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SURFACE VEHICLE STANDARD

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Disc Brake Dynamometer Squeal Noise Matrix

Foreword—A dynamometer test procedure known as AK Noise has been developed by a European working group that includes car manufacturers, braking system suppliers and friction material companies. This procedure follows the lines of the drag mode test procedures with an extension to include deceleration braking. In the US, a common approach is to use deceleration mode procedures emphasizing the replication of vehicle road test.

As we see a strong need for a global standardization of squeal noise dynamometer tests, a global squeal matrix has been developed that combines drag mode and deceleration mode tests. This procedure was presented to the SAE working group in February 1999.

Based on the AK drag, deceleration, and friction characterization modules, the matrix contains 25 sections and 1917 brake applications. This procedure owes much to the previous development of the AK procedures. This prior work is gratefully acknowledged.

1. Scope—This procedure is applicable to high frequency squeal type noise occurrences for passenger car and light truck type vehicles that are used under conventional operating conditions. The procedure does not encompass the consequences associated with changes in environment related to temperature and humidity variations.

1.1 Purpose—This recommended test practice is intended to establish a common universally recognized method for performing a series of screening test sequences that identify the propensity of a brake assembly to generate squeal noise under a variety of test conditions.

2. References—There are no referenced publications specified herein.

3. Definitions

3.1 Occurrence (absolute)—The percentage of the total brake applications where the peak sound level exceeded the threshold of 70 dB(A) or any other value that may be defined. It is calculated by dividing the number of brake applications with a sound level above the threshold by the total number of brake applications in the test.

3.2 Relative occurrence—The number of the stops in a particular test section where the peak sound level exceeded the threshold of 70 dB(A) divided by all of the brake applications where the sound level exceeded the threshold – expressed as a percentage.

4. Description—This matrix describes the test conditions and steps to investigate the influence of pressure, temperature and velocity on the squeal noise behaviour of disc brakes. This matrix is intended to replicate vehicle tests to get a fair comparison for different brake corner components.

5. Test Apparatus Definition

5.1 Operational Requirements

a. 60 kW (80.5 hp) or more driving power, as determined by the torque requirements of the brake under test
b. Speed range up to 100 km/h (62 mph)
c. Inertia may be actual flywheels, simulated, or a combination of the two
d. Reversal of rotation direction
e. Steady-state motor capability of at least 1500 Nm (1106 ft-lb)
f. Brake pressure ramp rate of 250 bar/s ± 50 bar/s (3625 ±725 lb/in^2-s)
g. Maximum of 160 bar (2320 lb/in^2) peak braking pressure

5.2 Environment Requirements

a. Humidity control is optional.
b. Air conditioning is recommended for ambient temperature control.
c. Cooling air shall be provided on the brake. Note that the airflow shall be controlled such that it will not be so high as to blow away wear debis or create noise above the background limit of 60 dB (A).
d. Allowable cooling air temperature range from –10 to 40 °C (14 to 104 °F).
e. Humidity range from 20% to 90% and is recorded.

5.3 Inertia

a. In the absence of a specification of the inertia to be used the follwing computation should be followed.
b. For a brake for a front application, the inertia is computed to be equivalent to 75% of one-half of the gross vehicle weight.
c. For a rear application, the inertia is computed to be equivalent to 25% of one-half of the gross vehicle weight.

5.4 Fixturing

a. The preferred method of mounting the brake is to use the entire suspension and axle. However it is recognized that it may not always be possible to use the entire suspension corner. In such cases, an undisturbed knuckle should be used.
b. It is recommended that the brake be mounted in the test apparatus using the actual vehicle suspension and axle components. The suspension components should be as complete as possible to the connection points with the vehicle structure. All bushings, including those at the structural connection points, should be utilized in the fixturing. The suspension corner assembly should be loaded to the normal operational conditions of the vehicle corner to insure proper alignments and compliance.
c. If it is not possible to utilize the full suspension corner, care should be taken to match as closely as possible the actual mounting and operating configurations. In such cases, there may be differences in the measured noise below 2000 Hz, when compared to on-vehicle performance.
d. The fixturing utilized must be reported

