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Low Water Tolerant Brake Fluids— SAE J1705 MAR85

SAE Recommended Practice
Approved March 1985

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Report of the Hydraulic Brake Systems Actuating Committee, approved March 1985.

1. Scope—This recommended practice was prepared by the Motor Vehicle Brake Fluids Subcommittee of the SAE Hydraulic Brake Systems Actuating Committee to provide engineers, designers, and manufacturers of motor vehicles with a set of minimum performance standards in order to assess the suitability of silicone and other low water tolerant type brake fluids (LWTF) for use in motor vehicle brake systems. These fluids are designed for use in braking systems fitted with rubber cups and seals made from natural rubber (NR), styrene-butadiene rubber (SBR), or a terpolymer of ethylene, propylene, and a diene (EPDM).

In the development of the recommended requirements and test procedures contained herein, it is concluded that the LWTF's must be functionally compatible with existing motor vehicle brake fluids conforming to SAE Standard J1703 and with braking systems designed for such fluids. To utilize LWTF's to the fullest advantage, they should not be mixed with other brake fluids. Inadvertent mixtures of LWTF's with fluids meeting SAE J1703 are not known to have any adverse effects on performance, but all combinations have not been tested. Vehicle manufacturer's recommendations should be followed where indicated. These fluids are not necessarily suitable for use in central hydraulic or pumped systems and are not intended for use below temperatures of −50°C (−58°F). Brake fluids covered under this recommended practice are not required to tolerate water and extreme caution should be exercised to prevent accidental entry of water which might lead to brake failure. Other performance characteristics of these LWTF's not covered in this recommended practice are discussed in the Appendix.

2. Requirements

2.1 Equilibrium Reflux Boiling Point (ERBP)

(a) When tested by the procedure specified in paragraph 3.1, the low water tolerant brake fluid shall have an ERBP of not less than 260°C (500°F).

(b) When tested by the procedure specified in paragraph 3.1.1, the low water tolerant brake fluid shall have a wet ERBP of not less than 180°C (356°F).

2.2 Viscosity—When tested by the procedure specified in paragraph 3.2, LWTF's shall have kinematic viscosities as follows:

(a) At −40°C (−40°F): not more than 900 mm²/s (900 cSt).

(b) At 25°C (77°F): not more than 50 mm²/s (50 cSt).

(c) At 100°C (212°F): not less than 1.5 mm²/s (1.5 cSt).

2.3 Corrosion—LWTF's, when tested by the procedure specified in paragraph 3.3, shall not cause corrosion exceeding the limits shown in Table 1. The metal strips outside the area of contact shall be neither pitted nor roughened to an extent discernible by the eye without magnification, but staining or discoloration is permitted. Roughening caused during assembly and disassembly shall be disregarded.

The fluid at the end of the test shall show no gelling at 23 ± 5°C (73 ± 9°F). No crystalline type deposit shall form and adhere to either the glass jar walls or the surface of metal strips. The fluid shall contain no more than 0.10% sediment by volume.

The rubber cup at the end of the test shall show no appreciable disintegration as evidenced by blisters or sloughing as indicated by carbon black separation on the surface of the rubber cup. The hardness of the rubber cup shall not decrease by more than 15 International Rubber Hardness degrees (IRHD) and the base diameter shall not increase by more than 1.40 mm (0.055 in).

2.4 Fluidity and Appearance at Low Temperature

(a) At −40°C (−40°F)—When LWTF's are tested by the procedure specified in paragraph 3.4(a), the fluid shall show no stratification, sediment, or crystals. Upon inversion of the sample bottle, the air bubble shall travel to the top of the fluid in not more than 10 s. Cloudiness is permissible, but on warming to room temperature 23 ± 5°C (73 ± 9°F), the fluid shall regain its original uniformity, appearance, and clarity.

(b) At −50°C (−58°F)—When LWTF's are tested by the procedure specified in paragraph 3.4(b), the fluid shall show no stratification, sediment, or crystals. Upon inversion of the sample bottle, the air bubble shall travel to the top of the fluid in not more than 35 s. Cloudiness is permissible, but on warming to room temperature 23 ± 5°C (73 ± 9°F), the fluid shall regain its original uniformity, appearance, and clarity.

2.5 Tolerance to High Humidity

(a) At −40°C (−40°F)—When LWTF's are tested by the procedure specified in paragraph 3.5, the fluid shall show no stratification, sediment, or crystals. Upon inversion of the centrifuge tube, the air bubble shall travel to top of the fluid in not more than 10 s. Cloudiness is permissible, but on warming to room temperature 23 ± 5°C (73 ± 9°F), the fluid shall regain its original uniformity, appearance, and clarity.

(b) At 60°C (140°F)—When LWTF's are tested by the procedure specified in paragraph 3.5, the fluid shall show no stratification; sediment shall not exceed 0.05% by volume after centrifuging.

2.6 Effect on Rubber—Rubber specimens, when tested as specified in paragraph 3.6, shall show no disintegration as evidenced by blisters or sloughing. Hardness changes, base diameter changes, and volume swell shall lie within the ranges given in Table 2.

2.7 Compatibility

(a) At −40°C (−40°F)—When LWTF's are tested by the procedure specified in paragraph 3.7(a), the fluid shall show no sedimentation or crystallization. Cloudiness is permissible, but on warming to room temperature 23 ± 5°C (73 ± 9°F), the mixture shall be no more cloudy than the original fluid under test.

(b) At 60°C (140°F)—When LWTF's are tested by the procedure specified in paragraph 3.7 (b), sedimentation shall not exceed 0.05% by volume after centrifuging.

2.8 Fluid Stability—When the brake fluid is tested according to paragraph 3.8, the ERBP shall not be less than 260°C (500°F).

2.9 Stroking Test—An LWTF, when tested by the procedure specified in paragraph 3.9, shall meet the following performance requirements:

(a) Metal parts shall not show corrosion as evidenced by pitting to an extent discernible to the naked eye, but staining or discoloration shall be permitted.

(b) The initial diameter of any cylinder or piston shall not change by more than 0.13 mm (0.005 in) during test.

(c) Rubber cups shall not decrease in hardness by more than 15 IRHD and shall not be in an unsatisfactory operating condition as evidenced by excessive amounts of scoring, scuffing, blistering, cracking, or change in shape from original appearance.

