SAE International®	SURFACE VEHICLE RECOMMENDED PRACTICE	SAE **J2521 APR2013**
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(R) Disc and Drum Brake Dynamometer Squeal Noise Test Procedure

RATIONALE

The current revision of the SAE J2521 includes updates and changes to (a) accommodate for modern testing technologies, (b) improve the squeal noise evaluation matrixes for disc and drum brakes, (c) bring the document into the new SAE format standard, (d) revise its formatting for clearer test sequences, and (e) improve and harmonize definitions, noise evaluation, test setup and conditions, test inertia calculations, and data analysis with other SAE dynamometer test procedures and recent standards and developments from the EKB/VDA working groups in Europe. Lastly, this revision uses lower final temperatures during the fade sections to better represent vehicle-level testing while offering a more severe fade schedule as optional.

FOREWORD

In the early 1990s a European working group including car manufacturers, braking system suppliers, and friction material companies, developed a dynamometer test procedure known as the AK Noise. This procedure uses two main modes (a) drag mode at low speed with a pressure application profile meant to induce instability and squeal noise, and (b) deceleration braking at moderate speeds at constant brake pressure; a common approach in the U.S., emphasizing the replication of vehicle road test. The SAE J2521 combines both braking modes to satisfy the strong need for a global standardization of squeal noise dynamometer tests. This procedure was first presented to the SAE working group in 1999. This procedure owes much to the previous development of the AK procedures. This prior work is gratefully acknowledged.

Both test matrixes (disc and drum) include three main schedules:

— Schedule A - standard: standard test sections with deceleration, drag, and forward/reverse sections at various temperatures and speeds.

— Schedule B - optional: noise during cold modules to assess noise propensity below 50 °C and at or below freezing level of zero degrees (0 °C).

— Schedule C - optional: noise after fade to assess the influence of high-temperature excursions on the noise propensity of a given brake.

This recommended practice establishes the minimum standard set of specifications regarding test setup, inertia-dynamometer characteristics, test sequence, and test report items. Deviations from or changes to this procedure to accommodate a specific project are feasible as long as they are discussed and agreed upon among the interested parties prior to commencing the actual staging and the testing activities.

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1. SCOPE

The SAE J2521 procedure is applicable to high frequency squeal noise occurrences for on-road passenger car and light trucks below 4,540 kg of GVWR. The procedure incorporates high temperature and low temperature test matrixes, but does not fully account for the effects of the environment on brake squeal. Much research is currently underway in this area and can potentially be incorporated in future revisions.

For the purposes of this test procedure, squeal is defined as peak noise levels equal to or above 70 dB(A) between 1.25 kHz and 16 kHz for tests using a full suspension corners or full axle assemblies, or between 2 kHz and 16 kHz for brakes not using a full suspension corner.

Before using this Recommended Practice for chassis dynamometer testing, review in detail the specifics related to at least (a) instrumentation including in-cabin microphones, (b) threshold levels for noise detection, (c) temperature control priority between front and rear axles, (d) vehicle loading and load distribution, (e) cooling air and environmental conditioning, and (f) detailed nomenclature and labeling of channels and sensors.

1.1 Purpose

This recommended test practice is intended to establish a common method to perform a series of screening test sequences that identify the propensity of a brake assembly to generate squeal noise under a variety of test conditions. The result is an evaluation of brake noise under a set of defined braking conditions that are believed most relevant to braking system development for automobiles.

A disc brake application matrix and a drum brake application matrix are defined to describe the test conditions and steps to investigate the influence of pressure, temperature and velocity on squeal noise behavior. Each matrix is intended to replicate vehicle tests to get a fair comparison for different brake corner components.

2. REFERENCES

2.1 Applicable Documents

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 International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J2789 Inertia Calculation for Single-Ended Dynamometer Testing

2.1.2 VDA publications

Available from the German Association of the Automotive Industry VDA (Verband der Automobilindustrie e.V.), Behrenstr. 35, 10117 Berlin, or http://www.vda.de/en/publikationen/publikationen_downloads/

VDA 300 Development Guideline on Quality Control of Disc Brake Linings

VDA 303 Description of Noisy Brake Applications Concerning Brake Squeal

VDA 305 Data Exchange Format Description

VDA 306 Definition of charts for the evaluation of brake noise data / Dynamometer

2.2 Related Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J2598 Automotive Disc Brake Pad Natural Frequency and Damping Test

SAE J2625 Automotive Vehicle Brake Squeal Test Recommend Practice

SAE J2786 Automotive Brake Noise and Vibration Standard Nomenclature

SAE J2933 Verification of Brake Rotor Modal Frequencies

SAE J3001 Brake Insulator Damping Measurement Procedure

IEC 61672-1 Electroacoustics - Sound level meters - Part 1: Specifications

IEC 61672-2 Electroacoustics - Sound level meters - Part 2: Pattern evaluation tests

IEC 61672-3 Electroacoustics - Sound level meters - Part 3: Periodic tests

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3. DEFINITIONS

To facilitate the application of this SAE Recommended Practice, the following definitions apply.

3.1 APPARENT FRICTION FOR DISC BRAKES

Per Equation 1:

$$\mu = \frac{10^6 \cdot T}{2 \cdot (p - p_{Threshold}) \cdot A_P \cdot r_{eff} \cdot \eta} \qquad \text{(Eq. 1)}$$

Where:

μ = apparent friction for disc brakes / unitless

3.2 DRUM BRAKE EFFECTIVENESS (C*)

Per Equation 2:

$$C^* = \frac{10^6 \cdot T}{(p - p_{Threshold}) \cdot A_P \cdot r_{eff} \cdot \eta} \qquad \text{(Eq. 2)}$$

Where:

C^*	= effectiveness for drum brakes / unitless
T	= output torque / N·m
p	= brake pressure / kPa
$p_{Threshold}$	= minimum pressure required to start developing braking torque. Unless otherwise indicated by the test requestor or measured as part of the project, use a zero value / kPa
A_P	= total piston area acting on one side of the caliper for disc brakes; or total wheel cylinder area for drum brakes / mm^2
r_{eff}	= radial distance from centerline of the piston to the axis of rotation for disc brakes; internal drum diameter divided by 2 for drum brakes, unless other dimensions are provided by the requestor / mm
η	= brake efficiency. Unless otherwise indicated by the test requestor or measured as part of the project, use 1 (100%)

For dynamic brake applications calculate the average-by-distance friction coefficient or effectiveness value between t_1 and t_2 per item 8.1. For brake drag applications calculate the average-by-time friction coefficient or effectiveness value between t_1 and t_3 per item 8.2.

3.3 GROSS VEHICLE WEIGHT – GVWR

Maximum vehicle weight indicated by the manufacturer / kgf

3.4 BRAKING SPEED

Linear speed at the onset of the brake application during stops or snubs where the speed reduces during the brake application

3.5 DRAG SPEED

Linear speed at the onset of the brake application during drag events where the speed remains constant during the brake application

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3.6 INITIAL BRAKE TEMPERATURE - IBT

Rotor or drum temperature at the start of the brake application / °C

3.7 TIRE DYNAMIC ROLLING RADIUS

Equivalent tire radius that will generate the Revolutions Per Mile (RPM) published by the tire manufacturer for the specific tire size per Equation 3. Use the tire dynamic rolling radius to calculate the dynamometer rotational speed for a given linear vehicle speed / mm

$$RR = \frac{1\ 609\ 344}{2 \cdot \pi \cdot RPM} \qquad \text{(Eq. 3)}$$

Where:

RR = tire dynamic rolling radius / mm

RPM = tire manufacturer specification for revolutions per mile and typically shown for the tire size on the manufacturer's website

4. TEST EQUIPMENT

4.1 Single-ended brake inertia-dynamometer capable of performing dynamic brake applications with deceleration- or pressure-controlled brake applications. Also, capable of conducting brake drag at constant pressure, and brake drags with brake pressure profiles.

4.2 Reversible motor and drive control capable of conducting the brake drag applications at no less than 90 % of the nominal drag speed.

NOTE: Calculate motor torque based on the highest of the three following values (a) brake drag at base speed and 32.5 bar brake pressure, (b) acceleration rate during brake fade modules, and (c) motor torque used for inertia-simulation during dynamic brake applications.

4.3 Control system capable of performing brake applications at constant pressure, pressure profiles, or constant deceleration (torque control)

4.3.1 Pressure ramp rate of at least 100 bar/s (see item 8.1) and a maximum pressure of at least 160 bar

4.3.2 Overshoot of less than 1 bar during dynamic brake applications

4.3.3 Average pressure control within 0.25 bar of target value (set-point) during pressure profiles

4.3.4 Deceleration control and overshoot within 0.5 m/s² of target value (set-point)

4.4 Cooling air system directed at the brake.

4.4.1 Control the air speed such that it will not be so high as to blow away wear debris or create noise above the background limit of 64 dB(A) above 900 Hz. The cooling air remains on during the brake events.

NOTE 1: The 64 dB(A) limit provides 6 dB(A) separation which is a 2:1 separation or half the threshold limit to detect noisy brake events above 70 dB(A)

NOTE 2: Depending upon the project, other threshold levels could be more appropriate, like brake noise evaluation for electric vehicles. In such cases, confirm with the test requestor and the testing facility

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4.4.2 Set up the duct outlet 300 to 400 mm away from the rotor outside diameter with air duct with a hydraulic diameter (200-300) mm. Adjust cooling air to 10 m/s (35 km/h) measured at the duct outlet; if needed, adjust to meet the background noise level from item 4.4.1.

NOTE 1: In cases where the above conditions cannot be achieved, define with the test requestor and document it on the final test report

NOTE 2: Alternatively, adjust cooling air flow between 1 000 to 2 000 m^3/h while ensuring background noise level per 4.4.1

NOTE 3: Since the cooling air setup is a critical subsystem of the inertia dynamometer which effects test variability and test duration, ensure proper definitions and test conditions are defined for the test project. Measure airflow, assess cooling rates at specific temperatures and test speeds, review cycle times, and observe overall temperature regimes during the tests to better understand the conditions and effects on noise and friction behavior.

4.4.3 Optional - Environmental control system. Except for the cold modules below 25 °C, control brake cooling air temperature to 25 °C ± 5 °C, and relative humidity to 50 %RH ± 10 %RH - equivalent to 7.90 to 11.93 g/kg, or 9,24 to 13.86 g/m^3 absolute humidity at sea level and 25 °C. Use a psychrometric chart to find acceptable air temperature and relative humidity combinations. During cold modules below the dew point of the environmental control system, control only the cooling air temperature. See Figure 1 for two typical setups of cooling air for disc brake assemblies. Document on the test report the actual cooling air orientation relative to the brake and the brake rotation.

NOTE 1: It is recommended during cold sections to set the cooling air temperature approximately 10 °C below the IBT

NOTE 2: In order to keep similar and consistent cooling behavior of the brake assembly (including noise insulators or shims) for the same project, in addition to keeping the cooling air setup the same, use the same fixture orientation (left- or right-hand) in agreement with the test requestor and the testing facility