6. Measurements

6.1 Noise Transducer Location (see Figure 1):

a. 10 cm outboard from wheel hub face along the centerline of the axle.
b. 50 cm above and perpendicular to the centerline of the axle

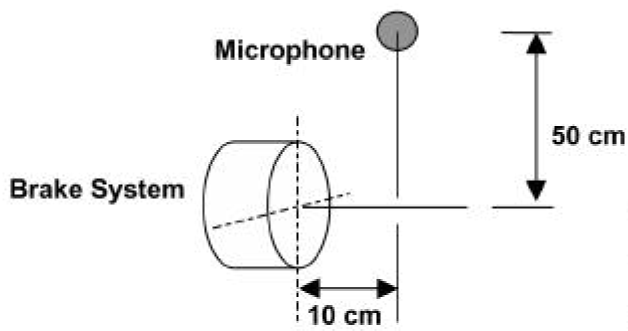

FIGURE 1—MICROPHONE ORIENTATION

6.2 Noise Measurements

a. Measurement duration: the same as the duration of brake application for all sections
b. 0.9 kHz high pass filter
c. 17 kHz signal bandwidth
d. The maximum permissible background noise level is 60 dB (A) above 0.9 kHz
e. 800 line spectral resolution
f. Peak Level Hold in spectrum
g. "Fast" evaluation mode or sampling equivalent
h. A - weighted
i. A threshold of $\geq$ 70 dB (A) will be used for recording sound

6.3 Temperature Measurements

a. The recommended method for measuring rotor temperature is using an infrared measurement on the inboard face of the outside diameter of the disc. When using infrared measurements the outside diameter of the rotor should be coated with a material that will provide an emissivity consistent with that required by the infrared measurement system.
b. As an alternative embedded thermocouples may be used to monitor the rotor temperature. This approach is not the preferred method since embedding the thermocouple may lead to changes in the rotor and its noise performance. It will be set at a depth of 0.5 mm ± 0.1 mm (0.020 in ± 0.004 in) from the outer surface. When high temperature fade tests are done, a thermocouple on the backing plate is recommended to monitor temperature.
c. Redundant temperature measurements should be made to prevent accidental overheating.

7. Brake Operations – Modelled on AK Noise Test Procedure

7.1 Operating Conditions

a. Brake snubbing operation from 80 to 30 km/h (see Figure 2) under different braking pressures is performed during the bedding program.
b. The braking time, t, is a result of the test rig inertia or is adapted to match the desired vehicle configuration.

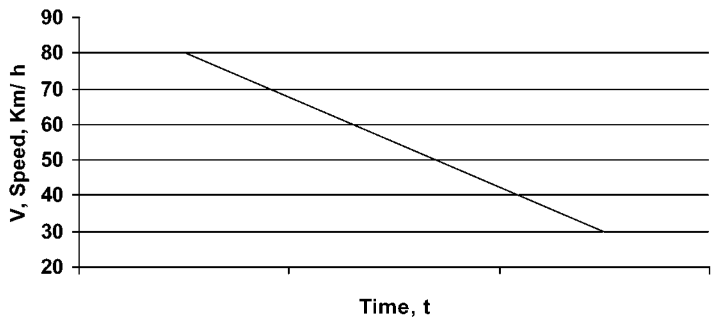

FIGURE 2—BRAKE OPERATIONS

7.2 Drag Operation (constant speed brake applications)

a. In order to evaluate brake noises, brake drag operations are required according to the following braking pressure ramp shown (Figure 3).
b. The increase of the brake pressure is 1 bar per second from Pn (normal mean value) –2.5 bar to P_n+2.5 bar at the same speed. The total braking time shall be 10 s.
c. Before the brake drag operation, the temperature of the rotor shall be adjusted by warming or cooling operations.
d. The test speeds shall be 3 km/h and 10 km/h.
e. For the special case of 0 bar pressure, the pressure operating range should be from 0 bar to 2.5 bar and back to 0 bar.

