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SURFACE VEHICLE RECOMMENDED PRACTICE

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GLOSSARY OF TERMS—LUBRICATED FRICTION SYSTEMS

1. ***Scope***—This SAE Recommended Practice defines the principal terms and equations pertaining to automotive automatic transmission clutch plate, band, or other wet-friction systems. The terms apply directly to friction-system testing as is typically conducted on inertia-stop test equipment. Some terms can be directly applied to the analysis of friction in the transmission or brake assembly and other friction-test equipment.

The glossary presents terms used to describe the set-up, testing, and results of tests as shown in Figure 1, which were taken on a clutch SAE No. 2 machine.

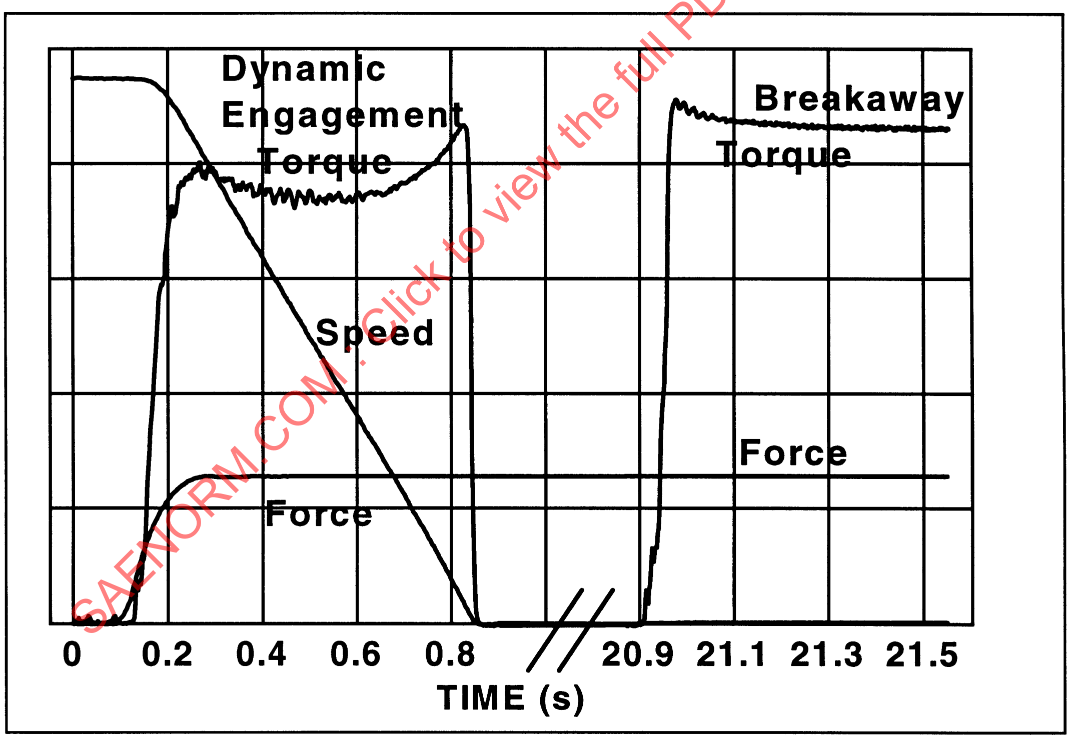

FIGURE 1—SAMPLE TESTS

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The glossary is intended to provide a collection of definitions in the hope of eliminating confusion in terminology and a common set of terms for improving the state-of-the-art of friction-system development and their application to passenger cars and trucks.

This document focuses on the terminology of friction-system testing. References for this type of testing are shown in Section 2.

2. References

2.1 Related Publications—The following publications form a part of this specification to the extent specified herein. The latest issue 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 J1499—Band Friction Test Machine (SAE) Guidelines
SAE Paper 670051—Putting Automatic Transmission Clutch Friction Researchers on Speaking Terms

2.1.2 FORD MOTOR COMPANY PUBLICATION—Available from Ford Motor Company, Components Engineering Department, 36200 Plymouth Road, Box 14, Livonia, MI 48150-1442.

Ford MERCON® Specification

2.1.3 GENERAL MOTORS PUBLICATION—Available from General Motors Corporation, Powertrain Division, M/C 965, Ecorse and Wiard Roads, Ypsilanti, MI 48198-6918.

GM DEXRON®-III Specification, GM6297M

3. Definitions—See Table 1.

4. Friction System

4.1 Friction Elements

4.1.1 FRICTION SURFACES, n_f —Number of surfaces wherein a friction material and a reaction surface are in contact.

4.1.2 GROSS AREA, A_g —Total area of friction material per friction surface. This area <u>includes</u> material not in contact because of grooves, holes, slots, etc.

