



SURFACE VEHICLE RECOMMENDED PRACTICE

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Brake Hydraulic Component Low Pressure Flow Rate Measurement

RATIONALE

The purpose of this recommended practice is to provide a standardized set of test conditions, methodology, data processing, and reporting for the measurement of fluid flows across brake hydraulic components. This recommended practice addresses these topics for the low pressure differential regime (defined as below 1 bar pressure differential, as typical on the feed side of a hydraulic pump).

Below are noted key points in the rationale used by the founding task force to set the parameters in this recommended practice:

Every effort was made to give the user flexibility to define the test specimen (as a component or subsystem comprised of multiple components) according to the measurement needs, but provide enough structure to ensure repeatable measurements from lab to lab. It is critical that a clear definition of the test specimen be determined before the test and documented with the test results.

FOREWORD

This Foreword is included with the intention of providing future users with information regarding the background and rationale that guided the development of this standard.

The expectation of the founding task force was that a similar test apparatus and test conditions could be usefully applied to a wide range of hydraulic components in the brake system. It was also determined that distinctly different flow regimes would generally be of interest. The low pressure differential regime, which is covered in this recommended practice, is generally below 1 bar pressure differential and would apply to components such as the master cylinder, master cylinder to chassis controls unit pipes, flex-hoses, and couplings, and check valves. It was anticipated that this would be useful towards characterizing flow that affects the response time of hydraulic pumps due to fluid feed conditions (such as Electronic Stability Control and Active Cruise Control). The high pressure differential regime, which can involve very high, transient pressure differentials, usually results for components that are downstream of a high pressure source, such as a hydraulic pump or a power-assisted master cylinder during a panic apply or step-input condition. Flow measurement for hydraulic brake components with pressure differentials above 1 bar is addressed in recommended practice SAE J3052.

Two test classifications are defined, to fit with two commonly occurring needs for flow data, but with different priorities. The first classification seeks to establish uniform test conditions from lab to lab, so that components may be validated to a specification for flow characteristics. The second classification seeks to establish the most realistic in-vehicle test set-up, so that flow data may be generated to support system-level modeling activities.

A negative pressure source was specified in order to be consistent with actual vehicle usage for some of the components to which this document is expected to be applied.

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Documents

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A pressure range of 200 to 400 mBar was specified for component validation (Test Classification 1), in order to avoid excessively high flows (in ambient conditions) on the high end of the pressure range, and excessively low flows (in cold conditions) on the low end of the pressure range. This pressure range was expanded up to 100 to 700 mBar for Test Classification 2, in order to generate a more thorough mapping of component performance versus operating conditions.

The transient portion of the flow measurements (e.g., the ramp up from static fluid to fully developed flow) is not recorded or analyzed. The founding task force recognized that the transient behavior may govern system-level behavior such as pressure response times and therefore be of interest, however, the transient behavior may also be highly dependent upon the pressure source. The founding task force deemed that the complexity in the test set-up of insuring accurate transient/flow acceleration behavior would be prohibitive and in many cases unnecessary, and therefore based this document on steady-state flow characterization only.

1. SCOPE

The SAE Recommended Practice specifies a standardize method and test procedure to measure low pressure differential (< 1bar) brake component brake fluid flow performance. The standard can be utilized for flow measurements across hydraulic brake components such as master cylinders, apply system to chassis controls piping, or other sources of flow restriction in the low pressure side of the hydraulic brake system. It covers materials, manufacturing processes, and general properties required to meet the wide range of service encountered in automotive application. This specification covers only low pressure differential fluid flow and does not include measurement recommended practice for High Pressure differential (> 1 bar) flows.

2. REFERENCES

There are no referenced publications specified herein.

3. TEST CLASSIFICATIONS

Two different test classifications are defined, each related to a different purpose for the testing. The classifications are listed below:

3.1 Classification 1 - Component Validation

Flow measurement for comparison to specification, and for comparing one component design to another.

- a. Brake Fluid – use the current SAE standard reference fluid (RM6606 at the time of initial publication of this standard). Test fluid properties are to be measured before test (viscosity, density, and water content). An alternate fluid may be used if agreed to by all stakeholders in the test result.
- b. Plumbing and test fixturing not part of test specimen – specified in sufficient detail to allow re-creation of test conditions.

3.2 Classification 2 - Model Input Generation

Flow measurement to characterize flow through a component for modeling and performance diagnostics.

- a. Brake Fluid – Design intent fluid, test under design intent conditions.
- b. Test specimen will typically be an entire subsystem (e.g., complete master cylinder and connection pipes to ESC unit)

4. LOW PRESSURE DIFFERENTIAL TEST PROCEDURE AND SET-UP

4.1 Test Apparatus

Please refer to figures 1 through 3 for diagrams and an example photograph of the test apparatus. Recommended specifications for some equipment may be found in Appendix A (based on equipment used in the development of this recommended practice).