(d) The base diameter of the rubber cups shall not increase by more than 0.9 mm (0.035 in).

(e) The average lip diameter interference set of the rubber cups shall not be greater than 65%.

(f) During any period of 24 000 strokes, the volume loss of fluid shall not be greater than 36 mL.

(g) The cylinder pistons shall not seize or function improperly throughout the test.

(h) The volume loss of fluid during the 100 strokes at the end of the test shall not be more than 36 mL.

(i) The fluid at the end of the test shall not be in an unsatisfactory operating condition as evidenced by sludging, gelling, or abrasive grittiness, and sediment in either the master cylinder or the wheel cylinders shall not exceed 1.5% by volume after allowing the fluid to stand 24 h at room temperature and then centrifuging.

(j) Brake cylinder walls and other metal parts shall be free of deposits which are abrasive or which cannot be removed when rubbed with a cloth wetted with isopropyl alcohol.

3. Test Procedure

3.1 Equilibrium Reflux Boiling Point—Determine the equilibrium reflux boiling point of the fluid by ASTM D1120, Method of Test for Boiling Point of Engine Antifreezes, with the following exceptions:

APPARATUS

3(d) Thermometer—ASTM E1, 76 mm immersion, calibrated. Use ASTM 3C or 3F thermometer. For fluids boiling below 300°C (572°F), ASTM 2C or 2F thermometer may be used.

3(e) Heat Source—Use a suitable Variac-controlled 100 mL heating

TABLE 1—CORROSION TEST STRIPS AND MASS CHANGES

Test Specimens[a]	Max Permissible Mass Change mg/cm² of Surface
Tinned Iron	0.1
Steel	0.1
Aluminum	0.1
Cast Iron	0.1
Brass	0.2
Copper	0.2

[a] Obtainable from the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

TABLE 2—EFFECT ON RUBBER

Type	Test Specimen	Volume Swell %	Base Diameter Change	Change in Hardness	Test Temperature		Time Hours
					°C	°F	
SBR	SAE RM-3a	(+5 to +20)	0.15 to 1.4 mm (0.006 to 0.055 in)	(0 to −10)	25 ± 2	77 ± 4	168 ± 2
	SAE RM-3a	(+5 to +20)	0.15 to 1.4 mm (0.006 to 0.055 in	(0 to −10)	70 ± 2	158 ± 4	70 ± 2
	SAE RM-3a	(+5 to +20)	0.15 to 1.4 mm (0.006 to 0.055 in)	(0 to −15)	120 ± 2	248 ± 4	70 ± 2
Polychloroprene	SAE RM-68	(−5 to +10)	—	(+3 to −10)	25 ± 2	77 ± 4	168 ± 2
	SAE RM-68	(−5 to +10)	—	(+3 to −10)	70 ± 2	158 ± 4	70 ± 2
	SAE RM-68	(+5 to +10)	—	(+3 to −10)	100 ± 2	212 ± 4	70 ± 2
EPR	SAE RM-69	(0 to +10)	—	(0 to −10)	25 ± 2	77 ± 4	168 ± 2
	SAE RM-69	(0 to +10)	—	(0 to −10)	70 ± 2	158 ± 4	70 ± 2
	SAE RM-69	(0 to +10)	—	(0 to −10)	120 ± 2	248 ± 4	70 ± 2
Natural	SAE NR-X	(+5 to +20)	0.15 to 1.4 mm (0.006 to 0.055 in)	(0 to −10)	25 ± 2	77 ± 4	168 ± 2
	SAE NR-X	(+5 to +20)	0.15 to 1.4 mm (0.006 to 0.055 in)	(0 to −10)	70 ± 2	158 ± 4	70 ± 2

mantle designed to fit the flask, capable of supplying the heat required to conform to the specified heating and reflux rates. [Supplier: GLAS COL Apparatus Co., Terre Haute, IN. Serial number: 135464. 230 W, 135 V (max).]

PREPARATION OF APPARATUS

5(*d*)—Thoroughly clean and dry all glassware before use. Attach the flask to the condenser. Place the mantle under the flask and support it with a suitable ring clamp and laboratory type stand, holding the whole assembly in place by a clamp.

NOTE: Place the whole assembly in an area free from drafts or other types of sudden temperature changes.

PROCEDURE

6(*c*)—When everything is in readiness, turn on the condenser water and apply heat to the flask at such a rate that the fluid is refluxing in 10 ± 2 min at a rate in excess of 1 drop/s.

The reflux rate shall not exceed 5 drop/s. Immediately adjust heat input to obtain a specified equilibrium reflux rate of 1–2 drop/s over the next 5 ± 2 min period. Maintain a timed and constant equilibrium reflux rate of 1–2 drop/s for an additional 2 min; record the average value of four temperature readings taken at 30 s intervals as the equilibrium reflux boiling point.

If the temperature exceeds 260°C (500°F), the test shall be stopped and the temperature recorded as exceeding 260°C (500°F).

3.1.1 WET ERBP—Humidify the fluid as described in paragraph 3.5 and determine the boiling point as described in paragraph 3.1.

3.2 Viscosity—Determine the kinematic viscosity of the fluid by ASTM D445.

3.2.1 Report the viscosity to the nearest centistoke (mm^2/s).

3.3 Corrosion—Prepare two sets of strips from each of the metals listed in Table 1. Drill a hole between 4 and 5 mm (0.16 and 0.20 in) in diameter and about 6 mm (¼ 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 320A and 400A waterproof carborundum papers 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; then place them in a desiccator containing desiccant and maintained at 23 ± 5°C (73 ± 9°F) for at least 1 h before weighing. 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 in the order tinned iron, steel, aluminum, cast iron, brass, and copper, 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 between adjacent strips for a distance of at least 6 cm from the free ends of the strips. Immerse strip assemblies in 90% ethanol to eliminate fingerprints; dry thoroughly with clean compressed air; handle only with clean, dry forceps thereafter.