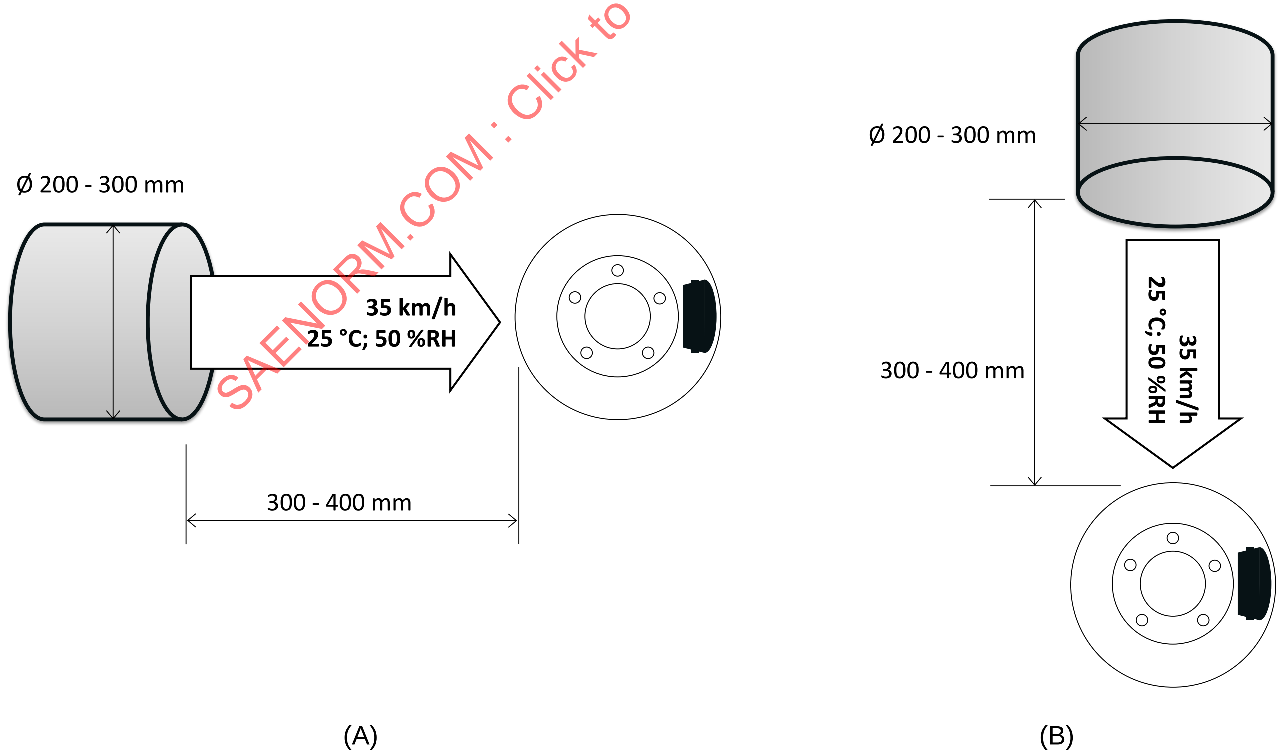

FIGURE 1 - RECOMMENDED SETUP FOR COOLING AIR (A) HORIZONTAL LAYOUT, (B) VERTICAL LAYOUT

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4.5 Automatic data collection system capable of recording digitally the following channels at 50 Hz minimum:

4.5.1 Brake equivalent linear speed / km/h

4.5.2 Brake input pressure / kPa

4.5.3 Brake output torque / N·m

4.5.4 Calculated brake apparent friction or effectiveness per items 3.1 and 3.2

4.5.5 (optional) Brake fluid displacement / mm^3

4.6 Automatic data collection system capable of recording the following channels at 10 Hz minimum:

4.6.1 Brake rotor or drum temperature / °C

4.6.2 (optional) Brake pad or brake shoe temperature / °C

4.6.3 Cooling air temperature, relative humidity (or absolute humidity), and speed (or airflow)

5. TEST FIXTURE

The test fixture is of significant influence on the test complexity, logistics associated with the test preparation and setup, and ultimately can influence the dominant frequencies observed during the test. The fixture level specified for a given project is the results of multiple decisions and shall remain the same for the same project or noise investigation. Table 1 indicates the hardware required for each fixture level. Unless otherwise specified by the test requestor, fixture L2 is the recommended level as default.

5.1 Build the test fixture using as much as feasible the actual vehicle suspension and axle components. The suspension components should be as complete as possible to the connection points with the vehicle structure. This includes all bushings, including those at the structural connection points. However, certain projects specify a fixture using the knuckle assembly only to mount the brake corner and to connect to the inertia dynamometer tailstock. Also, it may not always be possible to use the entire suspension corner. In such cases, use an undisturbed knuckle assembly to fabricate the test fixture.

NOTE 1: In order to minimize frequency coalescence between the fixture and the brake assembly, when feasible, prefill the fixture frame with a noise-absorbing material like play sand or similar.

NOTE 2: When requested, conduct Frequency Response Function (FRF) natural frequency, or mobility measurements on the main components (friction material, rotor or drum, caliper, caliper brackets, brake backing plate assembly for drum brakes, knuckle or axle-end, etc.) to characterize the natural frequencies of the test fixture and brake assembly combined. Conduct the FRF at multiple locations, directions, and with the brake pressure applied at the typical pressures expected during the test. This type of measurements requires special preparation and proper instructions in agreement with the test requestor. See SAE J2933 and SAE J2598 for reference and examples for brake pads and brake rotors.

NOTE 3: In order to minimize test results variability, for the same project, use the same fixture level and fixture design. Ideally, when requiring multiple fixtures for the same project, use the same source for fixture fabrication.

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TABLE 1 - FIXTURE LEVELS AND COMPONENTS REQUIRED

	Fixture level		
Component	L1 (knuckle)	L2 (suspension)	L3 (full-axle)
Brake disc or drum	yes	yes	yes
Friction material	yes	yes	yes
Brake caliper or wheel cylinder	yes	yes	yes
Wheel bearing	yes	yes	yes
Wheel hub	yes	yes	yes
Drive shaft (when applicable)	yes	yes	yes
Wheel center (optional)	optional	optional	optional
Upper and lower control arms	—	yes	yes
Control arms bushings	—	yes	yes
Stabilizer arm		yes	yes
Spring, strut, or and shock absorber	—	yes	yes
Strut or shock absorber bushings	—	yes	yes
Subframe	—	—	yes
Subframe bushings	—	—	yes
Wheel and tire (optional)	optional	optional	optional

For L2 or L3 fixtures impose a preload to the corner assembly to replicate its normal (or specified) operating condition. This ensures proper alignment, compliance, and transmissibility within the assembly. The preferred method of loading is to use a single compliant tension element (or compression underneath the knuckle) acting vertically, but not restricting vibration in the vehicle longitudinal or lateral directions. Other methods to impose preloading include:

a. A wheel-and-tire assembly riding on a roller of suitable size and geometry

b. An external bearing assembly connected to the driveline rotating the brake rotor or drum - typically a constant velocity shaft

c. Loading the assembly through a soft connector from underneath the knuckle or hub carrier

When applying a preload with additional components (bearings or wheel-and-tire assemblies) verify with the test requestor the proper method to minimize background noise (like using tires with the treads machined) or special algorithms to compensate for any additional background noise during the data collection and data analysis.

5.2 Specify for the project the method required to drive the brake corner (direct connection to the dynamometer shaft, spool-driver in combination with a constant velocity drive shaft, wheel center driver with constant velocity drive shaft, etc.) and the details regarding the driver material and design. See Figure 2.

NOTE 1: The drive system and connection to the main dynamometer can significantly influence the noise propensity of a given brake and the dominant frequencies during the test. Document and use the same design and material for the same project as a best practice to reduce test-to-test and dyno-to-dyno variability.

NOTE 2: When feasible or when indicated by the test requestor, the spool-driver design should mimic the interface and force distribution of a reference wheel design.

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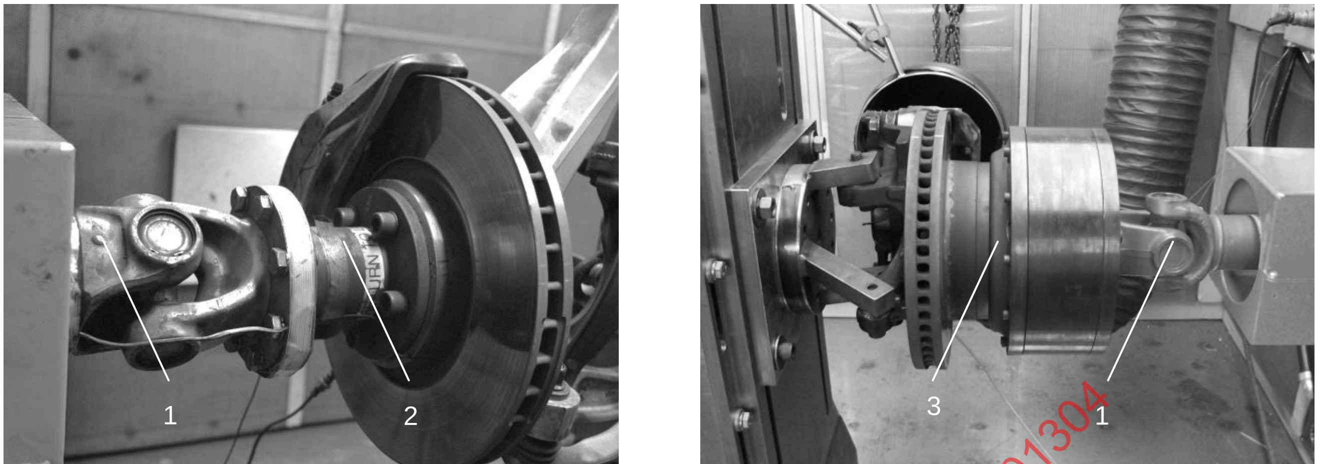

(A) (B)

1. Constant velocity drive shaft
2. Spool-driver
3. Wheel center driver

FIGURE 2 - BRAKE DRIVING SYSTEM (A) SPOOL DRIVER, (B) WHEEL CENTER DRIVER

5.3 Report the brake fixture level and the drive method used for a given test project (see EKB 3010).

6. TEST INERTIA

Unless otherwise indicated by the test requestor, determine the test inertia per the default or the torque index methods on SAE J2789 with the vehicle loaded at GVWR at deceleration levels below 0.65 g.

7. PARTS PREPARATION AND TEST SETUP

7.1 Temperature measurement

7.1.1 Unless otherwise specified by the test requestor, use new rotor and brake pads, or new drum and brake shoe linings for each test.

7.1.2 For brake rotors, install thermocouple at a depth of 1.0 mm on the outboard face near the centerline of the braking surface.

NOTE: As an alternative method for measuring rotor temperature, and in agreement with the test requestor, use an infrared measurement on the outside diameter of the inboard face of the disc. When using infrared measurements apply the outside diameter of the rotor coat with a heat-resistant black non-reflective paint that will provide an emissivity consistent with that required by the infrared measurement system. Obtain the correct emissivity settings from the test requestor or using an agreed-upon method. When using this method - unless readily available for the rotor design - perform a trial test to establish the correlation of the infrared reading with the embedded thermocouple. At appropriate intervals during testing ensure dust or debris does not accumulate on the lens.

7.1.3 Optional - For brake pads, install one thermocouple at a depth of 2.0 mm near the center of the friction surface on each pad. For disc brake pads with grooves, install the thermocouple at least 4.0 mm from the groove edge on the leading side of the pad. For inboard pads on single piston calipers, install the thermocouple on the leading side, 3 to 4 mm from the piston outside diameter near the center of the friction surface

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7.1.4 When conducting schedule C (including fade section), confirm with the test requestor the need and location for additional thermocouple on the backing plate or noise shim to monitor temperature

7.1.5 For brake drums, install thermocouple at a depth of 1.0 mm on the centerline of the braking surface.

7.1.6 Optional - For brake shoes, install a thermocouple at a depth of 1.0 mm near the center of the friction surface of the most heavily loaded shoe.

7.1.7 Use the same temperature measurement and location for the same project.

7.1.8 When using a different control thermocouple for the test, document and report on the final test report

7.1.9 The use of redundant temperature measurements can prevent accidental overheating due to thermocouple or wiring failure.

7.2 Microphone location

Position the microphone in the vertical plane and perpendicular to the brake axis and pointing downwards. Locate the center of the microphone (a) 100 mm outboard from the wheel hub mounting surface along the centerline of the axle, (b) 500 mm above the bake rotating axis, and (c) on the vertical plane of the rotor or drum axis. See Figure 3.

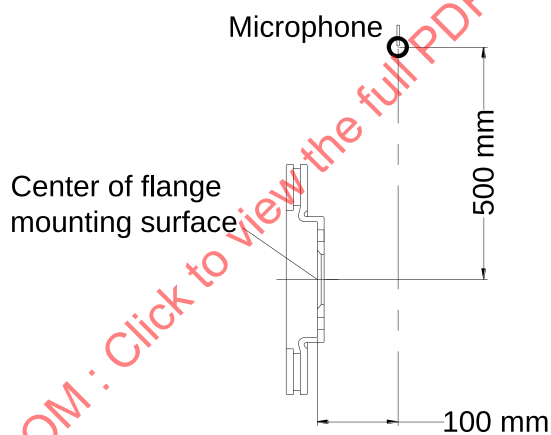

FIGURE 3 - MICROPHONE ORIENTATION AND POSITION RELATIVE TO FLANGE CENTER

7.3 Noise measurements settings

7.3.1 Unless otherwise specified by the test requestor, use a microphone conforming to IEC 61672-1 Class 2 or better with a corresponding windscreen.

7.3.2 Use a calibrator according to IEC 60942 of the same class of the microphone at 1 kHz, before and after the test.

7.3.3 Use a frequency analyzer and/or digital data acquisition system to record the sound spectrum in the time domain. The system must compute and record narrowband sound pressure spectra using the following parameters and capabilities:

7.3.3.1 500 to 20 000 Hz frequency bandwidth, with a frequency resolution of 25 Hz

7.3.3.2 Peak-hold averaging with 66.7 % overlap processing

7.3.3.3 Apply Hanning windowing to the time-based records

7.3.3.4 Anti-aliasing filtering

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7.3.3.5 A–type signal weighting

7.3.4 Measure the Sound Pressure Level (SPL) in dB(A) throughout the duration of each brake application for all sections.

