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SURFACE VEHICLE RECOMMENDED PRACTICE

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Submitted for recognition as an American National Standard

(R) Front-Wheel-Drive Constant Velocity Joint Boot Seals

Foreword—This SAE Recommended Practice is intended as a guide toward performance related standard practice and is subject to change to keep pace with experience and technical advances.

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1. Scope

1.1 This SAE Recommended Practice outlines the qualification testing and performance related criteria of elastomeric boot seals used in constant velocity joint applications. These applications are referred to as front-wheel-drive halfshafts or axles, but can also be utilized in rear-wheel-drive halfshaft applications. For additional information regarding CV joint systems and their applications refer to SAE AE-7 "Universal Joint and Driveshaft Design Manual."

1.2 The grease type and grease quantities, clamps and clamping mechanisms of an assembly are critical and considered to be the same as OEM, service, or aftermarket designation. Although joint lubricating grease and clamping mechanism are not addressed in this document, they are critical to a total system performance.

1.3 The purpose of this document is to establish a uniform practice for those in the surface vehicle industry that specify and/or manufacture CV joint boot seals (boots) for OEM or aftermarket use with respect to qualification testing for physical and mechanical properties.

1.4 This document is not intended to include or address propeller shaft, Power Take Off, heavy equipment, and marine boot seal applications.

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 AE-7—Universal Joint and Driveshaft Design Manual
SAE J200—Rubber Materials in Automotive Applications
SAE J1344—Marking of Plastic Parts
SAE J3000—Plastic Materials in Automotive Applications

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

ASTM D 395—Rubber Property—Compression Set
ASTM D 412—Rubber Properties in Tension
ASTM D 471—Rubber Properties—Effect of Liquids
ASTM D 573—Rubber—Deterioration in an Air Oven
ASTM D 624—Rubber Property—Tear Resistance
ASTM D 638—Plastic Property—Tensile Strength
ASTM D 746—Rubber Property—Low Temperature Brittleness
ASTM D 792—Rubber Property—Specific Gravity
ASTM D 1149—Rubber Deterioration—Surface Ozone Cracking in a Chamber
ASTM D 1505—Rubber Property—Specific Gravity
ASTM D 1525—Plastic Property—Vicat Softening Point
ASTM D 2000—Rubber Products in Automotive Applications
ASTM D 2137—Rubber Property—Brittleness Point of Flexible Polymers and Coated Fabrics
ASTM D 2240—Rubber Property—Durometer Hardness
ASTM D 2663—Rubber Compound—Dispersion of Carbon Black
ASTM D 3395—Rubber Deterioration—Dynamic Ozone Cracking in a Chamber
ASTM D 3418—Plastic Property—Melting Point

2.1.3 DIN AND ISO PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

DIN 53 504—Determination of tensile strength at break, tensile strength, elongation at break and stress values in a tensile test
ISO 37—Rubber, vulcanized—Determination of tensile stress—strain properties, Second Edition

3. Application

3.1 This method is for use in evaluating performance properties (Table 1) of rotating CV joint boot seals.

a. Outboard non-plunging steering CV joint installation for operation at approximately 45 degrees angle.
b. Inboard plunging (stroking) and fixed non-steering CV joint installation for operation at approximately 20 degrees angle.

3.2 This document is applicable to boot seals of flexible elastomeric material including synthetic rubbers and thermoplastic elastomers. (Appendix A).

3.3 The values in Tables 2 and 3 are based on the collective experience of the North American OEM and aftermarket CV joint boot seal industry. Not all material candidates that meet the slab specimen properties in Table 3, and not all molded boot seal candidates that meet the values in Table 2 would necessarily make a boot seal that can pass the dynamic requirements in Table 1.

3.4 Boot seal manufacturers are encouraged to mark material family identification symbols to aid in recycling and/or disposal of CV joint boot seals at the end of their life cycle. Manufacturers are recommended to follow SAE J1344 as appropriate for marking of materials.

4. Performance Test Procedures

4.1 The test parameters and performance requirements of the CV joint boot seals are summarized in Table 1. Refer to Sections 5 and 6 for specific test procedures.

4.2 There are differences between rubber and TPE test performance requirements as outlined as follows and in Table 1. These differences are due to the rubber and TPE boot sealing systems responding differently under real world situations. The additional requirements for TPE are to evaluate the total sealing system package including grease and clamps.

a. Rubber Outboard: 5.1, 5.3, 5.4
b. Rubber Plunge: 6.1, 6.3, 6.4
c. TPE Outboard: 5.1, 5.2, 5.3, 5.4, 5.5
d. TPE Plunge: 6.1, 6.2, 6.3, 6.4, 6.5

5. Outboard CV Joint Boot Seal (Rotating, Non-Plunging—For each of the following tests, assemble a new boot seal to the shaft and CV joint with the proper clamps and grease quantities. A minimum of 2 boot seals should be run per test. The assembly is mounted in a horizontal plane for the following tests.

a. Break in of outboard CV Joint is recommended to prevent overheating the joint and affecting the boot seal performance.

5.1 Cold Test—All Boot Seals—(Figure 1).

5.1.1 At 0 degree angle, allow the assembly to soak at room temperature for 12 h minimum prior to starting test. After the 12 h (72 h for TPE) soak cycle, rotate the assembly at 1000 RPM, 0 degree angle and room temperature for 5 min in order to uniformly distribute the grease. The room temperature soak is required to allow the elastomer compliance to adjust to the sealing surfaces and clamps.

5.1.2 Set the joint angle at 10 degrees, soak the assembly for 8 h minimum at –40 °C prior to running the test.

5.1.3 Accelerate the assembly to 1000 RPM within 10 s. Run for 10 min at 1000 RPM at 10 degrees angle, while maintaining –40 °C.

5.1.4 Re-soak for 50 min minimum at –40 °C.

5.1.5 Repeat 5.1.3 and 5.1.4 for 20 cycles.

5.1.6 Continue with the same boot seal and set the joint angle at 35 degrees. If the CV joint cannot obtain 35 degrees angle, then set angle at 2 degrees less than its maximum attainable angle. Soak the assembly for 50 min at –40 °C.

5.1.7 Accelerate the Assembly to 100 RPM within 5 s. Run for 10 min at 100 RPM at 35 degrees angle (or 2 degrees less than maximum joint) while maintaining –40 °C.

5.1.8 Re-soak for 50 minutes minimum at –40 °C.

5.1.9 Repeat 5.1.7 and 5.1.8 for 10 cycles.

5.1.10 PASS/FAIL CRITERIA—The boot seal shall have no through cracks, holes, excessive deformation or distress, grease leakage or discharge.

5.2 Cold Test—TPE Boot Seals only (heat age)— –40 °C (Figure 1).

5.2.1 At 0 degree angle, place the TPE Boot Seal assembly in an oven or environmental chamber at room temperature. Gradually (usually within 1 h) increase the temperature to 80 °C. Soak for 336 h. The assembly should be rotated a minimum of one time per day (five times/per week) to thoroughly coat the inside of the boot seal with heated grease. After each rotation a “new section” of the boot seal will be “down”. If placed in an environmental chamber, the assembly can be rotated at a slow speed (less than 50 RPM) without affecting the performance of the test.