4.1.3 NET AREA, A_n —This area <u>does not include</u> material not in contact because of grooves, holes, slots, etc. See Equation 1:

$$A_n = A_g - (\text{Noncontacting Area}) \quad \text{(Eq. 1)}$$

TABLE 1—SYMBOLOGY AND INDEX

Notation	Name	Section
A_g	Gross area	3.1.2
A_n	Net area	3.1.3
A_p	Apply piston area	4.1.1
C_p	Clutch pack clearance	3.3.1
E	Energy	5.2.1
F_A	Apply force	4.1.3
H	Average power	5.3.1
I_e	Effective Inertia	5.1
N	Breakaway drive speed	8.4.1
P_p	Apply pressure`	4.1.2
Q	Flow rate	7.1.4
T	Period of time	6.2
V	Fill volume	7.2
c_i	Interface clearance	3.3.2
e_g	Gross energy flux	5.2.2
e_n	Net energy flux	5.2.3
h_g	Gross power flux	5.3.2
h_n	Net power flux	5.3.3
n_f	Friction surfaces	3.1.1
n_r	Reaction surfaces	3.2.2
p_g	Gross unit pressure	4.2.1
p_n	Net unit pressure	4.2.2
q	Specific flow rate	7.1.5
E/M	Endpoint-to-midpoint ratio	8.4.1
Δt	Time interval	5.1
$\Delta\omega$	Speed change	5.1
δ	Reaction plate thickness	3.2.1
μ	Friction coefficient	8.2
Ψ	Torque time	6.3.4
τ	Torque	6.4

TABLE 1—SYMBOLOGY AND INDEX

Notation	Name	Section
ϕ	Stop time	6.3.3
θ	Angle of wrap	8.2

4.1.4 EFFECTIVE RADIUS, r_e —The radius of annular clutch-friction material at which the sum of the frictional forces effectively act. See Equation 2:

$$r_e = \frac{2\left(r_0^3 - r_i^3\right)}{3\left(r_0^2 - r_i^2\right)} \qquad \text{(Eq. 2)}$$

4.2 Reaction Elements

4.2.1 REACTION PLATE THICKNESS, δ_r —Thickness of reaction plate or the frictional material core plate if single-sided plates.

4.2.2 REACTION SURFACES, n_r —Number of working reaction surfaces which contribute to the torque output.

4.3 Installation Setup

4.3.1 CLUTCH PACK CLEARANCE, C_p —Axial clearance in the clutch pack when the apply force is released.

4.3.2 INTERFACE CLEARANCE, c_i —Average axial distance between reacting surfaces when the apply force is released. See Equation 3:

$$c_i = c_p / n_f \qquad \text{(Eq. 3)}$$

5. Apply System

5.1 Apply Force

5.1.1 APPLY PISTON AREA, A_p —Effective area of the piston on which the pressure acts to generate the apply force.

5.1.2 APPLY PRESSURE, P_p —Pressure acting on the apply piston area to generate the apply force.

5.1.3 APPLY FORCE, F_A —Measured directly or calculated. See Equation 4:

$$F_A = A_p P_p \qquad \text{(Eq. 4)}$$

5.1.4 FORCE APPLIED—This indicates that force is applied to engage the friction elements.

5.1.5 FORCE RELEASED—The apply force on the friction elements has been removed.

5.2 Friction Material Pressures

5.2.1 GROSS UNIT PRESSURE, p_g—Apply force divided by the gross area. See Equation 5:

$$p_g = \frac{F_A}{A_g} \qquad \text{(Eq. 5)}$$

5.2.2 NET UNIT PRESSURE, p_n —Apply force divided by the contact area. See Equation 6:

$$p_n = \frac{F_A}{A_n} \quad \text{(Eq. 6)}$$

6. *Energy System*

6.1 Effective Inertia, I_e—Rotating inertia which the friction elements work against. See Equation 7:

$$I_e = \frac{\tau_{dAvg}\Delta t}{\Delta\omega} \quad \text{(Eq. 7)}$$

where:

