

METHOD - PRESSURE DROP TESTS FOR FUEL SYSTEM COMPONENTS

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.
- 1.2 Introduction: Although written specifically for fuel system components, the methods and suggestions presented herein may be equally applicable to pressure drop tests of other fluid handling devices passing other incompressible fluids.

A pressure drop test is performed on a specimen to establish the static energy (pressure) loss resulting from flow of fluid 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 drop" 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.

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1.2 Introduction (Cont'd):

The "double piezometer tube" method presented herein (ref. paragraph 3) differs in that two differential gages are used, and only one test is conducted. By simple algebraic manipulation of 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 gages.

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 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 paragraph 5. 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.

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.

1.2 Introduction (Cont'd):

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 "sprays" fluid freely in air or under the liquid level as intended. In this case, the downstream lines to the differential pressure gages are omitted, and the downstream gage ports are kept open and dry. Otherwise, the methods of paragraph 3 apply.* As with the different size tube test described above, 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 energy loss in the specimen. Again, cavitation errors may result. Also note that the pressure drop is different when the shower head is spraying into air or under liquid level. This is primarily due to the effects of submersion on exit velocity.

*NOTE "Head" pressure effects must be considered. If feasible, keep the setup horizontal with the gage at the same horizontal elevation. Otherwise, note the relative gage elevation and correct data accordingly. When spraying under liquid level, note tank liquid levels during test for correction of pressure drop head data.

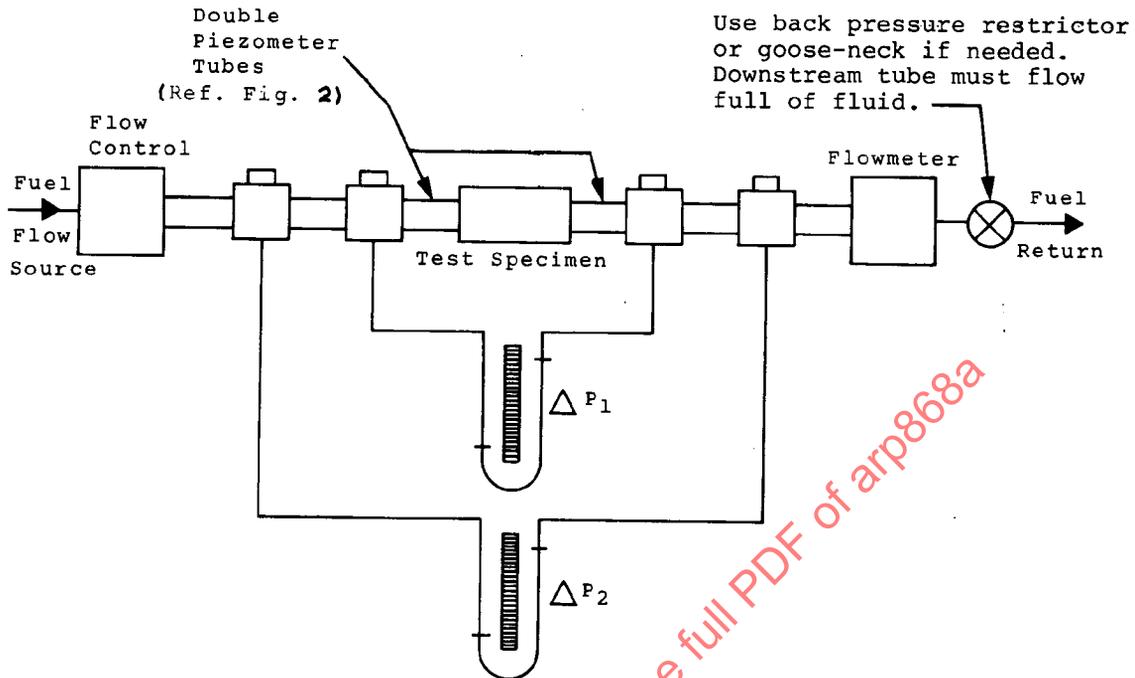
2. REFERENCE:

