

Submitted for recognition as an American National Standard

**REMANUFACTURED HYDRAULIC MASTER CYLINDER FOR MOTOR VEHICLE BRAKES—  
GENERAL CHARACTERISTICS AND TEST PROCEDURE**

**Foreword**—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

- 1. Scope**—This SAE Recommended Practice specifies the general characteristics and test procedure to define the minimum characteristics, performance, and durability requirements. It is applicable to remanufactured assemblies (factory rebuild) only.

This document applies to master cylinder assemblies and components of current established designs but does not cover fluid level sensors, integral proportioning valves or those master cylinders used in anti-lock brake or traction control systems. These will be covered by other standards.

The minimum characteristics, performance, and durability requirements are specified in SAE J1694.

- 1.1 Type**—This document applies to remanufactured (factory rebuild) dual and single master cylinders used in hydraulically operated brake systems of highway vehicles. It covers cylinders used in passenger car, truck, bus, and similar vehicles utilizing motor vehicle brake systems. Refer to SAE J1153 for the standard applicable to new assemblies from commercial production.

**2. References**

- 2.1 Applicable Publications**—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the latest revision of SAE publications shall apply.

- 2.1.1 SAE PUBLICATIONS**—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1153—Hydraulic Master Cylinders for Motor Vehicle Brakes—Test Procedure

SAE J1601—Rubber Cups for Hydraulic Actuating Cylinders

SAE J1694—Remanufactured Hydraulic Master Cylinder for Motor Vehicle Brakes—Performance Requirements

- 2.1.2 FMVSS PUBLICATION**—Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-9371.

FMVSS 116

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### 3. General Characteristics

#### 3.1 Elastomeric Components

NOTE—SAE J1601 may be utilized in conjunction with this document as it relates to cups.

- 3.1.1 All elastomeric seal components must be new and compatible with the appropriate brake fluid at the temperatures defined in this specification. Cover diaphragms, reservoir grommets, and reservoir connection hoses may be reused if they are in good condition, appropriately cleaned and meet the requirements of this document.
- 3.1.2 All elastomeric seals and components shall duplicate the intended function of the original equipment equivalent (e.g., replacing an "O"-ring with a lip type seal may not totally duplicate the intended function in actual operation).

#### 3.2 Bore Finish/Diameter and Vent Hole Diameter

- 3.2.1 The surface finish of the bore and diametral bore to piston clearance with appropriate seals (e.g., oversize, special design, etc.) shall meet all requirements of this document. Special reference to the test procedure sections for apply/release, leakage, replenishing, physical strength, high-temperature durability, and cold-temperature operation is necessary.
- 3.2.2 The cylinder bore shall be free of imperfections which would impair the function on the vehicle as evidenced by the durability and cold-temperature operation is necessary.

**3.3 Vent Port(s)**—The diameter of the vent port(s) shall be such that the durability requirements will be met with the seals selected for the application. Vent port(s) can be cleaned by other than a metal tool or carefully blown out.

**3.4 Structural or Surface Impairment**—All components metal, plastic, or elastomeric must be free of structural or surface damage which would impair the function, durability, or safety of the unit in field service. Consideration of heat, pressure, vibration, cold, etc., as well as normal field power (pressure) bleeding must be taken into consideration. Components such as reservoirs with cracks, pistons with corrosion voids in contact with seals, etc., must be reviewed and meet the requirements of this test procedure.

#### 3.5 Production Leakage and Function Test

- 3.5.1 All units must meet a 100% production leakage test prior to shipment. The production test shall include tests for static leakage as well as leakage during movement of the piston(s) through full stroke, function, venting, and reservoir to master cylinder body seal if applicable (e.g., composite).
- 3.5.2 Upon successfully meeting the 100% production test requirements, the unit must be identified clearly in a readily seen location with the word REMANUFACTURED (or appropriate abbreviation) using brake fluid resistant marking.
- 3.5.3 It is recommended that a date code and remanufacturer identification also be included. These can be permanently marked on the master cylinder to show it has satisfactorily met the 100% production leakage and function test requirements.

