SAE International

SURFACE VEHICLE STANDARD

J1601 MAR2011

Issued 1975-05
Stabilized 2011-03

Superseding J1601 JUL97

Rubber Cups for Hydraulic Actuating Cylinders

RATIONALE

The technical report covers technology, products, or processes which are mature and not likely to change in the foreseeable future.

STABILIZED NOTICE

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1. ***Scope—***These specifications cover molded cups 51 mm (2 in) in diameter and under, compounded from high temperature resistant rubber for use in hydraulic actuating cylinders employing motor vehicle brake fluid conforming to the requirements specified in SAE J1703 and SAE J1705.

These specifications cover the performance tests of hydraulic brake cups under specified conditions and do not include requirements relating to chemical composition, tensile strength, and elongation of the rubber compound.

Disc brake seals are not covered by this document.

2. ***References***

2.1 **Applicable Publications—**The following publications form a part of this specification to the extent specified herein. Unless Otherwise indicated, the latest issue of SAE Publications shall apply.

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

SAE J1703—Motor Vehicle Brake Fluid
SAE J1705—Low Water Tolerant Brake Fluids

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 91— Test Method for Precipitation Number of Lubricating Oils
ASTM D 471— Test Method for Rubber Property—Effect of Liquids
ASTM D 1415— Test Method for Rubber Property—International Hardness
ASTM D 2240— Test Method for Rubber Property—Durometer Hardness
ASTM E 1—Specification for ASTM Thermometers
ASTM E 145—Specification for Gravity—Convection and Forced- Ventilation Ovens

3. ***General Material Requirements***

3.1 **Workmanship and Finish—**Cups shall be free from blisters, pinholes, cracks, protuberances, embedded foreign material, or other physical defects, which can be detected by thorough inspection, and shall conform to the dimensions specified on the drawings.

3.2 Marking—The identification mark of the manufacturer as recorded by the Rubber Manufacturers Association and other details as specified on drawings shall be molded into each cup.

3.3 Packaging—Cups shall be packaged to meet requirements specified by the purchaser.

3.4 Sampling—The minimum lot on which complete specification tests shall be conducted for quality control testing, or the frequency of any specific type test used to control production, shall be agreed on by the manufacturer and the purchaser.

4. Test Requirements

4.1 Fluid Resistance

4.1.1 RESISTANCE TO BRAKE FLUIDS AT ELEVATED TEMPERATURE—After being subjected to the test for resistance to fluid at elevated temperature as prescribed in 5.1, the cups shall conform to the requirements specified in Table 1. The cups shall show no excessive disintegration as evidenced by blisters or sloughing.

TABLE 1—FLUID RESISTANCE AT ELEVATED TEMPERATURES

	Elastomers Lower Swelling[1]	Elastomers Higher Swelling[2]
Change in		
Volume	0 to +10%	+5 to +20%
Outside diameter, lip	0 to +4.0%	0 to +5.75%
Outside diameter, base	0 to +4.0%	0 to +5.75%
Hardness, ASTM D 1415, degrees	–15 to 0	–15 to 0

1. Lower Swelling elastomers are typically EP or EPDM.
2. Higher Swelling elastomers are typically SBR.

4.1.2 RESISTANCE TO WATER AT ELEVATED TEMPERATURE—After being subjected to the test for resistance to fluid (using distilled water) at elevated temperature as prescribed in 5.1, the cups shall conform to the requirements specified as follows. The cups shall show no excessive disintegration as evidenced by blisters or sloughing.

4.1.2.1 Water Resistance at Elevated Temperatures

a. Change in Volume +5.0% Maximum swell

4.2 Precipitation—Not more than 0.3% sediment by volume shall be formed in the centrifuge tube after the cups have been tested as specified in 5.2.

4.3 Wheel Cylinder Heat Pressure Stroking—Wheel cylinder cups when tested by the procedure specified in 5.3 shall meet the following performance requirements:

4.3.1 LIP DIAMETER CHANGE—The minimum lip diameter of wheel cylinder cups after the stroking test shall be greater than the wheel cylinder bore by the minimum dimensions specified in Table 2.

TABLE 2—WHEEL CYLINDER CUPS—EXCESS OVER BORE (APPROPRIATE FOR HIGHER SWELLING MATERIALS ONLY)

Diameter, mm (in)	mm (in) min
Through 25.4 (1)	0.508 (0.020)
Over 25.4 (1) through 38.1 (1-1/2)	0.635 (0.025)
Over 38.1 (1-1/2) through 50.8 (2)	0.762 (0.030)

4.3.2 LEAKAGE—Constant dampness past the cups or fluid discoloration of the filter paper on two or more inspections shall be cause for rejection.

4.3.3 CORROSION—Pistons and cylinder bore shall not show corrosion as evidenced by pitting to an extent discernible to the naked eye, but stain or discoloration shall be permitted.

4.3.4 CHANGE IN HARDNESS—Rubber cups shall not decrease in hardness by more than 15 degrees when tested in accordance with the procedure as specified in 5.7.

4.3.5 CONDITION OF TEST CUP—Wheel cylinder cups shall not show excessive deterioration such as scoring, scuffing, blistering, cracking, chipping (heel abrasion), or change in shape from original appearance.