Measure the base diameter of two standard SAE RM-3A SBR cups using an optical comparator or micrometer, to the nearest 0.02 mm (0.001 in) along the centerline of the SAE and rubber type identifications and at right angles to this centerline. Take the measurements within 0.4 mm (0.016 in) of the bottom edge and parallel to the base of the cup. Discard any cup if the two measured diameters differ by more than 0.08 mm (0.003 in). Average the two readings of each cup. Support the rubber cup on a rubber anvil or cylinder having a flat circular top surface of at least 19 mm diameter, a thickness of at least 9 mm, and hardness within 5 IRHD of the hardness of the rubber test cup. Determine the hardness of each cup thus supported, using the standard instrument and procedure specified in ASTM D1415, Method of Test for International Hardness of Vulcanized Natural and Synthetic Rubbers. (NOTE: ASTM D2240, Method of Test for Indentation Hardness of Rubber and Plastics by Means of a Durometer, may be used for quality control and routine tests if the Type A durometer is equipped with a fixture for keeping the plane of the pressure foot on the durometer parallel to the plane of the cup face during measurement.) Obtain two straight-sided, round, glass jars, having a capacity of approximately 475 mL and inner dimensions of approximately 100 mm in height and 75 mm in diameter (SAE RM-49). Grind the lip of each jar flat with the use of 400A waterproof carborundum paper and a flat surface as required to insure proper sealing. Place one rubber cup with lip edge facing up, in each of the two glass jars. Use only tinned steel lids vented with a hole 0.8 ± 0.1 mm in diameter. Place a Teflon disc seal with a hole diameter slightly larger than the hole in the tinned steel lid in each lid. Insert a metal strip assembly inside each cup with the bolted end in contact with the concavity of the cup and the free end extending upward in the jar.

Add test fluid, humidified in accordance with paragraph 3.5 in sufficient amount to cover the metal strip assembly to a depth of approximately 10 mm (0.39 in). Tighten the lids and place the two jars in a gravity convection oven conforming to ASTM E145 Type 1A and maintained at 100 ± 2°C (212 ± 4°F), for 120 ± 2 h. Allow the jars to cool at 23 ± 5°C (73 ± 9°F) for 60–90 min.

Immediately following the cooling period, take the rubber cups from the jars with forceps, removing loose adhering sediment by agitating the cup in the fluid. Rinse both cups in isopropyl alcohol and air dry. Examine them for evidence of sloughing, blisters, and other forms of disintegration. Measure the base diameter and hardness of each cup within 15 min after removal from the fluid.

Next, take the metal strips from the jars with forceps, again removing loose adhering sediment by agitation of the metal strip assembly in the fluid. Examine assemblies and jars for adhering crystalline deposits; disassemble the metal strips, removing adhering fluid by flushing with isopropyl alcohol. 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 desiccant and maintained at 23 ± 5°C (73 ± 9°F)] for at least 1 h. Weigh each strip to the nearest 0.1 mg. Determine the difference in mass of each metal strip and divide by its total surface area in square centimeters. Average the calculated values for the duplicates and report to the nearest 0.01 mg/cm^2. In the event of a marginal pass on inspection, or of a failure in only one of the duplicates, another set of duplicate test samples shall be run. Both repeat samples must meet all the requirements of paragraph 2.3. Examine the test fluid in the jars for gelling. Agitate the fluid in jars to suspend and uniformly disperse sediment, then transfer a 100 mL portion of this fluid to an ASTM cone-shaped centrifuge tube. Determine percent sediment as described in paragraph 5(b) of ASTM D91.

3.4 Fluidity and Appearance of Low Temperatures

(a) At −40°C (−40°F)—Place 100 mL of the test fluid in a screw-top glass sample bottle having a capacity of approximately 125 mL, an outside diameter of about 37 mm, and overall height of about 155 mm. Cap the bottle tightly and place in a cold bath maintained at −40 ± 2°C (−40 ± 4°F) for 144 ± 4 h. Remove the bottle from the bath, quickly wipe the bottle with a clean lint-free cloth saturated with isopropyl alcohol, and examine the fluid for evidence of stratification, sediment, or crystals.

Invert the bottle and determine the number of seconds required for the air bubble to travel to the top of the fluid. Allow the fluid to warm to room temperature 23 ± 5°C (73 ± 9°F); if necessary allow to stand for as long as 4 h. Examine the fluid for clarity and appearance by comparing it to an original sample of the test fluid in an identical container.

(b) At −50°C (−58°F)—Place 100 mL of fluid in a glass sample bottle (same as in the −40°F test above). Cap the bottle tightly and place in a cold bath maintained at −50 ± 2°C (−58 ± 4°F) for 6 ± 0.2 h. Remove the bottle from the bath, quickly wipe the bottle with a clean lint-free cloth saturated with isopropyl alcohol, and examine the fluid for evidence of stratification, sediment, and crystals. Invert the bottle and determine the number of seconds required for the air bubble to travel to the top of the fluid. Allow the fluid to warm to room temperature 23 ± 5°C (73 ± 9°F); if necessary allow to stand for as long as 4 h. Examine the fluid for clarity and appearance by comparing it to a sample of the original test fluid in an identical container.

3.5 Tolerance for High Humidity

3.5.1 Apparatus for Humidification (See fig. 7)—Test apparatus shall consist of:

(a) Glass Jars and Lids—Four SAE RM-49 corrosion test jars. Each shall have a capacity of about 475 mL and approximate inner dimensions of 100 mm in height by 85 mm in diameter. Use matching lids (RM-63) having new, clean inserts, unaffected by the test fluid and providing water-vapor proof seals.

(b) Desiccator and Cover—Bowl-form glass desiccators, about 250 mm inside diameter, having matching tubulated covers fitted with No. 8 rubber stoppers. Four are required.

(c) Desiccator Plate—Procelain desiccator plates perforated with 5 mm (0.20 in) diameter holes approximately 15 mm on centers. Approximately 230 mm diameter, without feet, glazed one side (Coors 60003 or equal). Four are required.

Note: Minor variations in the humidification apparatus will not affect the end results, provided that identical set ups are used for both the reference and test fluids.

3.5.2 Reagents and Materials

(a) Ammonium sulfate $(NH_4)_2 SO_4$, Reagent or A.C.S. grade.

(b) Distilled water.

(c) SAE RM-71 reference fluid.

