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(R) Method-Pressure Drop Tests for Fuel System Components

RATIONALE

This revision expands the scope of the original document content beyond the use of piezometer rings for the measurement of pressure in fuel system applications. Further details are provided for measurement of flow and pressure in general applications with the use of industry standard instrumentation.

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Documents

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Figure 1 Test setup – pressure tap design..... 15

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Figure 3 Test Setup - fuel pressure drop measurement 17

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1. SCOPE

This document describes recommended methods, associated equipment, and test setups to assist in understanding and conducting pressure drop tests on fuel system components. Background information and suggestions are provided to improve accuracy and repeatability of test results. Although written specifically for fuel system components, the methods, equipment, and suggestions presented herein apply equally to pressure drop tests conducted on any equipment utilizing incompressible fluids.

1.1 Purpose

The purpose of conducting a pressure drop test on a component is to establish the energy (pressure) loss resulting from flowing liquid into one port and out another port under stated conditions such as flow rate, attitude, degree of flow obstruction or opening, flow direction, fluid density, viscosity, and temperature. Resulting pressure drop data may be used to predict or compare relative pressure drop of similar devices, or it may be used as input to flow simulation analyses in conjunction with pressure drop data of associated piping and other components.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 Handbook of Hydraulic Resistance, Coefficients of Local Resistance and of Friction, I.E. Idelchik, 1960.

2.2 Hydraulic Institute Standards for Centrifugal, Rotary, and Reciprocating Pumps, Twelfth Edition, 1969.

3. RECOMMENDED PRACTICES

3.1 General

3.1.1 Test Liquid

Any test liquid having specific gravity and viscosity similar to the liquid intended for use in the final application may be used. Upon completion of testing, the observed pressure drop value may be numerically corrected for other operating conditions. Actual values of test liquid specific gravity and viscosity should be measured and recorded at the time of testing.

3.1.2 Units of Measurement

The units of measurement such as flow, pressure, density, etc. will be stated or implied in the performance requirements for the component being tested. Ideally, these units will be used uniformly throughout all test readings, recordings, and mathematics. When conversions are necessary, they must be performed using appropriate universal conversion factors and equations. Paragraph 3.6 addresses such conversions.

3.2 Instrumentation and Equipment

In order to determine the pressure drop characteristics of a component assembly, it is necessary to subject the unit under Test (UUT) to a known flow rate and subsequently measure the drop in static pressure from the inlet port to the outlet port. To achieve this end, a flow meter will be needed to determine the through flow and a type of pressure gage will be needed to determine the differential pressure from inlet to outlet.

Pressure gages and flowmeters are sensitive test instruments, and the accuracy of test data depends upon several factors. Before each test, observe each instrument for evidence of appropriate storage, handling, calibration and installation. During testing, be sure to follow all instructions and/or guidelines for safe and accurate operation.

3.2.1 Flowmeters

Flowmeters are inserted in-line with the UUT and function to determine the rate of flow traveling within a closed conduit. There are several types of flow meters available as outlined below. Careful consideration should be given to determine the optimum way to measure the flow characteristic in order to select the best flow measuring device.

Flow meters typically fall into one of four categories:

- a. **Differential pressure flow meter** – A differential flow meter measures a differential pressure across a controlled flow area and then uses a calibration curve to determine the rate of flow. Some types of differential flow meters include orifice plates, flow nozzles, and venturi tubes. A variable area rotameter uses the differential pressure across a metered float to find an equilibrium position that can be directly read to determine flow rate.
- b. **Velocity flow meter** – A velocity flow meter measures the fluid speed (velocity) at one or more points in the flow stream and then correlates the fluid speed to flow rate. Types of velocity meters are pitot tubes, a calorimetric flowmeter, a turbine flowmeter, and a vortex flow meter.
- c. **Positive displacement flow meter** – A positive displacement flow meter measures fluid flow using precision fitted rotors. Known, fixed volumes are displaced between the rotors and rotation of the rotors are proportional to the volume of fluid being displaced. The number of rotations is counted by a pulse transmitter and converted to flow rate.
- d. **Mass flow meter** – A mass flow meter provides a direct measurement of the mass flow without needing to measure another variable that is used to infer flow rate. Types of mass flow meters include a thermal flow meter and a Coriolis flowmeter.