4.4 Master Cylinder Heat Pressure Stroking—Master cylinder cups when tested by the procedure specified in 5.4, shall meet the following performance requirements.

4.4.1 LIP DIAMETER CHANGE—The minimum lip diameter of master cylinder cups after the stroking test shall be greater than the master cylinder bore by the minimum dimensions specified in Table 3.

TABLE 3—MASTER CYLINDER CUPS—EXCESS OVER BORE (APPROPRIATE FOR HIGHER SWELLING MATERIALS ONLY)

Diameter, mm (in)	mm (in) min
Through 25.4 (1)	0.381 (0.015)
Over 25.4 (1) through 38.1 (1-1/2)	0.508 (0.020)
Over 38.1 (1-1/2) through 50.8 (2)	0.635 (0.025)

4.4.2 LEAKAGE—Constant dampness past the secondary cup or fluid discoloration of the filter paper on two or more inspections shall be cause for rejection.

4.4.3 CORROSION—Piston and cylinder bore shall not show corrosion as evidenced by pitting to an extent discernible to the naked eye, but staining or discoloration shall be permitted.

4.4.4 CHANGE IN HARDNESS—The hardness of the primary and secondary master cylinder test cups shall not decrease in hardness by more than 15 degrees when tested according to the procedure specified in 5.7.

4.4.5 CONDITION OF TEST CUPS—The primary and secondary cups shall not show excessive deterioration such as scoring, scuffing, blistering, cracking, chipping (heel abrasion), or change in shape from original appearance.

4.5 Low Temperature Performance

4.5.1 LEAKAGE—No leakage of fluid shall occur when cylinder cups are tested according to the procedure specified in 5.5.1.

4.5.2 BEND TEST—The cylinder cup shall not crack and shall return to its approximate original shape within 1 min when tested according to the procedure specified in 5.5.2.

4.6 Oven Aging—Cylinder cups when tested according to the procedure specified in 5.6 shall meet the following requirements:

4.6.1 CHANGE IN HARDNESS—The change in hardness shall be within the limits of –5 to +5 degrees.

4.6.2 CONDITION OF TEST CUPS—The cups shall show no evidence of deterioration, or change in shape from original appearance.

4.7 Corrosion Resistance—Cups when tested by the procedure specified in 5.8 shall not cause corrosion exceeding the limits shown in Table 4. The metal strips outside of the area where the strips are in contact shall neither be pitted nor roughened to an extent discernible to the naked eye, but staining or discoloration is permitted.

The fluid water mixtures at end of test shall show no jelling at 23 °C ± 5 °C (73.4 °F ± 9 °F). No crystalline type deposits shall form and adhere to either the glass jar walls or the surface of metal strips. The fluid-water mixture shall contain no more than 0.20% sediment by volume. The fluid-water mixture shall have a pH value of not less than 7.0, nor more than 11.5.

TABLE 4—CORROSION TEST STRIPS AND WEIGHT CHANGES

Test Strip (1)	RM No.	Max Permissible Weight Change, mg/cm^2 of Surface
Tinned Iron	6a	0.2
Steel	7	0.2
Aluminum	8	0.1
Cast Iron	9	0.2
Brass	10	0.4
Copper	11	0.4
Zinc	ISO-2	0.4

1. Test strips may be obtained from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

4.8 Storage Corrosion—After 12 cycles in the humidity cabinet when run according to the procedure specified in 5.9, there shall be no evidence of corrosion adhering to or penetrating the wall of the cylinder bore which was in contact with the test cup. Slight discoloration (staining) or any corrosion or spots away from the contact surface of the test cups shall not be cause for rejection.

5. Test Procedures

5.1 Resistance to Fluid at Elevated Temperature—Dimensional test.

5.1.1 APPARATUS—Micrometer, shadowgraph, or other suitable apparatus to measure accurately to 0.02 mm (0.001 in) and glass containers[1] of approximately 250 cm^3 (1/2 pt) capacity which can be tightly sealed (RM-51 and RM-52).

5.1.2 TEST SPECIMENS

a. Four cups shall be used for testing at 120 °C (248 °F)
b. Two cups shall be used for water testing at 70 °C (158 °F)

5.1.3 PROCEDURE—The cups shall be rinsed in isopropyl alcohol and wiped dry with a clean, lint-free cloth to remove dirt and packing debris. Cups shall not be left in the alcohol for more than 30 s. The lip and base diameters shall be measured to the nearest 0.02 mm (0.001 in) taking the average of two readings at right angles to each other. Care shall be taken when measuring the diameters before and after aging that the measurements be taken in the same manner and at the same locations.

Determine and record the initial hardness of the test cups. Refer to 5.7 and Figure 1.

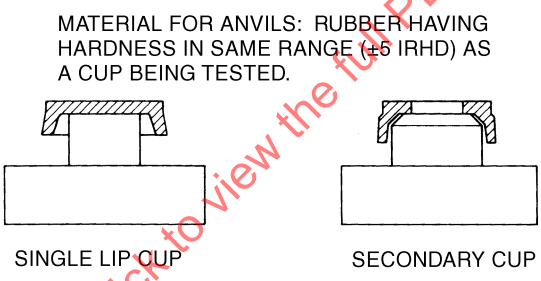

FIGURE 1—ANVIL FOR MEASURING HARDNESS (DESIGN TO ACCOMMODATE SEAL GEOMETRY)

The volume of each cup shall be determined in the following manner: Weigh the cups in air (M_1) to the nearest milligram and then weigh the cup immersed in distilled water at room temperature (M_2).[2] Quickly dip each specimen in isopropyl alcohol and then blot dry with filter paper free of lint and foreign material.