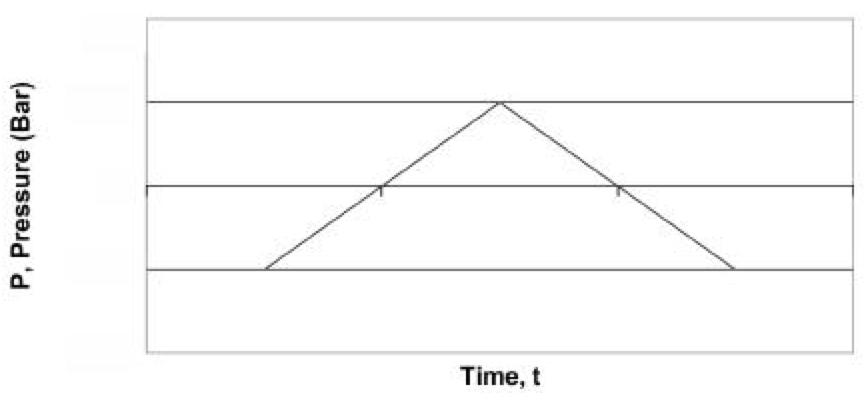

FIGURE 3—BRAKING PRESSURE RAMP

7.3 Deceleration Braking Operations

a. It is required to reduce the speed from 50 km/h to 0 km/h as shown in Figure 4 with defined normal pressure. The braking time is either obtained from the test rig inertia or adapted to match the desired vehicle configuration.

b. The rate of pressure increase during these cycles must be at least of 250 bar/s ± 50 bar/s (3625 lb/in^2-s ±725 lb/in^2-s)

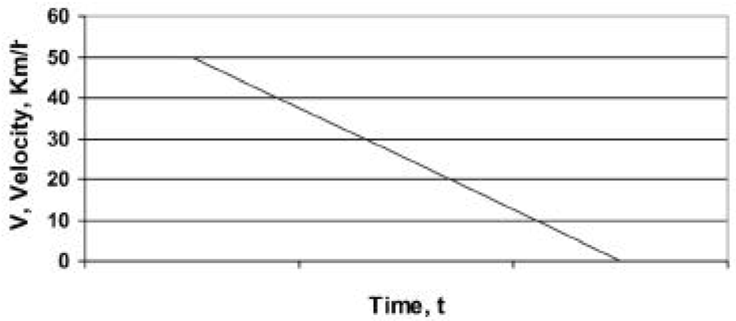

FIGURE 4—STOP OPERATION

7.4 Warm-up Operation

a. If the temperature decreases below the initial temperature of the next braking condition, brake warm up is required by a drag brake operation at 50 km/h with a 20 bar braking pressure until the initial braking temperature is reached.

7.5 Intermediate Conditioning and Warmup

a. This operation is designed to provide conditioning and warmup between the end of the drag cycle and the beginning of the forward-backward section.

b. A series of stops are executed to warmup the brake to 150 °C while also providing conditioning.

7.6 Temperature Fade Operation—The Temperature Fade cycle is temperature and torque controlled. The brake torque is calculated from the weight of the car, the brake force distribution, the dynamic tire radius, and the rate of deceleration. The torque is computed to provide a 0.4 g deceleration.

Starting temperatures for the fade operation brake applications are shown in Tables 1 and 2:

TABLE 1—FRONT DISC FADE INITIAL TEMPERATURES

Application Number	Temperature, °C	Application Number	Temperature, °C
1	100	9	465
2	215	10	483
3	283	11	498
4	330	12	513
5	367	13	526
6	398	14	539
7	423	15	550
8	446		

TABLE 2—REAR DISC FADE INITIAL TEMPERATURES

Application Number	Temperature, °C	Application Number	Temperature, °C
1	100	9	303
2	164	10	313
3	201	11	321
4	228	12	329
5	248	13	337
6	265	14	344
7	280	15	350
8	292		

If the initial temperature steps from the tables above are not obtained, perform a drag apply at 80 km/h with a torque equivalent to 0.2 g deceleration to warm-up the brake. The warm-up procedure should be applied for no more than 20 s. Noise evaluation will only be carried out on the stops where the initial temperature matches those in the appropriate table above.