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, fluid flow rate, fluid type, fluid temperature, and ambient temperature. Requirements may be per MIL-F-8615, the detail specifications, or as otherwise required. Follow suggestions of paragraph 4 as applicable.
- C. Record simultaneous readings of flow rate and both differential pressures, ΔP_1 and ΔP_2 .
- D. Calculate specimen pressure drop (ref. paragraph 5):
$$\Delta P_s = 2\Delta P_1 - \Delta P_2$$
- E. Repeat for other flow rates as required.
- F. Reduce data and correct for density or other conditions as required.

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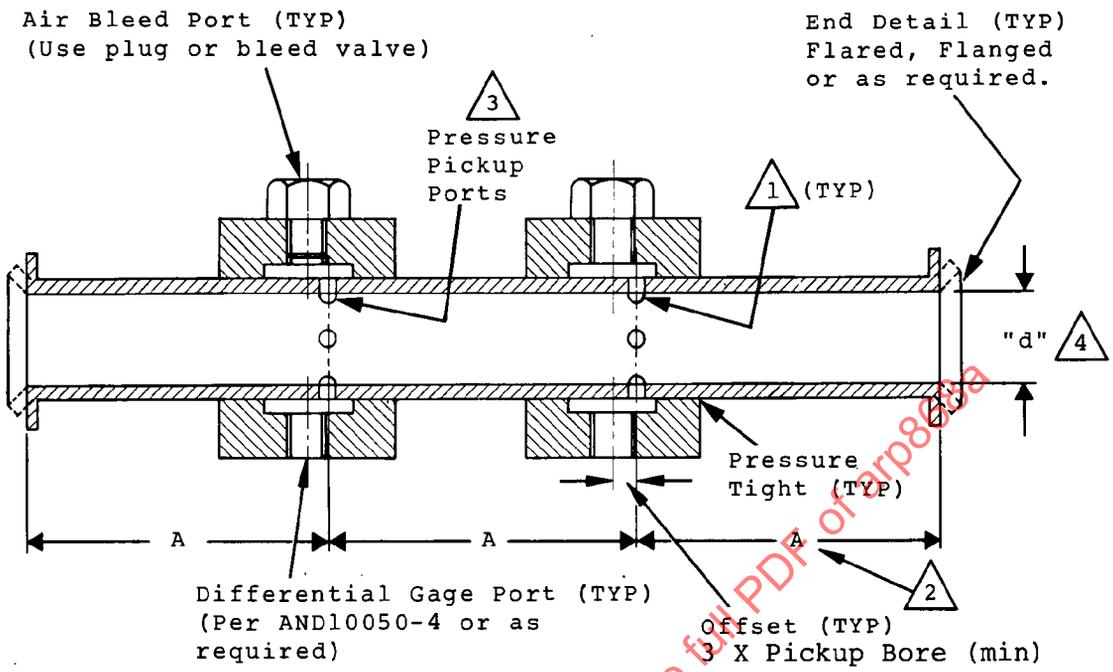


TEST SETUP - FUEL PRESSURE DROP (TYP)

FIGURE 1

NOTE:

- 1 Omit fittings whenever feasible. Keep the bores of fittings which join the double piezometer tubes to the specimen equal to "d"; and concentric with and aligned with "d". (Ref. 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 horizontal with both double piezometer tubes in the same horizontal plane to avoid "head errors". If not horizontal, analyze system and apply suitable head error corrections, considering the true fluid density. Note that the height location of differential gages or manometers (above or below), when bled of air do not introduce "head" errors.



DOUBLE PIEZOMETER TUBE (TYP)
FIGURE 2

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 (.06 to .125 inch ref) dia through.
- 4 Dia "d" must be straight and true (e.g. $\phi .010$).
- 5 Material: Rigid and smooth (e.g. stainless steel, aluminum alloy).
- 6 Calibrate per paragraph 4.6.