Two cups shall be completely immersed in 75 cm^3 of each of the specified test fluids, as outlined in Appendices A and B, in suitable glass containers, and the containers shall be sealed to prevent vapor loss. The containers shall be placed in an oven at 120 °C ± 2 °C (248 °F ± 3.6 °F) for a period of 70 h ± 2 h.

Two cups shall be completely immersed in 75 cm^3 of distilled water, in suitable glass contianers, and the containers sealed to prevent vapor loss. The containers shall be placed in an oven at 70 °C ± 2 °C (158 °F ± 3.6 °F) for a period of 166 h ± 2 h. At the end of the heating period, remove the cups from the oven and allow to cool in the container at 23 °C ± 5 °C (73.4 °F ± 9 °F) for 60 to 90 min. At the end of the cooling period, remove the cups from the container and rinse in isopropyl alcohol and wipe dry with a clean, lint-free cloth. Cups shall not remain in the alcohol for more than 30 s.

1. Suitable test jars and tinned steel lids can be obtained from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.
2. A trace of a suitable wetting agent not large enough to significantly affect the specific weight of the water should be added to the distilled water to eliminate small air bubbles from being trapped on the rubber surface during the weighing process.

After removal from the alcohol and drying, weigh each specimen in air (M_3), again to the nearest milligram, then reweigh immersed in room temperature distilled water (M_4) to determine water displacement after hot fluid immersion.

The final volume, dimensions, and hardness of each cup shall be determined within 30 to 60 min after rinsing in alcohol.

5.1.4 CALCULATION AND REPORT

5.1.4.1 *Volume Change*—Shall be reported as a percentage of the original volume. The calculation shall be made as follows in Equation 1:

$$\%\ \text{increase in volume} = \frac{(M_3 - M_4) - (M_1 - M_2)}{(M_1 - M_2)} \times 100 \qquad \text{(Eq. 1)}$$

where:

M_1 = initial mass in air
M_2 = initial mass in water
M_3 = mass in air after immersion in test fluid
M_4 = mass in water after test

5.1.4.2 *Dimensional Changes*—The original measurements shall be subtracted from the measurements taken after the test and the difference reported as a percentage of the original diameters.

5.1.4.3 Change in hardness shall be determined and recorded.

5.1.4.4 Examine the cups for disintegration as evidenced by blisters or sloughing.

5.2 Precipitation Test

5.2.1 APPARATUS—Glass containers[1] having a capacity of approximately 250 cm^3 (1/2 pt) and inner dimensions of approximately 125 mm (5 in) in height and 50 mm (2 in) in diameter which can be tightly sealed, and a cone-shaped centrifuge tube of 100 cm^3 capacity.

5.2.2 TEST SPECIMENS—Four cups shall be used.

5.2.3 PROCEDURE—To determine the precipitation characteristics of the test cups, place two cups in a suitable glass container containing 75 cm^3 of each of the test fluids specified in Appendices A and B. Each container shall be sealed to prevent vapor loss and placed in an oven at 120 °C ± 2 °C (248 °F ± 3.6 °F) for 70 h ± 2 h. At the end of the heating period, remove the container from the oven and allow to cool at room temperature for 24 h after which the cups are removed. The contents of the jar shall be thoroughly agitated and transferred to a cone-shaped centrifuge tube of 100 cm^3 capacity and the sediment determined as described in 5(b) of ASTM D 91.

1. See Footnote 1.

5.3 Wheel Cylinder Heat Pressure Stroking

5.3.1 APPARATUS

5.3.1.1 *Oven*—A well designed, uniformly heated, standard dry air oven conforming to the requirements for Type 11B oven in ASTM E 145.

5.3.1.2 *Actuating Heat Pressure Stroking Fixture for Wheel Cylinder Cups*—The actuating heat pressure stroking fixture shall be designed to provide a 3.8 mm ± 1.7 mm (0.15 in ± 0.07 in) movement of each piston. During the total movement of the piston, the pressure shall increase to 7.0 MPa ± 0.3 MPa (1000 psi ± 50 psi). The rate of operation shall be held at a uniform reciprocating motion of 1000 strokes/h ± 100 strokes/h. Figure 2 illustrates a recommended pressure MPa (psi) versus wheel cylinder piston movement curve for wheel cylinders within 12.7 to 50.8 mm (1/2 to 2 in) diameter.

NOTE—A new wheel cylinder assembly must be used for each test.