7.3.5 Ensure the background noise level inside the test chamber with the cooling air system operating does not have peaks above 64 dB(A) above 900 Hz

7.3.6 Noise measurement duration (recording) is the same as the duration of the brake application for all sections; from t_0 to t_4 for dynamic and brake drag applications

7.3.7 Noise measurement period for analysis from t_1 to t_3 for dynamic and brake drag applications

7.3.8 Microphone information may be saved as peak hold spectra, time recordings, peak-hold history at fixed intervals, or peak dB(A) and corresponding frequency at fixed interval

7.3.9 Optional - Use accelerometers to validate noisy brake events. Define with the test requestor the quantity, location, and data validation technique prior to commence testing

7.4 For disc brakes, the assembled lateral run-out shall not to exceed 50 µm when measured on the outboard surface and 10 mm from the outside diameter.

7.5 For drum brakes, set the diametric cage clearance to the value indicated by the test requestor, the vehicle service manual, or the brake assembly print. If no other information is available, set the diametric cage clearance to 0.6-0.8 mm, measured at the center of the shoes. Rotate to check for excessive drag and adjust if necessary.

8. TEST CYCLES

8.1 Dynamic Brake Application

Figure 4 illustrates the main time-stamps used to characterize the brake application.

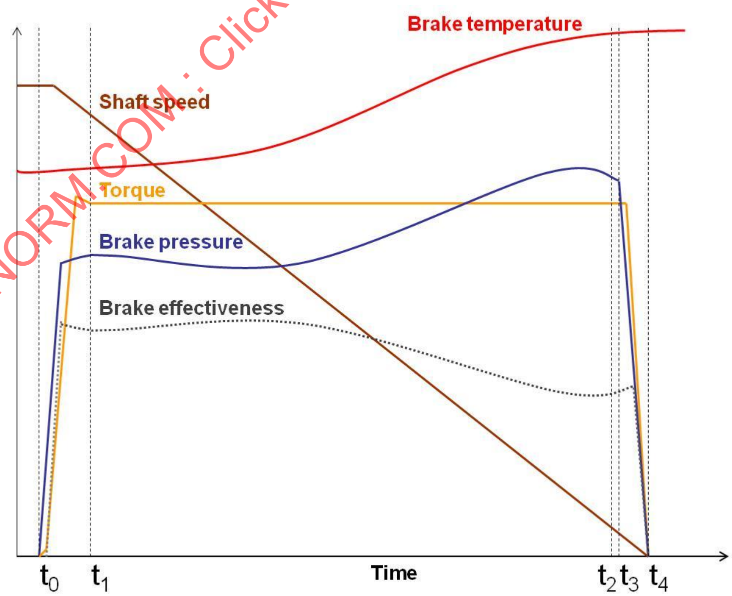

FIGURE 4 - TYPICAL BRAKE APPLICATION TIME STAMPS

To achieve the target pressure or deceleration level during dynamic braking cycles use a pressure ramp rate of 150 bar/s ± 50 bar/s.

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8.1.1 Time t_0

Brake application initiation. At this time, the pressure starts to rise.

8.1.2 Time t_1

Time at level reached. At this time, the brake reaches its target level for torque or pressure control. At time t_1, the calculation of average by time and the average by distance begins.

8.1.3 Time t_2

Time at the end of averages. At time t_2 the inertia-dynamometer data acquisition system terminates the calculation of average by time and average by distance. Time t_2 is the end of the stable portion of the brake application. t_2 is defined as the time at which speed is 0.5 km/h above the release speed (t_3).

8.1.4 Time t_3

Time at release speed. At time t_3, the inertia-dynamometer servo controller releases the brake (specified in 8.1.3).

8.1.5 Time t_4

Time at brake pressure and torque lost. At time t_4, pressure and torque are below the minimum thresholds. The inertia-dynamometer considers the braking event complete.

8.2 Brake Drag Application for low-speed and backward/forward modules

Figure 5 illustrates the main time-stamps used to characterize the brake drag application at constant brake speed.

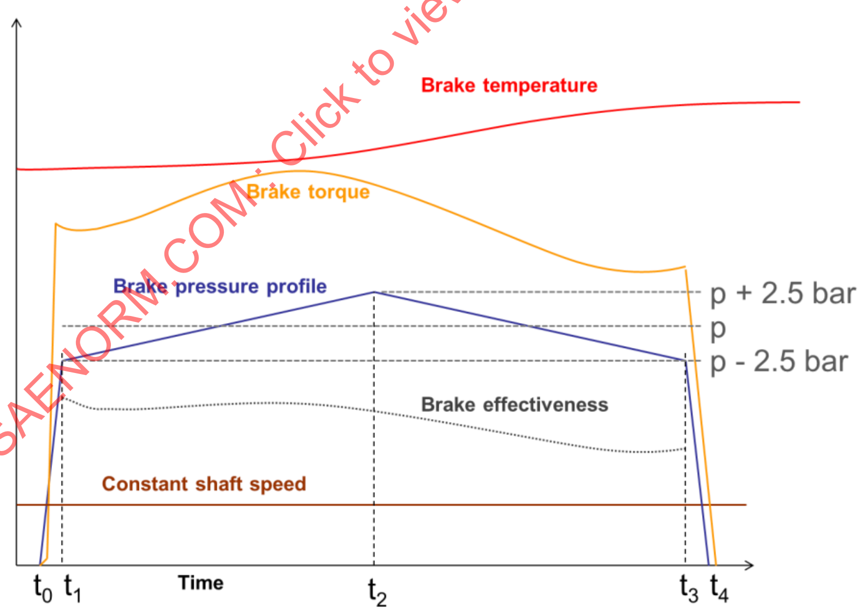

FIGURE 5 - TYPICAL BRAKE DRAG APPLICATION WITH TIME STAMPS

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8.2.1 Time t_0

Brake application initiation. At this time, the pressure starts to rise. The ramp rate from t_0 to t_1 should provide a rise time to the nominal pressure minus 2.5 bar of 0.5 s.

8.2.2 Time t_1

Time at start of the 1 bar/s pressure profile - equal to 0.5 s. At time t_1 brake pressure is equal to the nominal pressure minus 2.5 bar. At time t_1, the calculation of average-by-time effectiveness begins. For the zero-bar pressure profile t_1 equals 2.5 s.

NOTE: 1 bar = 100 kPa = 0.1 MPa = 14.5 psi

8.2.3 Time t_2

Time at the middle of the 1 bar/s profile - equal to 5.5 s. At time t_2 brake pressure is equal to the nominal pressure plus 2.5 bar. For the zero-bar pressure profile t_2 equals 5 s.

8.2.4 Time t_3

Time at end of the 1 bar/s pressure profile - equal to 10.5 s. At time t_3 brake pressure is again equal to the nominal pressure minus 2.5 bar. At time t_3, the calculation of average-by-time effectiveness finishes. For the zero-bar pressure profile t_3 equals 7.5 s.

8.2.5 Time t_4

Time at brake pressure and torque lost - equal to 11 s. At time t_4, pressure and torque are below the minimum thresholds. The inertia-dynamometer considers the braking event complete. For the zero-bar pressure profile t_4 equals 10 s. The ramp rate from t_3 to t_4 should provide a pressure release time from the nominal pressure minus 2.5 bar down to zero of 0.5 s.

Figures 6 illustrate the pressure profiles during brake drag application.

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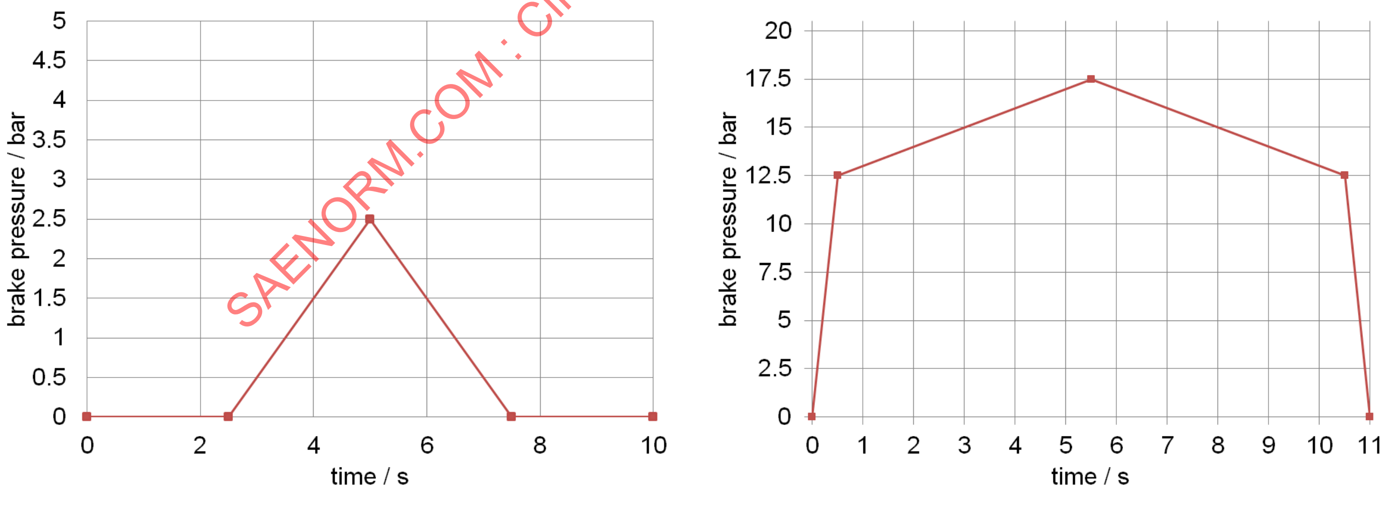

(A) (B)

FIGURE 6 - PRESSURE PROFILE DURING BRAKE DRAG APPLICATIONS
(A) ZERO-BAR PROFILE (B) EXAMPLE OF 15-BAR PROFILE

8.3 IBT control

8.3.1 Brake warm-up operation for dynamic or brake drag applications

If the temperature decreases below the IBT for the next braking condition, warm up the brake by conducting brake drag operation at 50 km/h until the brake temperature is 5 °C above the IBT for the next normal brake application. Control brake pressure at 20 bar for disc brakes, and at 30 bar for drum brakes. Do not conduct brake warm-up for sections with an IBT at or below 30 °C.

NOTE: In cases when a brake warm-up is required for sections with an IBT at or below 30 °C (e.g.: when restarting the test after a test interruption), conduct brake warm-ups at 25 km/h and control brake pressure at 10 bar for disc brakes, and at 15 bar for drum brakes

8.3.2 Brake warm-up during the fade schedules

If the IBT is not obtained (see item 8.4), perform a brake drag apply at 80 km/h with a torque equivalent to 1.96 m/s² deceleration to warm-up the brake. The warm-up procedure should be applied for no more than 20 s. Conducts the noise evaluation only during the stops where the initial temperature matches those indicated for the corresponding schedule.

8.3.3 Brake cool down

If the brake temperature is 5 °C or above the IBT of the next brake application, rotate the brake at 20 km/h until the brake cools down to within 5 °C of the IBT.

8.3.4 Cold temperature soak

When conducting schedule B, cool down the test chamber to 10 °C below the IBT before initiating the brake soak period; see item 4.4.3.

8.4 Brake fade temperatures

The brake fade section is intended to heat up the brake in preparation for the post-fade friction and noise evaluation. The IBTs for each brake application during the fade operation uses a logarithmic temperature profile per Eq. 4.

$$IBT_n = \frac{(IBT_{15} - IBT_1) \cdot \ln(n)}{\ln(15)} + IBT_1 \qquad \text{(Eq. 4)}$$

Where:

n = brake application number; between 1 and 15

IBT_n = Initial brake temperature for the n_{th} brake application / °C

IBT_1 = Initial brake temperature for the first brake application / °C

IBT_{15} = Initial brake temperature for the last brake application / °C

The different fade schedules for disc or drum and front or rear brakes are shown on Table 2 and depicted in Figure 7. The optional fade schedules are more severe and provide higher temperatures. Unless otherwise specified by the test requestor, conduct the standard fade schedule and keep it the same for a given project.