**3.6 Shipping Protection**—Shipping protection shall be installed following the 100% production test to prevent foreign debris not compatible with or soluble in brake fluid from entering any openings such as outlet port(s) of the master cylinder. Reservoir port(s) or reservoir(s) for those units shipped without reservoir cover(s) must also be protected.

### 3.7 Consolidation of Assemblies or Components

- 3.7.1 Consolidation of master cylinder assemblies or components shall be done in such a manner as to assure the functional properties of the unit shall meet the original requirements. This includes but is not limited to piston displacement, reservoir volume, mounting interface dimensions, etc.
- 3.7.2 Outlet/brake tube adapters are acceptable so long as they provide adequate sealing, correct interface, and brake tube clearance from surrounding components.

### 3.8 Test Timing

- 3.8.1 The tests outlined in this procedure are required to qualify basic components, suppliers, and manufacturing processes to assure total product qualification. Where there is a range of dimensions, tolerances, or materials, the extreme limits must be tested to qualify the total product under all intermediate conditions.
- 3.8.2 Some or all of these tests will be required to be conducted periodically to qualify new or assure continued qualification of current components, suppliers, and manufacturing processes.

- 3.9 **Cleanliness**—Production remanufactured assemblies shall be tested per the following to assure the processes are sufficient to meet the internal cleanliness requirements before shipment.

Sample size and frequency shall be a minimum of one sample of each type (closed reservoir, open reservoir, composite, etc.) selected each day for the cleanliness procedure. If one of the samples fails the acceptance requirements, two more shall be selected from the same production lot. If either of these two fail to meet the acceptance requirements, that production lot shall be rejected and evaluated for rewash. The following procedure is to be used:

- 3.9.1 Clean the outside of the master cylinder with clean isopropyl alcohol and dispose of the alcohol.
- 3.9.2 Disassemble the master cylinder.  
  
NOTE—The reservoir of a composite assembly should not be disassembled from the cylinder body unless necessary to disassemble the cylinder components.
- 3.9.3 Wash the bore and reservoir with clean isopropyl alcohol which has been filtered through a 5  $\mu\text{m}$  filter. All alcohol is to be collected in a clean container.
- 3.9.4 Wash each individual part in clean alcohol.
- 3.9.5 Thoroughly wash a 5  $\mu\text{m}$  filter with isopropyl alcohol. Bake the filter at  $90\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$  ( $194\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ) for a minimum of 10 min.
- 3.9.6 Filter alcohol used in steps 3.9.3 and 3.9.4 through the filter prepared in 3.9.5.
- 3.9.7 Dry the filter in a draft-free heat chamber. Weigh the foreign particles and examine the filter residue.

- 4. **Test Apparatus**—The basic apparatus shall be that shown and arranged in Figure 1 or equivalent. All hydraulic lines and fittings shall be of sufficient size as to permit unrestricted flow to and from test master cylinder(s). The apparatus shall operate per the following description and as called for in Section 6. It is desirable to have the test apparatus portable to facilitate cold, hot, and room temperature bench testing.

**4.1 Displacement Mechanism**—The displacement mechanism(s) connected to the master cylinder outlet(s) shall restrict the master cylinder(s) output performance to the shaded area of Figure 2. In addition, the heel of the pressure cup(s) on the piston(s) shall be past the vent port(s) before a pressure of 345 kPa (50.0 psi) is attained. The master cylinder outlet pressure(s) shall rise smoothly to a maximum of 6900 kPa  $\pm$  690 kPa (1000 psi  $\pm$  100 psi) within 60 to 80% of the total piston travel.

**4.2 Stroking Mechanism**—The stroking mechanism shall contain a mounting plate to which the master cylinder can be attached. The actuating pushrod shall be compatible with the master cylinder piston socket and shall operate coaxially within 2 degrees of the master cylinder bore longitudinal axis. The fixture shall be constructed such that full release of the master cylinder piston is obtained.

NOTE—In most current master cylinders with the pistons released, the primary piston is maintained in position by the power-assist pushrod so the seals are in the proper relationship to the vent ports. The primary piston is normally not in contact with the snap ring when in the released position. A master cylinder being tested must be set up so the pistons and seals are in this proper relationship to the vent ports for all pertinent testing to be conducted per this procedure. This is accomplished by setting the primary piston socket to mounting face dimension as it would be when mounted to the power assist unit. The power assist pushrod to mounting face dimension (commonly referred to as the "X dimension Figure 3) must be determined and duplicated with the subject master cylinder in the test fixture.