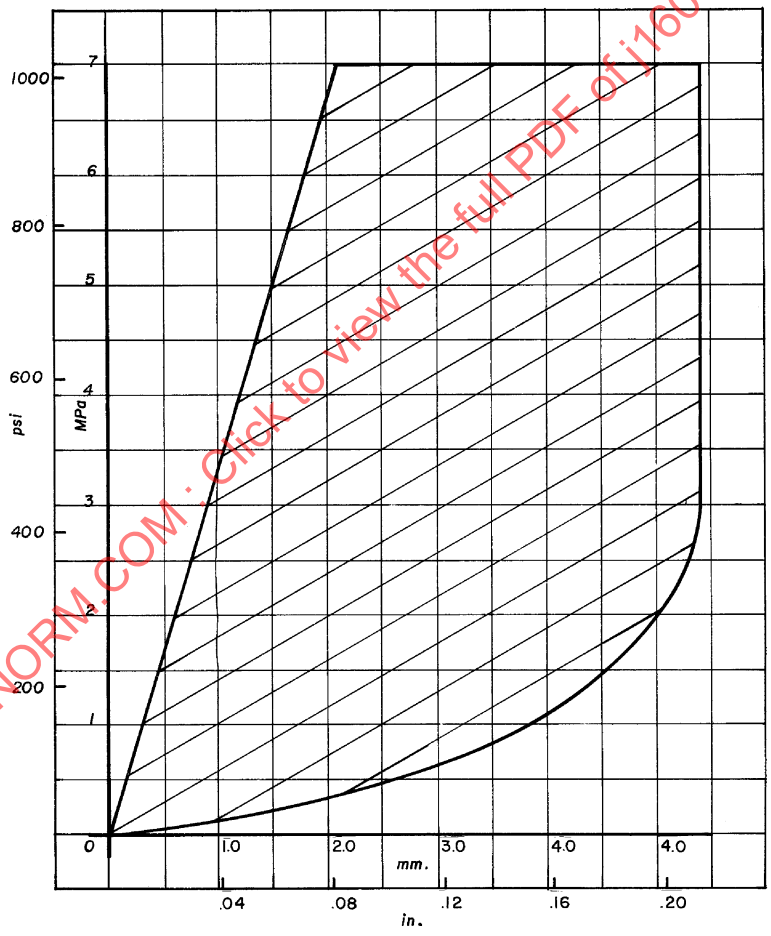

FIGURE 2—TYPICAL WHEEL CYLINDER CUP MOVEMENT VERSUS PRESSURE—12.7 TO 50.8 mm (1/2 TO 2 in) DIAMETER

5.3.2 TEST SPECIMENS—Two wheel cylinder cups shall be used as test specimens.

5.3.3 PROCEDURE—The wheel cylinder cups shall be rinsed in isopropyl alcohol and wiped dry with a clean, lint-free cloth to remove dirt and packing debris. Cups shall not remain in the alcohol for more than 30 s.

The lip diameter measurement shall be determined to the nearest 0.02 mm (0.001 in), taking the average of two readings at right angles to each other. In the case of double lip cups, these measurements shall be taken after the cup has been assembled on the piston. Determine and record the initial hardness of the test cups. The internal parts, which may include among other things cups, piston springs, expanders, etc., shall be installed in a wheel cylinder of known diameter using the test fluid specified in Appendix A as a lubricant. (Boots shall not be used.) Install the wheel cylinder assembly on the stroking fixture. The stroking fixture assembly shall be placed in an oven and actuated for 70 h at 120 °C ± 2 °C (248 °F ± 3.6 °F). After 1 h minimum operation, place a sheet of filter paper under each end of the wheel cylinder to catch and determine leakage. Inspect filter paper at least twice for discoloration at not less than 24 h intervals. Filter paper is to be changed if discolored from fluid leakage. The actuating means and the oven heater shall be shut off at the termination of the 70 h stroking period with the master cylinder piston in the "off" position to relieve retained pressure in the system. After 1 h cooling period with the oven door open and a ventilating fan on, disconnect the fluid line at the wheel cylinder inlet. Remove the entire stroking test fixture containing the test wheel cylinder from the oven and allow to cool for 22 h ± 2 h at room temperature. Immediately after completion of the 22 h cooling period, careful inspection shall be made to check for fluid leaks past the cups and results recorded, the fluid shall be drained from the system, and the cups shall be removed from the wheel cylinder. Double lip cups shall be measured before removal from the pistons. The cups shall be rinsed in isopropyl alcohol and dried with compressed air. Cups shall not remain in the alcohol for more than 30 s. Inspect cups for scoring, scuffing, blistering, cracking, chipping (heel abrasion), and change in shape from original appearance.

Inspect cylinder parts, recording any pitting on pistons and cylinder walls.

Determine and record the change in hardness.

The lip diameter of each cylinder cup shall be measured within 30 to 60 min after removal from the wheel cylinder and the difference between the actual cylinder bore and the lip diameter after the test shall be reported (excess over bore - Table 2).

5.4 Master Cylinder Heat Pressure Stroking

5.4.1 APPARATUS

5.4.1.1 A well-designed, uniformly heated, standard dry air oven conforming to the requirements for Type 11B oven prescribed in ASTM E 145.

