The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J2490

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Submitted for recognition as an American National Standard

SAE No. 2 Friction Test Machine μPvt Test

1. ***Scope—***This SAE Recommended Practice is intended as the definition of a standard test, which may be subject to frequent change to keep pace with experience and technical advances. This should be kept in mind when considering its use.

The SAE No. 2 Friction Test Machine is used to evaluate the friction characteristics of automatic transmission plate clutches with automotive transmission fluids. It can also be used to conduct durability tests on wet friction systems.

The specific purpose of this document is to define a μPVT Test for the evaluation of the variation of wet friction system performance as a function of speed, temperature, and pressure. This procedure is intended as a standard for both suppliers and end users.

The only variables selected by the supplier or user of the friction system are:

a. Friction Material
b. Fluid
c. Reaction Plates

These three variables must be clearly identified when reporting the results of this test. If any of the test parameters or system hardware as described in this document are changed, other than the friction material, test fluid, or reaction plates, the data may not be reported as having been obtained using this document.

This procedure is intended to evaluate the endpoint/midpoint ratios, midpoint and breakaway coefficients. The procedure can be used to demonstrate changes that occur between the different levels of engagement speed, sump temperature and apply pressure. Refer to SAE J2487, SAE J2488, or SAE J2489 for coefficient variations due to changes in power level.

The procedure, as described in detail in Table 1, consists of four 50 cycle break-in levels at 3500 r/min with increasing steps of apply pressure, followed by 16 levels consisting of 25 dynamic engagements and one breakaway following completion of the 25th dynamic cycle. The 16 levels are achieved by varying initial engagement speed, apply pressure and oil sump temperature while the inertia is kept constant at 0.701 kg-m^2.

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 version of SAE publications shall apply.

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

SAE J286—SAE No. 2 Clutch Friction Test Machine Guidelines
SAE J1646—Glossary of Terms—Lubricated Friction Systems
SAE J2487—SAE No. 2 Friction Test Machine 3600 r/min Stepped Power Test
SAE J2488—SAE No. 2 Friction Test Machine 6000 r/min Stepped Power Test
SAE J2489—SAE No. 2 Friction Test Machine Durability Test

2.2 Related Publications—The following publications are for information purposes only and are not a required part of this specification.

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

SAE J1499—SAE Band Friction Test Machine (SAE) Test Machine Guidelines
SAE Paper 670051—New Fixture for Testing Friction Materials for Automatic Transmission Clutch

2.2.2 FORD MOTOR COMPANY PUBLICATION—Available from Ford Motor Company, FSATF Committee, 35500 Plymouth Road, Box 215, Livonia MI 48150.

Ford MERCON® V Specification

2.2.3 GENERAL MOTOR PUBLICATION—Available from GM Research & Development Center, General Motors Corporation, Technology Licensing, 30500 Mound Road, M/C 480-106-160, Warren, MI 48090-9055.

GM DEXRON®-III Specification, GM6417M

2.2.4 DAIMLER CHRYSLER PUBLICATION—Available from Daimler Chrysler Corporation, Engineering Standards Group, 800 Chrysler Drive East, Auburn Hills, MI 48326-2757.

Daimler Chrysler Specification MS9602

3. Test Equipment

3.1 SAE No. 2 Friction Test Machine with breakaway accessory.

3.2 Flywheel to deliver desired kinetic energy. The flywheel is required to provide the specified total system inertia of 0.701 kg-m^2 as shown in Tables 1A and 1B.

3.3 Data Acquisition—At not less than 1000 samples per second and storage system with at least four channels with response as follows:

a. Torque Channel, Bandwidth, 500 Hz.
b. Apply Pressure Channel, Bandwidth, 500 Hz.
c. Speed Channel, Bandwidth, 500 Hz.
d. Test Fluid Temperature Channel, Bandwidth, 3 Hz.
(All channels are to be calibrated to maintain ±2% accuracy throughout the range of 10% of full scale to full scale.)

TABLE 1A—REQUIRED PARAMETERS
μPVT TEST

Test Level	Cycles	Inertia (kg-m^2)	Speed (r/min)	Kinetic Energy	Apply Pressure (kPa)	Oil Inlet Temperature (deg C)	
BI 1	50	0.701	3500	47.09	165	50	
BI 2	50	0.701	3500	47.09	235	50	Break-In
BI 3	50	0.701	3500	47.09	305	50	Levels 1 - 4
BI 4	50	0.701	3500	47.09	370	50	
A	25	0.701	750	2.16	83	50	
B	25	0.701	1500	8.65	83	50	
C	25	0.701	750	2.16	166	50	Low Pressure
D	25	0.701	1500	8.65	166	50	and Speed
E	25	0.701	750	2.16	83	110	Levels A - H
F	25	0.701	1500	8.65	83	110	
G	25	0.701	750	2.16	166	110	
H	25	0.701	1500	8.65	166	110	
I	25	0.701	2700	28.02	248	110	
J	25	0.701	3500	47.09	248	110	
K	25	0.701	2700	28.02	373	110	High Pressure
L	25	0.701	3500	47.09	373	110	and Speed
M	25	0.701	2700	28.02	248	50	Levels I - P
N	25	0.701	3500	47.09	248	50	
O	25	0.701	2700	28.02	373	50	
P	25	0.701	3500	47.09	373	50	

TABLE 1B—FLYWHEELS REQUIRED FOR THE TEST:

Code	Quantity	Inertia (kg-m^2)
A	1	As required to achieve an effective inertia of 0.701 kg-m^2

3.4 Instrumentation

a. Torque Transducer—Full bridge, strain gage type, combined nonlinearity and hysteresis effects not to exceed 0.5% of full scale, such as Lebow Load Cell, Model 3397.
b. Apply Pressure Transducer—Full bridge, strain gage type, combined nonlinearity and hysteresis effects not to exceed 0.5% of full scale, such as Sensotech, Model TJU708-12.
c. Speed Transducer—Optical Encoder, such as BEI Model 924-01002-4839. For drive motor.
d. Thermocouple(s)—Type J with high-impedance amplifier and cold junction compensator.

3.5 Test Fluid System (Figure 1C in SAE J286)—Heated sump including immersion or jacket heater with sufficient watt density for test fluid temperature control and the associated hardware for external fluid flow control. Care should be taken that the fluid is not altered or modified by contact with the immersion heater by ensuring that the heater does not exceed a power density of 2 W/cm^2.

3.6 Lubrication System Flow Configuration

3.6.1 EXTERNAL FLOW—(See Figure 1C in SAE J1646)—This represents the configuration wherein an external pump supplies fluid at a specific flow rate through a line to the centerline of the shaft. A flow meter must be installed in the line to the cover to measure the flow supplied to the head and the drain to the sump is from the 5, 6, and 7 o'clock positions.

3.7 Adapters and Reaction Plates—The required friction, reaction plates, hub, retainer and pressure plates and spacers are all described in Appendix A.

3.8 Apply Piston Seal

a. VITON®
b. Teflon®--Recommended for use in high temperature fluid tests.

4. Typical Operating Conditions and Test Parameters

4.1 Piston Area—15 110 mm^2.

4.2 Piston Available Travel—4.57 mm.

4.3 Piston Apply Pressure—As required in Tables 1A and 1B for each test level. Allowable variation in apply pressure is ±0.5%. See Reference SAE J1646 for definitions.

a. Start Threshold - Torque
b. Stop Threshold - Torque

4.4 Piston Apply Pressure Rise—The apply pressure must be stable at the required level within 100 ms for stability (for the highest pressure level). The maximum overshoot must not exceed 2% of the required pressure level.