3.5.3 Preparation of Apparatus—Lubricate ground-glass joint of desiccator with suitable stopcock grease. Load each desiccator with 450 ± 25 g of ammonium sulfate and add 125 ± 10 mL of distilled water. Surface of the salt slurry shall lie within 45 ± 7 mm of the top surface of the desiccator plate. Place the desiccators in an area with the temperature controlled at 23 ± 5°C (73 ± 9°F) throughout the humidification procedure. Load the desiccators with the slurry and allow to condition with the desiccator cover on, test jar inside, and stoppers in place, at least 12 h before use. Use a fresh charge of salt slurry for each test.

3.5.4 Humidification Procedure—Pipette 100 ± 1 mL of the brake fluid into a test jar through the desiccator cover and replace the rubber stopper. Prepare a duplicate test sample and two duplicate specimens of the RM-71 reference fluid. Adjust water contents of the SAE RM-71 fluid to 0.50 ± 0.05% by weight at start of test. At intervals, remove rubber stopper in the top of each desiccator containing SAE RM-71 fluid. Using a long needled hypodermic syringe, take a sample of not more than 2 mL from each jar and determine its water content by the Karl Fischer procedure (ASTM E203) or equivalent. Remove no more than 20 mL of fluid from each SAE RM-71 sample during humidification. When the water content of the SAE fluid reaches 3.70 ± 0.05% by weight (average of the duplicates), remove the two test fluid specimens (jars) from their desiccators and promptly cap each tightly. Fill a coneshaped centrifuge tube (as described in paragraph 3.1 of ASTM D91) with 100 mL of humidified fluid (remainder is available for other tests as required).

3.5.5 Alternate (Bulk) Humidification Procedure (See Notes Following)—Lubricate the ground-glass joint of a 250 mm ID bowl-form desiccator having matching tubulated glass cover and fitted with a No. 8 rubber stopper. Pour 450 ± 10 mL of distilled water into the dessicator and insert a perforated porcelain plate (Coors No. 60003 or equal). Immediately place two open RM-49 corrosion test jars each containing 350 ± 5 mL of the test brake fluid, into the desiccator, replace desiccator cover, and insert at once into an ASTM E145, Type IIA, forced-ventilation oven set at 50 ± 1°C (122 ± 2°F). Place an identical desiccator set up having two jars containing Reference Fluid RM-71 in the oven at the same time. The water content of the RM-71 fluid at the start of exposure shall have been adjusted to 0.50 ± 0.05% by weight (Karl Fischer analysis or equivalent).

Periodically during oven humidification, remove the rubber stopper from the desiccator containing the control fluid. Using a hypodermic syringe with a long needle, quickly sample each jar and determine its individual water content. When the average water content of the control fluid has reached 3.70 ± 0.05% by weight, remove desiccator containing the test fluid at once from the oven and seal the test jars promptly, using screw-cap jar lids with suitable vapor-proof liners (RM-63). Allow the sealed jars to cool for 60–90 min at 23 ± 5°C (73 ± 9°F).

Notes on Alternate Procedure

(a) The bulk procedure may be run with either one, two, three, or four jars per desiccator, and jars may be filled from 150 to 350 mL as desired.

(b) Minor variations in equipment used are not critical. However, it is very important that all desiccator set ups in a given run be identical, and that an ASTM Type IIB oven of ample size be used.

3.5.6 Procedure for Humidity Tolerance Determination

(a) At −40°C (−40°F)—Pour 100 mL of the humidified fluid into an ASTM coneshaped centrifuge tube described in paragraph 3.1 of ASTM D91. Seal the tube and place in a cold bath maintained at −40 ± 2°C (−40 ± 4°F) for 144 ± 4 h. Remove the centrifuge tube from the bath, quickly wipe with a clean, lint-free cloth saturated with isopropyl alcohol or acetone, and examine the fluid for evidence of stratification, sediment, or crystals. Invert the tube and determine the number of seconds required for the air bubble to travel to the top of the fluid. (The air bubble shall be considered to have reached the top of the fluid when the top of the bubble reaches the 2 mL graduation of the centrifuge tube.) Allow the fluid to warm to room temperature 23 ± 5°C (73 ± 9°F); if necessary allow to stand for as long as 4 h. Examine the fluid for appearance and clarity by comparing it to an as-received sample of the test fluid in an identical container.

(b) At 60°C (140°F)—Place the centrifuge tube from paragraph 3.5.6 in a gravity convection oven conforming to ASTM E145 Type 1A and maintained at 60 ± 2°C (140 ± 4°F) for 22 ± 2 h. Then remove tube from oven and immediately examine the fluid for evidence of stratification. Determine percent sediment by volume as described in paragraph 5.2 of ASTM D91.

3.6 Effect on Rubber—Use test specimens for test procedures in paragraphs 3.6.1 and 3.6.2 (either standard cups or 1 × 1 in test specimens) as described in Table 2. The specimens shall be rinsed in isopropyl alcohol and quickly air-dried to remove any dirt and packing debris. The specimens shall not remain in the alcohol for more than 30 s. Allow the rubber specimens to stabilize at 23 ± 5°C (73 ± 9°F) prior to measuring volume and hardness, also base diameter of cups as described in paragraph 3.3. Weigh the specimen in air (M_1) to the nearest milligram and then weigh the specimens immersed in room temperature distilled water (M_2) containing no more than 0.2% of a suitable wetting agent. Pluronic L-61 (BASF Wyandotte) or equivalent has been found to be acceptable.

3.6.1 Exposure at Room Temperature—Place two rubber specimens in a straight-sided, screw-top, round glass jar having a capacity of approximately 250 mL, inner dimensions of approximately 125 mm in height and 50 mm in diameter, and containing sufficient glass beads (4–6 mm diameter) to cover approximately two-thirds of the jar bottom. Immerse the two specimens in 75 mL of test fluid. Promptly seal the jar, using a steel lid provided with a foil or polytetrafluoroethylene faced cork or pulp insert. Store at 25 ± 2°C for 168 ± 2 h. Remove rubber specimens from fluid, rinse in isopropyl alcohol, and quickly air dry. Specimens shall not remain in alcohol for more than 30 s.