5.4.1.2 *Actuating Heat Pressure Stroking Machine for Master Cylinder Cups*—The stroking machine shall consist of a suitable means for actuating the master cylinder containing the test specimens at the rate of 1000 strokes/h ± 100 strokes/h. The total piston movement shall be sufficient to cover approximately 90% of the total available stroke. On all master cylinders having a total stroke of 63 mm (2-1/2 in) or more, they shall be heat, pressure, and stroke tested at 90% of the 63 mm (2-1/2 in) stroke, or 57 mm (2-1/4 in). The rate of stroke shall be 800 strokes/h ± 80 strokes/h. Full pressure 7 MPa (1000 psi) shall be attained and maintained for 3 mm (1/8 in) of the stroke or 1 s maximum.

Figure 3 illustrates a typical master cylinder cup stroking apparatus. Figure 4 illustrates typical pressures in MPa (psi) versus the master cylinder piston movement obtained with three wheel cylinders of approximately 22 mm (7/8 in) diameter mounted in the three stroking fixtures as shown in Figure 3 actuated by a 25 mm (1 in) diameter master cylinder. The total stroke of the master cylinder shall be 25 mm (1 in).

The initial movement of approximately 14 to 15 mm (9/16 to 5/8 in) shall be at a rate providing a gradual buildup of pressure not to exceed 1 MPa (150 psi). This shall permit the primary cup to pass over the compensating port at a low pressure. The balance of the stroke shall provide a gradual buildup of pressure to 7.0 MPa ± 0.3 MPa (1000 psi ± 50 psi) during the last 1.6 to 3.20 mm (1/16 to 1/8 in) of stroke. This remaining stroke at 7.0 MPa ± 0.3 MPa (1000 psi ± 50 psi) shall be held constant by an adjustable relief valve.

The master cylinder shall be located in a uniformly heated, dry air oven and the fluid temperature in the master cylinder reservoir shall be maintained at 120 °C ± 2 °C (248 °F ± 3.6 °F).

NOTE—A new master cylinder must be used for each test. It is recommended that at least 0.05 to 0.13 mm (0.002 to 0.005 in) clearance be allowed between the master cylinder piston and the master cylinder bore when conducting a master cylinder stroking test.

