Recommended Practice for Testing of Thread Compound for Rotary Shouldered Connections

API RECOMMENDED PRACTICE 7A1 (RP 7A1)
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OFFICIAL PUBLICATION

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This is the first edition of RP 7A1. It was approved by letter ballot following the 1991 Standardization Conference. This subject was formerly covered by Bul 7A1 from 1980 until its withdrawal in 1985.

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d. CAUTION: Some thread compounds contain toxic or hazardous materials. The Material Safety Data Sheets for thread compounds should be read and observed. Store and dispose of containers and unused compound in accordance with federal, state, and local regulations.

e. *This standard shall become effective on the date printed on the cover but may be used voluntarily from the date of distribution.*

SCOPE

a. This recommended practice is under the jurisdiction of the API Committee on Standardization of Drilling and Servicing Equipment.

b. This recommended practice provides recommendations for testing the frictional performance of thread compounds for rotary shouldered connections. For additional information regarding development of this recommended practice, refer to IADC/SPE 23844[1]. All manufacturers, users and others conducting rotary shouldered connection thread compound tests in accordance with this recommended practice are encouraged to submit suggested revisions to the Director of the Production Department, American Petroleum Institute, 1201 Main Street, Suite 2535, Dallas, Texas 75202-3904.

c. Paragraphs 4.1 and 4.2 include provisions whereby a manufacturer may state on the compound label that the manufacturer's compound conforms to API Recommended Practice 7A1. One of the conditions for this is that the manufacturer shall retain the laboratory test results for review on request. API does not evaluate or validate such test reports. API does not in any way approve or make any representation or warranty with regard to a particular compound, its test results, or facilities used for such tests.

d. Conversions of U.S. customary values to International System (SI) metric units are provided throughout the text of this recommended practice in parenthesis, e.g., 6 inch (152.4 mm). The factors to be used for conversion of U.S. customary values to SI units were taken from API Publication 2564, and are listed below:

LENGTH:

1 inch (in) = 25.4 millimeters (mm) exactly

TORQUE:

1 foot-pound (ft-lb) = 1.355818 newton-meters (N-m)

STRESS:

1 pound per square inch (psi) = 0.006894757 Mega-pascal (MPa)

VOLUME:

1 US gallon (gal) = 3.785412 liters (L)

TEMPERATURE: The following formula was used to convert degrees Fahrenheit (F) to degrees Celsius (C): °C = (5/9) • (°F-32).

e. DEFINITIONS.

Friction Factor — the ratio of the frictional performance of a compound relative to a specific reference compound. Is used as a multiplier to correct the make-up torque for rotary shouldered connections for a compound. See Section 3.

Frictional Performance — the reaction of the thread compound in combination with the test specimen as related to the coefficient of friction.

Reference Compound — a laboratory test compound formulated to produce consistent results from batch to batch that is used as a calibration standard.

Shall — is used to indicate that a provision is mandatory only when used in conjunction with the marking requirements of Section 4 of this Recommended Practice.

Should — is used to indicate that a provision is not mandatory but recommended as good practice.

May — is used to indicate that a provision is optional.

f. REFERENCED DOCUMENTS.

1. **General.** This specification includes by reference, either in total or in part, other API, industry, and government standards listed in Table 1.0.

2. **Equivalent Standards.** Other nationally or internationally recognized standards shall be submitted to and approved by API for inclusion in this specification prior to their use as equivalent standards.

TABLE 1.0
REFERENCED DOCUMENTS

1. CAS — *Chemical Abstracts Service*
2. API Spec 7 — *Specification for Rotary Drilling Equipment*
3. API RP 7G — *Recommended Practice for Drill Stem Design and Operating Limits*
4. ASTM E 11 — *Specification for Wire Cloth Sieves for Testing Purposes*
5. ASTM D 445 — *Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)*
6. ASTM D 128 — *Analysis of Lubricating Grease*
7. ASTM D 217 — *Standard Test Method for Cone Penetration of Lubricating Grease*
8. ASTM D 1301 — *Method for Chemical Analysis of White Lead Pigments*
9. ASME B1.1-1989 — *American Society of Mechanical Engineers — Unified Inch Screw Threads*

[1]E. I. Bailey and J. E. Smith: "Testing Thread Compounds for Rotary-Shouldered Connections" IADC/SPE Paper 23844 presented at the 1992 IADC/SPE Drilling Conference in New Orleans, LA.