τ_{dAvg} = Average torque over the time period Δt

6.2 Energy

6.2.1 ENERGY, E —Work done by the friction element during a dynamic engagement. See Equation 8:

$$E = \frac{1}{2}I_e\omega^2 \quad \text{(Eq. 8)}$$

6.2.2 GROSS ENERGY FLUX, e_g —Energy divided by the total gross area. See Equation 9:

$$e_g = \frac{E}{n_f A_g} \quad \text{(Eq. 9)}$$

6.2.3 NET ENERGY FLUX, e_n —Energy divided by the total contact area. See Equation 10:

$$e_n = \frac{E}{n_f A_n} \quad \text{(Eq. 10)}$$

6.3 Power

6.3.1 AVERAGE POWER, H—Average power during the engagement. See Equation 11:

$$H = \frac{E}{\phi} \quad \text{(Eq. 11)}$$

6.3.2 GROSS POWER FLUX, h_g—Average power divided by the total gross area. See Equation 12:

$$h_g = \frac{H}{n_f A_g} \quad \text{(Eq. 12)}$$

6.3.3 NET POWER FLUX, h_n —Average power divided by the total contact area. See Equation 13:

$$h_n = \frac{H}{n_f A_n} \quad \text{(Eq. 13)}$$

7. *System Measurements/Controls*

7.1 Modes of Operation—Typical modes of operation are: dynamic engagement, breakaway, continuous-slip, and drag.

7.1.1 DYNAMIC ENGAGEMENT—A test of the friction system by the application of a specified apply force schedule from a specific engagement speed (see Figures 2, 3, and 4).