5.2.2 Remove from oven and allow to cool to room temperature and place in the test chamber. If the assembly is already in a test chamber, proceed to step 5.2.3.

5.2.3 At 0 degree angle, and room temperature, rotate the assembly at 1000 RPM for 5 min to uniformly distribute the grease.

5.2.4 Continue with the same boot seal and set the joint angle at 10 degrees soak the assembly for 8 h minimum at –40 °C prior to running the test.

5.2.5 Accelerate the assembly to 1000 RPM within 10 s. Run for 10 min at 1000 RPM at 10 degrees angle while maintaining –40 °C.

5.2.6 Re-soak for 50 min minimum at –40 °C.

5.2.7 Repeat 5.2.5 and 5.2.6 for 20 cycles.

5.2.8 Continue with the same boot seal and set the joint angle at 35 degrees. If the CV joint cannot obtain 35 degree angle, then set angle at 2 degrees less than its maximum attainable angle. Soak the assembly for 50 min at –40 °C.

5.2.9 Accelerate the assembly to 100 RPM within 5 s. Run for 10 min at 100 RPM at 35 degrees angle (or 2 degrees less than maximum joint) while maintaining –40 °C.

5.2.10 Re-soak for 50 min minimum at –40 °C.

5.2.11 Repeat 5.2.9 and 5.2.10 for 10 cycles

5.2.12 PASS/FAIL CRITERIA—The boot seal shall have no through cracks, holes, excessive deformation or distress, grease leakage or discharge.

5.3 Radial Expansion Test—All Boot Seals—(Figure 2).

5.3.1 A determination of the static profile of the boot seal is made by mechanical probe, light beam, or photography prior to starting the test.

5.3.2 The test is conducted at room temperature and 0 degree joint angle.

5.3.3 The assembly is accelerated gradually to 1500 RPM within 2 min. Rotation at 1500 RPM is to be maintained for 10 min minimum.

5.3.4 PASS/FAIL CRITERIA—Radial expansion should not exceed 5 mm during 5.3.3.

5.4 Hot Test—All Boot Seals—(Figure 3).

5.4.1 The test can be conducted with either new boot seals or the boot seals that have completed the radial expansion test (5.3).

5.4.2 At 0 degree angle, allow the assembly to soak at room temperature for 12 h minimum prior to starting test (72 h for TPE). After the 12 h (72 h for TPE) soak cycle, rotate the assembly at 1000 RPM, 0 degree angle and room temperature for 5 min in order to uniformly distribute the grease. The room temperature soak is required to allow the elastomer compliance to adjust the sealing surfaces and clamps.

5.4.3 Set the joint angle at 10 degrees. Soak the assembly at 80 °C for 2 h minimum prior to running test. Run at 1000 RPM for 20 h at 80 °C with constant 10 degree angle.

5.4.4 Continue with the same boot seal and adjust test angle to 40 degrees. If the CV joint cannot attain 40 degrees angle, then set angle at 2 degrees less than its maximum attainable angle. Run at 200 RPM for 5 h minimum at 80 °C.

5.4.5 PASS/FAIL CRITERIA—The boot seal shall have no through cracks, holes, excessive deformation or distress, grease leakage or discharge. During hot tests the light oils from the grease can permeate through the boot seal material. The presence of this oil film on the outside surface of the boot seal is acceptable.

5.5 Hot Test—PE Boot Seals only (heat age)—(Figure 3).

5.5.1 At 0 degree angle, place the assembly in an oven or environmental chamber at room temperature. Gradually (usually within 1 h) increase the temperature to 80 °C. Soak for 336 h. The assembly should be rotated a minimum of one time per day (five times/per week) to thoroughly coat the inside of the boot with heated grease. After each rotation a “new section” of the boot will be “down”. If placed in an environmental chamber, the assembly can be rotated at a slow speed (less than 50 RPM) without affecting the performance of the test.

5.5.2 Remove from oven and allow to cool to room temperature and place in the test chamber. If the assembly is already in a test chamber, proceed to step 5.5.3.

5.5.3 At 0 degree angle, and room temperature or 80 °C rotate the assembly at 1000 RPM for 5 min to uniformly distribute the grease.

5.5.4 Set the joint angle at 10 degrees. Soak the assembly at 80 °C for 2 h minimum prior to running test. Run at 1000 RPM for 20 h at 80 °C with a constant 10 degree angle.

5.5.5 Continue with the same boot seal and adjust test angle to 40 degrees. If the CV joint cannot attain 40 degrees angle, then set angle at 2 degrees less than its maximum attainable angle. Run at 200 RPM for 5 h minimum at 80 °C.

5.5.6 PASS/FAIL CRITERIA—The boot seal shall have no through cracks, holes, excessive deformation or distress, grease leakage or discharge. During hot tests the light oils from the grease can permeate through the boot seal material. The presence of this oil film on the outside surface of the boot seal is acceptable.

6. Inboard CV Joint Boot Sea—(Rotating, Plunging, and Fixed Non-Steering)—For each of the following tests, assemble new boot seal to the shaft and CV joint with the proper clamps and grease quantities. A minimum of 2 boot seals should be run per test. The assembly is mounted in a horizontal plane for the following tests.

a. Definition of Joint center and Test Position (Figure 4)

1. Joint center of a plunging CV joint is defined as the average of two positions of plunge (stroke) at zero degree angle. Full-in is defined as metal-to-metal contact of the inner joint members and the outer member(s). Internal springs and centering devices should be removed prior to making this measurement and be re-installed for testing. Full-out is defined as the maximum extended condition due to mechanical stops or the capability of the joint to transmit full torque.
2. Total plunge length variation for testing should be ±10 mm from the joint center. If the plunge capability of the joint is less than 24 mm, the plunge should be retracted from the plunge limit of the joint. The joint is positioned 2 mm from both the full-in and full-out positions at the test angle, so as not to test in an interference or potentially damaging condition.

b. Break in for “Ball Type” joint is recommended to prevent overheating the joint and affecting boot performance. “Roller Type” joints do not require break in.

6.1 Cold Test—All Boot Seals (Figure 1).

6.1.1 At 0 degree angle, allow the assembly to soak at room temperature for 12 h minimum prior to starting test (72 h for TPE). After the 12 h (72 h for TPE) soak cycle, rotate the assembly at 1000 RPM, 0 degree angle and room temperature for 5 min in order to uniformly distribute the grease. The room temperature soak is required to allow the elastomer compliance to adjust to the sealing surfaces and clamps. Plunge position is not critical for this portion of the test.

6.1.2 At 12 degrees joint angle and +10 mm plunge from joint center, soak the assembly for 8 h minimum at –40 °C prior to running the test. If the joint cannot attain 12 degrees angle, then set angle at 2 degrees less than its maximum attainable angle.

6.1.3 Accelerate the assembly to 1000 RPM within 10 s. Run for 10 min at 1000 RPM at 12 degrees angle while maintaining –40 °C.

6.1.4 Re-soak for 50 min minimum at –40 °C.

6.1.5 Repeat 6.1.3 and 6.1.4 for 10 cycles.

6.1.6 Continue with the same boot seal. Set the plunge joint at –10 mm from joint center at 12 degrees angle, soak the assembly for 50 min at –40 °C prior to running test.