The stroking mechanism may accommodate multiple master cylinders if desired.

Means must be provided for the stroking mechanism to stroke the master cylinder both singly and cyclically. For single-stroke operation, the means must be capable of generating a minimum of 20 680 kPa (3000 psi) pressure in the master cylinder.

The means shall also be capable of applying the pushrod to generate pressure that will provide for full master cylinder stroke and allow holding of a fixed-stroke position. For cyclic operation, the stroking mechanism shall be capable of applying the pushrod to generate 10 340 kPa  $\pm$  690 kPa (1500 psi  $\pm$  100 psi), at a rate that can be adjustable from 250 to 1000 cycles/h. The pushrod shall be stroked forward at a smooth rate and allow the piston(s) to return rapidly to the retracted position(s). The time cycle shall be adjusted to allow maximum time for forward stroking while insuring the piston(s) return to the fully retracted position before the start of the next forward stroke.

Means must also be provided for a 207 kPa  $\pm$  7 kPa (30 psi  $\pm$  1 psi) air pressure source to be applied to the outlet port(s).

### 4.3 Instrumentation

4.3.1 Two hydraulic pressure measuring devices shall be employed for each outlet port. One shall have a range of 0 to 207 kPa (0 to 30.0 psi) and the other shall have a range of 0 to 20 680 kPa (0 to 3000 psi). Both shall be of the type which require small hydraulic displacement and are equipped with a bleeder and shut-off valve. Pressure measuring device(s) accuracy shall be  $\pm$ 1.0% or better.