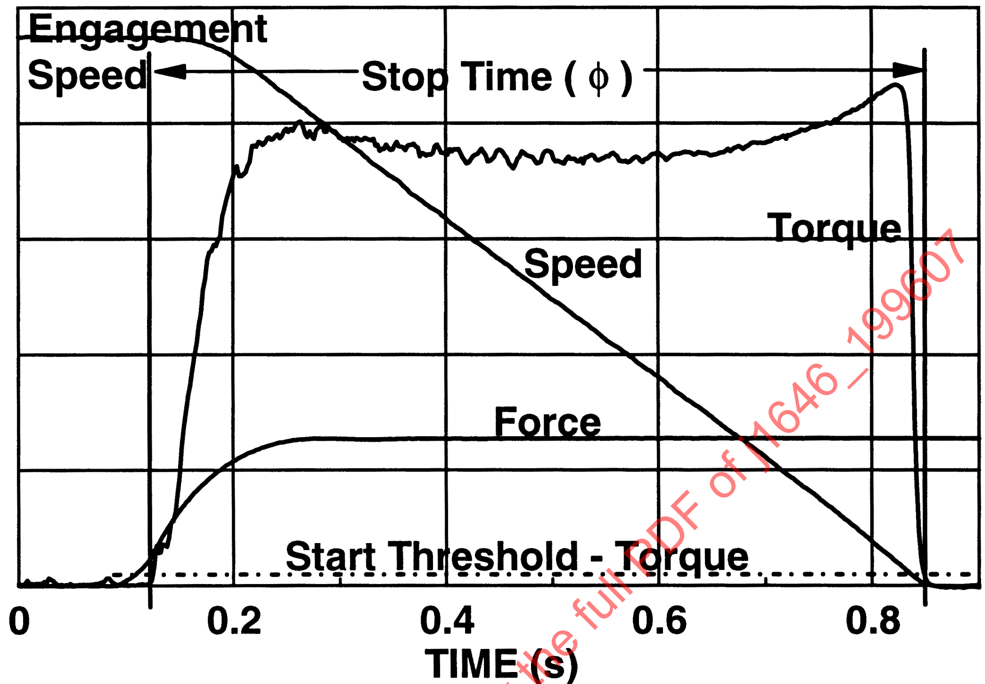


FIGURE 2—DYNAMIC ENGAGEMENT

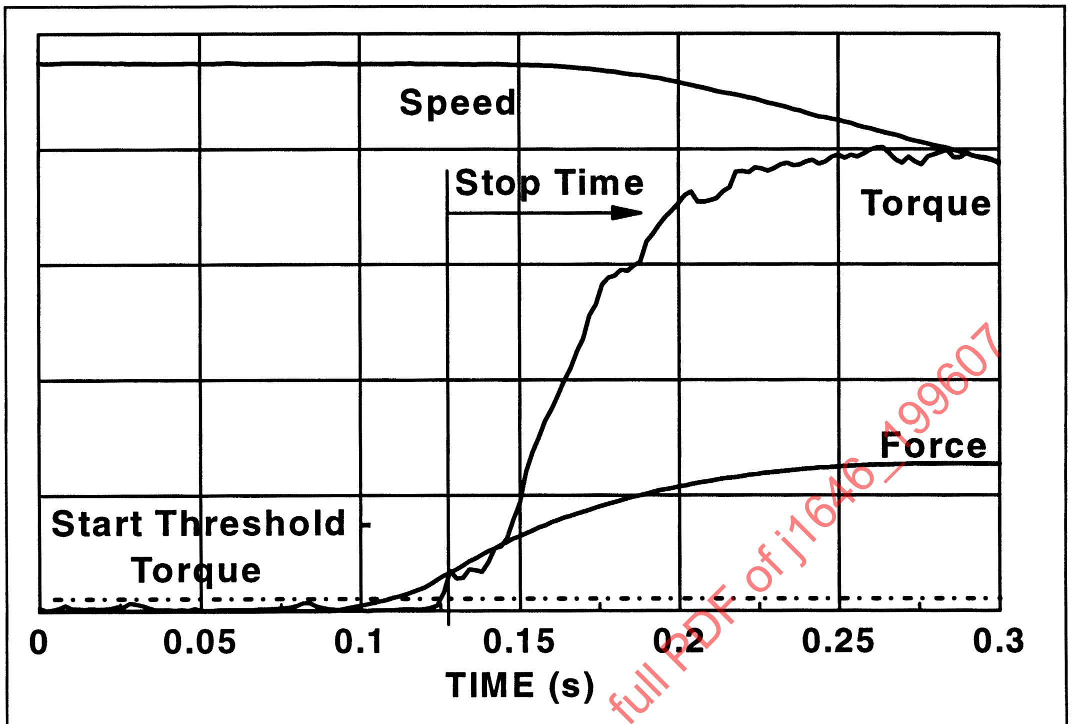


FIGURE 3—START OF ENGAGEMENT

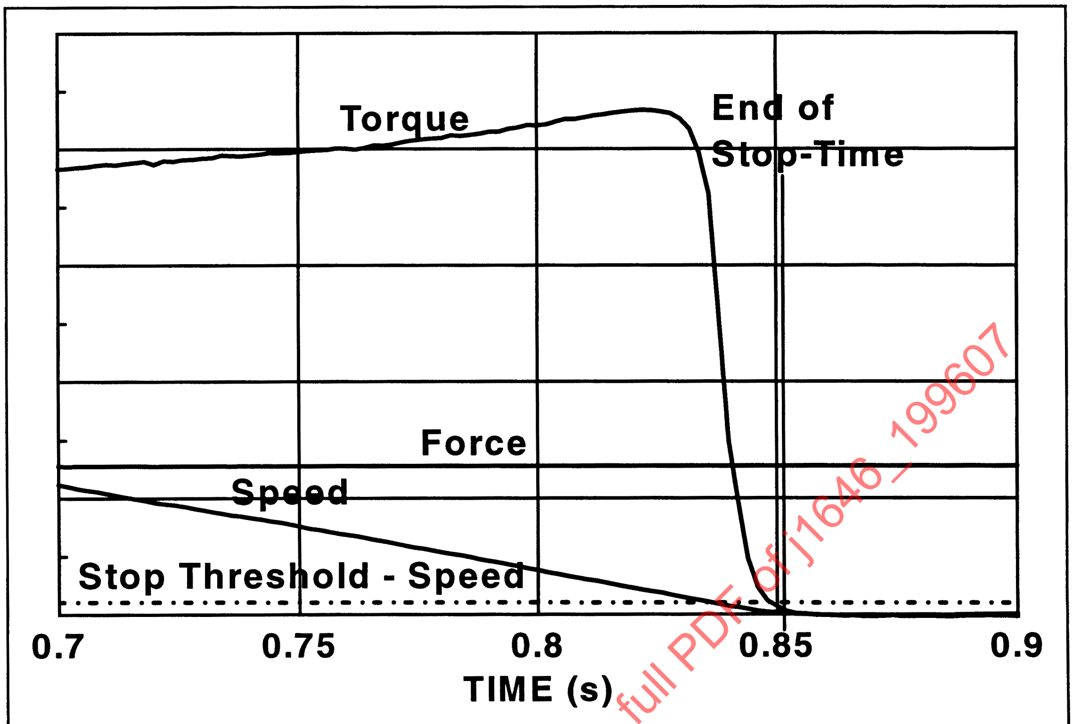


FIGURE 4—END OF ENGAGEMENT

7.1.2 BREAKAWAY—A test of the friction system when the drive motor is off and the breakaway device accelerates the applied friction elements from zero to a specified rotational speed. This test is typically conducted at a specified time following a dynamic engagement (see Figure 5).