6.1.7 Accelerate the assembly to 1000 RPM within 10 s. Run for 10 min at 1000 RPM at 12 degrees angle while maintaining –40 °C.

6.1.8 Re-soak for 50 min minimum at –40 °C.

6.1.9 Repeat 6.1.7 and 6.1.8 for 10 cycles minimum.

6.1.10 For ethylene/acrylic (Vamac®) applications, conduct the previous test at –30 °C rather than –40 °C.

6.1.11 PASS/FAIL CRITERIA—The boot seal shall have no through cracks, holes, excessive deformation or distress, grease leakage or discharge.

6.2 Cold Test—TPE Boots only (heat age)— –40 °C (Figure 1).

6.2.1 At 0 degree angle, place the assembly in an oven or environmental chamber at room temperature. Gradually (usually within 1 h) increase the temperature to 80 °C. Soak for 336 h. The assembly should be rotated a minimum of one time per day (five times/per week) to thoroughly coat the inside of the boot seal with heated grease. After each rotation a “new section” of the boot seal will be “down”. If placed in an environmental chamber, the assembly can be rotated at a slow speed (less than 50 RPM) without affecting the performance of the test. Plunge position is not critical for this portion of the test.

6.2.2 Remove from oven and allow to cool to room temperature and place in the test chamber. If the assembly is already in a test chamber, proceed to step 6.2.3.

6.2.3 At 0 degree joint angle, joint center, and room temperature, rotate the assembly at 1000 RPM for 5 min to uniformly distribute the grease.

6.2.4 Continue with the same boot seal. Set the plunge joint at +10 mm from joint center at 12 degrees angle, soak the assembly for 8 h at –40 °C prior to running test.

6.2.5 Accelerate the assembly to 1000 RPM within 10 s. Run for 10 min at 1000 RPM at 12 degrees angle while maintaining –40 °C.

6.2.6 Re-soak for 50 min minimum at –40 °C.

6.2.7 Repeat 6.2.5 and 6.2.6 for 10 cycles.

6.2.8 Continue with the same boot seal. Set the plunge joint at –10 mm from joint center at 12 degrees angle, soak the assembly for 50 min at –40 °C prior to running test.

6.2.9 Accelerate the assembly to 1000 RPM within 10 s. Run for 10 min at 1000 RPM at 12 degrees angle while maintaining –40 °C.

6.2.10 Re-soak for 50 min minimum at –40 °C.

6.2.11 Repeat 6.2.9 and 6.2.10 for 10 cycles

6.2.12 PASS/FAIL CRITERIA-—The boot seal shall have no through cracks, holes, excessive deformation or distress, grease leakage or discharge.

6.3 Radial Expansion Test—All Boot Seals—(Figure 2).

6.3.1 A determination of the static profile of the boot seal is made by mechanical probe, light beam, or photography prior to starting the test.

6.3.2 The test is conducted at room temperature and 0 degree joint angle. Plunge position to be set at joint center.

6.3.3 The assembly is accelerated gradually to 1500 RPM within 2 min. Rotation at 1500 RPM is to be maintained for 10 min minimum.

6.3.4 PASS/FAIL CRITERIA—Radial expansion should not exceed 5 mm during 6.3.3.

6.4 Hot Test—All Boot Seals—(Figure 3).

6.4.1 The test can be conducted with either new boot seals or the boot seals that have completed the radial expansion test (6.3).

6.4.2 At 0 degree angle, allow the assembly to soak at room temperature for 12 h minimum prior to starting test (72 h for TPE). After the 12 hours (72 h for TPE) soak cycle, rotate the assembly at 1000 RPM, 0 degree angle and room temperature for 5 min in order to uniformly distribute the grease. The room temperature soak is required to allow the elastomer compliance to adjust the sealing surfaces and clamps. Plunge position is not critical for this portion of the test.

6.4.3 Set the joint angle at 12 degrees and plunge at +10 mm from joint center. If the joint cannot attain 12 degrees angle, then set angle at 2 degrees less than its maximum attainable angle. Soak the assembly at 80 °C for 2 h minimum prior to running the test. Run at 1000 RPM for 20 h at 80 °C.

6.4.4 Continue with the same boot seal and adjust plunge to be –10 mm from joint center. Run at 1000 RPM for 20 h minimum at 80 °C.

6.4.5 For high temperature applications where materials such as silicone rubber, ethylene/acrylic (Vamac®), or similar material may be required, conduct the previous test at 150 °C rather than 80 °C. To prevent the boot from ballooning during this accelerated test the boot may be vented.

6.4.6 PASS/FAIL CRITERIA—The boot seal shall have no through cracks, holes, excessive deformation or distress, grease leakage or discharge. During hot tests the light oils from the grease can permeate through the boot seal material. The presence of this oil film on the outside surface of the boot seal is acceptable.

6.5 Hot Test—TPE Boot Seals only (heat age)—(Figure 3).

6.5.1 At 0 degree angle, place the assembly in an oven or environmental chamber at room temperature. Gradually (usually within 1 h) increase the temperature to 80 °C. Soak for 336 h. The assembly should be rotated a minimum of one time per day (five times/per week) to thoroughly coat the inside of the boot seal with heated grease. After each rotation a “new section” of the boot seal will be “down”. If placed in an environmental chamber, the assembly can be rotated at a slow speed (less than 50 RPM) without affecting the performance of the test. Plunge position is not critical for this portion of the test.

6.5.2 Remove from oven and allow to cool to room temperature and place in the test chamber. If the assembly is already in the test chamber, proceed to step 6.5.3.

6.5.3 At 0 degree angle and with the temperature between room temperature and 80 °C, rotate the assembly at 1000 RPM for 5 min to uniformly distribute the grease.

6.5.4 Set the joint angle at 12 degrees and plunge at +10 mm from joint center. If the joint cannot attain 12 degrees angle, then set angle at 2 degrees less than its maximum attainable angle. Soak the assembly at 80 °C for 2 h minimum prior to running the test. Run at 1000 RPM for 20 h at 80 °C.

6.5.5 Continue with the same boot seal. Set the plunge joint at –10 mm from joint center at 12 degrees angle. Run at 1000 RPM for 20 h at 80 °C with at constant 12 degree angle.

6.5.6 PASS/FAIL CRITERIA—The boot seal shall have no through cracks, holes, excessive deformation or distress, grease leakage or discharge. During hot tests, the light oils from the grease can permeate through the boot seal material. The presence of this oil film on the outside surface of the boot seal is acceptable.

7. Physical and Material Properties

7.1 The molded boot seal specimen and material slab specimen property profiles detailed in Tables 2 and 3 are included in this document as a guideline only. To be in compliance with SAE J2028, the boot seals are required to pass Sections 4, 5, and 6.

7.2 Section 7 is included to:

a. Establish guidelines for the type of testing that should be implemented in boot seal manufacturing and material manufacturing for CV joint boot seal applications.
b. Assist the boot seal manufacturer and material supplier to monitor and improve boot seal quality.

7.3 Each molder and material supplier should:

a. Develop their own values based on each process and material
b. Try to decrease the spread of the values tracked as part of a continuous improvement process.