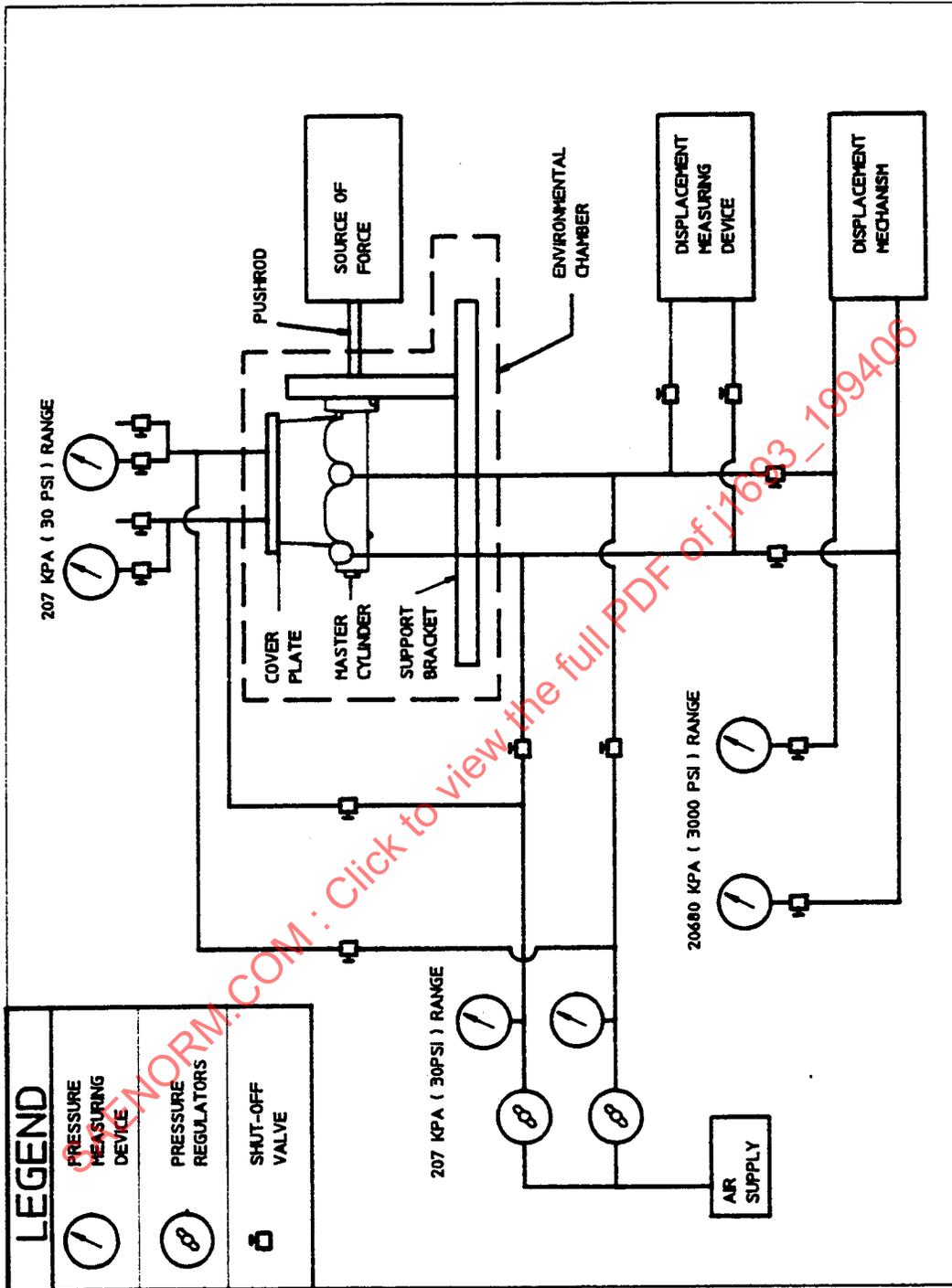


FIGURE 1—TEST APPARATUS

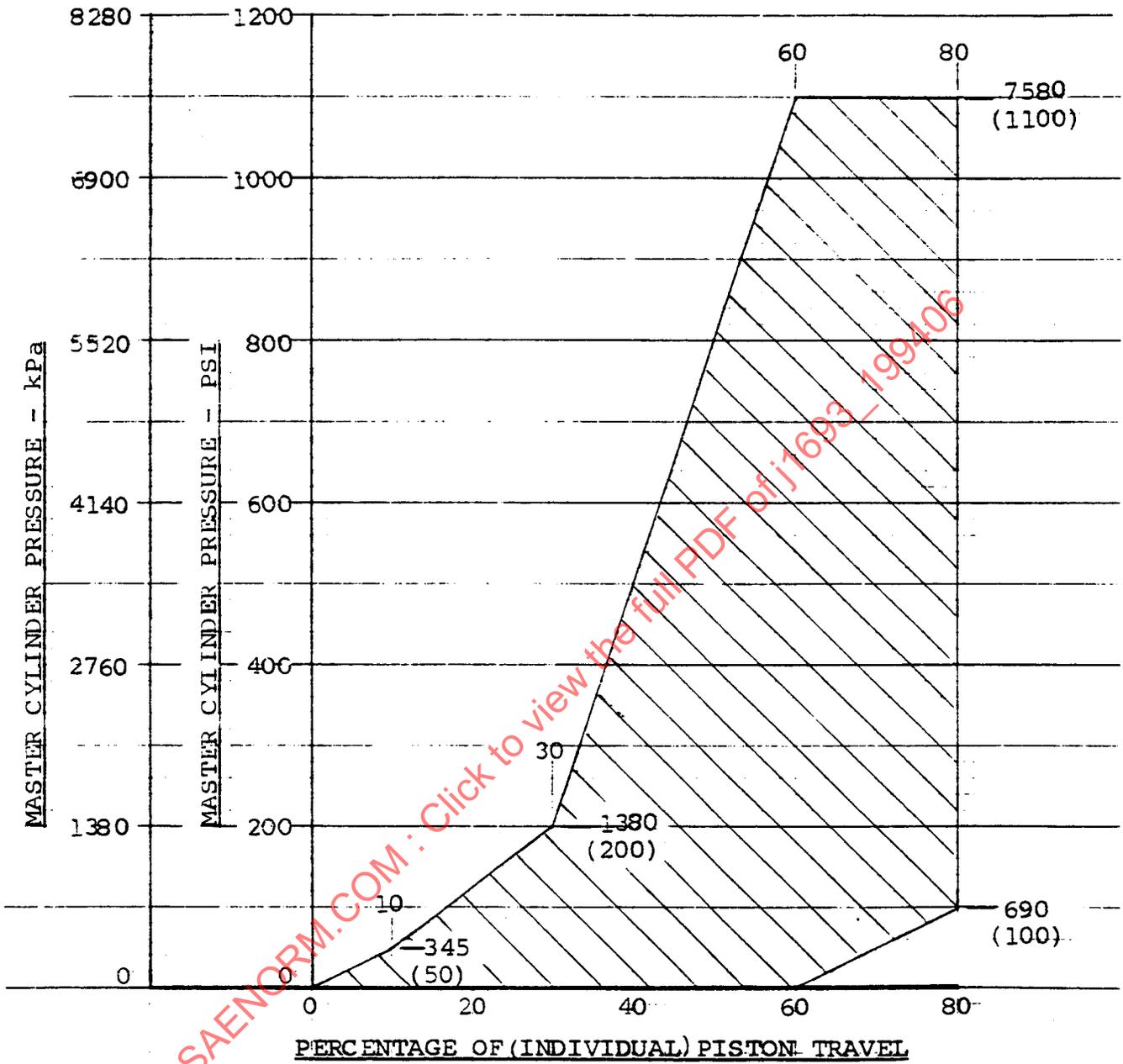


FIGURE 2—RECOMMENDED STROKING PERFORMANCE CURVES

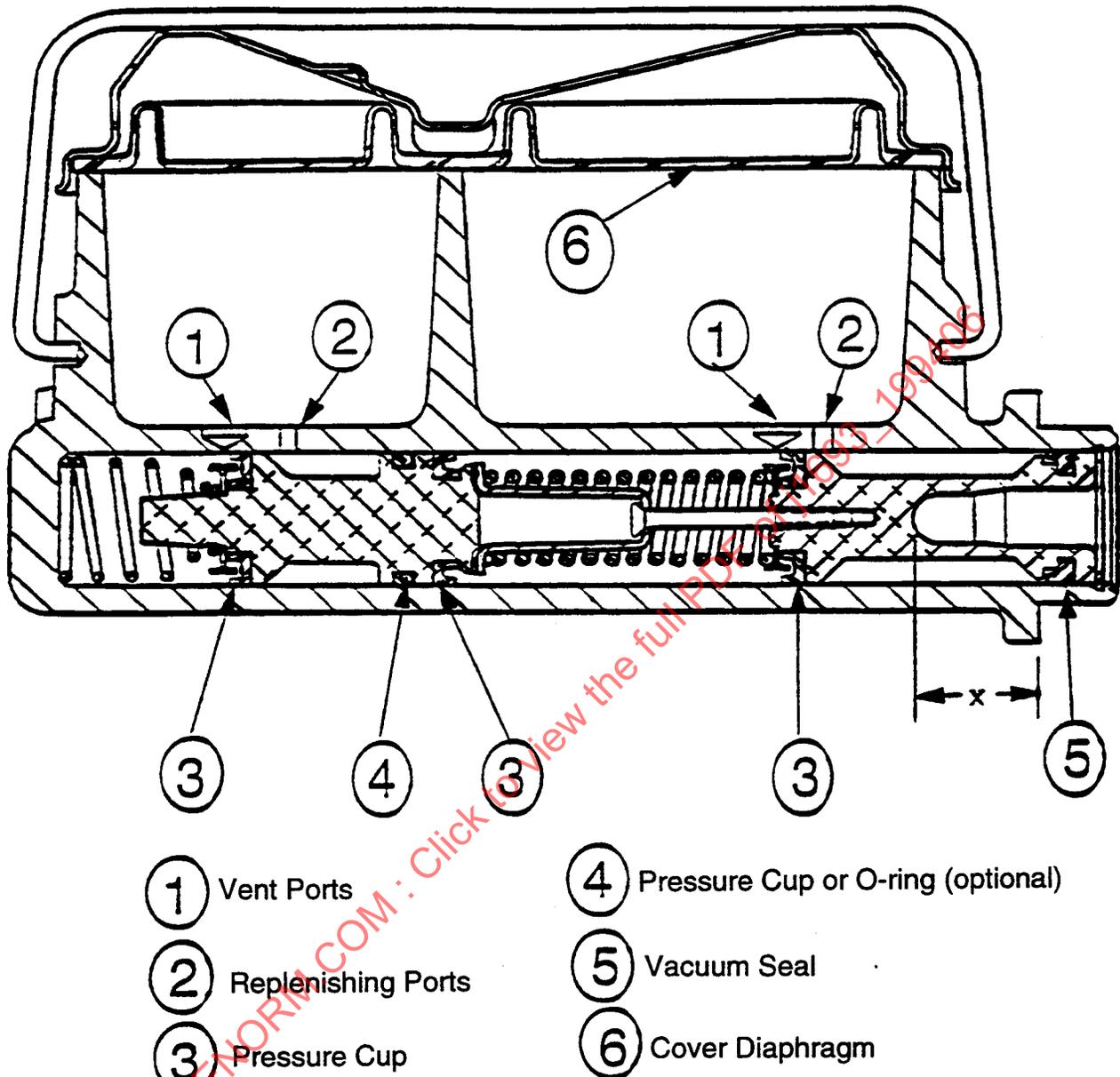


FIGURE 3—MASTER CYLINDER NOMENCLATURE

- 4.3.2 Suitable displacement measuring equipment shall be provided, accurate to 0.1 mL or better.
- 4.3.3 Short lengths of tubing with suitable connections shall be provided in order to bleed flow fluid from outlet(s) into reservoir(s).
- 4.3.4 Proper air fittings with pressure measuring device(s) and shut-off valves shall be provided.
- 4.3.5 Suitable graduated cylinder shall be provided capable of measuring fluid volumes, accurate to 1 mL or better.

#### 4.4 Environmental Equipment

- 4.4.1 HEATED AIR BATH CABINET—An insulated oven or cabinet shall be provided having sufficient capacity to house test apparatus. A suitable thermostatically controlled heating system is required to maintain a temperature of  $120\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$  ( $248\text{ }^{\circ}\text{F} \pm 5\text{ }^{\circ}\text{F}$ ). Heaters shall be shielded to prevent direct radiation to master cylinder(s).