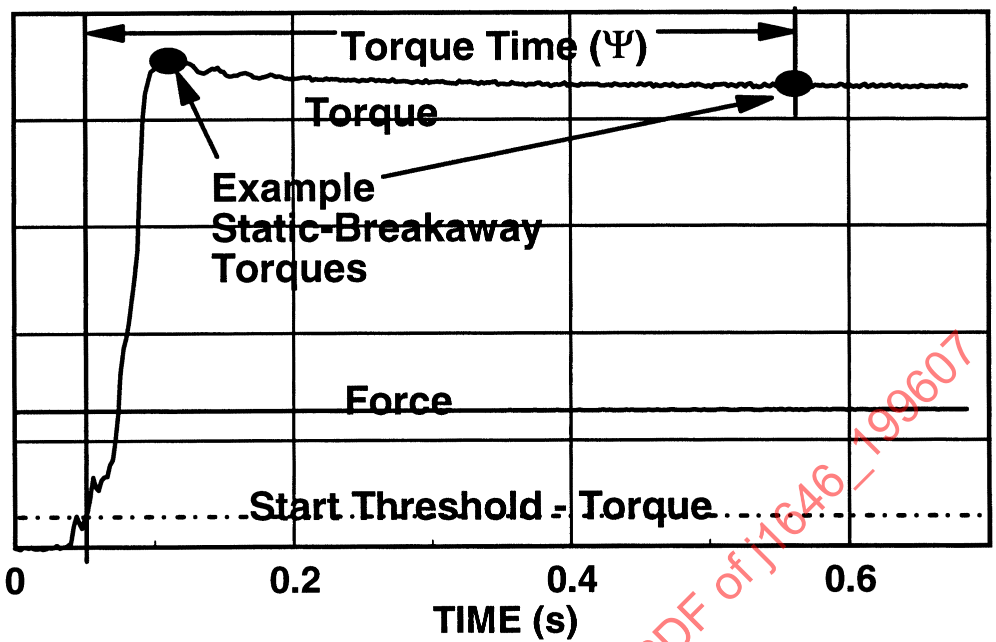


FIGURE 5—BREAKAWAY

7.1.3 CONTINUOUS-SLIP—A test wherein the drive motor maintains a specified rotational speed with the friction elements applied.

7.1.4 DRAG—A test wherein the drive motor maintains a specified rotational speed with the apply force off.

7.2 Cycle—A series of events repeated during friction-system testing. Periods in a cycle may include a fluid temperature stabilization period, a coast period to the desired engagement speed, apply period, and cooling period. When breakaway friction measurements are made, a cycle may include dwell, soak, and breakaway periods (see Figures 1 and 6).

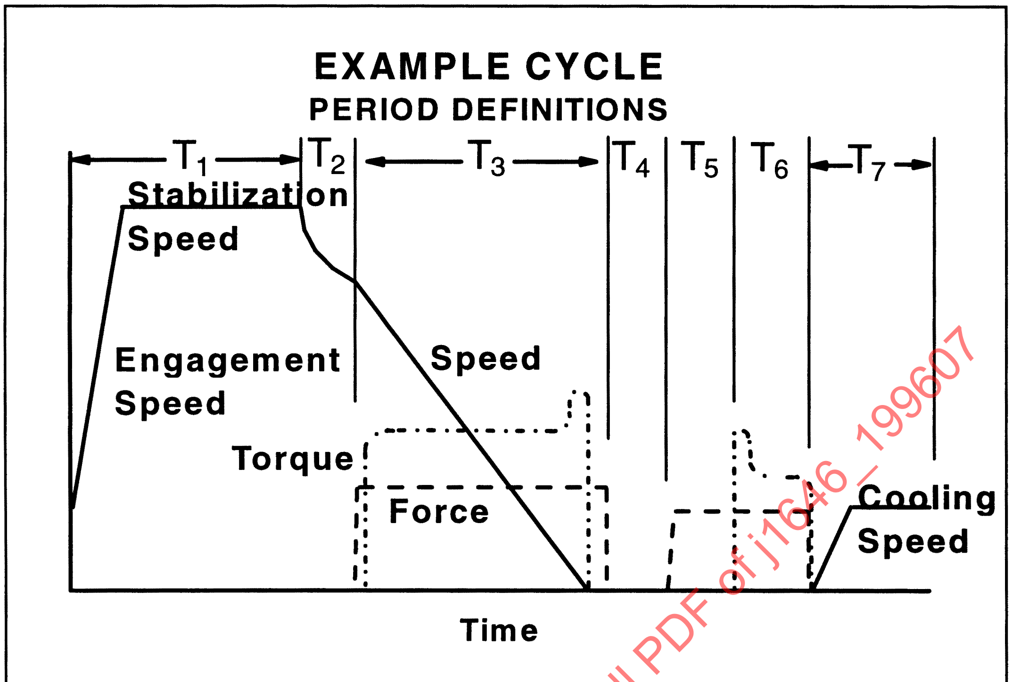


FIGURE 6—EXAMPLE CYCLE

7.2.1 STABILIZATION PERIOD, T_1—Period of time following the cooling period when the clutch is released and rotating at the stabilization speed. The stabilization period is completed when all conditions of speed and temperature have reached equilibrium or steady-state conditions (there are no transients present). The stabilization speed must be greater than or equal to the engagement speed (see Figure 6).