7.4 The values in Tables 2 and 3 are based on the collective experience of the North American OEM and after market CV joint boot seal industry. Not all material candidates that meet the slab specimen properties in Table 3, and not all molded boot seal candidates that meet the values in Table 2 would necessarily make a boot seal that can pass the dynamic requirement in Table 1.

TABLE 1—TEST PARAMETERS AND PERFORMANCE REQUIREMENTS SUMMARY

Application	Cold Rubber/TPE	Cold TPE Only Heat Aged(1)	Radial Expansion Rubber/TPE	Hot Rubber/TPE	Hot TPE Only Heat Age(1)
Outboard CV Joint Boot Seal (Non-Plunging)					
Performance Test Procedure (Reference)	5.1	5.2	5.3	5.4	5.5
Room Temperature Soak (h), Min. (after clamping)	12 | 72	0	0	12 | 72	0
Heat Age Assembly (h) (80 °C, Rotate Daily)	0	336	0	0	336
Grease Distribution	5 Min @ 1000 RPM	0	5 Min @ 1000 RPM	5 Min @ 1000 RPM	5 Min @ 1000 RPM
Angle	[10° & 35°]	[10° & 35°]	0°	[10° & 40°]	[10× & 40×]
Temperature (°C)	–40	–40	Room Temperature	80	80
Initial Soak (h) (@ angle and temperature)	8	8	0	2	2
Speed (RPM)	[1000 & 100]	[1000 & 100]	1500	[1000 & 200]	[1000 & 200]
Requirement	[20 Cycles & 10 Cycles] Minimum	[20 Cycles & 10 Cycles] Minimum	Radial Growth after 10 Min 5mm Maximum	[20 h & 5 h] Minimum	[20 h & 5 h] Minimum
Inboard CV Joint Boot Seal (Plunging and Fixed Non-Steering):					
(Performance Test Procedure) Reference	6.1	6.2	6.3	6.4	6.5
Room Temperature Soak (h) (after clamping)	12 | 72	0	0	12 | 72	0
Heat Age Assembly (h) (80 °C, Rotate Daily)	0	336	0	0	336
Grease Distribution	5 Min. @ 1000 RPM	0	5 Min. @ 1000 RPM	5 Min. @ 1000 RPM	5 Min. @ 1000 RPM
Angle	12°	12°	0°	12°	12°
Temperature (°C)	–40(2)	–40	Room Temperature	80(3)	80
Initial Soak (h) (@ angle & temperature)	8	8	0	2	2
Speed (RPM)	1000	1000	1500	1000	1000
Plunge (Stroke) Position (mm)-From Joint Center(4) [Not required for fixed non-steering joints].	[+10 & –10 mm]	[+10 & –10 mm]	0 mm	[+10 & –10 mm]	[+10 & –10 mm]
Requirement	[10 Cycles & 10 Cycles] Minimum	[10 Cycles & 10 Cycles] Minimum	Radial Growth after 10 Minutes 5mm Maximum	[20 h & 20 h] Minimum	[20 h & 20 h] Minimum

1. For TPE only: Heat Age the joint assembly (joint, boot seal, grease, and clamps) at the stated temperature.
2. For Vamac® applications, temperature = –30 °C.
3. For Vamac® and silicone rubber applications, temperature = 150 °C vented.
4. Plunge Joint position from Joint center. Refer to Figure 4.

TABLE 2—AS MOLDED BOOT SEAL SPECIMEN PROPERTIES
(GUIDELINE ONLY—NOT A SPECIFICATION)

Original Properties	ASTM Method	Rubber (J200) CR (Neoprene)	Rubber (J200) AEM (Vamac®)	Rubber (J200) SI or VMG (Silicone)	TPE (J3000) TEEE (Hytrel®/Arnitel®)	TPE (J3000) TEO (Santoprene®/ Sarlink®)	TPE (J3000) TPUR (Urethane)
Hardness, 2 or 4 Ply,(1) Shore A, Shore D, 5 Second Delay	D 2240 D 2240	55 to 65 —	55 to 70 —	55 to 65 —	— 37 to 55	50(A) to 50(D)	70(A) to 60(D)
Tensile Strength, Mpa(2)	D 412, Die C(3) D 638	8 Min. —	6.4 Min. ---	4.8 Min. ---	— 18.0 Min.	4.4 Min. —	— 18.0 Min.
Modulus @ 100%, MPa @10% MPa	D412 D 638	1.2 —	2.2 Min. —	4.8 Min. —	— 3.0 Min.	2.0 Min. —	— 3.0 Min.
Elongation @ Break, %	D412 D 638	200 Min. —	150 Min. —	300 Min. —	— 200 Min.	260 Min. —	— 350 Min.
Compression Set 100 °C-22h, 2 or 4 Ply	D 395, Method B	70% Max.	50% Max.	35% Max.	Not Applicable	Not Applicable	Not Applicable
Dispersion Carbon Black Dispersion Torn Surface Method Reflected Light Method	D 2663, Method A	4.0 Min.	N/A	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Specific Gravity	D 792 or D 1505	1.2 to 1.5	1.0 to 1.4	1.1 to 1.6	1.1 to 1.2	0.9 to 1.0	1.1 to 1.2

1. Hardness and compression set values are from 2 to 4 ply sections of the as-molded boot seal. This total thickness is likely to be less than the recommended values as outlined in procedures of ASTM D 2240 and D 395. Typical as-molded specimen sources are shown in Figures 5 and 6.
2. Tensile, modulus, and elongation to be tested at knit line (or parting line). Refer to Figures 5 and 6.
3. The ASTM D 412, Die C is too large for testing some boot seals. Equivalent tensile strength, modulus, and elongation properties may be obtained with smaller dumbbells. Suggested dumbbell of specimen dies are shown in Figure 7.