4. SUGGESTIONS FOR IMPROVING TEST RESULT ACCURACY:

4.1 Observe all notes on Figure 1 and Figure 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 assure observation and elimination of air bubbles. Before test, bleed air and run the system sufficiently long 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; fluidically, by affecting the specimen, or 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 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.

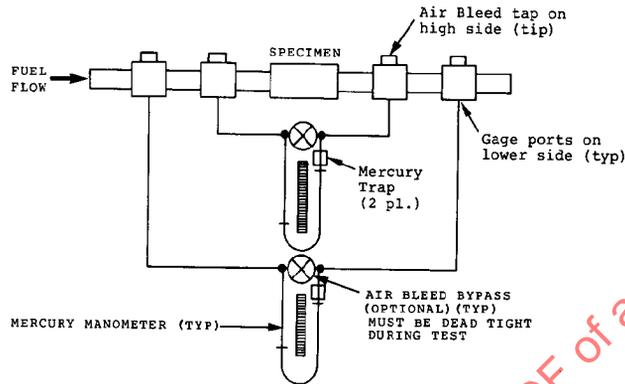
4.5 Assure proper calibration and installation of flowmeters, differential pressure gages, and piezometer tubes.

4.6 Calibration of a set of two single or double piezometer tubes may be performed by a test using a typical fuel and the method of paragraph 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 dia "d" of each accurately aligned with the other. Avoid fittings. Any fitting used should be as short as possible and must have its bore equal to "d". Even so, it will add a small pressure drop error. The pressure drop should equal zero for all flow rates tested. If not, check accuracy of dimensions "A", inspect intersections per note 1 Figure 2, check system for leaks or air bubbles, check fitting bores, and check other notes and suggestions of this document.

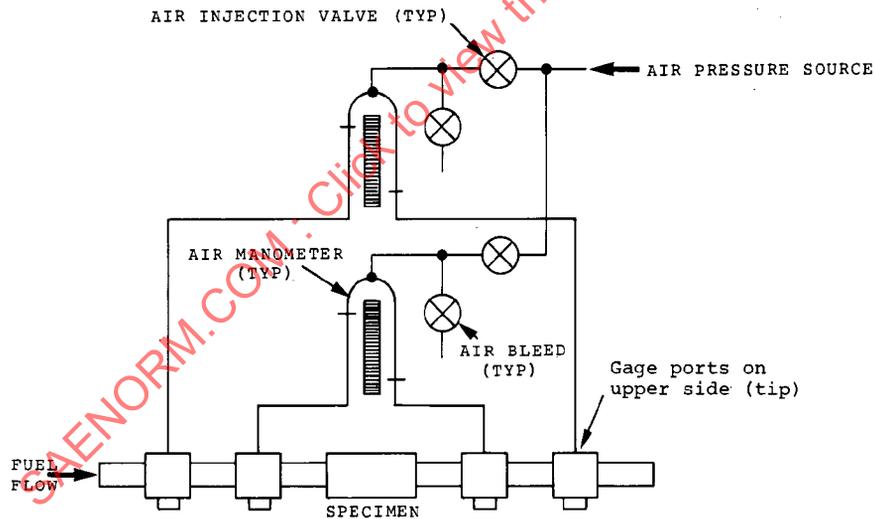
4.7 When performing a pressure drop test run, always increase flow rate to each test point before taking readings. Do not overshoot flow rate and then reduce flow to any test point. If hysteresis data are of interest, perform a second test run starting at the maximum and reducing flow rate to each test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

4.8 Setup for Mercury Manometer:

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



4.9 Setup for Fuel Manometer:



NOTE:

- A. Useful where pressure drop is within measuring range of manometers. (Usually 50 inches of fluid max.)
- B. 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 area. Then close air injectors and proceed with test.