- 4.4.2 COLD CHAMBER—A cold chamber shall be provided having sufficient capacity to house test apparatus. It shall be capable of maintaining a uniform atmosphere of cold dry air at  $-40$  to  $-42.8\text{ }^{\circ}\text{C}$  ( $-40$  to  $-45\text{ }^{\circ}\text{F}$ ).
- 4.4.3 HUMIDITY CABINET—A humidity cabinet shall be provided having sufficient capacity to house test apparatus. It shall be capable of maintaining a relative humidity between 80 and 90% at  $21\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$  ( $70\text{ }^{\circ}\text{F} \pm 5\text{ }^{\circ}\text{F}$ ) and  $46.1\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$  ( $115\text{ }^{\circ}\text{F} \pm 5\text{ }^{\circ}\text{F}$ ).
- 4.4.4 TEST FITTINGS AND MATERIAL—Test hydraulic fluid shall conform to the appropriate fluid for the master cylinder(s) being tested. The compatibility fluid of SAE J1703<sup>1</sup> is recommended if the master cylinder uses DOT 3 (FMVSS 116) fluid. The hydraulic connector to the master cylinder shall be of the type used by the vehicle manufacturer.

5. **Test Sample**—The master cylinder shall come from one of the sources described in 1.1. It shall have not have been used after remanufacture, and shall not be disassembled prior to testing except as noted in Section 3.
6. **Test Setup and Procedure**—Tests shall be conducted in the sequence shown and at room temperature except where otherwise specified. The master cylinder shall not be disassembled until after all tests are completed or unless testing is discontinued.

NOTE 1—Refer to 4.2 for the proper setup of the master cylinders especially when in the released position.

NOTE 2—When outlet ports are pressurized on dual master cylinders, both ports must be pressurized simultaneously.

NOTE 3—When fully stroking master cylinders which do not incorporate internal stroke limiting means, care shall be exercised to avoid damage to spring(s), retainer(s), cup(s), etc.