4.5 Piston Release Pressure—30 to 100 kPa and must be 0 kPa during the apply period.

4.6 Effective Inertia—The μPVT test inertia remains constant for the entire test. A flywheel specific to an individual dynamometer is required to attain the inertia of 0.701 kg-m^2. See Tables 1A and 1B.

4.7 Engagement Speed Range

Break-in—4 pressure leves at 3500 r/min.
Low Speed Sequence—4 levels at 750 r/min and 4 levels at 1500 r/min.
High Speed Sequence—4 Levels at 2700 r/min and 4 levels at 3500 r/min.

All dynamic speeds are ±20 r/min.

4.8 Kinetic Energy—As shown in Tables 1A and 1B. These kinetic energy values must be as required for the specific level. The allowable variation in kinetic energy is ±5%.

4.9 Breakaway Speed—4.37 r/min.

4.10 Test Fluid

a. Quantity—18 L, minimum, and must be replaced with new fluid at the beginning of the procedure.
b. Temperature—50 °C ± 5 °C for break-in levels 1-4, levels A-D and M-P; 110 °C ± 5 °C for levels E-L measured in the inlet line as shown in Appendix A.
c. Test Fluid Flow—The test fluid flow rate is 1.0 L/min. ± 0.05 L/min.
d. Fluid Flow Configuration—The flow configuration is External Flow as described in SAE J1646 and 3.8.

4.11 Pack Clearance—1.143 mm ± 0.127 mm

4.12 Test Periods—Refer to SAE J1646 for the definitions of the test periods. The total period for one dynamic engagement cycle is 30 s ± 1 s.

a. T_1, Stabilization Period— 24 s ± 0.5 s
b. T_2, Coast Period—0
c. T_3, Apply Period—2 s ± 0.1 s
d. T_4, Dwell Period—4 s ± 0.5 s
e. T_5, Soak Period—2.5 s ± 2.5 s
f. T_6, Breakaway Period—2 s ± 0.5 s
g. T_7, Cooling Period—0

5. General Test Information

5.1 Clean—Prior to each test, the fixture and sump must be cleaned thoroughly and fixture and sump washed with solvent. The sump is then filled with the new test fluid.

5.2 Inspect—Inspect rotating shaft seal for deterioration and replace, if necessary. If this seal is replaced, also replace the non-rotating lip seals.

5.3 Soak—Soak friction elements in the test fluid for at least 10 minutes at room temperature.

5.4 Install Clutch Pack—Install a reaction plate to contact the pressure plate. Follow with a friction assembly, reaction plate, and so on until all the required components have been installed. The last plate to be installed must be a reaction plate. Spacer thickness must be selected to ensure that the pack clearance is as defined in 4.11. The pack configuration is PRFRFRFRFRSC, where P is the piston, R is a reaction plate, F a friction plate, S the spacer plate (as required) and C the cover. Reaction plates may be used as the spacer. To verify axial alignment of hub oil holes and friction plates, refer to Appendix A.

5.5 Install Housing Cover—Start the circulation pump and the temperature controller to heat the fluid and internal elements to the required control temperature, as given in 4.10.

5.6 Install Flywheels—Install the flywheel required to achieve the correct effective inertia.

5.7 Check Fluid Flow and Temperature—Check, with the motor off, that the fluid control temperature and the flow rate are as given in 4.10.

5.8 Start Test—Initiate the testing for the first break-in level, as defined in Tables 1A and 1B.

a. Set the apply pressure per Tables 1A and 1B. The stop time is allowed to float for each test level.
b. Initiate the testing for the required level as defined in Tables 1A and 1B.

6. Data Acquisition

6.1 Data Acquisition Rate—For digital data acquisition systems the data is to be recorded at 1000 samples per second per channel using a 15 ms time constant RC filter. (Filtering will slew data. Preferred method is to record all raw data and manipulate later.)

6.2 Data Averaging and Filtering—Data is to be averaged at the specified location in either the time or speed domain as specified in 6.1 with midpoint coefficient average values calculated using data points ±80 ms on both sides of the required calculation point. Endpoint coefficient average values are calculated from non-filtered peak torque data measured in the last 100ms of the engagement. For the 1000 Hz sampling rate the averages are based on 161 data points.

6.3 Coefficient Calculations—Coefficients are calculated for the following dynamic coefficient at every 25th engagement. (Reference SAE J1646)

Midpoint dynamic - $_{50\%}\mu_d$

The breakaway coefficients, obtained following every 25th dynamic engagement at each level, is defined as:

Breakaway coefficient - $_{1.0}\mu_{s4.37}$

7. Data Reporting

7.1 Data Tables—A data table showing the friction material, separator plate and fluid along with the system performance at each level in terms of the coefficients and ratios as given in 6.3. An example Table is given in Appendix B.

7.2 Figures—There are two figures required in reporting the results of this test. Examples of the two figures are given in Appendix B.

a. Figure of the midpoint dynamic coefficient verus the level number.
b. Figure of the E/M ratio and breakaway coefficient versus level number.

If the system does not successfully complete both the 25 dynamic engagements and the breakaway test, there is no data reported for that level. Alternatively, only data for the successful completion of a level are to be reported. Failure is defined as complete destruction of the friction material/system. (Report number of cycles into level at which failure occurred.)

7.3 Optional Data—Instantaneous plots of the 25th dynamic engagement at each level may be provided. Examples of such optional data are shown in Appendix B.

PREPARED BY THE SAE AUTOMATIC TRANSMISSION FRICTION STANDARDS COMMITTEE

APPENDIX A

A.1 This appendix contains the following prints describing the friction assembly, reaction plates, adapters, hub, and pressure plates required for this test procedure.

TABLE A1—TEST COMPONENTS AND ASSEMBLY LAYOUT

File Name	Description
ITEM 1	Adapter Ring
ITEM 2	Separator Retainer
ITEM 3	Pressure Plate
ITEM 4	Friction Plate Hub
ITEM 5	Separator Plate
ITEM 6	Friction Plate Assembly
ITEM 7	Retaining Ring (External)
ITEM 8	Retaining Ring (Internal)
ITEM 9	3 Plate Spacer (10.18 Thick)
ITEM 10	4 Plate Spacer (6.45 Thick)
ITEM 11	Splined Hub Spacer
ITEM 12	Spiro-Lock Retaining Ring
	3 Plate Assembly Cross Section
	4 Plate Assembly Cross Section