After drying, first weigh each specimen in air (M_3) to the nearest milligram, then weigh in distilled water (M_4) at 23 ± 5°C (73 ± 9°F). Next measure base diameter (on cups) and hardness. All measurements must be completed within 60 min after removal from the test fluid.

3.6.2 Exposure at Elevated Temperature—Place two rubber specimens in a straight-sided, screw-top, round glass jar having a capacity of approximately 250 mL, inner dimensions of approximately 125 mm in height and 50 mm in diameter, and containing sufficient glass beads (4–6 mm diameter) to cover approximately two-thirds of the jar bottom. Immerse the two specimens in 75 mL of test fluid. Promptly seal the jar, using a steel lid provided with a foil or polytetrafluorethylene faced cork or pulp insert. Place in a forced ventilation oven (Type IIA of ASTM E145) and store at the specified test temperature (see Table 2). After completion of the heating period, remove from oven and allow to cool 60–90 min at 23 ± 5°C (73 ± 9°F). Remove rubber specimens from fluid, rinse in isopropyl alcohol, and quickly air dry. Specimens shall not remain in alcohol for more than 30 s.

After drying, first weigh each specimen in air (M_3) to the nearest milligram, then weigh in distilled water (M_4) at 23 ± 5°C (73 ± 9°F). Next measure base diameter (on cups) and hardness. All measurements must be completed within 60 min after removal from the test fluid.

3.6.3 Calculation and Reporting—Volume change shall be as a percentage of the original volume, calculated as follows:

$$\text{Percent volume change} = \frac{(M_3 - M_4) - (M_1 - M_2)}{(M_1 - M_2)} \times 100$$

Where: M_1 = Initial mass in air
M_2 = Initial mass in water
M_3 = Final mass in air
M_4 = Final mass in water

Calculate and report the change in volume and hardness after exposure. Measure and report the change in base diameter for cups. Examine the exposure rubber specimens for blistering or sloughing. Determine conformance to requirements as set forth in Table 2.

3.7 Compatibility

(a) At −40°C (−40°F)—Mix 50 mL of LWTF with 50 mL of SAE RM-70-03 silicone base compatibility fluid and pour this mixture into an ASTM cone-shaped centrifuge tube described in paragraph 3.1 of ASTM D91, seal. Place the centrifuge tube for 144 ± 4 h in a cold bath maintained at −40 ± 2°C (40 ± 4°F). Remove tube from bath, quickly wipe with a clean, lint-free cloth saturated with isopropyl alcohol or acetone, and examine fluid for sedimentation and crystallization. Allow fluid to warm to room temperature 23 ± 5°C (73 ± 9°F). If necessary, allow to stand for as long as 4 h. Examine the fluid for appearance and clarity by comparing it to an as-received sample of the test fluid in an identical container. Repeat the above procedure using RM-66-03.

(b) At 60°C (140°F)—Place the centrifuge tubes of paragraph 2.7 in a gravity convection oven conforming to ASTM E145 Type 1A and maintained at 60 ± 2°C (140 ± 4°F) for 22 ± 2 h. Remove tube from oven and determine percent sediment by volume as described in paragraph 5.2 of ASTM D91.

3.8 Fluid Stability—Heat a new sample of the original test brake fluid to a temperature 185 ± 2°C (365 ± 4°F) by the procedure specified in paragraph 3.1 and maintain at that temperature for 2 h. Then determine the boiling point of this fluid as specified in paragraph 3.1. If the temperature exceeds 260°C (500°F), the test can be stopped and the value reported as exceeding 260°C (500°F).

3.9 Stroking Test Procedure[1]—Use the following procedure to evaluate the lubrication quality of the brake fluid.

3.9.1 Test Apparatus and Material—Use the Fig. 2 stroking fixture type apparatus with the following components arranged as shown in Fig. 1. The drum and shoe apparatus as described in SAE J1703 may be used as an alternative test system.

(a) Master Cylinder Assembly—One cast iron housing hydraulic brake master cylinder having a diameter of approximately 28 mm (1⅛ in) and fitted with an uncoated steel standpipe. Master cylinder used is SAE RM-15a 28 mm (1⅛ in) diameter or equivalent.

(b) Brake Assemblies—Three cast iron housing straight bore hydraulic brake wheel cylinder assemblies having a diameter approximately 28 mm (1⅛ in). Wheel cylinder used is SAE RM-14a with stroking adapter mounting plates to hold the brake wheel cylinder assemblies as shown in Fig. 2.

(c) Braking Pressure Actuating Mechanism—A suitable actuating mechanism for applying a force to the master cylinder push rod without side thrust.

The amount of force applied by the actuating mechanism shall be adjustable and capable of supplying sufficient stroke and thrust to the master cylinder to create a pressure of at least 70 kg/cm² (1000 psi) in the simulated brake system. A hydraulic gauge and pressure recorder, capable of establishing the pressure curve of the system and monitoring the pressure developed, shall be installed on a hydraulic line extending from the master cylinder to the outside of the oven. This line shall be provided with a shut-off valve and a bleeding valve for removing air from the connection tubing.

The actuating mechanism shall be designed to provide a stroking rate of approximately 1000 strokes/h. The pressure buildup rate versus cylinder stroke and time shall correspond to Fig. 3.

(d) Heated Air Bath Cabinet—An insulated cabinet or oven having sufficient capacity to house the three wheel cylinder fixture assemblies, master cylinder, and necessary connection. A suitable thermostatically-controlled heating system is required to maintain a brake fluid temperature of 120 ± 5°C (248 ± 9°F). Heaters shall be shielded to prevent direct radiation to wheel or master cylinders. Fluid temperature shall be monitored at random intervals during the test at the master cylinder reservoir, using a temperature recording device.