When selecting flowmeters, it is important to consider the required flow range, sensitivity, hysteresis, readout units, accuracy, and dynamic response as related to the test needs. Before selecting a flow meter, an error analysis is advised to verify suitability for the intended purpose.

Sometimes it may be desirable to map pressure drop as a function of flow by sweeping through the test flow range while collecting data real-time using a computerized data acquisition system. In these cases, it is important to understand the dynamic response of the flowmeter being used. Some flowmeter processors include user selectable features to digitally smooth the flow signal. This feature can slow the dynamic response of the flowmeter. While response time delay is usually on the order of seconds, a continuous sweep can cause an incorrect pairing of flow and pressure data in the computer file.

For example, if smoothing is set to 2 seconds, a line of data taken at a time t pairs the real time pressure with a flow that occurred at $t + 2s$. Depending on sweep rate, this data could significantly misrepresent the pressure drop performance of the component. A complete understanding of instrumentation settings is strongly recommended for any type of transient pressure drop testing.

3.2.2 Pressure Measurement Devices

Once the flow rate has been determined, a device must be selected to determine the differential pressure from the inlet port to the outlet port of the UUT.

When selecting a pressure measurement device, it is important to consider the required pressure range, sensitivity, hysteresis, and accuracy as related to the required measurement. Before selecting a device, an error analysis is advised to verify suitability for the intended purpose. For simplicity, unless otherwise appropriate, the term "gage" will be used to refer to the pressure measuring device.

3.2.2.1 Manometer Type Gages

In applications where the pressure drop is expected to be small, the traditional measurement tool is a manometer. Manometer liquid should be compatible with the test liquid. Either differential or single-reading types may be used (for manometers, these are the double-leg or single-leg types).

For measuring each differential pressure, one differential gage or two single gages may be used. The differential pressure gage is strongly recommended because its use substantially reduces time, labor, gage mechanical errors, and reading errors. In addition, its use automatically offsets elevation (head) effects and eliminates any need for gage elevation error corrections. If two single gages are used, they should be installed at the same elevation to eliminate the potential need for elevation error corrections. For precision, the levels of the manometer liquids within the two wells should be at the same elevation.

Piezometer tubes, a type of manometer, provide the recommended ten diameters length (minimum) of flow straightening upstream and downstream of the test specimen. They also provide ports of appropriate configuration and locations for convenient and repeatable means of sensing the differential pressures during testing. Sets of piezometer tubes should be identical and as described in Figure 1.

Except in special cases requiring only one piezometer tube, or tubes of differential diameters, identical pairs of piezometer tubes should be used. They should be marked for flow direction and upstream and downstream position and used accordingly. When selecting piezometer tube sets, the inside diameters "d" should be matched as closely as possible with the inlet and outlet port diameters of the test specimen.

Depending on the type of fittings on the piezometer tubes and the test specimen, attaching fittings may be required. Any additional pressure drop attributable to such fittings is charged to the test specimen automatically by the method of test. Therefore, the use of such fittings should be avoided if possible. If they are necessary, they should be short and straight, with smooth inside diameters the same as those of the piezometer tubes and concentrically aligned. The degree of error attributable to such fittings may be small enough to be ignored. When large or critical, they should be identified by analysis or test and subtracted.

3.2.2.2 Electronic and Dial Gages

For applications where the anticipated pressure drop values are larger, an electronic or mechanical pressure transducer is commonly used. There are several types of transducers. Four common groupings of pressure transducer are: strain gauge transducers, capacitance pressure transducers, potentiometric pressure transducers, and resonant wire transducers. This discussion will focus on the most common type, which is a strain gauge transducer.

A transducer converts the sensed pressure into an analog electrical signal that is read by an instrumentation system. The conversion of pressure to an electrical signal is achieved by physical deformation of strain gages that are bonded onto a diaphragm. The applied pressure produces a deflection in the diaphragm which introduces a strain to the gages which is converted to a signal proportional to the sensed pressure. Refer to Figure 2 for a cross section view of a typical diaphragm based pressure sensor.