These temperatures are determined using a logarithmic formula:

$$T_{AN} = (T_{A15} - T_{A1}) / 1n(15) - 1n(N) + T_{A1} \quad \text{(Eq. 1)}$$

where:

T_{AN} = initial temperature for a particular application number (AN), °C
T_{A15} = initial temperature for the fifteenth brake application, °C
T_{A1} = initial temperature for the first brake application, °C
N = application number (1-15)

8. ***Friction Coefficient***—The evaluation of the friction coefficient will only be performed at the prescribed temperature steps. The friction coefficient for a stop is an average over the time of the stop. The friction coefficient is determined using Equation 2:

$$\mu = \frac{Md_{Brake}}{2(p - p_{Threshold})^{*}A_{Piston}{}^{*}r_{eff}{}^{*}\eta} \quad \text{(Eq. 2)}$$

where:

μ = coefficient of friction
Md_{Brake} = brake torque,Nm
p = pressure, bar
$p_{Threshold}$ = threshold pressure, bar
A_{Piston} = piston area, mm^2
r_{eff} = effective rotor radius, mm
η = efficiency — assumed to be 100%

The threshold is 0.5 bar for a disc brake. The effective rotor radius is defined as the radius to the center of the piston. Start the evaluation at 90% of the reference value (pressure or torque). End the evaluation at 90% of the reference value (pressure or torque).

9. Test Matrix (Several Sections Modelled on AK Test Procedure)— The test matrix is described in the following sections.

9.1 Break-In (According to AK Noise Procedure), Section 9.1 (30)— See Table 3.

TABLE 3—SECTION 9.1—BREAK-IN (ACCORDING TO AK NOISE PROCEDURE), SECTION 9.1 (30)

Cycle	# Of Applications	Initial Speed	Final speed	Pressure (bar)	Initial Temp.
1.1	30	80 km/h	30 km/h	30	100 °C

9.2 Bedding (32)—As Defined in AK Master—Section 9.2— See Table 4.

TABLE 4—SECTION 9.2—BEDDING (32)—AS DEFINED IN AK MASTER—SECTION 9.2

Cycle	# Of Applications	Initial Speed	Final speed	Pressure (bar)	Initial Temp.
2.1	32	80 km/h	30 km/h	15, 30, 15, 18, 22, 38, 15, 26, 18, 34, 15, 26, 15, 22, 30, 46, 26, 51, 22, 18, 42, 15, 18, 46, 26, 15, 34, 22, 18, 30, 18, 38	100 °C

9.3 Optional Section 9.3—Friction Characteristic Value After Break-In (6)—(As defined in AK Master)—Section 3— See Table 5.

TABLE 5—OPTIONAL SECTION 9.3—FRICTION CHARACTERISTIC VALUE AFTER BREAK-IN (6)—(AS DEFINED IN AK MASTER)—SECTION 3

Cycle	# Of Applications	Initial Speed	Final speed	Pressure (bar)	Initial Temp.
3.1	6	80 km/h	30 km/h	30	100 °C

9.4 Drag Module (266)— See Table 6.

TABLE 6—SECTION 9.4—DRAG MODULE (266)

Cycle	# Of Applications	Initial Speed	Pressure (bar)	Initial Temp.
4.1	14	3 & 10 km/h (Alternate)	0, 30, 5, 25, 10, 20, 15	50 °C
4.2	same	same	same	75 °C
4.3	same	same	same	100 °C
4.4	same	same	same	125 °C
4.5	same	same	same	150 °C
4.6	same	same	same	175 °C
4.7	same	same	same	200 °C
4.8	same	same	same	225 °C
4.9	same	same	same	250 °C
4.10	same	same	same	300 °C
4.11	same	same	same	250 °C
4.12	same	same	same	225 °C
4.13	same	same	same	200 °C
4.14	same	same	same	175 °C
4.15	same	same	same	150 °C
4.16	same	same	same	125 °C
4.17	same	same	same	100 °C
4.18	same	same	same	75 °C
4.19	same	same	same	50 °C

9.5 Intermediate Conditioning and Warm-Up Module (24)—See Table 7.

TABLE 7—SECTION 9.5—INTERMEDIATE CONDITIONING AND WARM-UP MODULE (24)[1]

Cycle	# of Applications	Initial Speed	Final speed	Pressure (bar)	Initial Temp.
5.1	12	50 km/h	0 km/h	30, 5, 25, 10, 20, 15	100 °C
5.2	same	same	same	same	150 °C