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TABLE 2 - INITIAL BRAKE TEMPERATURES DURING FADE MODULES

Brake type	Disc				Drum	
Axle	Front axle		Rear axle			
Schedule	Standard	Optional	Standard	Optional	Standard	Optional
stop 1 / °C	100	100	100	100	100	100
stop 15 / °C	450	550	250	350	200	300
Stop number	Initial brake temperature / °C					
1	100	100	100	100	100	100
2	190	215	138	164	126	151
3	242	283	161	201	141	181
4	279	330	177	228	151	202
5	308	367	189	249	159	219
6	332	398	199	265	166	232
7	351	423	208	280	172	244
8	369	446	215	292	177	254
9	384	465	222	303	181	262
10	398	483	228	313	185	270
11	410	498	233	321	189	277
12	421	513	238	329	192	284
13	432	526	242	337	195	289
14	441	539	246	344	197	295
15	450	550	250	350	200	300

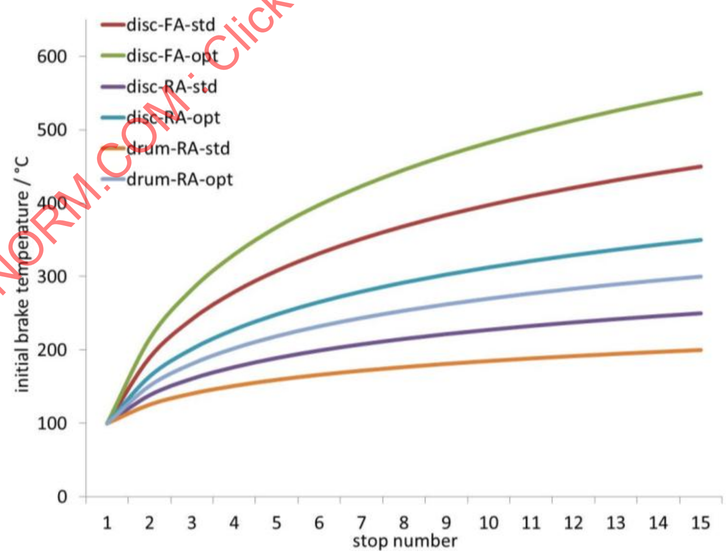

FIGURE 7 - BRAKE FADE TEMPERATURES FOR ALL THE TEST SCHEDULES

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9. TEST SEQUENCES NOMENCLATURE

Since actual testing projects assess brake squeal under multiple options (disc or drum, standard or optional fade temperatures, and other minimum temperatures during the cold module) it is important to clearly identify the actual test sequence requested (or conducted) when specifying (or comparing) test results. Use the following nomenclature to identify the test performed. See items 10.3 for disc brakes and item 11.3 for drum brakes.

Brake-axle-schedules(cold temperature)(fade temperature)

Where:

brake: disc or drum

axle: front (FA) or rear (RA)

schedules: schedules A, B, or C and the sequence actually requested or conducted

(cold temperature): lowest initial brake temperature set-point during the cold module

(fade temperature): maximum initial brake temperature during the fade module; see Table 2

There are three schedules within each test matrix, which can be combined in different modes and with different temperatures during the cold and the fade modules. Unless indicated by the test requestor, do not conduct schedules B or C as they are optional sections - denoted by an (*) on Tables 5 and 8.

EXAMPLE: disc-FA-ABC(0)(450) means: test conducted on a disc brake, front axle, all modules included (A, B, and C), cold module conducted at zero degrees centigrade (0 °C), and fade module conducted with a maximum IBT of 450 °C.

9.1 Before conducting schedule B confirm with the test requestor the lowest temperature and the temperature steps. Confirm with the test requestor any additional temperature steps or modifications to the standard temperatures.

9.2 Before conducting schedule C confirm with the test requestor the fade schedule per item 8.4.

10. DISC BRAKE TEST PARAMETERS AND TEST MATRIX

10.1 Summary for disc brake test matrix

Table 3 indicates the number of brake applications with noise analysis for each option and the corresponding cumulative brake applications for disc brake tests (front or rear; standard or optional sections; schedules A, B, C, or combinations). The nomenclature to indicate the sections and the temperatures selected for the test is indicated on the second row:

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TABLE 3 - NUMBER OF BRAKE APPLICATIONS FOR DISC BRAKES

				Brake-axle-schedules(cold temperature)(fade temperature)									
				disc-FA-A	disc-FA-AB(0)	disc-FA-ABC (0) (450)	disc-FA-ABC (0) (550)	disc-RA-ABC (0) (250)	disc-RA-ABC (0) (350)	disc-FA-AC (-) (450)	disc-FA-AC (-) (550)	disc-RA-AC (-) (250)	disc-RA-AC (-) (350)
Schedule	Sections per schedule		Brake events	Cumulative brake applications									
A	1-18 (standard)[1]		1430	1430	1430	1430	1430	1430	1430	1430	1430	1430	1430
B	19-24 (cold)		460	—	1890	1890	1890	1890	1890	—	—	—	—
C	25-31 (after fade)[2]		487	—	—	2377	2377	2377	2377	1917	1917	1917	1917
	Axle	Fade type	Fade / °C	Schedule C included in the test									
Disc	FA	standard	450	—	—	yes	—	—	—	yes	—	—	—
		optional	550	—	—	—	yes	—	—	—	yes	—	—
	RA	standard	250	—	—	—	—	yes	—	—	—	yes	—
		optional	350	—	—	—	—	—	yes	—	—		yes
Total brake applications for entire test				1430	1890	2377	2377	2377	2377	1917	1917	1917	1917

NOTES:
[1] subtract 28 brake applications when testing rear brakes
[2] subtract 14 brake applications when testing rear brakes

10.2 Pressure profiles and constant pressure sequences for disc brakes

Different modules use different sequences to combine pressure profiles, braking/drag speeds, and initial brake temperatures to build the entire test matrix. Figures 8 to 13 illustrate the pressure and speeds for each type of module during the disc brake test matrix. The actual sequence on Table 5 indicates the initial brake temperature for all brake events during a particular cycle. The corresponding braking or drag speed is shown between () for each brake event. Apply the test sequences at each temperature step during the applicable cycle before moving on to the next temperature step.

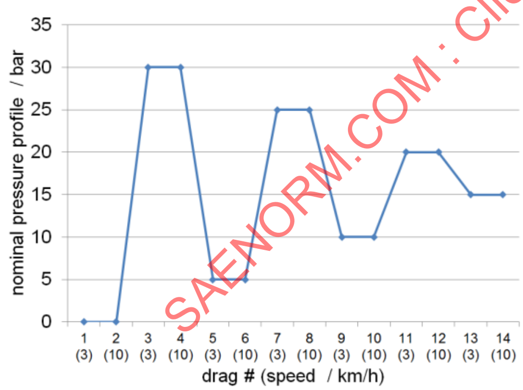

FIGURE 8 - DISC DRAG MODULE (3 & 10 KM/H)

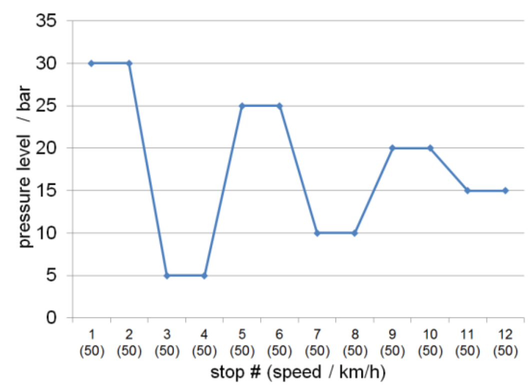

FIGURE 9 - DISC INTERMEDIATE CONDITIONING AND WARM-UP STOP MODULE (50 KM/H)

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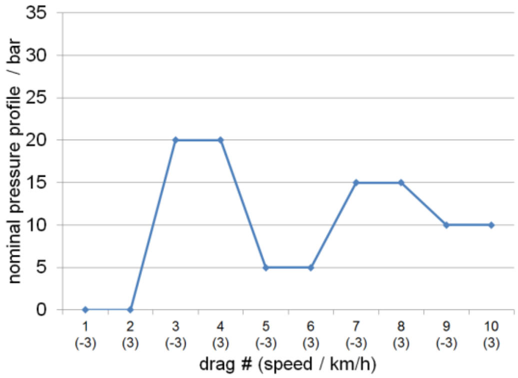

FIGURE 10 - DISC BACKWARD / FORWARD DRAG MODULE (-3 & 3 KM/H)

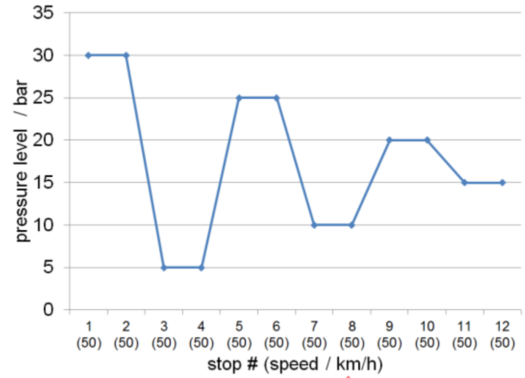

FIGURE 11 - DISC DECELERATION STOP MODULE (50 KM/H)

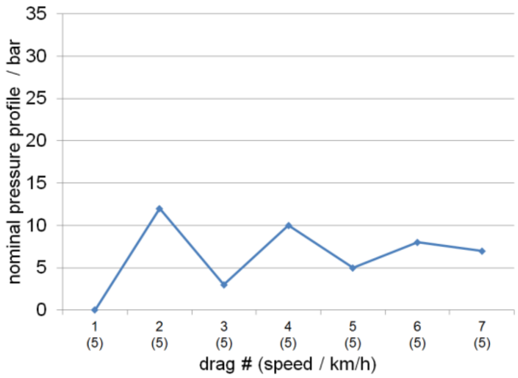

FIGURE 12 - DISC COLD LOW SPEED DRAG MODULE (5 KM/H)

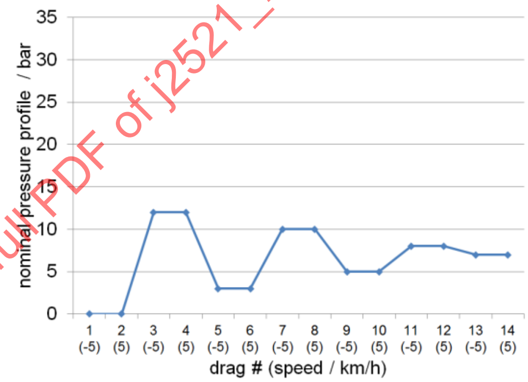

FIGURE 13 - DISC COLD BACKWARD / FORWARD LOW SPEED DRAG MODULE (-5 & 5 KM/H)

10.3 Test matrix and parameters

The different sections within the disc test matrix combine different speed, temperature, and pressure steps to generate the total number of brake applications. Table 4 illustrates these combinations and the calculation to generate the number of brake applications per section. Drag applications use a pressure profile, while stops use a constant pressure levels.

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TABLE 4 - TOTAL BRAKE APPLICATIONS PER TYPE OF SECTION WHEN USING COMBINATIONS OF SPEED, TEMPERATURE, AND PRESSURE LEVELS FOR DISC BRAKE MATRIX

Sections	Module description	Pressure control	Pressure levels N_p	Test speeds N_s	Repetitions at each speed N_r	Temperature steps N_t	Total brake events per section $N_T=N_pxN_sxN_rxN_t$
4, 9, 14, and 27	Drag module — Fig. 8	Profile	7	2	1	19 (17)	266 (238)
5, 10, 15, and 28	Intermediate conditioning and warm-up — Fig. 9	Constant	6	1	2	2	24
6, 11, 16, and 29	Backward / forward drag — Fig. 10	Profile	5	2	1	5	50
7, 12, 17, and 30	Deceleration stops — Fig. 11	Constant	6	1	2	9	108
19 and 22	Cold drag / low speed — Fig. 12	Profile	7	1	1	11	77
20 and 23	Cold backward / forward drag — Fig. 13	Profile	7	2	1	7	98

NOTE: numbers in () for sections 4, 9, 14, and 27 apply to rear brake testing

Table 5 indicates the test sequence, modules, cycles, number of brake events, and the specific set-points for each type of brake application. For sections combining multiple brake pressures, brake speeds, repetitions, and brake temperature steps, the test sequence splits the module into cycles. E.g.: section 4.a – Drag module for front brakes – includes 19 cycles; one at each IBT (50 to 300 °C and back to 50 °C, in 25 to 50 °C steps). Each cycle includes two brake drag applications (one at 3 km/h and one at 10 km/h) per item 8.2 at each test pressure (0, 30, 5, 25, 10, 20, and 15 bar). At the end of each cycle, the brake temperature is increased (or decreased) to the next IBT and the cycle repeats. The (↑) symbol indicates the test conditions from the row above apply.