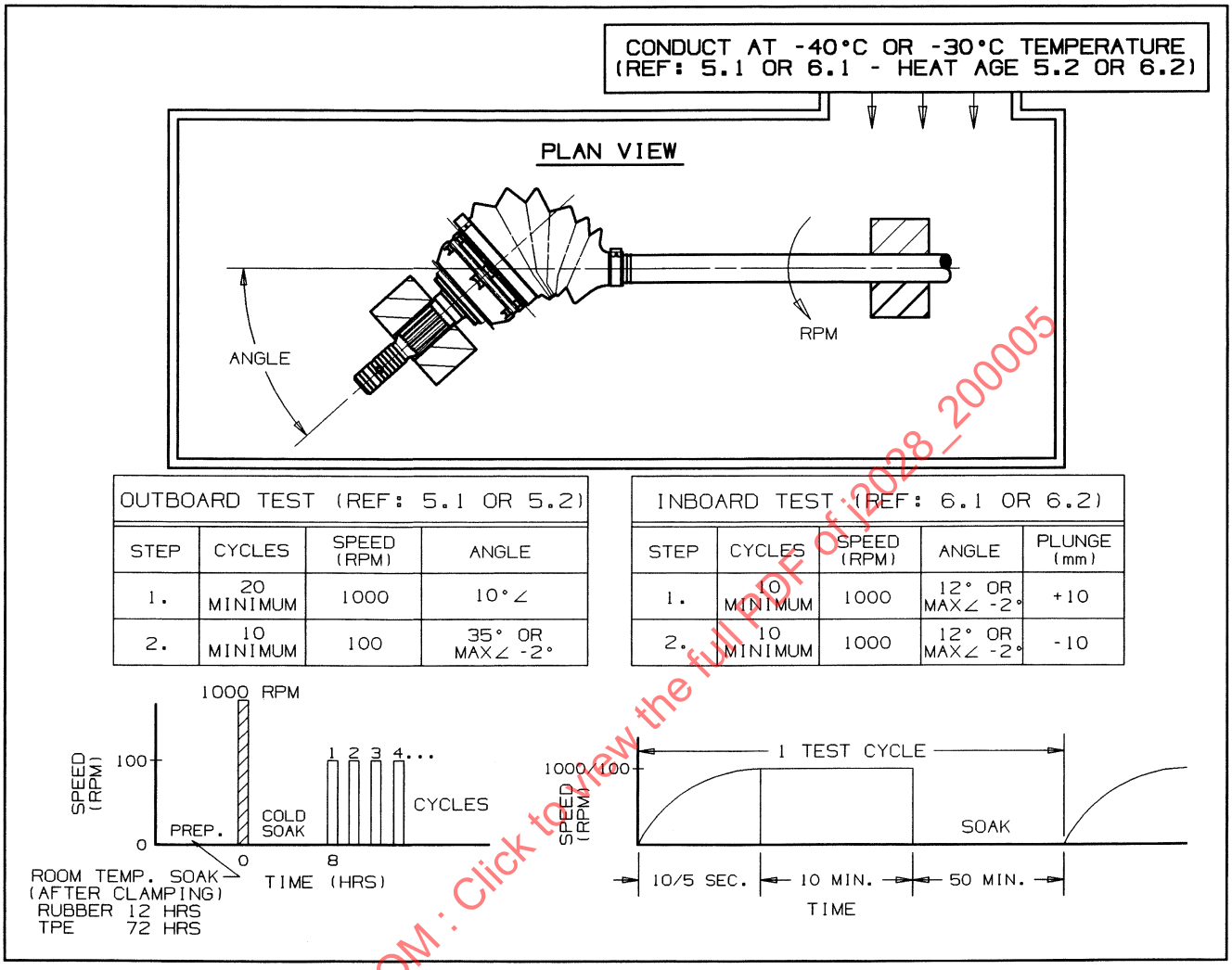
TABLE 3—SLAB SPECIMEN MATERIAL PROPERTIES (GUIDELINE ONLY—NOT A SPECIFICATION)

	ASTM Method	Rubber J200 CR (Neoprene)	Rubber J200 AEM (Vamac®)	Rubber J200 SI or VMG (Silicone)	TPE - J3000 TEEE (Hytrel®/Arnitel®)	TPE - J3000 TEO (Santoprene®/Sarlink®)	TPE - J3000 TPUR (Urethane)
Original Properties[1]		Per D 412	Per D 412	Per D 412	Per D 638	Per D 412	Per D 638
Hardness Shore, 2-Ply (Scale)	D 2240	55 to 65 pts.(A)	55 to 70 pts.(A)	55 to 65 pts.(A)	37 to 55 (D)	50(A) to 50(D)	70(A) to 60(D)
Tensile Strength, MPa	D 412,Die C,D 638	12 Min.	8 Min.	7 Min.	18 min.	4.4 min.	23 min.
Modulus @ 100%,MPa,	D 412,	1.2 Min.	2.4 Min	1.2 Min.	—	2.0 min.	—
@10% For TPE	D 638	—	—	—	3 Min.	—	4 min.
Elongation, %	D 412,D 638	300 Min.	225 Min.	400 Min.	200 Min.	260 min.	450 min.
Tear Strength, kN/m	D 624, Die C	25 Min.	18 Min.	—	80 Min.	19 min.	55 min.
	D 624, Die B Nicked	—	—	20 Min.	—	—	—
Heat Age - Air							
70h at Temp/336h for TPE	D 573	100 °C	150 °C	200 °C	125 °C	125 °C	125 °C
Hardness Change	D 2240	–10 to + 5 Pts.	0 to +15 pts.	–10 to +15 pts.	–10 to + 10 pts.	–4 to + 5 pts.	—
Tensile Strength Change	D 412,D 638	–30 to +10%	–20 to +10%	–30 to +15%	–30 to 0%	–10 to +15	–15 to 0%
Elongation Change	D 412,D 638	–40 to +10%	–20 to +10%	–50 to +10%	–40 to +30%	-30 to +22	–20 to +20%
Heat Age - Oil No. 1							
70 h at Temperature	D 573	100 °C	125 °C	150 °C			100 °C
Hardness Change	D 2240	–10 to +15 pts.	–10 to +15 pts.	–10 to +15 pts.	Not Required	Not Required	—
Tensile Strength Change	D 412,D 638	–30 to +10%	–30 to +10%	–30 to +15%			–5 to +5%
Elongation Change	D 412,D 638	–30 to +10%	–30 to +10%	–30 to –15%			–15 to +15%
Heat Age - Oil No. IRM 903							
70 h at Temperature	D 573	100 °C	125 °C	150 °C		125 °C	
Volume Change	D 471	0 to +80%	0 to +50%	0 to +80%	Not Required	0 to 106%	Not Required
Heat Age - Grease[2]							
70h at Temp/336h for TPE	D 573	100 °C	125 °C	150 °C	125 °C	125 °C	125 °C
Hardness Change	D 2240	–20 to +5 pts.	–15 to +15 pts.	–10 to +15 pts.	–10 to +10pts.	–22 to 0 pts.	—
Tensile Strength Change	D 412,D 638	–30 to +10%	–30 to +10%	–30 to +10%	–30 to 0%	–30 to 0%	–35 to 10%
Elongation Change	D 412,D 638	–30 to +10%	–30 to +10%	–30 to +10%	–40 to +30%	–40 to 0%	–15 to +15%
Volume Change	D 471	0 to +30%	0 to +30%	0 to +30%	—	—	—
Weight Change	D 471	—	—	—	0 to +15%	0 to +60%	—
Low Temperature Brittleness[3]	D 2137,Method A	–40 °C	–40 °C	–55 °C	–70 °C	–40 °C	–80 °C
3 m at Temperature	D 746	No Cracks	No Cracks	No Cracks	No Cracks	No Cracks	No Cracks
Compression Set							
22 h at Temperature	D 395, Method B Solid	100 °C 50% Max.	125 °C 50% Max.	150 °C 50% Max.	Not Required	Not Required	70 °C 70% Max

TABLE 3—SLAB SPECIMEN MATERIAL PROPERTIES (GUIDELINE ONLY—NOT A SPECIFICATION) (CONTINUED)

	ASTM Method	Rubber J200 CR (Neoprene)	Rubber J200 AEM (Vamac®)	Rubber J200 SI or VMG (Silicone)	TPE - J3000 TEEE (Hytrel®/Arnitel®)	TPE - J3000 TEO (Santoprene®/Sarlink®)	TPE - J3000 TPUR (Urethane)
Ozone Resistance Static 50 pphm,40 °C, 70 h 20% Elongation	D 1149 Specimen A	No Cracks	No Cracks	Not Required	Not Required	Not Required	Not Required
Dynamic 50 pphm, 40 °C, 70 h 0 to 25% Elong/0.5 Hz (30 cpm) No edge coating permitted.	D 3395 Method A	No Cracks	No Cracks	Not Required	Not Required	Not Required	Not Required
Specific Gravity	D 792 D 1505	— 1.2 to 1.5	— 1.0 to 1.4	— 1.1 to 1.6	1.0 to 1.2 —	0.9 to 1.0 —	1.0 to 1.2 —
Vicat Softening °C	D 1525 Rate A	Not Applicable	Not Applicable	Not Applicable	150 Min.	Not Applicable	60 - 150
Melting Point °C	D 3418	Not Applicable	Not Applicable	Not Applicable	200 Min.	165 Min.	170 Min.