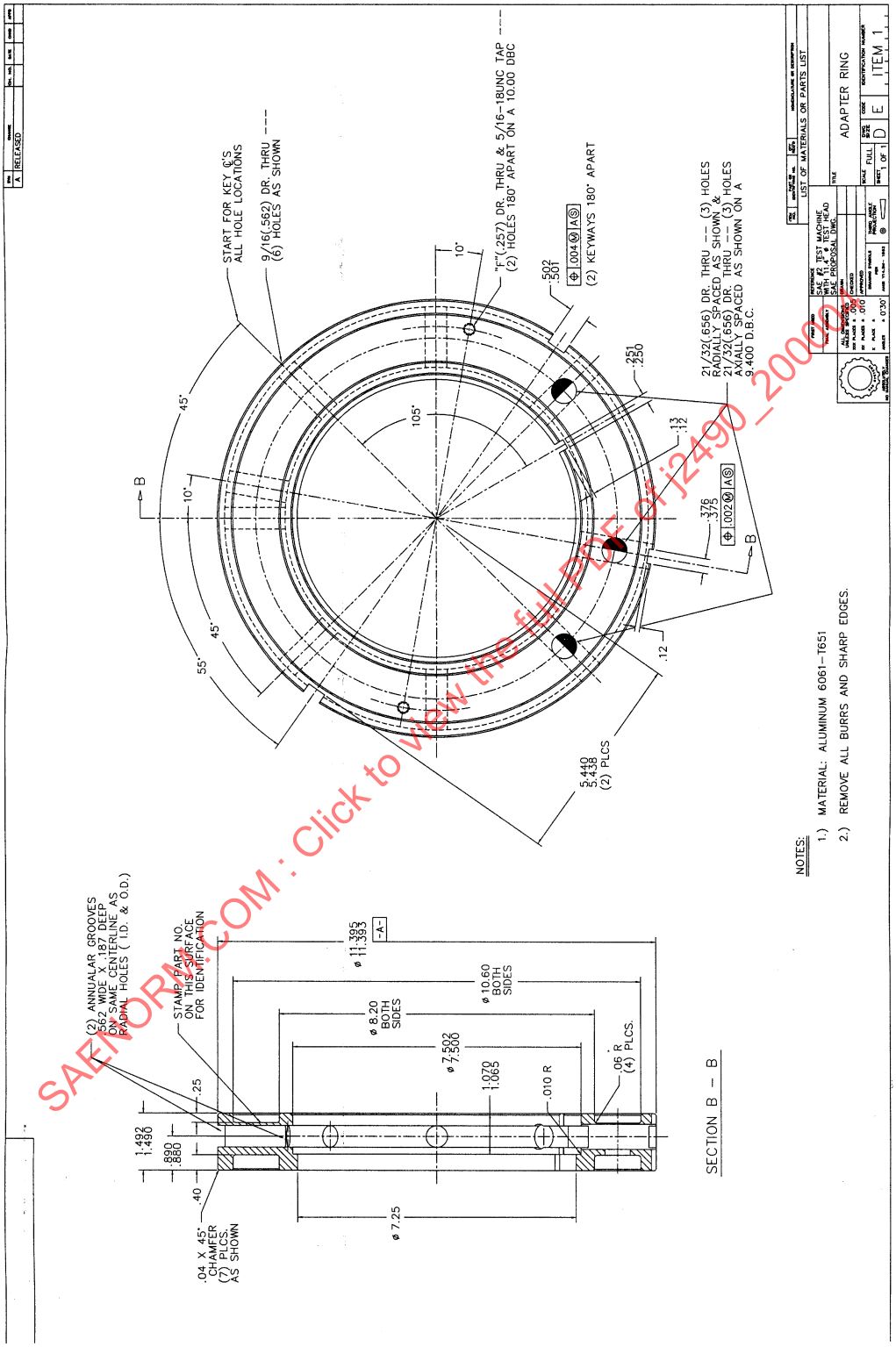

FIGURE A1—ITEM 1—ADAPTER RING

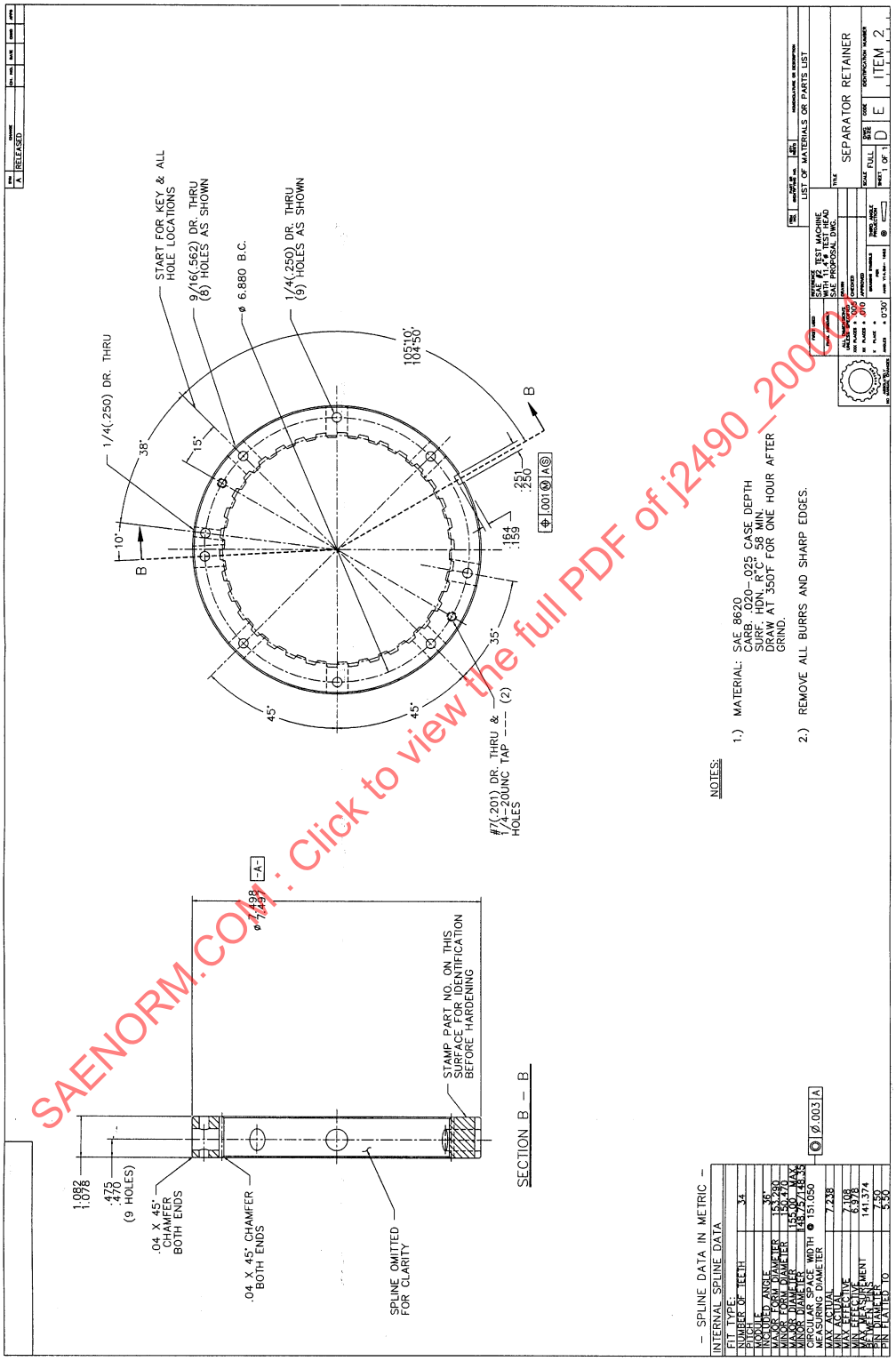

FIGURE A2—ITEM 2—SEPARATOR RETAINER