7.2.2 COAST PERIOD, T_2—Period of time when the drive motor is off and the apply force is released and, because of drag, the rotational speed coasts down to the desired engagement speed (see Figure 6).

7.2.3 APPLY PERIOD, T_3—Period of time, which includes the dynamic engagement mode, when the drive motor is coasting and force is applied (see Figures 2 and 6).

7.2.4 DWELL PERIOD, T_4—Period of time when the friction elements are at zero speed and the apply force is released (see Figure 6).

7.2.5 SOAK PERIOD, T_5—Period of time when the friction elements are at zero speed and the force is applied (see Figure 6).

7.2.6 BREAKAWAY PERIOD, T_6—Period of time when the drive motor is not rotating and the applied friction elements are accelerated by the breakaway drive to a specified rotational speed (see Figures 5 and 6).

7.2.7 COOLING PERIOD, T_7—Period of time when the apply force is zero and the friction elements are rotating at some pre-set speed. This cooling speed may be the stabilization speed (see Figure 6).

7.3 Time, t—Time as measured from the start threshold of a mode within a given period (see Figures 2, 3, and 5).

7.3.1 START THRESHOLD—A predetermined level of either apply pressure, force, speed, or torque which is used to establish zero-time in a mode (see Figures 3 and 5).

7.3.2 STOP THRESHOLD—A predetermined level of either speed or torque which is used to establish the end of a mode (see Figure 4).

7.3.3 STOP TIME, Φ—Time interval between start and stop threshold during a dynamic engagement (see Figure 2).

7.3.4 TORQUE TIME, Ψ—Time interval from the start threshold to the point of measurement during a breakaway test (see Figure 5).

7.4 Torque, τ

7.4.1 FRICTION TORQUE—Torque generated by the application of the friction system (see Figures 3 and 6).

7.4.2 DRAG TORQUE—Torque generated when the friction elements are rotated and there is no apply force on the elements.

7.5 Speed, ω

7.5.1 ROTATIONAL SPEED—Relative rotational speed of friction elements with respect to the reaction elements.

7.5.2 ENGAGEMENT SPEED—The relative rotational speed of the friction elements at the start of the engagement (see Figure 2).

8. Lubrication System

8.1 Flow Configurations

8.1.1 GRAVITY FLOW—This represents the configuration wherein the head top fitting is connected to the bottom of a vented reservoir located above the head (see Figure 7a).

8.1.2 CENTRIFUGAL FLOW—This represents the configuration wherein discharge from the head is connected to a vented reservoir located above the head and a return line is provided from the bottom of the reservoir to the centerline of the cover. A flow meter may be installed in the line to the cover (see Figure 7b).

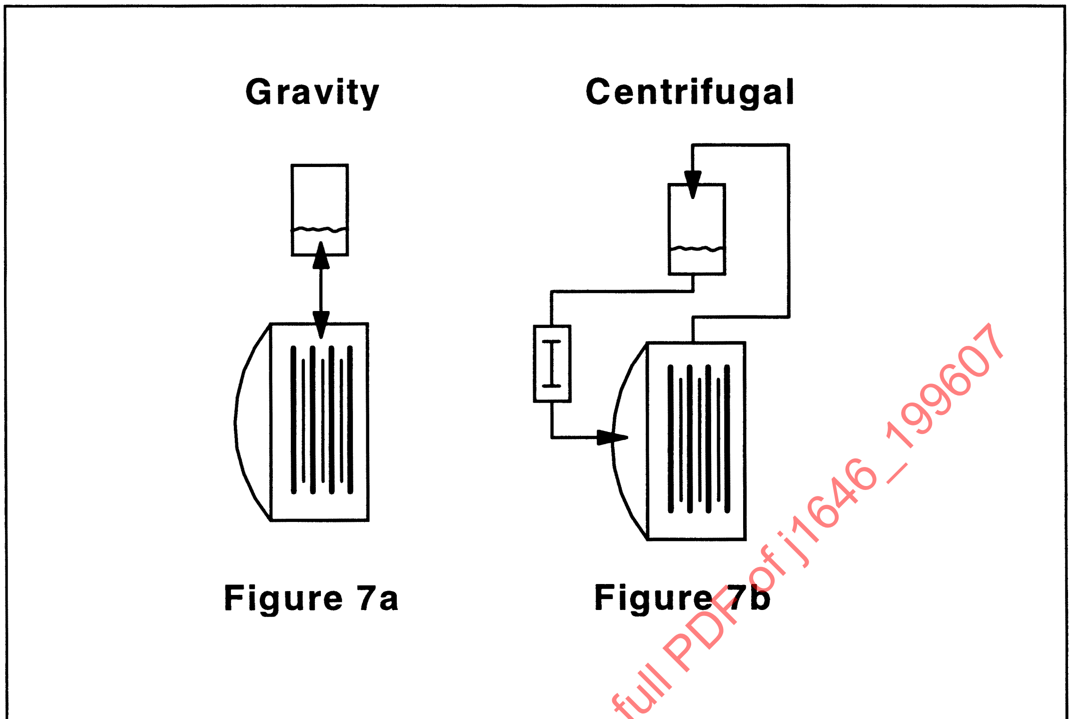
8.1.3 EXTERNAL FLOW—This represents the configuration wherein an external pump supplies fluid at a specific flow rate through a line to the centerline of the cover. A flow meter may be installed in the line to the cover (see Figure 7c).