SECTION 1
GENERAL

1.1 The Purpose.

This document defines:

a. the procedure for determining the friction factor of rotary shouldered connection thread compounds.

b. the recommended marking of the thread compound containers.

c. the calculation procedure for rotary shouldered connection make-up torque.

This document outlines a procedure for determining thread compound frictional performance, describes the statistical analysis method for evaluating the test results, and shows how to use the results of the tests. Using the results from this test does not guarantee failure-free rotary shouldered connection service in the field. This information should assist the user in selecting the most appropriate make-up torque for the thread compound in use.

1.2 Summary of the Test Procedure. The relative frictional performance of a thread compound is determined by using a threaded, shouldered bolt type specimen and recording torque versus turns data as shown in Figure 1. One cycle is defined as a single make and break of the specimen. A minimum of eight cycles shall constitute one test run for either the reference compound or the test compound. A complete test will consist of three runs as follows:

a. a calibration run performed using the reference compound.

b. a run performed using the test compound.

c. a repeat run using the reference compound.

The friction factor for the thread compound is determined by dividing the test compound result by the average of the reference compound results. Other properties of thread compounds such as galling prevention and resistance to downhole make-up are currently outside the scope of this recommended practice.

1.3 The Reference Compound. This test method utilizes a reference compound to simultaneously calibrate the specimen, the loading machine, and the instrumentation. It is a simple mixture of common components that can be readily mixed and will yield consistent results when tested in the manner described in the following sections. This reference compound is not intended for use as a thread compound and is only a laboratory calibration material.

The Reference Compound composition is:

Component	Percent by Weight
Lead Powder	60.0 ± 1.0
Grease Base	40.0 ± 1.0
Total	100.0

Lead powder shall conform to the following requirements:

Free metal content, % minimum (latest edition of ASTM D 1301)		95
Lead oxide content, % maximum (latest edition of ASTM D 1301)		5
Particle size:		
Pass No. 50 sieve,	% minimum	100
On No. 100 sieve,	% maximum	1
On No. 200 sieve	% minimum	5
	% maximum	25
Pass No. 325 sieve,	% minimum	40
	% maximum	80

(sieve designation as per the latest edition of ASTM E 11)

The grease base shall conform to the following requirements:

Consistency:		
Worked Penetration (60 strokes) (latest edition of ASTM D 217)		265-295
Thickener:		
Lithium 12-hydroxystearate		
Percent by weight,	% minimum	7
	% maximum	9
(latest edition of ASTM D 128)		
Base Oil:		
Petroleum/Non-synthetic		
Viscosity	@ 40 °C	115 cSt minimum
		170 cSt maximum
	@ 100 °C	9.5 cSt minimum
		14.0 cSt maximum

(latest edition of ASTM D 445)

NOTE: *The grease base shall contain no additives such as extreme pressure, anti-wear, or any other that could affect the frictional properties of the reference compound.*

WARNING: *Lead (CAS No. 7439-92-1) has been determined to be toxic. Mark, store, report and dispose of reference compound in accordance with federal, state, and local regulations.*

1.4 The Test Specimen. The test specimen is shown in Figure 2. The threads are 1-8 UNC and shall conform to ASME B1.1-1989 with a 2A and a 2B fit. The material of the specimen shall be AISI 4130 steel bar (UNS G41300) quenched and tempered to a Brinell hardness range of 285 to 341 through the complete cross section. The shoulder and the thread of each component shall be single-point cut without removing the part from the chuck to assure that the shoulder is perpendicular to the axis of the threads. The surface finish on mating surfaces shall be 32 ± 16 microinches RMS (0,8 ± 0,4 micrometer Ra). There shall be no surface treatment on the machined surfaces of the test specimen.

