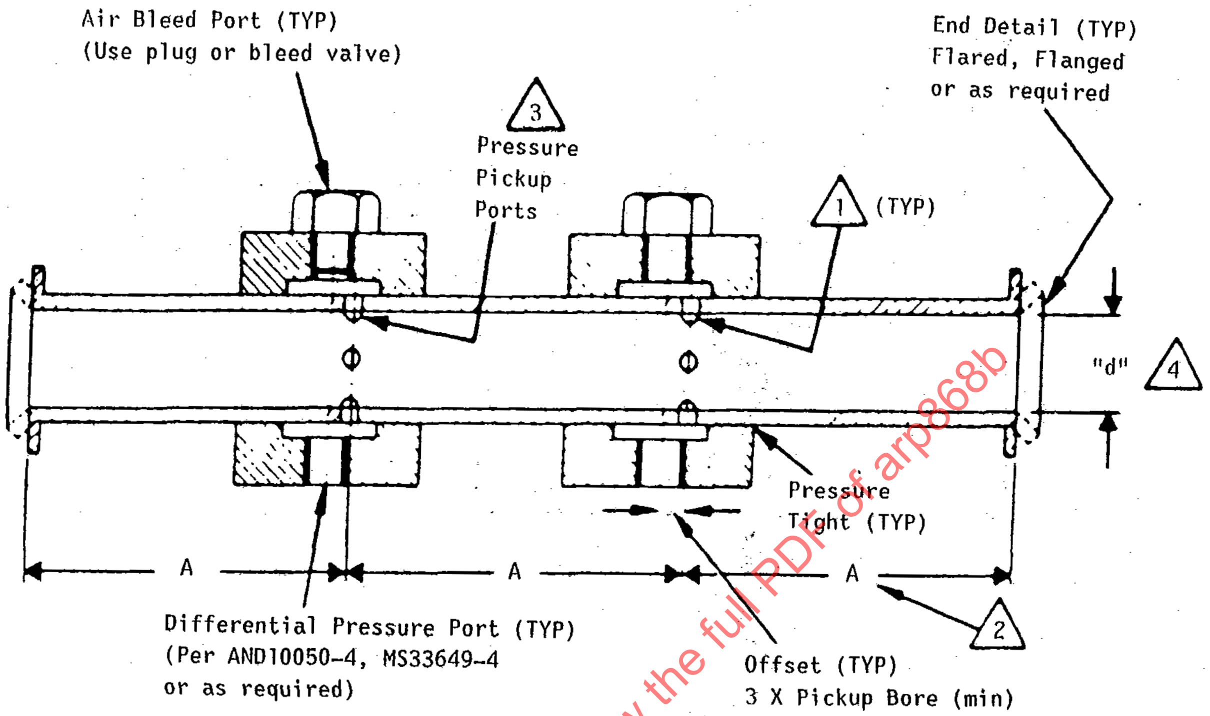

FIGURE 2 - Double Piezometer Tube

NOTE:

△1 Intersection of pressure pickup ports and bore "d" must be smooth, clean, and free from burrs. This is extremely important to accurate results. All intersections should be carefully inspected with a borescope, or other suitable methods.

△2 A = 10d (min)

NOTE: Whatever A is chosen, e.g., 10d, 13.2d, 20d, each A on both piezometer tubes must be identical.

△3 For each location, use 2 to 6 pressure pickup ports (radial holes) of 15 to 32 mm (0.06 to 0.125 inch ref) dia through.

△4 Diameter "d" must be straight and true, e.g., [0 | .010].

5. Material: Rigid and smooth stainless steel or aluminum alloy.

6. Calibrate per 4.6.

4.8 Setup for Mercury Manometer (see Figure 3):

CAUTION: Certain laboratories forbid the use of mercury manometers due to danger of contamination.

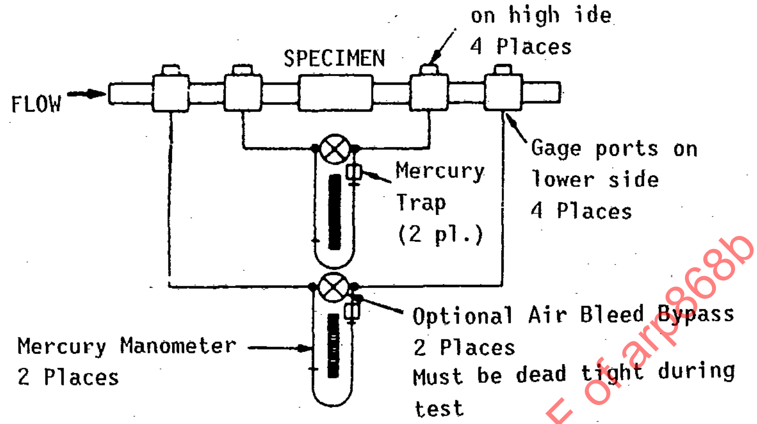

FIGURE 3 - Setup for Mercury Manometer

4.9 Setup for Fuel Manometer (see Figure 4):

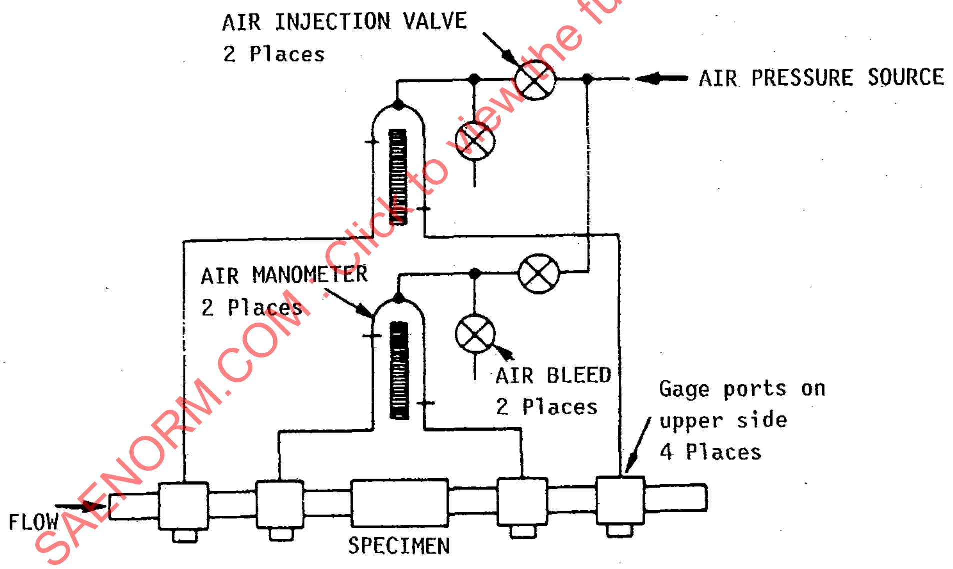

FIGURE 4 - Setup for Fuel Manometer

NOTE:

1. Useful where pressure drop is within measuring range of manometers, usually 50 inches of liquid maximum.

2. Open air bleeds and fill gage lines with fuel, purging all air. Close air bleeds. Then crack air injectors to inject a bubble of air within the measurement elevation. Then close air injectors and proceed with test.