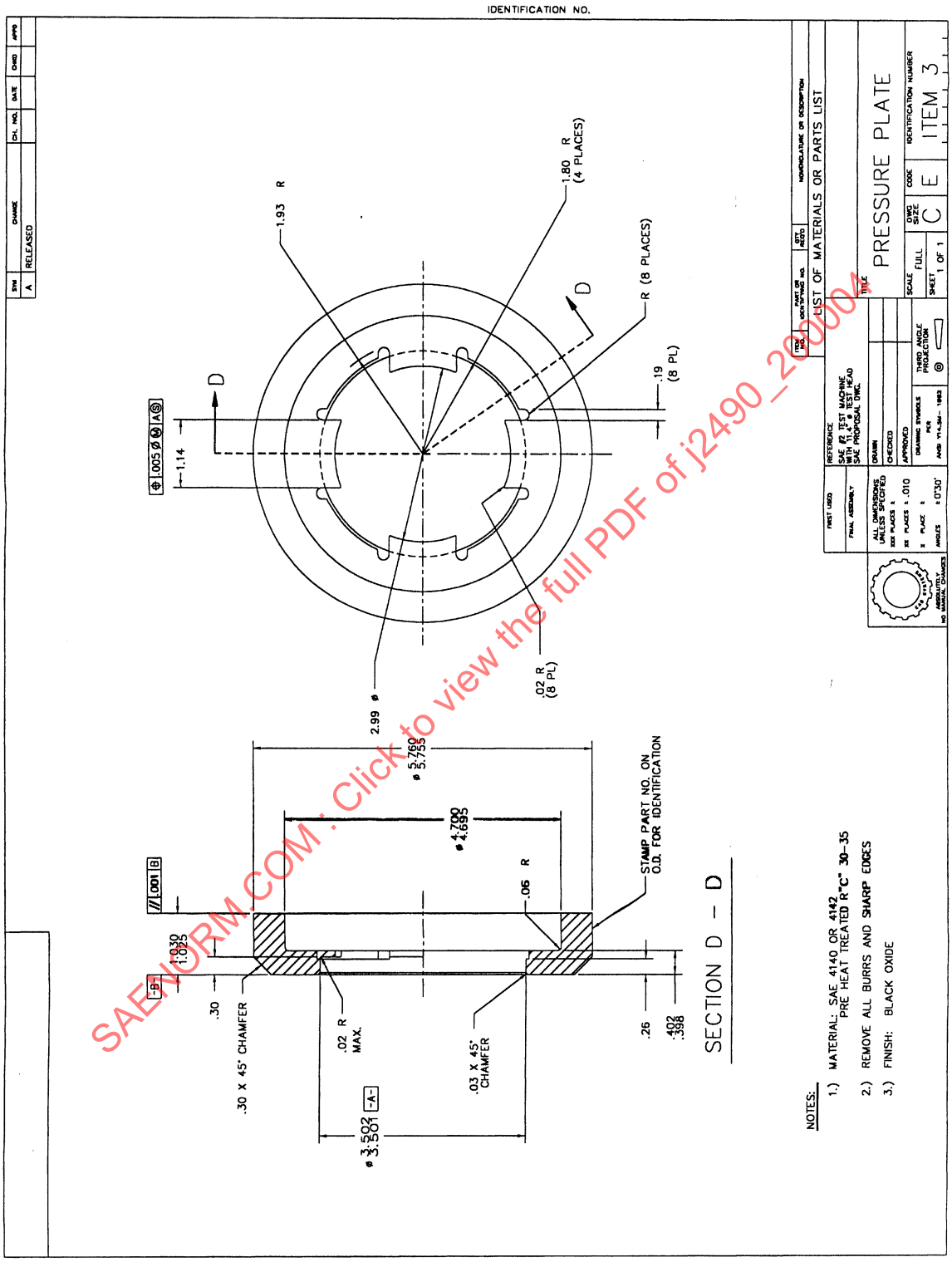

FIGURE A3—ITEM 3—PRESSURE PLATE

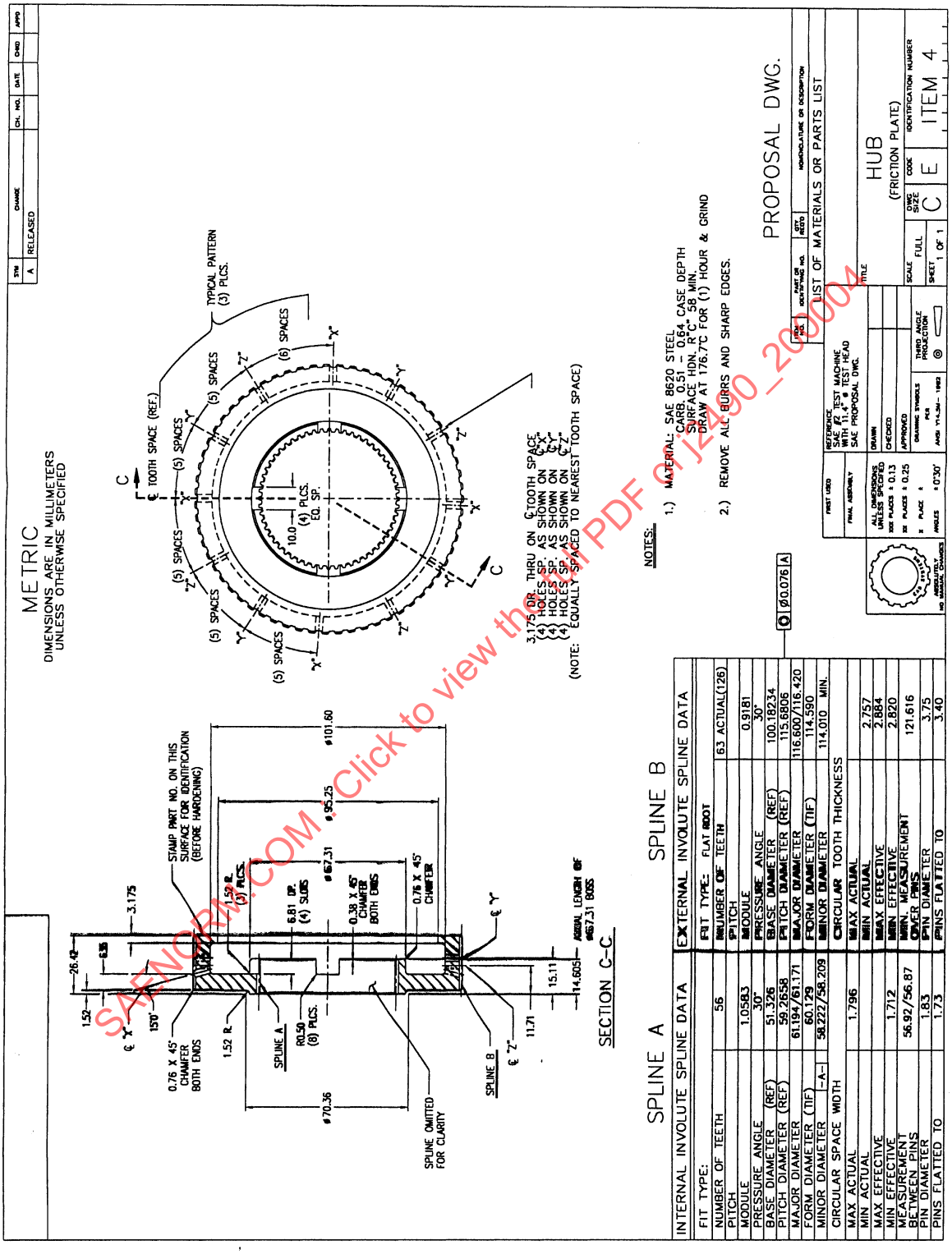

FIGURE A4—ITEM 4—FRICTION PLATE HUB