1.5 The Test Apparatus. The thread compound shall be tested in a machine capable of applying an increasing torque at a uniform rate to the specimen while recording the torque and rotation. The torque on the specimen shall be between 200 and 300 ft-lb (270 and 408 N-m) when the friction data is taken. The data acquisition instrumentation may be either analog or digital. Care must be taken to assure that the frequency response of either type system is adequate to acquire representative data.

An example of a mechanical system is shown in Figure 3. The test machine consists of three sections. The first section of the machine is the motor/gearbox that supplies the rotation and torque to the specimen. The rotation speed shall be 1 RPM ± 10%. The torque capability of the machine shall be at least 350 ft-lb (475 N-m) and shall be reversible. The second section of the machine is the torque transducer and resists rotation of the specimen and produces an output signal that is proportional to the applied torque. This transducer should have a maximum capability between 400 and 800 ft-lb (542 and 1085 N-m). The third section of the machine is the rotation transducer that produces an output signal that is proportional to the angle through which the specimen is rotated.

The signal from the rotation and torque transducers shall be recorded in such a way that there is a one-to-one correspondence between data points for torque and data points for rotation.

1.6 The Test Conditions. This test shall be conducted with the apparatus, the reference compound, and the test compound at a temperature between 60°F (15°C) and 100°F (32°C). The relative humidity shall be between 20% and 95% and non-condensing. The apparatus, environment, and the test compounds are not required to simultaneously be at the same temperature, but rather within the prescribed range. Results of tests performed at conditions outside of those listed above shall be so noted.