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TABLE 5 - DISC BRAKE SQUEAL MATRIX

Module	Section description	# of Stops/ Drags total	Braking/Drag Speed / km/h	Release speed / km/h	Initial brake temperature / °C	Control level (pressure unless noted) / bar	Pressure control mode	Brake events per cycle
	Initial inspection and measurements	Measure brake pads and rotor, inspect parts for initial condition, fit and function, and verify instrumentation setup (accelerometer attachment and position when applicable)						
	Microphone calibration	Verify using a calibrated sound source a microphone reading of 94 dB(A) at 1 kHz						
	Background noise verification	Verify background noise is below 64 dB(A) at 900 Hz or higher						
1	Break-in	30	80	30	100	30	Constant	30
2	Burnish (conduct one brake application at each pressure step)	32	80	30	100	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	Constant	32
3	Friction characteristic after burnish (1)	6	80	30	100	30	Constant	6
4.a	Drag module front brakes (1) — Fig. 8.a	266	3 & 10 alternating	3 & 10 alternating	—	0, 30, 5, 25, 10, 20, 15	Profile	—
4.1 to 4.19	Drag cycles (one cycle at each temperature)		↑	↑	50, 75, 100, 125, 150, 175, 200, 225, 250, 300, 250, 225, 200, 175, 150, 125, 100, 75, 50	↑	↑	14

TABLE 5 - DISC BRAKE SQUEAL MATRIX (CONTINUED)

Module	Section description	# of Stops/ Drags total	Braking/Drag Speed / km/h	Release speed / km/h	Initial brake temperature / °C	Control level (pressure unless noted) / bar	Pressure control mode	Brake events per cycle
4.b	Drag module rear brakes (1) — Fig. 8.b	238	3 & 10 alternating	3 & 10 alternating	—	0, 30, 5, 25, 10, 20, 15	Profile	—
4.1 to 4.17	Drag cycles (one cycle at each temperature)		↑	↑	50, 75, 100, 125, 150, 175, 200, 225, 250, 225, 200, 175, 150, 125, 100, 75, 50	↑	↑	14
5	Intermediate conditioning stops and warm-up module (1) — Fig. 9	24	50	0.5	—	30, 5, 25, 10, 20, 15	Constant	—
5.1 – 5.2	Intermediate conditioning cycles (one cycle at each temperature)		↑	↑	100, 150	↑	↑	12
6	Backward/forward drag module (1) — Fig. 10	50	-3 & 3 alternating	-3 & 3 alternating	—	0, 20, 5, 15, 10	Profile	—
6.1 to 6.5	Backward/forward drag cycles (one cycle at each temperature)		↑	↑	150, 125, 100, 75, 50	↑	↑	10
7	Deceleration stops module (1) — Fig. 11	108	50	0.5	—	30, 5, 25, 10, 20, 15	Constant	—
7.1 to 7.9	Deceleration stop cycles (one cycle at each temperature)		↑	↑	50, 100, 150, 200, 250, 200, 150, 100, 50	↑	↑	12
8	Friction characteristic (2)	6	80	30	100	30	Constant	6
9.a	Drag module front brakes (1) — Fig. 8.a	266	3 & 10 alternating	3 & 10 alternating	—	0, 30, 5, 25, 10, 20, 15	Profile	—
9.1 to 9.19	Drag cycles (one cycle at each temperature)		↑	↑	50, 75, 100, 125, 150, 175, 200, 225, 250, 300, 250, 225, 200, 175, 150, 125, 100, 75, 50	↑	↑	14
9.b	Drag module rear brakes (1) — Fig. 8.b	238	3 & 10 alternating	3 & 10 alternating	—	0, 30, 5, 25, 10, 20, 15	Profile	—
9.1 to 9.17	Drag cycles (one cycle at each temperature)		↑	↑	50, 75, 100, 125, 150, 175, 200, 225, 250, 225, 200, 175, 150, 125, 100, 75, 50	↑	↑	14
10	Intermediate conditioning stops and warm-up module (2) — Fig. 9	24	50	0.5	—	30, 5, 25, 10, 20, 15	Constant	—
10.1 – 10.2	Intermediate conditioning cycles (one cycle at each temperature)		↑	↑	100, 150	↑	↑	12
11	Backward/forward drag module (2) — Fig. 10	50	-3 & 3 alternating	-3 & 3 alternating	—	0, 20, 5, 15, 10	Profile	—
11.1 to 11.5	Backward/forward drag cycles (one cycle at each temperature)		↑	↑	150, 125, 100, 75, 50	↑	↑	10
12	Deceleration stops module (2) — Fig. 11	108	50	0.5	—	30, 5, 25, 10, 20, 15	Constant	—
12.1 to 12.9	Deceleration stop cycles (one cycle at each temperature)		↑	↑	50, 100, 150, 200, 250, 200, 150, 100, 50	↑	↑	12

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TABLE 5 - DISC BRAKE SQUEAL MATRIX (CONTINUED)

Module	Section description	# of Stops/ Drags total	Braking/Drag Speed / km/h	Release speed / km/h	Initial brake temperature / °C	Control level (pressure unless noted) / bar	Pressure control mode	Brake events per cycle
13	Friction characteristic module (2)	6	80	30	100	30	Constant	6
14.a	Drag module front brakes (1) — Fig. 8.a	266	3 & 10 alternating	3 & 10 alternating	—	0, 30, 5, 25, 10, 20, 15	Profile	—
14.1 to 14.19	Drag cycles (one cycle at each temperature)		↑	↑	50, 75, 100, 125, 150, 175, 200, 225, 250, 300, 250, 225, 200, 175, 150, 125, 100, 75, 50	↑	↑	14
14.b	Drag module rear brakes (1) — Fig. 8.b	238	3 & 10 alternating	3 & 10 alternating	—	0, 30, 5, 25, 10, 20, 15	Profile	—
14.1 to 14.17	Drag cycles (one cycle at each temperature)		↑	↑	50, 75, 100, 125, 150, 175, 200, 225, 250, 225, 200, 175, 150, 125, 100, 75, 50	↑	↑	14
15	Intermediate conditioning stops and warm-up module (3) — Fig. 9	24	50	0.5	—	30, 5, 25, 10, 20, 15	Constant	—
15.1 – 15.2	Intermediate conditioning cycles (one cycle at each temperature)		↑	↑	100, 150	↑	↑	12
16	Backward/forward drag module (3) — Fig. 10	50	-3 & 3 alternating	-3 & 3 alternating	—	0, 20, 5, 15, 10	Profile	—
16.1 to 16.5	Backward/forward drag cycles (one cycle at each temperature)		↑	↑	150, 125, 100, 75, 50	↑	↑	10
17	Deceleration stops module (3) — Fig. 11	108	50	0.5	—	30, 5, 25, 10, 20, 15	Constant	—
17.1 to 17.9	Deceleration stop cycles (one cycle at each temperature)		↑	↑	50, 100, 150, 200, 250, 200, 150, 100, 50	↑	↑	12
18	Friction characteristic module (4)	6	80	30	100	30	Constant	6
	Background noise verification	Verify background noise is below 64 dB(A) at 900 Hz or higher						
	Microphone calibration	Verify using a calibrated sound source a microphone reading of 94 dB(A) at 1 kHz						
	Final inspection and measurements for schedule Disc-A	Measure wear and inspect parts for structural integrity, friction material delaminating, detachment, lifting, leaks, missing or broken hardware, braking surface condition, noise insulator condition and integrity, and instrumentation setup (accelerometer attachment and position when applicable)						
	End of test schedule Disc-A							
19*	Cold drag / low speed module (1) — Fig. 12	77	5	5	—	0, 12, 3, 10, 5, 8, 7	Profile	—
19.0	Cold drag soak	Bring the test chamber to approximately 10 °C below the cold soak IBT Soak brake assembly without rotating or applying brake pressure for 45 to 60 minutes after reaching the IBT set-point						
19.1 to 19.11	Cold drag / low speed cycle (one cycle at each temperature)		↑	↑	0, 10, 20, 30, 40, 50, 40, 30, 20, 10, 0	↑	↑	7
20*	Cold drag / moderate speed module (1)	55	30	30	—	20 bar at 20 bar/s 4 s total duration	20 bar/s	—
20.1 to 20.11	Cold drag / moderate speed cycle (one cycle at each temperature)		↑	↑	0, 10, 20, 30, 40, 50, 40, 30, 20, 10, 0	↑	↑	5

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TABLE 5 - DISC BRAKE SQUEAL MATRIX (CONTINUED)

Module	Section description	# of Stops/ Drags total	Braking/Drag Speed / km/h	Release speed / km/h	Initial brake temperature / °C	Control level (pressure unless noted) / bar	Pressure control mode	Brake events per cycle
21*	Cold backward/forward drag module (1) — Fig. 13	98	-5 & 5 alternating	-5 & 5 alternating	—	0, 12, 3, 10, 5, 8, 7	Profile	—
21.1 to 21.7	Cold backward/forward cycle (one cycle at each temperature)		↑	↑	0, 5, 10, 20, 30, 40, 50	↑	↑	14
22*	Cold drag / low speed module (2) — Fig. 12	77	5	5	—	0, 12, 3, 10, 5, 8, 7	Profile	—
22.1 to 22.11	Cold drag / low speed cycle (one cycle at each temperature)		↑	↑	0, 10, 20, 30, 40, 50, 40, 30, 20, 10, 0	↑	↑	7
23*	Cold drag / moderate speed module (2)	55	30	30	—	20 bar at 20 bar/s 4 s total duration	20 bar/s	—
23.1 to 23.11	Cold drag / moderate speed cycle (one cycle at each temperature)		↑	↑	0, 10, 20, 30, 40, 50, 40, 30, 20, 10, 0	↑	↑	5
24*	Cold backward/forward drag module (2) — Fig. 13	98	-5 & 5 alternating	-5 & 5 alternating	—	0, 12, 3, 10, 5, 8, 7	Profile	—
24.1 to 24.7	Cold backward/forward cycle (one cycle at each temperature)		↑	↑	0, 5, 10, 20, 30, 40, 50	↑	↑	14
	Background noise verification	Verify background noise is below 64 dB(A) at 900 Hz or higher						
	Microphone calibration	Verify using a calibrated sound source a microphone reading of 94 dB(A) at 1 kHz						
	Final inspection and measurements for schedule Disc-B	Measure wear and inspect parts for structural integrity, friction material delaminating, detachment, lifting, leaks, missing or broken hardware, braking surface condition, noise insulator condition and integrity, and instrumentation setup (accelerometer attachment and position when applicable)						
	End of test schedule Disc-B							
25*	Temperature fade stop module	15	100	0.5	see section 8.4 and Table 2	3.92 m/s²	Constant	15
26*	Recovery subs module	18	80	30	100	30	Constant	18
27.a*	Drag module front brakes (1) — Fig. 8.a	266	3 & 10 alternating	3 & 10 alternating	–	0, 30, 5, 25, 10, 20, 15	Profile	–
27.1 to 27.19	Drag cycles (one cycle at each temperature)		↑	↑	50, 75, 100, 125, 150, 175, 200, 225, 250, 300, 250, 225, 200, 175, 150, 125, 100, 75, 50	↑	↑	14
27.b*	Drag module rear brakes (1) — Fig. 8.b	238	3 & 10 alternating	3 & 10 alternating	–	0, 30, 5, 25, 10, 20, 15	Profile	–
27.1 to 27.17	Drag cycles (one cycle at each temperature)		↑	↑	50, 75, 100, 125, 150, 175, 200, 225, 250, 225, 200, 175, 150, 125, 100, 75, 50	↑	↑	14
28*	Intermediate conditioning stops and warm-up module (4) — Fig. 9	24	50	0.5	–	30, 5, 25, 10, 20, 15	Constant	–
28.1 – 28.2	Intermediate conditioning cycles (one cycle at each temperature)		↑	↑	100, 150	↑	↑	12

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TABLE 5 - DISC BRAKE SQUEAL MATRIX (CONTINUED)