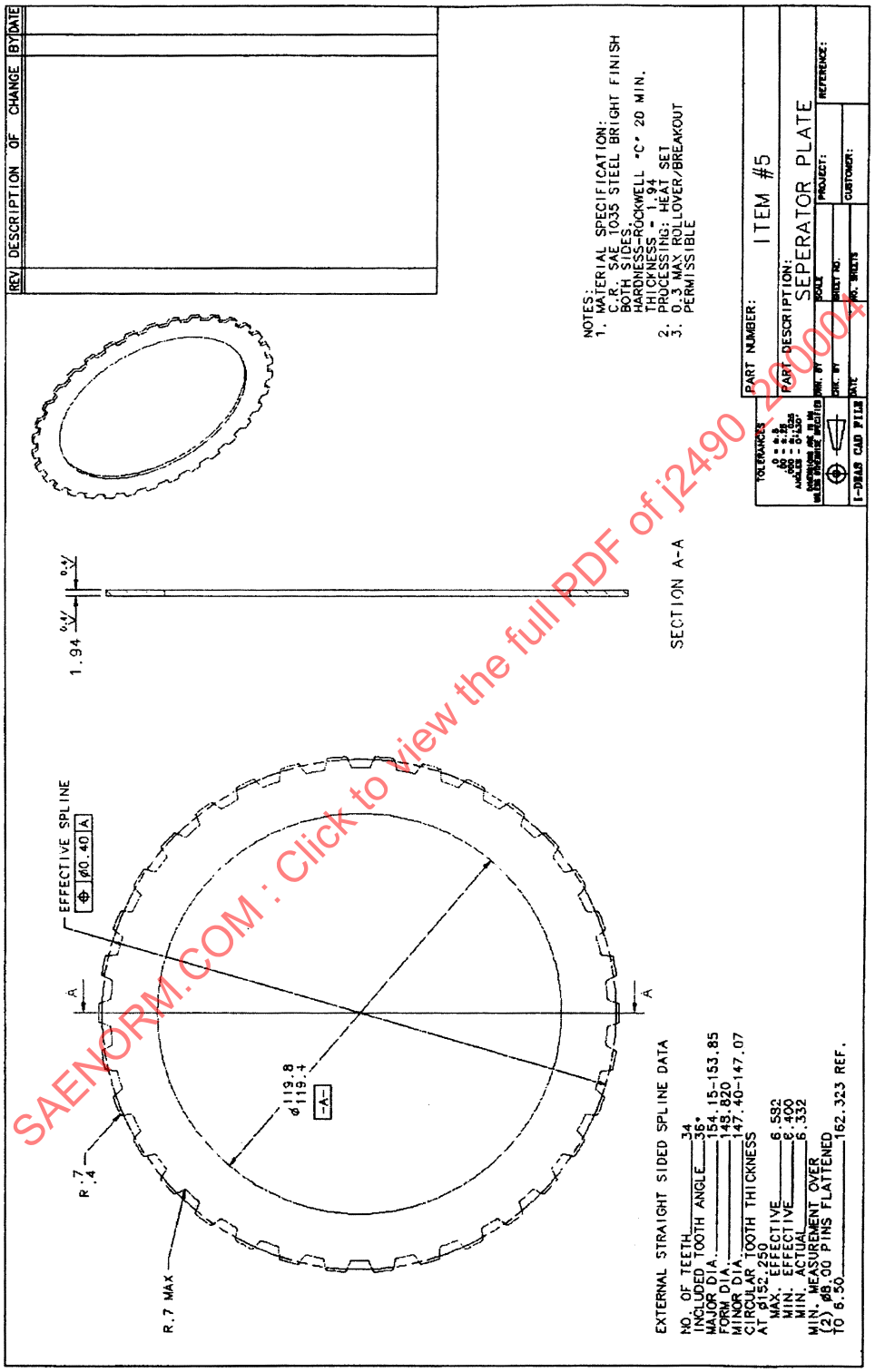

FIGURE A5—ITEM 5—SEPARATOR PLATE

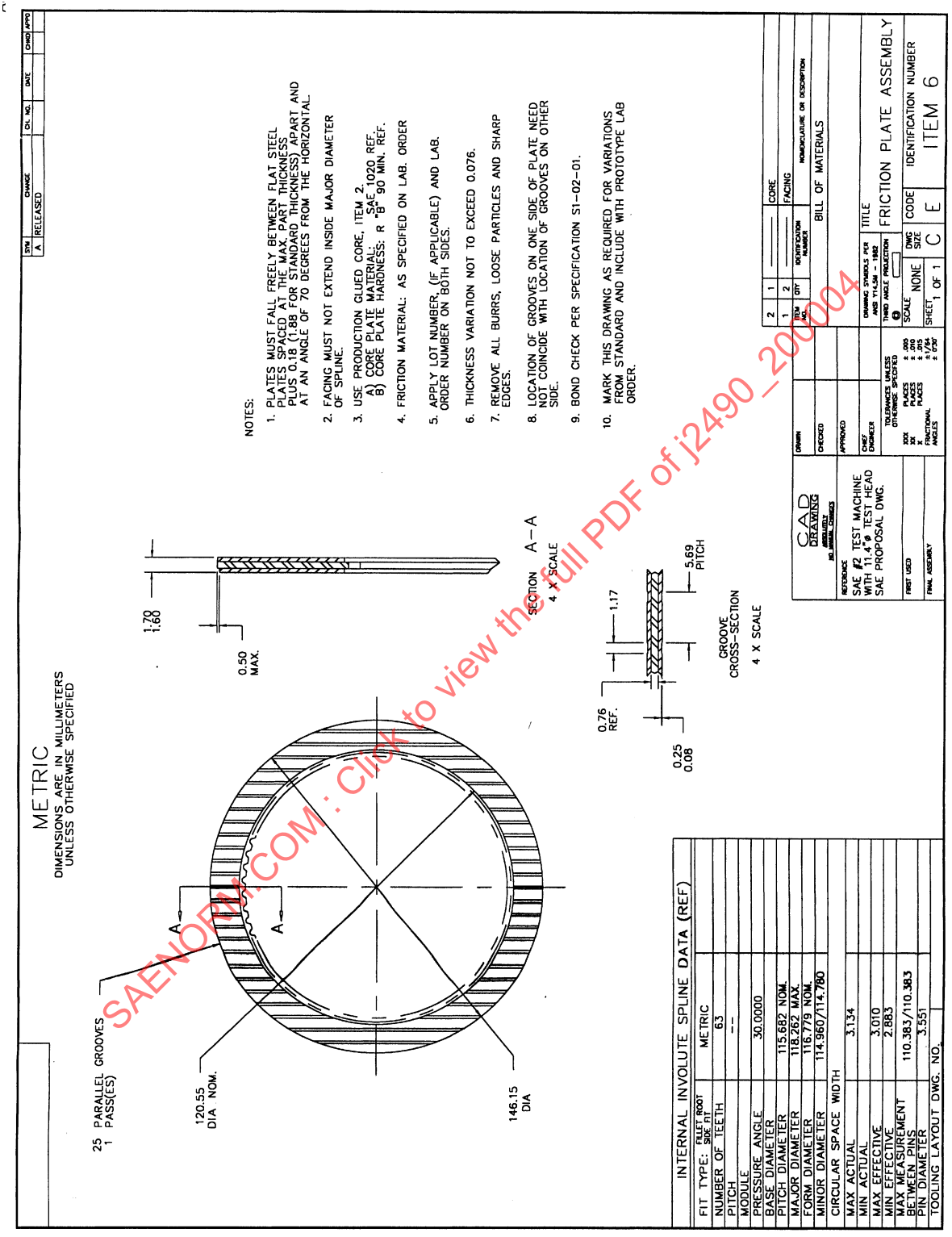

FIGURE A6—ITEM 6—FRICTION PLATE ASSEMBLY