1. For TPE properties tensile, modulus, and elongation, use ASTM D 638 in place of ASTM D 412, TPE hardness after 5 s delay, TPE modulus at 10%, MPa.
2. Same as OEM or Service Designation TPE at 336 h, 2 sided, full immersion.
3. For TPE properties low temperature brittleness per ASTM D 746.



OUTBOARD TEST (REF: 5.1 OR 5.2)

STEP	CYCLES	SPEED (RPM)	ANGLE
1.	20 MINIMUM	1000	10° ∠
2.	10 MINIMUM	100	35° OR MAX∠ -2°

INBOARD TEST (REF: 6.1 OR 6.2)

STEP	CYCLES	SPEED (RPM)	ANGLE	PLUNGE (mm)
1.	10 MINIMUM	1000	12° OR MAX∠ -2°	+10
2.	10 MINIMUM	1000	12° OR MAX∠ -2°	-10

FIGURE 1—COLD TEST

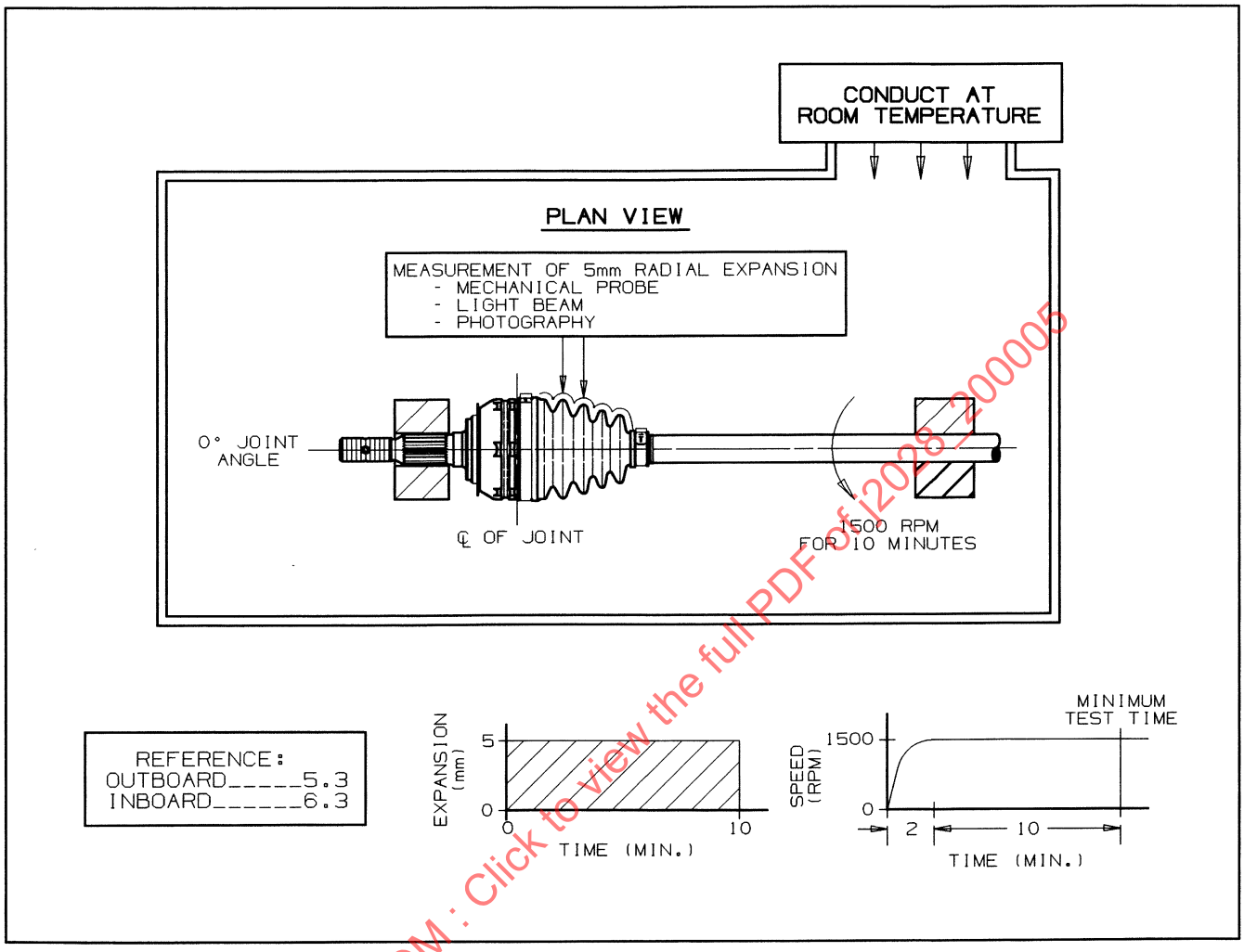
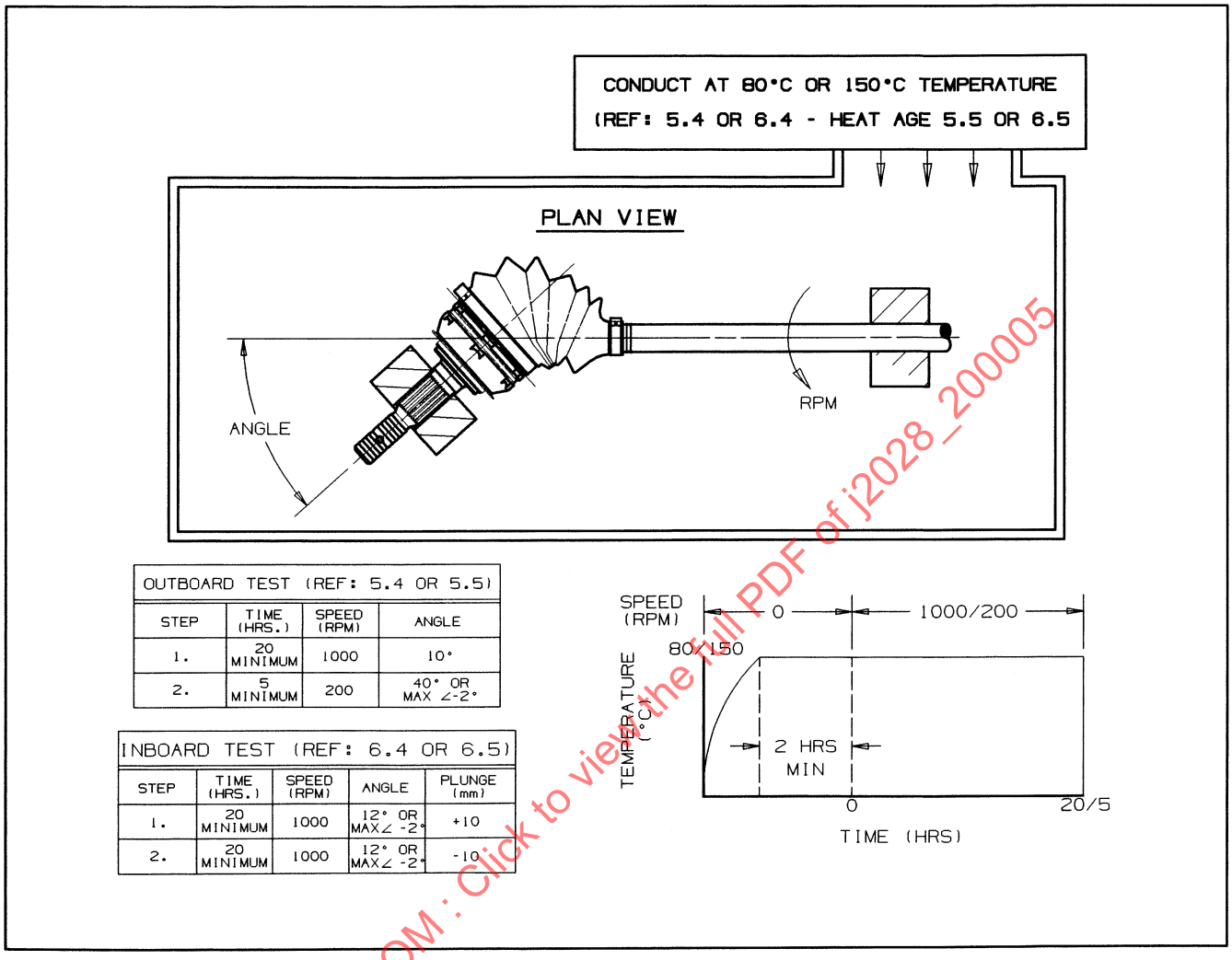