Module	Section description	# of Stops/ Drags total	Braking/Drag Speed / km/h	Release speed / km/h	Initial brake temperature / °C	Control level (pressure unless noted) / bar	Pressure control mode	Brake events per cycle
29*	Backward/forward drag module (4) — Fig. 10	50	-3 & 3 alternating	-3 & 3 alternating	–	0, 20, 5, 15, 10	Profile	–
29.1 to 6.5	Backward/forward drag cycles (one cycle at each temperature)		↑	↑	150, 125, 100, 75, 50	↑	↑	10
30*	Deceleration stops module (4) — Fig. 11	108	50	0.5	–	30, 5, 25, 10, 20, 15	Constant	–
30.1 to 30.9	Deceleration stop cycles (one cycle at each temperature)		↑	↑	50, 100, 150, 200, 250, 200, 150, 100, 50	↑	↑	12
31*	Friction characteristic (5)	6	80	30	100	30	Constant	6
	Background noise verification	Verify background noise is below 64 dB(A) at 900 Hz or higher						
	Microphone calibration	Verify using a calibrated sound source a microphone reading of 94 dB(A) at 1 kHz						
	Final inspection and measurements for schedule Disc-C	Measure wear and inspect parts for structural integrity, friction material delaminating, detachment, lifting, leaks, missing or broken hardware, braking surface condition, noise insulator condition and integrity, and instrumentation setup (accelerometer attachment and position when applicable)						
	End of test schedule Disc-C							

11. DRUM BRAKE TEST PARAMETERS AND TEST MATRIX

11.1 Summary for drum brake test matrix

Similar to item 10.1, Table 6 indicates the number of brake applications with noise analysis for each option and the corresponding cumulative brake applications for drum brake tests (front or rear; standard or optional sections; schedules A, B, C, or combinations). The nomenclature to indicate the sections and the temperatures selected for the test is indicated on the second row:

TABLE 6 - NUMBER OF BRAKE APPLICATIONS FOR DRUM BRAKES

				Brake-axle-schedules(cold temperature)(fade temperature)					
				drum-RA-A	drum-RA-AB(0)	drum-RA-ABC(0)(200)	drum-RA-ABC(0)(300)	drum-RA-AC(-)(200)	drum-RA-AC(-)(300)
Schedule	Sections per schedule		Brake events	Cumulative brake applications					
A	1-18 (standard sections)		1908	1908	1908	1908	1908	1908	1908
B	19-24 (cold matrix)		506	—	2414	2414	2414	—	—
C	25-31 (after fade)		363	—	—	2777	2777	2271	2271
Brake	Axle	Fade type	Fade / °C	Schedule C included in the test					
Drum	RA	standard	200	—	—	yes	—	yes	—
		optional	300	—	—	—	yes		yes
Total brake applications for entire test				1908	2414	2777	2777	2271	2271

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11.2 Pressure profiles and constant pressure sequences for drum brakes

Similar to item 10.2, Figures 14 to 19 illustrate the different combination of test speeds and pressure levels for each type of brake application.

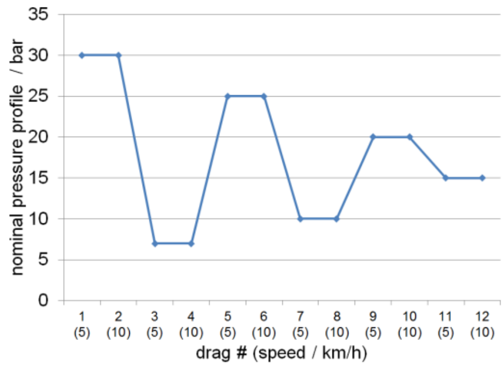

FIGURE 14 - DRUM LOW SPEED DRAG MODULE (5 & 10 KM/H)

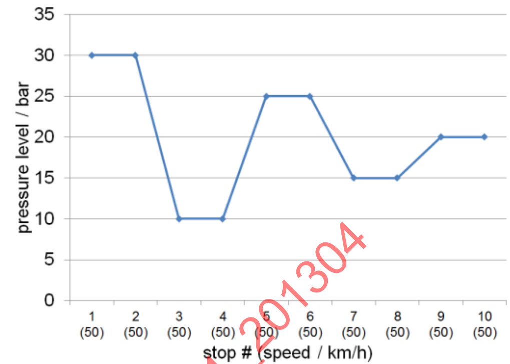

FIGURE 15 - DRUM CONDITIONING STOPS MODULE (50 KM/H)

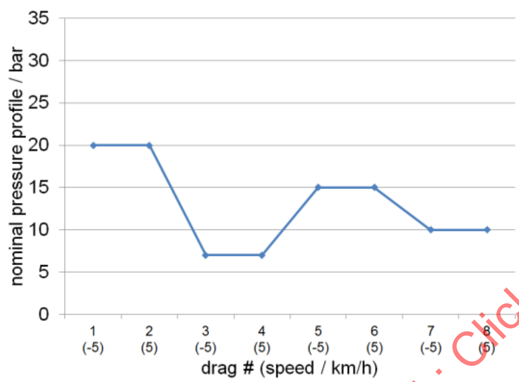

FIGURE 16 - DRUM BACKWARD / FORWARD LOW SPEED DRAG MODULE (-5 & 5 KM/H)

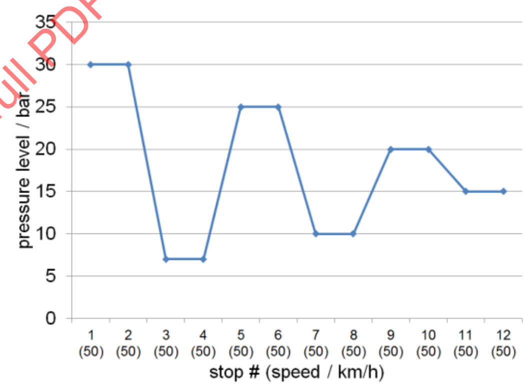

FIGURE 17 - DRUM DECELERATION STOP MODULE (50 KM/H)

FIGURE 18 - DRUM COLD DRAG / LOW-SPEED MODULE (5 KM/H)

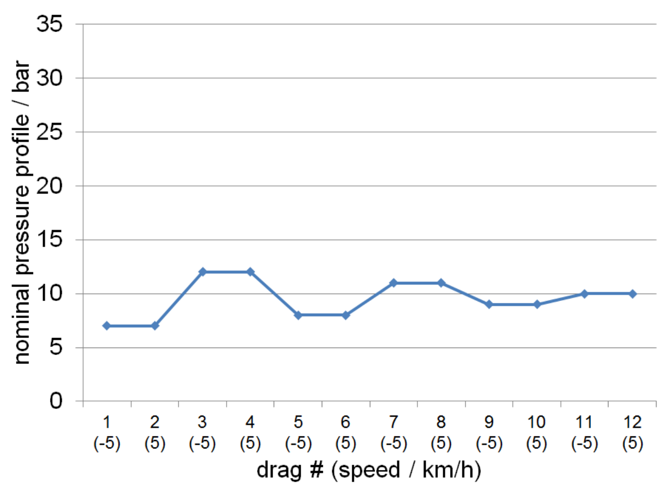

FIGURE 19 - DRUM COLD BACKWARD / FORWARD DRAG MODULE (-5 & 5 KM/H)

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11.3 Test matrix and parameters

The different sections within the drum test matrix combine different speed, temperature, and pressure steps to generate the total number of brake applications. Table 7 illustrates these combinations and the calculation to generate the number of brake applications per section. Drag applications use a pressure profile, while stops use a constant pressure levels.

TABLE 7 - TOTAL BRAKE APPLICATIONS PER TYPE OF SECTION WHEN USING COMBINATIONS OF SPEED, TEMPERATURE, AND PRESSURE LEVELS FOR DRUM BRAKE MATRIX

Sections	Module description	Pressure control	Pressure levels N_p	Test speeds N_s	Repetitions at each speed N_r	Temperature steps N_t	Total brake events per section $N_T=N_pxN_sxN_rxN_t$
3, 9. 14, and 27	Drag module — Fig. 14	Profile	6	2	1	11	132
4, 10, 15, and 28	Intermediate conditioning and warm-up — Fig. 15	Constant	5	1	2	2	20
5, 11, 16, and 29	Backward / forward drag — Fig. 16	Profile	4	2	1	5	40
6, 12, 17, and 30	Deceleration stops — Fig. 17	Constant	6	1	2	11	132
19, and 22	Cold drag / low speed — Fig. 18	Profile	6	1	1	11	66
20, and 23	Cold drag / moderate speed	Ramp to constant	1	1	5	11	55
21, and 24	Cold backward / forward drag — Fig. 19	Profile	6	2	1	11	132

Similar to item 10.3, Table 8 indicates the test sequence, modules, cycles, number of brake events, and the specific set-points for each type of brake application.

TABLE 8 - DRUM BRAKE NOISE MATRIX

Module	Section description	# of Stops/ Drags total	Braking/Drag Speed / km/h	Release speed / km/h	Initial brake temperature / °C	Control level (pressure unless noted) / bar	Pressure control mode	Brake events per cycle
	Initial inspection and measurements	Measure brake shoes and drum, inspect parts for initial condition, fit and function, and verify instrumentation setup (accelerometer attachment and position when applicable)						
	Microphone calibration	Verify using a calibrated sound source a microphone reading of 94 dB(A) at 1 kHz						
	Background noise verification	Verify background noise is below 64 dB(A) at 900 Hz or higher						
1	Burnish	202	80	0.5	100 or 1.6 km cycle distance	—	Constant	—
1.1 to 1.8	Burnish cycle at moderate speed (one cycle at each temperature)		↑	↑	↑	2.94, 0.98, 2.45, 1.96, 2.94, 0.98, 2.45, 1.96 m/s²	↑	25
1.9	Burnish cycle at low speed (one cycle at each temperature)		-40	-.05	↑	2.94 m/s²	↑	2
2	Friction characteristic after burnish (1)	6	80	0.5	100	30	Constant	6

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TABLE 8 - DRUM BRAKE NOISE MATRIX (CONTINUED)

Module	Section description	# of Stops/ Drags total	Braking/Drag Speed / km/h	Release speed / km/h	Initial brake temperature / °C	Control level (pressure unless noted) / bar	Pressure control mode	Brake events per cycle
3	Drag module (1) — Fig. 14	132	5 & 10 alternating	5 & 10 alternating	—	30, 5, 25, 10, 20, 15	Profile	—
3.1 to 3.11	Drag cycles (one cycle at each temperature)		↑	↑	75, 100, 125, 150, 175, 200, 175, 150, 125, 100, 75	↑	↑	12
4	Intermediate conditioning stops module (1) — Fig. 15	20	50	0.5	—	30, 10, 25, 15, 20	Constant	—
4.1 – 4.2	Intermediate conditioning cycles		↑	↑	100, 150	↑	↑	10
5	Backward/forward drag module (1) — Fig. 16	40	-5 & 5 alternating	-5 & 5 alternating	—	20, 5, 15, 10	Profile	—
5.1 to 5.5	Backward/forward cycle (one cycle at each temperature)		↑	↑	150, 125, 100, 75, 50	↑	↑	8
6	Deceleration stops module (1) — Fig. 17	132	50	0.5	—	30, 7, 25, 10, 20, 15	Constant	—
6.1 to 6.11	Deceleration stop cycles (one cycle at each temperature)		↑	↑	75, 100, 125, 150, 175, 200, 175, 150, 125, 100, 75	↑	↑	12
7.a	Second burnish at 100 °C	202	80	0.5	100 or 1.6 km cycle distance	—	Constant	—
7.1 to 7.8	Burnish cycle at moderate speed		↑	↑	↑	2.94, 0.98, 2.45, 1.96, 2.94, 0.98, 2.45, 1.96 m/s²	↑	25
7.9	Burnish cycle at low speed		40 revolutions per minute	2 revolutions per minute	↑	2.94 m/s²	↑	2
7.b	Second burnish at 150 °C	102	80	0.5	150	—	Constant	—
7.10 to 7.13	Burnish cycle at moderate speed (conduct 25 stops at each deceleration step)		↑	↑	↑	2.94, 0.98, 2.45, 1.96 m/s²	↑	25
7.14	Burnish cycle at low speed		40 revolutions per minute	2 revolutions per minute	↑	2.94 m/s²	↑	2
7.c	Second burnish at 200 °C	102	80	0.5	200	—	Constant	—
7.15 to 7.18	Burnish cycle at moderate speed (conduct 25 stops at each deceleration step)		↑	↑	↑	2.94, 0.98, 2.45, 1.96 m/s²	↑	25
7.19	Burnish cycle at low speed		40 revolutions per minute	2 revolutions per minute	↑	2.94 m/s²	↑	2
7.d	Second burnish at 150 °C	102	80	0.5	150	—	Constant	—
7.20 to 7.23	Burnish cycle at moderate speed (conduct 25 stops at each deceleration step)		↑	↑	↑	2.94, 0.98, 2.45, 1.96 m/s²	↑	25
7.24	Burnish cycle at low speed		40 revolutions per minute	2 revolutions per minute	↑	2.94 m/s²	↑	2

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TABLE 8 - DRUM BRAKE NOISE MATRIX (CONTINUED)