3.9.2 Preparation of Test Apparatus

(a) Wheel Cylinder Assemblies—Use new wheel cylinder assemblies, SAE RM-14a or equivalent having diameters as specified in paragraph 3.9.1 (b). Pistons (SAE RM-12) shall be made from unanodized SAE AA2024 aluminum alloy. Disassemble cylinders and discard rubber cups. Clean all metal parts with isopropanol and dry with clean compressed air. Inspect the working surfaces of all metal parts for scoring, galling, or pitting, and cylinder bore roughness, and discard all defective parts. Remove any stains on cylinder walls with crocus cloth and isopropanol. If stains cannot be removed, discard the cylinder. Measure the internal diameter of each cylinder at locations approximately 19 mm (0.75 in) from each end of the cylinder bore, taking measurements in line with the hydraulic inlet opening and at right angles to the center line. Discard the cylinder if any of these four readings exceeds maximum or minimum limits of 28.66 − 28.60 mm (1.1285 − 1.126 in). Measure the outside diameter of each piston at two points approximately 90 deg apart. Discard any piston if either reading exceeds maximum or minimum limits of 28.55 − 28.52 mm (1.124 − 1.123 in). Select parts to insure that the clearance between each piston and mating cylinder is within 0.08 − 0.13 mm (0.003 − 0.005 in). Use new standard SAE RM-3 SBR cups as specified in Fig. 4 that are free of lint and dirt. Discard any cups showing imperfections such as cuts, tooling marks, molding flaws, or blisters. Measure the lip and base diameters of all test cups with an optical comparator or a micrometer to the nearest 0.025 mm (0.001 in) along the center line of SAE and rubber type identifications and right angles to this center line. Determine base diameter measurements within 0.8 mm (0.032 in) of the bottom edge and parallel to the base of the cup. Discard any cups if the two measured lip or base diameters differ by more than 0.08 mm (0.003 in). Average the lip and base diameters of each cup. Determine the hardness of all cups by the procedure specified in paragraph 3.3. Clean rubber parts with isopropanol and a lint-free cloth. Dry with clean compressed air. Dip the rubber and metal parts of the wheel cylinders, except housings, in the fluid to be tested and install them in accordance with manufacturer's instructions. Rubber boots may be retained on the cylinders if a small section in removed on the bottom to observe leakage. Manually stroke the cylinders to insure that they operate easily. Install cylinder in the simulated brake system.

(b) Master Cylinder Assembly—Use a new SAE RM-15b master cylinder having an SAE RM-13-02 aluminum alloy piston and new standard SAE RM-4a and RM-5a SBR cups as specified in Figs. 5 and 6. Inspect and clean all parts as specified in paragraph 3.9.2 (a). Measure each land of the master cylinder piston at two points approximately 90 deg apart. Discard the piston if any of these readings exceeds maximum or minimum limits of 28.55 − 28.52 mm (1.124 − 1.123 in). Dip the secondary cup in the test brake fluid, assemble on the piston, and maintain the assembly in a vertical position at 23 ± 5°C (73 ± 9°F) for at least 2 h. Determine the lip and base diameter of the secondary cup as installed on the piston and the primary cup at locations shown in Fig. 5. Inspect the relief and supply ports of the master cylinder and discard the cylinder if these ports have burrs or wire edges. Measure the internal diameter of the cylinder at two locations: approximately mid-way between the relief and supply ports and approximately 19 mm (0.75 in) beyond the relief port toward the bottom or discharge end of the bore, taking measurements at each location in the vertical and horizontal centerlines of the bore. Discard the cylinder if any reading exceeds maximum or minimum limits of 28.65 − 28.58 mm (1.128 − 1.125 in). Dip the rubber and metal parts of the master cylinder, except the housing, in the fluid to be tested and install them in accordance with manufacturer's instructions. Discard boot and push rod assembly. Manually stroke the master cylinder to insure that it operates easily. Install the master cylinder in the simulated brake system.

(c) Use double-wall steel tubing (SAE RM-57 or -58) or equivalent, meeting SAE J527. Tubing from one outlet of master cylinder to the pair of wheel cylinders or to the single wheel cylinder, shall alternately be replaced with new tubing for each test [minimum length 915 mm (3 ft)]. Uniformity in tubing size is desirable between master cylinder and wheel cylinder; 6.3 mm (¼ in) tubing is more adaptable with available tube connectors. The standard SAE RM-15a master cylinder has two outlets for tubing, both of which should be used.

(d) Assembly and Adjustment of Test Apparatus—Install wheel and master cylinders. Fill the system with test fluid, bleeding all wheel cylinders and the pressure equipment and gauges to remove entrapped air from the system.

Operate the actuator manually to apply a pressure of more than the required operating pressure and inspect the system for leaks. Adjust the actuator to obtain a pressure of 70 ± 3.5 kg/cm² (1000 ± 5 psi). Fig. 3 illustrates the pressure build-up versus the master cylinder piston movement with the stroking fixture apparatus illustrated in Figs. 1 and 2. The pressure is relatively low during the first part of the stroke and then builds up to 70 ± 3.5 kg/cm² (1000 ± 50 psi) at the end of the stroke of approximately 25 mm (1 in). The pressure build-up rate versus cylinder

[1] This procedure is identical to the one found in SAE J1703 JAN80.