1. Run 2 stops for each pressure. Continue this for the remaining pressures.

9.6 Backward/Forward (50)—See Table 8.

TABLE 8—SECTION 9.6—BACKWARD/FORWARD (50)

Cycle	# of Applications	Initial Speed	Pressure (bar)	Initial Temp.
6.1	10	-3, 3 km/h (Alternate)	0, 20, 5, 15, 10	150 °C
6.2	same	same	same	125 °C
6.3	same	same	same	100 °C
6.4	same	same	same	75 °C
6.5	same	same	same	50 °C

9.7 Deceleration Module (108)—See Table 9.

TABLE 9—SECTION 9.7—DECELERATION MODULE (108)[1]

Cycle	# of Applications	Initial Speed	Final speed	Pressure (bar)	Initial Temp.
7.1	12	50 km/h	0 km/h	30, 5, 25, 10, 20, 15	50 °C
7.2	same	same	same	same	100 °C
7.3	same	same	same	same	150 °C
7.4	same	same	same	same	200 °C
7.5	same	same	same	same	250 °C
7.6	same	same	same	same	200 °C
7.7	same	same	same	same	150 °C
7.8	same	same	same	same	100 °C
7.9	same	same	same	same	50 °C

1. Run 2 stops for each pressure. For example, 5 bar at 50 °C for 2 stops. Then run 10 bar at 50 °C for 2 stops. Continue this for the remaining pressures. Do this for all 9 cycles.

9.8 Friction Characterisitic Value After Break-In (6)—Section 8—Repeat Section 3.

9.9 Drag Module (266)—Section 9—Repeat Section 4.

9.10 Intermediate Conditioning and Warm-Up Module (24)—Section 10—Repeat Section 5.

9.11 Backward/Forward—Section 11—Repeat Section 6.

9.12 Deceleration Module (108)—Section 12—Repeat Section 7.

9.13 Friction Characteristic Value after Break-In (6)—Section 13—Repeat Section 3.

9.14 Drag Module (266)—Section 14—Repeat Section 4.

9.15 Intermediate Conditioning and Warm-up Module (242)—Section 15—Repeat Section 5.

9.16 Backward/Forward (50)—Section 16—Repeat Section 6.

9.17 Deceleration Module (108)—Section 17—Repeat Section 7.

9.18 Friction Characteristic Value after Break-In (6)—Section 18—Repeat Section 3.

9.19 Optional Sections—Noise After Fade and Recovery—Section 19—Sections 19 to 25 are optional. The noise data from these sections will represent the squeals generated after severe fade and recovery. See Table 10.

TABLE 10—SECTION 9.19—TEMPERATURE FADE MODULE (15)

Cycle	# of Applications	Initial Speed	Final speed	Deceleration (g)	Max. Pressure (bar)	Initial Temp. (°C)
19.1	15	100 km/h	0 km/h	0.4	160	100, 215, 283, 330, 367, 398, 423, 446, 465, 483, 498, 513, 526, 539, 550

9.20 Recovery (18)—Section 20—See Table 11.

TABLE 11—SECTION 9.20—RECOVERY (18)

Cycle	# of Applications	Initial Speed	Final speed	Pressure (bar)	Initial Temp.
20.1	18	80 km/h	30 km/h	30	100 °C

9.21 Drag Module (266)—Section 21—Repeat Section 4.

9.22 Intermediate Conditioning and Warm-Up Module (24)—Section 22—Repeat Section 5.

9.23 Backward/Forward (50)—Section 23—Repeat Section 6.

9.24 Deceleration Module (108)—Section 24—Repeat Section 7.

9.25 Friction Characteristic Value after Break-In (6)—Section 25—Repeat Section 3.

10. Summary of Results—Figures 5 to 7 represent the recommended formats for reporting the results of this test procedrure. These figures provide a recommended summary of the overall test results. It is not necessary that the format of these figures be duplicated exactly. It is recommended that two sets of data presentations be used when the optional fade module test is included. This permits data comparisons before and after fade and avoids confusion between results.