8.1.4 FLOW RATE, Q—Fluid flow rate to the test head at a specific time in the cycle.

8.1.5 SPECIFIC FLOW RATE, q—Flow rate per unit area of friction material, computed as shown in Equation 14:

$$q = \frac{Q}{n_f A_g} \qquad \text{(Eq. 14)}$$

8.2 Fill Volume, V—The volume of fluid used in the test.



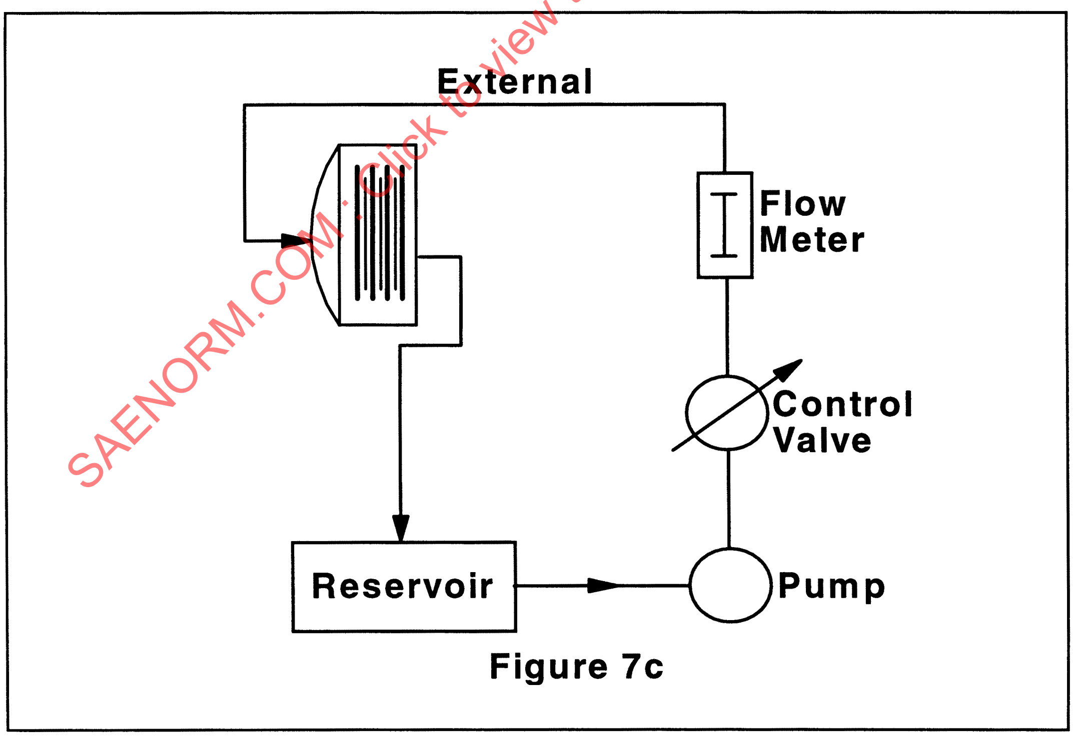


FIGURE 7—FLOW CONFIGURATIONS

8.3 Fill Level—Fill level is measured by a sight gage when the test fluid is at room temperature, the test fixture is fully assembled, all rotating components are stationary, and the apply force is off.

8.4 Fluid Control Temperature—The fluid temperature that is measured at a specific location in the test head at a specific time in the cycle.

9. Analysis

9.1 Conventions—These conventions are to be used when reporting results in order to define the specifics of the measurements. Test conditions such as engagement speed, apply pressure, inertia, breakaway motor speed, and control temperature are to be specified in the test procedure. The conventions do not define the test conditions, but specify the time and speed during the cycle when the data is reported.