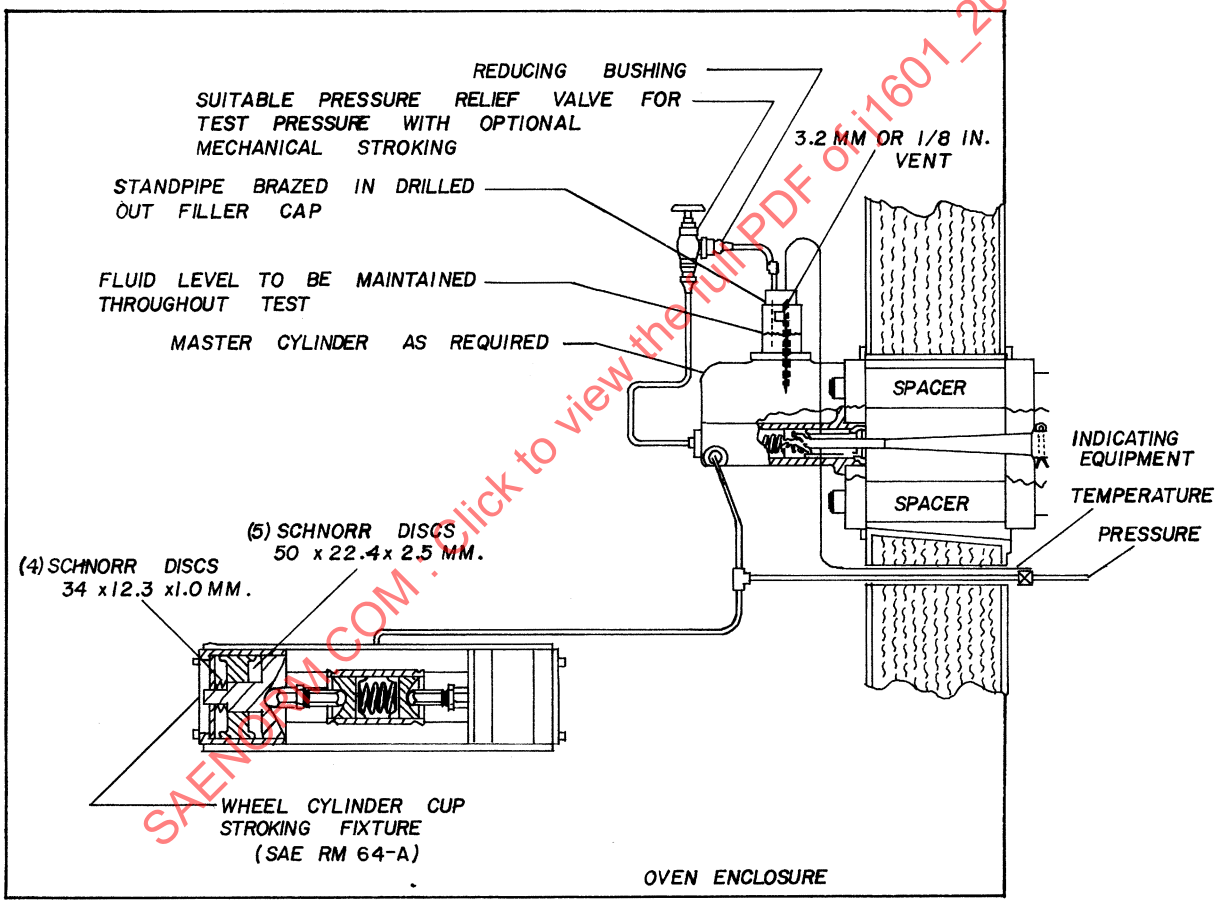

FIGURE 3—MASTER CYLINDER CUP STROKING APPARATUS

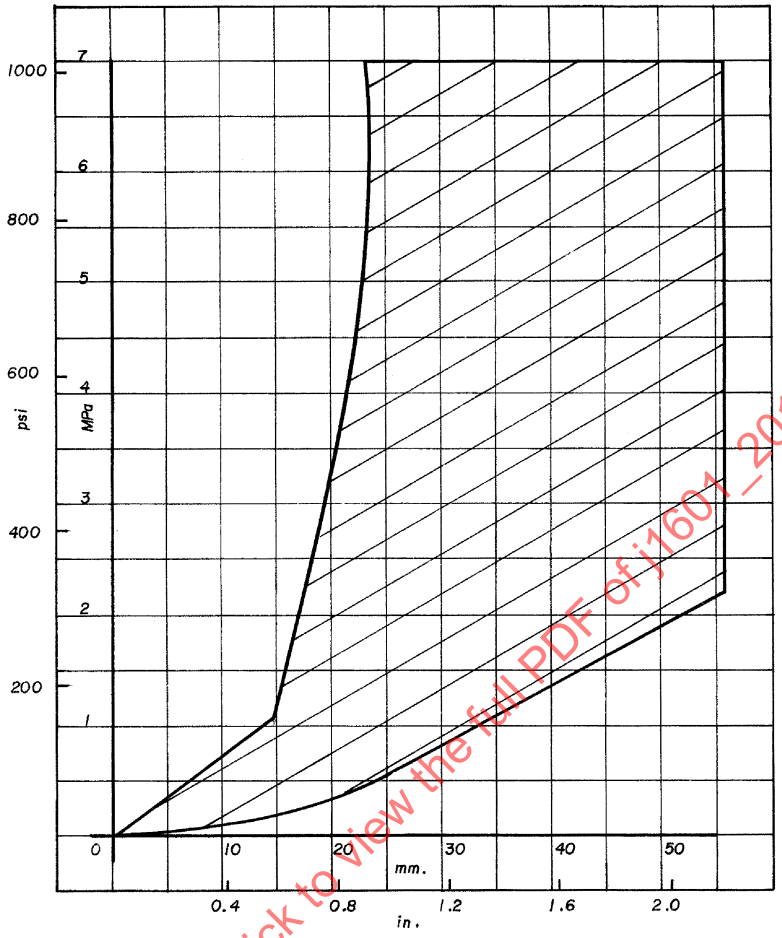

FIGURE 4—TYPICAL STROKING TEST FOR MASTER CYLINDER CUP
(25 mm or 1 in)

5.4.2 TEST SPECIMENS—One primary and one secondary cup shall be used for test specimens.

5.4.3 PROCEDURE—The cups shall be rinsed in isopropyl alcohol and wiped dry with a clean, lint-free cloth to remove dirt and packing debris. Cups shall not remain in the alcohol for more than 30 s.

Determine and record the initial hardness of the test cups. The lip diameter of the primary and secondary cups shall be measured and recorded to the nearest 0.02 mm (0.001 in), taking the average of two readings at right angles to each other. The lip diameter of the secondary cup shall be measured after the cup has been assembled on the piston.

The cups and master cylinder internal parts shall be dipped in the test fluid specified in Appendix A and the cylinder walls coated with the specified test fluid before assembly.

The master cylinder assembly, after installation in an oven, shall be operated for 70 h at the rate of 1000 strokes/h ± 100 strokes/h at a temperature of 120 °C ± 2 °C (248 °F ± 3.6 °F) as described in 5.4.1. After approximately 1 h of stroking to allow for evaporation of excess lubricant used at assembly, place a sheet of filter paper under the secondary cup of the master cylinder to catch and determine leakage past the secondary cup. The heat and actuating means shall be shut off at the termination of the 70 h stroking period with the master cylinder in the "off" position to relieve retained pressure in the master cylinder. After 1 h cooling period with the oven door open and the ventilating fan on, disconnect the fluid line at the master cylinder outlet. Remove the master cylinder from the oven and allow to cool for 22 h ± 2 h at room temperature. Immediately after completion of the 22 h cooling period, careful inspection shall be made to check for fluid leakage past the master cylinder secondary cup. The fluid shall be drained from the master cylinder. The primary cup shall be removed from the cylinder, rinsed with isopropyl alcohol, and dried with compressed air. The secondary cup on the piston shall be rinsed in isopropyl alcohol, dried with compressed air, and the lip diameter measured before removal from the piston. Cups shall not remain in the alcohol for more than 30 s. Inspect cups for deterioration such as scoring, scuffing, blistering, cracking, chipping (heel abrasion), and change in shape from original appearance. Inspect cylinder parts, recording any pitting on piston or cylinder walls. The lip diameter of the primary cup shall be measured within 30 to 60 min after removal from the cylinder and the difference between the actual cylinder bore and the lip diameter after the test shall be determined and recorded for both primary and secondary cups.