SAE J2521 Test Report

Test Identification		Date:	
Pad Description		Disc	
Caliper		Shim	
Fixture Description:		Anchor	
Vehicle		Dyno	
Notes:			

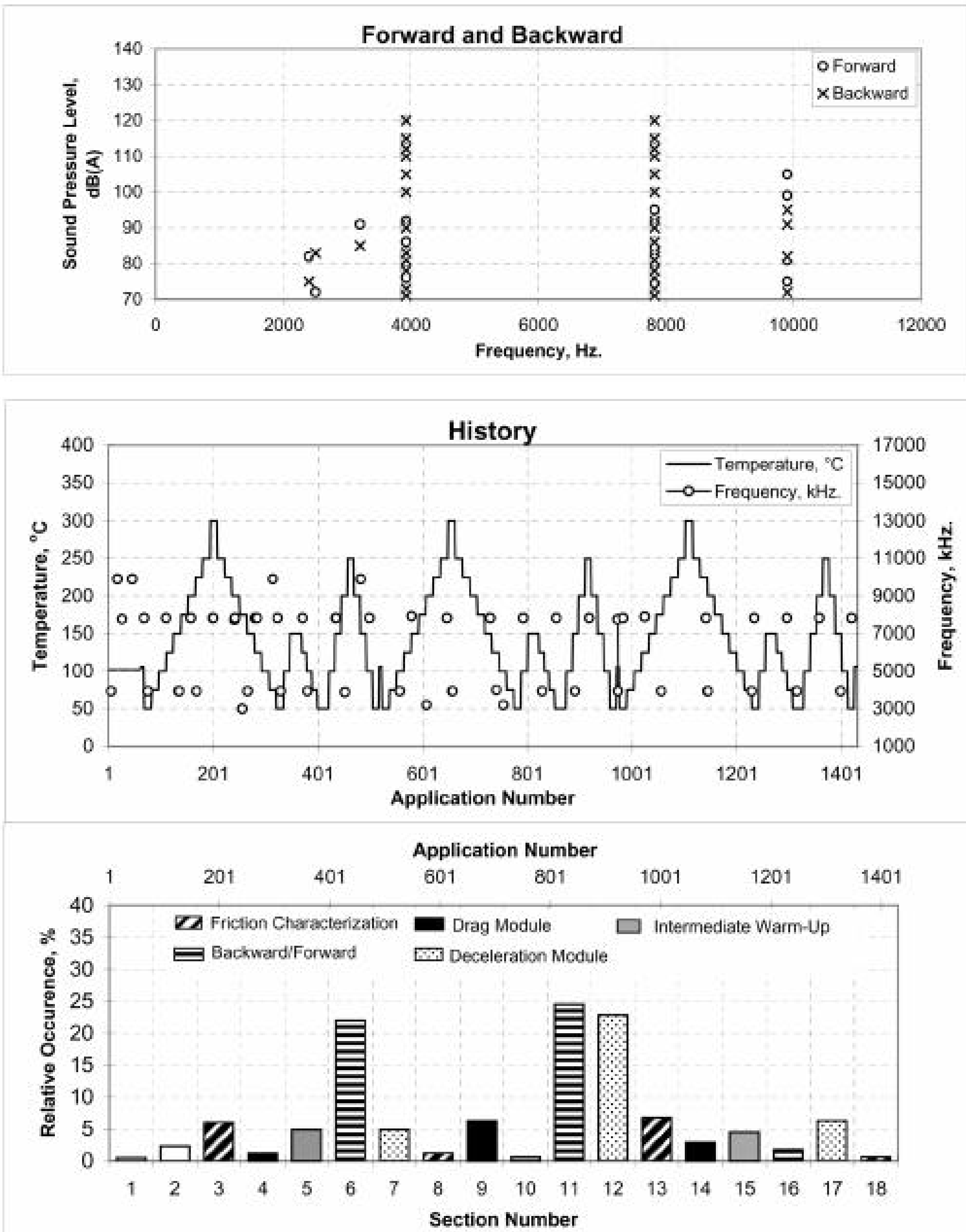

FIGURE 5—HISTORICAL SUMMARY OF RESULTS

SAE J2521 Test Report

Test Identification				Date:	
Pad Description			Disc		
	Caliper		Shim		
Fixture Description:			Anchor		
Vehicle			Dyno		
Notes:					