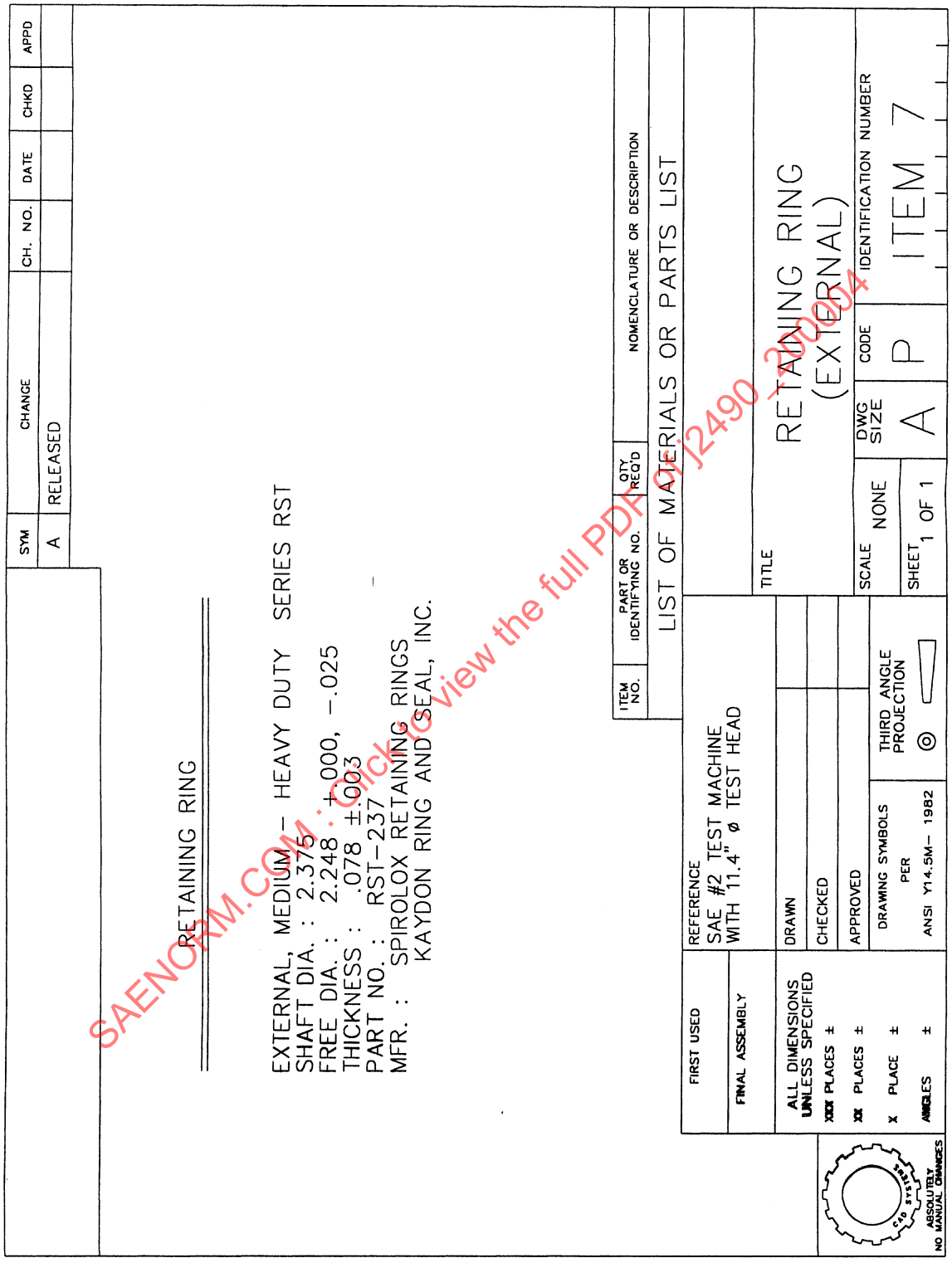

FIGURE A7—ITEM 7—RETAINING RING (EXTERNAL)

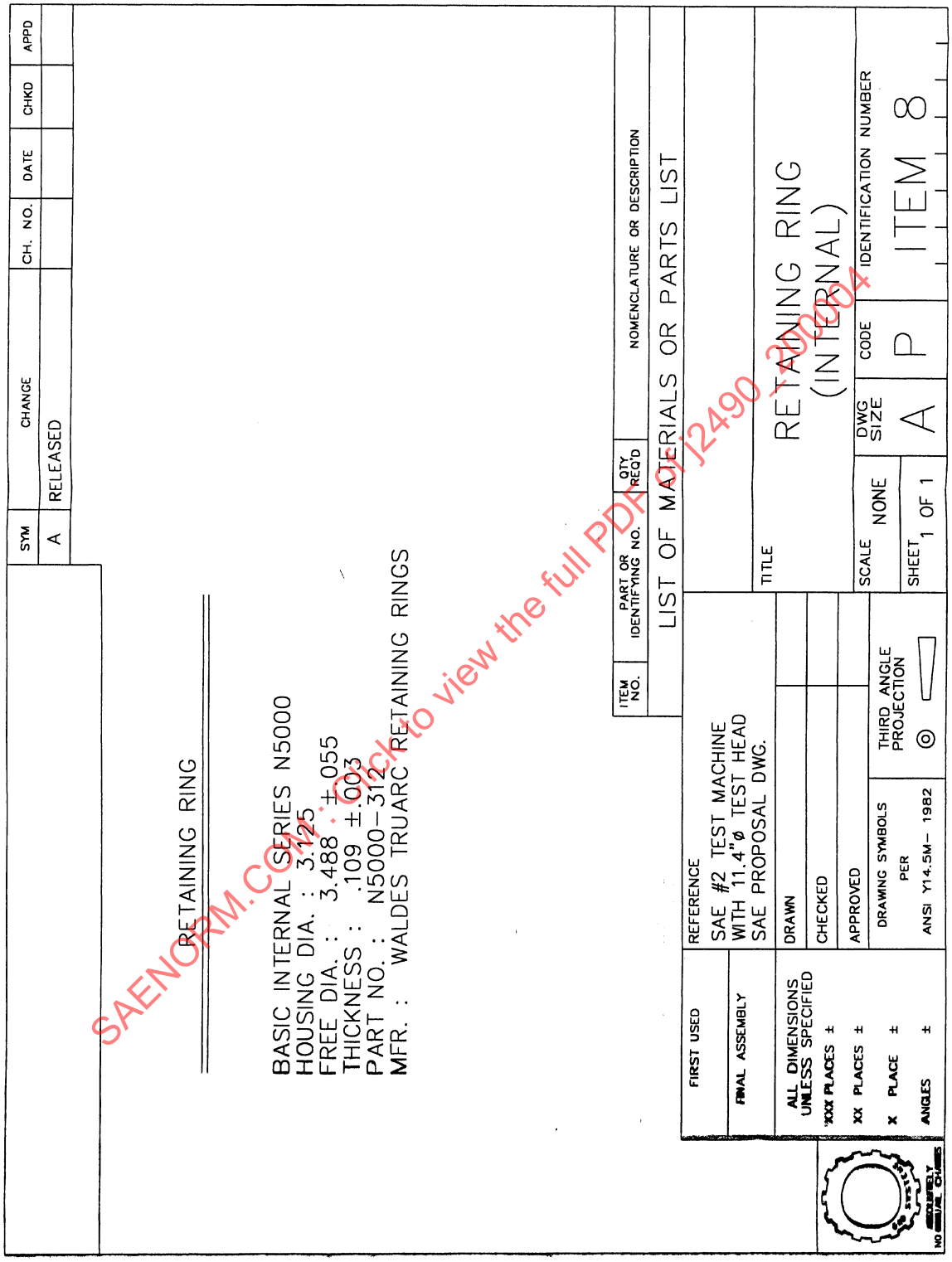

FIGURE A8—ITEM 8—RETAINING RING (INTERNAL)