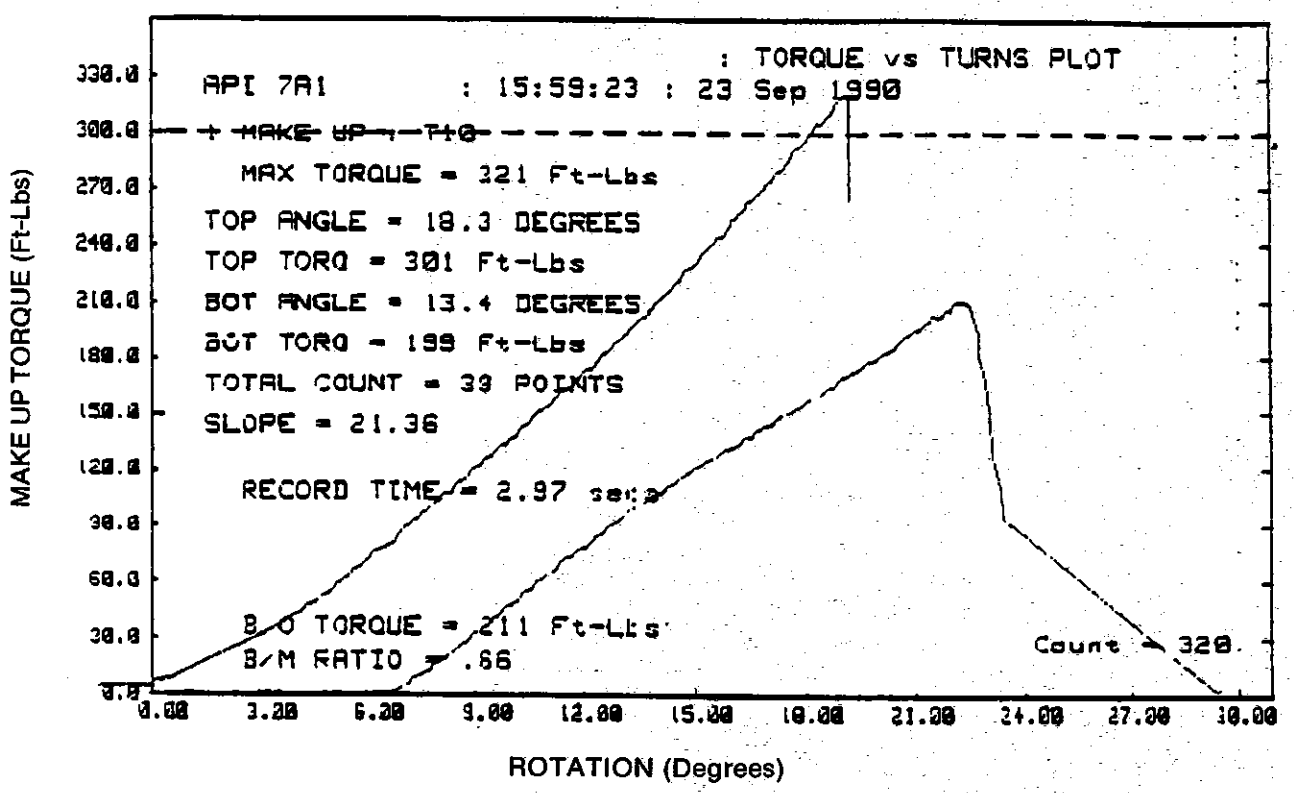

FIGURE 1
PLOT OF TYPICAL TORQUE VS. TURN DATA