Determine and record the change in hardness within 30 to 60 min after removal from the cylinder.

5.5 Low Temperature Performance

5.5.1 LEAKAGE

5.5.1.1 *Apparatus*—The leakage test apparatus shall include the following:

5.5.1.1.1 A cold chamber large enough to permit arrangement of the test apparatus within and to permit the operator to check and operate the apparatus without removal from the chamber.

5.5.1.1.2 A master cylinder and wheel cylinder so connected that their operation closely approximates the brake system in actual service. The apparatus shown in Figure 5 has been found satisfactory. The cylinder bore containing the test cups shall meet the dimensional limitations and bore finish requirements specified by the manufacturer.

5.5.1.1.3 The retractor spring shall be such as to require not more than 0.35 MPa (50 psi) line pressure to make a complete stroke at room temperature.

5.5.1.2 *Test Specimens*—Two wheel cylinder cups, one primary and one secondary master cylinder cup shall be used for test cups.

5.5.1.3 *Procedure*—The test cups shall be rinsed in isopropyl alcohol and wiped dry with a clean, lint-free cloth. The cups shall not remain in the alcohol for more than 30 s. The test cups shall be assembled in the test cylinder. During assembly of the cylinder assembly, the cylinder walls shall be coated with and each other part dipped in the test fluid specified in Appendix A. The wheel and master cylinder assembly containing the test cups shall be installed on the test apparatus in the cold chamber. The system shall be filled with test fluid and all air bled from the system. Boots shall not be used. The complete actuating system shall be enclosed in the cold chamber and subjected to a temperature of –40 to –43 °C (–40 to –45.4 °F) for 120 h. The piston and cups shall remain in a static position during the first 72 h of the test and thereafter shall be actuated 6 strokes at 0.7 MPa (100 psi) and 6 strokes at 3.5 MPa (500 psi) each 24 h (after 72, 96, and 120 h). The strokes shall be approximately 1 min apart, and the piston shall return to the stop after each stroke. No leakage shall occur during the 120 h test period.

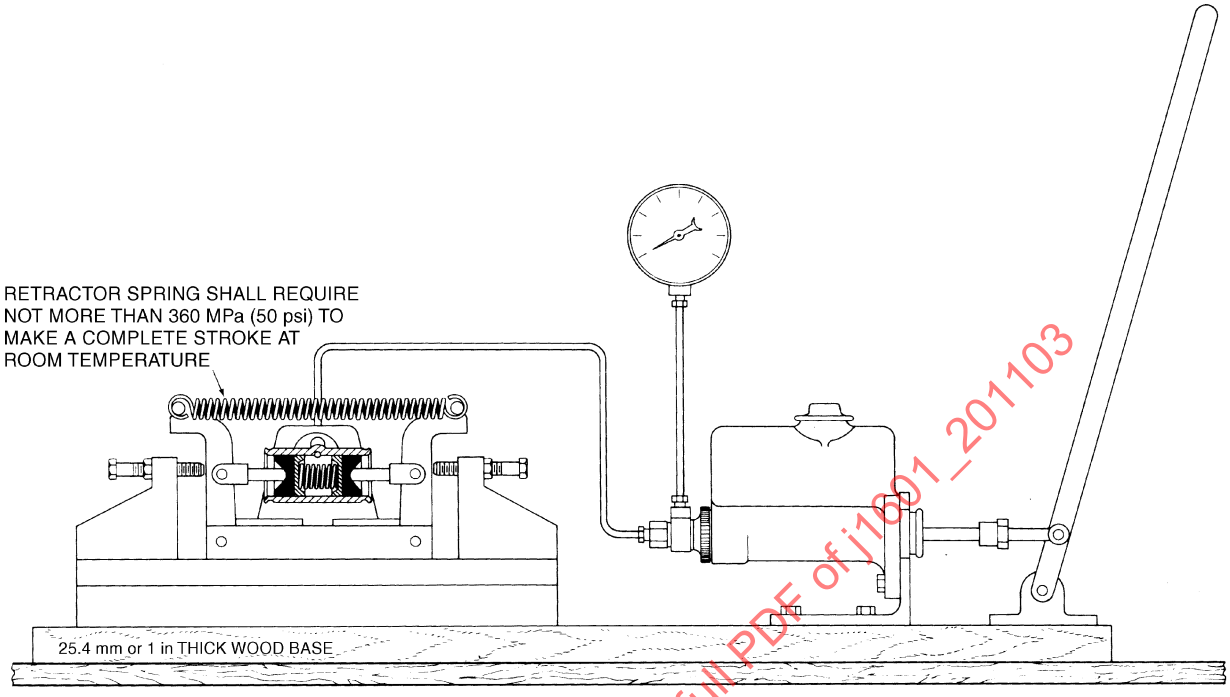

FIGURE 5—LOW TEMPERATURE LEAKAGE TEST APPARATUS

5.5.2 BEND TEST

5.5.2.1 *Test Specimen*—One cup shall be used.