4.1.1 Test Specimen

The object of the test may be a single component, such as a master cylinder, or it may be a set of components in series, such as a master cylinder, a connecting pipe to an chassis controls unit, and a flex-pipe with couplings. If the subject of the test is a single component, than any additional plumbing installed to connect the specimen to instrumentation shall be selected to have negligible flow resistance in comparison to the component on test (see 4.1.10). The definition of the test specimen may have an impact on the flow measurements – for example, a different flow vs. pressure drop behavior may be measured on a master cylinder and remote reservoir subsystem, versus a measurement of the master cylinder by itself. It is important that what is considered the test specimen be well defined in the test documentation.

4.1.2 Negative Pressure (Vacuum) Source

A source (typically a vacuum source or a hydraulic pump) capable of generating a sustained pressure differential across the test specimen between 15 millibar and 700 millibar shall be applied to the outlet side fixturing of the test specimen.

For Component Validation Classification, the pressure source must be capable of achieving an initial (start of test) pressure differential within 2% of the target value, and must maintain the pressure within 5% of the target while the flow measurement takes place.

4.1.3 Environmental Enclosure

The test specimen, the brake fluid supply, and the fluid-carrying portion of the test fixturing shall be enclosed in an environmental chamber capable of maintaining temperatures between -25 °C and 25 °C. The required accuracy is + 0 /- 3 °C.

4.1.4 Test Fixturing

The test specimen, plumbing, and fluid reservoir shall be mounted in fixture to securely hold the components in the intended position through the test. If the test specimen is a brake master cylinder, then the fixturing shall include a provision for setting the input rod/plunger to the desired position relative to the master cylinder body.

4.1.5 Pressure Transducers

The test rig shall be equipped with electronic pressure transducers for measuring the hydraulic pressure differential across the test specimen (the placement shall exclude the flow meter from the measurement). The minimum required accuracy of the pressure transducer(s) is 0.5% of full scale accuracy. Full scale is recommended to be as close to 1 bar as practicable. A minimum of two individual pressure transducers, or a differential pressure transducer that can span the test specimen, is required.

4.1.6 Flow Meter

The test rig shall be equipped with an electronic flow meter to record brake fluid flow through the test specimen. The flow meter is typically installed in between the test specimen and the differential pressure source. The minimum required accuracy 0.05% of full scale accuracy. The recommended range of the flow meter is 0 to 30 cc/s.

4.1.7 Thermocouples

Thermocouples shall be installed in the test chamber and in the center of the fluid reservoir.

4.1.8 Viscometer (REQUIRED for Component Validation classification, optional for Model Input Generation classification)

The test rig shall be equipped with a viscometer plumbed into the hydraulic circuit downstream of the pressure transducers (upstream of the pressure source). The viscometer shall be installed in a manner that allows measurement of the brake fluid viscosity while in test conditions (in the environmental chamber, if applicable) just prior to a flow measurement being conducted. It is acceptable to install the viscometer in parallel to the test specimen and to use valves to open and close the flow of fluid to the viscometer.

4.1.9 Junctions and Valves

The use of junctions and valves should be minimized within the hydraulic flow path over which the pressure differential is measured (including the test specimen). Piping and tubing that is not part of the test specimen should be selected to minimize the flow disturbance within the test specimen (this generally means avoiding sudden transitions in pipe size, and keeping junctions and valves as far away from the test specimen as practicable). It is recommended that valves be of the ball or plug type (typically with a 90 deg turn from open to closed), with a seal design that can withstand temperatures down to -40 °C. This type of valve will minimize the change in flow path cross-sectional area over the valve.

4.1.10 Test Fixture Hydraulic Pipe Diameter

The diameter of the piping in the hydraulic circuit outside of the test specimen can affect the flow measurement in two ways. (1) Fixture piping between the test specimen and either the upstream or the downstream pressure transducer can affect the flow characteristics if not sized correctly, and (2) fixture piping that completes the hydraulic circuit outside of the pressure transducers can contribute to excessive heating of the working fluid (brake fluid) and/or limit the flows that can be achieved if not sized adequately. It is recommended that the next larger industry standard size relative to the largest diameter pipe in the test specimen (if applicable) or relative to the largest port size (port size refers to the inner diameter of the flow passage of the port) in the test specimen (if applicable) be selected.

Flow losses in fixture piping will vary approximately according to the equations below:

$$Q = \frac{\pi \cdot D^4}{128 \cdot \nu \cdot \rho \cdot L} \cdot \Delta P \quad \text{or} \quad \Delta P = 128 \cdot Q \cdot \frac{\nu \cdot \rho \cdot L}{\pi \cdot D^4}$$

Where:

D = diameter of the pipe (m)

ν = viscosity of the fluid (m²/s)

ρ = density of fluid (kg/m³)

L = length of the pipe in (m)

Q = volumetric flow (m³/s)

ΔP = pressure drop over the pipe in (Pa)