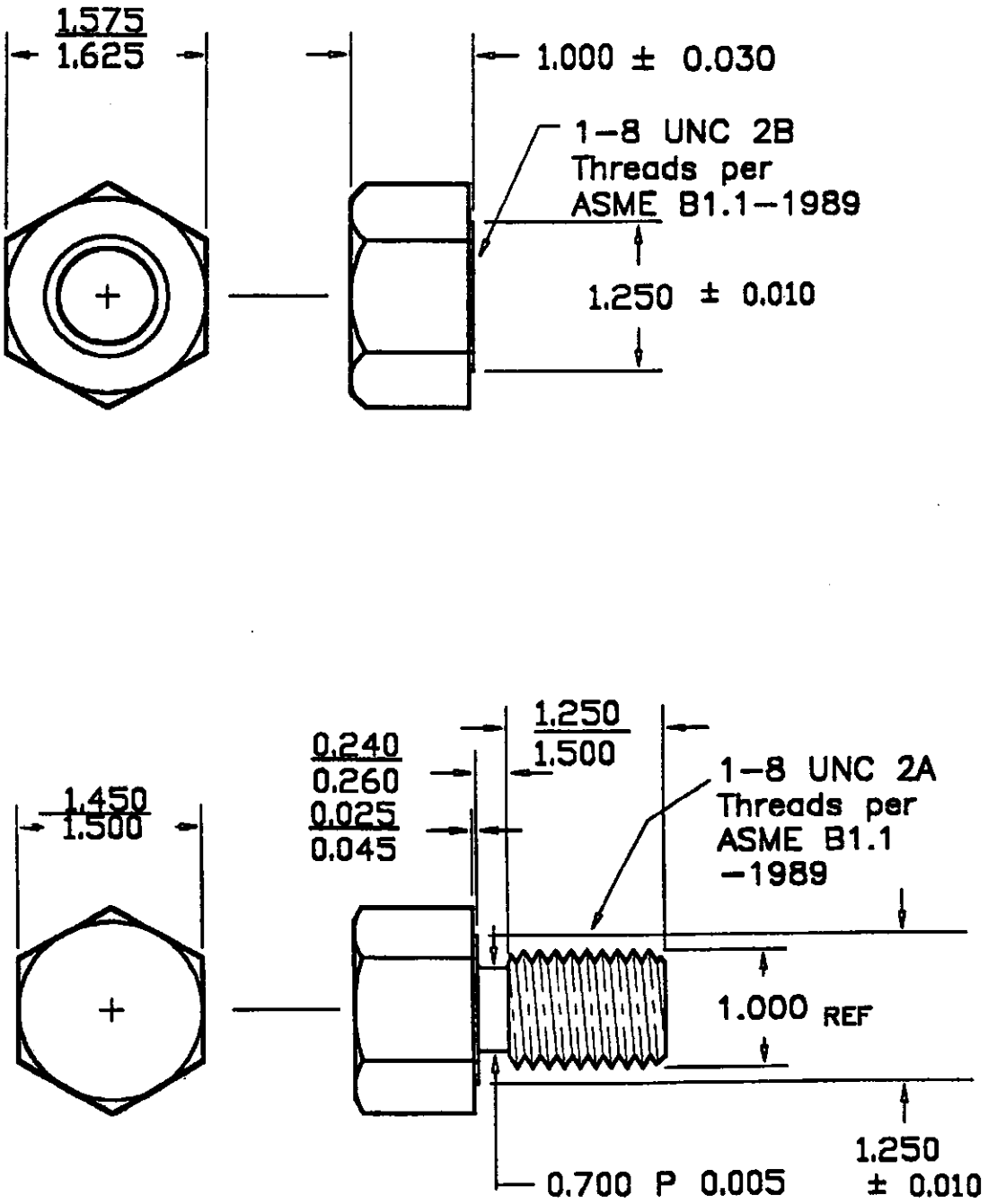

FIGURE 2
TEST SPECIMEN
(ALL DIMENSIONS IN INCHES)