5.5.2.2 *Procedure*—The test cup after being subjected to 22 h at –40 to –43 °C (–40 to –45.4 °F) shall be bent through an angle of approximately 90 degrees and immediately released. (The cold cup shall be bent while in the cold chamber and shall be handled to prevent warming). Within 1 min, examine the test cup for cracking and change in shape from original appearance.

5.6 Oven Aging

5.6.1 Two test cups shall be rinsed in isopropyl alcohol and wiped dry with a clean, lint-free cloth to remove dirt and packing debris. Cups shall not remain in the alcohol for more than 30 s. The hardness of the cups shall be determined and recorded. The two test cups shall be placed in a Type 11B oven, as prescribed in ASTM E 145, and subjected to hot air heating at 100 °C ± 2 °C (212 °F ± 3.6 °F) for 70 h. At the termination of the 70 h heating period, the cups shall be removed from the oven and allowed to cool for 16 to 96 h at room temperature.

The cups shall be inspected for blistering, or change in shape from original appearance. The hardness after aging shall be determined and recorded.

5.7 Hardness Determination

5.7.1 APPARATUS

5.7.1.1 International rubber hardness tester as described in ASTM D 1415.

5.7.1.2 Type A durometer as described in ASTM D 2240.

5.7.1.3 Rubber anvil or cylinder having a flat circular top surface at least 19 mm (0.65 in) in diameter, a thickness of at least 9 mm (0.35 in), and a hardness within 5 IRHD of the hardness of the rubber test cup. See Figure 1 for one design of anvil. The anvil design can be altered in accordance with the geometry of the cup or seal design.

5.7.2 PROCEDURE—The rubber cup shall be placed on a rubber anvil or cylinder as shown in Figure 1. The hardness of the cups is then measured by the procedure specified in ASTM D 1415 (ASTM D 2240 if a type A durometer is used).

5.8 Corrosion—Prepare two sets of strips from each of the metals listed in Table 4, each strip having a surface area of 25 cm^2 ± 5 cm^2 (3.875 in^2 ± 0.775 in^2), (approximately 8 cm (3.15 in) long, 1.3 cm (0.50 in) wide, and not more than 0.6 cm (0.24 in) thick. Drill a hole between 4 and 5 mm (0.16 and 0.20 in) in diameter and about 6 mm (0.24 in) from one end of each strip. With the exception of the tinned iron strips, clean the strips by abrading them on all surface areas with 320 A waterproof carborundum paper (RM-29) and isopropyl alcohol until all surface scratches, cuts, and pits are removed from the strips, using a new piece of carborundum paper for each different type of metal. Wash the strips, including the tinned iron, with isopropyl alcohol and dry the strips with a clean, lint-free cloth and place the strips in a desiccator containing desiccant maintained at 23 °C ± 5 °C (73.4 °F ± 9 °F) for at least 1 h. Handle the strips with clean forceps after polishing to avoid fingerprint contamination.

Weigh each strip to the nearest 0.1 mg and assemble each set of strips on an uncoated steel bolt (RM-61) in the order tinned iron, steel, aluminum, cast iron, brass, copper, and zinc, so that the strips are in electrolytic contact. Bend the strips, other than cast iron, so that there is a separation of at least 3 mm (0.125 in) between adjacent strips for a distance of about 6 cm (2.36 in) from the free end of the strips. Immerse strip assemblies in isopropyl alcohol or ethanol to eliminate fingerprints and then handle only with clean forceps. Place one rubber cup with lip edges facing up, in each of two straight-sided round glass jars[1] having a capacity of approximately 475 mL and inner dimensions of approximately 100 mm (4 in) in height and 75 mm (3 in) in diameter. Use only tinned steel lids vented with a hole 0.8 mm ± 0.1 mm (0.032 in ± 0.003 in) in diameter. To the RM-49 corrosion test jar, apply four wrappings of 3/4 in Teflon tape around the jar threads allowing a 1/8 in height above the top of the jar. Insert a metal strip assembly inside one cup in each jar with the pinned end in contact with the concavity of the cup and the free end extending upward in the jar. Mix 760 mL of SAE RM66-04 compatibility fluid with 40 mL of distilled water.

Add a sufficient amount (400 mL) of the mixture to cover the metal strip assembly in each jar to a depth of approximately 10 mm (0.40 in) above the tops of the strips listed in Table 4. Tighten the lids and place the jars in an oven maintained at 100 °C ± 2 °C (212 °F ± 3.6 °F) for 120 h ± 2 h. Allow the jars to cool at 23 °C ± 5 °C (73.4 °F ± 9 °F) for 60 to 90 min. Immediately following the cooling period, remove the metal strips from the jars by use of forceps, removing loose adhering sediment by agitation of the metal strip assembly in the fluid in the jar. Examine test strips and test jars for adhering crystalline deposit, disassemble the metal strips, remove adhering fluid by flushing with water and clean individual strips by wiping with a cloth wetted with isopropyl alcohol. Examine the strips for evidence of corrosion and pitting. Place strips in a desiccator containing a desiccant maintained at 23 °C ± 5 °C (73.4 °F ± 9 °F) for at least 1 h. Weigh each strip to the nearest 0.1 mg. Determine the difference in weight of each metal strip and divide the difference by the total surface area of the metal strip measured in square centimeters. Average the results for the two strips of each type of metal.

1. See Footnote 1.