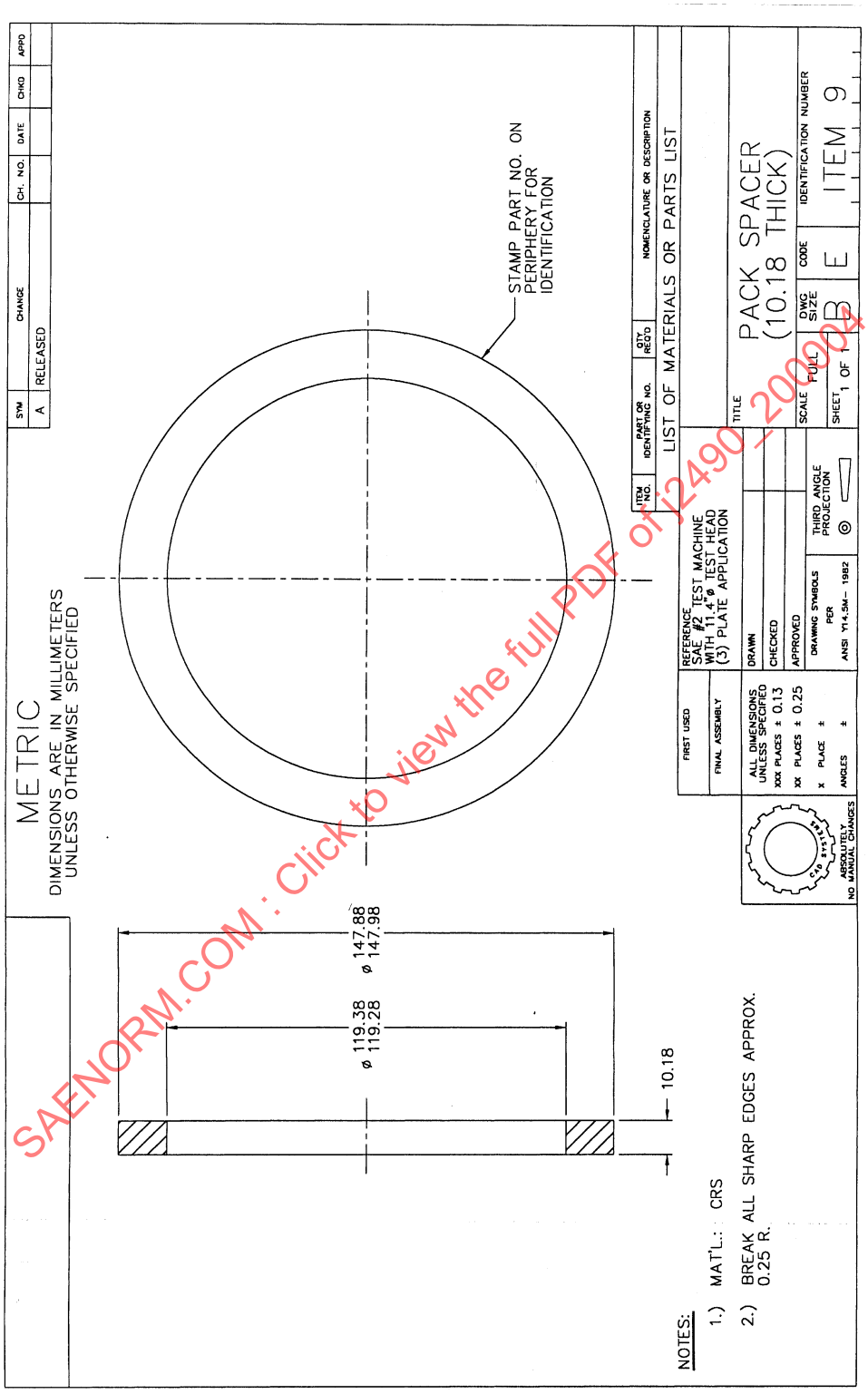

FIGURE A9—ITEM 9—3 PLATE PACK SPACER (10.18 THICK)

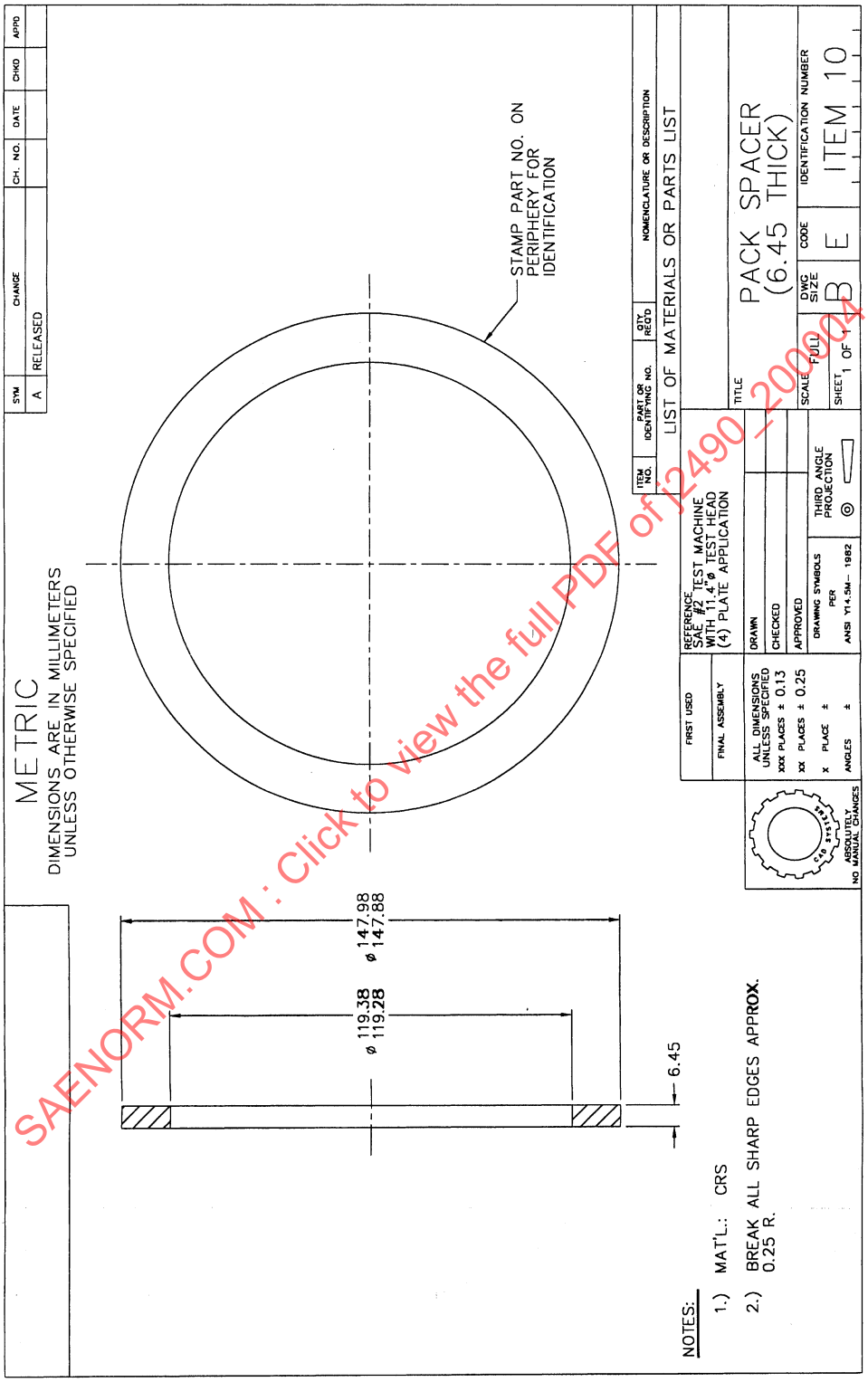

FIGURE A10—ITEM 10—4 PLATE PACK SPACER (6.45 THICK)