Pressure transducers can be configured to measure absolute pressure, gage pressure, or differential pressure based upon how pressure is directed to the two sides of the diaphragm. With the "high" side of the gage set to one pressure port, the "low" side of the gage can be sealed to vacuum (absolute pressure), or it can be open to atmospheric pressure (gage pressure), or it can be connected to another pressure port downstream of the "high" side port (differential pressure).

Several key factors to consider when selecting a pressure transducer include:

- Pressure range (ensure the instrument has the proper range of pressure across all normal and abnormal operating conditions)
- Fluid media (consideration of any material incompatibility with the fluid media)
- Temperature range and installation environment (compensation for extreme temperature, vibration, or a corrosive environment needs to be considered)

- Accuracy (gage accuracy can vary from 0.05% to 1% of the gage maximum pressure capability)
- Type of output signal (typical outputs are millivolts, volts, and milliamps)

When a strain gage based pressure transducer cannot be used for an application, a "Dial" type pressure gage can be used for direct measurement of the static pressure in a system. This type of gage requires no electrical connections and operates on the principle of a Bourdon tube or a bellows. As the pressure increases, the position of the mechanical element inside the gage is altered, which changes the position of a needle indicator on the face of the Dial gage. The position of the needle provides a direct readout of the static pressure.

3.3 Test Setups

The net pressure drop value derived from testing a component should be the pressure drop of the component alone and not include pressure drop effects associated with the test setup. Paragraph 3.2 discussed two types of devices for measuring pressure in a closed conduit system. The first device was a piezometer tube, which measures static pressure as a displaced column of liquid (a type of manometer). The test setup for a piezometer tube is discussed in 3.3.1. The second device was a pressure transducer that utilizes the resistance change in a strain gage bridge or the displacement of a mechanical element to determine static pressure. The test setup for a pressure transducer is discussed in 3.3.2.

3.3.1 Testing using Piezometer Tubes

Setup effects are generally attributed to the component attaching fittings and the piezometer tubes upstream and downstream of the component. The pressure drop of the piezometer tubes alone may be relatively large and requires data correction. That part of the measured pressure drop in a test setup which is attributable to the piezometer tubes is called the "tare pressure drop." The methods presented herein provide for deduction of the "tare pressure drop" to yield the pressure drop of the component alone including that of any attaching fittings.

The two basic methods for conducting pressure drop tests with piezometer tubes and making data corrections are presented. They are the "single" and the "double" piezometer tube methods. The test setups and construction of a piezometer tube are shown in Figures 1 and 3. Except as noted, the methods and suggestions herein apply equally to the use of single or double piezometer tubes. If possible, it is advisable to locate the pressure sensing ports ten to twelve diameters away from the UUT to ensure any anomalies due to fluid velocity are minimized.

Note that the measured pressures are gage pressures yielding "static" pressure drop values. Note also that most pressure drop test setups are horizontal and use identical upstream and downstream piezometer tubes. Given this, no corrections are needed for upstream to downstream differential elevation or velocity effects. Special cases where these effects must be considered are discussed later.

Component entry or exit losses into the UUT are included in the measured results. Corrections to remove these losses are not normally performed as these effects are considered to be chargeable to the component. If a single piezometer tube is used, a normal tare test is required using two single piezometer tubes and using half the measured tare values.

3.3.1.1 Single Piezometer Tube Method

Probably the most common pressure drop test method is the "single piezometer tube" method. Using this method, two successive tests are conducted. The first test yields "gross" data and the test setup includes two single piezometer tubes, a differential pressure gage, attaching fittings and the test specimen. In the second "tare" test, the test specimen is removed, and the single piezometer tubes are jointed together. In both tests, pressure drop values are measured over a range of flow rates as required to measure the pressure drop characteristics of the test specimen and the setup. "Tare" results are then suitably deducted from "gross" to yield component "net static" pressure drop. Note that this deduction, as discussed in 3.5 requires the plotting of curves using regression analysis or curve averaging of both "gross" and "tare" data to compensate for data scatter then reading "gross" and "tare" pressure drop values at identical flow rates from the curves before subtraction. This method will yield valid results with minimum test apparatus length, complexity and cost.