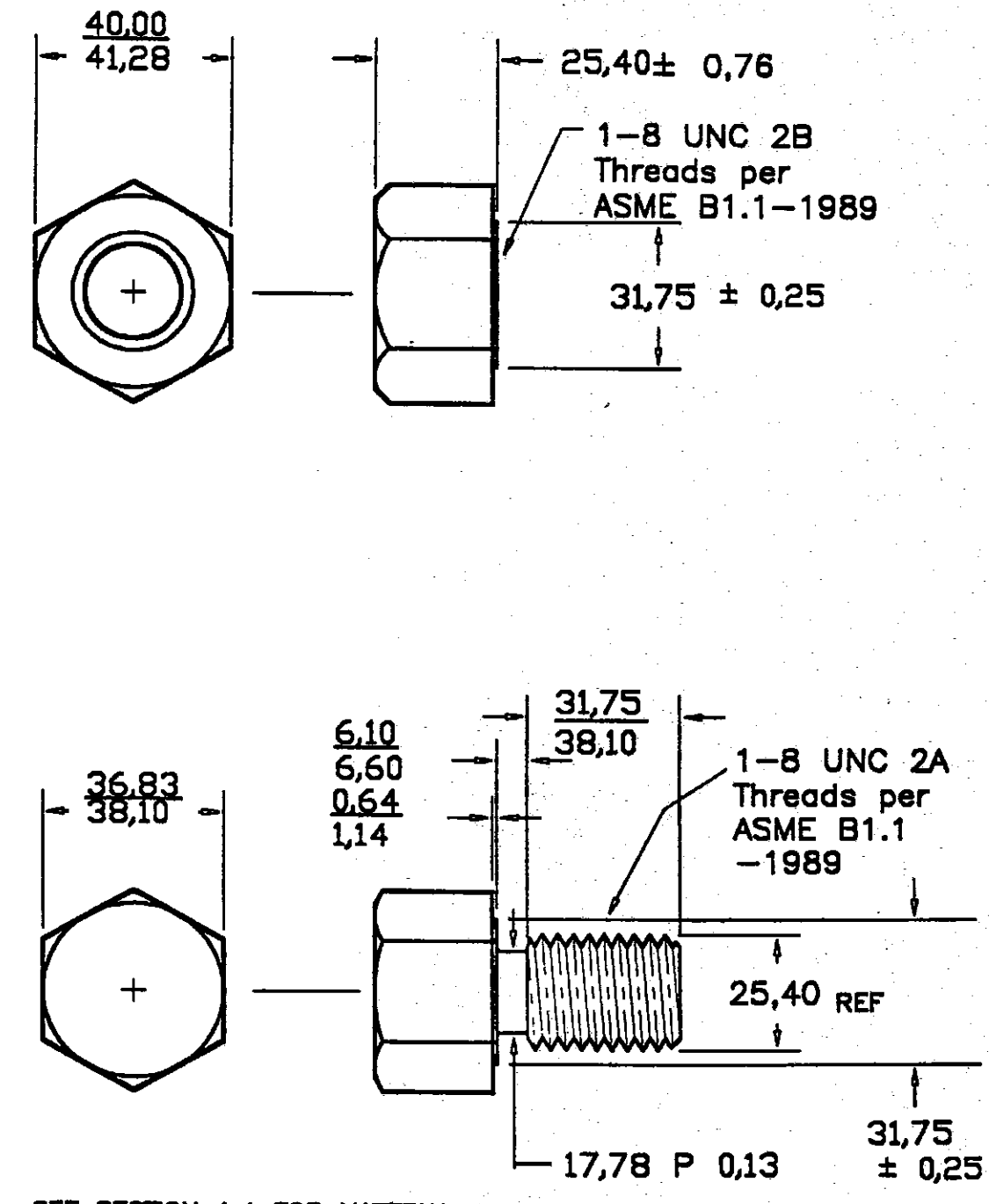

FIGURE 2M
TEST SPECIMEN
(ALL DIMENSIONS IN MM)