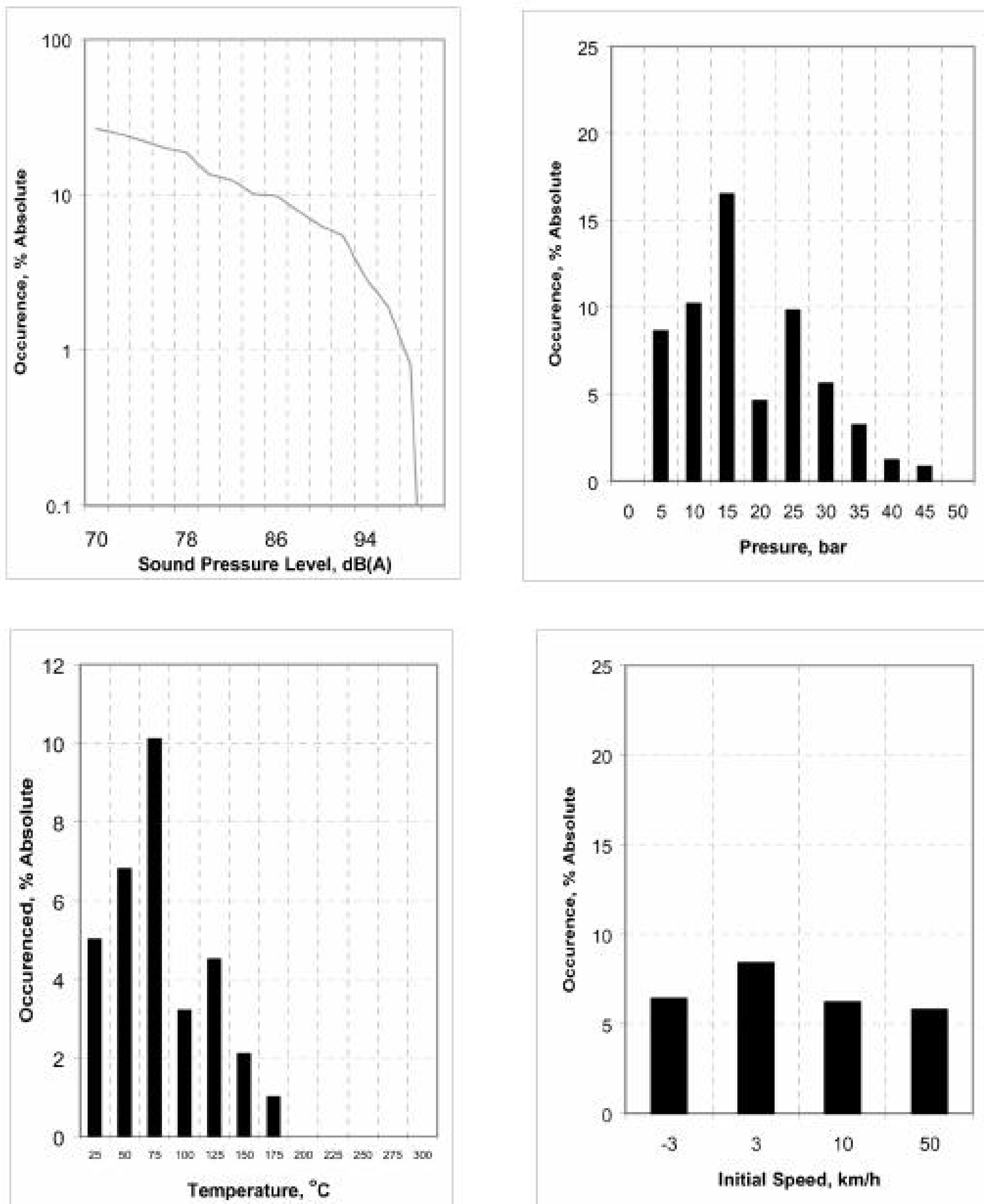

FIGURE 6—SUMMARY OF NOISE OCCURRENCE VARIATION

SAE J2521 Test Report

Test Identification			Date:	
Pad Description			Disc	
	Caliper		Shim	
Fixture Description:			Anchor	
Vehicle			Dyno	
Notes:				