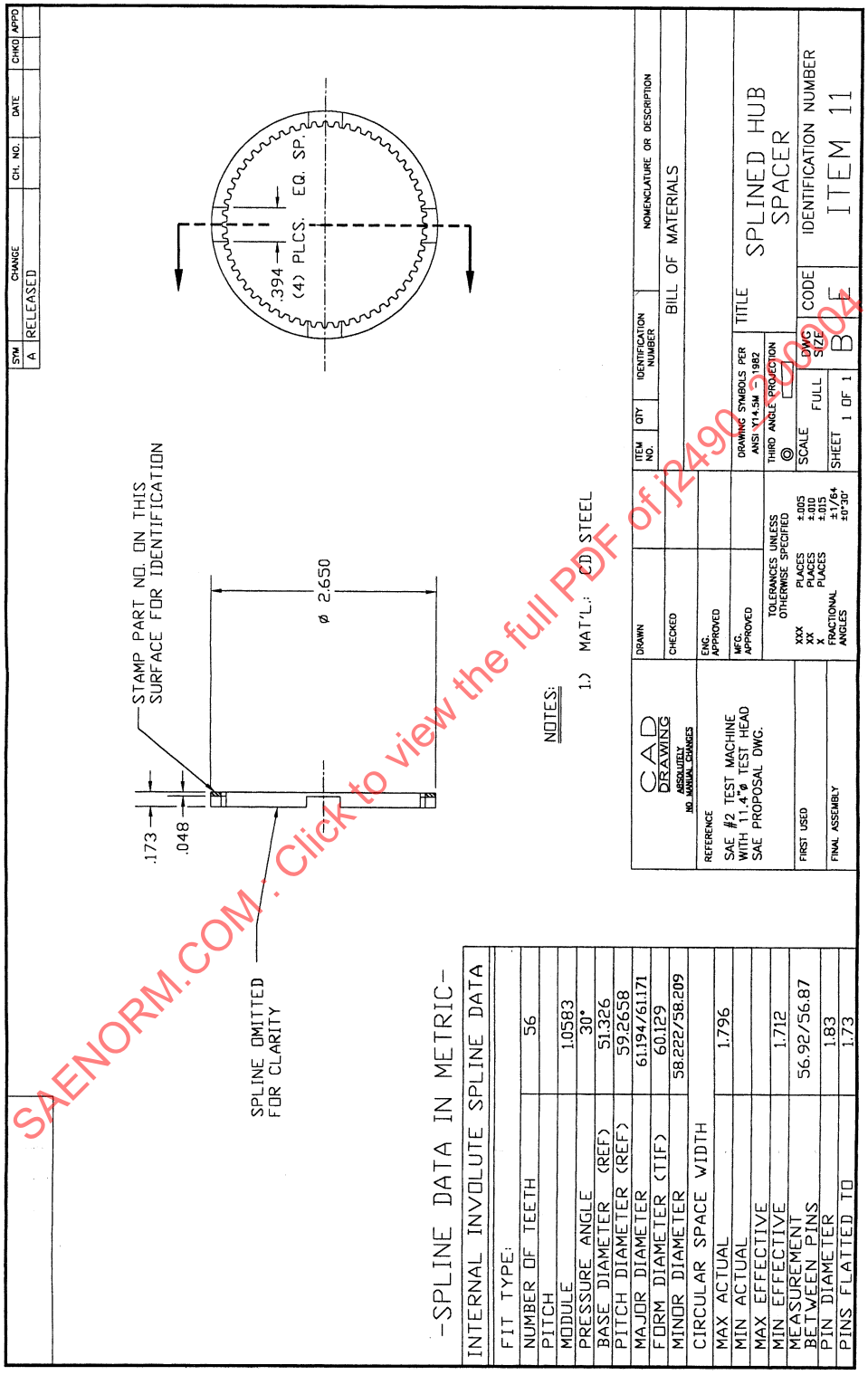

FIGURE A11—ITEM 11—SPLINED HUB SPACER

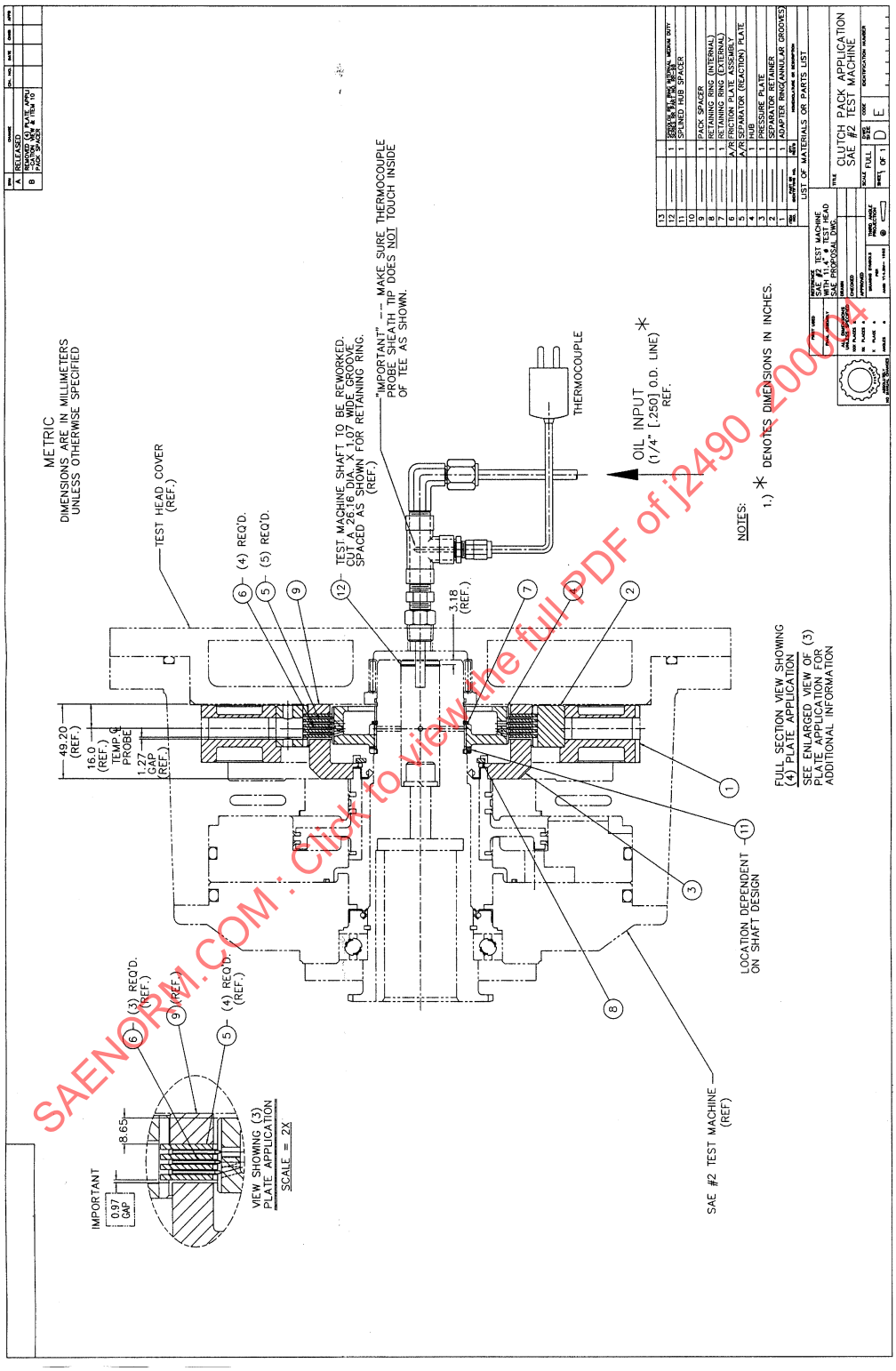

FIGURE A12A—ITEM 12A—SPIRO-LOCK RETAINING RING—
3 PLATE ASSEMBLY CROSS SECTION