- 6.1 **Unrestricted Apply and Release**—Remove shipping plug(s) from master cylinder outlet port(s) and stroke the piston through full design stroke five times and allow it to return by the return spring load.
- 6.2 **Venting**—Install master cylinder on the mounting plate and tighten mounting bolts. Make certain the pushrod is properly aligned with the cylinder bore longitudinal axis within 2 degrees. Adjust pushrod to allow piston(s) to return to normal released position per 4.2.
- 6.2.1 Remove reservoir cover and connect  $207\text{ kPa} \pm 7\text{ kPa}$  ( $30.0\text{ psi} \pm 1\text{ psi}$ ) air supply to the outlet port(s). Bore venting will be indicated by air flow from the vent port(s).
- 6.2.2 Without changing the setup in procedure 6.2.1, stroke the input rod a minimum of 5.1 mm (0.200 in). Apply  $207\text{ kPa} \pm 7\text{ kPa}$  ( $30.0\text{ psi} \pm 1\text{ psi}$ ) air pressure to the outlet port(s) and observe that no air is flowing from the vent port(s).

1. Compatibility fluid available from SAE, Warrendale, PA.

**6.3 Residual Pressure Valve**—For master cylinders with residual check valve(s) only, release the pushrod to allow piston(s) to return to the normal released position per 4.2.

6.3.1 Cap (both) reservoir(s), apply 207 kPa  $\pm$  7 kPa (30.0 psi  $\pm$  1 psi) maximum air pressure through cap with outlet port(s) open.

6.3.2 Open (both) reservoir(s) and apply air pressure to outlet port(s) as specified in the manufacturer's data for residual valve operation check.

**6.4 Applied Leakage**—Stroke piston(s) a minimum of 5.1 mm (0.200 in) such that the vent port(s) is(are) closed and mechanically restrain piston(s) from releasing. Apply 207 kPa  $\pm$  7 kPa (30.0 psi  $\pm$  1 psi) constant air pressure to the outlet port(s). Cap reservoir(s) with pressure measuring device(s) mounted through the cap.

6.4.1 Stroke the pistons once to full design stroke at no more than 6.35 mm/s (0.25 in/s) and allow to return to starting restrained position. Record reservoir pressure device(s) pressure after 30 s  $\pm$  1 s stabilization period.

6.4.2 Remove piston restraint and disconnect air pressure source from outlet port(s). Connect low pressure hydraulic pressure measuring device(s). Fill the test setup with clean brake fluid to the manufacturer's recommended level and bleed air from master cylinder and pressure measuring device(s) by stroking until the exiting fluid stream is free of bubbles. If bleed screws are present, open for required bleeding then tighten to nominal torque specified by the manufacturer.

NOTE—During the following procedures 6.4.3 and 6.4.4, allow 15 to 20 s such that the pressure shall stabilize and then record pressure at end of 30 s  $\pm$  1 s interval. If the specified pressure cannot be obtained simultaneously in both pressure chambers on any one application of a dual master cylinder, repeat the procedure to obtain the specified pressure for each individual chamber.

6.4.3 Apply master cylinder to build up 138 kPa  $\pm$  14 kPa (20.0 psi  $\pm$  2 psi) pressure. Hold pushrod in applied position and observe pressure measuring device(s) for pressure drop.

6.4.4 Replace low-pressure measuring device(s) with high-pressure device(s) and bleed. Stroke piston(s) sufficiently for seal(s) to pass vent hole(s) at approximately atmospheric pressure. Repeat procedure 6.4.3 for high-pressure test of 6900 kPa  $\pm$  690 kPa (1000 psi  $\pm$  100 psi).

**6.5 Fluid Displacement**—Suitable fluid displacement measuring equipment shall be connected to cylinder port(s) with shut-off valve(s) between measuring equipment and outlet(s). The cylinder and equipment shall be bled of air before starting test measurements. The cylinder shall be stroked to its full design stroke for five full applications at 2.5 mm/s (0.1 in/s) maximum velocity with a minimum of 5 s interval between strokes. Close shut-off valves at end of each application and while cylinder is being returned to release position (reference 4.2). Make-up fluid may be added to the reservoir(s). The fluid volume discharge from the outlet(s) at the end of each stroke shall be recorded. Calculate and record the average of all trials.

**6.6 Replenishing**—From the results obtained in procedure 6.5, calculate the variation between each application and the average obtained in procedure 6.5 and determine the percentage variation for each of the five full applications.