9.2 Friction Coefficient, μ—The Greek letter, μ, is used to represent the coefficient of friction.

a. For plate testing (see SAE J286) use Equation 15:

$$\mu = \frac{\tau}{r_e F_A n_f} \qquad \text{(Eq. 15)}$$

b. For band testing (see SAE J1499) use Equation 16:

$$\mu = \frac{1}{\theta}\ln\left[\frac{\tau + P_p A_p r_d}{P_p A_p r_d}\right] \text{ Energized} \qquad \text{(Eq. 16)}$$

$$\mu = \frac{1}{\theta}\ln\left[\frac{P_p A_p r_d}{P_p A_p r_d - \tau}\right] \text{ De-energized}$$

where:

r_d= Radius of the drum

θ= Angle of the wrap

To indicate a dynamic engagement coefficient, use the subscript 'd' immediately after the μ symbol. The subscript 's' is used for breakaway and continuous-slip measurements.

Subscripts before the μ symbol indicate the time basis of measurement (units of seconds are assumed). For example: $2^{\mu}d$ would describe the dynamic coefficient of friction 2 s into an engagement.

Subscripts following the μ symbol indicate the speed basis of measurement (units of r/min are assumed). Therefore, μ_{d100} would indicate a measurement of the dynamic coefficient at 100 r/min during an engagement.

For continuous-slip measurements $2h^{\mu}d200$ would indicate data taken after 2 h of slip at 200 r/min.

This continuous-slip example indicates that the convention is meant to be flexible. The time and speed units need not be seconds or r/min. If other units are used, the units must be explicitly stated. The goal is to have the manner in which the coefficient was obtained clearly specified in the notation.

The symbol $50\%^{\mu}d$, for example, represents the dynamic coefficient measured at the midpoint of the stop time. Note that the speed subscript is not required since the percent of stop-time is sufficient to specify how the data was obtained.

Additional subscripts are given as follows:

a. Max—Maximum
b. Avg—Average

9.2.1 EXAMPLES—Examples of proper and improper use follow.

a. Improper

μ_s—Conditions of measurement not specified

$\mu_s 0.72$—Speed of 0.72 r/min specified but time not indicated

μ_d—Conditions of measurement not specified

b. Proper

$0\text{-}25\%^{\mu}d\text{Max}$—Maximum dynamic coefficient in first quarter of stop time

or

$\leq 25\%^{\mu}d\text{Max}$

$0\text{-}100\%^{\mu}d\text{Avg}$—Average dynamic coefficient over the entire stop time

$50\%^{\mu}d$—Dynamic coefficient at half of stop time

$^{\mu}d1800$—Dynamic coefficient at 1800 r/min

$75\text{-}100\%^{\mu}d\text{Max}$—Maximum dynamic coefficient in last quarter of stop time

or

$\geq 75\%^{\mu}d\text{Max}$

$\leq 0.2^{\mu}s\text{Max}5$—Maximum breakaway coefficient at 5 r/min in first two tenths of a second

$2^{\mu}s4.37$—Breakaway coefficient at 2 s at 4.37 r/min

$3m^{\mu}s60$—Continuous-slip coefficient at 3 min at 60 r/min

Subscripts may also be used for torque or force.

9.3 Reference Coefficients—These terms are typically used when describing friction traces. They must be fully specified, as in the examples shown in 9.2.1, to be meaningful.

In the case of a dynamic engagement there are four common reference coefficients: the initial, midpoint, endpoint, and average. These four reference coefficients are defined in 9.3.1 through 9.3.4.

Use of the time and speed subscripts is necessary and sufficient to indicate where in the dynamic engagement the coefficient is being determined; however, terminology is provided to standardize on these four coefficients.

For the breakaway test there are also numerous terms used to describe the associated measurements; however, in this case no attempt is made to provide more specificity than the torque time of the measurement and the final steady-state rotational speed for the friction assembly.

9.3.1 INITIAL COEFFICIENT—Friction coefficient measured at the start of a dynamic engagement mode (see Figure 8b). For example:

$$<20\%^{\mu}dMax$$

9.3.2 MIDPOINT COEFFICIENT—Friction coefficient measured at the midpoint of a dynamic engagement mode (see Figure 8b). For example:

$$50\%^{\mu}d$$

or

$$^{\mu}d50\%$$

9.3.3 ENDPOINT DYNAMIC COEFFICIENT—Coefficient measured at the end of a dynamic engagement mode (see Figures 8a and 8b). For example:

$$\geq 90\%^{\mu}dMax$$

or

$$(\phi - 0.05)^{\mu}dMax$$

9.3.4 AVERAGE DYNAMIC COEFFICIENT, μ_Φ—Average friction coefficient during an engagement. See Equation 17:

$$\mu_\phi = \frac{I_e \omega}{r_e F_{AAvg} \phi n_f} \quad \text{(Eq. 17)}$$

where:

ω= Engagement speed

F_{AAvg}= Average apply force over the stop-time, ϕ