Module	Section description	# of Stops/ Drags total	Braking/Drag Speed / km/h	Release speed / km/h	Initial brake temperature / °C	Control level (pressure unless noted) / bar	Pressure control mode	Brake events per cycle
7.e	Second burnish at 100 °C	102	80	0.5	100	—	Constant	—
7.25 to 7.28	Burnish cycle at moderate speed (conduct 25 stops at each deceleration step)		↑	↑	↑	2.94, 0.98, 2.45, 1.96 m/s²	↑	25
7.29	Burnish cycle at low speed		40 revolutions per minute	2 revolutions per minute	↑	2.94 m/s²	↑	2
7.f	Second burnish at 125 °C	100	80	0.5	125	—	Constant	—
7.30 to 7.33	Burnish cycle at moderate speed (conduct 25 stops at each deceleration step)		↑	↑	↑	2.94, 0.98, 2.45, 1.96 m/s²	↑	25
8	Friction characteristic (2)	6	80	0.5	100	30	Constant	6
9	Drag module (2) — Fig. 14	132	5 & 10 alternating	5 & 10 alternating	—	30, 5, 25, 10, 20, 15	Profile	—
9.1 to 9.11	Drag cycles (one cycle at each temperature)		↑	↑	75, 100, 125, 150, 175, 200, 175, 150, 125, 100, 75	↑	↑	12
10	Intermediate conditioning stops module (2) — Fig. 15	20	50	0.5	—	30, 10, 25, 15, 20	Constant	—
10.1 – 10.2	Intermediate conditioning cycles		↑	↑	100, 150	↑	↑	10
11	Backward/forward drag module ((2) — Fig. 16	40	-5 & 5 alternating	-5 & 5 alternating	—	20, 5, 15, 10	Profile	—
11.1 to 11.5	Backward/forward cycle (one cycle at each temperature)		↑	↑	150, 125, 100, 75, 50	↑	↑	8
12	Deceleration stops module (2) — Fig. 17	132	50	0.5	—	30, 5, 25, 10, 20, 15	Constant	—
12.1 to 12.11	Deceleration stop cycles (one cycle at each temperature)		↑	↑	75, 100, 125, 150, 175, 200, 175, 150, 125, 100, 75	↑	↑	12
13	Friction characteristic (3)	6	80	0.5	100	30	Constant	6
14	Drag module (3) — Fig. 14	132	5 & 10 alternating	5 & 10 alternating	—	30, 5, 25, 10, 20, 15	Profile	—
14.1 to 14.11	Drag cycles (one cycle at each temperature)		↑	↑	75, 100, 125, 150, 175, 200, 175, 150, 125, 100, 75	↑	↑	12
15	Intermediate conditioning stops module (3) — Fig. 15	20	50	0.5	—	30, 10, 25, 15, 20	Constant	—
15.1 – 15.2	Intermediate conditioning cycles		↑	↑	100, 150	↑	↑	10
16	Backward/forward drag module (3) — Fig. 16	40	-5 & 5 alternating	-5 & 5 alternating	—	20, 5, 15, 10	Profile	—
16.1 to 16.5	Backward/forward cycle (one cycle at each temperature)		↑	↑	150, 125, 100, 75, 50	↑	↑	8

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TABLE 8 - DRUM BRAKE NOISE MATRIX (CONTINUED)

Module	Section description	# of Stops/ Drags total	Braking/Drag Speed / km/h	Release speed / km/h	Initial brake temperature / °C	Control level (pressure unless noted) / bar	Pressure control mode	Brake events per cycle
17	Deceleration stops module (3) — Fig. 17	132	50	0.5	—	30, 5, 25, 10, 20, 15	Constant	—
17.1 to 17.11	Deceleration stop cycles (one cycle at each temperature)		↑	↑	75, 100, 125, 150, 175, 200, 175, 150, 125, 100, 75	↑	↑	12
18	Friction characteristic module (4)	6	80	30	100	30	Constant	6
	Background noise verification	Verify background noise is below 64 dB(A) at 900 Hz or higher						
	Microphone calibration	Verify using a calibrated sound source a microphone reading of 94 dB(A) at 1 kHz						
	Final inspection and measurements for schedule Drum-A	Measure wear and inspect parts for structural integrity, friction material delaminating, detachment, lifting, leaks, missing or broken hardware, braking surface condition, and instrumentation setup (accelerometer attachment and position when applicable)						
19*	Cold drag / low speed module (1) — Fig. 18	66	5	5	—	7, 12, 8, 11, 9, 10	Profile	—
19.0	Cold drag soak	Bring the test chamber to approximately 10 °C below the cold soak IBT Soak brake assembly without rotating or applying brake pressure for 45 to 60 minutes after reaching the IBT set-point						
19.1 to 19.11	Cold drag / low speed cycle (one cycle at each temperature)		↑	↑	0, 10, 20, 30, 40, 50, 40, 30, 20, 10, 0	↑	↑	6
20*	Cold drag / moderate speed module (1)	55	30	30	—	20 bar at 20 bar/s 4 s total duration	20 bar/s	—
20.1 to 20.11	Cold drag / moderate speed cycle (one cycle at each temperature)		↑	↑	0, 10, 20, 30, 40, 50, 40, 30, 20, 10, 0	↑	↑	5
21*	Cold backward/forward drag module (1) — Fig. 19	132	-5 & 5 alternating	-5 & 5 alternating	—	7, 12, 8, 11, 9, 10	Profile	—
21.1 to 21.7	Cold backward/forward cycle (one cycle at each temperature)		↑	↑	0, 10, 20, 30, 40, 50, 40, 30, 20, 10, 0	↑	↑	12
22*	Cold drag / low speed module (2) — Fig. 18	66	5	5	—	7, 12, 8, 11, 9, 10	Profile	—
22.1 to 22.11	Cold drag / low speed cycle (one cycle at each temperature)		↑	↑	0, 10, 20, 30, 40, 50, 40, 30, 20, 10, 0	↑	↑	6
23*	Cold drag / moderate speed module (2)	55	30	30	—	20 bar at 20 bar/s 3 s total duration	20 bar/s	—
23.1 to 23.11	Cold drag / moderate speed cycle (one cycle at each temperature)		↑	↑	0, 10, 20, 30, 40, 50, 40, 30, 20, 10, 0	↑	↑	5

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TABLE 8 - DRUM BRAKE NOISE MATRIX (CONTINUED)

Module	Section description	# of Stops/ Drags total	Braking/Drag Speed / km/h	Release speed / km/h	Initial brake temperature / °C	Control level (pressure unless noted) / bar	Pressure control mode	Brake events per cycle
24*	Cold backward/forward drag module (2) — Fig. 19	132	-5 & 5 alternating	-5 & 5 alternating	—	7, 12, 8, 11, 9, 10	Profile	—
24.1 to 24.7	Cold backward/forward cycle (one cycle at each temperature)		↑	↑	0, 10, 20, 30, 40, 50, 40, 30, 20, 10, 0	↑	↑	12
	Background noise verification	Verify background noise is below 64 dB(A) at 900 Hz or higher						
	Microphone calibration	Verify using a calibrated sound source a microphone reading of 94 dB(A) at 1 kHz						
	Final inspection and measurements for schedule Drum-B	Measure wear and inspect parts for structural integrity, friction material delaminating, detachment, lifting, leaks, missing or broken hardware, braking surface condition, and instrumentation setup (accelerometer attachment and position when applicable)						
25*	Temperature fade stop module	15	100	0.5	see section 8.4 and Table 2	3.92 m/s²	Constant	15
26*	Recovery subs module	18	80	30	100	30	Constant	18
27*	Drag module (4) — Fig. 14	132	5 & 10 alternating	5 & 10 alternating	—	30, 5, 25, 10, 20, 15	Profile	—
27.1 to 27.11	Drag cycles (one cycle at each temperature)		↑	↑	75, 100, 125, 150, 175, 200, 175, 150, 125, 100, 75	↑	↑	12
28*	Intermediate conditioning stops module (4) — Fig. 15	20	50	0.5	—	30, 10, 25, 15, 20	Constant	—
28.1 – 28.2	Intermediate conditioning cycles		↑	↑	100, 150	↑	↑	10
29*	Backward/forward drag module (4) — Fig. 16	40	-5 & 5 alternating	-5 & 5 alternating	—	20, 5, 15, 10	Profile	—
29.1 to 29.5	Backward/forward cycle (one cycle at each temperature)		↑	↑	150, 125, 100, 75, 50	↑	↑	8
30*	Deceleration stops module (4) — Fig. 17	132	50	0.5	—	30, 5, 25, 10, 20, 15	Constant	—
30.1 to 30.11	Deceleration stop cycles (one cycle at each temperature)		↑	↑	75, 100, 125, 150, 175, 200, 175, 150, 125, 100, 75	↑	↑	12
31*	Friction characteristic (4)	6	80	0.5	100	30	Constant	6
	Background noise verification	Verify background noise is below 64 dB(A) at 900 Hz or higher						
	Microphone calibration	Verify using a calibrated sound source a microphone reading of 94 dB(A) at 1 kHz						
	Final inspection and measurements for schedule Drum-C	Measure wear and inspect parts for structural integrity, friction material delaminating, detachment, lifting, leaks, missing or broken hardware, braking surface condition, and instrumentation setup (accelerometer attachment and position when applicable)						
	End of test schedule Drum-C							

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12. NOISY BRAKE APPLICATIONS

Unless specified by the test requestor, use the following definitions for a noisy brake event (see VDA 303)

12.1 Frequency ranges to report noisy brake applications:

12.1.1 Lower limit of 2 kHz when utilizing a knuckle fixture (L1); or 1.25 kHz when utilizing a full suspension corner (L2), or full axle (L3) fixtures;

12.1.2 Upper limit of 16 kHz

12.2 At least one peak equal to or greater than 70 dB(A) within the frequency range, separate from the closest peak by at least 150 Hz (or 2.5% of the peak frequency), and 6 dB(A) above the mean noise level measure for the range of ± 75 Hz (or ±1.25% of the frequency) above and below the peak level

NOTE 1: the actual test report will include separate charts for the maximum peak and the three loudest peaks for all brake applications with sound pressure level equal to or greater than 70 dB(A)

NOTE 2: as only squeal noise is considered as part of the evaluation, the treatment of other types of noise that might occur during the test needs discussion and decision from the test requestor, prior to testing and generating the corresponding test report

13. SUMMARY OF TEST RESULTS

In order to present test results in a systematic manner, combine charts and tabular results as the default and minimum test report structure and layout (see Appendix A).

13.1 Use charts to provide graphical depiction of the different noisy brake events per item 12 in relationship with (or as a function of) brake temperature, pressure, speed, test history, and frequency.

13.2 Summary table of noisy brake events per item 12 and occurrence for different types of brake applications for each frequency range. See example in Table 9.

13.3 Optional - Digital pictures showing the cooling air setup, fixture design, and driving method.

13.4 Optional - Digital pictures showing the friction material, the brake rotor or drum, and the noise insulator (when applicable) at the end of the test.

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TABLE 9 - TABULAR SUMMARY OF NOISY STOPS PER TYPE OF SECTION AND FREQUENCY CLASS

		Number of noisy stops				Percentage of noisy stops			
Frequency range	Threshold	Overall	Drag	Decel	Back/ Fwd	Overall	Drag	Decel	Back/Fwd
2 kHz to 16 kHz	>70 dB(A)	32	30	2	0	2.2%	3.8%	0.4%	0.0%
	>80 dB(A)	7	7	0	0	0.5%	0.9%	0.0%	0.0%
2 kHz to 4 kHz	>70 dB(A)	32	30	2	0	2.2%	3.8%	0.4%	0.0%
	>80 dB(A)	7	7	0	0	0.5%	0.9%	0.0%	0.0%
4 kHz to 6 kHz	>70 dB(A)	5	5	0	0	0.3%	0.6%	0.0%	0.0%
	>80 dB(A)	0	0	0	0	0.0%	0.0%	0.0%	0.0%
6 kHz to 10 kHz	>70 dB(A)	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	>80 dB(A)	0	0	0	0	0.0%	0.0%	0.0%	0.0%
10 kHz to 14 kHz	>70 dB(A)	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	>80 dB(A)	0	0	0	0	0.0%	0.0%	0.0%	0.0%
14 kHz to 16 kHz	>70 dB(A)	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	>80 dB(A)	0	0	0	0	0.0%	0.0%	0.0%	0.0%
		Total number of brake applications				1430	798	482	150

14. TEST INPUT PARAMETERS AND SETUP PER EKB 3010

In order to develop robust testing practices, the EKB (European Working Group for Brake NVH) has developed a comprehensive definition of test parameters for the test. The ability to better document (1) project, (2) general brake setup, (3) measurement setup, (4) test setup and dynamometer conditions, (5) suspension or full-axle fixture (L2 or L3) description, (6) knuckle fixture (L1) description, (7) caliper parameters, (8) rotor parameters, and (9) brake pad parameters provides the opportunity to conduct tests at different facilities or using different dynamometers under repeatability and reproducibility conditions. In addition, allows a simpler and more reliable comparison among different test results. See Appendix B.