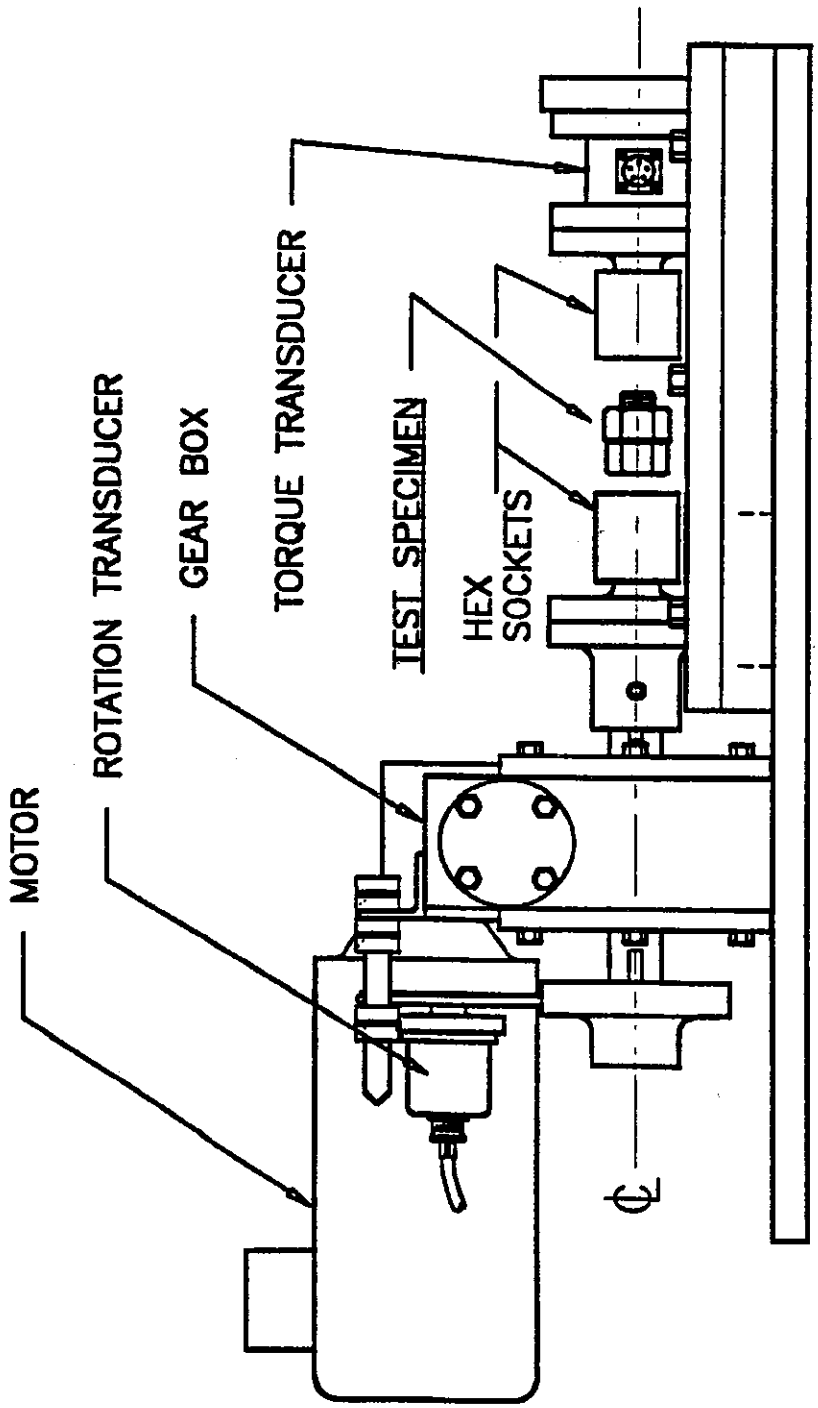

FIGURE 3
TEST APPARATUS

SECTION 2
THREAD COMPOUND TEST PROCEDURE

2.1 New Specimen Break-in. Each newly manufactured specimen shall be subjected to 20 make and break cycles using the reference compound before actual tests are performed. The specimen shall then be cleaned using the recommended procedure.

2.2 Specimen Cleaning. The specimen shall be cleaned with any appropriate solvent, wire brushed to remove any plated soft metal, and degreased. The specimen shall then be dried before applying the next test compound.

CAUTION: Solvents and degreasers may contain hazardous materials. Material Safety Data Sheets should be read and the precautions observed when handling products of this type.

2.3 Sample Submission and Storage. The sample of the compound to be tested shall be submitted in a clean, leak proof container that can be sealed to prevent evaporation of any volatile materials or the possible contamination of the compound. The sample volume should be at least eight fluid ounces (≈250 cc). The sample should not be stored in temperatures outside the range of 60-100°F (15-32°C). If the sample is submitted in a container larger than 1 gallon (≈4 liters), a convenient portion for storage and testing may be transferred to a smaller container that meets the above requirements. It is extremely important that before the transfer of the sample to an alternate container, or prior to the actual test procedure, that the sample is stirred to insure homogeneity. Care should be taken when stirring the sample that material is not scraped or abraded from the container itself that could contaminate the sample and affect test results.

2.4 Torque Test. All mating surfaces of the test specimen shall be coated with a liberal layer of the thread compound. The specimen shall then be made-up hand-tight and placed in the testing machine. The initial or hand-tight torque shall not exceed 10 ft-lb (≈14 N-m). The torque and the rotation shall then be recorded as the torque is increased to 310 ± 10 ft-lb (420 ± 14 N-m). After these data are recorded, the specimen shall be loosened by applying a torque in the opposite direction. The specimen shall then be removed from the testing machine. The two parts of the specimen shall be unscrewed sufficiently to expose all but two or three threads, and more thread compound shall be reapplied to the mating surfaces. The specimen shall then be made-up hand-tight and replaced in the test machine. The next set of data shall then be taken. This procedure shall be repeated a minimum of eight to a maximum of ten cycles. A minimum of eight cycles shall constitute one run and be used for the calculations in Section 2.6. If more than eight cycles are performed, the operator may select to neglect any of the extra cycles.