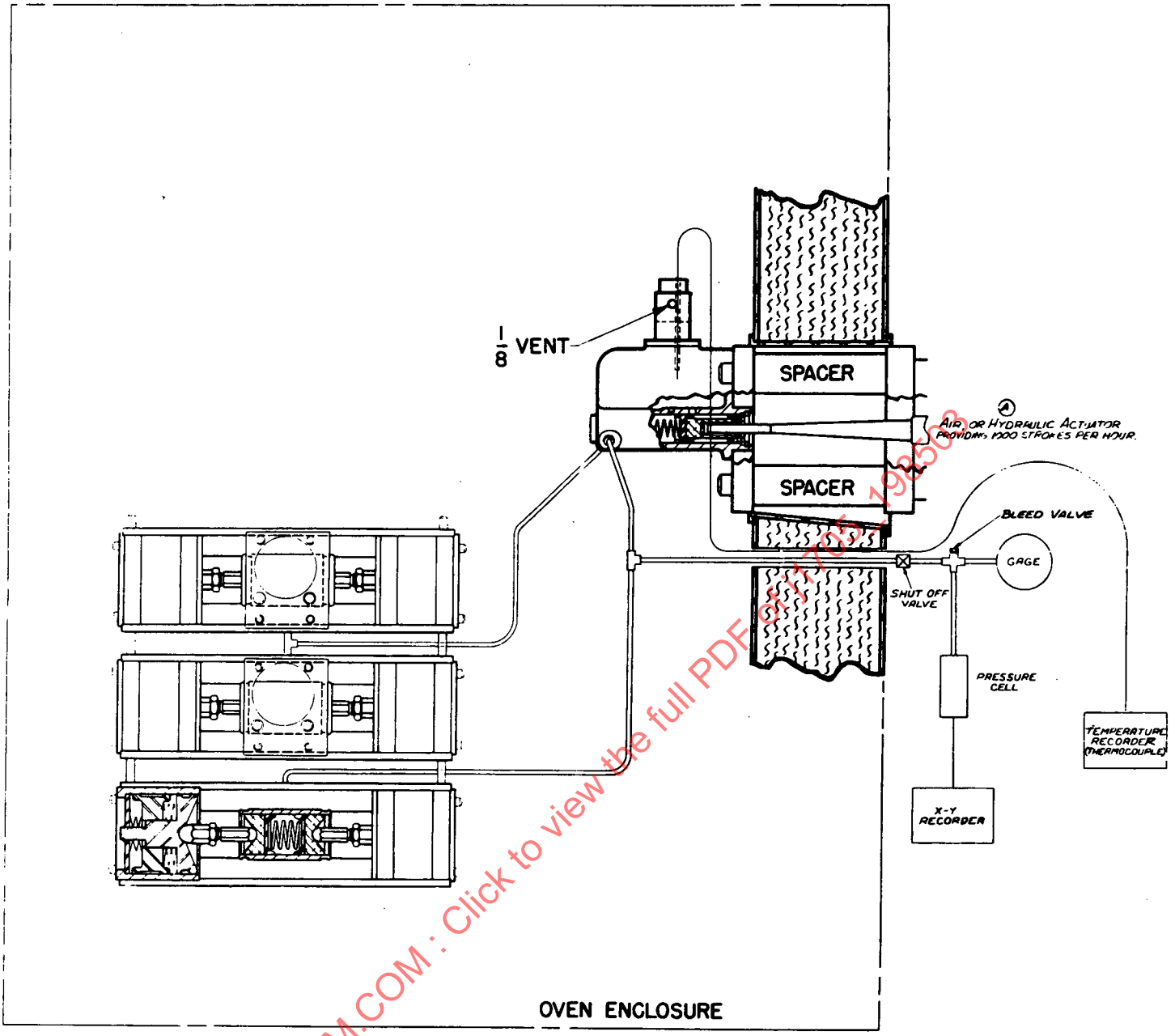

FIG. 1—STROKING TEST APPARATUS

stroke and time shall correspond to Fig. 3. The wheel cylinder piston travel is approximately 4.8 ± 0.24 mm (0.19 ± 0.01 in) when a pressure of 70 ± 3.5 kg/cm² (1000 ± 50 psi) is reached. Adjust the stroking rate to 1000 ± 100 strokes/h. Record the fluid level in the master cylinder standpipe at 23 ± 5°C (73 ± 9°F) with the master cylinder piston in the fully returned position.

3.9.3 TEST PROCEDURE—Run a pressure versus stroke curve utilizing the pressure recorder at room temperature before stroking, after the fluid is at the test temperature, before shutdown at the test temperature, and at room temperature after stroking. Operate the system of 16 000 ± 1000 cycles at 23 ± 5°C (73.4 ± 9°F). Repair any leaks and add fluid to the master cylinder standpipe to bring the fluid level to the level originally recorded at room temperature with the piston fully returned.

Start test again and raise the temperature of the fluid in the master cylinder within 6 ± 2 h to 120 ± 5°C (248 ± 9°F). During test, observe operation of the master cylinder for complete piston return and wheel cylinders for proper operation. Observe fluid level in relation to the room temperature level at random intervals. Continue the test to 85 000 total recorded strokes which shall include the number of strokes during operation at 23 ± 5°C (73.4 ± 9°F), the number of strokes required to bring the system to the operating temperature of 120 ± 5°C (248 ± 9°F), plus the number of strokes at this operating temperature. Stop the test, and with the master cylinder piston in the fully returned position to relieve retained pressure in the system, allow the equipment to cool to room temperature.

Record the amount of fluid required to replenish any loss of fluid to the 23 ± 5°C (73 ± 9°F) level originally recorded. Stroke the assembly an additional 100 strokes 23 ± 5°C (73 ± 9°F) and 70 ± 3.5 kg/cm² (1000 ± 50 psi), examine wheel cylinders for leakage, and add and record volume of fluid required to bring the fluid level to the 23 ± 5°C (73 ± 9°F) original level.

Within 16 h, remove the master and wheel cylinders from the system, retaining the fluid in the cylinders by immediately capping or plugging the ports. Disassemble the cylinders, collecting the fluid from the master cylinder and wheel cylinders in a glass jar. Record any sludge, gel, or abrasive grit present in the test fluid. When collecting the stroked fluid, all the residue which has been deposited on the rubber and metal internal parts should be removed by rinsing and agitating such parts in the stroked fluid and using a soft brush to assure that all loose adhering sediment is collected.

Clean rubber cups in isopropanol, and dry with clean, compressed air. Inspect cups for tackiness, scoring, scuffing, blistering, cracking, chipping