15. NOTES

15.1 Marginal Indicia

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE 2521 TASK FORCE OF THE SAE BRAKE NVH COMMITTEE

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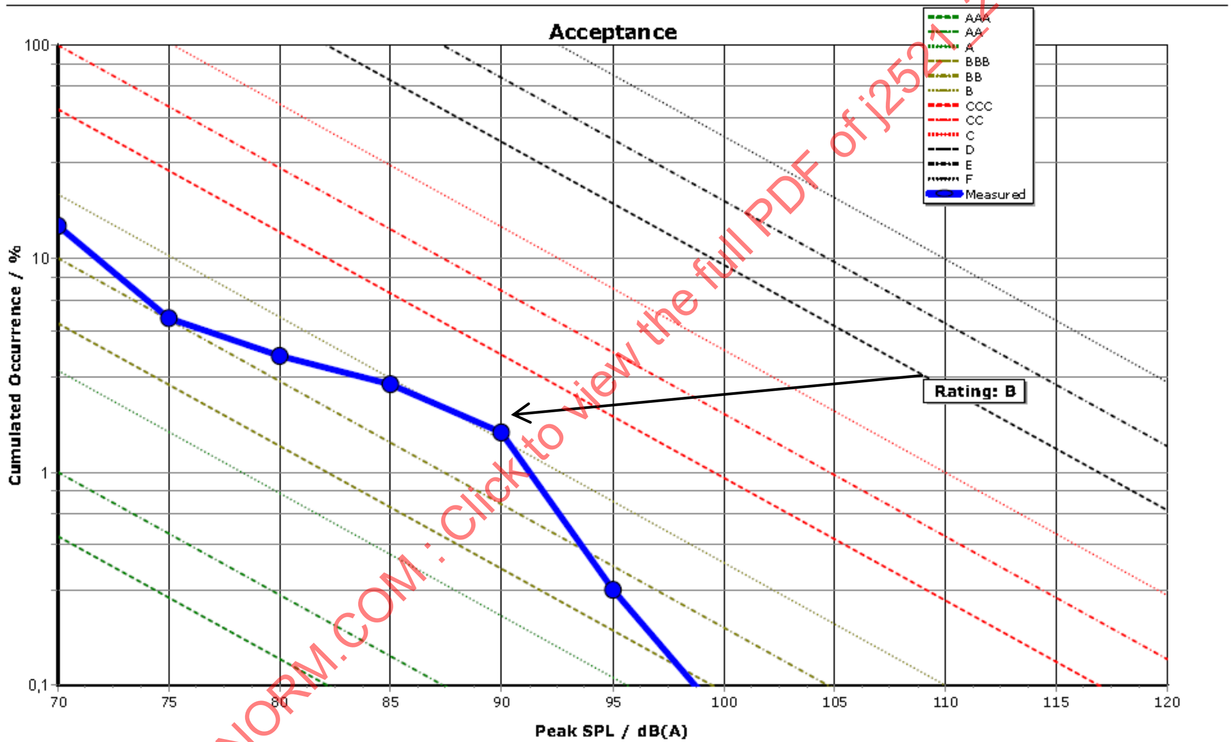
APPENDIX A - NOISE AND FRICTION SUMMARIES

A.1 VDA 306

This guideline defines charts for the evaluation of brake noise. It is valid only for test runs with a brake assembly on the brake tester or for vehicles on a chassis dynamometer. In the examination of several brakes, use the charts individually for the respective brake data.

A.1.1 Acceptance chart for sound pressure level classes

This chart illustrates the cumulative occurrence as a function of sound pressure level overlaid with recommended rating levels. The rating represent a systematic ranking consolidating legacy evaluation systems using a letter coding (AAA–F) were chosen to avoid any confusion with the more familiar "standard rating" numbers 1–10. This provides an exact definition while still allowing companies to use their own (often existing) interpretations on what is a "9" or a "borderline" result. See Figure A.1.



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Courtesy of EKB/VDA

FIGURE A.1 - ACCEPTANCE CHART FOR CUMMULATIVE NOISE OCCURRENCE PER PEAK SPL PER VDA 306

A.1.2 Definition of rating system and rating lines

A.1.2.1 Slope of the ranking lines

Companies within the EKB NVH working group used various definitions of the graph in the past. But almost all of them use a line intercepting the vertical axis at 20% for 70 dB(A), and the horizontal axis at 0.1% for 110 dB(A). So this line (labeled "B") - as it is widely used - was chosen to define the slope for all other (parallel) lines to complete the noise rankings.

A.1.2.2 Step between adjacent rankings

With the slope being set, all other lines are given by their cumulative occurrence values at 70 dB(A) chosen as 0.5, 1, 3, 5, 10, 20, 50, 100, 200, 500, 1 000, and 2 000 %. The line at 3% ("A" ranking) was agreed because a line intersecting the 70 dB(A) level at 3% (and approximately intersecting 95 dB(A) at 0.1%) was already in use within several companies. Even though the 3% step was not in line with the overall series, it was included to consider current test reports and noise evaluation criteria among different companies. The lines of equivalent rating on Figure A.1 are derived using Equation A.1.

$$h_{SPL\text{-}R} = h_{70-R} \cdot 1.0673E4 \cdot e^{-0.1325 SPL} \qquad \text{(Eq. A.1)}$$

Where:

$h_{SPL\text{-}R}$ = cumulative noise occurrence at a given SPL for a given rating line (AAA–F)

$h_{70\text{-}R}$ = cumulative noise occurrence at 70 dB(A) for a given rating line (AAA–F)

SPL = sound pressure level at which the rating line value is investigated

The steps between consecutive rating lines (except the 3% line) follow an 11-step geometric series with an increment of $\sqrt[11]{2{,}000/0.5}$ between consecutive ratings, and then approximated to the nearest multiple of 10 for ease of understanding.

TABLE A.1 - CUMMULATIVE NOISE OCCURRENCE AT GIVEN SPL AND RATING LINES AAA–F

SPL / dB(A)	Cumulative percent of noisy brake events at 70 dB(A)											
	0.5	1.0	3.0	5.0	10.0	20.0	50	100	200	500	1000	2000
	Percent of noisy events by noise ranking at specific sound pressure levels / %											
	AAA	AA	A	BBB	BB	B	CCC	CC	C	D	E	F
70	0.50	1.00	3.00	5.00	10.00	20.00	50.00	100.00	200.00	500.00	1000.00	2000.00
75	0.26	0.52	1.55	2.58	5.16	10.31	25.78	51.57	103.13	257.83	515.67	1031.34
80	0.13	0.27	0.80	1.33	2.66	5.32	13.30	26.59	53.18	132.96	265.91	531.83
85	0.07	0.14	0.41	0.69	1.37	2.74	6.86	13.71	27.42	68.56	137.12	274.25
90	0.04	0.07	0.21	0.35	0.71	1.41	3.54	7.07	14.14	35.36	70.71	141.42
95	0.02	0.04	0.11	0.18	0.36	0.73	1.82	3.65	7.29	18.23	36.46	72.93
100	0.01	0.02	0.06	0.09	0.19	0.38	0.94	1.88	3.76	9.40	18.80	37.61
105	0.00	0.01	0.03	0.05	0.10	0.19	0.48	0.97	1.94	4.85	9.70	19.39
110	0.00	0.01	0.02	0.03	0.05	0.10	0.25	0.50	1.00	2.50	5.00	10.00
115	0.00	0.00	0.01	0.01	0.03	0.05	0.13	0.26	0.52	1.29	2.58	5.16
120	0.00	0.00	0.00	0.01	0.01	0.03	0.07	0.13	0.27	0.66	1.33	2.66

Cumulative percent occurrences below 0.1% or above 100%. Values not shown in the acceptance chart
Cumulative occurrences above 0.1% and below or equal to 10%
Cumulative occurrences above 10% and below or equal to 100%

A.1.3 History chart for frequency and temperature

Display the frequency of noisy brake events at the main peaks and the corresponding IBT during the entire test sequence. Optionally, include additional temperatures, e.g., brake pad. See Figure A.2.

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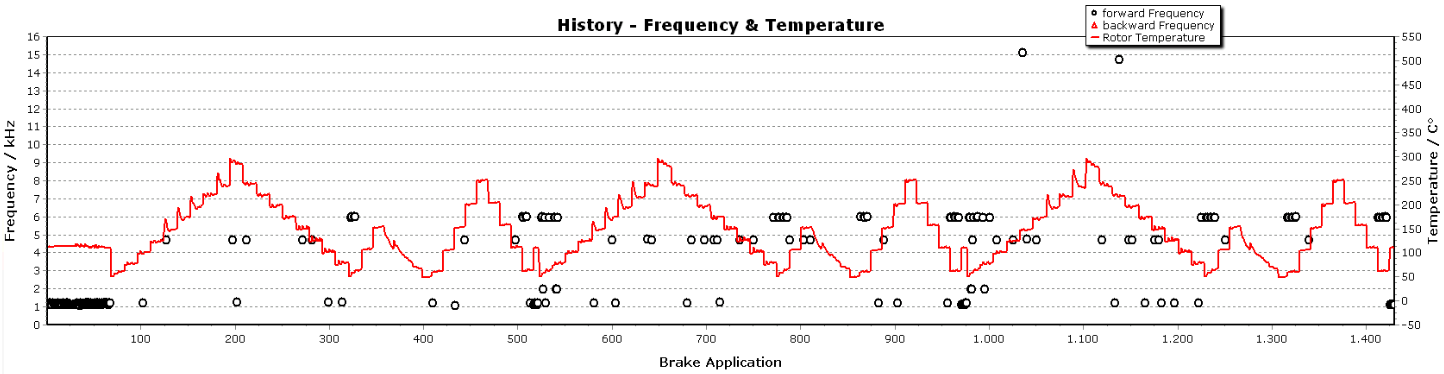
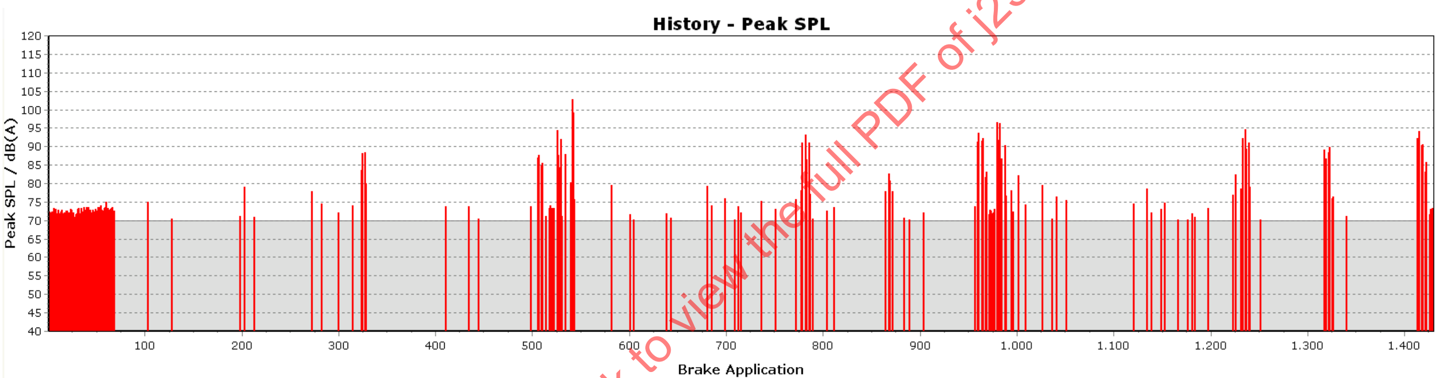


Courtesy of EKB/VDA

FIGURE A.2 - HISTORY CHART FOR FREQUENCY AND TEMPERATURE PER VDA 306

A.1.4 History chart for peak SPL and brake application

Display the SPL for all the noisy brake events during the entire test sequence. See Figure A.3.



Courtesy of EKB/VDA

FIGURE A.3 - HISTORY CHART FOR PEAK SPL AND BRAKING HISTORY PER VDA 306

A.1.5 Main peak chart

Display the loudest instance of squeal within the frequency range and its associated frequency for each brake application. See Figure A.4.

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