**6.7 Physical Strength**—Connect high-pressure measuring device(s) to outlet port(s). Apply pushrod force to develop 20 680 kPa  $\pm$  1030 kPa (3000 psi  $\pm$  150 psi) pressure for 15 s  $\pm$  5 s.

Observe pressure-measuring device(s) for an abrupt decline in pressure and master cylinder for fluid leakage.

**6.8 High-Temperature Durability**—Place stroking mechanism with master cylinder mounted and filled with fluid to the manufacturer's recommended level into the heated air bath cabinet. Connect the displacement mechanism(s) to the outlet port(s) of the cylinder.

The system shall be bled and carefully dried of fluid. Set the stroking mechanism to cycle at 1000 apply/release cycles/h  $\pm$  100 apply/release cycles/h (3.27 to 4.0 s/cycle). Adjust the input force to the master cylinder and/or adjust the displacement mechanism(s) to stroke (each) master cylinder piston 60 to 80% of its full stroke at output pressure(s) of 6900 kPa  $\pm$  690 kPa (1000 psi  $\pm$  100 psi). The rate of pressure rise versus travel shall fall within the shaded limits of Figure 2. Place leak trap(s) under the entrance to the master cylinder bore(s) and commence stroking while raising the temperature of the cabinet to 120 °C  $\pm$  3 °C (248 psi  $\pm$  5 psi) within 2 to 6 h.

6.8.1 Periodically observe the master cylinder for fluid disturbance in the reservoir(s) as an indication of bore venting.

NOTE—In some cases there may be no fluid disturbance and on dual output cylinders only one chamber/reservoir will give fluid disturbance as an indication of proper venting.

6.8.2 Discontinue stroking at the end of 30 h continuous apply cycles. Inspect the master cylinder for external leakage.

6.8.3 Remove the master cylinder from heated air bath chamber and immediately repeat procedure 6.4.3.

6.8.4 Immediately following procedure 6.8.3 (while master cylinder remains hot) repeat procedure 6.4.4.

## 6.9 Static Leakage

6.9.1 Immediately following procedure 6.8 (while master cylinder remains hot), disconnect displacement mechanisms and plug outlet(s). Cylinder body and area(s) around outlet(s) and seal(s) shall be dry before starting test. Place master cylinder in the design position, filled with brake fluid to manufacturer's recommended level for a minimum of 12 h. Observe and measure any fluid leakage.

6.9.2 MASTER CYLINDER IN INVERTED POSITION—Master cylinder with reservoir(s) sealed to atmosphere shall be tested for reservoir seal leakage by mounting the master cylinder in an inverted position with reservoir cover(s) on the bottom. Cylinder with vented reservoir cover(s) shall be tested by suitably plugging all cover vent(s). Mounting shall be such that the weight of the assembly or external means shall not aid the reservoir sealing. Cylinder body and area(s) around the outlet(s) shall be dry before starting test. Allow master cylinder to remain in inverted position filled with brake fluid for a minimum of 20 min. Observe and measure any fluid leakage.

**6.10 Cold-Temperature Operation**—Place stroking mechanism with the master cylinder mounted and filled with brake fluid to the manufacturer' recommended level into the cold chamber. Connect the displacement mechanism(s) to the outlet port(s) of the cylinder. The system shall be bled and carefully dried of fluid. Set the stroking mechanism to cycle at 250 apply/release cycles/h  $\pm$  25 apply/release cycles/h (13.1 to 16 s/cycle). Adjust the input force to the master cylinder and/or adjust the displacement mechanism(s) to stroke master cylinder piston(s) 60 to 80% of its full stroke at output pressure(s) of 6900 kPa  $\pm$  690 kPa (1000 psi  $\pm$  100 psi). The rate of pressure rise versus travel shall fall within the shaded limits of Figure 2 at ambient temperature. Place empty leak traps under the entrance to the master cylinder bore(s), and lower the temperature to  $-40$  to  $-42.8$  °C ( $-40$  to  $-45$  °F) within 18 h. Commence stroking after a minimum of 4 h soak at the test temperature.

6.10.1 Observe master cylinder for fluid disturbance in the reservoir(s) as an indication of venting. See Note in 6.8.1.