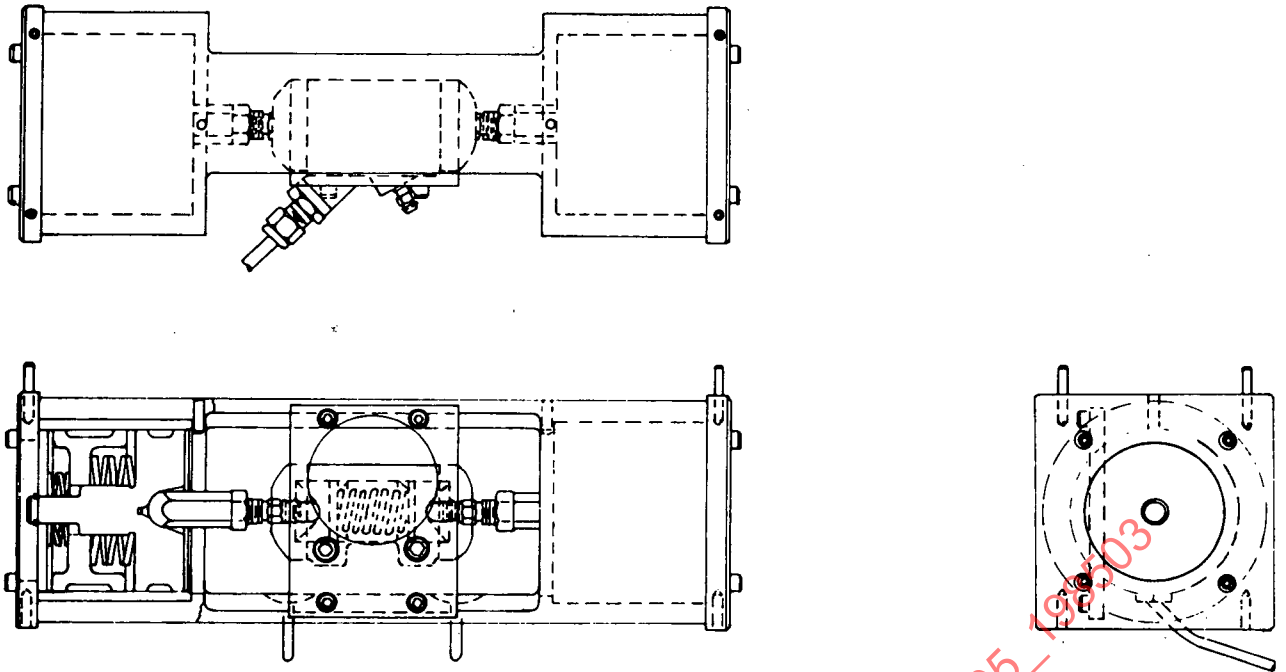

FIG. 2—STROKING FIXTURE APPARATUS

(heel abrasions), and change in shape from original appearance. Within 12 h after disassembly, measure the lip and base diameter of each cylinder cup by the procedure specified in paragraph 3.9.2 (a) with the exception that the lip or base diameters of cups may differ by more than 0.08 mm (0.003 in). Determine the hardness of each cup by the procedure specified in paragraph 3.3.

Within 1 h after draining cylinders, agitate fluid in glass jar to suspend and uniformly disperse sediment and transfer a 100 mL portion of this fluid to an ASTM cone-shaped centrifuge tube and determine percent sediment as described in paragraph 5 (b) of ASTM D91. Inspect cylinder parts, recording any gum deposits, and rub any deposits adhering to cylinder walls with a cloth wetted with isopropanol to determine abrasiveness and removability. Clean cylinder parts in isopropanol, dry with compressed air, and inspect for pitting and scoring on pistons and cylinder

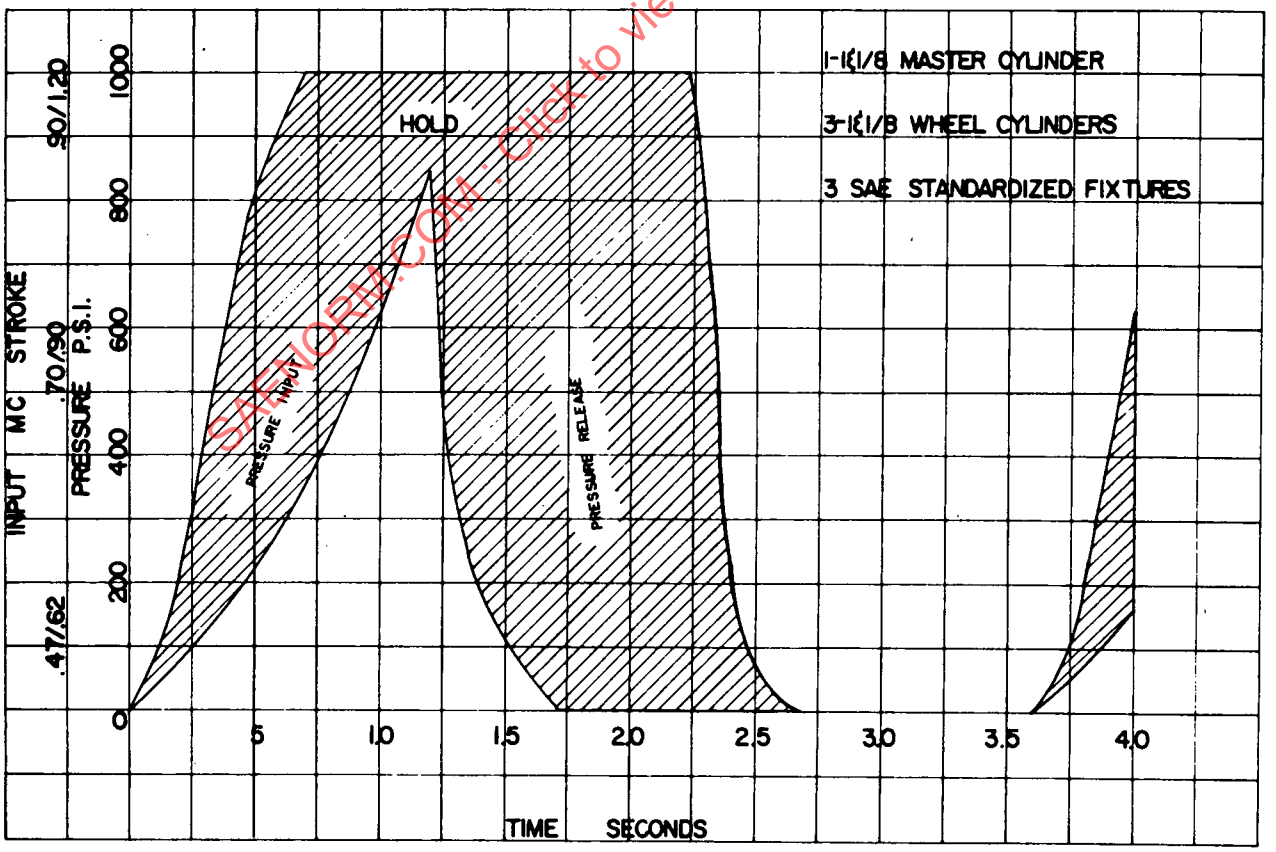

FIG. 3—MASTER CYLINDER STROKE