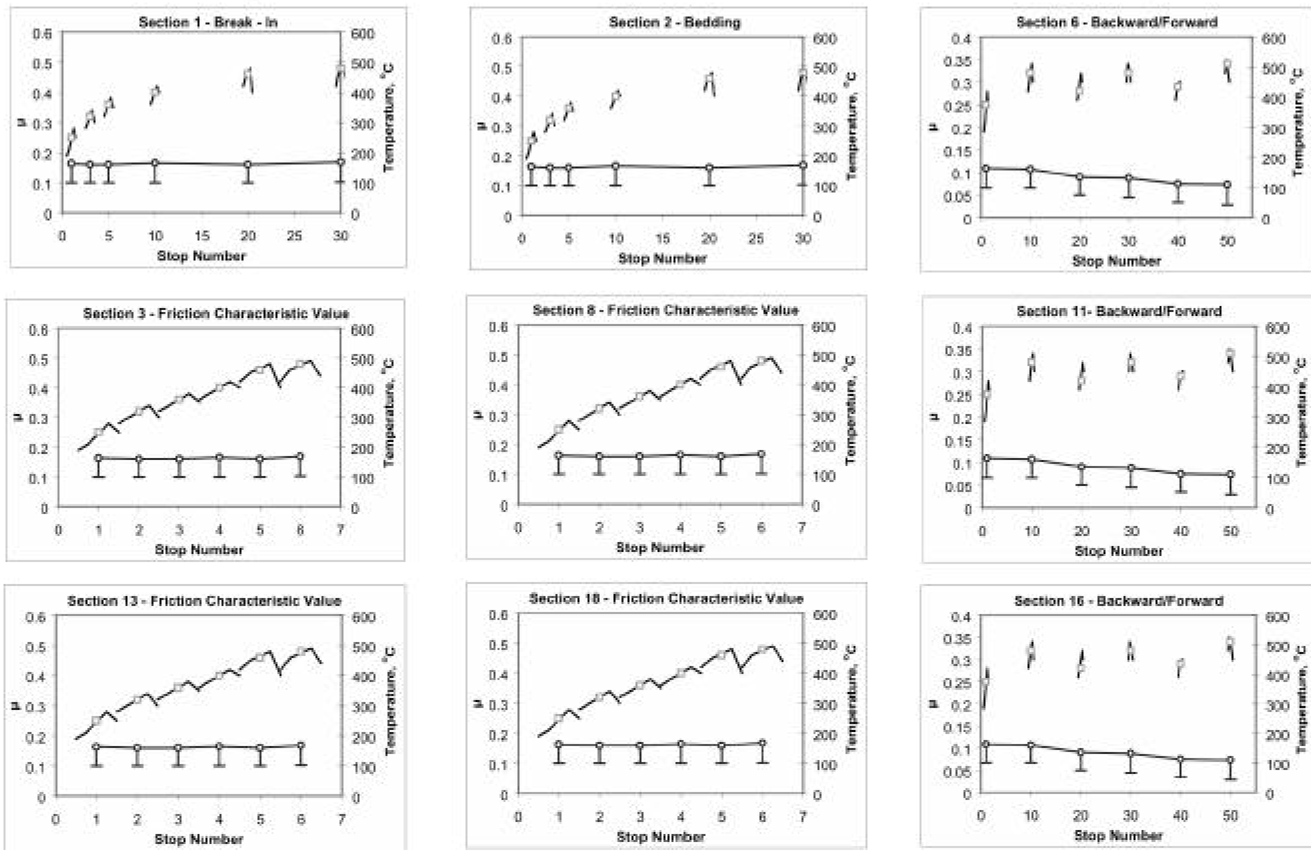

FIGURE 7—SUMMARY OF FRICTION CHARACTERISTIC VARIATION

PREPARED BY THE SAE DYNAMOMETER TEST CODE STANDARDS COMMITTEE

Rationale—Not applicable.

Relationship of SAE Standard to ISO Standard—Not applicable.

Application—This procedure is applicable to high frequency squeal type noise occurrences for passenger car and light truck type vehicles that are used under conventional operating conditions. The procedure does not encompass the consequences associated with changes in environment related to temperature and humidity variations.

Reference Section—There are no referenced publications specified herein.

Developed by the SAE Dynamometer Test Code Standards Committee