FIGURE 2—RADIAL EXPANSION TEST



OUTBOARD TEST (REF: 5.4 OR 5.5)

STEP	TIME (HRS.)	SPEED (RPM)	ANGLE
1.	20 MINIMUM	1000	10°
2.	5 MINIMUM	200	40° OR MAX ∠-2°

INBOARD TEST (REF: 6.4 OR 6.5)

STEP	TIME (HRS.)	SPEED (RPM)	ANGLE	PLUNGE (mm)
1.	20 MINIMUM	1000	12° OR MAX∠ -2°	+10
2.	20 MINIMUM	1000	12° OR MAX∠ -2°	-10

FIGURE 3—HOT TEST

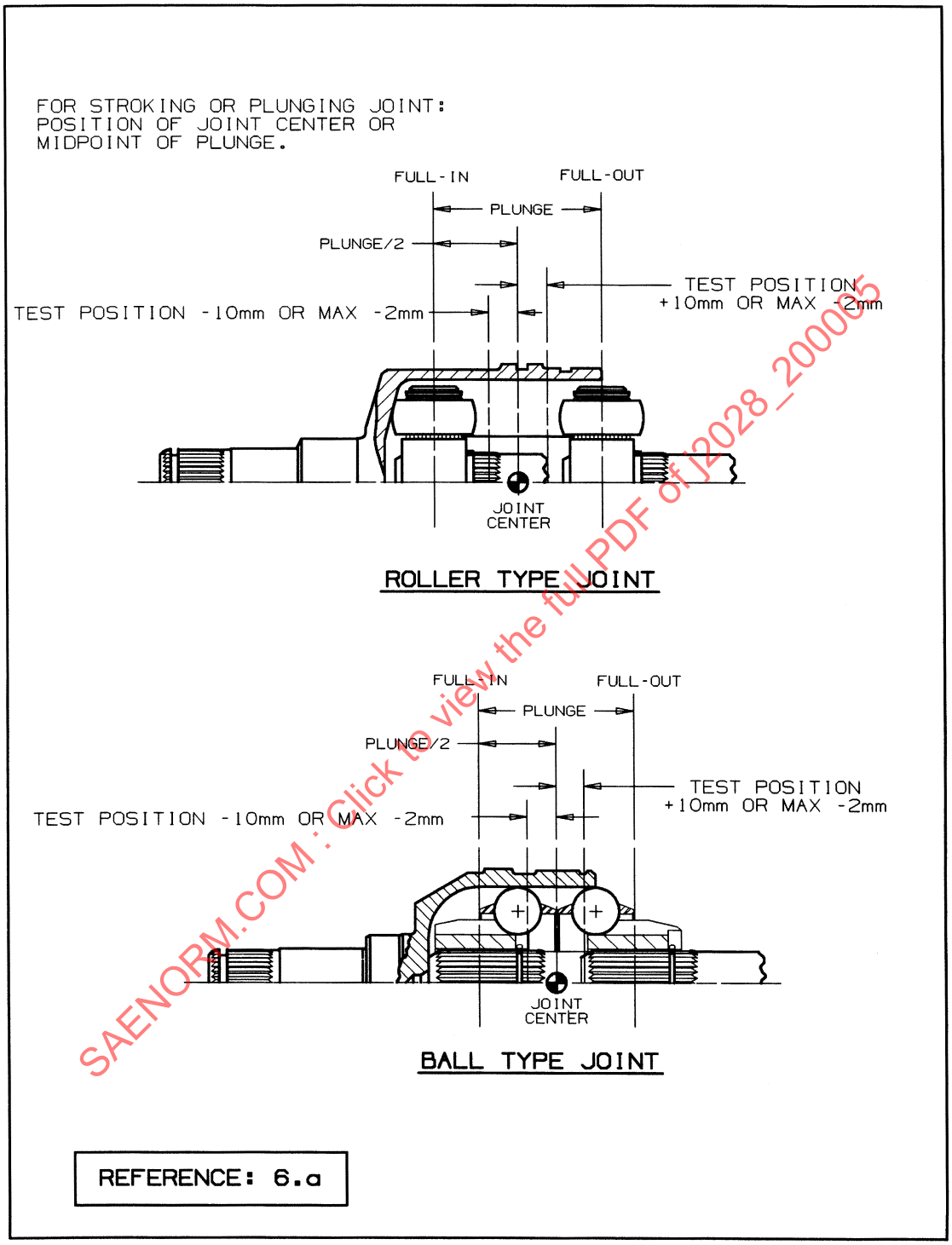


FIGURE 4—DEFINITION OF JOINT CENTER AND TEST POSITION

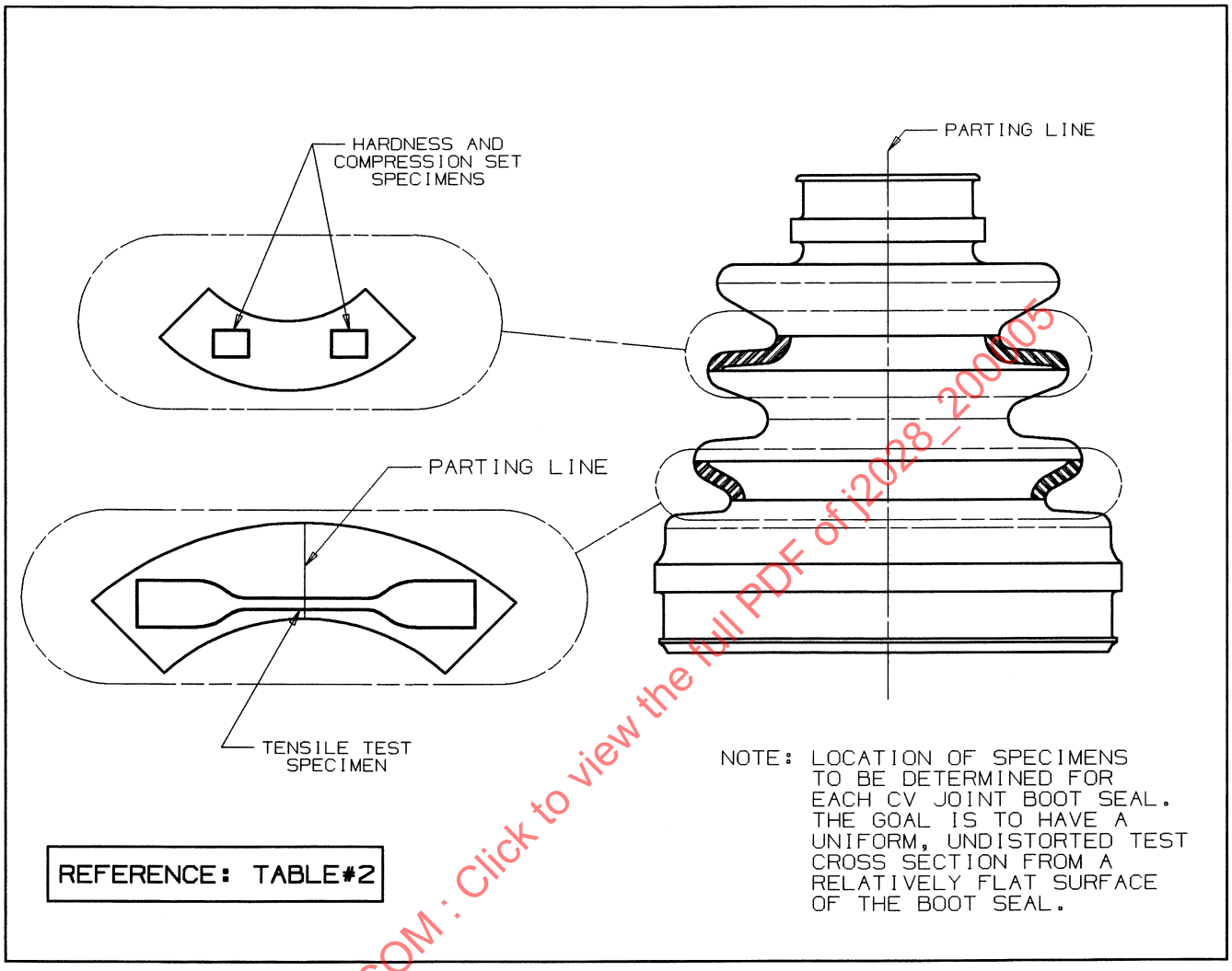


FIGURE 5—TYPICAL AS MOLDED SPECIMEN SOURCE—RUBBER BOOT SEAL

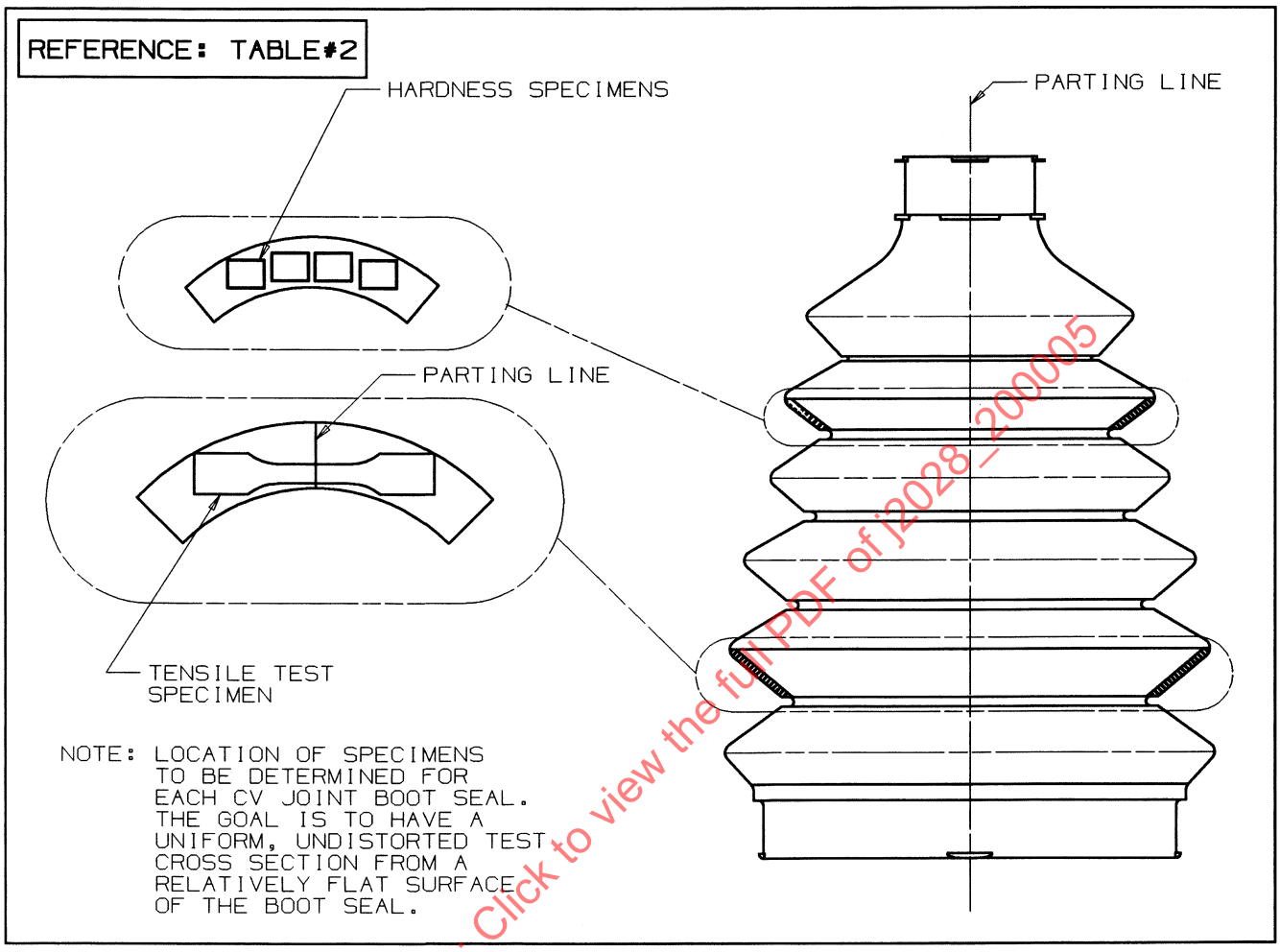


FIGURE 6—TYPICAL AS MOLDED—TPE BOOT SEAL