2.5 Test Specimen Inspection. After a run has been completed, the specimen shall be cleaned as described in Section 2.2. If there are any signs of galling of the mating surfaces, the compound is rejected and the test is complete. The diameter of the cylindrical section of the specimen shall be determined to within 0.001 inch (0.025 mm) and recorded before and after each compound test so that yielding of the specimen will be detected. This measurement should be taken each time the specimen is cleaned. If the diameter change exceeds 0.005 inch (0.127 mm), the test is invalid.

2.6 Data Reduction. For each individual torque versus rotation test on any compound, the result of that test is the slope m of the least-squares fit of a straight line to the torque versus rotation data over the range of torque from 200 to 300 ft-lb (270 to 408 N-m). At least twenty pairs of data points shall be used for this analysis.

$$m = \frac{n \bullet \Sigma(T \bullet A) - \Sigma T \bullet \Sigma A}{n \bullet \Sigma(A^2) - (\Sigma A)^2} \quad (1)$$

where

A = Measured Angle Data Point

T = Measured Torque Data Point

n = number of data pairs

• = multiplication sign

These resulting slopes (m) will be statistically analyzed to determine the average of the eight runs (S) and the standard deviation. In the following, N=8:

$$S = \frac{\Sigma m}{N} \quad (2)$$

$$\text{VARIANCE} = \frac{N \bullet \Sigma(m^2) - (\Sigma m)^2}{N \bullet (N-1)} \quad (3)$$

$$\text{STANDARD DEVIATION} = \sqrt{\text{VARIANCE}} \quad (4)$$

If one standard deviation is greater than 6% of the average, the test is not valid.

2.7 The Friction Factor. The friction factor for the thread compound is:

$$FF = \frac{2 \bullet S_2}{S_1 + S_3} \quad (5)$$

where

S_1 = average slope for 1st reference compound runs

S_2 = average slope for thread compound runs

S_3 = average slope for 2nd reference compound runs

SECTION 3
APPLICATION OF FRICTION FACTOR

Recommended make-up torque for rotary shouldered connections were calculated using a coefficient of friction of 0.08 and are tabulated in API RP 7G. A thread compound with a friction factor other than 1.00 does not have a coefficient of friction of 0.08 and uncorrected tabulated torque values can result in improperly made-up connections.

The thread compound friction factor is used to correct the make-up torque for drill stem elements.

Thread compound performance is based on this test procedure and not a specific friction factor. Drilling conditions exist where a friction factor of greater or less than 1.00 is beneficial.

The make-up torque can be corrected by multiplying the make-up torque value found in RP 7G by the friction factor of the compound.

Example:

Drill pipe assembly — 5", 19.50, G-105 premium with 5½ x 3¼ NC50 tool joints

Make-up Torque from Table 2.12 of API RP 7G — 21,914 ft-lbs

Thread compound Friction Factor — 0.92

Corrected make-up torque

21,914 x 0.92 = 20,161 ft-lbs

SECTION 4
TEST CERTIFICATION AND MARKING

4.1 Test Certification. Thread compound manufacturers wishing to comply with this recommended practice shall display the frictional performance data of their compound according to the guidelines in Section 4.2. The thread compound manufacturer shall provide, upon request, certified copies of the test results that were obtained using the methods and equipment described in this practice. The results shall include the manufacturer's name, product name, date of testing, and the name of the testing laboratory.

4.2 Marking. Thread compounds which have been tested in accordance with this recommended practice (API RP 7A1) may be so labeled. The label shall contain a reference to "API RP 7A1" and "FRICTION FACTOR = X.XX" or "FF (7A1) = X.XX". There shall be no more or less than three digits with two digits to the right of the decimal point.

NOTE: *Drilling conditions exist where a friction factor other than 1.00 is acceptable and/or desirable, therefore product conformance is based on the test methods described in this recommended practice and not on a specific value of the friction factor.*

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